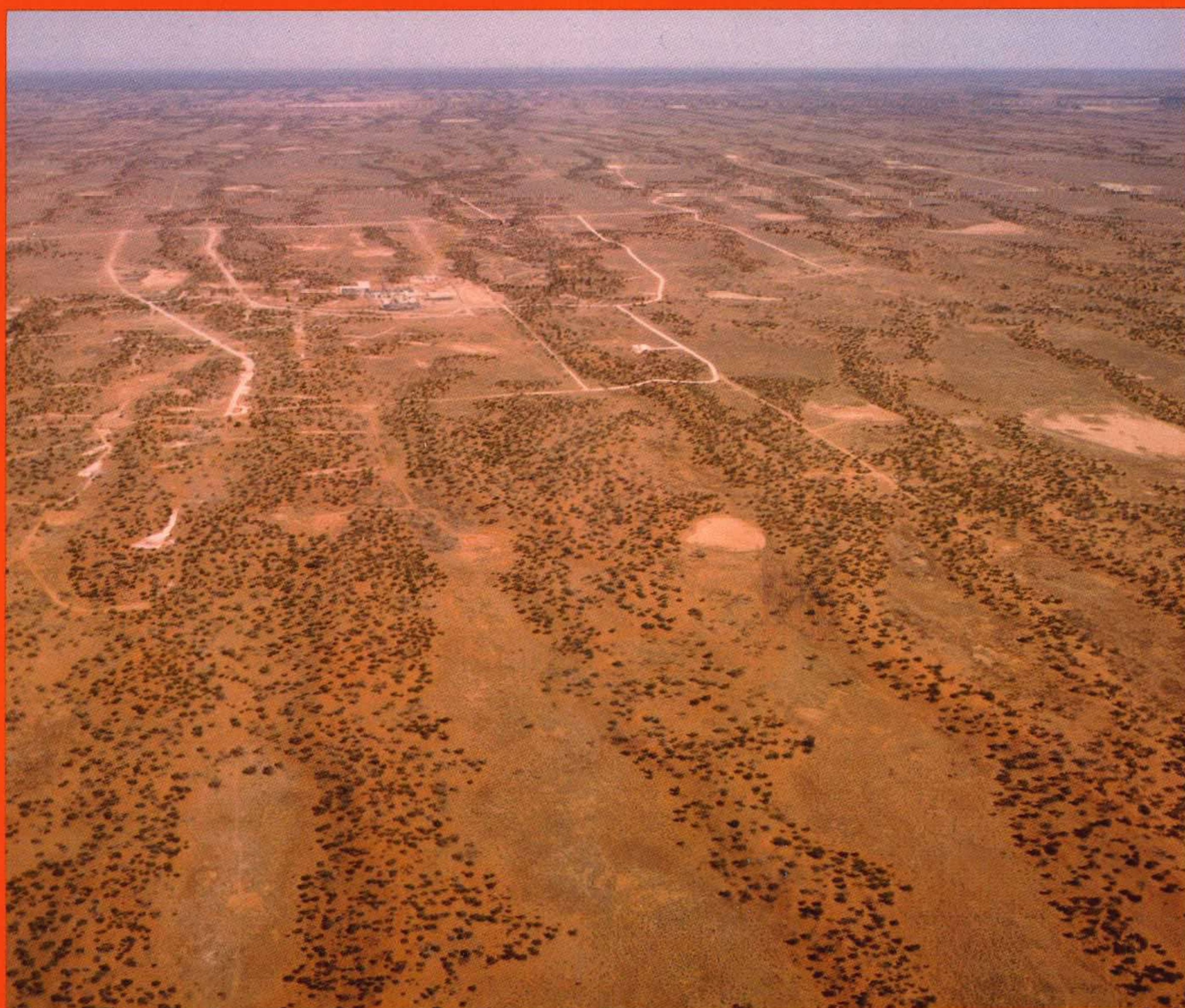
ROXBY MANAGEMENT SERVICES PTY LTD

OLYMPIC DAM PROJECT

Draft Environmental Impact Statement



Kinhill-Stearns Roger

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Draft Environmental Impact Statement

Prepared for
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October 1982

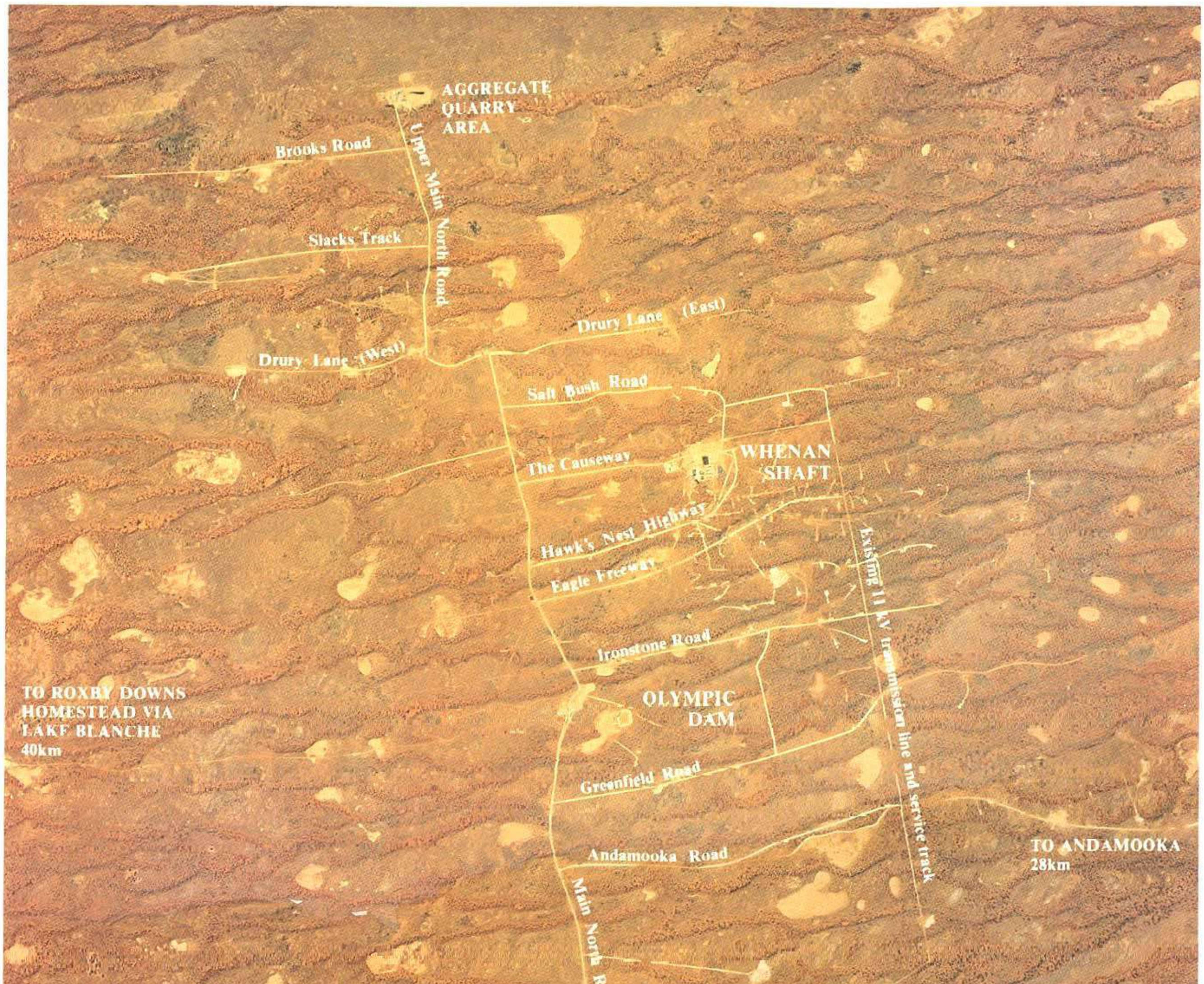
First published 1982
Reprinted 1983

ISBN 0 9593023 0 1

Printed by Mitchell Press Pty Ltd, Adelaide

ACKNOWLEDGEMENTS

Permission is acknowledged from the Director-General, South Australian Lands Department, to reproduce the base maps and aerial photographs used for the frontispiece and Figures 1.2, 2.23, 3.2, 3.18, 6.10, 10.3, 10.4, 10.6, 10.7 and 11.8; and from the Director, Australian LANDSAT Station, Department of Science and Technology, to reproduce the LANDSAT imagery used for Figure 3.1.



Existing Development at Olympic Dam (August, 1981)

Preface

This Draft Environmental Impact Statement has been prepared in response to the State and Commonwealth Governments' environmental impact assessment requirements.

As the Olympic Dam Project will require export approval from the Commonwealth Minister for Trade and Resources, the Minister for Home Affairs and Environment has directed that an Environmental Impact Statement (EIS) be prepared under the Environment Protection (Impact of Proposals) Act 1974-75.

At the time of preparation of this Draft EIS, the South Australian Parliament had passed legislation relating to environmental impact assessment, although the relevant sections had not been proclaimed. However, under a State Cabinet directive, the Minister of Environment and Planning may request that an EIS be prepared where, in his opinion, a project is of major social, economic or environmental importance.

This Draft EIS has been prepared by Roxby Management Services Pty Ltd, acting as manager for a joint venture comprising Roxby Mining Corporation Pty Ltd, BP Australia Limited and BP Petroleum Development Limited (the Joint Venturers). Guidelines for the preparation of this document have been jointly agreed between the State and Commonwealth Governments in consultation with Roxby Management Services. These guidelines indicate the areas which should be considered in the preparation of an EIS.

Following receipt of public submissions on this Draft EIS, Roxby Management Services will be required to prepare a Supplement to the Draft EIS in accordance with Section 8.1 of the Administrative Procedures under the Environment Protection (Impact of Proposals) Act 1974-75. The Supplement will address significant issues relevant to the Project which are raised by public submissions. Together, this Draft EIS and the Supplement will form the Final EIS on which the assessments of the respective Ministers will be based.

The Project which is the subject of this environmental assessment is described in Chapter 2. Development associated with the present exploration activity at Olympic Dam has already been subject to environmental assessment: the South Australian Department of Mines and Energy required the preparation of Declarations of Environmental Factors for the sinking of the Whenan exploration shaft and for the construction of the all-weather access road from Olympic Dam via Purple Downs to Phillip Ponds.

This Draft EIS has been prepared at a time when development planning for the Project is sufficiently advanced to make a proper evaluation of environmental effects, while still being early enough for environmental factors to be considered in Project design decisions together with technical and economic factors. However, some aspects of the development have yet to be finalized, and the final feasibility study which is soon to commence may result in changes to the proposed development approach. Such changes or finalization of details will be notified to government and, should these changes result in significant additional environmental impacts, further environmental assessment may be required.

The Indenture Agreement relating to the Project which was recently ratified by Parliament contains a number of commitments by the Joint Venturers to environmental management. One of the requirements is for the Joint Venturers to submit for Ministerial approval triennial programmes for the protection and management of the environment, and to report annually on the implementation of these programmes. The Draft EIS refers extensively to other relevant aspects of the Indenture Agreement. However, since the Indenture Agreement is a lengthy and complex document, any reference made in the Draft EIS to specific clauses is intended to convey only the main intent of the relevant clause, rather than its full detail. Should a more comprehensive reference be required, the Indenture Agreement itself should be consulted.

It should also be noted that the development of the Project will require action by public authorities as well as by the Joint Venturers. For example, the sealing of the road connecting Olympic Dam to the Stuart Highway at Pimba will be undertaken by the South Australian Highways Department, the extension of telecommunications facilities to Olympic Dam is expected to be undertaken by Telecom Australia, and administration of the town will be under the authority of a specially constituted municipality. Any required documentation of the environmental effects of actions taken by public authorities in relation to works not defined in Chapter 2 of this Draft EIS will be the responsibility of the respective authorities.

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Summary

OBJECTIVE (Chapter 1)

The Olympic Dam deposit is one of the world's major undeveloped mineral resources, and preliminary estimates indicate that it contains at least 2,000 million tonnes of mineralized material, with an average grade of about 1.6% copper, 0.6 kilograms per tonne of uranium oxide and 0.6 grams per tonne of gold. The deposit was discovered by Western Mining Corporation Limited (WMC) in 1975 and is being evaluated by a joint venture formed between Roxby Mining Corporation Pty Ltd (a wholly owned subsidiary of WMC) and BP Australia Limited and BP Petroleum Development Limited (both subsidiaries of British Petroleum).

The objective of the Olympic Dam Project is to extract and process the ore for the production and sale of copper, uranium oxide and the associated precious metals. Although the scale of development will be determined by the final feasibility study yet to be undertaken, for planning purposes production capacity has been set at 150,000 tonnes per annum of copper metal and associated products. The facilities required to achieve this production capacity are:

- an underground mine to extract approximately 6,500,000 tonnes of ore per annum;
- a processing plant on site with an annual production capacity of 150,000 tonnes of copper, together with 3,000 tonnes of uranium oxide, 3,400 kilograms of gold, and up to 23,000 kilograms of silver;
- associated facilities for the mine and plant, including a tailings retention system, workshops and offices, and other services;
- a town to accommodate up to 9,000 people;
- other infrastructure to service the mine, plant and town, including a 33 megalitre per day water supply, a power supply of up to 130 megawatts, and transportation and communication facilities.

Commitment to proceed with commercial development, which on this scale would involve an estimated total expenditure of $1,400 million (expressed in December 1981 dollars), can only be made on completion of the final feasibility study. This study cannot commence until State and Commonwealth Government environmental assessments have been received.

THE PROJECT (Chapter 2)

Mine development

The zones of currently economic mineralization are at depths ranging from approximately 350 to 650 metres. For access to the ore and mine development, two shafts and one decline will be constructed. The Whenan Shaft is currently being sunk as part of the exploration programme to obtain bulk metallurgical samples and to permit underground exposure of the orebody. It is a 6.5 by 3.5 metre shaft with a possible ultimate depth of 730 metres. A second shaft, with a circular cross-section of 7.5 metres diameter, will be sunk to about 800 metres. A decline about 3 kilometres long, 7.5 metres wide, and 4.5 metres high, will be developed from the surface to connect with the mine internal ramp system.

Ore will be extracted by a variety of proven methods depending on the characteristics of the ore zone. The methods presently favoured are open stoping for the thicker ore zones, post-pillar cut-and-fill for ore zones of between 10 and 25 metres thick, and room-and-pillar for thinner ore zones. The mine will use several transport systems to move materials and people. These will include diesel or electric vehicles for ore haulage from stopes; trains, trucks or conveyors for underground ore transport; skips to raise crushed ore to the surface; pipelines and vehicles to convey mine consumables; and vehicles to transport mine personnel.

Mine ventilation systems will circulate about 8 tonnes of fresh air for each tonne of ore mined. Intake fans on the surface will drive air into the mine and up to the work faces, while exhaust fans on the surface will draw air from work areas, expelling it through exhaust raise shafts. The saline groundwater in the aquifer above the mining area will be dewatered in advance of mining and pumped to an evaporation pond. Where appropriate, back-filling of the mine will be achieved mainly using quarried dolomitic limestone. A quarry with a capacity of 3,500,000 tonnes per annum will be developed for mine-fill and other uses. Only limited use will be made of tailings as fill, because of their unsuitable physical characteristics for the proposed mining methods.

Ore processing

Ore will be conveyed from the mine to a concentrator, where grinding and flotation will produce two outputs for further processing. One will be sulphide concentrate, containing more than 90% of the copper and 70% of the gold and silver. The other will be flotation tailings, containing uranium and the remainder of the copper. Metallurgical testing has indicated three processing options for the sulphide concentrate and two for the flotation tailings. Final plant design may include any one or a combination of these methods to ensure the most efficient and economic treatment.

The first two alternatives for concentrate processing produce a pure form of 'electrowon copper'. One of these options involves roasting, leaching and electrowinning processes, while the other requires pressure leaching and electrowinning. For both these options, precious metals will be extracted from the leach residues by cyanidation. The third option for processing the concentrate is by smelting and converting to produce 'blister copper' containing valuable impurities of gold and silver. Subsequent electrorefining is required before the copper can be used for fabrication and to separate the precious metal content. Such a refining step is not presently envisaged for the Project.

Flotation tailings will be treated to produce uranium oxide by atmospheric or pressure leach circuits using sulphuric acid as the leaching agent.

Associated facilities

Laboratories, workshops, stores, offices and other services will be required to support the mine and processing operations. Other than the manufacture of sulphuric acid, which is an integral part of the main process operations, no major on-site manufacturing of chemical inputs is currently contemplated.

The tailings from the treatment plant will be placed in a retention system using a subaerial deposition method. The tailings retention system will consist of four adjacent but separate storage cells, each 100 hectares in size, with perimeter embankments constructed from local materials. Tailings will be deposited in the cells on a cyclical basis which will allow the deposited layer in one cell to settle, dry and consolidate while tailings are deposited in other cells. Controlled reduction of tailings' moisture content will produce a compact and stable tailings mass, and a continuous water cover will not be required. There will be a central decant structure to collect excess liquor and stormwater run-off which will be pumped to a lined evaporation basin.

Town

The mine, plant, and associated facilities will directly employ about 2,400 people on site during operation. It is anticipated that a further 700 people will be employed at Olympic Dam as consequential workers in government and other industries serving the Project and its direct workforce. This employment base should result in about 8,000 people being resident in the town during the early years of production, and it is anticipated that this number will gradually rise to 9,000 at the level of production contemplated. The town site is in sand dune and swale country, about 10 kilometres south of the plant area. The design, planning and construction of the town will be of a standard commensurate with its permanent nature. Land suitable for development in the vicinity of the town site allows for a possible ultimate population of 30,000.

Other Project infrastructure

Water for the Project will be supplied from two borefields to be developed in the Great Artesian Basin. During construction, about 6 megalitres per day will be pumped through a pipeline from a borefield some 100 kilometres north-east of Olympic Dam. To meet the operational requirement of the Project (estimated to be 33 megalitres per day), a second borefield which is a further 50 kilometres to the north-east will be developed. This will require a separate pipeline. As the raw water will have a total dissolved solids content ranging between 1,500 and 2,500 milligrams per litre, a portion will be desalinated to produce potable water. Power for bores and pumping stations will be supplied through a 66 kilovolt transmission line from the Project substation.

The initial power requirements for the Project will be met by constructing a 132 kilovolt line from Woomera. This will supply power during construction, until a 275 kilovolt line from Port Augusta is built to meet the Project's operational needs (which could be up to 130 megawatts). Under the Indenture Agreement between the Joint Venturers and the South Australian Government, the Electricity Trust of South Australia will make available to the Project up to 150 megawatts from the State's electrical distribution system.

The main transport facilities which will be developed as part of the Project include a sealed road from Pimba (on the Stuart Highway) to Olympic Dam, a distance of approximately 90 kilometres, and a sealed airstrip to a standard suitable for medium sized jet aircraft. A standard gauge rail spur from Woomera or Pimba has been allowed for in land use planning and plant layout, but is not contemplated as part of the present proposal.

Normal telecommunication facilities will be provided, including a microwave link from Woomera connected with the national telecommunications network.

A security and vermin-proof fence will be constructed around the mine, plant and tailings area, and the vermin-proof fence will be extended to enclose the airstrip and town site.

TERRESTRIAL ENVIRONMENT (Chapter 3)

Regional environment

There are two main types of environmental associations in the Olympic Dam region. One association, in which the entire Project Area is located, is characterized by extensive longitudinal east-west sand dunes and interdune corridors in which structured soils of the underlying plain are exposed. The Project Area represents less than 2% of this widespread association. The other type of environmental association is characterized by flat to gently rolling stony tableland strewn with gibbers. This occurs to the east and south of the Project Area.

Terrain

The landforms in the Study Area are generally related to two main factors: the weathering of the underlying rocks, and the superimposition of wind-blown sand over the extensive tableland surface throughout the region. In terms of erosion susceptibility, six terrain features were identified: stony tablelands, sand dune ridges, interdune corridors, drainage depressions, low stony rises, and dune fields. The sand dune ridges and dune fields show the greatest potential for erosion, especially in areas of instability (areas without vegetative cover) where blowouts can form, leading to dune deflation and sand movement during infrequent times of high winds. The higher percentages of silt and clay in the soils on the stony tablelands, interdune corridors, drainage depressions, and low stony rises, in addition to the presence of gravel as a reinforcing material or as a surface shield, reduce the erosion potential of these terrain features. Potential sand movement can be controlled by limiting the degree of disturbance on sand dunes, by retention of vegetative cover where possible, and by early stabilization of any areas which show sand drift or which require disturbance of dune ridges. Other minor potential impacts associated with alterations to surface drainage and sediment movement can be accommodated by appropriate engineering design.

Hydrology

The crests of the sand dunes form a mosaic of small closed catchments. With high average evaporation (about 3,000 millimetres per annum) and low average rainfall (160 millimetres per annum), run-off events are infrequent and soil moisture contents are low. The dunes have infiltration rates higher than the maximum rainfall intensity, while the swales and depressions are relatively impermeable. The introduction of substantial areas of impermeable surfaces due to development will lead to some minor increases in run-off, but these will be accommodated by drainage systems and compensating basins. The effect of the closed catchments will be to contain run-off within the immediate vicinity of the Project Area. The localized increases in soil moisture levels arising from the watering of gardens and recreation areas will promote increased plant growth.

Flora

The two main vegetation suites in the region are related to the two principal types of environmental associations: stony tablelands support a low chenopod shrubland, while the dune fields have a recurring pattern of woodlands or tall shrublands on sands and chenopod shrublands on structured soils of interdunal corridors. Grazing by stock and rabbits has degraded the vegetation in the Project Area, and in any case this type of vegetation is widely replicated. Therefore, except for isolated communities associated with drainage features, it has little conservation significance. Vegetative cover does, however, play a significant role in preventing erosion, as well as having amenity value (particularly the groves of western myalls and other tree species). Although some vegetation clearance will occur as a result of development, the Joint Venturers' policy of vegetation retention or rehabilitation of vegetated areas is an important consideration in reducing vegetation impacts, and has been incorporated in siting decisions, particularly in relation to the town. In addition, the exclusion of stock from the area, the control of rabbits, the creation of buffer zones, and garden and amenity planting will all assist in further mitigating adverse effects on vegetation.

Fauna

Pastoral activity and the introduction of exotic species have substantially reduced the number of native mammals present in the Olympic Dam region. Reptiles have been affected to a lesser degree. Although habitat loss due to Project development will occur, the area involved is extremely small compared with the regional extent of the available habitat. Some species of avifauna will be disadvantaged by habitat loss while others will benefit from the increased availability of water and food resulting from Project development. Some loss of avifauna may occur as a result of the acid liquor evaporation pond.

LAND USE (Chapter 4)

Pastoralism, the principal land use in the area, commenced during the 1860s and 1870s, and its viability has always been dependent on the region's erratic rainfall. Other land uses include weapons testing at Woomera; mining at Andamooka and at Stuart Creek for opal, and at Mount Gunson for copper; and limited tourist activity, mostly near Lake Eyre and the mound springs areas. Pastoral settlement is dispersed, while other settlement is related to weapons testing, mining activity, and transportation service centres associated with the Stuart Highway, Trans Australia Railway and Port Augusta to Marree railway.

Pastoral activity will be the land use most directly affected by Project development. There will be beneficial consequences, with better access to town services, stock water supply and transportation facilities, while the adverse impacts will comprise a small loss of land and some land severance, minor stock losses from vehicle/stock accidents, and some danger to stock and property from the increased population in the area. Where necessary and appropriate, compensation will be made for loss of land or loss of production. As the 200 square kilometres of the Project Area represents only 10% of Roxby Downs Station (which totals 2,000 square kilometres), this effect is relatively minor. The Project will also have indirect effects on land use, through the recreational activities of the town population and through improvements in regional access.

ABORIGINAL ENVIRONMENT (Chapter 5)

Archaeology

Archaeological sites which are evidence of past occupation by Aboriginal people are widespread throughout the region in which the Study Area is situated. The nature and distribution of archaeological sites which were used for economic activities by Aboriginal people are closely related to terrain patterns. Campsites are generally on sand, with the richest and most diverse being located adjacent to areas likely to hold water after heavy rainfall. Knapping floors and quarries are usually in close proximity to sources of raw materials, and the material used reflects the rock type of the surface geology. The greatest frequency of sites is found in widely spaced dune fields, which combine the advantages of sand on which to camp, rain-collecting depressions for water supply, and raw material for stone tools. The frequency of sites declines with increasing dune density (and decreasing frequency of claypans). Dune fields overlying low stony rises (a source of silcrete for stone tools) have the highest site frequency. On stony tableland and dissection slopes, sites are confined to rock outcrops used for quarries and knapping floors and to isolated dunes used as campsites. Such sites are infrequent, but those which do occur are large in area and dense in artefacts. Artefact material is generally silcrete in dune fields (especially where there are low stony rises), chert in areas of Andamooka Limestone, and quartz in Arcoona Quartzite.

The operations area is located predominantly in widely spaced dune fields overlying low stony rises. Archaeological sites with a high density but low diversity of artefacts are therefore frequent. The town site is in more closely spaced dune fields where a lower frequency of sites occurs. The types of archaeological sites within the Project Area are not unique, as there are large tracts of country surrounding Olympic Dam which contain essentially the same range of site types in the same environmental settings. Thus, general preservation of archaeological sites in the Project Area is not warranted. However, nine sites were identified as being noteworthy from a scientific point of view, and more detailed recording or salvage collection will be carried out at three of these sites to gather further insights into the archaeology of the area. In addition, seventeen stone features were located in the general vicinity of the Project Area, five of which have definite artificial components consistent with Aboriginal origins. None of these sites will be directly affected by the development, and the Joint Venturers have restricted access in the areas surrounding the sites. Before further action can be formulated in relation to these features, an indication of their Aboriginal significance is required.

Anthropology

The weight of evidence from the literature implies that the Project Area is within traditional Kuyani territory near the band of country where Kuyani and Kokatha tribal areas traditionally meet. Arabana territory is further north, and that of the Pangkala is to the south. It is many years since the general area was inhabited by Aboriginal people following a traditional lifestyle: by the late 1940s, when Woomera was established, there were very few tribalized Aborigines in the Range area. However, people of Arabana, Kuyani and Kokatha descent were employed on stations near Olympic Dam until the early 1970s. Migration of Aboriginal people from the area has been to missions such as Koonibba and Yalata, and to towns, particularly Port Augusta.

It has not been possible to conduct anthropological surveys of the Study Area. The last known speaker of Kuyani has died and, while discussions were held with the Kokatha during the eighteen months leading to publication of this Draft Environmental Impact Statement, detailed agreement on an approach to anthropological research was still to be reached with the Kokatha people at the time of writing. A preliminary agreement was, however, being discussed on an approach to site survey work. Arabana people have provided confirmation of certain Kuyani myths and, through fieldwork, have indicated sites of significance to the north of the Project Area.

Nevertheless, anthropologists and others have previously recorded much of the mythology of the region and have located and identified sites of significance. This information identifies no mythological sites in the Olympic Dam Project Area, although two sites are within 15 kilometres of the Project Area and another three are within 50 kilometres. Kuyani and Arabana mythology is generally centred on the mound springs area, about 100 kilometres to the north; Kokatha mythology is centred on Ooldea, about 500 kilometres to the west.

UNDERGROUND ENVIRONMENT (Chapter 6)

Geology of the orebody

The Olympic Dam deposit occurs in a sequence of unmetamorphosed sedimentary breccias of Proterozoic age. This breccia sequence is overlain by about 350 metres of unmineralized cover sediments of the Stuart Shelf. The bulk of the known ore grade mineralization occurs in geologic members dominated by matrix-rich polymict breccias, with the matrices composed mainly of hematite. Two types of copper mineralization occur: bornite-chalcopyrite-pyrite in hematite-rich breccias, and chalcocite-bornite mineralization generally in lenses and veins.

Hydrogeology

The main aquifer in the region is the Arcoona Quartzite Member of the cover sediments. It is a fractured rock aquifer in which groundwater movement is very slowly eastwards towards the Lake Torrens area. It contains water of high salinity not suitable for human or stock consumption. Some use is made of lower salinity water of near potable quality which occurs in limited quantities in some areas of surficial sediments separated from the underlying saline aquifers. The breccia sequence hosting the mineralized area is a minor aquifer of limited permeability and higher salinity than the Arcoona Quartzite.

The mine area will be dewatered in advance of mining operations. This will create a cone of depression in the groundwater potentiometric surface, redirecting local groundwater movement towards the mine area during mining and for some hundreds of years after mining ceases. After the cessation of mining, groundwater will move towards the mined out area, with groundwater in the breccia sequence mixing with remnant mine water which may have pockets of acid water with high heavy metal content. Eventually, however, the groundwater will resume its present very slow movement eastwards. There will be no effect on the quality of groundwater in the surficial sediments, in the Arcoona Quartzite, or in the Great Artesian Basin which is geologically separated from the Project Area and lies some 100 kilometres to the north of Olympic Dam.

Seismicity

The Adelaide Geosyncline which lies to the east of Olympic Dam is a seismically active zone. However, earthquake risk at a level requiring design consideration diminishes sharply away from the Geosyncline.

According to the requirements of the Standards Association of Australia Earthquake Code, earthquakes with peak ground velocities of 0.05 metres per second are not expected to cause structural damage to normal buildings not designed specifically to resist earthquakes. Earthquakes even of this low intensity have a return period of 3,500 years at Olympic Dam.

TAILINGS RETENTION SYSTEM Chapter 7)

System operation

Six million tonnes per annum of tailings slurry will be pumped from the metallurgical plant in a rubber-lined steel pipe to the 400 hectare tailings storage area, where the tailings will be deposited by subaerial deposition. The tailings storage will be subdivided into four cells, and the tailings will be discharged from the perimeter of the storage onto a gently sloping beach in one of these cells. The tailings will settle across the beach, and any free liquor will flow into a sump common to all four cells of the storage. The decanted liquor will be pumped to a separate 50 hectare evaporation pond adjacent to the tailings storage.

In a typical twenty-eight day deposition cycle, a layer of 200 millimetres of tailings slurry will be placed in one cell over a seven-day period and then allowed to settle, dry, and consolidate over twenty-one days, during which time the other cells will be receiving tailings slurry. By the end of the drying cycle, the evaporation of moisture will reduce the degree of saturation of the tailings to around 90%. This will mean that 90% of the voids within the tailings will contain liquor. As such, the tailings will absorb moisture during the deposition of the next layer of tailings slurry, but this moisture will be drawn back to the surface and evaporated during the next drying cycle. The target level of 90% saturation will be low enough to form a high strength tailings mass with a density of 1.9 tonnes per cubic metre. As the tailings will not consolidate any further, long-term structural stability is ensured.

Control of radon emanation and seepage

By maintaining the moisture content at about 90% saturation, radon gas emanation from the tailings surface can be regulated. In addition, the drying process will create a high strength competent surface not susceptible to wind erosion. Seepage through the deposited tailings will be restricted because of the low permeability of the tailings, and the capacity of the dried tailings to absorb moisture. Model testing indicates that the depth of penetration of a wetting front is approximately 400 millimetres. Thus, it will only be during initial deposition (up to the first six months) that the wetting front could be expected to reach the base of the tailings storage. Under normal conditions, it is likely that such seepage would be drawn back to the surface and evaporated. Even if this did not occur, seepage during this initial period would only be sufficient to saturate a depth of less than 1 m below the tailings. A long period of exceptionally high rainfall might also lead to minor seepage through the tailings.

Pipelines carrying tailings slurry to the tailings storage, or decant liquor to the decant evaporation pond, will be bunded or placed in culverts to contain spillage in the unlikely event of a pipeline failure.

At decommissioning, an average of 1.5 metres of soil cover and 0.5 metres of quarried rock will be placed on the tailings surface to provide protection from long-term wind and water erosion. This will provide a stable and maintenance-free structure for the long term and will attenuate radon emission. Contouring of the surface will ensure that water is confined within the tailings structure and will allow only shallow pools to form which will evaporate rapidly.

OTHER WASTES AND EMISSIONS (Chapter 8)

Meteorology

The climate at Olympic Dam is warm to hot in summer and mild to cool in winter, with long hours of sunshine, very low and unreliable rainfall, and high evaporation rates throughout the year. Winds are predominantly from southern quadrants in spring and summer, and from the north-west quadrant in winter. In autumn, winds are lighter and mainly from the south-east or north quadrants. Night-time inversions between 100 and 400 metres are frequent, breaking up as a result of solar heating by mid-morning and reforming after sunset.

Air emissions

In relation to air quality considerations, the main plant emissions will be sulphur oxides, oxides of nitrogen, and hydrogen fluoride. The main sources of sulphur oxides will be the acid plant, coal-fired process steam boilers, and the smelter furnace, with minor amounts from the concentrate dryer and yellowcake calciner. Oxides of nitrogen will be emitted from the boilers and the concentrate dryer. Fluoride in the ore will be converted to hydrogen fluoride during the roasting of concentrates or during the smelting of copper, and the minor amounts not collected in gas cleaning prior to acid production will be emitted from the acid plant. All predicted emission concentrations are within the relevant National Health and Medical Research Council recommendations for emission standards.

Maximum ground level concentrations have been predicted for each emission. Peak concentrations will occur during unstable atmospheric conditions with moderate wind speeds. For sulphur dioxide from a single source, the predicted maximum three-minute-averaged ground level concentration from the acid plant is 485 micrograms per cubic metre at 20°C, compared with the allowable criterion of 532 micrograms per cubic metre. The maximum for combined sulphur dioxide sources is 560 micrograms per cubic metre, compared with the criterion of 1,064 micrograms per cubic metre. For nitrogen oxides, the maximum is 28 micrograms per cubic metre, compared with the criterion of 325 micrograms per cubic metre, while for hydrogen fluoride the maximum is 3 micrograms per cubic metre, compared with the criterion of 21 micrograms per cubic metre. Long-term concentrations of all emissions are also well below relevant standards.

Dust emissions generated from handling process materials such as pyrolusite, coal, sulphur and silica sand, as well as dust from quarry operations, will be controlled to meet the relevant occupational health recommendations of the National Health and Medical Research Council. Primary roads will be sealed to minimize dust from this source, while secondary lightly trafficked roads will be watered as necessary. Appropriate safety practices will be followed in the handling and use of toxic process chemicals.

Noise

Predictions have been made of the Project related noise levels likely to be experienced in the town, which will be 10 kilometres away from the operations area. The frequency and intensity of noise from all operational components which might represent potentially significant noise sources have been combined by computer model, and meteorological conditions which may accentuate noise reception, such as wind direction or inversion presence, have been considered for 'worst case' situations. The resulting predictions are that, even under these worst case situations and allowing for tonality, the maximum effective noise level in the town due to Project operations will be 36 dBA. This is well below the South Australian regulatory standard of 45 dBA for urban residential areas at night, and is as low as the probable night-time background noise levels in the town.

The quarry, which will be situated about 15 kilometres north of the town, is unlikely to provide a source of annoyance at that distance. Provision has been made for buffer zones between the town and other intermittent noise sources, in order to reduce possible annoyance. The main road buffer zone will be 150 metres wide, while a buffer zone of about 350 metres in width will be provided for the possible future railway.

Within the town itself, air-conditioning noise will be the most likely source of annoyance. The noise level of the air-conditioners to be installed by the Joint Venturers will therefore be one of the selection criteria for this equipment. As industrial areas can also be a source of noise annoyance in residential areas, these areas will be separated in planning for the town.

Solid waste

The town will be the major source of solid waste, which will consist of household and garden refuse, construction materials, and commercial and industrial waste. To dispose of these wastes, the Joint Venturers will establish a sanitary landfill in the town area, which will be operated by the municipality.

Project operations will generate a relatively small amount of solid waste, which will include both contaminated and uncontaminated wastes. To dispose of the latter, salvageable materials such as scrap metal will be sold, while unsalvageable waste will be disposed of in the mine landfill tip adjacent to the tailings storage facility. Contaminated waste will be decontaminated where possible and the salvageable portion sold. That portion of the contaminated waste which is not salvageable will be drummed where possible, and disposed of in a separate area of the mine landfill.

RADIATION ASSESSMENT (Chapter 9)

Radiation standards

Project planning has taken into account the Joint Venturers' obligations under the Indenture Agreement to adhere to the radiological protection standards required by the Commonwealth of Australia's Code of Practice on Radiation Protection in the Mining and Milling of Uranium Ores 1980 (Code of Practice), and the codes or recommendations of the International Commission on Radiological Protection (ICRP), the International Atomic Energy Agency (IAEA) and the National Health and Medical Research Council (NHMRC). These standards relate to the control of exposure to radiation above naturally occurring background levels both for employees and for members of the public. Three mechanisms of exposure have been considered in relation to uranium mining and processing: external exposure to gamma radiation, inhalation and retention of radon decay products (radon daughters), and inhalation or ingestion of radioactive particulates.

Project radiation sources and incremental exposure levels

The principal sources of incremental radiation exposure from underground mining are radon gas from in situ, broken and crushed ore (insofar as it gives rise to concentrations of radon daughters), radioactive particulates in respirable dust, and gamma radiation. Above ground sources comprise radon gas, its decay products and radioactive particulates in respirable dust emitted from mine vents, ore transfer and processing, and the tailings retention area; and gamma radiation from the tailings retention area, ore processing and drummed yellowcake. The various radiation exposure pathways have been considered for different employee categories and for town residents.

The limitation of exposure to radon daughters in underground mining is considered of prime importance to the protection of employee health. The mine ventilation system and mining methods will be designed to control radon daughter exposure in any year to 1 WLM (Working Level Month), which is one-quarter of the maximum permissible exposure in the Code of Practice. With the relatively low uranium content of the ore, silica inhalation rather than inhalation of radioactive particulates governs the permissible dust concentrations in the mine working areas. Exposure from radioactive dust is estimated to be one-thirtieth of the permissible level. Gamma radiation exposure is estimated at one-tenth of permissible levels. It is predicted that plant employees will be exposed to lower radon daughter and radioactive particulate levels than mine employees, while gamma radiation during yellowcake packaging and drying is expected to be slightly higher but still only one-fifth the permissible level.

In addition to meeting the individual limits for the different exposure mechanisms, the Joint Venturers undertake to limit overall exposure of employees to radiation by limiting the combined contribution from all mechanisms (radon daughters, gamma radiation and radioactive particulates). This goes a step beyond the Code of Practice requirements, and is consistent with the more recent ICRP recommendations on radiation protection.

The Joint Venturers have adopted a similar combined criterion for overall exposure of members of the public in relation to maximum permissible concentrations set out in the Code of Practice for members of the public, which are more stringent than permissible employee exposure limits. Possible pathways for public exposure above natural background levels are through inhalation of radon daughters and respirable radioactive particulates dispersed from the operations area, and through ingestion of incremental increases in radioactivity above that already contained in drinking water or in locally produced meat and vegetables. Conservative estimates indicate that the total contribution of increases in exposure for office workers at the main administration office in the plant area is a factor of forty below the Joint Venturers' combined criterion for public exposure. For town residents, this factor is seventy-five. This can be compared with exposure from natural radiation sources which is one-sixth of the same criterion. Thus, the increase in radiation exposure due to Project operations is not only well below the Code limits, but it also represents only a small addition to the normal background levels to which people living in a continental land mass are continually exposed.

At Project completion, the plant and mine will cease to be sources of radiation exposure. Although the tailings retention area will continue to emit radon after decommissioning, surface protection consisting of an average 1.5 metres of soil and an additional 0.5 metres of quarried rock will reduce this radon emanation by a factor of four.

Yellowcake Transport

It is planned to transport uranium concentrate (yellowcake) by road from Olympic Dam to Port Adelaide via Pimba and Port Augusta. Relevant South Australian legislation governing such transport is expected to incorporate Commonwealth legislation, which in turn closely follows IAEA criteria for the transport of 'low specific activity materials' (which include uranium concentrate). The concentrate will be packaged in steel drums, which in turn will be secured in export shipping containers. Experience at other Australian uranium operations where this packaging method is employed indicates that radiation levels at the surface of the load will be a small fraction of IAEA limits. While the chances of an accident of sufficient severity to cause a spillage of yellowcake are small, contingency plans for cleaning up and monitoring spillage will be prepared.

Radiation monitoring

Regular operational monitoring of radioactive contaminant levels will be carried out by the Joint Venturers to enable adherence to commitments regarding exposure limits agreed with statutory authorities. This monitoring will not only provide data for documentation of personnel exposures, but also for procedural controls to limit individual exposure, and will act as a check on the functioning of ventilation and other engineering systems. Baseline monitoring of natural radiation in the Olympic Dam area has been in progress for two years to provide a benchmark against which to measure the incremental exposure from Project operations. Occupational monitoring is presently carried out for the protection of workers handling drill core samples and for those involved in underground exploratory mining.

Regular monitoring reports are being forwarded to the appropriate authorities, and this will continue throughout Project operations. Personal radiation results will be made available to individual employees upon their request, but will otherwise remain confidential. The Joint Venturers are also committed to providing regular briefing and information services to employees and town residents, explaining the basis of radiation protection being employed on the Project and the results of the monitoring programmes.

PROJECT INFRASTRUCTURE (Chapter 10)

Electricity supply

Initial power for the construction phase at Olympic Dam will be provided by a 132 kilovolt transmission line from Woomera, which will supply up to 30 megawatts from the existing Port Augusta to Woomera line. To provide the total of 100 to 130 megawatts required for Project operation, a 275 kilovolt line from Port Augusta will be constructed. It is expected that this power requirement can be met from currently planned additions to the Electricity Trust of South Australia's generating capacity. The route of the 275 kilovolt line will parallel the existing line from Port Augusta to Mount Gunson, and then join the corridor of the 132 kilovolt line at a point 6 km east of Woomera, remaining in this corridor until reaching Olympic Dam. This last section of dual lines will require a 100 metre wide corridor to provide for line separation, construction access and a service road. As no new service road will be required for the 145 kilometre section to Mount Gunson, land disturbance over this section will be confined to transmission tower sites, and environmental impact is therefore considered minimal. For the 115 kilometre section from Mount Gunson to Olympic Dam, tower construction and a service road as well as stringing of lines will involve some vegetation clearance and minor alterations to surface hydrology, both of which can initiate soil erosion and sand movement. However, vegetation clearance will be kept to a practical minimum, and disturbed areas will be rehabilitated in keeping with operation and maintenance requirements. Drainage and soil stabilization measures will be adopted where practicable to alleviate erosion impacts. During the stage of tower siting, surveys for archaeological sites will be undertaken. The route has been selected to avoid airfields, homesteads and sites of environmental significance. An exposed outcrop of the Andamooka carbonate sequence, a feature of geological significance near Purple Lake, will also be avoided, although the crossing of Lake Windabout will require at least one tower to be sited in the lake bed, with a causeway constructed for access.

Water pipeline corridor

During Project construction, water will be supplied at a rate of 6 megalitres per day by a pipeline from Borefield A on the southern margin of the Great Artesian Basin near Bopeechee, 100 kilometres north-east of Olympic Dam. To provide the additional water necessary to meet the operational Project demand of 33 megalitres per day, a second pipeline will be built from Borefield B deeper in the Great Artesian Basin, 50 kilometres north-east of Borefield A. A 50 metre wide corridor will be required to accommodate both pipelines, the 66 kilovolt transmission line (to provide power for pumps) and the 6 metre wide access road, as well as to provide construction access and sufficient pipeline/transmission line separation to avoid induced electrical currents.

The pipeline alignment has been chosen as the most direct route which takes account of environmental constraints, such as significant drainage depressions, gullies, escarpments, and mound springs. For the first 46 kilometres, the corridor crosses an east-west trending dune field. In this section, dunes are generally crossed at right angles to minimize the impact. The dunes change direction north of this point to almost north-south for the next 29 kilometres, allowing the corridor to be sited in swales parallel to the dune direction. Use has been made of the abandoned Marree to Alice Springs railway alignment for 9 kilometres from Bopeechee, following which the route goes north-east to Borefield B, crossing 37 kilometres of gypcrete/siltstone tableland with entrenched shallow water courses. Crossings of some drainage depressions, creek channels, and areas of dune instability will be given special attention in relation to erosion control and drainage. The corridor generally avoids areas of significant vegetation. It does however involve the clearance of some bullock bush and native pittosporum which, while classified as protected plants, are widespread in the region. In addition, the corridor bisects a stand of Sarcostemma australe which has a restricted occurrence in the region. An ungrazed dune field, rare in this pastoral country, will also be traversed by the corridor. However, this area will not be significantly affected, and the long deviation which would be required to avoid this dune field is not warranted. If an above ground pipeline is selected, stock and vehicle crossings will be provided in appropriate locations to minimize severance of pastoral land. Five archaeological sites considered of some scientific significance were identified in the corridor and will be subject to further recording.

Off-road vehicle movement by employees and contractors will be limited during construction and operation to minimize environmental damage. However, improved regional accessibility, while increasing the tourist potential of the area by removing one of the major constraints to tourist activity, has the potential for environmental damage which cannot be controlled by the Joint Venturers.

Borefield development

About five bores will be installed at Borefield A, with four operating at any one time. This will achieve an abstraction rate of 6 megalitres per day from the Cadna-owie Formation, a fine to medium grained sandstone which forms a southern extension to the Great Artesian Basin. At Borefield B, seven to ten bores (with two or three on stand-by) will abstract 27 megalitres per day from what is believed to be the Algebuckina Sandstone. At the time of writing, investigations were in progress to finalize bore locations and to obtain more detailed knowledge of the hydraulic parameters of the aquifers.

Water quality within the Basin generally has a salinity of 500 to 1,500 milligrams per litre (total dissolved solids) with high sodium bicarbonate levels. This water is generally unsuitable for irrigation because of the high sodium content and residual alkalinity. Salinity increases at the margins, with Borefield B ranging from 1,400 to 1,800 milligrams per litre, while the range at Borefield A is from 1,700 to 2,700 milligrams per litre. To the north-west of the borefields, sulphate levels are high, making the water corrosive and difficult to treat to provide a potable supply.

Further development of the Great Artesian Basin as a water resource is possible because the recharge rate is currently only about 2% of the water available for recharge. Increasing extraction will produce a steeper hydraulic gradient in the aquifer (thereby inducing greater recharge), as well as a lowering of the groundwater pressure throughout the Great Artesian Basin (resulting in a reduction in flows from existing bores and springs as well as a reduction in leakage from the aquifer), until a new equilibrium between recharge and discharge is established.

Current discharge from the entire Basin is estimated to be 3,100 megalitres per day, of which 45% is lost through vertical leakage to overlying sediments, and 6% is discharge from springs. The remaining 49% is bore discharge, of which less than 10% is used. Within 50 kilometres of the borefields, discharge through vertical leakage is estimated to be between 32 and 48 megalitres per day, while bores discharge about 13 megalitres per day (of which less than 1 megalitre per day is used for domestic purposes or livestock watering), and springs discharge about 1 megalitre per day.

The effects of pumping a total of 33 megalitres per day from the two borefields have been predicted by computer model. As the estimated current outflow in the nearby region is in excess of the required yield, the extraction will be balanced by the imposed reduction in other discharges (principally the upward leakage through the overlying shale, but also bore and spring flows). The flows in bores close to the borefields will be significantly reduced (at Crow's Nest Bore within the boundary of Borefield B, for example, a 100% reduction is predicted, while 25 kilometres away at Charles Angas Bore the reduction will be only 18%). The terms of the Indenture Agreement protect the rights of existing users, and the Joint Venturers must either make alternative supplies available or come to other suitable arrangements with users who are adversely affected. Furthermore, the Special Water Licence to be granted to the Joint Venturers under the terms of the Indenture Agreement requires the Joint Venturers to install and maintain an approved groundwater monitoring system, and to report annually on aquifer response and future water management.

The effect on mound springs in the area is of environmental significance. Mound springs are formed by the build-up of calcium carbonate which precipitates out of the waters of artesian springs and by the deposition of sediments transported to the surface by artesian waters. These springs occur along the southern and western margins of the Great Artesian Basin from Queensland through northern South Australia. Some are still active, some are waning in activity due to lowering of water pressure in the Basin from groundwater use, while others are inactive or extinct. The mound springs are of historical significance, as they provided a focus for early European settlement, being the only permanent source of water in the region. They are also of scientific importance, as some support rare vegetation and aquatic fauna, while the mechanism of their formation makes them of geomorphological interest. In addition, as the centre of Kuyani and Arabana mythology, the mound springs area is also of anthropological and archaeological significance.

The introduction of cattle and rabbits, and the presence of pastoralists and tourists have generated grazing and trampling pressures which have resulted in the degradation of many of the springs. The construction of the borefields will have no direct effects on mound springs, but pumping will reduce the flows in eight springs, including a 17 to 33% reduction for Hermit Hill Springs (a mound spring complex with some conservation significance). Further studies of mound springs and the development of measures to mitigate the effects on significant mound springs will be conducted in conjunction with the Department of Environment and Planning's current mound spring survey work and the Department of Mines and Energy's bore rehabilitation programme.

Other infrastructure

The existing transportation system within the region has sufficient capacity to accommodate the transport requirements of the Project. The Joint Venturers have already constructed an all-weather road from Olympic Dam to Pimba on the Stuart Highway. A rail spur from Pimba to Olympic Dam may be built in the future, subject to technical and economic review, but is not proposed in this Draft EIS. This spur would connect the Project to the Trans Australia Railway standard gauge line. Port Adelaide is the only South Australian sea port with the necessary facilities to service the Project, although some upgrading of bulk unloading facilities may be required to handle sulphur and pyrolusite. The existing airstrip at Olympic Dam is adequate for construction purposes, but a higher standard facility closer to the town will be required during Project operation. It is anticipated that connection with the national telecommunications network will be via microwave link from Woomera, to be installed by Telecom Australia.

SOCIAL EFFECTS AND TOWN DESIGN (Chapter 11)

Population, workforce and accommodation

To operate and maintain the Olympic Dam Project at a production level of 150,000 tonnes per annum of copper will require a permanent on-site workforce of approximately 2,400 people, with a further 700 supporting workers in government and service industries. This workforce and its dependants are expected to give rise to a total population of some 8,000 people by the fourth year of operation of the Project, subsequently rising to 9,000 people at the production capacity contemplated. It is the Joint Venturers' intention to develop a permanent, comfortable and stable living environment in a new town at Olympic Dam, to be built some 10 kilometres south of the operations area. Although initial development will be carried out by the Joint Venturers under the provisions of the Indenture Agreement, the town will, from its inception, be an 'open town' administered by a municipality.

The forecast structure of the workforce will give the town in its initial years many of the social characteristics observed in other mining towns, such as a significant proportion of shift workers, the predominance of one employer, higher median incomes, and a largely male workforce. Initially, the population of the town is expected to have high percentages of larger than average sized families, and of people aged from twenty to forty. There will also be more young children but noticeably fewer teenagers and elderly people than in established towns. Possibly a quarter of the population of Olympic Dam may be overseas-born. However, this demographic structure will change as the town matures.

The majority of the married workforce is expected to have a preference for detached houses with gardens, with approximately 1,600 houses being required by the fourth year of production. In addition, accommodation for 800 single workers will be provided in units or flats, while caravan park facilities will be provided for a further 150 families. The climatic characteristics of Olympic Dam will influence housing design, and an adequate water supply will be required to sustain grassed areas and vegetation which are important in mitigating the effects of the climate, and in contributing to the creation of a pleasant town environment.

Town planning and facilities

Social, cultural and recreational facilities will be provided to a level appropriate to a town of 9,000 people, with due regard to its location. Facilities will include three pre-schools, three primary schools, one high school, a library, a hospital, State and local government service and administration centres, commercial facilities, and a wide range of opportunities for passive and active recreation. Certain of these will be funded by the State Government under the provisions of the Indenture Agreement. The special needs of a rapidly growing and relatively isolated community will be catered for, with community welfare facilities and support services being directed particularly towards the needs of young families, and the encouragement of the development of self-help groups.

In the conceptual design of the town, particular attention has been paid to the effects of climate, and to the preservation of vegetation and sand dunes at the town site. The layout of the town will facilitate ease of access to the main centre and to local centres, while maintaining privacy and safety for residents. In anticipation that the town may continue to develop for a variety of reasons, sufficient land has been reserved at the town site to accommodate an ultimate population of 30,000.

ECONOMIC EFFECTS (Chapter 12)

The Olympic Dam Project will generate a significant increase in economic activity in South Australia. The $1,400 million construction expenditure (which excludes interest and is expressed in December 1981 dollars) is estimated to increase economic output in the South Australian economy by between $233 million and $638 million each year during the four-year construction period. Once in production at the proposed capacity, the annual Project expenditure of $117 million on goods and services is predicted to increase South Australian economic production by between $88 million and $213 million. The Project will broaden and strengthen the State's economic base, and is expected to add between 32 and 43% to the State's present level of export income.

During the construction phase, the Project is forecast to generate an average of approximately 9,300 to 18,600 jobs, while the production phase is estimated to generate between 5,700 and 8,300 jobs. However, the total number of new jobs generated in South Australia will depend ultimately on the ability of the economies of the State and the Northern Region to meet the Project's demands for goods and services. Clause 12 of the Indenture Agreement obliges the Joint Venturers, subject to normal commercial considerations, to utilize South Australian labour and materials as far as practicable.

The Project will contribute considerable royalty and payroll tax revenue to the State Government. Royalties from the Project have been calculated to average between $18 million and $28 million per year, while payroll tax payments are estimated at about $2.4 million for each year of production. Corporate taxation and personal income tax paid by the on-site construction and production workforce will contribute a significant amount to the Federal Treasury, while the Project's indirect and induced economic effects could increase payroll and personal income tax receipts to between three and seven times that derived from the directly employed workforce.

Figure 1.1
LOCATION OF OLYMPIC DAM

CHAPTER ONE

Objective and Background

1.1 OBJECTIVE

The Olympic Dam Project is based on a very large copper-uranium deposit located approximately 520 km north-north-west of Adelaide, South Australia (Figure 1.1). The deposit was discovered by Western Mining Corporation Limited (WMC) in 1975. The Olympic Dam Joint Venture was subsequently formed in July 1979 between Roxby Mining Corporation Pty Ltd (a subsidiary of WMC), and BP Australia Limited and BP Petroleum Development Limited (both subsidiaries of British Petroleum), to evaluate and develop the deposit. Roxby Management Services Pty Ltd (RMS) was established by WMC in 1978, and appointed by the Joint Venturers to manage the Olympic Dam Project on their behalf under the terms of the Joint Venture Agreement. The principal terms of this Agreement were approved by both the South Australian and the Commonwealth Governments.

The deposit is one of the world's major undeveloped mineral resources. A preliminary estimate indicates that it contains at least 2,000 million tonnes of mineralized material, with an average grade of about 1.6 % copper, 0.6 kg/t of uranium oxide, and 0.6 g/t of gold. It also contains recoverable silver and significant amounts of rare earth oxides. The known mineralization extends over an area of 7 by 4 km, and much of the drilling over this large area is necessarily widely spaced. The above estimate is therefore not of sufficient accuracy to represent an ore reserve, but is an indication of the total amount of mineralization discovered so far. The degree of mineralization is variable throughout this area. There are locations where drilling results indicate significant tonnages of mineralization containing approximately twice these average grades of copper, uranium, and gold, although not necessarily concurrently. Again, drilling densities in these areas to date are insufficient for estimation of firm ore reserves.

The objective of the Olympic Dam Project is to extract and process the ore on site for the production and sale of copper, uranium oxide, and the associated gold and silver. The scale of development will be determined by the final feasibility study yet to be undertaken. However, the intended capacity for which WMC and BP have provided special financial relationships under their Joint Venture Agreement is 150,000 t/a of copper metal and associated products. This is the production capacity which has been addressed in this Draft Environmental Impact Statement (Draft EIS) and, for the purposes of this Draft EIS, it is considered to continue for a thirty-year period.

The following facilities will be required to achieve this production capacity:

- an underground mine to extract approximately 6,500,000 t/a of ore;
- a processing plant on site with an annual production capacity of 150,000 t of copper, together with 3,000 t of uranium oxide, 3,400 kg of gold, and up to 23,000 kg of silver;
- associated facilities for the mine and plant, including a tailings retention system, workshops and other services;
- a town to accommodate up to 9,000 people;
- other infrastructure to service the mine, plant and town, including a 33 ML/d water supply, a power supply of up to 130 MW, and transportation and communication facilities.

Figure 1.2 shows the proposed development superimposed upon an aerial photograph of the Olympic Dam area. A boundary fence delineates the Project Area, which incorporates the two principal areas of development: the town site in the south, and the controlled access area containing the main operations areas (the mine shaft, plant and tailings retention areas). The locations of major infrastructure facilities such as the airfield and the services corridors are also shown.

The size and nature of the mineralization is considered by the Joint Venturers to justify a commitment to an expenditure of $100 million in exploration, evaluation, and feasibility studies. However, commercial development on the scale outlined above would involve an estimated capital expenditure of $1,400 million (excluding interest, and expressed in December 1981 dollars). Such a commitment would only be made by the Joint Venturers in the light of estimates of long-term returns and having regard to the attendant commercial, financial and technical risks. This evaluation cannot be made until the final feasibility study is completed.

Following receipt of environmental assessments from both the Commonwealth and State Governments, the Joint Venturers will proceed with the final feasibility study. Under the terms of the Indenture Agreement between the Joint Venturers and the South Australian Government, this study is required to be completed by 31 December 1984.

The terms of the Indenture Agreement further require the Joint Venturers to notify the Minister responsible for the administration of the Act ratifying the Indenture of a decision to proceed with commercial development. This notification must be made before 31 December 1987. The Minister may, at the request of the Joint Venturers, extend this date either if the Minister accepts the Joint Venturers' certification that it is economically impracticable for them to make a commitment to proceed at that time or, alternatively, if an independent expert confirms such a view. However, the deferment of a commitment to proceed may not be extended beyond 31 December 1991.

While the Joint Venturers may approach potential buyers of uranium oxide to ascertain their interest in the purchase of the output of the Project, the Joint Venturers are prohibited by Commonwealth Government legislation from entering into any detailed commercial negotiations or commitments for the sale of uranium oxide until Development Status has been granted by the Commonwealth Government. Such status cannot be achieved until environmental assessments have been completed by both the Commonwealth and State authorities.

Figure 1.2
MAIN ELEMENTS OF PROPOSED DEVELOPMENT

1.2 PROJECT HISTORY

1961 to 1975

WMC has been exploring South Australia for copper deposits since 1961. In 1972 a review of regional historical data combined with various geological models led WMC geologists to focus on the Stuart Shelf. Large scale surveys indicated a number of coincident gravity and magnetic anomalies, suggesting to them that the Olympic Dam area warranted further exploration.

Exploration Licence 190 was granted over that area in May 1975 and, by July, the first drill hole, RD1, had intersected low-grade copper mineralization (approximately 1%) 353 m below the surface. Subsequent analysis showed that the mineralization also contained minor amounts of uranium and gold.

1976 to 1979

By 1976, eight diamond drill holes had been completed, and a total of thirteen were completed by the end of 1977. WMC's Chairman reported to the Company's 1977 Annual General Meeting that drilling had outlined a large prospective ore position and, because of the likely size of the project, WMC was considering a joint venture for project development.

Discussions with interested companies resulted in the formation of a joint venture with the BP Group, announced on 27 July 1979. In conjunction with the signing of the Joint Venture Agreement, WMC transferred its ownership interest in the Project to Roxby Mining Corporation Pty Ltd, a wholly owned subsidiary of WMC. Ownership of the Project is held as follows: Roxby Mining Corporation Pty Ltd 51%, BP Australia Limited 36½%, and BP Petroleum Development Limited (a company incorporated in the United Kingdom) 12½%.

In late 1979 permanent single quarters were established at Olympic Dam, and eight diamond drills were operating by the end of the year. While exploration continued, the Joint Venturers began to carry out metallurgical testing and other work necessary to undertake the evaluation of the Project.

1980 to 1982

In May 1980, the decision was made to sink an exploration shaft (the Whenan Shaft) to a depth of approximately 500 m. During that year three additional diamond drills were put into operation, engineering facilities associated with the exploration shaft were constructed, work on the shaft commenced, and the village was expanded by the addition of housing and caravan park accommodation.

The environmental baseline studies, which have provided much of the information used in this Draft EIS, were commenced in late 1980 and have been continuous since that time.

Exploration Licence 783, which was taken out in 1981, covers the area of exploration activity of the Joint Venturers. As Figure 1.3 shows, this includes parts of Roxby Downs and Andamooka Stations. The landing strip and village have been excluded from this licence and are the subjects of miscellaneous purpose licences. The shaft site and the existing quarry are included in other leases granted under the Mining Act.

An Indenture Agreement between the Joint Venturers and the South Australian Government, setting out the terms and conditions of development and production, was ratified by the South Australian Parliament in June 1982. The principal matters with which the Indenture Agreement is concerned are:

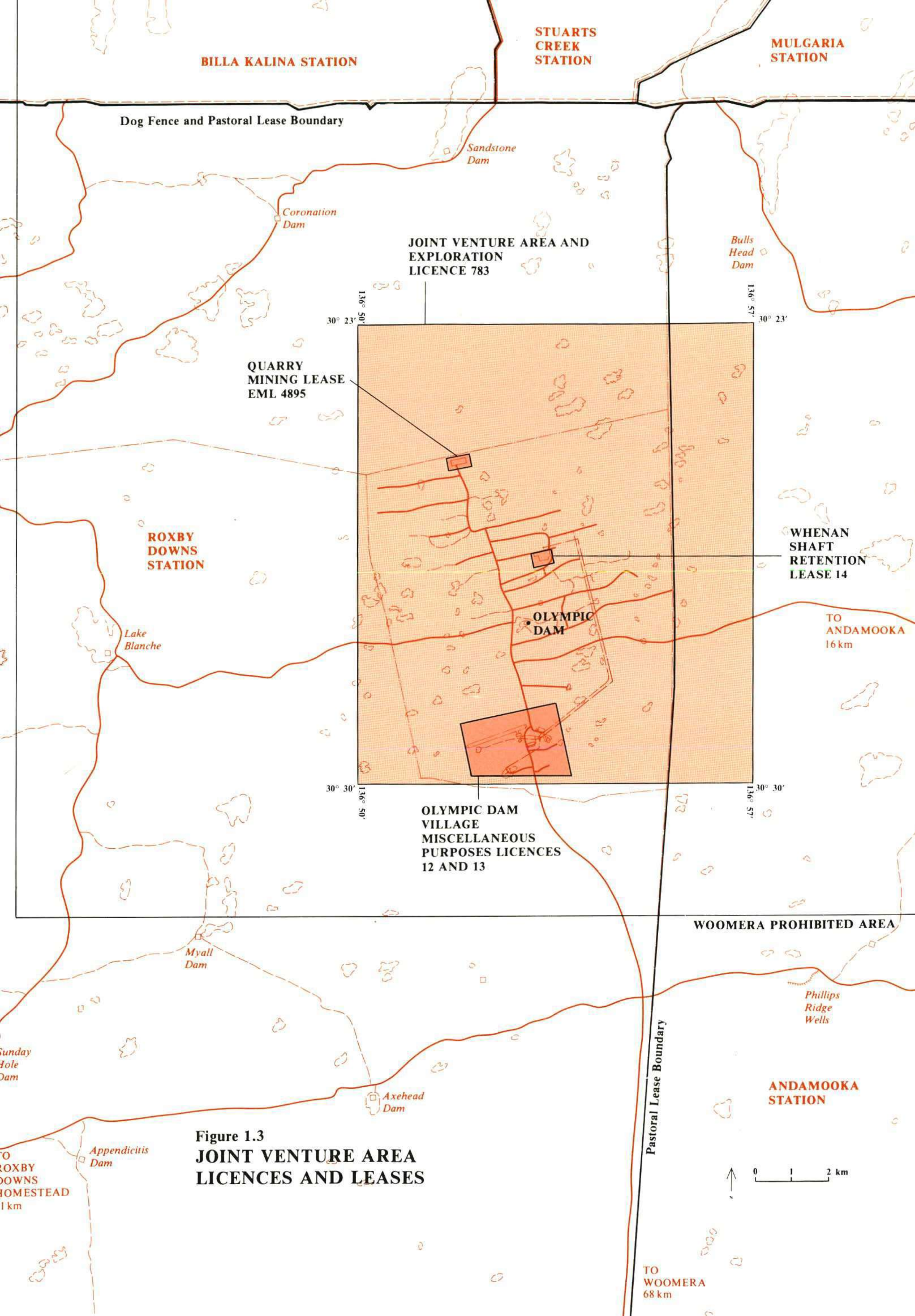


Figure 1.3
JOINT VENTURE AREA LICENCES AND LEASES

- the obligations of the Joint Venturers, and conditions relating to the development
- security of tenure for the Joint Venturers, and access to services
- the amount of royalties payable by the Joint Venturers.

The Indenture Agreement defines the Joint Venture Area boundary within which the mine and plant are to be located. However, the town site is located within the Woomera Prohibited Area which lies to the south and west of the Joint Venture Area boundary. At the time of writing, negotiations were progressing between the State and Commonwealth Governments to alter the Woomera Prohibited Area boundary.

1.3 EXISTING FACILITIES AND SITE DEVELOPMENT

Exploration drilling has been continuous since 1975, with a maximum of thirteen diamond and three percussion drills operating at any one time. Drilling has been on an 800 m grid to define the limits, shape and geological environment of the deposit, with closer spaced drilling in areas of greater interest to investigate continuity of mineralization. To the end of June 1982, more than 300 holes had been drilled.

Work on the Whenan exploration shaft development to the 500 m level will be completed by October 1982. Ore samples have been extracted for metallurgical pilot studies during the sinking programme, and further samples will be taken as development progresses.

Equipment and maintenance workshops, drill core sample preparation and storage facilities, and office buildings have been erected on site, and workforce accommodation for 300 people has been constructed at Olympic Dam. These accommodation facilities currently include single quarters for 160 people, a housing area of sixteen houses, and a caravan park with thirty-six sites. The village also has a cafeteria, wet canteen and a supermarket.

Existing development in the Project Area is shown on Figure 1.4, with development related to the mine shaft area detailed on Figure 1.5.

Infrastructure and services already provided at Olympic Dam include:

- on-site water storage of 2 ML (or thirty days' current use), replenished daily by road train tankers from Woomera

- 4 MW of power supplied by on-site diesel generators

- an 8 m wide, all-weather, gravelled road connecting to the Stuart Highway at Pimba, 90 km to the south

- a 1,600 by 90 m unsealed airstrip (constructed to Commonwealth Department of Transport licensing standards) used by daily charter flights to and from Adelaide and by scheduled air services.

At the time of preparation of this Draft EIS, the Joint Venturers had expended $75 million (expressed as present day dollars) in exploration and site development.

1.4 PROJECT TIMING

Feasibility phase

At the time of writing, activity in relation to the Olympic Dam Project was associated with the preliminary stages of the final feasibility study. Ore reserve drilling for mine

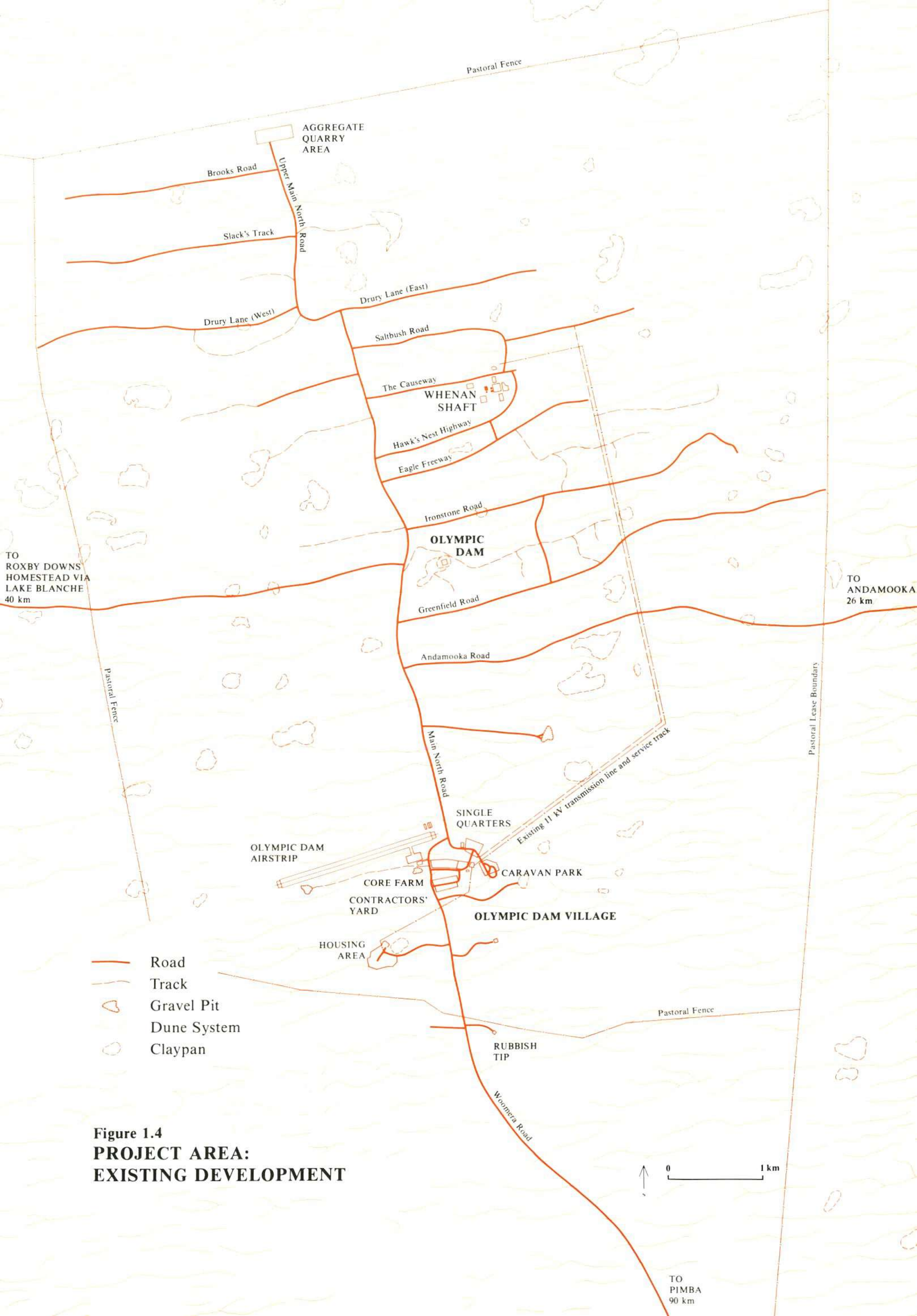


Figure 1.4
PROJECT AREA: EXISTING DEVELOPMENT

planning purposes and exploration development from the Whenan Shaft commenced during 1982. The purposes of the development programme are to provide access to the mineralization to allow the ore reserve to be confirmed by underground investigation, and to obtain large ore samples for metallurgical testing.

Metallurgical activity in the feasibility phase will comprise process selection and off-site testing of ore in order to prove the viability of the selected process. Conceptual design of the main plant will then be undertaken. The process selected and the results of off-site tests may indicate the necessity for more substantial on-site pilot testing. However, this is not at present considered necessary, as the results of tests to date have indicated generally consistent metallurgical behaviour.

Water will continue to be transported by road tanker from Woomera for the duration of the feasibility phase, although this may be supplemented by water which has been transported by road tanker from the Great Artesian Basin and treated in a pilot desalination plant. In addition, activity will be directed to proving the supply in the Great Artesian Basin, and to designing the borefields pipelines and a treatment system. Power will continue to be supplied by on-site diesel generating sets as at present. Accommodation will be provided in the present village, which will be extended as necessary, and final design for the initial stage of the town will be undertaken.

Completion of the final feasibility study will be followed by a period in which marketing and financing arrangements will be completed, and evaluation and approval reached by the Joint Venturers, financiers and government authorities.

Timing of commitment

In addition to the procedural reasons set out in Section 1.1, the timing of commitment to commercial production and of the rate of production build-up to 150,000 t/a of copper is dependent on a number of factors.

Firstly, it is not practical or realistic to assume that this output will be achieved immediately operations commence. Mining operations must be developed over a considerable period before design capacity can be achieved. The actual duration will depend on the outcome of detailed mine planning work, and will be dictated by such factors as the dimensions of the ore positions immediately available for development, and the number of positions where such development will be required in order to achieve the desired mine capacity.

Secondly, for technical, marketing and economic reasons, the detailed feasibility studies could demonstrate the desirability of establishing the process facilities in a phased manner, rather than attempting to construct and commission the total capacity at one time.

An important part of the final feasibility study will therefore be the determination of a time schedule for mine production and processing throughput, which will necessarily be strongly influenced by financing and marketing considerations which cannot be assessed or negotiated until environmental assessments have been completed. The schedule in Figure 1.6 illustrates the development path presently considered by the Joint Venturers to represent the most likely sequence of major activities during the construction, commissioning, and early production years. For the reasons described above, it is expressed in terms of Project years rather than actual calendar years.

Construction/production phase

Following Project commitment, the final design and construction of the major Project facilities will commence.

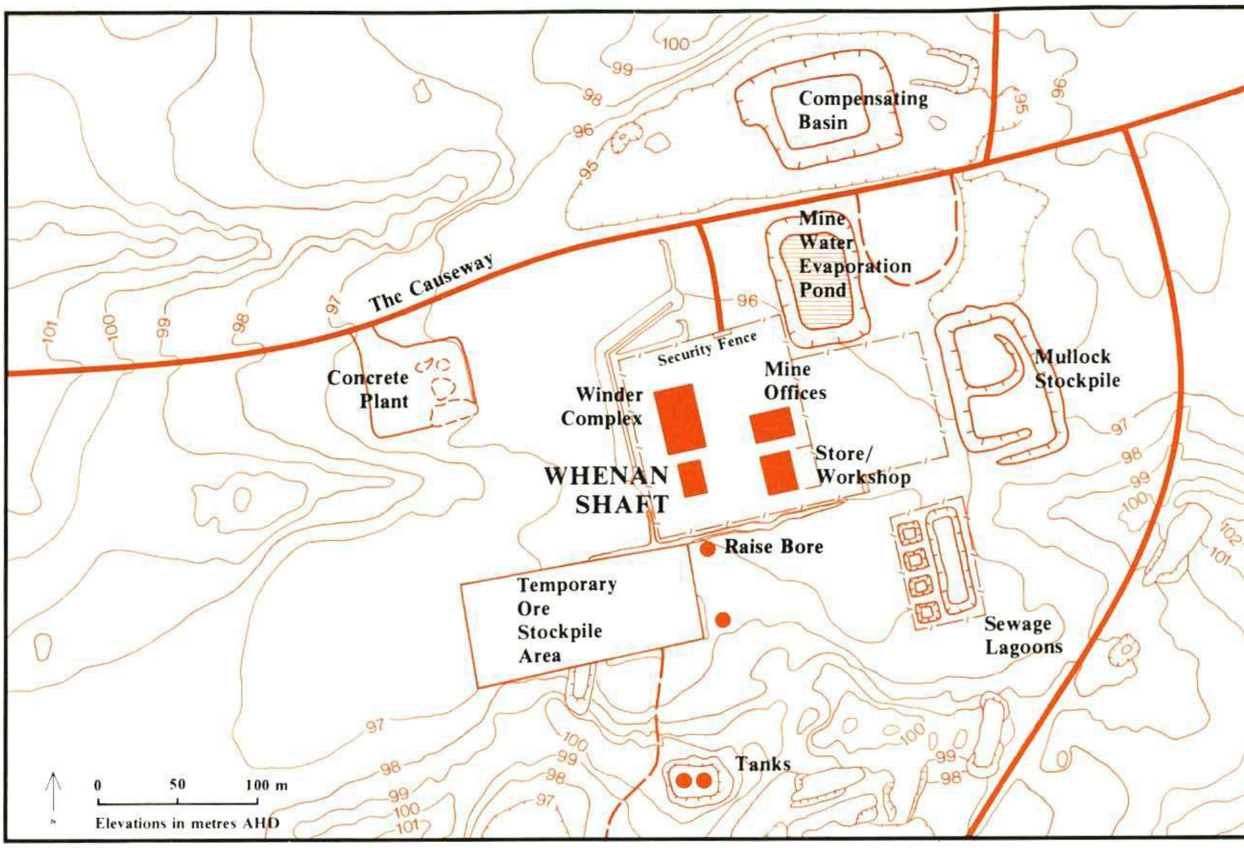
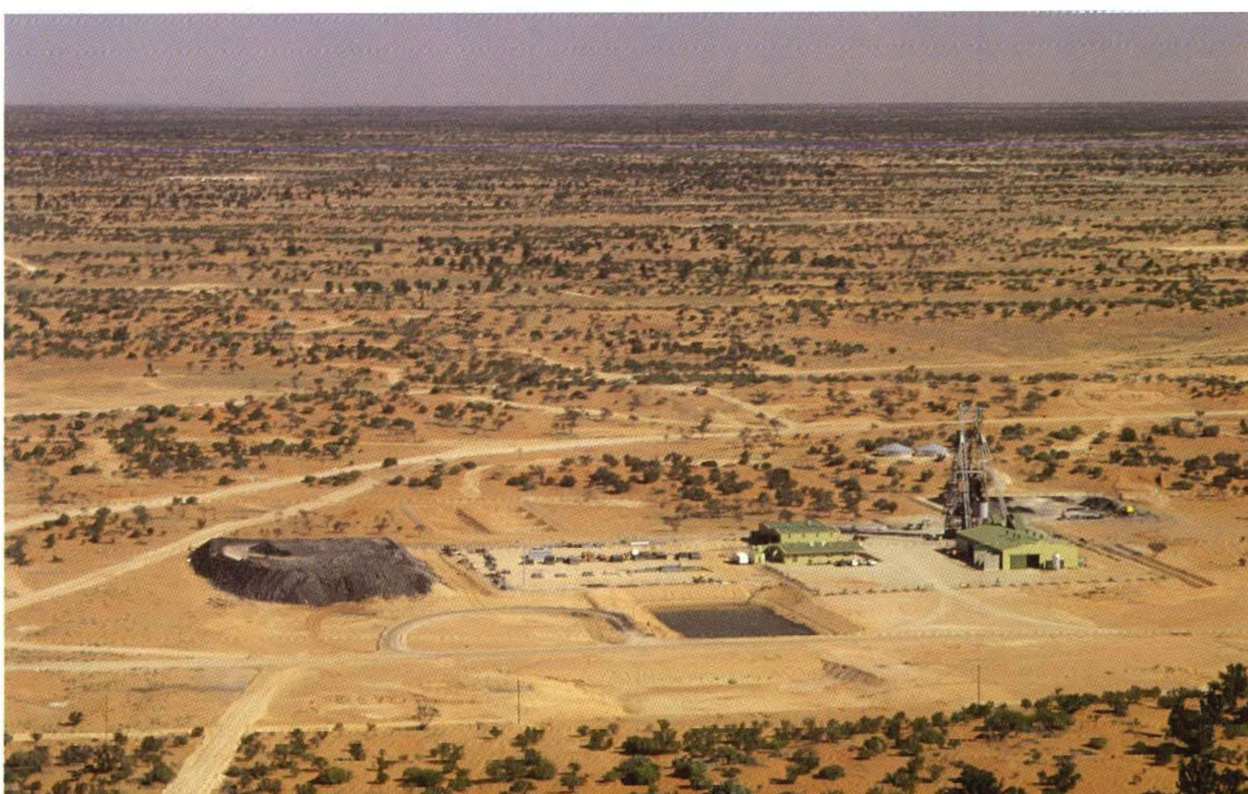


Figure 1.5
MINE AREA: EXISTING DEVELOPMENT



Oblique aerial photograph of Whenan Shaft area (March, 1982) looking south

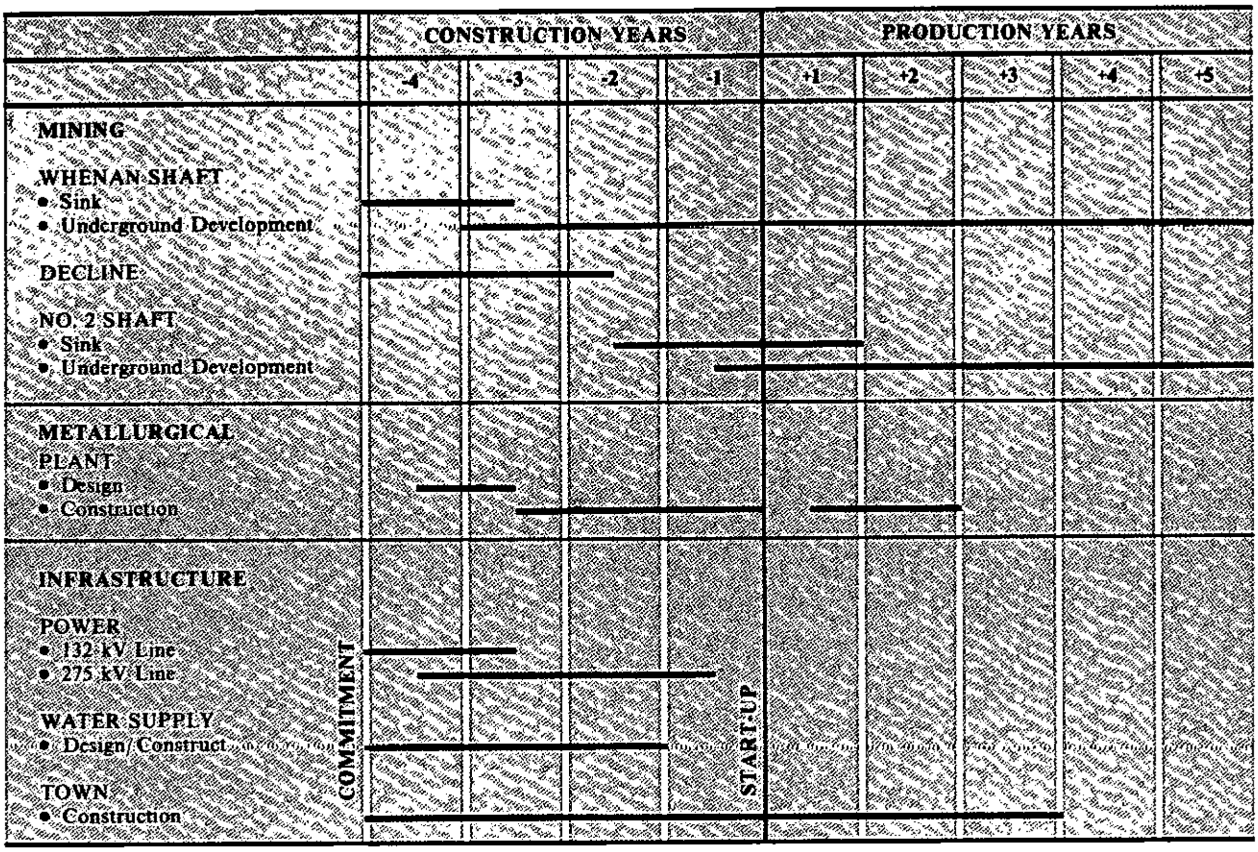


Figure 1.6
PROPOSED DEVELOPMENT SCHEDULE

A further programme of underground development will be initiated from the existing Whenan Shaft. Construction of the decline from the surface will commence as soon as possible after commitment, and will be completed within approximately thirty months. The sinking of the second shaft (No. 2 Shaft) will commence after a period of design and site preparation. Production from the mine will then commence (approximately four years after commitment), will build up steadily, and could be expected to reach full production within five years of start-up. This period from start-up to achievement of full capacity recognizes the time required to undertake the underground mine development necessary to attain full production levels.

The main metallurgical plant will probably be constructed in two stages. The first stage, which will occupy two and a half years, will include site works, the first stage of the copper extraction and recovery circuit, and the uranium extraction and recovery circuit. The second stage will be completed to coincide with increasing output rates from the mine.

Final engineering design of the initial water supply will commence after Project commitment. The ultimate supply of both potable and process water will be the Great Artesian Basin, with the first pipeline to the Basin and associated facilities being completed about three years after commitment. Although this is earlier than necessary for the process supply, potable water will be required for construction personnel and for the initial town population.

The build-up in construction and mining activities, together with the initial occupation of the town, will require an additional power supply until such time as the 275 kV line from Port Augusta is completed. In order to provide this interim supply, a 132 kV transmission line from Woomera will be constructed.

1.5 PRODUCTS AND MARKETS

Value of production

At a production rate of 150,000 t/a of copper, 3,000 t/a of uranium oxide (U_3O_8), 3,400 kg/a of gold, and 23,000 kg/a of silver, the Olympic Dam Project would rank among the ten largest copper producers in the world. At these production rates, the annual value of production could range between $A442 million and $A658 million depending on the metal prices assumed (Table 1.1).

Table 1.1 Estimated range of annual value of production ($A million)*

U_3O_8 price	Copper $A1,500/t	Copper $A2,000/t	Copper $A2,500/t
$A25/lb	441.5	516.5	591.5
$A30/lb	474.5	549.5	624.5
$A35/lb	507.6	582.6	657.6

* Gold and silver prices are assumed in the table as $A400.00 per ounce ($12,860/kg) and $A10.00 per ounce ($321.50/kg) respectively, contributing an annual total of $A51 million to the value of production.

The principal uses and markets for copper and uranium, the Project's major products, are discussed below.

Copper: use and markets

Copper is commonly marketed and sold as:

- **copper concentrate:** containing typically 25 to 60% copper in the form of sulphides. These must be processed further to produce marketable primary copper, usually by smelting and electrorefining, or by leaching and electrowinning;

- **blister copper:** a relatively impure (approximately 98%) copper, the product of smelting and converting of copper concentrate. If gold and silver are present in the concentrate, most will report in the blister copper as valuable impurities. Further refining is required prior to fabrication and to separate the gold and silver;

- **electrorefined copper cathode:** an almost pure copper product used directly in fabrication. It is produced by electrically depositing copper from an anode cast from blister copper onto a cathode;

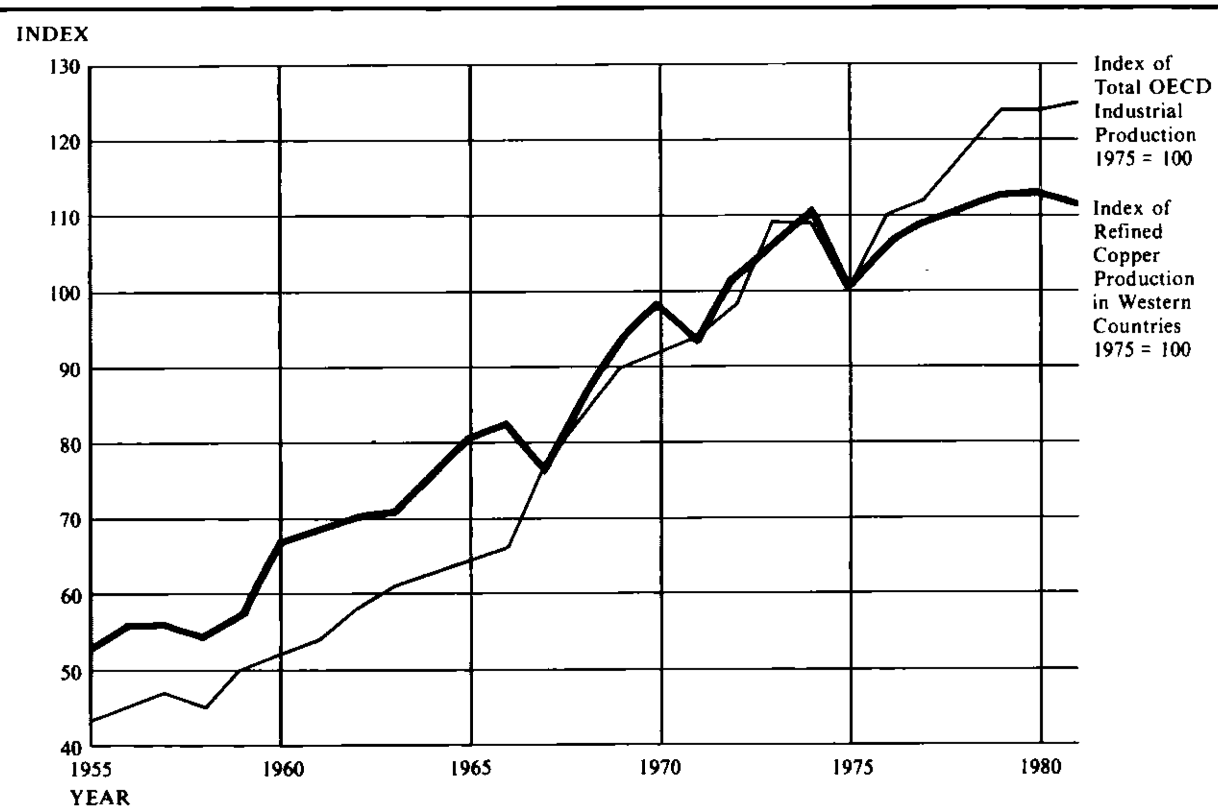
- **electrowon copper cathode:** generally of a similar quality to electrorefined copper cathode. It is produced by electrically depositing copper from a leach solution onto a cathode. This product is in general use for fabrication, with the exception of certain limited electrical applications.

Gold and silver present in copper concentrate may be recovered by separate treatment associated with electrowinning of copper. Processing at Olympic Dam will result in production of either high quality electrowon copper cathodes or blister copper.

The main consumers of copper are the more developed industrial economies. In 1980, 53% of end use consumption was in electrical applications, 21% in general and industrial engineering, 12% in building and construction, 11% in the transport industry, and 3% in other applications. Within each of these sectors, copper and its alloys have a wide variety of applications. Minor uses include coinage, ordnance and agriculture. About 70% of world copper consumption is as copper metal, with most of the remainder consumed as alloys, mainly brasses, bronzes and cupro-nickels, with small quantities used in the manufacture of chemicals.

Copper possesses high electrical and heat conductivity, corrosion resistance, and good alloying, rolling and drawing qualities. The main substitutes for copper are aluminium for power cables, plastic for household water piping, and optical fibres for telecommunications. Additional substitution is expected to be limited, although increased efficiency in construction design and transport applications may continue the trend towards a reduced weight of copper per component unit produced. Extensive research into the development of new copper alloys is being directed towards retaining and extending markets, particularly in general engineering applications.

Long-term forecasts of the demand for copper are based on the relationship between resource use and income. The intensity of use of copper declines as economies mature, industrial production rises, and efficiency of use increases (Figure 1.7). Forecasts of industrial production growth over the period to 2000 indicate that growth will average 25 to 30% below the 1951 to 1975 annual rates. The average growth rate of copper consumption is forecast at 2.6% per annum to the end of the century while the upper and lower limits for growth rates are forecast to be 3 and 2% respectively.



Source: OECD (1982), Metallgesellschaft (1980)

Figure 1.7

RELATIONSHIP OF WESTERN WORLD COPPER PRODUCTION TO OECD INDUSTRIAL PRODUCTION

Using the figure of 7.3 million tonnes as the average annual refined copper consumption for the western world from 1978 to 1981, the forecast of copper demand in 1990 is 9.4 million tonnes, and in 1995, 10.7 million tonnes. The incremental consumption is 2.1 million tonnes and 3.4 million tonnes respectively. If mine production is to satisfy 85% of this increment, new mine production required to 1990 is 1.8 million tonnes per annum, and to 1995, 2.9 million tonnes per annum (assuming no closure of existing operations). These significant increases in copper demand, plus any loss of production resulting from closures, must be met by new supply sources and, where feasible, by expansion of existing operations. The long lead time involved between the discovery of significant deposits and large-scale commercial production means that the deposits likely to be developed to satisfy this incremental demand will generally be among those currently known. The projects likely to be developed first are those which are viable on the current cost structure of the industry.

Uranium: use and markets

Uranium is a relatively common element, about as abundant as tin and about one thousand times more abundant than gold. Its industrial use is mainly confined to the production of electricity in nuclear power stations, although other important applications include the production of radio-isotopes used extensively in medical, industrial and scientific research.

Naturally occurring uranium contains three separate isotopes. One isotope (uranium-235) has the unique property of being able to undergo controlled nuclear fission, releasing very large amounts of energy. This energy, released in a nuclear power reactor, provides the heat for steam-raising and the production of electricity by conventional turbo-generators. Other power stations use coal or hydrocarbon fuels to provide this heat.

Naturally occurring uranium contains approximately 0.7% of the uranium-235 isotope. Most nuclear power reactors which are currently in operation or in the planning stages require uranium fuels enriched to about 3% uranium-235. Most uranium concentrate (or yellowcake) is chemically refined and processed into uranium hexafluoride (UF_6) at a conversion plant, and then further upgraded in an enrichment plant by isotopic separation. The enriched UF_6 is sent to a fuel fabrication plant where the fuel assemblies (which form the core of the nuclear power reactor) are manufactured. None of these activities are presently carried out in Australia.

At the end of 1981, there were 500 nuclear power reactors in operation, under construction, or on order, in thirty countries (including Communist countries); 272 units with a total capacity of 153,772 MW were commercially operable. As a comparison, this is more than seventy-five times the present capacity of the South Australian electricity generating system. There will be a marked increase in the number of operable nuclear power reactors over the next three to four years, as units presently at advanced construction stages are commissioned. Total nuclear generating capacity for all user countries except the United States has increased steadily. In the latter, total nuclear generating capacity has declined since 1977-1978, mainly as a result of the cancellation of units previously on order. These cancellations result principally from decreased economic growth leading to reduced forecasts of future electricity demand, and from increased construction costs due to regulatory delays, inflation and high interest rates.

In the United Kingdom, some thirty thermal nuclear power stations have been designed and constructed, representing almost 500 reactor years of operational experience since the 1950s. In 1980, the British Government announced a further expansion of the nuclear power industry, designed to raise the proportion of total electric power generated in the United Kingdom by nuclear reactors from 20 to 30%.

Estimates of future nuclear generating capacity and associated uranium demand were published by the Uranium Institute, London (1981). The Institute's most probable forecast of uranium requirements of western world countries, together with estimates of the supply capabilities of existing uranium mines and those under construction, are shown in Figure 1.8. These forecasts are based on an appraisal of each country's ability to implement its nuclear power programme. In the case of the United States, it is assumed that only currently operating and committed reactors will contribute to the forecasts of total installed capacity by 1995. In other countries new reactor commitments are expected.

Recent economic conditions of recession, depressed total world energy consumption growth rates, and lower electricity growth have reduced the level of commitment to, and resulted in deferment of, both coal and uranium fuelled power stations. Uranium spot prices have fallen, although consumption is increasing. Some high cost uranium producers, particularly in the United States, have withdrawn from the industry, while others have reduced output. Some new mines with favourable cost structures have been brought into production. Stocks continue to be high, but a balance between western world consumption and production of uranium is expected to be established during the mid-1980s.

However, by the late 1980s, the depletion of reserves in existing mines, coupled with increasing demand as nuclear power capacity continues to expand, will provide opportunities for competitive new uranium supply capacity to be established.

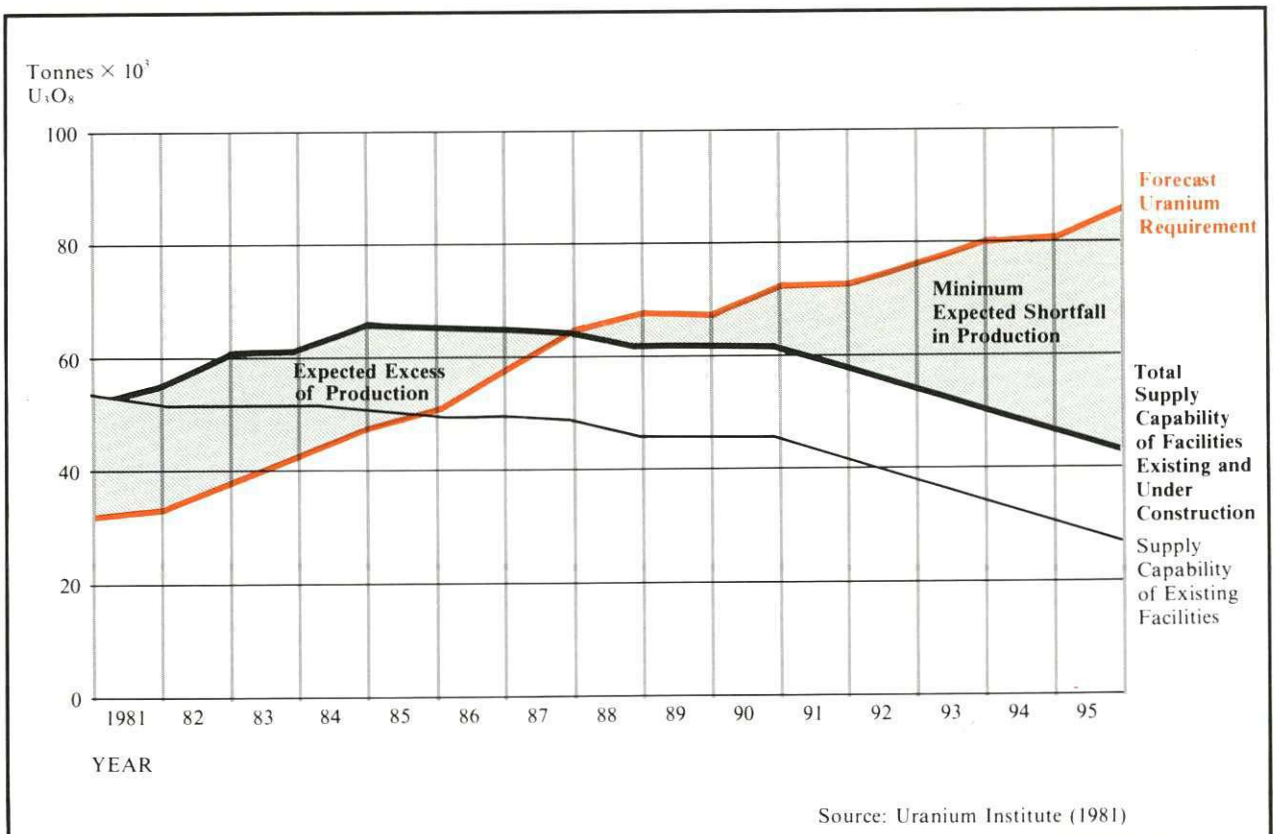


Figure 1.8
URANIUM SUPPLY/DEMAND COMPARISON

1.6 CONSEQUENCES OF NOT PROCEEDING WITH THE PROJECT

The copper market

If the Olympic Dam Project did not proceed, the effect on the copper market would be minor. Although at a production rate of 150,000 t/a the Project would be a very large individual producer, this production would still only represent about 2% of western world copper production. There are a number of other large projects at varying stages of development throughout the world, many situated in South America (notably in Chile, Peru and Argentina). Copper production foregone at Olympic Dam would therefore be replaced by expansions of existing projects, or by the development of new projects.

There are no alternative copper projects in South Australia, and very few projects within Australia, which could even partially replace the proposed copper production at Olympic Dam. Replacement production would therefore be substantially sourced overseas, and the benefits of development lost to this country.

The uranium market

The impact of not proceeding with the Olympic Dam Project would be more significant on the uranium market. At the expected production rate of 3,000 t/a, Olympic Dam would represent about 7% of present world production. As with copper, there are a number of alternative projects awaiting development, particularly in Canada and as a by-product of gold mining in South Africa. If uranium were not produced at Olympic Dam, uranium demand would be met by increased output from existing projects or by the development of new projects.

South Australia has alternative sources of uranium production, but these are not of sufficient size to be able to replace the uranium production proposed at Olympic Dam by increasing their planned capacity. There could be some increase in production in mines elsewhere in Australia which could partly replace Olympic Dam uranium. However, a significant proportion of the replacement production could occur in the overseas countries nominated above, and the benefits of development would accrue to these countries.

The South Australian economy

The economic benefits for South Australia estimated to accrue from the Project are very substantial and include:

- the creation of between 9,300 and 18,600 new jobs in South Australia during the construction phase;
- an increase in the total output of the South Australian economy of between $230 million and $640 million per annum during the construction phase;
- the creation of between 5,700 and 8,330 new permanent jobs in South Australia during production at Olympic Dam;
- an increase in the total output of the South Australian economy of between $88 million and $213 million per annum during production;
- receipt by the State of South Australia of between $18 million and $28 million per annum in royalties from the Project during production;
- substantially increased tax revenue for the State of South Australia and the Commonwealth from payroll, corporate, sales and personal taxes;

- a significant strengthening of the South Australian economic base: the Project will add a new industry to the State and increase the value of South Australian exports by between 30 and 40%;

- the development of a major new population centre in the north of the State.

Should the Olympic Dam Project not proceed, these benefits would be lost to the South Australian economy. Neither the jobs nor the capital would be readily transferred to other projects or production areas in this State, and there are no alternative developments with the same potential for employment in South Australia, particularly in a long-term context. Funds for the Olympic Dam Project will probably come mainly from overseas sources, and would be dedicated to the development of the specific resource at Olympic Dam and, thus, not be transferable to other employment creating projects. These funds would neither compete with, nor be available for, alternative projects or other domestic purposes in South Australia, as the Olympic Dam Project will be competing on international financial markets with similar projects in other countries.

1.7 STRUCTURE OF THE REPORT

The structure of this Draft EIS has been derived from consideration of the most effective way to describe the scale and physical characteristics of the Olympic Dam Project, and those environmental factors which studies by the Joint Venturers' consultants have identified as the most relevant in assessing the environmental effects of the Project.

Major elements of the Project have been broadly categorized as follows:

- surface facilities required for mining and processing

- underground development

- effluents and emissions arising from the above, with particular reference to the movement of radioactive material through the mining and processing stages

- supporting services, with particular reference to major supply corridors to and from the site

- accommodation of the workforce

- expenditure of funds and creation of employment opportunities.

The physical elements of the Project are described in detail in Chapter 2.

Subsequent chapters (Chapters 3 to 12) describe the effects of the Project on the existing environment, with environmental aspects grouped according to their relationship to major elements of the Project as shown in Table 1.2. Each chapter commences with a summary, followed by a description of any relevant methodological or other background information.

Of necessity, the document contains a significant number of technical terms which may not be familiar to readers, and a glossary of these technical terms has therefore been included as an appendix. Technical abbreviations used in the document are contained in a second appendix, while references are brought together as a third appendix, categorized by the chapter in which they occur. The people involved in the preparation of the Draft EIS are listed in a fourth appendix. Additional technical reports used in the preparation of this Draft EIS have been submitted to the Department of Home Affairs and Environment, and to the Department of Environment and Planning, and inquiries relating to this material should be directed to these departments.

Table 1.2 Report structure

Major Project element	Environmental considerations	Chapter number
Surface development	. Terrestrial environment	3
	. Land use	4
	. Aboriginal environment	5
Underground development	. Geology . Hydrogeology . Seismicity	6
Effluents and emissions from the development	. Tailings storage	7
	. Air emissions . Solid waste . Noise	8
	. Radiation	9
Infrastructure development	. Power supply . Water supply . Other infrastructure	10
Community and economic development	. Social effects . Town design	11
	. Economic effects	12

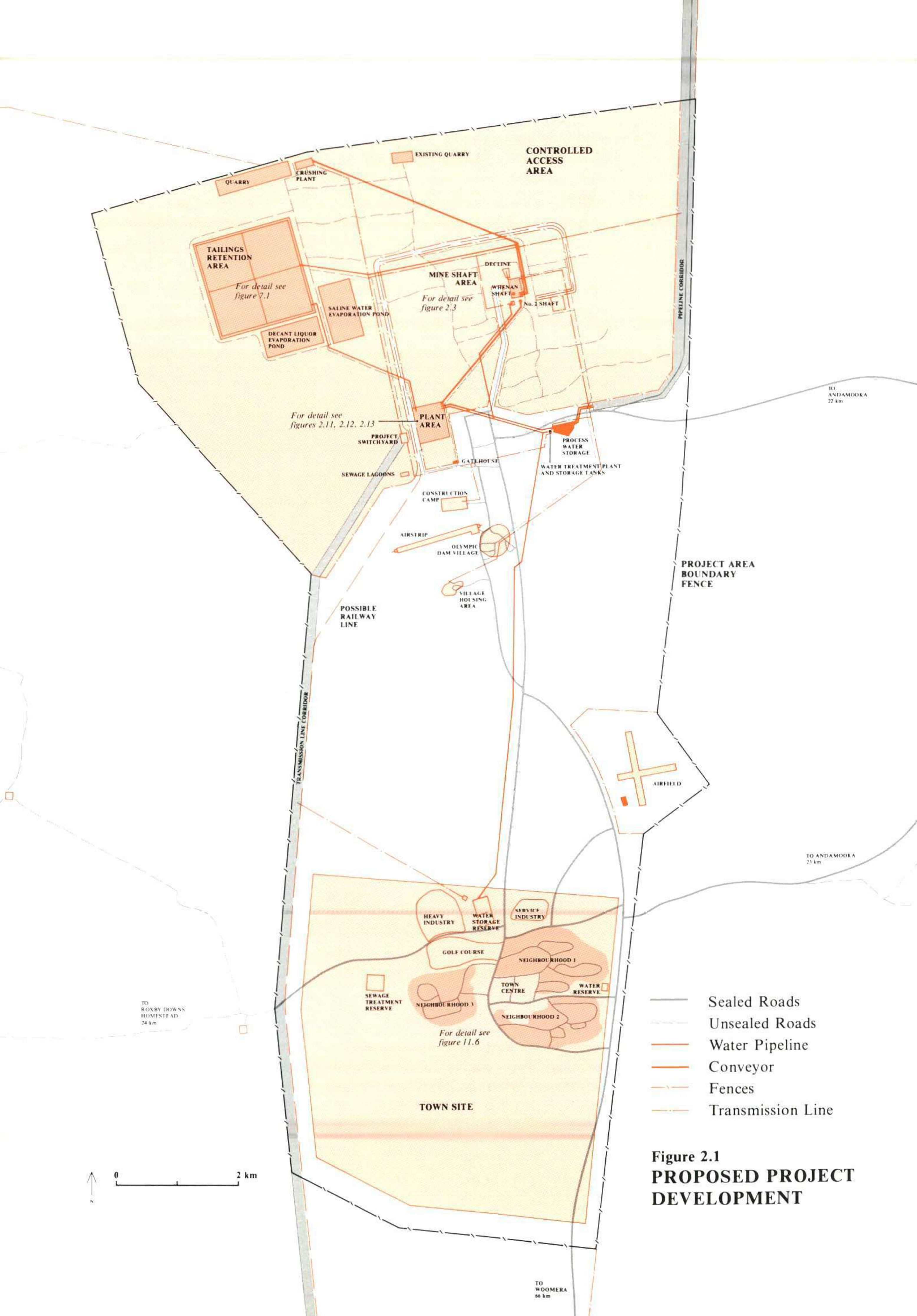


Figure 2.1
PROPOSED PROJECT DEVELOPMENT

CHAPTER TWO

Project Description

2.1 INTRODUCTION

The Olympic Dam Project will be an integrated production complex comprising an underground mine and associated quarry, a metallurgical treatment plant, workshops, stores and offices. Support facilities will include a town, power and water supplies, communication services, and transportation facilities. Development planned for the Project site is shown in Figure 2.1. This chapter describes the various Project elements associated with the Project Area and the alternatives which have been considered in the decision making process.

This chapter commences with a brief summary of the geology of the deposit (Section 2.2), as the location and type of mineralization govern the mining and ore processing methods which will be employed.

Section 2.3 presents the approaches currently favoured for mining the ore. Approximately 6,500,000 t of ore will be mined each year by proven mining methods including open stoping, room-and-pillar, and post-pillar cut-and-fill. The particular method used will depend on the varying ore types and geological setting. Access to the mine will be provided through two shafts and a decline. Ventilation will be provided to underground workings through the access openings and ventilation raises at a rate of approximately 2,200 m^3 of air per second.

Section 2.4 discusses the methods of ore processing which are presently being evaluated, using ore samples from drill core and from the Whenan Shaft. The plant may use any one of the methods being considered, or a combination of these, to ensure the most efficient treatment. All proposed ore treatment methods include a concentrator for grinding and flotation of ore to produce a sulphide concentrate which will contain most of the copper from the ore. This concentrate may be roasted, leached and electrowon (RLE); smelted and converted (SC); or pressure leached and electrowon (PLE). The SC circuit will produce blister copper containing gold and silver, while both the leach circuits will produce electrowon copper cathode with gold/silver bullion as a by-product. Tailings from the concentrator will be treated to produce uranium oxide by atmospheric leach (AL) or pressure leach (PL) circuits using sulphuric acid as the leaching agent.

The effluents and emissions resulting from processing the ore are discussed in Section 2.5. The main component of process waste is the tailings, which will be placed in a tailings retention system (TRS) by subaerial deposition. A more detailed description of the TRS is given in Chapter 7. Other sources of wastewater are also identified, as well as sources of air emissions, solid waste and noise.

The infrastructure requirements for the Project are discussed in Section 2.6. Water will be supplied through two pipelines from the Great Artesian Basin at the rate of about 33 ML/d. A portion of this water will be desalinated to provide potable water to the town, plant, mine and offices. A 132 kV power transmission line will be constructed from Woomera and a 275 kV line from Port Augusta to provide electrical power to meet Project needs. Transportation infrastructure will include upgrading the existing road from Woomera, construction of a new airport near the town, and provision for a possible rail spur from Pimba.

Section 2.7 describes the general design of the town, to be established about 10 km south of the plant. It is planned to accommodate approximately 9,000 people initially, and will be administered by a municipality. Services, including schools, police and fire protection, social and medical services, and normal public amenities will be provided. A more detailed description of the town for specific impact assessment purposes is provided in Chapter 11.

Alternatives considered in relation to the proposed development are presented in Section 2.8. The option of extracting only copper and precious metals is discussed, as well as other possible mining methods. Alternative water supplies to that of the Great Artesian Basin are examined; a comparison is made between the subaerial tailings deposition method and other methods of deposition which were considered; and there is a discussion of the range of options considered in town development and in the location of town sites.

2.2 GEOLOGICAL SUMMARY

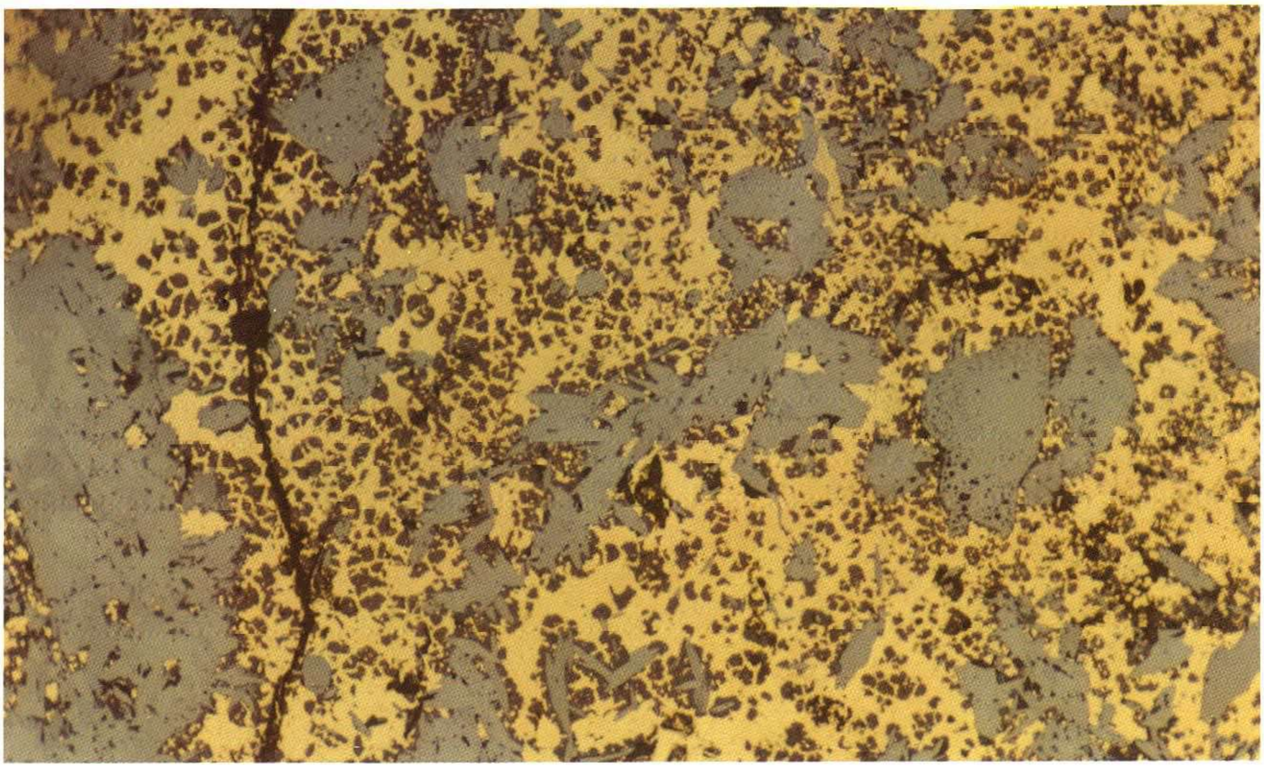
The following brief description of the orebody geology and mineralogy is provided, to indicate the depth of the deposit and the characteristics influencing the mining and ore processing methods selected. A more detailed description of the geology is provided in Chapter 6.

The Olympic Dam copper-uranium-gold deposit occurs beneath flat-lying barren sedimentary rocks, ranging in thickness from 270 to 370 m. The mineralization consists of a complex association of fine grained copper sulphide minerals, uranium minerals, gold, silver, and rare earth minerals, contained in a sequence of coarse grained sedimentary rocks (breccias) more than 1 km thick. Two principal types of mineralization are present in the breccia sequence:

- Type 1 consists of bornite, chalcopyrite, and pyrite, with associated uranium and rare earth minerals and gold. The main gangue constituents are hematite, quartz and sericite, with lesser amounts of fluorite, carbonate and chlorite. Ore zones of this type range from 30 to 250 m in thickness, are usually flat-lying or gently dipping, have a wide areal extent, and occur throughout the area of mineralization.

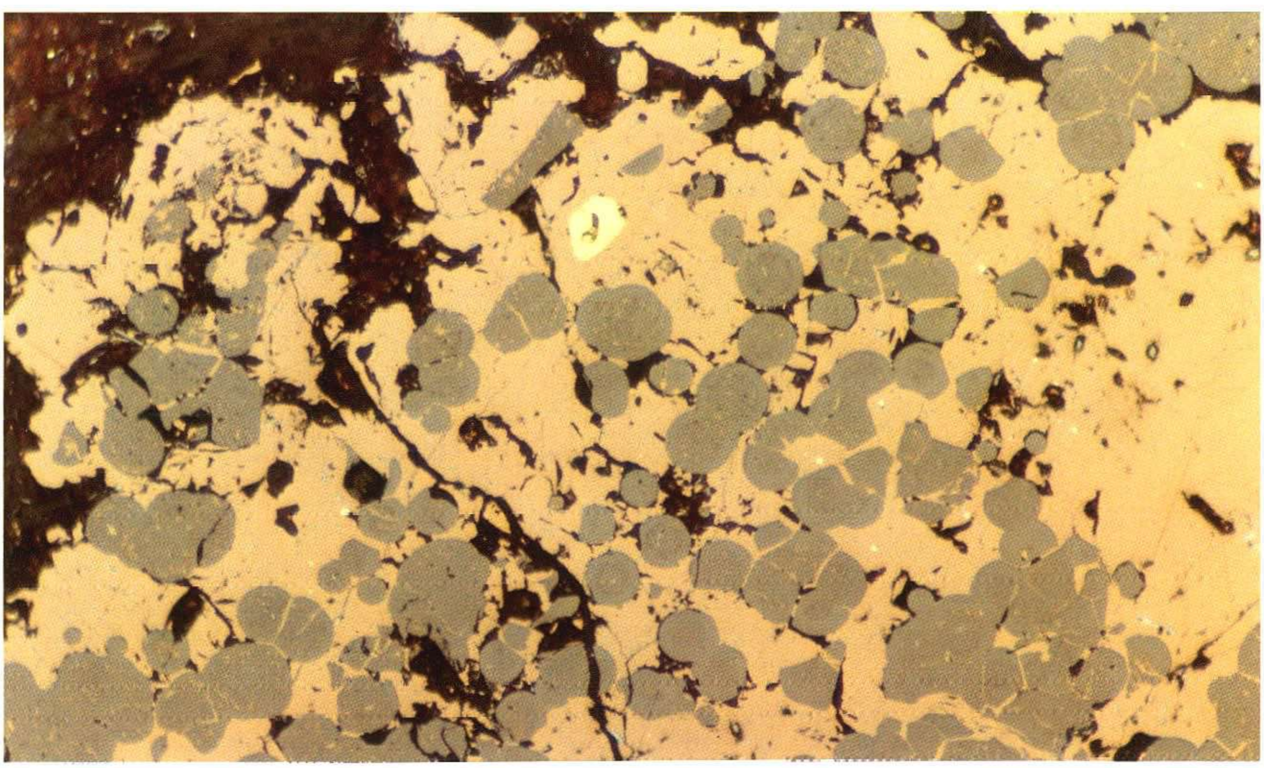
- Type 2 consists of chalcocite and bornite, with associated uranium and rare earth minerals and gold. The main gangue minerals are hematite and quartz, with lesser fluorite and minor sericite. Carbonate and chlorite are not present. Ore zones are much thinner than Type 1 zones, ranging from 5 to 50 m in thickness, and are confined to a linear north-west trending zone overlying Type 1 mineralization.

The two photomicrographs presented in Figure 2.2 are typical of the sulphide/uranium associations for both ore types. As a guide to scale, the area of the top photograph is



Chalcopyrite (yellow) with fine grained inclusions of uraninite (brown) and coarser hematite (grey).

0 50 μm



Bornite (pale pink) with rounded inclusions of uraninite (grey) and pyrite (pale yellow) in a quartz, sericite gangue (top left corner).

0 20 μm

Figure 2.2
PHOTOMICROGRAPHS OF SULPHIDE/URANIUM ASSOCIATIONS

approximately equal to 1/40th the area of the head of a pin, while the area of the sample in the bottom photograph is about 1/200th of a pin head in size.

2.3 MINING

Proposed surface development for the mine is illustrated on Figure 2.3. The mine access points (Whenan Shaft, No. 2 Shaft and decline) are shown, as well as the surface stockpiles for below ore grade material and mullock, the infrastructure connections for conveyors, rail and road, and the surface support facilities such as workshops, storage areas and car parks. Approximately 6,500,000 t of ore will be mined each year, on a basis of three shifts per day, five days per week (for a total of 250 days each year).

2.3.1 Mining method

The method of mining selected for any particular ore zone will be dependent upon the size of the ore zone, depth, ore grade, geological properties and other factors. Proven mining methods will be used, and those currently favoured (based on present knowledge of likely mining conditions) include open stoping, room-and-pillar, and post-pillar cut-and-fill. An isometric view of the pattern of mineralization and mine development is given on Figure 2.4, with each of the preferred mining methods shown in its correct relationship to the size of ore zones. The connection of the mining areas to the mine access points is also indicated. The applicability of mining methods to ore zone types is discussed below, together with a general description of each mining method.

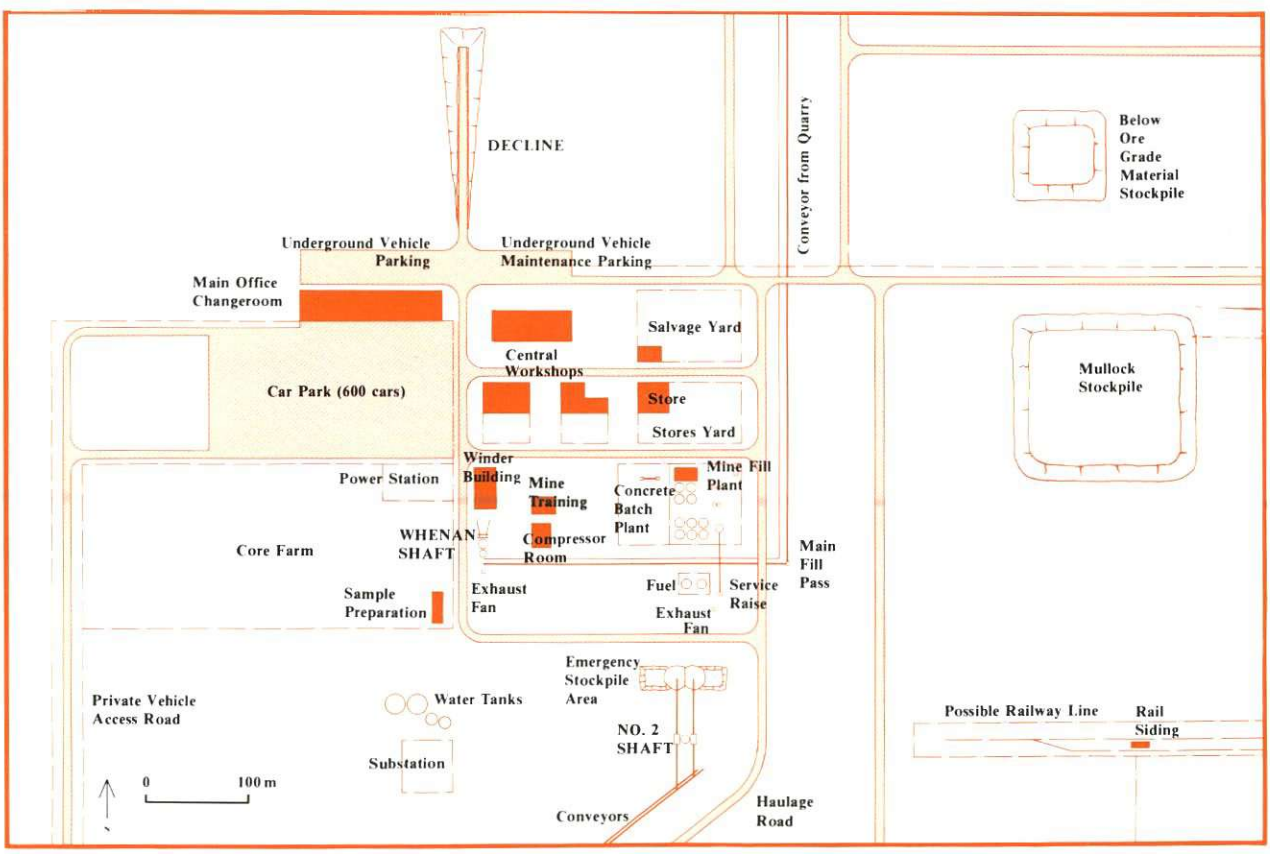


Figure 2.3
MINE SHAFT AREA: PROPOSED SURFACE DEVELOPMENT

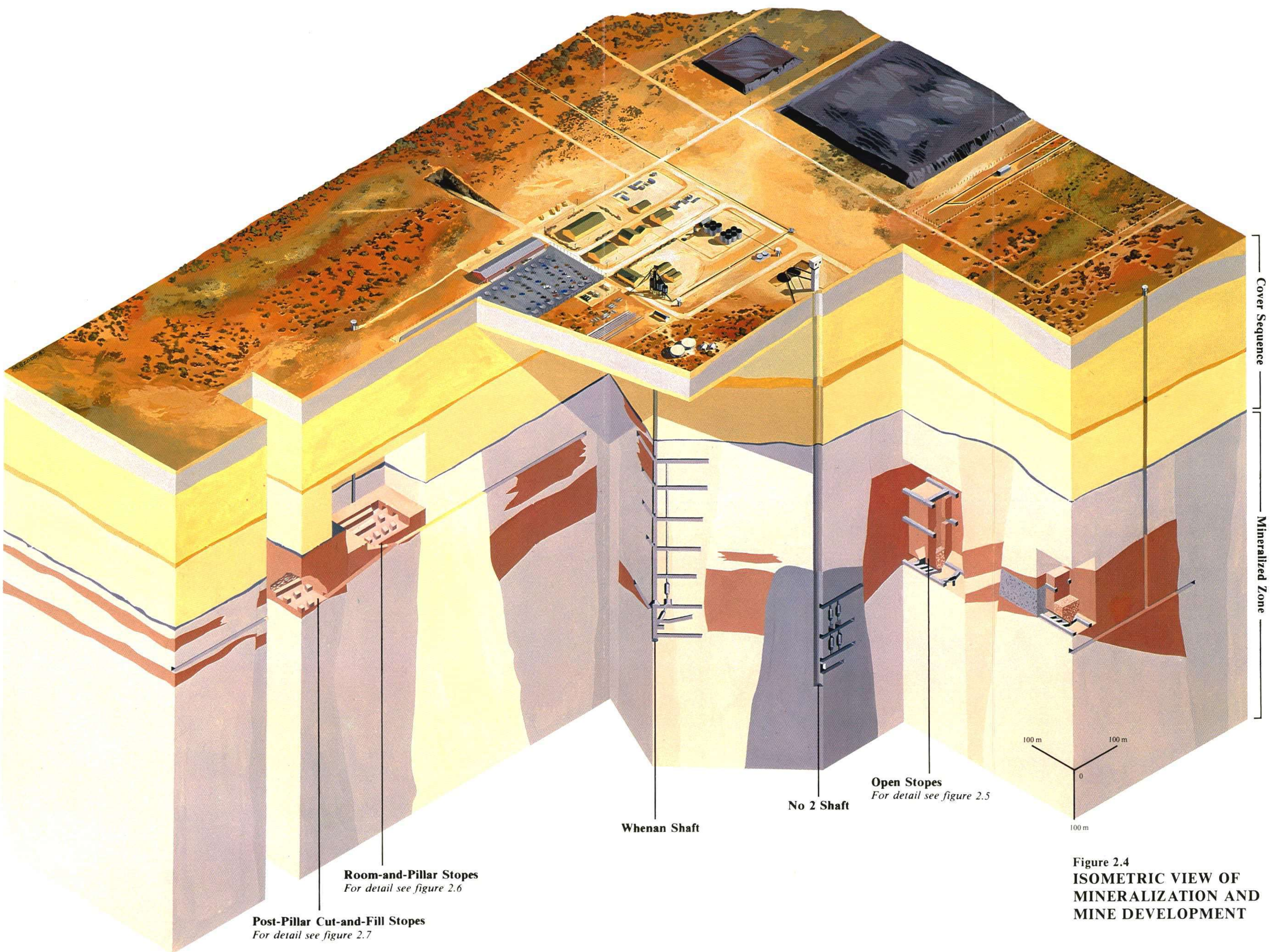


Figure 2.4
ISOMETRIC VIEW OF MINERALIZATION AND MINE DEVELOPMENT

Open stoping

In ore zones thicker than 50 m, an open stoping method with back-fill will probably be used. Each main ore block will be divided into alternating stope panels and main transverse pillars, each about 120 m wide. The main transverse pillars will provide regional ground support while the stope panels are being mined. The panels and main pillars will each be subdivided into stoping blocks (typically 40 by 40 m), which will run the full height (up to 120 m) of the mining block as shown in Figure 2.5. The panels and main pillars will both contain remnant pillars which assist long-term ground support. These will be extracted by firing explosives in large diameter blast holes once both the panels and main pillars have been mined and back-filled. Primary stopes will be mined first and filled, with the secondary stopes then being extracted individually. Following this, the main pillar panel will be extracted in a similar way to the stoping panel. Mass blasting will be used wherever possible, to limit the frequency of firing. Ore will be extracted from the stopes at the drawpoints by diesel or electric load/haul/dump (LHD) units. The LHD units will dump into ore passes, which will feed the haulage level. Once a main ore block has been mined, including remnant pillars, extraction level remnants will be mined to the extent which ground conditions permit.

Stopes will be filled with any one or a combination of quarried or waste rock, quarried and crushed aggregate, or hydraulic fill with or without cement, depending on extraction ratios and support requirements. Crushed and screened rock will be delivered to the main fill passes via conveyor from the quarry stockpile. Rock will be transported by conveyor or LHD units from the base of the central fill passes to a raise-bored hole in the exploration level above the stopes, where it will be discharged through the raise into the stopes. Hydraulic fill will be delivered to the stopes through a pipeline system.

Room-and-pillar

Ore zones which are relatively thin (less than 10 m in thickness) and flat-lying (less than 25° dip) will be mined by room-and-pillar methods illustrated in Figure 2.6. Using this method, rooms approximately 5 m wide and 5 m high will be driven along the ore strike. Pillars will be formed by driving breakthroughs between rooms, with the resulting island pillars being approximately 4 by 6 m. Stoping will utilize mechanized drill jumbos and conventional blasting techniques.

Ore blocks will normally be developed before production commences, to ensure through-ventilation. Air will enter the rooms from the access ramp and be passed directly from the rooms to an exhaust airway.

The room-and-pillar method is to be used for blocks up to 10 m thick. For the blocks between 5 and 10 m high, the top 5 m of the room will be extracted first so that the top can be rock bolted to stabilize the roof section if necessary. The floor will then be benched down to the limit of the ore.

Post-pillar cut-and-fill

For ore blocks between 10 and 25 m thick, mining will typically be by the post-pillar cut-and-fill method shown in Figure 2.7. Stope development will commence at the base of the ore block and proceed upwards. The first 6 m above the base of the block will be mined in a manner similar to the room-and-pillar method. The lower 3 m of the initial slice will then be filled, and mining will proceed in 3 m high slices. Roof support will be by island pillars approximately 6 m square, with the actual size depending on rock mechanics investigations and site experience.

Back-filling allows the vertical progression of the stoping operation, and provides lateral support for the post-pillars which are formed from the initial island pillars as mining progresses upwards. Fill will consist of waste rock or quarried rock dumped in the stope

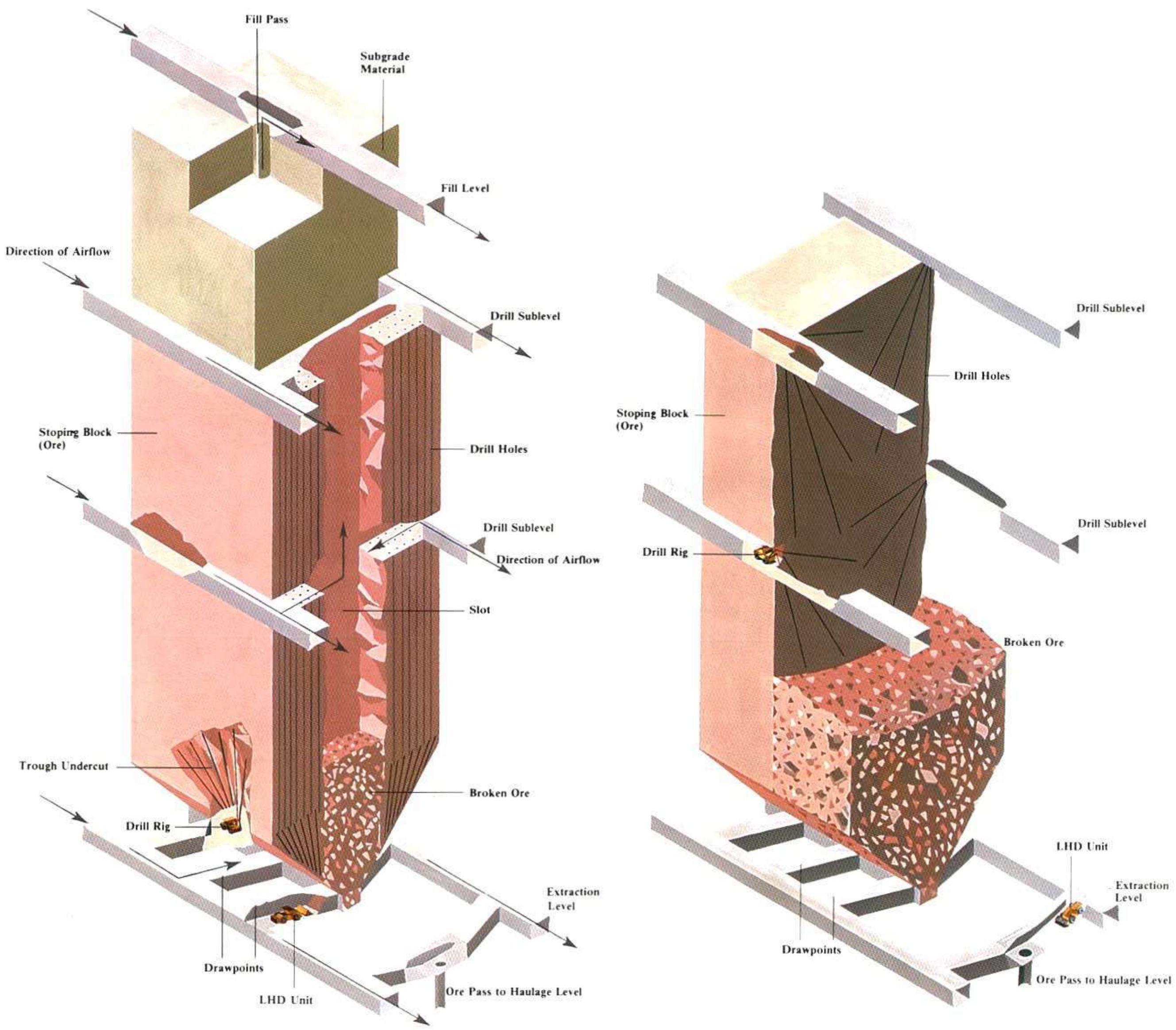


Figure 2.5
TYPICAL OPEN STOPE MINING

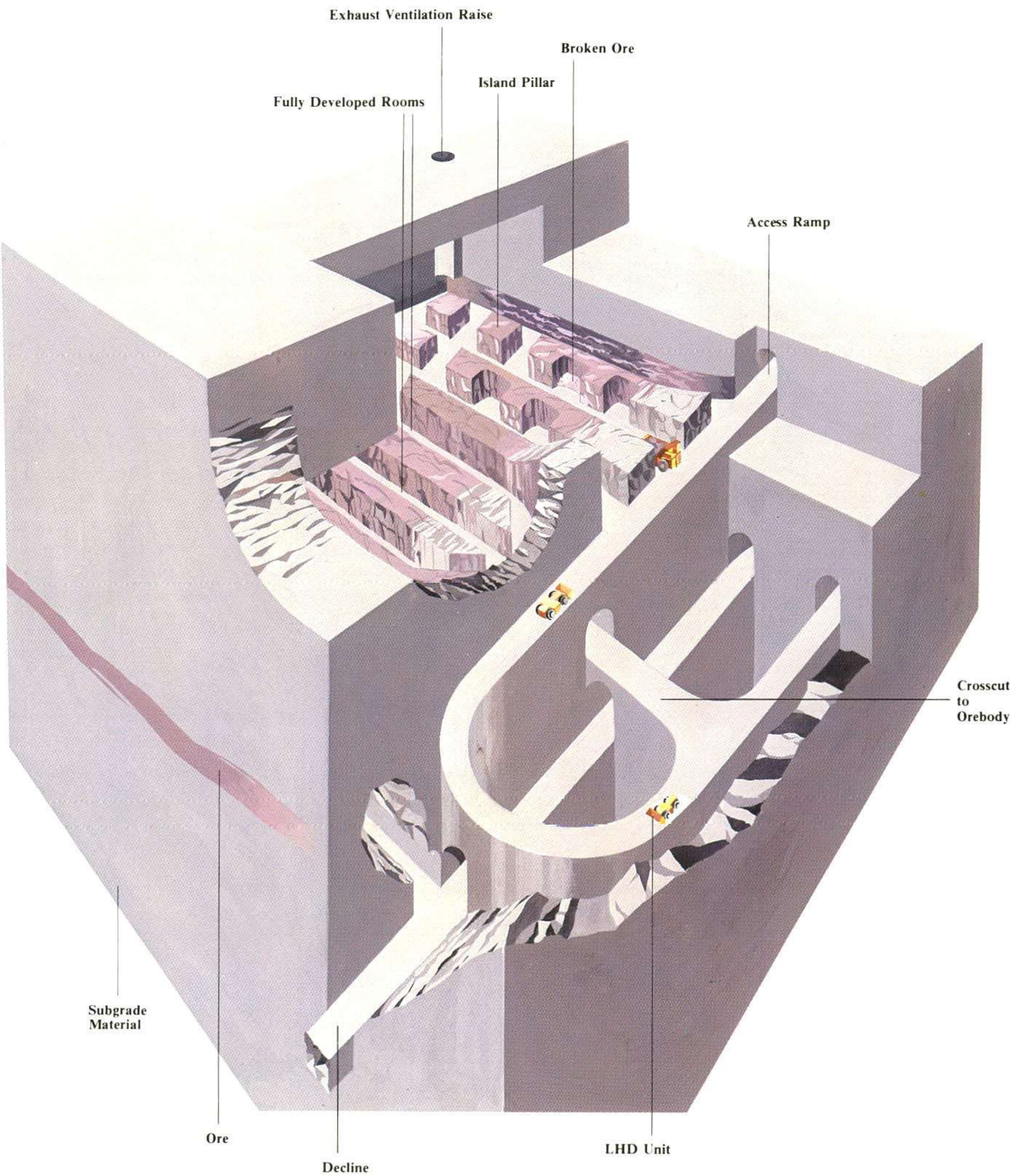


Figure 2.6
TYPICAL ROOM-AND-PILLAR MINING

by truck and spread by bulldozer, and hydraulic fill piped to the stope. The top 0.3 m of hydraulic fill placed in each lift will be cemented to reduce dilution of ore due to the presence of fill. Cementing of this top layer will also provide a better working surface for mobile equipment. Three metres will be left between the fill and the backs of the stopes at the completion of each fill cycle, to allow room for spreading the fill. Working on top of the cemented fill, the mining of the ore will proceed upwards to the top of the ore block.

2.3.2 Access

Three mine access openings are planned (Figures 2.3 and 2.4). The first of these is the Whenan Shaft which is currently being developed. It is a 6.5 by 3.5 m vertical shaft with a possible ultimate depth of 730 m. This shaft is partly lined and shotcreted, and could be used for ore haulage, for waste rock hoisting (with on-surface facilities to recycle mullock for underground fill), and for mine servicing.

The second opening will be a decline approximately 3 km long, 7.5 m wide, and 4.5 m high, with a slope of 11%. This will be developed using either a continuous rock cutting machine or by conventional means (drill and blast). The base of the decline will join the internal ramp system, providing access to the various levels of the mine for the transport of men, equipment and material.

The third mine access opening will be the No. 2 Shaft, which is expected to be a vertical circular shaft 7.5 m in diameter and 800 m deep, lined with shotcrete. Its main function will be for ore haulage, using wirerope-guided skips.

2.3.3 Ventilation

The mine ventilation system will be designed to meet standards set by all the relevant statutory authorities in relation to concentrations of radon daughter products, diesel fumes, blasting fumes, dust, and the maintenance of satisfactory working conditions underground.

Generally, maximum ventilation efficiencies will be achieved by:

- segmenting the stoping areas into ventilating districts
- back-filling mined out stopes to reduce the potential radon daughter generating areas (with the general exception of room-and-pillar stopes)
- using a 'once through' ventilation system
- avoiding 'series' ventilation to ensure that fresh air is supplied to each working place
- limiting the air residence time according to requirements to reduce radon daughter build-up in the air
- using a push/pull ventilation system for flexibility and to assist in ventilation control
- preventing recirculation of air
- ensuring water is kept away from intake airways wherever possible
- the effective use of water for dust suppression.

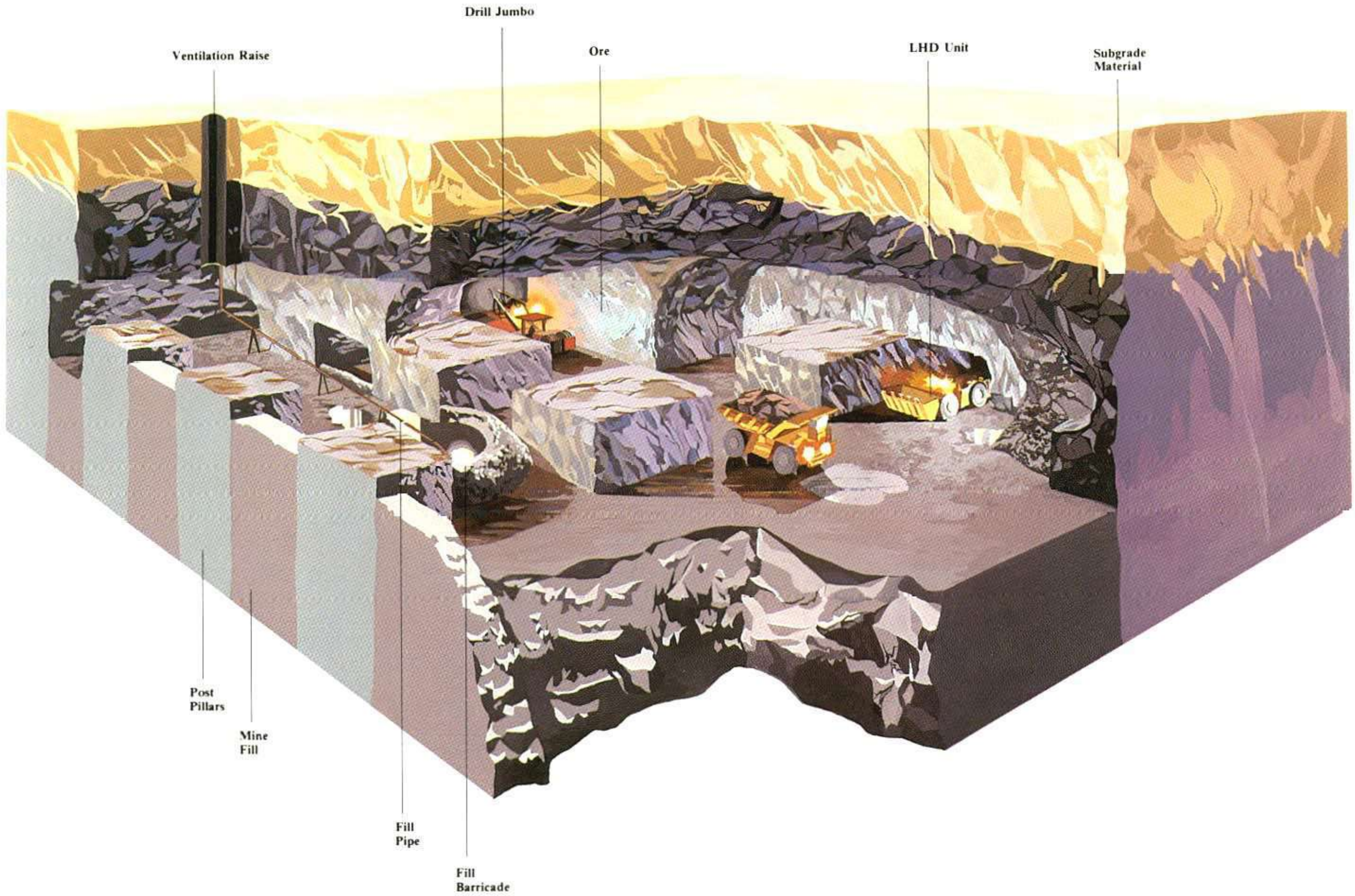


Figure 2.7
TYPICAL POST-PILLAR CUT-AND-FILL MINING

It has been estimated that approximately 2,200 m^3 /s of air will be required for mine ventilation. Air will be forced into the mine by intake fans, and drawn through the mine by exhaust fans (as shown schematically on Figure 2.8). Fans of similar capacity will be located on top of intake and exhaust raises situated around the perimeter of the orebody. Generally, air will be downcast on one side of the stoping area and upcast on the opposite side. The number of fans required will depend on the specific stoping layouts. The proposed volume circulation of air in the mine will be at least 8 t of air for each tonne of ore mined.

General design criteria for the ventilation system are as follows:

. air velocity in all transport and personnel access openings:	=	0.5 m/s
. air velocity in ore producing areas (not including mined out areas which will be sealed and kept under a negative pressure):	=	1 m/s
. air velocity in development ends:	=	0.5 m/s
. maximum air velocity in horizontal or decline intake airways where employees travel or work:	=	6 m/s
. air velocity in horizontal or decline return airways:	=	4 to 10 m/s
. maximum air velocity in downcast service shaft:	=	10 m/s
. air residence time after contact with ore before reaching return airways:	=	15 mins.

All producing (stoping) areas will have through-ventilation. Dead ends, such as headings being developed, will be ventilated by forcing air through ventilation ducting to the face being advanced.

Air temperatures increase with depth, due to the geothermal gradient; therefore refrigeration of air may be required below the 600 m level, especially for large openings such as crusher stations, workshops, and long development ends.

2.3.4 Transportation

The decline and the Whenan Shaft will provide access for transporting personnel and materials to and from the mine. Material flow through the mine is shown schematically in Figure 2.9.

Ore will be hauled from the stopes to ore passes by diesel or electric LHD units. From the base of the passes, ore will be loaded by chute onto electrically driven ore trains, diesel or electric trucks, or conveyors, for transport to underground storage bins at the No. 2 Shaft. A single-level loading station will be situated at each shaft. Ore will be crushed to a size of less than 200 mm prior to loading into the ore skips for haulage up the shafts to the surface.

Mullock from the development headings will be trucked directly into the stopes as fill, or stockpiled on the surface to be reclaimed later for stope fill. Below ore grade material will be stockpiled on the surface for possible later treatment.

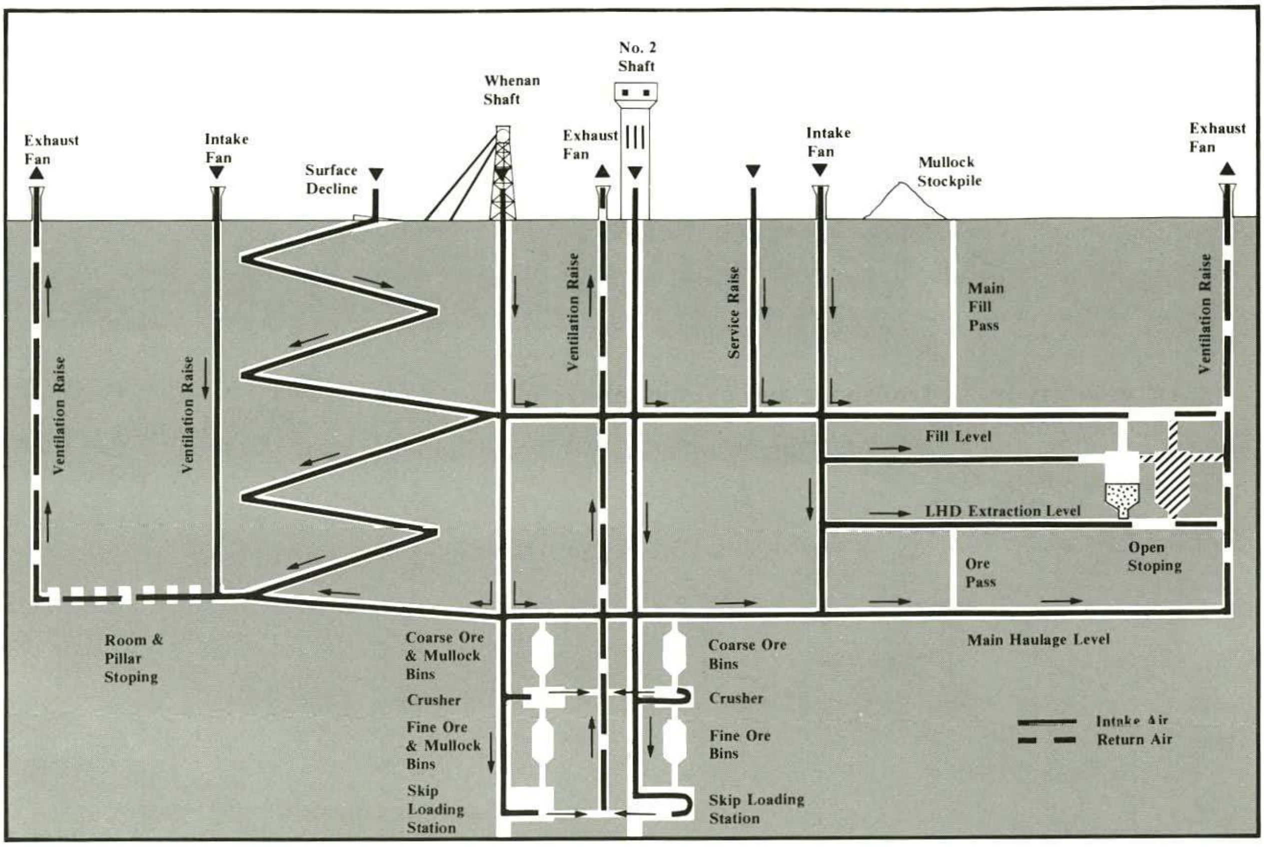


Figure 2.8
MINE VENTILATION: SCHEMATIC FLOW DIAGRAM

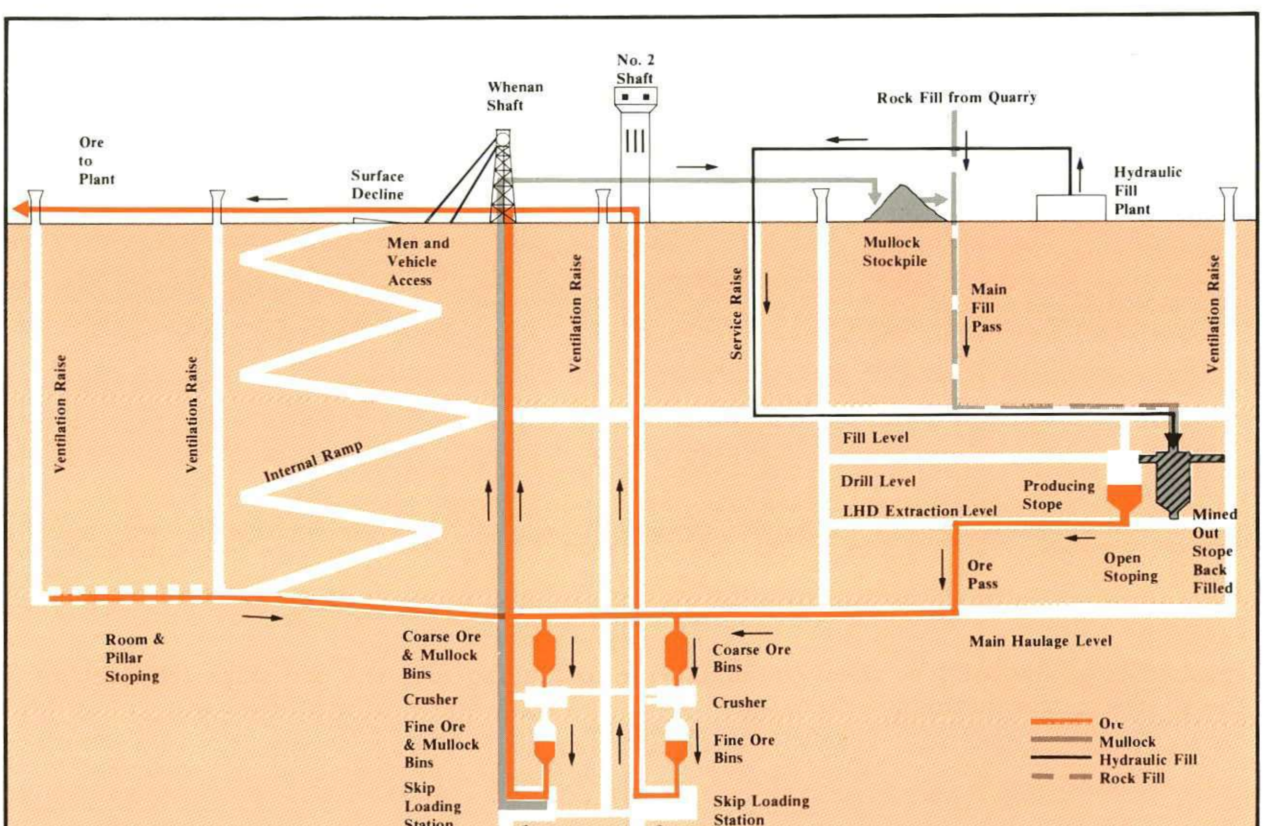


Figure 2.9
MINE MATERIALS: SCHEMATIC FLOW DIAGRAM

Mine consumables such as fuel, hydraulic fill, compressed air, and water for underground use, will be delivered through pipelines from the surface. Fuel receiving tanks will be located at refuelling bays.

Batch consumables such as explosives and concrete will be transported through the decline by vehicles specially allocated for these purposes. Articulated personnel carriers and conventional highway vehicles will be utilized for transporting personnel.

2.3.5 Ground support

Ground support comprises the measures used to provide adequate stability for underground openings. In general, the Olympic Dam rocks are competent and, based on evidence from drill cores and the Whenan Shaft development, natural ground conditions are expected to be good.

Mechanical support

Support for development headings will be provided where required either by rock bolts, shotcrete or steel sets, timber, or concrete. Operating stope support will be provided by large regional pillars and cable or rock bolts if necessary. After the adjacent stopes have been mined and filled, the regional pillars will be mined, with support being provided by the fill material.

Mine-fill

Fill is required in two of the three mining methods currently favoured (post-pillar cut-and-fill and open stoping). The room-and-pillar areas will generally remain unfilled, as the remaining rock pillars will provide any required long-term support.

Available sources of fill are:

- quarried dolomitic limestone
- mullock from underground development
- rejected below ore grade material
- dune sand
- hydraulic fill extracted from plant tailings.

The use of dune sand is not currently favoured because its rounded grain shape and size distribution are not suitable for a competent fill.

For post-pillar cut-and-fill, the fill used must be able to:

- be graded to form a level surface
- provide the lateral support required for the post-pillars
- provide a sound working floor for the large mobile equipment used
- allow the vertical progress of the mining operation.

These requirements would be satisfied by any of the following materials:

- crushed dolomitic limestone
- development mullock
- hydraulic fill recovered from plant tailings.

Hydraulic fill may require the addition of some cement to stabilize the working surface.

The open stoping method requires fill which is strong enough to provide regional support to the mined out area and able to stand vertically as a free face for more than 100 m, to ensure that fill does not dilute the ore being extracted alongside. To achieve this, the fill must not segregate during placement. It is particularly important that any hydraulic fill used in this method is free draining enough to allow its water content to drain off. Suitable fill for use with this method would be:

- crushed dolomitic limestone (mullock or below grade material) with cement slurry
- crushed dolomitic limestone (mullock or below grade material) with cemented hydraulic fill from tailings
- cemented hydraulic fill (if the vertical face is not too high).

The use of cement may be reduced in any of the above fills by replacement with ground smelter slag or fly ash, both of which exhibit pozzolanic properties.

A test programme to evaluate the suitability of various types of fill for use at Olympic Dam has been under way since March 1981, and will be continued in order to refine proposed filling techniques. It is expected that, under favourable conditions, up to 20% of tailings can be used as mine-fill.

Mullock stockpile

During the development stage of the mine, the mullock or waste rock will be hauled to the surface (as there is no requirement at that stage for underground fill) and will be stockpiled in an area to the east of the Whenan Shaft (Figure 2.3). The maximum size of the mullock stockpile will be about 1 million tonnes, which will occupy an area of approximately 150 by 150 m to a height of 20 m. The stockpile will not contain any significant quantities of ore grade material. As mining commences and rock-fill is required, the mullock will be recycled underground. The stockpile will therefore progressively diminish until all surface mullock has been used.

2.3.6 Quarry for mine-fill

The mining operation will include a dolomitic limestone quarry to be located approximately 800 m north of the northern boundary of the tailings storage area (Figure 2.1). This location has been selected because the dolomitic Andamooka Limestone is generally close to the surface in this area.

The products of the quarry will have several uses, including:

- mine-fill
- road surfacing material
- rock armouring for erosion control on tailings embankments
- rock cover for decommissioning of tailings areas
- concrete aggregate for general use.

Total production from the quarry will be about 3,500,000 t/a, with mine-fill constituting the primary use.

Operating conditions

The limestone quarry will be operated in a conventional manner. Overburden will be removed by bulldozers and scrapers, with limestone being drilled and blasted, and then extracted by a conventional truck and shovel operation. It is expected that some quarry operations will be carried out on a three shift per day basis while others, such as overburden removal, will be undertaken on a more intermittent basis. The distance from the quarry to the northern boundary of the town site is about 15 km. The attenuation provided by this distance, together with the intermittent nature of blasting, will prevent quarry operations from becoming a noise nuisance in residential areas. Further details of noise emissions are given in Chapter 8.

Rehabilitation

Rehabilitation of the quarry will be undertaken on a progressive basis as part of the environmental management programme required under Clause 11 of the Indenture Agreement. The batters at the quarry edge will be broken down and overburden will be respread and lightly ripped to provide seed traps, with some contouring if necessary to avoid erosion. Regeneration is expected to occur naturally, although reseeding of certain areas using indigenous seed stock may be necessary to aid natural revegetation.

2.3.7 Below ore grade material stockpile

In an underground mining operation, extensive surface stockpiling of material is not necessary. While some material which must be brought to the surface during the initial development period will be of sub-economic grade mineralized material, this stockpile will remain small as, during production, most material will be readily classified either as waste or as treatable ore. It is expected that about 150,000 to 200,000 t of this material will be stockpiled, which will occupy an area of approximately 60 by 60 m to a height of 20 m. This stockpile will be sited to the north of the mullock stockpile (Figure 2.3).

The grade of this stockpile will vary from time to time. On an incremental basis, it is economic to treat any material already mined and hoisted to the surface if its treatment cost is equal to, or less than, the value of the recoverable metal contained in the ore. Thus, it is not possible to predict the grade of the stockpile material, as this will be dependent on the current cost of treatment and on changing metal prices.

Drainage systems will divert surface run-off from surrounding areas away from the stockpile. Experience with the existing temporary ore storage area has shown that dusting of stockpiles does not occur. Even on reclaim, little dust is generated, due to the cementation which occurs in the stacked ore. Radon release is not expected to be a problem, as measurements made above the present ore stockpile (even in still air conditions) show only background radon levels. Nevertheless, conservative assumptions have been made in assessing emissions from stockpiles (Chapter 9).

The ore has a low sulphur content (in the order of 2%) and the sulphides are generally non-reactive in arid environments. It is not expected, therefore, that the stockpiles containing mineralized material will generate acidic run-off, and this expectation has been confirmed by experience with the present temporary ore stockpiles. The stockpiles will be bunded, however, to contain any particulates which might be washed off by rain.

2.4 ORE PROCESSING

Ore will be hoisted to the surface and transported to the metallurgical plant for treatment. The main components of the plant will be the concentrator, the concentrate processing circuit and the flotation tailings processing circuit, all of which will operate nominally for twenty-four hours per day every day of the year. Ore comminution and flotation cells in the concentrator will produce a bulk sulphide concentrate containing in excess of 90% of the copper and 70% of the precious metals. The flotation tailings will contain the bulk of the uranium.

Several methods of treatment are being considered for concentrate and flotation tailings processing. As shown on Figure 2.10, concentrates may be processed by one of three

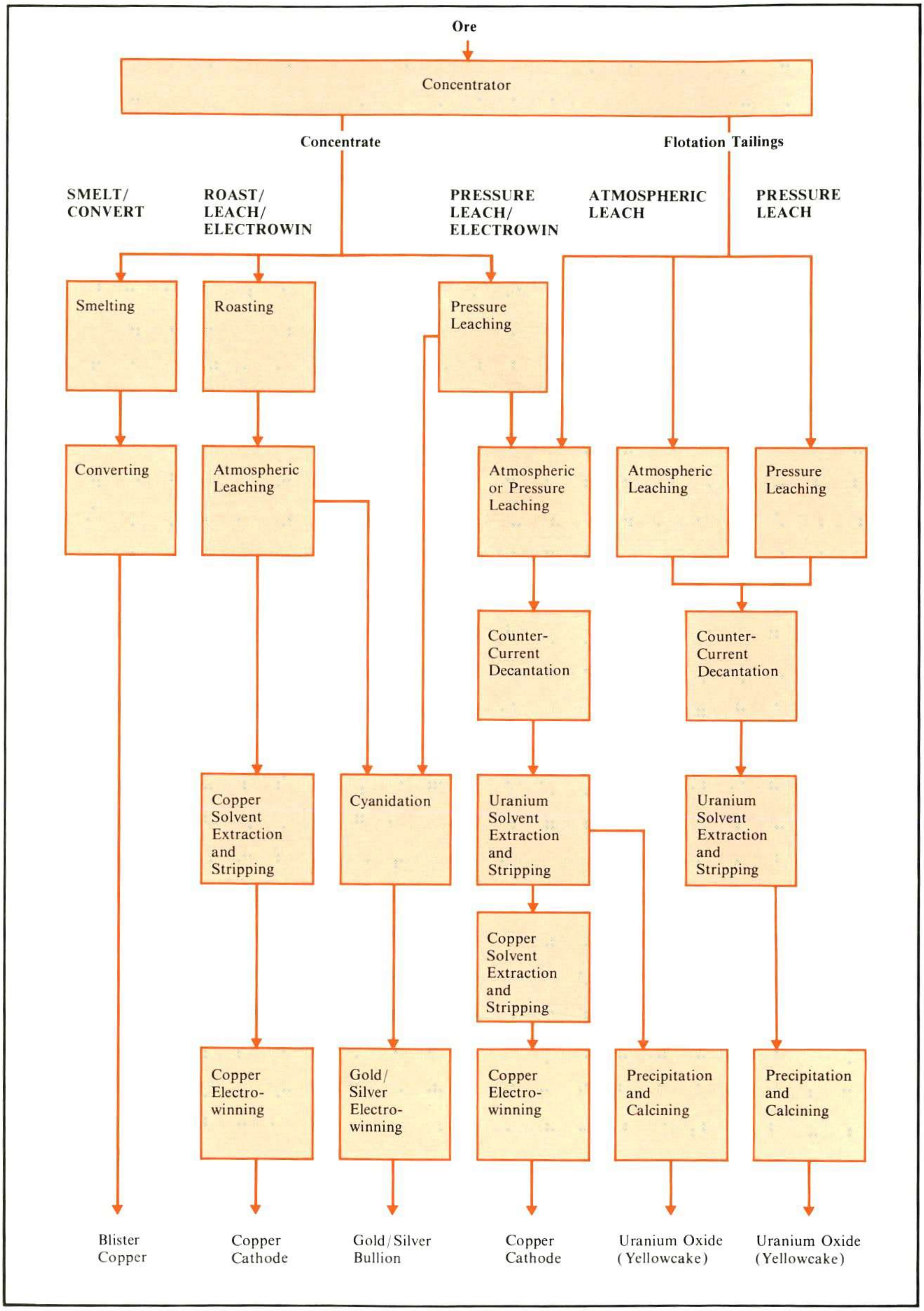


Figure 2.10

SCHEMATIC DIAGRAM OF PROCESS OPTIONS

methods: roasting, leaching and electrowinning (RLE); smelting and converting (SC); or pressure leaching and electrowinning (PLE). In the RLE and PLE options, high purity copper cathode is produced, with the residue from the concentrate leaching process being processed further by cyanidation and electrowinning to produce gold/silver bullion. In the SC option, blister copper is produced containing the gold and silver as valuable impurities.

Flotation tailings may be processed by atmospheric leaching (AL) or pressure leaching (PL) to extract the uranium. The principal difference between these options is in the conditions under which the uranium is leached from the flotation tailings. Subsequent processing steps of countercurrent decantation, solvent extraction and stripping, and precipitation and calcining are common to both options.

It should also be noted that in the PLE option for concentrate processing, the flotation tailings are added to the leached concentrate for a combined atmospheric or pressure leach. After countercurrent decantation, uranium solvent extraction and stripping then occurs, following which the pregnant solution containing uranium is passed through a precipitation and calcining step. The copper contained in the raffinate (barren solution from uranium extraction) passes through a solvent extraction and stripping step for copper followed by electrowinning to copper cathode.

Layouts for the plant area for these different processing options are shown on Figures 2.11, 2.12 and 2.13.

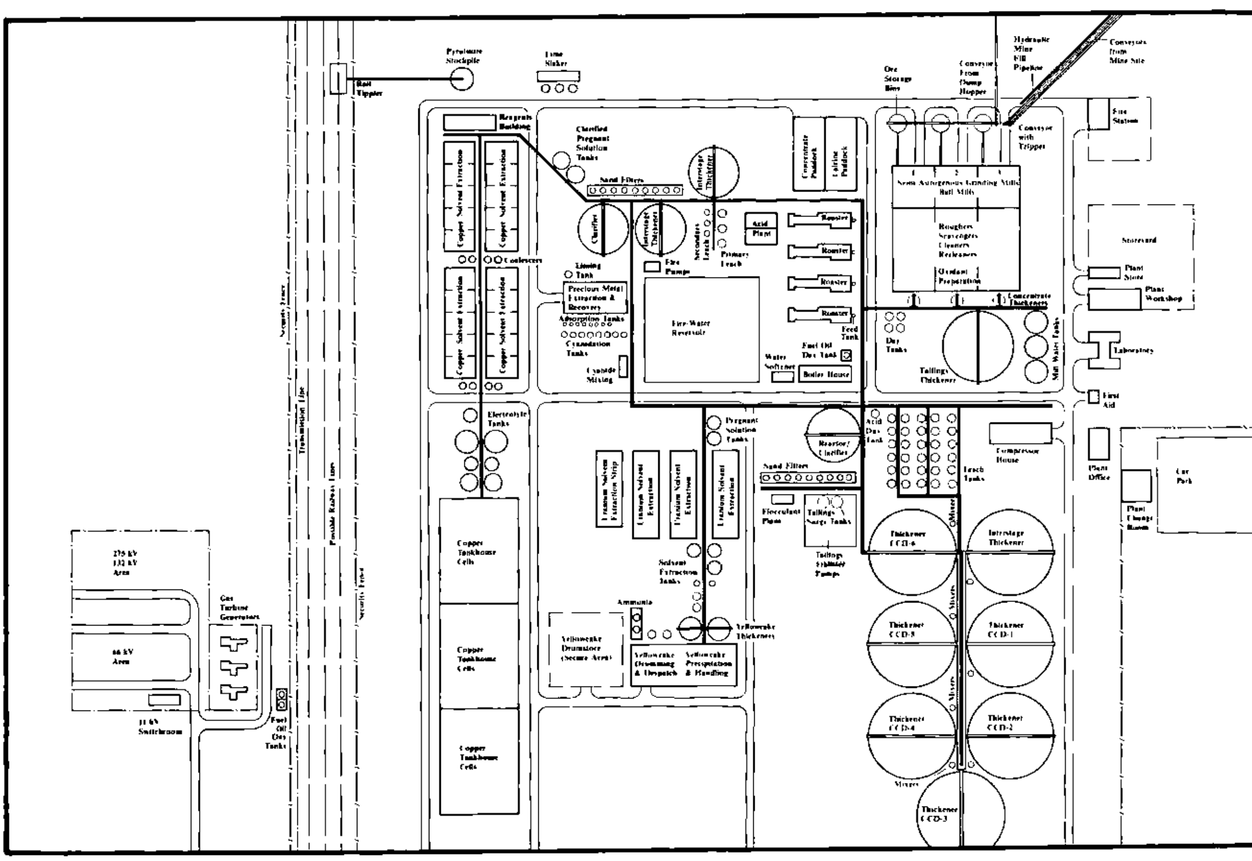


Figure 2.11

PROPOSED PLANT LAYOUT: ROAST/LEACH/ELECTROWIN OPTION

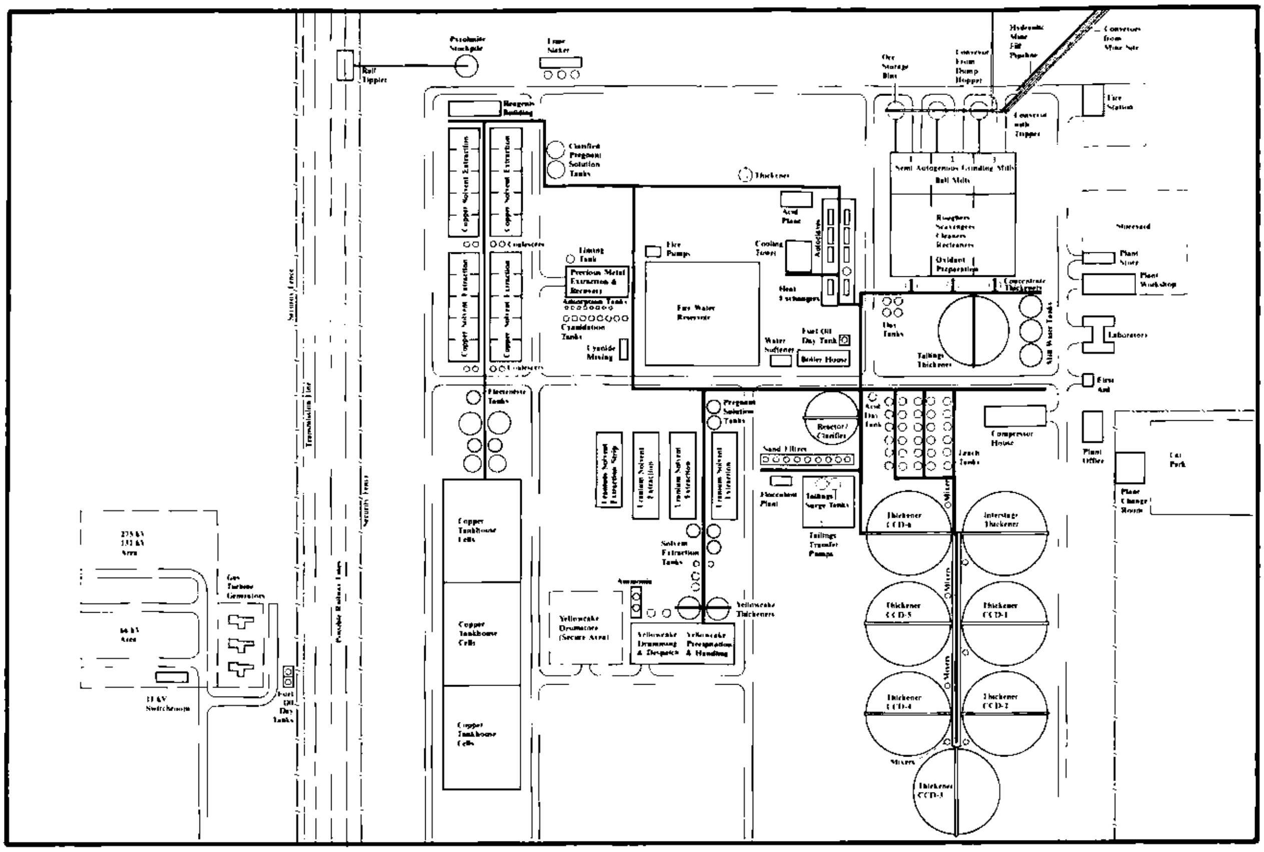


Figure 2.12
PROPOSED PLANT LAYOUT: PRESSURE LEACH/ELECTROWIN OPTION

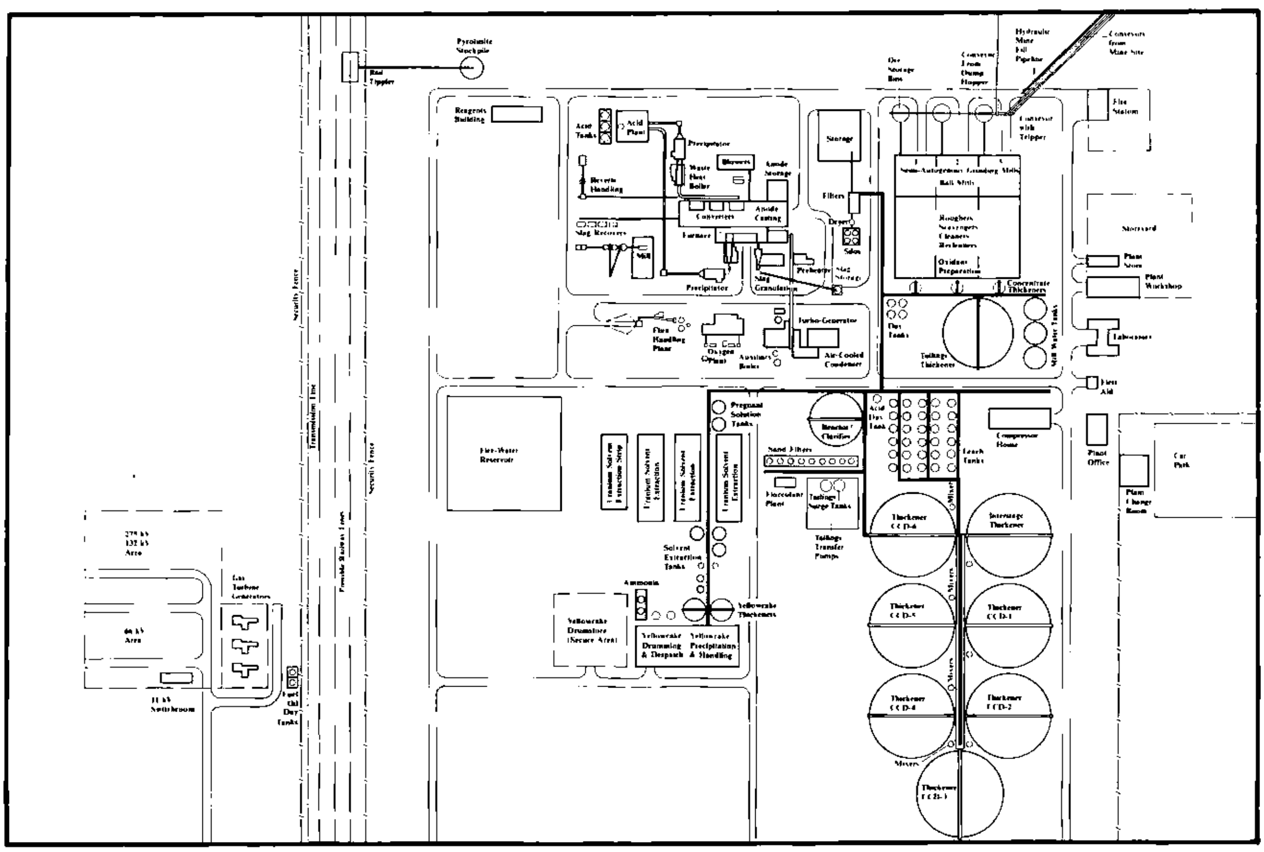


Figure 2.13
PROPOSED PLANT LAYOUT: SMELT/CONVERT OPTION

2.4.1 Ore handling

Ore which has been hoisted to the surface will be dumped into a surge bin before transportation to the plant. This ore will be moist from dust suppression measures used underground, and the surface conveyor system will also be covered to prevent ore dust from being blown from the conveyor. Transfer points will either be enclosed or have dust suppression devices such as water sprays or negative-pressure dust collectors.

Material which has been extracted during mine development will be temporarily stored on the surface. Mineralized material which is below ore grade will be stockpiled separately on the surface, and may either be processed at some later date by blending with higher grade ore, or used as mine-fill.

In the event of mine-to-plant conveyor failure, the mine shaft surge bin will be capable of containing approximately one hour's production. Once this bin is full, ore will be diverted to an ore storage pad for temporary storage. Ore will be reclaimed from the temporary storage pad by front-end loader, and either transported to the plant by truck or loaded back into the shaft surge bin. About three days' storage capacity will be maintained at the plant in covered live ore storage bins.

2.4.2 Concentrator

A schematic diagram of the concentrator operations, setting out the comminution and flotation processes, is shown on Figure 2.14.

Comminution

Ore crushed underground to less than 200 mm will be reduced to the fine size required for flotation separation (less than 75 µm) by conventional methods, including crushing and screening, autogenous or semi-autogenous grinding, ball milling and/or pebble milling.

Feed conveyors will receive ore from storage bins and deliver it to the primary grinding mill feed chute. The conveyors will be enclosed or covered, and dust collection or dust suppression devices will be installed at transfer points. Recycled process water will also be added to the mill feed, creating a slurry of 68 to 75% solids.

Present planning is based on a two-stage grinding process. The ore will be ground initially in semi-autogenous grinding (SAG) mills. Steel balls (approximately 75 mm in diameter) may be added to these mills to allow efficient use of energy and to ensure the necessary grinding capacity. The secondary grinding mills (ball mills) will operate in closed circuit with hydrocyclones to separate a minus 75 µm (200 Tyler mesh) product. Oversize (cyclone underflow) will be returned to the mill feed, while minus 75 µm ore will be fed to the flotation circuit as a slurry containing approximately 30% solids.

Flotation

A conventional flotation circuit will be used consisting of rougher cells and two-stage cleaner cells collecting all sulphides to produce a bulk sulphide concentrate.

Collectors including sodium ethyl xanthate and/or sodium dithiophosphate will be added to the flotation feed slurry to create hydrophobic sulphides. A mixture of methyl isobutyl carbinol and a polyglycol will be added as frother. Collectors and frothers will be diluted with water to a 1% solution and then added to the system at the rate of about 0.025 and 0.05 kg/t of ore respectively.

Parallel trains of rougher cells will provide the first stage of separation of sulphides from gangue minerals. The sulphides as concentrate will be passed for further upgrading

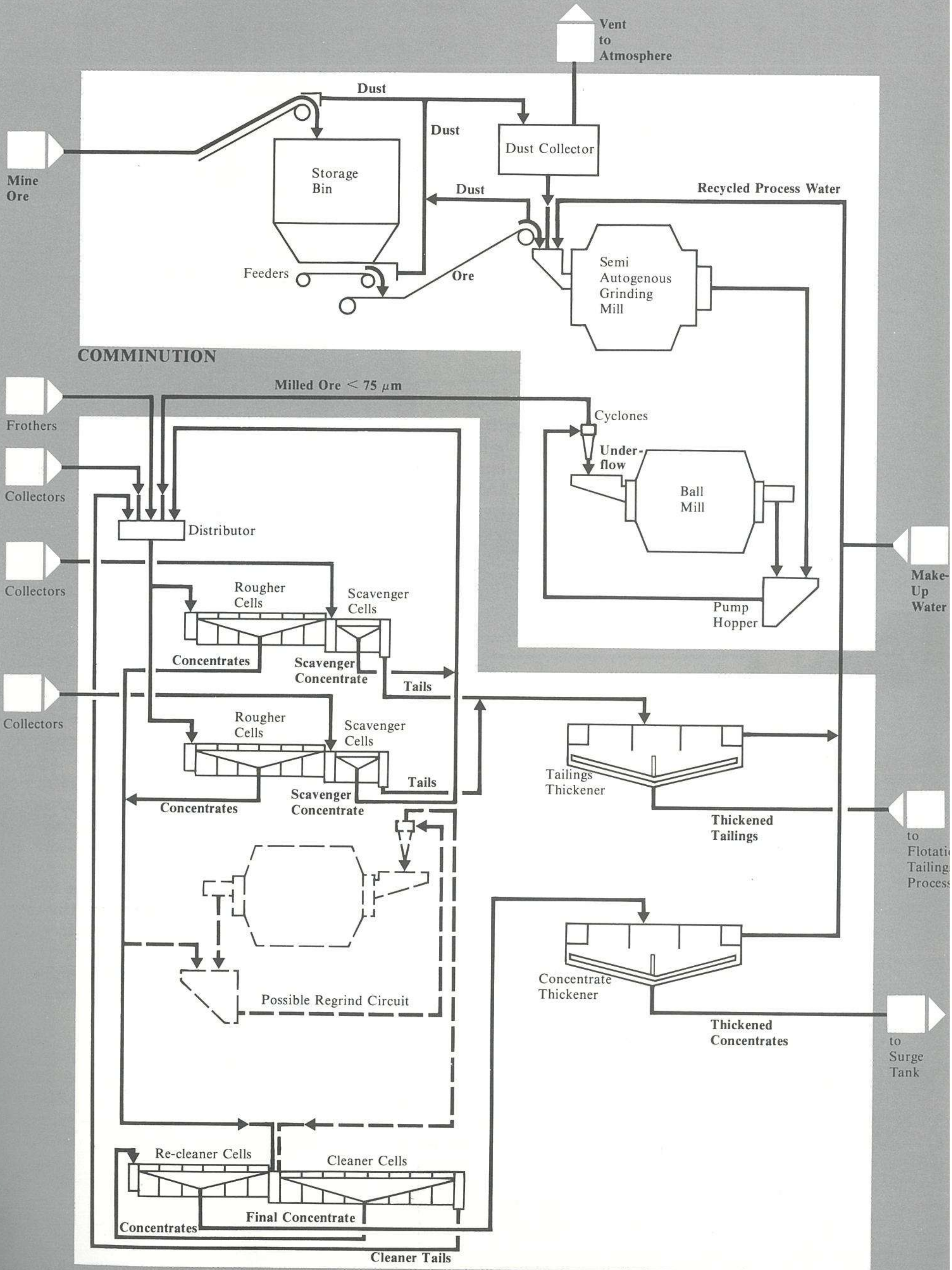


Figure 2.14
CONCENTRATOR: SCHEMATIC FLOW DIAGRAM

to cleaner and recleaner cells. The gangue minerals as tails from the rougher cells will pass to the scavenger cells, where additional collectors will be added. The scavenger concentrate will then be returned to the distributor. The scavenger tails will pass to a thickener for dewatering to 60% solids before passing to the flotation tailings processing circuit for extraction of uranium. Water removed in thickening will be recycled to the grinding section.

Concentrates from the rougher cells may be reground in a separate ball mill before passing to the cleaner and recleaner cells. Final concentrate from the recleaner cells will be thickened and transported to storage within the concentrate processing circuit. Make-up water will be added to the concentrator circuit to balance water removed from that circuit in the thickened concentrate and flotation tailings.

2.4.3 Concentrate processing

The concentrate processing circuit will treat flotation concentrate to produce copper, gold and silver. The three methods being considered for use at the plant are detailed below. Metallurgical pilot studies are presently under way to determine the most efficient method of ore treatment, and the final plant design may use any one or a combination of RLE, PLE or SC treatment methods. For the RLE and PLE options, an additional processing circuit for recovery of precious metals by cyanidation would be required.

Roasting, leaching and electrowinning

Process flow for the roast/leach/electrowin (RLE) circuit is shown on Figure 2.15.

Using this method, concentrate would be transferred to the RLE circuit as a thickened slurry at about 60% solids, either directly from the concentrator or from the repulping of concentrates held in storage. The slurry would be fed from a surge tank into a fluid bed roaster operating at about $700^{\circ}C$ to produce a copper oxide/copper sulphate calcine. The roast would be autogenous with the addition of fuel only being necessary for start-up. Off-gas from the roaster would pass through a gas clean-up system (including a cyclone, wet gas scrubber and electrostatic precipitator) to remove particulates, prior to the cleaned gas being passed to a sulphuric acid plant. A bleed stream from the scrubbing tower would pass to the calcine leach circuit.

Calcine discharging from the roaster would be quenched in dilute sulphuric acid as the first part of a two-stage countercurrent leach dissolving both copper and any contained uranium. The main supply of acid would come from the barren solution (raffinate) from the copper solvent extraction step. Copper leach residues would be filtered and washed, before passing to a cyanidation section for the recovery of precious metals. The copper containing leach solutions (liquor overflow) would be conditioned, clarified and filtered to remove any suspended solids, which would be returned to the leach circuit.

The clarified copper-containing solution would pass to solvent extraction (SX) where copper would be transferred to an immiscible organic phase. Raffinate would be returned to the copper leaching circuit. The copper would be stripped from the organic phase by strongly acidic spent electrolyte from the tankhouse. The copper-rich (pregnant) electrolyte would return to the electrowinning tankhouse for the production of high purity copper cathode.

Lead anodes and copper cathodes would be used, with the copper from the solution being electroplated out of the acid solution onto the copper cathodes. Voltage across the electrolyte would be 2 to 2.5 V. Electricity consumption in electrowinning would be approximately 2,700 kWh/t of copper produced. Cathodes would be lifted from the tank, washed, and stored for transport.

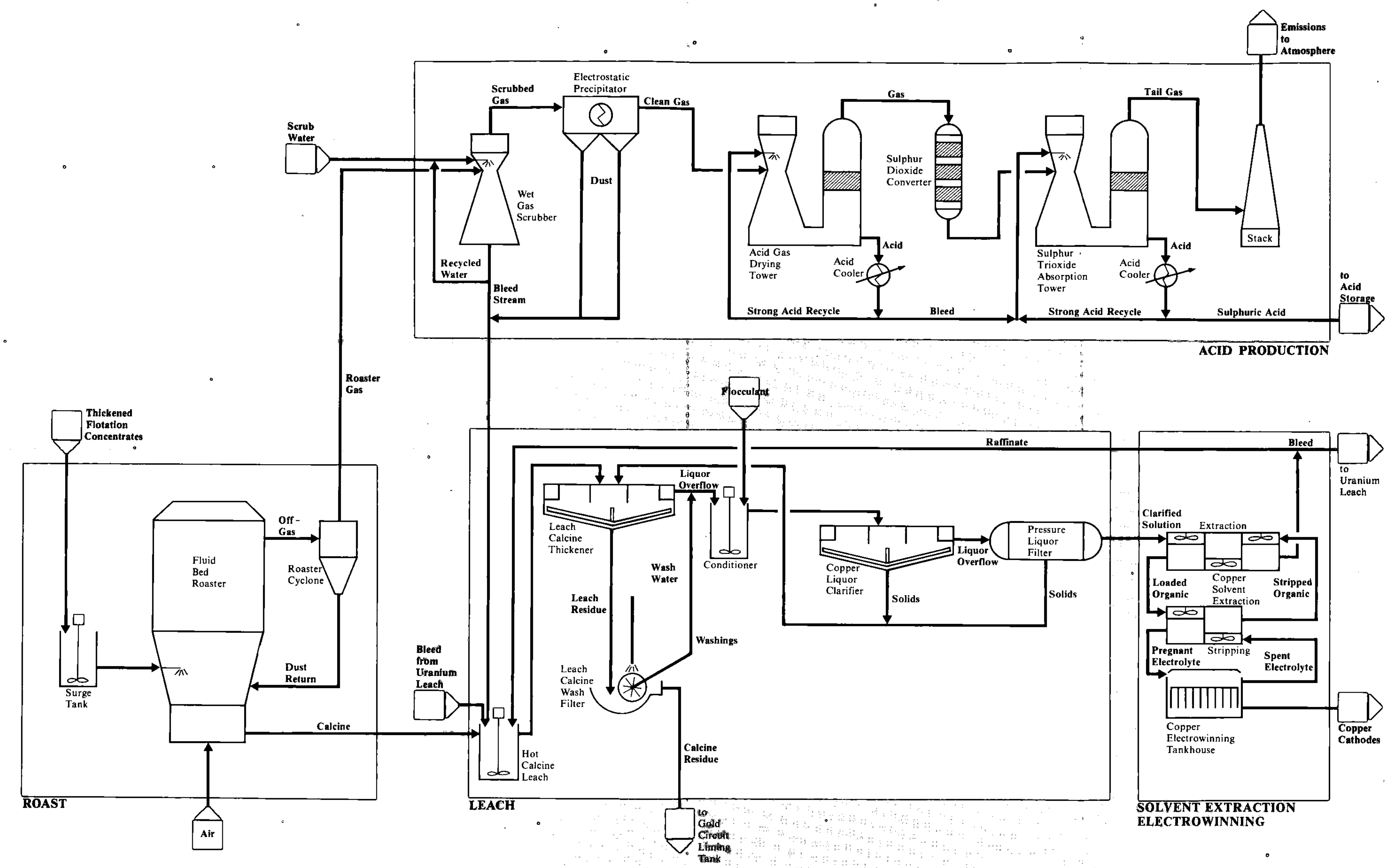


Figure 2.15
CONCENTRATE PROCESSING ROAST/LEACH/ELECTROWIN OPTION: SCHEMATIC FLOW DIAGRAM

About 1.5 t of acid would be generated in the electrolyte for each tonne of copper produced, and would be made available to the tailings uranium leach section via a bleed of raffinate from the copper SX section. This bleed stream would also transfer uranium taken into solution in the copper section to the tailings uranium leach section.

Roaster off-gases containing up to 7% sulphur dioxide (SO_2) would pass through a gas cleaning train to a contact type sulphuric acid plant, which would produce concentrated sulphuric acid for use in the tailings uranium leach section. Some quantity of acid may also be purchased. The gas cleaning train is designed to prevent chemical poisoning and physical blockage of acid plant catalyst beds and to reduce mist emissions from the acid plant stack. It would consist of wet scrubbing towers coupled with gas coolers and electrostatic mist precipitators.

Cleaned gas would pass to a drying tower, where residual moisture would be removed by a circulating strong sulphuric acid spray system, before being heated and forced through a multiple tray catalytic converter using a booster blower. In the converter, the SO_2 and oxygen contents of the gas would be combined to form sulphur trioxide (SO_3). This is an exothermic reaction and gas strengths would be high enough to maintain autothermal operation, where heat removed from the converter outlet gas is used to preheat new feed gas from the drying tower. Water absorbed in the acid drying tower would necessitate an acid bleed, which is used in the final absorption tower to absorb SO_3, producing new strong sulphuric acid. Water, fumes and solids removed in the gas cleaning train would be returned to the copper leach circuit. Stack emissions would consist of nitrogen and traces of sulphur oxides.

If sufficient acid for leaching operations is not produced from roaster off-gases and electrowinning, then a supplementary source of acid would be used. Acid may be transported to the site or produced on site by burning elemental sulphur with the gases going to the acid plant. Metallurgical studies conducted on ore from the Whenan Shaft will determine the amount of imported sulphur, if any, which would be required.

Pressure leaching and electrowinning

Process flow for the concentrate pressure leach/electrowin (PLE) circuit is shown in Figure 2.16. By comparison with the RLE process route in which sulphide concentrates would be converted to a soluble form by roasting, in the pressure leach route copper sulphides would be rendered soluble by leaching at 220^{o}C in acid solutions with oxygen present.

Thickened concentrates would be pumped at high pressure through a heat exchanger to a primary autoclave. Gases evolved from the primary autoclave, carbon dioxide (CO_2) and hydrogen fluoride (HF), would be scrubbed with the scrub liquor returned to the tailings leach circuit. Slurry from the primary autoclave would pass to multi-stage secondary autoclaves to complete the extraction of copper, with an oxygen stream flowing countercurrent to the solids. Slurry from the final autoclave would pass through the heat exchanger to transfer some of its heat content to the incoming stream of new feed. The slurry would pass through a system of let down chokes and flash tanks to reduce temperature and pressure before being discharged into a thickener.

Thickener underflow (the residue from the leach) would be filtered, washed, and passed to the cyanidation section for the recovery of precious metals. Thickener overflow, containing copper and some uranium in solution, would pass to the flotation tailings uranium leach section where the copper and uranium would be recovered by separate solvent extraction (SX) circuits.

The copper SX circuit would be similar to that described under RLE, with the final product being high purity copper cathode. The uranium SX circuit would be similar to that described under tailings processing, with the final product being yellowcake.

From the concentrate pressure leach part of the circuit, the sulphur content of the sulphide concentrates would be converted in the autoclaves into sulphuric acid as part of the high pressure leach under oxygen. This acid would then be transferred to the tailings uranium leach section. Acid requirements additional to that generated in the pressure leach would be either transported to the site or produced by burning elemental sulphur and passing the SO_2 so produced through a contact acid plant. The operation of the acid plant would be similar to that described for the RLE option.

Cyanidation

Process flow for the gold circuit to obtain precious metals by cyanidation is shown on Figure 2.17. The circuit would be similar for residues from the RLE or PLE concentrate processing circuits.

Washed leach residues would be pumped to the cyanidation plant, where they would be neutralized with lime and ground in closed circuit with a cyclone for size control. The ground slurry would be leached in a dilute cyanide solution (0.05% sodium cyanide) in a series of aerated agitated leach tanks to dissolve precious metals.

The dissolved metals would be recovered from solution using the carbon-in-pulp (CIP) process. In this process the leached slurry would be mixed with powdered activated charcoal which selectively adsorbs the precious metals from solution. The charcoal would be of a slightly coarser size than the slurry particles, and would be screened from the slurry when it became sufficiently loaded with gold and silver. The flow of charcoal would be countercurrent to the flow of slurry.

The tailing slurry from which the charcoal has been removed would still contain liquor with dissolved sodium cyanide. This liquor would be separated from the residue solids using vacuum wash filters and returned to the gold mill circuit as make-up water. The washed solids would contain trace amounts of combined cyanides which would be destroyed when they were pumped to the uranium leach circuit tailings sump.

Loaded charcoal would be stripped of gold and silver, using hot alkaline cyanide solution, and the solution would be circulated through the charcoal stripping tank (or elution tank) in series with an electrowinning cell. Gold and silver would plate out on the cell cathodes, and the metals would be recovered from the cathodes either by replating in an additional electrolytic cell or by fire refining. The stripped charcoal would be reactivated by heating in a rotary kiln and would then be recycled to the CIP adsorption circuit.

Smelting and converting

Process flow for smelting and converting (SC) of concentrate is shown in Figure 2.18.

Concentrate from the flotation circuit would be thickened, filtered and stored. Reclaimed filter cake would be transferred to the furnace building, where it would be mixed with flux (ground silica) and then dried in oil-fired fluid bed dryers. Entrained dry concentrate would be removed from the dryer off-gas stream in a multi-stage gas cleaning system.

Elemental sulphur would be added to the concentrate-flux blend to achieve autogenous smelting and process control, and the mixture would be delivered to a flash furnace. Using the flash smelting process, air enriched with oxygen would be injected with dry concentrates in the burners, providing the correct combustion conditions.

During start-up, oil burners would be required to heat and charge the furnace, but during normal operations smelting would be autogenous and no external heat would be required. At smelting temperature (1,200^{o}C), copper minerals would be partially oxidized to form

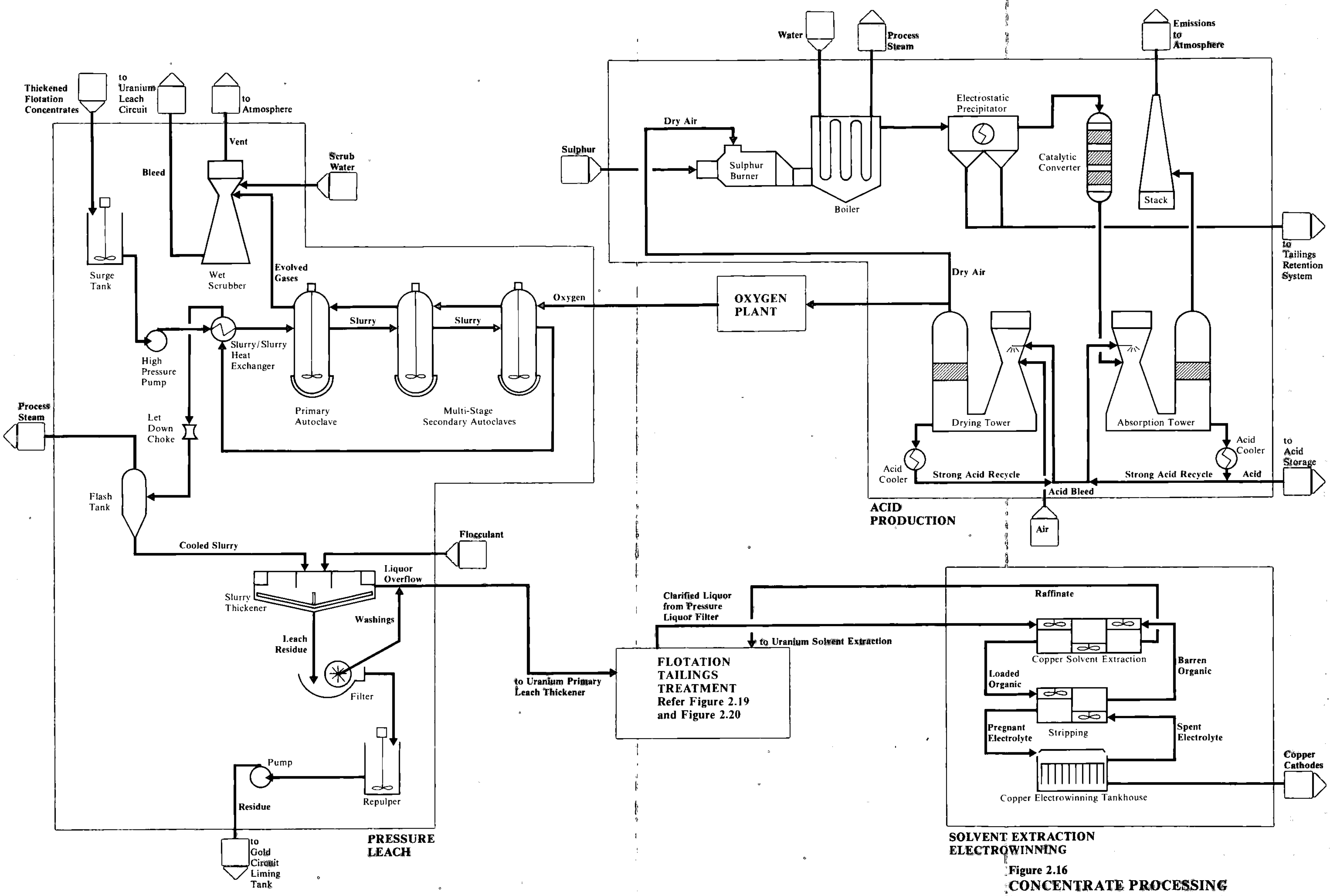


Figure 2.16
CONCENTRATE PROCESSING PRESSURE LEACH/ELECTROWIN OPTION: SCHEMATIC FLOW DIAGRAM

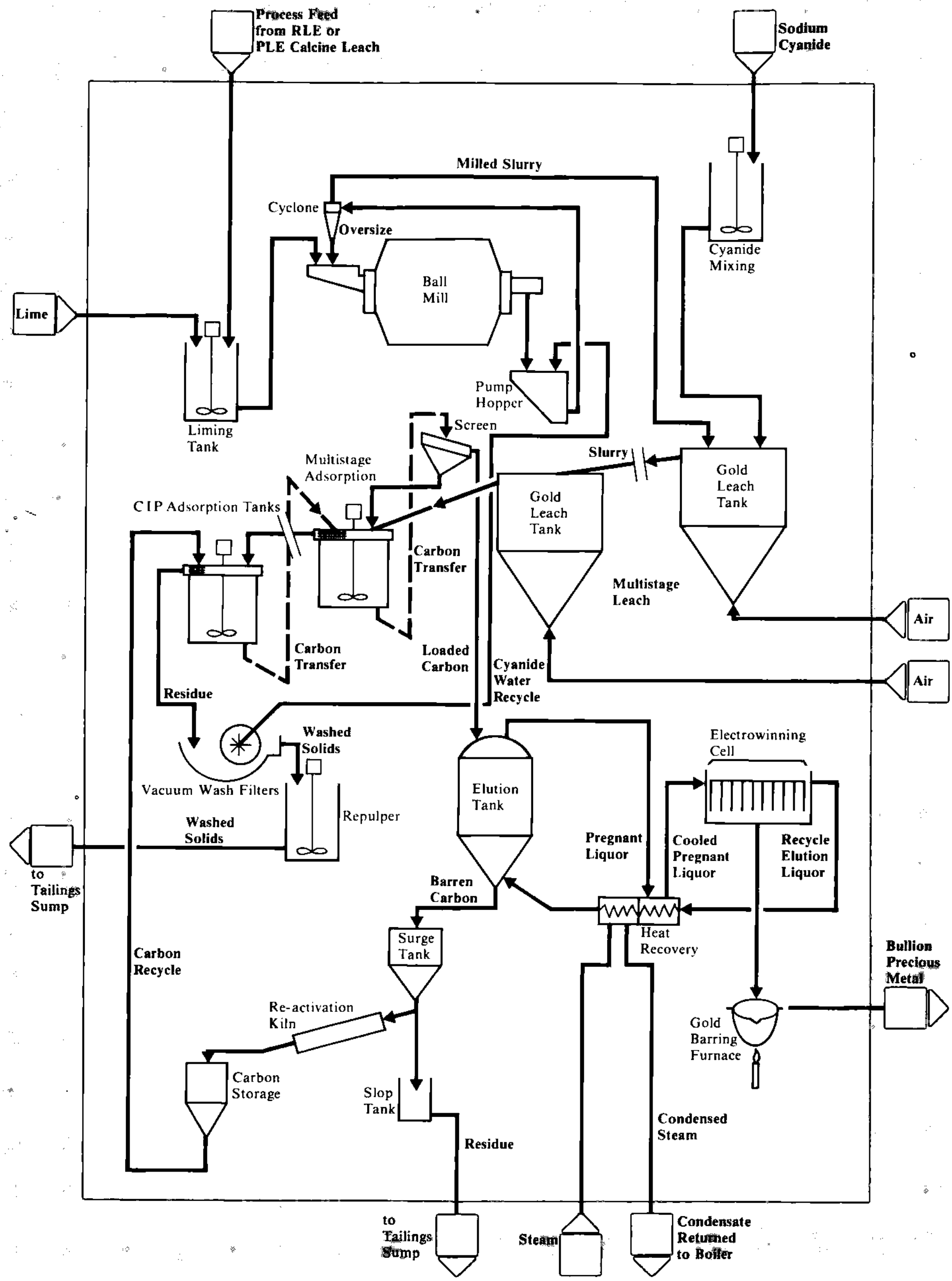


Figure 2.17
GOLD CIRCUIT: SCHEMATIC FLOW DIAGRAM

copper sulphide (Cu_2S) which, with iron sulphides, would form matte, a mixture of Cu_2S and ferrous sulphide (FeS). Excess iron from pyrite and copper minerals would be oxidized to form ferrous oxide (FeO) which would react with silica to form a slag.

Slag and matte are almost immiscible as liquids during smelting, with the slag layer floating on the matte. Matte and slag would be drawn off periodically to maintain near constant levels of both components in the furnace. Slag from the furnace would be tapped into large ladles for cooling, while matte would be transferred by large ladles to converters.

Off-gas from the furnace would contain SO_2. Before delivery to the sulphuric acid plant, the gases would be cooled from about 1,200 $^{\circ}C$ to 315 $^{\circ}C$ in a waste heat boiler, and cleaned in a hot electrostatic precipitator. Dust removed from the gas stream would be recycled to the furnace. Steam from the waste heat boiler would be used in the uranium leach circuit. The cleaned gas would pass to a contact sulphuric acid plant similar to that described for the RLE process for concentrates.

The purpose of converting is to remove iron, sulphur and other impurities from matte, producing blister copper which contains approximately 98.5% copper. Converting would be carried out in cylindrical Pierce-Smith converters, typically 4 m in diameter by 9.2 m in length. Molten matte would be transferred by ladle after tapping from the furnace, and charged into the mouth of the converter which would be tilted forward to receive the matte. Conversion to blister copper would be a two-step operation: first, slag-forming to remove iron, and then oxidation to remove sulphur.

The slag-forming stage would be accomplished by adding silica flux and blowing air through the converter. This oxidizes FeS in the matte to form FeO which reacts with silica to form a slag, which would be periodically discharged through the converter mouth into a slag ladle.

After slag removal, the converter would be recharged with matte and the process repeated until the remaining matte was of sufficient quantity for the oxidation stage. The converter slag would be returned to the flash furnace. During oxidation, air would be blown through the charge until the matte had been nearly completely oxidized to copper.

By tilting the converter, the copper would be poured into a ladle from which it would be cast into slabs, cooled, and stored for transport as blister copper. Precious metals including gold and silver would be contained in the copper matte and would comprise some of the impurities associated with blister copper. Further refining would be required to remove and recover these metals, and to purify the copper prior to use in fabrication.

Slag from the furnace would contain significant amounts of copper and any minor amounts of uranium associated with the concentrates. The slag would be cooled slowly, to promote the growth of copper bearing crystals in the slag. After the slag had solidified, it would be removed from the ladle, further cooled, broken up, crushed, and the copper content recovered by flotation in a separate circuit. Slag concentrates would be added to the concentrate from the primary flotation circuit prior to thickening and filtering and then returned to the furnace. Tailings from slag flotation may be used as mine-fill or, alternatively, pumped to the TRS. A possible future option for some of this slag to be treated to recover uranium is being investigated.

Off-gas from the converter would be cooled to about 300°C, cleaned by an electrostatic precipitator, and transferred to the acid plant. Under some conditions, oxygen enrichment of the converter air to 23 to 25% O_2 may be practised, increasing the SO_2 content of the off-gas. The converter hood would be designed to provide adequate tightness to maintain SO_2 concentration at about 4.5% or greater with no oxygen enrichment.

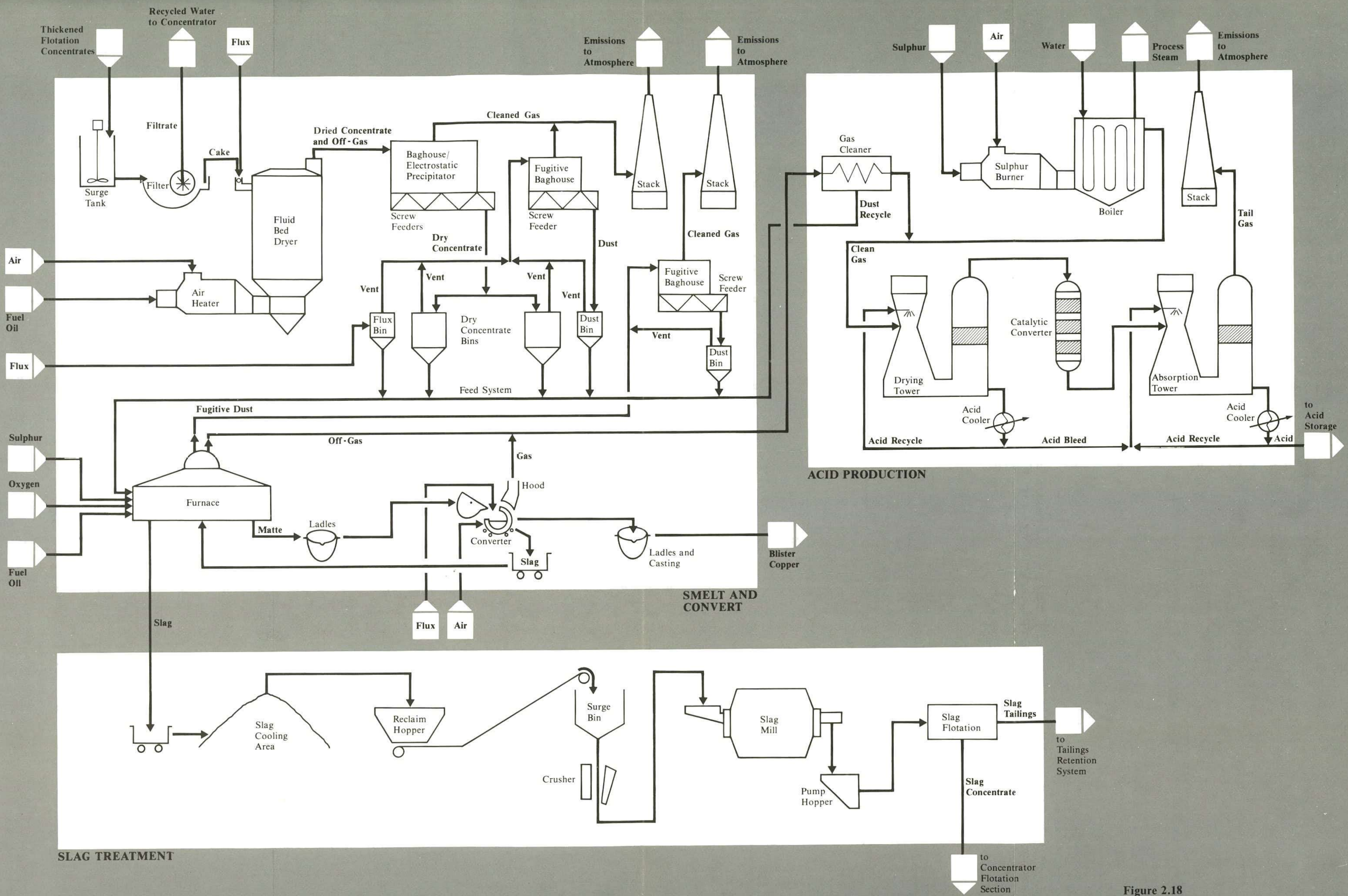


Figure 2.18
CONCENTRATE PROCESSING SMELT/CONVERT OPTION: SCHEMATIC FLOW DIAGRAM

2.4.4 Flotation tailings processing

Tailings from the flotation circuit would be thickened to about 60% solids, with excess water being returned to the grinding section of the concentrator. The thickened tailings would be leached with sulphuric acid either by atmospheric leaching (AL) or pressure leaching (PL) to dissolve the uranium and that part of the copper minerals not collected by flotation.

Atmospheric leaching

Process flow for atmospheric leaching is shown on Figure 2.19, with plant layout for atmospheric leaching being shown on Figures 2.11 to 2.13.

Atmospheric leaching would be carried out in one or possibly two stages, in rubber-lined agitated leach vessels at approximately 60°C for sixteen to twenty-four hours. Manganese dioxide (MnO_2) as pyrolusite would be added to aid in the dissolution of the uranium, approximately 90% of which would be extracted during the leach. Slurry discharge (or hot leached pulp) would be combined and washed by a countercurrent decantation (CCD) circuit consisting of several thickeners in series. Flocculant would be used to enhance the settling characteristics of the solids.

A rake mechanism would move the settled solids in each thickener to a withdrawal point, for pumping to the next thickener. Underflow from the last CCD unit would be the final residue, and would be pumped to the TRS. Raffinate from the uranium solvent extraction section would be used as new wash solution on the final CCD unit, while thickener overflows would advance countercurrent to the solids.

Overflow from the interstage leach thickener would be clarified to limit entrained solids and sent to the SX plant. Here the uranium containing feed solution would be mixed with an organic solvent having a high selectivity for uranium ions. Mixer/settlers would be used in series for the transfer of the uranium to the organic phase.

Following solvent extraction, the raffinate would be recycled as the wash stream to the last thickener in the CCD circuit.

The uranium-rich loaded organic liquid would be washed in a separate mixer/settler to remove entrained solids, then stripped using acidified sodium chloride/ammonium sulphate. The stripping solution would then be mixed with the pregnant organic solution to transfer uranium from the organic phase to the strip liquor. The solutions would be settled, with the barren organic solution being recycled to the extraction circuit and the strip liquor being pumped to the precipitation circuit.

Ammonia would be added to the strip liquor causing the uranium to be precipitated as ammonium diuranate (ADU). The precipitate would be thickened and fed to a calciner operating at about 600°C to oxidize the ADU to uranium oxide (U_3O_8). This product would be discharged to a bin prior to drumming. Drumming will be fully automated within an enclosed booth. The walls, floors and ceilings of the booth will be smooth to facilitate cleaning. Drums of yellowcake will be stored in a separate secure storage area prior to shipment from the site.

Combustion gases from the calciner would be scrubbed prior to discharge to the atmosphere, and the liquor from the wet scrubber would then be returned to the uranium solvent extraction circuit.

Pressure leaching

Process flow for tailings pressure leaching is shown in Figure 2.20. Plant layout for pressure leaching would be similar to that for atmospheric leaching, except that the primary leach tanks would be replaced by multi-stage autoclaves.

In this process, the feed material (flotation tailings thickened to 60% solids, which contain most of the uranium and a small amount of copper) would be delivered into the primary uranium leach, which is an agitated repulp tank. Here it would be mixed with countercurrent solution containing acid, dissolved uranium and copper from the secondary pressure leach circuit. The resultant diluted slurry would be fed to the primary atmospheric acid leach circuit in which acid released in the secondary leach would be utilized and some uranium would be extracted. The output from the primary leach would be thickened with the solids being pumped to the secondary pressure leach. The primary leach solution (or pregnant solution) would be pumped to the clarification section to prepare it for uranium extraction.

The thickened solids from the primary leach, after addition of further acid, would be passed through a slurry-to-slurry heat exchanger, the heat being transferred from the slurry discharging from the secondary leach circuit to the incoming slurry stream. The heated slurry would pass first through a preleach vessel. The gases evolved during leaching (CO_2 and HF) would be vented to a wet scrubber with subsequent discharge of the CO_2 to the atmosphere.

The slurry discharge from the preleach vessel would then pass through multi-stage autoclaves with countercurrent flow of air or oxygen. Discharge from the final autoclave would be passed through the heat exchanger and then let down in pressure and temperature through a choke and flash tank system discharging to the multi-stage countercurrent decantation system. The CCD washing of leach discharge slurry and treatment of pregnant leach solution by clarification, solvent extraction, precipitation and ADU calcination would be the same for both the PL and AL process methods.

2.4.5 Metallurgical analytical services

Sample preparation will be in a well ventilated facility with all off-gases being cleaned in a high efficiency dust collector. All drying and laboratory digestion operations will also be well ventilated, with the off-gases being cleaned in a high efficiency wet scrubber before being vented to the atmosphere. Scrubber effluent and all liquid and solid residues from the laboratory will be combined and pumped to the uranium leach tailings sump for transfer to the TRS.

2.5 EFFLUENTS AND EMISSIONS

The main sources of air emissions and wastewater effluents associated with ore processing are identified on Figures 2.14 to 2.20. These emissions are summarized below, together with brief descriptions of solid wastes and noise emissions. Industrial safety aspects relating to emissions and other occupational hazards are also discussed. The details relevant to the assessment of impact, including likely quantities of emissions and their relevant physical and chemical characteristics, are provided in relation to tailings in Chapter 7, and in relation to other emissions in Chapter 8. A detailed discussion of radioactive emissions is provided in Chapter 9.

2.5.1 Tailings containment

Tailings retention system

The tailings retention system (TRS) will comprise a tailings storage facility with a decant system, and a decanted liquor evaporation pond. It will be sited in the tailings retention area, approximately 3 km north-west of the plant area (Figure 2.1). The tailings storage facility, occupying an area of 400 ha, will provide permanent storage for the tailings.

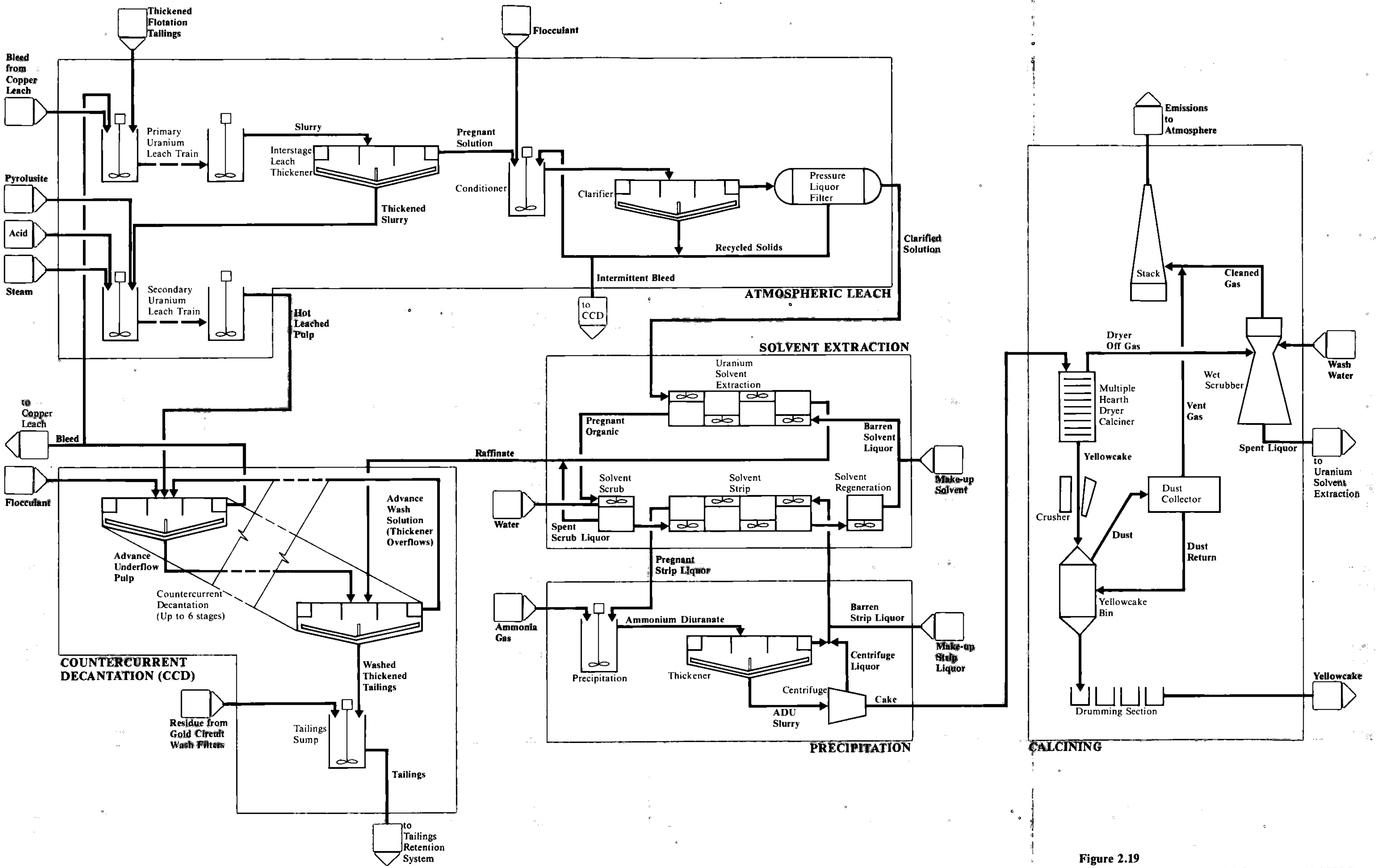


Figure 2.19
FLOTATION TAILINGS PROCESSING ATMOSPHERIC LEACH OPTION: SCHEMATIC FLOW DIAGRAM

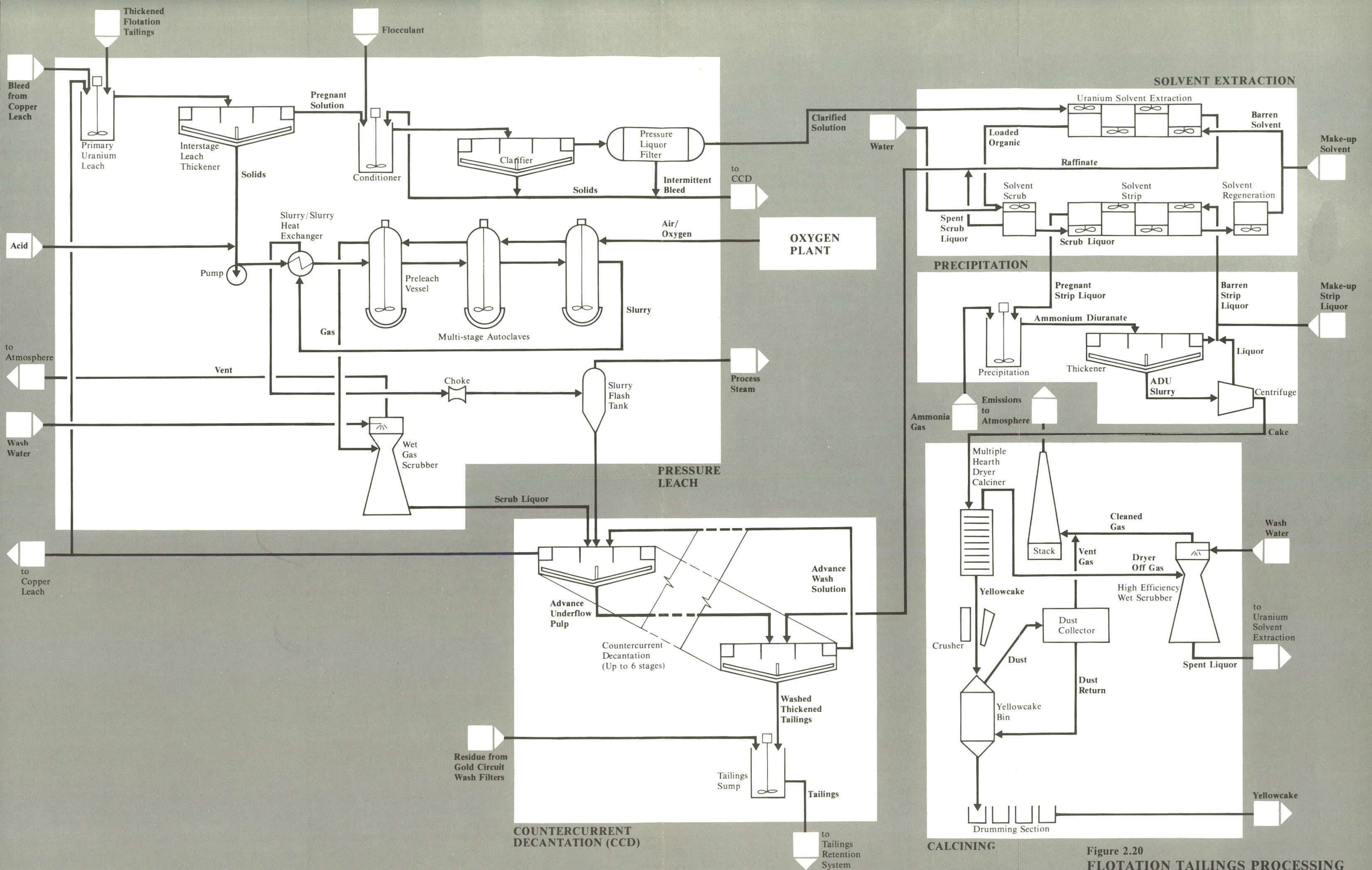


Figure 2.20
FLOTATION TAILINGS PROCESSING PRESSURE LEACH OPTION: SCHEMATIC FLOW DIAGRAM

An adjacent evaporation pond will be used for the evaporation of decanted tailings liquor during the life of the Project, and will be removed at the end of the operation. This will cover approximately 50 ha, and will be lined with a synthetic membrane.

The tailings storage facility will be square in plan, and divided by two transverse embankments creating four separate bays of equal area. All embankments will be constructed from the local swale and sand dune materials. A concrete decant structure will be located in the centre of the facility to decant tailings liquor from all four bays. The tailings storage facility and decant structure will initially be constructed to a height of 10 m. As additional storage capacity is required, the embankments and decant structure will be raised in 5 m increments to achieve a total height of 30 m after thirty years of operation.

TRS operation

The tailings will be discharged into the storage using the subaerial deposition method. They will be deposited in thin layers in the four separate storage areas on a cyclical basis, with the cycle times calculated to permit the reduction of the moisture content of each deposited layer to a predetermined level. At this level, the tailings will be partially saturated, and will result in the laminated development of a dense high strength mass retaining sufficient moisture to effect the necessary radon attenuation. Cycle times can be varied as required during operations to take account of seasonal variations in evaporation rates.

Supernatant liquor will be released from the tailings during the deposition cycle and for a few days after deposition has stopped as the tailings settle. The supernatant liquor and all rainfall on the storage surface will be directed to controlled decants, and then through channels to a centrally located sump, from where it will be pumped to the lined evaporation pond. Sufficient pumping capacity will be installed in the sump to ensure that all run-off resulting from a 1 in 200 year 72-hour storm (210 mm) will be removed from the storage facility within approximately forty days. Cyclical deposition of the tailings into each of the four separate storage areas will permit total evaporation of any remaining free standing liquor.

The stored tailings will not be subject to further consolidation following commissioning, and at Project completion the exposed tailings surfaces within the TRS will be totally covered by earth and rock armour.

2.5.2 Emissions to air

Emission levels of dust, which is the principal emission from the concentrator, will be low, as the ore from the mine will be moist, and the grinding and flotation circuits will be wet systems. Dust generated from conveyors to ore storage and grinding mills will be controlled by covering conveyors, by using water sprays or dust collection at transfer points, and by enclosing live ore storage bins at the mine and plant.

In the RLE circuit, the major emission will be the tail gas from the acid plant, the principal pollutant of which will be SO_2, with very small amounts of HF. There is also a strong economic incentive to keep these emissions at low levels. The Joint Venturers intend to maximize the recovery of SO_2 in the acid plant as it will provide a significant source for the production of sulphuric acid. If capture is not maximized, any shortfall must be made up by importing and burning elemental sulphur. Hydrogen fluoride removal (as part of precleaning of gases before acid production) is necessary to prevent poisoning of the catalyst in the sulphur dioxide converter. Minor amounts of acid mist will be present in the electrowinning tankhouse.

For the PLE circuit, the tail gas from the acid plant will also be the main emission, with minor acid mist produced in the electrowinning tankhouse. In addition to these sources, there will be the gases evolved from the autoclaves used in the pressure leach process. These gases, containing CO_2 and HF, will be passed through a wet scrubber and the liquid effluent returned to the uranium leach circuit.

In the SC option, the furnace fugitive gas collection system and the fluid bed concentrate dryer will be additional emission sources. Off-gas from the fluid bed dryer will be passed through a baghouse and electrostatic precipitator. The emissions to the atmosphere will be SO_2 and nitrogen oxides, with only minor quantities of particulates remaining in the emission flow. The dust collected will be returned to the process. Fugitive dust from the furnace, which will be collected in a high efficiency dust collection system, will also be returned to the process.

In both the AL and PL circuits for treatment of flotation tailings from the concentrator, two emissions will be the combustion gases from the calciner and dust from the yellowcake bin. The combustion gases from the calciner will be passed through a wet scrubber, with the spent liquor being fed to the uranium solvent extraction circuit. Dust from the yellowcake bin and yellowcake packaging area will be collected in a baghouse, and returned to the bin.

For the PL option for flotation tailings, there will be a similar emission from the autoclaves to that described for the pressure leaching of concentrate. The gases evolved from the autoclaves will be scrubbed, and the emission to the atmosphere will contain CO_2 and HF. The HF emission will be controlled in the same manner as in the pressure leaching of concentrate.

2.5.3 Wastewater

Wastewater generated by the Project will arise from:

- process wastewater and site laboratory waste;
- saline water from dewatering of the sediments overlying the orebody, water pumped from the mine (including wash down and drilling water and some seepage from back-filling operations), and saline groundwater infiltrating into underground openings;
- sewage from the mine, plant, workshops and offices;
- miscellaneous wastewater arising from such events as equipment washdown, and pipe breaks and spillage clean-up outside contained sections of the plant, and from stormwater run-off from roofs, roads, paving, and other surfaces at the mine, plant and workshop areas.

Process wastewater disposal

For all the process options, nearly all the liquid effluents from individual process sections will be recycled back to the process, as these effluents will still contain minor quantities of valuable mineral constituents. The only operational waste streams from the process options will be the following two from the precious metal recovery circuit:

- the washed solids residue from the CIP adsorption process
- the reject carbon slurry from the recyling of the barren carbon solids.

The washed solids residue will contain trace amounts of combined cyanides. When this effluent is pumped to the tailing sump of the uranium leach circuit, the residual complexed cyanide will decompose by combination with the acidic uranium tailings in a well ventilated agitated tank before being pumped to the TRS. Minor amounts of hydrogen cyanide gas will be released in this operation, but experience from equivalent operations elsewhere indicates that the rate of emission is not likely to create a hazard to operators.

The reject carbon slurry is an aqueous solution containing carbon particles which are too fine to be reused in the CIP adsorption process. This slurry is separated from the barren carbon return flow in a surge tank and diverted to a slop tank. It is then pumped to the tailings surge tank for storage in the TRS.

Intermittent flushing of tanks will be carried out for maintenance purposes. In addition, there is the possibility of accidental spillages and pipe breaks within process areas. Each area within the plant will therefore have a wastewater containment system, to ensure that wastewater generated from such events will be contained, drained to a sump within the area, and pumped back into that section of the process.

Mine dewatering and mine wastewater

The sediments overlying the breccia sequence hosting the mineralized area will be dewatered prior to mining. This highly saline groundwater will be pumped to a separate clay-lined evaporation basin of 75 ha, adjacent to the TRS (Figure 2.1). As it will not be possible to dewater all areas prior to mining, some small inflows can be expected to continue during operations, and there will also be a minor inflow from the breccia sequence.

Water will be required during mining for such activities as drilling, washing equipment, wetting broken ore and placement of hydraulic fill. If the quality of mine water is suitable, it will be used for process make-up water, although contamination from oil, sludge and other sources, or the salinity of this wastewater, may preclude this possibility. If plant reuse of mine water is not possible, it will also be pumped to the TRS for disposal by evaporation.

Sewage

Sewage flow from principal works areas will be pumped to a site to the west of the plant (Figure 2.1), where it will undergo conventional treatment. Effluent will be periodically tested and, if suitable, it will be used for local irrigation. If, however, the water is contaminated, it will be pumped to the TRS for evaporation. At remote smaller locations, such as the quarry, borefields, and tailings retention area, septic tanks will be used for disposal of sewage flow.

Miscellaneous wastewater

Wastewater from events occurring outside a contained section (such as from exterior pipe breaks and spillage clean-up from roads, and at equipment washdown pads) will be collected in sumps. From there it will be pumped to the TRS for evaporation. Stormwater run-off will be collected in an excavated pond and pumped back to the plant circuit as make-up water.

2.5.4 Solid waste

The mine, processing plant and support facilities will generate small amounts of solid wastes, including:

- normal office wastes such as paper
- worn out clothing such as overalls, gloves and boots

- oil drums
- broken metal from equipment
- obsolete pieces of equipment
- workshop waste such as metal cuttings.

These wastes will be separated into contaminated and uncontaminated wastes. Uncontaminated waste considered salvageable, such as scrap metal, will be sold, while uncontaminated materials not considered salvageable will be disposed of in the mine landfill tip, which will be situated adjacent to the tailings storage area. Material which is considered contaminated will either be decontaminated by washing down where appropriate, or placed in steel drums. Salvageable material will be sold, and non-salvageable material will be disposed of in the mine landfill tip.

The waste will be disposed of on a regular basis (probably weekly), and covered with soil. The South Australian Waste Management Commission Act of 1979 will be taken into account in the construction and operation of the disposal facility.

2.5.5 Noise sources

The principal noise sources associated with the Project will be:

- the ventilation fans, conveyor belt drives, mine compressors, winder motors and ore dumping bins associated with the mine;

- grinding mills, pumps, blowers, and motors associated with the processing circuits. For the smelter option, the converter operation and the burners in the furnace would be additional sources;

- quarry operations;

- transformer stations;

- traffic.

The Joint Venturers will specify that the noise level from individual items of equipment must not exceed 85 dBA at 1 m. The combined effects of these noise emissions are discussed in Section 8.4.

2.5.6 Industrial safety aspects of the Project

The Project operations will involve typical occupational risks associated with the mining and extractive metallurgical industries. All normal State laws apply with respect to the Joint Venturers' responsibility for controlling these hazards and providing safe systems of work. Compliance with regulations will be subject to checking by inspectors from the Department of Mines and Energy, who have the authority to give directives and to order suspension of operations in the interests of safety or where there is undue impact upon the environment.

A safety policy statement drawn up by the Joint Venturers will be provided to all new employees. This policy will provide for specific safety and health related input to all aspects of design, in conformity with accepted safety standards. These standards are discussed further in Section 8.4. A specific safety audit is envisaged at the detailed design stage. The policy also provides for development of employee training programmes to increase awareness of potential hazards and safety related procedures, and defines provision of a 'safe system of work' on a day-to-day basis as a line management responsibility.

In the mine and metallurgical plant, there are hazards which arise either from acute exposure or from chronic exposure, and the following is an indicative, but not exhaustive, listing of sources of hazard:

- Risks from acute exposure:

Rock falls	Hot slurries, solutions and equipment surfaces
Mechanical equipment	Acid, alkali and cyanide solutions
Electrical equipment	Kerosene
Mobile equipment	Lime
High pressure air	Noxious gases: carbon monoxide, nitrogen oxides, sulphur oxides, and ammonia
High pressure water	Heat stress
High pressure hydraulic fluid	Manual handling.
High pressure steam	

- Risks from chronic exposure:

Noise	Inert dust
Silica	Process reagents
Solvents	Radiation exposure.
Diesel fumes	

The ranking of these potential hygiene and safety hazards will differ between the various areas, and the priorities for control will be responsive to these variations. Protective measures to provide for safety and contaminant control will be built in at the design stage. The aim will be to eliminate or reduce to the minimum the necessity for special protective clothing or respiratory protection for personnel, as general area environmental acceptability is considered preferable.

The design of the treatment plant will feature safety equipment for personnel protection. Safety showers and eyewash stations will be provided in all areas where hazardous chemicals or conditions dictate, and access to hazardous areas will be restricted. In the areas of ammonia and cyanide storage, self-contained breathing apparatus will be provided. Particular attention will be paid to layout of clear access ways and escape routes.

The solvent extraction plants will include major fire protection systems based on automatic protection of personnel and equipment via deluge cooling sprays. These will allow an adequate period, with the fire under control, to properly carry out procedures for extinguishing the fire.

2.6 PROJECT INFRASTRUCTURE

Infrastructure will be developed to meet Project needs for water, power, transportation and communications during construction and operation. Major corridor development for water and power transmission is shown on Figure 2.21. To meet transportation demands, a new airport will be constructed near the town; a rail spur may also be constructed in the future from Woomera or Pimba, with investigations into design and alignment being made at a later date. A central services area, containing workshops, storage and support facilities, will be established within the Project Area.

2.6.1 Power supply

Power supply for the Project will be developed by the Joint Venturers in two stages: a 132 kV line will be constructed from Woomera to supplement on-site generation during construction and initial town occupation, while a 275 kV line from Port Augusta will be built to meet Project needs during production. From the Project switchyard, 66 kV and 11 kV lines will extend to the mine, plant, town, borefields and other installations.

132 kV transmission line

The 132 kV transmission line will commence at a switchyard to be constructed approximately 3 km south of Woomera, adjacent to the existing 132 kV line, and will terminate at the Project switchyard adjacent to the plant. The route selected is clear of the permanent facilities at Woomera and those proposed at the Project site. The width of the corridor will be approximately 100 m to accommodate the 132 kV line and the necessary minimum clearance of 60 m from the 275 kV line from Port Augusta, and will also contain a 6 m wide service road.

The 132 kV line will be of conventional construction, using lattice towers, and either steel and concrete stobie poles or reinforced concrete tubular poles. Its capacity will be adequate for the 30 MW available at Woomera.

275 kV transmission line

The 275 kV transmission line will be constructed from switching facilities at the Electricity Trust of South Australia's substation near Port Augusta. The preferred route from this substation parallels the existing 132 kV line to the east of Port Augusta, and would use the existing service road and corridor to a point about 35 km south-east of Woomera, just south of Mount Gunson. From there, the existing line veers slightly west directly towards Woomera. The new line, however, would continue towards the 132 kV line corridor to Olympic Dam, which it would join at a point 6 km east of Woomera, and then remain in this corridor until reaching the Project switchyard.

The Indenture Agreement obliges the Electricity Trust of South Australia to make available to the Joint Venturers up to 150 MW of power.

Stand-by power supply

The provision of two incoming transmission lines provides a degree of security of supply. However, an emergency power supply will also be provided which could be used in the event of a total outage of the transmission lines. Essential services to the mine, plant and town can thus be maintained, ensuring that mining personnel can be brought up from underground, and that continuous electrical supply is available to critical sections of the plant. This emergency power will be supplied by gas turbine sets with a total installed capacity of approximately 30 MW. These sets will be situated adjacent to the Project switchyard.

2.6.2 Water supply

The Joint Venturers will supply water for the Project from two borefields to be developed in the Great Artesian Basin. The pipeline route and borefield locations are detailed in Chapter 10. With the possible exception of some very minor deviations where necessary to avoid particular features such as isolated higher sand dunes, the pipeline alignment has been finalized. However, at the time of writing, the final siting of the individual bores remained to be determined, although it is expected that they would be within the borefield areas and close to the positions indicated.

During the construction period, about 6 ML/d will be pumped through a pipeline from Borefield A, approximately 100 km north-east of Olympic Dam. However, as this borefield cannot supply sufficient quantities of water to meet Project demands during production (estimated to average about 33 ML/d), Borefield B will be developed

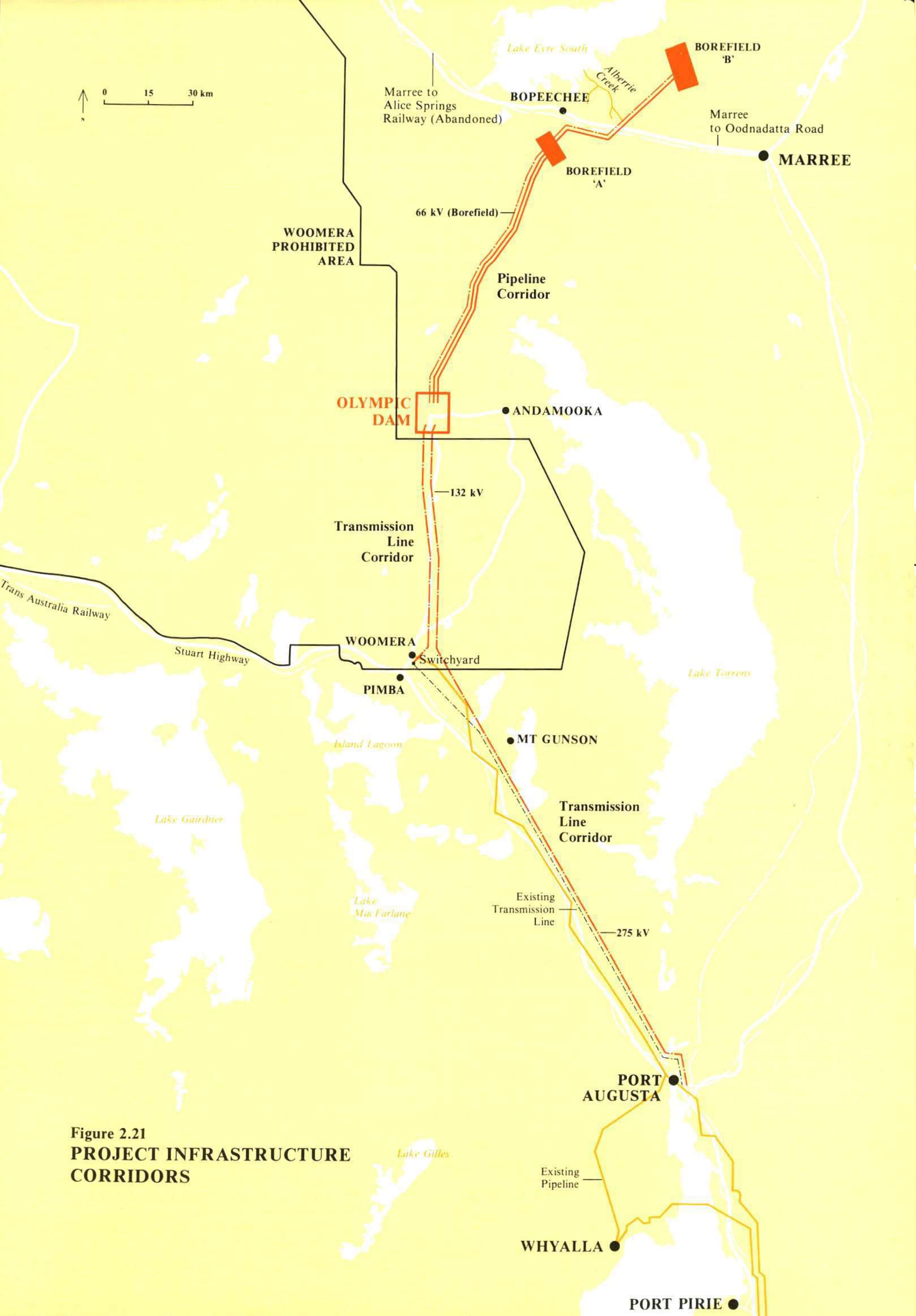


Figure 2.21
PROJECT INFRASTRUCTURE CORRIDORS

approximately 50 km north-east of Borefield A. About five bores, spaced at intervals up to 1,500 m apart, will be developed in Borefield A, and another seven to ten bores spaced at similar intervals will be developed in Borefield B. Each borefield will be serviced by a separate pipeline, with both pipelines being parallel from Olympic Dam to Borefield A. Power for the bores and pumping stations will be supplied through a 66 kV transmission line from the Olympic Dam substation.

Water demand

The water supply system has been designed to meet projected requirements for the plant, mine and town. The design will enable daily requirements to be pumped in twenty-two hours, with evaporation loss resulting from open storages being considered in pipe and pump design.

Average daily process and potable water requirements during production are indicated in Table 2.1.

Table 2.1 Average daily water requirements

	Process water (ML)	Potable water (ML)
Mine	-	1.9
Plant	23.3	-
Central services area	-	1.1
Town	-	6.5
Total	23.3	9.5

Borefield A

Borefield A will be pumped at an average rate of 6 ML/d over the life of the Project, meeting water requirements during construction and initial town occupation and supplementing the water supply during production. Normally, four of the five bores will be operating at any given time.

Buried pipelines will act as collectors to bring water from the bores to the forwarding pumping station, which will be located at the near margin of the borefield. It will consist of an open pump pond and enclosed pumping station, a switchyard, and other equipment. The pumping station switchyard and pond will be enclosed by a vermin-proof fence. A booster station located approximately 50 km from Olympic Dam will be similar to the forwarding station, except that the pond will be replaced by an open circular steel or concrete tank for water balancing.

The underground pipeline from the forwarding station to the Project site will be approximately 350 mm in diameter. A 6 m gravel service road will be developed parallel to this pipeline for construction purposes and to provide service access to the borefields and pumping stations. Allowance will be made for later road expansion to 12 m. Power for the pumping stations and bores will be provided by an overhead 66 kV transmission line, commencing at the Olympic Dam substation and parallelling the pipeline for most of its length. A transformer will reduce voltage to 11 kV at the forwarding station for distribution to each bore, and individual bores will have transformers for further reduction to 415 V. A design width of 50 m has been adopted for this corridor, based on the minimum required to contain these services, to permit construction, and to avoid the possibility of induced electrical currents in any steel sections of pipelines. However, disturbance or clearance of vegetation will not be required over the whole width, and revegetation will be encouraged except where adjacent to the access road and transmission lines.

Borefield B

Water will be pumped from Borefield B at a rate of up to 27 ML/d to meet production demands. Seven to ten bores will be constructed at this borefield, and normally two or more bores will be kept on stand-by.

Collector lines will be installed, and a forwarding station similar to that at Borefield A will be constructed. In addition, the forwarding station serving Borefield A will be equipped with pumps and balancing tank storage capacity to service the additional pipeline from Borefield B.

The pipeline from Borefield B will be 600 to 800 mm in diameter, and final design considerations will determine whether this will be placed above or below ground. This pipeline will parallel the Borefield A pipeline, and then extend north-east to the Marree-Oodnadatta road and rail alignment. It will follow the trackbed of the railway to a point 6 km west of Alberrie Creek, then branch north-east to Borefield B. Existing trackbed structures will be used where available for creek crossings. The 66 kV line serving Borefield A will be extended parallel to the pipeline. The access road will be developed from Borefield A to the railway, and from there to Borefield B. The Marree to Oodnadatta road will be used to provide access between Bopeechee and Alberrie Creek.

Water treatment

The water drawn from the borefields is too high in contained salts and fluoride for direct use as a potable supply, but is suitable for process use without treatment (Table 2.2). A schematic diagram of storage and treatment facilities at the Project is shown in Figure 2.22.

Table 2.2 Quality of water from borefields area

Chemical characteristic	Borefield A	Borefield B	NHMRC and AWRC guidelines*
Total solids (mg/L)	2,220 - 3,700	1,280 - 1,950	1,500
Calcium (mg/L)	15 - 34	3 - 12	200
Chloride (mg/L)	135 - 1,000	100 - 480	600
Total iron (mg/L)	Up to 1.1	-	1.0
Magnesium (mg/L)	13 - 35	0.4 - 11.5	150
Sulphate (mg/L)	50 - 360	5 - 34	400
Sodium (mg/L)	830 - 1,250	520 - 700	-
Nitrate (as N) (mg/L)	<1	<1	10
Fluoride (mg/L)	0.7 - 4.2	3.1 - 4.0	1.5
Total hardness (mg/L	93 - 230	19 - 66	600
Radium - 226 (mBq/L)	63	26	400
pH	7.1 - 8.0	7.5 - 8.1	6.5 - 9.2

* Desirable current criteria for quality of drinking water published jointly by the National Health and Medical Research Council and the Australian Water Resources Council (Commonwealth of Australia 1980).

Potable water (meeting the standards and requirements of the South Australian Health Commission) will be obtained by desalination of portion of the incoming borefield water in a reverse osmosis or electrodialysis plant located adjacent to the raw water storage.

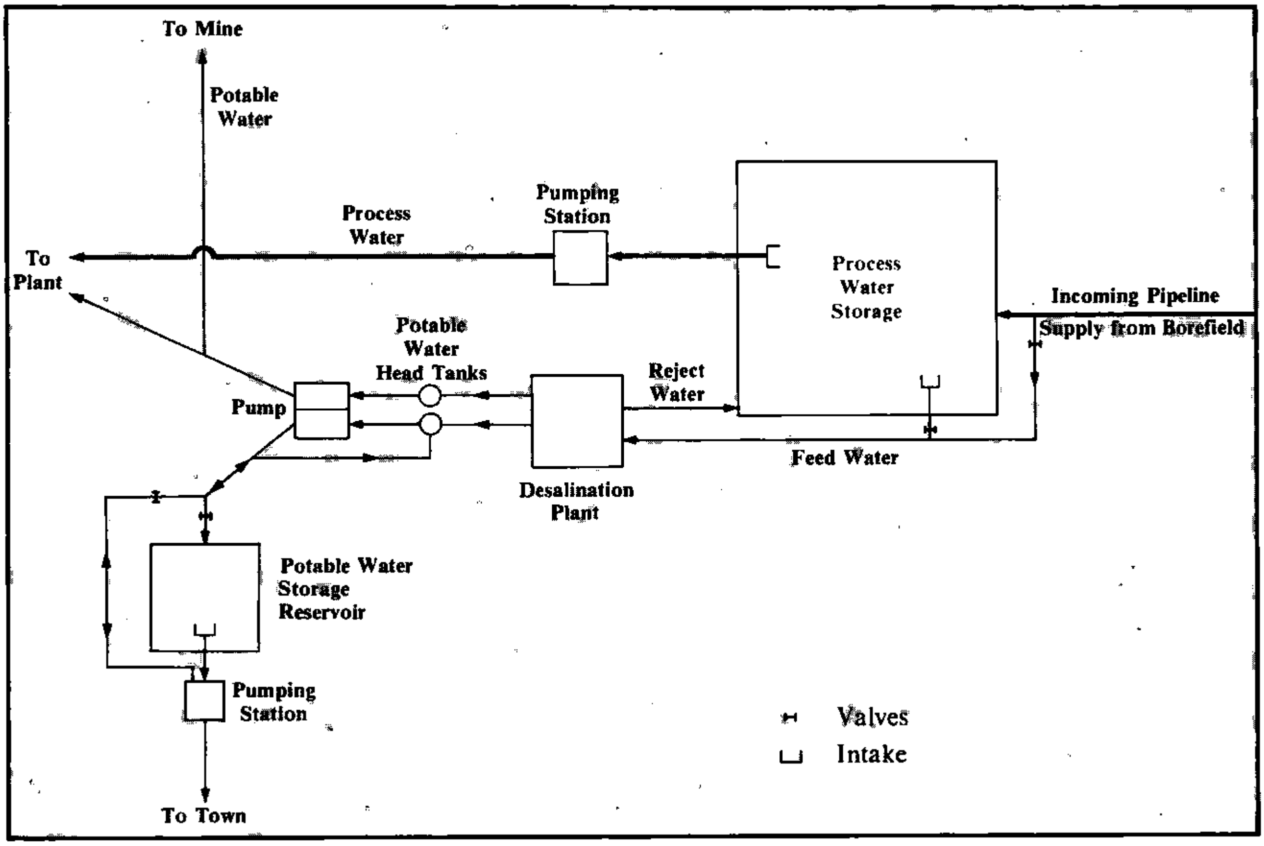


Figure 2.22

PROJECT WATER STORAGE AND TREATMENT: SCHEMATIC DIAGRAM

Brine discharge from this plant will be added to the process supply. These treatment facilities will be built in stages to meet Project demands, and the higher quality water from Borefield B will be used for plant feed as soon as it becomes available.

Water storage

Process (raw) water storage: The water pipelines will discharge into a process water storage to be located about 2 km east of the plant area (Figure 2.1). This open storage will contain a minimum of fourteen days' average usage to provide for interruptions to borefield supply, for fluctuations in demand, and for emergency use. The containment will be an excavated basin with raised embankments on an existing claypan. Process water will be pumped directly from this storage to the plant. The desalination feed for the potable supply will, under normal conditions, come directly from the incoming pipeline, with emergency feed only coming from the process water storage.

Potable water storage: A further major storage adjacent to the town will be provided for potable water supplied from the desalination plant (Figure 2.1). This reservoir will be of sufficient capacity to cover seasonal fluctuations in demand, permitting the desalination plant to operate at a near constant rate throughout the year. The storage will also provide emergency capacity for town and mine requirements in the event of interruptions to supply from the desalination plant. The probable design for this potable water storage will be based on that used at WMC's Kambalda nickel mining operations. This consists of a 'turkey nest' type circular excavation with a cut-and-fill circular embankment, clay lined, and with rip-rap protection. The Kambalda storage has a capacity of approximately 180 ML and has been in satisfactory service for about eight years. An alternative (also in use at Kambalda for about fourteen years) is of similar construction, but with concrete lining. Perimeter fencing will prevent access by animals.

Dust contamination of the potable supply has not been a problem at Kambalda or at other similar installations situated in comparable climatic zones. It is anticipated that, with prohibition of grazing and traffic, and with eradication of vermin in the general area surrounding the storage, vegetation density will increase and dust conditions should be reduced to a minimum. Any dust settling on the storage would normally form a silt deposit on the storage floor and would not be disturbed.

2.6.3 Other infrastructure

Roads

The primary means of transporting material to and from the site during construction will be along the existing roadway from the Stuart Highway, a distance of approximately 90 km. This roadway will be progressively upgraded and sealed by the Highways Department. Access roads between the town, village, plant, mine and airstrip will also be sealed to accommodate the anticipated traffic volume (Figure 2.1). Newly constructed access roads for transmission lines and the pipeline will be surfaced but unsealed, as will secondary Project Area access roads.

Airfield

The existing east-west airstrip has recently been upgraded to licensed standard. Development at this site will be limited to the present standard, with the possibility of light sealing and strip lighting installation to permit continued use through the construction phase of the Project.

In the longer term, it is probable that the town population and Project activity will necessitate the provision of a higher standard airfield suited to Fokker F-28 jet aircraft, although the funding and construction arrangements for this facility have yet to be finalized. The preferable alignment of the main runway would be north-south. This would require additional width, length and pavement strengths, and greatly improved facilities, which could not reasonably be provided at the existing site. The new site, which is considerably closer to the town site (Figure 2.1), will eliminate extra travelling and be better suited to the ultimate requirements.

Rail spur

A standard gauge rail spur may be constructed from Woomera or Pimba, with the timing of this development being dependent on a future economic and technical review. Corridor provision from the plant area to south of the town site has been made (Figure 2.1), although the track route from Pimba has not been finally selected.

Communications

At present, Olympic Dam has seven temporary radio link exchange lines to the Andamooka Exchange, and these will remain (with increases as necessary) during construction.

The permanent trunk system from Woomera will be established by Telecom for incoming and outgoing telecommunications. It will connect to a public exchange in the town which will serve all town telephone installations, as well as connecting to the Project PABX to be installed in the main administration building.

Boundary fence

The operations area will be enclosed by a 1.8 m high vermin-proof security fence, with access through a control gate near the office complex (Figure 2.1). The main purpose of this controlled access area will be to restrict access of the general public to the mine and processing area.

The vermin-proof fence will be extended to enclose the airstrip and town. It will be constructed to the recommendations of the Department of Agriculture, and will be high enough to exclude emus, kangaroos and vermin.

2.6.4 Central services area

The size and location of the central services facilities are shown on Figures 2.11 to 2.13, and include:

- **Site laboratory:** This facility will cater for metallurgical, geological, environmental and radiation safety analytical requirements. The geological and environmental section will have a service and research facility covering the full range of analysis normally required in a major mining operation. The metallurgical section will provide the normal analytical services required for process control, and will also incorporate some research capability, while the radiation section will provide gravimetric and radiometric analyses.

- **Central workshop complex:** This will be equipped for maintenance, fitting and turning, boilermaking, building services and light vehicle maintenance.

- **Main store complex:** Both open and covered storage will be provided in a storage compound, the perimeter of which will be separately fenced. Goods will therefore be able to be delivered without entry to controlled access areas. This complex will be served by truck traffic during construction and by truck or rail traffic during operation.

- **First aid centre:** This small casualty centre will have facilities to meet mine health requirements and regulations. Parking will be available for two ambulances.

- **Project fire station:** This will include provision for two fire engines.

- **Administration office:** Accommodation for approximately 250 administrative, metallurgical and engineering staff will be provided. Other mining and geological staff, together with some engineering staff, will be accommodated at the main mine office at the mine site.

- **Miscellaneous services:** A variety of minor service facilities will be available in this central area, including change rooms, a bath house and gatehouse.

2.6.5 Resource requirements

Set out in Table 2.3 are the major resource inputs required for the mine and plant operations based on current knowledge of the processes to be employed and possible sources of materials.

In terms of infrastructure inputs, it is impossible at this stage to predict quantities of materials required during construction, other than to outline the areas in which they will be required and the types of materials likely to be used. The major areas of activity will be as follows:

- metallurgical plant area
- mining area surface works
- town and associated facilities, including construction village

- access and local roadworks
- transmission line construction from Woomera and Port Augusta, and to the borefields
- main water supply pipelines from the Great Artesian Basin to Olympic Dam
- local water reticulation and desalination plant
- tailings retention area
- quarry for underground fill and surface works.

Table 2.3 Operational inputs for mine and plant

Inputs	Expected source	Approximate quantity t/a
For mine:		
Support steel	South Australia	150
Cement	South Australia	65,000
Explosives	Australia	3,000
Drill steel	Imported	80
Rock bolts and other miscellaneous steel	Australia	5,000
Tyres	South Australia/imported	40
Other mine consumables	South Australia/Australia	2,000
For plant:		
Sulphur	Imported	90,000
Manganese dioxide	Australia	90,000
Silica sand	South Australia	80,000
Salt	South Australia	3,200
Grinding balls	Australia	13,000
Mill liners	Australia	2,000
Empty drums (approx. 12,000)	South Australia	-
Reagents		
- S.X - oxime, amine	Imported	600
- Kerosene	South Australia	3,500
- Flocculant	Imported	600
- Ammonia	Australia	3,000

The basic materials required for these construction activities will include:

- aggregate, sand, cement and bitumen
- steel, timber, cladding and other general building materials
- metallurgical process equipment manufactured from steel, rubber and specialized plastics
- electrical cables (both overhead and underground) manufactured from copper, steel and aluminium, and electric motors
- piping - asbestos cement, ductile iron, plastic, steel
- instruments, insulators, transformers, and switchgear
- fencing
- office equipment
- communications equipment.

It is probable that aggregate and sand will be obtained locally. Most of the other items will be obtained from South Australian suppliers, although certain items of specialized equipment and materials will necessarily be provided either from elsewhere in Australia or from overseas.

Requirements of town residents for such items as groceries and consumer goods have not been quantified.

Energy requirements have been estimated as follows:

. distillate	6 ML/a
. fuel oil	2,500 t/a
. coal	80,000 t/a
. electrical energy	850 x 10^6 kWh/a.

The following estimates give the approximate quantities of Project outputs (which will be principally for export):

. copper	150,000 t/a
. yellowcake	3,000 t/a
. gold	3,400 kg/a
. silver	up to 23,000 kg/a.

2.7 TOWN

A permanent on-site workforce of approximately 2,400 people, with a further 700 supporting workers in government and service industries will be required in order to operate and maintain the Olympic Dam Project at a production level of 150,000 t/a of copper. This workforce together with its dependants is expected to give rise to a total population of some 8,000 people by the fourth year of operation of the Project, subsequently rising to 9,000 people at the production capacity contemplated. It is the Joint Venturers' intention to develop a permanent, comfortable and stable living environment in a new town at Olympic Dam. Although initial development will be carried out by the Joint Venturers under the provisions of the Indenture Agreement, the town will, from its inception, be under the control of a municipality.

The site of the proposed town is in sand dune and swale country on Roxby Downs Station, approximately 10 km south of the plant area (Figure 2.1). The town site encompasses an area of approximately 3,100 ha, which is sufficient to accommodate an ultimate population of 30,000.

Chapter 11 describes the proposed town in detail, and the policies for its development and administration. The following is a brief description of the basis for, and scale of, the proposed town development.

2.7.1 Workforce and population forecasts

The forecast size of the town is derived from estimates of the Project workforce and the resultant population required for a production level of 150,000 t/a of copper. These estimates have been developed from studies of workforce characteristics and population structures of other mining towns in Australia.

The estimated direct Project workforce comprises both Joint Venturers' personnel and employees of contractors employed by the Joint Venturers. For a Project construction period of four years, the direct Project workforce is forecast to rise to a peak of about

3,300 workers in the year prior to the start of production, and will stabilize at around 2,400 when the mine is at full production. The Joint Venturers' workforce is forecast to rise to about 800 at the start of the year prior to production, then increase sharply to 1,800 at the start of production and stabilize at around 2,200 at full production. Contractor employment is forecast to rise quickly to around 2,500 during the construction period and then fall to approximately 250 during the first few years of production.

These workforce estimates have provided the basis for predicting total population levels and housing requirements. The permanent workforce will be housed in the town, which is expected to expand from a population of less than 1,000 in the second year of construction to about 8,000 in the fourth year of production.

2.7.2 Accommodation

A high standard of family housing, long-stay caravan accommodation and permanent accommodation for single employees will be provided in the town. The short-term construction workforce will be accommodated separately in an expansion of the existing village facilities, and will therefore be living some 7 km from the town. The distribution of accommodation types assumes that, by production year 4, approximately 6% of the total population will live in caravans, 10% in single person accommodation, and the remaining 84% in houses. During the construction phase of the Project, the proportion requiring single person accommodation will be considerably higher.

No exceptional physical characteristics exist which would prevent normal engineering and housing construction standards and practices from being applied at the town site. Particular attention will be paid by the Joint Venturers to matters such as interior comfort, landscaping, and amenities. Company houses will be insulated in external walls and ceilings, and provided with suitable shading to minimize summer heat gain. Houses will have enclosed yards for privacy, and adequate water supplies will be available to give residents the option of establishing and maintaining lawns, gardens and shade trees. However, the adoption of garden styles which allow for the low rainfall characteristics of the region will be encouraged.

2.7.3 Social facility requirements

The social, cultural and recreational facilities to be established at Olympic Dam are expected to include the range of services and facilities which would be found in most towns with a population of 9,000 people. The responsibility for the funding of these facilities will be shared by the Joint Venturers and the State as defined in the Indenture Agreement. The scope of, and requirements for, those facilities normally provided by State Government departments and authorities have been determined after consultation with the relevant authorities. Municipal requirements have been assessed by comparison with established municipalities, taking into account the particular circumstances which apply, and provision of these have been agreed upon with the State Government. It is anticipated that the open town concept will encourage private entrepreneurs to provide additional facilities. The normal range of Commonwealth Government services can also be expected to be established as the town develops.

The Indenture Agreement contains provision for the establishment (appropriate to the town population) of the following facilities:

- schools
- medical and dental facilities
- police station
- kindergarten and pre-school centres

- local government offices
- library
- auditorium
- works depot
- swimming pool complex
- playing fields and sporting facilities
- fire and ambulance service
- other appropriate community facilities.

In the period of initial occupation of the town, school children will be transported by bus to Andamooka or Woomera.

Schools and other government buildings and services will be provided to normal standards applicable in the State. Provision will be made for air-conditioning in schools and kindergartens, and probably also in community buildings.

2.7.4 Town design

In the conceptual design of the town, particular attention has been paid to mitigating the effects of climate and to the preservation of vegetation and dunes at the town site.

It is intended that, from inception, the town centre will provide the principal focus, and at the planned development size of around 9,000 people most of the population will live within 2 km of this centre. It is envisaged that the growth of facilities and services will keep pace with the community's requirements, with smaller neighbourhood multi-purpose centres developing to complement the level of services offered in the town centre. These neighbourhood centres would probably comprise a cluster of commercial and community facilities including shops, a pre-school and a primary school.

The land budget of 896 ha to accommodate the needs of a town population of 9,000 also includes provision for recreation facilities and open space requirements as well as separate industrial areas and refuse disposal sites. In anticipation that the town may continue to develop beyond a population of 9,000, sufficient land is available at the town site to accommodate an ultimate population of 30,000.

2.7.5 Services

Although the site is not prone to water erosion, bared areas are vulnerable to wind erosion, and this will be taken into account in street design. Streets will be paved and sealed from kerb to kerb and, where justified by pedestrian traffic, will be provided with a paved footpath on at least one side. Street verges will be of sufficient width to accommodate essential services, they will be surfaced to minimize dust, and planted with street trees where practicable.

The town will be fenced within a buffer zone to prevent access by rabbits and other herbivores. Particular attention will be given to structural and other land use control measures to ensure the preservation of an adequate green belt. Harmful land uses such as trail bike riding will be directed to suitable locations outside the town to prevent nuisance problems such as vegetation destruction and dust generation.

Planning assumes that a water supply of suitable quality will be available to the town to meet the following consumption demands:

- mean daily consumption (excluding playing fields, parks and gardens): 650 L/capita

- mean daily consumption for maximum month (1.3 x mean daily consumption): 845 L/capita
- maximum daily consumption (1.8 x mean daily consumption): 1,170 L/capita.

Reclamation and recycling of sewage effluent and stormwater will provide a supplementary supply and will be an integral part of the general management of water resources. Rainfall and run-off design allowances will generally be in accordance with Australian standards.

The sewerage scheme will consist of gravity reticulation discharging into pump sumps at the low points of catchments. The pumping stations will discharge into rising mains, terminating at the treatment works situated at an appropriate distance from developed areas of the town. Treatment will be by conventional means in either oxidation ponds or ditches with effluent chlorinated for reuse in irrigation.

Electricity from the town switchyard will be distributed in 11 kV transmission lines to low voltage transformer locations throughout the town. In general, the Joint Venturers have a preference for underground reticulation of electricity, subject to final assessment at the time of development. Reticulation to premises and for street lighting will be to recognized standards.

2.7.6 Waste management

Town waste disposal will be under the control of the municipality. It is anticipated that disposal of refuse will be in a sanitary landfill, as this is the most economical and practical process of waste disposal for the area. The details of the town waste disposal system will be based on normal practices accepted by State authorities in other towns of similar size.

The disposal area will be located sufficiently far from the town to avoid adverse impacts, and it is anticipated that the municipality will manage the landfill to prevent problems associated with wind-blown refuse and to limit areas providing an open food source for birds.

2.8 ALTERNATIVES CONSIDERED

Previous sections of this chapter have described various components of the Project and the proposed development approach. In assessing the various alternatives which exist for many of these components, the policy of the Joint Venturers has been to consider alternatives which were perceived as practicable, and then to select a preferred alternative wherever this could be achieved. Areas where practical alternatives were considered include:

- metallurgical process routes, with an option of extracting copper only
- mining methods
- tailings disposal methods
- water supply sources
- power generation
- town sites.

In the case of the metallurgical process routes, it has not yet been possible to select a preferred route, and all the routes which were considered practical have therefore been assessed. In the case of the other areas, preferred options were selected based on considerations of economic, engineering, environmental and technological aspects of each alternative. The options which were considered, but are not currently favoured, are discussed below.

2.8.1 Option for copper extraction only

The uranium minerals are intimately associated with both types of copper sulphide ore in fine grained matrices (Figure 2.2 and Section 6.1). The deposit does not contain discrete zones of copper mineralization which can be mined separately from uranium mineralization, and therefore all ore mined will contain both copper and uranium minerals. Following mining, selective metallurgical extraction of only copper and precious metals from the ore is technologically possible. However, this has major economic drawbacks.

Based on the range of revenues considered in Chapter 1, this option of extracting only copper would result in a loss of expected revenue of between $A165 million and $A231 million annually, representing 28 to 46% of total Project revenue. Even given consequent reductions in operating and capital costs associated with uranium extraction, the Project would not be viable on this basis. This is because many of the capital and operating costs are independent of the uranium circuit. If only copper were to be extracted, there would still be requirements for a similar sized water pipeline, transmission lines, and town, the capital costs related to the mine would be unchanged, and the operating costs associated with mining and with the infrastructure components mentioned above would also remain substantially unaltered.

Based on historical and predicted trends in the selling price of copper, it would not be economically viable to develop the deposit by extracting only copper and precious metals from the ore.

2.8.2 Alternative mining methods

With the current knowledge of the orebody, three methods of mining are currently favoured for use at Olympic Dam. These have been carefully selected and adapted as appropriate, considering engineering, safety, environmental and economic factors with respect to the:

- size of the deposit
- shape and location of the deposit
- mineral concentration and value
- physical properties of ore, adjacent rock and overlying strata
- inferred geological structure of the ore blocks.

The following two additional mining methods have also been considered but are not favoured for the reasons discussed.

Open pit

Mining the deposit by open pit was initially investigated, but the depth to the top of the ore block closest to the surface and the lack of clear definition of the ore limits suggest that mining by this method would not be suitable. The cost of overburden removal would financially disadvantage the Project because of the very large initial capital expenditures involved, and the lag of several years which would occur before ore could be extracted. The very large amount of overburden and waste rock would also present a significant environmental problem as, assuming that overburden could be piled as high as 50 to 60 m, an area in excess of 100 km^2 would be required for storage. The variable grade, location and geometry of the ore blocks further indicate that major scheduling and grade control problems would be incurred.

Ventilation difficulties would be encountered for a deep open pit in the arid Olympic Dam area, as inversions would reduce inpit air circulation. In an underground mine, however, ventilation can be controlled by mechanical means. Also, a greater surface area of ore is exposed at one time in an open pit, increasing the radon emanation, while in an underground operation this can be limited by progressive back-filling.

The open pit method does have some advantages, however. Overall recovery of ore would increase, and a lower grade of ore could be mined and processed because of the lower operating costs. Nevertheless, these advantages do not compensate for the disadvantages, and this method is not currently considered a viable alternative.

Caving

Neither sublevel caving nor block caving are currently favoured as alternative mining methods, primarily because of the variable grade and location of the ore and the high strength of the unmineralized rock below the cover sequence. Sublevel caving involves development of sublevels between, and parallel to, main levels, at distances from 8 to 15 m, leaving an 8 to 12 m column of rock to be fragmented by blasting. As the rock is blasted, it collapses into the sublevel and is then removed, and the overburden immediately caves onto the fragmented ore. Block caving is a method whereby relatively large blocks are undercut and allowed to collapse as ore is removed through drawpoints at the base of the blocks. Caving is permitted until the ore has been removed.

While both of these caving methods are possible, each has the following significant disadvantages:

- mine ventilation would be difficult to control;
- the grade of ore would be significantly diluted by the addition of barren and subgrade material;
- caving would have to be induced in many places, as ore is frequently overlain by thick, very strong rock beneath the Tregolana Shale;
- siting of surface facilities would be difficult, because of the lateral extent of the ore, and the surface effects of the caving operation;
- currently uneconomic mineralization (which may later become economic) may be rendered irretrievable.

2.8.3 Alternative water supplies

Water supply options which have been considered include:

- local groundwater, with or without treatment
- regional surface water supplies (with storage reservoirs)
- pipeline from southern sources (e.g. River Murray)
- pipeline supply from the Great Artesian Basin.

Local groundwater is highly saline (in excess of 20,000 mg/L) and suitable for very limited purposes only. The lack of a suitable quantity of available water, and the extensive treatment which would be required, make use of this water physically, technologically, and environmentally impracticable for process or potable purposes.

While local stormwater run-off will be of a quality suitable for most purposes, this would at best provide a limited and unreliable supplementary supply. Stormwater run-off which can be reasonably harvested, however, will be reused where practicable.

A potential source of surface water supply might be the exploitation of run-off from the lower Flinders Ranges. Potential dam sites exist on the Willochra and Hookina Creeks (South Australian Department for the Environment 1980), and there are river flow gauging stations in the catchment areas of both creeks. A partially rated gauging station, with a catchment area of 6,240 km², is located on Willochra Creek at Partacoona, while a non-rated gauging station, with a catchment area of 375 km², is located on Mernmerna Creek at Arkaba. These sources could be used to provide larger scale water supplies for mining or industrial use alone, or in conjunction with other sources (Engineering and Water Supply Department, pers. comm.). However, their location is remote from Olympic Dam, the reliability of the initial supply is uncertain, costs would be excessive, and the yield would be inadequate for Project requirements.

In the absence of suitable local groundwater or surface water sources, the two water supplies considered to be capable of supplying the Project requirements were:

- River Murray water, either from the existing Morgan to Whyalla pipeline at Port Augusta, or directly from Morgan
- the Great Artesian Basin.

The availability of potable water from the River Murray for future development in the Northern Region (including the Iron Triangle) is not considered to be a problem for the forseeable future (Iron Triangle Study Group 1982). However, the spare capacity of existing pipelines is insufficient to transport the total water requirements of the Olympic Dam Project. The quantity of water available from the Port Augusta to Woomera pipeline at Woomera would be adequate only for an interim supply, while the quantity of water available for the Project from the Morgan to Whyalla pipeline at Port Augusta (a distance of 270 km from Olympic Dam) is expected to be limited to 9 ML/d. While this water would be of potable quality and require no further treatment, a further Project supply of approximately 24 ML/d would still be required to meet process water needs. If River Murray water were to be used for process purposes, it would require an additional pipeline from Morgan to Olympic Dam, a distance of approximately 500 km. If the River Murray were to be used as a source of potable water only, a process water supply from the Great Artesian Basin would still be necessary. Economic considerations, related to the capital and operating costs of such pipelines, as well as the higher risk during drought of supply restrictions to existing River Murray commitments if additional demands are to be met, make this alternative unacceptable.

2.8.4 Alternative approaches to tailings containment

The scheme briefly outlined in Section 2.5.1 and described more fully in Chapter 7 has several advantages over other methods of tailings storage. To allow comparisons to be drawn between the proposed scheme and some of the possible alternatives, a brief description of alternative schemes is given below together with a discussion of the advantages and disadvantages of each.

Subaerial deposition without additional evaporation areas

For this alternative, four separate storage areas would be provided to permit the total containment of all free liquor resulting from each deposition cycle. No decanting of liquor, even following heavy storms, would take place. This method would require a considerably larger storage area (784 ha) for complete containment and evaporation of liquor over a thirty-year operation period. The embankments would be constructed progressively: initially a height of 3 m would be required, with subsequent stages of construction bringing the thirty-year height to 15 m.

Tailings would be discharged from spigot pipes laid on opposite embankments of each of the four storages and deposited in layers. Each layer would be permitted to settle, consolidate and desiccate to regulated levels of saturation. The cycle time for deposition would allow all free liquor to evaporate from the surface of each storage prior to the placement of subsequent layers of tailings. During periods of high rainfall, liquor might pond for several cycles, but this would not be to the detriment of the operation and stability of the storages because of the flexibility afforded by subaerial deposition methods.

The advantages of this alternative are that no provision for decanting liquor would be required and no separate decant evaporation pond would be necessary. Staged construction would permit lower initial capital costs, despite the fact that the embankments would be much longer than in the preferred scheme.

However, the disadvantage of this scheme is that the areas of each storage would be about twice those of the adopted scheme. While this would not be detrimental to the stability of the storage, it would result in greater radon emanation levels during both the operating and post-operating phases. It would also have a greater environmental impact because of the larger areas of land required for storage of tailings and for excavation of embankments and cover material for decommissioning.

Subaqueous storage

The second alternative considered was subaqueous storage. In this method the tailings would be discharged into water, and a continuous water cover would be maintained during the life of the facility. Although there have been several tailings storages designed, constructed, and operated in Australia using this technique, it is considered that the method is not appropriate for the Olympic Dam site. The concept of depositing and storing tailings below a constant minimum water cover was developed to reduce radon emanation from the tailings storage during the operating period. While water cover would generally achieve this aim, it would fail to satisfy the other important objectives considered by the Joint Venturers in their tailings containment considerations (Section 7.1).

To provide the storage needed for a thirty-year operation, this method would require an area of approximately 575 ha, with embankments constructed to a height of 30 m. While other combinations of area and embankment height would provide the storage volume required, these dimensions were considered to offer the most reasonable balance between embankment height and area in limiting the loss of liquor by seepage and evaporation, which in any event would be high. The embankments would be designed and constructed as water retaining structures, since a hydrostatic head would act at all times on both the embankments and the foundations. However, materials suited for this type of embankment construction are not available in sufficient quantity at Olympic Dam, while foundation conditions are not amenable to containment for the structural security required. The tailings would be deposited from pontoon mounted discharge points, which would be moved frequently as the cones of deposited tailings rose towards the surface of the water cover. Tailings could not be deposited from the embankments, as beaching would occur, thus exposing the tailings.

The resultant mass of stored tailings would remain in a saturated state and give rise to seepage for a very long period following any decommissioning. Significant amounts of seepage would also occur during the operational phase as, although every attempt would be made to provide watertight embankments and foundations, it would be impossible to totally prevent losses.

The considerable evaporation losses, especially during the summer months, would also require very large volumes of make-up water to maintain the water cover. Some 55,000 m^3/d of additional water would be required in winter months to balance evaporation and seepage losses, while during the summer months the additional water requirements would be approximately 115,000 m^3/d. These quantities of water represent about two to four times the presently envisaged water requirements for the total Project and would be a very substantial additional burden on pumping and water supply requirements from the Great Artesian Basin.

A further practical problem would be the distribution of tailings to ensure the maintenance of a water cover. The physical proportions of the pipework involved would make the operation of a barge deposition system difficult and this, coupled with the known problems of continually trying to sound and plot the contours of the tailings surface, cast doubts on the overall practicability of such a system.

The tailings deposited subaqueously would have a very low in situ density and strength. The density could be up to 40% less than would result from the proposed method, thus requiring considerably more storage capacity. Because of the very low strength of the tailings, decommissioning would not be possible for a number of years following the completion of tailings deposition.

Disposal of tailings underground

Unless tailings have a very coarse size distribution, they must be processed before being suitable for use as mine-fill. This process consists of removing the very fine fraction (slimes) and modifying the remainder of the material to produce a fill. (At present it is envisaged that up to 20% of the mine back-fill requirements could be provided by the coarse fraction of processed tailings.) The removal of slimes is necessary to produce a free draining fill, otherwise it may build up a high hydrostatic head when placed, causing retaining walls to fail, and it may also undergo liquefaction, flushing to lower levels of the mine. The gradational size distribution is necessary to act as a filter to retain added cement and to provide a physically stronger fill.

In addition, the conditions which make the surface tailings structure a solid competent mass (high net evaporation drying the tailings, and layered deposition) are not achievable underground. Therefore the tailings would, if not processed, remain saturated for very long periods underground and would not develop such competence.

Neutralization of tailings

Tailings could be neutralized prior to deposition either with purchased lime or with calcined dolomitic limestone. This option was not selected however, as it offers no significant advantages, while presenting the following disadvantages:

- Tailings neutralized with lime would have an in situ density of about 1.6 t/m^3 and those neutralized with calcined dolomitic limestone about 1.3 t/m^3. Therefore, the volume of neutralized tailings would be about 20 to 50% greater than acid tailings, and the areal extent of the tailings storage would be correspondingly larger.

- The surface of neutralized tailings is more friable, has more cracks, and there is no bonding between layers. Greater dust emissions would therefore result, and the chance of solids overflow into the central decant would be increased.

- Neutralized tailings have a higher viscosity, requiring a lower pulp density for pumping and hence a higher water usage.

- Massive scaling of pipes, valves, and all exposed metal surfaces would result from neutralization.

- Neutralization would require the quarrying of additional dolomitic limestone or the purchase of lime, resulting in higher operating costs and a larger quarry area.

Neutralization of tailings causes heavy metals to precipitate in the tailings liquor, thus reducing the levels of these contaminants if seepage occurs. For this reason, tailings deposited subaqueously in mining projects in the Northern Territory are neutralized prior to deposition. This would not be a significant advantage at Olympic Dam, however, as the subaerial method of deposition will effectively eliminate seepage.

2.8.5 On-site power generation

In the early construction stages of the Project, extensions to the existing on-site diesel power station will be built. However, on-site power generation is considered neither practicable nor economic for the production phase, as it involves high capital and operating costs (especially for fuel), as well as logistical problems. It was therefore decided that, in the long term, only emergency on-site power would be installed, with all other power being supplied from the State power system following the construction of high voltage transmission lines connecting to this grid.

2.8.6 Alternative town sites

A number of options were considered in town site location, as well as the possibility of expanding Woomera and Andamooka. A comparison between the proposed site and the alternatives considered is presented below.

Woomera

Woomera is approximately 80 km south of Olympic Dam, located on a stony plateau which is characterized by a low open chenopod shrubland and the absence of trees and tall shrubs. The facilities at Woomera have supported a population of 6,000, although the present population is now only about 2,000. It has been a closed town until recently, and therefore has not developed all the facilities normally associated with a regional service centre.

The possible use of Woomera was rejected primarily because of its distance from Olympic Dam. Eighty kilometres was considered too great a distance for daily commuting of a large workforce. In addition, the stark plateau landscape was considered less attractive than available alternatives closer to the site.

Andamooka

Andamooka is about 30 km east of Olympic Dam on gullied, gibber covered terrain. Andamooka has a population of about 400 and acts as a local service centre for the opal mining workforce and associated population. It is not a planned town and has no local government administration. Some existing services, such as schools and police, are being used by the present Olympic Dam population.

To provide a suitable town for the Project workforce, a major expansion of Andamooka would be required. However, the site is unsuitable for such expansion, and this option might not be favoured by the existing residents. In addition, a 30 km travel distance for the Olympic Dam workforce, although not grossly inconvenient, is not desirable when other closer options exist. Thus, Andamooka was not considered to be the most appropriate site for the new town.

New town site options

A detailed investigation was undertaken of other suitable sites within reasonable proximity to the Project Area. A distance of about 8 to 16 km from the mining area was considered to be sufficient to provide a suitable environmental buffer and to diminish radiation levels to at least an order of magnitude below public exposure limits, while being close enough to enable tolerable commuting times for the workforce. A general arc curving from the west southward to the east was considered desirable for town location, as most traffic and services would come from the south.

The following six possible sites (Figure 2.23) were selected from aerial photography and were subsequently inspected:

- Site 1 Lake Blanche: west of the Joint Venture Area
- Site 2 Myall Dam West: west-south-west
- Site 3 Myall Dam East: south-west
- Site 4 Axehead Dam: south (the proposed site)
- Site 5 Phillips Ridge: south-east
- Site 6 12 Mile Dam: east-south-east.

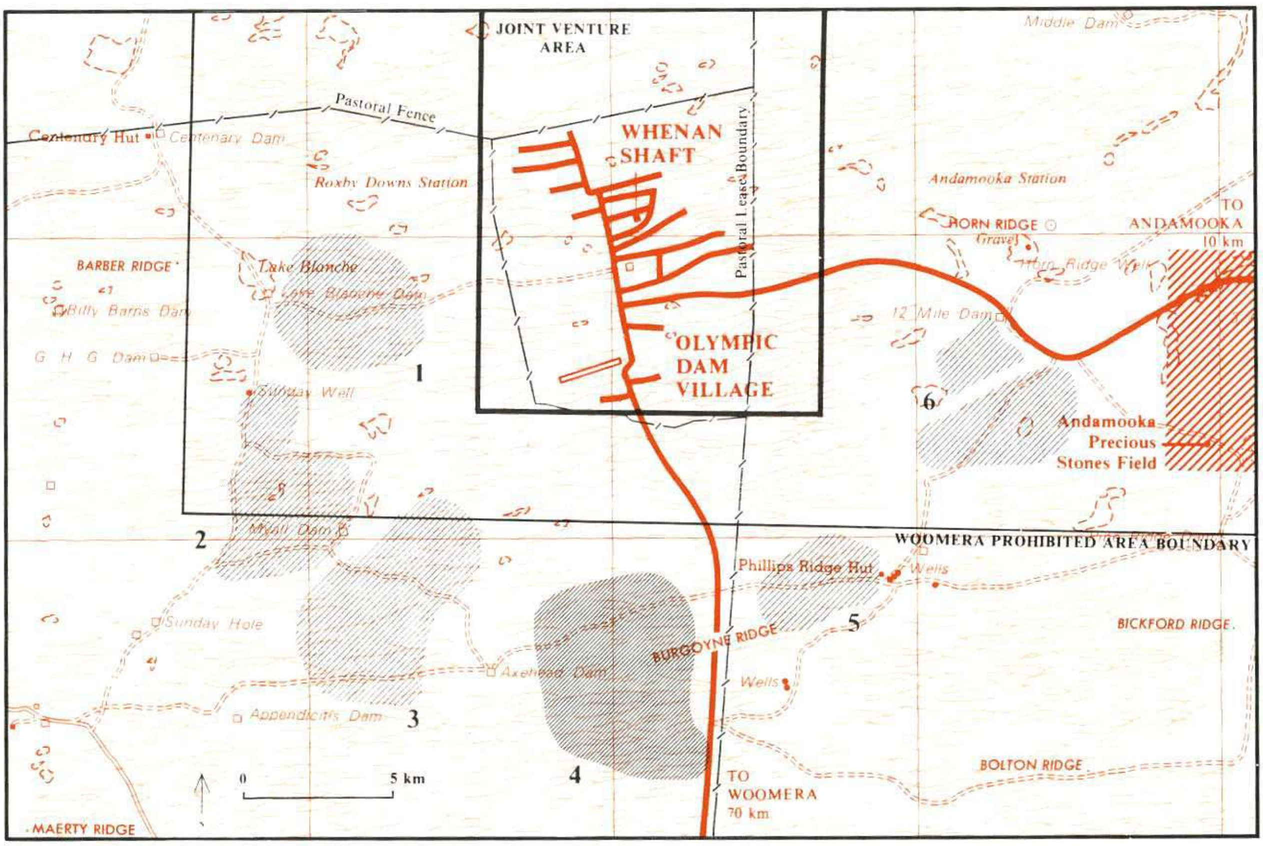


Figure 2.23
ALTERNATIVE TOWN SITES

The discussion below summarizes the factors which were considered in comparing the alternative sites:

- **Amount of land amenable to urban development:** A basic area of 1,500 to 1,800 ha, with the capability of expansion to between 2,400 and 2,500 ha, was considered essential. Myall Dam East (Site 3) and Axehead Dam (Site 4) are the most suitable on this criterion, each with approximately 2,000 ha suitable for development. Lake Blanche (Site 1), Myall Dam West (Site 2), and 12 Mile Dam (Site 6) are adequate, with around 1,600 ha. However, Phillips Ridge (Site 5) is too small, with less than 700 ha amenable to development.

- **Impact of town location on land severance of adjoining pastoral properties:** Sites 4 and 5 are near the boundary of Roxby Downs and Andamooka Stations and would have the least impact. With respect to location of watering points, fencing, and intensity of use, Sites 1, 2 and 3 on Roxby Downs Station would lead to severance problems, with the town site cutting off stock access to water. Site 6 on Andamooka Station also has a possibility of producing similar severance difficulties.

- **Proximity to the existing services corridor:** Sites 4 and 5 would be preferred on this criterion, being closer to the corridor for transport and infrastructure access.

- **Ease of construction of urban facilities:** Site 6 has disadvantages due to a relatively higher rock horizon than the other sites, while there would also be development difficulties for Site 5 because of the steepness of the dunes. Reasonable ease of construction was indicated for the other sites.

- **Flood-prone areas:** All sites have some claypans and depressions which would be subject to occasional inundation. However, Site 5 has an excessive area of depressed land which would make expansion difficult. Sites 1, 4 and 6 were considered to be the least disadvantaged in terms of area of land subject to inundation.

- **General amenity:** The presence of trees on the site was considered an important factor. Trees are found more abundantly in sand dune country, which also offers the best soil conditions for new growth. Thus Sites 1, 4 and 5, which are characterized by this type of terrain, offer the best prospects for long-lasting natural treescapes. Sites 1 and 5 exhibit grazing damage, Sites 2 and 3 have predominantly saltbush cover and are generally devoid of trees, while Site 6 is a bare, heavily gibbered plain without any significant vegetation.

- **Horticultural aspects:** Sites with predominant areas of sand dunes offer better prospects for attractive town development than sites exhibiting large areas of saltbush-clad swales. Sites 1 and 4 are better placed in this regard than the other sites.

From this review of factors, Site 4 (Axehead Dam) was selected as the proposed town site. This site has the largest area amenable to urban development. It is near a pastoral station boundary thereby minimizing effects of land severance. It is well located in relation to the road and other infrastructure services corridors. No construction difficulties are expected, and the area of depressed land is not significant. From an amenity viewpoint, the site has more tree cover, and the extent of sand over the site offers reasonable scope for further vegetative growth. Although the site is within the Woomera Prohibited Area, changing the boundary is unlikely to present a significant problem and, at the time of writing, the Commonwealth and State Governments were negotiating appropriate changes to the eastern boundary of the Prohibited Area in the vicinity of the Olympic Dam Project site. Drilling of the area has confirmed that the site is not underlain by mineralization.

CHAPTER THREE

Terrestrial Environment

SUMMARY

Regional environment

There are two main types of environmental associations in the Olympic Dam region. One association, in which the entire Project Area is located, is characterized by extensive longitudinal east-west sand dunes and interdune corridors in which structured soils of the underlying plain are exposed. The Project Area represents less than 2% of this widespread association. The other type of environmental association is characterized by flat to gently rolling stony tableland strewn with gibbers. This occurs to the east and south of the Project Area.

Terrain

The landforms in the Study Area are generally related to two main factors: the weathering of the underlying rocks, and the superimposition of wind-blown sand over the extensive tableland surface throughout the region. In terms of erosion susceptibility, six terrain features were identified: stony tablelands, sand dune ridges, interdune corridors, drainage depressions, low stony rises, and dune fields. The sand dune ridges and dune fields show the greatest potential for erosion, especially in areas of instability (areas without vegetative cover) where blowouts can form, leading to dune deflation and sand movement during infrequent times of high winds. The higher percentages of silt and clay in the soils on the stony tablelands, interdune corridors, drainage depressions, and low stony rises, in addition to the presence of gravel as a reinforcing material or as a surface shield, reduce the erosion potential of these terrain features. Potential sand movement can be controlled by limiting the degree of disturbance on sand dunes, by retention of vegetative cover where possible, and by early stabilization of any areas which show sand drift or which require disturbance of dune ridges. Other minor potential impacts associated with alterations to surface drainage and sediment movement can be accommodated by appropriate engineering design.

Hydrology

The crests of the sand dunes form a mosaic of small closed catchments. With high average evaporation (about 3,000 millimetres per annum) and low average rainfall (160 millimetres per annum), run-off events are infrequent and soil moisture contents

are low. The dunes have infiltration rates higher than the maximum rainfall intensity, while the swales and depressions are relatively impermeable. The introduction of substantial areas of impermeable surfaces due to development will lead to some minor increases in run-off, but these will be accommodated by drainage systems and compensating basins. The effect of the closed catchments will be to contain run-off within the immediate vicinity of the Project Area. The localized increases in soil moisture levels arising from the watering of gardens and recreation areas will promote increased plant growth.

Flora

The two main vegetation suites in the region are related to the two principal types of environmental associations: stony tablelands support a low chenopod shrubland, while the dune fields have a recurring pattern of woodlands or tall shrublands on sands and chenopod shrublands on structured soils of interdunal corridors. Grazing by stock and rabbits has degraded the vegetation in the Project Area, and in any case this type of vegetation is widely replicated. Therefore, except for isolated communities associated with drainage features, it has little conservation significance. Vegetative cover does, however, play a significant role in preventing erosion, as well as having amenity value (particularly the groves of western myalls and other tree species). Although some vegetation clearance will occur as a result of development, the Joint Venturers' policy of vegetation retention or rehabilitation of vegetated areas is an important consideration in reducing vegetation impacts, and has been incorporated in siting decisions, particularly in relation to the town. In addition, the exclusion of stock from the area, the control of rabbits, the creation of buffer zones, and garden and amenity planting will all assist in further mitigating adverse effects on vegetation.

Fauna

Pastoral activity and the introduction of exotic species have substantially reduced the number of native mammals present in the Olympic Dam region. Reptiles have been affected to a lesser degree. Although habitat loss due to Project development will occur, the area involved is extremely small compared with the regional extent of the available habitat. Some species of avifauna will be disadvantaged by habitat loss while others will benefit from the increased availability of water and food resulting from Project development. Some loss of avifauna may occur as a result of the acid liquor evaporation pond.

3.1 REGIONAL ENVIRONMENT OF THE PROJECT AREA

On a regional scale, Laut et al. (1977) have defined environmental associations which comprise a particular recurring combination or sequence of landforms with similar vegetation cover. Environmental associations are therefore useful in describing the broad physical and ecological environments of the region. There are three environmental associations within the region incorporating the Olympic Dam Project Area: the Moondiepitchnie, Woomera and Andamooka environmental associations (Figure 3.1).

- **Moondiepitchnie:** The Moondiepitchnie environmental association can be described as an undulating plain, often with extensive sand sheets, dunes, and low silcrete-capped rises, featuring a mixed cover of tall open shrubland with a chenopod shrub or grass understorey, low chenopod shrubland, and woodland with a tussock grass understorey. Its primary characteristic in the Study Area is the sequence of more or less linear east-west oriented dunes of siliceous sand and interdune corridors (or swales) in which the underlying soils are exposed (Figure 3.1). The dune sands contrast with the soils of the corridors, which are generally loamy or clayey, frequently with a variable gibber coating, or covered by thin sand sheets. The

Figure 3.1
ENVIRONMENTAL ASSOCIATIONS

spatial rhythm of dune and swale soils enforces a similarly pronounced rhythm on the vegetation: dunes normally carry woodlands, while corridors carry low shrublands, although localized exceptions do occur. This alternation of dune and swale, and of woodland and shrubland, creates the impression most characteristic of the region - of a landscape which is highly variable over very small distances, but uniform and monotonous overall. Dune density (determined by spacing between crests) varies considerably, and accounts for a number of different terrain units and vegetation sequences throughout the dune fields. Drainage of the Moondiepitchnie is internal, into claypans and depressions between the sand ridges. On Figure 3.1 a series of older north-south trending relict dunes or strandlines in the form of low stony rises can also be seen underlying portions of the association (Ambrose and Flint 1981).

- **Woomera:** The Woomera environmental association, which includes the Arcoona Plateau, consists of a tableland of essentially undisturbed Proterozoic sediments capped by the Arcoona Quartzite. The surface of the plateau is flat or gently rolling, strewn with gibbers and mantled by moderately deep red duplex soils. A dendritic drainage pattern has evolved over much of the plateau proper, although a regular joint system exerts a strong control. Numerous short channels with steep gradients radiate from the margins of the main tablelands. Around these are coalescent streams and small outwash fans although, after rain, streams are soon dissipated in the surrounding sand plains. In the upper levels of the tablelands, drainage channels are wide, shallow, and generally ill-defined, with surface waters mostly being collected in gilgai depressions or in occasional canegrass swamps. At lower levels, drainage channels coalesce to form prominent tree lined creeks and, when stream erosion has proceeded to the stage where basement rocks are exposed, cliffs are commonly developed.

- **Andamooka:** The Andamooka environmental association comprises a tableland formation similar to that of the Woomera environmental association (particularly the Arcoona Plateau), but with a greater degree of plateau dissection and with slightly different combinations of landforms and soils. Both environmental associations have dominant chenopod shrublands with a general absence of tree species.

The region is dominated by the Moondiepitchnie environmental association. Its area is 13,000 km^2, constituting a remarkably large expanse of country with the same basic features. Laut et al. (1977) recognized and mapped environmental associations within South Australia as small as 50 km^2 and the median area for environmental associations is only about 1,400 km^2. The mine, plant, town site and significant portions of the infrastructure corridors are located in the Moondiepitchnie environmental association. The Baseline Study Area, used for more detailed description of the terrain and vegetation in the near vicinity of the Olympic Dam Project Area (Figure 3.1), is predominantly in the Moondiepitchnie environmental association, with the eastern margin overlapping into the Andamooka environmental association.

The Olympic Dam Project Area of about 200 km^2 is less than 2% of the Moondiepitchnie environmental association. Thus, in a regional context, the area which will be directly affected by the Project represents a small part of a widespread environment.

3.2 TERRAIN

3.2.1 Terrain description

Within the Study Area the landforms and soils form two distinct suites: those created by the weathering of the underlying rocks of Cambrian to Cretaceous age, and others of more recent aeolian origin which have been superimposed on the landscape. The underlying rocks consist of the Arcoona Quartzite, the Andamooka Limestone, and Cretaceous kaolinitic siltstones, which on a regional scale are relatively flat-lying units. Although varying thicknesses of these materials have been removed during past erosional cycles, the resulting surface remains essentially flat, consisting of extensive stony tableland. In places where extensive deep erosion has occurred, the rocks have been cut down almost to sea level, and claypans, swamps and lagoons have formed at the terminal points of the internal drainage systems. The more recent Quaternary deposits form a thin veneer of aeolian origin over much of the tableland surface. In many places these form the most dominant feature of the landscape, consisting of a series of east-west oriented red quartz sand dunes.

The characteristics of the tableland surface vary considerably over the Study Area and depend on the underlying rock type and the thickness of the Quaternary sediments. The dune fields display a similarity of form and soils which are different from the characteristics of the underlying surface.

Over most of the southern part of the Study Area where the Arcoona Quartzite is the underlying rock type, the tableland shows extensive gilgai formation and the surface is littered with dark brown flat gibbers. The soils are brown and red-brown clays of high plasticity, showing large volume changes with changes in moisture content, and are highly dispersive. Calcareous material is not present in the profile, but gypsum occurs mainly in bands and crystalline pockets. Where run-off occurs from this tableland, it forms saline lakes and lagoons.

Towards the east of the Study Area the tableland surface shows similar characteristics, except that occasional large rounded boulders occur on the gibber strewn surface and drainage is often into fresh or brackish canegrass swamps. The underlying rock in this area is a kaolinitic siltstone which, in the Andamooka area, contains precious opal in conglomerate bands. The surface shows gilgai formation, but this is less extensive than on the Arcoona tableland. Lime is present in the profile either as a calcareous silt or as calcrete rubble. Minor occurrences of this surface are also found in the vicinity of Purple Downs Station homestead and to the east of the existing quarry at Olympic Dam.

In the Project Area the underlying rock type is the Andamooka Limestone. This rock is covered by up to 10 m of Quaternary sediments. In some areas the bedrock is very shallow and outcrop occurs in some places. The tableland surface is generally undulating, with sandy textured soils and extensive occurrences of gibber in the swale areas. The soils contain large quantities of calcareous material, possibly derived from weathering of the underlying rock. Where the limestone is deeper, the soils are still sandy textured, and contain considerable quantities of lime. Drainage is into claypans, vegetated shallow depressions, or occasionally into small dolines. A series of approximately north-south trending low stony rises (Figure 3.1) also occurs through this area, dividing the land surface into a number of discrete catchments, each of which generally contains a depression or claypan at the lowest point. These low stony rises are probably silicified strandlines associated with an old Tertiary lake system (Ambrose and Flint 1981).

Superimposed on these various tableland surfaces is the Quaternary series of east-west trending red quartz sand dunes. These vary in height up to 10 m, in width to a maximum of 300 m, and in spacing from about 100 m to several kilometres. When closely spaced, the interdune areas form gentle concave swales covered with sandy soil, and are often well vegetated with trees and shrubs. Where more widely spaced, the tableland surface is exposed with its more silty and clayey sandy soils, gibber and drainage features.

3.2.2 Terrain mapping

Terrain patterns

The terrain classification consists of categorizations firstly on the basis of underlying geology (since this has influenced the varying characteristics of the tableland surface), and secondly on the density of the dune formation. Six landform types have been delineated for each rock type, with broad expanses of the tableland surfaces classified as the first pattern, and completely sand covered surfaces as the sixth. Landform on the various rock types thus becomes more similar as the density of the dunes increases; when the sand cover is complete they become indistinguishable.

For the terrain classification, the rock types or geological regimes are described as follows:

- Quaternary deposits (Q) - sand ridges and dune fields with interdunal corridors (swales) and claypans;

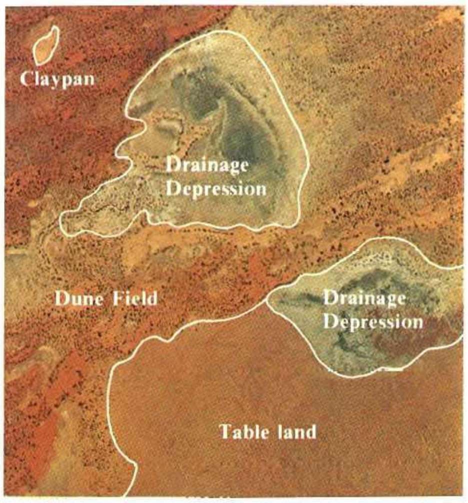
  and (Qs) - sand ridges, dune fields and claypans superimposed on an older system of northerly trending low stony rises or dunes;
- Cretaceous siltstone (K) - kaolinitic siltstones, shales, and sandstones, with cobbles;
- Andamooka Limestone (A) - dolomitic limestone;
- Arcoona Quartzite (P) - quartzite.

The landform types are described as follows:

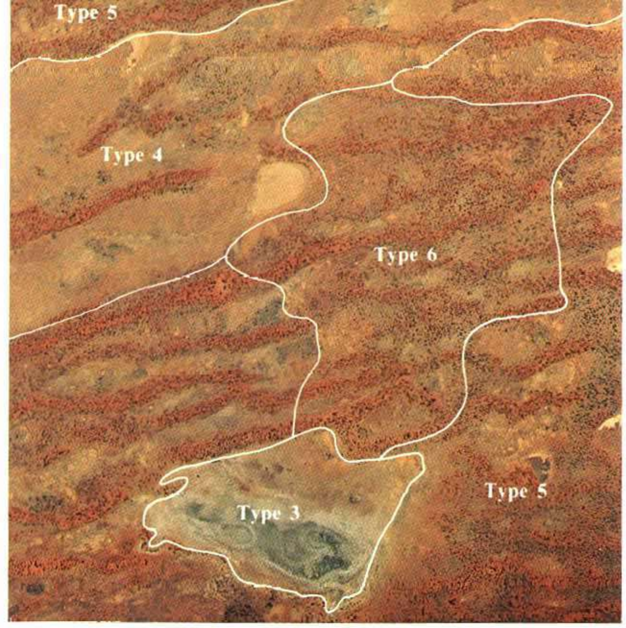
- Tableland (1) - almost flat tableland surface, with no dune ridges present;
- Dissection slopes (2) - dissection slopes of the tableland, generally with no dune ridges;
- Drainage areas (3) - broad concave depressional drainage areas which can contain sand ridges;
- Widely spaced dunes (4) - almost flat tableland surface with widely spaced sand ridges (up to 30% of the area of the pattern);
- Moderately spaced dunes (5) - almost flat tableland surface with between 30 and 60% of the area consisting of sand ridges;
- Closely spaced dunes (6) - almost flat tableland surface with between 60 and 80% of the area covered by sand ridges.

The terrain pattern classification system consists of a simple alphanumeric coding combining these geological and landform types. For example, pattern type A6 refers to Andamooka Limestone tableland with closely spaced east-west trending dunes. Examples of the terrain patterns and the differences between landform types are shown in Figure 3.2.

Terrain pattern types described for the Study Area are listed and mapped in Figure 3.3 at a scale originally of 1:40,000 (reduced here to 1:125,000). This level of mapping is appropriate for the classification and comparison of large areas of land, as it delineates recurring terrain features which form distinctive landscape types. It has consequently been carried out for the entire Study Area.



a Aerial photograph showing distinction between tableland (landform type 1), drainage areas (landform type 3), and widely to moderately spaced dune fields (landform types 4 and 5).



b Aerial photograph showing distinction between widely spaced dunes (landform type 4), moderately spaced dunes (landform type 5), and closely spaced dunes (landform type 6).

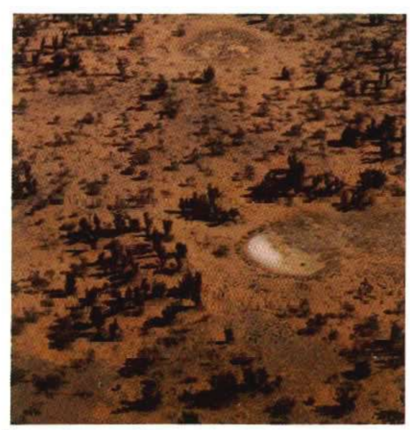
c Oblique aerial photograph looking west along widely spaced and moderately spaced east-west Quaternary sand ridges of Qs4/Qs5 patterns. Note claypans occur where dunes coalesce, or at the intersections of east-west dunes and north-south low stony rises.

d Terrain pattern Q5 looking along the interdunal corridor (swale) towards a drainage depression. Note low profile of the sand dunes.

e Terrain pattern Qs4 showing low stony rise across swale and claypan in right foreground.

f Terrain pattern K1 showing typical tableland surface.

g Cretaceous siltstone tableland surface (K1), overlying Andamooka Limestone and Arcoona Quartzite exposed in the dissection slope (A2 and P2) which leads into a drainage depression containing Quaternary deposits (Q3).



h Oblique aerial photograph showing claypan among widely spaced sand dunes (Q4).

Figure 3.2
EXAMPLES OF TERRAIN PATTERNS

Terrain units

Terrain patterns have been subdivided into terrain units, which are the smallest landform unit with consistent physiographic characteristics. Terrain units have simple surface forms and usually occur on a single rock or parent material type and have, within reasonable limits, uniform soils or surficial materials. The terrain unit descriptors (Table 3.1) show the divisions of slope range, slope form and soil type which have been used in the numerical referencing of the terrain units. These descriptors are the principal factors in determining susceptibility to erosion and thus form a suitable basis for assessment of terrain-related impacts.

Table 3.1 Terrain unit descriptors

No.	Physiographic description	Slope range
0	Flat, generally large drainage depressions subject to inundation, and minor stream channels and erosion gullies. Includes salt lakes, claypans and swamp areas.	Flat
1	Very gently sloping planar tableland surfaces, often adjacent to drainage depressions.	Generally less than 2%
2	Broadly rounded convex 'plateau' surfaces often trending north-south across swales, forming the watershed between adjacent catchment areas and drainage depressions.	Generally less than 2% but up to 5%
3	Broadly rounded crestal areas of low dunes.	Less than 10%
4	More sharply rounded crestal areas of higher dunes, often with depressed concave 'blowouts' generally to the south.	10-20%
5	Elevated tableland surface, gently or sharply undulating, with generally up to 1 m relief but occasionally up to 2 m.	Less than 10%
6	Gently to moderately sloping planar slopes below dune crests.	10-30%

No.	Soil type	Classification USC*
0	Rock outcrop and skeletal soils (0.3 m deep) on weathered rock.	-
1	Gravelly or stony soils, often on weathered rock.	GP, GM, GC
2	Uniform sands with little or no fines (silt or clay) content.	SP, SP-SM, SP-SC
3	Sandy uniform, gradational or weak texture contrast, coarse to medium textured soils of low plasticity; calcareous silt often finely dispersed throughout the lower parts of the profile.	SM-SC, SC
4	Sandy soils showing moderate texture contrast, coarse to medium textured, with calcareous silt either finely dispersed or in pockets.	SM / SC-CL
5	Sandy clay soils of low to medium plasticity, becoming very silty or gravelly at depth.	CL / GC, ML
6	Clay soils of medium to high plasticity showing gradational profile or weak texture contrast; a thin surface veneer of coarser texture may occur locally; often stratified layers of coarser texture and gypsum in the lower parts of the profile.	CL / CH

* Unified Soil Classification system (United States Department of Interior 1963)

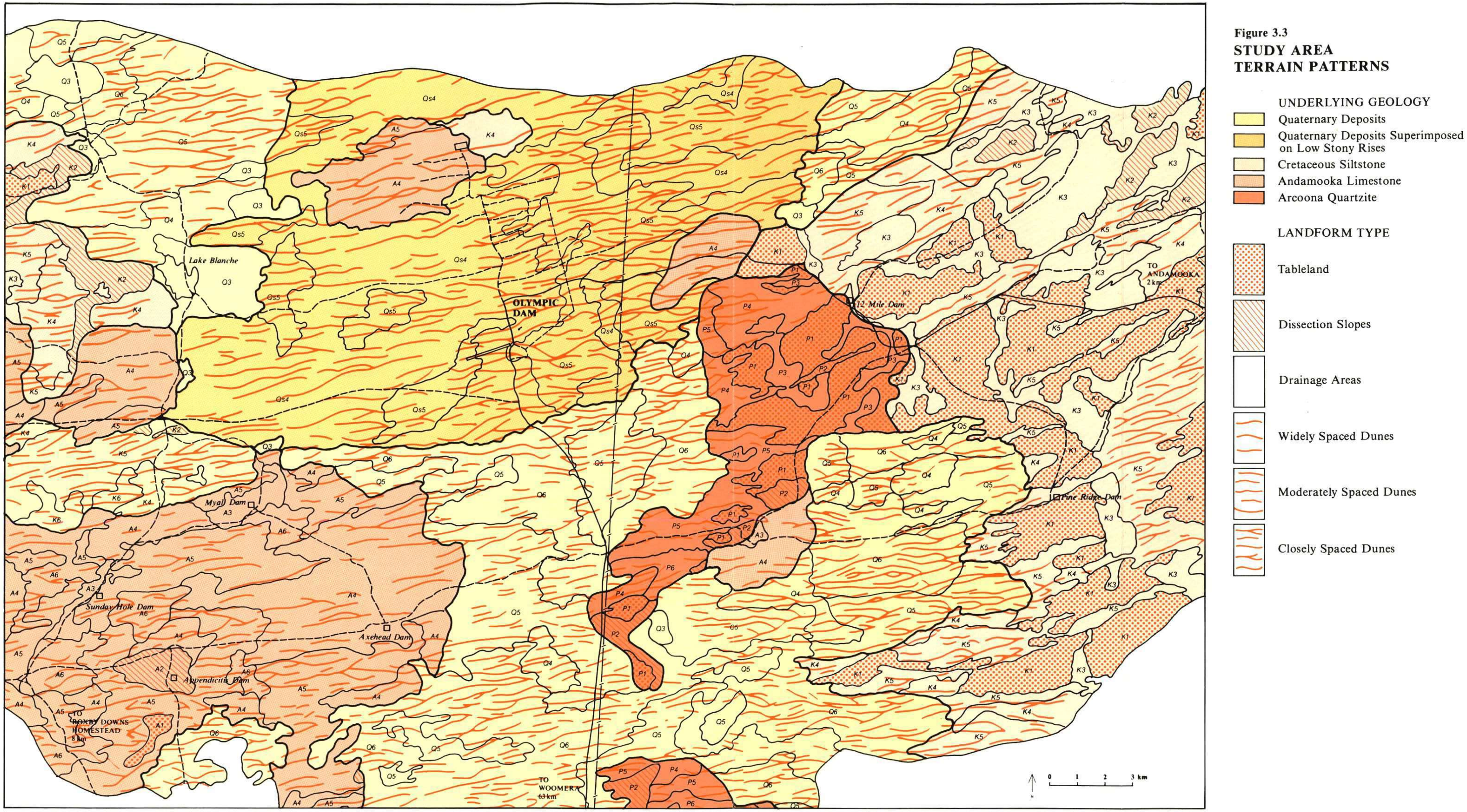


Figure 3.3
STUDY AREA TERRAIN PATTERNS

Terrain unit notation lists the physiographic type first and soil type last. For example, terrain unit 14 is a gently sloping tableland surface (physiographic description 1) with sandy soils showing moderate texture contrast (soil type 4, Table 3.1). For some terrain units a dual symbol has been used for the soil referencing number. This indicates that both soil types are likely to occur in close proximity within the unit. For example, terrain unit 50'4 is a gently undulating tableland surface (physiographic description 5) with rock outcrop on the rises (soil type 0) and sandy soils in the depressions (soil type 4), with the apostrophe indicating a mixture of these two soil types.

Terrain features

For the purpose of discussing the susceptibility to erosion (for impact associated with terrain units), it is possible to consider similar types of terrain units together. Six terrain features have been recognized which summarize the range of terrain units present within the Study Area (Figure 3.4), and can be described as follows (the related terrain units are shown in brackets):

- stony tableland (10'4, 50'4) - a flat or very gently sloping tableland surface;
- narrow interdune corridors and sandy swales (13, 14, 10'4) - gently sloping linear concave depressions between sand dune ridges;
- drainage depressions (03, 04, 06) - flat claypans, swamps, and very gently concave terminal drainage areas;
- low stony rises (20'4, 21, 21'4) - low stony elevated areas rising above the tableland by up to 3 m, usually siliceous, probably relict strandlines;
- dune fields (13, 32, 52, 53) - undulating dune fields often with some linear ridges trending east-west but with no flat interdune tableland surfaces exposed;
- sand dune ridges (32, 42, 63) - linear sand dunes trending in an east-west direction and elevated above the tableland surface by up to 10 m.

The terrain features are recognizable landforms which, in combination, form the terrain patterns defined above. The terrain patterns within which these features occur are shown in Table 3.2.

Table 3.2 Occurrence of terrain features in terrain patterns

Terrain feature	Terrain patterns in which terrain features principally occur
Stony tableland	P1, K1, A1
Narrow interdune corridors	Q4, Qs4, K4, A4, P4; Q5, Qs5, K5, A5, P5
Drainage depressions	Q3, K3, A3, P3; Q4, Qs4, K4, A4, P4
Low stony rises	Qs4, K4; Qs5
Dune fields	Q5, Qs5; Q6, K6, A6, P6
Sand ridges	Q4, Qs4, K4, A4, P4; Q5, Qs5, K5, A5, P5

Susceptibility to erosion of the various terrain units

Most of the soils in the Study Area are susceptible to erosion by wind and/or water. Their combined stability is dependent on a number of features which include the following:

- the percentage of silt and clay fines in the sand soils
- the presence of gravel as a reinforcing material or as a surface shield
- the presence of a surface skin over the silty sands of the interdune areas
- the type of vegetative cover.

The silt and clay fines in the sands can form very strong bonds, particularly when the percentage of clay fines is high (SC type materials, Table 3.1). When the percentage is low (probably 10%) and consists mainly of silt, the bonds are much weaker and easily broken when dry. The bonds are formed as the soils dry, and are broken by disturbance or rewetting. When broken, the soils are generally easily eroded by wind and water. The gravelly soils (calcretes or silcretes) are very resistant to erosion and help to stabilize the sands and clays with which they often occur. The quartzite gibbers found on the flatter tableland areas often occur in scald areas with well cemented clayey sands which are quite resistant to erosion. Where gibbers occur on looser unconsolidated sands and clays, they can act as a shield against erosion.

On many of the silty sand soils of the tableland areas (SM and SP-SM, Table 3.1), there is a darker coloured thin surface skin, or crust, up to 5 mm thick. This skin appears to be formed by a combination of cementing by the finer silt and clay particles and organic matter. The skin is easily broken when the soil is dry, revealing the very loosely bonded sands beneath, but when intact it protects these sands from wind erosion.

Annual and perennial plants, shrubs, and trees provide the main protection against erosion of the sand soils of both the dunes and interdune areas. In the swales of the closely spaced dune ridges and in the wider interdune areas of the tableland surface, the saltbush and bluebush cover is generally of a sufficient density to shield the surface sand from the effect of wind action. In the dune ridges, however, the vegetative cover is seldom sufficiently dense to stop some blowouts occurring.

The scale used for rating individual terrain units for their susceptibility to erosion is given in Table 3.3 and has been based on observations of the Olympic Dam area and on consideration of soil properties and surface slopes. Separate assessments have been made for susceptibility to erosion by wind and by water, and these are shown in Table 3.4. The terrain units in this table have been grouped under the terrain features in which they usually occur. It is evident from Table 3.4 that the main potential for surface disturbance is related to wind erosion of dune fields and sand ridges. Further discussion of sand dune development and movement in relation to the wind regime at Olympic Dam is therefore discussed below.

3.2.3 Sand dune development and sand movement

Origin of dune fields

The dunes in the Olympic Dam region form part of the Australian desert dune field which occupies about 20% of the continent. These dune systems were formed during the Pleistocene, between 14,000 and 25,000 years ago (Bowler et al. 1976; Wasson, pers. comm.). Work by Callen et al. (1982) on dunes in the Lake Frome area showed them to consist of at least three phases of aeolian deposition, with a partly consolidated core beneath the modern drift sand. Radiocarbon dating gave the cores of the dunes as greater than 44,000 years old. The overlying dunes ranged in age from 30,000 up to the youngest Pleistocene dune of 14,000 years.

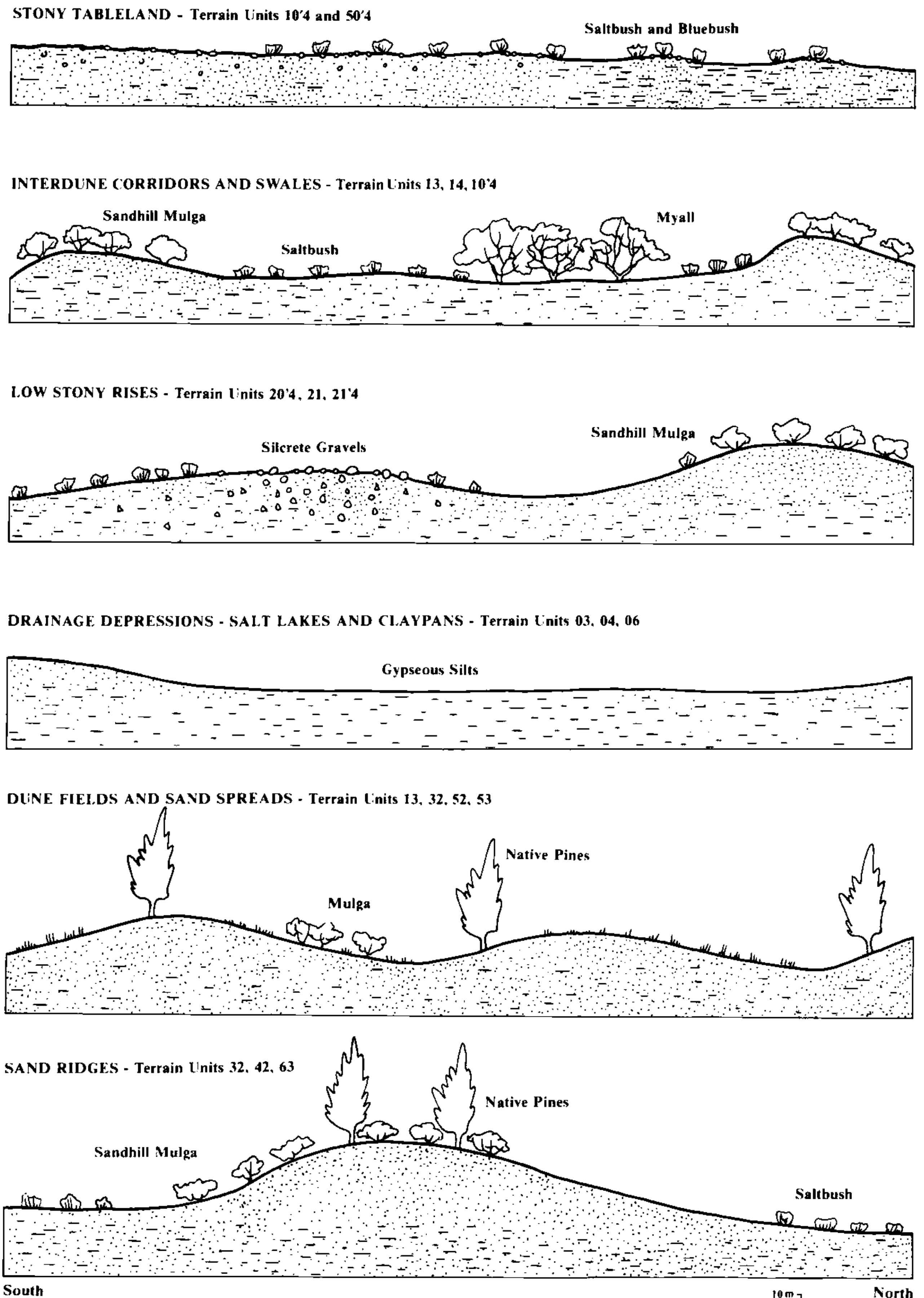


Figure 3.4
TERRAIN FEATURE PROFILES

10 m
Approximate Scale 0
0 10 20 m

In the Olympic Dam area there appears to be a capping of about 1 to 2 m of partially mobile late Holocene sand in the dune crests. Wasson (pers. comm.) has found this sand to range from 750 to 2,500 years old from carbon-14 dating of carbonates.

Table 3.3 Erosion susceptibility of soils within terrain units

Rating	Explanation	Implications
L - low susceptibility to erosion	Materials considered to be very resistant to natural disturbing forces, and containing no dispersive layers.	No protection required after construction of roads or other structures which affect the land surface.
M - moderate susceptibility	Materials which are often stable in the natural state, although erosion can be induced by destruction of inter-particle bonding, dispersion of clay materials or loss of vegetative cover. Erosion, when occurring, is often confined to local areas.	Consequences of erosion can vary considerably. Often only a thin surface layer of weakly bonded sand will be lost, but restoration of underlying stronger soils can be difficult in arid areas. Loss of material can lead to dust nuisance, rilling of surface and silting of drainage structures.
H - high susceptibility	Materials inherently unstable and relying totally on other mitigating factors for stability. Erosion, when it occurs, may influence other stable areas, causing deterioration and eventual soil loss.	Consequences of erosion need to be determined, and management policies adopted which recognize and ensure integrity of mitigating factors.

At present, most of the dune fields experience few winds above the threshold velocity for their surface sand movement. During the Pleistocene, sand mobility was much greater due both to greater windiness (i.e. the percentage of time with winds greater than 8 m/s measured at 10 m above ground level), and to lower evapotranspiration which reflected the smaller amount of vegetative cover then available to reduce sand movement. Wind speed records near Olympic Dam for 1982 show windiness values of 4 to 13%. Ash and Wasson (1982) estimate windiness to have been at least 20% higher during the Pleistocene in semi-arid parts of Australia.

The dune ridges are longitudinal in form with the direction parallel to the resultant of sand shifting winds (i.e. the vector addition of winds greater than the threshold velocity for sand movement). Longitudinal dunes are considered to form in a bi-directional wind regime (Wopfner and Twidale 1967; Fryberger 1979). In the Olympic Dam region, the dominant sand-moving winds during the Pleistocene would have been north-west and south-west associated with anticyclonic pressure systems moving across the continent. These winds would have caused a zig-zag movement of sand in an easterly direction, resulting in the general eastward trend of the dunes in the region. The present wind regime also results in a net easterly movement of sand.

Variations in dune density

At terrain pattern mapping level, dune density or spacing varies considerably over the Study Area. Four levels of dune density were defined: landform types 1, 2 and 3 all display little or no dune formation, while landform types 4, 5 and 6 indicate increasing dune density from 30 to 80% in areal extent. This dune density variation is illustrated by oblique and aerial photographs in Figure 3.2.

Table 3.4 Erosion susceptibility of terrain units

Terrain units and description	Susceptibility to erosion*	
	Wind	Water
Stony tableland		
10'4 - flat elevated tableland	L	L
50'4 - gently undulating elevated tableland	L	L
Narrow interdune corridors and sandy swales		
13 - thin sand spreads/gentle footslopes of dunes	M	L
14 - flat to gently sloping swale of structured soils	L	L-M
10'4 - flat swale of structured soils	L	L
Drainage depressions		
03 - small depressions with sand sheets	M	L
04 - longer depressions in swales, flood-prone	L	L
06 - claypans	L	L
Low stony rises		
20'4 - elevated gently rounded tableland with skeletal soils	L	L
21 - elevated gently rounded tableland	L	L
21'4 - elevated gently rounded tableland with gilgai	L	L
Dune fields		
13 - thin sand spreads, gentle footslopes of dunes	M	L
32 - broadly rounded flatter dunes	M-H	L
52 - gently undulating sand sheets at higher elevations	M-H	L
53 - gently undulating sand sheets at lower elevations	M	L
Sand ridges		
32 - broadly rounded, flatter dunes	M-H	L
42 - long, linear, higher dune ridges	H	L
63 - steeply sloping footslopes of dunes	M-H	L

* Susceptibility to erosion ratings, L = low, M = medium, H = high, as detailed in Table 3.3

The variation in dune density and orientation may be attributed to topographic influences which caused local variations in wind exposure during the Pleistocene, and which are evident during the present on a smaller scale. It would appear that, in the more exposed parts of the tableland surface, dune ridges are generally widely spaced. In contrast, sand accumulations and densely spaced dunes occur on the eastern side of the more depressed areas, as these areas are more sheltered from prevailing winds and accumulate water borne sediments.

Sand movement

Ash and Wasson (1982) have found that the desert dunes of Australia show low mobility, and they attribute this principally to the low percentage of time when wind velocities exceed the threshold movement for sand. Sand movement mainly takes place after instability is initiated, and it is confined to dune crests. Blowouts generally form through loss of vegetative cover due to such factors as overgrazing, fires, or die-back of ground cover in drier periods.

Wasson (pers. comm.) suggested that for this region the threshold velocity for sand movement is about 5.5 m/s when wind speed is measured at 1 m above the ground (or 8.9 m/s at 10 m, which is anemometer height for most meteorological stations at Olympic Dam). Wind data for Olympic Dam in 1981 was analysed for occurrence of wind speeds above this threshold velocity. Considerable seasonal variation was found: spring and winter were the periods of greatest sand drift potential, summer showed a lower drift potential, while in autumn almost no winds were recorded above threshold velocity. South-west winds were most prevalent in spring, with west winds in winter. Summer winds were variable, but predominantly from the south. The resultant wind direction for sand movement was east-north-east, which is consistent with the general dune direction at Olympic Dam.

The eastward and southward movements of sand were measured by sand traps. The highest rate of movement was 1.1 kg/m.h (i.e. 1.1 kg of sand moving per metre width of dune in one hour), measured in an exposed dune with minimal vegetative cover. If this rate occurred for a year over an entire dune, it would produce a movement of approximately 1.4 m. This can be compared with sand movement of 2.4×10^{-4} kg/m.h measured for a sand ridge in the town site, which translates to dune movement of only 0.2 mm per year.

3.2.4 Terrain impact and mitigation

The potential for soil disturbance and erosion in relation to terrain features is described below for varying degrees of development activity, together with the direct consequences which would arise from these impacts. Indirect effects related to surface water flow and sediment transport are then discussed. This provides the basis for summarizing the potential impacts relating to development, and for identifying appropriate mitigation measures to prevent or control such impacts for each of the terrain patterns and for the Project Area as a whole.

Potential for soil disturbance and erosion

For each of the terrain features, the potential impacts for soil disturbance and erosion which can arise due to development activity are summarized in Table 3.5. Six ranges of pedestrian and vehicular activity in increasing intensity and generally increasing effect are considered.

The low intensity activities will produce little effect on stony tablelands, drainage depressions, and low stony rises. However, these activities could cause some surface disturbance in the interdune corridors, while in dune fields (and particularly on sand ridges) deflation could result after loss or reduction of the vegetative cover, even at relatively low intensities of activity.

Under more intense development activity involving heavy vehicles, breakdown of the soil surface could occur on stony tablelands, interdune corridors, drainage depressions and, to a lesser extent, on the low stony rises. Under intense activity, dune fields and sand ridges could undergo greater degrees of deflation, which would possibly lead to formation of drifts at very high intensities of activity.

Table 3.5 Impacts of development activity on terrain features

Activity	Stony tableland	Interdune corridors	Drainage depressions	Low stony rises	Dune field sand spreads	Sand ridges
Light foot traffic	No effect	Breakdown of of surface	No effect	No effect	Little effect	Little effect
Concentrated foot traffic	No effect	Breakdown of surface skin	No effect	No effect	Slight deflation, some breaking of low shrubs reducing erosion protection	More severe deflation, some breaking of low shrubs reducing erosion protection
Single vehicle	No effect	Breaking of vegetation and surface skin	No effect	No effect	Some breaking of low shrubs reducing erosion protection	Some breaking of low shrubs reducing erosion protection
Multiple vehicles	Some rutting, particularly when wet. Prone to track erosion in sloping areas	Complete loss of vegetation, leaving surface exposed to erosion	Some rutting when wet	Little effect	Loss of vegetation and deflation	Loss of vegetation and deflation
Minor construction traffic	Breakup of surface	Loss of vegetation, breakdown of surface	Breakup of surface	Little effect	Loss of vegetation and deflation	Loss of vegetation and deflation
Major construction traffic	Complete disturbance of surface, leading to erosion	Exposure of surfaces from which dispersion and run-off occur	Breakup of surface	Breakup of surface, otherwise little effect	Complete loss of vegetation, deflation and drifts	Complete loss of vegetation, deflation and drifts

If no mitigatory action is taken, the probable direct consequences for each of the terrain features are considered to be as follows:

- stony tableland:
  - dust from trafficked areas
  - water erosion of channels on sloping surfaces;
- interdune corridors:
  - loss of silty sand surface and creation of hardpan;
- drainage depressions:
  - increased volume of dust and sand which will blow out to the east;
- low stony rises:
  - little effect;
- dune fields and sand spreads:
  - with loss of vegetation, sand will become mobile, and there will be a general sand movement to the east;
- sand ridges:
  - with loss of vegetation, sand will become mobile, and there will be a general sand movement to the east along dune ridges;
  - after deflation of a ridge to several metres, the effect of wind will tend to be reduced by more erosion-resistant sands and by the width of the deflation zone, unless development activity continues in the area.

Indirect effects of development

The main indirect effects which can occur with development and which would require preventive action or control are:

- **Alteration of surface water flows:** The wide swales of terrain patterns A4, Qs4, and Qs5 show many signs of downslope movement of water, particularly on more elevated surfaces with little sand cover (terrain unit nos. 10'4, 21, 20'4 and 50'4). Water running off these surfaces generally soaks into the sandy soils of the adjacent dunes (terrain unit nos. 32, 53 or 63) or runs downslope into the interdune corridors (terrain unit no. 14), occasionally causing some minor scouring.

  The creation of artificial barriers such as roads across the swale surface in these units could modify the natural surface water flows, causing ponding in some areas, and possible scouring where water flows are concentrated. Ponding can create local wet areas with different associations of vegetation, but may also deny water from other areas of vegetation downslope which have previously relied on that water supply. Most of these potential modifications will be offset by the provision of through-drainage engineered to prevent scour.

- **Alteration of sediment movement:** The creation of barriers across those areas showing downslope movement of water could also affect the natural system of sediment transport, with the potential to lead to:

  - sand and silt accumulation at barriers where water ponds
  - scouring at any channels through the barriers.

  The deposition of sediments at barriers could lead to a general depletion of soils downslope, which would eventually create large scalds as the surface sands disappear. The approach to drainage design described above will offset these effects. However, some ponding and sediment deposition will occur.

- **Alteration of wind-blown sand movements:** The main wind-blown sand movements occurring at the site are:

  - the eastward movement of sediment from the eastern shores of claypans and swale depressions located at terminal points of the internal drainage system

  - the zig-zag movement of sands (blowouts to the south, followed by more gentle movements to the east and north-east) along the sand ridges.

  Any excavation or raised barrier across the direction of sand movement has the potential to slowly accumulate sand. Sand accretion would be spasmodic, depending on the vegetative cover and the amount of free sand upwind (i.e. to the west).

- **Creation of differential pressure zones:** The erection of large structures will lead to changes in the local wind pattern, and this is expected to have some effect on wind-blown sand movement. Structures placed within the dune ridge system will change the pattern of sand deposition, and channelling of winds along the sides of structures could increase velocities, leading to subsequent sand scour. Unless protected, footings would be undermined, mainly on the northern and western sides of the structures, with sand accretion on the southern and eastern sides. Attention to detail in engineering design will reduce the severity and extent of these effects. Nevertheless, it will be necessary to rely primarily on soil stabilization of those surfaces exposed to this action.

- **Flooding of areas:** Long-term inundation of areas would eventually create claypan-like surfaces. Large quantities of silt and sand would accumulate on the bottom of the flooded area and, should drying eventually occur, the surface would resemble those exposed in many of the larger dams and claypans of the area during dry periods. Similar conditions would occur in the bottom of large borrow pits which hold water after heavy rain. The dispersive nature of the clays within the soil tends to have a sealing effect on the bottom and sides of excavations, as they become almost impermeable when dispersed in a layer. This will be offset by deep contour ripping of excavations to improve vertical drainage and to encourage natural revegetation suitable to the modified soil conditions.

Mitigation measures

Table 3.6 summarizes the potential impacts associated with each terrain pattern type together with the appropriate mitigation measures to ameliorate adverse effects. All the potential terrain-related impacts are amenable to mitigation either through suitable planning and design of development or through the control of construction activities. For example, potential sand movement can be controlled by retention of vegetation where practicable, and by stabilizing any areas which show sand drift or where dune ridges will be disturbed. Dust generation due to surface breakdown of trafficked areas on tablelands can be controlled either by sheeting or watering.

Project Area impact assessment

Figure 3.5 shows the terrain patterns associated with the Project Area. The locations of the plant and mine shaft areas have been determined by functional layout considerations and are mainly in Qs4 (widely spaced dune field of Quaternary deposits superimposed on low stony rises), with minor portions in Qs5 (moderately spaced dune field of Quaternary deposit superimposed on low stony rises). There will be significant landform changes within the localized areas of the plant and mine shaft development, and stabilization and drainage works will be required to control erosion and to contain changes in surface water flows.

The tailings retention area will be located to the west of the plant area, mainly within terrain patterns Qs4 and A4 (widely spaced dune field overlying Andamooka Limestone). Further to the west again, terrain pattern Qs5 dominates, and has probably resulted from a build-up of sand blown from the claypan known as Lake Blanche. The dune ridges show characteristics similar to those noted elsewhere, with more instability within the Qs4 pattern than in the Qs5. Therefore, where construction cuts across dune ridges, stabilization of exposed dune faces will be undertaken to prevent sand movement into the tailings retention area. The Qs5 pattern to the west will act as an effective barrier to most sand movement, particularly as its vegetative cover is expected to remain intact.

The Project's road network and the airfield runway alignments have been planned to ensure that, in most cases, the transport corridors either cross the dune ridge system at right angles to its trend or remain within the swale areas. Roads crossing dune ridges will be stabilized and then sheeted with calcrete. Batters will be stabilized by mulch spraying, or by respreading of brush and chipped vegetation. In effect, such construction creates a wide stablized blowout, through which strong winds can blow without restraint, removing any sand which collects there. As the sand supply is from the west, dune ridges on opposite sides of cuttings are likely to be affected differently. Roads in swale areas will be sheeted with calcrete (or other suitable materials) to reduce dust generation, and to enable all-weather passage.

Table 3.6 Potential impacts and mitigation measures for terrain patterns

Terrain pattern	Landform type and range of impacts	Mitigation measures
A1, K1, P1	**Tableland**	
	1. Interception and concentration of surface flows.	1. Keep drainage dispersed where possible.
	2. Erosion of dispersive soils (P1 and K1).	2. Channel flows through stabilized or lined drains.
	3. Rutting of surface by construction traffic in wet weather.	3. Provide pavements where possible for construction traffic.
	4. Dust from trafficked areas.	4. Either provide sheeted surfaces and pavements for traffic, or water unsheeted areas.
A2, K2, P2	**Dissection slopes**	
	1. Interception of surface flows.	1. Provide pipes, culverts etc.
	2. Channelling of flows alongside embankments or trenches.	2. Ensure adequate drainage through embankments, and stabilize soil surface.
	3. Scarring and erosion of surfaces caused by difficult working conditions.	3. Minimize construction traffic and confine to prepared access roads.
	4. Alteration to sediment movement pattern.	4. Keep drainage lines open where practicable, and avoid re-routing.
A3, K3, P3, Q3	**Drainage areas**	
	1. Alteration to areas of swamplands and claypans.	1. Ensure construction works in catchment areas do not affect drainage.
	2. Accelerated erosion due to erection of structures within drainage channels.	2. Place footings outside channels where practicable, or provide adequate protection for footings.
A4, K4, P4, Qs4	**Widely spaced dunes**	
	1. Loss of vegetation leading to increased sand movement generally.	1. Avoid unnecessary removal of vegetation.
	2. Localized sand movements caused by construction of corridors through dune ridges.	2. Stabilize potentional erosion areas.
	3. Alteration to drainage pattern within swales.	3. Provide adequate drainage through any barriers created across swales.
	4. Alteration to sediment movement towards terminal drainage points in swales.	4. Engineer drainage facilities to reduce ponding and asssociated sediment build-up.
	5. Creation of hardpan surfaces.	5. Retain saltbush and bluebush in swales where practicable.
	6. Loss of sand from windward side of structures.	6. Provide stabilized or sheeted pavements in areas where deflation is likely to occur.
A5, K5, P5, Q5, Qs5	**Moderately spaced dunes**	
	1. Loss of vegetation, leading to increased sand movement.	1. Refrain from removal of vegetation.
	2. Localized sand movement caused by construction of corridors through dune ridges.	2. Stabilize potential erosion areas.
	3. Creation of hardpan surfaces.	3. Retain saltbush and bluebush in swales; where hardpan occurs, cover with sand.
	4. Loss of sand from windward side of structures.	4. Provide stabilized or sheeted pavements in areas where deflation is likely to occur.
A6, K6, Q6, Qs6	**Closely spaced dunes**	
	1. Loss of vegetation leading to increased sand movement.	1. Refrain from removal of vegetation.
	2. Localized sand movement caused by construction of corridors through dune ridges.	2. Stabilize potential erosion areas.
	3. Loss of sand from windward side of structures.	3. Provide stabilized or sheeted pavements in areas where deflation is likely to occur.

The town site is in Q5 (moderately spaced dune field of Quaternary deposits) and Q6 (closely spaced dune field of Quaternary deposits) which exhibit the following characteristics:

- Within the Q5 pattern the dunes are sheltered and well vegetated. Sand movements through this area are slow and will remain so, providing vegetative cover is maintained. However, should loss of vegetation occur on ridges, blowouts may form. The Joint Venturers' policy of retention of vegetation will be an important factor in erosion mitigation, and vegetation on the dune ridges adjacent to buildings will be safeguarded against uncontrolled access.

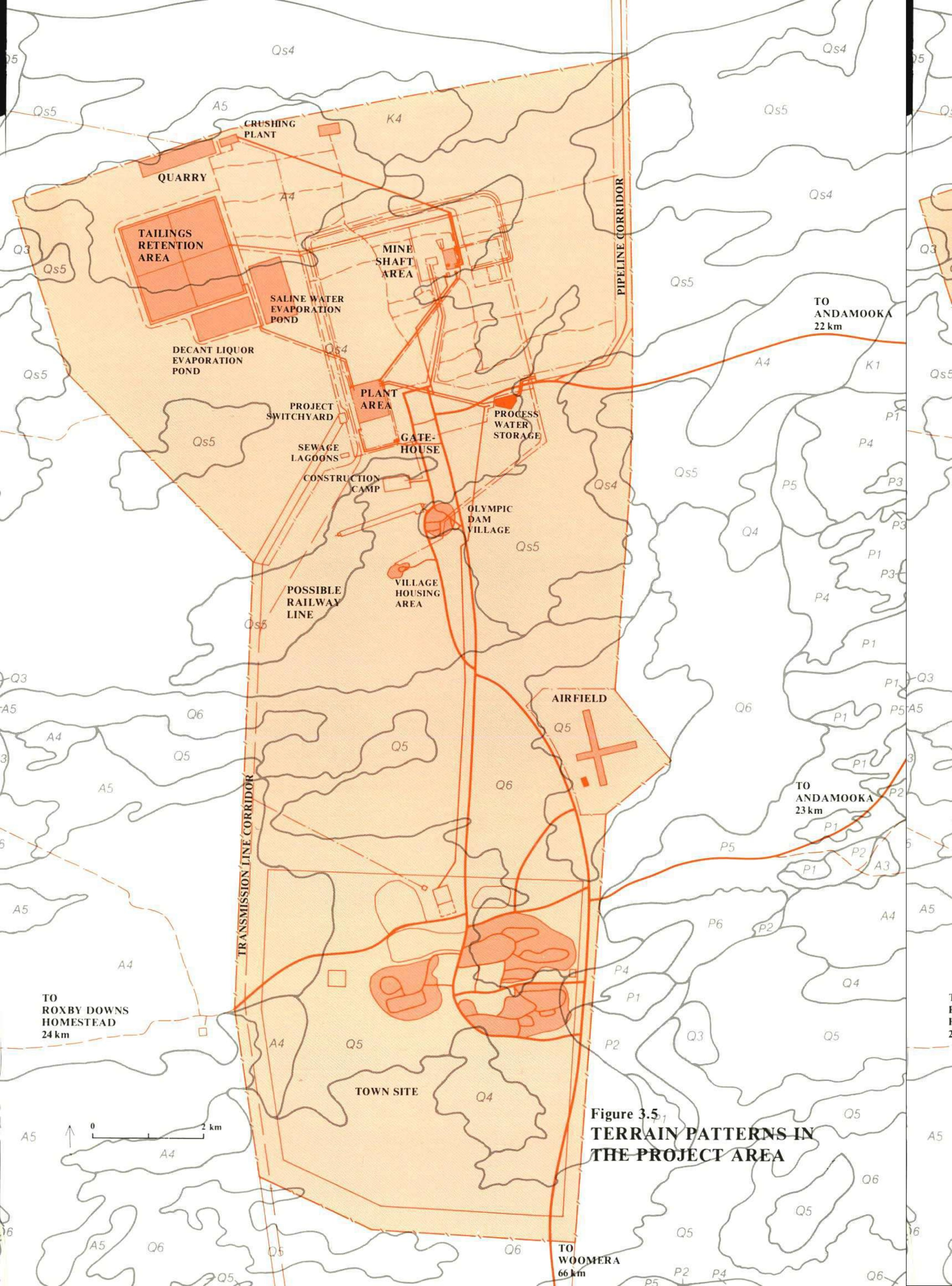


Figure 3.5
TERRAIN PATTERNS IN THE PROJECT AREA

- In the Q6 pattern, where dune ridges coalesce into sand spreads and fields with only vaguely preferred orientation, areas of potential instability are harder to predict. Generally, these areas appear more stable than sand in the Q5 type dunes, but this is probably because these large sand accumulations are not subjected to the stronger winds occurring on the ridges of the more exposed tableland surfaces.

In relation to impacts, the terrain features present in the town site have been assessed for general suitability for development as follows:

- Interdune corridors and swales: These are suitable in the more elevated, drained areas, although filling is likely to be required in lower parts prior to construction of roads and buildings. Many of the swale surfaces are subject to minor infrequent inundation, and proper design will be necessary to ensure that water will not remain after periods of heavy rain.

- Drainage depressions: Without significant drainage alterations, these are unsuitable for buildings. Road access can be achieved with filling, although the subsequent alteration to drainage patterns would need evaluation at the final design stage.

- Low dune ridges and sand sheets: These are suitable for development, providing vegetative cover is retained or appropriate stabilization is undertaken.

- Sand ridges: These are generally unsuitable for development.

These terrain-related factors are important considerations in the conceptual town design, and are discussed further in Chapter 11.

Long-term effects

In the long term, loss of vegetation in any area of sandy soils would lead to erosion by either wind or water. With loss of vegetation, the higher sand ridges would suffer increased deflation and flattening, and the form of the steeper ridges (terrain unit no. 42) would become more like rounded dunes (terrain unit no. 32). Where ridges are initially close together (within about 100 m), sand sheets may also cover the swales and form an undulating pattern of low ridges (similar to terrain unit no. 53). Although the rounded flatter dunes (terrain unit no. 32) are generally less susceptible to blowout formation and erosion, minor sand movement would also occur with loss of vegetation.

Within the swale areas, loss of vegetation would lead to erosion of the upper silty sand layer. This would cause deterioration of the soil horizon which supports most of the plant species, and the resulting surface would be inhospitable for plant regeneration. Run-off during heavy rainstorms would also be increased, with consequent scouring of channels and siltation of drainage structures and pondage areas.

The long-standing policy of the Joint Venturers of retaining as much vegetation cover as possible will avoid many of these problems. To minimize the likelihood of long-term problems of sand drift, erosion, and siltation, the following specific measures will be adopted:

- Any development within a swale area will have access closely controlled and the vegetation upslope safeguarded.

- Run-off waters from pavements, buildings, and other impermeable surfaces will be directed into lined channels where necessary to avoid scour.

- Any development involving the removal of dune ridges will include stabilization measures such as mulching, brush spreading and hard surfacing.

- Where appropriate, disturbed areas likely to erode will either be ripped to promote revegetation, or stabilized with surfacing or mulching. Excavated areas in clayey, silty soil will be deep-ripped to encourage natural revegetation.

- Cleared vegetation with its associated topsoil will be retained for brush spreading. Larger tree trunks will be chipped for spreading.

3.3 SURFACE HYDROLOGY

3.3.1 Characteristics of the catchments

The Project Area is a mosaic of small closed catchments, which range in area from 10 to 300 ha. The boundaries of these in relation to the Project Area are shown in Figure 3.6. There are no well defined water courses in the Project Area, although some closed catchments have discernible drainage lines at points where water flows into claypans. Typically, each catchment consists of the following:

- a catchment boundary formed by the crests of sand dunes which carry the dominant woody vegetation of the area and overlie the clay soils;

- an upper interdune corridor (swale) which may carry sparse vegetation of saltbush, or which may have no vegetation. The soil in such areas tends to be a clay, silty clay or clay loam;

- a lower depression, often a claypan, which is bare or covered with gibbers. Many of the lower pan areas show a strong mosaic polygonal cracking characteristic. On wetting, the dry clay swells, causing the cracks to disappear. The presence of these cracks (at least initially) provides an entry point for water to pass into the clay soil.

Results of measurements of relative infiltration capacities of the different soils in the area indicate the following:

- The upper and middle levels of sand dunes have indicated infiltration capacities estimated to be from 1,000 to 3,500 mm/h. The lower dunes have an indicated capacity to absorb between 500 and 2,000 mm/h. While these high figures are likely to be overestimates, actual infiltration capacities should nevertheless be greater than any expected rainfall intensity.

- The claypans and swales have low infiltration capacities after a period of inundation, although the initial rate of infiltration may be high due to entry of water through mosaic cracking.

3.3.2 Hydrologic processes

In fifty years of records for the area, annual rainfall totals have ranged from around 30 mm to more than 500 mm. The pan evaporation is in excess of 3,000 mm/a, and the average monthly pan evaporation is well in excess of the average monthly rainfall for all months of the year. In addition, the nearest groundwater is approximately 50 m below the soil surface, and there are no known instances of surface expression of groundwater in the area.

The environment is arid, and in most periods of the year no natural free water can be found in the vicinity of the Project Area. The catchment areas and grades are inadequate to generate sufficient run-off to form the incised drainage channels which are often found in larger catchments in arid areas. Surface water movement is predominantly by overland flow over relatively short distances within closed catchments.

The capture of rainfall

Hydrologic studies in arid environments (Australian Water Resources Council 1972) have indicated that during rainfall events the following processes occur:

- On claypans and interdune corridors, rainfall or run-off enters the surface cracks, causing the clay to expand and thereby 'seal' the surface against further entry of infiltrated water. Complete closure of the cracks may take several days but, if the water persists, ponding of water in claypans results, leading to overland flow across areas of sloping claypan, and ultimately to the formation of temporary ponds in the lowest areas.

- On adjacent sand dune slopes, most rainfall infiltrates into the sand surface and the volume of water passing to interdune corridors is restricted to a very small proportion resulting from downslope movement of raindrop splash.

Water infiltrating into the clay soil would be subject to loss by evaporation and transpiration. The strong adsorption and capillary forces in these soils will result in longer term moisture contents which are substantially higher than those in dune material. There is no indication of deep groundwater recharge through the soil, but recharge may occur in isolated locations such as where dolines are present.

Water balance

With high evaporation and low rainfall, not only are run-off events infrequent but soil moisture availability is also low. A detailed evaluation of soil moisture availability for plant growth has been conducted for Pimba using rainfall records for the period 1915-1977 (McAlpine 1978). The results of this evaluation for Pimba, which has a mean annual rainfall of 185 mm, would be indicative of the water balance in the vicinity of Olympic Dam which has a mean annual rainfall of 161 mm as measured at Roxby Downs Station (1931-1977).

The evaluation assumed that weekly rainfall was an input to soil moisture storage. However, soil moisture loss by evapotranspiration was assumed to be equal to 50% of Class A pan evaporation where soil moisture levels were above 50% of available soil storage capacity (assumed to be 100 mm), and equal to 25% of pan evaporation if soil moisture was below this level. The median statistics for rainfall, potential evaporation, and soil moisture availability for plant growth over this fifty-year period are shown in Figure 3.7. The results indicate that in 50% of years, soil moisture available for plants rises above zero only for eighteen weeks of the year and then only to 10% of available water capacity. The evaluation also determined that in 25% of years, available soil moisture is greater than zero for twenty-two weeks, reaching a maximum of 35% of available water capacity.

Extreme hydrologic events

Should an extremely high rainfall event occur in the vicinity of Olympic Dam, a very considerable ponding of water in the depressions and claypans could be expected to occur. This water, and the water infiltrating through the base of sand dunes, would lead to an areally extensive perched water-table. This would result in a downward percolation of water (probably along fracture zones, faults, and rock joints), which may lead to recharge of groundwater. Based on observations in other environments and the reported observations of Verhoen (1977), it is probable that rainfall such as that which occurred during the two years 1973 and 1974 (which totalled 954 mm at Roxby Downs Station) would have led to at least some groundwater recharge in this environment.

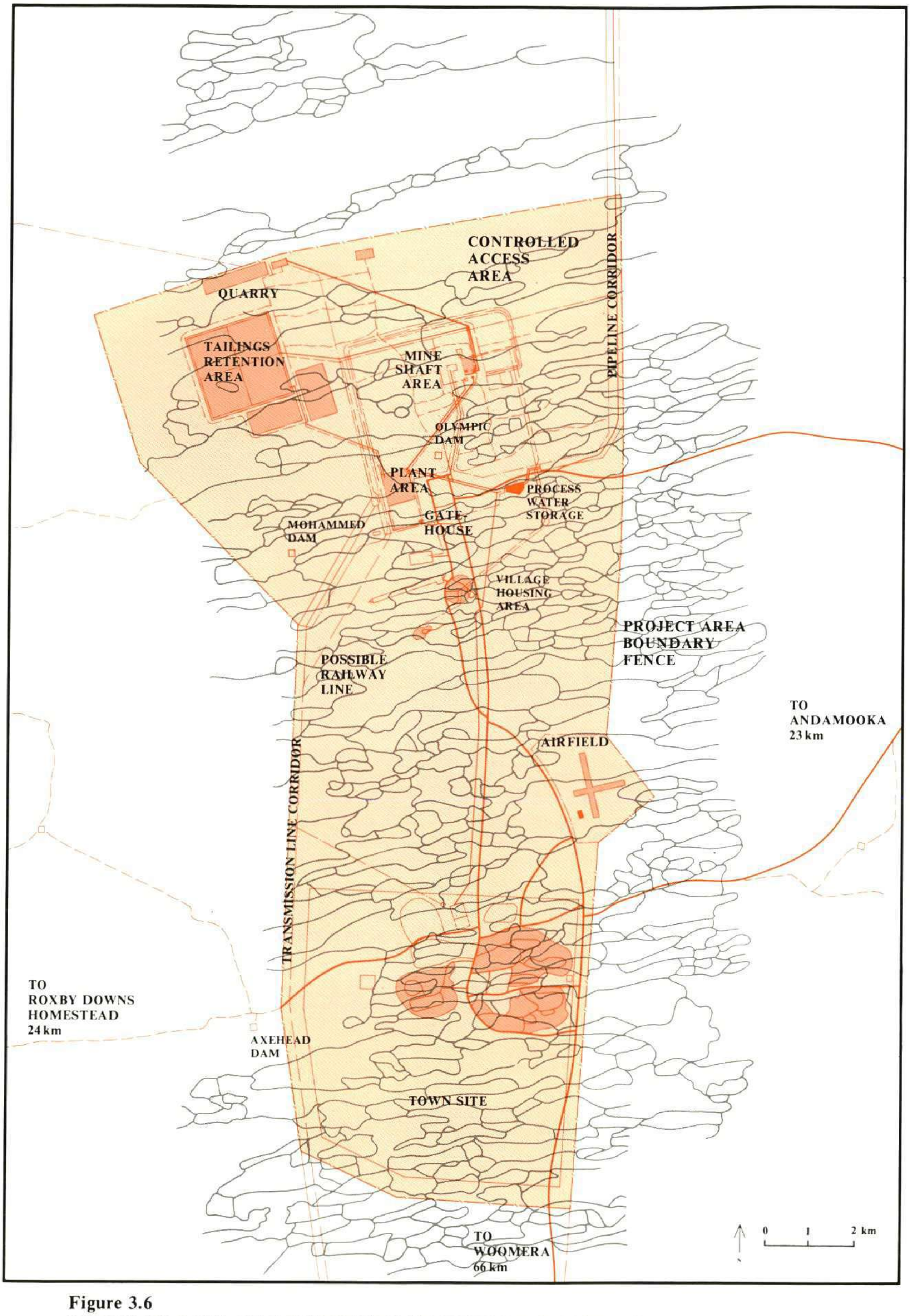


Figure 3.6
HYDROLOGY CATCHMENTS IN THE PROJECT AREA

3.3.3 Surface hydrologic changes induced by the development

Project construction will lead to hydrologic changes caused by the introduction of:

- substantial areas of impervious surfaces associated with roads, parking areas, compacted zones, and roofs
- large quantities of treated and domestic wastewaters and garden watering.

The location of areas proposed for development likely to induce hydrologic change is shown on Figure 3.6, and the effects of this development are discussed below.

Run-off from impervious areas

In an environment in which clay, silty clay and clay loam soils with low permeability occupy a substantial proportion of any given catchment, the introduction of additional impervious surfaces is unlikely to have a marked hydrologic effect. The large number of small closed catchments will effectively contain run-off within each separate catchment. However, there will be an increase in the volume of run-off ponded in depressions, and hence an increase in the time taken for such pondage to evaporate after rain ceases. Where appropriate, water will be collected and used for irrigation.

The catchment which includes the Whenan Shaft and associated development (Figure 3.8) provides an example of the extent of these hydrologic effects and the manner in which they can be accommodated in plant development. The Whenan Shaft is located in a catchment area of 140 ha which is relatively elongated in an east-west direction. For geological reasons, the shaft is located in what was once the lowest position within the catchment. For functional reasons, the current associated developments are located adjacent to the shaft, and include a concrete batching plant, a mullock stockpile and storage areas. Additional facilities such as car parks, roads, core farm, and buildings will also be developed within the catchment. The net result of these developments will be an alteration of the hydrologic regime of the Whenan Shaft catchment.

However, to avoid inundation, the collar around the shaft and other working areas have been built on raised pads formed by excavated earth, with the excavation being used as a compensating basin to receive storm run-off. The compensating basin and the height of the raised pads were designed to accommodate the increased run-off resulting from the greater impervious area as well as the loss of claypan storage resulting from the construction of the raised pads. For rainfall events of up to 50 mm, the depth of ponding after development will be less than natural conditions because of the compensating basin. For a 100 mm rainfall event, the depth of ponding will increase from 1.2 m under natural conditions to 1.35 m after development.

Run-off from areas liable to contamination by ore or plant spillage will be collected in sumps of adequate capacity to receive design storms. This water will be passed to the plant circuit as process water or to the tailings retention system for evaporation.

Section 11.6.6 discusses the manner in which run-off considerations have been incorporated in the conceptual town design.

Introduction of piped water

The main Project water supply, which will have salinities ranging from 1,500 to 2,500 ppm, will be piped from the Great Artesian Basin. This brackish water will be used directly in processing, and a portion of it will also be desalinated to provide potable water for the town, mine and plant. The hydrologic impacts associated with the introduction of this water will depend upon its uses and the methods of disposal, which will be as follows:

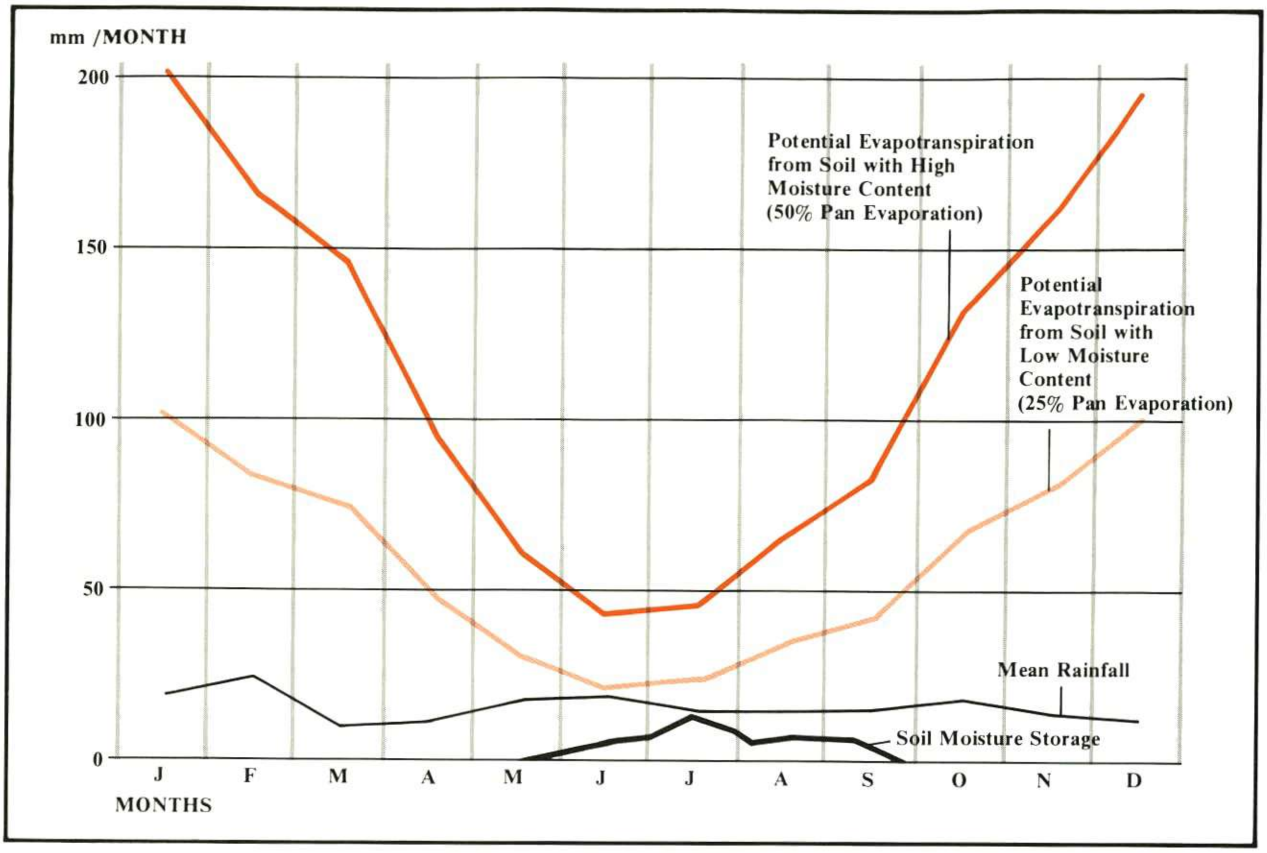


Figure 3.7
WATER BALANCE FOR PIMBA

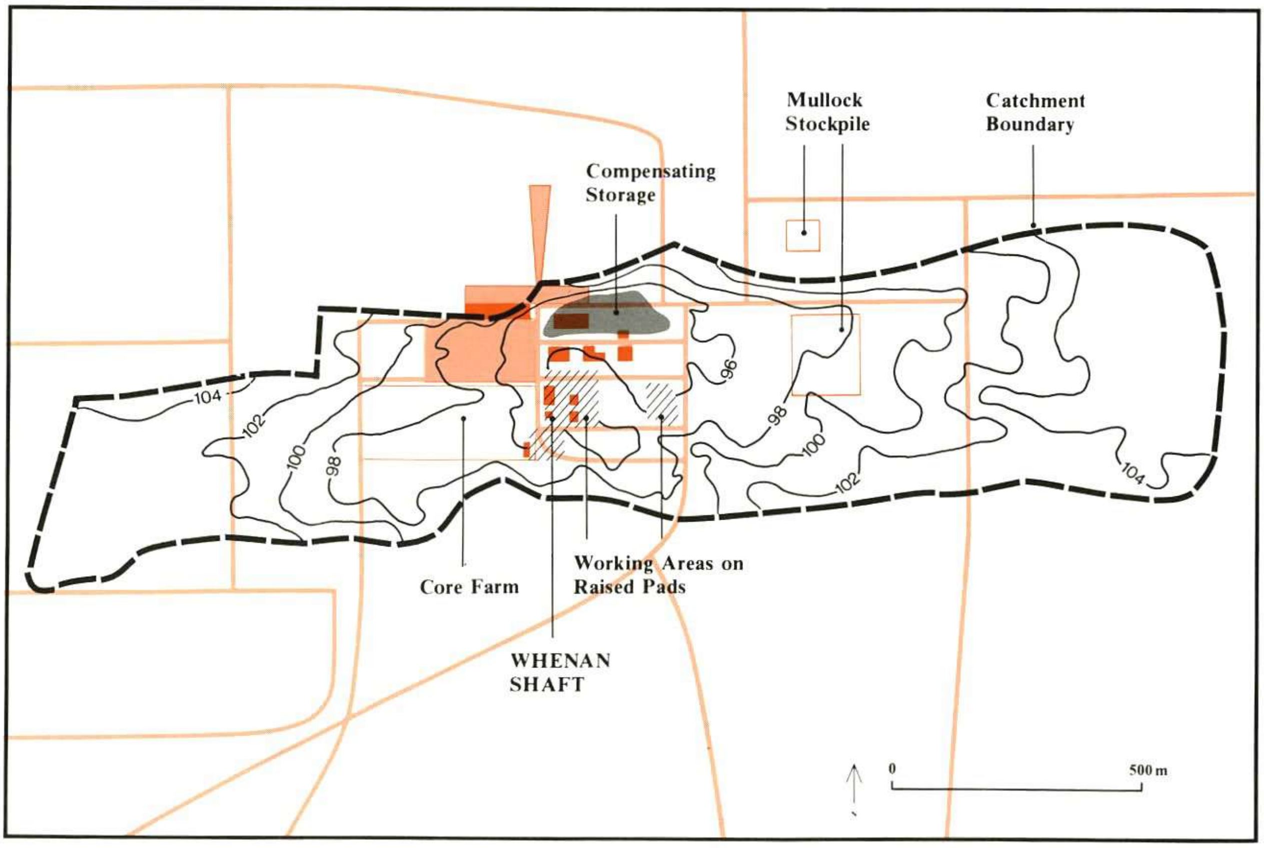


Figure 3.8
WHENAN SHAFT CATCHMENT AREA

- Process water will either be recycled within the plant or discharged to the tailings retention system for evaporation.

- Potable water will be stored after desalination, and distributed for use throughout the Project Area. Wastewater will be piped to the sewage treatment works: if, following this process, it is of suitable quality, it may be used for irrigation, otherwise it will be discharged to evaporation basins.

- Potable quality water will be used for watering gardens, recreation areas, and amenity plantings.

- Some brackish water will be used for dust control and for vegetation tolerant of this quality of water.

The total volume of water discharged directly to the ground will be small relative to potential evaporation. Thus the main hydrologic effect will be limited to an increase in soil moisture in the local area of water application. The maximum application rate would be about 1,250 mm/a on gardens, which is approximately one-third of the annual evaporation rate of more than 3,000 mm/a, but substantially more than the annual rainfall of 160 mm/a. Minor amounts of water will also be lost from water storages and evaporation ponds through seepage.

3.4 FLORA

Two distinct structural suites of vegetation are found in the Olympic Dam region: low shrublands on the stony tablelands of the Andamooka and Woomera environmental associations, and woodlands or tall shrublands on the dune fields with associated low shrublands in the interdunal areas of the Moondiepitchnie environmental association. There is one major plant association on the stony tablelands, and, while the dune fields display a marked local variety in plant species, they have an overall unity of composition. The occurrence of woodlands on deep sands of the dune fields is one of the more distinctive regional vegetation features, and reflects plant/water balance relationships. There is no significant aquifer in the region within reach of the various tree species: they must rely purely on rainfall recharge of soil water. Except on sands, there is normally insufficient soil water available to maintain extensive stands of trees or even tall shrubs.

3.4.1 Vegetation in the Study Area

Basis of mapping

Broadscale vegetation mapping at a scale of 1:40,000 was carried out for the Study Area (reduced in Figure 3.9 to 1:125,000). There are two main suites of vegetation covering almost the entire Study Area: the vegetation associated with stony tableland, and that associated with the dune fields. Common to both, however, is vegetation associated with drainage. Although small in areal terms, drainage vegetation has biological significance as habitat and also for the plant species present, which increases its importance beyond that indicated by its areal extent.

Table 3.7 divides the vegetation mapping units into three principal categories: (A) vegetation of the dune fields, (B) vegetation of stony tableland, and (C) vegetation associated with drainage. This relationship between vegetation and landform sequences is then further defined. For vegetation associated with dune fields, a distinction is made between dense and open dunes. For tableland vegetations, vegetation on Andamooka Limestone is categorized separately from other areas of stony tableland.

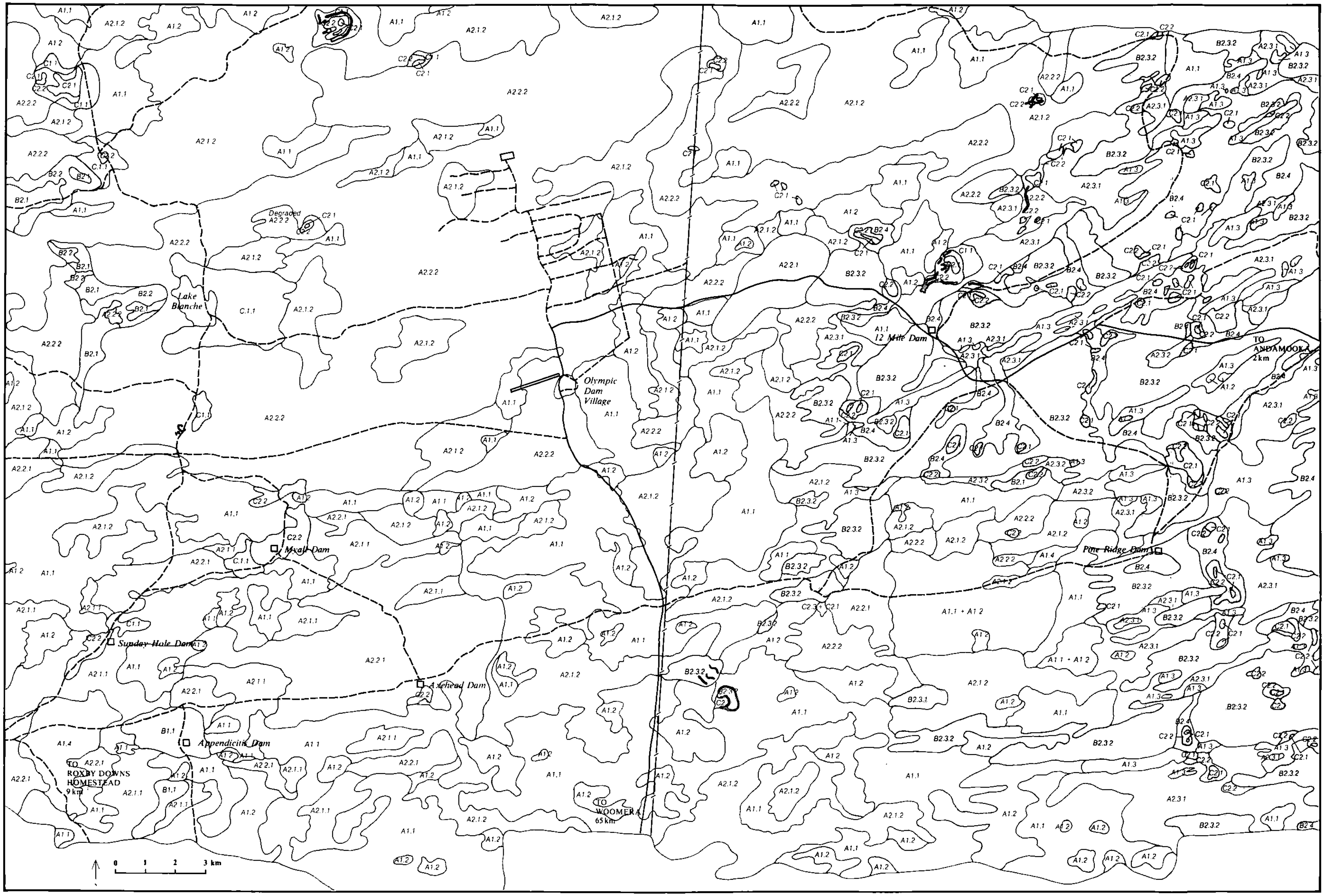


Figure 3.9
STUDY AREA VEGETATION

Vegetation Associated with Dunefields

A1.1, A1.2, A1.3, A1.4, A2.1.1, A2.1.2, A2.2.1, A2.2.2, A2.3.1, A2.3.2.

Vegetation Associated with Stony Tableland

B1.1, B2.1, B2.2, B2.3.1, B2.3.2, B2.4.

Vegetation Associated with Local Drainage

C1.1, C2.1, C2.2.

C2.3

For Descriptions of the Vegetation Mapping Units refer to Table 3.7

Table 3.7 Description of vegetation mapping units

Vegetation mapping units	Character species	Main understorey or associated species
A VEGETATION IN AREAS OF DUNE FIELD		
A1 VEGETATION SEQUENCES ASSOCIATED WITH DENSE DUNES		
A1.1 Mulga woodlands * (Primarily associated with Q6, as well as parts of A6, K6, and densest sections of Q5, Qs5, A5 and K5.) **	Sandhill mulgas (Acacia linophylla and A. ramulosa) on sand ridges with mulga (A. aneura and A. brachystachya) in narrow sandy swales or interdune depressions, as continuous low open woodlands or tall open shrubland.	Understorey dominated by grasses, Aristida browniana on slopes and ridges and A. contorta on interdune areas. Wider swales may occasionally contain a low open shrubland of saltbush (Atriplex vesicaria). Native pine (Callitris columellaris) frequently present as small groves on deep sand. Bullock bush (Heterodendrum oleaefolium) on dunes as scattered individuals or small groves.
A1.2 Pine woodlands (Q6, Qs6, A6, densest dunes of Q5, Qs5, A5 and K5.)	Native pine (Callitris columellaris) on ridges and slopes as continuous low open woodland.	Sandhill mulga (Acacia linophylla) and mulga (A. aneura) present in small groves or as individuals interspersed between pines. Hopbush (Dodonaea angustissima) frequently present on pine grove fringes or as a very sparse tall shrub layer within groves. General absence of significant ground cover: grasses indicative of surface mobility, such as Plagiosetum refractum, present but with low cover, very occasional clumps of perennial grasses such as Eragrostis laniflora and Eriachne helmsii.
A1.3 Sandhill canegrass grasslands (Sand ridges in geological regimes K and P.)	Sandhill canegrass (Zygochloa paradoxa) hummock grassland as the main vegetative cover on isolated sand ridges crossing the Andamooka Plateau, together with a sparse tall shrub layer of hopbush (Dodonaea angustissima) and sandhill wattle (Acacia ligulata) within dune systems on the Andamooka Plateau and at Purple Downs.	On isolated ridges sandhill canegrass is the only species of any consequence. Within multiple dunes it may be associated with sandhill mulga (Acacia linophylla) or interspersed between pine (Callitris columellaris) groves.
A1.4 Mulga/myall mixed woodlands (A6 and densest portions of A5.)	Sandhill mulga (Acacia linophylla) on upper parts of sand ridges, mulga (A. aneura and A. brachystachya) on lower slopes and sandier interdune areas, western myall (A. papyrocarpa) on calcareous sandy loams of interdune areas: in all cases as low open woodland or tall open shrubland.	Grasses, Aristida browniana on ridges and slopes and A. contorta on lower slopes and sandier interdune areas; saltbush (Atriplex vesicaria) or Sclerolaena spp. as low open shrubland about myall groves. Ground cover within myall groves minimal, largely myall litter. Bullock bush (Heterodendrum oleaefolium) scattered throughout dunes as individuals or in small groves.
A2 VEGETATION SEQUENCES ASSOCIATED WITH OPEN DUNES		
A2.1 Vegetation sequence of medium density dunes		
A2.1.1 Mulga woodland - saltbush/bluebush low open shrubland sequence (A5, except for most closely spaced dune segments.) **A2.1.2 Mulga woodland - saltbush/low bluebush low open shrubland sequence** (Q5, Qs5, and slight occurrences on K5, except for most closely spaced dune segments.)	Sandhill mulga (Acacia linophylla and A. ramulosa) tall open shrublands on ridges and upper dune slopes with more mobile areas containing sandhill wattle (A. ligulata), hopbush (Dodonaea angustissima) and Cassia spp.; mulga (Acacia aneura and A. brachystachya) tall open shrubland/low open woodland at dune bases, on transverse sandy rises and occasionally in drainage hollows; saltbush (Atriplex vesicaria) low open shrubland between dunes, with low bluebush (Maireana astrotricha) appearing in wider swales (A2.1.1, A2.1.2), and bluebush (M. sedifolia) appearing in wider swales where limestone outcrops or nears soil surface (A2.1.1); numerous and frequent western myall (Acacia papyrocarpa) groves, more so in A2.1.1 than in A2.1.2.	Mulga areas as described for dense dune vegetations. Sandhill wattle and hopbush areas typically with little herbage under grazing. Enneapogon spp. grasses in swale areas. Pine (Callitris columellaris) present in sandhill mulga as individuals or distinct linear groves.
A2.2 Vegetation sequences associated with widely spaced dunes		
A2.2.1 Mulga woodland/sandhill wattle tall open shrubland - saltbush/ bluebush low open shrubland sequence (A4.)	Sandhill mulga (Acacia linophylla) tall open shrubland on larger sand ridges, mulga (A. aneura and A. brachystachya) on lower slopes, sandy rises, and in interdune drainage. More mobile areas on sand ridges with sandhill wattle and hopbush (A. ligulata and Dodonaea angustissima) frequent. Interdune areas of low open shrubland, saltbush (Atriplex vesicaria) +/- low bluebush (Maireana astrotricha) or, where limestone outcrops or nears soil surface, bluebush (M. sedifolia). Myall (Acacia papyrocarpa) groves present, but less frequent than for sub-parallel dune sequences.	Pine (Callitris columellaris) in scattered small groves. Dune areas as for sub-parallel dune sequences. Grasses in swales dominated by Enneapogon avenaceus during survey; speargrass (Stipa nitida) can be expected following winter rains. In areas with bluebush, or where bluebush was formerly present, Cassia nemophila var. coriacea bushes are frequent. Bullock bush (Heterodendrum oleaefolium) frequent on lower dune slopes, as individuals or scattered sparse groves.
A2.2.2 Mulga woodland/sandhill wattle tall open shrubland - saltbush/low bluebush low open shrubland sequence (Q4, Qs4.)	Dune areas: sandhill wattle (Acacia ligulata) and hopbush (Dodonaea angustissima) tall open shrubland/open shrubland on most sand ridge crests, sandhill mulga (Acacia linophylla and A. ramulosa) on sand ridge slopes, Mulga (A. aneura) at sand ridge bases and on sandy rises in swales. Interdune areas: saltbush (Atriplex vesicaria) low open shrubland with low bluebush (Maireana astrotricha) increasing in frequency where silcrete ridges present.	Grasses (Aristida spp.) on dune slopes and flanks, little ground cover under wattle and hopbush. Pine groves present on ridgetops but infrequent. Enneapogon spp. associated with low shrublands of interdune areas, with Sclerolaena divaricata in drainage areas and about frequent natural small scalds. Myall groves present, but rare. Bullock bush frequent on lower dune slopes, as individuals or sparse groves.
A2.3 Vegetation sequence of stony tableland dune fields		
A2.3.1 Sandhill wattle tall open shrubland/native pine woodland/mulga woodland on red sands (Primarily P5, but also on P4, P6, K4, K5, K6.)	Tall open shrubland of sandhill wattle (Acacia ligulata) and hopbush (Dodonaea angustissima) interspersed with native pine (Callitris columellaris) on sand ridges. In sandy interdune depressions, tall open shrubland of mulga (Acacia aneura and A. brachystachya).	Swale areas were probably once chenopod shrubland; some areas of saltbush still present. On sand ridge slopes, sandhill mulga (Acacia linophylla) and bullock bush (Heterodendrum oleaefolium) with sandhill canegrass in more mobile areas. Ephemeral, largely grassy, ground cover. This unit shares the same suite of species and the same general patterning of distribution as the dense dune and sub-parallel dune sequences.
A2.3.2 Sandhill wattle tall open shrubland/native pine woodland/mulga on gypseous sands (Q5, T5.)	See A2.3.1. differs in greater height of sand ridges, with significant areas of gypseous sands present.	See A2.3.1. The area is notable for the absence over much of it of species normally found in dune areas, e.g. bullock bush.

* Those mapping units shown in bold face type are those illustrated in Figure 3.9, 3.15 and 3.16.

** Information in brackets indicates the terrain patterns associated with each vegetation mapping unit

Table 3.7 (continued)

Vegetation mapping units	Character species	Main understorey or associated species
B VEGETATIONS OF PLATEAUX AND STONY TABLELANDS		
B1 VEGETATIONS ON ANDAMOOKA LIMESTONE		
B1.1 Bluebush/saltbush and Ptilotus low open shrubland * (A1, A2.) **	Bluebush (Maireana sedifolia) low open shrubland with saltbush (Atriplex vesicaria) on shallow or skeletal soils over sheet limestone on plateau surfaces: Ptilotus obovatus replacing both on dissection slopes.	Small short-lived chenopod shrubs. Areas degraded by overgrazing characterized by Sclerolaena (Bassia) spp., Cassia nemophila var. coriacea common. Trees few.
B2 VEGETATIONS OF STONY TABLELAND		
B2.1 Saltbush/low bluebush low open shrublands (K1, K2, K7.)	Saltbush (Atriplex vesicaria) and low bluebush (Maireana astrotricha) low open shrubland without pronounced patterning in local distributions on tableland landscapes containing small poorly defined crabholes and drainage areas with grasses Enneapogon avenaceus and Eragrostis spp.	Samphire, numerous Sclerolaena spp., marked absence of trees and tall shrubs. Grasses frequently found in small crabholes include Sporobolus spp. and neverfail (Eragrostis setifolia).
B2.2 Ptilotus low open shrubland (K2, P2.)	Varies with locality. Most common character plants are samphire (Sclerostegia tenuis) as a very sparse low open shrubland on gentler slopes, and Ptilotus obovatus on steeper slopes.	Sclerolaena spp., occasionally low bluebush (Maireana astrotricha).
B2.3 Saltbush low open shrublands of patterned soils (shelf/crabhole sequences) (P1, P2, some of K1, overlaps into P3, K3.)		
B2.3.1 Atriplex vesicaria (tableland ecotype) low open shrubland with pronounced patterning	Tableland ecotype of saltbush (Atriplex vesicaria) with grasses Eragrostis falcata and E. setifolia as low shrubland growing in +/- gibber free crabholes, with Sclerolaena spp. providing a very sparse ephemeral cover on intervening gibber shelves. Patterning is much more pronounced, with larger and better defined crabhole and shelf areas, on the Arcoona Plateau (B2.3.1) than on the Andamooka Plateau (B2.3.2).	Frankenia pauciflora and samphires in more saline areas (particularly shelves in B2.3.2), Sclerochlamys brachyptera and S. patenticuspis on shelves, Ixiolaena leptolepis, Sporobolus spp. and other herbs and grasses in crabholes. Marked absence of trees or tall shrubs.
B2.3.2 Atriplex vesicaria (tableland ecotype) low open shrubland without pronounced patterning: most of this unit degraded to Eragrostis and ephemeral species	(as for B2.3.1)	(as for B2.3.1)
B2.4 Sclerolaena divaricata low open shrubland (P3.)	Sclerolaena divaricata low open shrubland of tableland drainage areas, found in a highly patterned sequence of bare, closely packed platey gibber shelves devoid of vegetation, alternating with poorly developed crabholes containing vegetation.	Saltbush (Atriplex vesicaria), Frankenia pauciflora, Sclerochlamys brachyptera, Sclerolaena spp., no trees or tall shrubs.
C VEGETATIONS ASSOCIATED WITH LOCAL DRAINAGE		
C1 ON CONCAVE DRAINAGE DEPRESSIONS TO THE EAST OF LARGE SWAMPS AND SMALL LAKES		
C1.1 Dead finish/mulga tall open shrublands (Q3, A3, less commonly P3, K3.)	Dead finish (Acacia tetragonophylla) and mulga (A. aneura and A. brachystachya) as sparse tall open shrubland of broad depressions on eastern borders of large pans and swamps, on clayey soils with a thin and patchy veneer of sand or sandy clay loams.	Characteristically, very high diversity of ephemeral herbs and grasses but with very low cover.
C2 VEGETATIONS OF SWAMPS, LAGOONS AND THEIR FRINGES		
C2.1 Canegrass (Various, but generally pattern no. 3.)	Canegrass (Eragrostis australasica) tall tussock grassland of freshwater swamps subject to frequent inundation.	Lignum (Muehlenbeckia cunninghamii), which in less well-defined swamps may be more frequent than canegrass. Understorey of neverfail (Eragrostis setifolia) and cottonbush (Maireana aphylla).
C2.2 Cottonbush open and low open shrublands (Various, but generally pattern no. 3.)	Cottonbush (Maireana aphylla) low open or occasionally open shrubland about upper margins of canegrass swamps less subject to inundation than canegrass areas, or in local drainage lines or pockets.	Lignum (Muehlenbeckia cunninghamii) on lower lying ground, saltbush (Atriplex vesicaria and Sclerolaena divaricata on higher ground, frequently neverfail (Eragrostis setifolia).
C2.3 Tea tree fringing tall open shrublands (Q3, K3, P3.)	Tea tree (Melaleuca pauperiflora) in tall open shrubland occasionally fringing swamps, lagoons and watercourses, on gypseous clays usually with a thin veneer of gypseous sands, and sometimes extending into deeper sands and kopi dune areas.	Broombush (Melaleuca uncinata). Jessup (1951) reports dryland tea tree (M. lanceolata) as the most commonly occurring species of this formation and, while this does not appear to be the case within the Study Area, the species can nevertheless be expected to occur occasionally. Tea tree stands observed were almost devoid of ground cover.
C2.4 Samphire low open shrublands (Q3.)	Samphires Halosarcia indica and Sclerostegia tenuis on saline alluvial soils of lagoon floors, with isolated occurrences about some stock dams with saline inflow. Very sparse on lagoon floors, with cover less than 5%; cover 30-40% about dams.	May be mixed with Frankenia pauciflora on fringes of lagoons.
C2.5 Mulga swamps and solution cavities (Various within geological regimes A, Q and Qs.)	Mulga (Acacia brachystachya and less frequently A. aneura) and dead finish (A. tetragonophylla) tall shrubland/open scrub with a well-developed shrub layer in small circular depressions of interdune areas, and in and around solution cavities.	Associated tall shrubs or trees: native pittosporum (Pittosporum phylliraeoides), bullock bush (Heterodendrum oleaefolium), Acacia oswaldii, Cassia nemophila vars platypoda and coriacea, Eremophila spp. particularly E. glabra. Herbs and grasses present and often luxuriant in solution cavities, particularly the grass Brachiaria praetervisa.

* Those mapping units shown in bold face type are those illustrated in Figure 3.9, 3.15 and 3.16.

** Information in brackets indicates the terrain patterns associated with each vegetation mapping unit

Vegetation associated with drainage is subdivided into that fringing large drainage depressions and that fringing the smaller swamps and lagoons. In some instances a third division is made according to character species or character species' sequences. The main understorey or associated species for each vegetation sequence is also described.

These vegetation mapping units are vegetation sequences with recurring patterns of plant species repeated over substantial areas. The individual patterning of plant species occurs over distances too short to be mapped for the Study Area. For example, sand depth (which is an important factor associated with plant types) varies continuously in the dune fields. Character species are used to describe vegetation sequences rather than plant associations, as their use allows a more sensitive approach to description of variation in vegetation. Character species are defined as those plant species which, for reasons of size, appearance, or frequency, dominate the visual appearance of a given community. A character species is usually, although not necessarily, an ecologically dominant species within its local community. More than one character species may be found in a given area and one character species may be common to more than one mapping unit.

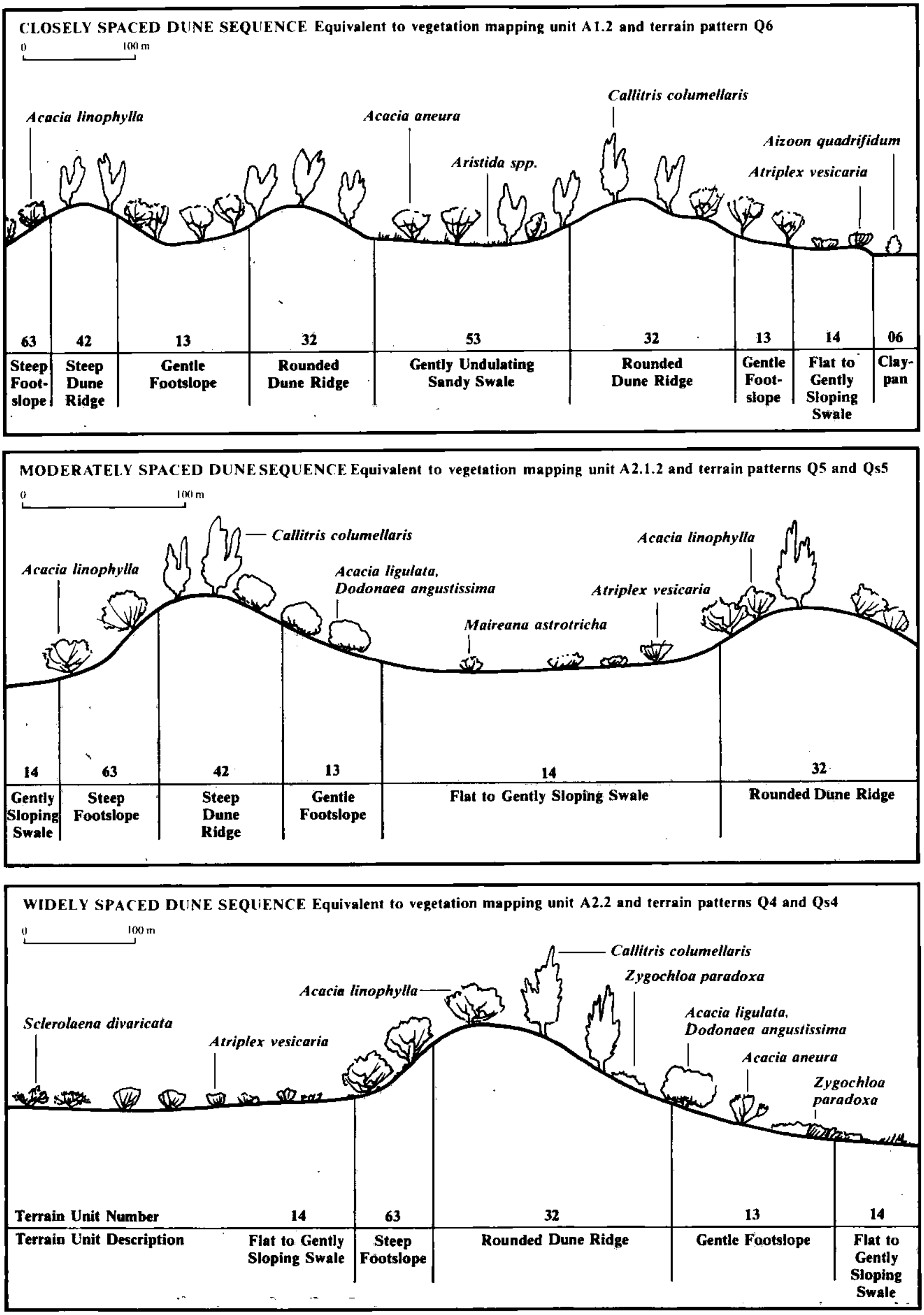
Dune field sequences

The dune field areas have two quite distinct groups of species: those species associated with a sand substrate, and those associated with structured soils. The boundary between the two becomes blurred because of continuous variation of sand depth over the underlying plateau surfaces, ranging from no sand at all to deep sand. Where dunes are very close together (mapping unit A1), the sand depth is such that normally the underlying soils are not exposed, and vegetation composition relates to sand cover rather than underlying substrate. Vegetation is characteristically tall open shrubland or low open woodland. Figure 3.10 shows a profile of one such vegetation sequence on dense dunes - a pine woodland (mapping unit A1.2) with native pine (Callitris columellaris) on deeper sands of the ridges, and sandhill mulga (Acacia linophylla) and mulga (A. aneura) on shallower sands between the ridges. This vegetation unit is also illustrated in Figure 3.11(b), and other associated species are noted in Table 3.7. Other dense dune sequences have different character species - sandhill mulga (mapping unit A1.1), sandhill canegrass (mapping unit A1.3), and mulga/western myall (mapping unit A1.4).

For mapping unit A1.1 which occurs on the most stable deep sands of closely spaced dunes, sandhill mulga frequently provides the bulk of the perennial vegetative cover on sand ridges, with mulga in narrow sandy swales and interdune depressions (Figure 3.11(a)). Where the dunes are more widely spaced, sandhill mulga tends to be on the steeper, southerly dune faces rather than on the crests or northern faces. A number of other trees or tall shrubs may be associated with it, in particular native pine and bullock bush (Heterodendrum oleaefolium).

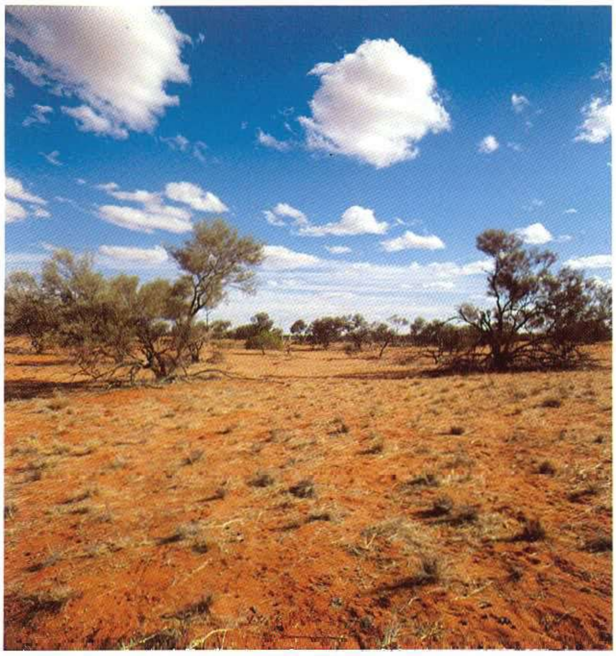
Sandhill canegrass (Zygochloa paradoxa) forms a distinctive hummock grassland (mapping unit A1.3) on the more mobile dunes and may be associated with sandhill mulga or interspersed with native pine groves (Figure 3.11(c)).

In the mulga/myall woodlands (mapping unit A1.4), sandhill mulga occurs on the upper parts of sand ridges, and mulga (Acacia aneura and A. brachystachya) on the lower slopes and sandier interdune areas where shallow sands of 1.5 m or less overlie calcareous sandy clay loams, often with heavy lime at depth. Western myall (A. papyrocarpa) can be considered an oddity in one sense, being a tree species with a probable water requirement at least as great as trees on sands, but which occurs on calcareous sandy loams of interdune areas generally lacking the capacity to provide sufficient water for trees.

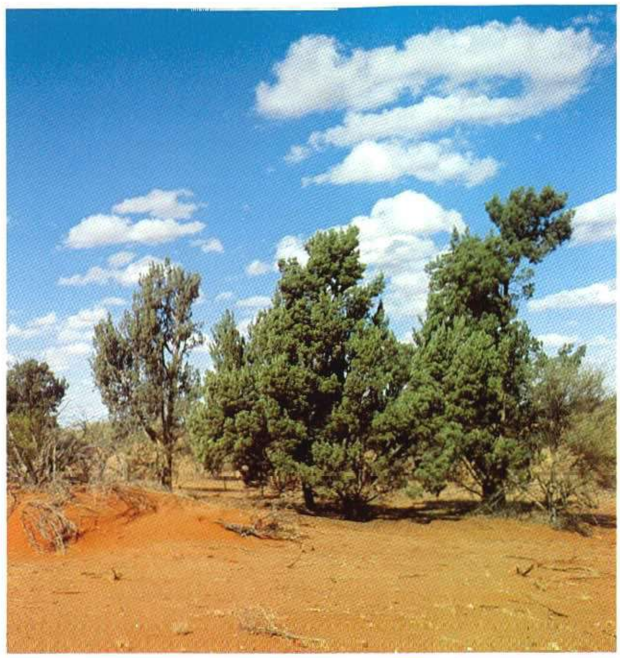


Note: Vertical dimensions not to scale.

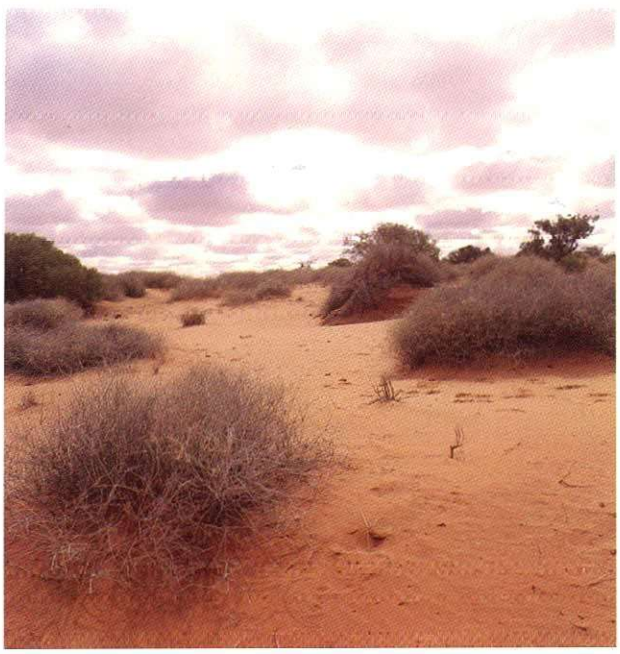
Figure 3.10
DUNEFIELD VEGETATION SEQUENCES



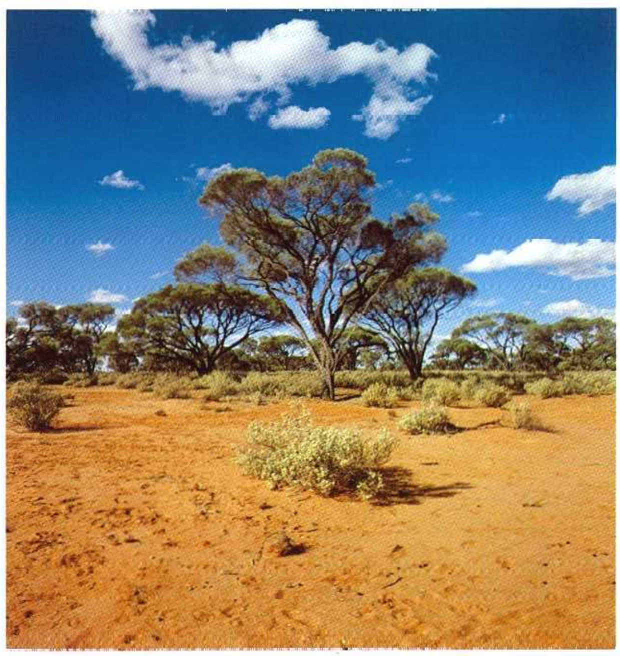
a Mapping unit A1.1. Mulga woodland (*Acacia aneura*).



b Mapping unit A1.2. Native pine woodland (*Callitris columellaris*). Note mobile sand where loss of understorey vegetation has occurred.



c Mapping unit A1.3. Sandhill canegrass (*Zygochloa paradoxa*).



d Mapping unit A2.1.1. Western myall groves (*Acacia papyrocarpa*), with saltbush (*Atriplex vesicaria*) understorey.

Figure 3.11
ILLUSTRATIONS OF VEGETATION (1)

Where dunes are further apart, underlying substrates become exposed in the interdunal corridors (mapping unit A2). Suites of species are restricted either to the dune sands or to the underlying substrate. Vegetation is characteristically a repetitive sequence of low or tall open woodland on dunes grading into a treeless low open shrubland between dunes. The example in Figure 3.10 of a vegetation sequence on medium density dune fields shows some of the same species on the dune ridges as on the dense dunes - sandhill mulga and native pine, but different species on the shallower sands of the footslopes - sandhill wattle (A. ligulata) and hopbush (Dodonaea angustissima), while on the structured soils of the tableland surface in the interdunal corridors the character species are saltbush (Atriplex vesicaria) and low bluebush (Maireana astrotricha). This is characteristic of medium density dunes overlying recent silts and clays (mapping unit A2.1.2). A similar vegetation sequence occurs for medium density dunes overlying Andamooka Limestone, except that bluebush (M. sedifolia) is the dominant character species for the interdunal corridor (mapping unit A2.1.1). Groves of western myall are frequent, particularly in A2.1.1 (Figure 3.11(d)).

The vegetation sequences vary both with the spacing of dunes and with the nature of the exposed substrate in the interdunal corridors. On widely spaced dunes (mapping unit A2.2) the character species are sandhill mulga on sand ridges, and mulga on lower slopes (Figure 3.10). Sandhill wattle is associated with more mobile dunes (Figure 3.12(a)). For the interdunal corridors, saltbush and bluebush are found on limestone (mapping unit A2.2.1), as shown in Figure 3.12(b), while saltbush and low bluebush are found on red calcareous earths (mapping unit A2.2.2).

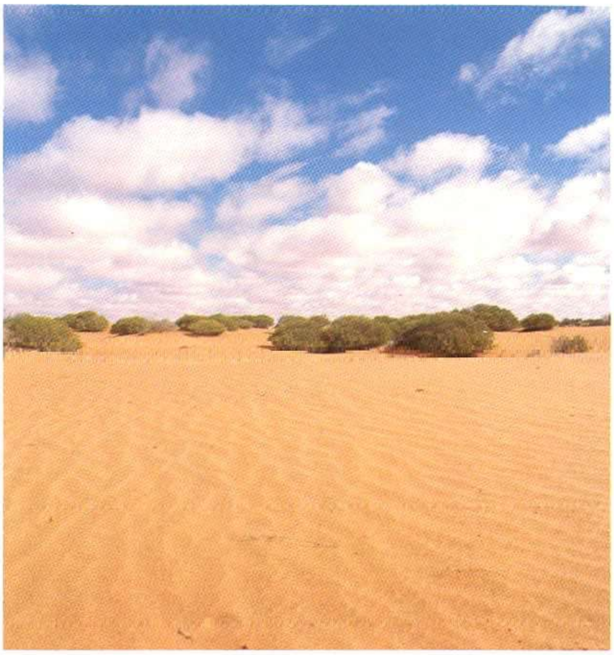
Figure 3.12(c) illustrates the patterning of vegetation through mapping unit A2.2.2 showing the species' gradation with sand depth - native pine on the dune ridge, sandhill mulga and bullock bush in the middle of the dune, and sandhill wattle at the base - as well as the tall shrubland on the dune changing to low saltbush shrubland in the swale.

Where sand dunes occur on stony tableland (mapping unit A2.3), there is a tall open shrubland of sandhill wattle and hopbush interspersed with native pine on sand ridges. In areas of red sands (mapping unit A2.3.1 primarily on Arcoona Quartzite), sandhill mulga and bullock bush with sandhill canegrass are the main associated species, and there is lower perennial grass cover than found with other vegetation sequences on dune fields. On gypseous sands (mapping unit A2.3.2.) the vegetation sequences are similar to A2.3.1, except for a notable absence of species such as bullock bush normally found in dune areas.

Tableland sequences

Vegetation on tablelands is much more homogeneous than the dune field vegetation. For mapping purposes, a distinction is made between vegetation associated with the relatively small areas where limestone is exposed or close to the surface, and vegetation in areas of stony tableland. Where limestone is present (mapping unit B1.1), there is bluebush low open shrubland with saltbush on the plateau surfaces, replaced by Ptilotus obovatus on dissection slopes.

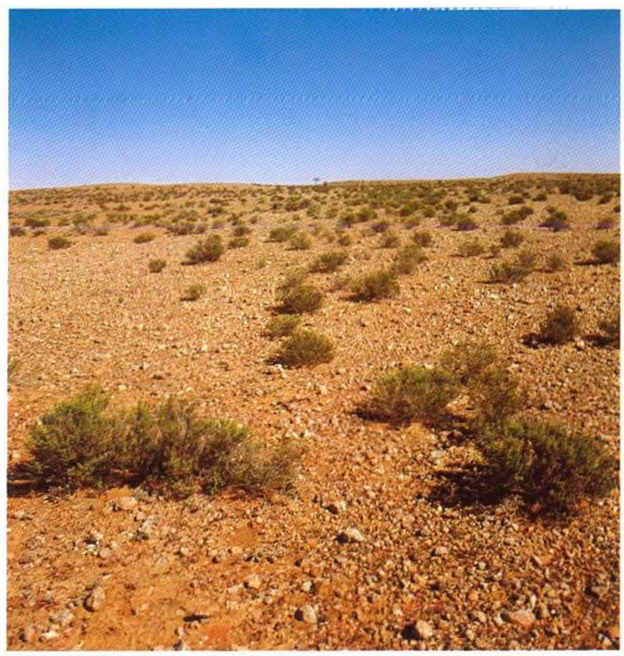
For vegetation sequences associated with stony tableland, mapping units have been defined in terms of patterning relating to terrain characteristics. Stony tableland soils are typically heavy textured, gypseous and frequently highly saline. Their vegetation is characterized by a complete lack of trees or tall shrubs, which is a consequence of both the soil texture and salinity. Saltbush is the major character species of the treeless open shrubland on the Arcoona Plateau and much of the Andamooka Plateau. However, grazing pressure has significantly reduced the extent of this saltbush cover, particularly on the Andamooka Plateau. Variation in vegetation occurs, firstly, through local patterning (on a scale of 10 to 50 m) in plant distribution, resulting from the alternation of closely packed gibber shelves carrying almost no vegetation with gibber-free depressions (crabholes) containing most of the vegetation and, secondly, through the presence of dissection slopes and creek lines.



a Mapping unit A2.2.2. Area of mobile sand with sandhill wattle (*Acacia ligulata*).

b Mapping unit A2.2.1. Swale with bluebush (*Maireana sedifolia*), and saltbush (*Atriplex vesicaria*).

c Vegetation mapping unit A2.2.2. Dune vegetation sequence with native pine (*Callitris columellaris*) at the top, sandhill mulga (*Acacia linophylla*) and bullock bush (*Heterodendrum oleaefolium*) in middle of the dune and sandhill wattle (*Acacia ligulata*) at the base. Saltbush (*Atriplex vesicaria*) on the swale in foreground.



d Mapping unit B2.2. Dissection slope sequence with samphire (*Sclerostegia tenuis*).

Figure 3.12
ILLUSTRATIONS OF VEGETATION (2)

Mapping unit B2.1 is a saltbush and low bluebush low open shrubland without pronounced patterning on tableland landscapes, and with poorly defined crabholes and drainage areas carrying Enneapogon avenaceus and Eragrostis spp. grasses. The presence of samphire (Sclerostegia spp.) indicates high soil salinity. Mapping unit B2.3 displays local patterning with gibber-free crabholes carrying a tableland ecotype of saltbush low shrubland together with Eragrostis falcata and E. setifolia grasses. The intervening gibber shelves have a very sparse ephemeral cover of Sclerolaena (Bassia) spp. This patterning is more pronounced on the Arcoona Plateau (mapping unit B2.3.1) than on the Andamooka Plateau (mapping B2.3.2) reflecting the better defined crabhole and shelf areas on the Arcoona Plateau. Other grasses, particularly species of Astrebla and Sporobolus also seem to be more frequent on the Arcoona Plateau. Frankenia pauciflora and samphires are associated with the more saline areas particularly in B2.3.2.

Certain tableland drainage areas carry a Sclerolaena divaricata low open shrubland in a highly patterned sequence of bare, closely packed platey gibber shelves devoid of vegetation, alternating with poorly developed crabholes containing vegetation (mapping unit B2.4). This vegetation is characteristically featured in gently sloping drainage areas and frequently on the boundaries of swamps. The main associated species are saltbush, Frankenia pauciflora, Sclerochlamys brachyptera and various Sclerolaena species.

Dissection slopes which retain many of the vegetative features of the tablelands frequently show various sequences of species correlated with slope and exposure of underlying strata (mapping unit B2.2). On steeper slopes there is Ptilotus obovatus low open shrubland, and samphire (Sclerostegia tenuis) as a very sparse low open shrubland on gentler slopes (Figure 3.12(d). Associated species include Sclerolaena spp. and occasionally low bluebush.

Vegetation associated with drainage

Areas of inundation both in dune fields and tablelands, although small in size, contain distinctive vegetation. The species present depend primarily upon the frequency of inundation, the salinity of the soils, or the terrain characteristics.

Associated with depressions and deflation areas adjacent to larger swamps, small lakes and some claypans are sparse, tall, open shrublands, with dead finish (Acacia tetragonophylla) and mulga (A. aneura and A. brachystachya) - mapping unit C1.1. This vegetation has been distinguished from swamp vegetation (mapping unit C2) as it has many similarities with typical swale vegetation. High species richness was recorded, with the majority of species being ephemerals (e.g. Goodenia pinnatifida and Zygophyllum aurantiacum) considered to be indicative of vegetation degraded by grazing and scald formation.

Swamp areas frequently inundated (for an arid environment) carry a tall grassland of perennial canegrass (Eragrostis australasica) usually in association with lignum (Muehlenbeckia cunninghamii) - mapping unit C2.1. The perennial shortgrasses Eragrostis setifolia and E. falcata (neverfail) dominate the ground cover in such areas. This vegetation sequence is shown in profile in Figure 3.13.

In fresh water swamps less subject to inundation than canegrass areas, the character species is cottonbush (Maireana aphylla) forming a low open, or occasionally open, shrubland (mapping unit C2.2). It occurs on the upper margins of canegrass swamps (Figure 3.13) and in local drainage lines. Lignum is present on lower lying ground, while on higher ground saltbush and Sclerolaena divaricata are found.

The fringes of lakes and water courses sometimes possess a fringing woodland of tea tree (Melaleuca pauperiflora) and occasionally broombush (M. uncinata) - mapping unit C2.3, as shown in profile in Figure 3.13. These are infrequent in the Study Area, but are more common elsewhere in the region (Lay 1972; Jessup 1951). All tea tree areas inspected in

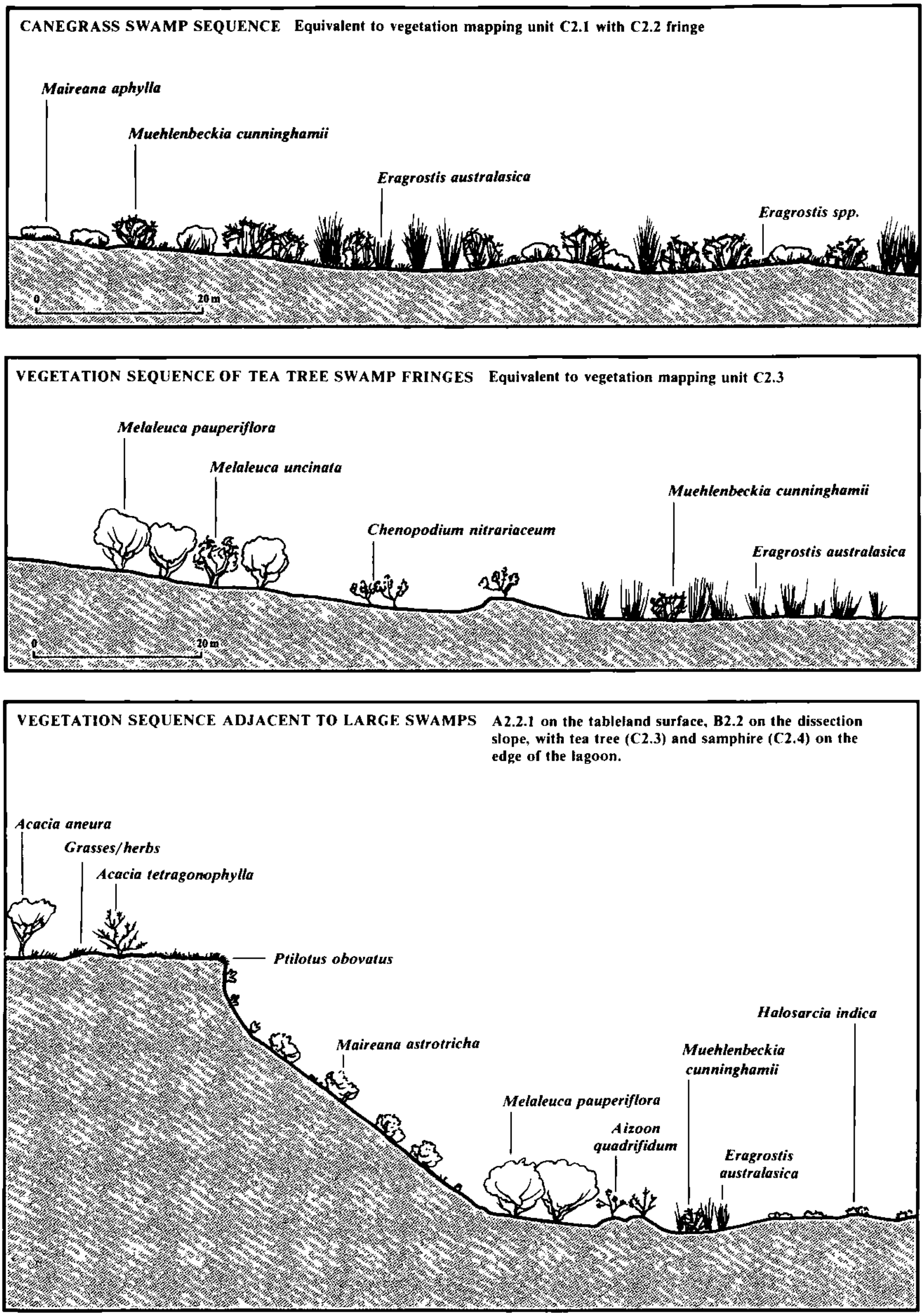


Figure 3.13
DRAINAGE-RELATED VEGETATION SEQUENCES

the Study Area possess no other ground cover, which could be a consequence of swamps acting as a focus for grazing.

Where conditions are more saline, samphire communities (Halosarcia indica and Sclerostegia tenuis) are found (mapping unit C2.4). There are few of these in the Study Area, and they usually occur at large lagoons, with local occurrences around some station dams (e.g. Myall Dam on Roxby Downs). Figure 3.13 shows in profile the vegetation adjacent to a large lagoon with C.2.4 samphire low open shrubland (Halosarcia indica) at the base and a fringe of C.2.3 tea tree shrubland (Melaleuca pauperiflora). Also shown on the escarpment is B2.2 Ptilotus low open shrubland, typical of tableland dissection slopes, and A.2.2.1 mulga woodland (Acacia aneura) on the sand cover of the tableland surface.

Figure 3.14(a) shows a sequence of the swamp fringe vegetation. At the edge of the claypan, in relatively saline conditions, samphire (Halosarcia indica) occurs. Further from the edge in less saline conditions canegrass (Eragrostis australasica) predominates. On the outer fringe is a tea tree woodland.

The densest vegetation encountered in the Study Area, and the least abundant in terms of the proportion of the Study Area occupied, is open scrub associated with swamps and solution cavities in the Andamooka Limestone (mapping unit C2.5). This is illustrated in Figure 3.14(b). Mulga (Acacia brachystachya and less frequently A. aneura), bullock bush, dead finish, A. oswaldii, and native pittosporum (Pittosporum phylliraeoides) provide most of the scrub cover.

Although not mapped as a separate vegetation unit, incised water courses of tablelands show marked contrasts to the plateau surfaces and slopes by their possession of a tall shrubland or occasionally low woodland (Figure 3.14(c)). In the deeper water courses, the woodland may be dominated by tea tree, but it is more usual for a mixture of dead finish, some mulga, native pittosporum, bullock bush and a native plum variety (Santalum lanceolatum).

3.4.2 Status and significance of vegetation

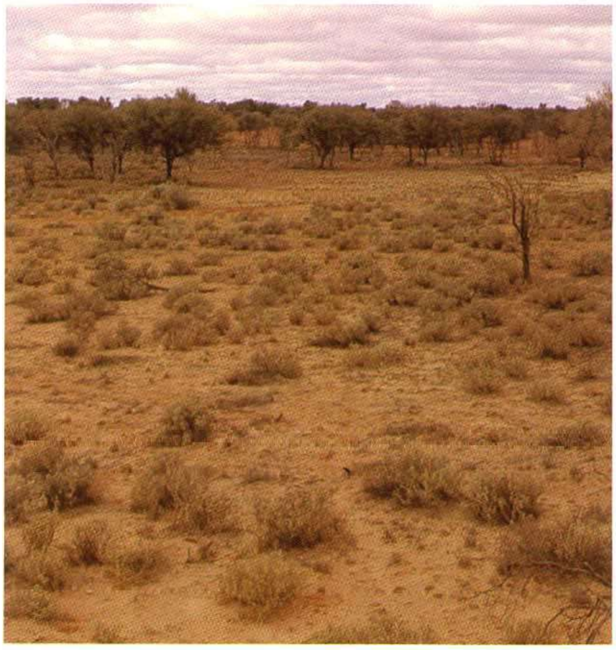
The status and significance of the Study Area vegetation are related to the degree to which past land use has altered the original vegetation, the extent to which similar vegetation is conserved elsewhere, and the occurrence of protected and rare plant species.

Effects of past land use

The vegetation of the region has been degraded by past land use. The main changes are due to grazing by stock and rabbits; to timber harvesting for commercial use, firewood and fencing; and to changing fire regimes.

Damage occurring in South Australian arid range lands due to stock grazing was recognized last century (Goyder in SAPP No. 78, 1865-66; Dixon 1892). In areas with ready water supplies, such as the Flinders Ranges, overgrazing had eliminated most of the original perennial shrub vegetation and created grasslands by the turn of the century (Barker 1970; Vickery et al. 1975). This pattern of degradation continued as new areas were brought into production (Ratcliffe 1936; Fatchen 1978). In areas such as the region around Olympic Dam, chenopod shrublands (e.g. saltbush/bluebush shrublands in the Study Area) have suffered the most degradation (Newman and Condon 1969). As part of his surveys, Jessup devised a method (based on observations of shrub densities in relation to soil type) which allowed estimation of densities prior to introduction of stock. The ratio of computed original bush densities to the densities he observed in 1945-50 illustrates the severity of the damage in the region. Ratios of original densities to those of 1950

a Typical swamp fringe, Coorlay Lagoon. Claypan right foreground samphire (*Halosarcia indica*) on edge of lagoon, with canegrass (*Eragrostis australasica*) and tea tree (*Melaleuca pauperiflora*) midphoto at base of escarpment.



b Mapping unit C2.5. Mulga (*Acacia aneura*) groves in a mulga 'swamp' bordering a local drainage depression. In the foreground saltbush (*Atriplex vesicaria*) and iceplant (*Aizoon quadrifidium*).

c Table Creek at Coorlay Lagoon. *Ptilotus obovatus* on dissection slopes, foreground, dead finish (*Acacia tetragonophylla*) along creek bank right background, and *Maireana pyramidata* and *Sclerolaena divaricata* in the creek, middle ground.

Figure 3.14
ILLUSTRATIONS OF VEGETATION (3)

are 22:12 in the northern part of Roxby Downs, 59:20 for some areas nearer Roxby Downs Station and 14:3 about the homestead, with the most spectacular losses being recorded on the Purple Downs and Roxby Downs Station boundaries near Coorlay Lagoon (35:2). These major changes in vegetation resemble the documented decimation of shrub species by pastoralism in similar country elsewhere (Fatchen 1978). In the Study Area itself, the most notable effects are the widespread thinning and removal of perennial shrub species' populations (particularly around stock watering points), and the apparent failure of major tree species to recruit.

Rabbits are a major problem in the Australian arid zone, where warren complexes are easily established in the light soils. Although their numbers are partially controlled by indigenous and introduced predators, by myxomatosis, and by the harsh climatic conditions, rabbits breed periodically to plague proportions in times of abundant feed. The main controlling factor then becomes lack of feed during times of drought, which results in major damage to established trees, shrubs and freshly germinated perennial plants. Cochrane and McDonald (1966) and Crisp (1978) have demonstrated that viable regeneration of these species (in particular myall and mulga) is dependent on the almost total absence of rabbits. In the Olympic Dam Project Area, rabbits are mainly established in the low sand dunes and their immediate margins, but they forage across much of the gibber-covered swale areas. Assessment by officers of the Vertebrate Pest Control Authority (Downward 1980) has shown that their density and distribution would be similar to that for comparable areas in other parts of the arid zone. It is notable that field observations in the Study Area indicated no regeneration of native pine, and almost no regeneration of mulgas or myall. Western myall has characteristic growth stages (Lange and Purdie 1976) enabling age estimation. Almost all myalls observed were more than seventy-five years old, a small number were aged between thirty and sixty, while only one or two seedlings were noted.

European settlement has had other direct effects on the vegetation. Local timber has usually been used for firewood and fencing. Fatchen and Reid (1980) cite an example where native pine stands on sand ridges have been reduced to half their original density over 120 years of harvesting. Cleland (1930) documents the almost complete elimination of sandalwood (Santalum spicatum) from the north-west during 1928-29, when the trees were cut for sale in Asia.

It has been suggested that Aborigines maintained particular vegetations by their frequent and widespread setting of fires (Tindale 1959), and that the advent of Europeans brought about landscape changes simply by altering the fire regimes. Bolton and Latz (1978) and Latz and Griffin (1977) suggest that there has been a major diminution of the frequency of wildfires but an increase in the intensity of those wildfires which do occur. This is a result of European settlement and the migration of nomadic tribes from arid areas, with Europeans actively preventing indiscriminate fire-setting. Lay (1976) has demonstrated that many of the perennial tree species in the southern rangelands are adversely affected by intense fire, hence 'the European prevention of what amounted to fuel reduction burning ... may well have resulted in landscape change' (Fatchen and Reid 1980).

Conservation status of vegetation

The main vegetation sequences on dune fields and tablelands are widely replicated outside the Study Area. Even the drainage-related vegetation sequences which are uncommon (i.e. tea tree woodlands fringing swamps, and mulga/dead finish open scrub associated with solution cavities) are widespread, although infrequent, outside the Study Area. Thus the vegetation of the Study Area is not considered to possess any special regional significance.

However, despite recent park acquisitions in the north-east of the State and on the Nullarbor by the South Australian National Parks and Wildlife Service, many of the arid landscapes of South Australia remain poorly represented within parks or other reserves.

In particular, there is no conservation reserve within the north-west pastoral area, and vegetations specific to this region (especially those of the stony tablelands) therefore have no representation in reserves at all. Other vegetations owe much of their current conservation to the existence of two very large but distant desert parks, one in the far west of the State and the other in the Simpson Desert. The conservation status of vegetations in the Study Area, based on that recognized by Specht et al. (1974), is indicated in Table 3.8.

Table 3.8 Conservation status in South Australia of communities found in the Study Area

Community (Specht et al. 1974)	Equivalent in this study	Conservation status	
		Specht et al. 1974	Current*
Low open woodland			
Callitris columellaris	Native pine	Reasonable	Reasonable
Acacia papyrocarpa	Myall	Reasonable	Reasonable
Tall shrubland			
Acacia aneura - A. brachystachya	Mulga	Reasonable	Reasonable
A. linophylla - A. ramulosa	Sandhill mulga	Probably reasonable	Probably reasonable
Acacia - Eremophila - Dodonaea - Cassia	Sandhill wattle - hopbush	Reasonable	Reasonable
Low shrubland			
Atriplex vesicaria	Saltbush - low bluebush	Reasonable	Good
Atriplex vesicaria - Ixiolaena leptolepis	Saltbush (tableland)	Nil	Nil
Maireana sedifolia	Bluebush	Reasonable	Good
Maireana astrotricha	Saltbush - low bluebush	Reasonable	Reasonable
Maireana aphylla	Cottonbush (swamp fringes)	Nil	Nil
Muehlenbeckia cunnighamii	Canegrass (associated species)	Moderate	Moderate
Halosarcia and others	Samphire swamps	Reasonable	Reasonable
Hummock grassland			
Zygochloa paradoxa	Sandhill canegrass	Excellent	Excellent
Tussock grassland			
Eragrostis australasica	Canegrass swamps	Nil	Little
Not listed by Specht et al.	Tea tree swamps and fringes (Melaleuca pauperiflora - M. uncinata - M. lanceolata)	-	Nil

* Estimated on basis of arid zone reserve creation since 1974.

Occurrence of protected and rare plant species

A list of species known to be present in the Study Area is given in Table 3.9. The following plants, protected under the National Parks and Wildlife Act 1972-1981, are found in the Study Area:

- bullock bush (Heterodendrum oleaefolium)
- emu bush (Eremophila longifolia)
- quandong (Santalum acuminatum)
- native pittosporum (Pittosporum phylliraeoides)
- Sturt pea (Clianthus formosus).

Note that sandalwood (Santalum spicatum), which is protected under the Sandalwood Act 1930-1975, was not observed in the Study Area, although it may be present.

Table 3.9 Plant species known to be in Study Area

Marsilieaceae
Marsilea drummondii

Cupressaceae
Callitris columellaris

Aizoaceae
Aizoon quadrifidum
Carpobrotus rossii

Amaranthaceae
Amaranthus grandiflorus (2)
Ptilotus obovatus
Ptilotus polystachyus

Asteraceae
Angianthus pusillus
Brachyscome ciliaris
Craspedia sp.
Ixiolaena leptolepis
Minuria denticulata
Minuria leptophylla
Myriocephalus stuartii

Boraginaceae
Echium plantagineum
Trichodesma zeylanicum

Brassicaceae
Brassica tournefortii
Lepidium sp.

Caesalpiniaceae
Cassia nemophila var. coriacea
Cassia nemophila var. platypoda

Campanulaceae
Wahlenbergia sp.

Chenopodiaceae
Atriplex inflata
Atriplex limbata
Atriplex spongiosa
Atriplex velutinella
Atriplex vesicaria
Babbagia acroptera
Chenopodium nitrariaceum
Dissocarpus paradoxus
Enchylaena tomentosa
Halosarcia indica subsp. leiostachya (formerly Arthrocnemum leiostachyum) (2)
Maireana aphylla
Maireana astrotricha
Maireana brevifolia
Maireana erioclada
Maireana georgei
Maireana pentatropis
Maireana pyramidata
Maireana sclerolaenoides (formerly Sclerolaena sclerolaenoides)
Maireana sedifolia
Malacocera tricornis (?)
Rhagodia nutans
Rhagodia spinescens var. deltophylla
Salsola kali
Sclerochlamys brachyptera (formerly Sclerolaena brachyptera)
Sclerolaena decurrens
Sclerolaena diacantha
Sclerolaena divaricata
Sclerolaena intricata
Sclerolaean lanicuspis
Sclerolaena obliquicuspis
Sclerolaena patenticuspis
Sclerolaena ventricosa
Sclerostegia tenuis (formerly Pachycornia tenuis)

Convolvulaceae
Convolvulus erubescens

Cucurbitaceae
Citrullus lanatus (formerly Citrullus vulgaris)

Euphorbiaceae
Euphorbia drummondii
Euphorbia tannensis
Phyllanthus fuernrohrii

Fabaceae
Clianthus formosus
Crotalaria cunninghamii
Crotalaria dissitiflora
Swainsona microcalyx subsp. adenophylla
Indigofera sp. aff. I. brevidens var. uncinata
Tephrosia sphaerospora

Frankeniaceae
Frankenia pauciflora

Geraniaceae
Erodium cyngnorum

Goodeniaceae
Goodenia cycloptera
Goodenia pinnatifida

Lamiaceae
Teucrium racemosum

Loranthaceae
Lysiana exocarpi
Lysiana murrayi

Malvaceae
Abutilon otocarpum
Hibiscus krichhauffianus
Malvastrum americanum
Sida ammophila
Sida corrugata vars.
Sida fibulifera
Sida virgata

Mimosaceae
Acacia aneura
Acacia brachystachya
Acacia kempeana
Acacia ligulata
Acacia linophylla
Acacia oswaldii
Acacia papyrocarpa (formerly A. sowdenii) (3)
Acacia ramulosa (1)
Acacia tetragonophylla

Myoporaceae
Eremophila duttonii
Eremophila glabra
Eremophila latrobei
Eremophila longifolia
Eremophila paisleyi (1)
Eremophila sturtii

Myrtaceae
Melaleuca pauperiflora
Melaleuca uncinata

Nyctaginaceae
Boerhavia diffusa

Pittosporaceae
Pittosporum phylliraeoides

Polygonaceae
Muehlenbeckia cunninghamii

Portulacaceae
Calandrinia remota
Portulaca oleracea

Proteaceae
Hakea leucoptera

Santalaceae
Exocarpos aphyllus
Santalum acuminatum
Santalum lanceolatum

Sapindaceae
Dodonaea angustissima (formerly Dodonaea attenuata)
Heterodendrum oleaefolium

Scrophulariaceae
Morgania floribunda

Solanaceae
Lycium australe
Nicotiana glauca
Solanum spp.

Tetragoniaceae
Tetragonia eremaea

Zygophyllaceae
Tribulus terrestris
Zygophyllum aurantiacum

Poaceae
Aristida browniana
Aristida contorta
Astrebla spp.
Brachiaria praetervisa
Dactyloctenium radulans
Enneapogon avenaceus
Enneapogon cylindricus
Enneapogon polyphyllus
Eragrostis australasica
Eragrostis dielsii
Eragrostis falcata
Eragrostis laniflora (1)
Eragrostis setifolia
Eriachne helmsii (1)
Neurachne munroi (1)
Panicum sp.
Paractaenum novae-hollandiae
Plagiosetum refractum
Sporobolus actinocladus
Stipa nitida
Tragus australianus
Tripogon loliiformis (1)
Triraphis mollis
Zygochloa paradoxa

(1) Species rare as noted by Specht et al. (1974).
(2) Species depleted (population originally widespread but now reduced in area) as noted by Specht et al. (1974).
(3) Species of geographical importance as noted by Specht et al. (1974).

Bullock bush

Bullock bush is one of the most commonly occurring secondary species in the dune fields of the Study Area. As with other palatable shrub and tree species, bullock bush shows little regeneration within the Study Area, except for occasional cases in areas where stock fail to penetrate.

Emu bush

Emu bush is rare. There appears to be no area of concentration, and the few occurrences noted are dispersed through the dune fields. The species appears to be regenerating satisfactorily.

Quandongs

Although quandongs are generally uncommon in the Study Area, there are some local concentrations. These are found in association with myall, but only in those groves over Andamooka Limestone (geological regime A). However, the frequency of myall groves known to be in this regime indicates that quandongs would be more frequently encountered further to the south in the Study Area, outside the areas of the field survey.

Native pittosporum

Native pittosporum is uncommon in the Study Area, except in the tableland creeks (where it is a common member of the creek community), in solution cavities (where one or two individuals are usually present), and at some stock dams. Individuals are usually found surrounded by a group of juveniles which are generally heavily grazed.

Sturt pea: The Sturt pea has been noted in large concentrations at only two localities in the Study Area. The species can be expected to be reasonably frequent in dune field areas when seasons are appropriate. It is, however, considerably reduced by domestic grazing.

3.4.3 Vegetation impacts and mitigation

Figure 3.15 shows the outline of the proposed development within the Project Area in relation to the vegetation mapping units. The operations area is almost entirely in A2.2.2 - mulga woodland/sandhill wattle tall open shrubland on widely spaced dunes, with saltbush/low bluebush low open shrubland on red calcareous earths in the interdunal corridors. The town will be sited amongst a mixture of dune field vegetation sequences. The southern part of the town development is in A2.1.2 (mulga woodland tall open shrubland on moderately spaced dunes, with saltbush/low bluebush low open shrubland in the interdunal corridors), the north-eastern part is in A1.1 (mulga woodlands on closely spaced dunes), while the north-western part is in A1.2 (native pine woodlands on closely spaced dunes).

As noted above, the vegetation of the Study Area has been degraded by past grazing and is widely replicated throughout the region. In addition, there are only limited vegetation types of some conservation significance in the Project Area: the infrequent occurrences of mulga swamps, open scrubs associated with solution cavities, and canegrass swamps. Therefore, in assessing impacts in relation to vegetation, the primary importance of the native vegetation in the Project Area is considered to be its role in preventing erosion. In the town area, additional consideration is given to the amenity value of vegetation, particularly the western myall groves.

Stability and resilience

There is a distinction between the vegetation associated with sand and that associated with structured soils in relation to their roles in the control of soil erosion. The perennial shrub vegetation of the structured soils (saltbush and bluebush) provides a major guard against erosion, as it has high stability (ability to resist damage). However, if this shrub cover is removed, so is the initial erosion protection. Where gibber pavements are present, this may have no further consequences other than a reduction in long-term plant productivity, and slight changes in surface hydrology. Where gibbers are not available as a subsidiary soil protection, surface soils will be lost through water and wind erosion. The shrub vegetation has low resilience (ability to recover from damage), the consequences of which are scald formations, and the necessity of using mechanical means for regeneration. Thus, despite a high initial stability, the perennial shrublands on structured soils have very little resiliency.

The ground cover of sand areas is dominated by grasses and herbs which tend to be ephemeral. They appear rapidly after rains, but die off quickly with the return of drought conditions. The trees and tall shrubs on sands provide the main long-term erosion protection, but the ephemeral nature of the understorey means that, for much of the time, the sand surface will not be bound and local surface drift will be present, even in the absence of any imposed impact. Ephemerals when present, even if dead, can bind the sand surface and minimize sand movement (Fatchen and Barker 1979), but as they are easily removed (through grazing by stock or rabbits, or by human trampling) local drift is readily initiated. However, the reproductive capacity and growth habit of ephemerals is such that, following effective rain, a crop will rapidly appear and restrict such local drift. Therefore, while vegetation on sands has low stability, it possesses high resiliency.

Species relationship to dune mobility

Four sets of character species are recognized on deep sands (surface sands deeper than 1.5 m). In approximate order of increasing dune mobility these are:

- sandhill mulga (Acacia linophylla and A. ramulosa)
- native pine (Callitris columellaris)
- sandhill wattle/hopbush (Acacia ligulata and Dodonaea angustissima)
- sandhill canegrass (Zygochloa paradoxa).

Sandhill mulga woodlands have extensive ephemeral cover under favourable conditions: up to 70% cover was recorded by Graetz and Tongway (1980). Actively growing ephemerals providing cover of this magnitude will almost completely eliminate any surface sand movement, although disappearance of such cover under drought conditions would lead to an increase in drift.

Native pine groves are almost devoid of ground cover, which is believed to result from an allelopathic effect (the leaching of a toxin from native pine foliage or ground litter which inhibits the germination or growth of potential understorey species). Minor local drift is present in pine groves as a consequence of this lack of ground cover, but the trees themselves prevent such drift assuming major proportions.

The sandhill wattle/hopbush tall shrubland is associated with blowouts and mobile areas in dunes. Sandhill canegrass hummock grassland, which is usually associated with isolated dunes, is indicative of areas of sand drift. Thus an indication of the degree of sand movement (dune movement, blowouts, local drift, and drift in dry conditions) can be obtained from the distribution of these character species on sand dunes.

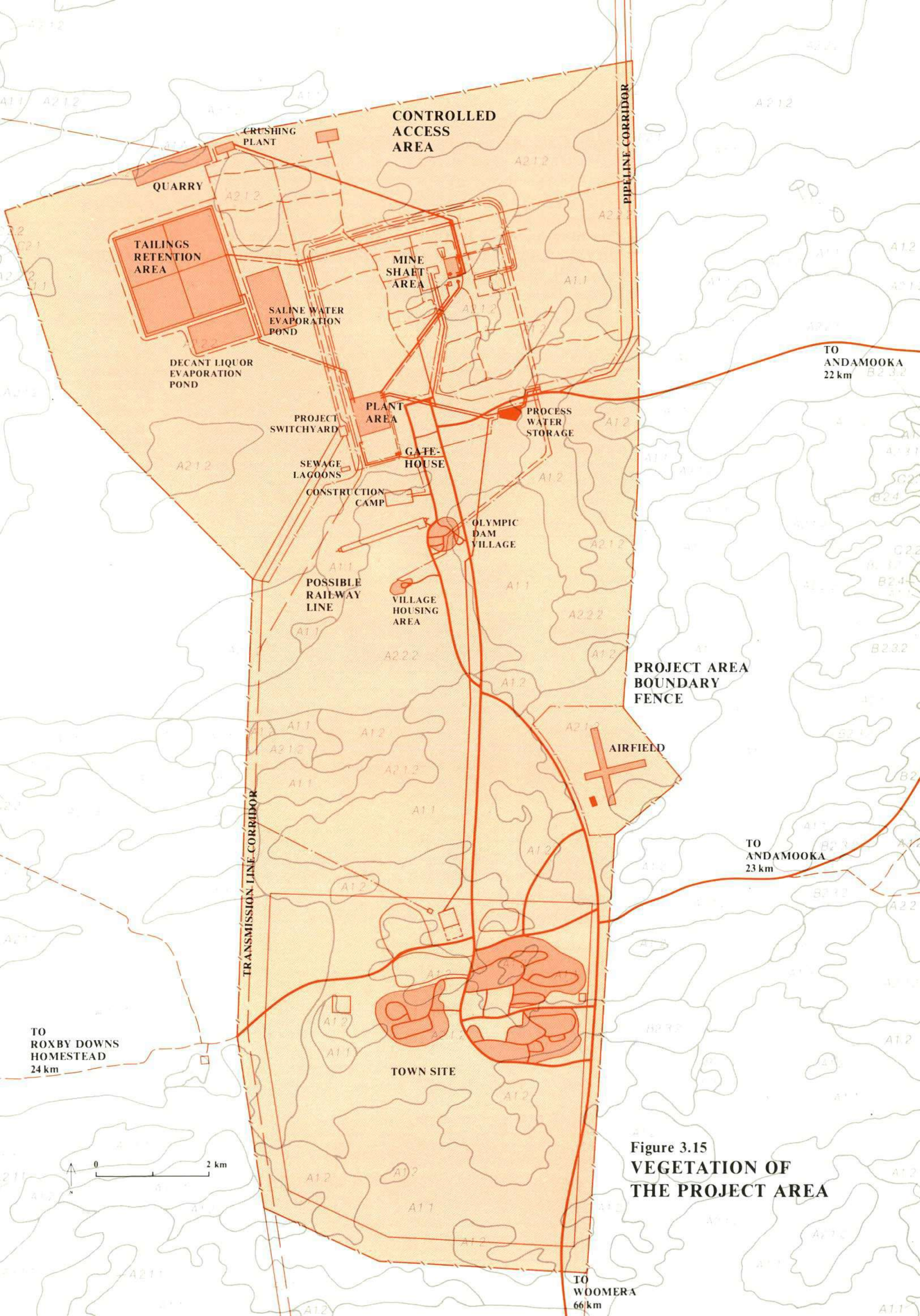


Figure 3.15
VEGETATION OF THE PROJECT AREA

Operations area

Figure 3.16 shows the vegetation in the operations area which has some conservation significance (all associated with drainage features - mulga swamps, open scrub around solution cavities, and canegrass swamps), as well as areas with some potential for sand movement (sandhill wattle/hopbush on sand ridges and native pine groves). There are only infrequent, isolated occurrences of drainage-related vegetation in this area.

The sand ridges contain a high proportion of sandhill wattle/hopbush cover, indicating potential for blowout formation, although major areas of blowouts are confined to the east of the tailings retention area. Sandhill canegrass, indicating more active sand movement, is generally absent, with the only small area being at a break in the dune ridge crossed by the main north access road (east of the tailings retention area). Pockets of native pine are present, but these are generally away from the principal areas of development. The more stable mulga woodlands are on the eastern margins of the mine and plant areas.

The areas of intense development (the tailings retention area, plant area, mine area surface development, and quarry) will require the elimination of the existing vegetation. New roads and other transport corridors such as conveyors will also require vegetation clearance. However, as the area of vegetation which will be cleared is small compared with the total area over which similar vegetation occurs, and as significant areas of native vegetation will remain between the cleared areas, this impact is not considered significant.

Of the various air emissions from the mining and process operations, sulphur dioxide and hydrogen fluoride have the most potential for impact on the surrounding vegetation. Above certain threshold levels, sulphur dioxide and hydrogen fluoride are phytotoxic to certain plants. Below 40 pphm (1,064 $\mu g/m^3$ at $20^{\circ}C$), the sulphur dioxide gas tends to be oxidized quickly as it is absorbed, and interference with functions such as photosynthesis is slight. As the predicted yearly average ground concentrations of sulphur dioxide are 20 $\mu g/m^3$ (Chapter 8), no adverse impact is expected to occur to vegetation due to sulphur dioxide. In the case of hydrogen fluoride, studies have shown that species sensitive to fluoride may exhibit necrosis (die-off of the tips or margins of leaves) when long-term average concentrations of gaseous fluoride exceed about 0.25 $\mu g/m^3$. As the maximum long-term average concentration for hydrogen fluoride as a result of plant emissions is 0.05 $\mu g/m^3$, no adverse impact is anticipated even for species sensitive to fluoride.

Loss of vegetation leading to increased sand movement is probably the main environmental concern. In detailed site planning, high priority will be given to the retention of vegetation, particularly on dune fields, by locating development and roads where practicable in interdune corridors and by limiting cross-dune connections. Careful rehabilitation and land management will ensure that areas which are cleared or damaged will be adequately restored.

The current limited regeneration of tree species, which are important for the long-term containment of sand movement, will be improved by eliminating stock grazing and controlling rabbit populations. Increases in the ephemeral understorey on dunes will also be likely to result from this programme, further reducing local sand movement. This programme will involve the erection of stock and vermin-proof fencing around the Project Area, followed by a systematic rabbit control programme. Experimental broad acre 1080 poisoning followed by warren destruction has already been successfully employed in the Olympic Dam village area.

In addition, Clause 25(1)(b) of the Indenture Agreement includes the provision for a mine buffer zone, within which access may be restricted to safeguard the public, the workforce, and the environment, in relation to Project operations. Such a buffer zone

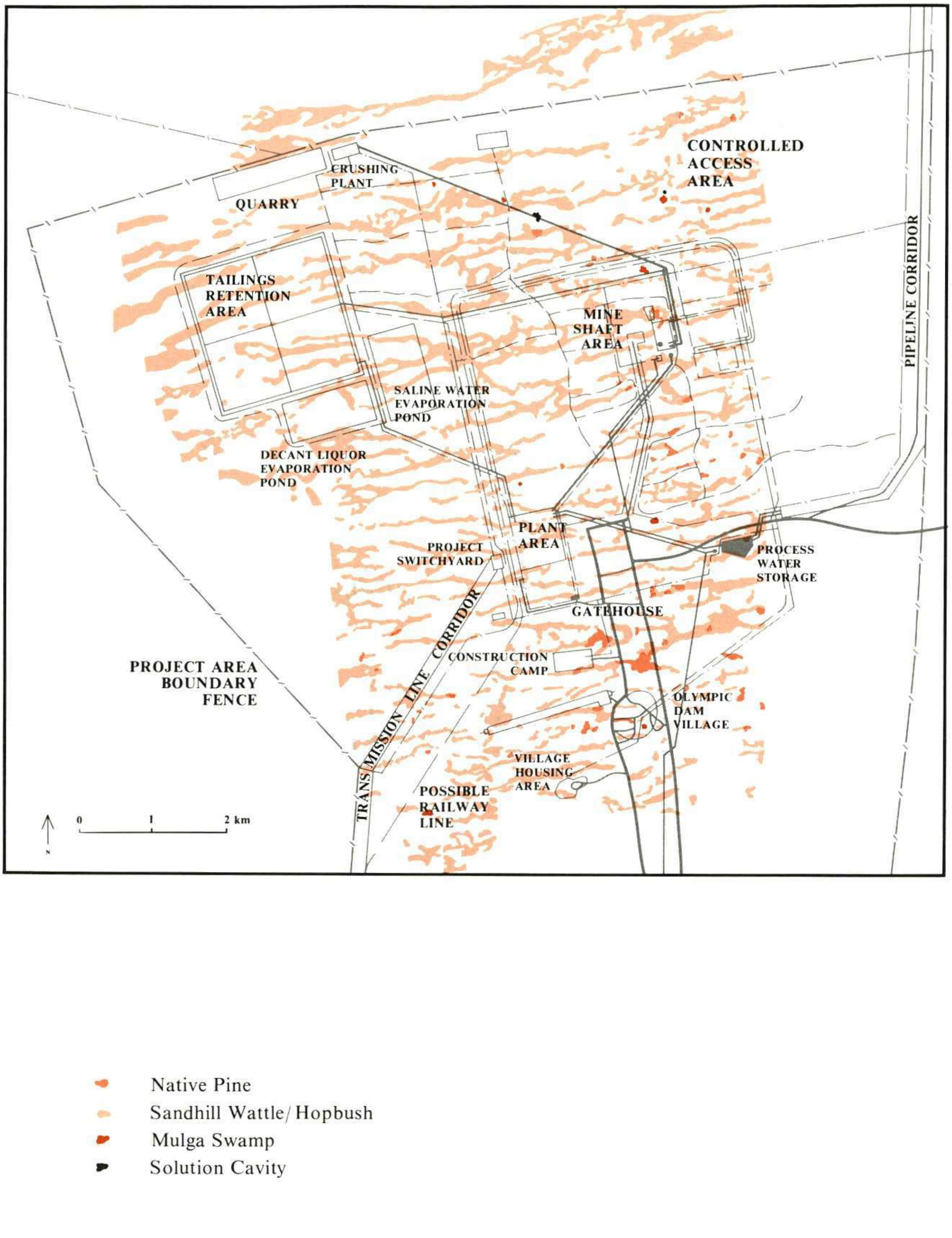


Figure 3.16
VEGETATION OF ENVIRONMENTAL SIGNIFICANCE IN THE OPERATIONS AREA

would assist in confining vegetation impacts to areas of development, and thus help to retain the integrity of the landscape and its amenity value.

Legally protected plant species occurring within the operations area are bullock bush, emu bush and quandong. Bullock bush is common in the operations area, emu bush is present only as occasional groups or individuals (mainly associated with mulga swamps), while quandong is found in scattered small groups or, more rarely, in association with western myall groves. To compensate for possible loss of such protected species and because these species are attractive tall shrubs or small trees, they will be incorporated in general amenity plantings. Other protected species such as native pittosporum and Sturt pea form part of the current amenity planting at Olympic Dam. Seed collection and experimental germination of other species such as bullock bush is continuing.

Town site

The relationship between town planning and vegetation is discussed further in Chapter 11. General impact and mitigation considerations are discussed here, while the manner in which these considerations will be incorporated in town design are addressed in Section 11.6.7.

The vegetation of the town site is predominantly mulga woodlands, which are characteristic of stable dune fields. There are only isolated groves of native pine where local drift can occur, and even fewer areas where sandhill wattle/hopbush tall shrubland occurs which can be associated with dune blowouts. Thus, in its natural state, the town site has a low propensity for sand movement.

Vegetation with some conservation significance is almost absent from the town site. Two small mulga swamps and one canegrass swamp occur in the eastern margin of the town, while several larger mulga swamps occur to the west of the town. There are no open scrub communities associated with solution cavities.

Swales of moderate width which are common to a large area of the town frequently contain groves of western myall, with either a grassy cover or a low open shrubland of saltbush. In areas of moderately spaced dunes, western myall groves tend to be more frequent around the edges of swales and internal drainage areas. These western myall groves are considered significant for their amenity value, as this tree is the only shady species in the area, it is shapely, and it provides an immediate source of town trees. The myalls do not require a water subsidy above that provided by direct rainfall and run-off, although they may show a marked growth response if additional water is provided (as exhibited by the myalls in the present Olympic Dam caravan park).

Heavy grazing pressure has also affected the perennial shrubland in swale areas. These areas would once have carried saltbush, but in many instances vegetation cover has been reduced to ephemeral species.

Legally protected plant species occurring within the area are bullock bush, emu bush and quandong. Bullock bush, while common, does not appear to be as frequent as in the operations area. Emu bush is present only as occasional groups of individuals, mainly associated with the chain of mulga swamps to the west of the town area. Quandong is found in scattered small groups or individually in association with western myall groves.

Town development will be more dispersed and less intense than development in the operations area. There is also more flexibility available in the layout of the town development than for the operations area, so more opportunity exists to reduce the degree of impact. Some vegetation clearance will be required in establishing the town, although garden planting and watering of native and exotic species will increase the vegetative cover of areas not built upon. The town site vegetation has no particular regional significance, as there are no vegetation types not represented elsewhere, and the main considerations therefore are the retention of amenity and the maintenance of landform stability. On this basis, the following design criteria in relation to vegetation will be incorporated with other factors in town planning:

- the maintenance of existing vegetation where practicable, particularly drainage-related vegetation such as mulga and canegrass swamps;
- the avoidance where practicable of dune areas sensitive to disturbance or likely to present sand drift problems and, where not practicable, the protection of such areas by surface treatment;
- the general siting of most roads parallel to dunes in swale areas, and the minimization of cross-dune roading;
- the alignment of roads, where possible, to avoid stands of myalls, which may result in sinuous rather than straight roads;
- the siting of development primarily in swale areas;
- the siting of houses near, or between, individual trees, but not in place of them;
- ensuring that an adequate water supply is available to myalls, either by avoiding interception of run-off to myall groves or, alternatively, providing water to compensate for interception loss.

Indirect impacts

The influence of the Project will extend over a larger area than that of the Project Area itself. In particular, the recreational use of the surrounding country will affect the vegetation in the region. Potential impacts are likely to include vegetation damage due to off-road vehicle movement, use of picnic sites at points of interest resulting in a reduced vegetation cover and increased erosion, and the removal of timber for firewood and other uses. Recreation impacts are more likely to be concentrated at distinctive landscape features, and swamp areas containing vegetation with some conservation significance can therefore be expected to receive more intense use.

The incidence of wildfires is expected to increase, primarily in the remnant vegetation in the vicinity of the town site and in informal recreation areas. The primary sources of ignition are expected to be domestic rubbish burning, children, and poorly managed barbecue fires. Fire incidence will usually be limited by seasonal conditions, and fires are likely to be of low intensity. However, some loss of trees and ground cover can be anticipated.

3.4.4 Flora monitoring

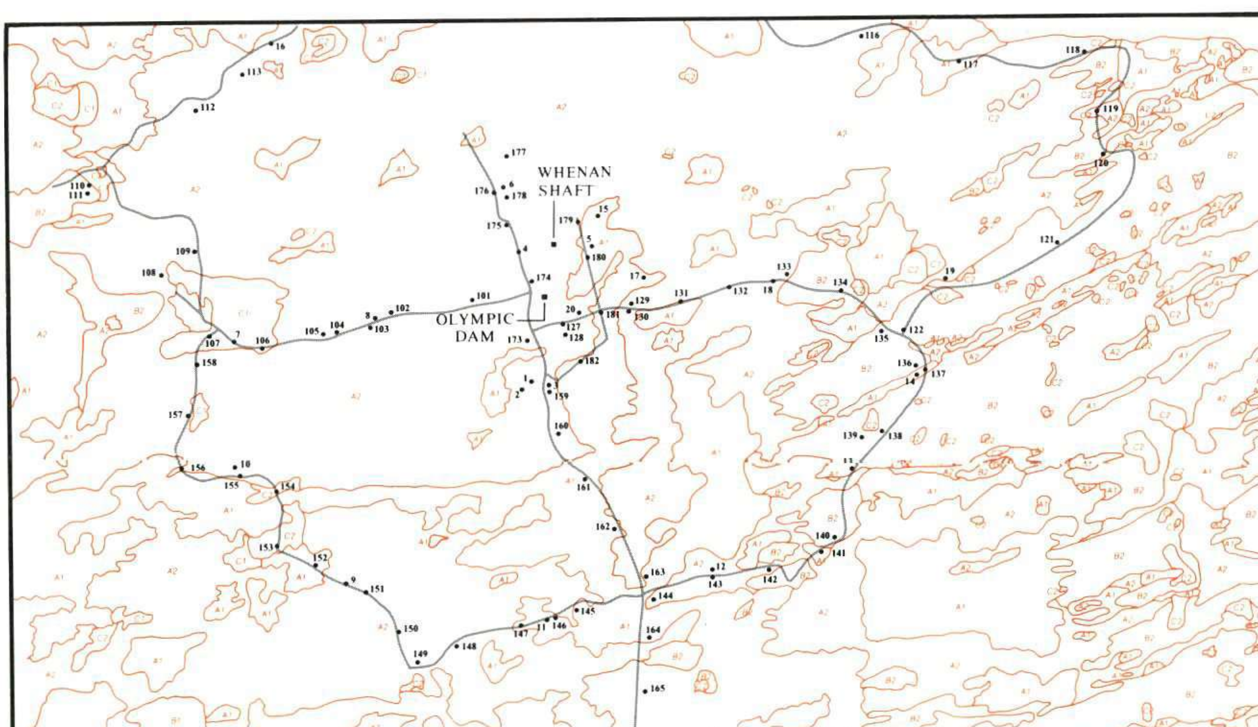
A vegetation monitoring programme has been established by Roxby Management Services at Olympic Dam to provide an understanding of:

- the normal changes in vegetation, both seasonal and long-term
- the relationship of vegetation to landscape processes and integrity
- the relative influences and effects of the development and other land uses (not only to monitor impacts, but also as an input to site management).

Relevant information has been obtained using the following techniques:

- vehicle traverses for broad scale evaluation of gross changes in vegetation type and distribution;
- 50 m radius quadrats at seventy-eight points along the vehicle traverses to record species present, vegetative structure, dominant character species, and associated landform and soil types;
- photopoints for taking stereopair photographs for visual appreciation, identification of larger individual plants, tracing of shrub and tree canopy outlines, direct density counts, and biomass estimation;
- 10 m^2 quadrats in the photofield for plant species' frequency, density, and cover, as well as compound indices such as plant diversity coefficients and species' importance values;
- species/area plots (100 x 10 m with a series of smaller quadrats) within the photofield to measure changes in species richness and to develop a species/area curve;
- perennial shrub counts of species considered important to landform stability on 100 x 1 m transects to measure changes in cover and density.

The location of the vehicle traverses and monitoring points are shown in Figure 3.17. The information recorded in relation to the monitoring points is as follows:



Note: Vegetation Mapping Units (refer Table 3.7)

Figure 3.17

FLORA MONITORING SITES

- 50 m radius quadrats: all monitoring points numbered greater than 100 recorded at least once every five years;

- photopoints: monitoring points 1 to 21 recorded at approximately six-monthly intervals;

- photofield quadrats: monitoring points 1 to 21 (except 6 and 19) at approximately six-monthly intervals;

- species/area plots: monitoring points 1 to 21 (except 6 and 19) at approximately six-monthly intervals;

- perennial shrub counts: monitoring points 2, 4, 8, 9, 16, 102, 112, 113 and 177 on an annual basis.

3.5 FAUNA

3.5.1 Mammals

The mammals in the vicinity of Olympic Dam were sampled using traplines in representative habitats and along transects through major terrain types (Figure 3.18). The traplines were sited to sample a comprehensive range of possible mammal habitats, with emphasis on the Project Area and the routes of infrastructure corridors near the Project Area. These habitats were selected on the bases of:

- soil, plant and topographic divergence
- the presence of suitable cover and home sites
- sufficient diversity of food
- experience of mammal occurrence in similar environments.

Within each habitat, pockets of least disturbance and freshest growth were examined, and the sites of maximum observed mammal activity among such pockets were trapped. Most habitats were sampled in opposing seasons and at two widely spaced locations (or more than two if the habitat was especially widespread in the region, or if initial results were considered inconclusive). Transects across major terrain types were sited to estimate relative population densities of medium to large ubiquitous mammals. The three transects chosen covered gibber tableland, widely spaced dune sequences, and the more closely spaced dune fields with the repetitive ridge/swale depression pattern. Routes were chosen to sample maximum variation in each terrain type over about 30 km.

The native and introduced species found during the fieldwork, and mammals suspected of being present based on other surveys in nearby areas but not found, are listed below.

Native species

Planigale gilesi (Paucident Planigale): locally common, but apparently restricted to cracking clay depressions with Mitchell grass (Astrebla spp.) and sparse low shrubs on gibber tableland. Caught only in spring north of Bulls Head Vermin Gate (Figure 3.18, trapline 13) and west of Mirage Lagoon (traplines 23, 24 and 25). No comparable habitat was found within the Project Area. All females had recently-born pouch young, indicating spring breeding. Elsewhere in Australia this species is locally common in scattered pockets of similar habitat and also in sedgeland around swamps across north-eastern South Australia, south-western Queensland and northern New South Wales. Future collecting will almost certainly reveal it to be more profusely distributed within this range.

Sminthopsis macroura (Stripe-faced Dunnart): common but apparently restricted to dense canegrass (Eragrostis australasica) swamp with deep crabholes, and cracking clays with relatively close shrub cover on gibber tableland. This species has been caught in autumn on a swamp south-west of the Project Area (trapline 4/15), and on gibber tableland west of Mirage Lagoon (traplines 23, 24 and 25), and again in spring at the same localities as well as on a swamp east of the Project Area (trapline 21) and on gibber tableland north of Bulls Head Vermin Gate (trapline 13). No comparable habitat was found in the Project Area. The few swamps present in the Project Area were too severely degraded by cattle to be suitable. Subadults were taken in May and juveniles in October, indicating both late summer and early spring breeding. Elsewhere in Australia this species is common in a variety of habitats affording good cover throughout the arid interior.

Sminthopsis crassicaudata (Fat-tailed Dunnart): common throughout the Project Area and the surrounding region in all habitats sampled, except stony creek beds. This species has been caught in autumn on stony swale with saltbush (Atriplex vesicaria)/bluebush (Maireana sedifolia) shrubland and grasses at the operations area (trapline 7), and on gibber tableland with sparse ephemeral herbs and grasses south of 12 Mile Dam (by hand), then in spring at a lignum (Muehlenbeckia cunninghamii) swamp with crabholes south of Bulls Head Vermin Gate (trapline 14) and a canegrass swamp with crabholes south-west of the Project Area (trapline 4/15), on gibber tablelands with cracking clays and relatively close shrub cover west of Mirage Lagoon (trapline 25) and with open shrub cover north of Pine Ridge Dam (by hand), on sand plain with western myall (Acacia papyrocarpa) woodland over saltbush/bluebush shrubland west of Myall Dam (trapline 3), also on dunes with various plant associations, viz. canegrass (Zygochloa paradoxa) east of Purple Downs homestead (trapline 18) and south of Bulls Head Vermin Gate (trapline 14), speargrass (Stipa spp.) north of Myall Dam (trapline 5), saltbush and grasses under mulga (Acacia aneura) and hopbush (Dodonaea angustissima) east of Axehead Dam (trapline 17), native pine (Callitris columellaris) over bare sand east of Axehead Dam (trapline 16), bindyi (Sclerolaena spp.) and grasses under mulga west of Coorlay Lagoon (trapline 19), and a tall shrubland of hopbush, needlebush (Hakea leucoptera), tarbush (Eremophila glabra), kangaroo bush (Cassia spp.) and wattle (Acacia spp.) over bare sand north-west of the Project Area (trapline 12). Additional specimens have been taken in the Project Area by reptile collectors in winter on a bare dune with mulga and hopbush 500 m east of the Whenan Shaft, and by Roxby Management Services' personnel on a swale with saltbush/bluebush shrubland 2.5 km north-north-east of Olympic Dam. Juveniles were taken in October, indicating breeding in early spring. Elsewhere in Australia this species is common in a wide variety of habitats spanning temperate, semi-arid, and arid areas of the continent.

Macropus robustus (Euro): locally common, but restricted to the escarpments and feeder creeks around Coorlay Lagoon. No comparable habitat was found in the Project Area. Young of all ages have been observed in both autumn and spring, indicating continuous breeding. Elsewhere in Australia this species varies from common to abundant on suitable rocky habitats throughout the arid interior and on the east coast.

Macropus rufus (Red Kangaroo): common in all woodland, shrubland and grassland habitats throughout the Project Area, the town site and the surrounding region, especially on the sand plains north-west of Axehead Dam, the gibber tableland south of 12 Mile Dam and the dune/swales south of Burgoyne Ridge. Young of all ages were observed in both autumn and spring, indicating continuous breeding. Population densities on the three major terrain types in the region, estimated by night transect counts, revealed no significant seasonal variation. Estimates were: gibber tableland (transect 1) $8.6/km^2$ in autumn and $9.6/km^2$ in spring, sand plain (transect 2) $30/km^2$ in autumn and $26/km^2$ in spring, and dune/swale (transect 3) $21.1/km^2$ in both autumn and spring. Elsewhere in Australia this species varies from common to abundant throughout the arid interior, although its numbers fluctuate widely in response to regional droughts.

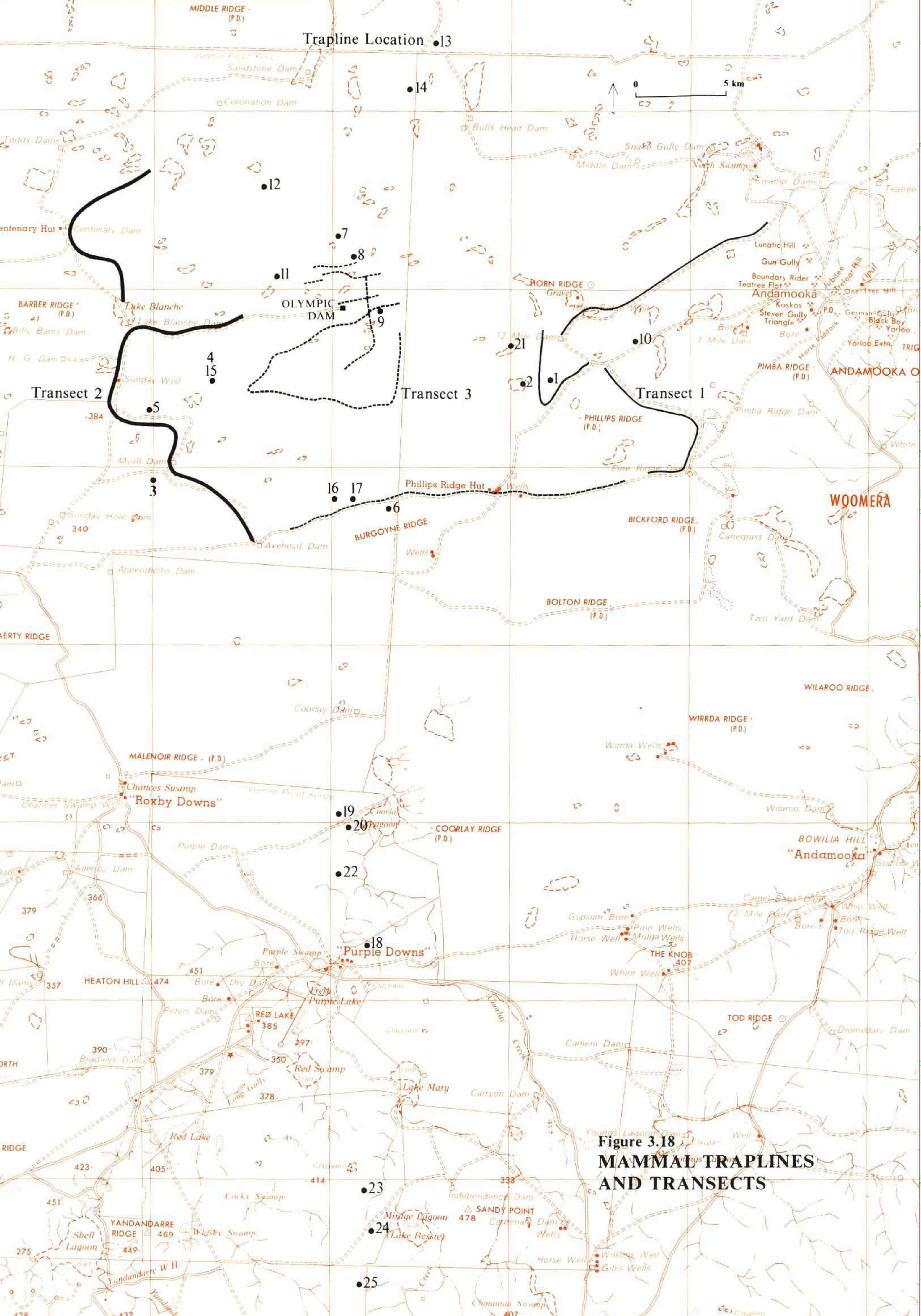


Figure 3.18
MAMMAL TRAPLINES AND TRANSECTS

Leggadina forresti (Forrest's Mouse): apparently uncommon, and restricted to cracking clays with relative close shrub cover on gibber tableland. Only one specimen has been caught in spring, west of Mirage Lagoon (trapline 23). Comparable habitat occurs north of the State Dog Fence near Bulls Head Vermin Gate, and in the adjacent region of Billa Kalina to the north-west (where this species has also been captured recently), but none were found in the Project Area. The single sample caught in mid-October was a juvenile about five weeks old, indicating early spring breeding. Elsewhere in Australia this species is common (but never very numerous) in a wide variety of arid habitats throughout the centre. In the southern Lake Eyre Basin it seems to prefer low shrublands on stony or clay plains.

Tadarida australis (White-striped Mastiff Bat): common over all wooded habitats, especially myall woodland and mulga scrub, throughout the Project Area and the surrounding region, but only collected in autumn. Not one sample was either caught or seen in spring, and a recent survey on Billa Kalina confirmed its absence from that region in late summer also. This could indicate emigration of the population to another climatic zone during the warmer months. Elsewhere in Australia this species is common in both coastal and arid forests and woodlands across the southern half of the continent, excluding Tasmania. It roosts in tree-spouts either singly or in groups of up to five.

Tadarida planiceps (Flat-headed Mastiff Bat): common, but apparently only in spring, over the belt of myall woodland extending from Phillips Ridge Well westwards to beyond Axehead Dam. Not collected anywhere in autumn and never collected over the Project Area, but may inhabit other areas of suitable woodland in the region during spring. Elsewhere in Australia this species is common in semi-arid woodlands throughout the southern half of the continent. It roosts under bark or in dead trees and old buildings, usually in small groups but occasionally in colonies of up to one hundred.

Nycticeius greyii (Little Broad-nosed Bat): common, but apparently only in spring, over myall and mulga woodland in an arc south of the development site between Phillips Ridge and Myall Dam. Not caught anywhere in autumn, and never caught over the Project Area, but may inhabit other areas of suitable woodland in the region during spring. Elsewhere in Australia this species is common in open woodland throughout much of the inland. It roosts in tree-spouts, either singly or in groups of up to fifteen.

Nyctophilus geoffroyi (Lesser Long-eared Bat): common, but apparently only from spring through summer, and restricted to sheltered, well timbered locations. Caught in spring along a deep, dry, well-wooded creek bed west of Coorlay Lagoon (trapline 20) and in summer by Roxby Management Services' personnel near a small densely vegetated solution doline in the Project Area about 1 km north-north-east of the Whenan Shaft. Not caught anywhere in autumn. Elsewhere in Australia this species is common in most habitats throughout the continent, except on Arnhem Land and Cape York. It normally roosts in hollow trees or under bark in groups of up to five, but it sometimes lives in caves, and larger groups are occasionally found in buildings.

Canis familiaris dingo (Dingo): common, but only north of the State vermin fence on Billa Kalina and Stuarts Creek. Not found in the Project Area. Elsewhere in Australia this subspecies in its pure form is common in all habitats outside sheep zones, but rare and destroyed as vermin if found within the latter.

Introduced species

Mus musculus (House Mouse): common to abundant in swamps, creek beds, and on dunes throughout the region; uncommon but at times erupting to abundance in all other habitats including human structures. Caught on traplines 1, 2, 4, 5, 8-10, 12-21 and 23-25, also around the Whenan Shaft and the Olympic Dam village. Juveniles were present in April-May and October-November, indicating opportunistic breeding after both summer and winter rains.

Oryctolagus cuniculus (Rabbit): uncommon on gibber tableland, but superabundant in other habitats throughout the region, especially on low dunes. Juveniles were most plentiful in October-November, indicating an early spring breeding peak. Population densities on the three major terrain types in the region, estimated by night transect counts, revealed significant seasonal variation in favoured habitats. Estimates were: gibber tableland (transect 1) 20/km^2 in autumn and 27/km^2 in spring, sand plain (transect 2) 101/km^2 in autumn and 192/km^2 in spring, and dune/swale (transect 3) 143/km^2 in autumn and 311/km^2 in spring.

Felis catus (Cat): uncommon on gibber tableland but abundant throughout other habitats of the region, including human settlements. Pregnant females were present in October-November, indicating spring breeding. Analyses of stomach contents from thirty cats shot in various habitats during both autumn and spring yielded no native mammal remains. Food was mainly rabbit, with proportionately decreasing amounts of reptiles, birds, scorpions, centipedes, locusts and house mice. Population densities on the three major terrain types in the region, estimated by night transect counts, revealed some seasonal variation in favoured habitats. Estimates were: gibber tableland (transect 1) none seen on transect in autumn or spring, sand plain (transect 2) 0.6/km^2 in autumn and 2.7/km^2 in spring, and dune/swale (transect 3) 0.6/km^2 in autumn and 4/km^2 in spring.

Vulpes vulpes (Fox): common in all habitats throughout the region. Analyses of stomach contents from fifteen foxes shot in various habitats during both autumn and spring yielded no native mammal remains. Food was almost entirely rabbit, with some fruits and seeds and a small proportion of scorpions, centipedes, locusts and beetles. Population densities on the three major terrain types in the region, estimated by night transect counts, revealed some seasonal variation, but lower spring numbers may reflect intensive winter shooting for pelts. Estimates were: gibber tableland (transect 1) 1/km^2 in autumn and 0.3/km^2 in spring, sand plain (transect 2) 0.8/km^2 in autumn and 0.6/km^2 in spring, and dune/swale (transect 3) 1.1/km^2 in autumn and 0.5/km^2 in spring.

Mammals suspected of being present

Planigale tenuirostris (Narrow-nosed Planigale): recent surveys in the similar and adjacent regions of Billa Kalina to the north-west and Mulgaria to the north-east have proved this species to occur in both. It is reasonable to assume, because of habitat continuity, that it will also be found in the Olympic Dam region but it has so far avoided capture. If present, it is likely to be restricted to its usual habitat of cracking clays on gibber tableland such as those north of Bulls Head Vermin Gate, west of Mirage Lagoon and north of Pine Ridge Dam. Elsewhere in Australia this species is locally common in similar areas of cracking clays across central South Australia, northern New South Wales and southern Queensland.

Antechinomys laniger (Kultarr): recent museum specimens from the similar regions of Wirraminna to the south and Oodnadatta to the north show that the Olympic Dam region is within the range of this species and, because its preferred habitats include dunes, gibber tableland and mulga scrub, all of which are widespread around Olympic Dam, it is reasonable to assume it might be found there. This probability was strengthened by the fact that drilling and local station personnel reported five sightings of 'small hopping mice with long bushy tails' in the region during the past year. Such a description could fit only a Kultarr or one of the true hopping mice (Notomys spp.). Hopping mice are doubtful candidates because they are relatively easy to catch, communal rodents, which live in easily recognizable burrows and are unlikely to have been overlooked on the surveys. The Kultarr, on the other hand, is a notoriously evasive, solitary and nomadic marsupial insectivore, which could easily have missed detection. Elsewhere in Australia this species is apparently uncommon, but nevertheless evenly distributed, in a wide variety of habitats throughout the inland. Its uncommon status is almost certainly more presumed than real, and due to the fact that it is difficult to collect.

Impact and mitigation

The environment of the Olympic Dam region has become increasingly degraded over more than a century of pastoral exploitation. In addition, the region has been overrun for nearly a century by an exotic herbivore (the rabbit), two exotic predators (the fox and the cat), and an exotic granivore (the house mouse).

Many native mammals once found in the region have now vanished because they could not adjust to the altered environment created by these aliens. Those still living there are either tough and adaptable opportunists which have learned to survive in the altered environment, or highly mobile aerialists which were immune to predation by man, foxes and cats, did not compete with house mice, and were unaffected by the vegetational changes resulting from stock and rabbit grazing.

All species of native mammals found (or suspected of being present) in the region share one or other of these life strategies. They are all widespread, secure and, at least locally, common, not only around Olympic Dam but also in the State of South Australia and throughout their large ranges elsewhere in Australia.

No rare or endangered species of native mammals were detected in the Study Area and, given the known ecological requirements of possible candidates plus the degraded nature of all habitats, it is almost inconceivable that any could be present. Furthermore, no rare native mammal habitats were discovered, and no regionally significant native mammal habitats were found to be unique to the Project Area or to the access corridors.

Development of the operations area, the town, and the access corridors for essential services will eliminate the majority of terrestrial native mammals from the sites affected, because they will be unable to tolerate the soil disturbance and alteration of ground vegetation involved. Few will actually be killed by construction operations, since construction will necessarily proceed slowly and sequentially, allowing most to escape. Some, however, may later succumb to territorial conflicts imposed during re-establishment. Aerial native mammals will be less dispossessed, because they are not so dependent on ground conditions and, although they may lose some potential roosts, will still be able to feed over the affected sites.

It is inevitable that, when the Project proceeds, some loss of native mammals and their habitats must be expected. However, because no rare or endangered mammals or regionally unique mammal habitats will suffer, these impacts are not considered to be significant. Any losses sustained will involve only widespread, common and secure species or their habitats, and will be of such minimal proportions that the overall viability of both will be unimpaired, not only in the context of their total Australian distributions but also in the Olympic Dam region.

For the larger more nomadic species, such as kangaroos, euros and dingoes, no major barriers which would impede their normal mobility will be erected other than the vermin-proof fence which will surround the Project Area. Pipelines will either be buried, or, if raised, crossings will be provided where appropriate.

Where practicable, rain collecting depressions will be kept away from roadsides. As kangaroos are attracted to these after rains and are often startled by passing traffic while drinking, vehicular accidents may result.

Unlike terrestrial species, bats (the aerial mammals of the region) will benefit from measures designed to conserve trees. All bats in the region need trees both as roosts and as reservoirs for their insect prey and, although trees of any type are important, their favourites are the hollow-spouted myalls which are most profuse in a belt traversing the northern sector of the town site. As many of these myalls as possible will be preserved in the town because of their amenity value.

3.5.2 Avifauna

Regional context

The Australian arid zone supports a distinctive 'Eyrean' avifauna (Spencer 1896; Keast 1981), albeit with some debate on its precise geographical and compositional definition. Schodde (1982) identifies ten water birds and seventy-eight land birds, the evolutionary origins of which probably lie in arid Australia. However, 220 species are currently distributed naturally and extensively in inland Australia, the majority having evolved in less arid parts of the continent or elsewhere. Fatchen and Reid (1980) identified 184 species considered to be potential inhabitants of the Olympic Dam region on the basis of vegetation, terrain and bird distributional data. Some 127 have currently been recorded.

An important characteristic of the Eyrean faunal subregion is its size: it encompasses the Australian arid zone (or 70% of the continent). Most of the birds of this zone have enormous geographical ranges, many almost spanning the continent, with only a few restricted to small areas.

Available habitats in the Olympic Dam area have affinities with the sand ridge deserts in the Lake Eyre basin, the western myall woodland of northern Eyre Peninsula, the mulga woodlands of the Great Victoria Desert and the more central arid areas, the chenopod steppes of the Nullarbor and, to a lesser extent, the native pine woodlands of the Flinders Ranges (Fatchen and Reid 1980). In consequence, the avifauna is moderately diverse. Two important arid habitats which are widespread in the southern arid zone but largely lacking in the Olympic Dam area are eucalypt-lined water courses and hills or ranges. Accordingly, there are avifaunal differences between the Study Area and adjacent regions in which these habitats are well represented (Badman 1979, 1981).

Incidence of species

Table 3.10 gives the results of seasonal surveys in 1981, which recorded 116 species, including two non-natives. Of the eleven additional species recorded prior to 1981 (but not during baseline surveys), about half were encountered by McGilp (1949) in the phenomenally good winter of 1947. Sixty-three per cent of the species recorded in 1981 are common in the State, 30% are moderately common and the remainder are uncommon. None is regarded as rare or vagrant in South Australia.

Table 3.10 also lists abundance data, by month, for the land birds recorded during four field trips in 1981. The largest number of species was recorded in September (seventy-four) with the least in March (fifty-nine). On average, 17.6 species were recorded in March traverses compared with twenty-seven species in September. Several factors are responsible for the seasonal variation evident in Table 3.10. Arid zone birds exhibit varying degrees of sedentariness. Some will be vagrants in the Study Area, occurring only occasionally and not breeding. The Peregrine Falcon, Australian Hobby and Black-shouldered Kite are best considered vagrants in the area at present. Other species will be frequent visitors either on a seasonal (migratory) or irregular (nomadic) basis. The Masked Wood-swallow, White-winged Triller, Red-backed Kingfisher, Crimson Chat and Rainbow Bee-eater are good examples. Some species maintain resident breeding populations which are augmented by influxes of nomadic conspecifics (members of the same species) when conditions are suitable, either on a seasonal or an irregular basis. The Australian Raven, Little Crow, Zebra Finch, Galah, Spiny-cheeked Honeyeater and Bourke's Parrot are probable examples in the Study Area. Finally, some sedentary species doubtless maintain a permanent breeding population which is subject to fluctuations in density, not through immigration and emigration, but through breeding in good seasons and decline in drought. These would include the Grey Butcherbird and Australian Magpie in the Study Area.

Table 3.10 Abundance of birds in the Olympic Dam region during baseline surveys, 1981

	SA Status	March	May	September	December
Emu Dromaius novaehollandiae	MC	0.07	0.22	0.12	0.10
W Hoary-headed Grebe Poliocephalus poliocephalus	MC	(1;3)	(4;5)	(3;28)	(2;4)
W Australasian Grebe Tachybaptus novaehollandiae	C		(1;1)	(1;4)	
W Great Cormorant Phalacrocorax carbo	C	(1;1)		(1;1)	
W Pied Cormorant Phalacrocorax varius	C				(1;1)
W Little Black Cormorant Phalacrocorax sulcirostris	C			(1;1)	
W Little Pied Cormorant Phalacrocorax melanoleucos	C		0.02		
W White-faced Heron Ardea novaehollandiae	C	(2;1)	0.15		(1;1)
W Straw-necked Ibis Threskiornis spinicollis	C			(1;1)	
W Black Swan Cygnus atratus	C			(1;138)	
W Freckled Duck Stictonetta naevosa	U			(1;4)	
W Australian Shelduck Tadorna tadornoides	C	(1;1)			
W Pacific Black Duck Anas superciliosa	C	0.02			
W Grey Teal Anas gibberifrons	C	0.05	0.10	(3;68)	(2;3)
W Chestnut Teal Anas castanea	MC			(1;1)	
W Australian Shoveler Anas rhynchotis	U		(1;2)		
W Pink-eared Duck Malacorhynchus membranaceus	MC			(3;3)	
W Hardhead Aythya australis	MC			(1;12)	
W Maned Duck Chenonetta jubata	C	0.05	(1;4)		
Black-shouldered Kite Elanus notatus	C	(1;1)			
Black Kite Milvus migrans	C	0.71	0.80	0.88	0.98
Whistling Kite Haliastur sphenurus	C	0.46	0.49	0.49	0.61
Brown Goshawk Accipiter fasciatus	MC	0.02			
Wedge-tailed Eagle Aquila audax	MC	0.49	0.44	0.49	0.46
Little Eagle Hieraaetus morphnoides	MC	0.05	0.05	0.20	0.22
Spotted Harrier Circus assimilis	MC				0.02
Black Falcon Falco subniger	MC	0.10	(4;1)	(1;1)	0.07
Peregrine Falcon Falco peregrinus	U				(1;1)
Australian Hobby Falco longipennis	MC	0.02			
Brown Falcon Falco berigora	C	0.22	0.12	0.41	0.49
Australian Kestrel Falco cenchroides	C	0.17	0.34	0.59	0.51
Little Button-quail Turnix velox	C			(2;1)	(1;1)
W Eurasian Coot Fulica atra	C		(1;1)	(1;300)	
W Masked Lapwing Vanellus miles	C	0.07	0.02	(3;6)	(1;4)
Banded Lapwing Vanellus tricolor	MC	(1;3)	(1;3)	0.02	(2;2)
W Red-capped Plover Charadrius ruficapillus	C	(1;170)	(1;10)	(1;32)	
W Black-fronted Plover Charadrius melanops	C	(3;4)	0.02	(2;2)	(3;1)
Inland Dotterel Peltohyas australis	MC		(1;12)	(1;1)	(1;14)
W Black-winged Stilt Himantopus himantopus	C			(1;2)	
W Banded Stilt Cladorhynchus leucocephalus	MC		0.05		
W Red-necked Avocet Recurvirostra novaehollandiae	MC	(1;12)	(1;1)	(1;1)	
W Greenshank Tringa nebularia	C	(1;18)			
W Sharp-tailed Sandpiper Calidris acuminata	C	(1;180)		(1;32)	
W Red-necked Stint Calidris ruficollis	C	(1;43)		(1;2)	
W Curlew Sandpiper Calidris ferruginea	C	(1;9)		(1;10)	
Australian Pratincole Stiltia isabella	MC			0.02	(1;1)
W Silver Gull Larus novaehollandiae	C	0.02	(1;1)	(1;60)	
W Whisked Tern Chlidonias hybrida	C			(1;10)	
W Gull-billed Tern Gelochelidon nilotica	U	(1;25)		(1;7)	
Common Bronzewing Phaps chalcoptera	C	0.07	0.07	0.22	0.20
Crested Pigeon Ocyphaps lophotes	C	0.88	0.88	0.95	0.88
Galah Cacatua roseicapilla	C	0.29	0.54	0.80	0.49
Little Corella Cacatua sanguinea	MC	(1;2)	(1;300)	0.02	
Pink Cockatoo Cacatua leadbeateri	U	(1;6)	0.02		
Cockatiel Nymphicus hollandicus	C		0.02	0.24	(1;2)
Budgerigar Melopsittacus undulatus	C	0.02	(1;1)	0.59	
Mulga Parrot Psephotus varius	C	0.41	0.54	0.51	0.59
Blue Bonnet Northiella haematogaster	MC	0.61	0.83	0.63	0.76
Bourke's Parrot Neophema bourkii	MC	0.20	0.10	0.12	0.12
Pallid Cuckoo Cuculus pallidus	C		0.07	0.24	
Black-eared Cuckoo Chrysococcyx osculans	U		0.02	0.05	
Horsfield's Bronze-Cuckoo Chrysococcyx basalis	C		0.07	0.49	0.02
Southern Boobook Ninox novaeseelandiae	C			(1;1)	
Tawny Frogmouth Podargus strigoides	C		0.05	0.02	
Australian Owlet-nightjar Aegotheles cristatus	MC		(1;1)		
Red-backed Kingfisher Halcyon pyrrhopygia	MC			0.27	0.15
Rainbow Bee-eater Merops ornatus	C	0.17			0.15
White-backed Swallow Cheramoeca leucosternum	C	0.15	0.51	0.22	0.27
Welcome Swallow Hirundo neoxena	C	0.15	0.39	0.37	0.15
Tree Martin Cecropis nigricans	C	0.07	0.07	0.05	0.05
Fairy Martin Cecropis ariel	C			(1;5)	
Richard's Pipit Anthus novaeseelandiae	C	0.34	0.73	0.76	0.59
Black-faced Cuckoo-shrike Coracina novaehollandiae	C	0.05	0.20	0.24	0.20

Table 3.10 (continued)

	SA Status	March	May	September	December
Ground Cuckoo-shrike Coracina maxima	U	0.10	0.07	0.10	0.10
White-winged Triller Lalage sueurii	MC			0.20	0.05
Red-capped Robin Petroica goodenovii	MC	0.22	0.54	0.34	0.15
Hooded Robin Melanodryas cucullata	MC	0.05	0.05	0.22	0.15
Rufous Whistler Pachycephala rufiventris	MC	0.05	0.37	0.24	0.22
Grey Shrike-thrush Colluricincla harmonica	C	0.12	0.29	0.51	0.27
Crested Bellbird Oreoica gutturalis	MC	0.29	0.54	0.83	0.66
Grey Fantail Rhipidura fuliginosa	C			0.05	
Willie Wagtail Rhipidura leucophrys	C	0.76	0.95	0.66	0.80
Cinnamon Quail-thrush Cinclosoma cinnamomeum	C	0.12	0.34	0.34	0.20
White-browed Babbler Pomatostomus superciliosus	C	0.68	0.80	0.80	0.83
Rufous Songlark Cinclorhamphus mathewsi	MC	0.02		0.02	
Brown Songlark Cinclorhamphus cruralis	C	(1;2)	0.05	0.02	
Splendid Fairy-wren Malurus splendens	MC				0.02
Variegated Fairy-wren Malurus lamberti	C	0.59	0.66	0.68	0.68
White-winged Fairy-wren Malurus leucopterus	C	0.49	0.46	0.56	0.56
Calamanthus Sericornis fuliginosus	MC	(1;2)	0.02	(3;6)	0.02
Inland Thornbill Acanthiza apicalis	C	0.32	0.46	0.44	0.41
Chestnut-rumped Thornbill Acanthiza uropygialis	C	0.61	0.90	0.83	0.83
Yellow-rumped Thornbill Acanthiza chrysorrhoa	C	0.17	0.34	0.54	0.29
Southern Whiteface Aphelocephala leucopsis	C	0,56	0.78	0.68	0.63
Varied Sittella Daphoenositta chrysoptera	U	0.02	0.07	0.12	0.02
Spiny-cheeked Honeyeater Acanthagenys rufogularis	C	0.37	0.85	0.93	0.78
Yellow-throated Miner Manorina flavigula	C	0.73	0.80	0.78	0.78
Singing Honeyeater Lichenostomus virescens	C	0.88	0.98	0.95	0.93
White-plumed Honeyeater Lichenostomus penicillatus	C			(1;1)	(1;2)
White-fronted Honeyeater Phylidonyris albifrons	MC	0.02		0.20	
Crimson Chat Ephthianura tricolor	MC			0.37	0.02
Orange Chat Ephthianura aurifrons	C	0.07	0.07	0.07	
Gibberbird Ashbyia lovensis	MC			(1;3)	0.05
Mistletoebird Dicaeum hirundinaceum	C		0.24	0.15	(1;2)
* House Sparrow Passer domesticus	C		0.15	0.22	0.05
Zebra Finch Poephila guttata	C	0.59	0.88	0.76	0.61
* Common Starling Sturnus vulgaris	C		(1;3)	(2;4)	
Australian Magpie-lark Grallina cyanoleuca	C	0.27	0.27	0.24	0.34
White-breasted Woodswallow Artamus leucorhynchus	MC	(1;5)			
Masked Woodswallow Artamus personatus	MC			0.22	
White-browed Woodswallow Artamus superciliosus	MC			(1;6)	
Black-faced Woodswallow Artamus cinereus	C	0.80	0.93	0.95	0.90
Grey Butcherbird Cracticus torquatus	C	0.71	0.90	0.76	0.80
Australian Magpie Gymnorhina tibicen	C	0.76	0.80	0.78	0.80
Australian Raven Corvus coronoides	C	0.80	0.71	0.63	0.76
Little Crow Corvus bennetti	C	0.56	0.78	0.78	0.93

(W) Water birds.

* Exotic species.

Note: Abundance data is expressed either as frequencies or bracketed integers. Frequencies are the proportion of traverses (n=41) in which species were recorded. The abundance of species not recorded during traverses is expressed as two bracketed integers, (x; y), where x is the number of localities separated by more than 1 km in which the species was recorded, and y, the mean number of individuals per locality.

The status of species in South Australia is recorded as follows:

C - common
MC - moderately common
U - uncommon
R - rare
V - vagrant.

Table 3.11 demonstrates that 95%, or all but two, of the thirty-eight species strongly suspected of being permanent residents in the Olympic Dam region were recorded. Of the eighty-one species thought to be frequent visitors to the region or having a moderate chance of being resident, 78% were recorded during 1981. Of the sixty-five species suspected of being infrequent visitors or having a slight possibility of being resident, 26% were recorded. Conditions in 1981 were reasonably good, at least between March and September, and several large water bodies in the region supported a fairly diverse assemblage of water birds. If the year had been dry, fewer species of water bird would have been encountered and the percentage of species in the 'moderate' and 'slight probability' categories would have been smaller. It is apparent, then, that the 1981 studies revealed little in the way of species' incidence which was not anticipated from the literature.

Table 3.11 **Comparison of the potential and recorded number of species in the Study Area**

	No. of species in the potential avifauna	No. of species recorded in 1980 (%)	No. of species recorded in 1981 (%)
Species suspected of being permanently resident:	38	31 (82%)	36 (95%)
Species suspected of being frequent visitors, or with a moderate chance of being resident:	81	14 (17%)	63 (78%)
Species suspected of being frequent visitors, or with a slight chance of being resident:	65	2 (3%)	17 (26%)
Species not listed in the potential avifauna:	-	0	0
Total	184	47	116

Seasonal variation can also be caused by changes in detectability associated with behavioural changes during breeding and non-breeding periods, population movement of nomadic and migratory species, sampling error and variation, and population increase from local breeding.

Habitat preference

Of the three principal vegetation types mapped (dune field, stony tableland, and local drainage), dune field, which supports the greatest diversity of plant species and formations, also supports the largest number of birds. Thirty-two species of water birds were recorded at station dams, natural lakes and swamps.

Rare and threatened species

Seven rare or threatened species listed under the National Parks and Wildlife Act have been described as possible inhabitants of the Olympic Dam region: the Freckled Duck, Pink Cockatoo, Australian Bustard, Bush Thick-knee, Plains-wanderer, Scarlet-chested Parrot, and the Chestnut-breasted Whiteface. As part of the environmental monitoring programme, these species will be observed and measures established (such as habitat protection) to reduce adverse impacts of the development on these species.

Impacts and mitigation

It is likely that densities of many native birds will be reduced in the immediate vicinity of the Project Area as a result of habitat clearance, as well as human activity and disturbance. Minor impact is also expected from destruction of birds by pet dogs and cats in the town area, feral animals outside the town, bird strikes at the airport, and transmission line strike or electrocution. Because of the extensive replication of such habitat in the region, this impact is considered minor. However, further study is required to determine whether the Project will interfere with local populations of Hooded Robin and Splendid Fairy-wren, as these populations may have regional significance.

Beyond the Project Area, at Coorlay Lagoon and other major natural lakes and swamps, human intrusion (depending on its frequency and timing) has the potential to affect the regional breeding success and status of several species of water birds. Permanent water bodies developed as part of the Project may lessen the importance of natural water bodies as refuges for water birds, and may increase the region's potential as a refuge during drought. However, many water birds require an undisturbed site for breeding, and the Joint Venturers will examine the factors involved in creating 'breeding islands' in water storages to provide such areas.

Several aspects of the Project are expected to lead to the colonization of new habitat by some birds or to increases in present populations. Table 3.12 lists these species and the factors facilitating colonization or increase. These factors include vegetation clearance (which will favour ground-feeding birds), increased water supply (which will favour introduced species), increased nesting sites in buildings and other facilities (favouring species which tolerate human presence) and rubbish disposal areas (favouring scavenging birds). Large increases are expected in some species, but in each case populations will be more or less restricted to the Project Area. Regional effects on avifauna due to these local increases are not anticipated. A few species not included in Table 3.12 will consume insects attracted to lights in the town, around the plant, and at the airstrip. This is a local effect and is not expected to lead to significant population increases of any species.

Table 3.12 Birds which will benefit from Project development

Bird species	Vegetation clearance	Increased water supply	Increased nesting sites	Rubbish	Other
Emu	+				
Black Kite				+	
Brown Falcon	+				+
Australian Kestrel	+				
Little Button-quail	+				
Masked Lapwing					+
Feral Pigeon		+			
Crested Pigeon		+			
Budgerigar		+			
Red-backed Kingfisher			+		
White-backed Swallow			+		
Welcome Swallow			+		
Fairy Martin			+		
Richard's Pipit	+				
Willie Wagtail					+
Rufous Songlark	+				
Brown Songlark	+				
House Sparrow		+	+		
Zebra Finch		+	+		
Common Starling		+	+		
Australian Magpie-lark					+
Australian Magpie	+				
Australian Raven			+	+	
Little Crow			+		

\+ Indicates the aspect of Project development which benefits that species.

The provision of large and permanent water bodies by the Project may attract species of water bird otherwise rare or vagrant in the region on a more frequent basis. Existing populations will also benefit to some degree. However, these changes are unlikely to have a significant impact on the existing avifauna.

The acid liquor evaporation pond in the tailings retention area has the potential for major local impact on avifauna, and possibly for major regional impact in the case of water birds, because of the high acidity of the liquid. It is probable that water birds will land on the pond, particularly at night when visibility is reduced, and that land birds will attempt to drink there. The problem will be exacerbated in drought when there are few other water sources, and perhaps during the annual autumn and spring migration of holarctic shore birds. Fatalities and injuries are likely for birds which drink from the acid liquor evaporation pond, and the Joint Venturers will therefore consider various techniques to distract birds from the pond.

3.5.3 Reptiles

Incidence of species

Sixty-three species of reptile could be expected in the region immediately to the west of Lake Torrens (which includes the Olympic Dam area). Several of these species would be on the borders of their range however, and may not be present. Forty-five species were trapped during four field expeditions in 1981 covering all potential habitat types. A clear division was found between swale and dune species. Table 3.13 lists those reptiles known or likely to occur in the area. None of the species found or expected are classified as rare, threatened, or endangered.

The physiology of reptiles allows them to utilize arid habitats successfully, and in consequence they are the most populous and diverse terrestrial vertebrate group in arid Australian environments such as Olympic Dam. Stomach content analyses of specimens caught during surveys at Olympic Dam indicated that termites and ants were the most numerous prey items of reptiles in the area.

Modification of the habitat from pastoral use and the introduction of feral mammals (particularly cats and foxes) has reduced populations of some reptiles. The Thorny Devil has been affected by reduction in ground cover and may now be extinct in the Olympic Dam region. However, some large reptiles, such as Gould's goanna, the Mulga Snake, and Western Brown Snake, have benefitted from the introduction of the common house mouse which serves as abundant prey for these reptiles, and their numbers have probably increased in areas of human activity where house mouse concentrations occur.

Impact and mitigation measures

There are no reptiles exclusive to the Olympic Dam region, and therefore the Project will not have any major impact on the State's reptile fauna.

Vegetation clearance in certain development areas will preclude the return of reptiles to those sites, but some areas (such as untouched dunes within the town site and operations area) will retain some of their reptile fauna. The viability of such populations will depend on their size and predator control. Certain developed areas, such as solid waste disposal sites and outdoor equipment storage areas, may favour a few species. They are unlikely to be more than a minor problem, however, which will be further minimized by populace education.

High road verges will discourage off-road vehicle activity and also inhibit small reptiles from advancing onto the road, but will not limit movements of large reptiles. Domestic fences may interfere with movement of larger reptiles, particularly goannas, large skinks and snakes in the town, but this will be beneficial where venomous snakes are concerned. In areas where vermin-proof fences are constructed to exclude rabbits from an area to be rehabilitated, interference with reptile movement must be accepted.

Table 3.13 Reptiles of the Olympic Dam area

Species	Common name	Found in Project Area	Found in Olympic Dam region	Not found but may be present
Gekkonidae				
Rhynchoedura ornata	Beaked Gecko	+	+	
Lucasium damaeum	Beaded Gecko	+	+	
Gehyra variegata	Dtella	+	+	
Diplodactylus stenodactylus		+	-	
Diplodactylus conspicillatus	Fat-tailed Gecko	+	+	
Diplodactylus ciliaris	Spiny-tailed Gecko	+	+	
Diplodactylus tessellatus	Tessellated Gecko	+	+	
Diplodactylus vittatus	Stone Gecko	-	-	+
Diplodactylus byrnei		-	-	+
Nephrurus levis	Knob-tailed Gecko	+	+	
Heteronotia binoei	Binoe's Gecko	+	+	
Phyllurus milii	Thick-tailed Gecko	-	+	
Pygopodidae				
Pygopus nigriceps	Black-headed Scalyfoot	+	+	
Pygopus lepidopodus	Common Scalyfoot	-	-	+
Lialis burtonis	Burtons Legless Lizard	-	+	
Delma australis		-	-	+
Varanidae				
Varanus gouldii	Gould's Goanna	+	+	
Varanus gilleni	Gillen's Goanna	-	+	
Agamidae				
Tympanocryptis lineata	Earless Dragon	+	+	
Tympanocryptis tetraporophora	Earless Dragon	-	+	+
Tympanocryptis intima	Earless Dragon	+	+	
Amphibolurus vitticeps	Bearded Dragon	+	+	
Amphibolurus inermis	Netted Dragon	+	+	
Amphibolurus pictus	Painted Dragon	+	+	
Amphibolurus fordi	Military Dragon	+	+	
Moloch horridus	Thorny Devil	-	-	+
Diporiphora winneckei	Two-lined Dragon	-	-	+
Scincidae				
Tiliqua rugosa	Sleepy Lizard	+	+	
Tiliqua occipitalis	Western Bluetongue	+	+	
Lerista labialis		+	+	
Lerista xanthura		-	+	
Lerista frosti		-	+	
Lerista desertorum		-	+	
Lerista muelleri		-	-	+
Lerista bougainvillii	Bougainvilles Skink	-	-	+
Lerista bipes		-	-	+
Ctenotus regius	Striped Skink	+	+	
Ctenotus schomburgkii	Striped Skink	+	+	
Ctenotus atlas	Striped Skink	+	+	
Ctenotus strauchii	Striped Skink	+	+	
Ctenotus brooksi	Striped Skink	+	+	
Ctenotus uber	Striped Skink	-	+	
Ctenotus leonhardii	Striped Skink	+	-	
Ctenotus sp.	Striped Skink	-	+	
Ctenotus leae	Striped Skink	-	-	+
Menetia greyii	Greys Skink	+	+	
Morethia adelaidensis	Snake-eyed Skink	+	+	
Morethia boulengeri	Snake-eyed Skink	-	-	+
Erimiascincus richardsoni	Desert Banded Skink	+	+	
Cryptoblepharus boutonii		-	-	+
Typhlopidae				
Typhlina endotera	Blind Snake	+	+	
Typhlina australis	Blind Snake	-	-	+
Typhlina bituberculata	Blind Snake	-	-	+
Elapidae				
Pseudonaja nuchalis	Western Brown Snake	+	+	
Pseudonaja modesta	Collared Brown Snake	+	+	
Pseudechis australis	Mulga Snake	+	+	
Simoselaps bertholdi	Desert Banded Snake	+	+	
Simoselaps fasciolatus	Narrow-banded Snake	+	+	
Suta suta	Curl Snake	-	+	
Demansia psammophis	Yellow-faced Whip Snake	-	-	+
Unechis gouldi	Black-headed Snake	-	-	+
Unechis monachus	Hooded Snake	-	-	+
Vermicella annulata	Bandy-Bandy	-	-	+

Cats are particularly destructive to small animal populations, including reptiles, and efforts will be made to control the feral cat population in the area. Significant numbers of mice around buildings and waste disposal sites will attract adult venomous snakes, and solid waste disposal sites and outdoor stores of equipment providing habitat for mice and lizards will therefore be sited away from residential areas.

3.5.4 Amphibians

Rainfall during the study period was inadequate to permit field collection of frogs. Tadpoles of the trilling frog, Neobatrachus centralis, were collected from Olympic Dam. The only other species likely to be found in the area during wetter periods is the spotted grass frog, Limnodynastes tasmaniensis. These species breed in claypans in the Olympic Dam region and they will not be displaced by mining and associated activities. The acidity of the evaporation pond will be too high to allow frogs to colonize the pond.

CHAPTER FOUR

Land Use

SUMMARY

Pastoralism, the principal land use in the area, commenced during the 1860s and 1870s, and its viability has always been dependent on the region's erratic rainfall. Other land uses include weapons testing at Woomera; mining at Andamooka and at Stuart Creek for opal, and at Mount Gunson for copper; and limited tourist activity, mostly near Lake Eyre and the mound springs areas. Pastoral settlement is dispersed, while other settlement is related to weapons testing, mining activity, and transportation service centres associated with the Stuart Highway, Trans Australia Railway and Port Augusta to Marree railway.

Pastoral activity will be the land use most directly affected by Project development. There will be beneficial consequences, with better access to town services, stock water supply and transportation facilities, while the adverse impacts will comprise a small loss of land and some land severance, minor stock losses from vehicle/stock accidents, and some danger to stock and property from the increased population in the area. Where necessary and appropriate, compensation will be made for loss of land or loss of production. As the 200 square kilometres of the Project Area represents only 10% of Roxby Downs Station (which totals 2,000 square kilometres), this effect is relatively minor. The Project will also have indirect effects on land use, through the recreational activities of the town population and through improvements in regional access. This chapter discusses the effects of the Project Area development upon land use, while Chapter 10 discusses the effects on land use of the infrastructure corridors.

4.1 EXISTING AND HISTORICAL LAND USE

The current land use pattern and its historical evolution are examined in this section. Figure 4.1 indicates the location of the various geographical features relevant to the historical development of the current land use in the area of interest (defined in Section 4.1.3).

It should be noted that, while the most extensive land use in the area is pastoralism, the main influences upon the pattern of settlement (both currently and in the future) are the status of the transport network and the fortunes of the mining, tourist, and weapons research industries.

The development of pastoralism in the area is tied very closely to the historical development of pastoralism in northern South Australia. Bowes (1968) is of the opinion that the early pattern of land settlement in South Australia was 'often determined by economic and political factors as much as the natural potentiality of the land'. Within South Australia during the years 1856 to 1890, lands with a wide range of soils, vegetation, and climate were occupied. Since that time, the pattern of land use within the State has varied as a result of changing economic, political, social and environmental factors. In the northern parts of South Australia, one of the most significant influences upon the pattern of land settlement has been the erratic rainfall. The assessment of the capability of these lands has been based upon trial and error, and the history of settlement in these northern areas is one of periods of misjudgement and retreat, followed by periods of correct assessment and advance (Bowes 1968).

4.1.1 Early exploration

In 1839, Edward John Eyre sighted and named Lake Torrens from Mount Eyre, and followed 90 km of its eastern shore (South Australian Department for the Environment 1980). Eyre described the northern parts of the State which he traversed as a region of brine and desolation (Bowes 1968), and this report was to deter development of this region for nearly twenty years. In 1840, J.F. Horrocks undertook an expedition, the first in Australia to use camels, with the objective of reaching the interior by a route to the west of Lake Torrens. Horrocks reached Lake Dutton, where he was accidently killed (SADE 1980). Two years later, in 1842, C. Dutton followed Eyre's tracks around the head of Spencer Gulf. While on this expedition Dutton disappeared, and later evidence indicated that he had penetrated as far as the landform now known as Dutton Bluff (SADE 1980). A government sponsored party led by Babbage explored the country at the head of Spencer Gulf and to the north-west between Lake Gairdner and Lake Torrens in 1853 (SADE 1980).

John McDouall Stuart undertook three expeditions (in 1853, 1858, and 1862) which traversed the area to the north of Port Augusta. On the first expedition, Stuart explored the country at the head of Spencer Gulf and between Lake Gairdner and Lake Torrens. Following this, he led an expedition financed by William Finke to Andamooka, Yarra Wurta Cliff, and Stuart Range, and from there south to Denial Bay (where Ceduna is now located) via Mount Eba, Lake Younghusband and the Gawler Ranges, encircling the area traversed by Babbage. As part of his third expedition, Stuart crossed the continent to the Gulf of Carpentaria, again traversing the country to the west of Lake Torrens (SADE 1980).

4.1.2 Pastoral expansion

Pastoral activities began in South Australia in the late 1830s with the issuing of grazing licences to those wishing to use lands outside the surveyed 'hundreds' for grazing. The licences were replaced shortly afterwards by fourteen-year pastoral leases. These were issued as an interim measure, as the expectation at that time was that pastoral lands would eventually be used for other purposes (Vickery et al. 1981).

As a consequence of Eyre's reports, it was popularly believed that a great horseshoe of salt water barred the way to an expansion of the pastoral areas into the north of the State. However, in mid-1857, while surveying and exploring these areas under instruction from the South Australian Government, Goyder reported (Bowes 1968):

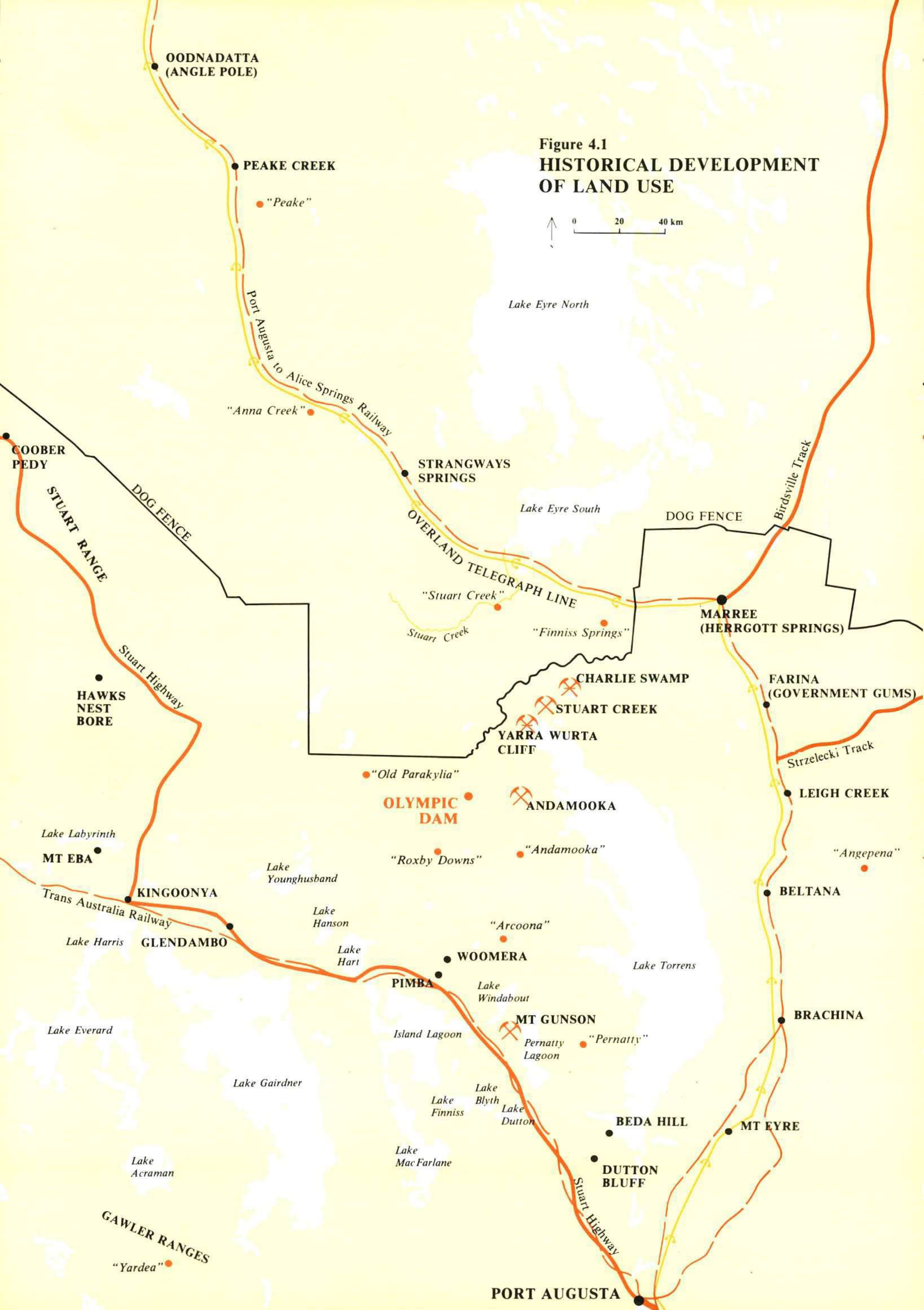


Figure 4.1
HISTORICAL DEVELOPMENT OF LAND USE

> vegetation of the most luxuriant kind, ... placid waters, disturbed only by the enjoyment of the waterfowl, ... and a sheet of fresh water ... emanating from a number of delicious springs.

Within months of Goyder's reports, pastoralists began driving sheep and cattle beyond the area which had been believed to be impenetrable and inhospitable. This expansion occurred despite subsequent reports by the Surveyor-General, Colonel Freeling, which were less favourable than Goyder's (Bowes 1968).

By 1860, the country on the eastern side of Lake Torrens had been occupied by pastoralists. At this time, the only knowledge of the area to the north-west of Port Augusta and to the west of Lake Torrens was that provided by Goyder, Swindon, Babbage, Oakden and Hulkes, Warburton, Gregory, Stuart, and others who had left no written record (Bowes 1968; SADE 1980). In 1859, J.F. Haywood, William Brown, and William Marchant explored the country within a short distance of the western side of Lake Torrens, while Oakden and Hulkes explored the country further westward. Oakden and Hulkes reported good pastoral country and took pastoral leases (including Oakden Hills) as confirmation of their optimism. However, drought forced them to abandon the leases, and the country was not leased again until the late 1860s (Cockburn 1925; Richardson 1925; SADE 1980).

The discovery of the mound springs along the southern edge of Lake Eyre and the definition of their distribution by explorers such as Warburton, Babbage, Stuart and Goyder resulted in the rapid development of pastoralism in those areas which could be serviced by this source of water. Between 1859 and 1862, pastoral leases were taken up in the area bordering the south-western corner of Lake Eyre from Finniss Springs Station to the current Anna Creek Station (SADE 1979).

By 1864, the pastoral expansion in the north-east had advanced through Angepena, and on to Lake Hope at the northern tip of the Flinders Ranges. The northern edge of the pastoral expansion was represented by Mount Margaret Station (now known as Peake) on the shores of Lake Eyre. Isolated stations were located on the western side of Lake Torrens at Pernatty and Arcoona, and further to the west there was a group of stations on the southern shore of Lake Gairdner, the principal one being Yardea.

The rate of pastoral expansion was even more rapid after a new system of leasing pastoral land was introduced in 1863. The expansion of pastoralism into the north-west of South Australia was, in the opinion of Bowes (1968), largely brought about by people who saw the pastoral industry as an area of investment or speculation. While a number of the leaseholders sought to gain their profits through the long-term development of leases, others were more interested in short-term gains, taking up new leases or preferential rights in favourable positions and then reselling them when values had risen as a result of the expansion of the pastoral industry or of the provision of transport facilities.

The majority of the pastoral leases in the area to the north-west of Port Augusta were taken up during the 1860s and 1870s. Pastoral activity reached its peak in the late 1880s, and by the 1890s all the original north-west leases had expired. Since that time there have been many changes in the ownership and boundaries of the pastoral leases in the area. These changes have generally reflected modifications in the economic viability of the various leases caused by perturbations in the regional environment such as drought or the relocation of transportation facilities (Cockburn 1925; Richardson 1925; Bowes 1968; SADE 1980).

The history of Roxby Downs Station, where the Olympic Dam deposit is located, is one example of this pattern of changing lease ownership and lease boundaries. The evidence available to the Pastoral Board indicates that the original Roxby Downs Station (which forms part of the current station) was part of Parakylia Station (Pastoral Board, pers. comm.). In 1875-76, A.M. Wooldridge took up a pastoral lease over approximately 5,100 km^2 of land to the west of Lake Torrens. The lease was then subdivided, with one portion becoming part of Andamooka Station, the north-western portion being transferred to the Chewings brothers to form Parakylia Station, and the balance forming Arcoona Station (Cockburn 1925; Richardson 1925). In July 1912, the Collins brothers of Collinsville Station, Burra, took up a pastoral lease of 3,628 km^2 described as Blocks 273 and 273a of Parakylia. The lease was cancelled in February 1914 for non-payment of rent.

In December 1918, another pastoral lease was issued to William Henry Greenfield over Block 273d of Parakylia, an area of 264 km^2. This lease was transferred to David John Greenfield and Walter John Greenfield in June 1928. Another block of Parakylia (Block 273c of 159 km^2) was leased to Norman Alexander Richardson in September 1910. This lease was transferred in September 1920 to David Greenfield, who also acquired the pastoral lease to Block 270c of Andamooka Station which had an area of 855 km^2.

The formation of the current Roxby Downs Station took place on 1 January 1932. The original Richardson lease and the original Andamooka lease were consolidated to form one lease, called Roxby Downs, in the name of David Greenfield, over an area of 1,010 km^2. A second pastoral lease was also issued to David and Walter Greenfield on this date. This lease, which covered an area of 990 km^2, incorporated the original lease held by William Greenfield together with an area of the old Collins brothers' lease. In March 1949, this second lease held in joint names was transferred to David Greenfield, who then became the sole lessee of both portions of Roxby Downs Station. In 1963, the two leases were consolidated into a new pastoral lease which covered an area of 2,000 km^2, the present title to Roxby Downs. The present Roxby Downs homestead stands on an original portion of the Andamooka Station known as Chances Swamp (Richardson 1925). The lease issued in 1963, taken out in the name of Roxby Downs Limited, is due to expire in 2005, and was purchased in February 1964 by Sandstone Pastoral Pty Ltd, the current lessees (Pastoral Board, pers. comm.).

The first Pastoral Act, introduced in 1893, established the Pastoral Board and the system of forty-two-year pastoral leases. This original legislation was amended significantly in 1927 following a Royal Commission into the pastoral industry. Further significant amendments were made in 1939, when the Pastoral Board was authorized to prevent degradation of the soil and vegetation by controlling livestock numbers on pastoral leases (Vickery et al. 1981).

4.1.3 Current pastoral use

In the area of interest (the area covered by Figure 4.2), the pastoral industry has evolved from its tentative beginnings during the 1860s and 1870s to give the land use and land tenure pattern shown. The current land use is based on cattle grazing to the north of the Dog Fence, with sheep grazing to the south. Stocking rates in the area are of the order of 5 sheep/km^2 and 0.5 cattle/km^2 (SADE 1980). The tenure of the various stations is held under expiring pastoral leases issued under the provisions of the Pastoral Act, 1936-1976. Most of the current leases were renewed in 1960, following an amendment to the Act which enabled the lessees to apply for new forty-two-year leases, and the majority of leases will now expire between 2005 and 2010. A pastoral lease grants a lessee the right to occupy the area of land specified and to use it for grazing livestock. These grazing rights are issued subject to certain conditions contained on the lease and in the Act relating to renewal rights, rights of access, non-payment of rent, vermin control, timber clearing, and allowable stocking rates. The rights of the mining industry to use lands held under pastoral lease are specified in the Mining Act, 1971-1981. There is a lack of clarity regarding the access rights of both the general public and the pastoralists to lands held under pastoral lease. On several occasions recommendations have been made to the South Australian Government that the legislation regarding public access be clarified (Vickery et al. 1981).

A recent inquiry into the administration, management and tenure of South Australia's pastoral lands framed a series of recommendations regarding the future control of the pastoral industry in South Australia's arid lands. These recommendations included the retention of the present tenure system of forty-two-year pastoral leases, and the establishment of an Arid Lands Authority to administer land use in the arid lands (Vickery et al. 1981). A Bill placed before the Parliament to amend the Pastoral Act (to provide for perpetual pastoral leases and to restrict vehicular access to designated roads) was defeated in the Legislative Council in June 1982, and has not been returned for further consideration.

The six stations within the immediate vicinity of the Project Area are:

- Roxby Downs
- Purple Downs
- Andamooka
- Arcoona
- Parakylia
- Billa Kalina.

The total area of these six stations is approximately 23,000 km^2 . Three of the stations have owner-managers, while the remainder are owned by Adelaide-based companies and operated by resident managers.

Arcoona runs sheep only, while Roxby Downs, Purple Downs, Andamooka and Parakylia run both sheep and cattle. Billa Kalina, which is situated to the north of the Dog Fence, runs cattle only. The leases for the six stations stipulate a maximum total stocking rate of 140,000 sheep equivalents (one head of cattle being equivalent to six sheep). In the period 1976 to 1981 the total six-year average sheep equivalents for the stations were of the order of 100,000.

The average number of animals which can be carried on a pastoral property is almost directly proportional to the availability, quality, and location of watering points. In the Olympic Dam area, stock rely on dams which harvest the surface run-off resulting from the region's erratic rainfall. These small dams, up to 10 m in depth, are sunk at the lowest points of some of the larger closed catchments. Local clay is used to seal the base of these dams to reduce infiltration, and drainage channels leading to the dams are often cut to increase run-off. Although during heavy rain these dams will accumulate water and may even fill, the region's high evaporation and low variable rainfall make these an unreliable water supply. In the vicinity of the Project Area dams occur about 12 km apart. They include Olympic Dam, Axehead Dam, Myall Dam, Mohammed Dam, and Lake Blanche on Roxby Downs Station, and 12 Mile Dam, Bulls Head Dam and Phillips Ridge Dam on Andamooka Station.

The South Australian Department of Agriculture is currently conducting a programme to eradicate two extremely serious diseases which affect cattle: brucellosis and tuberculosis. In the pastoral and settled areas, properties carrying affected stock are quarantined until all stock are free of the diseases. This poses a considerable problem in northern areas, as all fences, gates, and ramps must be maintained in stock-proof condition. Fortunately, the incidence of both diseases is low in the area of interest.

4.1.4 The Dog Fence

The development of the Dog Fence closely parallels the history of pastoral expansion. The erection of fences to exclude dingoes from sheep lands began shortly after

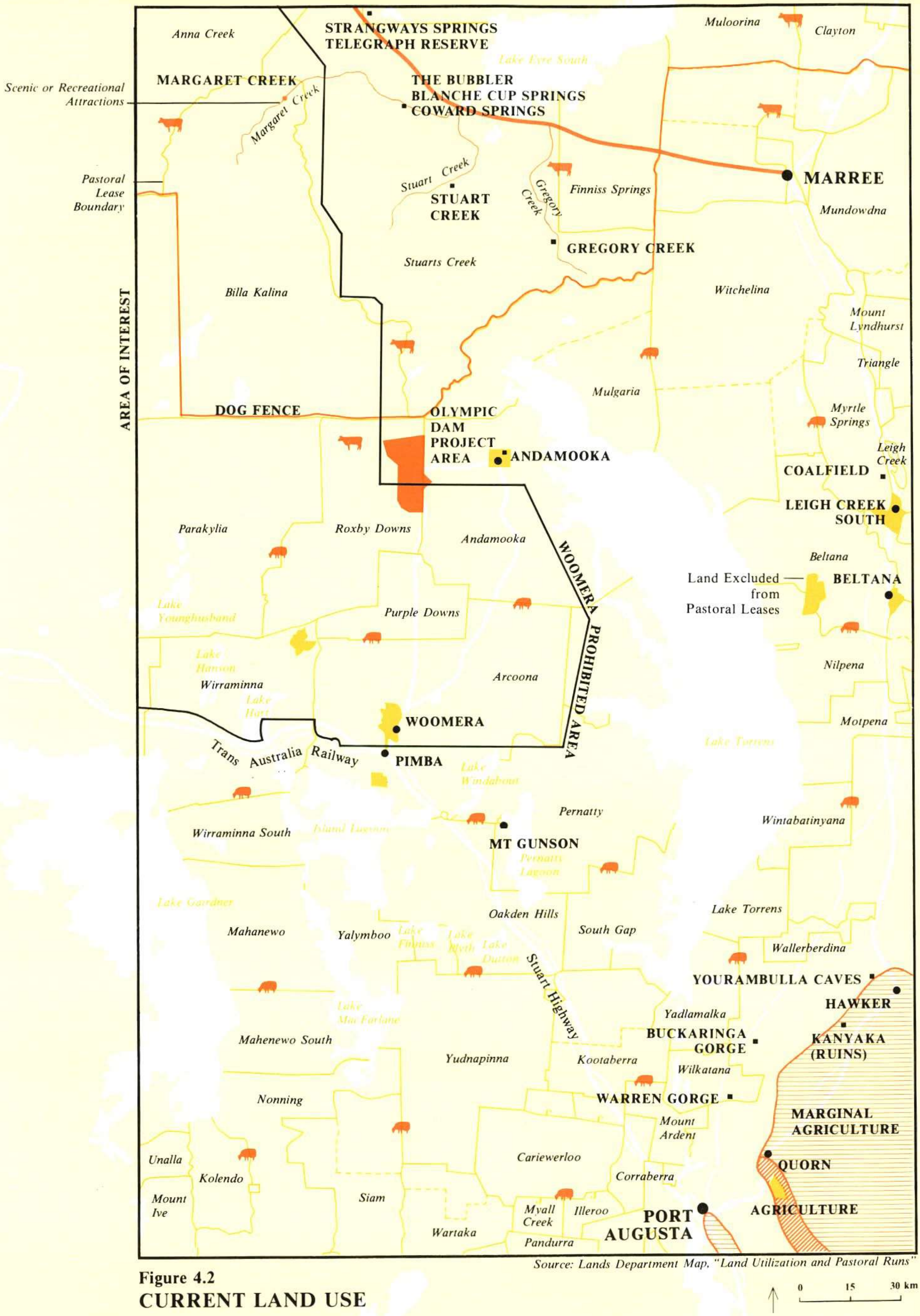


Figure 4.2
CURRENT LAND USE

pastoralists started to control livestock by means of fences instead of using shepherds. In 1896, an Act was passed which enabled 'Vermin Fenced Districts' to be formed. Each district was managed by a board which arranged the financing, building and maintenance of dog-proof fences. With the progressive formation of vermin districts, the area enclosed by dog-proof fences expanded to the west, north-west, and north. At the same time, a large number of private landholders in the north-east were also constructing dog-proof fences. The eventual result was an almost continuous outer fence in an arc from the New South Wales border to a point on the Great Australian Bight, 140 km from the Western Australian border. When it became apparent that this outer fence, with minor additions, would form a continuous and effective barrier, many of the inside fences were allowed to fall into disrepair and a number of Vermin Fenced Districts were abolished. This meant that pastoralists and Vermin Fenced Districts adjoining the outer fence were paying for the total cost of maintaining that fence, while many of the pastoralists in inner areas obtained the benefits. Representations from the pastoralists resulted in the passing of the Dog Fence Act in 1936. This Act provided for the establishment and maintenance of a continuous dog-proof fence across the northern part of the State to prevent the entry of wild dogs into sheep grazing areas.

Currently, most of the Dog Fence is privately owned and maintained, extending for 2,208 km from the Great Australian Bight to the New South Wales border. Of the total length, only 100 km are owned by the Crown. The current location of the Dog Fence in relation to the Olympic Dam Project is shown on Figure 4.2. Fence owners receive an annual subsidy towards the cost of maintenance from the Dog Fence Fund, which is financed by the rating of pastoralists together with a government subsidy (Vickery et al. 1981). Sections of the fence range in age from two to eighty years, and its structure and condition vary considerably. The opinion has been expressed that the present funding mechanism would place an impossible burden on any lessee ordered by the Board to replace a section of the fence (Vickery et al. 1981). The approval of the Dog Fence Board must be obtained prior to the opening of the fence or the installation of any new gates (Pastoral Board, pers. comm.).

4.1.5 Mining

The history of mining development in the area is fragmented and ill-defined. In 1862, Charles Swindon is reported to have brought back to Adelaide gold specimens allegedly discovered near Andamooka (SADE 1980). Shortly after his return, Swindon became ill and died before being able to pass on information about the location of his discovery (Richardson 1925).

Copper was discovered at Mount Gunson in 1875. In 1898 copper mining operations commenced near Pernatty Lagoon, and by 1912 the Bottrill motor tractor was being used to haul copper ore to Port Augusta. Small tonnages of ore were mined and treated by various operating companies over a fifty-year period. Manganese deposits located in the same district were brought into production in 1915 (SADE 1980). Extensive exploration by CSR Limited in the Mount Gunson area resulted in the discovery of the Cattle Grid deposit in 1973. The following year an open cut copper mine and a processing plant with a capacity of 9,000 t/a of contained copper in concentrates were established by CSR. The copper concentrates from Mount Gunson are transported to Whyalla for shipment to overseas smelters. CSR has for several years been undertaking an exploration programme in areas adjacent to the present mine. If additional reserves are not proven, and if mining continues at the current rate, the estimated life of the mine is another four years (Iron Triangle Study Group 1982). All employees at Mount Gunson are housed on site, the population of the township totalling about 250 people. Recreational and commercial facilities provided include a bar, small shop, swimming pool, tennis courts and cinema. There is a primary school at Mount Gunson, but high school students travel by bus to Woomera each day (SADE 1980).

Opal was first discovered in the area at Charlie Swamp in 1904. The Andamooka opal field was discovered in 1930 by Sam Brooks and R. Shepherd. The first miners were Treloar and Evans, and the first recorded production in 1933 was valued at £A962 (Carr et al. 1979). In the period 1933 to 1972 the workings expanded to occupy an area approximately 13 by 5 km. However, the failure to discover a major new field since 1971 (despite a subsidized mining programme) has resulted in a steady decline in Andamooka's population (Carr et al. 1979). Opal mining has also been undertaken at Stuart Creek and Yarra Wurta Cliff (Figure 4.1).

The town of Andamooka has evolved in a haphazard manner along the bed of a small creek and adjoining ridges, and has been characterized by a fluctuating population with a large proportion of itinerant and short-term workers (SADE 1980). Its current population is about 400. There is no local government authority, and the general administration of the town is the responsibility of the Andamooka Progress Association in conjuction with the Outback Areas Trust. The South Australian Lands Department issues annual licences for residential, commercial and industrial purposes in the town. A town boundary has been surveyed, with the intention of controlling expansion, and consideration has been given to the introduction of more permanent tenure. It has been reported that, as a consequence of poor siting, the town centre is experiencing major planning problems, with inadequately defined roads, uncontrolled parking, and cramped block arrangements in the town centre (SADE 1980). The town has a limited range of commercial, social and recreational facilities, and plays only a minor service role for surrounding areas. The facilities available include two general stores, a six-bed hospital, a police station, and an area school.

Opal prospecting and mining are largely confined to a relatively compact area around the Andamooka township, with smaller fields located at Stuart Creek and Charlie Swamp near the northern tip of Lake Torrens (Figure 4.3). Mining is either by various forms of shaft and stope, or by open cut methods using bulldozers.

A deposit of high-grade barite outcrops on the floor of Pernatty Lagoon, adjacent to the manganese deposits near the western shore. The deposit forms a rise above the general lake level, and is traceable as a succession of patches forming a narrow lode of 500 m in length (SADE 1980). White and grey laminated clays are also mined for ceramic purposes at Wooculla, near Pernatty Lagoon.

Mineral exploration and production is controlled by the Mining Act, 1971-1981. Under the terms of the Act, the Director of Mines can issue an exploration licence to any person satisfying certain criteria. The licence authorizes that person to prospect for minerals within the area specified on the lease, subject to certain conditions, for a period of up to two years. The conditions imposed on the licence may relate to issues such as environmental protection, the protection of heritage items, and compensation. The licence does not provide the right to produce minerals from the lease. Figure 4.3 details the extent and ownership of exploration licences in the area studied.

A mineral claim confers upon the owner an exclusive right to conduct mining operations in the area delineated on the claim, and to apply for a mineral lease in respect of that area. The owner of a claim is not authorized to remove more than 1 t of material from the claim, and if the claim is not converted to a mining lease within one year the claim lapses. A mining lease is a renewable lease for up to twenty-one years, which authorizes the holder to conduct mining operations and to sell or dispose of minerals recovered in the area delineated on the lease. Figure 4.3 details the principal known mineral deposits in the area of interest.

4.1.6 Woomera

Following the end of the war in 1945, the United Kingdom initiated a long range missile development project. After considering a number of options, the UK Government approached the Australian Government with a view to establishing a weapons research and testing facility in Australia to service the project. The then Australian Prime Minister, Mr Ben Chifley, assented to the proposal on the condition that Australia be allowed to enter into the project on an equal basis.

The requirements were for an industrial facility for the research and development activities and at least one thousand miles of open country for the firing, observation and recovery of rockets. The first requirement was satisfied by the use of a disused munitions factory near Salisbury. The second requirement was met by the declaration in 1946 of two immense areas of Australia as 'Prohibited Areas'. The first area, which was for the impact of long range weapons, was located in the north-west of Western Australia. The second area, in South Australia, which contained the actual rocket range, extended from Lake Torrens and Lake Eyre in the east to the Western Australian border, and from the Trans Australia Railway line in the south to 110 km short of the Northern Territory border. The extent of the Woomera Prohibited Area has altered with time, and the current boundary in the Olympic Dam region is shown in Figure 4.2.

The establishment of the rocket range had little effect on the pastoral industry. No pastoral leases were cancelled to accommodate the range, although small areas of some leases were annexed for particular facilities (for example, parts of the Arcoona lease, Figure 4.2). No homesteads were moved. However, the operation of the range did create some early problems for the pastoralists, with gates being left open and fences and tracks being damaged. This situation was alleviated in 1949, with the appointment of a Range Overseer, whose primary functions were to maintain constant and direct contact with the pastoralists and to acquaint the men at the range with the pastoralists' problems (Southall 1962).

Work started on the construction of the rocket range in 1947. The facilities provided included airfields, roads, pipelines, telephone lines, launching facilities, and a town to accommodate the range personnel. The town, named Woomera, was located about 8 km north of Pimba, a settlement on the Trans Australia Railway. The town and other range facilities were serviced by the construction of a 132 kV transmission line and a 250 mm water supply pipeline from Port Augusta, roads from the Stuart Highway, and a spur railway line from Pimba. (These facilities are discussed further in Chapter 10).

Prior to the cancellation of the Blue Streak project in the early 1960s, a number of long range weapon or research vehicles were tested at the Woomera rocket range. These included Skylark, Long Tom, Zulu Squire and Blue Steel. Although weapons testing continued during the early 1960s, the function of the range was modified by the provision of facilities for satellite tracking and deep space research (Southall 1962). The range is now primarily used as a residential base for the Joint Defence Space Communications Station, Nurrungar. Since 1974, Woomera's population has declined from approximately 4,000 to 2,300 as a consequence of the scaling down of testing activities (South Australian Highways Department 1978; ITS 1982).

As a consequence of its past security requirements, Woomera has not been able to function as a regional service centre and, until February 1982, a security pass was required to enter the town. Some of the station lessees, however, had permission to shop there. Woomera has a wide range of commercial, social and recreational facilities including a post office, Telecom depot, State police station, ABC radio and television relays, swimming pools, churches, stores, licensed clubs, banks, a fifty-bed hospital, doctors and a dentist. Currently all residences are located on Crown land, although some service facilities have been granted ninety-nine-year leases to their sites. A Defence Department report containing recommendations on the future land tenure system for Woomera is expected later this year. With the lifting of access restrictions to the town area, a temporary caravan park has been provided and accommodation is available for visitors in the Defence Department Hostel.

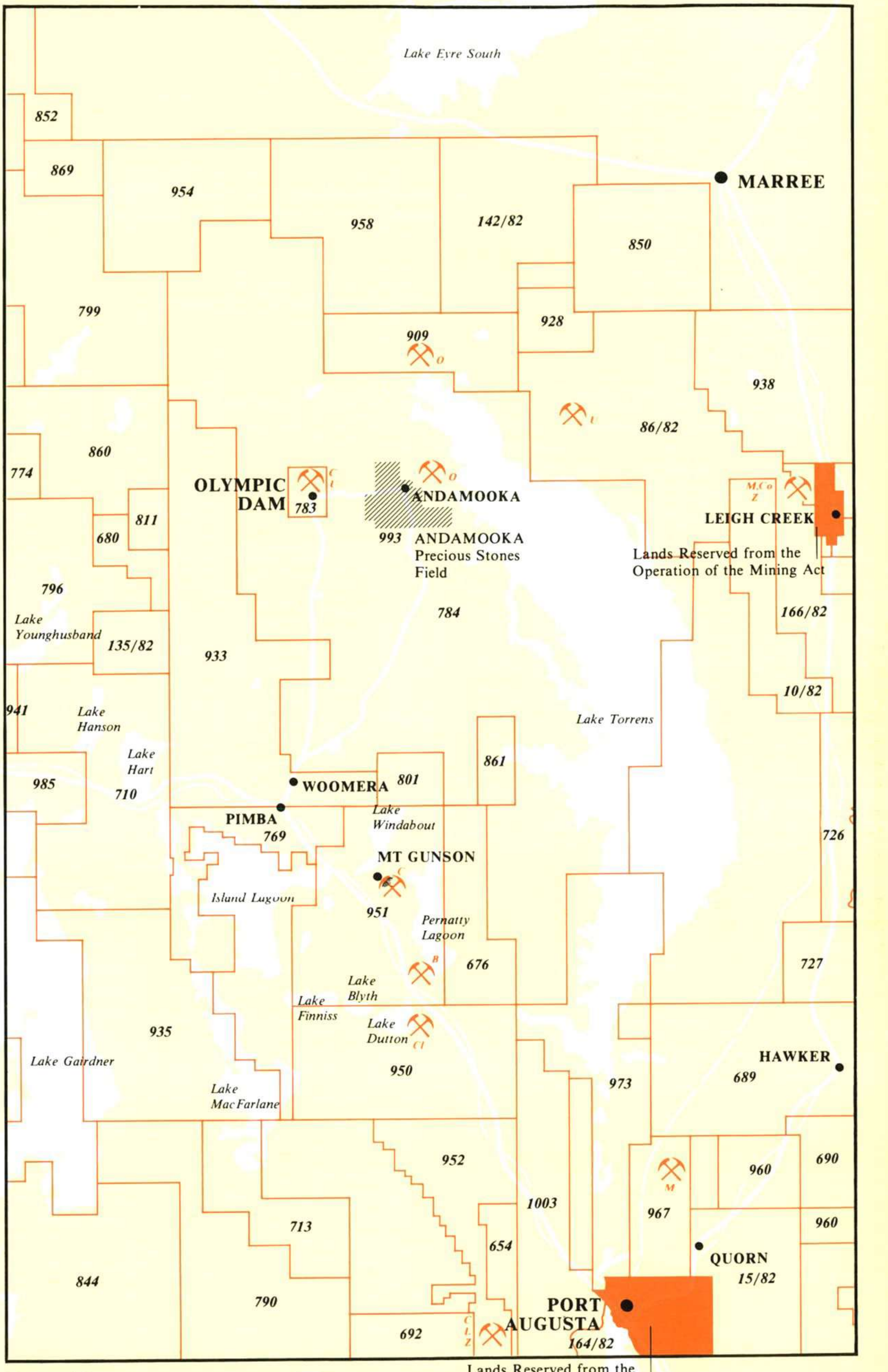
- **654** BHP Minerals Ltd 29/6/82
- **676** Seltrust Mining Corp Pty Ltd 20/7/82
- **680** Esso Exploration and Production Aust Inc 27/7/82
- **689** Swan Resources Ltd and Freeport of Aust Inc 10/8/82
- **690** Swan Resources Ltd and Freeport of Aust Inc 10/8/82
- **692** Samedan Oil Corporation 10/8/82
- **710** Afmeco Pty Ltd 4/9/82
- **713** Afmeco Pty Ltd 4/9/82
- **726** BHP Minerals Ltd 21/9/82
- **727** BHP Minerals Ltd 21/9/82
- **769** Seltrust Mining Corporation Pty Ltd 7/12/82
- **774** Shell Company of Aust Ltd 11/1/83
- **783** Roxby Mining Corp Pty Ltd, BP Aust Ltd and BP Petroleum Development Ltd 15/1/83
- **784** Western Mining Corp Ltd, BP Aust Ltd and BP Petroleum Development Ltd 15/1/83
- **790** BHP Minerals Ltd 11/2/83
- **796** AGIP Australia Pty Ltd 11/2/83
- **799** AGIP Australia Pty Ltd 11/2/83
- **801** Seltrust Mining Corp Pty Ltd 11/2/83
- **811** Esso Exploration and Production Aust Inc 1/3/83
- **844** Stockdale Prospecting Ltd 3/5/83
- **850** Utah Devel Co 19/7/82
- **852** Stockdale Prospecting Ltd 19/7/82
- **860** Stockdale Prospecting Ltd 19/7/82
- **861** Seltrust Mining Corp Pty Ltd 19/7/82
- **869** Santos Ltd 10/8/82
- **909** Amoco Minerals Aust Co 18/10/82
- **928** Seaham Explorations Pty Ltd 15/11/82
- **933** Seltrust Mining Corp Pty Ltd 15/11/82
- **935** Afmeco Pty Ltd 15/11/82
- **938** Electricity Trust of SA 29/11/82
- **941** Aquitaine Aust Minerals Pty Ltd 29/11/82
- **950** CSR Ltd 20/12/82
- **951** CSR Ltd 20/12/82
- **952** CSR Ltd 20/12/82
- **954** Stockdale Prospecting Ltd 7/1/83
- **958** Stockdale Prospecting Ltd 7/1/83
- **960** Freeport of Aust Inc and Swan Resources Ltd 17/1/83
- **967** Urangesellschaft Aust Pty Ltd 22/2/83
- **973** Delhi Petroleum Pty Ltd 17/3/83
- **985** Esso Exploration and Production Aust Inc 28/3/83
- **993** Western Mining Corp Ltd, BP Aust Ltd, BP Petroleum Development Ltd 29/4/84
- **1003** BHP Minerals Ltd 18/4/83

Lease Applied for

10/82	135/82
15/82	142/82
86/82	164/82
110/82	166/82

Principal Mineral Deposits

- B Barite
- C Copper
- Cl Clay
- Co Coal
- L Lead
- M Magnesite
- O Opal
- U Uranium
- Z Zinc



Lands Reserved from the Operation of the Mining Act

0 15 30 km

Figure 4.3
MINERAL DEPOSITS AND EXPLORATION LICENCES

WHYALLA

PORT PIRIE

Source: Department of Mines and Energy Plan, *Exploration Licences*
SADE: 1980
Note: Information correct as at 1.6.82

4.1.7 Transport and communications

The historical development of the transport and communications systems in the area of interest has been closely tied to the historical development of land use in the area, and to that of the nation's transport and communications networks. The construction of the Overland Telegraph Line from Adelaide to Darwin, the Port Augusta to Alice Springs railway line, the Port Augusta to Kalgoorlie railway line, and the Stuart Highway have all been important influences on the historical development of the area studied.

The construction of the 3,200 km Overland Telegraph Line, which was commenced in June 1870 and completed in 1872, included eleven repeater stations, three of which were at Peake, Strangways Springs and Beltana. The southern section of the route is shown in Figure 4.1. The mound springs provided an accessible water supply and their distribution along the southern and western edges of the Great Artesian Basin had a significant influence on the selection of the route for the line. The Overland Telegraph Line has now been replaced by a microwave link from Adelaide to Darwin via Queensland (Australian Post Office 1972; Telecom Australia 1977).

The major transport routes in the area of interest are:

- Port Augusta to Marree railway line
- Port Augusta to Kalgoorlie railway line (Trans Australia Railway)
- Stuart Highway.

These three routes focus on the City of Port Augusta, the main regional centre serving the area studied (Chapter 12).

The small settlement of Pimba (population approximately ten) is 90 km south of Olympic Dam. It exists to service the Stuart Highway and the Trans Australia Railway, and its roadhouse provides some limited facilities for travellers. In the draft recommendations of the Stuart Highway Roaduser Facilities Committee, Pimba was designated as a minor service centre (SADE 1980).

Development of rail links

The history of the Port Augusta to Alice Springs railway has been extensively detailed by Fuller (1975). Some years after the discovery of the mound springs, a camel transport network developed based on Herrgott Springs (now known as Marree). This network included the Birdsville Track, the Strzelecki Track to Innamincka, a track through Blanchewater (at the northern tip of the Flinders Ranges) eastwards into New South Wales, and a track to Alice Springs and other far northern repeater stations on the Overland Telegraph Line. Later, following the opening of the Western Australian goldfields, cameleers pushed out another supply route south-westwards through Tarcoola and Eucla to Coolgardie and Kalgoorlie. To complete the transport network, Herrgott Springs was connected to Port Augusta by way of a well-settled supply route which passed through Government Gums (now known as Farina) and Beltana. As well as being the focus of a camel transport network, Herrgott Springs serviced the pastoral industry which was developing in the region, acting as a place where drovers travelling from far northern stations to markets in the south could spell their sheep. In time, a railway line was constructed between Port Augusta and Herrgott Springs, to upgrade this major link in the transport network and to service the pastoral industry. The line was constructed from Port Augusta in four stages, the work commencing in October 1877 and being completed in January 1884.

The arrival of the line in Herrgott Springs was marked by substantial debate regarding the route of a northward extension. Considerable thought was given to extending the line north-north-eastwards towards Queensland (towards either Birdsville or Innamincka) instead of north-west. Finally, it was resolved to extend the railway to Angle Pole (now known as Oodnadatta), a decision greatly influenced by the presence of mound springs along the border of the Great Artesian Basin. Construction of the Herrgott Springs to Angle Pole section began in July 1884, reaching Stuart Creek in June 1886, Strangways Springs in March 1887, and Angle Pole in January 1891. The period 1891 to 1926 was marked by further debate, this time over the merits of forming a north-south rail link. Finally in 1926 a decision was made to extend the line from Oodnadatta to Alice Springs. This section of the line was constructed by the Commonwealth Railways (the earlier sections had been constructed by the South Australian Government), with the survey work beginning in April 1926 and the line being taken over for traffic in February 1929.

As a consequence of the additional traffic generated by the development of the Leigh Creek coalfield, the section of the line from Port Augusta to Marree was upgraded, rerouted and converted to standard gauge. This work was completed in June 1957 (Fuller 1975). In April 1975, work commenced on a standard gauge connection from Tarcoola (on the Trans Australia Railway) to Alice Springs. This work was completed in September 1980, rendering the Marree to Alice Springs section of the old railway redundant. This section of the old line was closed in November 1980 (SADE 1980).

One consequence of these actions has been a change in the transport patterns within the region. The eastern area which was served by the old railway now relies more heavily on road transport, while the western area is better served by rail transport (SAHD 1978). A second consequence of these modifications has been the alteration of the settlement pattern of the area. Townships such as Marree and Oodnadatta, which served the old railway line, have suffered a decline in population and a change in function, now acting as service centres for the Aboriginal community, the surrounding pastoral industry and tourists (South Australian Department of Environment and Planning 1982).

The construction of the standard gauge railway line from Port Augusta to Kalgoorlie via Pimba, Kingoonya, Tarcoola and Cook (the Trans Australia Railway) commenced in 1912 and was finished in October 1917. Since that time, the line has been an important link in the nation's east-west transport network. Rolling stock and sections of the track have been upgraded on several occasions to reduce operating costs and travelling times (SADEP 1982).

The Stuart Highway

The Stuart Highway is the major road link between Port Augusta and the Northern Territory border. Historically, the route within South Australia (via Pimba, Kingoonya, Coober Pedy and Kulgera) developed from station tracks which were formed to connect station to station, or station to bore or yard. The route which evolved was indirect, and is considered by the South Australian Highways Department (1978) to have developed more by chance than design. The indications are that the first vehicles to use the route to reach the Northern Territory did so during the late 1930s.

Over time, dissatisfaction grew with the condition of the Stuart Highway, particularly as it was the main road link to the Northern Territory. This dissatisfaction was due mainly to three factors: the road was unsealed except for sections between Pimba and Port Augusta, movement along the road was severely disrupted by rain, and thick palls of dust often drastically reduced visibility. In 1974 the Australian Government assumed financial responsibility for the development of Australia's national highways, and a major study was undertaken to assess alternative routes for an improved Stuart Highway between Port Augusta and the Northern Territory border.

In 1978 the Final EIS for the section of the Stuart Highway from Port Augusta to the Northern Territory border was released by the South Australian Highways Department. A preferred corridor 10 km wide was selected from among seven alternatives, within which the precise alignment was to be determined later. Among the seven corridors considered, four (Routes 2, 4, 5 and 6) went within 30 km of the Olympic Dam Project Area. The preferred corridor was Route 3 (which was the second shortest), from Pimba to Coondambo to Hawks Nest Bore to Coober Pedy to the Northern Territory border. The staged construction of the Stuart Highway along this new alignment commenced in 1980 and is scheduled for completion in 1987.

The completion of a sealed Stuart Highway is expected to give rise to an increase of more than 70% in traffic volumes on the highway, with a considerable increase in the proportion of cars in this traffic. The major impacts of the highway upgrading are predicted to be felt by the towns of Kingoonya and Coober Pedy, both of which are outside the defined area of interest of the Olympic Dam Project. Pimba's local economy is also expected to derive some benefit from the increased traffic and the possibility of increased tourism (SAHD 1978).

4.1.8 Tourism and recreation

In 1975, the South Australian Government Tourist Bureau undertook a Tourist Development Survey for the Far North of South Australia (South Australian Government Tourist Bureau 1975). The distinct scenic and recreational attractions which this report identified in the Olympic Dam region included:

- the water courses of Lake Eyre Basin
- mound springs, in particular Blanche Cup and The Bubbler
- Andamooka
- Strangways Springs repeater station.

All of these sites have been plotted on Figure 4.2.

The extensive sand plains of the Lake Eyre Basin lie to the east of the Breakaway escarpment. This area is crossed by a large number of tree-lined water courses (including the Gregory, Stuart, Margaret, Neales, Peake, Woodmurra, Macumba and Alberga Creeks) which drain from the Western Plateau and the Denison Ranges.

Along the southern and western margins of the Great Artesian Basin there is a belt of country extending in an arc along the old Marree to Alice Springs railway line, where artesian water rises naturally to the surface as mound springs. Blanche Cup and The Bubbler are two mound springs of particular interest near Coward Springs on the Marree to Oodnadatta road. Blanche Cup is a near symmetrical cone with a clear pool of water at its peak, while The Bubbler is a shallow pool in which emerging water and gases produce convulsions of sand and mud. (Section 10.3.3 discusses mound springs in more detail.)

Tourists are catered for at Andamooka by organized inspections of opal mines, as well as by full-day and half-day tours of the surrounding country.

Near Strangways Springs repeater station (35 km north of Coward Springs, close to the Marree to Oodnadatta road) are the ruins of one of the original eleven repeater stations built along the route of the Overland Telegraph Line in 1870-72. These ruins have been declared an historic reserve.

Another attraction in the region, but outside the area of interest, is the Breakaway escarpment, a continuous escarpment defining the eastern edge of the Australian Shield, which extends for 250 km in an arc from Oodnadatta to Andamooka. Currently, the most accessible segments of the arc are the Arckaringa Hills adjacent to the road from Oodnadatta to Mount Willoughby on the Stuart Highway. The escarpment terminates on the western edge of the area of interest.

The South Australian Government Tourist Bureau report indicated that the high cost, prolonged travelling times, and climatic extremes restricted tourism in the region. While an observable increase in visitor penetration has occurred in recent years, it has been focused on Coober Pedy, and the total number of visitors to the entire Far North region is low when compared with numbers elsewhere. Visitors to the region are either in transit (particularly on the Stuart Highway), touring the area over a prolonged period, or on organized tours of up to two weeks. Nearly all visitors travel in the area between March and November to avoid the high summer temperatures. One of the conclusions to emerge from the report was that poor road conditions have minimized the use of conventional cars by visitors to the area. This was seen to be the major constraint on the growth of tourism in the region (SAGTB 1975).

4.1.9 Local public consultation

Western Mining Corporation has been undertaking exploration in the Olympic Dam region since 1975 and has enjoyed 'good neighbour' relations with surrounding pastoralists and with Andamooka residents. There has been regular consultation between field supervisors and pastoralists, and Western Mining Corporation's regional managers followed a policy of formally notifying pastoralists of planned works and activities on pastoral lands within the lease area. The company also participated in a government sponsored public meeting held in Andamooka relating to proposed changes to mining legislation within the proclaimed Precious Stones Field.

Following the formation of the Joint Venture, Roxby Management Services' line managers have maintained regular contact with pastoralists on matters such as road relocation and upgrading, stock grid placement, fence construction or repair, and the relocation of stock watering points when required as a result of alienation of surface waters by drilling operations. Higher level discussions have also been held between senior company representatives and the lessees of Roxby Downs to advise on proposed developments.

As part of the environmental studies programme associated with the Project, an agricultural and farm management consultant was engaged by Roxby Management Services to conduct discussions with the owners or managers of the six stations adjacent to the Project Area. These discussions were conducted on an informal basis, with the aim of ascertaining current perceptions of the effect which the Project is expected to have on station management. Pastoralists in the Olympic Dam area were found to be basically concerned with the following issues (discussed in Section 4.2.2):

- the potential for an increase in vehicle/livestock accidents
- interruption of surface run-off into dams
- the increased population in the area, and the potential increase in interference to pastoral activities caused by fire, shooters, dogs and vandals.

At a less official level, good neighbour relationships have also developed, with a number of local pastoralists and Andamooka residents regularly participating in sporting and social events at Olympic Dam. Pastoralists who have lived in the area over a long period have also assisted with the compilation of historical data discussed elsewhere in this document, relating to movements of people and pastoral activities in the region prior to, and following, the establishment of Woomera.

4.1.10 Factors influencing the location of facilities

The Department of Environment and Planning has noted that there appear to be duplications, omissions and a lack of co-ordination in much of the current system of management and administration of the Far North of South Australia (SADEP 1982). This is seen to be a consequence of the changing emphasis in land use, with a movement away from the traditional pastoral dominance to a complex array of uses including pastoralism, mining, defence, transport, tourism, recreation, wildlife management and conservation.

A number of State Government departments and agencies have responsibilities in the Far North. As yet, there is no local government, although most local communities have progress associations or similar bodies. The location of facilities within the area of interest is influenced by the requirements of development plans prepared under the provisions of the Planning and Development Act, 1966-1981, and by the need to avoid National Parks and Wildlife Act reserves, sites of geological significance, sites on the Register of the National Estate, and areas of scenic or recreational attraction. Although Clause 28 of the Indenture Agreement secures for the Joint Venturers the right to carry out mining and provide power and water, whenever practicable the requirements of development plans will be considered by the Joint Venturers in the location, design and construction of Project facilities.

The area studied is covered by two separate authorized development plans (Figure 4.4):

- the Far North Planning Area Development Plan
- the Flinders Ranges Planning Area Development Plan.

The Far North Planning Area Development Plan, which was declared an Authorized Development Plan in March 1982, establishes a series of development control principles to guide public and private development in those areas where control is exercised either under the Planning and Development Act or through lease conditions under the Crown Lands Act or any other relevant Act. The principles contained within this Plan relate to:

- orderly growth of settlements
- development outside settlements
- suitability of land and buildings
- traffic and parking
- environmental protection
- mineral resources.

In particular, the environmental protection guidelines within the Far North Development Plan require that developments should not destroy or lessen the value of any significant item of natural or man-made heritage, and should not generally take place near an area proposed for consideration as an area of special environmental significance until such time as a management plan has been prepared (SADEP 1982). Figure 4.4 shows the distribution of features of special environmental or heritage significance which occur in the area studied, including the Hermit Hill mound springs complex, the Coward Springs mound springs complex (including The Bubbler and Blanche Cup Springs), Island Lagoon and Pernatty Lagoon.

The Flinders Ranges Planning Area Development Plan (South Australian State Planning Office 1973), which was authorized in February 1973, also establishes a set of general principles to guide development. Only a small portion of the area of interest lies within this planning area, and the only component of the Olympic Dam Project which will be within it is a section of the southern transmission line corridor (Figure 2.21). The principles contained within this Plan relate to:

- orderly and economic development

- land use zoning

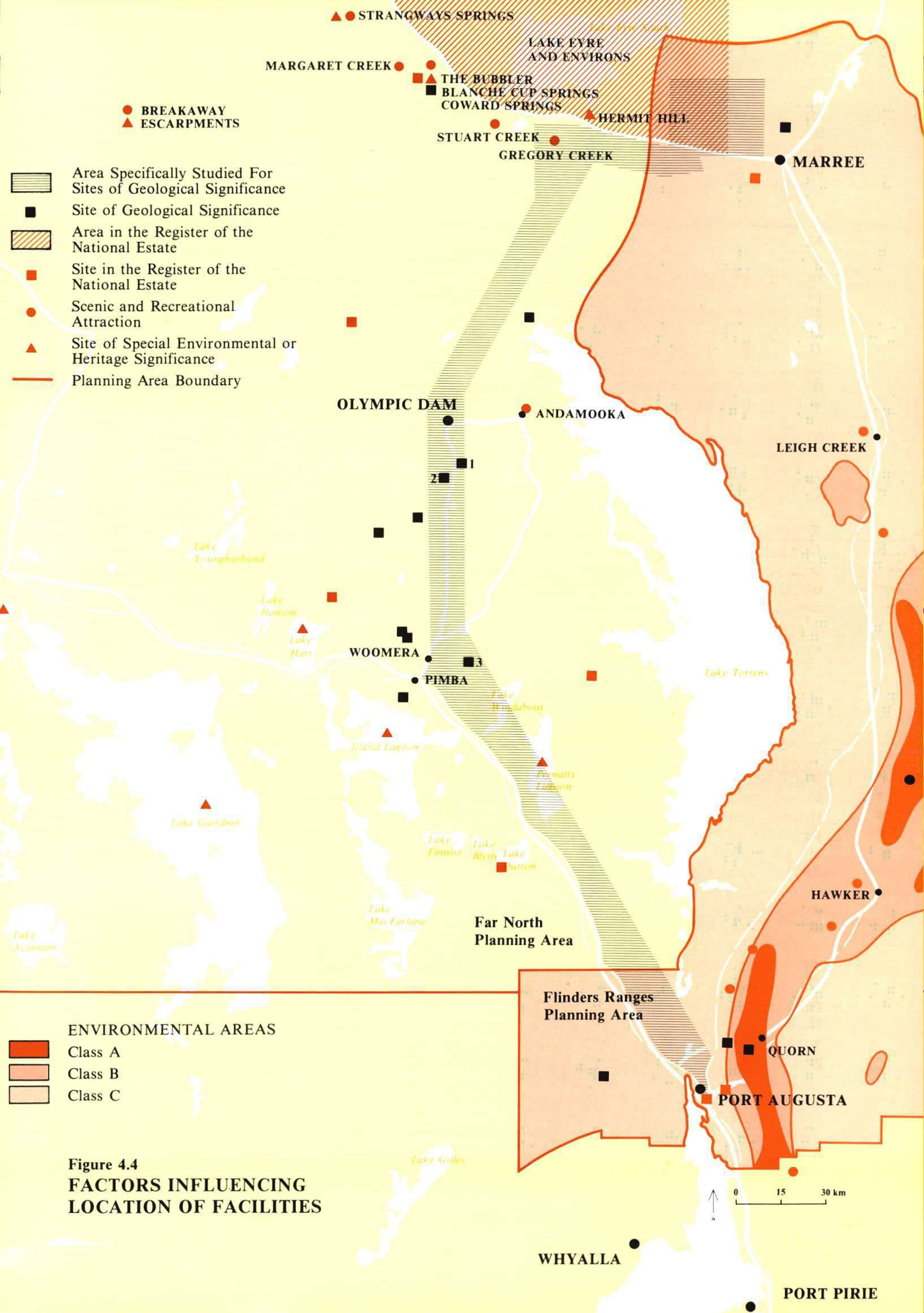


Figure 4.4
FACTORS INFLUENCING LOCATION OF FACILITIES

- reservation of land for public purposes

- traffic and parking

- conservation, preservation or enhancement of areas of visual significance

- preservation of buildings or sites of architectural, historical or scientific interest, or beauty

- preservation of vegetation

- outdoor advertising

- suitability of buildings

- prospecting, mining, quarrying and similar extractive and associated manufacturing industries

- redevelopment of substandard areas.

The Plan divides the rural lands of the planning area into the following three environmental classes:

- Class A: areas of high scenic value or scientific interest, or suitable for conservation as areas in which people may walk or seek recreation in attractive natural environments containing little evidence of human impact. Only minimal development is permitted in these areas.

- Class B: areas constituting the immediate foreground of the most prominent ranges, and containing many features of outstanding natural beauty. Although it is intended to keep these lands generally free of development, some small-scale development is permitted.

- Class C: all remaining rural lands in the planning area, including the generally flat land of low scenic value on either side of the Flinders Ranges and the relatively low uplands in the north-west portions of the Ranges. The primary land use is pastoral.

No reserves coming under the National Parks and Wildlife Act, 1972-1981, occur in the area of interest.

Figure 4.4 shows three sites of geological significance in the vicinity of the infrastructure corridors, together with other sites noted in the immediate vicinity. Site 1 on the western shore of Coorlay Lagoon and Site 2 around the margins of Purple Lake are considered to be 'the best exposed outcrops of the base of the Andamooka carbonate sequence on the Stuart Shelf west of Lake Torrens' (South Australian Museum, pers. comm.). Fossil cones thought to be from casuarinas of Cainozoic age have been found at Site 3 near The Pines homestead, although the source of these fossils has not yet been located.

Only one site in the Register of the National Estate was identified in the vicinity of the infrastructure corridors. This and other sites in the immediate vicinity have been plotted on Figure 4.4. The northern portion of the corridor falls within an area of 2,100,000 ha designated as Lake Eyre and environs (refer Section 10.2.3 for further discussion). There are no sites which have been nominated for inclusion on the Register of State Heritage Items within the corridor.

Areas of tourist interest discussed in Section 4.1.8 have also been plotted on this figure.

4.2 LAND USE IMPACTS AND MITIGATION MEASURES

While pastoral activities comprise the most extensive land use in the area of interest, a number of isolated settlements owe their current status, and their future, to one or more of the following industries:

- transportation
- mining and exploration
- tourism and recreation
- weapons testing, satellite tracking and deep space research.

As the Project will alter the land use and land tenure pattern in the area of interest, these impacts have been assessed to determine whether they will affect the viability of existing land uses, and whether they will be compatible with adjoining land uses. Only those land use impacts in the immediate vicinity of the Project Area have been studied in this chapter; land use impacts associated with the infrastructure corridors are discussed in Chapter 10. The basic conclusion has been that most of the direct effects of Project development within the immediate vicinity will be upon the pastoral industry.

However, the introduction of 9,000 people into the Far North region of South Australia (which currently has an approximate population of 10,000), will also have indirect effects on land use. These indirect effects will be associated with recreational and other activities of the Olympic Dam town population rather than with their work-related activities connected with Project construction or operation. Indirect effects include such aspects as the greater use of transport facilities and increased patronage of tourist attractions.

While the Joint Venturers propose to adopt a variety of mitigation measures to alleviate the direct impacts on pastoralists (Section 4.2.2), indirect impacts will be in areas outside the jurisdiction of the Joint Venturers. Thus, actions by others with the appropriate authority may be required in relation to these indirect impacts.

4.2.1 Land use and land tenure pattern

Figure 2.1 depicts the land use pattern which will be developed within the Project Area. Although the details of land tenure have yet to be finally defined, the Indenture Agreement provides the basis for the various forms of land tenure which will exist within the Project Area.

The operations area will be held under a Special Mining Lease in accordance with the provisions of Clause 19 of the Indenture Agreement. This lease will provide the Joint Venturers with exclusive rights of occupation and possession. In the first instance the lease will be for fifty years, with the right to extend for up to a further fifty years. It is expected that the boundaries of the Special Mining Lease will be those of the current Joint Venture Exploration Licence, modified where necessary to accommodate the tailings retention area and any other surface facilities outside the current lease boundaries. In accordance with Clause 24(6) of the Indenture Agreement, freehold titles over areas of land required for surface facilities in the operations area will be granted to the Joint Venturers by the State. These freehold titles will revert to the State two years after the termination of the Special Mining Lease.

Following the recent ratification of the Indenture Agreement, the State is able to dedicate an area for town purposes, including a town buffer zone. The dedicated land will be placed in the care of the responsible Minister until a Project Notice is issued, upon receipt of which an area (agreed by the Joint Venturers and the Minister) will be declared a municipality. (Further discussion of the clauses of the Indenture Agreement relevant to town development, together with details of municipal management, are provided in Chapter 11.)

Clause 24 of the Indenture Agreement provides for subdivision of the necessary portions of the land dedicated for town purposes, and the granting of freehold title over the allotments to the Joint Venturers. The land may be subdivided either by the Joint Venturers or by the State.

Special buffer zones will be created around both the operations area and the town, in accordance with Clause 25(1) of the Indenture Agreement. The mine buffer zone surrounding the operations area will be leased to the Joint Venturers, who will be responsible for fencing it to restrict unauthorized access and for keeping it free of vermin and pests. The town buffer zone will be leased to the municipality, which will be responsible for the maintenance of any fencing and for keeping the land free of vermin and pests. No development will be permitted within the town buffer zone (with the exception of infrastructure development) and access will be restricted.

Land not held under Special Mining Lease or Special Buffer Zone Lease or not dedicated for town purposes may continue to be held under pastoral lease by the current lessees.

4.2.2 Pastoral use

The Project has the potential to impact upon existing pastoral leases in a number of ways. Positive effects are expected to be:

- access to town facilities
- the availability of a reliable stock water supply
- improved transportation,

while the potentially adverse impacts are expected to be:

- division and loss of land
- vehicle/stock accidents
- danger to stock
- vandalism.

Access to town facilities

An obvious benefit to the pastoralists in the areas adjacent to the Project will be the convenience afforded by ready access to the wide range of commercial, medical and educational facilities in the new town. Currently, facilities of this type are located at considerable distances from the homesteads, and access is generally by way of roads of less than average standard. While some lessees prefer to have some degree of isolation, this should not be affected as no homesteads are in close proximity to the Project Area.

Stock water supply

As noted in Section 4.1, the viability of the pastoral leases in the area is very much influenced by the vagaries of drought. Water for the Project is to be supplied by pipelines from two borefields located in the Great Artesian Basin to the north of the Project Area (Section 2.5.5) and, while this water will not be of potable quality, it will be suitable for the watering of stock. Clauses 13 (13)(a) and (b) of the Indenture Agreement make provision for third party usage of water obtained from the borefields, with this usage to be a matter for negotiation between the Joint Venturers and the third party. Stock water could be made available from the pipeline to five of the six stations in the vicinity of the Project Area (the exception being Arcoona), and such provision may offer the stations a buffer against the effects of drought.

Improved transportation

Benefits will be afforded to the region's pastoralists by the improved transportation system developed to service the Project, which is discussed in Section 10.4.

Division and loss of land

As shown on Figure 4.2, the greatest loss of pastoral land will occur on Roxby Downs Station. The development of the Project will require the annexation of approximately 200 km^2 , which is about 10% of this station's area. If an even distribution of waters and edible vegetation is assumed, a reduction in lease stocking capacity of 2,000 sheep equivalents is implied. The only other loss of land will occur on Andamooka Station, where it will be necessary to annex a small area (about 1 km^2) for the construction of the airport.

Under Clause 31 of the Indenture Agreement, the Joint Venturers are responsible for payment of reasonable compensation for loss of land and/or the loss of production from any land required by the Joint Venturers for the purposes of the Project. In the case of Roxby Downs, an agreement has been reached with the lessees, and it is likely that portions of Purple Downs (currently held under pastoral lease by Western Mining Corporation) will be transferred to Roxby Downs as replacement for annexed land.

A further consideration is that development works such as roads can cut off parts of water catchment areas for stock dams, thus reducing the volume of water available for storage. The only stock dam affected by development within the Project Area is Olympic Dam, with current exploration activity preventing its use as a stock water supply. An agreement has been reached with the owner of Roxby Downs Station for the provision of an alternative stock water supply, the quantity of which is equivalent to that which would have been available in Olympic Dam based on the amount of run-off stored, the quantity used and evaporation rates.

The alienation of areas of land by development can create the potential for land parcels which cannot be grazed efficiently. This fact was recognized in the Declaration of Environmental Factors for the Phillip Ponds to Olympic Dam road, in which the lessees signified their agreement to the road alignment and in which a commitment was provided to construct new fences or realign existing fences to minimize the effects on grazing (Kinhill 1981). However, the currently defined fencing pattern for the Project Area does not create any land parcels which cannot be grazed efficiently.

Vehicle/stock accidents

North of Port Augusta, the general practice is to leave transportation corridors unfenced. Examples of this practice are the Stuart Highway, which is currently being upgraded, and the recently completed Tarcoola to Alice Springs railway. Where transportation corridors dissect pastoral leases there is a risk of vehicle/stock accidents, particularly in the proximity of borrow pits which provide a temporary source of water following rains.

This problem will be at least partly counteracted by the vermin-proof fences which will be erected around the Project Area as shown on Figure 2.1. The fences will exclude stock, as well as emus, kangaroos and vermin, from entering the Project Area, and will therefore reduce the risk of vehicle/livestock accidents.

Danger to stock and vandalism

Particular concerns of the pastoralists in relation to the population influx are the potential dangers to stock if shooters and town dogs have unrestricted access to the leases, the property damage which could result from the activities of pilferers and vandals, and the effects on stock control and livestock disease eradication programmes which the failure to close gates or the cutting of fences could cause. There is also a likelihood that the greater population in the area, together with the increased vegetation which can be expected in parts of the Project Area due to destocking and vermin control, will increase the risk of fire.

However, the Joint Venturers' continuing programme of identifying issues of concern to pastoralists and informing Project personnel of these concerns can be expected to keep both vandalism and the danger to stock at a minimum. It is intended to continue the existing dialogue with pastoralists on two levels: the first at executive level on an intermittent basis, and the second at the on-site staff level on a continuous basis.

In addition, the Environmental Officer to be employed on the Project (Section 4.1.9) will perform a similar function to that which was performed by the Range Overseer on the Woomera Rocket Range (Section 4.1.6), thus providing a further communication link between the pastoralists and the Project personnel.

4.2.3 Mining

Clauses 19(12) and 20(10) of the Indenture Agreement protect the rights of opal miners in the Andamooka Precious Stones Field to a depth of 50 m with respect to the Special Mining Lease and Special Exploration Licences.

4.2.4 Tourism and recreation

While Figure 4.2 indicates that there are no areas of scenic or recreational attraction in the Project Area, the Olympic Dam development may have some indirect effects on tourism and recreation. For example, the Project itself may become a tourist attraction, thus increasing the number of visitors to the region, while the Olympic Dam town population will also swell general tourist activity by visiting regional areas of interest. In addition, the improvements in transportation and accommodation facilities will moderate one of the principal restraints on tourism in the region.

4.2.5 Weapons research

Figure 4.2 indicates that the portion of the Project Area containing the town is situated in the current Woomera Prohibited Area. At the time of writing, negotiations to modify the boundaries of this area were currently being held between the State and the Commonwealth Governments. Boundary modifications of this type have occurred within the Project Area in the past, and it is expected that the necessary changes will be agreed to on this occasion. The areas involved are no longer required for their original purpose in relation to rocket testing.

4.3 LONG-TERM USE OF THE PROJECT AREA

The Project as defined in this Draft EIS will be be in production for thirty years. Continuation of mining and processing after that date will be dependent on prevailing economic conditions which cannot be predicted at this stage. However, the size of the orebody is such that it will have the capacity to sustain a large-scale operation for many years beyond the time period contemplated herein, particularly as the production and infrastructure facilities will by then be well established. In Australia and overseas there are many examples of mining operations on large orebodies which have continued for much longer than thirty-year periods. Ore has been mined at Broken Hill and Kalgoorlie, for example, since before the turn of the century, while mining commenced at Mount Isa in 1924.

Because of its very long life span, it is not possible to state precisely what measures will need to be undertaken on the eventual abandonment of the Project. However, the Joint Venturers will conform to the appropriate legislation prevailing at that time and to the best industry practices in their abandonment procedures.

CHAPTER FIVE

Aboriginal Environment

SUMMARY

Archaeology

Archaeological sites which are evidence of past occupation by Aboriginal people are widespread throughout the region in which the Study Area is situated. The nature and distribution of archaeological sites which were used for economic activities by Aboriginal people are closely related to terrain patterns. Campsites are generally on sand, with the richest and most diverse being located adjacent to areas likely to hold water after heavy rainfall. Knapping floors and quarries are usually in close proximity to sources of raw materials, and the material used reflects the rock type of the surface geology. The greatest frequency of sites is found in widely spaced dune fields, which combine the advantages of sand on which to camp, rain-collecting depressions for water supply, and raw material for stone tools. The frequency of sites declines with increasing dune density (and decreasing frequency of claypans). Dune fields overlying low stony rises (a source of silcrete for stone tools) have the highest site frequency. On stony tableland and dissection slopes, sites are confined to rock outcrops used for quarries and knapping floors and to isolated dunes used as campsites. Such sites are infrequent, but those which do occur are large in area and dense in artefacts. Artefact material is generally silcrete in dune fields (especially where there are low stony rises), chert in areas of Andamooka Limestone, and quartz in Arcoona Quartzite.

The operations area is located predominantly in widely spaced dune fields overlying low stony rises. Archaeological sites with a high density but low diversity of artefacts are therefore frequent. The town site is in more closely spaced dune fields where a lower frequency of sites occurs. The types of archaeological sites within the Project Area are not unique, as there are large tracts of country surrounding Olympic Dam which contain essentially the same range of site types in the same environmental settings. Thus, general preservation of archaeological sites in the Project Area is not warranted. However, nine sites were identified as being noteworthy from a scientific point of view, and more detailed recording or salvage collection will be carried out at three of these sites to gather further insights into the archaeology of the area. In addition, seventeen stone features were located in the general vicinity of the Project Area, five of which have definite artificial components consistent with Aboriginal origins. None of these sites will be directly affected by the development, and the Joint Venturers have restricted access in the areas surrounding the sites. Before further action can be formulated in relation to these features, an indication of their Aboriginal significance is required.

Anthropology

The weight of evidence from the literature implies that the Project Area is within traditional Kuyani territory near the band of country where Kuyani and Kokatha tribal areas traditionally meet. Arabana territory is further north, and that of the Pangkala is to the south. It is many years since the general area was inhabited by Aboriginal people following a traditional lifestyle: by the late 1940s, when Woomera was established, there were very few tribalized Aborigines in the Range area. However, people of Arabana, Kuyani and Kokatha descent were employed on stations near Olympic Dam until the early 1970s. Migration of Aboriginal people from the area has been to missions such as Koonibba and Yalata, and to towns, particularly Port Augusta.

It has not been possible to conduct anthropological surveys of the Study Area. The last speaker of Kuyani has died and, while discussions were held with the Kokatha during the eighteen months leading to publication of this Draft Environmental Impact Statement (EIS), detailed agreement on an approach to anthropological research was still to be reached with the Kokatha people at the time of writing. A preliminary agreement was, however, being discussed on an approach to site survey work. Arabana people have provided confirmation of certain Kuyani myths and, through fieldwork, have indicated sites of significance to the north of the Project Area.

Nevertheless, anthropologists and others have previously recorded much of the mythology of the region and have located and identified sites of significance. This information identifies no mythological sites in the Olympic Dam Project Area, although two sites are within 15 kilometres of the Project Area and another three are within 50 kilometres. Kuyani and Arabana mythology is generally centred on the mound springs area, about 100 kilometres to the north; Kokatha mythology is centred on Ooldea, about 500 kilometres to the west.

5.1 ARCHAEOLOGY

5.1.1 Archaeological information

Archaeological information is primarily concerned with past evidence of Aboriginal occupation in an area. This is usually expressed in the form of archaeological sites of the following types:

- **quarries:** from which either stone for flaked or ground-edged artefacts or ochre have been extracted;

- **surface scatters of stone artefacts:** where worked stone and other evidence of Aboriginal occupation remain in the landscape. Two categories of artefact scatters can be defined:

  - knapping floors, which are discrete scatters of artefacts anywhere in the landscape (including quarries) resulting from stone being worked at those locations. The criterion for a knapping floor is that the original block of stone can be largely reconstructed from the scattered pieces of flaked stone;

  - campsites, consisting of general artefact scatters which may contain flaked or ground stone artefacts, hearth stones (or other transported stones, called manuports) and charcoal from fires, and food remains such as bone and shell. Campsites may occur as surface scatters of material, or as stratified deposits where there have been repeated occupations. These scatters do not necessarily indicate that Aboriginal people actually camped on the site, but only that some type of activity was carried out there;

- **burial sites:** which in this area would generally occur in soft sand;
- **engraving sites:** where Aboriginal people have engraved, shaped or impacted rock surfaces;
- **paintings:** where rock surfaces have been decorated by ochre, charcoal or blood;
- **stone arrangements:** which may vary from simple cairns or piles of rock to more elaborate arrangements, such as patterns of stone laid out to form circles and other designs, or standing slabs of rock held upright by stones around the base. Some stone arrangements were used in ceremonial activities while others may represent sacred or totemic sites. Other stone features were constructed by Aboriginal people for secular purposes, such as route markers, or as ground supports for shelters, animal or seed traps, or hides.

For EIS purposes, archaeological investigations involve the following procedures:

- ascertaining the type and distribution of archaeological sites in the region
- surveying archaeological sites which could potentially be affected by the proposed development
- assessing the relative importance of archaeological sites, and undertaking actions to mitigate the effect of development on such sites.

It should be noted that the information presented below on archaeological survey work undertaken for this Draft EIS is presented in sufficient detail only to indicate the nature of sites present in the Study Area and the types of impacts which might arise. More detailed site descriptions and supporting information have been lodged by Roxby Management Services (RMS) on a confidential basis with the Heritage Conservation Branch of the Department of Environment and Planning.

5.1.2 Archaeological surveys

Baseline surveys

Prior to the studies for this Draft EIS, the region including Olympic Dam had not been subjected to intensive archaeological scrutiny. Thus, in order to assess the potential for archaeological impact associated with the Olympic Dam Project, it was first necessary to obtain a general understanding of the archaeology of the region. The main elements of this baseline survey work were:

- a sample survey of terrain patterns in the Baseline Study Area, to determine the relationship between archaeological sites and landforms;
- the development of a predictive statement concerning the nature and distribution of archaeological sites in the general area of Olympic Dam;
- a survey of a traverse through the broader region around Olympic Dam to test the validity of the predictive model, and to place potentially impacted areas in a regional context.

The area covered by these surveys is indicated in Figure 5.1. Earlier archaeological survey work for the 80 km road south from Olympic Dam village to Phillip Ponds (near Woomera) and for the housing area south-east of the village was incorporated in the baseline and regional testing studies.

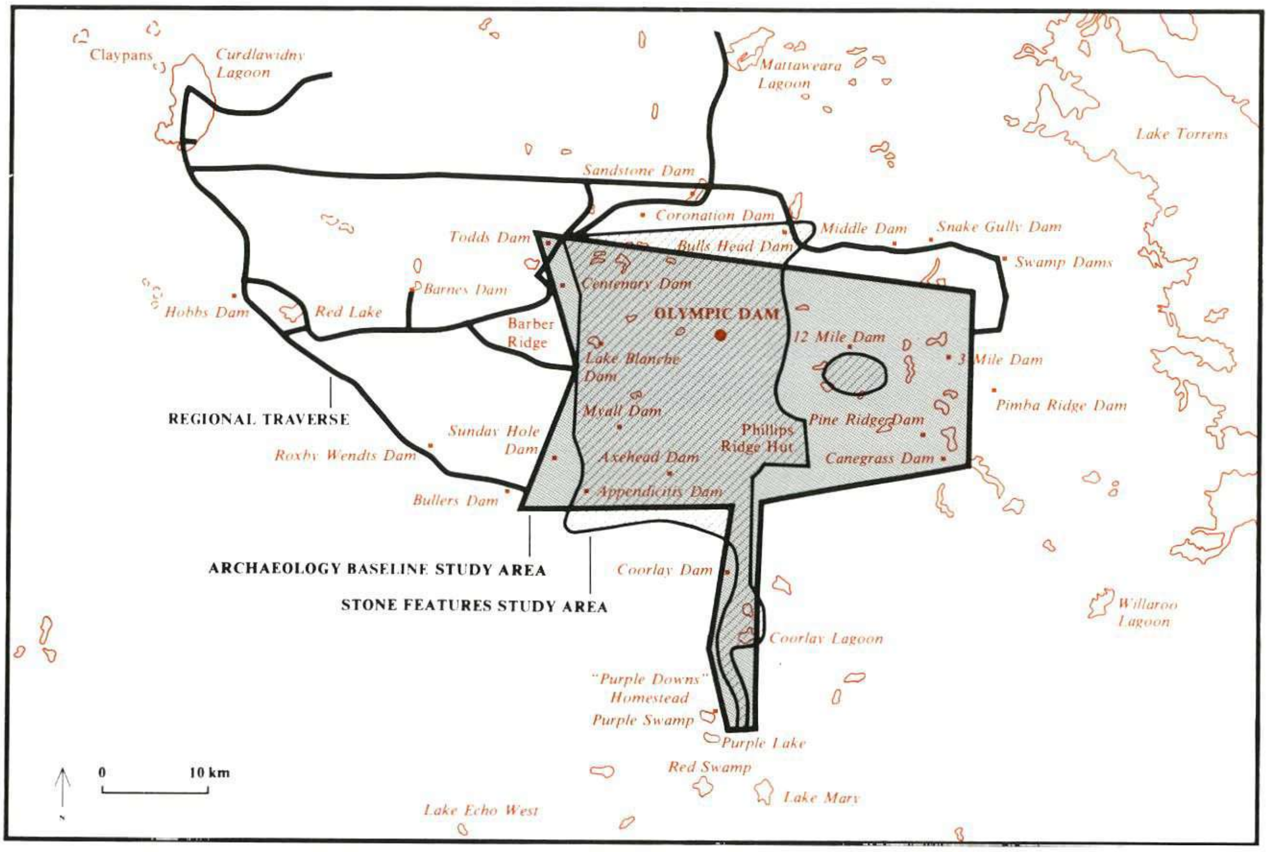


Figure 5.1
ARCHAEOLOGICAL SURVEY AREAS

Impact assessment surveys

On the basis of the predictive statement, a field programme involving detailed surveying and recording of sites was formulated. Development areas were selectively sampled in order to provide specific recommendations concerning sites which could be affected, and to allow a general assessment to be made of direct and indirect impacts on archaeological sites. This assessment included areas which will be directly affected but which were not surveyed, as well as known sites which, although not directly affected, may be indirectly affected, for example by the recreational activities of the town residents.

Stone features had been observed by geologists and field crews in a number of claypans. All claypans in the vicinity of the Project Area (Figure 5.1) were therefore inspected, and an assessment made of the likelihood of these stone features being stone arrangements of Aboriginal origin.

The area around the Whenan Shaft had been surveyed separately prior to the main impact assessment survey. The surveys for infrastructure corridors are discussed in Chapter 10.

5.1.3 Sample survey of terrain patterns

The results of the earlier archaeological surveys for the road from Olympic Dam to Phillip Ponds, together with research findings from other parts of arid Australia, demonstrate that the nature and distribution of archaeological sites in this landscape are generally very strongly influenced by environmental factors such as climate, landforms and their associated soils and vegetation, surface and subsurface hydrology, and bedrock geology. These factors in turn influence the availability of plant and animal foods and other organic raw materials, of water, of raw materials for stone artefacts, and of suitable campsites. Furthermore, environmental factors such as the extent of vegetation cover, and of erosion and deposition of sediment, affect the degree of visibility of archaeological remains. For these reasons, the predictive statement was based primarily on environmental criteria.

The climate of the Study Area is mild to hot in summer and mild to cold in winter, with low and unreliable rainfall and high evaporation throughout the year (Section 8.1). At a very broad level, the Study Area consists of a tract of country dominated by dune fields (the Moondiepitchnie environmental association) which interfingers along its eastern margin with the gibber-covered Andamooka plateau (Andamooka environmental association). To the south lie the gibber plains of the Woomera environmental association (Section 3.2). The terrain pattern information (Section 3.3) proved to be ideal for the establishment of a sampling strategy for the following reasons:

- The terrain patterns are defined in terms which allow clear distinctions to be made between different archaeological environments.

- The terrain pattern maps are at the same scale as the aerial photographs used in the field (1:40,000), enabling the sample areas and sites investigated in the course of this study to be accurately located and related to their environmental setting.

- These maps can be used as a basis for the planning of future development of the Project Area. Accordingly, by preparing the archaeological predictive statement in terms of the same environmental criteria, it should be possible for the Joint Venturers and the State archaeological authorities to directly assess the archaeology of any given area (and the impact of the development on sites) by referring to the terrain pattern of that area.

The main elements of the terrain patterns (which are described in detail in Section 3.3) are as follows:

- Geological regime

  Q - recent aeolian sand ridges, dune fields and claypans
  Qs - as for Q, but overlying silicified aeolian sands
  K - Cretaceous kaolinitic siltstones, shales and sandstones
  A - Cambrian Andamooka Limestone
  P - Precambrian quartzites and sandstones.

- Landform types

  1 - flat to gently undulating plateau surfaces;

  2 - steeply dissected plateau surfaces with low rounded hills;

  3 - broad, slightly concave drainage depressions surrounding large claypans;

  4 - plateau surfaces with widely-spaced east-west trending sand dunes and numerous, often large, claypans in the interdune corridors;

  5 - plateau surfaces with moderately spaced, generally east-west trending sand dunes covering 30 to 60% of the landscape. Claypans are smaller and much less common than in landform type 4;

  6 - plateau surfaces with closely spaced, vaguely east-west trending sand dunes covering up to 80% of the landscape. Pans are uncommon.

Landform types 1, 2 and 3 represent successive stages in the history of dissection of the plateau surfaces which dominate the landscape. Landform types 4, 5 and 6 are distinguished from each other, and from types 1, 2 and 3, by their progressively increased cover of sand.

Sampling strategy and fieldwork procedures

In selecting areas for study, and in making such a selection unbiased and capable of accurate prediction, the procedure known as 'stratified random sampling' was used. This is a well tested survey method, in which the survey area is divided up into a series of strata or classes, from each of which an example is randomly chosen for investigation. This procedure ensures the random selection of areas for study, while at the same time ensuring that different types of area (in this case based on differences in environment) are represented in the sample.

The basis of the stratification was the environmental information on the terrain pattern maps. The random samples were drawn systematically from the twenty-four different terrain patterns in the Project Area covered by these map sheets. There is generally more than one mapped occurrence of each terrain pattern, the maximum being seventeen for K4. For the purposes of the baseline study, each of these mapped occurrences was defined as a terrain locality and numbered, giving it a unique identification. Altogether, 194 terrain localities are represented by the twenty-four terrain patterns. The procedures by which sample areas were randomly selected were as follows:

- The numbered terrain localities for each terrain pattern type were ordered randomly, using a table of random numbers.

- The terrain locality at the top of each of these lists (i.e. the first random selection), was chosen as the area representative of that particular terrain pattern.

- If the locality randomly placed first on the list was either inaccessible, or regarded as being not typical of the particular terrain pattern, or too small to be isolated from the influence of surrounding terrain localities, it was rejected, and the next area examined. This process was continued until an area was found which could not be excluded on the basis of any of these three criteria.

- A portion of each of these terrain localities was then systematically and intensively traversed on foot; the remainder of the sample area was examined cursorily by vehicle traverse. The areas surveyed were at least 0.3 to 0.5 km^2 in area and located, where possible, away from boundaries with other types of terrain pattern.

Much of the mining development will take place in Qs4/13, one of the localities randomly selected for study. For this reason, and because of its large area, the sites recorded in the present Olympic Dam housing area (which is within Q4/13) are included in the random sample data for this locality. In the course of driving across the Study Area between sample localities, a number of additional areas were selected for study, further observations were made, and sites recorded.

In each of the surveyed areas, the following information was recorded:

- the frequency of archaeological sites in the sample area, using the following five categories: 'very low', 'low', 'medium', 'high' and 'very high';

- the areal extent of each site and the density of artefacts on them (quantified in Table 5.1);

- the types and proportions of raw materials of which artefacts were made;

- the nature and sizes of the artefacts;

- the presence of any implement types;

- the topographic and stratigraphic position of the site, which influences the degree to which sites are concentrated in certain terrain units within a terrain locality, and the likelihood of such sites being visible.

Table 5.1 Summary statistics for the sites located in the randomly sampled areas

Landform type	Summary statistics	Geology					Total
		P	A	K	Qs	Q	
2	Average size (m²)		50	9×10^2			4.5×10^2
	Average number of artefacts		10	4.5×10^4			2×10^4
	Average density (per m²)		0.2	50			25
	Raw material		C, (S)	S			S, C
	Number of sites		1	1			2
3	Average size (m²)		450	900		3×10^3	1.5×10^3
	Average number of artefacts		2×10^4	9×10^3		300	3×10^4
	Average density (per m²)		50	10		0.1	20
	Raw material		S, C, (L)	S, (C)		S, (C, Q)	S, (C, Q, L)
	Number of sites		3	1		1	5
4	Average size (m²)	100	90	325	180	200	170
	Average number of artefacts	250	35	170	450	200	380
	Average density (per m²)	2.5	0.4	0.5	2.5	1	2
	Raw material	S, (C)	C, (Q)	S, (C, Q)	S, (Q, C)	S, (C, Qtz)	S, (Q, C)
	Number of sites	2	2	4	29	4	41
5	Average size (m²)	45		100	100	175	140
	Average number of artefacts	45		100	20	20	50
	Average density (per m²)	1		1	0.2	0.1	0.4
	Raw material	S, Q, (C)		S, (C, Q)	S, (C)	S, (C, Q)	S, (C, Q)
	Number of sites	3		1	1	2	7

Note: S = silcrete, C = chert, Q = quartzite, L = limestone, Qtz = quartz, with brackets indicating minor amounts of that material present in the raw material assemblages.

The frequency of sites in the different terrain pattern types

An estimate was made of the relative frequency of sites in different terrain pattern types. The frequency can be expressed as a measure of the average number of sites per unit area; however, in reality, the sites are invariably clustered or concentrated in certain parts of the landscape. The following major patterns emerged in the field:

- Areas with widely spaced dunes (landform type 4) contained the highest average number of sites.

- The greatest concentration of sites occurred in areas with numerous pans (again landform type 4), on dunes adjacent to large depressions which hold water (landform type 3), on isolated dunes in gibber plains (landform type 1), and in areas where rock types suitable for knapping outcrop.

- With regard to raw material, sites were most concentrated around silcrete outcrops in geological regime Qs and to a lesser extent in K. Sites were also concentrated near the extensive outcrops of chert cobbles in the Andamooka Limestone (A) in the vicinity of Coorlay Lagoon.

The number of sites recorded in each of the randomly sampled terrain pattern types is shown in Table 5.2, while Table 5.3 records the numbers of sites in the baseline and housing area surveys. This data confirms the results of field observations summarized above, namely, that sites occur most frequently in landform type 4 and where silcrete crops out (especially Qs). It should be noted that sites in dunes are usually only exposed in blowouts, and hence the true number of sites in such areas is likely to be underestimated. Few sites were found on the intact and dissected gibber-mantled plateaux (landform types 1 and 2), except where suitable raw materials for knapping crop out or where isolated dunes occur, and few were found in areas with extensive sand cover (landform type 6).

Table 5.2 **The number of sites recorded in the random sample localities**

Landform type	Geology P	A	K	Qs	Q	Total	(%)
1	0	-	0	-	-	0	(0)
2	0	1	2	-	-	3	(5)
3	0	3	1	-	1	5	(9)
4	2	2	4	29	4	41	(75)
5	3	0	1	0	2	6	(11)
6	0	0	0	-	0	0	(0)
Total	5	6	8	29	7	55	(100)
(%)	(9)	(11)	(14)	(53)	(13)	(100)	

Note: Zero indicates none present, while a dash indicates that it is not applicable.

Table 5.3 **Total number of sites recorded in the baseline and housing area surveys**

Landform type	Geology P	A	K	Qs	Q	Total	(%)
1	0	-	3	-	-	3	(4)
2	0	1	2	-	-	3	(4)
3	0	3	1	-	3	7	(9)
4	2	3	5	29	9	48	(62)
5	4	0	8	1	3	16	(20)
6	0	0	0	-	1	1	(1)
Total	6	7	19	30	16	78	(100)
(%)	(8)	(9)	(24)	(38)	(21)	(100)	

Note: Zero indicates none present, while a dash indicates that it is not applicable.

The sizes of sites

The average sizes of sites recorded in the random sample areas are summarized in Table 5.1. The size of a site was defined as the horizontal area which it covered, expressed in square metres. However, as sites in dunes are usually exposed in blowouts, it is common for the areal extent of sand deflation to arbitrarily define the size of such a site, and thus the actual size is likely to be underestimated. The major patterns in the sizes of sites were as follows:

- Too few sites were recorded in landform types 1 and 6 to allow generalizations to be made.

- In landform type 2, and by inference type 1, where suitable raw materials crop out, quarries and knapping floors generally covering very large areas (tens of thousands of square metres) are likely to occur (e.g. K1 and K2). Other types of sites are likely to be very small in area.

- All the sites recorded in landform type 3 covered large areas (thousands of square metres).

- In landform type 4, the sites were usually 100 to 300 m^2 in area. This is smaller than for landform type 3, but greater than for landform type 5 where the average size was around 100 m^2.

The density of artefacts on sites

The density of artefacts varies greatly depending on the type of site and its environmental setting (Table 5.4). However, the following patterns emerged:

- Sites in landform types 1 and 6 occur so infrequently that it is not possible to generalize.

- The types of sites which have the greatest density of artefacts are often those representing specialized activities such as quarrying and knapping. Such types dominate the sites occurring in landform type 2, and by inference in type 1.

- The very high densities of artefacts on sites in A3 and K3 (drainage depressions in Andamooka Limestone and kaolinitic siltstones), together with the evidence of large size and diversity of raw material, suggest that heavy and repeated occupation has taken place in areas where these sites are concentrated (on dunes around the large drainage depressions).

- Sites in landform types 4 and 5 generally have consistent densities of artefacts of around 1 to 2/m^2. Densities are higher in type 4 than in type 5, as are the frequency and size of sites.

- Only one possible cairn was found in the Study Area and this was at Lake Blanche. Although definitely artificial, its origin is uncertain. There is no evidence that any of the rocks have been flaked, nor are there any associated stone artefacts to suggest an Aboriginal origin.

Table 5.4 The correlation between site type and terrain pattern type for all sites in the baseline and housing area surveys

Landform type	Quarry	Knapping floor	Campsite	Possible cairn
1	1	2	-	-
2	2	2	1	-
3	-	2	7	-
4	3	8	44	-
5	-	-	17	-
6	-	1	1	-
Lake Blanche	-	-	-	1

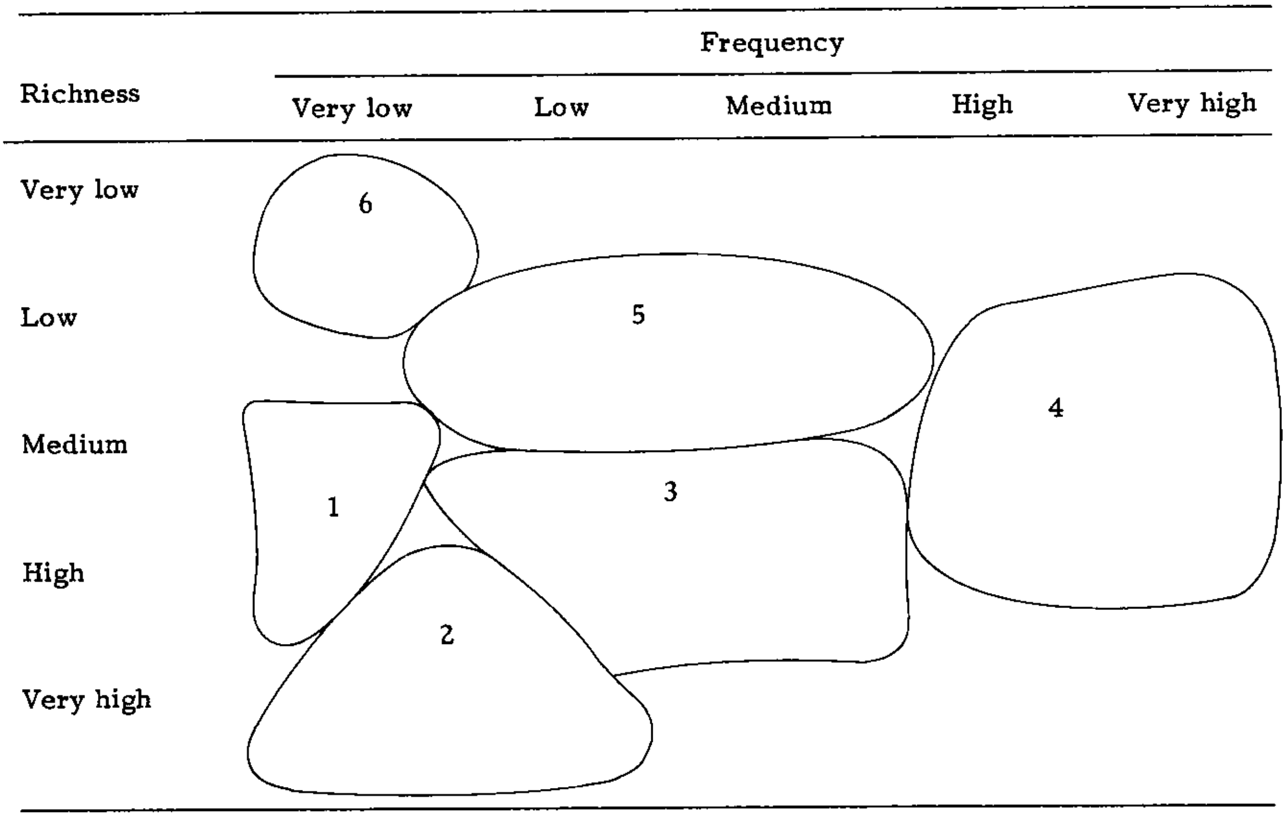
Note: Sites can be listed under more than one site type, e.g. campsite/knapping floor.

Site richness

As an overall indicator of 'richness', the total number of artefacts in a site was estimated from the average density of artefacts multiplied by its area. The estimated average total numbers of artefacts in sites in the random survey area are shown in

Table 5.1; the relationships between landform type and site richness and frequency are given in Table 5.5.

Table 5.5 Comparison of site frequency with site richness for the various landform types*



* Numbers are those of landform types.

In summary, the relationships given in this table are as follows:

- Landform type 2, and by inference type 1, has very occasional but often extremely rich quarries and knapping floors where suitable rocks outcrop. The most significant case surveyed had tens of thousands of artefacts.
- In landform type 3, where sites are more frequent, the average total number of artefacts is approximately the same (tens of thousands). Thus, although rich sites occur in this landform type, they are concentrated in limited parts of the landscape.
- In landform type 4, where sites are even more frequent, the average number of artefacts is very much lower, around 400 per site. Thus, in these areas, sites of medium to low richness have a high frequency.
- Sites in landform type 5 have on average fifty artefacts; therefore, it can be said that sites of a low richness occur with a low to medium frequency.
- In landform type 6, sites occur too infrequently to allow a precise assessment of richness, but it is taken to be generally low.

Implement types

The types and numbers of implements found in the Study Area are of special interest, particularly as some types occur much less commonly than might be expected. The implement types found and their major characteristics are detailed below:

- Geometric backed blades occurred at a large number of sites. They were mostly made of silcrete, using characteristic manufacturing techniques.

- Adzes, including tulas and burrens, were present. Implements of tula morphology (semi-circular or partly circular shaped implements for chisel-type uses) have been ethnographically recorded in similar arid environments in Central Australia as woodworking artefacts, so their presence here is not unexpected. However, burrens are not reported from South Australia. Both the burrens and the tulas were almost always made of chert.

- Few unifacial points were found, and almost none were of the typical pirri (Eyrean) or Fulham pirri forms (symmetrical points with completely trimmed outer face and plain inner face), although this part of South Australia is considered to be one of the areas in which this tool type flourished (Campbell and Noone 1943, Campbell 1960). The unifacial points found were often only retouched on one margin, at the distal end, and they occurred in a large variety of sizes. All the unifacial points were made of silcrete and now have a distinctive weathered patina.

- Very few large slabs of grindstone were observed, and it is assumed that they occur infrequently in the Study Area. However, this scarcity of grinding stones has important implications for the subsistence economy of the inhabitants. In many other parts of arid Australia, Aboriginal people depended heavily on grass seeds and on the seeds and nuts of a variety of shrubs and trees, which they ground into flour. The people subsisting on the resources in the Study Area were presumably not heavily exploiting such seeds and nuts.

- The only horsehoof cores (trimmed flake implements of large size and weight resembling a horse hoof in shape) were made of silcrete, and were found mainly near quarries.

Raw material usage

The raw materials found in each site relate closely to the availability of suitable raw materials from the local geological regimes, which are as follows:

- Qs (recent dune fields) - silcrete
- K (Cretaceous siltstones) - quartzite, locally silcrete
- A (Andamooka Limestone) - chert
- P (Arcoona Quartzite) - quartzite.

Silcrete appears to have been the preferred raw material over most of the area for the manufacture of flaked stone artefacts and, since sources of silcrete were never more than a few kilometres from any of the sites, its occurrence in raw material assemblages is ubiquitous. However, in a few areas of Andamooka Limestone where chert occurs abundantly, this material dominates the artefact assemblages.

In landform types 1 and 2, the diversity of raw materials on sites is extremely low, which is consistent with the specialist activities (quarrying and knapping of locally available raw materials) which were conducted in these areas. Sites in landform types 3, 4, 5 and 6 (where suitable raw materials are scarce) generally have a much more diverse range of raw materials in assemblages, reflecting the necessity for transporting these materials from other areas. Nevertheless, where suitable raw material is locally available, it tends to dominate the assemblages on campsites (and is the only material on the source quarries). In areas on Qs (and on K along the western margin of the Study Area), local silcrete is widely available and often makes up more than 95% of the artefacts in campsites.

Age of sites

In investigations such as this, where sites occur in the open and there is no apparent association of archaeological remains and organic materials which could be radiocarbon dated, the only practical indicators of the age of sites are their stratigraphic positions (considered in conjunction with topographic locality) and the presence of artefacts which can be approximately dated.

In the case of sites on dunes, it has become clear in the course of the various surveys carried out in the Study Area and infrastructure corridors that the archaeological remains are invariably being exposed in the top metre or so of loose sand. Close inspection was given to those areas where the cores of the dunes were exposed by wind deflation, fluvial gullying, or in road cuttings. In many cases the core material consisted of loose sand, but in other dunes (especially the large transverse dunes to the east of the landform type 3 drainage depressions) the cores were carbonate and/or clay-rich and indurated. Not a single artefact was found eroding out of the cores of such dunes. The results of research into the age and origin of these arid zone dune fields suggest strongly that they were largely formed in late Pleistocene times, but that the cappings of loose sand have remained mobile during the Holocene period. On the basis of this geomorphic evidence, it is concluded that most, if not all, of the archaeological material must date from the last 10,000 years.

However, the general character of the artefact assemblages is consistent with their belonging largely, if not entirely, to the 'small tool tradition'. The most useful time markers of this tradition are the backed blades which occur so commonly in the Study Area. Elsewhere in Australia, it has been established that backed blades were manufactured only between 5,000 years and (less certainly) 1,000 years ago. Unifacial points appear to have a similar age range. It is concluded, therefore, that the Study Area was effectively occupied only during the last 5,000 years, and that the bulk of the archaeological material dates from that period.

Variations in archaeological sites within terrain pattern types

Within terrain pattern types or individual terrain localities, there are variations in the frequency and nature of sites, which may be summarized as follows:

- Sites occur more frequently on dunes adjacent to pans than on dunes away from pans, reflecting a preference for camping on sand near water supplies.
- Sites near the pans have a greater diversity of raw material types than those further away.
- Quarries and knapping floors are clustered around outcrops of rock suitable for the manufacture of stone artefacts. The frequency and location of these sites is therefore very much determined by the location of such outcrops, although the richness of these sites is also influenced by such factors as proximity to water, and to sand on which to sit while knapping.
- Sites on the margin of a particular terrain locality can be influenced, often strongly, by neighbouring localities.

Variations in archaeological sites between terrain pattern types

Clearly, the preferred environmental setting for past Aboriginal activity was one where dunes, pans with water, and raw materials could be found in close proximity. These different landscape elements need not all occur within the one landform type, as evidenced in the discussion below, where very rich sites occur in the dunes of landform types 4 and 5 where these abut large drainage depressions (landform type 3). Similarly, where a tract of gibber plain (landform type 1) abuts a dune field (landform types 4 or 5), those dunes immediately adjacent to the plain (or no more than about 100 m away) contain by far the richest sites. Hence, in considering the archaeological remains in any given terrain locality, it is important to distinguish between core areas and boundary areas, as the latter is likely to have been influenced by adjacent terrain localities.

5.1.4 Predictive statement for the nature and distribution of sites

This predictive statement (which is tabulated in Table 5.6) is couched in terms of the types, frequency and sizes of sites, the nature and densities of artefacts and the diversity of raw materials.

Table 5.6 Summary of the nature and distribution of archaeological sites in the Study Area

Landform type	Summary statistics	Geology					Average for landform type
		P	A	K	Qs	Q	
1	Frequency*	very low		low			low
	Size**	-		-			-
	Density †	-		-			-
	RM diversity ††	-		-			-
2	Frequency	very low	low	low			low
	Size	-	medium	very large			very large
	Density	-	medium	very high			very high
	RM diversity	-	low	low			low
3	Frequency	very low	low	low		low	low
	Size	-	very large	large		very large	very large
	Density	-	very high	very high		low	very high
	RM diversity	-	high	average		high	high
4	Frequency	low	low	average	very high	high	high
	Size	large	medium	large	large	large	large
	Density	high	medium	medium	high	high	high
	RM diversity	average	average	high	average	high	high
5	Frequency	average	very low	high	low	low	average
	Size	medium	-	large	large	large	large
	Density	high	-	high	medium	medium	medium
	RM diversity	average	-	average	low	average	average
6	Frequency	very low	very low	very low		low	low
	Size	-	-	-		-	-
	Density	-	-	-		-	-
	RM diversity	-	-	-		-	-

* Frequency of sites in each terrain pattern is based on the following subjective scale: very low, low, average, high, very high.

** The scale for the size of site is: 10 m (small), 10-99 m (medium), 100-999 m (large), 1,000 m or greater (very large).

† The scale for the density of artefacts is: 0.1/m (low), 0.1-1/m (medium), 1-10/m (high), greater than 10/m (very high).

†† The scale for raw material (RM) diversity is: more than 90% one type of raw material (low), two types of raw material (average), three or more types of raw material, each more than 10%, (high).

Note: Dashes indicate insufficient information on which to base a summary statement. Gaps indicate that the particular combination of geology and landform does not exist.

In terms of the different landform types, the predictions are as follows.

Landform types 1 and 2 (plateau surfaces)

Generally, sites occur infrequently in these landform types and, when they do, they are usually quarries and knapping floors where locally available raw materials have been exploited. Often the sites are very large and have very high density artefact scatters.

Because of the specialized nature of the activities carried out on these sites, the diversity of raw materials is extremely low and there are rarely any implement types. Where isolated dunes occur within these landform types, they may contain rich, diverse campsites.

Terrain patterns P1, P2, and A2 generally have only sparse but localized sources of raw material: quartzite in the case of P (Arcoona Quartzite), and chert in the case of A (Andamooka Limestone). Terrain patterns K1 and K2 (in Cretaceous siltstones) are more complex. Along the western margins of the Study Area these terrain patterns are characterized by lags of silcrete cobbles, much of good quality, and here very rich and extensive quarry sites and knapping floors occur. Elsewhere, silcrete occurs only very infrequently but, where it does, quarry sites are to be found. Similar sites also occur infrequently where there are good quality quartzite cobbles and boulders.

It is difficult to predict the location of sites in these landform types except where suitable raw materials and isolated dunes are known to occur.

Landform type 3 (drainage depressions)

While campsites and associated knapping floors occur infrequently in landform type 3, they can predictably be found on sand dunes around the margins of the large moisture holding depressions which characterize this landform type. In many cases, the dunes upon which such sites occur are mapped as being within landform type 3. Equivalent sites occurring with similar frequency can also be found in the longitudinal dunes of landform types 4 and 5 adjacent to the depressions.

These sites tend to be very large and to have very high densities of artefacts. There is also a very high diversity of raw material types and a wide range of implement types, including the occasional piece of grinding stone. This combination of characteristics indicates that these drainage depressions and their associated dunes acted as focal points for occupation and supported a wide range of activities. Such sites are rated as being of particular importance in the Study Area.

Landform type 4 (widely spaced dune fields)

In general, sites in this landform type are medium to large in size, and have medium to high densities of artefacts (including a range of implement types) made from a low to average diversity of raw materials. Variations in the nature and frequency of sites are strongly dependent upon the geological regime. In terrain patterns P4, A4, and to a lesser extent K4, most of the sites are campsites on sand dunes, and tend to be concentrated around the interdunal pans. In these terrain patterns, sites occur with low to average frequency. In contrast, in Qs4 (and to a lesser extent in Q4) where silcrete outcrops, quarry sites and associated knapping floors also occur and the frequency of sites is very high.

Compared with landform types 1, 2 and 3, sites in landform type 4 are more evenly dispersed across the landscape. Campsites occur more frequently, are richer, and are more diverse on those sand dunes which are adjacent to pans. In contrast, sites in dunes adjacent to quarries (especially silcrete) tend to consist of knapping floors with a low diversity of raw material.

Predictably, the richest sites in this landform type are to be found in the dunes adjacent to areas where pans and silcrete quarries occur in close proximity.

Landform type 5 (moderately spaced dune fields)

The nature and distribution of sites in this landform follow the same pattern as that for landform type 4, except that sites occur much less frequently and tend to be less rich.

This is taken to reflect the less frequent occurrence of pans and of outcrops of raw material, due in part to the increased cover of sand.

Landform type 6 (closely spaced dune fields)

Sites occur very infrequently in landform type 6, presumably because of the greater extent of sand cover.

5.1.5 Regional testing of the predictive statement

Fieldwork procedures

The predictive statement developed in the baseline archaeological study was tested in areas outside the Project Area. Data was used from earlier surveys of the road to the south (Phillip Ponds to Purple Downs, discussed below), and a regional reconnaissance was undertaken in areas to the west and north of the Study Area (which topographical and geological maps indicated had a similar range of terrain types to that found in the Baseline Study Area). The areas selected for this reconnaissance were chosen not on a systematic basis, but on the basis of accessibility, amount of exposure, and whether the areas could be accurately located on maps. This expanded Study Area extended 60 km west-north-west of the Olympic Dam village to Curdlawidny Lagoon and 30 km north to Mattaweara Lagoon (Figure 5.1).

In discussing the results of this reconnaissance, the area was divided into the following three zones:

- Barber Ridge to Red Lake: a tract of dune field comprising landform types 4, 5 and 6, with widespread outcrops of silcrete;
- Red Lake to Curdlawidny Lagoon: an area dominated by large drainage depressions of landform type 3 surrounded by a tract of diverse dune field;
- Mattaweara Lagoon: a drainage depression of landform type 3, with a tract of dune field country to the north, and gibber plains of landform types 1 and 2 in its southern sections.

Results of regional survey

Generally, the nature and distribution of sites discussed in the road survey and in the regional reconnaissance accord closely with the predictive statement. It is concluded therefore, that this statement can be applied over the dune field and gibber plain tracts of country within a radius of at least 50 km from the Olympic Dam village, and probably much wider afield. Detailed results are set out below.

Phillip Ponds to Purple Downs road survey: A total of twenty-two campsites and one quarry were recorded on this route. The southern part of the route consists of featureless gibber plain (terrain patterns P1 and P2), where no sites were located, although a subsequent helicopter reconnaissance of isolated dunes on the gibber plain to the east of the road revealed sites on these dunes (as would be expected from the predictive statement). The northern part of the route crosses a dune field of landform types 4 and 5. Within this dune field the nature, frequency, and location of sites in the landscape broadly reflected:

- a preference for camping on sand;
- the location of the richest and most diverse sites in close proximity to the major claypans and canegrass depressions likely to hold water after heavy rainfall;

- the location of rich sites in close proximity to sources of raw material, in this case silcrete. Such sites generally also occurred close to pans and had an extremely low diversity of raw material and implement types.

Along parts of the route where the dunes are closely spaced and the swales tend to be mantled with sand, very few sites were recorded. The two richest sites both occurred adjacent to pans which were located in the relatively open swales.

Barber Ridge to Red Lake: The nature and location of sites observed in this area showed an excellent correlation with the predictive statement. In tracts of country of landform type 6 very few sites were observed, and those which were found consisted of very sparse scatters of artefacts. In contrast, in areas of landform type 4, especially where pans and stone raw materials (in this case silcrete) occur in close proximity, comparatively rich sites were identified (Table 5.7).

Table 5.7 Character of sites in the Barber Ridge–Red Lake dune field

Site no.	Density no./m²	Raw materials			Location with respect to:		Landform type
		Silcrete	Quartzite	Chert	Pans	Source of raw material	
180	2	d	m	m	+	+	4
181	5	d	m	m	+	+	4
200	0.01	d	-	-	-	-	5
201	1	d	m	m	+	+	4
202	2	d	m	m	++	+	4
203	10	d	m	-	++	+	4/5
204	1	d	m	m	+	+	5

Note: d = dominant
m = minor
++ = immediately adjacent
\+ = within 500 m
\- = not evident.

Red Lake to Curdlawidny Lagoon: The sites in the dune field away from the major drainage depressions correlated closely with the predictive statement. Of the three sites in the dune field close to these major depressions, two were located close to pronounced pans and had extremely rich and relatively diverse artefact assemblages (Table 5.8).

Sites within the drainage depressions were highly variable in character and environmental setting. With the exception of one site, sites on sand ridges fronting the major lake/lagoon surfaces were not particularly rich or diverse, and in general the richest and most diverse sites were immediately adjacent to local pans within the major depressions. In this area there was considerable exposure of late Pleistocene and early Holocene sediments, but no artefacts were found eroding out of them, suggesting that most if not all of the archaeological material recorded is late Holocene in age.

Mattaweara Lagoon: Within the gibber plain tract of country, the rich and diverse sites on isolated dunes and a quarry/knapping floor found on the gibber plain all fitted the predictive model. The sites around Mattaweara Lagoon and in the immediately adjacent dune field have comparatively rich and diverse artefact assemblages and, as expected, the amount of archaeological material reduces rapidly northwards into the dune field.

Table 5.8 **Character of sites in the Red Lake-Curdlawidny Lagoon area**

Site no.	Density no./m^2	Raw materials			Location with respect to:		Landform type
		Silcrete	Quartzite	Chert	Pans	Source of raw material	
Sites in the dune field away from the drainage depressions:							
187	0.1	d	m	m	-	-	5
189	0.2	d	-	-	-	-	5
190	5	d	m	m	++	+	4
198	0.1	d	m	-	+	-	4
199	10	d	m	-	+	+	4
Sites in the dune field adjacent to the drainage depressions:							
184	100	d	m	m	++	+	4
186	1	d	-	-	+	+	4
191	50	d	m	m	++	+	4

Note: d = dominant
m = minor
++ = immediately adjacent
\+ = within 500 m
\- = not evident.

5.1.6 Impact assessment surveys in the Project Area

The detailed site records formulated for the Project Area were selectively sampled in order to assess likely impacts and to establish mitigation measures. The fieldwork and recording strategies used in this stage, and the results of the survey, are reviewed here in sufficient detail only to indicate the basis of the conclusions reached, the assessments made of the archaeology of the area, and the recommendations made regarding mitigation and salvage requirements. A detailed account of this work is presented in a separate and confidential report, a copy of which has been submitted to the Heritage Conservation Branch of the Department of Environment and Planning.

Most of the central and western part of the operations area is in widely spaced dune fields, primarily in terrain pattern Qs4 but with a tract of A4 in the north-east corner. The eastern part of the area is of terrain pattern Qs5, with smaller areas of this pattern type in the south-west corner and along the southern margin of the mine development area.

Most of the town site area lies in a closely spaced dune field characterized by terrain patterns Q5 and Q6. Andamooka Limestone crops out along the north-western margin of the town site, and this limestone is overlain by widely spaced dunes in the far north-west corner. Along the central portion of the eastern margin of the town site is an area of Q4.

The following predictive statement (based on the criteria discussed in the baseline study) was made with respect to the nature and distribution of archaeological sites which would be found in these areas:

- In general, sites in landform type 4 would be medium to large in size, and have medium to high densities of artefacts (including a range of implement types) made on a low to average diversity of raw materials. Variations in the nature and frequency of sites would be strongly dependent upon geological regime. In terrain pattern Qs4, where silcrete crops out, campsites and campsites with knapping floors would occur in the dunes (especially around pans), with quarries and associated knapping floors in the swales, and the frequency of sites would be high. This situation pertains to much of the operations area. In contrast, in terrain pattern A4, campsites on sand dunes would be the most common type of site, and these would tend to be more closely concentrated around the interdunal pans. The frequency of sites would also be lower. This situation pertains to parts of both the operations area and the town site.

In general in landform type 4, campsites would occur more frequently, and would be richer and more diverse, on sand dunes adjacent to pans. In contrast, sites in dunes adjacent to quarries (especially silcrete) would tend to consist of knapping floors with a low diversity of raw material. Predictably, the richest sites would be found in the dunes adjacent to where pans and silcrete quarries occur in close proximity.

- In areas of landform type 5, the nature and distribution of sites would follow the same pattern as for landform type 4, except that sites would occur much less frequently and would tend to be less rich. Because of silcrete outcropping, the amount of archaeological material in Qs5 would nevertheless be higher than in Q5. Sites would occur very infrequently in landform type 6 because of the greater extent of sand cover.

  The eastern part of the operations area is on terrain pattern Qs5, and most of the town site is on either Q5 or Q6. The amounts of archaeological materials in these areas would therefore be expected to be noticeably less than in the areas on terrain patterns Qs4 and A4.

Survey and recording strategies

Because of the size of the area involved (about 25 km^2 in the operations area and 40 km^2 in the town site), it was neither practicable nor appropriate to survey the entire area. Therefore, a sampling strategy was developed to ensure that a representative sample of sites in the impact areas was recorded. From this sample, a rational assessment of impacts could be made, and mitigation measures or the necessity for further survey or salvage work determined where necessary. The sample areas in the Project Area were chosen on the following basis:

- Areas which had already been affected by development to varying degrees were excluded from consideration. These included the Whenan Shaft area (much of which had already been surveyed and the results of which are also described below) as well as the present village and associated infrastructure.

- Areas of Qs5 were also excluded, as previous survey work (including the Whenan Shaft survey and the infrastructure corridor surveys) had indicated that these had a paucity of archaeological materials and were less likely to contain scientifically important sites than areas of Qs4 and A4.

- In those areas which to date remain relatively undisturbed, the selection of samples was designed to allow investigation of sites across as much of the Project Area as possible, while at the same time ensuring that substantial parts of those areas which are to be most heavily impacted were included.

- Once areas were selected, their boundaries were established to ensure the inclusion of a variety of microenvironments, especially those both close to, and distant from, pans.

On this basis, three areas were selected in the operations area for detailed survey, and are labelled A, B and C on Figure 5.2.

A This area, in the north-west of the Project Area, overlaps a large part of the proposed tailings retention area. It was subdivided into a northern part (which is away from large pans and is of terrain pattern A4) and a southern part (where there are several large pans and the terrain pattern is Qs4).

B This area is close to the centre of the Project Area and covers parts of the plant area and workshop and store. The dunes in its southern part are westerly extensions of those included in Area C. It is almost entirely on terrain pattern Qs4.

C This area covers most of the process water storage area, the water treatment plant, and associated facilities. It is almost entirely on terrain pattern Qs4.

In the town site, a tract of land which included the only area likely to yield appreciable numbers of sites (terrain pattern A4) as well as an area of Q5 was selected for detailed survey. This is Area D shown on Figure 5.2. This sample had the advantage of being readily accessible from the Axehead Dam road. A transect south from this sample area across the Q5 and Q6 terrain patterns was made by vehicle.

A total of fifty working days was spent by the team on the systematic survey and recording of sites. The areas surveyed were about 60% of each of Areas A and B, and about 55% of Area C. The entire sample area chosen for the town site (Area D) was surveyed and a vehicle transect south through the core of the dune field was undertaken.

The crests and flanks of the dunes were completely surveyed on foot, as were all exposures on the floors and margins of pans. The swales were surveyed by vehicle traverse, and areas of ground surface with either bare soil or visible rock were inspected. Outcrops of silcrete were examined for evidence of quarrying.

In the previous surveys, the settings, nature and contents of the sites recorded were described in qualitative terms only. The dimensions of the sites, types and proportions of raw materials, and densities of artefacts, were estimated rather than measured, and couched in general terms such as 'backed blades are common', or 'chert flakes dominate'. This 'summary recording' can be done quickly, but has severe limitations when the data is analysed, and may prove in many cases to provide an inadequate record of the site for management purposes. Accordingly, for this stage of the survey an 'analytical recording' method was devised, aimed at providing quantitative data on the following:

- location of the site
- immediate environment of the site
- distance to water
- recorder's perception of the way in which the site had been affected by exposure
- size of the site
- contents of the site
- spatial pattern of the contents
- density of stone artefacts on the site
- types of raw materials from which the stone artefacts had been made
- sizes of the artefacts
- morphologies of the artefacts
- size and type of implements found.

The data was recorded in a format which will allow computer analysis of the results. In addition to obtaining the records specified on the recording form, notes of a more qualitative nature were also taken.

Not all sites were recorded analytically. Smaller sites (those having a total of less than about fifty artefacts) and sites where the maximum density of artefacts did not exceed about $5/m^2$ were generally recorded in summary form.

Site definition

The limits of open sites such as those in the Study Area are commonly difficult to define, especially where the density of material is sufficiently high for a 'background' scatter of artefacts of $1/10\ m^2$ - $1/100\ m^2$. The dense concentrations which might be defined as sites are superimposed on this background scatter. There is, therefore, a problem of site definition, which is compounded by the generally discontinuous exposure of these materials.

Most sites in the Study Area, other than quarries and associated knapping floors, occur in blowouts on the crests and flanks of dunes, where the limits of the sites are readily defined by the limits of the blowouts. The archaeological material is generally confined to the top metre or so of sand, and is rarely visible except where wind deflation has lowered the surface by at least 500 mm. The degree of exposure of archaeological materials on dunes appears to be relatively even across the landscape, and hence the sites recorded can be taken as an accurate, if incomplete, reflection of the true nature and distribution of materials on these landforms.

The definition of site limits is generally more problematical for sites in swales, on the floors of pans, or around their margins. Such sites commonly cover very large areas (tens of thousands of square metres) and are characterized by numerous distinct activity areas, such as quarried outcrops of rock and knapping floors set in a relatively dense background scatter of artefacts. Compared with the more precisely defined and smaller sites in dune blowouts, such sites are probably best seen as site complexes, although in this study they have been recorded as single sites.

Results of the Project Area surveys

The results of the surveys of Areas A, B, C, and D as well as the results of the Whenan Shaft survey are provided in Table 5.9. A total of 176 sites was recorded for Areas A, B, C, and D in the operations and town site areas. Of these, 147 were campsites or campsites with knapping floors, twenty-three were knapping floors only, and six were quarries, some with associated knapping floors.

For the Whenan Shaft area survey, thirty-two sites were recorded, comprising twenty-eight campsites (many with knapping floors) and four quarry sites with associated knapping floors. A number of isolated artefacts were also found.

In Area A, the frequency of sites is low at $9/km^2$ and there are few sites where the average density of artefacts in the scatters exceeds $5/m^2$. As a whole, this area has a paucity of pans likely to hold water after rain, especially in the north, which accounts for the relatively low frequency of sites and the low density of materials on them. It is noteworthy that while most sites lie within 500 m of water, the locations of more than 30% exceed this distance from water. In the northern part of the area, where there are very few pans which would hold water, the frequency of sites is particularly low at $6.5/km^2$ (thirteen sites in $2\ km^2$). In the southern part there is one large, pronounced pan with a number of sites clustered around it, but other large pans have very few sites around them. It appears that these pans do not in fact hold water to any greater extent than other less distinct pans which are readily identified in the field, but not on aerial photographs.

In Areas B and C, the frequency of sites is high at 20 to $24/km^2$, and about 35 to 40% of the sites have average densities of artefacts in excess of $5/m^2$. There appear to be several water-holding pans in these areas and, while most sites lie within 100 m of such

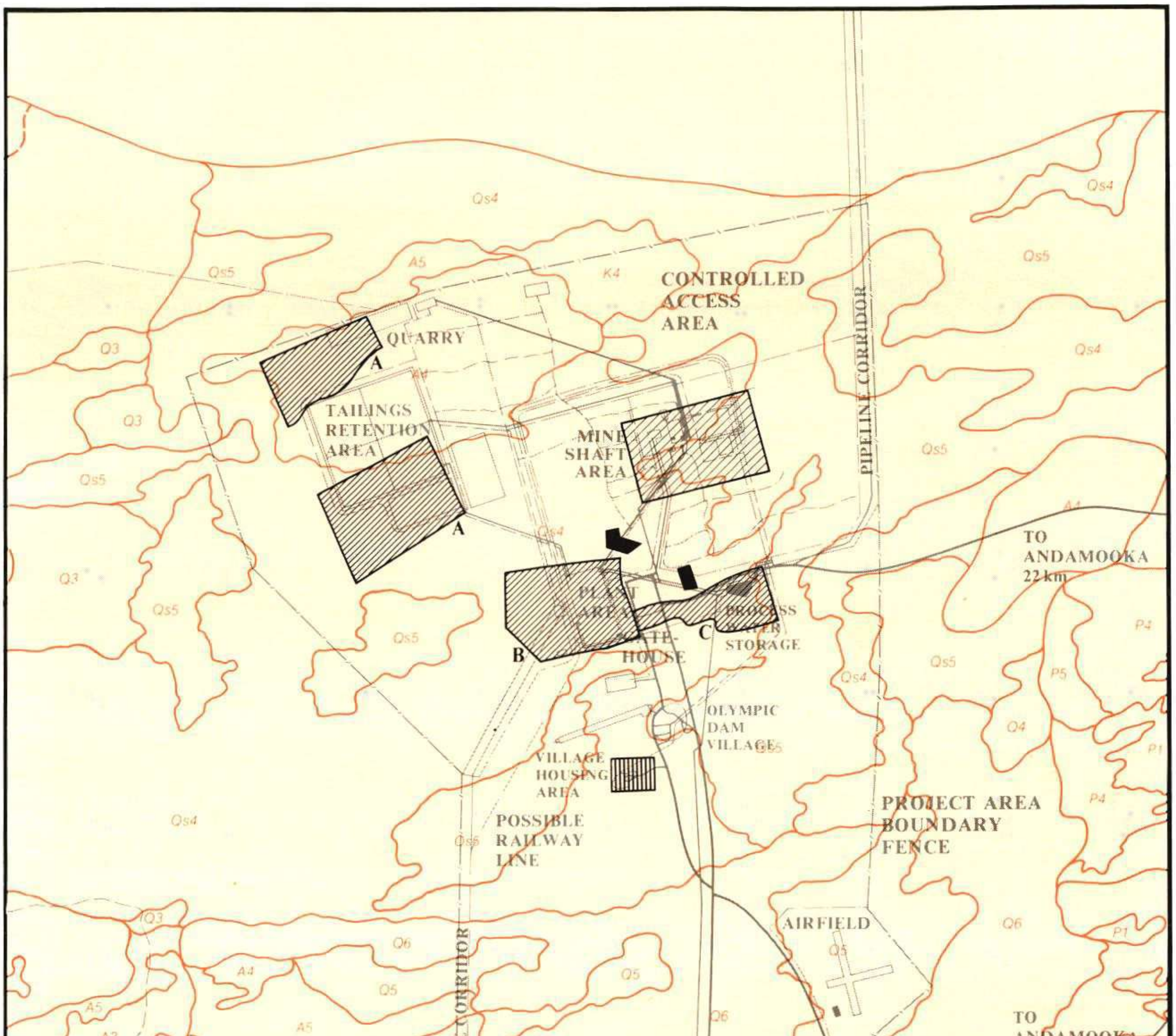


Figure 5.2

ARCHAEOLOGICAL SURVEYS IN THE PROJECT AREA

pans, there is no clear relationship between site distribution and proximity to water. The paucity of sites further than 500 m from water simply reflects the fact that very few parts of these sample areas lie further than this distance from pans. Sites with high density artefact scatters combined with a high diversity of raw materials and artefact types tend to be located close to pans, generally within 200 m.

Table 5.9 Characteristics of archaeological sites recorded in the Project Area surveys

Characteristics	Area A 209-259*	Area B 260-328*	Area C 329-371*	Area D 372-384*	Total
Total no. of sites	51	69	43	13	176
Campsites (and those with floors)	42	59	35	11	147
Knapping floors only	9	9	3	2	23
Quarries and knapping floors	0	1	5	0	6
Sites in each density class (%)					
$1/m^2$	(40)	(36)	(27)	(70)	
$1-5/m^2$	(52)	(31)	(33)	(30)	
$5-10/m^2$	(7)	(29)	(5)	(0)	
$10-25/m^2$	(1)	(4)	(25)	(0)	
$25-50/m^2$	(0)	(1)	(5)	(0)	
$+50/m^2$	(0)	(0)	(4)	(0)	
Campsites at following distances from water-holding pans (%)					
100 m	(26)	(50)	(63)	(40)	
100-500 m	(43)	(43)	(37)	(40)	
500-2,000 m	(31)	(7)	(0)	(20)	

* Olympic Dam Project site numbers.
Note: Percentages may not add due to rounding.

In Area D, the frequency of sites is low at $7/km^2$, and the density of artefacts in the scatters does not exceed $5/m^2$. Of the thirteen sites recorded, eleven were in close proximity to the only pan occurring in, or close to, the sample area, only two were found in the Q5 dune field, while none were recorded to the south in the Q5 and Q6 dune field.

For the Whenan Shaft area, the extent and depth of sand deflation was similar on all the dunes, and the nature and distribution of campsites indicated by the survey results were taken to be a reasonable reflection of the true nature and distribution of such sites. Very few blowouts less than 1 to 1.5 m deep contained artefacts, suggesting that archaeological remains on the dunes in this area were generally buried by at least 1 m of loose sand. A feature of these sites, especially those in the eastern half of the survey area, were the large numbers of unmodified small pebbles associated with the stone artefacts. Silcrete crops out in several places in the swales across the Study Area. Four quarries were recorded during this survey, and another had been recorded by Fitzpatrick (1980). Quartzite cobbles also occur widely in the swales but no good quality chert was observed. The nature and distribution of archaeological sites in the Whenan Shaft area was as expected for a tract of dune field grading between terrain types Qs4 and Qs5.

Silcrete occurs ubiquitously on sites in all areas. It overwhelmingly dominates the assemblages in Areas B and C (90 to 100% of the flaked material), with the remainder being made up of roughly equal proportions of chert and quartzite.

In Area A, quartzite is an important component of the assemblages (commonly up to 50% and occasionally much higher). A siliceous breccia, identified in the baseline study as being derived from the Andamooka Limestone, crops out locally in Area A, and sites near these outcrops tend to have a high proportion (up to 30%) of this material. Chert is common on sites in the northern part of Area A (up to 70%), but is generally only a minor component in the southern part of the area. This appears to reflect the difference in geological regime, the northern part being on Andamooka Limestone whereas the southern part is of Qs.

In Area D, which is on Andamooka Limestone, chert and silcrete occur in roughly equal, but highly variable, proportions on sites, and there is very little quartzite. Where this does occur, flakes and cores of quartzite tend to be the largest artefacts on sites, with those of chert being the smallest. Of the diagnostic and retouched artefacts, relatively few are made of quartzite, whereas in contrast a relatively high proportion are made of chert. Backed blades and unifacial points tend to be of silcrete, while tulas are generally of chert (Table 5.10). Again, very few unifacial points were recorded compared with tulas and backed blades. Two further burrens were recorded, confirming that they do occur in this region. Relatively few pieces of grindstone were found, and generally did not show evidence of the heavy grinding use which would have been required for seed preparation. Some pieces were, however, very heavily ground and were similar to seed grinding equipment to be found elsewhere in arid Australia.

Table 5.10 Implement types and their raw materials (survey areas A, B, C and D)

	Silcrete	Chert	Quartzite	Siliceous breccia	Sandstone	Total
Backed blades	26	6	1	0	0	33
Tulas	7	25	2	2	0	36
Burrens	1	1	0	0	0	2
Unifacial points	10	1	0	0	0	11
Amorphous retouch	140	70	25	3	0	238
Grindstones	0	0	28	0	1	29
Hammers and anvils	5	0	119	0	2	126

On the basis of the qualitative observations of the data base discussed above, it is concluded that there is a good correlation between the results of the survey and the predictive statement. Further, it is concluded that this data, when considered in conjunction with the findings of earlier surveys in and around the mine development and town site areas, forms a sound basis for making an assessment of the impact of the overall development on archaeological sites, and for putting forward recommendations concerning mitigation and the need for further work. Before such an assessment is made however, a number of sites recorded in the Project Area survey which are deemed to be of particular scientific value are described.

Sites of special scientific value

The following sites are noteworthy from a scientific point of view. (They are referenced by the number given in the more detailed reports supplied to the Heritage Conservation Branch of the Department of Environment and Planning.)

- Site 222, Area A - campsite with knapping floors:

  - Landform: Crestal blowout in dune immediately adjacent to the largest pan in the sample area, containing the knapping floor complex Site 259 described below.

  - Description: The site is about 85 x 60 m in area, and the artefact scatter averages 5 to 10/m². A range of silcrete dominates the assemblage, but there are appreciable amounts of quartzite and a wide range of cherts. The site is noteworthy for the large number and wide range of retouched artefacts (including backed blades and tulas), many of which appear to have been manufactured at the site.

- Site 237, Area A - campsite with knapping floors:

  - Landform: Crestal blowout in dune 500 m to the west of Sites 222 and 258.

  - Description: Over an area of about 160 x 40 m there is a scatter of artefacts at 1 to 5/m². There is a wide range of silcretes and cherts and some quartzite. Similarly to Site 222, this site has a large number of retouched artefacts (including backed blades and tulas), many of which appear to have been manufactured on the site.

- Site 258, Area A - campsite with knapping floors

  - Landform: On the western flank of a very small dune in a broad swale. The nearest water is within 500 m, and the surrounding swale is rich in good quality raw material including quartzite and chert.

  - Description: The site is about 50 x 30 m in area and contains a scatter of artefacts at 5 to 10/m². Quartzite is the dominant raw material, but there is also a diverse range of silcretes and cherts. The most noteworthy aspect of this site is the large number of tulas compared with other retouched artefacts, suggesting that tulas were manufactured on the site. Few such sites have been identified in the Study Area.

- Site 259, Area A - complex of knapping floors:

  - Landform: A kidney-shaped pan 600 x 300 m in area. This pan is the major landscape feature in the southern half of Area A.

  - Description: On the floor and margins of this pan are numerous knapping floors. More than fifty distinct knapping floors were recognized, most of quartzite, but others were on a wide range of chert types. A high proportion of these floors are still intact, with little of the artefactual material apparently having been removed. There is evidence that a wide range of knapping techniques were employed in working these materials.

- Site 299, Area B - campsite with knapping floors:

  - Landform: Crestal blowout in longitudinal dune. There is a pan within 100 m of the site.

  - Description: The site in 30 x 20 m in area, with the average density of the artefact scatter being 5 to 10/m², dominated by silcrete. The major characteristic of this site is the number of unfinished backed blades which it contains, and it appears that these artefacts were being manufactured on the site.

- Site 325, Area B - campsite:

  - Landform: In a crestal blowout on a longitudinal dune. Water available within 500 m.

  - Description: The site is 40 x 30 m in area and contains a scatter of artefacts at 5 to $10/m^2$. A range of silcrete varieties dominates the assemblage, but there are also varieties of chert and a little quartzite. The major feature of this site is the large number and variety of retouched artefacts and the large number of grindstones, some of which appear to have ochre on them.

- Site 330, Area C - campsite with knapping floors:

  - Landform: In a blowout on the southern flank of a dune within 100 m of a pronounced pan.

  - Description: The site is 20 x 6 m in area, and consists of two distinct silcrete knapping floors in a dispersed scatter of silcrete flakes and cores. The knapping floors contain very dense concentrations of artefacts (25 to $50/m^2$), they are still largely intact, and show a complex reduction technology. Knapping floors of this complexity and in such a good state of preservation are rare in the Study Area.

- Site 347, Area C - quarry/knapping floors:

  - Landform: A large, pronounced pan 500 x 250 m, littered with cobbles and boulders of silcrete and partially silicified sandstone.

  - Description: On the floor of the pan is a complex of quarried outcrops and knapping floors, all on silcrete. These features demonstrate the use of a wide range of knapping and quarrying techniques.

- Site 364, Area C - campsite with knapping floors:

  - Landform: Crestal blowout in dune adjacent to a small but pronounced pan.

  - Description: Over an area of about 30 x 20 m is a scatter of predominantly silcrete artefacts, at a density in excess of $50/m^2$ and in places up to $180/m^2$. This site has a very large number and wide range of retouched artefacts including tulas and backed blades. Most importantly, it also contains a number of unifacial points, and it appears from their nature and association with the material in some of the knapping floors that these implements were manufactured on the site. This is the only site in the area where evidence of such manufacture has been recorded. Further, the relevant knapping floors are eroding out of the flanks of the blowout and the possibility exists of finding stratified material by excavation.

5.1.7 Stone arrangements

The predictive statement developed above relates only to those sites which reflect the economic activities of the Aboriginal people who occupied the area. It therefore identifies quarries and surface scatters of artefacts in the form of knapping floors and campsites, but does not include stone arrangements. After on-site personnel reported the existence of possible stone arrangements on the floors of a number of claypans in the vicinity of the Olympic Dam Project Area, a separate survey specifically for stone features was undertaken by helicopter, covering the Project Area and the southern infrastructure corridor (Figure 5.1). The location and detailed description of these sites are not presented here, but have been given in a separate confidential report to the Heritage Conservation Branch. The references and numbering given below are consistent with those in this separate report.

Seventeen stone features were identified in the course of the survey and associated field work. Of these, five have a definite artificial component, one has a possible artificial component, five are most likely to be natural but resemble those with artificial components, while the remaining six are natural outcrops of silcrete. There is also one other natural stone configuration (SF17) which, in 1980, the Aboriginal Heritage Unit (now the Heritage Conservation Branch) suggested was a possible enthnographic site. Representatives of the Kokatha People's Committee have subsequently claimed this stone feature as being important to their people.

Of the stone features with a definite artificial component, there is little doubt that SF1 is Aboriginal in origin. It contains numerous stone lines and circles which are extensions of the natural gibber deposits, and extends over several hundred square metres. Similar stone arrangements elsewhere in South Australia are known to be of ceremonial significance to Aboriginal people.

It is more difficult to account for the other stone features with a definite artificial component. Whether they were constructed by Aboriginal people, by Afghans, by early European settlers, or by stockmen in more recent times, remains to be resolved. There is nothing in the character of any of these sites which is inconsistent with an Aboriginal origin. As the stone features with artificial components are similar to natural stone configurations, these natural configurations may also have been incorporated in Aboriginal mythology.

5.1.8 Project impact and mitigation measures

General considerations

A considerable amount of archaeological survey work has now been carried out in relation to the Olympic Dam Project, and the 437 sites recorded are detailed in Table 5.11. A predictive statement of the nature and distribution of archaeological sites (based primarily on mapped environmental criteria) has been developed and tested, and found to provide a sound basis for characterizing the archaeology likely to be encountered in a wide range of landscape settings. As noted, this predictive statement is applicable only to sites reflecting the economic exploitation of the resources of the region by its prehistoric inhabitants, and cannot be used directly to predict the nature and location of stone arrangements (although it can indicate the likely nature and frequency of such features). No burial sites were encountered in the course of any of these surveys.

On the basis of the predictive statement the impact of development activities can be assessed. The mining development will involve the construction of major roads, access tracks, buildings, plant, and tailings retention area, and the quarrying of limestone, sand, gravel and clay. There will also be considerable development of infrastructure, such as electricity transmission lines and water pipelines. As all the sites in the region are at or near the surface, activities requiring surface clearance will destroy or severely damage any sites in those areas. In general terms, the effects on archaeological sites for the different landforms are expected to be as follows:

- In landform type 6 and much of type 5, archaeological sites are likely to occur very infrequently and to be of relatively low scientific value. Accordingly, the protection and/or salvage of sites in these areas could be given a low priority in any management strategy.

Table 5.11 **Archaeological sites recorded in the Olympic Dam region surveys**

Survey area and Olympic Dam Project site numbers	Campsites (including knapping floors)	Knapping floors only	Quarries including knapping floors	Stone cairns	Total no. of sites
Road corridor, Olympic Dam to Purple Downs (Nos. 80-124)	41	1	2	1	45
Road corridor, Purple Downs to Phillip Ponds (Nos. 125-147)	22	0	1	0	23
Baseline survey (Nos. 1-58)	51	1	5	1	58
Housing area survey (Nos. 59-79)	16	4	1	0	21
Regional survey (Nos. 180-208)	27	0	2	0	29
Whenan Shaft survey (Nos. 148-179)	28	0	4	0	32
Project Area survey, Areas A, B, & C (Nos. 209-371)	136	21	6	0	163
Town site survey, Area D (Nos. 372-384)	11	2	0	0	13
Pipeline survey (Nos. 385-437)	48	0	5	0	53
Total	380	29	26	2	437

- In landform types 1 and 2, sites are also likely to occur very infrequently, although the larger and/or specialized sites (in both cases quarries with knapping floors) will generally be of more scientific value than sites in landform types 5 and 6 above. Sites are likely to occur more frequently on isolated dunes within these landforms and in areas where silcrete occurs (especially K1 and K2). With the exception of such areas, there is little chance that development activities in these landforms would affect scientifically important archaeological sites.

- In landform type 3, important sites are likely to occur in dunes around the major drainage depressions. It would be desirable if these sites could be maintained. However, where development of these sites occurs, those to be affected could first be thoroughly surveyed and salvage excavations/collections undertaken where necessary. Elsewhere in this landform there is very little risk that archaeological sites would be affected.

- In landform type 4, sites of scientific value occur widely across the landscape, and development in these areas will inevitably lead to the destruction of large numbers of sites. Localities on Qs4 (and to a lesser extent Qs5) are particularly archaeologically rich because of the widespread occurrence of silcrete. It must be stressed that much of the proposed development is to take place in Qs4 and Qs5.

Impacts in the Project Area

Approximately 40% of the operations area was surveyed. However, as the survey was not confined to areas to be directly impacted, the proportion of the area to be developed which was covered in the survey was considerably less than this (about 25%). This was because the survey strategy aimed at recording a representative sample of sites rather than only those sites likely to be impacted. When the areas covered by the Whenan Shaft and baseline study surveys are included (2.5 and 0.5 km^2 respectively), the total proportion surveyed rises to about 35 to 40%.

At the town site, less than 10% of the area was surveyed. However, this included a high proportion of the terrain pattern A4 landscape, deemed likely to be the main area to contain a reasonable number of sites. The only other area likely to contain a reasonable number of sites, terrain pattern Q4, was sampled in the baseline survey (Figure 5.2).

Most of the survey work carried out in these two areas involved recording at the analytical level, and a very large body of archaeological and environmental data for about two hundred sites has been gathered. This survey has confirmed at a detailed level that there are predictable patterns in the nature and distribution of sites across the landscape. It is concluded that further survey work within the limits of the Project Area would be unlikely to substantially add to, or alter, the understanding of archaeological sites within this area.

Much of the operations area, and part of the town site, covers areas of landform type 4 (especially Qs4). Within such areas, and to a lesser extent within those on landform type 5, archaeological materials occur widely across the landscape, and no possible management strategy could prevent the destruction of the large numbers of sites which will be directly affected. However, the suite of archaeological sites within these areas is not unique, as there are large tracts of country surrounding the Olympic Dam area which contain essentially the same range of site types in the same environmental settings. For most of the sites recorded it would be difficult to argue on grounds of uniqueness or on scientific grounds that they should be protected against damage, salvaged, or even recorded in greater detail. Several sites are, however, deemed to be of special scientific importance, and recommendations concerning the need for further work are made below. More detailed recording was not carried out at these sites because, in the time allocated for the survey, emphasis was placed on ensuring that a representative sample of sites was recorded, to allow an assessment to be made of how widespread such sites might be. Nor was any attempt made to salvage or excavate the materials on these sites.

Mitigation measures

Because archaeological materials occur ubiquitously over much of the area to be developed, no specific recommendations were made by the archaeologist concerning the siting of the components of the development. If any of these components were to be relocated on the basis of impact on archaeological sites, it is highly likely that similar sites at the newly selected locations would be similarly affected. However, damage to sites will be minimized by restricting heavy machinery movement where practicable. The dunes, and the floors and margins of pans are particularly archaeologically sensitive, and disturbance of these will be avoided as far as practicable.

In the light of survey work undertaken and the nature of the intended development, the following actions are proposed.

Project Area data: A representative sample of sites already recorded from the Project Area has provided a sufficiently detailed data base to allow the reconstruction of the salient features of their archaeology. No further survey work is considered warranted within the confines of the Project Area.

Stone features: None of the stone features is directly threatened by the proposed development, although a number of the smaller examples lie close to areas which will be developed. Exploration activity has been directed away from tracks leading to the major features. However, before a management plan can be formulated in relation to those sites, an indication of their Aboriginal significance is required. (Note that members of the Kokatha People's Committee assert that damage has occurred to a natural configuration of stones (SF17) which they claim is an initiation site. Much of the alleged damage is due to weathering processes, although two stones appear to have been broken in recent times, but when and by what agency cannot be established: RMS has undertaken exploration activities in the general area, pastoral activity has been practised in that area for many years, and Andamooka residents and other members of the general public have, until recently, had access to the area. On being advised of the Aboriginal interest in the site, RMS has restricted access to the area.)

Sites of special scientific value: A number of sites of special scientific value have been recorded. These will be the subject of even more detailed work, as they will provide insights into aspects of the archaeology of the area which could not be gained simply from recording the sites. These include aspects such as the manufacture and use of a variety of implement types, including backed blades, tulas, unifacial points and grindstones. It is therefore proposed that further recording, salvage, and excavation work be undertaken at these sites, which are listed below in order of priority:

- Site 364. This is a large, rich site with knapping floors, including examples resulting from the production of unifacial points. This site will be recorded in greater detail, and samples of the material, including knapping floors, will be systematically collected. Emphasis will be placed on locating and collecting the unifacial point knapping floors. This may involve excavation into the western flank of the blowout in which the site occurs.

- Site 259. This large complex of knapping floors will be recorded in detail and a selection of the floors (on the basis of raw materials used and techniques employed) will be collected.

- Site 330. The two complex, rich, and compact knapping floors making up most of this material will be systematically collected.

- Site 258. This rich campsite-knapping floor complex will be recorded in detail and a sample of the material collected.

- Sites 222 and 237. These sites will be recorded in similar detail to site 258 and, if deemed desirable, small, systematically collected samples will be salvaged.

- Site 325. This site will be recorded in detail, especially the wide range of artefact types and grindstones. No salvage work is considered necessary.

- Site 299. The knapping floor with the unfinished backed blades will be collected.

- Site 347. This complex of knapping floors-quarries will be recorded in detail and, if deemed desirable, a selection of the knapping floors will be collected.

5.2 ANTHROPOLOGY

5.2.1 Anthropological information

The anthropological information relevant for EIS purposes is concerned with the relationship between particular Aborigines and particular areas of land. This relationship is expressed in mythology and ceremony related to specific sites such as:

- creation sites
- increase sites
- initiation sites
- other ceremonial sites
- mortuary sites
- storage sites.

These sites may be natural features of the landscape such as rock outcrops, waterholes or distinctive landforms, or they may be artificially constructed such as burial sites or certain types of stone arrangements. The most significant sites are those where Aboriginal people still conduct ceremonies, and are referred to as 'living' sites. Sites of significance are normally elements of a myth or song series. Parts of such stories or songs and their associated rituals are 'owned' by an individual or totem group, and may be transmitted or inherited by other people. There may also be Aboriginal interest in sites with historic significance relating to past events or occupation.

At the commencement of anthropological studies, it was first necessary to establish the relevant Aboriginal groups associated with the region under study. The information available on tribal territories indicates that the Project Area is within traditional Kuyani territory near the band of country where Kuyani and Kokatha tribal areas traditionally meet. To the north of the Olympic Dam area lies the traditional territory of the Arabana who were closely linked culturally to the Kuyani.

The boundary between the Kuyani and Kokatha also represents a major cultural boundary between what Ellis (1978) refers to as the Central Lakes cultural complex (which includes the Kuyani and Arabana) and the Western Desert cultural complex (which includes the Kokatha). It should be noted, however, that these boundaries represent only approximate linguistic and cultural demarcations and, particularly in desert cultures, boundaries should not be considered rigid. Furthermore, Aboriginal mythology transcends such boundaries, with mythological stories crossing the traditional territory of more than one Aboriginal group. Therefore, complete songs and stories may not be owned by one Aboriginal tribe; rather, different tribes may be responsible for different portions of a particular mythological story or song series. Thus, a tribe's interest in sites of significance may extend beyond its traditional territory.

There are no known fluent speakers of Kuyani, nor any Kuyani people with knowledge of the local mythology, still living. However, many of the Kuyani mythological stories and song series have already been recorded from now deceased Kuyani, Arabana and Kokatha people. Arabana people have provided confirmation of certain Kuyani myths and indicated sites of significance to the north of the Project Area. Discussions with people of Kokatha descent in relation to undertaking anthropological research commenced in early 1981 and were still continuing at the time of writing. Arrangements which provide both adequate confidentiality in relation to secret information as well as verification of mythological sites have been discussed, but the details have yet to be finalized before fieldwork can commence. Thus, at the time of writing, no anthropological information was available from Kokatha people. However, anthropologists and others have been active in the broad region around Olympic Dam, and much of the mythology of the region has been recorded and is available through journals, tapes, books and articles.

For the material presented in this Draft EIS the following sources have been used:

- site records of the Heritage Conservation Branch of the Department of Environment and Planning;

- field inspections of sites known by Arabana and Dieri informants;

- anthropological, linguistic and musicological studies published by professional scholars (Austin, Ellis and Hercus 1976; Bates 1918, 1947; Berndt 1941, 1959;

Berndt R.M. and C.H. 1942, 1943, 1944, 1945, 1951; Black 1920; Elkin 1931, 1937, 1938, 1939-40; Ellis C.J. 1964, 1966a, 1966b; Ellis R.W. 1978; Helms 1892-96; Hercus 1974, 1975, 1980, 1981; Hercus and White 1973; Howitt 1904; Mathews 1900a, 1900b; Platt 1967, 1968, 1972; Schurmann 1879; Stirling 1914; Taplin 1879; Tindale 1959, 1974; White 1975, 1977, 1979; Woods 1879);

- ethnographic notes and historical studies published by missionaries, sociologists and amateur anthropologists (Curr 1886-87; Eylmann 1908; Fenner 1936; Gale 1964, 1966, 1969a, 1969b, 1972; Gale and Lawton 1969; Harms and Hoff 1951; Horne and Aiston 1924; Kingsmill 1886; Provis 1879; White 1969, 1972, 1978; Williams 1969);

- unpublished letters, field notes and tape recordings by both professional and amateur students of Aboriginal culture in the area (Bates 1931-32, undated; Ellis C.J. 1964b, 1966c; Layton 1977; Siebert 1899; Tindale 1928, 1938-39; Tindale and Epling 1952-54);

- archaeological surveys undertaken for the EIS baseline and impact assessment studies.

A number of detailed reports based on these sources has been provided to the Heritage Conservation Branch. These reports include locations of all known Aboriginal sites which, for reasons of confidentiality, are not reproduced in this Draft EIS.

Information on the following aspects is presented below:

- consultations and prior investigations
- information on tribal territories
- Aboriginal mythology
- contemporary Aboriginal history
- impact assessment and mitigation measures.

5.2.2 Consultation and prior investigations

In March 1977, initial contact was made by Western Mining Corporation Limited (WMC) with the Curator of Relics of the South Australian Museum and the Curator of Archaeology, prior to the establishment of the Joint Venture and RMS. At that time there were no known sites in the exploration licences held by WMC in the vicinity of Olympic Dam. Two sites to the south of the Stuart Shelf lease areas were known.

WMC was also advised that the following Aboriginal tribes are known to have traditional links with the region:

- Kokatha - to the south-west
- Kuyani - to the north-west
- Arabana - to the north,

and that the WMC exploration licence areas for both Olympic Dam and the Stuart Shelf were within the traditional territory of the Kuyani and Kokatha. At the time, it was thought that the Kokatha had effectively been rendered a 'non-viable' group by various events since 1850 and that sites within their area were largely 'dead' sites of archaeological interest only (refer also Aboriginal and Historic Relics Administration information in Pak Poy 1977). It was also thought that the Kuyani were almost extinct (South Australian Museum, pers. comm. March 1977).

On the basis of preliminary surveys by the Aboriginal and Historic Relics Preservation Unit, WMC was advised that:

- no sites were discovered which would affect the processes of mining;
- campsites were located at Lake Blanche, indicating a possibility of further sites to the east and, while these were not of a nature to create undue concern, a remote possibility existed for more important sites;
- to the best of the Unit's knowledge, the Olympic Dam area did not contain significant Aboriginal sites (Aboriginal and Historic Relics Preservation Unit, pers. comm. December 1977).

During the course of exploration activity on the Stuart Shelf, geological crews located and recorded a number of sites outside the Olympic Dam Project Area suspected of being Aboriginal in origin. Since 1977 WMC, and subsequently RMS, have been noting sites of historical relevance, including sites showing evidence of Aboriginal activity, on a register supplied by the Curator of Relics. This site information has been continually forwarded to the relevant authorities to consider for inclusion in the State Register. The Department for the Environment advised that there was an area containing a site north of the Olympic Dam lease area, and requested the exclusion of exploration activity in the vicinity of a nearby dam. Action was taken by RMS to implement that request.

When exploration activity advanced to the stage of considering the sinking of an exploratory shaft (the Whenan Shaft), the Aboriginal and Historic Relics Administration undertook a detailed survey of the square kilometre surrounding the proposed shaft site and a preliminary inspection of the Olympic Dam area in May 1980. Evidence of a possible ethnographic site was observed, and RMS was advised in June 1980 of the Department for the Environment's view that an ethnographic survey should be carried out as part of the overall investigations into environmental impacts. In September 1980, when RMS issued briefs to consultants for baseline studies prior to the preparation of an EIS, a requirement for archaeological and anthropological surveys was included.

EIS baseline study work was commissioned in December 1980, with field work generally commencing in the first quarter of 1981. After discussions with the Department for the Environment concerning appropriate guidelines for the conduct of the survey work, contact was made with the Kokatha People's Committee and a meeting arranged in May 1981, at which a representative from the Aboriginal Relics Unit introduced the EIS consultant's anthropologist to the Committee.

During this period (January 1981), the Kokatha People's Committee, through a solicitor acting on their behalf, contacted Roxby Mining Corporation Pty Ltd (RMC) and BP Australia Limited, two of the Olympic Dam Joint Venturers, to suggest discussions between the Kokatha people and representatives of the Joint Venturers about the proposed development. RMC replied (February 1981) that such discussions would be appropriate as part of the environmental investigations.

After discussions and correspondence with the Kokatha People's Committee, the EIS consultant proposed an approach to the anthropological research. This approach was based on arrangements established with representatives of the Kokatha People's Committee for an EIS undertaken for a different project a few months earlier. The basic elements of the proposed approach gave the Kokatha control over whom should act as their informants, the sites visited and recorded, and the extent to which information was divulged to:

- the anthropologist
- the EIS consultant
- the Joint Venturers
- the government
- the general public.

It should be noted that if positive action to protect sites is to be incorporated in the proposed development, certain information about sites and their locations is necessary.

It was also proposed that the Kokatha should review any reports on anthropological data concerning their sites and culture, with the right to amend sections for accuracy of information and the right to exclude sensitive or sacred information from publication. In addition, the proposed approach gave them rights of authorship and shared copyright over survey reports. The approach also included the provision of a separate report for the Kokatha on their culture, copyright of which would belong to them. The Kokatha People's Committee was unwilling to provide information under those proposed conditions, as it considered that the conditions did not provide the Kokatha with adequate control over the use of information. There was no question of the anthropologist's integrity or competence to perform the work.

The Kokatha undertook independent field inspections in late 1981 involving an anthropologist made available by the Pitjantjatjara Council, and on the basis of this work advised a meeting of State Government ministers, officials, and RMS staff, in December 1981, that there were no ethnographic sites of interest to the Kokatha. The Kokatha subsequently advised that 'there is fresh evidence that sites of significance may exist in the area'. However, at a meeting with RMS in May 1982 requested by the Kokatha People's Committee to discuss the matter, no such information was provided. At the time of writing, a satisfactory basis for exchange of anthropological information was still being sought with the Kokatha People's Committee. In the absence of anthropological research a greater reliance has been placed on available records of Kokatha sites, culture and movements in the region around Olympic Dam, as well as information from elders of other tribal groups whose territories are also near the area of interest.

It is fortunate that substantial anthropological research had been undertaken previously with Kuyani and Kokatha ritual leaders and with both male and female speakers of Kuyani and Kokatha, all of whom have recently died. In addition, independent verification of much of the information relating to the north of the Project Area and to the vicinity of the borefields was possible during field trips with Aboriginals of Arabana and Dieri descent.

The initial unwillingness of the Kokatha People's Committee to co-operate within the EIS framework also meant that the archaeological baseline work proceeded without Aboriginal involvement. Furthermore, despite a direct invitation to be present during the detailed survey and recording of sites for impact assessment purposes, none of their number took the opportunity to be present.

5.2.3 Information on tribal territories

The literature suggests that four linguistic groups are traditionally associated with the broad region surrounding Olympic Dam. These are the Kuyani in the east, the Kokatha in the west, the Arabana in the north and the Pangkala in the south. There is reasonable agreement on the location of tribal 'boundaries' (as shown on Figure 5.3) among different writers. All place the Olympic Dam Project Area in Kuyani territory, near the boundary with Kokatha traditional territory.

The earliest comprehensive map was prepared by Mathews (1900a), and showed the eastern boundary of 'Kookatha' (Kokatha) territory extending from the Stuart Range to take in Lake Phillipson, Mount Eba Station, Wilgena Station, Mount Finke and Lake Bring. Mathews identifies a 'Parnkalla' (Pangkala) nation with a 'Kooyeeunna' (Kuyani) and allied tribes occupying the country from South Lake Eyre, including Turret Range, Chambers Creek (Stuart Creek) and Screechowl Creek to Lake Torrens and south along its eastern shore as far as Nilpena Station. West of Lake Torrens, almost to the eastern shore of Lake Gairdner, Mathews refers to 'Hillary, Kakarraru and Yallingarra' as tribes of the Parnkalla nation. Tindale (1974) questions the reliability of Mathews' information for this area. He suggests Mathews has confused 'Hillary' with the Pangkala term for westerner, and interprets 'Kakarra' and 'Yallingarra' (terms meaning 'east') as possible references to eastern Kokatha. The territories of Kuyani and Arabana are stated by Mathews to meet at Margaret Creek.

Elkin spent nearly a year undertaking field work in South Australia during the course of which he contacted both Kokatha and Kuyani people. His boundary between Western Desert and Central Lakes ('Eastern Group' in Elkin's terminology) cultures is to the west of Lake Gairdner, placing Olympic Dam nearly 200 km into Kuyani territory (Elkin 1937). Arabana territory is shown to be in a similar location by other writers, except that it is shown extending south of the Stuart Range.

Tindale (1974) provides a tribal boundaries map and a description of the territory of all Australian Aboriginal tribes. His description of Kokatha territory is as follows: 'at Tarcoola, Kingoonya(h), Pimba and McDouall Peak; west to Ooldea and the Ooldea Range; north to Stuart Range and Lake Phillipson. The junction between Kokat(h)a and Pangkala territories is at the rather sudden drop down from the open plateau to the Acacia scrub-covered low hills.' For Kuyani, his territorial description is: 'from Parachilna north to Marree on west side of Flinders Ranges; north-east to Murnpeowie; around north end of Lake Torrens; west to Turret Range and Andamooka excluding Lake Torrens.' Tindale describes Arabana territory as: 'Neales River on the west side of Lake Eyre west to Stuart Range; Macumba Creek south to Coward Springs; at Oodnadatta, Lora Creek, Lake Cadibarrawirracanna and the Peake. Their boundary with the Kokat(h)a on the west is marked by the margin of the scarp of the western tableland near Coober Pedy.' For Pangkala, Tindale's description is: 'East side of Lake Torrens south of Edeowie and west of Kookina and Port Augusta; west of Lake Torrens to Island Lagoon and Yardea; at Woorakimba, Hesso, Yudnapinna, Gawler Ranges; south to Kimba, Darke Peak, Cleve and Franklin Harbour.'

General descriptions of the relevant tribal territories provided by others do not add substantially to the discussion, with the exception of Hercus, who, basing her conclusions on extensive fieldwork and recording in the area, says:

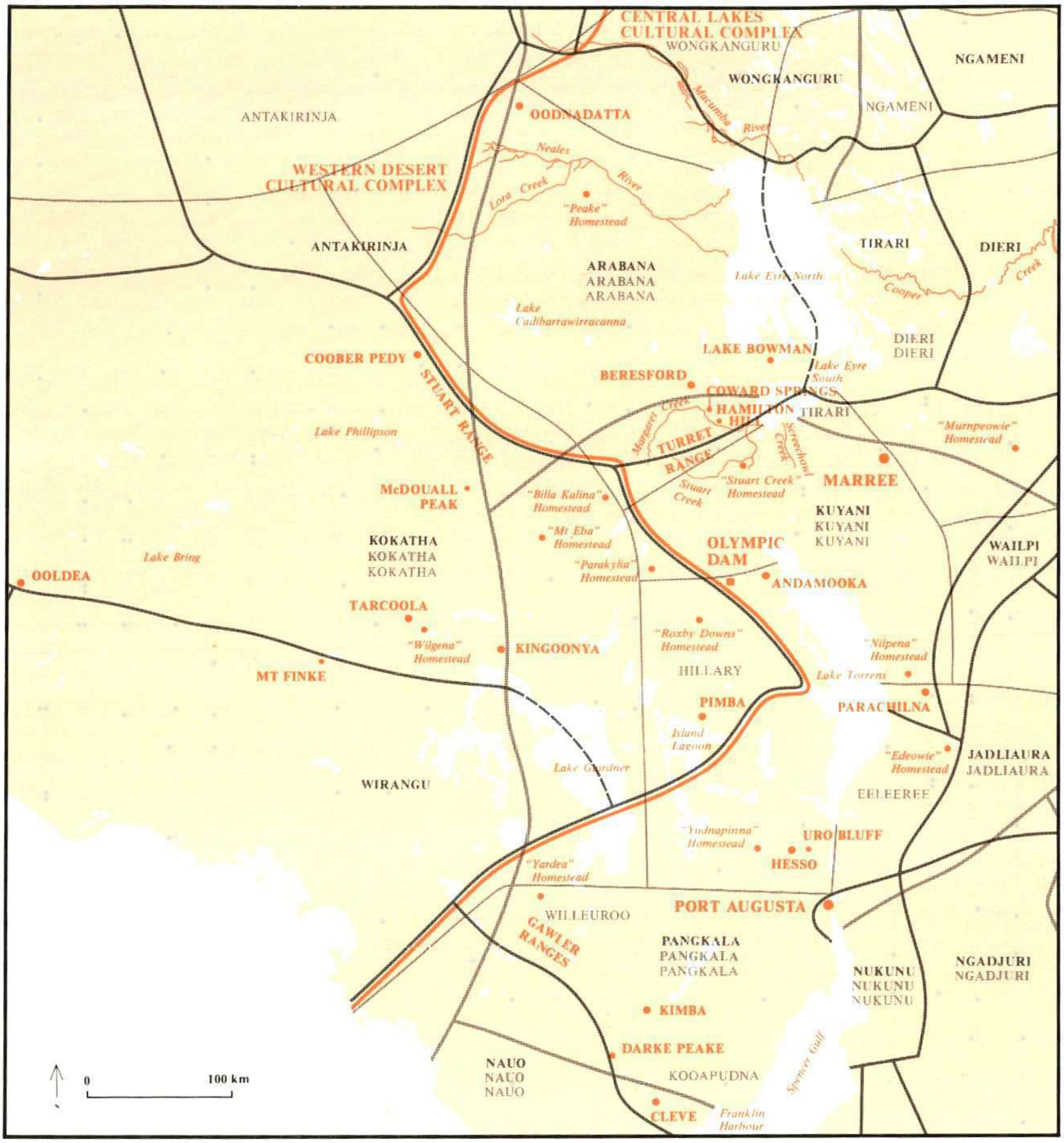
> 'The boundary between Guyani (Kuyani) and Gugada (Kokatha) country ran roughly in a north-west/south-easterly direction from the east side of Billa Kalina to the east side of Parakylia and Roxby Downs to Andamooka. Guyani traditions are therefore of importance to the (Olympic Dam Project) area. Immediately to the north of Billa Kalina was Arabana country.' (Hercus, pers. comm. 1981.)

These locations agree closely with Tindale (1974) and place Roxby Downs homestead west of the Kokatha/Kuyani boundary and Olympic Dam east of it.

The general consistency of these maps is notable, especially since each author uses a different basis for defining tribal boundaries. The map by Mathews was the first compilation of information from a wide range of sources supplemented by personal observation. Elkin's map was based on the distribution of kinship systems and other aspects of social organization. The map by Tindale not only combined much of the previous anthropological research but also reflected the correlation between the traditional tribal limits and ecological and geographical boundaries. Hercus's map was based on language distribution. The degree of correspondence in boundaries from these disparate sources provides important verification of the general pattern of the boundaries.

5.2.4 Aboriginal mythology

There are two broad cultural groupings which are relevant to the area of interest. One is the Western Desert cultural complex which includes the Kokatha and other groups west



Cultural Complex Boundary

TRIBAL BOUNDARIES

After Tindale (1974)

After Elkin (1937)

After Mathews (1900)

Figure 5.3
TRIBAL BOUNDARIES

of Olympic Dam. The other is the Central Lakes complex which includes Kuyani, Arabana and Pangkala. The boundary between these cultures is shown in Figure 5.3. The main distinguishing features between these cultural groupings were described by Elkin (1931) as follows:

- The Central Lakes tribes had divisions into named matrilineal moieties, each of which consisted of a number of totemic clans. This dual organization was absent in the Western Desert tribes, which lacked the moieties but possessed totemic clans.

- Certain features of the kinship system differed between the Western Desert culture (which was marked by a comparative paucity of terms) and the Central Lakes culture. This in turn was reflected in differences in marriage rules.

- Central Lakes culture was characterized by a patrilineal totemism of the 'talu' or increase type usually combined with a matrilineal totemism of the same kind, whereas Western Desert culture was characterized by a variety of local totemism in which a person's totem was determined by his place of birth. This difference in totemism was also reflected in differences in the relevant mythological theme associated with a person's totem.

- The pattern of cicatrization was different for fully initiated men. For Central Lakes tribes, it consisted of two vertical rows of short parallel scars, while for Western Desert tribes it consisted of two sets of six or eight slightly curved parallel scars with two horizontal scars raised under each of these two series.

In Western Desert culture, there was a distinctive relationship between people, land, totemism and mythology. A person's totem depended on the totem associated with his place of birth. This totemism was ceremonial. When fully initiated, a male had been taught the myths and ceremonies involving the culture-heroes related to his totem, and any increase ceremony related to that totem (Elkin 1931).

Berndt and Berndt, who conducted anthropological research at Ooldea and surrounding areas, provide copious references to sites of significance and their functions in Aboriginal religious and economic life in the region. They refer to increase centres associated with rituals concerned with the reproduction of natural phenomena, including flora, fauna and human beings. They discuss ceremonial sites such as Ooldea Soak, where people gathered for cult lodge, initiation, and other ceremonies, and refer to spirit centres associated with cult totems, noting that there was usually one main spirit centre in each local group's country. They show how the desert landscape was traversed by mythological routes, linking sites across vast distances, and indicate how these myths were associated with cult lodge ceremonies, song series, head-dresses, body paint designs and sacred carved objects.

Although the work of the Berndts contains no precise locational or other data on sites in the Olympic Dam area, it does show a 'gabi route' (string of water sources along which people travelled and usually also a dreaming track) running south from Oodnadatta through Arabana country, down the west side of Lake Torrens and into the Port Augusta area. While this route was not precisely defined by the Berndts, it has been possible to reconstruct it from known Aboriginal sites containing permanent water and from maps of the route taken by early explorers who used Aboriginal guides. The spacing of the watering points represents one day's journey for Aboriginal desert people. A further confirmation has come from pastoralists in the area who use these sources of reliable water for their stock. This would place the gabi route some 30 km east of the Olympic Dam Project Area.

Bates recorded a large number of named sites in Kokatha territory and other regions to the north and west. Bates's view was that the Kokatha were a widely drawn aggregate of culturally similar people from the desert interior which claimed Ooldea Soak (which is a permanent water source 500 km west of Olympic Dam) as their 'dhoogoorr gabbi' ('dreamtime water'). None of the sites recorded by Bates can be positively identified with the Olympic Dam area; indeed, all the sites recorded in this context appear to be more than 100 km to the west of Olympic Dam.

In the Central Lakes culture, each moiety consists of a number of totemic social groups. There are also patrilineal ceremonial totems ('pintara') and matrilineal ceremonial totems ('maduka' or 'amata'). Each person inherits from his father a totemic name, a piece of country associated with this totem and a mythological hero, a myth containing a story about the hero, and a ceremony usually related to the increase of the totemic species. Each of these ceremonial clans has a headman. The ceremony is performed by the pintara men who own the ceremony, with assistance from their sisters' sons who are said to be the 'bosses' of the performance and must see that it takes place.

In addition to inheriting the pintara from his father, a man also inherits the pintara of his mother and his mother's brother, which then becomes his maduka. After initiation, he is taught the myth and ritual of the mother's brother's pintara and may visit the sacred site and assist in the ritual as noted above. Both men and women inherit pintara and maduka, but the women have the name only and do not learn the myths or see the ritual. The men do so only after having passed through the 'wiljaru', the highest state of initiation.

Hercus has made numerous field trips over many years, predominantly in areas to the north of Olympic Dam, and has recorded many mythological stories and song series, as well as specifically locating their related sites of significance. These are predominantly Kuyani and Arabana in origin, but some extend into Kokatha territory. She has obtained her information from a variety of informants, both male and female, including a number of ritual leaders. This information was collected primarily for linguistic purposes and has not undergone cultural interpretation. The stories of the myths are presented below as a means of identifiying the general location of anthropological sites of significance. However, it should be noted that the myths are more than stories connecting sites, for mythology is the basis of Aboriginal culture. The stories embody social rules not only related to religious and moral aspects of Aboriginal society, but also to secular conduct.

An extensive myth, the 'Urumbula' (Native Cat), travels from Central Australia to Port Augusta through many tribal territorities. The ancestral 'Alchilpa Cat' named 'Malbuna' (in Aranda) travelled to Port Augusta with a group of cats to obtain a great ceremonial pole. An epic return journey to the north began, during which the cats were joined by many other ancestral creatures attracted by the pole. The myth is perpetuated throughout many tribal territories, with numerous stories of other exploits associated with the main group. The principal sites of mythological significance associated with the Urumbula are the main 'camps' of Malbuna, where re-enactments of the adventures of the cats are performed. In the area of interest around Olympic Dam, the nearest main camps are at Port Augusta and near Stuart Creek. Other minor sites would be nearer Olympic Dam, and indications are that the mythological trail follows the gabi route 30 km east of Olympic Dam.

One song series passes from Parachilna in Kuyani country, west across Lake Torrens into Kokatha country (south of Olympic Dam), then on to the north via Aranda country in Central Australia. This is the 'Two Women from Parachilna' song series, which appears to be part of a series of songs known generally under the title of 'The Two Women'. While there are a number of different versions, all invariably contain the general theme of the travels of two women being avidly pursued by a lecherous male. Each of the Aboriginal groups has ownership of, and the right to perform, that particular section of the song relating to the activities of the women within their territority.

'The Seven Sisters' represents another very long and complex series of myths and songs. It traces the travels of the seven sisters, commencing in Western Australia and moving across the desert interior into Kokatha country as far as Kingoonya. At Kingoonya the seven sisters meet the two women travelling from Port Augusta and the song lines intersect and incorporate parts of the other line's story. From there the seven sisters journey north-east through Kuyani and Arabana country to near Beresford and then to Lake Bowman. The Whirlwind coming from Coober Pedy picks them up from there and carries them across Lake Eyre to Dieri country, after which they cross the Cooper and travel into Wonganuru country.

There is also a Pangkala version of the 'Moon and Seven Sisters' which is believed to be a different song line. It describes a number of young men ('the boys with weary feet') associated with the Southern Cross, who chase the seven sisters. This route would appear to indicate the absolute limits of areas traversed at different times by tribal Pangkala in their seasonal hunt for food and includes the gabi route west of Lake Torrens.

There is an Aboriginal site named 'Madlumba', a name linguistically related to the Kuyani language, located 10 to 15 km west of Olympic Dam, which is believed to be a women's site associated with the Seven Sisters mythology.

The history of Yurgunangu, the Red-bellied Black Snake, and Gurgari, the Green Snake, is represented by a long mythological line stretching from Coolatta Springs (Northern Territory) in Aranda country to the south-western edge of Kuyani country. Many landforms are considered to have been formed by the activities of these snakes as they moved across the countryside, before finally disappearing into Margaret Spring. For example, Bangi-waruna ('ribs white') is the name of a group of mound springs around which the snakes had coiled while camping and which had turned their ribs white from the salt. About 40 km north of the Project Area there are three sites which figure in the Red-bellied Black Snake and Green Snake myth.

According to the Heritage Conservation Branch, another site about 15 km north-east of Olympic Dam is of Aboriginal cultural significance. However, its mythological connection is not known.

One other mythological trail is known in the general area of interest, but it passes well to the north of Olympic Dam in the vicinity of Billa Kalina and McDouall Peak. This trail marks the travels of the Wiljaru and a number of totemic ancestors connected with the Wiljaru, particularly the Turkey and the Bell Bird. The mythology is associated with a secondary initiation ceremony, the Wiljaru, during which the initiate had up to twelve deep cuts made in his back which left permanent scars.

In the mound springs area to the north of Olympic Dam there is a band of some twenty-four known mythological sites. This area figures in most of the myths recorded from Kuyani and Arabana informants. Present information indicates that the sites as far west as Hamilton Hill are identified particularly with the Kuyani, while those beyond there to the north are of significance to the Arabana.

In summary, the literature identifies no mythological sites in the Olympic Dam Project Area. There are two recorded sites within 15 km of the Project Area and another three within 50 km. A north-south water source route which features in much of the mythology is some 30 km east of the Project Area. Kokatha culture appears to have been generally centred on Ooldea, which is quite remote from the Olympic Dam Area. Literature on Kuyani mythology provides some information on sites in the general area, particularly to the north of the Project Area, although the areas of principal mythological significance are in the vicinity of the mound springs rather than near Olympic Dam.

5.2.5 Contemporary Aboriginal history

In recent times, the basic pattern of demographic change among the Aboriginal population in South Australia would appear to be as follows:

- Between the start of European settlement and the influenza epidemic of 1919, numbers decreased substantially. After 1919, population numbers stabilized, and then began to increase.

- Traditional patterns of movement related to hunting and food gathering, and to social and religious rites, were changed with the advent of European settlements. Pastoral activity restricted nomadic subsistence activities, as well as attracting Aboriginals to pastoral stations by the availability of food.

- European religious and philanthropic groups established Aboriginal missions at which Aboriginal people clustered, although in most cases the missions were some distance from the tribal territory of those people.

- Many of the Aboriginal people formerly based at missions, or in small towns and pastoral stations, have moved to urban centres such as Port Augusta and Adelaide, especially since the 1950s.

- There has been an increasing tendency for Aboriginals to take up employment and permanent residence, with a consequent reduction in the numbers of Aboriginal people following traditional lifestyles.

- These processes started earlier in the east and south of the State, and later in the west and north. However, this pattern of change was not entirely uniform, and some changes are still in progress today.

European settlement

In the area of interest, European settlement began in the early part of the second half of the nineteenth century and quickly settled down into a pattern of fixed and permanent pastoral activity. The establishment of the east-west railway line in 1915 had a significant effect on Western Desert peoples, bringing not only European settlement, but also European diseases (such as measles, chicken-pox, and whooping cough) to which Aboriginal people had little immunity. In addition, the great drought of 1914-15 resulted in an eastward and southward shift of Aboriginal people caused by pressure of peoples moving from the drier north. Elkin (1931) reports that depopulation of all but the north-western corner of South Australia was very far advanced in 1930.

By the time of the establishment of Woomera in the late 1940s, there were very few tribalized Aboriginals in the Woomera Range area. As such, the small risk associated with missiles to the Aboriginals present did not warrant mass transfer of Aboriginal people (Commonwealth of Australia 1947). It was recognized that contact between Aboriginal people and the Europeans associated with the Woomera facilities would accelerate the process of detribalization which was already occurring in the region.

More local knowledge was obtained by interviewing a number of pastoralists who had lived in the region for up to fifty years. They confirmed that it has been many years since the general area was inhabited by tribal Aboriginal people following a traditional lifestyle. However, people of Arabana, Kuyani and Kokatha descent had been employed on stations (including Roxby Downs, Parakylia, Billa Kalina and Stuarts Creek) until the early 1970s.

Missions

Koonibba mission was the first mission in the area of interest. It was established in 1898 by the Evangelical Lutheran Church and attracted descendants mainly of the Kokatha tribe but also Wirrangu people from the surrounding area. Nepabunna mission was established in 1930 by the United Aborigines Mission and was inhabited mainly by Aboriginal people from the Flinders Ranges, some of whom had indirect Kuyani ancestry.

Ooldea was also established in 1930 by the United Aborigines Mission. A number of Kokatha lived at Ooldea, and Kuyani are recorded as having visited there. It was abandoned in 1954 and the people then moved to Yalata. In 1937, Umeewarra, a Plymouth Brethren mission, was established at Port Augusta and is still in operation. A mission at Finniss Springs was set up by the United Aborigines Mission, with probably Kuyani, Arabana and some Kokatha in its population. It was abandoned in 1960 because of an inadequate water supply. Yalata mission was established in 1952 by the Evangelical Lutheran Church to accommodate Aboriginal people moved out of the Maralinga weapons testing areas north of Yalata. In 1963, the Department of Aboriginal Affairs established the Davenport Reserve adjacent to the Umeewarra mission. This reserve has attracted Aboriginals from all the northern part of the State right across to the Western Australian border and well into the Northern Territory. People of Kokatha descent are present at Davenport.

Migration patterns

Gale (1966) has identified the broad migration patterns of Aboriginal people within South Australia (Figure 5.4). These indicate that most of the former Aboriginal inhabitants of the western part of the area of interest moved south and south-east to Koonibba, to Port Augusta and possibly also to Oodnadatta, Andamooka and other towns on or near the main communication routes in the region. Those from the easterly portion of the area of interest appear to have moved to Finniss Springs, Nepabunna and Port Augusta.

5.2.6 Impact assessment and mitigation measures

From the information available in the literature and from fieldwork by others in the general region of Olympic Dam, it appears that there are no verified sites of anthropological significance in the Project Area. There is evidence of several Kuyani sites 10 to 50 km away from the Project Area; many Kuyani and Arabana sites have been identified to the north, particularly in the vicinity of the mound springs; and further to the west there are references to Kokatha sites (although there is no precise locational information on these). However, at the time of writing, it had not been possible to confirm through anthropological survey whether any other sites exist within the area of interest. There are no fluent speakers of Kuyani still living, and agreement on an approach to site surveys is still to be finalized with Kokatha people. Discussions are continuing, so that appropriate surveys can be completed in accordance with the EIS guidelines.

On the basis of their own field inspections in late 1981, the Kokatha People's Committee advised that there were no ethnographic sites in the vicinity of the Project. The Kokatha now advise that there is 'fresh evidence that sites of significance may exist in the area' but give no indication of the nature of this evidence or of the sites.

Even in the absence of verified sites, the Joint Venturers are still obliged to conduct their activities with reference to Aboriginal site protection legislation. The currently relevant legislation is contained in the Aboriginal and Historic Relics Preservation Act, 1965. (The Aboriginal Heritage Act, 1979, which supersedes the 1965 legislation, has been passed into law but is not yet in operation). The Roxby Downs (Indenture Ratification) Act, 1982, confirms the legal responsibility for protection of sites which would apply under the Aboriginal Heritage Act, 1979, and retains the penalty provisions relating to site damage. A modification of this 1979 Act contained in the Indenture Ratification Act relates to the declaration of protected areas, which is one of the management tools available to government to protect Aboriginal sites. In the first instance, declaration of protected areas is confined to significant sites identified during EIS preparation and assessment. However, the Joint Venturers shall not withhold consent to the subsequent declaration of protected areas under the Act in specified areas unless such a declaration impedes or disrupts operations, or endangers the health or safety of any person.

Source: Gale (1966)

Figure 5.4
ABORIGINAL MIGRATION PATTERNS

Furthermore, as has been the case in the past, the Joint Venturers will take steps to protect sites which are determined to be significant, and will continue education programmes informing key personnel working in the area about the types of Aboriginal sites and their responsibility for protecting these sites. Such programmes have already been implemented during the exploration phase for drilling crews and on-site personnel.

The potential exists for indirect impact on sites outside the area under the jurisdiction of the Joint Venturers. Hercus (pers. comm.) has quoted examples of damage to anthropological sites in the mound springs area due to stock, visitors, and road building activity. Further damage is likely to occur if the present situation continues and sites remain unprotected, as it is beyond the capability of the pastoralists, who have tenure of the land on which the sites occur, to provide effective protection. Indeed, with improved accessibility to the region resulting from the upgrading of roads to the Olympic Dam Area and to the borefields further north, together with the greater numbers of people in the region due to Project development, it is likely that the rate at which damage occurs will accelerate. The Joint Venturers can only control access to sites within the Project Area, and do not have the authority to control access to sites beyond this area. However, discussions with the relevant government authorities have commenced, with the aim of determining ways in which these indirect impacts might be mitigated.

CHAPTER SIX

Underground Environment

SUMMARY

Geology of the orebody

The Olympic Dam deposit occurs in a sequence of unmetamorphosed sedimentary breccias of Proterozoic age. This breccia sequence is overlain by about 350 metres of unmineralized cover sediments of the Stuart Shelf. The bulk of the known ore grade mineralization occurs in geologic members dominated by matrix-rich polymict breccias, with the matrices composed mainly of hematite. Two types of copper mineralization occur: bornite-chalcopyrite-pyrite in hematite-rich breccias, and chalcocite-bornite mineralization generally in lenses and veins.

Hydrogeology

The main aquifer in the region is the Arcoona Quartzite Member of the cover sediments. It is a fractured rock aquifer in which groundwater movement is very slowly eastwards towards the Lake Torrens area. It contains water of high salinity not suitable for human or stock consumption. Some use is made of lower salinity water of near potable quality which occurs in limited quantities in some areas of surficial sediments separated from the underlying saline aquifers.

The mine area will be dewatered in advance of mining operations. This will create a cone of depression in the groundwater potentiometric surface, redirecting local groundwater movement towards the mine area during mining and for some hundreds of years after mining ceases. After the cessation of mining, groundwater will move towards the mined out area, with groundwater in the breccia sequence mixing with remnant mine water which may have pockets of acid water with high heavy metal content. Eventually, however, the groundwater will resume its present very slow movement eastwards. There will be no effect on the quality of groundwater in the surficial sediments, in the Arcoona Quartzite, or in the Great Artesian Basin which is geologically separated from the Project Area and lies some 100 kilometres to the north of Olympic Dam.

Seismicity

The Adelaide Geosyncline which lies to the east of Olympic Dam is a seismically active zone. However, earthquake risk at a level requiring design consideration diminishes sharply away from the Geosyncline.

According to the requirements of the Standards Association of Australia Earthquake Code, earthquakes with peak ground velocities of 0.05 metres per second are not expected to cause structural damage to normal buildings not designed specifically to resist earthquakes. Earthquakes even of this low intensity have a return period of 3,500 years at Olympic Dam.

6.1 GEOLOGY OF THE OLYMPIC DAM DEPOSIT

6.1.1 Regional geology

The Olympic Dam deposit occurs within the Stuart Shelf region (Figure 6.1), an area of flat-lying Adelaidean and Cambrian sediments separated from the Adelaide Geosyncline to the east by a major zone of north-south faulting, termed the Torrens Hinge Zone by Thomson (1969). To the west and south-west, the sediment cover of the Stuart Shelf laps onto exposed rocks of the Gawler Craton.

The northern extension of the Shelf is overlain by late Palaeozoic and Mesozoic sediments of the Arckaringa and Great Artesian Basins. Although cover sediments in these basins are well documented, details of the underlying Adelaidean and Cambrian stratigraphy are poorly understood.

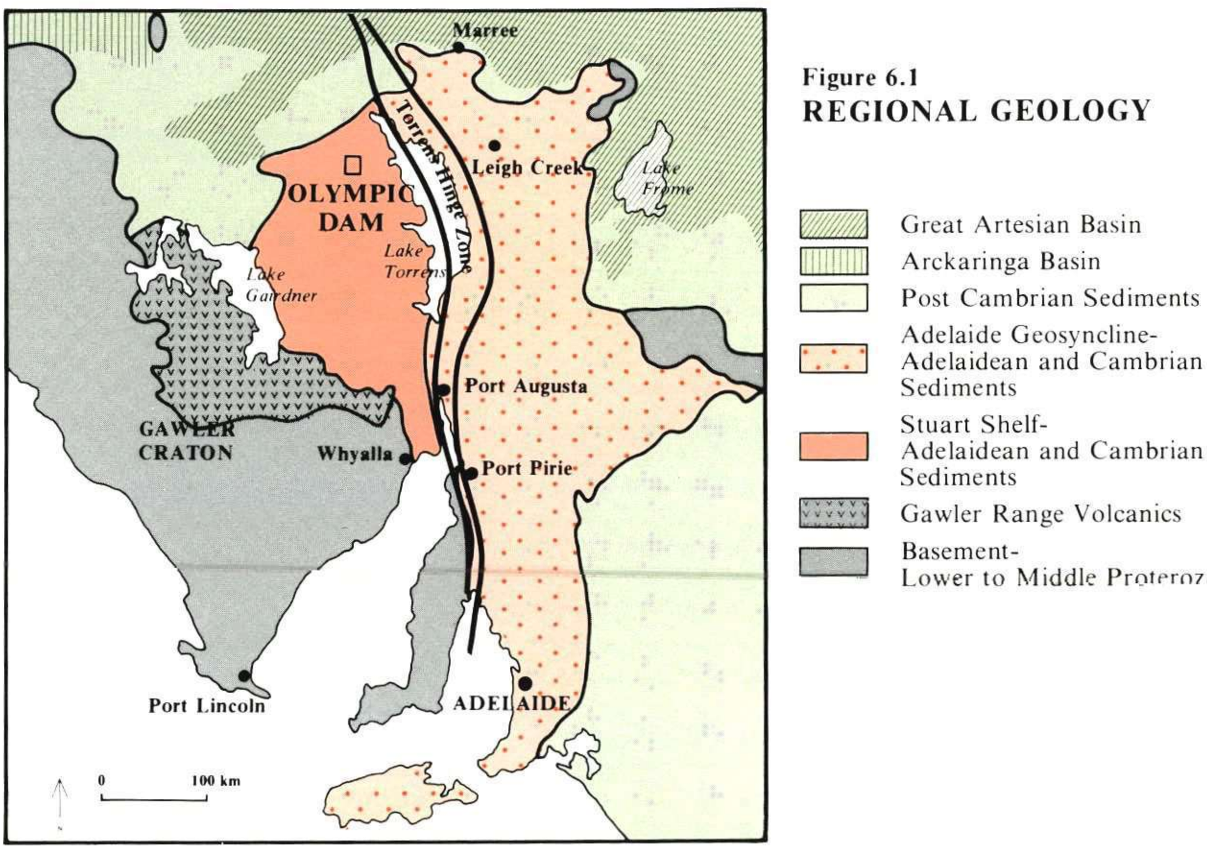


Figure 6.1
REGIONAL GEOLOGY

Gawler Craton

The early to middle Proterozoic Gawler Craton, which forms the crystalline basement to the Stuart Shelf region, is believed to consist of weakly metamorphosed sediments and foliated igneous rocks, intruded by granitic rocks, and overlain by relatively undeformed felsic volcanics (Gawler Range Volcanics in Figure 6.1). It is thought that this forms the basement within which the Olympic Dam deposit occurs.

Adelaide Geosyncline

Further to the east, and now represented by the Mount Lofty and Flinders Ranges, the Adelaide Geosyncline contains a sequence, several thousand metres thick, of Adelaidean and Cambrian sediments and minor basic volcanics. The rocks of the Adelaide Geosyncline have been affected by the Delmerian Orogeny which occurred 500 million years ago and resulted in deformation and granite intrusion. However, the Delmerian Orogeny does not appear to have affected the Stuart Shelf sediments.

Stuart Shelf

During sedimentation in the Adelaide Geosyncline, much of the Stuart Shelf region was an extensive shallow sea platform which underwent periodic marine incursions alternating with periods of erosion and limited sedimentation. The generally thinner, flat-lying sediments of the Stuart Shelf represent an incomplete record of the major sequences deposited in the Adelaide Geosyncline. Figure 6.2 shows a cross-section through the northern Stuart Shelf showing the sedimentary sequences in the Olympic Dam area.

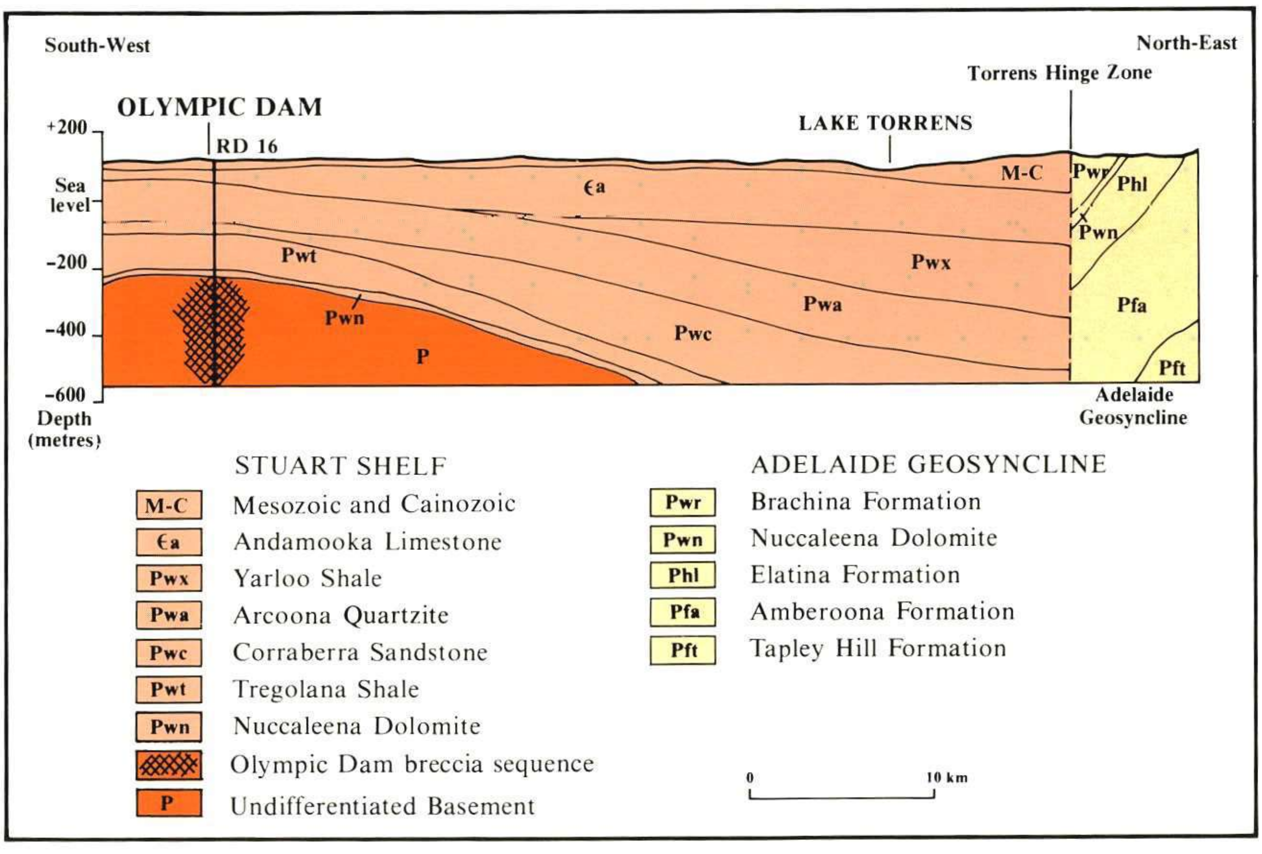


Figure 6.2
GEOLOGIC CROSS-SECTION OF NORTHERN STUART SHELF

About 350 m of cover sequence sediments occur in this area. These comprise outcropping Mesozoic and Cainozoic surficial sediments, Cambrian carbonates (Andamooka Limestone), Marinoan white and red sandstones (Arcoona Quartzite/Corraberra Sandstone), and brown and green shales (Tregolana Shale). Dolomitic bands (Nuccaleena Dolomite) and a thin polymict pebble conglomerate overlie the basement rocks on a major unconformity surface which represents a significant time break.

Great Artesian Basin

The southern boundary of the Great Artesian Basin, 100 km to the north of the Olympic Dam area, was formed by broad downwarping during late Palaeozoic times. Remnants of fractured and folded Adelaidean sediments occur near the southern and western edges of the Basin in a number of localities. The Basin contains sediments of Jurassic to early Cretaceous age, consisting of basal non-marine aquifer sands and sandstones (Algebuckina Sandstone and Cadna-owie Formation) overlain by confining grey shales and siltstones of late Cretaceous age (Bulldog Shale). Underlying Triassic and Permian sediments are regarded hydrogeologically as basement. Thin discontinuous outcrops of the Algebuckina Sandstone and the Cadna-owie Formation are also exposed on a pre-Mesozoic erosional surface near Andamooka and in scattered locations north of Lake Torrens.

6.1.2 Stratigraphy of the deposit

The Olympic Dam mineralization occurs within a sequence of unmetamorphosed sedimentary breccias of Proterozoic age which forms the basement to the flat-lying Adelaidean cover sediments of the Stuart Shelf (Figure 6.2). The contact between the basement and the overlying cover sediments is flat-lying with gentle undulations. This contact represents the eroded surface topography which existed at the time of the commencement of cover sequence sedimentation. There is a basement 'high' in the Olympic Dam Area, and as a result the overlying shelf sediments are only 250 to 370 m thick. Away from the basement high these sediments are more than 1,000 m thick, and older cover units not seen at Olympic Dam occur. The Proterozoic rocks hosting the Olympic Dam mineralization are dominantly sedimentary breccias and rudites, and are divided into two main lithostratigraphic units. These are the Olympic Dam Formation and the Greenfield Formation, both of which have several internal units or members. The local basement to the Olympic Dam Formation is assumed to be Myall Granite, which occurs laterally away from the deposit. The breccia sequence is greater than 1,000 m thick, and the base of this has not been penetrated by drilling. A composite stratigraphic section of the deposit is shown in Figure 6.3.

The bulk of the known ore grade mineralization occurs in the Black Hematite, Whenan and Brooks Members of the Olympic Dam Formation. These three members are all dominated by matrix-rich polymict breccias. A large number of different clast types are seen in these breccias, including Myall Granite, felsic, intermediate and mafic volcanics, hematite, terrigenous sediments, carbonate, fluorite, barite and sulphides. The matrices of the breccias are composed mainly of hematite. Sedimentary features such as graded bedding, load casts, scours, upwards fining units and cross-bedding are present, particularly in the Whenan Member. Lesser, but significant, mineralization is contained in the Upper Granite Breccia Member. The Lower Granite Breccia Member forms the lowest unit of the Olympic Dam Formation, and does not contain significant mineralization. The five members of the Olympic Dam Formation are not always present and complex facies relationships are found in many areas.

The Greenfield Formation (up to 700 m thick) has three members, and is preserved in downfaulted blocks where it has conformable contacts with the underlying Olympic Dam Formation. Hematite-rich breccias, volcanic breccias, and iron formation are the

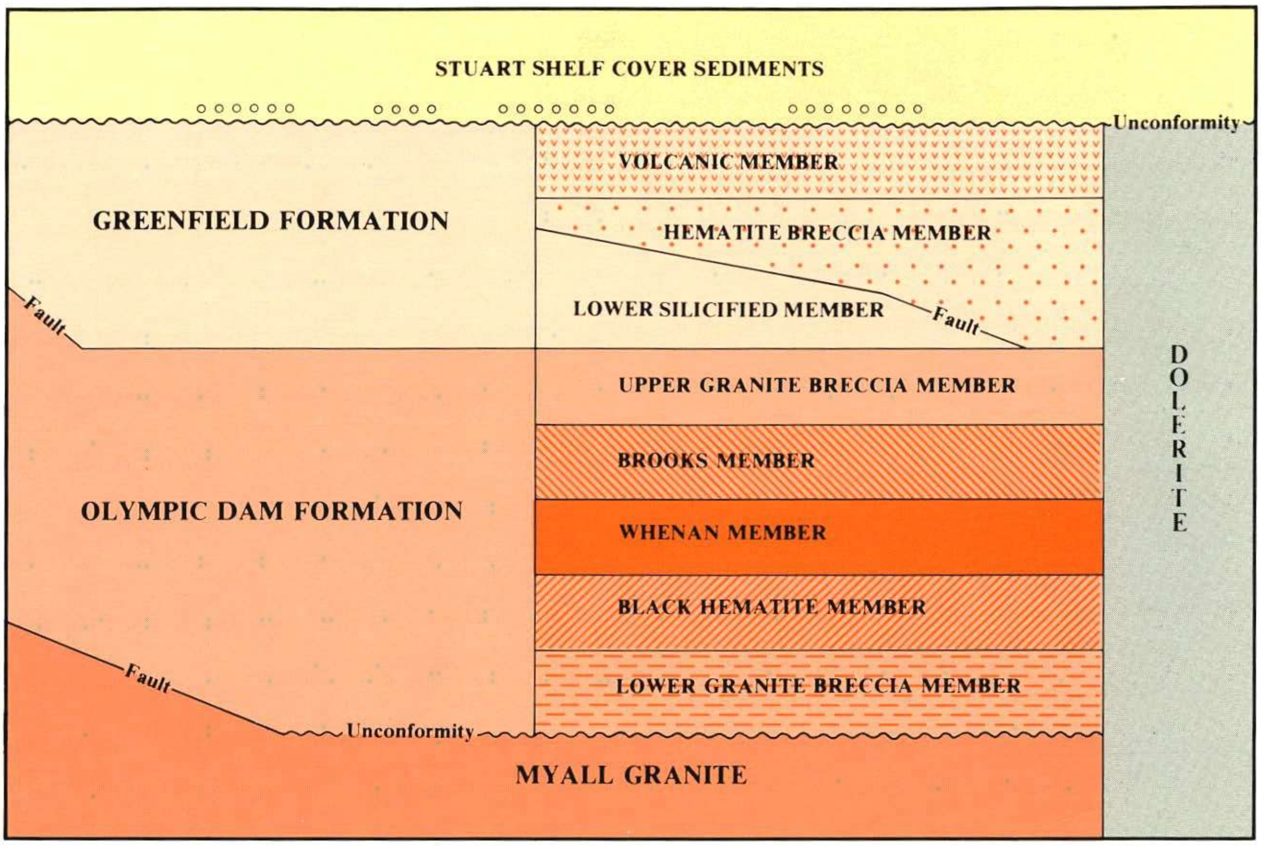


Figure 6.3
COMPOSITE STRATIGRAPHY OF THE DEPOSIT

dominant rock types, and mineralization is found in the lower part of the Formation, particularly in the Lower Silicified Member.

The youngest rock type seen in the Olympic Dam deposit is a dolerite which intrudes the Myall Granite, the Olympic Dam Formation, and the Greenfield Formation, but not the cover sequence.

Stratigraphic relationships of the rock types and mineralization are shown on Figure 6.4 for an west-east section along mine grid line 200,000 north.

6.1.3 Mineralization

A large number of copper and uranium mineralized intersections have been obtained by exploration and infill diamond drilling. The locations of these drill holes are shown in Figure 6.5. Diamond drilling to date has defined a large, elongated, mineralized zone about 7 km long and 4 km wide. Preliminary estimates of the size of the resource based on these intersections are discussed in Chapter 1.

Copper, uranium, gold, silver, and rare earth element mineralization extends throughout the breccia sequence at Olympic Dam, but is best developed in the matrix-rich polymict breccia units of the Olympic Dam Formation. Within the mineralized zone, there is normally a direct relationship between the intensity of sulphide mineralization and the amount of hematite-rich matrix in the host breccias. However, not all hematitic matrix-rich breccias are mineralized.

Individual mineralized intersections may be up to 250 m thick, typically containing, 1.6% copper, 0.06% uranium oxide, and lesser but significant amounts of gold and silver.

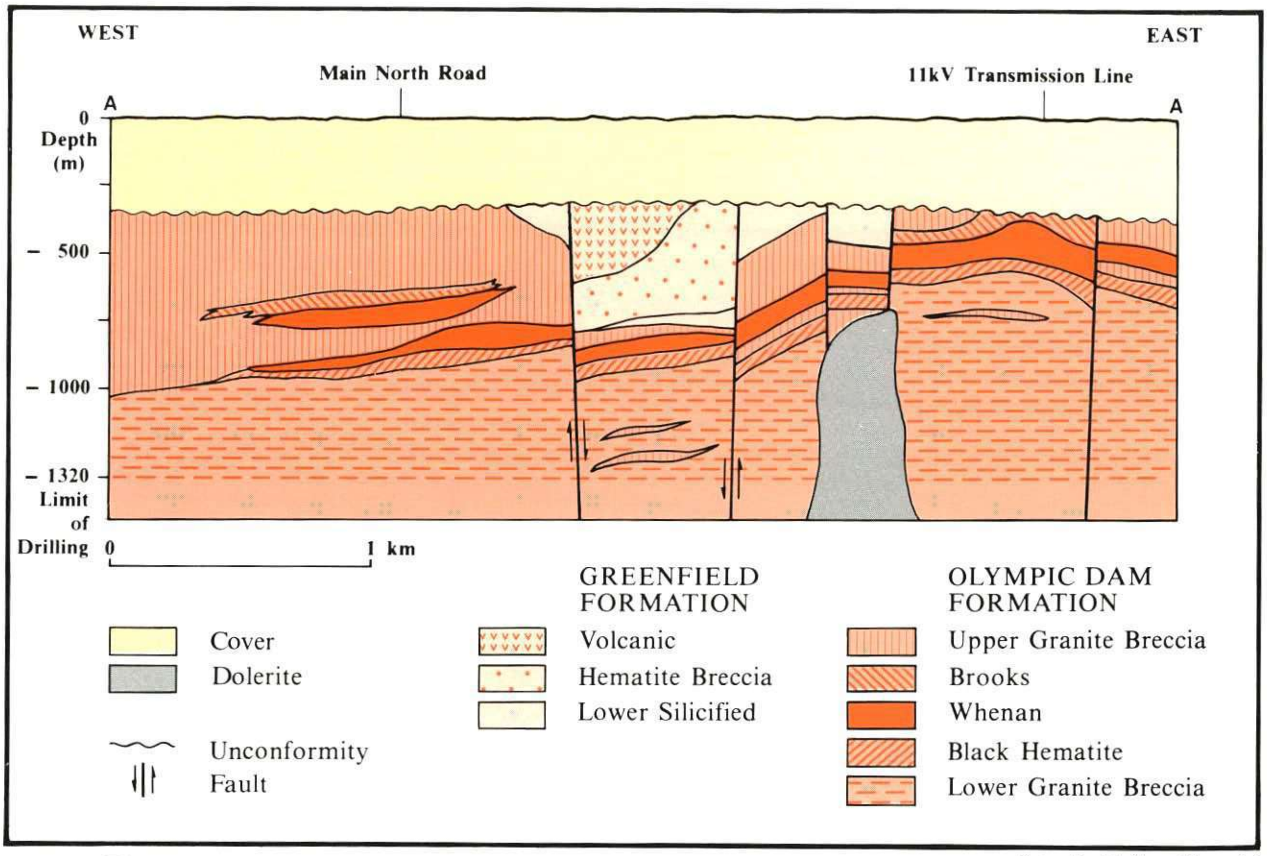


Figure 6.4

Note: See 'A-A' on Figure 6.5

GEOLOGIC CROSS-SECTION ALONG MINE GRID 200,000 NORTH

Mineralized zones have relatively low amounts of sulphides with a typical sulphur content of about 2%. Typical mineralization intersections are shown in Table 6.1. These intersections indicate the variations in copper and uranium oxide grades which are present in the zone of mineralization.

Two distinct types of copper mineralization are defined on the basis of sulphide assemblage, lithologic association and stratigraphic position. These two types are:

- **Type 1** ore comprises stratabound bornite ($Cu_5 FeS_4$), chalcopyrite ($CuFeS_2$), and pyrite (FeS_2), occurring as free grains and aggregates in the three hematite matrix-rich breccia members of the Olympic Dam Formation. The ore contains 5 to 20% sulphides. The bulk of the sulphides occur as even matrix disseminations. The uranium minerals uraninite (UO_2), coffinite ($U(SiO_4)_{1-x}(OH)_{4x}$), and brannerite ($(U, Ca, Ce)(Ti, Fe)_2 O_6$), and the rare earth element minerals bastnaesite ($(Ce, La) CO_3 (F, OH)$) and florencite ($CeAl_3(PO_4)_2(OH)_6$) are intimately associated with the sulphides. Minor amounts of covellite (CuS), carrollite ($Cu(Co,Ni)_2 S_4$) and cobaltite (CoAsS) are present.

  This is a broadly consistent vertical zoning of sulphides within the deposit. Pyrite and minor amounts of chalcopyrite occur in the Black Hematite Member and within thin lenses of the underlying Lower Granite Breccia Member. Chalcopyrite is dominant in the lower parts of the Whenan Member, with bornite at the top of the Member. Bornite and chalcocite occur in the Brooks Member. The mineralization is strongly stratabound, with sharp top and bottom contacts, coinciding with breccia unit contacts. Recoverable grades of copper do not always coincide with rock unit contacts, and internal assay cut-offs will apply.

Figure 6.5
LOCATION OF DRILL HOLES

The dominant gangue constituents are hematite, quartz, sericite and fluorite, with locally abundant carbonate and chlorite.

Type 2 ore, comprising chalcocite (Cu_2S) and bornite mineralization, often in cross-cutting lenses and veins, overlies Type 1 mineralization, and usually occurs in the Upper Granite Breccia Member of the Olympic Dam Formation or the Lower Silicified Member of the Greenfield Formation. The mineralization is not confined to a particular stratigraphic unit and its thickness does not relate to the thickness of its host unit. The sulphides are very closely associated with hematite and fluorite. Uranium and rare earth element minerals are the same as in Type 1. Generally, ore-grade intersections are much thinner, but higher in grade, than in Type 1.

The two types of mineralization are mutually exclusive, apart from some minor overlap. Figure 6.6 shows the distribution of these two types, with the linear distribution of the chalcocite-bornite type being readily apparent.

Table 6.1 **Typical mineralization intersections**

Intersection	Depth interval (m below surface)	Thickness (m)	Copper (%)	Uranium oxide (kg/t)
Intersection with average copper mineralization	510.0 - 514.0	4.0	0.02	0.05
	731.0 - 757.0	26.0	1.62	0.62
	766.0 - 785.0	19.0	1.16	0.49
	811.0 - 822.0	11.0	1.11	0.62
	830.0 - 853.0	23.0	3.42	0.88
	888.0 - 894.0	6.0	1.43	1.24
Intersection with above average copper mineralization	348.0 - 354.0	6.0	7.77	0.41
	354.0 - 373.0	19.0	3.82	0.17
	393.0 - 398.0	5.0	2.21	0.20
	406.0 - 416.0	10.0	0.61	0.76
	569.0 - 578.0	9.0	2.39	0.22
	656.0 - 670.0	14.0	1.11	0.63
	676.0 - 689.0	13.0	1.19	0.44
Intersection with below average copper mineralization	371.0 - 376.0	5.0	0.37	1.30
	461.0 - 467.0	6.0	0.74	0.79
	508.0 - 521.0	13.0	1.01	0.67
	556.0 - 580.0	24.0	1.19	0.47
	736.0 - 763.0	27.0	1.30	0.52

6.1.4 Structure

The deposit lies in the crest of an arcuate north to north-west trending basement high situated in the north-eastern part of the Stuart Shelf.

The major structure localizing the deposit is believed to be a fault-bounded trough or graben (Figure 6.7). The graben is not well defined, but trends north-west to south-east and is arched about a north-east to south-west axis. Vertical and transcurrent faulting occurs parallel to both the graben axis and the arch axis. A combination of arching,

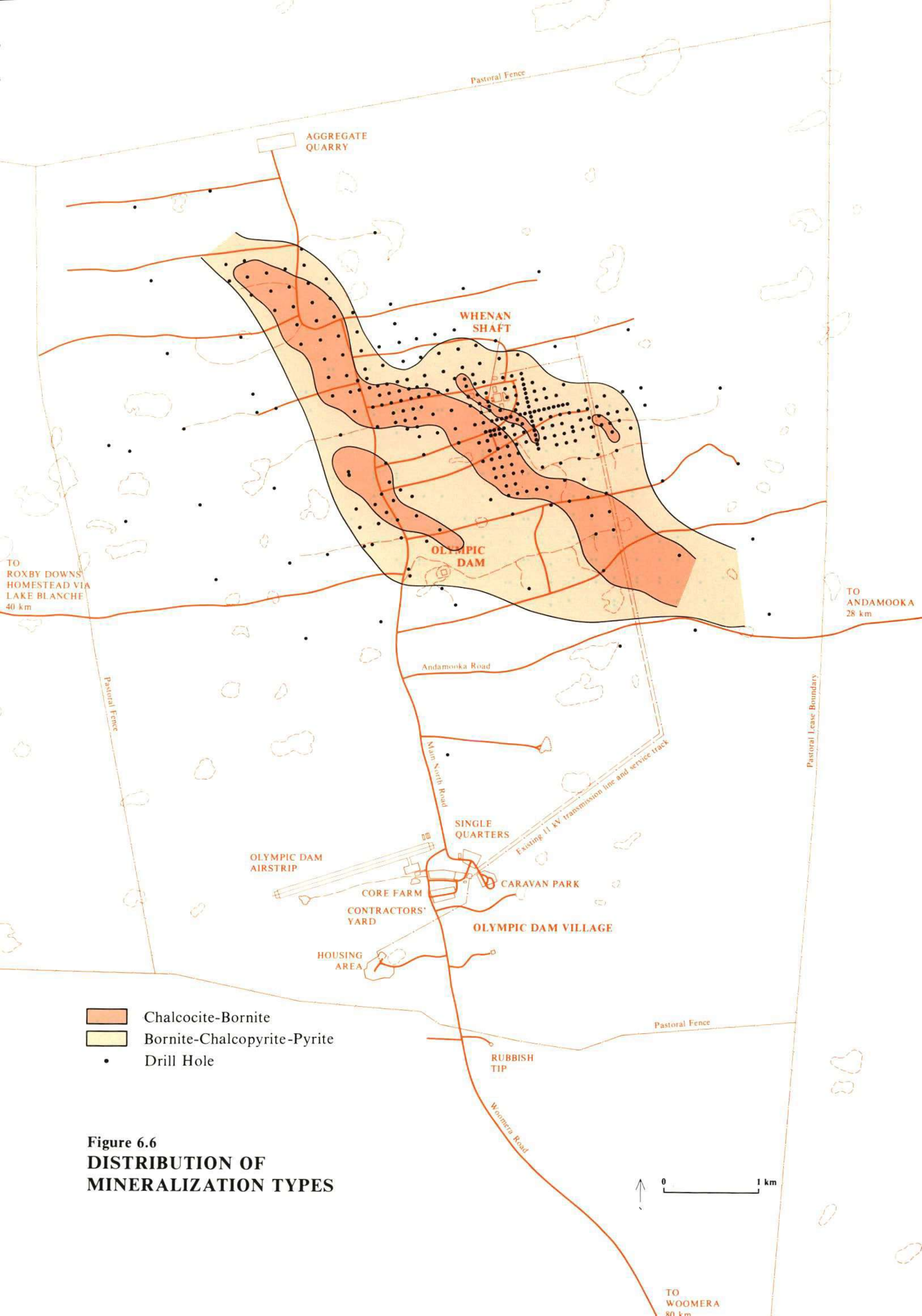


Figure 6.6
DISTRIBUTION OF MINERALIZATION TYPES

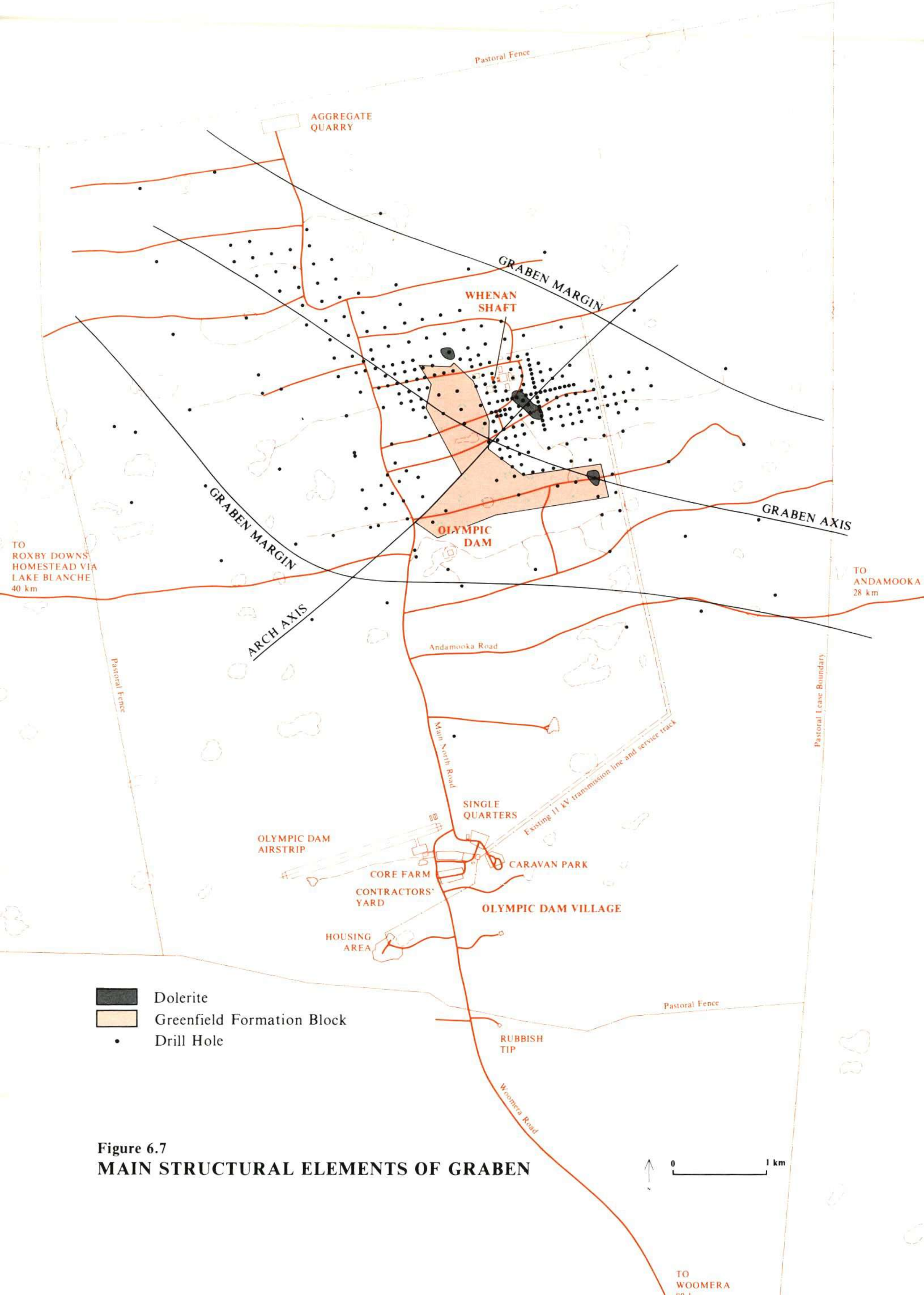


Figure 6.7

MAIN STRUCTURAL ELEMENTS OF GRABEN

faulting and erosion prior to the deposition of the Adelaidean cover sediments has exposed lower parts of the Olympic Dam Formation in the arch crest region. Higher units of the Olympic Dam Formation occur in the north-west and south-west quadrants (Figure 6.8). Remnants of the previously more extensive Greenfield Formation are preserved in downfaulted blocks in the central crest region. In the south-eastern half of the graben, the stratigraphic sequence dips to the south-west at 15 to 20^{o}, while in the north-west dips are to the north. There is local steepening and reversal of dips, resulting from faulting, slumping or local flexuring.

Faults parallel to the graben axis are older than those at a high angle to it, and lateral as well as vertical movement is indicated. The faults are nearly vertical and show no evidence of intense shearing. Older microgranite dykes in the lower part of the stratigraphy, and younger dolerite dykes or sills, are aligned parallel to the graben axis. The dolerite has intruded along faults in some areas, with the main locus of intrusion being in the crest of the structural arch, south-east of the Whenan Shaft.

6.2 HYDROGEOLOGY

The regional and local groundwater systems at Olympic Dam are discussed in the context of their relationship with mine development. This provides the basis for assessment of the effects associated with mine dewatering and of possible changes in groundwater quality.

6.2.1 Groundwater systems

Stratigraphic sequence in relation to hydrogeology

In the area around Olympic Dam the following stratigraphic units are of hydrogeologic relevance:

. Cainozoic

- Quaternary:	Surficial sediments
- Tertiary:	Eyre Formation

. Mesozoic

- Cretaceous:	Cadna-owie Formation
- Jurassic:	Algebuckina Sandstone

. Palaeozoic

- Cambrian:	Andamooka Limestone

. Proterozoic

- Adelaidean:	Arcoona Quartzite Corraberra Sandstone Tregolana Shale
- Carpentarian or Lower Adelaidean:	Breccia sequence (Greenfield Formation and Olympic Dam Formation)

The hydrogeologic characteristics of the formations are described below:

. **Surficial sediments:** The Quaternary sediments form a superficial cover of sand, silt and clay, with gypsum bands. Sands are predominant in the dunes, with silts and clays being more common in interdunal areas. The thickness of these sediments ranges from a few metres to more than 30 m in some areas, with the thicker zones probably representing ancient buried stream channels. The sediments are normally unsaturated, but a wetting front of transient saturation probably occurs for a short period after storms in areas of local pondage or water courses. Shallow bores into local areas of recharge within this sequence in the Andamooka area provide a limited source of domestic and stock water.

- **Eyre Formation:** This occurs as remnants of former Tertiary river channel deposits and is limited to small areas to the south and east of Purple Downs. The salinity of the water in this Formation restricts its uses.

- **Cadna-owie Formation and Algebuckina Sandstone:** These Formations, consisting of sandstone, grit and conglomerate, occur infrequently in the region. Their only importance is in the vicinity of Andamooka, where some shallow bores tap into a limited potable supply.

- **Andamooka Limestone:** The Andamooka Limestone is a fossiliferous, pale brown-grey, fine grained, well jointed dolomitic limestone of Cambrian age, which outcrops to the north-east and south-west of Olympic Dam. Isolated inliers project through the cover at a number of locations within the Project Area. Regional exploratory drilling has shown that the unit varies in thickness from approximately 40 m near the surface in the Acropolis and Olympic Dam areas to greater than 100 m thick at greater depth some 40 km to the north and north-east. The base of the carbonate sequence is best exposed around the western shore of Coorlay Lagoon about 25 km south of the Project Area (Johns 1968). Fossiliferous zones, which elsewhere occur approximately 100 m above the base, are not recorded in the Project Area.

  Where the soil cover is thin, a few dolines are visible on aerial photographs in the areas to the north of Andamooka where the unit is better developed. In the Project Area, terrain/floristic mapping and exploratory drilling have shown that small dolines of 2 to 3 m in diameter exist. These pipes are generally infilled with dune sand, red calcareous loams grading down to yellow claystone, calcareous sandy clay loam and finely divided gypsum. The dolines may represent a more direct path for limited recharge of groundwater.

  Some areas of perched water may occur, but these are of limited dimensions and probably intermittent in nature. In a series of drill holes around Olympic Dam for which significant water occurrences were recorded, only 5% found water at the base of the Andamooka Limestone. To the south and west of the Project Area, limited pastoral and domestic use is made of water in the Andamooka Limestone via shallow wells and bores.

- **Arcoona Quartzite and Corraberra Sandstone:** The Arcoona Quartzite, and to a lesser extent the Corraberra Sandstone, provide the main aquifer in the Olympic Dam area, and extend throughout the region of interest. The Arcoona Quartzite consists of flat-lying, red and white flaggy quartzite, and is about 140 m thick. It is underlain by the Corraberra Sandstone, which is variable in thickness but is generally in the order of 20 m. Groundwater occurs within fractures in both units but, as commonly found in fractured rock aquifers, yields are variable.

  The aquifer is characterized by marked variations in water levels, with changes in levels occurring over relatively short distances in the Olympic Dam area. The depths at which groundwater has been intersected during air drilling are shown in Figure 6.9. Generally, static water level is about 50 m below ground level, although it ranges from 45 to 60 m on the Australian Height Datum. Drilling results show a random relationship between depth and yield, but higher yields appear to be concentrated in the depth range from 160 to 200 m (the white basal section of the Arcoona Quartzite). It would appear that the upper red Arcoona Quartzite above about 160 m is generally less permeable than the lower white Arcoona Quartzite and

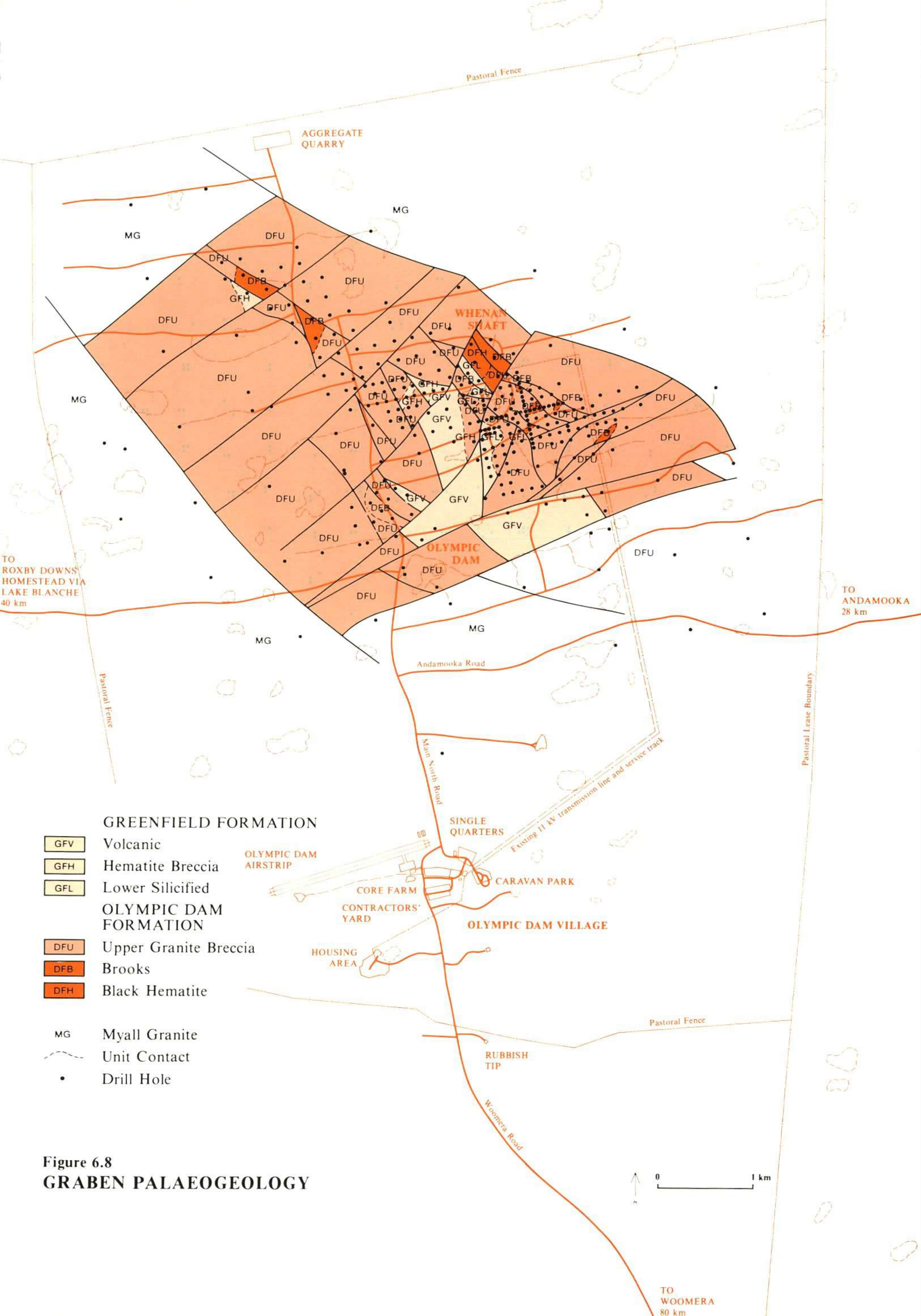


Figure 6.8
GRABEN PALAEOGEOLOGY

Corraberra Sandstone. The upper layer may act as a semi-confining bed to the deeper aquifer, although vertical leakage and horizontal flow can occur in this less permeable layer. There is thought to be a limited hydraulic connection between the Arcoona Quartzite and the Andamooka Limestone.

- **Tregolana Shale:** The Tregolana Shale is a laminated purple-brown and green shale with local cream dolomites at its base. The Shale has a very low permeability, but some horizontal and vertical permeability may occur where faults or fractures are present.

- **Breccia sequence:** The breccia sequence has been faulted since deposition; however, it has little or no primary porosity, and where the faults or fractures have been intersected there appears to be limited permeability. Although the potentiometric level in the breccia sequence appears to be similar to that in the Arcoona Quartzite, groundwater movement rates are at least several orders of magnitude lower than in the Arcoona Quartzite because the breccia permeability is much lower. No faults have been detected which extend from the breccia sequence into the overlying cover sediments.

Groundwater recharge and movement

The region comprises a complex interconnected system of fractures, with some areas having very limited hydraulic connection with adjacent areas. There is a regional trend for water levels to decrease to the east towards Lake Torrens. Figure 6.10 shows the information available on the area and, although the data is sparse, approximate water level contours have been drawn.

The regional contours indicate two areas of elevated water levels: one area south and south-west of Olympic Dam, and another area north of Andamooka. This suggests that areas of outcropping limestone are also areas of greatest regional recharge to the groundwater system. On a local scale, differential areal recharge is likely to be centred in claypans and other drainage depressions which, combined with poor hydraulic connection, could produce areas of groundwater 'mounds' which dissipate slowly. Such a mechanism would account for the variations in water levels observed in nearby drill holes and bores.

Recharge rates are small by comparison with the rainfall. Indicative values can be obtained from chloride balance calculations. Using an average chloride content of 4 mg/L for rainfall and the range of measured chloride contents for groundwater in the Olympic Dam area (7,000 to 18,600 mg/L), the following range of estimated recharge rates is obtained:

- the lowest rate - 36 m^3/km^2 per annum, or 0.02% of rainfall;
- the highest rate - 95 m^3/km^2 per annum, or 0.06% of rainfall.

Locally, the direction of groundwater movement can be expected to be quite variable, depending on the location of recharge areas, the orientation of fractures or other openings, and the hydraulic connection between the various conduits. On a regional scale, the water level contours indicate a general easterly groundwater movement.

The rate of regional groundwater movement is estimated to be approximately 0.05 m/d through the more permeable sections of the Arcoona Quartzite. The time required for water to flow from Olympic Dam to Lake Torrens would therefore be about 2,500 years, assuming the availability of a straight path of reasonable permeability.

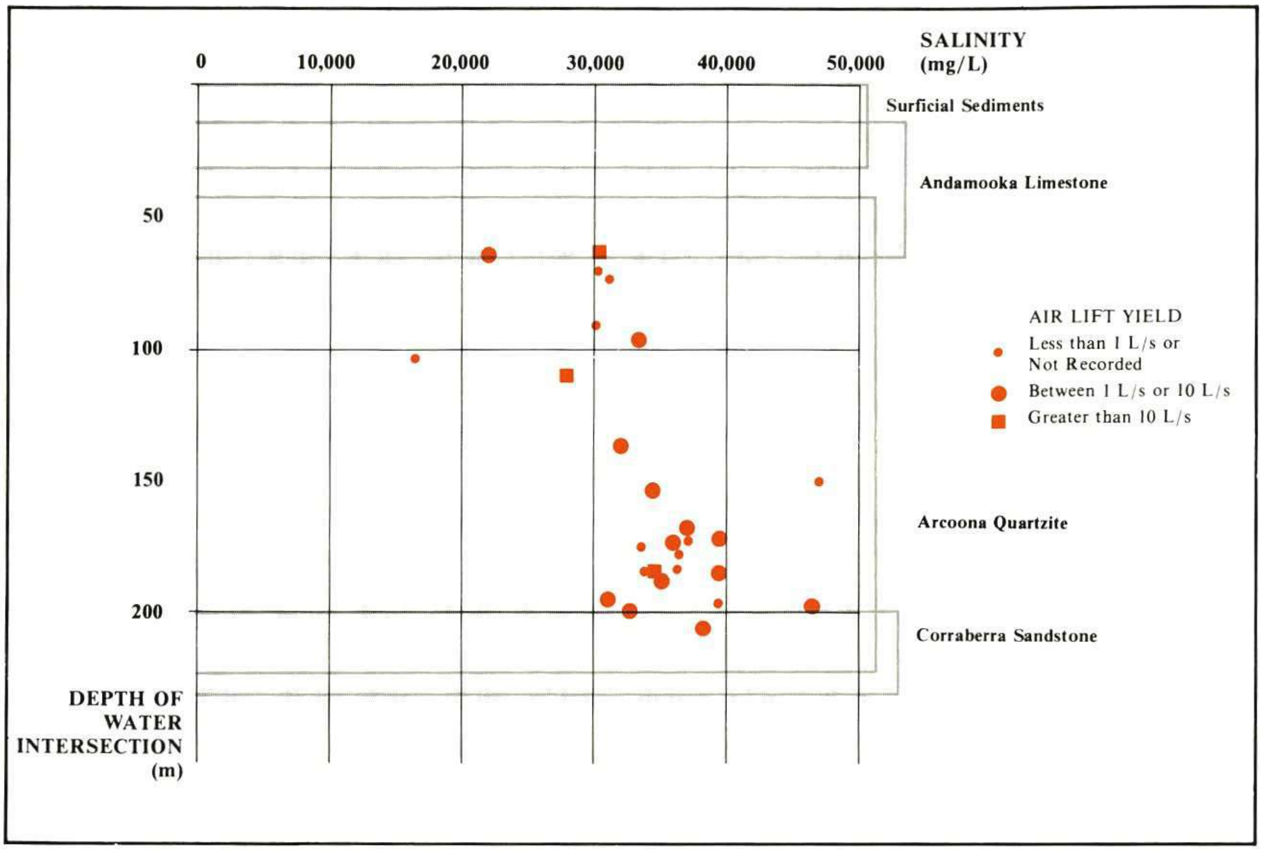


Figure 6.9
DEPTH OF GROUNDWATER INTERSECTION AND SALINITY VARIATION

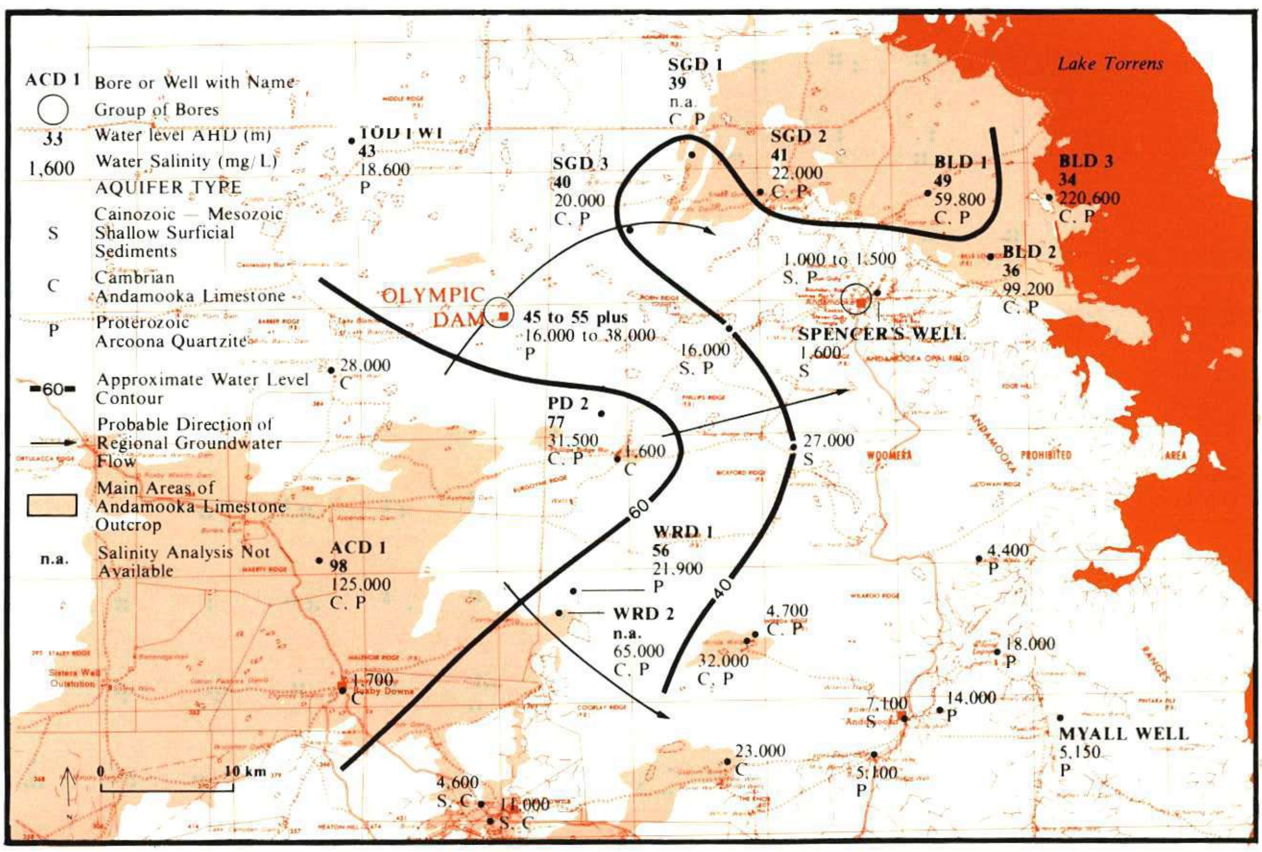


Figure 6.10
REGIONAL HYDROGEOLOGY

Groundwater quality and beneficial uses

Salinities vary markedly throughout the area of hydrogeologic interest, ranging from 1,000 mg/L in shallow stock wells to more than 200,000 mg/L in a deep bore near the western shore of Lake Torrens (Table 6.2 and Figure 6.10). Very little of the water is of potable or near potable quality. The records of approximately one hundred bores or wells which were drilled for water in the area show that:

- approximately 65% yielded water with a salinity of 10,000 mg/L or greater, and were usually abandoned;
- 25% yielded water with a salinity of between 2,000 and 10,000 mg/L. Some of these bores have been equipped for stock watering purposes (such as Myall Well, which taps the surface layers of the Arcoona Quartzite);
- 10% yielded small quantities of water with a salinity of less than 2,000 mg/L. These were generally the shallow bores and wells (approximately 10 m deep) sunk in local catchments tapping perched water isolated from the underlying more saline aquifers.

Table 6.2 Groundwater quality

	Regional bores					Arcoona Quartzite in Project Area						Breccia sequence in Project Area				
	Spencer's Well (1)	Myall Well (2)	PD2 (3)	BLD1 (3)	BLD3 (4)	RD234	RD235	RD188	RD81 (5)	RD81 (6)	Shaft	RD233	RD321	RD34 (7)	RD34 (8)	RD80
pH	7.9	7.7	7.4	7.2	4.1	7.15	6.85	6.9	8.0	7.6	7.8	6.95	6.8	7.7	6.8	7.3
TDS* (mg/L)	1,600	5,150	31,500	59,800	220,600	31,900	37,750	37,750	21,107	34,362	30,523	22,100	34,300	38,527	95,100	38,500
Calcium (mg/L)	180	545	255	980	4,690	690	840	930	537	743	710	590	910	560	1,630	650
Magnesium (mg/L)	30	88	815	1,200	1,640	890	1,100	1,100	550	857	790	570	990	1,020	1,090	860
Sodium (mg/L)	310	1,000	9,900	18,800	80,000	9,400	11,650	11,600	6,467	10,600	9,250	5,750	10,100	12,340	32,580	11,800
Potassium (mg/L)	0.6	5.2	90	110	650	54	65	63	37	48	49	37	60	70	430	125
Chloride (mg/L)	175	668	15,479	32,309	137,344	14,250	18,350	18,600	8,272	16,600	14,908	8,250	16,200	19,296	55,770	18,840
Sulphate (mg/L)	730	2,690	3,500	4,200	1,890	5,000	5,300	5,050	5,098	5,280	4,690	4,050	4,500	5,150	3,620	4,690
Bicarbonate (mg/L)	279	200	749	156	0	370	350	370	297	368	236	380	370	186	32	54
Iron (mg/L)	1.05	4.2	230	19.3	35.0	5.2	7.7	9.3				5.3	60			55
Manganese (mg/L)	<0.02	0.04	1.55	.046	2.3	0.5	0.85	0.9				0.5	1.4			2.85
Fluoride (mg/L)	0.79	1.4	0.41	1.4	0.27	2.5	1.5	1.5	<1	<1		3	1.5			1.1
Silicate (mg/L)						15.8	11.3	11.6				20.5	15.0			
Copper (µg/L)	<200	<200	400	<200	<200	910	80	70	<40	<40		350	280			<200
Lead (µg/L)	<200	<200	<200	<200	1,400	430	530	560				220	1,950			<200
Zinc (µg/L)	1,400	850	1,300	550	500	50	1,350	810	<10	150		7,350	56,000			2,150
Nickel (µg/L)						<10	<10	<10				<10	<10			
Cadmium (µg/L)						<10	<10	<10				<10	<10			
Uranium (µg/L)	2.5	42	<1	15.0	<1	14.5	1.5	1.5	36.0	98.0		13.5	12			2.6
Radium (Bq/L)	0.0185	0.037	0.037	0.085	3.515	1.480	2.405	2.405			0.777	0.925	2.590			0.592
Remarks	Bailed samples	Bailed samples	Bailed samples	Bailed samples	Bailed samples	Pumped sample	Pumped sample	Pumped sample	Airlift sample	Airlift sample	Water inflow	Pumped sample	Pumped sample	Pumped sample	Pumped sample	Bailed samples

* Total dissolved solids.
(1) In surficial sediments.
(2) To top of Arcoona Quartzite.
(3) Drawing from Andamooka Limestone and Arcoona Quartzite.
(4) Deep bore into Arcoona Quartzite.
(5) At 64 m.
(6) At 216 m.
(7) After 45 min.
(8) After 158 min.

In the Project Area therefore, groundwaters are very saline. Salinities in the Arcoona Quartzite generally range from 20,000 to 40,000 mg/L and in the breccia sequence from 21,000 to more than 95,000 mg/L. It is apparent that the level of salinity increases with depth (Figure 6.9). For example, in drillhole RD81 at Olympic Dam (Table 6.2), the airlift sample collected during drilling at a depth of 64 m had a salinity of 21,110 mg/L, while the sample collected at 216 m had a salinity of 34,360 mg/L.

The mean salinity of the breccia sequence samples is also marginally greater than in the Arcoona Quartzite, and further evidence from salinity variations apparent during continuous pumping suggests that much higher salinities occur in at least part of the basement complex. During pumping of drill hole RD34 at Olympic Dam, the salinity increased from 38,530 mg/L initially, to 95,100 mg/L after 158 minutes. This increase in salinity was accompanied by a rise in pH, a relative increase in sodium and potassium, a greater chloride content, and a decrease in sulphate and bicarbonate content. The temperature of the water also increased during pumping, indicating that deeper waters were being tapped.

The composition of dissolved solids also varies markedly between the groundwater systems, and appears to be depth related. The shallow, less saline waters are more akin chemically to rainwater which has dissolved calcium sulphate and sodium chloride during its passage through the soil layer. In the deeper more saline bores, the water is relatively richer in sodium chloride, indicative of processes of sulphate reduction, calcium and magnesium/carbonate and sulphate precipitation and base ion exchange, and/or the mixing effect with prior saline waters. The results noted above for RD34 are indicative of these effects.

The chemical composition of waters in the Arcoona Quartzite is generally uniform throughout the region, the water being essentially a sodium chloride water but with a consistently high sulphate content, which is typical of Stuart Shelf waters. The waters have a nearly neutral pH with a relatively high iron and manganese content, but with other heavy metal content of the order of 1.5 mg/L (Table 6.2). The groundwater in the breccia sequence resembles that in the Arcoona Quartzite, except for higher zinc and lead levels and an increasing sodium chloride content in the more saline sample.

Both shallow and deep holes throughout the area contain detectable amounts of uranium and radium. Some shallow bores and wells contain more uranium than do deeper holes - even those deeper holes in the vicinity of Olympic Dam. Radium-226 content is up to 2.5 Bq/L in the Project Area and generally less than 0.1 Bq/L elsewhere in the region.

Hydraulic parameters

The hydraulic parameters of the main stratigraphic units in the Project Area can be estimated from pumping tests, Lugeon tests, and airlift recovery tests conducted on bores in the Olympic Dam area and from inflows to the Whenan Shaft. Hydraulic parameters are highly variable, which is a typical feature of fractured rock aquifers.

It should be noted that hydraulic conductivity rates (permeabilities) for fractured rock aquifers refer to an apparent bulk average and do not indicate the hydraulic conductivity of the fractures. Hydraulic conductivity is a measurement of the volume of water per unit cross-sectional area which would move through the fractures and pore spaces in the aquifer under the influence of a unit gradient. Transmissivity values are also given, which refer to the volume of flow (m^3 /d) through a complete aquifer section of unit width (1 m) under the influence of a unit gradient.

In the Arcoona Quartzite, the main aquifer in the Project Area, transmissivities range from less than 1 to 290 m^3 /d.m with apparent permeabilities ranging from 0.001 m/d in unfractured zones to greater than 1 m/d in the more fractured areas. Analysis of the fall in water levels around the Whenan Shaft in response to shaft inflow indicates transmissivities of the order of 5 to 10 m^3 /d.m which give a bulk permeability of about 0.1 m/d.

Tests carried out on the Tregolana Shale and breccia sequence have indicated low values for transmissivity (0.01 to 0.1 m^3 /d.m) and permeability (0.001 to 0.0001 m/d). These are substantially lower than those in the Arcoona Quartzite. Major fracture and fault zones in the Tregolana Shale and the breccia sequence may have a higher value, but as yet no such zones have been detected.

The extent of any hydraulic connection between the breccia sequence and the Arcoona Quartzite has not been accurately established. The Tregolana Shale (the intervening formation) has a very low permeability. However, during pumping tests on the breccia sequence, a small reaction was recorded in observation bores in the Arcoona Quartzite, which may indicate the existence of tenuous flow paths between formations.

Falling head tests have been conducted on bores in the surficial sediments and in the Andamooka Limestone. For the surficial sediments, permeabilities range from 0.03 m/d for silty sections up to 4 m/d for the sands, with the most common range being from 0.1 to 0.6 m/d. A permeability of about 0.005 m/d is indicated for the Andamooka Limestone in the absence of major channels or fractures.

6.2.2 Impact of mining

Potential groundwater impacts due to mine development are associated with:

- mine dewatering and inflow, which will produce a cone of depression in the surrounding potentiometric surface;
- chemical changes in groundwater on re-entry to the mined out area after cessation of mining.

The potential for seepage to occur from the tailings retention system and other evaporation ponds to groundwater is discussed in Chapter 7.

Effect of existing shaft development

During sinking of the Whenan Shaft, some groundwater inflow occurred from the weathered top of the Arcoona Quartzite when the shaft was at 49 m below the shaft collar (several metres below the zone of saturation). Except for a continual weep, this flow ceased after four months. The major inflow occurred from a fracture zone between 160 and 190 m below the shaft collar, near the base of the Arcoona Quartzite, and this flow has been constant at a rate of 450 m^3 /d since the middle of 1981. The shaft is now almost to a depth of 500 m and is in the breccia sequence. No other inflow zones have been intersected.

The current groundwater inflow to the shaft has caused a cone of depression in the Arcoona Quartzite aquifer, the extent of which is shown in Figure 6.11. The cone of depression has an east-west elongation and has extended at least 1.5 km from the shaft along this axis. The elongated cone indicates greater permeability and hydraulic connection in this direction, possibly caused by the orientation of fractures. This cone of depression is still expanding. Water levels are being monitored to further delineate the detailed hydrogeological nature and variability of the area.

A best fit empirical description of the observed cone of depression in the Arcoona Quartzite aquifer can be obtained using the following average hydraulic parameters:

Permeability	=	0.1 m/d
Long-term storage coefficient	=	0.005
Leakage factor	=	3,000 m

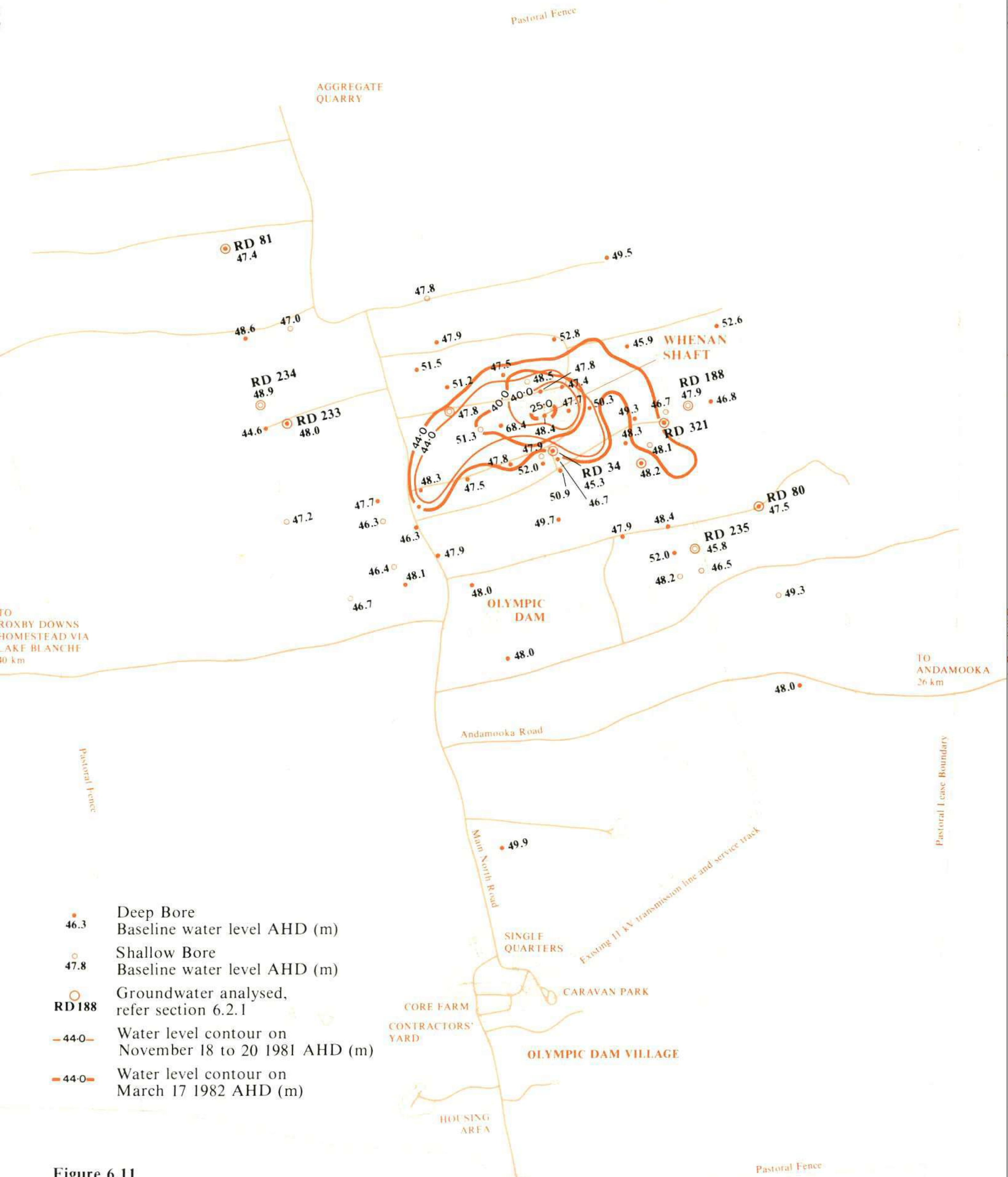


Figure 6.11

CONE OF DEPRESSION DUE TO WHENAN SHAFT DEVELOPMENT

The anisotropic nature of the aquifer and of the elongated cone of depression are best illustrated by the transmissivity values along the east-west axis which are about ten times those along the north-south axis.

Mine dewatering

It is proposed to dewater the Arcoona Quartzite aquifer in the mine area in advance of mining. Implementation of this dewatering scheme will involve pumping from exploration drill holes, with additional holes being drilled in selected areas. Pumping rates were estimated by a computer model assuming the average hydraulic parameters based on the effects of current shaft development. The initial pumping rate was estimated to be 7,600 kL/d, which would require up to thirty dewatering bores, each with a capacity of 260 kL/d. This rate would reduce to between 1,300 and 3,200 kL/d after ten years, and to between 1,000 and 2,000 kL/d in the long term (Figure 6.12). This pumping rate is flexible, and may be varied according to the rate at which dewatering is required. Water from the aquifer dewatering bores (with the exception of a small amount used for dust suppression) will be evaporated from a pond adjacent to the tailings retention system, details of which are contained in Chapter 7.

The minor amounts of groundwater which will continue to flow into the mine are estimated to rise from 500 kL/d in the first year of mining to a peak of 1,300 kL/d after five years, and thereafter declining to zero after about ten years. In addition to these inflows from the Arcoona Quartzite aquifer, there may be a maximum flow of approximately 200 kL/d into the mine from the breccia sequence, assuming no conduit for flow exists between the breccia sequence and the Arcoona Quartzite.

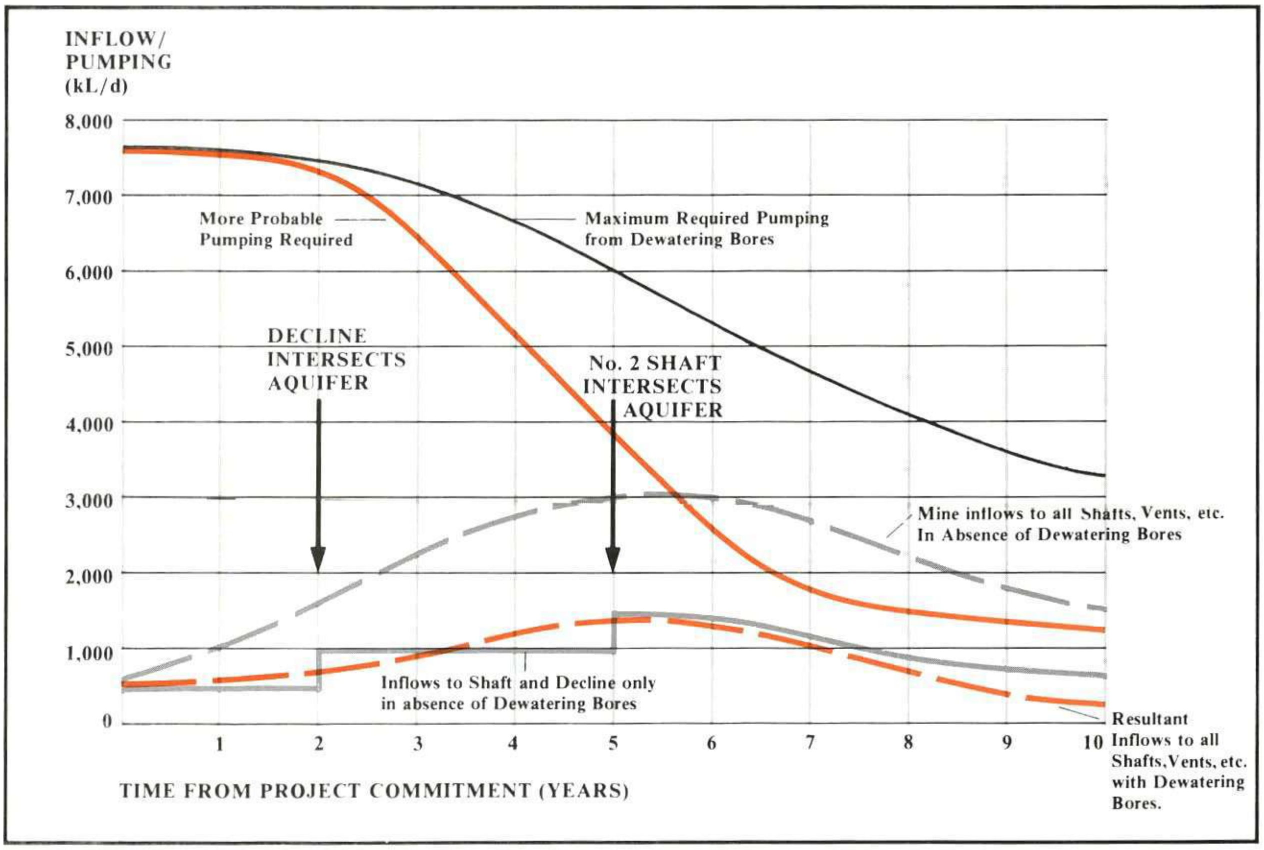


Figure 6.12
MINE GROUNDWATER INFLOW AND DEWATERING PUMPING RATES

This groundwater inflow will be pumped from the working areas of the mine, together with introduced water from the Great Artesian Basin supply which will be used for underground placement of hydraulic fill as well as for drilling, washing equipment, wetting broken ore, and other uses. The possible use of this water for process make-up water after suitable treatment will be investigated. If this use of mine water is not possible, then it will be pumped to the tailings retention system for evaporation.

The following alternatives to aquifer dewatering in advance of mining were also considered:

- Collection and pumping of groundwater inflow to the mine without grouting the shafts, ventilation raises and decline: inflows from the Arcoona Quartzite would be 1,000 kL/d in the first year, reaching a peak of 3,000 kL/d in five years, then declining to 1,500 kL/d after ten years, and stabilizing at 1,000 to 1,500 kL/d in the long term (Figure 6.12).

- Collection and pumping of groundwater inflow to the mine, with ventilation raises grouted and the shafts and the decline left ungrouted: mine inflows would be 500 kL/d initially, increasing to a peak of 1,400 kL/d at five years, and thereafter declining to 900 kL/d at ten years, with a long-term inflow of 400 to 500 kL/d (Figure 6.12).

Because of disadvantages associated with ventilation fan maintenance, additional ventilation costs, and increased mine humidity, direct inflows of highly saline water through ventilation raises are not considered acceptable. Therefore, either the ventilation raises must be grouted or the aquifer dewatered, thereby eliminating the first alternative.

Aquifer dewatering was preferred over the second option for the following reasons:

- cost savings which would result from not having to grout or line ventilation raises;

- the lower volume of saline groundwater which would enter the mine;

- lower pumping costs, as pumping would be from a higher level;

- the lower humidity within the mine, which would improve working conditions;

- the smaller volume of contaminated water which would need to be pumped from the mine, thereby reducing the area of the evaporation pond requiring impervious lining;

- the reduced possibility of high pressure inflows which could occur if the underground workings penetrated a fault zone interconnected to the overlying aquifer.

Impact of aquifer dewatering

The impact of mining on the Arcoona Quartzite aquifer will be the creation of a cone of depression in the potentiometric surface in the area surrounding the mine, as well as the removal of highly saline groundwater from the aquifer to the surface for disposal.

In the mine area, dewatering will theoretically reduce the water levels in the Arcoona Quartzite aquifer to the base of the Quartzite. About four times the amount of water will be removed compared with that which would flow into the mine if ventilation raises were grouted. The cone of depressed water levels will extend approximately 5 km from the edge of the dewatered area and, if regional conditions are similar to those in the mine area, an elongation of the cone of depression will occur along an east-west axis. The cone of depression in the breccia sequence will be much more localized because of the lower hydraulic conductivities of these rocks.

The effect of the cones of depression in the Arcoona Quartzite and the breccia sequence will be the redirection of groundwater movement into the mine area during mining and for some hundreds of years after mining ceases. Only when groundwater levels have returned to equilibrium conditions, will groundwater movement away from the mine area (to the east) again occur.

Water from aquifer dewatering will be evaporated from a clay-lined pond adjacent to the tailings storage facility (Chapter 7). Evaporation of water from dewatering bores will initially produce about 100,000 t/a of salts, declining to about 12,000 to 25,000 t/a in the long term.

Chemical changes in groundwater

On cessation of mining, groundwater movement will continue towards the mine area in both the Arcoona Quartzite and the breccia sequence, and will mix with any remnant mine water. Once equilibrium hydraulic gradients have been re-established, regional movement of groundwater from the mine area towards Lake Torrens will be restored. In the mine area, localized pockets of low pH water with a high heavy metal content will be present and will be mixed with groundwater in the breccia sequence. This groundwater will move very slowly eastwards, providing an opportunity for heavy metals to be fixed or diluted by neutralization, sorption, sulphate reduction and dispersion. However it should also be noted that, under natural conditions at depth under Lake Torrens, existing groundwater has a low pH and elevated heavy metals content as indicated by bore BLD3 in Table 6.2.

There will be no effect on the water quality of existing sources used for stock or domestic purposes in the region, as either the direction of water movement will be towards the mine during operation or, after closure, any remnant mine water will be confined to the breccia sequence groundwater.

Olympic Dam is 90 to 100 km to the south of the Great Artesian Basin aquifers and, as these aquifers are separated from the Olympic Dam area by relatively impermeable Cretaceous shales and at depth by buried ridges of older Proterozoic rocks, they will not be contaminated by mining operations at Olympic Dam.

Recent investigations by the Joint Venturers have confirmed that groundwater in the Basin aquifers flows from north to south, with the most southerly margins of the Basin being predominantly areas of discharge rather than recharge. Furthermore, hydraulic pressures in the aquifers are sufficient to prevent much closer, and in some instances more saline, waters than those at Olympic Dam from contaminating the aquifers.

After cessation of mining, the Arcoona Quartzite aquifer in the mine area will receive water of similar quality to that of existing groundwater from surrounding areas.

6.2.3 Groundwater monitoring

A groundwater monitoring programme will be established to:

- monitor the dewatering system to ensure mining requirements are met
- monitor the cone of depression
- detect any changes, so that remedial action can be taken if necessary.

For the Arcoona Quartzite aquifer, monitoring of dewatering and environmental water quality will be combined.

Monitoring of pumpage and water levels will be required for the management of the dewatering system. In addition, samples will be collected for analysis from selected bores close to surface areas of possible contamination. Properly constructed monitoring bores will be located around the Project Area boundary, and regular water level and quality monitoring of selected existing bores and wells outside the Project Area will also be undertaken.

The location and amount of any inflows to the mine will be noted, and samples will be taken periodically for analysis. Flow meters will be installed to enable measurements of flows into, and pumpage out of, the mine. Samples of water pumped out of the mine will be taken for analysis on a regular basis, to determine whether this water can be used in the plant circuit.

6.3 SEISMICITY

Earthquake magnitudes experienced in Australia are well below the scale of events experienced in serious earthquake risk areas such as California. Buildings in California are designed to withstand ground forces associated with earthquakes which are about four times greater than those considered in designing similar buildings in seismic risk areas in South Australia. The Bureau of Mineral Resources places Olympic Dam in Zone A on the Seismic Zone Map of Australia, which is the lower end of the earthquake risk scale. Drilling and mapping in the Olympic Dam area have indicated no direct evidence of faulting in the Stuart Shelf sediments, and Stewart and Weichert (1981) estimated that the site lay in SAA Earthquake Code Zone Zero representing a lower risk than that previously estimated by the Bureau of Mineral Resources. There are seismically active zones elsewhere in Australia which do require some design consideration for earthquake risk, and one such zone is the Adelaide Geosyncline lying to the east of Olympic Dam. However, the risk diminishes sharply away from the Geosyncline.

6.3.1 Seismic zoning

A significant number of the known earthquakes in South Australia have occurred in the vicinity of the Adelaide Geosyncline, which extends in an approximate north-south direction following the Mount Lofty and Flinders Ranges. The distribution of events recorded from 1883 to 1979 is shown on Figure 6.13 (Stewart and Weichert, 1981).

Seismic risk analysis throughout Australia was examined broadly in the SAA Earthquake Code AS 2121-1979, in which earthquake activity zones intended to encompass places of similar earthquake risk were drawn up for application in the design of general purpose buildings. These zone boundaries were constructed utilizing base data held by the Bureau of Mineral Resources, analytical methods and criteria available up to 1975, and the known seismic history and regional tectonics. However, because of the sporadic distribution of seismicity in several areas, the degree of precision in these zone boundaries is low. It has also been found that earthquake magnitudes given for South Australia were too high, and this had led to further inaccuracies in boundary assessment.

6.3.2 Measurement of earthquake magnitude in South Australia

The magnitude of an earthquake is a measure of the energy released, and is universally defined in terms of the Richter (1958) magnitude scale (M_L). Conversion of local magnitudes to the Richter scale is complicated by specific instrument characteristics and local seismic wave attenuation characteristics. The conversion formula,

$$M_L = 1.33\ M_n - 0.73 \qquad (1)$$

where M_n = local scale of magnitude,

originally developed by Stewart was adopted by the Bureau of Mineral Resources to convert all data magnitudes to Richter magnitudes. The data base for the Zone Map of the SAA Earthquake Code also relies on the use of this conversion.

In order to minimize dispersion in local magnitude estimates due to different instrumental band widths, Stewart (1975) subsequently established a scale to allow for the average source spectrum, geometrical attenuation, and frequency dependent absorption. He proposed that his original conversion formula (1) was not correct, and that a more realistic relationship would be:

$$M_L = 1.05\,M_n \qquad (2)$$

Stewart (pers. comm.) found that, with this revised formula, analyses of recurrence and risk using temporal subsets of the whole data set (which extends from 1883 to 1979) are in reasonable agreement, allowing for some random variation in earthquake occurrence. In addition, and most importantly from the point of view of risk analysis, the new formula indicates that predictions for the felt effects from the lower magnitude events probably require some reduction as a result of reductions in the converted M_L magnitudes from 1969 onwards. The Bureau of Mineral Resources now agrees that Stewart's new conversion formula is more likely to be correct, and advice is given to users of the earthquake file that the older conversion is incorrect.

6.3.3 Analysis of risk by the seismic moment method

Seismic risk in South Australia has recently been assessed by Stewart (unpublished) using the seismic moment method and data based on his new conversion formula. In this approach, activity in small source zones is expressed in terms of seismic moment, which is defined as the product of fault plane area, fault slip displacement and the shear strength of the rock. For some purposes this method is preferred to the use of magnitude or energy release as a measure of earthquake size, since a minimum of assumptions is made about the extent of the active areas, and zones are sufficiently small to be regarded as point sources. The observed limits of seismicity can therefore be more accurately reflected than in conventional regionalization techniques, in which seismic risk maps are smoothed by a subjective grouping into regions of uniform activity. On evidence now available, Stewart's seismic moment method of analysis using the new conversion formula for the base data appears to provide the most reasonable estimates for the site risk recurrence relationships. A similar conclusion has been drawn by Santos Ltd in relation to its proposed development at the Stony Point site.

In the seismic moment method, the attenuation relationship of Esteva (1976) for ground velocity and acceleration is used to model the attenuation effects. A comparison of observed velocity-distance-magnitude curves from South Australian data using the Esteva formulae suggests that the latter provide a useful guide for the prediction of ground movement at local sites to within a factor of 2. The equations probably tend to be conservative (i.e. to overestimate the ground motion). Thus, any errors arising from inaccuracies in the attenuation relationships employed are not likely to cause the real risks to appear appreciably, if at all, greater than the risks as calculated.

All velocities and accelerations obtained in the analysis are derived from the equations for peak values. These equations are based on an analysis of both horizontal and vertical component strong motion records of earthquakes, and should represent the peak values regardless of orientation. It should not be necessary, therefore, to apply further correction factors to the calculated peak ground motions to allow for horizontal movement larger than vertical movement, and some reduction factor might be appropriate if only vertical accelerations are being considered.

The recurrence relationships for peak ground velocity and acceleration have been computed by Stewart (unpublished) for parts of South Australia at points on a 0.2°

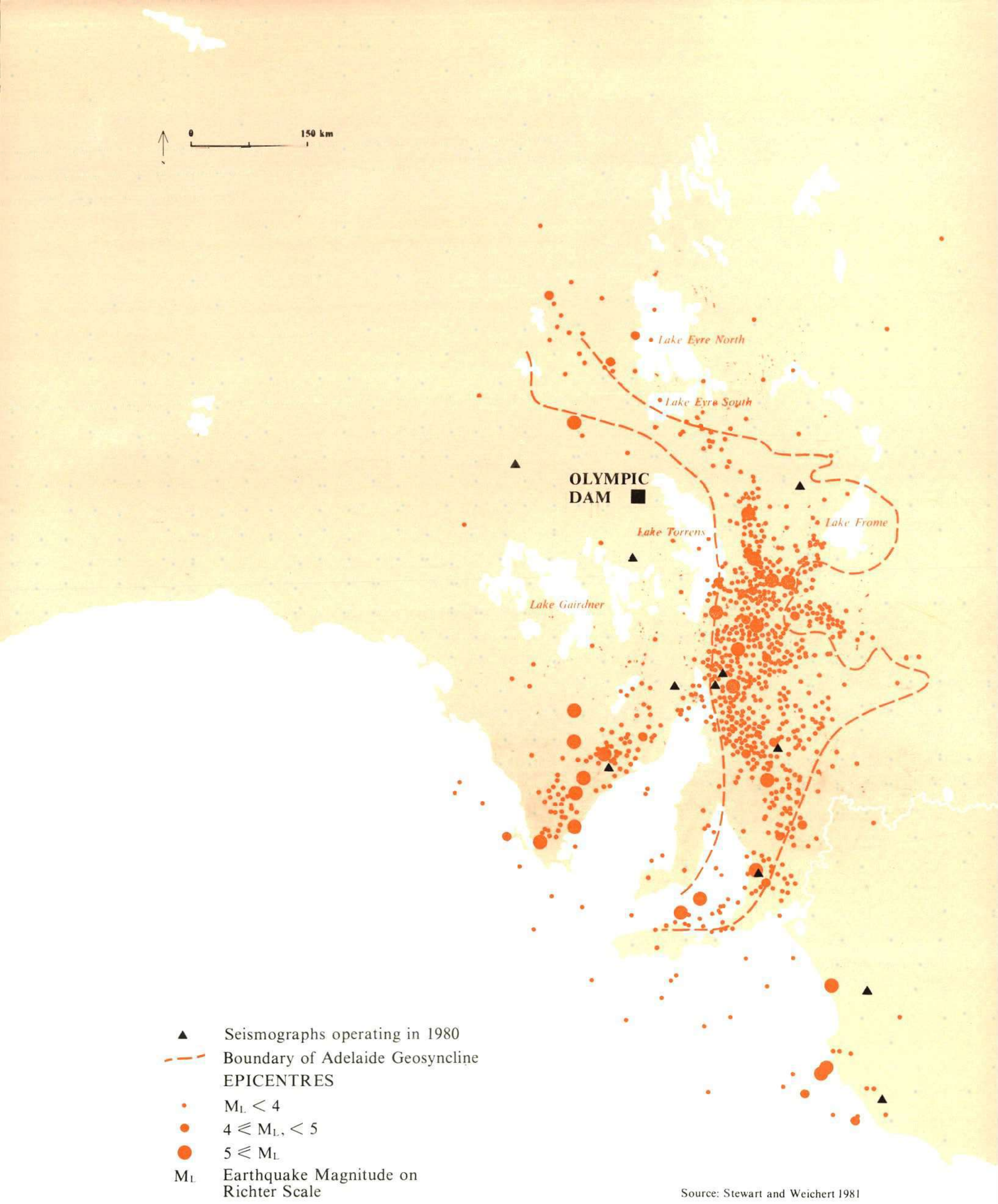


Figure 6.13
REGIONAL SEISMICITY

geographical grid. For the grid point at latitude 30.4° longitude 136.9°, which is taken as representative of the Olympic Dam site, Stewart's numerical values are listed in Table 6.3. Figure 6.14 shows the relationship between return periods for peak ground velocity associated with seismic activity and zoning for earthquake design considerations. Peak ground velocity is considered to be a convenient indicator of the potential for structural damage which is also related to earthquake intensity. The curves are plotted as earthquake intensity rather than magnitude, since magnitude is a measure of energy released at the epicentre while intensity is a measure of 'felt effects' at distances away from the epicentre. The relationship between magnitude and intensity will vary with attenuation effects, but Richter (1958) states that, close to the epicentre, intensity 1 is approximated by the equation $M_L = 1 + 2I/3$.

Table 6.3 Return periods for peak ground velocity and acceleration at Olympic Dam

Seismic parameters	50 years	100 years	200 years
Peak ground velocity (m/s)	0.009	0.012	0.016
Peak ground acceleration (percentage of acceleration due to gravity)	1.1	1.4	1.7

As a comparison with the SAA Earthquake Code, the recurrence relationship for peak ground velocity is plotted on Figure 6.14, which shows the Olympic Dam area as lying in Zone Zero, below Zone A as indicated in the Seismic Zone Map of Australia. There is no specified design requirement for structures in Zone Zero.

The SAA Earthquake Code states that earthquakes of intensity less than VI (or peak ground velocity of 0.05 m/s) are not expected to cause structural damage to normal buildings not specifically designed to resist earthquakes. It will be noted from Figure 6.14 that an event of this magnitude at Olympic Dam has a return period of 3,500 years. The effect on underground structures is not documented, although Stewart (pers. comm.) pointed out that, during earthquakes in North America, miners observed minimal movement underground while structures on the surface were visibly shaken.

6.3.4 Tectonic stability

Earthquake risk analysis cannot allow for major tectonic shifts in stability. Most of the seismic activity in the Olympic Dam area relates to the Adelaide Geosyncline east of this area. The Olympic Dam area forms part of the Stuart Shelf which, during the late Proterozoic, was a shallow water marine environment. Further to the east, thicker sedimentary sequences were deposited in the Adelaide Geosyncline. This Geosyncline has since been folded and faulted extensively, while the Stuart Shelf sediments have been virtually unaffected. The western edge of the Adelaide Geosyncline is marked by the north-trending belt of fractures of the Torrens Hinge Zone, which approximately follows the alignment of Lake Torrens east of the Olympic Dam area.

These sediments overlie older faulting, but evidence has not been found of this extending into the overlying Adelaidean sediments. The Torrens Hinge Zone is not well defined, and probably consists of a series of sub-parallel faults fringing the Adelaide Geosyncline in the east and the Stuart Shelf in the west. The faulting activity in this area is equivalent to the middle-Proterozoic activity of the sediments underlying the Stuart Shelf.

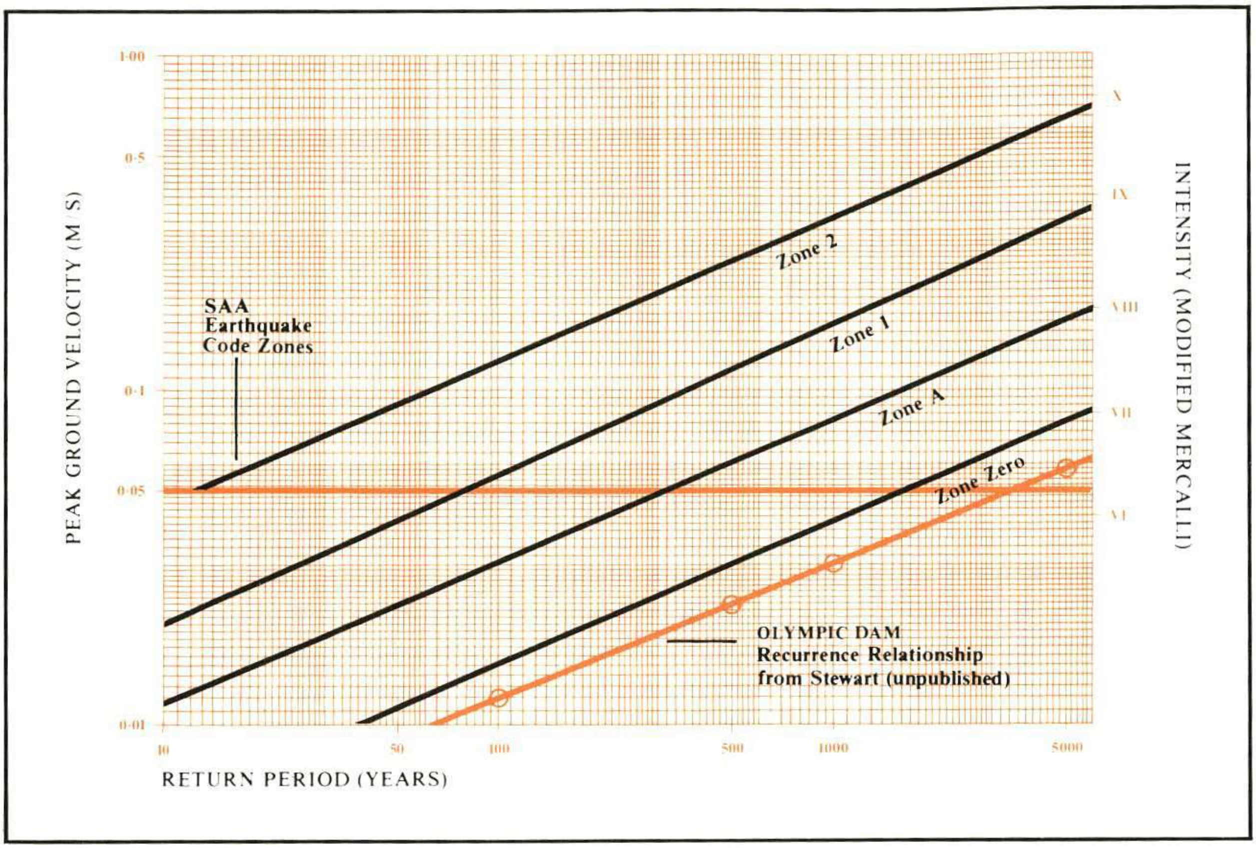


Figure 6.14
RETURN PERIODS FOR EARTHQUAKE INTENSITY

Therefore, unless there is a major shift in regional tectonic stability, it seems most unlikely that there would be any major earthquake activity in the Olympic Dam area associated with faulting. Two small events of magnitudes about $M_L 3$ were recorded in 1976 and 1978, both about 50 km from Olympic Dam, but neither event would have caused damage to structures in the Olympic Dam area.

CHAPTER SEVEN

Tailings Retention System

SUMMARY

Six million tonnes per annum of tailings slurry will be pumped from the metallurgical plant in a rubber-lined steel pipe to the 400 hectare tailings storage area, where the tailings will be deposited by subaerial deposition. The tailings storage will be subdivided into four cells, and the tailings will be discharged from the perimeter of the storage onto a gently sloping beach in one of these cells. The tailings will settle across the beach, and any free liquor will flow into a sump common to all four cells of the storage. The decanted liquor will be pumped to a separate 50 hectare evaporation pond adjacent to the tailings storage.

In a typical twenty-eight day deposition cycle, a layer of 200 millimetres of tailings slurry will be placed in one cell over a seven-day period and then allowed to settle, dry and consolidate over twenty-one days, during which time the other cells will be receiving tailings slurry. By the end of the drying cycle, the evaporation of moisture will reduce the degree of saturation of the tailings to around 90%. This will mean that 90% of the voids within the tailings will contain liquor. As such, the tailings will absorb moisture during the deposition of the next layer of tailings slurry, but this moisture will be drawn back to the surface and evaporated during the next drying cycle. The target level of 90% saturation will be low enough to form a high strength tailings mass with a density of 1.9 tonnes per cubic metre. As the tailings will not consolidate any further, long-term structural stability is ensured.

By maintaining the moisture content at about 90% saturation, radon gas emanation from the tailings surface can be regulated. In addition, the drying process will create a high strength competent surface not susceptible to wind erosion. Seepage through the deposited tailings will be restricted because of the low permeability of the tailings, and the capacity of the dried tailings to absorb moisture. Model testing indicates that the depth of penetration of a wetting front is approximately 400 millimetres. Thus, it will only be during initial deposition (up to the first six months) that the wetting front could be expected to reach the base of the tailings storage. Under normal conditions, it is likely that such seepage would be drawn back to the surface and evaporated. Even if this did not occur, seepage during this initial period would only be sufficient to saturate a

depth of less than 1 m below the tailings. A long period of exceptionally high rainfall might also lead to minor seepage through the tailings.

Pipelines carrying tailings slurry to the tailings storage, or decant liquor to the decant evaporation pond, will be bunded or placed in culverts to contain spillage in the unlikely event of a pipeline failure.

At decommissioning, an average of 1.5 metres of soil cover and 0.5 metres of quarried rock will be placed on the tailings surface to provide protection from long-term wind and water erosion. This will provide a stable and maintenance-free structure for the long term and will attenuate radon emission. Contouring of the surface will ensure that water is confined within the tailings structure and will allow only shallow pools to form which will evaporate rapidly.

7.1 DETAILS OF CONSTRUCTION

7.1.1 Description of the tailings retention system

The tailings retention system (TRS) comprises the tailings storage and the decant evaporation pond. Tailings will be pumped from the plant to the TRS through a pipeline, the corridor for which will be bunded to provide containment of any accidental spills. Wastewater from the mine will also be pumped to the tailings storage, while saline water from dewatering the aquifer overlying the mine area will be discharged into a separate evaporation pond located on the eastern side of the tailings storage.

The tailings retention area is approximately 3.5 km to the north-west of the plant area (Figure 2.1). The site selected for the TRS is relatively level, with large open swales interspersed with low east-west sand dunes. The dunes, which cover approximately 25% of the area, are generally between 4 and 5 m high in the southern part, and up to 7 m high towards the northern boundary. There is a general fall across the site of approximately 2 m from south to north.

The tailings storage will be constructed in stages and is designed to have sufficient capacity for a minimum thirty-year mining operation. The full plan area of 400 ha will be developed in the first stage when the retaining embankment will be constructed to a height of 10 m (Figure 7.1). Thereafter, the embankment will be raised in 5 m increments to a total height of 30 m. Construction of the decant structure will also be in stages to be compatible with the embankment.

The tailings storage will be divided by internal embankments into four independent cells. The tailings will be discharged into each of the cells on a cyclical basis. Any free liquor not evaporated from within the cells will be decanted through a centrally located pump-out system to a decant evaporation pond adjacent to the tailings storage.

Construction of the tailings storage, the decant evaporation pond, and the tailings pipeline corridor will be completed prior to the commencement of plant operation. The decant evaporation pond, which will be constructed very early in the programme, will initially be used in conjunction with the saline water evaporation pond to evaporate water recovered during the aquifer dewatering programme (Chapter 6).

Dune sand and swale material recovered from within the storage basin will be used for construction of the initial embankments. The dune sand varies from a clean wind-blown material at the surface to a more silty material towards the base of the dunes. The swale material is also variable, but basically consists of a silty clay with varying amounts of sands and gravel. Laboratory testing and existing embankments constructed on site have shown that both materials are competent and will be suitable for this purpose.

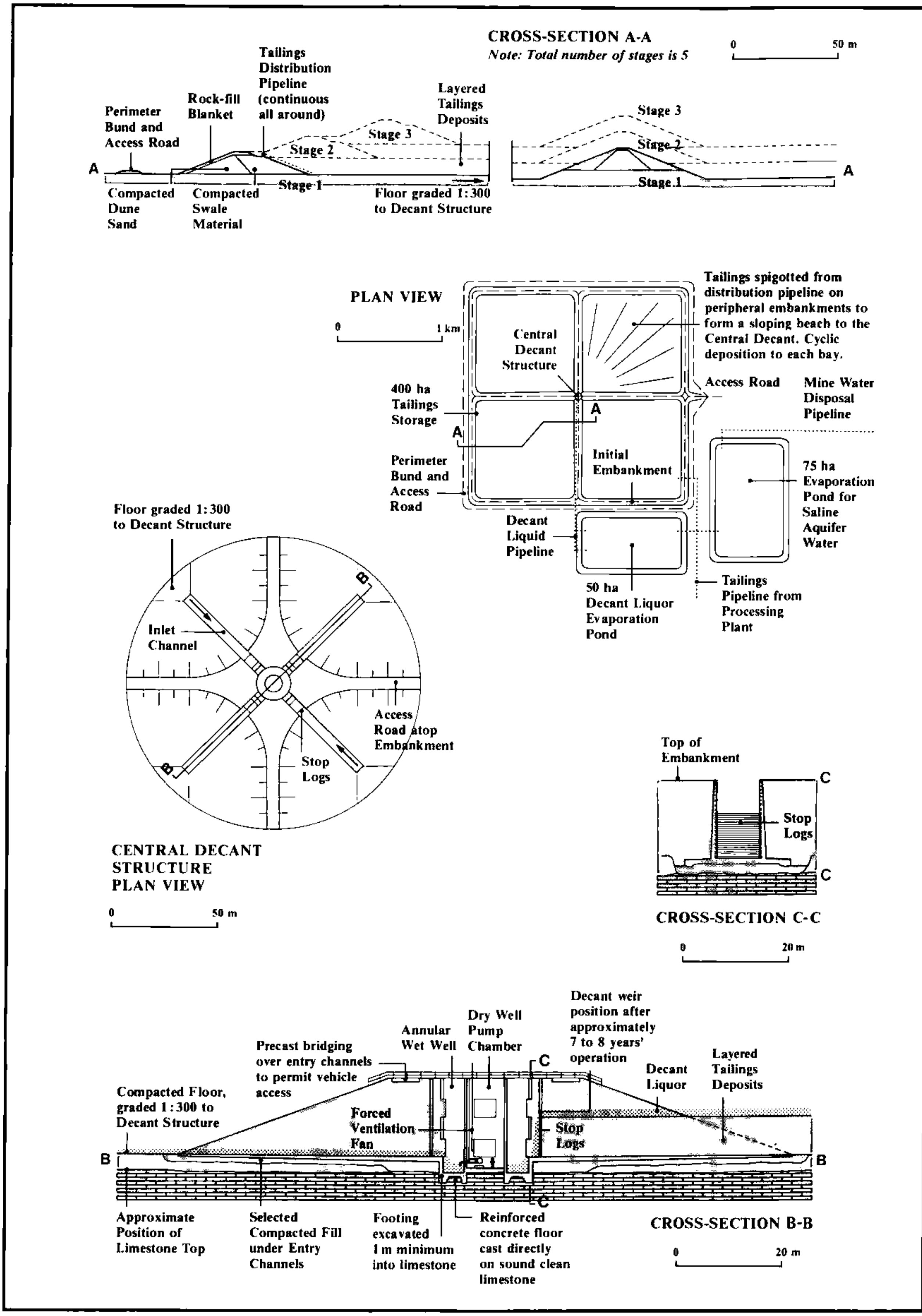


Figure 7.1
TAILINGS RETENTION SYSTEM

7.1.2 Tailings storage facility

The 10 m embankments for the first stage of the tailings storage will be constructed using a cut-to-fill operation. The earthworks will be balanced to effect the required shaping and grading of the basin floor, and to ensure that no external borrow areas will be required for this first stage. Subsequent stages of embankment construction will require fill to be obtained from borrow areas outside the storage basin.

The peripheral embankment (shown in Figure 7.1) will be constructed with 1 vertical to 2.5 horizontal side slopes and a main crest width of 6 m. A small berm will be provided 1 m below the main crest on the upstream side to carry the tailings distribution main. The main crest, which will provide vehicle access, will be covered with a suitable wearing course, and generally will be sloped inwards to direct incident rainfall into the basin.

The peripheral embankment will comprise two main zones to fully utilize the available local materials. The upstream or inward facing zone will be constructed from compacted swale material to provide an erosion resistant face with low permeability. The downstream or outside shell will be constructed from compacted dune sand, which in turn will be covered by 1 m of selected run-of-quarry rock obtained from the mine-fill quarry located to the north of the TRS. This rock-fill will be continuous down the outside face of each new stage and across the tailings strip to the previous embankment crest, thus providing total protection to all exterior faces of the storage. There will be no need for internal or external filters, as at no time will there be a phreatic surface either within the tailings adjacent to the embankment or within the embankment itself. There will be no seepage through the embankment to areas outside the storage.

The stability of the outer slope of the peripheral embankment has been conservatively assessed as having a factor of safety against shear failure in excess of 2. The tailings deposit will attain a state of partial saturation and a high relative density, which will preclude the possibility of liquefaction during seismic activity. If by remote chance seismic activity should occur (Chapter 6), the stability of the embankment would be unaffected, as it would not receive any additional loading from the tailings.

A low bund, about 15 m from the toe of the peripheral embankment, will be constructed to divert and pond stream flow from small catchments outside the tailings storage facility (Figure 7.1). This bund will be capped with a wearing surface to provide an access road around the storage. Run-off from the tailings storage embankment will be permitted to soak into the ground.

The internal embankments will subdivide the facility into four separate storages. Over the majority of their length these embankments will comprise a central core of compacted dune sand covered with an outside shell of compacted swale material to inhibit erosion. However, the last 100 m of each embankment adjacent to the central decant will be constructed entirely of compacted swale material, to minimize the possibility of short-term ponded liquor escaping through the internal embankments and into the underlying foundation zones.

By selecting a system of tailings storage which progressively dries the tailings in layers during placement, the high seepage potential associated with the storage of saturated tailings is avoided. However, during the placement of the initial tailings layer, there will be minor seepage into the bed material in the TRS and, in order to ensure that a competent layer of soil is in place between the tailings and the underlying dolomitic limestone to absorb and retain fugitive seepage, the following steps will be taken:

- The interface between the existing soil cover and limestone will be accurately located by a programme of seismic refraction and shallow bores.
- Where the thickness of soil cover over limestone is less than that desired, the limestone will be excavated to enable a sufficient depth of compacted fill to be

placed to achieve the desired soil cover. The excavated rock will be used for embankment armour.

- A geophysical survey will be conducted to locate dolines in the dolomitic limestone which, if present, will be back-filled and sealed.
- To provide a sound base for the concrete foundation of the decant well, excavation will be into rock after proof drilling and plugging.
- To ensure the competence of the base and to provide compaction to the upper soil layer, heavy compaction equipment will be used to roll the entire surface of the TRS.

As a further precaution against seepage, in the preparation and grading of the base in the decant area and under the embankments adjacent to the decant, use will be made of available clays to provide a barrier of low permeability under areas which may be subject to ponding after major storm events.

The base of the storage basin will be shaped to provide a fall from the peripheral embankment towards the central decant (Figure 7.1) to permit the initial layers of deposited tailings slurry to flow evenly across each storage bay. This will provide a rapid cover of tailings which will effectively seal the basin.

7.1.3 Pipeline corridor

The tailings delivery pipeline will be laid between protective bunds to confine any spillage of tailings which may occur in the unlikely event of pipe failure. As the bunds will be constructed from swale material excavated from within the corridor, no external borrow will be required. The channel formed by the bunds will be cross-bunded every 200 m to restrict the spread of any spillage and to limit clean-up. Close monitoring, instrumentation and fail-safe procedures adopted for the operation of the delivery system will ensure that only minor spillage will be possible. Any soil within the corridor contaminated as a result of such spillage will be removed with the tailings during clean-up and deposited within the confines of the tailings storage.

7.1.4 Decanting of tailings liquor

Each storage cell will be provided with a weir leading to a common sump. Free tailings liquor and incident rainfall will be decanted from the storage facility through this centrally located weir and sump arrangement (as shown in Figure 7.1).

Stop logs will be used at each weir to maintain a crest above the level of the tailings, but will be kept sufficiently low to minimize the volume of ponded liquor. Based on laboratory model studies and settling tests, it is anticipated that only very small amounts of solids will be present in the liquor once it reaches the pond, and therefore the retention time to ensure full settling of all tailings will be short. The pond size and the most appropriate height for each stop log will be determined once the operation commences. It is anticipated that the liquor ponded but not decanted during tailings deposition will be fully evaporated during the following dormant period.

The weir channels and central sump will be constructed from reinforced concrete and protected by an acid-resistant coating. The stop logs will also be made from reinforced concrete and suitably protected from the low pH liquor.

As the depth of deposited tailings increases, buttressing rock-fill or mass concrete will be provided to support the lower stop logs. The weir channels will be partially covered with reinforced concrete slabs to permit vehicle movement and crane access around, and to, the decant structure and pump well.

The central sump will act as a collector for the liquor flow over each weir, and will be equipped with duty and stand-by pumps. The decanted liquor and run-off from rainfall will be pumped to the evaporation pond or back to the tailings beaches. The pumps will be of the centrifugal type, installed in a dry well located within the central sump and protected against the low pH liquor. The pump well will be equipped with forced ventilation and a sump pump, and instrumentation will be provided to monitor pump operation.

7.1.5 Evaporation ponds

Two evaporation ponds will be constructed adjacent to the tailings storage facility. These ponds will be operated independently of each other, except for a short period prior to the start-up of the plant.

The 50 ha decant liquor pond will be located in an existing claypan south of the tailings storage. Compacted swale material will be used to construct the retaining embankments to a height of 7 m. The pond will be lined with a synthetic membrane, and a test programme to evaluate available liner types will be carried out. The liner chosen will be protected against physical damage and ultraviolet deterioration by a 600 mm thick layer of selected cover material placed in accordance with current practice. Rip-rap will be provided to dissipate waves impinging on the embankment faces.

A separate 75 ha evaporation pond on the eastern side of the tailings storage facility will be provided for evaporation of saline water pumped from the aquifer overlying the orebody. This pond will be provided with a clay liner to provide a very low permeability base. The embankments will be constructed to a height of 5.5 m with a low permeability zone on the upstream side. Rip-rap will be provided around the embankments to prevent erosion by wave action.

7.1.6 Staged construction

The initial TRS embankments will provide for the storage of tailings for the first ten years of operation. Thereafter, the embankments will be raised in stages, with each stage providing an additional five years' storage capacity (Figure 7.1).

Each stage will require the construction of 5 m high peripheral embankments and the raising of the internal embankments. The peripheral embankments will be constructed on the previously placed tailings, resulting in a 10 m wide strip between the inside crest line of the external embankments and the toe of the new embankments. This strip of tailings will be decommissioned in accordance with the techniques approved for decommissioning of the final tailings surface.

To permit unhindered construction and to allow normal operation of the facility to continue, the tailings ring main will be relocated during the staged raisings of embankments. Once each construction stage has been completed, the ring main will be relocated onto the new embankment crest.

7.2 OPERATING DESCRIPTION

7.2.1 Overview

The tailings slurry will be deposited into the tailings storage facility by spigotted discharge according to a predetermined strategy based on the subaerial deposition technique. Although the application of this technique to tailings storage is not new, the full advantages have not been previously exploited in Australia. Subaerial deposition is particularly suited to arid areas such as Olympic Dam.

A form of subaerial deposition has been in use for many years in other arid areas such as the Eastern Goldfields region in Western Australia where, traditionally, the embankments of the tailings storages have been raised using tailings deposited by spigotting. Experience has shown that deposition in thin layers, when dried by evaporation, results in the establishment of a competent tailings mass which is not subject to further settlement or consolidation, and is stable even under severe loading conditions. However, in contrast to normal practice elsewhere, it is emphasized that at Olympic Dam the peripheral embankment of the storage facility will be constructed not from tailings, but from earth and rock, which will protect the tailings from the long-term effects of wind and water erosion.

In general, subaerial techniques have been confined to areas where, under average conditions, there is a significant difference between the annual rainfall and the annual evaporation rates. This difference, which may typically show evaporation rates fifteen times that of the rainfall, allows a storage of sufficient area to be operated without any decanting of liquor. High evaporation rates also permit the rapid loss of excess contained liquor from within the layers of tailings, resulting in high densities and high strengths. At Olympic Dam the average annual rainfall is 161 mm and pan evaporation is 3,000 mm, giving a ratio of rainfall to evaporation of the order of 1 to 20. This provides an ideal environment for the application of the subaerial deposition method in terms of the overall liquor balance and the stability of the stored tailings.

Subaerial deposition of the tailings into the Olympic Dam storage facility will be achieved by spigotting the tailings to build up layered deposits within the earth-fill embankments. At the same time, a formalized deposition cycle will be introduced to ensure that each layer is brought to a below saturation, high in situ density condition prior to the placement of further layers. This will be accomplished by using four separate storages operated on a cyclical basis. There will not be any permanent ponding of liquor on the surface of the storage.

This tailings storage technique is considered to reflect not only the best current practicable technology, but also the most suitable method of storage for the location, considering climatic and topographical conditions. The system is flexible to operate, and is able to cope with extreme variations in either rainfall or evaporation.

The object of the method selected is to achieve the following conditions in the stored tailings:

- minimum practicable volume
- maximum practicable density
- lowest possible permeability
- negative pore pressures to eliminate seepage
- greatest practicable strength and stability with regard to long-term loading conditions
- competent foundation conditions for immediate placement of cover materials for decommissioning
- controlled radon emanation levels.

7.2.2 Tailings deposition modelling

Settling, drying and consolidation are essentially one dimensional processes, and can therefore be effectively modelled on a laboratory scale. In order to establish indicative characteristics specific to the Olympic Dam tailings following deposition, a laboratory model programme was conducted using tailings generated from small-scale metallurgical studies.

In the model work, the subaerial deposition of tailings was simulated by placing twelve layers in slurry thicknesses varying from 40 mm to approximately 200 mm. For each layer, measurements of under-drainage, supernatant, and liquor retained in the tailings were taken. The water balance of the model, showing the above quantities expressed as a percentage of the liquor present in each layer of slurry, is shown in Figure 7.2. These results demonstrate that after eight layers of tailings had been deposited, giving a total tailings thickness of approximately 300 mm, an effective seal was achieved at the base of the tailings.

Resaturation occurred to a depth of approximately 400 mm in previously deposited tailings. However, drying of each newly deposited layer induced capillary rise and evaporation of liquor from the underlying tailings, so that the whole mass of material again reverted to a state of partial saturation before the next layer was placed. Moisture content profiles in the model were measured before and after the placement of each new layer of tailings slurry, and the results of these measurements for Layer 8 are shown in Table 7.1. These results demonstrate that, after deposition, Layer 8 dried to approximately 90% saturation and, with the addition of each further layer, resaturated and subsequently dried once again to approximately 90% saturation.

This laboratory modelling work will be extended by the testing of a pilot scale tailings storage at Olympic Dam prior to finalization of the design.

Table 7.1 Degree of saturation of Layer 8 under subsequent deposition cycles

Day	Event	Degree of saturation of Layer 8
1	Deposition Layer 8	100%
3	Drying Layer 8	87%
7	Deposition Layer 9	100%
14	Drying Layer 9	87%
17	Deposition Layer 10	100%
28	Drying Layer 10	94%
46	Deposition Layer 11	100%
56	Drying Layer 11	86%
65	Deposition Layer 12	100%
81	Drying Layer 12	91%

7.2.3 Subaerial deposition

The tailings will be pumped from the plant to the tailings storage through a large diameter rubber-lined steel pipeline. The flow rate of slurry will be approximately 28,500 m^3/d. A main distribution pipe of similar design will be provided on the crest of the peripheral embankment to each of the four storage cells.

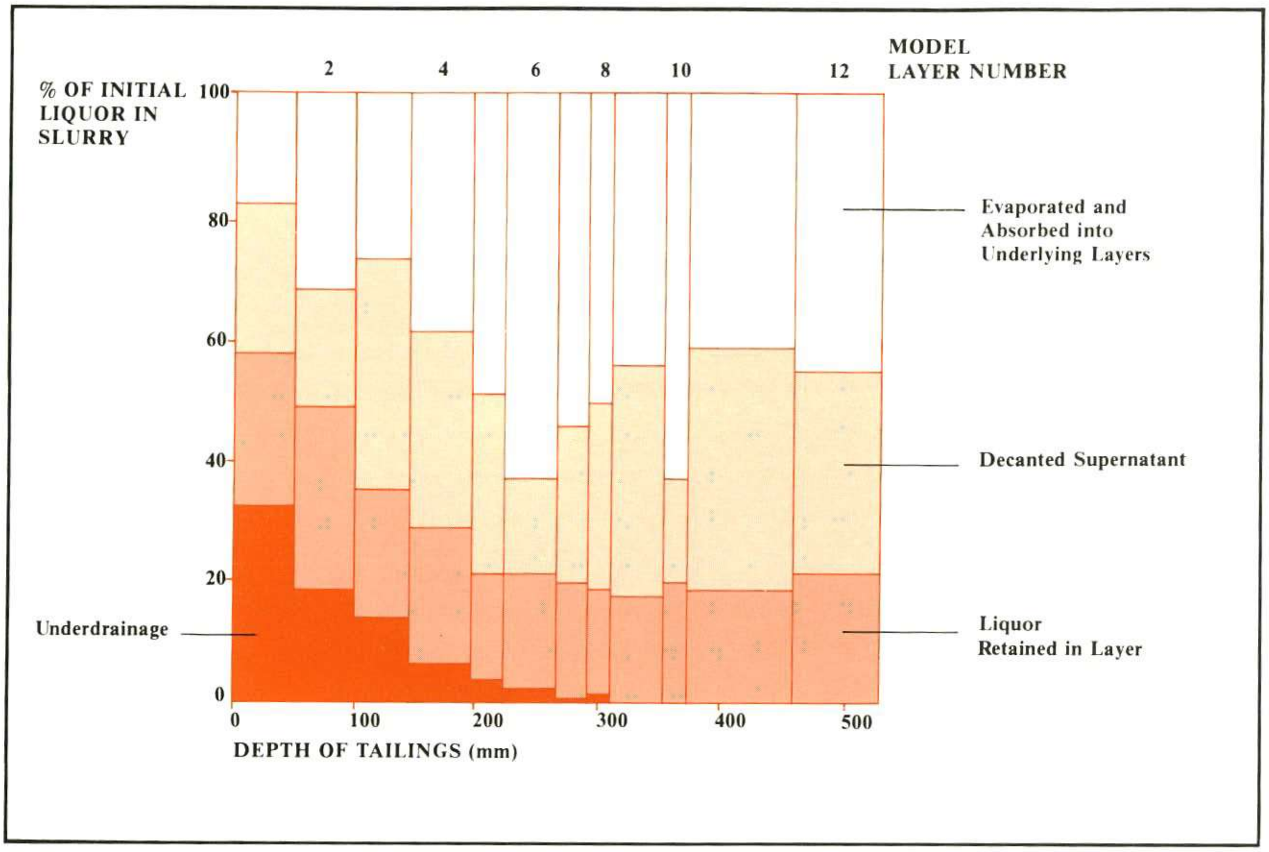


Figure 7.2

TAILINGS LIQUOR BALANCE

Spigot pipes will be used to place the tailings into each cell. They will be located close to the junction of the embankment and the tailings beach, with the individual pipes being placed end to end to provide for even tailings distribution over the total length of the peripheral embankment. Each pipe will be individually supplied with tailings slurry from a valved off-take on the distribution main. The pipes will be made from polyethylene or another suitable lightweight material with holes spaced at approximately 2 m intervals in the invert.

Each spigot pipe will be about 100 m long and will be supported approximately 1 m above beach level by stakes driven into the embankment face. The flow of tailings slurry from each spigot hole will be small and erosion below the spigot pipes will therefore be minimal. Spigot pipes will be operated in turn as the discharge volume and conditions demand, with sufficient pipes in use to distribute the available flow evenly. Typically, 300 m of spigot pipe could be in operation at any one time; however, the location of the spigotting will be determined from day to day to achieve uniform distribution of tailings over the cells. The entire surface of each storage cell will be covered with a generally even layer of tailings during each deposition period. The spigot pipes will be moved up the embankment face about once a year as the level of the tailings beach rises.

The tailings will be discharged into each storage cell on a cyclical basis, with each deposited layer being permitted to settle, dry, and consolidate prior to the placement of the next layer. Discharge will take place only from the peripheral embankment of each cell, and the tailings will therefore form a gently dished surface sloping towards the central decant.

For average ambient conditions, deposition into each cell will take place over a seven-day period. During this time, a layer depth equivalent to approximately 200 mm of tailings slurry will be built up over the entire surface of the previous layer. Deposition will then be redirected to an adjacent bay. With four cells in operation, the full cycle will take about twenty-eight days on average.

The process of settling and drying is fundamental to the overall plan of tailings placement and liquor management. Each deposited layer will be permitted to dry to a condition of partial saturation (i.e. the voids within the tailings mass will not be totally filled with liquor). During the consolidation process, the volume of the deposited tailings layer will decrease, initially by a reduction in depth, and then by lateral shrinkage as further drying takes place. As indicated in laboratory testing, the depth of the resulting random cracking will be limited to the immediate surface layers, and all joints will be filled with tailings as the subsequent layer is placed. An average in situ dry density of about 1.9 t/m^3 will be reached.

Moisture reduction will continue during the twenty-one-day drying period in the cycle until the degree of saturation (i.e. the voids in the tailings mass containing liquor) has dropped to around 90%. The capillary forces resulting from the tailings being below 100% saturation will ensure that the tailings do not release any liquor in the form of seepage, but will absorb water if recharged from the surface until fully resaturated (i.e. to a depth of approximately 400 mm as indicated by the test programme). This liquor will be drawn back to the surface and will evaporate during the drying period of the layer, so that the tailings mass will again be at approximately 90% saturation before the subsequent layer is placed, when the recharge and drying process will be repeated.

The target level of 90% saturation is low enough to ensure the development of a high in situ density and strength within the tailings. Drying will also result in a high equivalent preconsolidation pressure for the material. Loading from subsequent tailings deposition will therefore not cause further settlement, and the partially saturated condition will be maintained. The 90% saturation level also has importance with regard to radon attenuation (Section 7.4.1).

It is important to note that the deposition period and total cycle time are not critical to the overall performance of the storage, and sufficient flexibility will be available at all times to compensate for variations in seasonal evaporation rates, rainfall, and slurry flow rates. The period of twenty-eight days has been based upon achieving a target in situ density of 1.9 t/m^3 at 90% saturation under average ambient conditions. An in situ density close to this value can be attained at a saturation level above 90% and in less time than the twenty-one-day drying period allowed.

An increase in layer thickness, which would require a longer deposition time, could be necessary for instance if pipe maintenance were being undertaken in an adjacent bay and as a result the flow to that cell had to be delayed for several days. A decrease in layer thickness, resulting in a more rapid cycle time, could be required during periods of staged embankment construction which could cause one cell to be temporarily isolated.

The laboratory model programme has indicated the ability of the subaerial deposition system to recover from varying operating or climatic factors which may prevent optimum conditions from being reached from time to time. The thin layers and the potential for liquor loss by evaporation will readily permit excess liquor to be drawn from the tailings and the target saturation levels to be reached, even to depths of 1 m (i.e. more than ten normal layers). Prolonged abnormal operating conditions will not reduce the overall effectiveness of the deposition technique.

7.2.4 Characteristics of the tailings

The tailings which will be produced as a result of the mining, milling and metallurgical process will be a fine grained silt comprising rock forming minerals, hematite, silica and other silicates. Typical ranges for chemical constituents of the solids and liquor of the tailings slurry are given in Table 7.2.

Table 7.2 Typical chemical analysis – tailings slurry

Constituent	Liquor	Solids
Aluminium	4,000-7,000 mg/L	3-5 %
Arsenic	5-20 mg/L	40-150 ppm
Calcium	500-800 mg/L	2,000-10,000 ppm
Cadmium	1 mg/L	0.5 ppm
Cerium	1,000-2,000 mg/L	2,000-3,000 ppm
Cobalt	20-40 mg/L	10-45 ppm
Chromium	6-10 mg/L	10-20 ppm
Copper	300-1,000 mg/L	300-800 ppm
Fluorine	6,000-14,000 mg/L	5,000-10,000 ppm
Iron	5,000-38,000 mg/L	15-50 %
Mercury	0.05 mg/L	0.1 ppm
Potassium	600-1,600 mg/L	2-4 %
Magnesium	400-900 mg/L	1,000-3,000 ppm
Manganese	3,600-19,300 mg/L	30-50 ppm
Molybdenum	1-5 mg/L	20-60 ppm
Sodium	150-300 mg/L	300-600 ppm
Nickel	5-12 mg/L	3-10 ppm
Lead	1-8 mg/L	60-100 ppm
Sulphur	N/A	0.03-1.5 %
Selenium	2 mg/L	5-25 ppm
Silica	60-260 mg/L	10-25 %
Uranium oxide	2 mg/L	20-75 ppm
Vanadium	5-10 mg/L	40-60 ppm
Zinc	20-500 mg/L	50-100 ppm
Sulphate	50,000-150,000 mg/L	N/A
Radium-226	0.37 Bq/L	4.5-6.0 Bq/L
pH	approx. 1.5	n/a

Laboratory test work being carried out in conjunction with the tailings modelling is continuing, to determine all the relevant geotechnical parameters of the tailings. While the data is not yet complete, some of the known and anticipated values are given in Table 7.3. A particle size range of the tailings is shown in Table 7.4.

Table 7.3 Selected geotechnical parameters

Parameter	Value
Soil classification (USC)	ML
In situ density at end of cycle	1.9 t/m^3
Specific gravity	3.5
Relative density	110%
In situ moisture content at end of cycle	20%
Equivalent degree of saturation	90%
Permeability*	1.5 x 10^{-11} m/s
Cohesion*	0
Angle of internal friction*	38^{o}
Coefficient of consolidation	0.43 m^2 /a
Coefficient of volume decrease	1.1 x 10^{-4} KPA^{-1}

* Indicated values yet to be confirmed.

Table 7.4 Typical range of particle size distribution in the tailings

Screen size (μm)	Weight % retained	
	Lower limit of grind	Upper limit of grind
75	0.4	4.6
53	16.0	10.9
45	6.9	7.0
31	12.8	15.3
23	11.0	11.0
16	10.7	11.4
10.8	9.4	9.9
8.3	4.5	4.7
<8.3	28.3	25.2

The tailings will be pumped to the storage facility with the stripped process liquor and make-up water when necessary. The target density will be about 45% solids, which is considered the maximum consistent with economic pumping of the slurry. The tonnage of tailings to be stored will be 6,000,000 t/a, based on a rate of copper production of 150,000 t/a. The approximate volume of slurry discharged into the tailings storage would be 28,500 m^3 /d.

7.3 HYDROLOGY

The decant liquor evaporation pond will be sized to store and evaporate all decanted supernatant liquor and rainfall run-off pumped from the tailings storage during average annual conditions. Seasonal variations in evaporation, together with long return period rainfall events, have been taken into account in designing both the tailings storage and the evaporation pond against overtopping. The flexibility and control offered by the pump-out decant system will be of great importance in this regard.

Prior to the start of production, both the saline evaporation pond and the decant evaporation pond will be used to evaporate saline groundwater from mine area dewatering. As this initial period will be the time of greatest pumpage, the use of both storages will provide a greater surface area for evaporation. After the start of production (and the consequent need to operate the tailings storage), the saline evaporation pond will be operated independently of the decant evaporation pond.

7.3.1 Parameters adopted

Average conditions

The Olympic Dam area has an average annual rainfall of 161 mm, which is close to the minimum rainfall for Australia. Rainfall records dating from 1931, available from Roxby Downs Station (Chapter 8), show that rainfall is extremely variable, and intense storms, while rare, can occur at any time during the year.

In determining the decant liquor evaporation pond requirements, the parameters in Table 7.5 have been used for water balance calculations. The annual evaporation rate has been extrapolated from long-term data available from Woomera. The breakdown of evaporation loss between daytime and night-time is necessary to model actual conditions within the tailings storage.

Table 7.5 Parameters for decant evaporation pond

Parameter	Value
Production rate	16,400 t/d tailings
Tailings density (percentage solids)	45%
Liquor volume	20,000 m^3 /d
Liquor released as supernatant	6,000 m^3 /d
Average annual rainfall	161 mm (Roxby Downs Station)
Average annual evaporation	3,000 mm
Evaporation during daytime	80% daily rate
Evaporation during night-time	20% daily rate
Pan factor for evaporation on tailings surface	1.0
Pan factor for evaporation from evaporation pond	0.75
Area of storage facility	400 ha
Area of decant liquor evaporation pond	50 ha

Extreme rainfall events

In addition to examining the water balance of the tailings storage and the decant evaporation pond under average conditions, the effects of rainfall events with long return periods have been studied. Annual rainfall statistics for the sequence of the three wettest years (1973, 1974 and 1975) are shown in Table 7.6.

Table 7.6 Significant annual total rainfall, rank, and estimated return period at Roxby Downs homestead

Year	Rainfall	Rank*	Return periods
1973	372 mm	2	1 in 20 years
1974	582 mm	1	1 in 100 years
1975	299 mm	4	1 in 10 years
Total	1,253 mm		

* In order of significance from 1931 to 1979. In 1947, 304 mm were measured.

While only 1974 could be seen as significant when considered separately, the combined rainfall of these three consecutive years produces an extremely low probability event. The total rainfall of 1,253 mm is 2.6 times the average for the same period (3 by 161 mm). From the available data the 1 in 200 year 72-hour storm has been extrapolated: this would result in 210 mm of rainfall. The highest winter monthly total on record at Roxby Downs is 136 mm, while the highest summer total is 178 mm. The effects of both the three-year wet period and the 1 in 200 year storm are examined below.

7.3.2 Operation of decant liquor evaporation pond

Average conditions

The decant liquor evaporation pond has been sized to handle decanted run-off from the tailings storage resulting from average annual rainfall in addition to the decanted tailings liquor. Table 7.7 shows the estimated amount of tailings liquor which would pass to the decant for pumping to the evaporation pond on a monthly basis under average ambient conditions. The table has been based on a uniform production rate throughout the year. The assumed quantity of liquor available for decanting has been based upon the model work described in Section 7.2.2, which indicates that approximately 10% of total liquor would require decanting and evaporation. It is considered that, in practice, the actual quantity of decanted liquor will be less than the figure indicated.

Table 7.7 Supernatant tailings liquor to decant

Month	Supernatant liquor*						Excess liquor to decant evaporation pond (mm/d)	Total volume in decant evaporation pond (m^3/month)
	Daytime			Night-time				
	Amount released (mm/d)		Potential evaporation (mm/d)	Amount released (mm/d)		Potential evaporation (mm/d)		
April	3.0	-	5.3	3.0	-	1.3	1.7	51,000
May	3.0	-	3.2	3.0	-	0.8	2.2	68,200
June	3.0	-	2.2	3.0	-	0.5	3.3	99,000
July	3.0	-	2.5	3.0	-	0.6	2.9	89,900
August	3.0	-	3.6	3.0	-	0.9	2.1	65,100
September	3.0	-	5.2	3.0	-	1.3	1.7	51,000
October	3.0	-	7.2	3.0	-	1.8	1.2	37,200
November	3.0	-	9.3	3.0	-	2.3	0.7	21,000
December	3.0	-	11.1	3.0	-	2.8	0.2	6,200
January	3.0	-	11.3	3.0	-	2.8	0.2	6,200
February	3.0	-	9.9	3.0	-	2.5	0.5	14,000
March	3.0	-	8.3	3.0	-	2.1	0.9	27,900
Total (m^3/a)								536,000

* Supernatant or released liquor is estimated at 30% of the total liquor in the tailings slurry and corresponds to 6.0 mm of free liquor per day over the area of active beach.

The decanted tailings liquor, together with the run-off from incident rainfall on the tailings beaches, will be pumped to the decant liquor evaporation pond. Table 7.8 shows the liquor balance in this pond under average annual conditions of rainfall.

Table 7.8 Decant evaporation pond liquor balance

Month	Into pond			Out	Depth of liquor in pond (mm)
	Supernatant* (mm)	Incident precipitation (mm)	Tailings run-off** (mm)	Evaporation † (mm)	
April	102	8	45	148	7
May	136	15	84	93	149
June	198	12	67	61	365
July	180	11	62	72	546
August	130	13	73	105	657
September	102	11	62	146	686
October	74	16	90	210	656
November	42	9	50	262	495
December	12	11	62	323	257
January	12	18	101	329	59
February	28	26	146	261	0
March	56	13	73	242	0

* Supernatant depth is calculated by dividing decant evaporation pond volume given in Table 7.7 by pond area of 50 ha.

** Average run-off coefficient from tailings beaches = 0.70.

† Pan factor = 0.75.

Above average rainfall years

It is clear therefore that, if a succession of above average rainfall years were to occur, there would be a build-up of stored liquor and run-off within the decant evaporation pond which could be reduced only by a succession of below average years. Rather than relying on such an occurrence, alternative means of ensuring an acceptable liquor balance will be implemented.

High ambient temperatures during the summer months will result in increased evaporation capacity of the dormant beach areas within the tailings storage. These beach areas have been sized for an average tailings distribution cycle time, and in hot periods the required in situ beach conditions will be reached in less than the average period allowed. It is therefore intended to utilize this additional capacity whenever necessary to ensure that a progressive build-up of liquor does not occur in the decant evaporation pond.

During periods of above average rainfall, the distribution of liquor to the decant evaporation pond or to dormant tailings beaches will be varied to permit a controlled build-up of liquor in the pond over the winter months and a drawdown over summer. During winter, all liquor and run-off from rainfall will be pumped to the decant evaporation pond, causing a rise in the liquor level. From the commencement of the warmer months, all liquor will be pumped to the dormant beaches until the level within the decant evaporation pond has dropped to a predetermined point, at which time 'average' pumping will be resumed to maintain that level. The use of the tailings beaches as additional evaporation areas will be controlled to prevent interference with the requirements of the subaerial deposition of the tailings.

An examination of this strategy for the three years' wet sequence described in Section 7.3.1 has shown that, by permitting a controlled increase in the level of liquor in the decant evaporation pond, the size of the ponded run-off on the tailings storages would have been minimized, while optimum use would have been made of the excess evaporation capacity on the dormant tailings beaches. By using the driest tailings beach (i.e. 100 ha of beach area), the maximum depth of liquor reached in the decant evaporation pond would have been 1.78 m and the depth remaining at the end of the wet year sequence would have been virtually zero. The maximum size of the liquor pond around the decant would have been 79 ha or 20% of the total, which would have existed for approximately twenty-five days. If all the liquor were pumped to the decant evaporation pond without utilizing the beaches for evaporation, the maximum pond depth reached during the three-year wet sequence would have been 4.6 m. The evaporation pond will consequently be constructed with a depth of 7 m, thereby providing adequate security against overtopping.

At the entry to the decant evaporation pond, a deepened hopper type section will provide for the settlement of fines which might carry over from the tailings retention area. Any build-up of settled fines will be transferred by periodic use of sludge pumps back to the tailings storage.

Extreme storm event

The single event storm of 210 mm would produce 630,000 m^3 of run-off and result in 25% of the surface of the tailings storage being covered. This water would be evacuated to the evaporation pond or to the dormant tailings beaches in approximately forty days (less than two full cycles of tailings distribution). A depth of 200 mm (two settled layers of tailings) would have been placed during this time, and the moisture conditions within the tailings would rapidly be brought to below saturation during the drying of subsequent layers.

7.3.3 Evaporation of saline groundwater

It is planned to commence dewatering the aquifer overlying the orebody four years prior to the start-up of the metallurgical processing plant (Chapter 6). Initially, the saline water recovered will be pumped to both the decant liquor and the saline water evaporation ponds located adjacent to the tailings storage facility. Pumping to the two ponds, which will have a combined area of 125 ha, will continue until the metallurgical processing begins, at which stage the decant evaporation pond will revert to its primary function.

The rate at which the aquifer is pumped will be dependent upon the rate at which the recovered saline water can be evaporated, initially in the two ponds and later in the single 75 ha clay-lined pond. A water balance for the operation of the evaporation ponds during aquifer dewatering is given in Table 7.9. This shows that the required rate of aquifer pumping will be obtainable throughout each year, although there will be a build-up of water in the saline water evaporation pond once the decant liquor pond is no longer available. This will occur after four years of dewatering, when the required pumping rate will begin to decrease. The depth of water in the evaporation pond will reach 3.12 m after eight years, and will then steadily decrease. Above average rainfall would increase this depth and an adequate freeboard will be provided to ensure that overtopping cannot occur.

Table 7.9 Water balance for aquifer dewatering

Half year*		Daily pumping rate (m^3/d)	Daily potential evaporation (m^3/d)	Average daily change in water volume (m^3/d)	Half-yearly change in water volume (ML)	Volume to saline evaporation pond (ML)	Volume to decant evaporation pond (ML)	Volume stored in saline evaporation pond (ML)	Water depth in saline evaporation pond (m)
0	Summer	7,600	10,500	0	0	0	0	0	0
	Winter	7,600	3,800	+ 3,800	+ 694	+ 416	+ 278	416	0.55
1	Summer	7,500	10,500	- 3,000	- 548	- 329	- 219	87	0.12
	Winter	7,500	3,800	+ 3,700	+ 675	+ 405	+ 270	492	0.67
2	Summer	7,400	10,500	- 3,100	- 566	- 340	- 226	152	0.20
	Winter	7,400	3,800	+ 3,600	+ 657	+ 394	+ 263	546	0.73
3	Summer	7,100	10,500	- 3,400	- 621	- 373	- 248	173	0.23
	Winter	7,100	3,800	+ 3,300	+ 602	+ 361	+ 241	534	0.71
4	Summer	6,500	6,300	+ 200	+ 37	+ 37	**	571	0.76
	Winter	6,500	2,280	+ 4,220	+ 770	+ 770		1,341	1.79
5	Summer	5,800	6,300	- 500	- 91	- 91		1,250	1.67
	Winter	5,800	2,280	+ 3,520	+ 642	+ 642		1,892	2.52
6	Summer	5,200	6,300	- 1,100	- 201	- 201		1,691	2.25
	Winter	5,200	2,280	+ 2,920	+ 533	+ 533		2,224	2.96
7	Summer	4,600	6,300	- 1,700	- 310	- 310		1,914	2.55
	Winter	4,600	2,280	+ 2,320	+ 423	+ 423		2,337	3.12
8	Summer	4,100	6,300	- 2,200	- 402	- 402		1,935	2.58
	Winter	4,100	2,280	+ 1,820	+ 332	+ 332		2,267	3.02
9	Summer	3,600	6,300	- 2,700	- 493	- 493		1,774	2.37
	Winter	3,600	2,280	+ 1,320	+ 241	+ 241		2,015	2.69
10	Summer	3,200	6,300	- 3,100	- 566	- 566		1,449	1.93
	Winter	3,200	2,280	+ 920	+ 168	+ 168		1,617	2.16
LT	Summer †	2,000	6,300	- 4,300	- 785	- 785		832	1.11
	Winter	2,000	2,280	- 280	- 51	- 51		781	1.04
LT	Summer †	2,000	6,300	- 4,300	- 785	- 785		0	0
	Winter	2,000	2,280	- 280	- 51	- 51		0	0

* Numbers in this column relate to time from Project commitment. Summer/winter refers to the six months centred on these respective seasons.

** Decant evaporation pond not used for aquifer dewatering from year 4 onwards.

† LT = long term

7.3.4 Salt build-up in evaporation ponds

Both the liquor decanted from the tailings storage and the water pumped from the aquifer will be high in dissolved salts. As salts will build up within the ponds during the evaporation process, an allowance will be made for the consequent loss of effective pond depth.

The evaporation ponds will be divided into cells to allow a progressive build-up of salinity in one cell while other cells are in operation. The concentrated salt solution can then be pumped to the tailings storage area, as an alternative to allowing salt accumulation in the evaporation ponds.

Although the salts are anticipated to be stable when exposed, provision will be made to allow aquifer water to be pumped to the decant evaporation pond to maintain a minimum moisture content within the deposited salts.

7.4 CONTROL OF RADIONUCLIDES

In designing the TRS, the control of radionuclides has been an important consideration. Radionuclides and radiation associated with the disposal of tailings are present in four forms:

- radon gas
- radioactive dust particles
- dissolved radioactive constituents in the tailings liquor
- gamma radiation.

The quantities of the first three emissions are indicated below, while their contribution to radiation exposure pathways is discussed in Chapter 9. Gamma emissions are discussed in Section 9.4.

7.4.1 Radon gas

The emission of radon gas from the surface of the storage during operation will be regulated by maintaining the moisture content level of the tailings. The following equation based on diffusion theory has been used to predict radon emanation rates from tailings of thicknesses greater than 2 to 3 m:

$$J_t = Ra\ E\ d\ (\lambda\ D_{et}/P)^{\frac{1}{2}} \times 10^3$$

In this equation:

J_t	=	radon emanation rate ($Bq/m^2.s$)
Ra	=	concentration of radium (5.25 Bq/g)
E	=	emanation coefficient (0.2)
d	=	density of tailings (1,900 kg/m^3)
λ	=	decay constant of radon (2.1×10^{-6}/s)
P	=	porosity of tailings (0.45)
D_{et}	=	bulk diffusion coefficient (m^2/s).

From data published by Rogers et al. (1980) and Strong et al. (1981), and from data collected by WLPU Consultants (Aust.) Pty Ltd, a relationship has been derived by WLPU between the degree of saturation and the diffusion coefficient of a material. This relationship is:

$$D_{et} = 3.58 \times 10^{-6} \exp(-6.74 \times 10^{-2}\ S_r)$$

where D_{et} = bulk diffusion coefficient (m^2/s)

S_r = degree of saturation (%).

The above relationship used in conjunction with radon diffusion theory gives the relationship between degree of saturation and radon emanation shown in Figure 7.3.

During the course of the laboratory tailings model programme, measurements of the surface radon emanation were taken (Figure 7.3). The theoretical relationship used in the prediction of radon emanation from the tailings facility is in general agreement with the measured results (with the theoretical prediction conservatively overestimating radon emanation).

The cycle times for tailings deposition are calculated to achieve an average saturation rate of 90%. From Figure 7.3 it can be seen that at this degree of saturation the radon emanation rate is only marginally greater than that for fully saturated tailings. Some variation of the cycle time can be expected between winter and summer months to take account of the change in the period of drying required to achieve the target saturation level. If, because of periods of high evaporation or extended plant shutdown, the saturation drops below 90%, the radon emanation rate will increase as shown. From residual moisture content calculations, the expected minimum degree of saturation is 50%, at which point the surface radon emanation rate is still relatively low. Monitoring of the in situ moisture content will be carried out and adjustment of the deposition cycle times will be made to avoid excessive drying of the tailings. The radon emanation from the storage is discussed in more detail in Chapter 9.

7.4.2 Dusting of the tailings surface

The laboratory model work referred to in Section 7.2.2 has shown that at 90% saturation the tailings achieve a dry density of 1.9 t/m^3 and form a high strength competent surface not susceptible to wind erosion.

To investigate the dusting potential of the tailings surface in the event of the tailings drying to lower levels of saturation, wind flume tests on tailings at low moisture contents were carried out by the School of Civil and Mining Engineering of the University of Sydney. Trays of tailings slurry were dried, and then subjected to various combinations of wind velocity and temperature in the wind tunnel. Moisture contents and wind velocities used in the tests ranged between 1 to 24%, and 8 to 23 m/s respectively. Dust sampling was carried out by drawing off part of the airstream at the exit of the tunnel and passing it through a water bath collector. Resultant dust was separated by centrifuge and measured. Both observation and sampling showed that even at high wind velocities the driest samples failed to produce measurable dust. Some movement of salt flakes, precipitated by the rapid drying of the specimens, did take place during moderate to high velocity winds. Nevertheless, a conservative position has been adopted in examining the possible effect of dust emissions, and an allowance has been made for a contribution to the overall radionuclide levels from wind borne particles (Chapter 9).

7.4.3 Tailings liquor

Tailings liquor may be released from the retention system in four ways:

- a spill of tailings slurry
- a spill of decanted liquor
- seepage of liquor from tailings storage during initial deposition of tailings
- seepage of liquor through the deposited tailings after major storm events.

Spill of tailings slurry

Although it is possible for a spill of tailings slurry to occur due to a failure in either the main delivery pipeline or in the distribution pipe network, the probability of a major

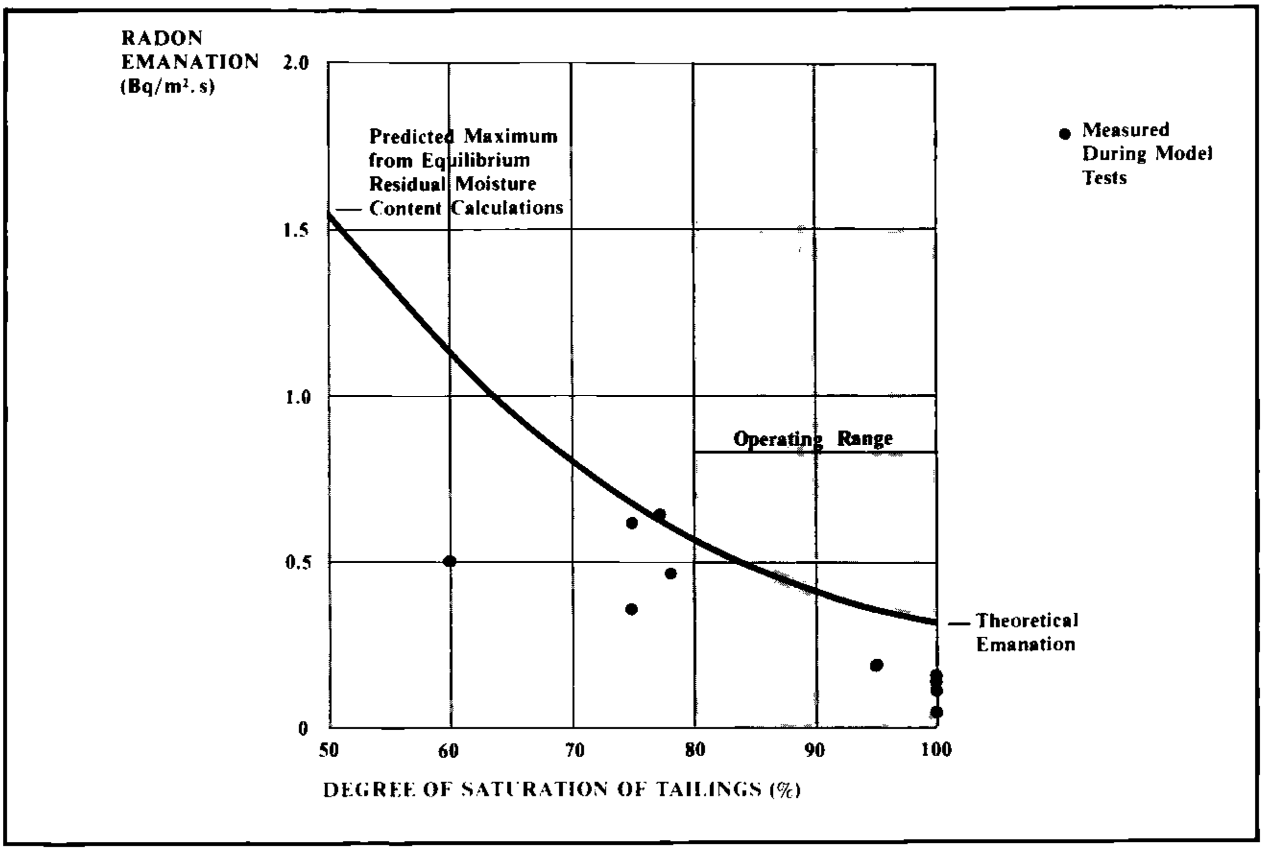


Figure 7.3
RADON EMANATION RATE IN RELATION TO DEGREE OF SATURATION

failure is considered very small. The pipes leading from the plant to the storage and those used to distribute the tailings slurry to each bay will be of rubber-lined steel, and designed with an adequate factor of safety against rupture. In addition, regular monitoring of the condition of the pipelines will disclose any need for replacement. The spigot pipes used for distributing the tailings slurry from the external embankments into each bay will be supplied from regularly maintained valved off-takes on the main distribution pipelines.

A spill from the main delivery pipeline would be contained within the pipeline corridor (Section 7.1.3), while spills from the distribution pipeline would flow directly into the facility from the pipeline berm.

Spill of decanted liquor

A failure of the pipeline carrying the liquor from the pumps to the evaporation pond could cause a spill of decanted liquor. Within the tailings storage, any such spillage would be contained within the embankments. For the section of pipeline between the outer embankment and the decant evaporation pond, the pipeline will be placed in a semi-circular culvert which will channel any spillage into the decant pond.

A perforation occurring in the membrane lining of the decant evaporation pond would comprise a further source of possible leakage. Should this occur, the cell affected would be taken out of operation, dewatered, and the perforation repaired.

The evaporation pond will be sized to accept normal decanted liquor flow and storm run-off, with an adequate margin against overtopping.

Initial deposition of tailings

Saturation of the base of the storage will occur to a limited depth during the initial deposition cycles, and will continue until the depth of consolidated tailings is sufficient to provide an effective seal. The results obtained from the laboratory model programme indicate that the depth of tailings required to effectively prevent seepage will be approximately 300 mm. The placing of five to six layers of tailings during five to six months of operation will be required to achieve this depth of consolidated material. The seepage will take place in the form of a wetting front advancing vertically downwards as the swale of the basin floor becomes saturated. During the drying cycle of the tailings, the negative pore pressures which develop will cause the capillary rise of liquor to the surface, not only from the tailings but also from the underlying swale. As a result, it can be expected that much of the seepage absorbed initially by the underlying swale will be drawn back to the surface of the tailings and evaporated.

Although it is difficult to calculate the precise quantity of effective seepage which will take place during the initial deposition cycles, it has been estimated that, if no seepage were drawn back to the surface by capillary action and evaporated, the total seepage which would take place during that period would be sufficient only to saturate the swale to a depth of less than 1 m below the tailings. Once the required depth of consolidated tailings has been established, the low vertical permeability of the material, together with the high capillary forces developed due to drying at the surface, will ensure that the deposit is maintained in a condition below saturation. No further seepage losses will occur.

The effects caused by a severe storm occurring prior to the establishment of an effective seal over the base of the storages has also been examined. In the analysis, it has been assumed that a 1 in 200 year 72-hour storm occurs when the basin foundations are covered by a 200 mm layer of tailings, i.e. two completed cycles, or approximately eight weeks after start-up. The storm run-off would take approximately forty days to pump out to the evaporation pond and, in that time, a quantity of water and liquor would pass through the tailings and penetrate the underlying swale to a depth of approximately 1.5 m. Once the ponded run-off and liquor had been decanted, the water which had infiltrated the swale would be drawn upwards by the capillary forces generated due to evaporation at the surface.

The only possibility of further infiltration into the Andamooka Limestone would be if dolines were present. (Isolated occurrences of dolines have been observed in the Study Area although not in the tailings retention area.) To guard against this possibility, a geophysical survey of the tailings area, as well as foundation drilling for the decant structure, will be undertaken to detect dolines. If any are discovered, they will be back-filled and sealed. The clay base preparation in the vicinity of the decant structure and the sedimentary cover over the Andamooka Limestone will serve to restrict any seepage to the limestone surface.

Major storm event on deposited tailings

During certain times of the year when evaporation rates are low, temporary ponding of liquor adjacent to the central decant weirs may occur, and may result in a small area of tailings remaining saturated. Management of the decant operation will minimize the area and depth of this ponding. The depth of tailings deposited over a period of low evaporation (which may encompass four to six deposition cycles) would not exceed 500 mm, which is considerably less than the depth to which drying would occur in the months of high evaporation rates. The moisture content of those tailings would be reduced to below saturation during the period of high evaporation. While the tailings are saturated and overlain by a shallow pond, the downward movement of liquor will be resisted by the low permeability of the underlying layers of tailings which have been previously subject to drying.

A conservative calculation has been carried out, assuming that an area of 50,000 m^2 of saturated tailings will be covered by liquor ponded to a depth of 0.5 m around the decant for six months. The resultant seepage (estimated at 700 m^3 /a) which passes from the saturated tailings layer into the underlying consolidated tailings would cause a wetting front to advance downwards. If such seepage reached the base of the tailings, it would have to pass through the prepared clay base (of low permeability) around the decant area before reaching cover sediments over the Andamooka Limestone.

Effects on groundwater

In the highly unlikely event that any seepage reached the groundwater table (at 50 m depth), it would mix with water already high in salts (Table 6.2), radium, and heavy metals content. Groundwater salinities are in excess of 20,000 mg/L making it unsuitable for either stock or human consumption. Radium-226 levels up to 2.6 Bq/L (i.e. more than six times the desirable level for stock and human consumption) have been measured. Iron, manganese, lead, fluoride and sulphate levels are also in excess of human consumption standards, and the groundwater therefore has no potential for beneficial use. Furthermore, the cone of depression associated with dewatering for mine operations will encompass this groundwater during the Project lifetime; thus, any seepage would be drawn to the dewatering wells and pumped to the saline water evaporation pond.

7.5 DECOMMISSIONING PROCEDURE

Decommissioning of the storage facility will be effected by removing all pipework, back-filling the central decant, and covering the surface of the tailings with a combination of swale material and quarried rock. The subaerial method of tailings disposal will ensure that the tailings in the storage facility attain a maximum practical density within the shortest possible time. Within a month of the deposition of the last layer of tailings, earthmoving equipment will commence placing the cover material. Decommissioning of the storage facility could be carried out at any stage during the life of the Project should it become necessary for any reason.

During the period of operation, as each stage is constructed, the outside faces of the embankment will be provided with the permanent rock protection necessary for the prevention of erosion by either wind or water. In addition, the surface of the tailings between the crest of the external embankment and the toe of the new embankment will be decommissioned at each stage of embankment construction.

The emphasis in the design of tailings cover is to provide an engineered barrier between the upper surface of the tailings and natural wind and water erosion forces. Present Project planning is based on placing an average of 1.5 m of swale material over the tailings surface (corresponding to a minimum of 1 m at any point allowing for placement tolerances), with a further 0.5 m cover of quarried rock placed over the swale material. The resulting attenuation of radon gas and gamma radiation is discussed in Chapter 9.

The broken rock cover will, in addition to providing erosion protection, inhibit evaporation from the underlying swale material, thus, in turn, reducing radon emanation through the swale cover. When placed over the tailings, the swale material will be slightly contoured to provide a more even ponding of run-off percolating through the rock cover and to prevent a concentration of water at the centre of the surface of the storage, while still containing any run-off water within the storage area.

When no longer required, the decant liquor evaporation pond and the saline evaporation pond will be decommisioned, and the areas which they occupied will be rehabilitated. The decant liquor pond will contain a layer of deposited salts which, together with the liner cover material, will be excavated and placed into the tailings storage prior to the placement of the decommissioning cover. The synthetic membrane liner will be removed, and either buried or destroyed together with other pieces of plant equipment, or placed into the tailings storage.

The saline evaporation pond will also contain a salt deposit which will be placed into the tailings storage together with any contaminated clay lining material and embankment fill. The remainder of the embankment fill will be spread evenly over the site, and the area suitably rehabilitated.

7.6 MONITORING

The monitoring of the performance of the tailings storage will form an integral part of the operating procedure. The following processes will be monitored on a routine basis:

- in situ moisture content on drying beaches
- radon emanation and gamma radiation over drying beaches and at various points around the embankments
- dust generation
- groundwater regimes in surrounding areas
- embankment pore pressure.

The in situ moisture content of the deposited tailings will be monitored, and the data thus obtained will be used to regulate the deposition cycles as required. Moisture content will be correlated against radon emanation and in situ density and, being relatively easy to measure, will be the ideal control parameter for overall storage performance. Sampling for respiratory dust will be carried out.

Radon gas, radon daughter, and gamma radiation readings will be taken in work places and the surrounds under a programme to be agreed upon with the responsible statutory authorities (Chapter 9).

The monitoring of the water-table below the storage facility will be carried out on a regular basis from standpipe piezometers positioned around the perimeter of the storage at selected locations. Additional piezometers will be installed within and beneath the retaining embankments.

All monitoring will be carried out to a programme approved by the relevant government authorities. Any departures from the programme will be noted, together with the reasons for the changes. All data gathered will be recorded, and will be available for scrutiny by the appropriate authorities.

CHAPTER EIGHT

Other Wastes and Emissions

SUMMARY

Meteorology

The climate at Olympic Dam is warm to hot in summer and mild to cool in winter, with long hours of sunshine, very low and unreliable rainfall, and high evaporation rates throughout the year. Winds are predominantly from southern quadrants in spring and summer, and from the north-west quadrant in winter. In autumn, winds are lighter and mainly from the south-east or north quadrants. Night-time inversions between 100 and 400 metres are frequent, breaking up as a result of solar heating by mid-morning and reforming after sunset.

Air emissions

In relation to air quality considerations, the main plant emissions will be sulphur oxides, oxides of nitrogen, and hydrogen fluoride. The main sources of sulphur oxides will be the acid plant, coal-fired process steam boilers, and the smelter furnace, with minor amounts from the concentrate dryer and yellowcake calciner. Oxides of nitrogen will be emitted from the boilers and the concentrate dryer. Fluoride in the ore will be converted to hydrogen fluoride during the roasting of concentrates or during the smelting of copper, and the minor amounts not collected in gas cleaning prior to acid production will be emitted from the acid plant. All predicted emission concentrations are within the relevant National Health and Medical Research Council recommendations for emission standards.

Maximum ground level concentrations have been predicted for each emission. Peak concentrations will occur during unstable atmospheric conditions with moderate wind speeds. For sulphur dioxide from a single source, the predicted maximum three-minute-averaged ground level concentration from the acid plant is 485 micrograms per cubic metre at 20^{o}C, compared with the allowable criterion of 532 micrograms per cubic metre. The maximum for combined sulphur dioxide sources is 560 micrograms per cubic metre, compared with the criterion of 1,064 micrograms per cubic metre. For nitrogen oxides, the maximum is 28 micrograms per cubic metre, compared with the criterion of 325 micrograms per cubic metre, while for hydrogen fluoride the maximum is 3 micrograms per cubic metre, compared with the criterion of 21 micrograms per cubic metre. Long-term concentrations of all emissions are also well below relevant standards.

Dust emissions generated from handling process materials such as pyrolusite, coal, sulphur and silica sand, as well as dust from quarry operations, will be controlled to meet the relevant occupational health recommendations of the National Health and Medical Research Council. Primary roads will be sealed to minimize dust from this source, while secondary lightly trafficked roads will be watered as necessary. Appropriate safety practices will be followed in the handling and use of toxic process chemicals.

Noise

Predictions have been made of the Project related noise levels likely to be experienced in the town, which will be 10 kilometres away from the operations area. The frequency and intensity of noise from all operational components which might represent potentially significant noise sources have been combined by computer model, and meteorological conditions which may accentuate noise reception, such as wind direction or inversion presence, have been considered for 'worst case' situations. The resulting predictions are that, even under these worst case situations and allowing for tonality, the maximum effective noise level in the town due to Project operations will be 36 dBA. This is well below the South Australian regulatory standard of 45 dBA for urban residential areas at night, and is as low as the probable night-time background noise levels in the town.

The quarry, which will be situated about 15 kilometres north of the town, is unlikely to provide a source of annoyance at that distance. Provision has been made for buffer zones between the town and other intermittent noise sources, in order to reduce possible annoyance. The main road buffer zone will be 150 metres wide, while a buffer zone of about 350 metres in width will be provided for the possible future railway.

Within the town itself, air-conditioning noise will be the most likely source of annoyance. The noise level of the air-conditioners to be installed by the Joint Venturers will therefore be one of the selection criteria for this equipment. As industrial areas can also be a source of noise annoyance in residential areas, these areas will be separated in planning for the town.

Solid waste

The town will be the major source of solid waste, which will consist of household and garden refuse, construction materials, and commercial and industrial waste. To dispose of these wastes, the Joint Venturers will establish a sanitary landfill in the town area, which will be operated by the municipality.

Project operations will generate a relatively small amount of solid waste, which will include both contaminated and uncontaminated wastes. To dispose of the latter, salvageable materials such as scrap metal will be sold, while unsalvageable waste will be disposed of in the mine landfill tip adjacent to the tailings storage facility. Contaminated waste will be decontaminated where possible and the salvageable portion sold. That portion of the contaminated waste which is not salvageable will be drummed where possible, and disposed of in a separate area of the mine landfill.

8.1 METEOROLOGY

Climatic considerations are relevant to such matters as evaporation area requirements, building design, certain aspects of plant design, amenity plantings, and rehabilitation measures. Air quality meteorology, which includes the wind regime and thermal structure of the local atmosphere, is the major factor influencing the transport and dispersion of emissions. This section presents meteorological data measured at Olympic Dam and nearby locations. The measurements relevant to emission transport and dispersion are then presented, to provide a basis for evaluation of atmospheric concentrations of emissions.

8.1.1 Measurement of meteorological factors

Measurement of temperature, rainfall, relative humidity, and wind speed and direction began in January 1980 at the Olympic Dam Village station. Subsequently, five additional stations were installed and the existing Village station modified, with data collection from all stations beginning in February 1981. The network of stations is shown in Figure 8.1, with a central station at Sandhill and an associated elevated station at Shaft Head, as well as three outlying stations at Bulls Head, Lake Blanche and Phillips Ridge. The parameters measured at the various locations (Table 8.1) include dry bulb temperature, barometric pressure, relative humidity, rainfall, wind speed and direction, solar radiation and inversion height. Anemometers were installed at these stations on 10 m towers, with the exception of Shaft Head (where anemometer height is 42 m) and Village (14 m). Seasonal averages of the measurements at Sandhill (Table 8.2) provide representative values for Olympic Dam.

Table 8.1 Meteorological parameters recorded

Station	Height (m)*	Parameter	Station	Height (m)*	Parameter
Bulls Head	101	Wind direction Wind speed	Sandhill	105	Wind direction Wind speed Dry bulb temperature Relative humidity Barometric pressure Rainfall Solar radiation Inversion height
Lake Blanche	83	Wind direction Wind speed			
Shaft Head	137	Wind direction Wind speed Dry bulb temperature Relative humidity	Village	119	Wind direction Wind speed Dry bulb temperature Relative humidity Rainfall
Phillips Ridge	101	Wind direction Wind speed Dry bulb temperature Relative humidity			

* Height in metres Australian Height Datum (AHD).

Table 8.2 Seasonal summary of meteorological measurements at Sandhill

Parameter	Spring	Summer	Autumn	Winter	Annual
Temperature (°C)					
Mean maximum	28.1	35.6	27.0	17.8	27.1
Mean minimum	13.5	21.4	14.1	7.2	14.1
Relative humidity (%)					
Mean maximum	64	52	72	90	69
Mean minimum	16	12	26	36	23
Rainfall					
Total (mm)	7.9	36.8	45.7	16.9	107.4
Rain days	8	6	16	7	37
Wind speed (m/s), mean	4	4	3	4	4
Solar radiation (W/m^2), Mean maximum	800	950	750	600	775

Many of the parameters recorded have been correlated with long-term data from Woomera and Andamooka, to determine whether data from these two areas represent the likely long-term situation at Olympic Dam. In general, a good correlation with all measured parameters was observed (Steedman 1982).

Surface air temperature

Average monthly temperature records are set out in Table 8.3, together with similar information recorded at Woomera to allow a comparison.

The area experiences hot summers, with the highest temperatures occurring in January and February, when the mean maximum is about 35°C and the minimum about 22°C. Occasional temperatures of above 40°C can occur between October and March. Over the twelve-month monitoring period, the highest recorded temperature at Sandhill was 48°C in December 1981. Winters are cool, with July being the coldest month and recording the lowest temperature (1.5°C) during the monitoring period.

Recorded temperatures at Sandhill indicate that Woomera is about 1°C cooler on average (Steedman 1982). Minimum and maximum temperatures lower than the long-term average were experienced except during March, when warmer temperatures occurred. Although the region has relatively uniform topography, in utilizing temperature data recorded at Woomera and Andamooka for long-term predictions at Olympic Dam, slight elevation differences must be taken into account. Based on a temperature gradient of 1°C per 100 m of the vertical air column, temperatures at Olympic Dam should average 0.5°C less than at Andamooka, and 0.5°C more than at Woomera.

Table 8.3 **Average monthly temperatures**

Month	Mean minimum (°C)					Mean maximum (°C)				
	S	P	H	W	W(LT)	S	P	H	W	W(LT)
March 1981	16.1	16.6	14.8	15.5	16.7	29.3	29.1	28.6	27.1	30.1
April	16.2	15.4	16.9	16.2	13.1	30.9	30.5	31.7	29.0	25.6
May	10.1	9.2	9.3	10.3	9.1	20.8	22.3	20.0	20.2	20.2
June	7.6	7.6	7.8	7.2	6.9	17.0	17.2	17.6	16.4	17.7
July	5.7	5.2	6.6	6.1	5.8	17.2	17.0	16.9	16.5	16.5
August	8.2	8.7	7.8	8.0	6.6	19.3	19.3	18.2	18.5	18.2
September	11.2	11.1	12.0	11.5	9.0	26.2	25.9	26.1	25.3	21.7
October	12.6	13.4	13.1	12.2	12.4	28.0	28.6	28.8	27.3	26.5
November	16.7	16.7	17.2	15.5	15.0	30.1	29.6	30.3	28.4	29.5
December	19.6	19.6	19.5	17.6	17.1	35.0	33.8	34.8	32.1	31.5
January 1982	22.6	21.8	24.0	21.0	19.3	36.9	36.0	37.0	34.5	34.0
February	22.1	22.1	22.6	20.8	18.9	34.9	34.2	35.4	34.6	33.1
Annual	14.1	14.0	13.5	13.5	12.5	27.1	27.0	27.1	25.8	25.4

Note: Measurements taken at Sandhill (S), Phillips Ridge (P), Shaft Head (H), and Woomera (W), with long-term average data from Woomera (W(LT)) provided as a comparison.

Source: Woomera data from Bureau of Meteorology.

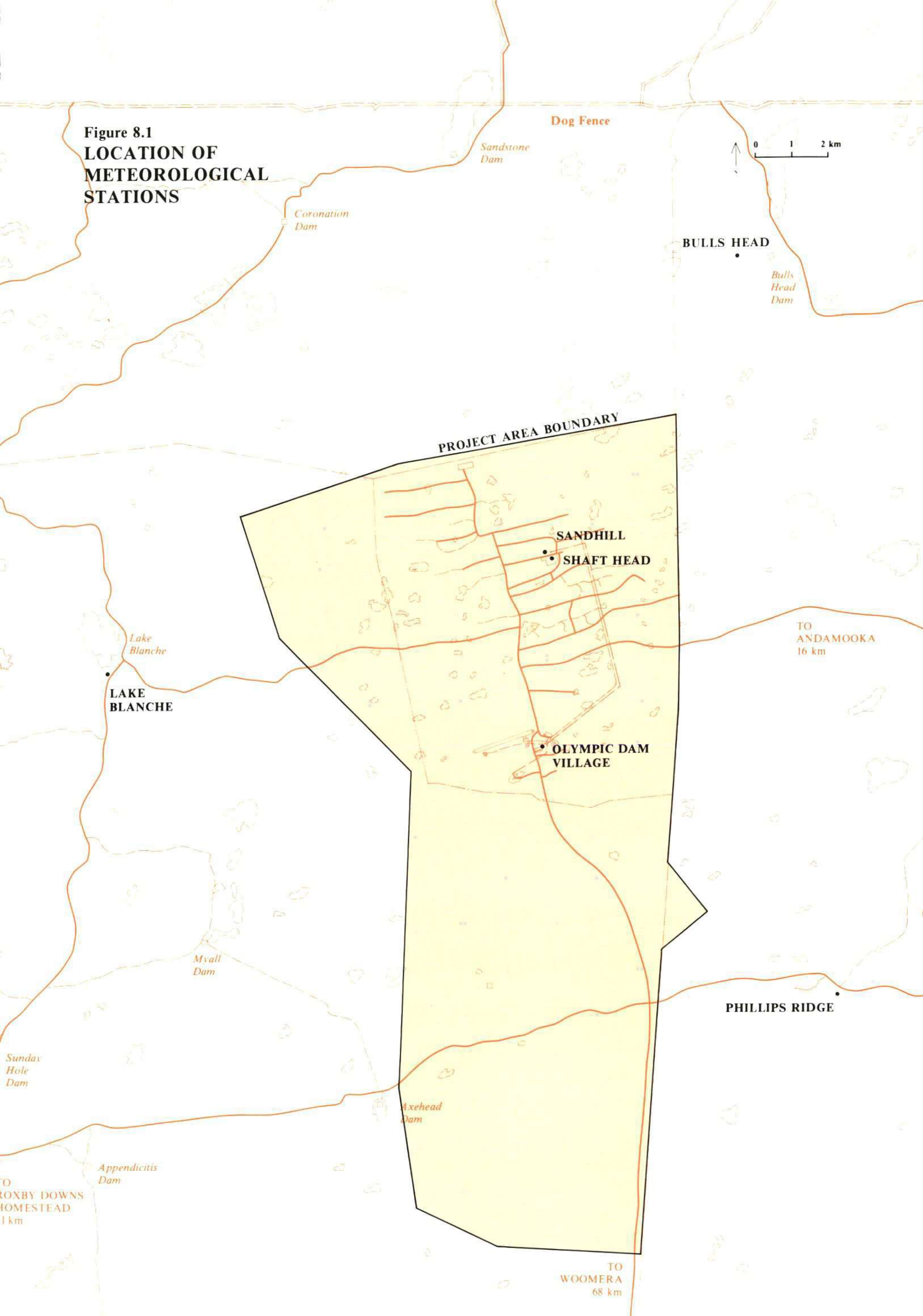


Figure 8.1
LOCATION OF METEOROLOGICAL STATIONS

Barometric pressure

The average monthly barometric pressures recorded at Sandhill and Woomera from March 1981 to February 1982 are given in Table 8.4. The slight seasonal increase in pressure from summer to winter is evident from the table.

Table 8.4 Average monthly barometric pressure

Month	Sandhill*	Woomera*
March 1981	998.3	998.8
April	997.5	998.6
May	1,000.0	1,000.0
June	994.1	993.5
July	999.9	1,000.0
August	996.1	996.3
September	1,000.5	999.5
October	996.5	997.8
November	993.3	993.5
December	993.2	992.6
January 1982	999.4	992.0
February	992.0	994.1

* Pressure is measured in millibars adjusted to mean sea level.

Surface relative humidity

Monthly relative humidities recorded at Sandhill, Phillips Ridge and Shaft Head have been compared with long-term monthly averages recorded at Woomera in Table 8.5. Relative humidity is highly sensitive to temperature variations in an inverse relationship, and temperature increases experienced in the summer months cause the average relative humidity to decrease accordingly.

Table 8.5 Average monthly relative humidities

Month	Mean minimum (%)				Mean maximum (%)			
	S	P	H	W(LT)	S	P	H	W(LT)
March 1981	22	22	28	30	69	66	64	70
April	20	20	22	28	66	64	57	67
May	36	27	37	39	80	72	69	73
June	39	37	42	46	92	89	84	86
July	38	36	42	46	91	84	83	86
August	31	29	34	40	86	82	75	83
September	19	19	21	27	63	59	55	67
October	13	13	16	22	62	58	57	68
November	17	18	21	26	66	63	62	69
December	10	11	15	19	54	52	55	61
January 1982	11	11	16	23	45	46	44	54
February	16	16	21	24	56	54	57	64
Annual	22.7	21.6	26.3	30.8	69.2	65.8	63.5	70.7

Note: Measurements taken at Sandhill (S), Phillips Ridge (P), and Shaft Head (H), compared with the long-term average at Woomera (W(LT)).

Source: Woomera data from Bureau of Meteorology 1975.

Rainfall

The Project is in an arid area which experiences a highly variable annual rainfall. At Roxby Downs Station, the recorded annual rainfall ranged from 33 to 582 mm between 1931 and 1977 (Table 8.6). In areas of high annual variability, years of high or low rainfall cause averages to become biased. Rainfall percentiles which indicate a ranking of the probability of an annual rainfall occurrence are therefore more informative and useful than rainfall averages. This is demonstrated at Andamooka, where the eight-year average rainfall was 203 mm, while the median rainfall was 165 mm for the same period. Median (50 percentile) annual rainfall at Olympic Dam is approximately 150 mm (Bureau of Meteorology). Periods of two to three months with no significant rain are experienced in most years.

Table 8.6 Monthly and annual rainfall at Roxby Downs Station (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1931	2	0	29	20	10	25	5	6	3	3	0	0	103
1932	0	18	2	3	35	5	8	17	24	18	8	7	145
1933	3	0	19	1	18	0	10	32	3	9	18	2	115
1934	0	13	9	0	0	7	10	3	3	28	51	0	124
1935	31	0	13	2	1	5	7	25	16	9	6	0	115
1936	15	4	5	0	0	0	6	15	0	13	4	4	68
1937	36	36	0	10	7	6	0	15	0	0	6	0	160
1938	2	37	0	0	1	16	11	19	0	50	0	0	136
1939	85	33	11	0	27	56	0	6	3	0	45	0	267
1940	7	0	7	0	7	*	*	2	5	6	0	0	33
1941	53	8	22	3	0	24	16	2	0	16	5	0	149
1942	9	3	0	1	14	14	5	4	7	0	7	0	64
1943	0	26	0	1	0	0	5	8	0	2	5	0	67
1944	4	21	0	3	2	0	4	3	2	1	0	12	52
1945	6	1	0	4	12	50	17	14	6	36	0	13	159
1946	*	*	*	*	*	*	*	*	*	*	*	*	
1947	0	13	178	27	0	6	8	16	0	45	11	0	304
1948	0	10	0	0	0	0	0	3	0	11	1	52	77
1949	0	33	23	67	67	5	0	2	80	34	0	0	271
1950	0	105	10	0	37	27	0	0	1	8	43	23	254
1951	0	0	22	8	0	44	12	0	5	0	3	2	96
1952	17	0	9	0	33	5	13	6	5	23	10	8	129
1953	31	80	0	8	0	2	0	35	0	4	0	52	212
1954	0	1	0	32	0	10	0	8	0	30	17	*	
1955	0	22	32	*	*	*	*	21	*	*	*	*	
1956	2	6	0	16	14	31	37	22	5	3	0	0	136
1957	0	0	4	4	0	16	5	3	0	10	0	47	89
1958	0	0	25	5	19	6	32	51	7	13	6	5	169
1959	3	9	30	7	11	7	17	4	*	3	16	5	112
1960	31	13	0	3	13	2	28	7	37	0	0	0	134
1961	*	*	*	*	*	*	*	*	*	*	*	*	
1962	19	0	6	0	34	0	21	2	4	13	0	4	103
1963	0	0	2	41	51	30	3	0	4	0	0	6	137
1964	5	4	0	3	6	2	10	2	106	18	0	10	166
1965	0	0	0	3	13	2	24	9	22	0	1	18	92
1966	19	66	11	3	24	11	0	13	0	5	4	49	205
1967	22	40	0	0	2	1	1	5	0	5	2	0	78
1968	153	*	*	*	*	*	*	*	*	*	*	*	
1969	3	22	25	5	35	21	39	21	0	14	8	1	194
1970	0	0	0	11	0	2	2	21	13	9	20	2	80
1971	0	14	33	7	0	35	11	19	7	0	53	19	198
1972	69	0	2	0	0	0	0	15	9	0	4	0	79
1973	12	97	8	16	3	36	66	55	10	27	19	45	372
1974	85	152	15	29	136	2	13	33	34	83	0	0	582
1975	0	66	4	8	12	9	11	16	18	104	0	51	299
1976	40	52	0	0	0	3	11	0	0	39	17	18	180
1977	0	0	1	*	*	*	*	*	*	*	*	*	

* Rainfall not recorded.
Source: Bureau of Meteorology.

Heavy falls can occur in any month. Significant rainfall events are usually associated with large scale rain-producing systems, which typically involve an inflow of moist tropical air aloft accompanied by a closed cyclonic circulation, or a trough, in the upper atmosphere. This can occur during surface anticyclones, but is usually associated with a surface low pressure system (Jensen and Wilson 1980).

Monthly and annual rainfall data recorded at Sandhill is presented in Table 8.7. The total of 107 mm measured represents a 33 percentile rainfall year (i.e. an annual rainfall which would be exceeded 66% of the time) for the area. The long-term averages for Woomera and Andamooka are presented in Tables 8.8 and 8.9 respectively. On average, falls of rain occur in the area on approximately forty days each year, with no marked seasonal variation in frequency. Large falls can occasionally occur over short periods, but sustained periods of intense rainfall are very rare. A rain-bearing cyclonic depression passed over Olympic Dam during five days in January 1981, resulting in 137 mm of rain. This demonstrates the potential for intense rainfalls, given a suitable combination of atmospheric conditions.

Table 8.7 Monthly and annual rainfall at Sandhill

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Year
Rainfall (mm)	0.0	5.9	4.6	35.2	8.6	0.1	7.9	0.9	1.4	6.0	18.3	18.5	107.4
Raindays	0	4	1	11	4	1	2	1	2	5	4	2	37
Rain hours	0	11	4	49	12	1	7	2	2	10	15	11	124

Note: Measurement from February 1981 to January 1982.

Table 8.8 Average monthly and annual rainfall at Woomera

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)													
Mean	18	25	14	14	18	16	19	15	16	13	13	10	191
Median	9	15	4	7	18	10	19	9	11	6	11	5	190
Raindays (mean)	3	2	3	3	5	5	6	6	5	4	4	3	49

Source: Bureau of Meteorology 1975.

Table 8.9 Average monthly and annual rainfall at Andamooka

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)													
Mean	28	29	12	22	12	20	17	19	9	9	13	13	203
Median	23	25	6	5	6	14	7	13	4	5	13	9	165
Raindays (mean)	5	2	2	2	2	6	3	5	4	3	3	2	39

Source: Bureau of Meteorology 1975.

As a result of generally low and erratic rainfall accompanied by high evaporation rates, droughts are a frequent occurrence, and prolonged droughts can occur. At Roxby Downs Station, for example, a total of only 163 mm of rain was recorded during the three years from 1942 to 1944.

Winds

Average annual wind speed and direction percentage occurrence data for each of the network stations is presented in Tables 8.10 to 8.15. Graphic representation of annual and monthly data for Sandhill is shown in the form of wind-roses in Figure 8.2. During spring and summer, winds from the southern quadrants were most prevalent. During autumn, winds were nearly all either from the south-east quadrant (46%) or the north quadrant (40%). During the winter months, winds from the north-west quadrant dominated. This seasonal change in mean wind direction has been variously termed a

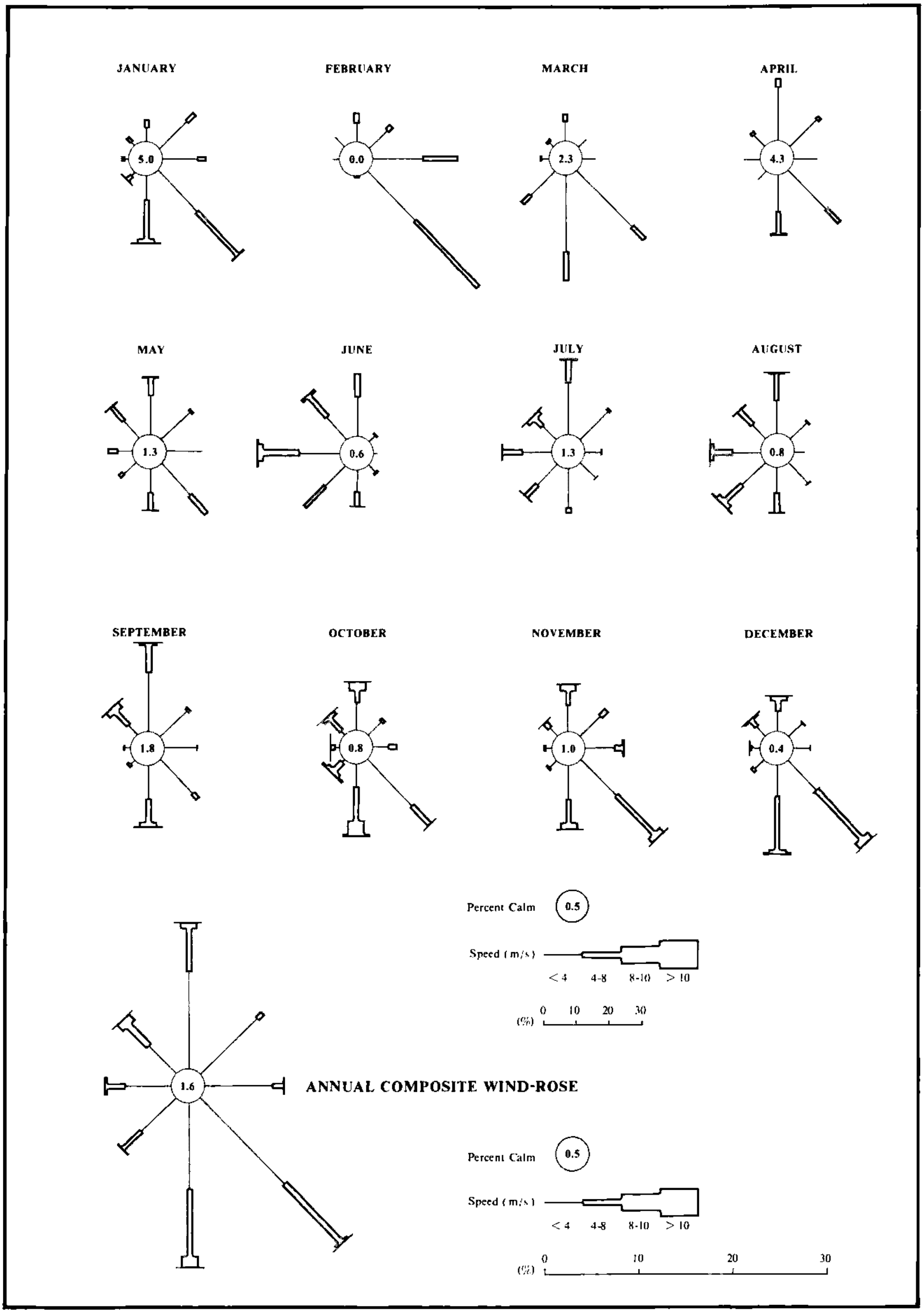


Figure 8.2
WIND-ROSES, SANDHILL METEOROLOGICAL STATION

Table 8.10 **Annual average wind speed-direction percentage occurrence at Sandhill**

Direction	Wind speed (m/s)								Totals
	0.1 to 2.0	2.1 to 4.0	4.1 to 6.0	6.1 to 8.0	8.1 to 10.0	10.1 to 12.0	12.1 to 14.0	14.1 and over	
North	3.8	6.8	3.2	1.8	0.6	0.1	*		16.3
North-east	4.1	4.0	0.8	0.2					9.2
East	3.3	3.1	0.8	0.1	*				7.4
South-east	3.9	9.1	6.4	2.7	0.3	*			22.5
South	2.8	5.5	4.2	3.4	1.0	0.1	0.1		17.1
South-west	1.9	2.9	1.7	0.7	0.2	0.1			7.4
West	1.8	2.8	1.5	0.8	0.2	0.1			7.3
North-west	2.0	2.6	2.0	1.4	0.6	0.1	0.1		8.8
Totals	23.7	37.0	20.6	11.1	2.9	0.5	0.1	0.0	

* Denotes occurrence is ≤ 0.05%.

Note: Occurrence of calms 4.0%.
Period of measurement 10 April 1981 to 15 March 1982.
7,821 data points at hourly intervals.

Table 8.11 **Annual average wind speed-direction percentage occurrence at Phillips Ridge**

Direction	Wind speed (m/s)								Totals
	0.1 to 2.0	2.1 to 4.0	4.1 to 6.0	6.1 to 8.0	8.1 to 10.0	10.1 to 12.0	12.1 to 14.0	14.1 and over	
North	1.2	2.9	1.9	1.1	0.7	0.2	*		8.1
North-east	4.0	5.4	3.8	1.4	0.6	0.1	*		15.4
East	1.7	2.9	1.0	0.2	*	*			5.8
South-east	2.0	4.3	3.7	1.5	0.3				11.7
South	3.9	7.9	7.0	5.6	1.7	0.2	0.1	*	26.5
South-west	3.0	4.3	3.3	2.6	1.7	0.7	0.2	*	15.8
West	1.0	2.9	1.9	1.4	0.7	0.3	0.1	*	8.3
North-west	0.8	2.7	1.9	1.0	0.5	0.1	*	*	7.1
Totals	17.8	33.2	24.5	14.8	6.3	1.5	0.4	0.2	

* Denotes occurrence is ≤ 0.05%.

Note: Occurrence of calms 1.3%.
Period of measurement 22 February 1981 to 15 March 1982.
9,175 data points at hourly intevals.

Table 8.12 **Annual average wind speed-direction percentage occurrence at Shaft Head**

Direction	Wind speed (m/s)								Totals
	0.1 to 2.0	2.1 to 4.0	4.1 to 6.0	6.1 to 8.0	8.1 to 10.0	10.1 to 12.0	12.1 to 14.0	14.1 and over	
North	0.3	1.1	3.3	2.6	1.3	0.7	0.3	0.1	9.7
North-east	0.4	2.7	4.3	4.8	1.5	0.5	0.2	0.1	14.6
East	0.5	2.4	3.5	2.2	0.4	0.1	*	*	9.1
South-east	0.4	2.2	3.9	3.3	0.6	*	*		10.5
South	0.4	2.8	8.1	6.3	4.1	1.4	0.3	0.1	23.5
South-west	0.3	2.5	3.9	3.6	3.1	1.7	0.9	0.4	16.4
West	0.2	2.1	2.0	2.4	1.4	0.9	0.5	0.4	9.9
North-west	0.2	1.1	2.0	1.6	0.7	0.5	0.1	*	6.2
Totals	2.6	16.9	31.2	26.8	13.1	5.9	2.4	1.1	

* Denotes occurrence is ≤0.05%.

Note: Occurrence of calms 0.0%.
Period of measurement 22 February 1981 to 15 March 1982.
9,178 data points at hourly intervals.

Table 8.13 **Annual average wind speed-direction percentage occurrence at Bulls Head**

Direction	Wind speed (m/s)								Totals
	0.1 to 2.0	2.1 to 4.0	4.1 to 6.0	6.1 to 8.0	8.1 to 10.0	10.1 to 12.0	12.1 to 14.0	14.1 and over	
North	1.5	3.6	2.7	1.5	1.1	0.5	0.1	*	11.0
North-east	1.8	4.1	3.2	1.2	0.4	0.2	0.1		11.0
East	1.6	5.0	2.0	0.5	0.1	*	*		9.1
South-east	1.4	5.6	4.3	2.4	0.6	0.1			14.4
South	1.2	6.9	6.3	6.1	3.4	0.7	0.1	0.1	24.8
South-west	1.4	4.5	3.3	2.5	1.8	0.9	0.3	0.1	14.9
West	.8	2.9	1.7	1.2	0.9	0.5	0.1	0.1	8.1
North-west	.6	2.1	1.7	1.1	0.7	0.2	*	0.1	6.6
Totals	10.4	34.7	25.1	16.5	9.0	3.3	0.7	0.3	

* Denotes occurrence is ≤0.05%.

Note: Occurrence of calms 0.1%.
Period of measurement 22 February 1981 to 15 March 1982.
9,178 data points at hourly intervals.

Table 8.14 **Annual average wind speed-direction percentage occurrence at Village**

Direction	Wind speed (m/s)								Totals
	0.1 to 2.0	2.1 to 4.0	4.1 to 6.0	6.1 to 8.0	8.1 to 10.0	10.1 to 12.0	12.1 to 14.0	14.1 and over	
North	1.6	7.7	4.9	2.2	0.8	0.1	*		17.4
North-east	1.6	6.6	2.1	0.3	*				10.6
East	1.8	4.7	1.0	0.1	*	*			7.6
South-east	2.2	8.0	5.1	0.1					16.9
South	2.6	8.0	6.2	3.3	0.6	0.1	0.1		20.8
South-west	1.5	4.0	2.7	1.9	0.8	0.3	*	*	11.2
West	1.1	3.1	1.8	1.2	0.7	0.1	0.1	*	8.1
North-west	0.9	2.6	1.6	1.1	0.4	*	*	*	6.6
Totals	13.4	44.7	25.3	11.4	3.5	0.7	0.2	0.1	

* Denotes occurrence is ≤0.05%.

Note: Occurrence of calms 0.8%.
Period of measurement 22 February 1981 to 7 February 1982.
7,938 data points at hourly intervals.

Table 8.15 **Annual average wind speed-direction percentage occurrence at Lake Blanche**

Direction	Wind speed (m/s)								Totals
	0.1 to 2.0	2.1 to 4.0	4.1 to 6.0	6.1 to 8.0	8.1 to 10.0	10.1 to 12.0	12.1 to 14.0	14.1 and over	
North	3.2	3.1	2.6	1.1	0.6	0.2	*	*	10.8
North-east	3.2	2.9	2.0	0.7	0.2	0.1			9.1
East	2.6	2.6	1.5	0.6	0.1	*	*		7.5
South-east	3.0	5.6	5.5	4.4	2.2	0.2	*	*	21.0
South	3.2	6.3	4.4	3.6	2.1	0.7	0.2	0.1	20.6
South-west	2.0	3.4	2.4	2.1	0.8	0.3	0.1	0.1	11.3
West	1.1	2.5	1.9	1.4	0.9	0.3	0.1	*	8.3
North-west	2.6	2.9	2.3	1.7	1.1	0.3	0.1	*	11.0
Totals	21.0	29.3	22.5	15.6	8.0	2.3	0.5	0.3	

* Denotes occurrence is ≤0.05%.

Note: Occurrence of calms 0.5%
Period of measurement 22 February 1981 to 13 March 1982.
8,646 data points at hourly intervals.

monsoonal effect or a continental sea breeze. It results from the seasonal change in mean pressure distribution over the continent, as discussed by Troup (1974), and is also influenced by the seasonal movement of the subtropical high pressure belt and associated weather systems. The tendency for southerly winds in summer and northerly winds in winter is common throughout southern Australia.

The mean wind speed is 4 m/s. This falls to 3 m/s in autumn, when the percentage of 'calms' increases and maximum recorded wind speed decreases. There is some variation in wind speed and direction across the Olympic Dam network. This natural variability is due largely to local variations in topographical conditions, particularly when low level inversions are present.

Strong winds are not prevalent in the area. At Woomera, winds exceeding 17.5 m/s (gales) are normally experienced only two to three times a year, with a maximum of seven occurrences in 1965.

Wind gusts at Woomera have exceeded 40 m/s three times since 1949. The highest recorded wind speed at Woomera is a gust of 46 m/s. Similar gusts would be possible at Olympic Dam. Wittingham (1964) noted that the majority of the annual maximum gusts at Woomera came from the south-west to north-west, and usually occurred between 1200 hours central standard time (CST) and 2100 hours CST in spring and summer. This suggests that these gusts have a strong association with thunderstorms. Very strong wind gusts can also occur with the passage of cold fronts and intense low pressure systems.

Solar radiation

Solar radiation provides the energy for the movement of the atmosphere. The amount of energy received at the earth's surface may be directly correlated with some of the measurable atmospheric effects which in turn have been correlated with wind speed to determine atmospheric stability classes as discussed in Section 8.1.2. For this reason, the incoming solar radiation (insolation) was measured at Sandhill at hourly intervals in units of watts per square metre (W/m^2).

Insolation measurements varied from 0 to 1,000 W/m^2. Seasonal changes in insolation values, caused by the relative positions of the sun and the earth, result in a sinusoidal curve of the maximum daily radiation levels. Daily variations result from occurrence of cloud cover. The summer maximum insolation of 1,000 W/m^2 was reached in December, while the maximum winter insolation was about 500 W/m^2.

8.1.2 Air pollution climatology

The vertical atmospheric temperature profile and its relationship with wind speed and direction, atmospheric stability, as well as the existence of inversion layers and correlating mixing heights, are important factors in the dispersion and transport of pollutants, and must be considered in predicting emission effects on ground level air quality. Normally, these characteristics are not directly measurable, but are obtained through correlation and evaluation of directly measurable data. The results obtained and their application in computer modelling of air quality are described below.

Wind and vertical temperature structure

Wind behaviour is closely related to the vertical temperature structure. In most cases wind is regarded as turbulent, exhibiting apparently random fluctuations in both speed and direction. Turbulence is a result of the interaction of wind with the surface of the earth (mechanical turbulence) and/or density variations associated with the vertical temperature structure of the atmosphere (thermal turbulence). While mechanical turbulence is completely independent of thermal turbulence, once mechanical turbulence has been initiated it may be enhanced or suppressed by the thermal structure of the atmosphere.

The natural vertical temperature gradient defines the types of stability conditions which are relevant in determining dispersion characteristics. Temperature gradients are defined in terms of the atmospheric lapse rate (i.e. the rate of decrease of atmospheric temperature with height) as follows:

- dry adiabatic lapse rate (the atmospheric lapse rate which gives thermodynamic equilibrium with height, i.e. 0.98^{o}C/100 m of height)
- environmental lapse rate (the actual atmospheric lapse rate)
- isothermal (an atmospheric lapse rate of zero, i.e. an unchanged temperature with height)
- inversion (a negative atmospheric lapse rate, i.e. an increasing temperature with height).

The vertical dry bulb temperature structure at Olympic Dam was determined from recorded temperature differences at Sandhill and Shaft Head which have a vertical separation of about 32 m. Throughout the year, the morning temperature at Sandhill generally exceeded that at Shaft Head while, during the afternoon and evening, the Shaft Head temperature generally exceeded that at Sandhill. Seasonal averages of this relationship are shown in Table 8.16.

Table 8.16 Seasonal daytime and night-time temperature gradients (^{o}C/m)

Season	Daytime	Night-time*
Summer	-0.060	+0.152
Autumn	-0.112	+0.020
Winter	-0.053	+0.098
Spring	-0.015	+0.185

* Inversion height <100 m.

In order to evaluate the vertical temperature gradient further, differences between temperatures at Shaft Head and Sandhill were correlated with wind speed and time of day. It was found on average that:

- at low wind speeds (0.1 to 2.0 m/s), Sandhill was 3 to 6^{o}C warmer in the day and 3 to 6^{o}C cooler at night;
- at wind speeds between 2.1 and 4.0 m/s, Sandhill was 0 to 5^{o}C warmer in the day and 0 to 5^{o}C cooler at night;
- when the wind speed was greater than 4 m/s, Sandhill was 0 to 4^{o}C warmer in the day and 3^{o}C cooler to 2^{o}C warmer at night.

The magnitude of the temperature difference was therefore found to be related to wind speed and the time of day.

Atmospheric stability

Atmospheric stability influences horizontal and vertical turbulent mixing, which in turn affects the rate of dispersion of airborne materials. Stability conditions are classified by means of the various Pasquill atmospheric classes ranging from Pasquill A, the most unstable condition, through Pasquill D, a neutral condition, to Pasquill F, the most stable condition. The three most common methods of estimating stability classes are derived from:

- correlation of wind speed and insolation
- the value of the standard deviation of the wind direction over a selected time interval (i.e. sigma theta)
- the vertical temperature gradient.

The method of stability classification used in evaluating convective mixing at Olympic Dam is based on wind speed and insolation adapted from Smith (1973). A comparison of sigma theta with the vertical temperature gradient from available parameters indicated a reasonable correlation (Steedman 1982). However, the high convective mixing experienced in the interior of Australia which has been documented in recent work (Carras and Williams 1981) suggests that modification of the wind speed and insolation classification methods were appropriate. (Details are contained in Steedman 1982.) This modification has been adopted for determination of Pasquill stability classes, and the joint occurrence of wind speed, wind direction, and Pasquill stability for the Village station is presented in Table 8.17.

Inversion layers and mixing heights

During stable conditions (Pasquill Stability Classes E and F), vertical stratification of the atmosphere occurs, which tends to inhibit atmospheric turbulence, thus reducing the extent of atmospheric mixing. When these stable conditions occur, therefore, inversions are probable. Two forms of temperature inversion mechanisms exist, namely, nocturnal radiation inversions and subsidence inversions. Nocturnal radiation inversions at lower levels (100 to 400 m) predominate at Olympic Dam, being recorded for 84% of nights. They are usually associated with clear night-time skies and light winds. Subsidence inversions occur under the influence of high pressure systems aloft at heights in excess of 1,000 m. When the upper layer of air subsides at a greater rate and consequently reaches a higher temperature than the lower layer, the inversion occurs.

Continuous information concerning the height of the temperature inversion was obtained from acoustic sounder data at Sandhill. Temperature profiles from a number of tethered radiosonde flights confirmed the inversion pattern information from the acoustic sounder.

A typical variation in stability and mixing height during the twenty-four hours of the day is shown in the acoustic sounder trace in Figure 8.3. During the night-time (approximately 0000 hours to 0700 hours and 1800 hours to 2400 hours), a clear layered echo which is characteristic of stable conditions, indicates an inversion at 100 m. As the sun rises (0700 hours), ground heating from solar radiation produces unstable conditions, and convection lifts the stable layer. From 0900 hours the stable layer rapidly ascends to a level above 1,000 m. Between 1200 hours and 1700 hours there is a 'weed' type echo (Hayashi 1980) characteristic of unstable conditions. After sunset (1730 hours), the sun no longer produces surface convective conditions, and stable conditions prevail. At night, heat is conductively transferred from the boundary layer to the ground where it radiates away from the earth. This results in an upward cooling of the surface layer to a typical height of 100 to 400 m (i.e. the height of the nocturnal inversion).

For long-term air quality modelling purposes, daily changes in mixing height were represented by a composite monthly average based on acoustic sounder and tethersonde data for heights below 1,000 m, while predictions of the height of the convective mixed layer above 1,000 m were based on mean temperature and wind data for Woomera.

Table 8.17 **Joint annual percentage occurrence of wind speed, wind direction and Pasquill stability**

Wind speed (m/s)	Pasquill stability	Direction N	NE	E	SE	S	SW	W	NW
0 to 2	A	0.13	0.13	0.14	0.18	0.21	0.01	0.09	0.07
	B	0.15	0.05	0.06	0.07	0.09	0.05	0.04	0.03
	C	0.12	0.12	0.13	0.16	0.19	0.11	0.08	0.06
	D	0.30	0.30	0.33	0.41	0.48	0.28	0.20	0.17
	E	0.28	0.28	0.32	0.39	0.46	0.26	0.19	0.16
	F	0.72	0.72	0.81	0.99	1.17	0.68	0.50	0.41
2 to 4	A	0.62	0.53	0.38	0.64	0.64	0.32	0.25	0.21
	B	0.26	0.22	0.16	0.27	0.27	0.14	0.11	0.09
	C	0.56	0.48	0.34	0.58	0.58	0.29	0.22	0.19
	D	1.43	1.22	0.87	1.48	1.48	0.74	0.58	0.48
	E	1.36	1.16	0.83	1.41	1.41	0.70	0.55	0.46
	F	3.48	2.98	2.12	3.61	3.61	1.81	1.40	1.17
4 to 6	A	0.39	0.17	0.08	0.41	0.50	0.22	0.14	0.13
	B	0.17	0.07	0.03	0.17	0.21	0.09	0.06	0.05
	C	0.35	0.15	0.07	0.37	0.45	0.19	0.13	0.12
	D	0.91	0.39	0.19	0.95	1.15	0.50	0.33	0.30
	E	0.86	0.37	0.18	0.90	1.09	0.48	0.32	0.28
	F	2.21	0.95	0.45	2.30	2.80	1.22	0.81	0.72
6 to 8	A	0.18	0.02	0.01	0.12	0.27	0.15	0.10	0.09
	B	0.07	0.01	0.00	0.05	0.11	0.06	0.04	0.04
	C	0.16	0.02	0.01	0.11	0.24	0.14	0.09	0.08
	D	0.41	0.06	0.02	0.28	0.61	0.35	0.22	0.20
	E	0.39	0.05	0.02	0.26	0.58	0.33	0.21	0.19
	F	0.99	0.14	0.05	0.68	0.49	0.86	0.54	0.50
8 to 10	A	0.06	0.00	0.00	0.01	0.05	0.06	0.06	0.03
	B	0.03	0.00	0.00	0.00	0.02	0.03	0.02	0.01
	C	0.06	0.00	0.00	0.01	0.04	0.06	0.05	0.03
	D	0.15	0.00	0.00	0.02	0.11	0.15	0.13	0.07
	E	0.14	0.00	0.00	0.02	0.11	0.14	0.12	0.07
	F	0.36	0.00	0.00	0.05	0.27	0.36	0.32	0.18
10 to 12	A	0.01	0.00	0.00	0.00	0.01	0.02	0.01	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
	C	0.01	0.00	0.00	0.00	0.01	0.05	0.01	0.00
	D	0.02	0.00	0.00	0.00	0.02	0.06	0.02	0.00
	E	0.02	0.00	0.00	0.00	0.02	0.05	0.02	0.00
	F	0.05	0.00	0.00	0.00	0.05	0.14	0.05	0.00
over 12	A	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
	D	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.00
	E	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.00
	F	0.00	0.00	0.00	0.00	0.05	0.00	0.05	0.00

Note: Number of values 3 x 8,624.

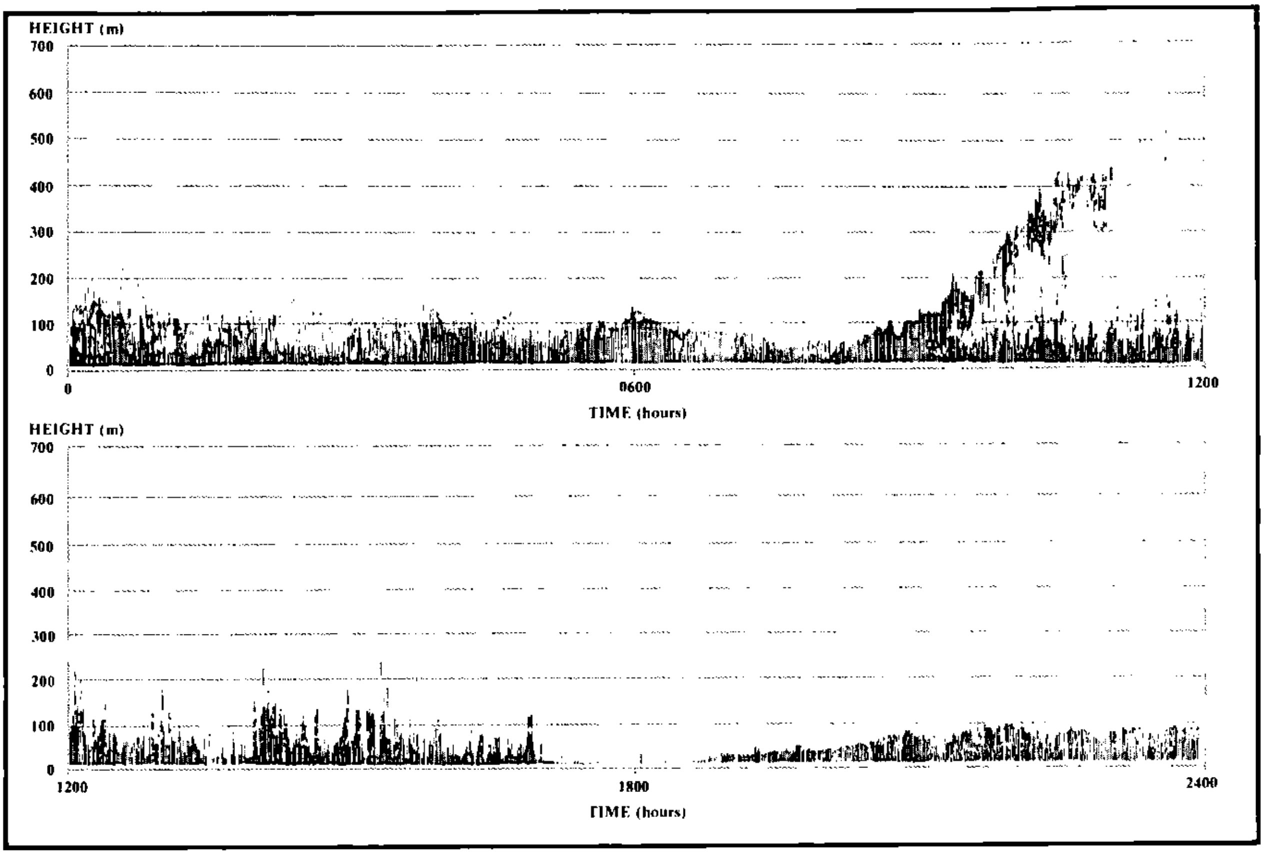


Figure 8.3
TYPICAL ACOUSTIC SOUNDER TRACE

Figure 8.4 shows the daily variation in mixing height averaged over months representative of each season. Figure 8.5 shows the variation in the monthly averages for the maximum daytime and night-time mixing heights.

8.1.3 Computer modelling

Two types of computer models were used to predict ground level concentrations of emissions from the Project. Short-term maximum predictions of non-radioactive gaseous emissions were modelled by a steady state model, while long-term average ground level concentrations of radioactive emissions were predicted by a time dependent puff model. The assumptions used, the methods of calculation, and a general description of the models are given below.

The steady state model

Modelling of emissions of sulphur dioxide, oxides of nitrogen, and hydrogen fluoride is primarily concerned with maximum ground level concentrations, and maximum concentrations to which workers and members of the public could be exposed. This is most readily accomplished by a model which assumes that emissions are released at a uniform rate and that meteorological conditions are constant (steady state). To account for differences in meteorological conditions, a number of different Pasquill stability classes, wind speeds, and mixing heights were modelled as described in Section 8.2.3.

The model used to predict short-term concentrations was a Pasquill-Gifford-Turner steady state model (Turner 1970, Pasquill 1974, Gifford 1975). Plume rise was calculated from a semi-empirical formula from Briggs (1975). The Briggs plume rise equation is

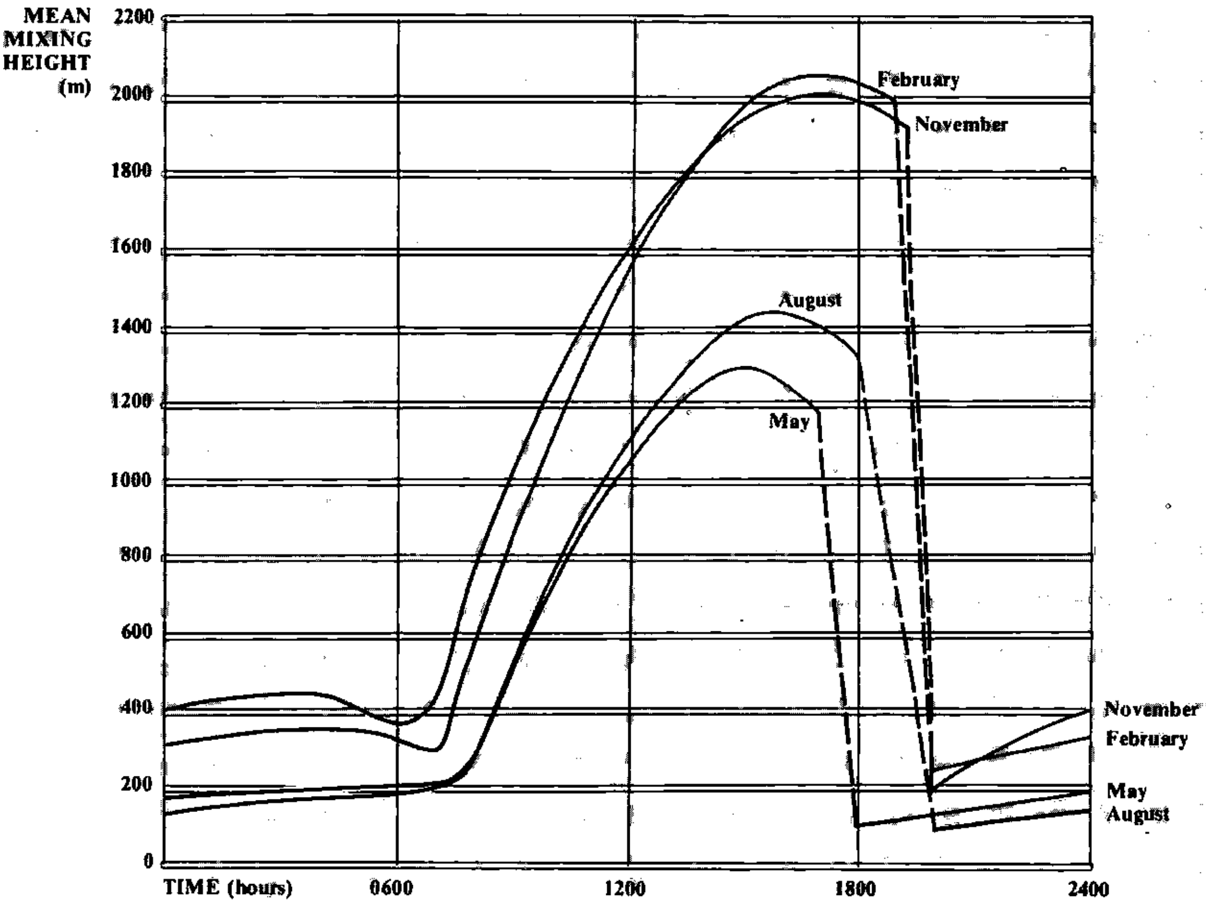


Figure 8.4
DAILY VARIATION IN MIXING HEIGHTS

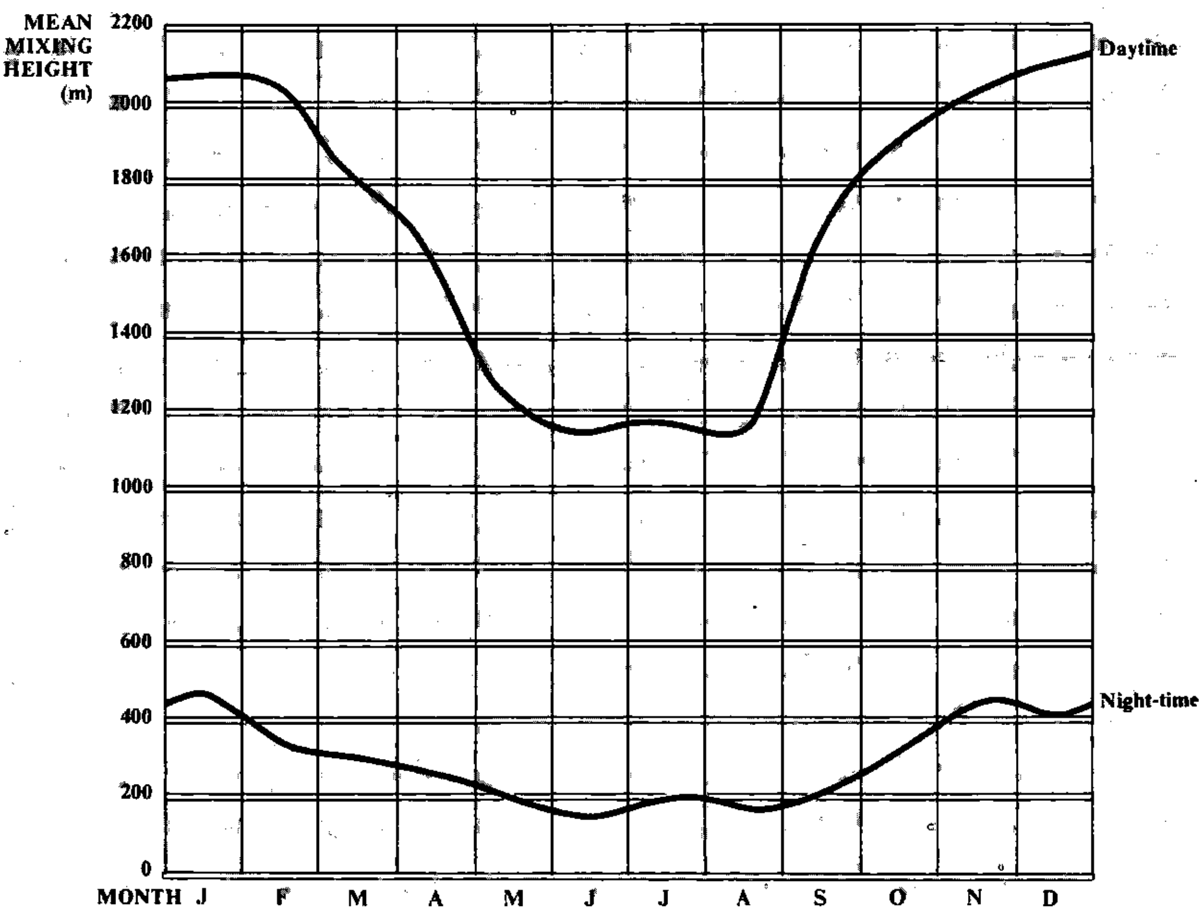


Figure 8.5
MONTHLY VARIATION IN MIXING HEIGHTS

based on observed data, and predicts that the extent to which the centreline of the plume will rise is dependent upon the downwind distance, the wind speed and the buoyancy due to density differences between the stack gas and the ambient air, the velocity of the gas, the radius of the stack, and the barometric pressure. The plume will generally continue to rise until it has travelled a downwind distance of about ten stack heights, where it levels off. The distance to the ground at this point is termed the effective emission height, which is the sum of the actual stack height plus the plume rise.

From the point at which the emission is released from the stack, the plume begins to disperse both horizontally and vertically. Pasquill (1961) developed vertical and horizontal air dispersion coefficients to predict concentrations, assuming that the dispersion follows a Gaussian distribution from the centreline of the plume. Using these coefficients, the concentrations at the ground directly beneath the centreline of the plume may be calculated. Generally, dispersion coefficients increase in value with distance from the source, and decrease at any specified distance with increasing stability. The effect at ground level is that, during unstable conditions, plumes disperse more rapidly and to a greater depth, resulting in higher ground level concentrations than during neutral or stable conditions.

The dispersion coefficients used for predicting concentrations in this chapter and in Chapter 9 were adopted from Pasquill (1974). In the absence of experimental data, these are considered to be the best practical coefficients for the Olympic Dam area. Further information concerning the model is contained in Section 8.2.

The puff model

The puff model used to predict long-term average ground level concentrations of radioactive emissions was based on Start and Wendell (1974), with modifications to include a variable puff release rate and incorporation of the Pasquill-Gifford-Turner diffusion coefficients used for modelling non-radioactive emissions. The model generated a series of puffs of sufficient strength to be equivalent to a continuous release rate. The frequency of the puffs was proportional to the wind speed, to maintain constant spacing between the puffs. Each of the puffs was dispersed within a grid 25 by 30 km. Grid receptor points were established at each kilometre throughout the grid.

The model is time-dependent, meaning that changes in atmospheric conditions with time are incorporated by the model to predict annual average ground level concentrations. Throughout the year, measured or calculated hourly values of stability, wind speed and direction, and mixing height were incorporated. The stability class and the mixing height were assumed to be constant throughout the grid. The wind speed and direction at each of the grid receptor points were interpolated from data collected at the meteorological stations. A representation of the hourly values used in the model during the first half of October is shown in Figure 8.6.

The amount of computing time which would be involved prevented calculation of the total concentration from each source in one computer run. The sources were therefore modelled independently, with the contribution from each of the sources being combined to determine the cumulative effect.

8.2 GASEOUS EMISSIONS

This section describes the sources and impacts of non-radioactive gaseous emissions from plant operations. In assessing the impact of these emissions on air quality, two general types of regulatory safeguards to protect the health and safety of the public are considered, i.e. those which control the amount, concentrations, or conditions of emission release, and those which apply to ambient ground level concentrations of pollutants in the air. Meteorological data presented in Section 8.1 has been combined with estimated plant emissions through the computer model to predict ground level concentrations of these emissions.

8.2.1 Sources of plant emissions

Plant operations emit the following non-radioactive gases which might impair air quality:

- sulphur oxides
- oxides of nitrogen
- minor amounts of hydrogen fluoride.

Each of these is quantitatively identified in relation to the component source, treatment before release, and conditions of release, for each of the process options described in Section 2.4.

Sulphur oxides

In the roast/leach/electrowin (RLE) and the pressure leach/electrowin (PLE) circuits, sulphur dioxide will be released from the acid plant, the boilers and the yellowcake calciner (Section 2.5.2). In the smelt/convert (SC) circuit, additional amounts of sulphur dioxide will be released from the concentrate dryer and the smelter. Evaluation of effects includes emissions from all sources.

Acid plant: In the RLE circuit, acid for leaching will be produced from roaster tail gas and, if additional acid is required, from the burning of elemental sulphur. In the PLE circuits, the only source of acid will be from the burning of elemental sulphur. The SC circuit will use smelter and converter off-gas and sulphur burning for acid production. The Joint Venturers intend to maximize the recovery of sulphur dioxide in the acid plant which is the most economical source of sulphur for conversion to sulphuric acid. If capture is not maximized, then any shortfall must be made up by importing and burning elemental sulphur. Acid quantities needed are almost entirely dependent upon the requirements for the leaching of flotation tailings, and therefore acid plant throughput of sulphur dioxide for all of the circuits is essentially the same. This will result in about the same level of emissions of sulphur dioxide from the acid plant regardless of the process option selected.

The acid plant will comprise two units. Total emissions of sulphur oxides are estimated to be 165 g/s. This is based on a single catalysis plant with system design or addition of wet scrubbers to achieve 98.8% sulphur dioxide recovery and 99.9% sulphur trioxide absorption. Emissions indicated by final design will be confirmed with the Air Quality Branch of the South Australian Department of Environment and Planning to ensure compliance with the Clean Air Regulations. If necessary, further emission reduction can be achieved by one or more of the following:

- design modifications to the plant
- adding final scrubbers
- adjusting the stack height.

Fugitive gases from smelting: Minor amounts of fugitive gases and dust will be emitted by the smelter. Collection of these will be necessary to ensure that the work environment within the smelter building meets appropriate health standards. These gases will not contain sufficient concentrations of sulphur dioxide to allow treatment within the acid plant and, after passing through a dust collection system, the sulphur dioxide will be emitted via the smelter stack at a rate of approximately 25 g/s.

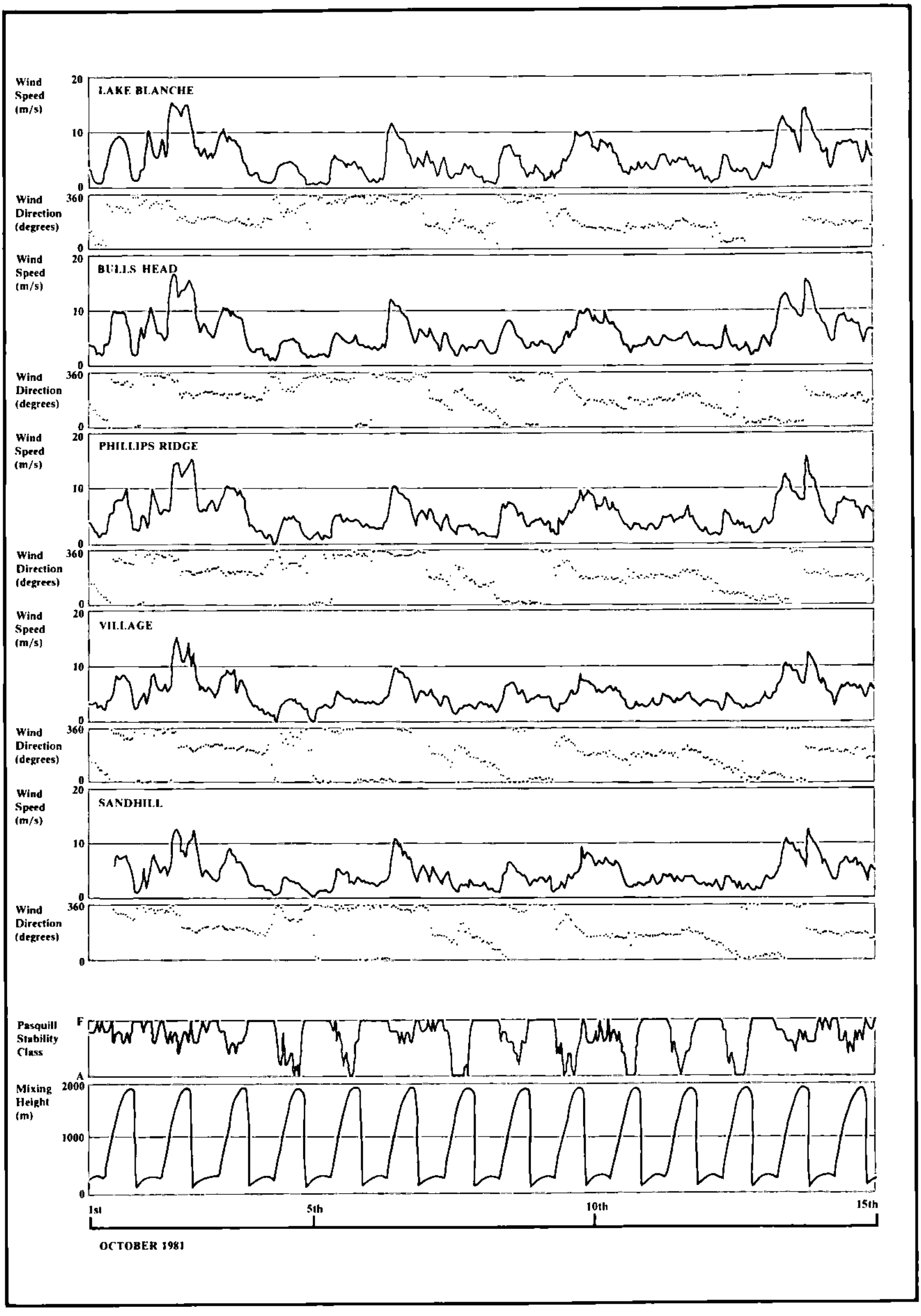


Figure 8.6
TYPICAL TIME SERIES INPUT TO AIR QUALITY MODEL

Fuel burning equipment: Sulphur contained in fuel used in fuel burning equipment will be released as sulphur dioxide upon combustion. Requirements for steam production have been assumed to be satisfied by burning of coal containing 0.8% sulphur by weight. It is conservatively assumed that all sulphur present in the coal will be oxidized to sulphur dioxide, resulting in about 44 g/s of sulphur dioxide leaving the process steam boilers. Fuel oil will be required for yellowcake calcining in all options considered, and for concentrate drying in the SC circuit. The yellowcake calciner gases will be cleaned by a scrubber prior to being emitted, which will remove more than 95% of the sulphur dioxide. The ammonium diuranate will contain minor amounts of sulphate which may dissociate and release sulphur dioxide. After scrubbing, the sulphur dioxide emission rate will be approximately 0.44 g/s. The use of fuel oil for concentrate drying will produce about 4.4 g/s of sulphur dioxide.

Oxides of nitrogen

Oxides of nitrogen are produced in fuel burning equipment from the high temperature reaction of atmospheric nitrogen and oxygen in the combustion zone, and from the partial oxidation of nitrogenous compounds contained in the fuel.

Emissions of oxides of nitrogen are predominantly nitrogen oxide (NO), but also contain a small amount of nitrogen dioxide (NO_2). Most nitrogen oxide is converted to nitrogen dioxide within a few hours of release.

Factors which affect the production of oxides of nitrogen are:

- flame and furnace temperature
- residence time of combustion gases at flame temperature
- rate of cooling of the gases
- the amount of excess air present in the flame.

The operating conditions of the roaster, calciner, smelter furnace, and converter will result in negligible emissions from these sources.

Estimates of emission rates from the boiler and concentrate dryer have been made, based on estimated fuel requirements and United States Environmental Protection Agency (USEPA 1977) emission factors, which indicate that oxides of nitrogen (which are conservatively assumed to be in the form of nitrogen dioxide) would be emitted at the rates of about 8.3 g/s from boilers and 1.4 g/s from the concentrate dryer. These can be compared with the emissions of oxides of nitrogen from combustion of briquetted brown coal which indicate that the level could be as low as 4.2 g/s (State Electricity Commission of Victoria 1974).

Hydrogen fluoride

The only source of fluoride will be from the ore. It has been conservatively assumed that hydrogen fluoride will be formed during roasting of concentrates and during smelting of copper. Since these two processes are exclusive, the total amount of hydrogen fluoride produced will not vary significantly if either the RLE or SC process is adopted. Laboratory test results indicate that fluoride will not be emitted from leaching operations, as it will remain in solution as a chemical complex.

Gaseous fluorides contaminate the vanadium pentoxide catalysts used in acid production. For this reason, off-gases from the roaster and the smelter will pass through a gas cleaning train which will reduce fluoride content. Based on the maximum design amount of fluoride allowed to enter the sulphur dioxide converter, and assuming that all fluoride entering the acid plant would pass through, emissions of hydrogen fluoride would be of the order of 1 g/s.

Fluoride emissions in the fugitive gas collection system of the smelter will be negligible. This is because concentrations of hydrogen fluoride will be very low within the smelter, and only a small amount of fugitive gases will escape from the smelter operations.

A summary of all emissions is given in Table 8.18.

Table 8.18 Process emissions to atmosphere

Process method	Process component	Emission		
		Sulphur oxides (g/s)	Oxides of nitrogen (g/s)	Hydrogen fluoride (g/s)
Roast/leach/electrowin or) Pressure leach/) electrowin)	Acid plant	165	Negligible	1
	Boilers	44	8.3	Negligible
	Calciner	0.44	Negligible	Negligible
Total RLE or PLE		209	8.3	1
Additional from Smelt/convert	Concentrate dryer	4.4	1.4	Negligible
	Smelter furnace	25	Negligible	Negligible
	Converter	*	Negligible	Negligible
Maximum total		239	9.7	1**

* Sulphur dioxide has been included in acid plant component.

** Hydrogen fluoride is not considered additive as, either the sources are exclusive or, if a combination of SC and RLE is used, the combined total will be equivalent to the total from either source independently.

8.2.2 Comparison of emission concentrations with standards

The concentration of pollutants in the gas streams of plant stacks must meet the requirements applied by the Air Quality Branch of the South Australian Department of Environment and Planning. The Air Quality Branch will apply the National Health and Medical Research Council (NHMRC) 'National Emission Standards for Air Pollutants' to plant emissions from the Olympic Dam Project. These NHMRC recommendations are applicable to emissions of sulphur trioxide, oxides of nitrogen, and hydrogen fluoride. No standard exists for emissions of sulphur dioxide.

Sulphur trioxide normally comprises about 2% of the total emissions of oxides of sulphur from fuel burning equipment (American Society of Mechanical Engineers Research Committee Report 1959). This gives values of about 1.1 g/s from the boiler, and 0.11 g/s from the concentrate dryer. Emissions of sulphur trioxide from the calciner and smelter may be slightly higher, and have therefore been conservatively assumed as 4% of the total or 0.02 g/s and 1.3 g/s respectively. The formation of acid in the acid plant is accomplished by the conversion of sulphur dioxide to sulphur trioxide, which is achieved through contact with the catalyst, and absorption of sulphur trioxide in strong acid. As the process absorbs about 99.9% of sulphur trioxide, nearly all emissions of oxides of sulphur will be in the form of sulphur dioxide which has not been converted to sulphur trioxide. The emission of sulphur trioxide from the acid plant is estimated to be 21 g/s.

A comparison of estimated plant emissions with NHMRC (1979) recommendations has been made in Table 8.19. As indicated in the table, all recommendations will be met.

Table 8.19 Comparison of NHMRC recommendations with estimated plant emissions

Source	Sulphur trioxide (g/m^3)		Oxides of nitrogen (g/m^3)		Hydrogen fluoride (g/m^3)	
	NHMRC	Plant	NHMRC	Plant	NHMRC	Plant
Acid plant	3.0	0.23	1.0	Negligible	0.05	0.01
Boilers	0.1	0.04	0.5	0.31	0.05	Negligible
Calciner	0.1	0.02	0.5	Negligible	0.05	Negligible
Concentrate dryer	0.1	0.01	0.5	0.07	0.05	Negligible
Smelter	0.1	0.02	0.5	Negligible	0.05	Negligible

8.2.3 Comparison of ground level concentrations with standards

The Air Quality Branch of the South Australian Department of Environment and Planning specifies minimum allowable stack heights to ensure that peak predicted ground level concentrations of sulphur dioxide, oxides of nitrogen and hydrogen fluoride do not exceed certain criteria levels. For sulphur dioxide, the criteria for maximum three-minute-averaged ground level concentrations are 20 parts per hundred million (pphm) from a single source, and 40 pphm for multiple sources. For nitrogen dioxide, the criteria is 17 pphm, and for hydrogen fluoride it is 2.5 pphm: these apply to all sources combined.

The steady state model described above was used to predict ground level concentrations. The exit and atmospheric conditions considered in the predictions are described below, followed by a comparison of predicted ground level concentrations with the air quality criteria.

Exit conditions

Stack exit velocity, temperature, and height influence the vertical extent of the rise of the plume from the stack, thereby affecting emission dispersion and downwind concentrations. The exit velocity and exit temperatures used are consistent with modern equipment of similar function and capacity, and have been conservatively estimated assuming no predischarge dilution. A summary of the stack heights, exit velocities, and temperatures used in modelling is given in Table 8.20.

Table 8.20 Stack release parameters used for modelling

Source	Height (m)	Radius (m)	Exit velocity (m/s)	Gas temperature (°C)
Acid plant Stack 1	60	1.8	6	80
Acid plant Stack 2	60	1.8	6	80
Boilers	40	1.4	8	250
Calciner	40	0.2	8	80
Dryer	50	0.9	8	80
Smelter	150	2.1	6	80

Atmospheric transport and dispersion

Ground level concentrations vary with wind speed, atmospheric stability and inversion height. The steady state computer model was run under a variety of conditions likely to occur in order to determine the maximum predicted ground level concentrations. Wind speeds were modelled at 1, 2, 4, 6, 8 and 10 m/s for stable (Pasquill F), neutral (Pasquill D) and unstable (Pasquill A) conditions. For neutral and stable conditions, the effects of mixing heights of 200 and 400 m were considered. As unstable conditions occur during the day when mixing heights are normally greater than 1,000 m, the effects of 1,000 and 2,000 m mixing heights were also examined. Diffusion variations with stability class were included from coefficients given by Pasquill (1974) and Gifford (1975), giving ground level concentrations representative of a ten-minute sampling time.

Predicted ground level concentrations

Ground level concentrations were calculated using the emissions given in Table 8.18, the exit parameters in Table 8.20 and atmospheric conditions discussed above. To evaluate compliance with single source criteria levels for sulphur dioxide, emissions from the acid plant were modelled. The worst case ten-minute-averaged ground level concentrations for sulphur dioxide from the acid plant are shown in Figure 8.7(a). These occur under unstable atmospheric conditions (Pasquill A), with a mixing height of 1,000 m and wind speed of 4 m/s, giving rise to 380 $\mu g/m^3$ at 650 m from the acid plant.

For comparison with air quality criteria which are in terms of three-minute-averaged ground level concentrations, a time-weighting correction factor (Turner 1970) has been applied to the predicted ten-minute-averaged values. Table 8.21 shows the maximum ground level concentrations for each wind speed considered as three-minute-averaged values. At 20°C, the single source sulphur dioxide criterion of 20 pphm is 532 $\mu g/m^3$. Thus the maximum predicted value of 485 $\mu g/m^3$ is well within the required limit.

Table 8.21 Worst case three-minute-averaged ground level concentrations of sulphur dioxide from the acid plant

Pasquill stability class/inversion height	Wind* speed (m/s)	Occurrence** (%)	Sulphur dioxide: Concentration ($\mu g/m^3$)	Sulphur dioxide: Downwind distance (m)
A	1	0.75	275	1,940
1,000 m	2	3.31	400	1,070
	4	4.00	485	650
	6	2.11	475	530
	8	0.85	460	460
	10	0.27	425	430
Allowable maximum	-	-	532	-

* Wind speed at 10 m above ground level.
** Percentage occurrence includes Pasquill Stability Classes A and B.

Ten-minute-averaged ground level concentrations for combined sulphur dioxide sources are shown in Figure 8.7(b), (c) and (d) for unstable, neutral, and stable atmospheric conditions respectively. To account for multiple emission points, all stacks were taken as coincident at a single location. This results in a peak value greater than if the emission points had been considered as separate. A maximum of 440 $\mu g/m^3$ at 600 m from the acid plant occurs under Pasquill Stability Class A conditions, with a mixing height of 1,000 m and a wind speed of 6 m/s.

Figures 8.8 and 8.9 show the predicted ten-minute-averaged ground level concentrations for nitrogen dioxide and hydrogen fluoride respectively under a range of atmospheric

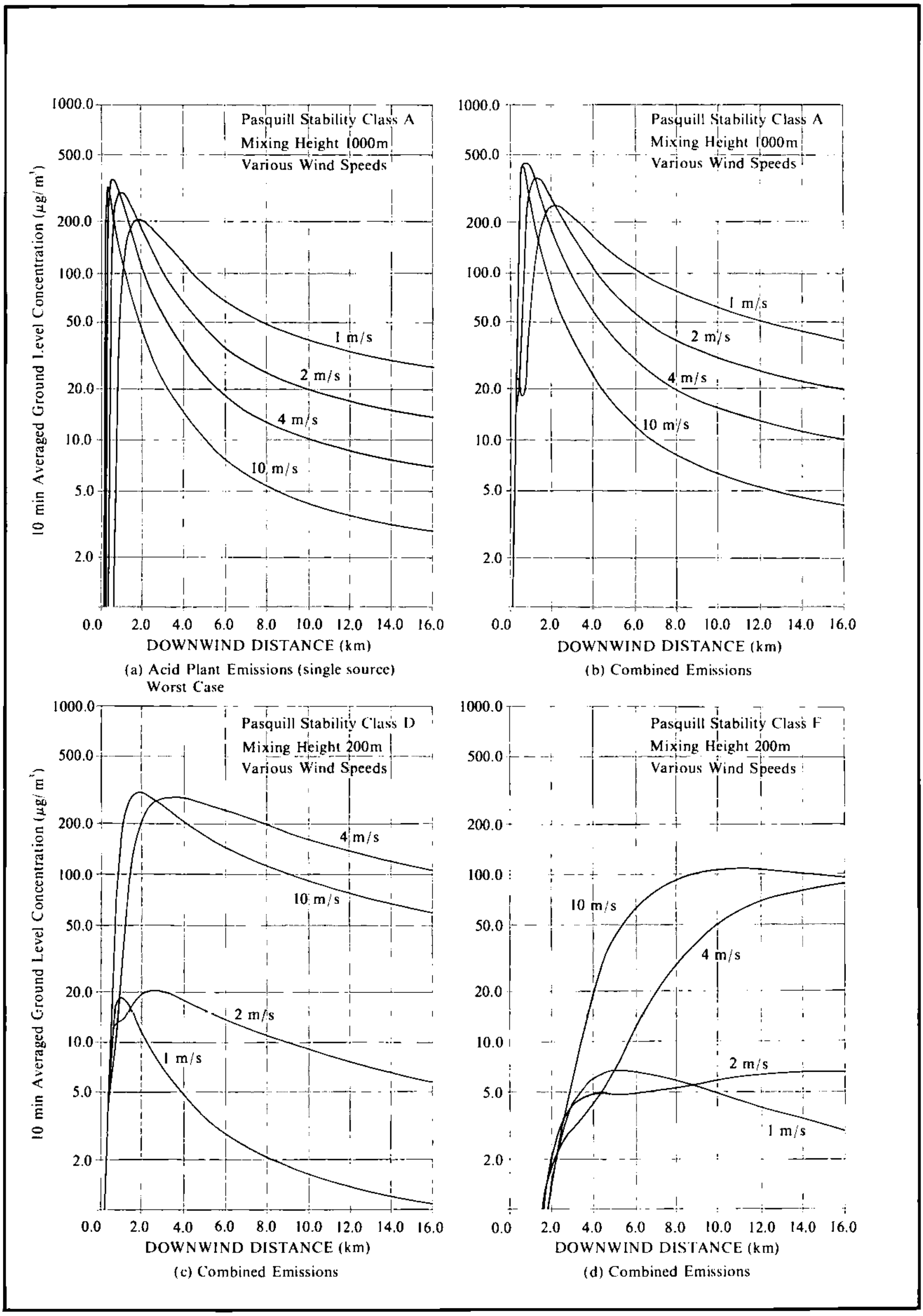


Figure 8.7

GROUND LEVEL CONCENTRATIONS OF SULPHUR DIOXIDE

stabilities and wind speeds. For nitrogen dioxide, the maximum predicted value is 22 μg/m³ at 470 m from the boiler stack under Pasquill Stability Class A with a 1,000 m mixing height and 8 m/s wind speed. For hydrogen fluoride, the maximum predicted value is 2 μg/m³ at 470 m from the plant under Pasquill Stability Class A with a 1,000 m mixing height and 6 m/s wind speed.

For comparison with air quality criteria, Table 8.22 shows the maximum ground level concentrations for sulphur dioxide, nitrogen dioxide and hydrogen fluoride from combined sources as three-minute-averaged values for the range of conditions considered. For sulphur dioxide, the maximum of 560 μg/m³ is about one-half of the allowable criterion level of 1,064 μg/m³ (40 pphm at 20°C), while the maximum concentration of hydrogen fluoride (3 μg/m³) represents less than 15% of the relevant criterion level of 21 μg/m³ (2.5 pphm at 20°C). The criterion level of nitrogen dioxide, 325 μg/m³ (17 pphm at 20°C), is fifteen times the predicted maximum three-minute-averaged ground level concentration of 22 μg/m³.

Table 8.22 Combined source maximum three-minute-averaged ground level concentrations, occurrence, and location

Pasquill stability class/ inversion height	Wind speed (m/s)	Occurrence** (%)	Sulphur dioxide		Nitrogen dioxide		Hydrogen fluoride	
			Concentration (μg/m³)	Downwind distance (m)	Concentration (μg/m³)	Downwind distance (m)	Concentration (μg/m³)	Downwind distance (m)
A 1,000 m	1	0.75	310	2,070	9	1,020	1	1,940
	2	3.31	450	1,180	15	1,670	2	1,130
	4	4.00	550	740	23	900	3	740
	6	2.11	560	600	25	650	3	570
	8	0.85	555	505	28	560	3	510
	10	0.27	510	480	28	460	3	450
D 200 m	1*	1.72	25	1,070	8	16,000	-	-
	2*	7.48	25	2,600	6	16,000	2	5,600
	4	9.09	350	3,460	18	5,000	3	2,940
	6	4.83	385	2,540	18	3,060	3	2,450
	8	1.94	390	2,200	19	2,410	3	2,140
	10	0.70	375	1,940	20	2,030	3	1,860
F 200 m	1*	4.17	10	5,000	-	-	-	-
	2*	18.20	10	15,000	1	16,000	<1	16,000
	4	22.00	110	16,000	5	16,000	<1	16,000
	6	11.11	125	16,000	6	16,000	<1	14,400
	8	4.21	130	13,000	6	11,600	<1	12,300
	10	1.61	130	11,500	5	10,000	<1	10,800
Allowable maximum	-	-	1,064	-	325	-	21	-

* For certain stack emissions, plume rise exceeds inversion height.

** Percentage occurrence of Pasquill Stability Class A includes A and B; Pasquill Stability Class D includes C and D; and Pasquill Stability Class F includes E and F.

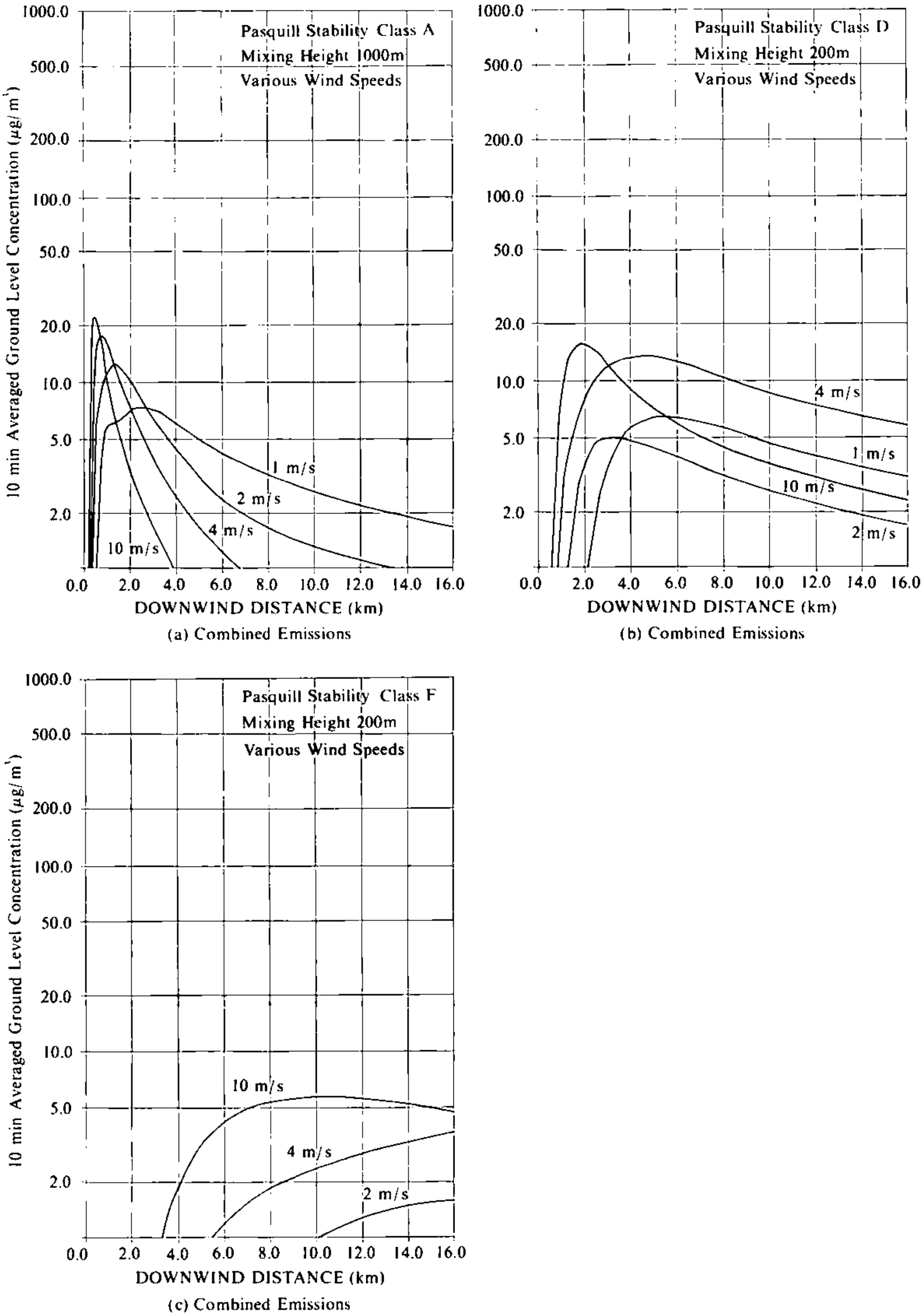
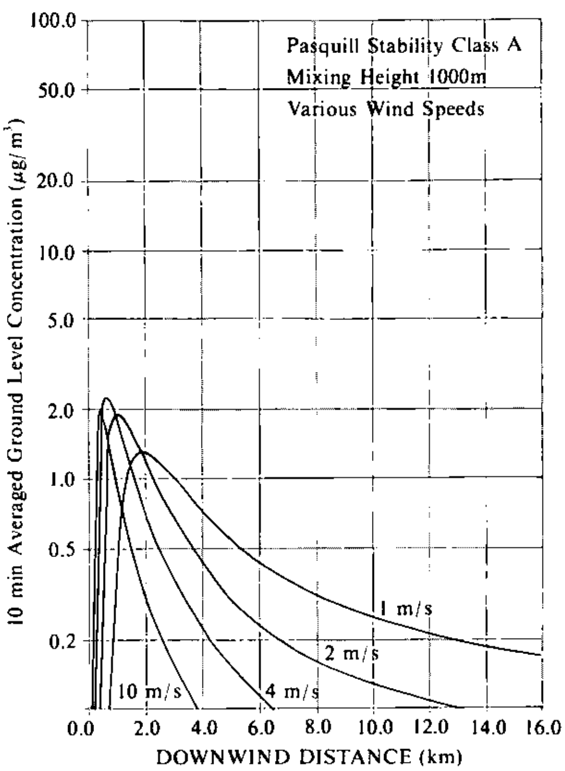
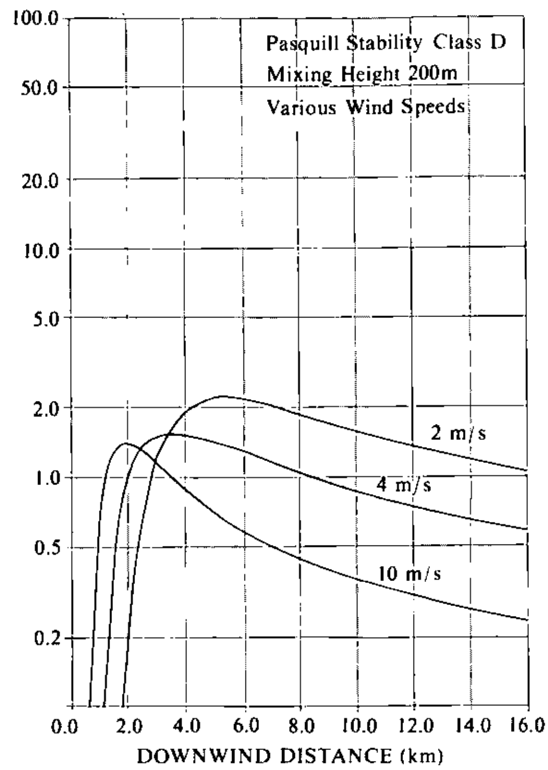


Figure 8.8

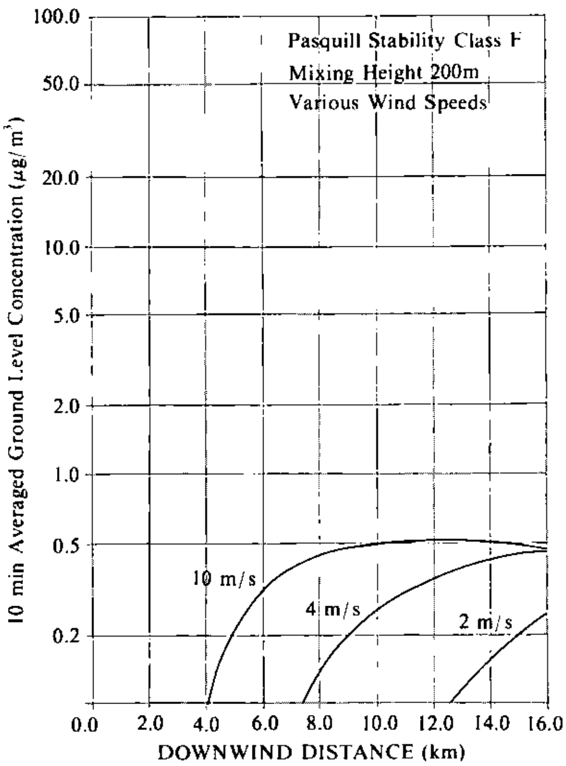
GROUND LEVEL CONCENTRATIONS OF NITROGEN DIOXIDE



(a) Combined Emissions



(b) Combined Emissions



(c) Combined Emissions

Figure 8.9

GROUND LEVEL CONCENTRATIONS OF HYDROGEN FLUORIDE

Evaluation of maximum predicted concentrations at other locations

Aside from maximum value locations, ground level concentrations at the administration office and in the town are of importance in evaluating potential exposure to members of the public. Predicted three-minute-averaged combined source maximum ground level concentrations at the office and at the northern end of the town are given in Table 8.23. Single source and multiple source criteria are met at all times at the administration office and the town.

Table 8.23 Maximum three-minute-averaged ground level concentrations at the administration office and town

Pasquill stability class	Wind speed (m/s)	Sulphur dioxide (μg/m³)		Nitrogen dioxide (μg/m³)		Hydrogen fluoride (μg/m³)	
		Administration office	Town	Administration office	Town	Administration office	Town
A	1	135	75	6	3	<1	<1
	2	450	40	14	1	3	<1
	4	465	20	19	-	2	-
	6	370	13	17	-	2	-
	8	305	10	14	-	1	-
	10	260	8	11	-	<1	-
D	1	22	3	-	6	-	-
	2	17	10	-	3	-	3
	4	45	195	4	11	-	<1
	6	115	160	6	8	<1	<1
	8	180	135	10	6	<1	<1
	10	240	110	14	5	<1	<1
F	1	<1	6	-	-	-	-
	2	<1	8	-	<1	-	-
	4	<1	70	-	3	-	<1
	6	<1	110	-	5	-	<1
	8	<1	125	-	6	-	<1
	10	<1	125	-	6	-	<1
Allowable maximum	-	1,064	1,064	325	325	21	21

Long-term ground level concentrations

Long-term ground level concentrations may be predicted using maximum predicted levels correlated with percentage occurrence of conditions from Table 8.17. Within Australia, few standards exist regulating long-term average ground level concentrations. Victoria has specified that ninety-day-averaged concentrations of hydrogen fluoride should not exceed 0.5 μg/m³. Calculated ninety-day averages at the administration office and at the northern boundary of the town are 0.02 μg/m³ and 0.05 μg/m³ respectively, which are well below this level.

The NHMRC (1981) has recommended that the annual average concentration of sulphur dioxide in the urban environment should not exceed 60 μg/m³. Annual average concentrations of sulphur dioxide at the administration office and at the northern boundary of the town have been calculated to be less than 10 μg/m³, also well below the recommended long-term level.

8.3 OTHER EMISSIONS AND CONTROL REQUIREMENTS

In addition to emissions to the atmosphere, there are other emission control requirements relating to occupational exposure. These principally refer to fugitive dust from plant operations, quarrying, and traffic movements, and to process chemicals, some of which can be toxic. This section discusses the occupational health standards applicable to the Project, the sources of fugitive dust, and the types of chemicals used and their control requirements.

Protective measures to provide for safety and contaminant control will be built in at the design stage. The aim will be to eliminate or reduce to a minimum the necessity for special personnel protective clothing or respiratory protection, as environmental acceptability is considered to be preferable. The frequency of airborne contaminant monitoring in the mine and plant will be dependent on the levels encountered and their variability.

8.3.1 Occupational health standards

The principal regulations in relation to contaminants in the working environment come under the South Australian Mines and Works Inspection Act, 1920-1978, although there are also relevant South Australian Department of Health Occupational Standards. For contaminants which do not have specified regulatory limits, the recommended values of the NHMRC (1975) will be used as a guide. All the requirements are expressed as time-weighted average threshold limit values (TWA-TLV) as defined by NHMRC (1975) and by the American Conference of Governmental Industrial Hygienists (ACGIH 1981).

Mines and Works Inspection Act

Contaminant levels specified in the regulations under this Act are as follows:

- carbon dioxide: not more than 5,000 parts per million (ppm)
- carbon monoxide: not more than 50 ppm
- nitric oxides: not more than 5 ppm
- hydrogen sulphide: not more than 5 ppm
- respirable silica: not more than 300 particles per cubic centimetre.

A further requirement is that workplace air shall not contain less than 20% oxygen.

The present regulations relating to the measurement of airborne silica specify measurement by konimeter. This will be replaced by selective gravimetric sampling, according to proposed amendments which have been circulated, and the recommended value given by the NHMRC (1975) will thereafter be adopted as the limit for average airborne respirable dust. The respirable silica limit which will apply in all Project operations is determined by the formula:

$$\text{NHMRC recommended value} = \frac{25}{\%\ \text{respirable free silica} + 5} \quad (\text{mg/m}^3)$$

The definition of respirable dust is complex and depends upon the density of the material and the shape of the particle. The respirable fraction contains no particles greater than 7.1 μm diameter, 50% of 5 μm size particles and greater percentages of particles smaller than 5 μm.

Department of Health Occupational Standards

The South Australian Department of Health Occupational Standards which are also relevant are:

- sulphur dioxide: not more than 5 ppm
- nitric oxide: not more than 25 ppm
- silica: not more than 0.2 mg/m^3
- respirable dust: not more than 5 mg/m^3.

NHMRC Recommendations

NHMRC (1975) provides recommended TWA-TLVs from a wide range of substances and mineral dust. These values for the principal resources used in ore processing are:

- pyrolusite: 5 mg/m^3 as manganese
- coal: 5 mg/m^3 respirable dust
- sulphur: 10 mg/m^3 total dust.

8.3.2 Fugitive dust

Process materials

Relatively small quantities of dust will result from the handling and storage of material necessary for the processing of ore, which include:

- pyrolusite (manganese dioxide), which will be used as an oxidant to aid in the leaching of flotation tailings (90,000 t/a);
- coal, which will be used to produce steam (80,000 t/a);
- sulphur, which may be burnt for a make-up source of sulphur dioxide used in acid production (up to 90,000 t/a);
- silica sand, which will be used as flux if the smelt/convert process option is adopted (80,000 t/a).

Handling facilities: Pyrolusite, sulphur and coal will be transported to the Project site by truck or train. They will be unloaded into bins from which they will be conveyed to separate stockpiles. The stockpiles will be situated on concrete pads with concrete bunds around the perimeter to trap particles removed from the stockpiles by saltation. Front-end loaders will reclaim sulphur and coal through an opening in the concrete bund two or three times per week for transport to bins within the plant. Pyrolusite will be reclaimed by underfeed conveyor. Unloading and handling transfer points will be designed and operated to control, suppress, or collect dust. Dust emissions at the stockpile discharge conveyor will be controlled using methods such as luffing conveyors or telescoping discharge chutes, and conveyors will also be covered. Pyrolusite will be conveyed from the stockpile to a bin at the plant as needed. Sand from local dunes will be kept in an unbunded open storage pad and front-end loaders will periodically reclaim the sand for transport to bins adjacent to the smelter. During handling, the same methods as those used for controlling dust from the other materials will be employed.

Stockpile size: Stockpiles will be sized to ensure a continuous supply to the plant. Sulphur and pyrolusite will require marine transport, which is generally associated with infrequent supply of bulk quantities. Therefore, provision has been made for stockpiles with a capacity of up to 40,000 t each (which is about four months' supply) to allow storage of bulk deliveries and to provide against uncertainties in supply. Coal will be transported by truck or rail and will require a maximum stockpile size of about 20,000 t. As sand will be obtained from local sources, a minimum amount will be maintained in the stockpile.

Emissions: Pyrolusite is a dense material with a particle size generally less than 10 mm. Because it is normally considered dusty, reclaim will be by means of an underfeed conveyor to minimize dust during this operation. Run-of-mine coal is generally smaller than 150 mm. Minor amounts of dust will arise during reclaim, and smaller amounts of dust at lower concentrations will be blown from the stockpile during windy days. Larger particles will move by saltation and be captured by the concrete bund. Smaller sized particles will quickly disperse. Sulphur will be transported as slated sulphur, which consists of pieces about 60 mm thick with varying lengths and widths. As the pieces abrade with each other during handling, some fine material will result. Minor amounts of these particles will be emitted during reclaim, while smaller quantities will be blown from the stockpile. Silica sand from the local dunes is fine to medium grained. Particle size distribution of sand from the town and mine sites indicated that 90% was larger than 0.2 mm and 100% was greater than 80 µm. It is unlikely therefore that exposure to respirable size particles (≤7.1 µm) will pose a problem.

In general, the greatest percentage of dust emitted from uncontrolled sources arises during the unloading and transferal of material, particularly while dumping or at conveyor drops onto stockpiles. The equipment and techniques proposed will keep concentrations of dust during these operations below the NHMRC (1975) recommended allowable levels. However, estimation of fugitive dust concentrations and release is difficult, as they are affected by a wide variety of factors including characteristics of the material, handling and storage methods and equipment, wind speed, and rainfall. All areas of handling will therefore be periodically monitored by gravimetric samplers, and sampling intervals will be determined based on results of previous monitoring. If it is determined that NHMRC recommended limits for worker exposure are being approached during sampling, corrective measures will be taken.

Quarry

Dust will be generated from mine-fill quarry operations during drilling, blasting, loading and hauling, crushing and screening. However, these are normal quarrying activities which often take place in populated areas.

The dolomitic limestone which will be quarried has a silica content of about 2.8%. Using the NHMRC formula for siliceous dust in Section 8.3.1, the recommended allowable concentration limit is 3.2 mg/m^3 (assuming all silica is respirable). The actual silica content reporting as respirable dust will be determined from analysis of selective gravimetric samplers.

Crushing and screening normally accounts for the largest portion of dust generated from quarries. Dust control, suppression, or collection equipment will be used for conveyors and transfer points, crushers, and screens. Water will be used in drilling to limit fugitive dust, while blasting methods will be carefully controlled to avoid causing excessive dust. The generation of dust during quarry operations will be controlled to maintain worker exposure to less than the NHMRC recommended level.

Roads

The primary roads will be sealed, thus eliminating them as a source of dust. Primary roads include:

- public roads between the town, village, plant, mine and airfield
- internal roads within the plant, store and workshop area
- heavily trafficked roads in the mine area.

The lightly trafficked secondary Project Area access roads will be surfaced but unsealed, and minor amounts of dust may arise. These roads will generally have intermittent usage. Unsealed secondary roads will be watered as necessary to control dust. Saline water, which has a crusting effect, is presently being used as an effective dust suppression measure on unsealed roads, and this method will be continued.

8.3.3 Process chemicals

About twenty chemicals and substances which are common to mineral processing will be used at Olympic Dam. Some of these are toxic. Chemicals which will have the greatest usage at the Olympic Dam plant have been identified in Section 2.4, and comprise:

- sulphuric acid
- flocculants
- collectors (sodium ethyl xanthate and/or sodium dithiophosphate)
- frothers (methyl isobutyl carbinol and a polyglycol)
- sodium cyanide
- ammonia.

The design of the treatment plant will feature safety equipment for personnel protection. Safety showers and eyewash stations will be provided in all areas where hazardous chemicals or conditions dictate, and access to hazardous areas will be restricted. In the areas of ammonia and cyanide storage, self-contained breathing apparatus will be provided. Particular attention will be paid to layout of clear access ways and escape routes.

To ensure that safe practices are followed for the handling of each toxic substance, a register will be prepared which will contain data on:

- the physical, chemical and toxic properties of each substance
- alternative names (where relevant) or brand names
- precautionary measures which should be taken in its use, handling and storage
- clothing and eye protection requirements
- degree of hazard involved
- effects of contact with eyes and skin, and effect of inhalation or ingestion
- first aid treatment which might be required
- appropriate fire extinguishing methods.

Employees will be instructed in the safe use and handling of these substances and in the use of the register, in which NHMRC recommended values will be followed. Appropriate engineering design and construction materials will also be used for plant and equipment in which these substances are used.

8.4 NOISE

8.4.1 Methodology of assessment

An assessment of noise was undertaken to identify potential impacts from Project operation upon residents of the town. The assessment involved:

- the identification of noise sources associated with Project operations, and the estimation of their power levels and frequency spectra;

- the prediction of noise levels received at the operations area boundary and within the town, allowing for attenuation or focusing effects during noise transmission;

- the assessment of received noise at the town by comparison with standards, annoyance criteria, and likely background levels for residential areas.

Noise sources

Noise sources were predicted from specific Project components which include the following:

- mine shaft area - winders, compressors, ore dumping, ventilation fans;
- plant area - crushers, vibrating feeders, pumps, motors, fans, blowers, smelter;
- quarry - mobile equipment, drills, crushers, and screening equipment;
- plant infrastructure - conveyors, transformers.

A sound power level spectrum was obtained for the equipment, based on information relating to similar equipment used elsewhere and on manufacturers' data (Vipac 1982).

Noise predictions

A computer model was used to predict noise levels along a 24 by 11 km grid with 'receptor points' at each kilometre. The model used the assumed sound power spectrum from each significant source. The noise contribution from each of these sources was calculated at each receptor point with allowance made for:

- attenuation with distance
- temperature and humidity effects on molecular absorption
- wind speed and direction effects on noise transmission
- focusing and reflection effects of temperature inversions
- attenuation due to barrier effects
- ground cover attenuation.

The resultant received noise spectrum at a receptor point is the sum of the individual contributions from each noise source.

Noise assessment

Noise levels predicted to occur at the town have been compared with regulations made under the South Australian Noise Control Act 1976, and the Australian Standard (AS) 1055-1978 'Code of Practice for Noise Assessment in Residential Areas'. These standards provide two means of evaluating the subjective responses which residents of the town may have. The likely degree of annoyance has also been assessed based upon the International Standards Organization (ISO) Recommendation R1996 'Assessment of Noise with Respect to Community Response'. In addition, the predicted noise levels arising from Project operations which will be received in the town are compared with expected background levels in residential areas.

Since the two standards used for assessing the predicted noise levels dictate to a large extent the approach taken in making the prediction, the policies and approaches adopted in setting these standards are first presented below (Section 8.4.2). This is followed by a comparison of the predicted noise levels with standards for both average and worst case conditions (Section 8.4.3). Other intermittent noise sources are also discussed. The noise contribution from Project operations is compared with predicted background noise levels in the town, and ways of reducing significant noise sources within the town itself are then discussed (Section 8.4.4).

Noise measurement

Noise levels are expressed in the A weighted sound level (dBA) measurement scale, which allows for the perceptual differences between the sounds which a human ear can perceive and absolute sound power levels. It is a logarithmic scale in which each increase of about 3 dBA represents a twofold increase in sound intensity. Table 8.24 compares noise levels in dBA with common sources of noise.

Table 8.24 Noise levels and relative loudness of typical noises

Relative loudness	Noise level (dBA)	Community noise (outdoor)	Home or industry noise (indoor)
Very loud	110	Boeing 707 or DC-8 at 1,800 m before landing.	Rock band.
	100	Boeing 737 or DC-9 at 1,800 m before landing. Motorcycle at 8 m.	Newspaper press.
Moderately loud	90	Diesel truck, 60 km/h at 15 m. Diesel train, 70 km/h at 30 m. Power mower at 8 m.	Food blender. Milling machine. Garbage disposal.
	80	High urban ambient sound. Passenger car at 8 m. Freeway at 15 m from pavement edge.	Baby crying. TV-audio. Vacuum cleaner.
	70		Electric typewriter at 3 m. Conversation.
Quiet	60	Air-conditioning condensing unit at 5 m. Large transformers at 30 m.	
	50	Bird calls. Lower-limit urban daytime ambient noise.	Average office.
	40	Wind in trees.	Soft music.
	30	Distant waterfall.	
Very quiet	20		
Just audible	10		Average whisper.
Threshold of hearing	0		

Source: L.L. Beranek (1971); Kinhill (1981).

8.4.2 Noise assessment criteria

South Australian regulations

South Australian regulations set a maximum permissible level for received noise, dependent on the receiving location and the time of day at which the noise source operates. For a predominantly industrial area, the maximum noise level considered acceptable is higher than that for a predominantly residential or rural area. Maximum permissible noise levels for various areas under South Australian regulations are presented in Table 8.25.

Table 8.25 Maximum permissible noise levels for different land uses

Land use	Maximum permissible noise levels dBA	
	0700-2200 hours	2200-0700 hours
Rural or predominantly rural	47	40
Urban residential	52	45
Urban residential with some commerce, or with a school, hospital or similar facility	55	45
Urban residential with some manufacturing industry, or with some place of public entertainment, place of public assembly or licensed premises	58	50
Predominantly commercial	65	60
Predominantly industrial	70	70

Under Clause 11(8) of the Indenture Agreement, the area of the Project including the town is to be described as 'predominantly industrial' for purposes of the Noise Control Act. However, for the purpose of evaluating the impact of noise in the town from the plant, the noise levels deemed appropriate for the 'urban residential' land use category defined in Table 8.25 have been adopted.

Reactions to noise depend not only on the noise level and time of day, but also on the type of noise. Particular characteristics of a noise, such as impulsiveness (e.g. hammering or banging), tones, or duration, may make a noise more annoying than if it were steady and broadband in nature (e.g. a fan heater or waterfall). Similarly, a noise which is not continuous over a length of time is generally not as annoying as one which is continuous. To allow for these effects, the received noise is adjusted either up or down. For example, if tonality is present, a +5 dBA adjustment would be made to the received noise in order to obtain an 'effective noise level' for noise impact assessment purposes.

Australian Standard 1055-1978

The Australian Standard 1055-1978 is intended as a general guide for evaluating noise in residential areas. It indicates that, if an intrusive noise is clearly audible over the existing background noise level, the noise is likely to be annoying. The Standard recognizes the need for adjustments to predicted levels based on tonality of the noise source or impulsiveness.

For planning purposes, the Standard gives calculated background sound levels $L_{(bg\ calc.)}$for different areas. Category R2 corresponds to a residential area with low density transportation which would appear to be comparable to the proposed town. The calculated background sound level given for category R2 is given in Table 8.26. The Standard suggests that levels of 5 dBA or less above the calculated background level may be considered of marginal significance.

Table 8.26 Calculated background noise levels (R2)

Day	Time of day	Noise level (dBA)
Monday to Friday	0600 to 0700	40
	0700 to 1800	50
	1800 to 2200	40
	2200 to 0600	35
Weekends and public holidays	0700 to 1800	45
	1800 to 2200	40
	2200 to 0700	35

ISO recommendations

ISO Recommendation 1996 gives an indication of the degree of annoyance and likely community response in relation to effective noise levels greater than the calculated background level. This is shown in Table 8.27. A similar table was included in the 1973 edition of the Australian Standard, but was omitted from the 1978 edition, as no solid evidence in the form of Australian complaint histories existed to support the table. However, in the absence of other data, ISO Recommendation 1996, as shown in Table 8.27, may still be used as a guideline.

Table 8.27 Estimated community response to noise

Amount by which the rating sound level exceeds the noise criterion (dBA)	Estimated community response	
	Category	Description
0	None	No observed reaction
5	Little	Sporadic complaints
10	Medium	Widespread complaints
15	Strong	Threats of community action
20	Very strong	Vigorous community action

8.4.3 Comparison of standards with predicted noise levels from Project sources

Predicted noise levels

Two cases were considered in the prediction of noise levels from Project sources. The first was a yearly energy-averaged prediction, the results of which are shown in Figure 8.10. The noise contours shown represent the total predicted contribution from Project operations, which can then be logarithmically added to background levels representative of the town. The maximum value in the town is 20 dBA (Leq) at the town's northern end. Such a level would be indistinguishable from background noise levels.

The second was a worst case situation with downwind propagation and an inversion present. Under such conditions, attenuation due to ground effects does not occur. The

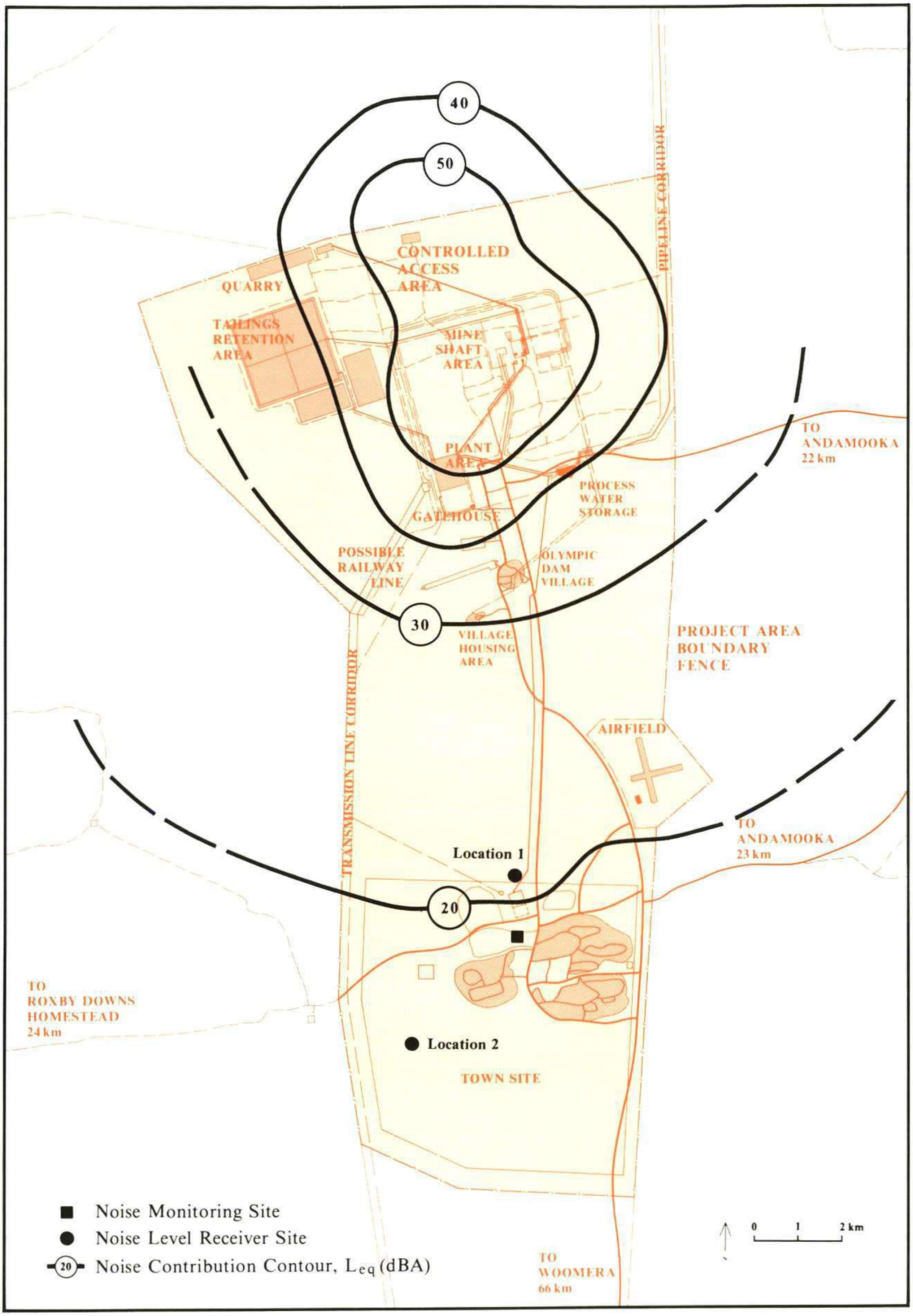


Figure 8.10
NOISE CONTRIBUTION FROM PROJECT SOURCES, ENERGY-AVERAGED PREDICTION

results are shown in Figure 8.11. The maximum value in the town is 31 dBA. Table 8.28 indicates the frequency spectra of the received noise for a point 3 km south of the plant, and for the northern end of the town (9 km south of the plant). The table shows the attenuation of the different frequency bands with distance. Attenuation has the greatest effect on higher frequencies. It can be seen that, with increasing distance from the plant, the spectra are generally dominated by the lower frequencies (in the 63 and 125 Hz octave bands).

Table 8.28 Frequency spectra of received noise for worst case situation

Octave band centre frequency (Hz)	3 km south of plant	Northern end of town (9 km south of plant)
63	51	45
125	50	43
250	44	32
500	34	22
1,000	26	22
2,000	24	20
4,000	22	19
8,000	21	18
dBA	39	31

Comparison with South Australian regulation limits

Two locations within the town site have been considered for comparison with the maximum permissible noise levels for Urban Residential areas from Table 8.25. One is on the northern boundary of the town site (Location 1), where the maximum contribution from Project sources is predicted to be heard, while the other is to the south of the town (Location 2), to indicate the range of effects (Figures 8.10 and 8.11). The predicted noise level from the Project has been adjusted by adding 5 dBA (to allow for tonality of fans and compressors) in order to determine the effective noise level. Therefore, the effective noise level in Table 8.29 is an adjusted sound level representing the amount of noise from Project operations during worst case meteorological conditions. A comparison of this effective noise level with the maximum permissible level indicates that complaints would not be considered justified.

Table 8.29 Comparison of received noise in the town with South Australian noise regulations

Location*	Noise level parameters (dBA)				Regulations' assessment of complaint
	Predicted level (worst case)	Effective level	Permissible levels		
			Daytime	Night-time	
Northern town boundary	31	36	52	45	Not justified
South of town	27	32	52	45	Not justified

* Locations are shown on Figures 8.10 and 8.11.

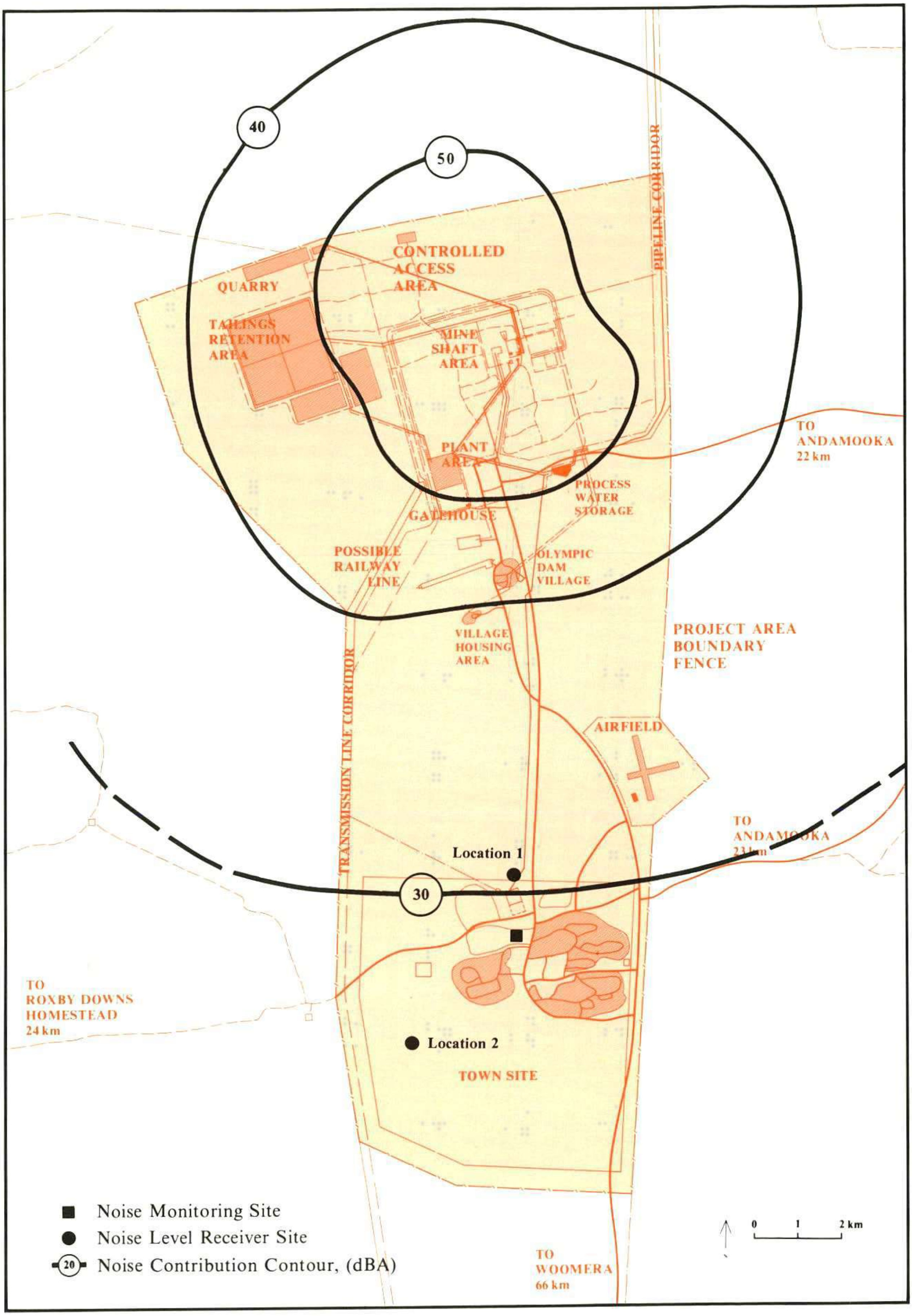


Figure 8.11

NOISE CONTRIBUTION FROM PROJECT SOURCES, WORST CASE PREDICTION

Comparison with AS 1055-1978

Comparison of predicted sound levels (L predicted) requires a 5 dBA increment for tonality to obtain the adjusted noise level (L adjusted). This adjusted level is then compared with the R2 calculated background noise level $L_{(bg\ calc.)}$ in order to determine if there is an excess. It can be seen from the results shown in Table 8.30 that, according to ISO:R1996, community complaints would not be expected.

Table 8.30 Comparison of predicted received noise in the town with Australian Standard 1055

	Northern town boundary	South of town
Noise level parameters (dBA)		
L predicted	31	27
L adjusted	36	32
AS 1055 $L_{(bg\ calc.)}$ R2	35	35
Excess	+1	-3
Community response according to ISO:R1996	None	None

Effect from intermittent sources

In addition to noise from fixed plant items, other noise sources to be considered include transportation noise and quarry blast noise.

Noise from transportation: It is recognized that noise from truck traffic or possibly from trains may cause some intermittent annoyance to nearby residents. To minimize the extent of this annoyance to those living in the town, buffer zones of about 350 m for the railway corridor and about 150 m for the road will be provided.

Air blast from the quarry: Blasting operations give rise to air blasts which are low frequency pressure waves of a similar nature to sound waves, but of a lower frequency (less than 20 Hz). If the overpressure is of sufficient magnitude, damage or nuisance may occur. However, the likely peak pressure level due to blasting is not expected to exceed 130 dB 'linear' at a distance of 1 km. (The 'linear' description refers to the fact that this value is the unweighted pressure level in contrast to the weighting normally applied to other sound signals to match human hearing characteristics.) Pressure levels decrease by 20 dB for each factor of 10 in distance as a result of wave divergence. Further attenuation will be provided by the tailings storage facility which will act as a barrier to blasting noise. The sound level at the town site will therefore be below 110 dB (linear), which is the limit specified by the State Pollution Control Commission of New South Wales for the assessment of blasting operations.

8.4.4 Comparison of Project noise with town background levels

In order to determine the contribution of the received Project related noise in the town to noise levels generated from sources within the town itself, an estimate has been made of expected background levels in residential areas of the town. Major noise sources within the town are also identified, and ways of mitigating those effects are discussed.

Expected background noise level in the town

Two significant studies on residential noise levels were carried out by the Building Research Establishment in England (Attenborough et al. 1976) and by the United States Environmental Protection Agency (USEPA 1971). The BRE study investigated 1,353 sites and produced a predictive model. According to this model, the background sound levels in a suburban area could vary from 33 dBA between 2400 and 0700 hours to 43 dBA during the day. The USEPA investigation considered eighteen locations, and the results suggest that the sound level which is exceeded 90% of the time (L_{90} level) for a small residential town is approximately 36 dBA. The predicted L_{90} level for an urban residential area is approximately 45 dBA.

The background noise levels in the town at Olympic Dam are likely to be significantly higher than these levels when window or wall mounted air-conditioners are operating. According to information from manufacturers, sound levels from room air-conditioners vary between 50 and 68 dBA measured 1 m from the units. Resultant noise levels at points 8 m, 16 m, and 32 m respectively from units in three adjacent homes would vary between 34 and 52 dBA. Therefore, background noise levels in the town could vary greatly. In residential areas the range may be from about 33 dBA up to a maximum of 45 dBA at night and to 52 dBA during the day. In industrial and commercial areas the maximum may be higher.

Combined noise level from Project and town sources

The combination of predicted Project noise with expected background levels may be evaluated through logarithmic addition of the levels. If a very low background level, say 33 dBA, is combined with the predicted maximum level at the northern end of the town of 31 dBA for worst case meteorological conditions, a total of 35 dBA is reached. The addition of a further 5 dBA to account for tonal components yields a value of 40 dBA. This level is below the South Australian regulations daytime and night-time maximum permissible levels for residential areas. As the background level increases, the audible effect will correspondingly decrease. At background levels greater than about 45 dBA, the effect from Project noise during worst case meteorological conditions will not be audible in the town. At distances greater than about 15 km from operations, noise from the Project will have no audible effect on areas where the existing ambient level is 30 dBA.

Noise sources in the town

The noise sources most likely to cause annoyance in residential areas are air-conditioning units, pool pumps, hotels and discotheques, and industrial premises (SADEP, pers. comm.). The possible noise levels associated with air-conditioning units are discussed above and, as a means of mitigation, the selection criteria for air-conditioners installed in homes by the Joint Venturers will include a review of manufacturers' noise data. Enclosures for pool pumps would reduce their potential for noise annoyance. In the conceptual town planning by the Joint Venturers, sites for industry have been located in areas separated from residential areas. This separation should reduce the possibility of noise annoyance to town residents. The siting of hotels and discotheques will be under the control of the municipality.

8.5 SOLID WASTE

Solid waste and garbage will be generated as a result of operations at the mine, plant, support facilities and town. This section describes the methods proposed for disposal of this waste from each of these sources.

8.5.1 Town waste

Solid waste from the town will consist of the normal household solid wastes, garden waste, housing construction material, and commercial and industrial waste. At an expected rate of solid waste generation of about 1.6 kg per capita per day, the quantity to be disposed of will be approximately 100 t per week.

Under Clause 22(2)(s) of the Indenture Agreement, the Joint Venturers will establish (with State Government funding) suitable garbage disposal facilities for these wastes. The operation of the facility will be the responsibility of the municipality, and will be regulated by the South Australian Waste Management Commission under the 'Waste Management Commission Act, 1979'. The issues which are relevant to this Draft EIS are therefore associated with the design and construction of the facility to ensure that disposal of these town wastes does not result in:

- a nuisance or offensive condition
- conditions injurious to health or safety
- damage to the environment.

This will be accomplished by appropriate consideration of:

- location with respect to nearby land utilization
- location with respect to hydrologic characteristics of the area
- fencing of the facility
- construction of internal roads
- necessary equipment for operation.

Disposal of waste will be by sanitary landfill. The landfill site will be located within the town boundaries at a sufficient distance from built-up areas to avoid problems from offensive odours, but still within 2 km of residential areas to discourage roadside dumping and littering. A direct all-weather access road will be provided to the landfill site.

During operation, the fill area will be progressively covered to reduce the attraction to birds and to minimize fly breeding. The airstrips are at a sufficient distance from the town to minimize bird strike problems. The design of the landfill will provide for disposal by either the trench or area method of disposal. The landfill will be located in a site which has deep soil and is not subject to flooding. Surface drainage will be directed away from the site, and covered areas will be contoured to shed run-off water away from areas of the landfill which are in use.

Equipment which is expected to be used in conjunction with the landfill will include compaction type collection trucks and compacting type earthmoving equipment. Allowance will be made for separate areas in the landfill site for disposal of car bodies, other solids, and garden wastes.

8.5.2 Mine and plant waste

The mine, plant and support facilities will generate a relatively small amount of waste which is unlikely to exceed 20 m^3 per week. This waste will include:

- normal office waste such as paper
- worn out clothing such as overalls, gloves and boots
- drums and packaging material
- broken metal and obsolete pieces of equipment
- workshop waste such as metal cuttings.

These wastes will be separated into contaminated and uncontaminated waste. Uncontaminated waste which is considered salvageable, such as scrap metal, will be sold, while the non-salvageable portion will be disposed of in the mine landfill tip situated adjacent to the tailings storage facility. Material which is considered contaminated by radioactivity will be decontaminated where possible by washing down. Salvageable material which has been decontaminated in this manner will be sold, and non-salvageable material will be disposed of in the mine landfill tip. When possible, contaminated material will be secured in steel drums prior to disposal, and will be placed in a separate area of the landfill. This area will be progressively covered with an average 1 m of swale material.

The tip will be designed, constructed and operated in a manner similar to the town landfill, only on a smaller scale. Location and environmental considerations are also similar. The landfill will be up to 5 m deep, and will be progressively covered and mounded to prevent run-off from entering the active areas.

CHAPTER NINE

Radiation Assessment

SUMMARY

Project planning has taken into account the Joint Venturers' obligations under the Indenture Agreement to adhere to the radiological protection standards required by the Commonwealth of Australia's Code of Practice on Radiation Protection in the Mining and Milling of Uranium Ores 1980 (Code of Practice), and the codes or recommendations of the International Commission on Radiological Protection (ICRP), the International Atomic Energy Agency (IAEA) and the National Health and Medical Research Council (NHMRC). These standards relate to the control of exposure to radiation above naturally occurring background levels both for employees and for members of the public. Three mechanisms of exposure have been considered in relation to uranium mining and processing: external exposure to gamma radiation, inhalation and retention of radon decay products (radon daughters), and inhalation or ingestion of radioactive particulates.

The principal sources of incremental radiation exposure from underground mining are radon gas from in situ, broken and crushed ore (insofar as it gives rise to concentrations of radon daughters), radioactive particulates in respirable dust, and gamma radiation. Above ground sources comprise radon gas, its decay products and radioactive particulates in respirable dust emitted from mine vents, ore transfer and processing, and the tailings retention area; and gamma radiation from the tailings retention area, ore processing and drummed yellowcake. The various radiation exposure pathways have been considered for different employee categories and for town residents.

The limitation of exposure to radon daughters in underground mining is considered of prime importance to the protection of employee health. The mine ventilation system and mining methods will be designed to control radon daughter exposure in any year to 1 WLM (working level month), which is one-quarter of the maximum permissible exposure in the Code of Practice. With the relatively low uranium content of the ore, silica inhalation rather than inhalation of radioactive particulates governs the permissible dust concentrations in the mine working areas. Exposure from radioactive dust is estimated to be one-thirtieth of the permissible level. Gamma radiation exposure is estimated at one-tenth of permissible levels. It is predicted that plant employees will be exposed to lower radon daughter and radioactive particulate levels than mine employees, while gamma radiation during yellowcake packaging and drying is expected to be slightly higher but still only one-fifth the permissible level.

In addition to meeting the individual limits for the different exposure mechanisms, the Joint Venturers undertake to limit overall exposure of employees to radiation by limiting the combined contribution from all mechanisms (radon daughters, gamma radiation and radioactive particulates). This goes a step beyond the Code of Practice requirements, and is consistent with the more recent ICRP recommendations on radiation protection.

The Joint Venturers have adopted a similar combined criterion for overall exposure of members of the public in relation to maximum permissible concentrations set out in the Code of Practice for members of the public, which are more stringent than permissible employee exposure limits. Possible pathways for public exposure above natural background levels are through inhalation of radon daughters and respirable radioactive particulates dispersed from the operations area, and through ingestion of incremental increases in radioactivity above that already contained in drinking water or in locally produced meat and vegetables. Conservative estimates indicate that the total contribution of increases in exposure for office workers at the main administration office in the plant area is a factor of forty below the Joint Venturers' combined criterion for public exposure. For town residents, this factor is seventy-five. This can be compared with exposure from natural radiation sources which is one-sixth of the same criterion. Thus, the increase in radiation exposure due to Project operations is not only well below the Code limits, but it also represents only a small addition to the normal background levels to which people living in a continental land mass are continually exposed.

At Project completion, the plant and mine will cease to be sources of radiation exposure. Although the tailings retention area will continue to emit radon after decommissioning, surface protection consisting of an average 1.5 metres of soil and an additional 0.5 metres of quarried rock will reduce this radon emanation by a factor of four.

It is planned to transport uranium concentrate by road from Olympic Dam to Port Adelaide via Pimba and Port Augusta. Relevant South Australian legislation governing such transport is expected to incorporate Commonwealth legislation, which in turn closely follows IAEA criteria for the transport of 'low specific activity materials' (which include uranium concentrate). The concentrate will be packaged in steel drums, which in turn will be secured in export shipping containers. Experience at other Australian uranium operations where this packaging method is employed indicates that radiation levels at the surface of the load will be a small fraction of IAEA limits. While the chances of an accident of sufficient severity to cause a spillage of yellowcake are small, contingency plans for cleaning up and monitoring spillage will be prepared.

Regular operational monitoring of radioactive contaminant levels will be carried out by the Joint Venturers to enable adherence to commitments regarding exposure limits agreed with statutory authorities. This monitoring will not only provide data for documentation of personnel exposures, but also for procedural controls to limit individual exposure, and will act as a check on the functioning of ventilation and other engineering systems. Baseline monitoring of natural radiation in the Olympic Dam area has been in progress for two years to provide a benchmark against which to measure the incremental exposure from Project operations. Occupational monitoring is presently carried out for the protection of workers handling drill core samples and for those involved in underground exploratory mining.

Regular monitoring reports are being forwarded to the appropriate authorities, and this will continue throughout Project operations. Personal radiation results will be made available to individual employees upon their request, but will otherwise remain confidential. The Joint Venturers are also committed to providing regular briefing and information services to employees and town residents, explaining the basis of radiation protection being employed on the Project and the results of the monitoring programmes.

9.1 INTRODUCTION

In the assessment of incremental radiation exposure due to Project operations above natural background levels, it is pertinent to consider the possible exposure pathways. Figure 9.1 shows the relevant mechanisms of exposure and the potential Project sources. Exposure to radiation from both natural and Project sources can occur through:

- the inhalation of airborne long-lived radionuclide particulates and radon daughters
- the ingestion of radionuclides contained in meat, vegetables or water
- external gamma radiation.

With respect to the mining and processing of uranium, the radionuclides considered are uranium-238 and the principal radioactive isotopes in its decay chain, namely, uranium-234, thorium-230, radium-226 and lead-210. Radionuclides are measured in terms of their activity (the number of radioactive atoms decaying per second) which, in the International System of Units (SI), is expressed in becquerels (Bq). A becquerel is one disintegration per second and equals approximately 27 picocuries (pCi).

Radon daughters are the short-lived radioactive isotopes (polonium-218, lead-214, bismuth-214 and polonium-214) produced by the decay of radon gas. The Working Level (WL) is the measure for the concentration in air of radon daughter atoms. One WL is the concentration of any mixture of radon daughters which will emit alpha radiation energy equal to 1.3 x 10^5 MeV of alpha energy per litre of air (where MeV, million electron volts, is the unit used to describe the energy content of alpha particles). The unit used for quantifying human exposure is Working Level Months (WLM). One WLM is the exposure to an average concentration of one WL for 170 hours.

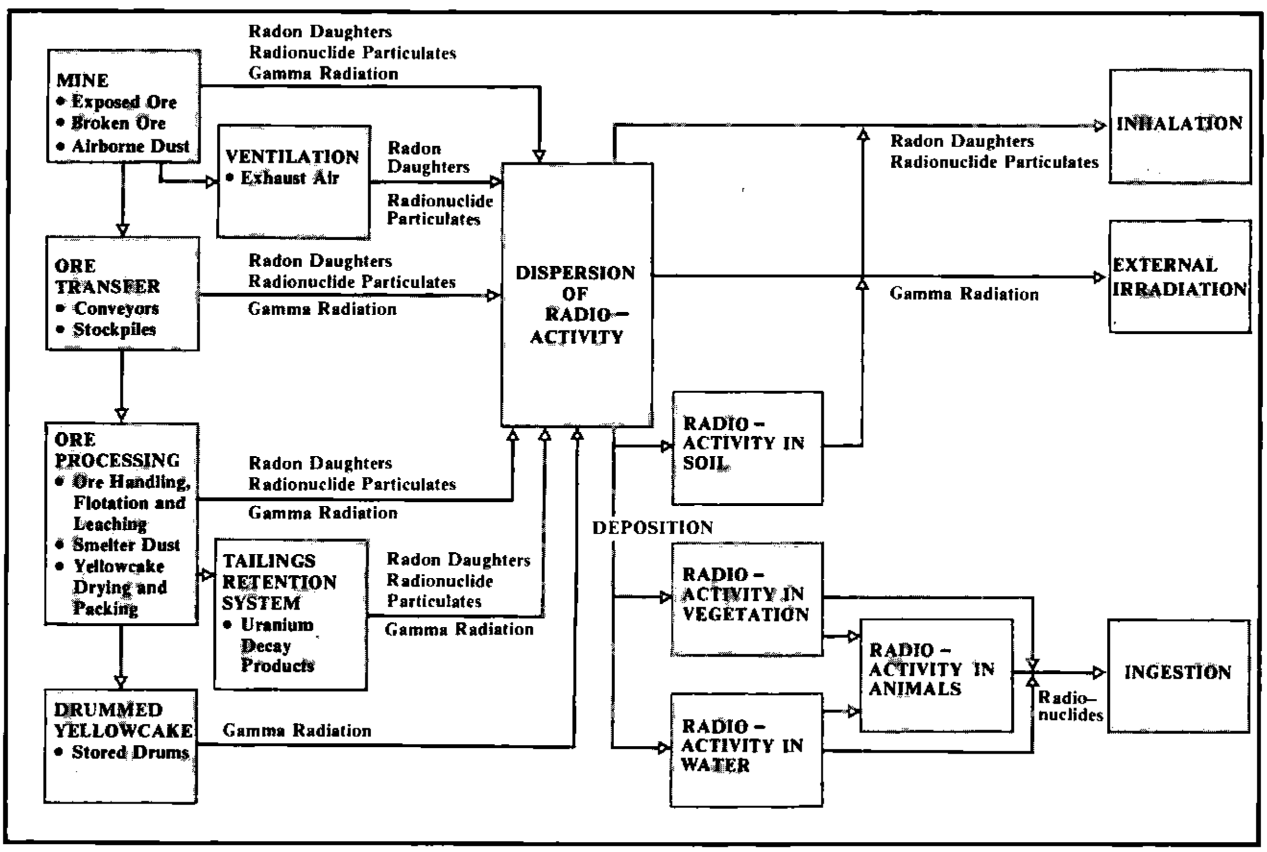


Figure 9.1
RADIATION EXPOSURE PATHWAYS

Gamma radiation is electromagnetic radiation similar to X-rays. A measure of the biological effect of an absorbed dose delivered by gamma radiation is expressed in terms of the 'dose equivalent'. The SI unit for dose equivalent is the sievert (Sv), which is numerically equal to 1 joule per kilogram and is equivalent to 100 rems.

Section 9.2 presents the results to August 1982 of the natural levels of radioactivity in samples of air, water, soil, vegetation, and animals, from the Olympic Dam area. These results provide the baseline data against which any incremental increases due to the Project can be detected.

Section 9.3 compares the relevant Code requirements in relation to incremental exposure for both Project employees and members of the public. The principal standards are contained in the Australian 'Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores 1980' (Code of Practice) and the recommendations of the International Commission on Radiological Protection (ICRP).

Section 9.4 quantifies the various sources of radionuclides, radon daughters and gamma radiation from the Project, which are shown in Figure 9.1. The dispersion of airborne contaminants is also analysed, to allow exposure estimates to be made.

Based on this information on sources and dispersion, dose estimates are made in Section 9.5 both for Project employees and for members of the public. These estimates are then compared with Code requirements presented in Section 9.3. In addition, a comparison is made with exposure from natural sources.

The safety provisions in relation to accidental spillages of yellowcake during handling, packaging and transport are addressed in Section 9.6.

Section 9.7 describes the general approach to radiation monitoring, as well as the proposed monitoring programmes. The present occupational monitoring programme for exploration and mine development work is discussed, as well as the monitoring which will be carried out during Project operation. This operational monitoring will comprise measurements of employee exposure, contaminant levels in workplaces, and radiation in the general environment relevant to public exposure.

Section 9.8 outlines the principles for the decommissioning of the Project once operations are complete.

9.2 ENVIRONMENTAL RADIATION LEVELS

9.2.1 Pre-operational radiation monitoring programme

A baseline survey is being undertaken to provide data on the radioactivity present in the natural environment. This baseline information can then be compared with radiation measurements taken during Project operations in order to detect any changes in radioactivity brought about by the Project. Data is being collected on the following natural radiation sources:

- Gamma radiation from terrestrial sources.

- Radon daughters:

  - ambient radon daughter concentration in air and its variability
  - radon concentration in air as the precursor to radon daughter formation in air
  - radon emanation from soils as the precursor to radon concentration in air.

- Radionuclides:
  - in local soil samples as a source of respirable dust, and as a partial determinant through its radium-226 content of the natural gamma dose rate and the radon emanation rate from soil
  - in airborne dust
  - in local surface water and groundwater
  - in local flora
  - in tissues of local animals.

Equipment being used in this monitoring programme is listed in Table 9.1.

Table 9.1 Equipment being used in present monitoring programme

Instrument	Used for
7 L2SF Amahsco personal dust pumps	Airborne contamination and dust collection
1 Nuclear Enterprises portable scaler rate meter PSR-6	Counting assembly
1 windowless scintillation detector WSD-50	Counting of alpha scintillations
1 Eberline scintillation alpha counter SAC-4	Alpha scintillation counter
2 L-5/10 Amahsco dust samplers	Air sampling of radon daughters
1 Eberline proportional alpha counter PAC-6	Surface contamination
1 Nuclear Enterprises portable contamination meter PCM5/1 and alpha probe AP-3	Surface contamination
1 Nuclear Enterprises hand monitor HM-6	Skin contamination
1 Eberline mini scaler MS-2	Counting assembly
2 Eberline portable rate meters PRM-7	Gamma detection
1 Eberline sodium iodide crystal model SPA4	Gamma detection
1 Eberline radon gas monitor RGM-2	Radon gas concentrations
1 Amersham 0.5 kBq Americium-241 source	Calibration source for alpha detection instruments
1 Eberline ore evaluator	Measuring % U_3O_8 in ore samples
1 Mettler electronic balance ME-30	Total dust measurements

9.2.2 Gamma radiation measurement

Gamma radiation

Thermoluminescent dosimeters (TLDs) supplied by the Australian Radiation Laboratory (ARL) are being used as environmental gamma radiation monitors at approximately forty sites within and surrounding the Project Area, including locations within the proposed town site.

The data indicates an average outdoors gamma dose equivalent level of 10 μSv per week, which is consistent with the average for a continental land mass. This figure has also been independently arrived at by ARL for the background gamma level, on the basis of investigation of some hundreds of TLD badges exposed at Olympic Dam.

9.2.3 Radon daughter measurement

Radon daughter concentrations in air

Rolle method (Leach and Lokan 1979) measurements are being performed on site. These are being taken out-of-doors near the environmental office building and at Sandhill meteorological station (Figure 9.2). Weather conditions are being noted, particularly cloudiness and wind strength. (For further details on meteorological monitoring, refer to Chapter 8.) A number of long period data collection runs have also been performed and, from these, information on the ambient level and variability of radon daughter concentrations is emerging.

Outdoor levels recorded at Sandhill meteorological station are of the order of 3×10^{-4} WL. These values compare with the derived limit for members of the public given in the Code of Practice of 1×10^{-2} WL.

It is important to note that the variability of these natural environmental levels of radon daughter concentrations is large, ranging over more than an order of magnitude. They can, on isolated occasions, reach a significant fraction of the derived limit for members of the public.

An integrating radon daughter dosimeter supplied by ARL has been run for two periods of approximately one month each outside the environmental office and at Sandhill meteorological station: the time-weighted average radon daughter concentrations were 5.8×10^{-4} WL and 2.7×10^{-4} WL respectively. Again, these figures are characteristic of air which has been traversing a continental land mass.

Radon in air

As part of the baseline studies, work is presently under way to attempt to correlate ambient radon levels with meteorological conditions. This is being performed by comparing hourly radon averages, using a continuously running radon gas monitor, with wind speed chart records and inversion presence or absence as reported by acoustic sounder. This work will continue throughout the winter and spring months.

Radon emanation from soils

Current investigations to determine the natural radon emanation rate of local soils will continue until mid-1983. The emanation measurements will be conducted at the same sites as those used for soil sampling, based on the technique using gamma-counting of charcoal filled canisters (Countess 1976). As well as quantifying the baseline soil emanation rate in the Project Area, the study is aimed at determining the variability in relation to soil type, moisture content, and location, particularly between dunes and swales.

9.2.4 Radionuclides

Soils

Soil samples have been collected from nineteen locations (Figure 9.2). At each location two samples were taken, the first of surface soil and the second at an approximate depth of 300 mm. These samples have been assayed for radionuclide content, namely uranium-238, radium-226, lead-210 and thorium-230, the results of which are summarized in Table 9.2.

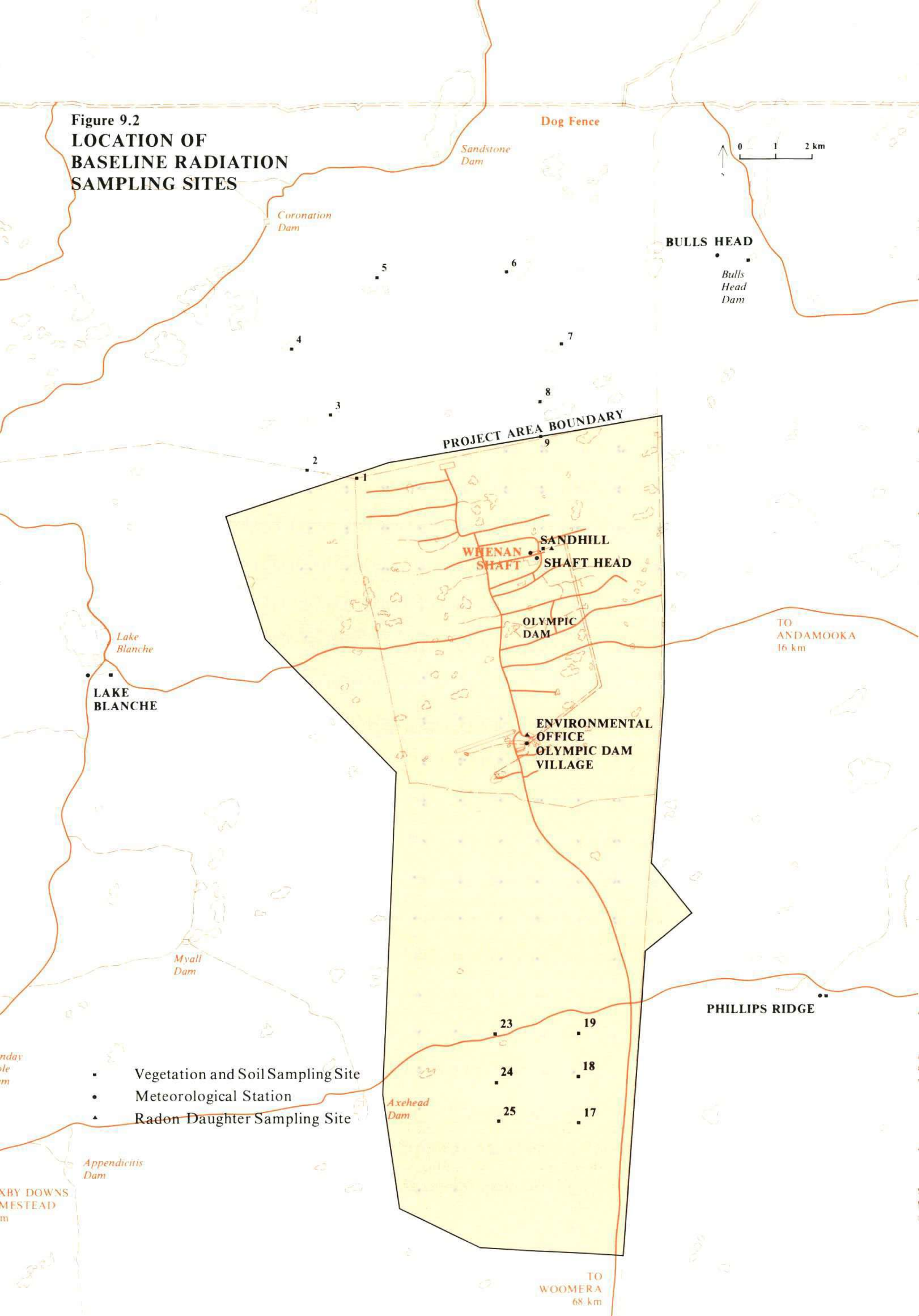


Figure 9.2
LOCATION OF BASELINE RADIATION SAMPLING SITES

Table 9.2 Radioactivity in soils

Soil (dry)	U-238 (Bq/g)	Th-230 (Bq/g)	Ra-226 (Bq/g)	Pb-210 (Bq/g)
Olympic Dam samples*	0.01	0.01	0.01	0.05
UNSCEAR (1977)**	0.02	0.02	0.02	0.03

* Average of surface and near surface samples from nineteen sites.
** United Nations Scientific Committee on the Effects of Atomic Radiation.

Soil radionuclide concentrations are generally low compared with levels quoted in review literature (United Nations Scientific Committee on the Effects of Atomic Radiation 1977). The tendency for lead-210 levels to be in excess of other radionuclides is well documented, and arises from the decay to lead-210 of radon daughters deposited out of the air.

Airborne dust

A continuous high-volume sampler is being run at the Sandhill meteorological station near the Whenan Shaft. Gravimetric results to date are of the order of 20 $\mu g/m^3$. Radiochemical analyses of the dust for total uranium and radium-226 are in progress. This programme is continuing on a permanent basis, and includes the specific aim of evaluating seasonal variability.

Surface and groundwater

Water samples are being collected from stock watering dams and from bores, and are being analysed for radionuclides. Results to date are summarized in Table 9.3.

Table 9.3 Typical activity concentrations in surface and groundwater

Source	U (total) (Bq/L)	Ra-226 (Bq/L)
Exploration bores and Whenan Shaft inflow (above ore zones)	0.1	1
Treated Olympic Dam drinking water	n.d.*	0.037
Dams within 15 km of Olympic Dam	0.05	0.04-0.2
Code derived limit for members of the public	37	0.37

* n.d. = not detected: detection limit 5 parts per billion which is equivalent to 0.05 Bq/L.

Flora

Characteristics governing the selection of vegetation have been palatability for stock and dominance in the region. As aerial deposition, especially in arid climates, generally far outweighs the root uptake, there has been no attempt to make a distinction between plants based on positive or negative concentration uptake factors.

Samples have been analysed for the radionuclides thorium-230, radium-226, lead-210 and natural uranium, the results of which are given in Table 9.4. Specific mention needs to be made of the lead-210 enhancement, which is considered to be due to deposition of radon daughters from the ambient air.

The species which have been taken for assay are:

- Acacia aneura (mulga)
- Acacia papyrocarpa (western myall)
- Dodonaea spp. (hopbush)
- Atriplex vesicaria (bladder saltbush)
- Kochia sedifolia (common bluebush)
- Eragrostis australasica (canegrass).

Samples have been composited into groups by species and area (Figure 9.1 and Table 9.4).

Table 9.4 Analytical results and locations of vegetation sampling programme

Species and area	Locations sampled	U-238 (Bq/g)	Th-230 (Bq/g)	Ra-226 (Bq/g)	Pb-210 (Bq/g)
Mulga Northern sector	9, 2, 4	1.9×10^{-4}	2.4×10^{-4}	2.2×10^{-4}	5.3×10^{-2}
Myall General	9, 18, 17	1.2×10^{-4}	1.4×10^{-4}	1.3×10^{-4}	3.8×10^{-2}
Hopbush North-west sector	2, 4, 5	2.6×10^{-4}	1.6×10^{-4}	1.7×10^{-4}	4.1×10^{-2}
Hopbush North-east sector	Sandhill, 9, 8, 7, 6	2.7×10^{-4}	1.6×10^{-4}	1.4×10^{-4}	3.8×10^{-2}
Hopbush Southern sector	19, 25, 23, Phillips Ridge	1.4×10^{-4}	1.2×10^{-4}	1.1×10^{-4}	2.7×10^{-2}
Saltbush North-west sector	1, 3, 4, 5	1.1×10^{-4}	2.3×10^{-4}	1.7×10^{-4}	2.6×10^{-2}
Saltbush North-east sector	Bulls Head, 9, 6, Sandhill	1.8×10^{-4}	3.3×10^{-4}	2.7×10^{-4}	3.1×10^{-2}
Bluebush North and west	1, 3, 8, Lake Blanche	8.9×10^{-4}	1.2×10^{-3}	7.4×10^{-4}	6.2×10^{-2}
Canegrass General	12 Mile Dam, 6	7.0×10^{-5}	1.5×10^{-4}	1.5×10^{-2}	3.8×10^{-2}
Mulga Southern sector	18, 23, 17, 25, 24	1.5×10^{-4}	2.3×10^{-4}	2.1×10^{-4}	3.6×10^{-2}

Animal tissue

Kangaroos, cattle, sheep and mice have been taken for analysis from the locations listed below:

- Kangaroos - 12 Mile Dam, Lake Blanche, town site, Arcoona Station;
- Cattle - 12 Mile Dam, Lake Blanche;
- Sheep - town site, Arcoona Station;
- Mice - local.

Analysis is being performed separately for radionuclide concentrations in the flesh, bone and liver in the larger animals, but analysis of the whole body only is being undertaken for the mice. Constituent analysis will include natural uranium, radium-226 and lead-210. These results were not available at the time of writing.

9.3 STANDARDS OF RADIOLOGICAL PROTECTION

9.3.1 Comparison of Code of Practice and ICRP recommendations

The Code of Practice

The Code of Practice specifies radiation standards and limits to protect workers and members of the public in uranium mining and milling operations. While providing an adequate basis for protection, the international standards on which it is based have been reviewed in recent years. A brief comparison of the Code of Practice with its international counterparts is therefore set out below.

ICRP recommendations

The basic recommendations of the ICRP are regarded by responsible authorities as providing a satisfactory basis for controlling human exposure to ionizing radiation in workplaces and in the general environment. The Commission issued its latest basic recommendations in 1977, and reaffirmed these with minor amendments (ICRP 1978, 1980) after reviewing later epidemiological and radiobiological evidence of radiation risks to man. National authorities derive codes of practice or statutory regulations from these ICRP recommendations in a manner suited to local conditions. The ICRP also promulgates recommendations on secondary aspects of radiological protection which individual countries may also adopt (ICRP 1979, 1980, 1981).

However, the Code of Practice derives from earlier basic recommendations of the ICRP (1966, amended 1969, 1971) and from earlier secondary recommendations dealing with internal irradiation (ICRP 1960, 1964, 1968). Several countries are, at present, in similar circumstances to Australia and are adapting their radiation controls to the new ICRP recommendations (European Communities Legislation 1980).

Mechanisms of exposure

Important aspects of the Code of Practice and the new ICRP recommendations are compared below for each of the three principal exposure mechanisms in uranium mining and milling (gamma irradiation, inhalation of short-lived radon daughters, and intake of long-lived radionuclides).

- Gamma radiation

  Gamma rays irradiate the human body more or less uniformly. The concern is to limit the overall risk of malignant diseases and of hereditary defects from such irradiation. There is direct comparability between the limit on the effective dose equivalent given by ICRP (1977) and the limit on the whole body dose equivalent in the Code of Practice. The numerical value of the limit for workers is the same in both instances, namely 0.05 Sv/a. The numerical value of the limit for members of the public is also the same, that is 0.005 Sv/a, although the discussion in paragraphs 118 to 122 of ICRP Publication No. 27 needs to be borne in mind, in which it is pointed out that for a critical group to approach such a level would require justification.

- Radon daughters

  With regard to radon daughters, the concern is to limit the risk of bronchial lung cancers. ICRP (1981) recommends an annual limit of exposure for workers of 4.8 WLM, but qualifies this by advising that allowance should be made for the other mechanisms of exposure. In the Code of Practice, on the other hand, the annual limit for radon daughter exposure of workers is 4 WLM without qualification. ICRP does not offer any recommendations for members of the public, but the annual limit of 0.4 WLM in the Code of Practice is not out of keeping with the ICRP approach to such matters, provided it is the incremental exposure to radon daughters from the Project which is being considered.

. Long-lived radionuclides

Intake of long-lived radionuclides, which occur in ore dust, yellowcake and plant tailings, may result from inhalation or ingestion or both. The uptake by the body and the retention of these radionuclides may vary according to their physical and chemical characteristics and may differ from one organ or tissue to another. As a result of an intake, however, an individual will be committed to some radiation dose, and the concern is again to limit the risk of malignant or hereditary effects. Committed doses are limited by use of Annual Limits of Intake of activity (in becquerels) for the various radionuclides.

Risk weighting factors

In the new ICRP (1977) recommendations, the overall risk from uniform irradiation of the body is analysed according to the contribution which separate organs or tissues make to the whole. The ICRP risk factors are shown in Table 9.5, where equal importance is attached to serious hereditary defects in children and grandchildren and to fatal malignancies in irradiated persons themselves. The fractional contributions, or risk weighting factors, are also shown. The concept of fractional risk enables the summation of dose equivalents from the various mechanisms of exposure which arise when the body is irradiated non-uniformly, as occurs pre-eminently when radionuclides are taken into the body.

Table 9.5 ICRP risk factors for serious hereditary defects and fatal malignancies from irradiation

Organ or tissue	Risk factor (per Sv)*	Fractional contribution**
Gonads (hereditary)	4×10^{-3}	0.25
Breast	2.5×10^{-3}	0.15
Red bone marrow	2×10^{-3}	0.12
Lung	2×10^{-3}	0.12
Thyroid	5×10^{-4}	0.03
Bone surfaces	5×10^{-4}	0.03
Remainder	5×10^{-3}	0.30
Whole body total	1.65×10^{-2}	1.00

* Refer to Table 9.6 for recommended dose limit to whole body (0.05 Sv).
** Or risk weighting factor.

Derived concentrations

From information on the metabolism of radionuclides, it is possible to relate intake in a year to the effective dose equivalent to which a worker would be committed in subsequent years. Having set a limit to the dose, a limit can then be set to the intake. It is possible, furthermore, to derive limits on air concentrations, for instance, through a model of inhalation. The ICRP has, in fact, recommended a set of derived air concentrations for workers based on this approach (ICRP 1979, 1980). Values for the long-lived radionuclides in uranium mining and milling are given in Table 9.6.

Table 9.6 Comparison of some important limits for radiation exposure of workers

Code of Practice		ICRP	
Parameter	Value	Parameter	Value
Annual dose equivalent limit to whole body	0.05 Sv	Annual limit on effective dose equivalent	0.05 Sv
Annual limit for radon daughter exposure	4 WLM	Annual limit for radon daughter exposure	4.8 WLM
Derived limits of concentrations in air*		Derived air concentrations*	
U (total)	3.7 Bq/m^3	U (total)	0.7 Bq/m^3
Th-230	0.37 Bq/m^3	Th-230	0.2 Bq/m^3
Ra-226	1.9 Bq/m^3	Ra-226	10 Bq/m^3
Pb-210	7.4 Bq/m^3	Pb-210	4 Bq/m^3

* For most insoluble or most avidly retained form of material.

To illustrate the use of these numbers, take as an example a worker who has been exposed throughout a given year to thorium-230 in air at a concentration of 0.2 Bq/m^3. Following intake, the worker would be committed to receiving over a period of five decades a whole body dose equivalent equal to a total of .05 Sv.

Adding doses

Suppose that a worker was committed to receiving an effective dose equivalent of 0.01 Sv as a result of inhaling ore dust during a year in the mine (i.e. one-fifth of the effective whole body limit), and suppose further that he had received an effective dose equivalent of 0.01 Sv in that year from gamma rays (a further one-fifth of the limit). In such circumstances, ICRP (1977, 1979, 1980, 1981) would require his exposure to radon daughters not to have exceeded 2.9 WLM (i.e three-fifths of 4.8 WLM).

Doses to organs

The Code of Practice, however, retains the concept of 'critical organs' in limiting non-uniform irradiation of the body. These organs are selected on the basis of their sensitivity to radiation and their importance to the whole organism, and individual dose equivalent limits are given for them. There is no requirement in the Code to add together the dose equivalents which several organs might receive from the various mechanisms.

From less advanced models of metabolism and inhalation, it is possible, for instance, to obtain derived limits of concentrations in air which are related to dose equivalent limits for individual organs. This is done for workers in the Code of Practice, and the values are also listed in Table 9.6. Derived limits of concentrations in air for members of the public are also given in the Code of Practice, but can only be inferred from ICRP.

Comparison of limits

When the two sets of limiting concentrations in air are compared in Table 9.6, individual differences are apparent: the Code of Practice is less restrictive for uranium, for example, but more restrictive for radium-226. However, the overall difference is not significant: the geometric mean of the ratios of Code of Practice values to ICRP values is only 1.4.

On the question of limits, therefore, the Code of Practice and the ICRP are generally compatible numerically. The major difference, however, is that the ICRP requires all exposures to be added on a common basis, whereas the Code of Practice treats each mechanism of exposure separately. The Joint Venturers will comply with the Code of Practice, and will also abide by the recommendations of the ICRP where these are more restrictive than the Code of Practice.

Under Clause 10 of the Indenture Agreement, the Joint Venturers are obliged to comply with the most stringent of the codes, standards or recommendations of the following:

- the Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores, 1980
- codes or recommendations of the ICRP
- codes or recommendations of the IAEA, in particular the 'Regulations for the Safe Transport of Radioactive Materials'
- codes based on studies or assessments by the NHMRC.

If any of the above are amended, the Joint Venturers must then comply with the amended codes, standards or recommendations.

9.3.2 Criteria for limitation of employee exposure

Overall exposure limit

In view of the above discussion, the Joint Venturers propose to limit the overall exposure of employees to radiation by limiting the contribution from all mechanisms, taken together, in a coherent manner. This intention is best expressed mathematically by the following inequality:

$$\frac{D}{0.05} + \frac{E}{4} + \sum_i \frac{I_i}{ALI_i} < 1 \qquad (1)$$

where D = annual dose equivalent from gamma rays (Sv)

E = annual exposure to radon daughters (WLM)

I_i = annual intake of radioactive element or nuclide 'i' (Bq), calculated from airborne concentrations and standard breathing rates

ALI_i = annual limit of intake by breathing of radioactive element or nuclide 'i' (Bq), calculated from Code derived limits and standard breathing rates

$\sum_i$ - signifies that all the radioactive elements and nuclides must be taken into account.

The denominator in each term refers to the appropriate numerical limit in the Code of Practice. If there is likely to be appreciable ingestion of radioactive material by workers (which the Joint Venturers' monitoring and hygiene controls will be directed towards avoiding), this mechanism will also be included.

A similar approach will be adopted with regard to members of the public (Section 9.3.3), the denominators reducing by an order of magnitude in the case of gamma radiation and radon daughters and a similar order for ALI_i, all in accordance with the Code of Practice limits.

The Joint Venturers are also required by the Code of Practice and by Clause 10 of the Indenture Agreement to ensure, not only that the appropriate limits are observed, but that the human exposure is reduced to the lowest reasonably achievable level, economic and social factors being taken into account.

Epidemiological evidence

There is a particular concern in uranium mining to limit the exposure of underground miners to radon daughters and thus to limit the consequent risk of lung cancer. The estimated cumulative lifetime risk coefficients put forward by the ICRP command wide acceptance and are one of the important bases on which the Commission made its recent recommendations for limiting exposure (ICRP 1981). The cumulative lifetime risk coefficients range from 1.5 to 4.5 x 10^{-4} per WLM.

These values rely heavily on the original study of uranium miners in America (Lundin et al. 1971) and on more recent work in Czechoslovakia (Sevc et al. 1976), but they also take account of the uranium and fluorspar mining data from Canada and some hard-rock mining experience in Sweden and Britain. More recently, fresh evidence has come from China to support these estimates, and also from studies for the Workmen's Compensation Board of Ontario, and from a retrospective study of Cornish tin miners (O'Riordan et al. 1981a).

The risk coefficients given above may reflect not only the effect of radon daughters, but also that of other possible carcinogens, cocarcinogens, and potentiating agents to which miners are exposed underground. These include operating plant emissions, cigarette smoke, and siliceous dust. Thus, the real risk coefficients for radon daughters alone are likely to be lower than those listed (Cohen 1982). There is also a measure of uncertainty about the estimates of exposure on which the epidemiological evidence is based (Dory 1979). If a single value were to be adopted, it would be closer to the bottom of the range, for the reasons given above.

To overcome such difficulties, the ICRP (1981) has also adopted a dosimetric approach by translating exposure into an effective dose equivalent. A model of the respiratory tract is formulated, and deposition and retention of the daughters is estimated from theoretical and experimental information.

Deposition is influenced mainly by the fraction of the potential alpha-energy carried by unattached daughter atoms, the size distribution of the radioactive aerosol, and the breathing rate of the worker. The most important tissue is the bronchial epithelium, in particular its basal cells, followed by the pulmonary epithelium.

Having estimated the absorbed dose to each of these regions of the lung, the ICRP applies the appropriate quality factor for alpha particles to determine the dose equivalent. The final step is to apply half the lung risk weighting factor of 0.12, as given in Table 9.5, to the bronchial and pulmonary irradiation, adding the answers to obtain the effective whole body dose equivalent. The effective dose equivalent per unit exposure for workers is 0.01 Sv/WLM (ICRP 1981). From Table 9.5 the risk associated with 0.01 Sv is seen to be 1.65 x 10^{-4}.

Risk implications and risk perspective

It is now possible to consider the risk implications of exposure to 1 WLM/a in the underground mine, which is the design level to which the Joint Venturers plan to control radon daughter exposure. The commitment to a design limit of 1 WLM/a for workers' exposure will ensure averages considerably below that figure, because of the statistical spread of results. Epidemiological and dosimetric data referred to above, taking into account ICRP guidance, suggests that the total lifetime risk of lung cancer is unlikely to exceed 2 x 10^{-4} per cumulative WLM. Taking a cumulative lifetime exposure of 30 WLM, and thirty years at risk after exposure, it can be suggested that the average annual risk of lung cancer is unlikely to exceed 2×10^{-4} (1 in 5,000). This risk can be compared with some other societal risks presented in Table 9.7.

Table 9.7 Average annual risk of death in the United Kingdom from accidents at work and other causes

Cause	Risk per year
Smoking ten cigarettes per day	5×10^{-3} (1 in 200)
Coal mining	2.5×10^{-4} (1 in 4,000)
Construction	2×10^{-4} (1 in 5,000)
Road accidents	2×10^{-4} (1 in 5,000)
Home accidents	1×10^{-4} (1 in 10,000)

Source: UK-National Radiological Protection Board.

It is also possible to assess the significance of such a risk by considering the incidence of lung cancer in the male population of South Australia. In 1980, there were reported to have been 359 fatal malignant neoplasms of the trachea, bronchus and lung among South Australian men (Commonwealth Bureau of Statistics 1980). These are likely to have occurred mainly in the bronchus. All the deaths occurred in the over twenty-five age group, of which there were 368,000 out of a total male population of 648,000. For Olympic Dam, age forty-five is the youngest age at which, even in the worst circumstances, a worker could be considered to have accumulated a lifetime exposure of 30 WLM. For the male population group over forty-five in South Australia, there were 352 fatal neoplasms out of a male population of 187,000 (i.e. 98% occurred in this age group). The annual risk of death from this cause is then approximately 1 in 500 in this age group. (The risk is reduced by a factor in excess of 4 for the female population). Thus the upper limit of risk enhancement for mine workers due to operational activities would be approximately 10%. The Joint Venturers will pursue a programme aimed at discouraging smoking among miners which, if successful, could be expected to reduce the existing baseline risk figure of 1 in 500.

9.3.3 Limitation of public exposure

Exposure pathways

The Code of Practice places limits on incremental increases in radiation exposure for members of the public due to the mining and milling of radioactive ores. The main radiation sources from the mine and plant are the dust emissions containing radionuclide particulates and radon gas which decays to radon daughters. Through airborne dispersion, these emissions can increase radiation exposure in areas beyond the mine and plant. Exposure can occur from these sources through inhalation of radon daughters or radionuclide particulates, and through ingestion of food contaminated by deposition of radionuclide particulates. In principle, deposition of radionuclides on the ground leads to an increase in gamma radiation. However, this effect is so insignificant that consideration is not warranted. Direct gamma radiation from the site may also be ignored, not only because it is low initially, but also because over the distance of a kilometre it is reduced by many orders of magnitude.

Inhalation of radionuclides

The Code of Practice requires that members of the public should not be exposed to airborne contaminants above certain derived limits of concentration. These are given in

Table 9.8 in units of Bq/m^3. These values come from earlier ICRP recommendations (ICRP 1959), and are based on the assumption that an adult member of the public breathes a standard volume of air during one year and is continuously exposed over fifty years. It is thus possible to compute a limit on annual intake for each contaminant, and this is also shown in Table 9.8 in units of Bq. Values for similar parameters inferred from the current ICRP (1979, 1980) recommendations are also given for comparison. In all cases, the most insoluble or avidly retained forms of the contaminants are listed. It can be seen that the present ICRP values are somewhat more restrictive than the Code of Practice values but, given the uncertainties associated with the models of human exposure from which they both arise, the two sets are deemed compatible.

Table 9.8 Limits of exposure of adult members of the public by inhalation

Contaminant	Derived limit of concentration Bq/m^3		Limit of annual intake Bq	
	Code	ICRP	Code	ICRP
U-238, U-234	1.5×10^{-1}	2×10^{-2}	1.1×10^{3}	1.5×10^{2}
Th-230	1.1×10^{-2}	9×10^{-3}	8.0×10^{1}	6×10^{1}
Ra-226	7.4×10^{-2}	3×10^{-1}	5.4×10^{2}	2×10^{3}
Pb-210	3.0×10^{-1}	1×10^{-1}	2.2×10^{3}	9×10^{2}
U-238, U-234	6 μg/m^3	-	4.4×10^{4} μg	-

Ingestion of radionuclides

For ingestion of long-lived contaminants, the Code of Practice requires that the derived limits of contaminant concentration in water should not exceed certain values. These values are given in Schedule 6 of the Code and are based on the ICRP assumption that an adult member of the public drinks a standard volume of water during one year. It is therefore possible in this case also to calculate a limit on annual intake for each contaminant. The results are given in Table 9.9, together with values for the same parameter inferred from the current ICRP recommendations. For this mechanism of exposure, the most soluble or transferable forms of the contaminants are considered. The Code of Practice values are somewhat more restrictive in this case, but once again the two sets of values are deemed compatible.

Table 9.9 Limits of annual intakc by ingestion

Contaminant	Code (Bq)	ICRP (Bq)
U-238, U-234	3×10^{4}	5×10^{4}
Th-230	6×10^{4}	1×10^{4}
Ra-226	3×10^{2}	7×10^{3}
Pb-210	3×10^{3}	2×10^{3}
U-238, U-234	1.6×10^{3} mg*	-

* Based on chemical toxicity as the limiting factor.

Inhalation of radon daughters

The annual limit of radon daughter exposure for members of the public is set at 0.4 WLM in the Code of Practice. The ICRP does not recommend a public limit, but recent developments in the dosimetry of radon-222 daughters are examined below as a guide to what the ICRP may eventually adopt.

In its recent recommendations on mining (ICRP 1981), the Commission set an annual limit of 4.8 WLM on the exposure of workers. This was deemed to correspond to an effective dose equivalent of 50 mSv, so that the conversion factor from exposure to dose may be said to be approximately 10 mSv per WLM. This factor is based on epidemiological and dosimetric evidence, although on purely dosimetric grounds it would be somewhat less.

There is no direct epidemiological evidence of excess lung cancers from domestic exposure to radon daughters, but the evidence from mining and from data on the spontaneous incidence of lung cancer before cigarette smoking became widespread have led to the authoritative suggestion (Evans et al. 1981) that a risk coefficient of 1×10^{-4} per WLM is a reasonable upper bound for domestic exposure. In ICRP (1977) terms, such a risk factor is associated with an effective dose equivalent of just over 5 mSv.

In the last few years, there has been considerable elaboration of a dosimetric concept called the regional lung dose model (Jacobi and Eisfield 1980; James et al. 1981; James 1982), which is applicable to exposure in mining, in the home, and elsewhere. The absorbed dose to the bronchial epithelium and alveolar tissue is estimated for unit exposure according to a geometric model of the respiratory tract, account being taken of the characteristics of the aerosol and the physiological behaviour of the radon daughters. Having obtained the amount of the absorbed dose, the appropriate ICRP (1977) quality factor is applied to determine the dose equivalent. The final steps are to apply half the ICRP lung weighting factor of 0.12 to the bronchial and alveolar dose equivalent and to add the answers to obtain the effective dose equivalent. This approach yields a reference conversion factor of just over 5 mSv per WLM (O'Riordan, pers. comm.) for indoor exposure in homes with low or moderate ventilation.

The implication of this value is that exposure to 1 WLM/a corresponds approximately to an effective whole body dose equivalent of 5 mSv/a, which is the dose equivalent limit recommended for members of the public by ICRP (1977). In this matter, therefore, the Code of Practice limit of 0.4 WLM/a is rather more stringent than the ICRP might possibly be. It should be noted that the conversion factor being advocated for outdoor exposure to radon decay products is about twice the indoor value.

Reference has so far been made only to adult members of the public. Concern is sometimes expressed about differential doses to young people as a result of exposure to radiation. In examining this question, long-lived radioactive material and radon daughters will be considered separately.

The dose equivalent commitment per unit activity intake by ingestion or inhalation is related to age at intake. The energy expenditure rate, which reflects the consumption of air and food, and hence activity intake rate, is also related to age. The product of dose equivalent per unit intake and activity intake rate at a low age, divided by their product for an adult, gives the relative age dependence of dose equivalent commitment for young people. As this does not depart significantly from unity for the radionuclides being considered here, and probably does not exceed two, it is reasonable to use the adult value for the public generally. Dose equivalent commitment refers either to effective dose or to organ dose (Adams 1981; ICRP 1979).

With radon daughters, there is a tendency for the dose conversion factor to increase in younger children, becoming essentially constant at six years of age due to the combined effect of thinner bronchial epithelium and greater intake in relation to body weight (James et al. 1981; James 1982). In the infant, intake relative to body weight is less, giving a slight compensatory reduction in dose conversion. The relative age dependence in this case also does not depart significantly from unity and does not exceed two, so that once again it is reasonable to use the adult value for general application.

In summary, the doses which children and adults receive under similar circumstances of exposure to radioactive material are somewhat different, but not to the extent that differential limits of intake or exposure should be adopted.

Limitation of overall exposure

The Joint Venturers propose to limit members of the public's incremental exposure resulting from the Project in a manner similar to that for employees, that is, by limiting the contribution from all mechanisms taken together. This intention is expressed mathematically as follows:

$$\frac{E}{0.4} + \underbrace{\sum_i \frac{I_i}{ALI_i}}_{\text{inhalation}} + \underbrace{\sum_i \frac{I}{ALI_i}}_{\text{ingestion}} < 1 \qquad (2)$$

where E = annual exposure to radon daughters (WLM)

I_i = annual intake by ingestion of radioactive element or nuclide 'i' (Bq)

ALI_i = limit of annual intake by ingestion or inhalation of radioactive element or nuclide 'i' (Bq)

$\sum_i$ - again signifies that all the radioactive elements and nuclides must be taken into account.

The further fraction taken for employees in expression (1) (i.e. the increment for gamma ray exposure) is too small to warrant consideration.

The denominator in each term refers to the appropriate numerical limit for members of the public as required by the Code of Practice. Values for the ALI inferred from the Code are in Tables 9.8 and 9.9. (Intake by ingestion or inhalation could be limited by use of a derived limit of concentration rather than on an annual basis.)

In the discussion in Section 9.5.2, this criterion will be applied to members of the public in the Project Area, to illustrate the degree of compliance with the Code of Practice.

9.4 SOURCE TERM ESTIMATES

9.4.1 Project sources of radiation

The principal sources of radiation arising from the Project are considered for two Project stages: the maximum production stage, and the post-operational stage. The first stage applies after approximately ten years of full production at 6,500,000 t/a. The second stage corresponds to the period commencing at mine closure, after the mill and adjacent areas have been cleared and rehabilitated, and the tailings storage area has been fully covered.

The source term estimates are the starting point for assessing the dispersion of radioisotopes and subsequent exposure of humans and animals to radiation above present background levels.

Maximum production stage

Exposure during the maximum production stage is considered both in terms of employees in workplaces at the site during working hours, and people in residence outside the controlled access area boundary where no controls on occupancy apply (Figure 2.1).

The principal radiation sources at Olympic Dam during production will be as follows:

- Underground mine
  - radon gas, giving rise to radon daughters, emitted from exposed ore in situ, and from broken and crushed ore;
  - airborne dust containing radionuclide particulates, and in particular the respirable component;
  - gamma radiation from in situ and broken ore.
- Mine ventilation
  - exhaust air from mine workings expelled to the atmosphere, containing radon gas and decay products, and dust containing radionuclides.
- Ore transfer
  - fugitive dust, containing radionuclides from ore conveying;
  - radon gas, gamma radiation, and fugitive dust containing radionuclides from ore stockpiles.
- Ore processing
  - radon gas released during handling, flotation and leaching of ore;
  - dust emissions from copper processing which contain radionuclide particulates;
  - uranium in dust emissions from yellowcake drying and packing;
  - gamma radiation from handling drummed yellowcake.
- Tailings retention system
  - fugitive dust containing radionuclides in the uranium decay chain but with most of the uranium extracted;
  - radon emanation from the deposited tailings in the tailings storage and salts in the decant evaporation pond.

The average ore grade of the Olympic Dam deposit, expressed as a percentage by weight of uranium oxide, has been taken as 0.05%. There will, however, be areas within the mine where the grade is in the order of two or three times this figure. These are relatively low concentrations compared with other ores being mined in Australia. Ore samples have been tested and have been found to be generally within ±10% of radiometric equilibrium. The ore has also been tested for natural thorium which has been found to occur at very low concentrations of approximately 30 to 50 ppm. The discussion which follows therefore considers the uranium decay chain without further reference to the thorium decay chain, as its contribution to radioactivity is negligible, and takes the specific activity of uranium and for its daughters, thorium-230, radium-226 and lead-210, as 5.25 Bq/g of ore.

Following the usual practice, uranium-235 and its decay products will not be considered in dose calculations due to inhalation or ingestion because of their low relative quantity and activity by comparison with uranium-238 and its chain.

The principal radiation sources are quantified below for radionuclide particulates contained in dust emissions, for radon gas emanation as a precursor to radon daughter exposure, and for gamma radiation. In addition, the dispersion of radioactivity away from mine and plant areas is analysed.

Post-production

In the post-production phase the plant and mine will cease to be above ground sources of radiation. The tailings retention area will continue to emit radon after decommissioning, although this will be attenuated by covering with soil and rock (Section 7.5). The dispersion of this source of radioactivity is also addressed below.

9.4.2 Dust emission source terms

Mine workings

Dust arisings in the mine will contain free silica (quartz) and diesel emissions, as well as radioactive particles. Core analyses have shown that the average quartz content in the material to be mined is approximately 15%, with a range of 5 to 30% within the mineralized zone. Experience in underground exploration to date at Olympic Dam, with its average low grade uranium assays, confirms that it is the control of silica inhalation which will govern the permissible dust concentrations in the working area. This is in accord with theoretical considerations (Borak et al. 1981). The maximum concentration of respirable dust in the air at workplaces as defined by the NHMRC depends on the free silica content in the dust. For a 30% free silica content, the recommended value is 0.7 mg/m^3 of respirable dust in air. There will be other elevated concentrations of dust arisings from the crusher operations and also from intermittent blasting of ore. The dust concentration in the air passing continuously from ventilated workplaces has been conservatively rounded upward to 1 mg/m^3, and applied to the planned continuous exhaust volume of 2,200 m^3/s to give just over 2 g/s at the surface exhaust vent. This is comparable with Canadian figures of 1 mg/m^3 out of upcast shafts measured for the Elliot Lake mines in Ontario (James F. McLaren and Associates 1978).

Mine dust control

Water will be used for dust suppression. This will include water injection during drilling, water sprays after blasting, washing down of walls, and wetting of piles of broken ore before moving. Sprays will also be used at ore passes and chutes and at the crushers. Ventilation of ore passes will be designed to remove dust produced during tipping of ore, while dust confinement will be provided by enclosures and exhaust ventilation at the crushers and conveyors.

An assessment of the amount of dust emitted from the underground crusher prior to release to the atmosphere will be assessed by a series of trials which will be carried out in consultation with the Department of Mines and Energy. For the purpose of this Draft EIS, an estimated 0.005% or (10 g/s) of all the ore passing through the crushers is taken to be exhausted to the return airway as respirable dust of 5 μm size or less. Dust from infrequent large scale blastings, such as those in open stoping, is not amenable to prediction, but will be allowed to settle for an adequate time prior to the recommencement of local full scale ventilation. The time period allowed for dust settlement will depend on operational experience. Nevertheless, this will be an additional source of dust arisings over and above that occurring with routine ventilation. The annual average estimate of dust emissions from the crushers has been doubled to 20 g/s to account for intermittent arisings from blasting and ventilation to non-workplaces.

The specific activity of the long-lived uranium-238 series radionuclides in the respirable dust will be higher than that for the average ore grade. Tests conducted by AMDEL on samples of ore after grinding indicate that an average factor of 1.5 is appropriate for Olympic Dam. Therefore, on average over the year, the estimated rate of particulate emissions to the air, including dust from ventilated workplaces and from crushing and blasting, will be 22 g/s with a specific activity of 1.5 x 5.25 = 7.9 Bq/g. In order to provide the most pessimistic input for dose equivalent calculations, all of this dust is assumed to be in the respirable size range.

The separation between mine exhaust and intake ducts is generally in excess of 300 m. Possible interaction between the exhaust and intake ducts has been considered by modelling the exhaust air dispersion for various combinations of Pasquill stability class and wind speeds. For the situation of Pasquill D stability and wind speeds in the range of 4 to 10 m/s, a contaminant concentration of 10 mg/m^3 (22 g/s total dust) at the exhausts is reduced to 0.3 $\mu g/m^3$ at the intakes, a negligible change of ambient air quality.

Plant operations

Crushed ore from the mine will in general be conveyed directly to the concentrator, while 6,000,000 t/a (dry weight) of flotation tailings will pass from the concentrator to the uranium extraction circuit, and 500,000 t/a of copper concentrates will pass to the concentrate processing circuit. From the results of laboratory scale tests, the copper flotation concentrates are expected to contain approximately 0.15% U_3O_8. Although this uranium enhancement in flotation concentrate occurs, the bulk of the uranium nevertheless reports to flotation tailings, which pass to the uranium extraction circuit. These flotation tailings are conservatively considered to retain an average of 0.05% U_3O_8.

Dust emissions from the uranium circuit will occur during ore conveying and yellowcake drying and packing. Design criteria for the dust extraction systems will be as specified in the 'Industrial Ventilation Manual of Recommended Practice' (American Conference of Governmental Industrial Hygienists 1980). Dust emissions from the copper extraction circuit will depend upon which of the options described in Chapter 2 is selected. The leaching circuits produce only minor dust, while the smelt/convert circuit produces dust which will pass out of the smelter stack at an estimated rate of 3.8 g/s. Table 9.10 sets out the predicted dust emissions from the plant.

Table 9.10 Dust arisings at the plant

Dust source	Respirable dust emission (g/s)	Respirable dust loss (Bq/s)*	Nuclides
Conveyor, surge bins (loss 3.6 x 10^{-5}**)	7×10^{0}	5.5×10^{1}	U Series
Yellowcake drier and packer (loss 2.2 x 10^{-5}**)	2×10^{-3}	2×10^{1}	U-238, U-234
Copper smelter	3.8×10^{0}	9.0×10^{1}	U Series

* Rn-222 and decay products considered separately.
** Western Mining Corporation (1979)

Note: Ore grade taken as 0.5% U_3O_8. Copper concentrates taken at 0.15% U_3O_8. Specific activity of fine dust is assumed to be 1.5 times the specific activity of ore. All dust loss assumed to be respirable (5 μm or less).

General dust control

Provision will be made in the general design and layout of treatment plant areas for the containment of spillages of material and for ease of subsequent clean-up. Concreted and bunded areas will therefore be provided wherever liquid or slurry spillages are likely, with high pressure hose connection points for washdown and sumps from which clean-up slurry will be pumped back to the appropriate parts of the process circuits. Areas where solid spillages are likely will be concreted, to provide for ease of clean-up by small skid-steered loaders. Areas available for dust resuspension will also be minimized. Vehicles and equipment will be subject to inspection and, where directed, washed down on a drained pad prior to leaving the controlled access area.

Dust extraction systems will be designed to pick up all dust particles of less than 20 μm which become airborne at transfer points, crushers and screens, by the use of enclosures and air velocities which prevent sedimentation. Ducting will be run from pick-up points at an angle greater than the angle of repose of deposited dust, to enable deposited material to slip back to the collection point. Flow velocities in ducts will be 20 m/s in general, and 30 m/s wherever very fine, dry, dusty material is to be handled.

Present planning is to provide for three days' storage of ore in covered bins at the treatment plant. However, for the purpose of assessment of environmental impact, it has been assumed that approximately 50,000 t of ore, with a surface area of 10,000 m^2, will be stockpiled above ground as a contingency mill feed. The top 1 mm of this stockpile is assumed to be continuously exposed to lift-off by the wind (Clark 1975), and the particulates of principal interest in public health aspects of the Project, the respirable fraction, are taken as particles up to a nominal 5 μm size. The percentage of respirable dust in the top 1 mm is taken as 15%, and its specific activity is 1.5 times the average for the ore. Table 9.11 gives the fraction of the top 1 mm of the stockpile calculated to be lifted off by winds at Olympic Dam. For a bulk density of 2.0 t/m^3 of crushed ore at the stockpile surface and an activity of 7.9 Bq/g dust for each of the individual long-lived uranium-238 series of radionuclides, the corresponding average rate of release of radioactivity is 1.5×10^{-5} $Bq/m^3.s$ over the full stockpile area of 10,000 m^2.

Table 9.11 Suspension rate of respirable particles from ore stockpiles

Wind speed (m/s)	Occurrence (%)	Suspension rate (fraction/s)	Mean suspension rate (fraction/s)
1.1 - 3.5	40	2×10^{-10}	8×10^{-11}
3.5 - 5.5	26	9×10^{-10}	2.3×10^{-10}
> 5.5	28	2.2×10^{-8}	6.1×10^{-9}
Total			6.4×10^{-9}

Particles other than 'respirable particles' move mainly by saltation, but also by short range transportation. These particles are assumed to be substantially retained within the drainage control bund surrounding the stockpile, with a narrow penumbra of surface particles deposited outside the perimeter.

Tailings retention system

The subaerial tailings retention system described in Chapter 7 requires each deposited layer of tailings to dry down to an average of about 90% of saturation moisture content prior to deposition of the subsequent layer. Each separate retention area comprises four cells, each of 1 km^2. Tailings are placed in one cell at a time, allowing progressive drying to occur in the other three cells.

The upper 1 mm of dry tailings surface is the zone of interest for respirable dust lift-off. This surface will dry out ahead of the required average layer moisture level being reached in each cell. Wind tunnel tests conducted at the University of New South Wales on dried Olympic Dam tailings indicate that the surface will be resistant to dusting (Section 7.4.2). However, to cover the possibility of some dusting occurring for the atmospheric dispersion calculations which follow, 1 km^2 of tailings has been considered prone to dust arising in a similar manner to the stockpile. This assumes the most conservative situation in terms of the tailings retention area.

Taking a uranium extraction efficiency of 95% and a concentration factor of 1.5 for the respirable dust proportion, the same procedures as those employed for the stockpile were used to estimate dust arisings, taking an in situ density of 1.9 t/m^3 for the deposited tailings as determined by experimental work, and a respirable fraction of 20% after grinding. The average rate of activity of respirable dust arisings per year thus calculated is shown in Table 9.12.

Table 9.12 Upper limit estimate of respirable dust arisings from tailings retention area over a year

Radionuclides	Emission rate (Bq/s)
U-238, U-234	1×10^0
Remainder of U series	2×10^1

Summary of respirable dust emissions

The estimates of annual average respirable dust emissions from the various operations sources are summarized in Table 9.13.

Table 9.13 Summary of respirable dust source terms at full production

Source	Emission rate for respirable dust (g/s)	Emission rate (Bq/s)	Nuclides
Mine exhaust vent	2.2×10^1	1.7×10^2	U series
Stockpile	1.9×10^{-2}	1.5×10^{-1}	U series
Plant			
Ore dust	7×10^0	5.5×10^1	U series
Yellowcake	2×10^{-3}	2×10^1	U-238, U-234
Copper smelter	3.8×10^0	9×10^1	U series
Tailings retention area	2.4×10^0	2×10^1	U series*
		1×10^0	U-238, U-234

* Excluding U-238, U-234.

9.4.3 Radon gas source terms

Mining

Tests of radon flux from the exposed surfaces of the orebody have been conducted at the 420 plat Whenan Shaft. (A plat is a horizontal opening from a shaft, this one being at 420 m depth in the Whenan Shaft.) The Countess method using activated charcoal-filled canisters placed on exposed walls in the orebody has produced values of approximately

0.3 Bq/m^2.s. An accumulator drum has indicated approximately 1 Bq/m^2.s. Calculations based on radon and radon daughter levels measured in the Whenan Shaft return air, with an estimate of the existing exposed orebody surfaces, give approximately 1 Bq/m^2.s. This includes a component due to broken rock on floors and from below ore grade areas. These tests will continue as exploration development progresses. Radon emanation tests on core samples and broken ore have shown values for the emanating coefficient (the proportion of total radon generated which is released to air) of between 5 and 20%. Further regular emanation studies will continue during the exploratory mining stage but, at the time of writing, radon flux from exposed ore surfaces was estimated at 3 Bq/m^2.s. It is expected that this estimate will be sufficient to allow for localized higher grade stoping areas.

Radon will also be released from stored ore and from minewater. With regard to minewater, dewatering of the aquifer above the orebody will be carried out in advance of mine development. Localized radon emissions from residual minewater inflow will be carefully monitored and controlled, where necessary by piping water away from collection points. However, the total radon emission to air from such inflows is not expected to be significant compared with the radon release from in situ and broken ore. As an example, radon release from an open stope of dimensions 50 x 50 x 100 m with 2 x 10^5 t of broken ore is considered below:

- Radon release from broken ore is calculated as follows:

$$R_b = m \times SA \times E \times \lambda$$

where R_b = radon release from broken ore (Bq/s)

m = mass of broken ore (2 x 10^{11}g)

SA = specific activity of ore (5.25 Bq/g)

E = emanation coefficient (0.1)

λ = decay constant of radon (2 x 10^{-6}/s).

- Radon release from in situ exposed ore is calculated as follows:

$$R_i = A \times J_i$$

where R_i = radon release from in situ ore (Bq/s)

A = surface area of walls, roof and floor (2.5 x 10^4 /m^2)

J_i = emanation rate of in situ ore (3 Bq/m^2.s).

- Total radon release (R_t) from a typical stope is the sum of R_b and R_i, or

$$R_t = 2.1 \times 10^5 \text{ Bq/s} + 7.5 \times 10^4 \text{ Bq/s}$$

$$= 2.85 \times 10^5 \text{ Bq/s}.$$

If ten such stopes were in production then the radon release to atmosphere from the mine would be approximately 3 x 10^6 Bq/s.

The example given is intended to be indicative only. Depending on the characteristics of individual stopes, the radon gas concentrations in stope exhausts is expected to range from 1 x 10^3 Bq/m^3 to 3.7 x 10^3 Bq/m^3. In order to be assured of a conservative estimate of radon for subsequent calculation of above ground radon daughter exposure, the upper level of this range (3.7×10^3 Bq/m^3) is considered in conjunction with the planned total ventilation rate at maximum production of 2,200 m^3/s. This gives a rate of radon release from all exhaust vents from all sources within the mine of 8.1×10^6 Bq/s.

Consideration has also been given to the operational limitation of radon daughter exposure at the workplaces. The basic commitment of the Joint Venturers is to provide a ventilation design in which the air velocity in occupied workplaces and air transit times through workings will be such as to give normally not more than 0.1 WL. This, in conjunction with the operational safeguards described in Chapter 2, will limit the total design exposure to radon daughters for mine workers to 1 WLM per year.

Radon daughter control

The ventilation design philosophy described in Section 2.3.3 has been developed to include as a numerical design criterion a maximum air transit time from intake to last occupied workplace of fifteen minutes. Stripping of pillars in room-and-pillar stopes will always be carried out by retreating into fresh air. Mined out stopes will be sealed from intake airways and provided with a leakage path to exhaust airways.

As an indicative example of the calculation of expected radon daughter concentrations, the development of a room-and-pillar stope can be considered. This will be developed by mining a drive through to connect with the exhaust airway, then extracting material to leave remnant pillars between the new drive and an earlier parallel drive. This is performed while retreating back towards fresh intake air. As a consequence of this mining method, the occupied area of a stope can be modelled by means of a 'tunnel model'.

Using, for example, a length of 200 m of drive, cross-section 4 x 5 m, air velocity 1 m/s, average age of air 1.7 minutes, and emanation rate of 3 Bq/m^2.s, approximately 5×10^{-3} WL is obtained for concentration in air of radon daughter atoms.

If two new drives had broken through to exhaust air and their pillars were being stripped, the effect would be to double the average age of air and to double the radon concentration. Radon daughter concentration can now be calculated to be 0.02 WL.

The commitment to design to 1 WLM per year is an important commitment to health safeguards made by the Joint Venturers, the level being a quarter of the maximum permissible under the Code of Practice of 4 WLM per annum.

Plant

It is assumed that all the radon passing into the pore space of the ore stockpile will be released to atmosphere. For a 50,000 t stockpile, the radon release rate then becomes 1×10^5 Bq/s; 9×10^4 Bq/s of radon are assumed to be released in handling, flotation and leaching of the ore at an average rate of 17,800 t/d.

As uranium plants in Australia have been designed to be open to the atmosphere, and thus well ventilated, they have not experienced problems with radon build-up. In this, Australian plants differ from the North American situation, where harsh winters dictate that as much of the treatment plant as possible be enclosed within buildings. Nevertheless the possible requirements for discrete ventilation systems within the plant to deal with localized sources of airborne contamination are recognized and will be taken into account in detailed design. Yellowcake is not a significant radon emitter, because of its low radium content.

Tailings

The subaerial deposition system for tailings is based on a progressive placement of slurry over tailings layers dried to an estimated annual average of 90% of saturation.

Theoretical analyses carried out for the subaerial deposition system proposed at Olympic Dam, supported by tests on experimental tailings incorporating surface layer shrinkage cracking, have shown that an average figure of 0.6 $Bq/m^2.s$ can be applied to the operational tailings area of 4.0 km^2 (Section 7.4.1).

The equilibrium tailings moisture content is estimated to be 12% by weight (corresponding to a 50% degree of saturation), and the corresponding radon emanation for Olympic Dam tailings is calculated to be 1.6 $Bq/m^2.s$ at that moisture content (Section 7.4.1). For the purpose of this Draft EIS assessment this figure has been conservatively doubled to 3.2 $Bq/m^2.s$.

Results from the United States for completely desiccated tailings expressed in terms of their radium content are 0.65 $Bq/m^2.s$ per Bq/g radium-226 (Bernhardt 1975). Olympic Dam tailings' radium-226 content is 5.25 Bq/g on average, suggesting a radon emanation rate of 3.4 $Bq/m^2.s$ for completely desiccated tailings. However, complete desiccation of Olympic Dam tailings will not occur as the tailings will be covered at the completion of deposition.

An average 1.5 m of compacted swale material with an additional 0.5 m of quarried rock is planned as tailings cover on decommissioning. Tests on the in situ moisture content of swale silty sands, taken in late April 1982 under typical dry conditions, gave the following values:

Depth below surface	Moisture content (% dry weight)
0.5 m	6.6 - 9.0
1.0 m	6.7 - 8.7
2.0 m	2.0 - 7.5

In this assessment, an equilibrium moisture content of 6% in the swale cover material is taken, with a consequent calculated reduction in radon flux from the long-term post-operational tailings surface of 75%, i.e. from 3.2 $Bq/m^2.s$ to less than 1 $Bq/m^2.s$ for tailings.

The radon emission source terms taken for the dispersion calculation are then as follows:

- At maximum production, the average over tailings surface: 0.6 $Bq/m^2.s$
- At post-production (long-term), the average over covered tailings: 1 $Bq/m^2.s$.

In addition, a lined 50 ha evaporation pond will be provided for decant liquor from tailings. Taking supernatant liquor delivery to correspond to a nominal evaporation rate of 3 m/a over thirty years of operation, the total radium-226 activity in the accumulated salts in the base of the evaporation pond would be of the order of 1×10^5 Bq/m^2 if the concentrated liquor were not returned to the tailings retention area. This can be compared with the total radium-226 activity in a 1 m depth of 0.05% grade ore of some 1×10^7 Bq/m^2. This radon emanation from the accumulated salts, even disallowing for further reduction due to water cover, is estimated to be 0.2 $Bq/m^2.s$. This figure has been taken into account in the atmospheric dispersion model.

A summary of the source terms is presented in Table 9.14.

Table 9.14 Summary of above ground radon source terms

Source	Emission characteristics		Rate of release of radon-222 (Bq/s)	
	Elevation (m)	Vertical velocity (m/s)	Full production	Post-production
Mine exhaust vents	15	20	8.1×10^6	-
Ore stockpile	GL*	-	1×10^5	-
Ore processing	30	10	9×10^4	-
Tailings storage	10	-	2.4×10^6	-
	30	-	-	4×10^6
Decant evaporation pond	GL*	-	1×10^5	-

* Ground level.

9.4.4 Gamma radiation source terms

The orebody, ore stockpiles, stores of drummed yellowcake, and the tailings retention area can be described as semi-infinite volumes for the purposes of estimating by theoretical means the principal sources of external irradiation (Radioactive Substances Advisory Committee 1971). The surface dose rate (dD/dt) is estimated from the expression:

$$dD/dt = 2.9 \times 10^{-1} KE \ (\mu Sv/h)$$

where K = specific activity (Bq/g)

E = mean energy per disintegration (MeV).

Ore body

For miners working in close proximity to the orebody, some shielding against gamma rays will be provided by the equipment. Evidence indicates that this shielding factor could be as high as two (Miller 1976) in an open cut situation. At Olympic Dam, working within the orebody, the shielding effect will be less and on the basis of conservatism in estimating radiation exposure no shielding has been assumed. For workers operating in underground locations outside the orebody limits (e.g. at the underground crushers) shielding would be provided by the machinery, and their exposure to gamma radiation would be correspondingly less.

In assessing the period of exposure to external irradiation over a year due to working in close proximity to the orebody, an estimate of 1,500 hours has been made as an upper value. This recognizes that routine mine operations will mean that the miner is not continuously at the ore faces during each shift. Applying an annual exposure period of 1,500 hours, the gamma dose (the principal source of irradiation interest) would be 4 mSv/a, derived from a surface dose rate dD/dt of 2.7 μSv/h in air from the orebody.

Experience in underground uranium mines elsewhere in the world indicates that miners' gamma doses can be maintained at acceptably low levels. For example, the French report 0.5 mrem/h (5 μSv/h) when working in stopes mining 0.1% U_3O_8 grade ore (Duhamel et al. 1964), while the Japanese have reported that, in mining of 0.58% ores in the Nakatsugo district in Japan in 1973, miners' cumulative doses for the year were 1 rem (10 mSv) or less (Kurokawa et al. 1976). In situ dose rate measurements on the 420 m plat at Whenan Shaft are in general agreement with the gamma dose levels within the orebodies referred to above. Personnel TLD badge results from the wearing periods which included excavation of the 420 plat were in the range 0.2 to 0.4 mSv per month, and are thus not inconsistent with the above. An instrument survey at the time of excavation of the 420 plat has given gamma dose rates of 3 to 4.5 μSv/h in a recently blasted heading, above broken rock grading 0.1 to 0.15% U_3O_8 according to a probe evaluator.

Ore stockpiles

Surface ore stockpiles available for contingency use will be worked by employees for only a few days each year. If a surface dose rate of 5mSv/h is assumed together with an exposure period of 200 hours per year, then gamma dose from this source for workers in the vicinity will be equal to 1 mSv/a.

Drummed yellowcake

In the case of yellowcake placed in steel drums, the effect of the surrounding steel (1.5 mm thickness) will be to absorb all the beta emissions and to reduce gamma surface dose rates from a calculated 7.3×10^{-2} mSv/h to 5.4×10^{-2} mSv/h for equilibriated yellowcake. This reduces further to 7×10^{-3} mSv/h for yellowcake of an average age of five days.

The yellowcake will be fed directly from storage bins into the steel drums by automatic processing, thereby removing the exposure path otherwise arising from beta radiation emissions from unpacked material. For plant employees working in close proximity to drummed yellowcake, an exposure time to gamma radiation of 1,500 hours per year is a realistic upper limit and the corresponding gamma surface dose exposure is 10 mSv/a.

Tailings retention area

Tailings management will require intermittent occupation of the perimeter areas to control pipe discharges. An annual occupation time working inside the outer embankment line is taken at 1,000 h/a. The gamma dose rates would be similar to those for the orebody, resulting in a dose of around 5 mSv/a.

Employee exposure

The estimates given above for annual average external irradiation of employees arising from the Project can be summarized as:

Mine	5 mSv/a
Yellowcake packaging/storing	10 mSv/a
Tailings retention area operation	5 mSv/a

Following Project completion and mine closure, the tailings retention area will be covered by an average of 2 m total thickness of soil and rock, which will reduce gamma dose rates at the upper surface by more than five orders of magnitude, making gamma emissions from the area totally indistinguishable from normal background levels.

Public exposure

For members of the public in the town during maximum production, the external irradiation increment arising from the Project will be indistinguishable from natural background because of the distances from the major sources of gamma radiation and from the tailings retention area in particular. The progressive covering of the tailings with soil and rock will reduce gamma ray penetration to minor values even immediately above the covered areas. Members of the public will continue to be subjected to normal terrestrial gamma irradiation, which delivers an annual dose equivalent to the whole body of about 0.5 mSv (Section 9.2.2).

9.4.5 Dispersion of radioactivity

The modelling of the dispersion of airborne contaminants released to the atmosphere employs climatic data which has been specifically accumulated for this Project during the period from February 1981 to February 1982. Continuous monitoring of temperature, humidity, wind speed and direction, barometric pressure, and solar radiation was conducted. The data was also checked against longer-term data reported for Woomera and Andamooka (Section 8.1). The computer model described in Section 8.1.3 is used in simulating dispersion. Each source release is simulated by releasing a series of discrete emissions or puffs at regular intervals. The effects of stack dimensions, emission exit velocities, and temperature are taken into account. Each puff, upon release, diffuses according to the Gaussian spread of the plume material under the influence of atmospheric factors corresponding to those measured during twelve months of field observations. The individual puffs are transported by the simulated wind fields and collected at receptors at each of the model grid points. The concentrations from a unit rate of release from each source are calculated at each grid point totalled over a whole year and then averaged to give annual average concentrations.

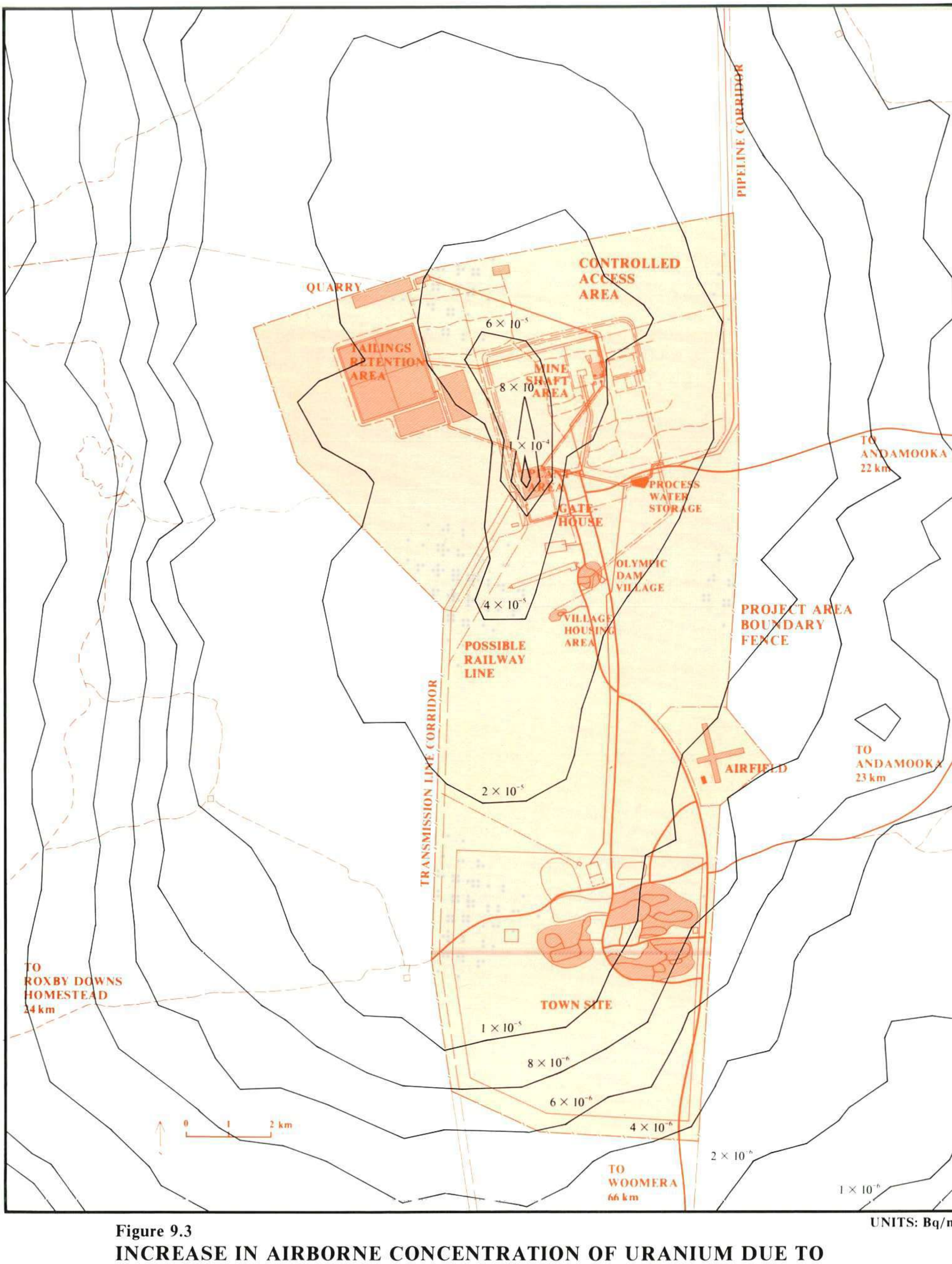
In areas away from plant operations and mine workings, incremental exposure arises from radionuclide particulates and radon daughters. Direct gamma radiation attenuates rapidly with distance, reducing about a millionfold over a kilometre.

For assessment of radiation exposure of members of the public, two locations on this grid are particularly relevant. The first is that part of the frequently occupied section of the town nearest to the operations area (taken to be the northern boundary of the industrial area in the north of the town). The second is the nearest location to radiation sources for employees not directly connected with the handling or processing of ore (taken to be the administration office on the eastern boundary of the plant area). The concentrations of radionuclides and radon daughters at these points are discussed below.

Radionuclides

Figure 9.3 shows the incremental increase in uranium concentration in air due to Project operations at full production, while Figure 9.4 shows the incremental increase for the other principal radionuclides in the uranium decay series. The annual average airborne concentration of uranium at the main administration office is 7×10^{-5} Bq/m^3, while for each of the other principal radionuclides in the uranium series (thorium-230, radium-226 and lead-210) the value is 6×10^{-5} Bq/m^3. For the nearest frequently occupied area in the town, the maximum annual average concentration values are 1.8×10^{-5} Bq/m^3 for uranium and 1.6×10^{-5} Bq/m^3 for the other radionuclides.

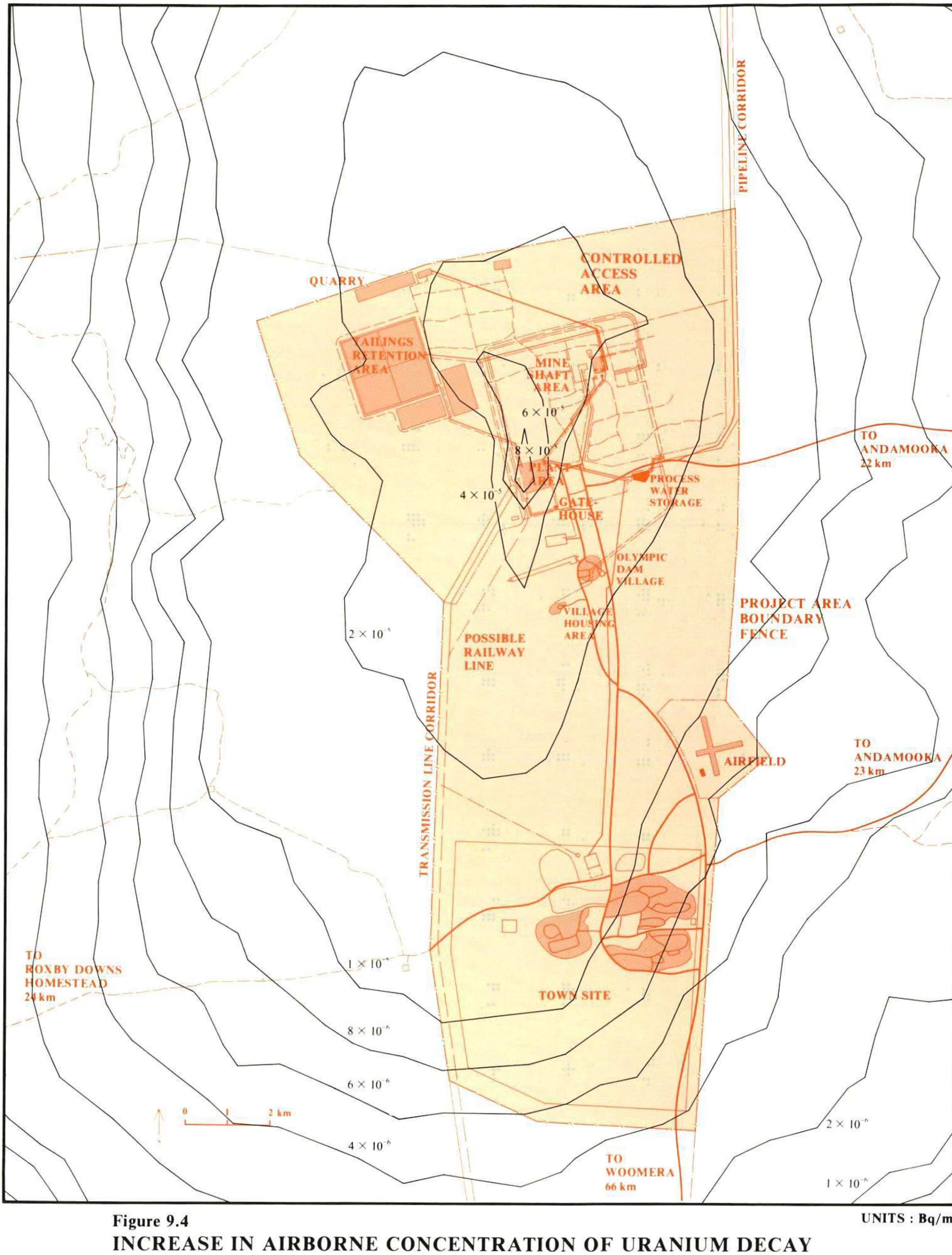
In Table 9.15, these maximum values are compared with the relevant derived limits from the Code of Practice. The comparison indicates that the maximum values for each radionuclide are well below the respective derived limits for members of the public. In the northern part of the town, corresponding to the occupied location nearest to the operations area, the concentrations at maximum production are at least three orders of magnitude (1:1,000) lower than the derived limits, while at the administration office the concentrations are at least two orders of magnitude (1:100) lower than the derived limits.



UNITS: Bq/m³

Figure 9.3

INCREASE IN AIRBORNE CONCENTRATION OF URANIUM DUE TO PROJECT OPERATIONS



UNITS : Bq/m³

Figure 9.4

INCREASE IN AIRBORNE CONCENTRATION OF URANIUM DECAY PRODUCTS DUE TO PROJECT OPERATIONS

Table 9.15 Annual average radionuclide concentrations in air during full production

	U-238 U-234 (Bq/m^3)	Th-230 (Bq/m^3)	Ra-226 (Bq/m^3)	Pb-210 (Bq/m^3)
Town (north end)	1.8×10^{-5}	1.6×10^{-5}	1.6×10^{-5}	1.6×10^{-5}
Administration office	7×10^{-5}	6×10^{-5}	6×10^{-5}	6×10^{-5}
Derived limit for members of the public	1.5×10^{-1}	1.1×10^{-2}	7.4×10^{-2}	3×10^{-1}

Radon daughters

Figure 9.5 shows the annual mean increment to the airborne concentrations of radon daughters due to Project operations at full production. The radon daughter concentrations are in Working Levels derived from the approximate expressions:

$$WL = 6.2 \times 10^{-6} \times (Rn) \times t^{0.85} \quad \text{for } t \leq 90 \text{ minutes}$$

$$WL = 2.7 \times 10^{-4} \times (Rn) \times t \quad \text{for } t > 90 \text{ minutes}$$

where (Rn) is radon concentration at the point of interest in Bq/m^3, and

WL is radon daughter concentration in Working Levels.

At the northern end of the town, the annual average radon daughter concentration increment is 5×10^{-5} WL, while at the administration office in the plant area the concentration is 1×10^{-4} WL. These are two and three orders of magnitude below the derived limit for radon daughters for members of the public of 1×10^{-2} WL. It should also be noted that natural background radiation as discussed in Section 9.2 is of the order of 3×10^{-4} WL.

The decay of radon gas also results in an additional source of radiation, lead-210. The activity concentration ratio of lead-210 to radon-222 in the air is 5×10^{-6} for an elapsed time of three hours (the assumed travel time to the town site some 10 km away from the source). Applying this factor to predicted radon concentrations at the northern end of the town at full production (0.36 Bq/m^3) gives a local lead-210 concentration of 1.8×10^{-6} Bq/m^3. This is an order of magnitude below the lead-210 levels from radionuclide particulates (Table 9.15) and more than two orders of magnitude below the normal ambient levels of lead-210 of 7.4×10^{-4} Bq/m^3 (UNSCEAR 1977). Therefore, lead-210 levels from radon decay are not considered further in this analysis of public exposure.

Post-production period

Figure 9.6 shows the incremental increase in radon daughter concentrations in the post-production period when mining and processing has ceased. The maximum concentration increment in the vicinity of the Project Area is 1×10^{-4} WL at the margins of the tailings storage. This is two orders of magnitude below the public exposure limit. At the northern end of the town the concentration increment is 1×10^{-5} WL, which is three orders of magnitude below the public exposure limit, and is negligible when compared with the natural background radon daughter levels as discussed above.

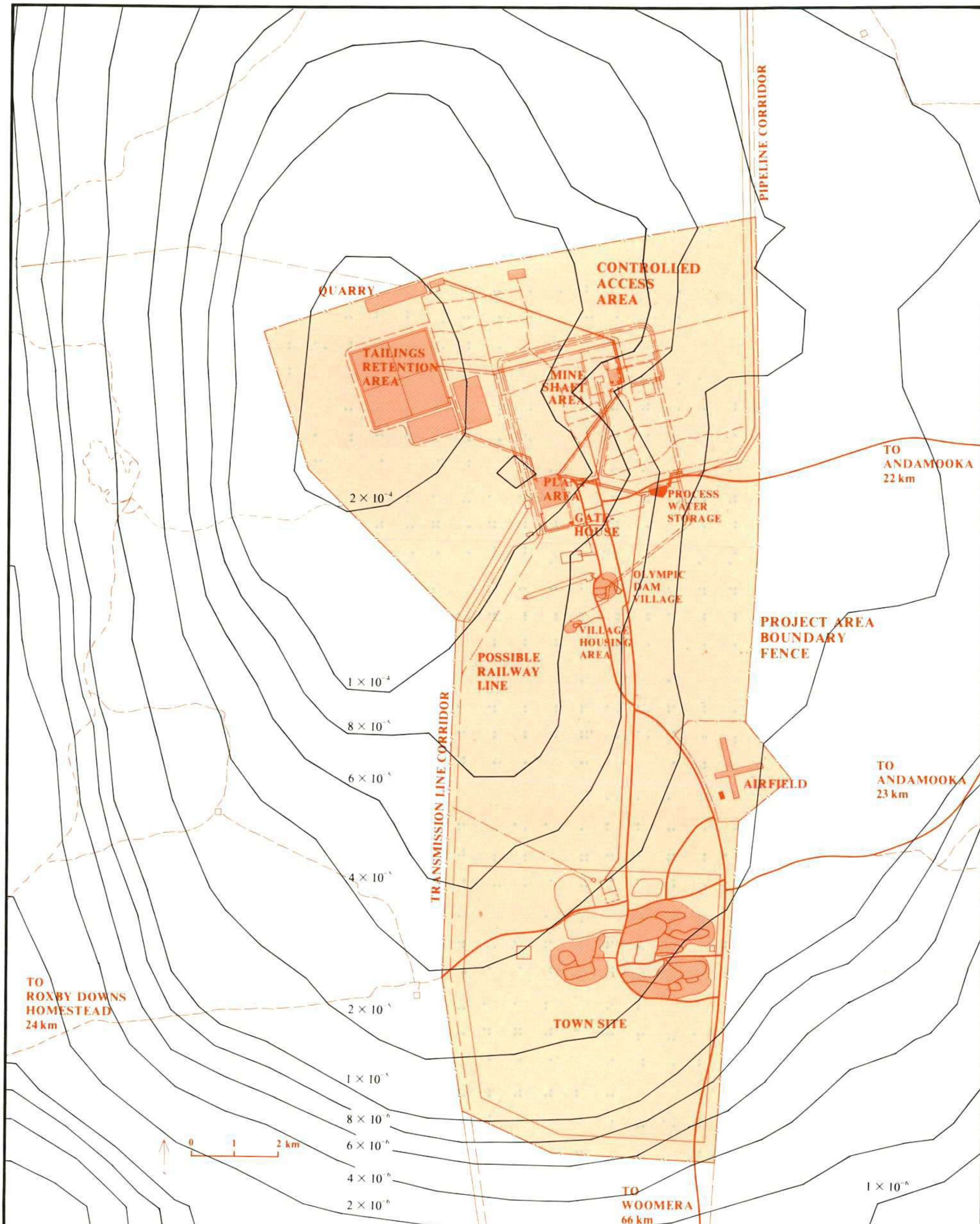
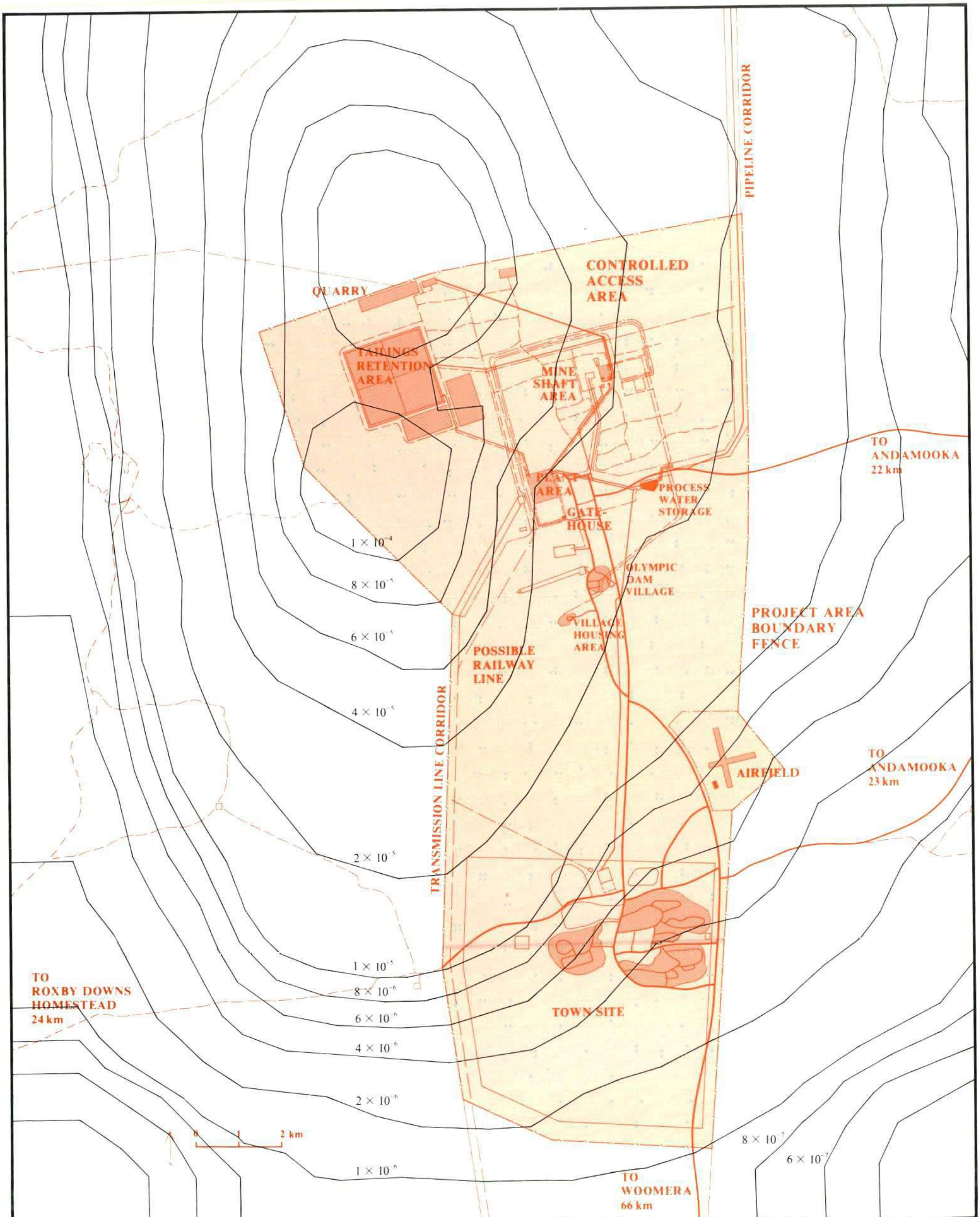


Figure 9.5 UNITS : WORKING LEVEL (W.L.)

INCREASE IN AIRBORNE CONCENTRATION OF RADON DAUGHTERS DUE TO PROJECT OPERATIONS



UNITS : WORKING LEVEL (W.L.)

Figure 9.6

INCREASE IN AIRBORNE CONCENTRATION OF RADON DAUGHTERS DURING POST-PRODUCTION PERIOD

9.5 RADIOACTIVITY DOSE ESTIMATES

9.5.1 Employee exposure

Testing for compliance with the criteria set out in Section 9.3.2 for limiting the overall exposure of employees to radiation now follows.

The Joint Venturers propose to limit the overall exposure of employees to radiation by limiting the contribution from all mechanisms, taken together, in a coherent manner. The mathematical expression of the limit is as follows:

$$\underbrace{\frac{D}{0.05}}_{\text{Gamma component}} + \underbrace{\frac{E}{4}}_{\text{Radon daughter component}} + \underbrace{\sum_i \frac{I_i}{ALI_i}}_{\text{Radionuclide component}} < 1 \qquad (1)$$

where D = annual dose equivalent from gamma rays (Sv)

E = annual exposure to radon daughters (WLM)

I_i = annual intake of radioactive element or nuclide 'i' (Bq)

ALI_i = annual limit of intake by breathing of radioactive element or nuclide 'i' (Bq).

$\sum_i$ - signifies that all the radioactive elements and nuclides must be taken into account.

Mine employees

Gamma radiation: For mine employees, gamma radiation exposure has been estimated to be 5×10^{-3} Sv/a (Section 9.4.4). This means the gamma component (D/0.05) is 0.1 in expression (1). While there will be some shielding from equipment which may reduce the exposure, this will be ignored for the purposes of making a conservative estimate.

Radon daughter exposure: In underground mines, exposure to radon daughters has been historically the dominant exposure mechanism. The example given in Section 9.4.3 indicates a radon daughter concentration of 0.02 WL. This gives rise to an annual exposure of about 0.2 WLM. The exposure to radon daughters will be strictly controlled by the design and operation of the ventilation system and mining methods to maintain low radon daughter concentrations in occupied workplaces to a design limit of 1 WLM/a. Operational procedures will be implemented to monitor adherence to the design exposure limit (Section 9.7.4).

This design exposure limit is one-quarter of the Code of Practice limit, thus making E/4 in expression (1) equal to 0.25.

Radionuclide exposure: Minimization of exposure to long-lived radionuclides in ore dust follows from the dust suppression criterion required in respect to silica, where continuous average dust concentrations of less than 1 mg/m^3 will be maintained in general working zones (Section 9.4.2). Exposure through inhalation of radionuclides can be estimated through derived limit concentrations (Table 9.6) assuming 1 mg/m^3 dust level with a specific activity of 7.9 Bq/g (Section 9.4.2). The inhalation portion of the radionuclide component expressed in derived limit concentrations is:

$$\sum_i \frac{C_i}{DLC_i}$$

where C_i = the time-weighted average concentration of radionuclide 'i' (Bq/m^3)

DLC_i = derived limit concentration for the same radio nuclide (Bq/m^3).

From Table 9.16 the inhalation component of expression (1) is about 0.03.

Table 9.16 Mine worker exposure to radionuclides through inhalation

Radionuclide	Concentration in air (C_i) (Bq/m^3)	Derived limit concentration (DLC_i) (Bq/m^3)	$\frac{C_i}{DLC_i}$
U-238, U-234	7.9×10^{-3}	3.7	.002
Th-230	7.9×10^{-3}	0.37	.021
Ra-226	7.9×10^{-3}	1.9	.004
Pb-210	7.9×10^{-3}	7.4	.002
Total inhalation component			.028

Exposure to radionuclides can also occur through direct ingestion (by transfer of dust from hands to mouth). Crib and washroom areas will be regularly cleaned, and those areas together with personnel will be regularly monitored to ensure high standards of personal radiation hygiene as laid down by the Code of Practice, thus rendering this source insignificant.

Summation of exposures: The overall exposure for mine employees is well within the employee exposure criterion (i.e. the limit in expression (1) above, which the Joint Venturers have adopted). The numerical terms in expression (1) are 0.1, 0.25 and 0.03 respectively, reflecting the Joint Venturers' commitment to reduce exposure to the lowest practicable level.

Plant employees

Gamma radiation: The maximum gamma radiation exposure for plant employees will be received by those working in yellowcake drying and packaging. The whole body dose equivalent in this instance could reach 0.01 Sv/a (Section 9.4.4) which is 0.2 of the maximum permissible.

Radon daughter exposure: Localized increases in radon daughter concentrations can occur which are greater than the mesoscale computer model dispersion predictions, particularly for plant employees working within, or immediately adjacent to, the tailings retention area.

Under conditions of low wind speed (0.5 m/sec.) and low inversion height (100 m), with normal operating emanation rates ($0.6\ Bq/m^2.s$ - Section 7.4.1), over 1500 hours per annum, a worker would receive a radon daughter exposure of 0.03 WLM. This is less than 0.01 of the 4 WLM/a limit for employees.

Radionuclide exposure: The plant areas are generally well ventilated, being open to the atmosphere. As airborne dust measurements in the plant area are unlikely to exceed $1\ mg/m^3$ (based on the experience of measurements at the Ranger and Nabarlek treatment plants), the inhalation component will be less than the 0.03 calculated above for mine employees.

Summation of exposures: The sum of the components (0.2 + 0.01 + 0.03) in expression (1) for plant employees is less than 0.25, i.e. about one-quarter of the strict criterion set by the Joint Venturers.

9.5.2 Exposure of members of the public

The expression in Section 9.3.3 which the Joint Venturers have adopted as the limit for Project related incremental exposure of members of the public is as follows:

$$\frac{E}{0.4} + \sum_i \frac{I_i}{ALI_i} + \sum_i \frac{I_i}{ALI_i} < 1 \qquad (2)$$

Radon daughter component — Radionuclide inhalation component — Radionuclide ingestion component

where E = annual exposure to radon daughters (WLM)

I_i = annual intake by inhalation or ingestion of radioactive element or nuclide 'i' (Bq)

ALI_i = annual limit of intake by inhalation or ingestion of radioactive element or nuclide 'i' (Bq), and

$\sum_i$ - signifies that all the radioactive elements and nuclides must be taken into account.

This expression is analysed below both for residents in the town and for office workers in the operations area. For comparative purposes, an analysis is also made of public exposure due to naturally occurring radiation sources.

Town residents

Radon daughter exposure: The annual average incremental increase in radon daughter concentration due to Project operations at the northern end of the town was estimated to be 5×10^{-5} WL (Section 9.4.5). This results in an annual exposure of $5 \times 10^{-5} \times (365 \times 24)/170 = 2.6 \times 10^{-3}$ WLM, and provides a radon daughter component (E/0.4) in expression (2) of 0.007.

Radionuclide inhalation: Table 9.15 summarized the incremental increases in annual average radionuclide concentrations in air during full production. Adding the fractional contributions of the radionuclides in terms of their derived limits of concentration, the radionuclide inhalation component is:

$$\frac{1.8 \times 10^{-5}}{1.5 \times 10^{-1}} + \frac{1.6 \times 10^{-5}}{1.1 \times 10^{-2}} + \frac{1.6 \times 10^{-5}}{7.4 \times 10^{-2}} + \frac{1.6 \times 10^{5}}{3 \times 10^{-1}}$$

Uranium fraction — Thorium fraction — Radium fraction — Lead fraction

= 0.002

Radionuclide ingestion through consumption of drinking water: This is one of the three possible pathways considered for incremental increase in radionuclide ingestion due to Project operations. Water supplies will be drawn from the Great Artesian Basin. Tests to date on this water suggest that the concentration of radium-226, the principal radionuclide of interest, will be less than 4×10^{-2} Bq/L, i.e. one-tenth of the Code of Practice limit for members of the public. Water supply from the Great Artesian Basin will not be influenced by the Project emissions, therefore there will be no incremental effect for inclusion in expression (2).

Radionuclide ingestion through consumption of locally produced meat: In considering this second possible pathway, a vegetation monitoring site 6 km west of Olympic Dam on the Lake Blanche Road, 2 km south of the tailings retention area, has been tested for exposure to dust emissions in order to assess the upper limit of impact of the Project on the dietary intake of sheep, cattle and kangaroos. The average annual ground level concentrations in air at the selected shrubland grazing site, derived from the dispersion model, are as follows for the maximum production phase:

U series (excluding U-238, U-234)	1.8 x 10^{-5} Bq/m
U-238, U-234	1.8 x 10^{-5} Bq/m
Radon daughters	2 x 10^{-4} WL.

The average yearly intake of vegetation from this area has been estimated for sheep, cattle and kangaroos, based on stocking rates of 8 ha, 30 ha and 20 ha per animal respectively (Fatchen 1982). Comparisons have been made between the intake from swale and sand dune areas, but for the purpose of this assessment the swale area has been used, as there is little difference between the two (Table 9.17).

Table 9.17 Estimates of annual average intake of vegetation by grazing animals

Animal	Annual average intake (kg)*		
	Saltbush	Grass	Other
Sheep	132	220	88
Cattle	1,642	1,460	548
Kangaroos		495	55

* = dry weight.

The forage available during any year is estimated to be 625 kg/ha dry weight, of which 150 kg is saltbush, 350 kg grasses and the remainder miscellaneous trees and bushes. Dust retention characteristics of the vegetation have been compared with those taken for another dry inland Australian site (Western Mining Corporation 1978) and a suitably conservative assumption of 0.5 for the dust retention factor has been used for Olympic Dam. A steady state of foliage dust accumulation is virtually reached in 100 days or so. Table 9.18 sets out the results of these calculations, which are compared with existing values taken from foliage samples at Olympic Dam. The figures have been drastically rounded up in recognition of the approximations inherent in the assumptions made. Transfer coefficients (USNRC 1980) have then been applied to estimate the uptake of incremental radionuclides in the flesh of cattle as a result of consuming fodder from the selected site.

Table 9.18 Incremental increase in radionuclide content of fresh flesh of cattle due to Project operations

Radionuclide	Existing activity in foliage at Olympic Dam (Bq/g)	Incremental activity in foliage due to Project operations (Bq/g)	Incremental activity uptake by cattle (Bq/g)
U-238,U234	6 x 10^{-4}	2 x 10^{-3}	7 x 10^{-6}
Th-230	4 x 10^{-4}	2 x 10^{-3}	4 x 10^{-6}
Ra-226	3 x 10^{-4}	2 x 10^{-3}	1 x 10^{-5}

As noted in Section 9.4.4, the Project operations barely disturb the long-term ambient concentrations of lead-210. As a check on the order of accuracy of the simulation methods adopted for incremental radioactivity, it is of interest to note the reasonable agreement between the actual measured lead-210 in vegetation and that assessed using an ambient concentration in air of 7.4×10^{-4} Bq/m .

Given the location of the test site, which is some 2 km south of the tailings retention area, and the general wide ranging grazing habits of sheep and cattle, the results will grossly overestimate the increases occurring during production. Nevertheless, changes in contaminant levels will be regularly monitored, and grazing will be regulated accordingly in the immediate vicinity of the operations area.

Human consumption of meat flesh is taken at 300 g/d on average. Of this, it is conservatively assumed that 20% will be from locally produced sources, although it is recognized that in practice this is likely to be a much lower percentage. Using these estimates for the activity of local meat, an estimate of the daily intake of incremental activity derived from that meat can be made for town residents. This in turn can be compared with the maximum permissible daily intake for members of the public derived from ICRP (1977) recommendations and the Code of Practice. The total ingestion contribution from this pathway is shown in Table 9.19 to be less than 0.0007. A similar exercise carried out for people eating only kangaroo flesh and viscera rather than the animal products assumed previously will yield fractions comparable with those of Table 9.19.

Table 9.19 Exposure through consumption of locally produced meat

Radionuclide	Activity in local meat intake (Bq/a)	Annual limit of intake (ALI) (Bq)	Fractional contribution to ingestion exposure
U-238,U-234	1.5×10^{-1}	3×10^{4}	5×10^{-6}
Th-230	9×10^{-2}	6×10^{4}	1.5×10^{-6}
Ra-226	2×10^{-1}	3×10^{2}	6.7×10^{-4}
Total contribution to ingestion exposure			6.8×10^{-4}

Radionuclide ingestion through consumption of local vegetables and fruits: Vegetable and fruit consumption in Australia is thought to be on average 0.4 kg/d (Hollingsworth and Hobson 1966), and a proportion of this could come from locally grown produce. From earlier discussion, the estimated annual average concentrations of contaminants in air at the northern end of the town closest to the operations area are as follows:

- U-238,U-234 — 1.8×10^{-5} Bq/m
- Th-230, Ra-226 — 1.6×10^{-5} Bq/m .

The soil at the town contains 4×10^{-2} Bq/g of radium-226, which is comparable to a typical inland soil. Irrigation water from the Great Artesian Basin will be substantially below Code of Practice limits for radioactivity consumption by members of the public. Generally, incremental increases in radioactivity in home grown produce as a result of dust deposition in the town soil and irrigation water will be negligible. However, the increases arising from dust deposition directly onto vegetables with assumed high retention characteristics (e.g. cauliflowers and cabbages) require consideration.

The approach used for this third pathway is similar to that employed to estimate the incremental increase in radioactivity in forage. In the case of vegetables, a similar retention factor of 0.5 has been taken (appropriate to cauliflowers and cabbages), with a contaminant removal half-life of twenty days and a further reduction of 50% in deposited radioactivity due to preparation for consumption. The average incremental intake in radioactivity (assuming 30% of the total consumption of 0.4 kg/d comprises locally grown vegetables) is shown in Table 9.20. This table also sets out the comparison between the estimated incremental activity received by ingestion from locally produced vegetables and the maximum permissible annual intake derived from the Code of Practice. The total contribution to ingestion exposure is about 0.003.

Table 9.20 Exposure through consumption of locally produced vegetables

Radionuclide	Activity in local vegetable intake (Bq/a)	Annual limit of intake (ALI) (Bq)	Fractional contribution to ingestion exposure
U-238,U-234	1.0×10^{0}	3×10^{4}	3×10^{-5}
Th-230	9×10^{-1}	6×10^{4}	1.5×10^{-5}
Ra-226	9×10^{-1}	3×10^{2}	3×10^{-3}
Total contribution to ingestion exposure			3×10^{-3}

Total radionuclide ingestion component: Total contribution to the incremental radionuclide ingestion component is therefore less than 0.004.

Summation of exposures: The various components for incremental exposure of town residents are:

- radon daughter component 0.007
- radionuclide inhalation component 0.002
- radionuclide ingestion component 0.004.

For expression (2), this gives a total of 0.013, which is therefore a factor of 75 below the design criterion which the Joint Venturers have set. This is principally due to the town being sited well clear of the operations area, and because of the operational safeguards already described for the mine, plant and tailings storage.

Office workers

As the radionuclide ingestion exposure for office workers will be the same as for the town residents, only the radon daughter and radionuclide inhalation exposures are analysed below.

Radon daughter exposure: From Section 9.4.5, the incremental increase in radon daughter concentration in air at the administration office is 1×10^{-4} WL. On a conservative basis of assuming continuous presence at the office, this results in an annual exposure of 5.2×10^{-3} WLM and provides a radon daughter component (E/0.4) in expression (2) of 0.013.

Radionuclide inhalation: From Table 9.15, the incremental increases in airborne radionuclide concentrations at the administration office give the following fractional contributions to the radionuclide inhalation component:

$$\frac{7 \times 10^{-5}}{1.5 \times 10^{-1}} + \frac{6 \times 10^{-5}}{1.1 \times 10^{-2}} + \frac{6 \times 10^{-5}}{7.4 \times 10^{-2}} + \frac{6 \times 10^{-5}}{3 \times 10^{-1}}$$

Uranium fraction + Thorium fraction + Radium fraction + Lead fraction

= 0.007.

Summation of exposures: The various components for incremental exposure for office workers are:

- radon daughter component 0.013
- radionuclide inhalation component 0.007
- radionuclide ingestion component 0.004.

This gives a total of 0.024 for expression (2) which is a factor of 40 below the design criterion.

Natural radiation exposure

To provide a further assessment of the level of incremental exposure to radiation due to Project operations, a comparison is made with the radiation exposure arising from naturally occurring sources of radioactivity. These are principally:

- background gamma radiation measured to be 10µSv per week (Section 9.2.2)

- ambient radon daughter concentrations measured to be about 3×10^{-4} WL (Section 9.2.3)

- radionuclide content of airborne dust, which has an average concentration of the order of 20µg/m³ and the activity of which can be assumed from radioactivity in soils (Table 9.2)

- radionuclide content of food, where the principal exposure is from the radium content of drinking water: this has been measured as 26 mBq/L from Borefield B and 63 mBq/L from Borefield A (Table 2.2).

Table 9.21 sets out the natural levels of these radiation exposure sources and compares the natural exposure with the Code of Practice limits for members of the public. The fractional contribution to the criterion for limitation of exposure to members of the public similar to expressions (1) and (2) used above is also calculated. It can be seen that exposure from natural sources is about one-sixth of the limit criterion and about an order of magnitude higher than the incremental exposure due to Project operations for office workers and town residents.

Table 9.21 Public exposure to natural radiation

Exposure component	Natural level	Natural exposure	Public exposure limit	Fractional contribution
Gamma radiation	10µSv/w	0.5 m Sv/a	5 m Sv/a	0.1
Radon daughters	3×10^{-4} WL	0.015 WLM/a	0.4 WLM/a	0.04
Airborne dust	20µg/m³			
U-238,U-234	.01 Bq/g	2×10^{-7} Bq/m³	1.5×10^{-1} Bq/m³	1×10^{-6}
Th-230	.01 Bq/g	2×10^{-7} Bq/m³	1.1×10^{-2} Bq/m³	2×10^{-5}
Ra-226	.01 Bq/g	2×10^{-7} Bq/m³	7.4×10^{-2} Bq/m³	3×10^{-6}
Pb-210	.05 Bq/g	1×10^{-6} Bq/m³	3.0×10^{-1} Bq/m³	3×10^{-6}
Ra-226* in water	33 mBq/L	3.3 Bq/m³	370 Bq/m³	0.01
Total natural exposure				0.15

* Weighted average of Borefield A and B radium content reduced to 10% of raw water value through desalination.

9.6 YELLOWCAKE HANDLING, PACKAGING, AND TRANSPORT

Handling and packaging

Exposure of workers involved in yellowcake handling and packaging within the plant will be controlled by engineering design aimed at minimizing the release of dust into the air and maximizing containment of spillage. Personal respiratory protection in the calcining and yellowcake packaging areas is regarded as an inferior method of protection to the provision of a clean atmosphere within the workplace, and the design intent is to limit the use of personal respiratory protection to certain maintenance procedures only.

Spillages of uranium concentrate within the plant area will be handled either by washing the material to sumps from which it will be pumped back into the circuit, or by vacuuming. In the event of any spillage outside the calcining or packaging area, or of a severe spillage inside, the spillage will be isolated, operators will be clothed in overalls and equipped with powered respirators, and clean-up will proceed until monitoring by the Radiation Safety Officer or his deputy indicates an acceptable level of decontamination as defined in the Code of Practice. The clean-up crew will change and shower after the completion of clean-up.

Transport regulations

Planning is presently proceeding on the basis that uranium concentrate will be transported by road to Port Adelaide via Pimba and Port Augusta. The option of rail transport is also under consideration. However, the discussion which follows is based on road transport.

Transport of uranium oxide in South Australia will be governed by South Australian regulations which are likely to follow those adopted internationally, in particular the IAEA regulations for the transport of radioactive materials. Under these regulations, uranium oxide is designated a low specific activity material. It will be packed into steel drums, which will limit the radiation sources to external radiation only. The drums will then be packed in export shipping containers for transport.

The Joint Venturers will be responsible for the entire transport operation up to and including off-loading at the port storage area. Experience with shipments from other Australian plants clearly indicates that radiation levels at the surface of the load will be a small fraction of IAEA regulatory limits (e.g. 0.05 m Sv/h, compared with 2 m Sv/h), and that drivers' dose rates will be well below the minimum dose applicable to that classification.

Transportation safeguards and monitoring

At maximum production, some seventy-five full vehicle loads of drummed and containerized uranium oxide per year will be taken over a 550 km route to the port. With a total distance to be travelled of 42,000 km/a and with truck road accident rates in Australia running at around one per 1,000,000 km travelled, there is a one in twenty-four chance of an accident in any year. The chance of a severe accident involving a substantial spillage of uranium concentrate by rupture of the steel drums is very substantially less, particularly as the drums are enclosed by the steel container. However, the Joint Venturers are committed to accident action planning as part of their operations programme.

Crews will be given instruction and refresher courses on the action to be taken in the event of an accident, and instructions will be clearly displayed in truck cabins. Local police will also be notified of these instructions. These procedures will be in accordance with agreements reached with the Health Commission. Uranium oxide spilt on the road or verge is not, however, a significant radiological hazard. It is of low specific activity and virtually insoluble in water. In the case of an accident, the Radiation Safety Officer would attend the scene as soon as possible to assess the nature of the loss and the appropriate means of retrieval. The spill would be isolated, defined by markers, and covered or wetted down. A trained team wearing protective clothing (commensurate with that required for manual operations involving uranium oxide in the plant) would clear the product using appropriate mechanical means designed to minimize dust arisings. This clearing would continue until surface contamination levels were around 3.7×10^5 Bq/m^2, which is approaching the limit of visual detection. The recovery team would be checked to ensure that skin contamination was at a level of 3.7×10^3 Bq/m^2 or less, again commensurate with plant hygiene requirements. The cleared product would then be returned to the plant for treatment.

Final details of the route for yellowcake transport will be the subject of future review and agreement with the South Australian Department of Transport. The route will cross a number of rivers and waterways, many of them dry, particularly during summer months. These include:

- the Gawler River
- the Light River
- the Wakefield River
- the Mambray Creek
- the causeway at Port Augusta
- the salt lake causeway at Wirrappa.

The risk of an accident occurring of sufficient severity to rupture both the drums and the container and to produce substantial spillage into a waterway along the route is at least two orders of magnitude less than a similar accident over dry land (based on the relative lengths of the route over land and water). If substantial spillage did occur, the Joint Venturers would mobilize equipment with the aim of recovering the material prior to its becoming dispersed in the waterway. This would be facilitated by the density, colour, and insolubility of yellowcake. Should recovery be seriously incomplete due to lack of access or similar difficulties, short-term monitoring of the waterway would be instituted to ensure that adequate dispersion had occurred.

This procedure, and the recovery procedures nominated for dry land, are similar in principle to those which would apply to toxic and/or inflammable substances routinely transported by road.

9.7 RADIATION MONITORING PROGRAMMES

9.7.1 Environmental radiation monitoring during operations

The aim of operational monitoring will be to detect changes from baseline conditions. Environmental monitoring to be undertaken during the operational phase will thus continue the monitoring presently being undertaken as part of the baseline studies. In all aspects of the development of this monitoring programme there will continue to be full consultation with the Department of Mines and Energy and with the South Australian Health Commission.

Meteorological data collection and high volume air sampling for dust will continue into the operational period, with analysis of filters by gravimetric and gross alpha counting methods to give three-monthly airborne uranium and radium time-weighted average concentrations.

Present baseline monitoring of radon is performed at the Sandhill meteorological station. In the operational period, monitoring of atmospheric radon and radon daughter levels will be performed at the town and at other public locations as part of the continuing environmental monitoring programme. Some of this work will be performed using continuous-running samplers already on site and operational (Section 9.2.1) while some will be by grab sampling at a frequency to be determined following consultation with the Department of Mines and Energy and the Health Commission.

Vegetation will be sampled on a yearly basis for radionuclides using the same species and the same locations as those used in the baseline study. Details of other biological monitoring will also be compatible with pre-operational baseline studies in terms of sampling location and species selection.

9.7.2 Present occupational radiation monitoring programme

Radiation monitoring is presently carried out by a full-time radiation technician on site at Olympic Dam for occupational radiation protection of core farm workers and underground miners who have contact with radioactive ores as part of their everyday work. The present programme of occupational monitoring (which covers both workplaces and personnel) is approved by the Department of Mines and Energy and the Health Commission, and is reviewed as operations change. The results of this programme, which is outlined in Table 9.22, are reported at regular intervals to both these Departments.

As a result of numerous measurements at the core farm and in the sample preparation building it is clear that, with regular cleaning of work areas and with proper maintenance of ventilation and dust extraction systems, surface and airborne contamination levels remain well under the Code of Practice limits. Gamma dose rates and radon daughter concentrations measured to date during the shaft sinking and plat cutting operations have all been well below these limits.

Table 9.22 Present monitoring programme

	Core farm	Shaft site	Environmental
Gamma radiation	TLD badges on workers (monthly cycle)	TLD badges on workers and instrument surveys weekly	TLDs used as environmental monitors
Radon daughters	Monthly measurements in sample preparation building	Twice weekly at sub-brace chamber and plats	Monthly, out of doors
Airborne radionuclides	Personal dust samples on selected workers weekly	Personal dust samples on selected workers weekly	High volume sampler filter renewed weekly
Surface contamination	Weekly inspections with alpha probe of work surfaces, crib room and workers' hands and clothes	Weekly inspections with alpha probe of workbenches, crib room and workers' hands and clothes	

9.7.3 Employee instruction for radiation safety

An education programme is being developed for Project employees. A Radiation Safety Manual has been written which is issued to all new employees in the core farm and the shaft area, including surface as well as underground workers. This manual has been discussed with the regulatory authorities and is subject to continuing review and improvement. All new designated employees as defined by the Code of Practice are at present individually instructed soon after appointment, although once operations commence on a larger scale more formal group lectures will be given. Periodic follow-up discussions are being held with core farm workers, underground miners, and staff groups.

9.7.4 Occupational monitoring programme during production

General philosophy

Regular operational monitoring of radioactive and non-radioactive contaminant levels will be carried out by the Joint Venturers to enable adherence to commitments to limit exposure agreed with the statutory authorities. Independent checking procedures will also be regularly conducted by the South Australian Department of Mines and Energy and the South Australian Health Commission.

One of the aims of the radiation monitoring programme is to generate data to serve as a basis for management decision-making. Thus the programme will specifically incorporate 'trigger points' (i.e. radiation levels below the Code levels) which, when exceeded for a specified time, will require a specific programme of actions to be undertaken within a set time scale. It is the explicit policy of the Joint Venturers to develop an appropriate series of responses designed specifically for each aspect of the operation. Action to be taken as a result of information provided by the monitoring plan will be in the nature of a graded response, depending on the level of radiation monitored and on whether radiation levels are decreasing or increasing. This action can be based on:

- the Code guideline suggesting 'protective action levels' which, when exceeded, trigger clearly defined responses;
- 'internal reporting levels' set by management, which provide operational supervisors with early warning to enable corrective action to be taken before operations are affected.

Because management will require warning of developing trends at levels significantly below protective action levels (PALs), and because any excursions above PALs will need to be well documented, it is probable that monitoring frequency will be greater than that recommended by the Code of Practice guidelines. The reporting of radiation hygiene hazards, contaminant sources, and excursions above PALs will be by formal written report, and will explicitly transfer responsibility for corrective action to the operational department involved.

Details of instruments and frequencies

Radiation monitoring must perform two separate functions:

- documentation of personnel exposures (integration over time);
- a control function, entailing information to line management concerning:
  - control of personnel exposures, including identification of undesirable trends and of uncharacteristically high readings;
  - engineering and procedures control, such as efficiency checks of ventilation and dust extraction systems, regular cleaning, and personal hygiene.

For documentation, dose integration over a long term (e.g. monthly) is appropriate. In the case of gamma exposure, TLDs will be used. However, long-period (monthly) personal dust monitors are not available, nor are long-period personal radon daughter monitors, although the latter are being developed. It is necessary therefore either for single shift measurements or for spot measurements to be taken, with longer-term exposures being calculated on the basis of these measurements and the worker's occupancy time in each situation.

On the other hand, the control tasks outlined above characteristically call for a more rapid return of information, and in these instances the personal dust monitor (which gives results for dust exposure over an eight hour shift a few hours after its completion) is appropriate. Correction of a poor work practice or alerting a supervisor to a need for maintenance must be carried out on the following day at the latest to enable effective action.

The 'instantaneous' nature of the result from the classic Geiger-type gamma survey monitor is appropriate for mapping of radiation areas; the same applies to alpha contamination probes used for checking surface contamination. Instantaneous dust monitors have been developed which will give a spot dust reading following thirty seconds of sampling. The Joint Venturers intend to use such equipment.

The proposed monitoring programme is set out in detail below. It must be pointed out that the Code of Practice explicitly requires approval by the regulatory authorities, which in South Australia are the Department of Mines and Energy and the Health Commission, and as a consequence these authorities will have considerable input into determining the details of this monitoring programme.

In the monitoring programme for gamma radiation, instrument surveys will be carried out as underground headings are opened up. The general workforce will be monitored by monthly TLD badge readings.

The major radon daughter survey work will consist of weekly surveys of workplaces and transport ways. These surveys will completely cover all mine working areas to identify radon sources, and the intervals at which these will be repeated will be dependent on the readings and as approved by the Department of Mines and Energy and the South Australian Health Commission. These area measurements will probably be made by the Rolle or Kusnetz method of measuring Working Levels, and will then be multiplied by worker occupancy times for the purpose of calculating personnel exposures. Personal radon daughter monitors have not yet been proven in the field, although they are in an advanced stage of development. These will be used once they have been proven in extended field trials.

For dust control, there will be regular patrolling with instantaneous dust monitors to check the efficiency of engineering control systems, for example by spot readings to check dust extraction systems and for investigation of dust concentration variations while operations are in progress. Full shift gravimetric dust samples will also be taken at regular intervals for free silica determinations.

Those personnel working for periods in areas where higher than average mine dust arisings can occur (e.g. rock bolting in recently blasted zones) will be subject to regular monitoring with full shift personnel dust samplers. The filters will be analysed by gravimetric and radiometric methods.

There will be continuously-running high volume air sampling stations at strategic locations at the mine upcast shafts and ore treatment plant. These samplers will be read weekly and will provide data for engineering control procedures feedback and for environmental monitoring.

Surface contamination surveys will be performed at weekly intervals in mine offices, mine workshops, cribrooms and changerooms and in other workplaces as required, and also on the skin and clothes of employees. Hand alpha contamination monitors will be installed in the treatment plant changerooms and crib rooms, and at the yellowcake calciner and packaging station.

Personal dose and exposure results will be updated at regular intervals, and will be made available for inspection by each employee on request. The results of the routine monitoring programme (Table 9.23) will be reported to the regulatory authorities at approved intervals.

Table 9.23 Proposed operational monitoring programme

Pathways	Personnel monitoring	Area monitoring	Environmental monitoring
Gamma	TLD badges: monthly on all who work inside supervised area	Instrument surveys: weekly in mine, monthly elsewhere	TLDs
Radon daughters	Personal monitors: when proven and available commercially	Weekly surveys via grab sampling and Rolle or Kusnetz alpha counting	ARL integrating WL-hour dosimeter heads; grab sampling
Radon		Continous radon monitor for use as an investigation tool	Continuous radon monitor for ambient air; charcoal canisters for emanation studies
Airborne ore dust	Full shift personal samplers: coverage and frequency to be as approved by DME and SAHC (by alpha-counting of filters)	Fixed location samplers (by weighing and alpha-counting of filters); surveys with instantaneous dust monitor (weekly)	High volume air samplers with weighing of filters
Surface contamination by ore dust (long-lived alpha emitters)	Weekly check by radiation technician of randomly selected workers' hands and clothes.	Weekly surveys with alpha probe, covering workplaces, offices, crib and washrooms and randomly selected workers.	Not applicable

9.8 PROPOSALS FOR POST-PROJECT DECOMMISSIONING

The assessment provided in this Draft EIS is based on production continuing for thirty years. The actual timing of completion of mining and processing at Olympic Dam will depend upon future economic factors and cannot be forecast with accuracy at this point.

Details of decommissioning and future use of the existing plant and facilities will depend upon the outcome of discussion and review between the Joint Venturers and the State Government. Because of the very long operational period involved, detailed commitments cannot be made at this stage.

Insofar as the mine, plant and tailings retention facilities are concerned, the Joint Venturers anticipate that the following broad principles would be observed:

- mine openings would be sealed;
- equipment and facilities which are not saleable would be disposed of as directed by the State Government;
- all Project monitoring data would be reviewed to finalize the location of a controlled access area boundary;
- placement of the cover for the tailings retention area would be completed as described in Chapter 7.

CHAPTER TEN

Project Infrastructure

SUMMARY

Electricity supply

Initial power for the construction phase at Olympic Dam will be provided by a 132 kilovolt transmission line from Woomera, which will supply up to 30 megawatts from the existing Port Augusta to Woomera line. To provide the total of 100 to 130 megawatts required for Project operation, a 275 kilovolt line from Port Augusta will be constructed. It is expected that this power requirement can be met from currently planned additions to the Electricity Trust of South Australia's generating capacity. The route of the 275 kilovolt line will parallel the existing line from Port Augusta to Mount Gunson, and then join the corridor of the 132 kilovolt line at a point 6 km east of Woomera, remaining in this corridor until reaching Olympic Dam. This last section of dual lines will require a 100 metre wide corridor to provide for line separation, construction access and a service road. As no new service road will be required for the 145 kilometre section to Mount Gunson, land disturbance over this section will be confined to transmission tower sites, and environmental impact is therefore considered minimal. For the 115 kilometre section from Mount Gunson to Olympic Dam, tower construction and a service road as well as stringing of lines will involve some vegetation clearance and minor alterations to surface hydrology, both of which can initiate soil erosion and sand movement. However, vegetation clearance will be kept to a practical minimum, and disturbed areas will be rehabilitated in keeping with operation and maintenance requirements. Drainage and soil stabilization measures will be adopted where practicable to alleviate erosion impacts. During the stage of tower siting, surveys for archaeological sites will be undertaken. The route has been selected to avoid airfields, homesteads and sites of environmental significance. An exposed outcrop of the Andamooka carbonate sequence, a feature of geological significance near Purple Lake, will also be avoided, although the crossing of Lake Windabout will require at least one tower to be sited in the lake bed, with a causeway constructed for access.

Water pipeline corridor

During Project construction, water will be supplied at a rate of 6 megalitres per day by a pipeline from Borefield A on the southern margin of the Great Artesian Basin near Bopeechee, 100 kilometres north-east of Olympic Dam. To provide the additional water necessary to meet the operational Project demand of 33 megalitres per day, a second pipeline will be built from Borefield B deeper in the Great Artesian Basin, 50 kilometres north-east of Borefield A. A 50 metre wide corridor will be required to accommodate both pipelines, the 66 kilovolt transmission line (to provide power for pumps) and the 6 metre wide access road, as well as to provide construction access and sufficient pipeline/transmission line separation to avoid induced electrical currents.

The pipeline alignment has been chosen as the most direct route which takes account of environmental constraints, such as significant drainage depressions, gullies, escarpments, and mound springs. For the first 46 kilometres, the corridor crosses an east-west trending dune field. In this section, dunes are generally crossed at right angles to minimize the impact. The dunes change direction north of this point to almost north-south for the next 29 kilometres, allowing the corridor to be sited in swales parallel to the dune direction. Use has been made of the abandoned Marree to Alice Springs railway alignment for 9 kilometres from Bopeechee, following which the route goes north-east to Borefield B, crossing 37 kilometres of gypcrete/siltstone tableland with entrenched shallow water courses. Crossings of some drainage depressions, creek channels, and areas of dune instability will be given special attention in relation to erosion control and drainage. The corridor generally avoids areas of significant vegetation. It does however involve the clearance of some bullock bush and native pittosporum which, while classified as protected plants, are widespread in the region. In addition, the corridor bisects a stand of Sarcostemma australe which has a restricted occurrence in the region. An ungrazed dune field, rare in this pastoral country, will also be traversed by the corridor. However, this area will not be significantly affected, and the long deviation which would be required to avoid this dune field is not warranted. If an above ground pipeline is selected, stock and vehicle crossings will be provided in appropriate locations to minimize severance of pastoral land. Five archaeological sites considered of some scientific significance were identified in the corridor and will be subject to further recording.

Off-road vehicle movement by employees and contractors will be limited during construction and operation to minimize environmental damage. However, improved regional accessibility, while increasing the tourist potential of the area by removing one of the major constraints to tourist activity, has the potential for environmental damage which cannot be controlled by the Joint Venturers.

Borefield development

About five bores will be installed at Borefield A, with four operating at any one time. This will achieve an abstraction rate of 6 megalitres per day from the Cadna-owie Formation, a fine to medium grained sandstone which forms a southern extension to the Great Artesian Basin. At Borefield B, seven to ten bores (with two or three on stand-by) will abstract 27 megalitres per day from what is believed to be the Algebuckina Sandstone. At the time of writing, investigations were in progress to finalize bore locations and to obtain more detailed knowledge of the hydraulic parameters of the aquifers.

Water quality within the Basin generally has a salinity of 500 to 1,500 milligrams per litre (total dissolved solids) with high sodium bicarbonate levels. This water is generally unsuitable for irrigation because of the high sodium content and residual alkalinity. Salinity increases at the margins, with Borefield B ranging from 1,400 to 1,800 milligrams per litre, while the range at Borefield A is from 1,700 to 2,700 milligrams per litre. To the north-west of the borefields, sulphate levels are high, making the water corrosive and difficult to treat to provide a potable supply.

Further development of the Great Artesian Basin as a water resource is possible because the recharge rate is currently only about 2% of the water available for recharge. Increasing extraction will produce a steeper hydraulic gradient in the aquifer (thereby inducing greater recharge), as well as a lowering of the groundwater pressure throughout the Great Artesian Basin (resulting in a reduction in flows from existing bores and springs as well as a reduction in leakage from the aquifer), until a new equilibrium between recharge and discharge is established.

Current discharge from the entire Basin is estimated to be 3,100 megalitres per day, of which 45% is lost through vertical leakage to overlying sediments, and 6% is discharge from springs. The remaining 49% is bore discharge, of which less than 10% is used. Within 50 kilometres of the borefields, discharge through vertical leakage is estimated to be between 32 and 48 megalitres per day, while bores discharge about 13 megalitres per day (of which less than 1 megalitre per day is used for domestic purposes or livestock watering), and springs discharge about 1 megalitre per day.

The effects of pumping a total of 33 megalitres per day from the two borefields have been predicted by computer model. As the estimated current outflow in the nearby region is in excess of the required yield, the extraction will be balanced by the imposed reduction in other discharges (principally the upward leakage through the overlying shale, but also bore and spring flows). The flows in bores close to the borefields will be significantly reduced (at Crow's Nest Bore within the boundary of Borefield B, for example, a 100% reduction is predicted, while 25 kilometres away at Charles Angas Bore the reduction will be only 18%). The terms of the Indenture Agreement protect the rights of existing users, and the Joint Venturers must either make alternative supplies available or come to other suitable arrangements with users who are adversely affected. Furthermore, the Special Water Licence to be granted to the Joint Venturers under the terms of the Indenture Agreement requires the Joint Venturers to install and maintain an approved groundwater monitoring system, and to report annually on aquifer response and future water management.

The effect on mound springs in the area is of environmental significance. Mound springs are formed by the build-up of calcium carbonate which precipitates out of the waters of artesian springs and by the deposition of sediments transported to the surface by artesian waters. These springs occur along the southern and western margins of the Great Artesian Basin from Queensland through northern South Australia. Some are still active, some are waning in activity due to lowering of water pressure in the Basin from groundwater use, while others are inactive or extinct. The mound springs are of historical significance, as they provided a focus for early European settlement, being the only permanent source of water in the region. They are also of scientific importance, as some support rare vegetation and aquatic fauna, while the mechanism of their formation makes them of geomorphological interest. In addition, as the centre of Kuyani and Arabana mythology, the mound springs area is also of anthropological and archaeological significance.

The introduction of cattle and rabbits, and the presence of pastoralists and tourists have generated grazing and trampling pressures which have resulted in the degradation of many of the springs. The construction of the borefields will have no direct effects on mound springs, but pumping will reduce the flows in eight springs, including a 17 to 33% reduction for Hermit Hill Springs (a mound spring complex with some conservation significance). Further studies of mound springs and the development of measures to mitigate the effects on significant mound springs will be conducted in conjunction with the Department of Environment and Planning's current mound spring survey work and the Department of Mines and Energy's bore rehabilitation programme.

Other infrastructure

The existing transportation system within the region has sufficient capacity to accommodate the transport requirements of the Project. The Joint Venturers have already constructed an all-weather road from Olympic Dam to Pimba on the Stuart Highway. A rail spur from Pimba to Olympic Dam may be built in the future, subject to technical and economic review, but is not proposed in this Draft EIS. This spur would connect the Project to the Trans Australia Railway standard gauge line. Port Adelaide is the only South Australian sea port with the necessary facilities to service the Project, although some upgrading of bulk unloading facilities may be required to handle sulphur and pyrolusite. The existing airstrip at Olympic Dam is adequate for construction purposes, but a higher standard facility closer to the town will be required during Project operation. It is anticipated that connection with the national telecommunications network will be via microwave link from Woomera, to be installed by Telecom Australia.

10.1 ELECTRICITY SUPPLY

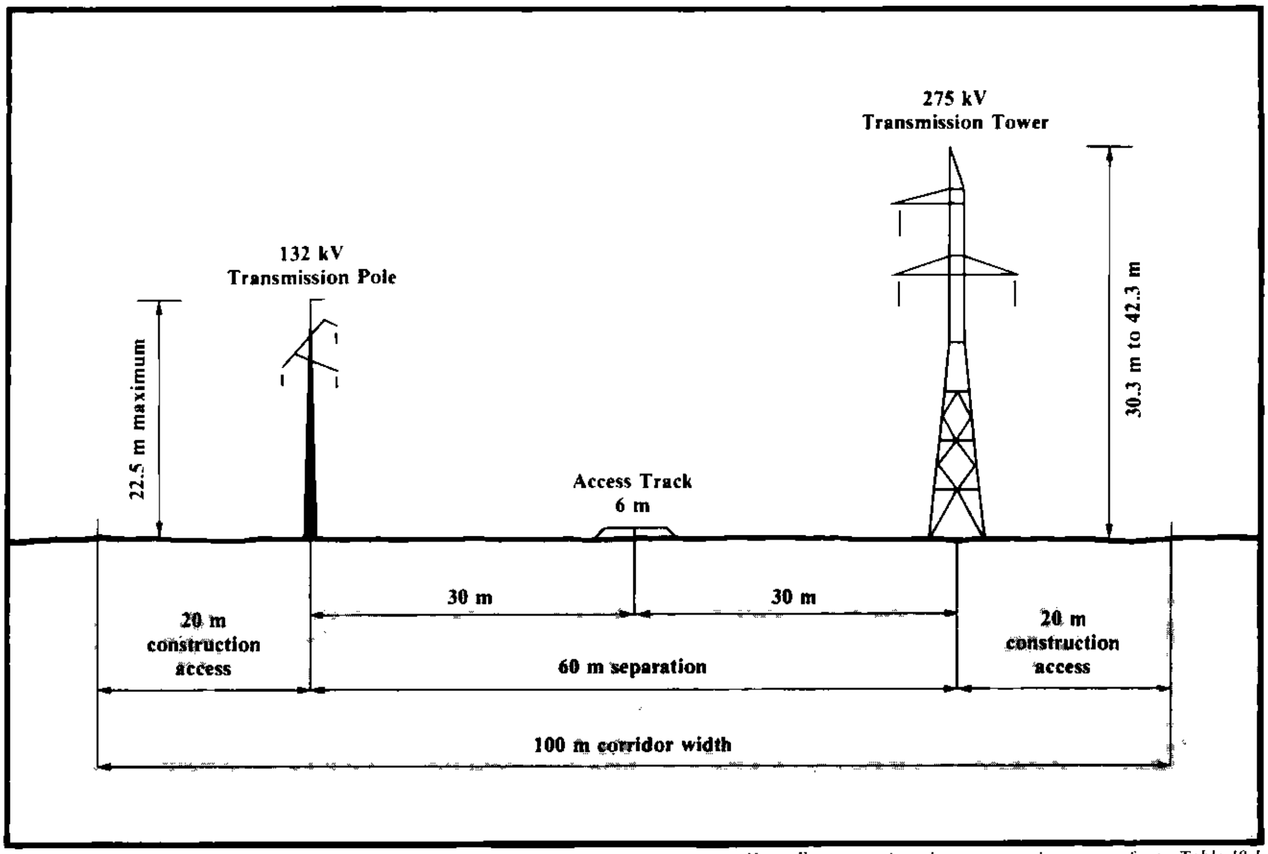
10.1.1 Proposed Project electricity supply

For construction purposes and during initial town occupation, 30 MW of power will be supplied by way of a 132 kV line constructed from Woomera. This will be supplemented by a 275 kV line from Port Augusta, to provide the total Project requirements during operation of between 100 and 130 MW. The corridor route for each line is shown on Figure 2.21. The 132 kV transmission line will commence at an onground switching station to be constructed approximately 3 km south of Woomera, adjacent to the existing 132 kV line servicing Woomera (Figure 10.1). The route selected is clear of the Woomera installations and those proposed at the mine and town. The 275 kV line will commence at the switching facilities at the Electricity Trust of South Australia (ETSA) substation at Davenport near Port Augusta. This corridor route parallels the existing 132 kV line to the east of Port Augusta, and will use the existing service road and corridor to a point about 35 km south-east of Woomera, just south of Mount Gunson, where the existing line veers slightly west to Woomera. From here, the new line will continue on a direct route to join the 132 kV line corridor to Olympic Dam at a point 6 km east of Woomera. It will then remain within this corridor until reaching the Project switchyard.

The 132 kV and the 275 kV transmission lines will be designed and constructed in accordance with normal ETSA standards (ETSA 1981a, 1981b; Terrain Analysis 1982) as required by Clause 18(20) of the Indenture Agreement. The alignment corridor for the dual lines will be approximately 100 m in width to accommodate the two lines and to provide the ETSA specified separation of 60 m (Figure 10.2). A 6 m wide cleared service track will be provided within the corridor for construction and maintenance access. The 132 kV line will be of conventional construction using steel lattice towers, stobie poles, or reinforced concrete tubular poles. The height of the towers for the 275 kV transmission line will vary between 30.3 and 42.3 m, while the maximum height of the poles for the 132 kV transmission line will be 22.5 m. Generally, the spacing between the towers will be approximately 420 m, and between the poles approximately 250 m. The line clearance criteria shown in Table 10.1 will be adopted for the design and construction of the transmission lines. The final tower or pole locations along the corridor will be determined by economic and engineering requirements, together with the environmental mitigation measures outlined in Section 10.1.4. The terrain along the corridor route will be a consideration in tower siting decisions as, in relatively flat country, span lengths can be increased without infringing the line clearance criteria. Cost optimization factors based on the relationship between tower height and span length will also be taken into account.

Access will generally be along the corridor, and gates or grids will be installed in all fences unless there is an existing gate in close proximity. The access track will be sheeted where the corridor crosses sand dunes or areas where surface deterioration could be expected due to vehicle activity. It is not envisaged that clearing of vegetation or disturbance will take place over the full width of the corridor, as it is the Joint Venturers' policy to clear only the minimum area required for construction

Figure 10.1
EXISTING INFRASTRUCTURE



Note: For vegetation clearance requirements refer to Table 10.1

Figure 10.2
TRANSMISSION LINE CORRIDOR, TYPICAL CROSS-SECTION

Table 10.1 Transmission line clearance criteria

Requirements	Clearance (m)		
	275 kV	132 kV	66 kV
Vertical ground clearance	7.6	6.7	6.7
Vertical clearance from railways	10.0	9.0	9.0
Vertical clearance from roads:			
Minimum	7.6	6.7	6.7
Desirable	9.1	9.1	9.1
Vegetation:			
Vertical clearance	3.0	3.0	3.0
Horizontal clearance	2.0	1.2	0.7

purposes, and to encourage revegetation of disturbed areas where appropriate. Generally an area of less than 1,000 m^2 at each tower site and about 100 m^2 at each pole site will be cleared of vegetation. Narrow strips along the alignment of each line will be cleared of all overhanging branches or trees to facilitate the stringing of conductors.

10.1.2 Alternative routes considered

The basis on which the selection of the transmission line corridor was made, and the alternatives which were considered, are discussed below.

Route around Port Augusta: An alternative route to that proposed to the east of Port Augusta was considered. This alternative route was parallel to the existing Port Augusta to Whyalla transmission lines which cross the head of Spencer Gulf to the west of Port Augusta. The alternative route then veered north to intersect the existing 132 kV line to Woomera about 20 km north-west of Port Augusta. This route was not favoured as it would:

- create further obstructions and diminish visual amenity by crossing the head of Spencer Gulf;
- pass in close proximity to the Port Augusta airstrip and other facilities;
- cross the existing 132 kV line to Woomera;
- be longer than the preferred route, and would require the establishment of a new corridor for the greater part of the distance;
- cross areas of tidal mangrove woodland which are mostly in an undisturbed condition (Butler et al. 1975).

Port Augusta to Mount Gunson: This portion of the route is already traversed by a corridor containing the existing Port Augusta to Woomera transmission line and water pipeline, the Trans Australia railway, and the Stuart Highway. The Joint Venturers concluded that the most appropriate route for this section of the transmission line was parallel and immediately adjacent to the existing 132 kV line to Woomera. Environmental factors precluded consideration of alternatives, as any new corridor with its associated access track would entail additional surface disturbance, and thus increase the environmental impact.

Port Augusta to Woomera: This section of the 275 kV line will be a straight line extension of the Port Augusta to Mount Gunson section of the corridor to meet the 132 kV line at a point 6 km north-east of Woomera. This route traverses stony tableland terrain, except where it crosses Lake Windabout and dissection slopes on its margins. While it would be possible to avoid Lake Windabout, such a deviation would involve two additional tension towers where the corridor would change direction, as well as a marginal increase in length. This deviation was rejected on economic grounds.

Woomera to Olympic Dam: During planning of the alignment of the existing road from Olympic Dam to Phillip Ponds the possibility of siting other services, notably a water pipeline, within the same corridor was envisaged. This road corridor was also considered as an alternative alignment for the transmission lines and possible rail spur between Woomera and Olympic Dam, as it is expected that for much of the distance between Woomera and Olympic Dam the railway would share a corridor with the transmission lines. However, after detailed consideration, an alignment to the west of the town and separate from the road corridor was selected for the transmission lines for the following reasons:

- For safety, operational, aesthetic and security reasons, it is desirable where practicable to have the two high voltage transmission lines at a distance from the main road.
- The siting of the railway and transmission lines within the road corridor, particularly in the section to the east of the town, would not readily permit adequate clearances from the proposed and existing airstrips.

- The siting of the railway on the same alignment as the road would necessitate several road/rail crossings on the most heavily trafficked Project roads, which would be undesirable from a safety aspect. However, there is merit in having the transmission lines and railway on one corridor where practicable to confine environmental impacts.

- Transmission lines require long straight alignments, which are not compatible with the road alignment.

- The alignment to the west of the town involves fewer sand dune crossings, and avoids the high ground to the east of the town.

- No additional clearing, roadworks, or surface disturbance would be involved, as a separate access track would be required for both alternatives.

- This alignment is more compatible with the town planning.

10.1.3 Impact on the electricity supply system

Capacity of the regional system

Woomera and Mount Gunson are connected to the ETSA electricity supply system by a 132 kV transmission line from the Davenport substation adjacent to the Thomas Playford Power Station at Port Augusta. With current load requirements, this line has sufficient capacity to transmit the additional 30 MW required by the Olympic Dam Project during the construction phase. The route of this line is shown on Figure 10.1. The line is currently owned by the Commonwealth Government, but Clause 18(5) of the Indenture Agreement requires the State to use its best endeavours to acquire ownership and control of the line if so requested by the Joint Venturers.

Capacity of the State system

The Olympic Dam Project at full plant production capacity of 150,000 t/a of copper has an estimated power requirement of up to 130 MW. Clause 18(3) of the Indenture Agreement places an obligation upon ETSA to supply up to 150 MW of electricity to the Joint Venturers on an incremental basis, subject to the provision of three years' notice of each increment.

The availability of electricity to supply future significant industrial or mining projects was assessed by the Iron Triangle Study Group (ITS 1982) for four scenarios of future development in the Northern Region. (Details of these scenarios are provided in Chapter 12.) These development predictions vary from Scenario 1, which assumes a relatively low level of future development based only on those developments considered almost certain to take place, to Scenario 4, which assumes a high level of future development and optimistic commencement dates which, in aggregate, has a low probability of occurring. The Olympic Dam Project is included in all scenarios, but with varying rates of production and dates of commencement, none of which exactly match the production capacity addressed in this Draft EIS.

For each scenario, the ITS compares the aggregate electricity demand needed to accommodate future development with the current and planned generating capacity in the ETSA electricity supply system up to 1992. For Scenario 4, which would place the greatest demands on the electricity supply system (including an assumed 160 MW for the Olympic Dam Project), up to 140 MW of new capacity would be required after 1988 to meet the requirements of all developments. However, the timing and level of this demand set out in Scenario 4 is regarded as being unlikely. For Scenario 2, considered to be the most likely future development pattern, there is an 85 MW surplus in uncommitted

ETSA capacity in 1992 assuming an 80 MW demand for the Olympic Dam Project. Thus, under this scenario, there would be sufficient generating capacity to accommodate the 130 MW maximum requirement if needed before 1992.

10.1.4 Environmental impact of transmission line corridor

An examination of previous environmental impact statements and assessments concerned with high voltage transmission lines indicates that there are a number of potential impacts associated with their construction and operation (ETSA 1981a, 1981b; South Australian Department of Environment and Planning 1981; Terrain Analysis 1982). These potential impacts are likely to be associated with:

- terrain
- vegetation
- archaeological sites
- land use
- sites of geological significance
- features of environmental or heritage significance
- visual amenity
- airfields
- residences or towns
- induced electrical fields
- noise
- fire risk.

The impact along most of the Port Augusta to Woomera section of the transmission line corridor will be incremental to that of already existing developments. This section of the corridor route will occupy an existing informal transport/services corridor, 145 km in length and of variable width, containing:

- the Trans Australia Railway
- the old Port Augusta to Woomera road
- the new alignment of the Stuart Highway
- the Port Augusta to Woomera water pipeline and its service road
- the Port Augusta to Woomera transmission line and its service road.

Given the existing level of development within this corridor, it is considered that the impact of the additional transmission line cannot be held to have as great a significance, a priori, as a new development would have in an otherwise development-free area.

In addressing the potential for impact of the transmission line corridor, the environmental associations through which the route passes are first described, in order to establish the general environmental setting. A discussion of impacts and mitigation measures relating to each of the broad categories noted above then follows.

Environmental associations

Figures 10.3 and 10.4 indicate the environmental associations which will be traversed by the transmission line corridor. These associations, with the reference numbers adopted by Laut et al. (1977) shown in brackets, are as follows:

Arden environmental association (7.2.1): For a distance of 20 km, the transmission line corridor will traverse the Arden environmental association, which has been described in general terms as a series of alluvial plains with common occurrences of short sand dunes. There are numerous small, shallow lakes along the overflow course of Lake Torrens, and tidal flats covered with low mangrove woodlands or samphire shrublands along the coastline. The plains and dunes have a degraded cover of low chenopod shrubland and low open woodland with a chenopod shrub understorey.

Simmens environmental association (7.1.1): The Simmens environmental association has been described as a quartzite plateau with steep escarpments and long footslopes, partly mantled by wind-blown sand. There are also minor areas of alluvial plains, sand dunes, beaches and tidal flats. The footslopes and plains are drained by shallow intermittent streams. The vegetative cover is low chenopod shrubland and low open woodland with a chenopod shrub understorey, and has been classified as 'disturbed natural' or 'degraded natural'. The transmission line corridor will traverse this association for a distance of 13 km.

Hesso environmental association (7.3.11): A gently undulating sandy plain is the dominant unit of the Hesso environmental association, which will be traversed by the transmission line corridor for a distance of 80 km. There are isolated occurrences of silcrete-capped hills, small shallow salt lakes, and short sand dunes. The vegetative cover, which is in a 'degraded natural' state, is a complex mixture of low open woodland, tall shrubland, tall open shrubland and open woodland (all of which have a chenopod shrub understorey), as well as low chenopod shrubland.

Mount Gunson environmental association (7.3.15): The Mount Gunson environmental association, which will be traversed by the transmission line corridor for a distance of 24 km, has been described in general terms as low sandstone or quartzite hills, with long footslopes drained by intermittent streams with broad flood plains. The hills and footslopes have a degraded cover of low chenopod shrublands, while the flood plains are mainly covered by low woodland with chenopod understorey, although there are small areas of woodland fringing the streams.

Oakden environmental association (7.3.13): The Oakden environmental association has been described as an undulating sand/sandstone plain with common occurrences of long sand dunes and low hills or rises of outcropping sandstone. There are isolated occurrences of small, shallow salt lakes. The vegetative cover, which is described as being in a 'degraded natural' state, is tall open shrubland and woodland with a mixed chenopod shrub and grass understorey, as well as low chenopod shrubland. The transmission line corridor will traverse this association for a distance of 12 km.

Woomera environmental association (7.3.20): The Woomera environmental association, which will be traversed by the transmission line corridor for a distance of 65 km, has already been discussed in Section 3.1. Briefly, it has been described as a quartzite-capped plateau with an undulating to hilly surface and with steep escarpments and long footslopes to the south. On the upper surfaces of the plateau, surface waters are mainly collected in gilgai depressions or in the occasional canegrass swamps. At lower levels, drainage is provided by tree-lined creeks. The dominant vegetative cover, which is in a 'degraded natural' state, is chenopod shrubland. Tall shrubland is found on the creek flood plains and small areas of the footslopes.

Moondiepitchnie environmental association (7.4.6): The transmission line corridor will traverse the Moondiepitchnie environmental association for a distance of 44 km. The association has been described as an undulating plain with sand sheets, dunes and occasional low stony rises, and small shallow drainage depressions (Section 3.1). The vegetative cover, which is generally in a 'degraded natural' state, is a mixture of tall open shrubland with chenopod shrub or grass understorey, low chenopod shrubland, and woodland with a tussock grass understorey.

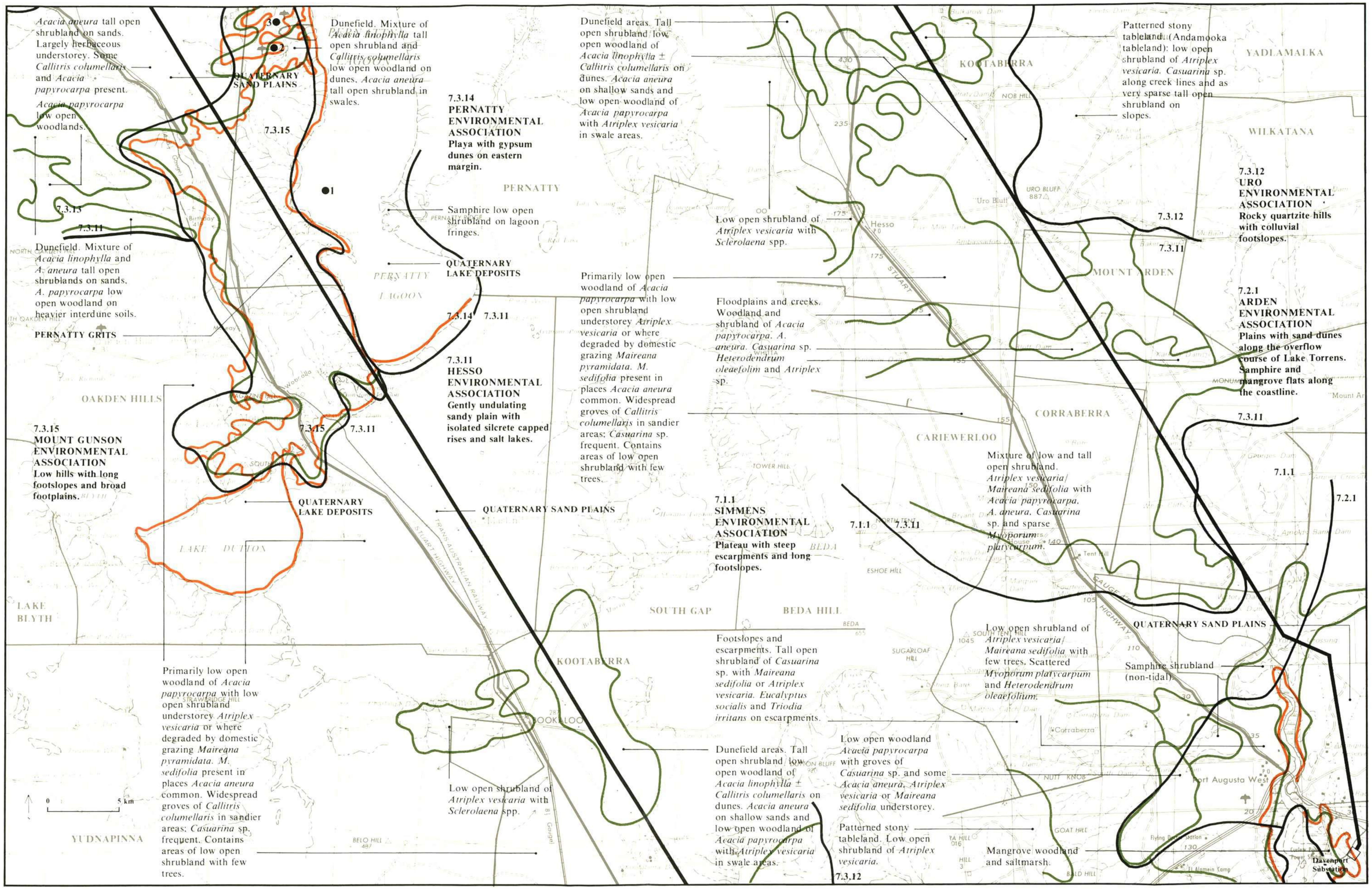


Figure 10.3
TRANSMISSION LINE CORRIDOR, PORT AUGUSTA TO PERNATTY LAGOON

- Transmission Line Corridor
- Existing Transmission Line
- Environmental Association Boundaries
- Geologic Regime Boundaries
- Vegetation Association Boundaries
- Roads
- Pastoral Lease Boundaries
- Airstrip
- Buildings
- Mine or Quarry

● SITES OF PARTICULAR INTEREST
1 Pernatty Lagoon
2 Mt Gunson Township
3 Mt Gunson Airstrip

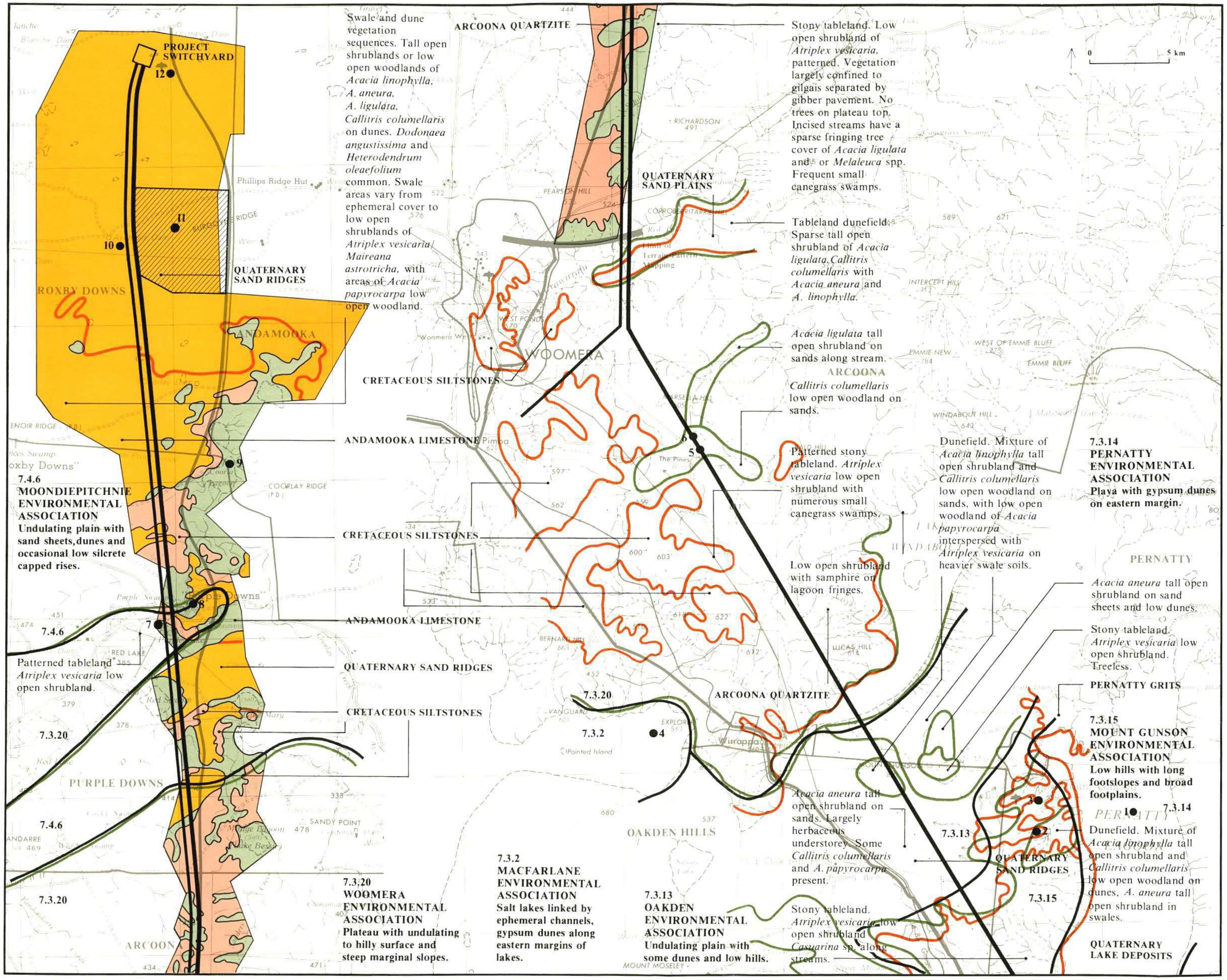


Figure 10.4
TRANSMISSION LINE CORRIDOR, PERNATTY LAGOON TO OLYMPIC DAM

- Transmission Line Corridor
- Existing Transmission Line

TERRAIN CATEGORIES

- Tableland
- Dune Field
- Drainage Depressions and Dissection Slopes
- Environmental Association Boundaries
- Geologic Regime Boundaries
- Vegetation Association Boundaries
- Roads
- Pastoral Lease Boundaries
- Airstrip
- Buildings
- Mine or Quarry

● SITES OF PARTICULAR INTEREST

1. Pernatty Lagoon
2. Mt Gunson Township
3. Mt Gunson Airstrip
4. Island Lagoon
5. "The Pines"
6. "The Pines" Fossil Site
7. Purple Lake
8. "Purple Downs" Homestead
9. Coorlay Lagoon
10. Mulga Swamps Near Axehead Dam
11. Town Site
12. Olympic Dam Airstrip

Terrain description

The following geological regimes will be traversed by the transmission line corridor (Figures 10.3 and 10.4):

- Recent alluvium and tidal flats at the head of Spencer Gulf
- Quaternary sand plains between Spencer Gulf and Pernatty Lagoon
- Proterozoic Pernatty Grits and sandstones on the western side of Pernatty Lagoon
- Quaternary east-west trending sand ridges between Pernatty Lagoon and Lake Windabout
- Cretaceous siltstones capping the dissected south-western part of the Andamooka Plateau
- Adelaidean Arcoona Quartzite capping the Arcoona Plateau as far north as Purple Swamp
- Quaternary east-west trending sand ridges overlying Cretaceous siltstones and Andamooka Limestone in the section from Mirage Lagoon to Olympic Dam.

The transmission line corridor route north of Port Augusta to Pernatty Lagoon crosses gently undulating sandy plains, with occasional low flat-topped hills and plateau surfaces of sandstones, grits and quartzites. The corridor will avoid these elevated features until it enters the gently undulating sandstone of the Pernatty Grit formation on the west of Pernatty Lagoon. While drainage on the sand plains is internal, with no apparent run-off, on the west of the lagoon numerous creek channels will be crossed.

North-west of Pernatty Lagoon to Lake Windabout, a broad belt of east-west trending sand ridges crosses the tableland surface. These dunes appear to be well vegetated and reasonably stable. From Lake Windabout to the existing Woomera to Andamooka road, the route crosses tableland surfaces of Cretaceous siltstones (similar to pattern K1 of the Study Area) and Arcoona Quartzite (pattern P1), with dissected escarpment slopes (pattern K2 and P2).

North of the existing Andamooka road the corridor route traverses the tableland surface of the Arcoona Plateau (Figure 10.3). This plateau consists of a low lying platform of essentially undisturbed Proterozoic sediments capped by a resistant quartzite member. In the vicinity of Red Swamp, 8 km of the corridor route traverses a segment of the dune fields of the Moondiepitchnie environmental association, then crosses a further section of the Arcoona Plateau to reach Purple Swamp. From Purple Swamp to Olympic Dam the corridor route again traverses the dune fields of the Moondiepitchnie environmental association.

The route from Woomera to Olympic Dam is generally clear of major drainage features. Surface drainage along this section of the route is usually internal into claypans, gilgai depressions or canegrass swamps, although more extensive drainage systems occur in several areas, particularly at the boundaries of the major geological units or along fault lines (Figure 10.3). Notable examples of these systems on the Woomera to Olympic Dam section of the route are Purple Lake and Purple Swamp. Their western, northern and southern shores are mostly bounded by steep dissected bedrock escarpments, while the eastern shores are less well defined and merge into a series of low gypseous mounds or sand dune spreads. Following the infrequent heavy rains which occur in this region, these basins receive run-off from the adjoining tablelands, and may hold this water for several years.

Terrain impacts and mitigation measures

For the 145 km section from Port Augusta to Mount Gunson, the construction of the new 275 kV transmission line is expected to have very little additional impact on the countryside. Examination of aerial photographs of the route of the existing transmission line indicates that the impact of the present access track and tower footings is minor. The line crosses considerable distances of very similar terrain and no unusual landforms are present. It is expected that the new line can be constructed and maintained from the same access track, thus further reducing any impact.

The 35 km section from Mount Gunson to the point 6 km north-east of Woomera where the 275 kV line will join the 132 kV line will necessitate a new corridor and access track. The corridor generally traverses stony tableland, except where it crosses the southern end of Lake Windabout. The lake width to be spanned is about 1,600 m, which will require one or more towers on the lake bed and a causeway for access.

A new corridor will also be required for the 80 km section from Woomera to Olympic Dam. This track will be unsealed, and where necessary will be sheeted with compacted borrow material (which will require the excavation of a limited number of borrow pits). The route crosses an area of dune ridges south of Purple Downs, then traverses an eroded remnant of the siltstone plateau prior to entering the sand ridge country south of the town site. The potential impacts on these various terrain features of this new line and access track from Woomera to Olympic Dam, as well as the mitigation measures to alleviate these impacts, are discussed below.

Tableland surfaces: On the undulating plateau surfaces, erosion can be initiated if the gibber strewn surface is broken and results in surface waters being channelled. The clay soils are prone to dispersion, and erosion is occurring naturally on the lower slopes adjacent to the escarpments where run-off is concentrated. It is recognized that construction traffic and vehicles moving across tableland surfaces can initiate or accelerate such erosion, and as a consequence it is intended to adopt the following mitigation measures:

- Off-road movement of vehicles during construction and operation will be limited.
- Where practicable, the removal of gibber (which is a natural guard against erosion) will be avoided in the construction of the access track and transmission towers.
- Construction traffic movements will be restricted in wet weather, to ensure that scars are not produced which could initiate run-off and erosion.

Dissection slopes: These slopes have been formed by erosion and cutting back of the tableland surfaces, and therefore must be regarded as unstable under present conditions. However, the mitigation measures to be adopted will provide adequate protection against the effects of the continuing erosion of the land surface, as well as ensuring that this erosion is not accelerated. Where crossings of escarpment slopes are required, the following mitigation measures will be adopted:

- Off-road movement of construction and operation vehicles will be limited.
- Culverts, pipes or invert crossings will be provided at all minor drainage lines, as well as at major streams and creeks.
- Sediment movement and accretion will be allowed for in the design of any drainage structures.

Drainage depressions and stream channels: The mapped margins of these features indicate where concentrated flows or ponding can occur. Flooding and surface run-off will generally occur at lower elevations than the feature boundary. Impacts within these features will generally be minimal, as the problems associated with crossing drainage areas are recognized, and accepted engineering design measures will be adopted to minimize the effects on the surrounding country. However, some of these features represent the terminal points of the drainage systems from the surrounding areas, and construction in these areas could result in alterations to the hydrologic regime, which in turn might lead to a local redistribution of the various character species. To reduce impacts, the following mitigation measures will be adopted:

- Construction will be avoided within large swamps.
- Sediment movement and accretion will be allowed for in the design of drainage structures.
- Embankments will be protected against large turbulent flows.
- Culverts, pipes or inverts will be provided to maintain the current pattern of surface water flows.

Dune fields: Along the transmission line corridor the route direction is generally perpendicular to the trend in the dune ridges. This will allow crossings to be made at the most favourable angle, thus reducing the likelihood of wind-blown sands collecting on the access roadway. The formation of local small-scale wind-blown sand deposits may occur, however, which could eventually encroach on the swale areas north and south of the crossing points. A very gradual deflation of the cut face on the eastern side may also result. The dune ridges appear to become progressively more unstable to the north, with a marked difference between the more stable ridges of the Pernatty Lagoon to Lake Windabout area and those between Purple Downs and Olympic Dam.

Mitigation measures to be adopted for the dune fields can be summarized as follows:

- Off-road movement of construction and operations vehicles will be limited.
- The access track will be surfaced with compacted local borrow material where it crosses dune ridges and sand sheets.
- The access track will be aligned to cross dunes at right angles where possible.
- Deep cuttings in dunes will be avoided where possible.
- Bare faces of cuttings will be stabilized.
- The track formation will be designed to ensure that it does not alter swale catchment boundaries in such a way that surface run-off is transferred to adjacent swales.
- Where the transmission towers will be constructed on dune ridges, a pad of stabilized material will be provided and disturbed areas rehabilitated.

Vegetation description

The vegetation associations which will be crossed by the transmission line corridor are shown in Figures 10.3 and 10.4. The route initially crosses samphire shrubland at the head of Spencer Gulf, and traverses saltbush/bluebush shrubland before entering extensive myall woodlands. The route to Woomera then passes through roughly equal proportions of western myall woodland and stony tableland vegetation (Atriplex vesicaria low open shrubland). It intersects some Acacia linophylla dune field similar to dune fields south of Olympic Dam, with western myall groves in swales. Across the Arcoona Plateau, the route also intersects a small area of tableland dune field before re-entering the main body of dune fields south of Purple Downs homestead. The tableland dune fields in general have a lower vegetative cover than those elsewhere on the alignment, and are considered to be more prone to erosion.

The entire length of the alignment will cross areas which, as they have been under pastoral use for more than a century, can be considered to be altered environments. Laut et al. (1977) classified all but the coastal environmental units along the route as 'degraded' or 'disturbed natural'. Over much of the western myall woodland in the Oakden environmental association for instance, domestic grazing has resulted in the original saltbush cover being replaced by Maireana pyramidata shrubland (Crocker and Skewes 1941), while on the tableland surfaces of Purple Downs Station perennial shrub cover has almost entirely disappeared (Dames and Moore 1981; Fatchen 1975 for examples near Pernatty Lagoon).

Vegetation impact and mitigation measures

The primary impact of the section of the transmission line corridor from Port Augusta to Woomera will be vegetation clearance in the western myall woodlands and dune fields. The vegetation encountered is well represented in the region, however, and there are no significant areas free from pastoral activity or other development. Increased public access is unlikely to be a major problem, as this is already well catered for by the Stuart Highway, the Woomera to Andamooka road, the Woomera to Olympic Dam road, and various station tracks.

North of Woomera, the corridor will diverge from the informal transport/services corridor and traverse land which is more development-free. Therefore, the potential exists for more significant impacts to occur, such as:

- vegetation removal to allow for the construction of the access track and transmission towers and for the stringing of conductors (refer Section 10.1.1 for extent of clearance);

- the spread of damage to vegetation by off-road recreational activity resulting from the provision of another means of vehicular access.

Most vegetation types which will be traversed by the corridor north of Woomera are well represented in the region, with the exception of a Melaleuca swamp fringe near Purple Downs Station and a series of mulga swamps near Axehead Dam. Removal of these uncommon vegetations would represent an adverse impact. The corridor will traverse the Melaleuca woodland fringing Purple Lake almost at right angles to the line of woodland, and consequently only a small area will be affected. Although Melaleuca woodlands are among the least common vegetation types in the region, the area affected represents only a small proportion of the regional distribution, and there is only a very small percentage of Melaleuca in the immediate locality. It is considered that the impact will have no regional significance.

Although mulga swamps are uncommon, there are scattered examples throughout the region. Generally, their significance lies not so much in the plant species represented as in the density of vegetative cover and the natural focus they provide for wildlife. From field inspections, the mulga swamps in question have frequent occurrences of emu bush (Eremophila longifolia), a protected species, and so appear to represent a local concentration of this usually uncommon plant. The local concentration may therefore be considered to have some regional significance. However, the impact which would occur if the mulga swamps were cleared for tower construction is considered to be acceptable in the light of the intention to retain similar swamp areas within the town and to use protected species in amenity plantings at Olympic Dam.

The impact of this section of the corridor will be on altered landscapes which are well represented in the region. The adoption of the mitigation measures outlined below is expected to result in impacts having only a slight regional significance.

Vegetation retention and rehabilitation: In the siting of towers and the access track, vegetation clearance will be minimized and, where possible, vegetation of botanical significance will be avoided. For areas disturbed during transmission line construction, the following measures will be adopted:

- Profiles of borrow pits and other disturbed areas will be rounded.
- Where applicable, top soil and other loose material will be respread.
- Disturbed surfaces will be lightly contour ripped to create seed traps and to reduce surface wind velocity.

Erosion control in dune fields: The regional dune systems, on the whole, can be regarded as reasonably stable, partly because of the perennial tall shrub/low tree cover and partly because of the rapid repair characteristics of many of the dune vegetations (Dames and Moore 1981, Graetz and Tongway 1980). However, even the most stable dunes have potential for sand movement once the vegetative cover is disturbed. The degree of vegetative cover, and therefore dune stability (Section 3.2.3), varies considerably along the corridor routes. Except for the dunes on the Arcoona Plateau, those between Port Augusta and Olympic Dam are generally well vegetated (Section 3.4.1).

Adoption of the terrain mitigation measures outlined previously will minimize erosion resulting from any vegetation removal in the dune field segments of the transmission line corridor. These measures include provisions that all roads and tracks crossing dune ridges or sand sheets be capped, that construction and operations vehicle traffic in dunes be limited to the formed tracks, that tracks cross dunes more or less perpendicularly to the dune trend, and that where practicable development will be avoided in the more sensitive dune areas. If safety or engineering needs necessitate the reduction of plant height between lines, then every attempt will be made to achieve this without removal of the tree species responsible for stabilizing the dunes.

Erosion control on tableland: It will be necessary for the transmission line corridor to cross tableland escarpments, in particular the steep south-east slopes of the Arcoona Plateau, as there are no viable alternative routes which avoid this crossing. As protection against water erosion will be needed, construction of the access track and tower pads will not take place directly down the fall line of an escarpment without the provision of water diversion works. In particular, the access track will be provided with frequent water barring.

Elsewhere, undulating plateau surfaces are still prone to water erosion (Graetz and Tongway 1979). On the Arcoona Plateau there is reasonable natural erosion protection provided by both vegetation and the gibber pavements. However, tableland surfaces on Purple Downs Station have had their vegetative cover reduced by overgrazing, leaving the gibber surface as the main protection against erosion. Wherever practicable, the gibber cover will be left undisturbed. Again, the main mitigation measures will be the construction of formed tracks with water barring, and limitation of off-road movement of construction and operations vehicles. Development will avoid drainage areas wherever practicable.

Where the corridor crosses a drainage feature, the access track will be diverted if practicable. However, where it is necessary to construct an access track across a drainage feature, pipes, culverts or inverts will be provided to maintain the existing hydrological regime.

Protected plants

Port Augusta to Woomera section: The alignment is likely to result in the removal of some protected species. Those occurring in the general area affected are listed below.

- Bullock bush (Heterodendrum oleaefolium) is common along larger water courses near Port Augusta, and other than on the Arcoona Plateau near Woomera it is a prominent element of dune field vegetation.

- Myoporum platycarpum occurs as scattered individuals in the Atriplex vesicaria shrublands around Port Augusta and is also present in woodlands further north.

- Quandong (Santalum acuminatum) and bitter quandong (S. murrayanum) are uncommon but widespread, primarily in the western myall (Acacia papyrocarpa) woodlands.

- Native pittosporum (Pittosporum phylliraeoides) is found most frequently along streams, including tableland creeks, but is also occasionally present on tableland surfaces (other than the Arcoona and Andamooka Plateaux).

- Emu bush (Eremophila longifolia) is uncommon. Individual plants may be found in swales within mulga dune fields, and may be present around small swamps or in other drainage features.

The transmission line corridor over the Port Augusta to Woomera section can be expected to result in the removal of a number of bullock bushes, particularly where it intersects drainage lines and dunes. Nearer Port Augusta it may also result in the removal of Myoporum platycarpum. Given its length, the corridor will probably intersect areas containing quandongs and also result in the removal of some native pittosporum. However, there is little likelihood that emu bushes would need to be removed. Loss of bullock bush is unlikely to be significant, due to its widespread and common occurrence. The extent of the vegetation types and landforms along the transmission line route suggest that, although some individuals of the other species mentioned may be lost, their regional populations will not be significantly affected.

Woomera to Olympic Dam: The distribution of protected plants along the easement of the Olympic Dam to Woomera road has been described in detail in Fatchen (1980). Bullock bush is a common constituent of dune field vegetation and, while the easement will intersect numerous groves, the loss will have no more than local significance. Native pittosporum is very infrequent but widespread, fringing creeks on the tableland north of Purple Downs Station and occurring elsewhere occasionally. Construction is likely to remove one or two individuals.

Quandong is found in association with western myall groves, with more than a quarter of these groves within the area surveyed containing at least one individual. The frequency of western myall would indicate that removal of quandongs during transmission line construction is unlikely to be significant other than in a purely local sense.

Emu bush is generally uncommon in the region, with two exceptions. In the first of these, bands of emu bush are found in places on the boundary between the Arcoona tableland and the dune fields (Fatchen 1980). The corridor may cross such a band, but in this case will be perpendicular to it, and the impact is therefore unlikely to be significant. Secondly, between Axehead Dam and the dune field to the east, the corridor runs through a north-south depression which contains a number of mulga swamps with emu bush thickets (Figure 10.3). In addition to the bands already mentioned, this local concentration of emu bush is one of four occurrences known in the Baseline Study Area and in the mapped sections of the infrastructure corridors. The number of specimens removed will depend on the actual alignment of the access track and the final positions selected for towers.

Archaeology

The route for the transmission line corridor has been divided into archaeological zones on the basis of interpretation of aerial photographs, and the environmental associations which are discussed below. A predictive statement has been made of the nature and location of archaeological sites which might be found in each zone. This predictive statement draws heavily on the results of surveys carried out in several areas of arid South Australia, including the Olympic Dam Project Area (Chapter 5), Redcliff, Stony Point and the Flinders Ranges (Hughes 1980; Lilley and Hughes 1981; Hiscock and Hughes 1981). Based upon the predictive statement of site distribution, an indication of the potential for impact is discussed. Further archaeological work is proposed before tower sites and the alignment of the new access track are finalized. It should be noted that a new access track is only required in the Moondiepitchnie, Woomera, and part of the Oakden environmental associations.

Arden environmental association (7.2.1): Based on other surveys in this association in the Redcliff area (Ross and Jeffrey 1974; Hughes 1980), campsites represented by scatters of artefacts with small amounts of bone and shell are likely to occur in the dunes which will be crossed by the transmission line. The archaeological rating of this section is high, and it is possible that tower sites located on sand dunes would coincide with archaeological sites.

Simmens environmental association (7.1.1): Previous surveys for a hydrocarbon liquids pipeline have found few archaeological sites and only isolated artefacts in this association. The archaeological significance rating is considered to be low. Sites are unlikely to be found on this stretch of the route, except where towers are located near sand dunes or possibly where there is suitable quartzite available.

Hesso environmental association (7.311): No previous surveys have been carried out; however, by analogy with similar landscapes to the north, campsites are likely to occur on dunes, while quarries and knapping floors will be found in areas with suitable raw material. The archaeological significance rating is considered to be medium. Along this section of the corridor the potential exists for tower sites and archaeological sites to coincide, particularly in the vicinity of Uro Bluff which is known to be a place of significance to Aboriginal people.

Mount Gunson environmental association (7.3.15): Surveys have not been carried out previously. Campsites are likely to occur on dunes, and knapping floors may occur in areas with suitable quartzite raw material. The archaeological significance rating is considered to be medium. The potential exists for tower sites and archaeological sites to coincide.

Oakden environmental association (7.3.13): Surveys have not been carried out previously. Campsites will occur in the dunes, but in the absence of suitable local raw materials the density of artefacts will be relatively low, and quarries and knapping floors will be either rare or absent. The archaeological significance rating is considered to be low. Thus there is little likelihood of archaeological sites being affected by the tower sites south of Mount Gunson or by the tower sites and new access track required north of Mount Gunson, except possibly in sand dune areas.

Woomera environmental association (7.3.20): The archaeological survey for the road from Phillip Ponds to Olympic Dam found no sites on this gibber plain. However, isolated dunes in drainage depressions are likely to be rich in archaeological remains. The archaeological significance rating, as well as the likelihood that the access track alignment or tower locations would coincide with archaeological sites, are considered to be very low except locally on dunes.

Moondiepitchnie environmental association (7.4.6): Extensive survey work has been carried out in this association, as detailed in Chapter 5. Compared with the rest of the route, this stage will cover areas with large numbers of often rich campsites, quarries and knapping floors. In particular, important sites are likely to occur in dunes around major drainage depressions. The archaeological significance rating is considered to be high. It is likely therefore that, within this association, both the access track alignment and tower sites will coincide with archaeological sites. In particular, there is a possibility that the access track and transmission towers could coincide with important sites in the dune fields around Purple Lake, Purple Swamp and Coorlay Lagoon (Figure 10.3).

When the location of the towers has been finalized, the following measures will be adopted:

- Where the corridor parallels the existing transmission line within the Arden, Hesso, Mount Gunson and Oakden environmental associations, an archaeological survey of the transmission tower sites will be undertaken.

- Within the Simmens environmental association, the tower sites will be inspected.

- The tower sites and access track alignment within the Oakden environmental association, where the corridor diverges from the existing transmission line, and in the Woomera environmental association, will be surveyed.

- A systematic survey of the access track alignment and sites will be undertaken within the Moondiepitchnie environmental association. If any sites of special scientific importance are located, the service track will be rerouted, or the tower site relocated, to avoid damaging the site and to obviate the need for salvage work.

Land use

The 275 kV transmission line, which will start from the Davenport substation and parallel the existing Port Augusta to Woomera transmission line, will skirt the outer residential areas of the city of Port Augusta before crossing pastoral lands to a point just south of Mount Gunson. From Mount Gunson to Olympic Dam the corridor will also traverse pastoral lands. The stations traversed by the corridor include:

- Mount Arden
- Kootaberra
- Oakden Hills
- Pernatty
- Arcoona
- Purple Downs
- Roxby Downs.

In accordance with the provisions of Clauses 18(11) and 31 of the Indenture Agreement, easements for the corridor will be negotiated when the final tower positions have been determined. As the transmission line corridor will not restrict livestock movement, land alienation is not expected.

Sites of geological significance

Three sites of geological significance have been identified in the vicinity of the corridor (Section 4.1 and Figure 10.3). Site 1 on the western shore of Coorlay Lagoon and Site 2 around the margins of Purple Lake are considered to be 'the best exposed outcrops of the base of the Andamooka carbonate sequence on the Stuart Shelf west of Lake Torrens' (South Australian Museum, pers. comm.; and Johns 1968). Site 3 is in the vicinity of The Pines. Fossil seed cones of Cainozoic age thought to be from a Casuarina species have been found at this site, although the actual fossil source has not yet been located (South Australian Museum, pers. comm.).

As the corridor is approximately 2.5 km west of Coorlay Lagoon and 400 m east of Purple Lake, these sites will not be directly affected by corridor development. Although the corridor will traverse the site of geological significance at The Pines, the South Australian Museum has been provided with details of the alignment in this area so that investigations may be undertaken to ensure that the fossil source is not endangered.

Features of special environmental or heritage significance

The Far North Planning Area Development Plan has identified a number of features of special environmental significance which should not be destroyed or lessened in value by any development until a management plan has been prepared (Section 4.1). Two such features occurring in the general vicinity of the corridor are:

- Pernatty Lagoon
- Island Lagoon.

However, neither of these features will be affected by the transmission line corridor.

Visual amenity

There are no designated tourist or recreational attractions in the immediate vicinity of the transmission line corridor. Limited sections of the line will be visible to travellers on the Trans Australia Railway, on the Stuart Highway, and on the roads from Woomera to Olympic Dam and to Andamooka.

From Port Augusta to near Mount Gunson, the new line will be parallel to (and immediately to the east of) the existing transmission line. The new line, which will be between 2 and 10 km from the Stuart Highway and the Trans Australia Railway, is not expected to be any more visually dominant than the existing transmission line. Any visual impairment is considered to be more than outweighed by the benefits obtained from confining development to an existing corridor.

Following its divergence near Mount Gunson from the corridor of the existing transmission line, the new transmission line corridor will cross the existing Woomera to Andamooka road 3 km east of its intersection with the Olympic Dam road. The use of this road will be discontinued for other than local access.

Along the Woomera to Olympic Dam road, which is now the main through road to Andamooka, the transmission lines will be a dominant visual element for a length of approximately 25 km north from the junction with the Andamooka road. The country traversed is sparsely vegetated tableland with some areas of dune field having low open woodland cover. The corridor is less than 1 km from the road for much of this length, crossing the road at one point at a very shallow angle (Figure 10.3). The transmission line will therefore represent an impairment to visual amenity.

Airfields

The alignment of the new transmission line between the town and the Project switchyard has been determined by the need to maintain airspace clearances for the existing licensed standard airstrip at the Olympic Dam village, assuming that the towers for the 275 kV transmission line will be 30.3 m high in the vicinity of the airstrip. The line will be approximately 6 km from the threshold on the approach to the runway at Mount Gunson, and about 8 km from the airstrip at Woomera. Therefore, the corridor will not interfere with the operation of the Mount Gunson, Olympic Dam, or Woomera airfields.

Residences and towns

The transmission line corridor will pass within 5.5 km of Mount Gunson, 2 km of Woomera (132 kV line only), 400 m of the proposed town at Olympic Dam, 700 m of

Uro Bluff homestead, 700 m of Kootaberra homestead, about 150 m of The Pines (an old homestead which has been abandoned) and 700 m of Purple Downs homestead. It is the experience of ETSA (1981a, 1981b) with existing 275 kV transmission lines that there is no noticeable interference to radio signals at distances of 100 m or more from lines of this type. A minimum separation of 250 m between the line and houses will therefore be adopted. It is also the experience of ETSA (1981a, 1981b) that, in areas where poor television reception is now being obtained, the nearby presence of transmission lines may result in some further reduction in picture quality.

Induced electrical fields

An electrical field exists near all high voltage transmission lines. The line will be designed to ensure that induced charges will be harmless, including those in fences, and that normal pastoral activities will not be affected (ETSA 1981a, 1981b).

Noise

Slight noise will emanate from the lines due to wind vibration of the conductors or corona discharge. It is expected that the noise would be barely noticeable under the line in normal weather and would be imperceptible away from the line (ETSA 1981a, 1981b).

Fire risk

The routes of both lines cross pastoral areas in which grass or bushfires could occur. The standards set by ETSA for the construction and the physical and electrical characteristics of high voltage transmission lines make it unlikely that the lines would cause a fire.

The conductors will be protected from lightning strikes by earthwires and the steel towers will be earthed. Any electrical fault will be interrupted by high speed protection equipment operating circuit breakers at the ends of the line (ETSA 1981a, 1981b).

10.2 WATER SUPPLY

10.2.1 Project water supply

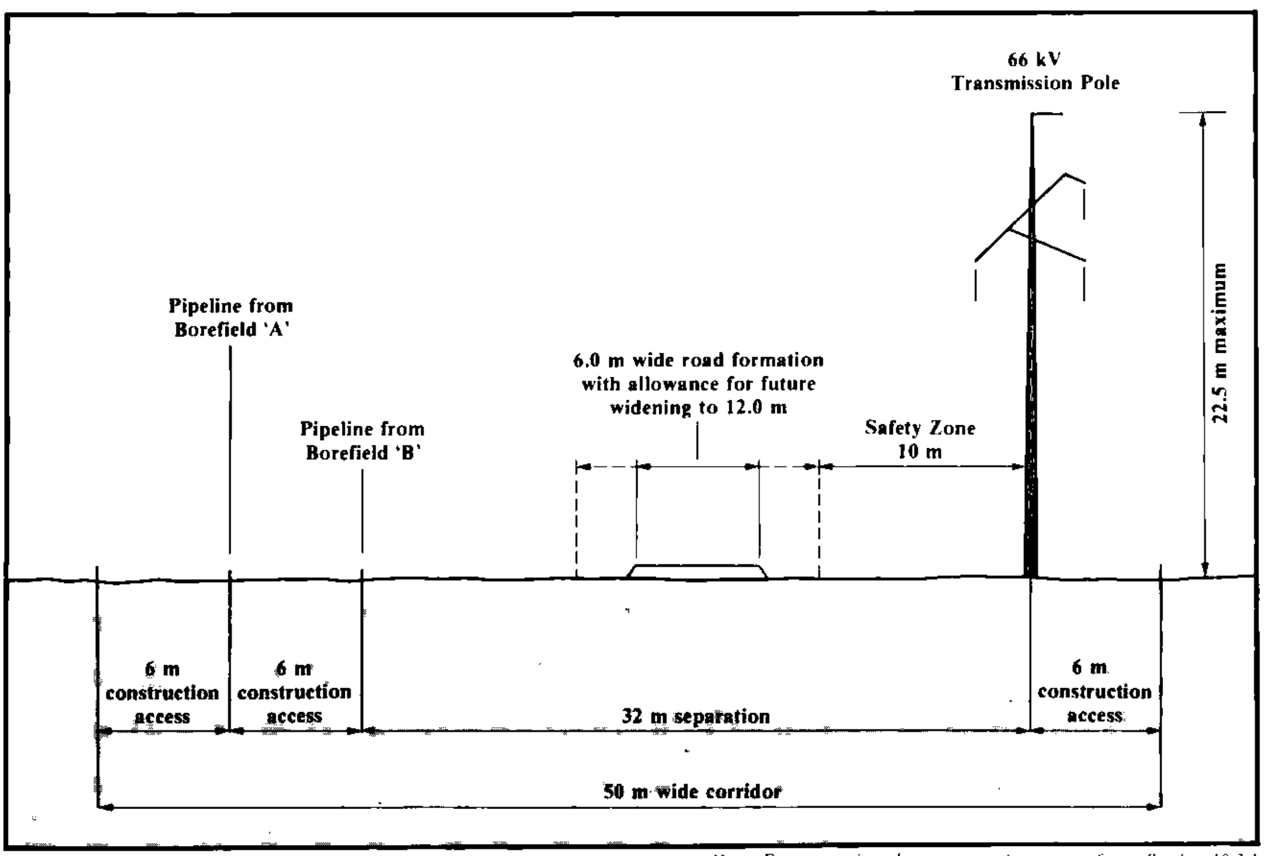
Water for the Project will be supplied by pipelines from two borefields to be developed in the Great Artesian Basin. The route for the pipeline corridor and the borefield locations are shown in Figure 2.21. Potable and raw water will be stored at the Project site to compensate for interruptions to supply, seasonal fluctuations in demand, and emergency requirements. Potable water will be supplied from a reverse osmosis or electrodialysis desalination plant adjacent to the raw water terminal storage. The water supply system is described below, followed by a description of the environmental effects of the pipeline corridor. The effects of water extraction from the borefields is addressed in Section 10.3.

Initially, about 6 ML/d will be pumped through a pipeline from Borefield A, some 100 km north-east of Olympic Dam. Available water from this borefield will meet the needs of construction and initial town development, but will not be sufficient to meet Project demands during production which, including evaporation loss, is expected to be about 33 ML/d. To provide the additional water, Borefield B will be developed approximately 50 km north-east of Borefield A. Each borefield will be served by a separate pipeline, with both pipelines being parallel from Olympic Dam to Borefield A. Power for the pumping stations and bores will be provided by an overhead 66 kV transmission line commencing at the Olympic Dam substation and running parallel with the pipeline over most of its length.

A corridor width of 50 m has been adopted, which is considered to be the minimum width necessary to contain the two pipelines, access road, and transmission line, with the necessary clearances to permit construction, and to avoid the development of induced electrical fields in any steel pipelines which may be used. This corridor width would permit expansion of the road to 12 m wide, although the Joint Venturers do not envisage that this width will be needed for Project purposes. A typical cross-section of the pipeline corridor is shown in Figure 10.5. The line clearance criteria to be adopted for the design and construction of the 66 kV transmission line are set out in Table 10.1.

The Joint Venturers' policy of minimizing vegetation clearance will be followed, and it is expected that, within the 50 m corridor, it will be necessary to clear or cut vegetation only for the road, pipelines, and conductor stringing, plus the transmission pole sites. For the total length of the corridor, the average width of vegetation clearance is expected to be 10 m. It will also be necessary to excavate a limited number of borrow pits for road sheeting, and these will be located a practicable distance away from the road verges to minimize effects on visual amenity and to restrict the development of stock and fauna watering points adjacent to roads.

The forwarding pumping station (Pump Station No. 2) at the near margin of Borefield A will consist of an open storage pond. The pump station will be housed in a steel-framed shed on a concrete floor. A switchyard at the station will transform the incoming 66 kV supply to 415 V for pump operation and 11 kV for forwarding to the individual bores. Individual bores will have transformers for further reduction to 415 V. Telemetry will be provided to enable the bores and pumping stations to be monitored, controlled, and operated from Olympic Dam. The pump works and pond will be enclosed by a chain mesh fence. The underground pipeline from the forwarding station to the Project site will be approximately 350 mm in diameter. About 50 km from Olympic Dam there will be a booster station (Pump Station No. 1) similar to the forwarding station, but with the pond replaced by an open circular steel tank for water balancing.



Note: For vegetation clearance requirements refer to Section 10.3.1

Figure 10.5
PIPELINE CORRIDOR, TYPICAL CROSS-SECTION

At Borefield B a forwarding station (Pump Station No. 3) similar to that at Borefield A will be constructed. Pump Stations Nos 1 and 2 will be equipped with additional pumps and balancing tank storage capacity to service the additional pipeline from Borefield B, which will be 600 to 800 mm in diameter. At the time of writing, a decision had not yet been made on whether this pipeline would be above or below ground.

10.2.2 Pipeline corridor route selection

In selecting the route to be followed by the pipeline corridor from the Great Artesian Basin to Olympic Dam, the Joint Venturers studied the region from aerial photographs, available detailed mapping, and ground traverses. The most direct route was selected, compatible with the following environmental and land use considerations:

- Severance of pastoral land should be minimized.
- Areas considered to be environmentally sensitive should be avoided.
- Difficult terrain and the crossing of escarpments where erosion might be initiated should be avoided as far as practicable, and disturbance of dunes should be minimized.
- Any significant water courses should be avoided where practicable.
- Any other significant features of environmental value, such as large canegrass swamps, should also be avoided as far as practicable.

Low level colour aerial photographs were taken and used for route alignment, and the alignment was then traversed prior to final route selection. The selected route is not the most direct route, but is considered by the Joint Venturers to be the most direct route which will satisfy the above constraints.

The following considerations influenced the route chosen and Figure 10.6 shows the features which controlled this route selection:

- In order to minimize the impact on pastoral activities and avoid locations of Project development, the section of the route from Olympic Dam to the Dog Fence (approximately 15 km) follows the existing boundary fence and track separating Roxby Downs and Andamooka stations.
- From the Dog Fence to Pump Station No. 1 (approximately 35 km), the preferred route has been selected to generally avoid the canegrass swamps and significant drainage areas immediately north of the Dog Fence, around Peapeanana Ridge, and around the site of Pump Station No. 1. This section of the route specifically avoids the Yarra Wurta escarpment and remains within the boundaries of the Dog Fence to the east and the boundary fence between Stuarts Creek and Billa Kalina to the west.
- Between Pump Stations Nos 1 and 2 (approximately 42 km), the route traverses an area of approximately north-south trending dunes. This area could not have been avoided without a significant detour. However, the route has been carefully located within the swale areas paralleling the dunes, to avoid the more unstable areas wherever practicable.
- South of Bopeechee, there is a series of water courses and a deeply gullied tableland area. The route has been sited further to the west to avoid this area, and to minimize the length and number of creek crossings.

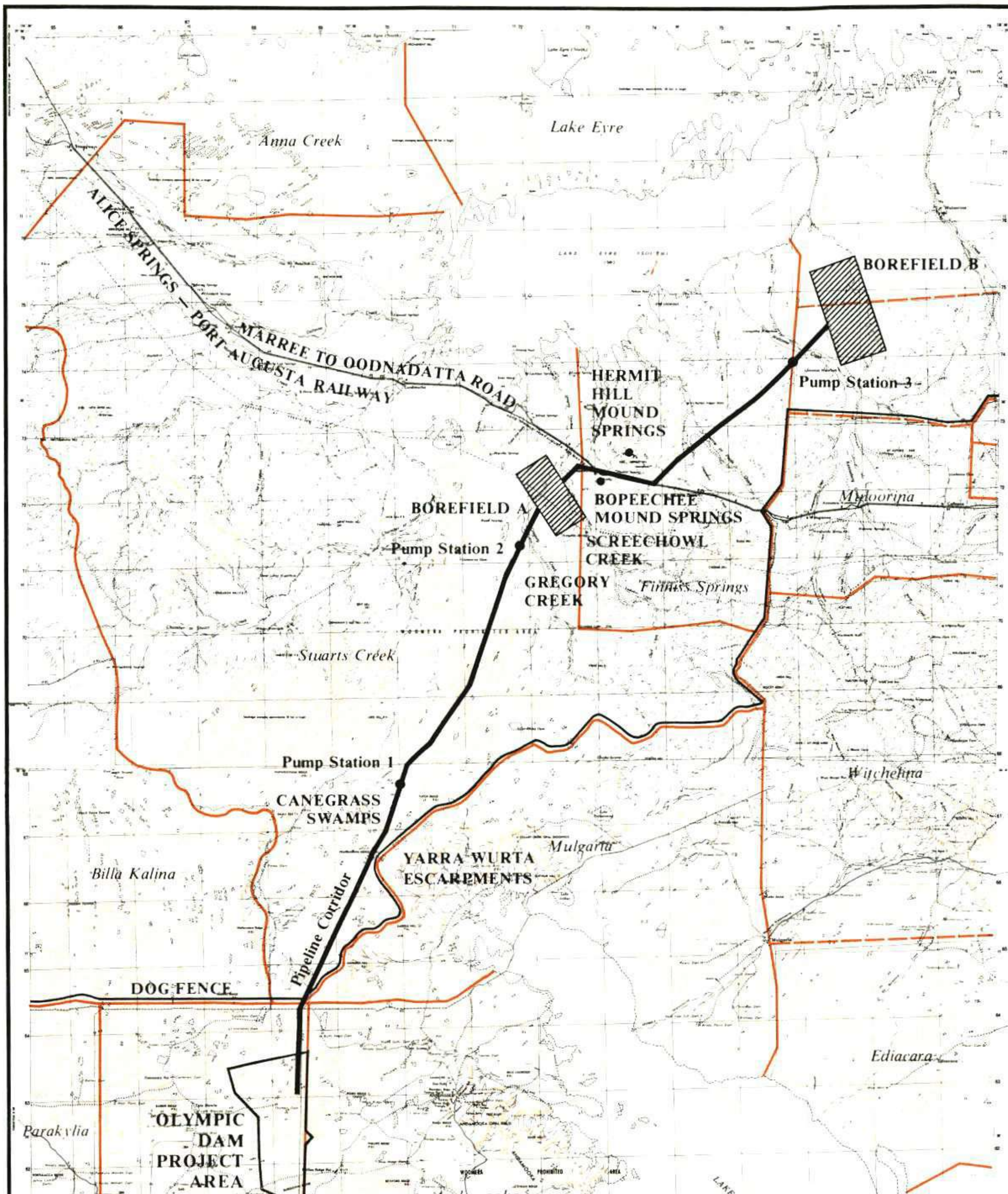


Figure 10.6
PIPELINE CORRIDOR, FEATURES CONTROLLING ROUTE SELECTION

- The trackbed of the abandoned section of the Alice Springs to Port Augusta railway is used east of Bopeechee in order to utilize existing engineering works and to minimize further environmental impact. This route is clear of the mound springs in the Bopeechee area, and avoids Hermit Hill which is designated in the Far North Planning Area Development Plan as an area to be considered as a site of special or environmental significance. The existing Marree to Oodnadatta Road can be used to provide access to the pipeline between Bopeechee and Alberrie Creek.

- Given the uniformity of country north of the railway line, all routes were perceived as having similar impacts. The most direct route from Alberrie Creek to Borefield B will therefore be followed.

The corridor alignment from Olympic Dam to Borefield A has been surveyed and pegged, and defines the pipeline easement (unless for technical or environmental considerations minor deviations are considered desirable). The trackbed of the abandoned section of the Alice Springs to Port Augusta railway defines the corridor to a point approximately 6 km west of Alberrie Creek. The final alignment will be pegged from this point to Borefield B following the completion of the necessary survey work.

10.2.3 Environmental description of the pipeline corridor

The various environmental factors relevant to impact assessment of the borefield services corridor are set out on Figure 10.7.

Environmental associations

The pipeline corridor traverses the following two environmental associations described by Laut et al. (1977):

Moondiepitchnie environmental association (7.4.6): The pipeline corridor traverses the Moondiepitchnie environmental association for a distance of 75 km, an association which has already been discussed in Sections 3.1 and 10.1.4. In general terms, the association has been described as an undulating plain with sand sheets, dunes and occasional low silcrete-capped rises, and small shallow drainage depressions. The vegetative cover, which is mostly in a 'degraded natural' state, is a mixture of tall open shrubland with a chenopod shrub or grass understorey, low chenopod shrubland, and woodland with a tussock grass understorey.

Marree environmental association (8.3.5): The Marree environmental association is traversed by the pipeline corridor for the remainder of its length, a distance of 75 km. Borefield A and the southern portion of Borefield B also lie within this association, which has been described in general terms as gently undulating gypcrete/siltstone tablelands and porcellanite plains, with common occurrences of sand dunes and isolated occurrences of gypcrete escarpments. Drainage is by entrenched creeks, varying in width between 5 and 500 m, which flow intermittently. There is a mixed vegetative cover in a 'degraded natural' state comprising chenopod shrubland, tall open shrubland with a chenopod shrub and grass understorey and fringing woodland on creek floodplains.

Terrain description

From north of Olympic Dam to the Bopeechee siding, the underlying rocks consist of Cretaceous, grey carbonaceous siltstones and shales (Figure 10.7). These shales are overlain by the Quaternary sand ridges, which change direction from a general east-west trend in the southern parts of the corridor to a north-north-east/south-south-west trend north of Canegrass Dam. Approximately 32 km south of the railway line, the sand ridges terminate in the more dissected country forming the southern catchments of the Gregory and Screechowl Creeks, where many 'breakaway' escarpment slopes reveal the underlying

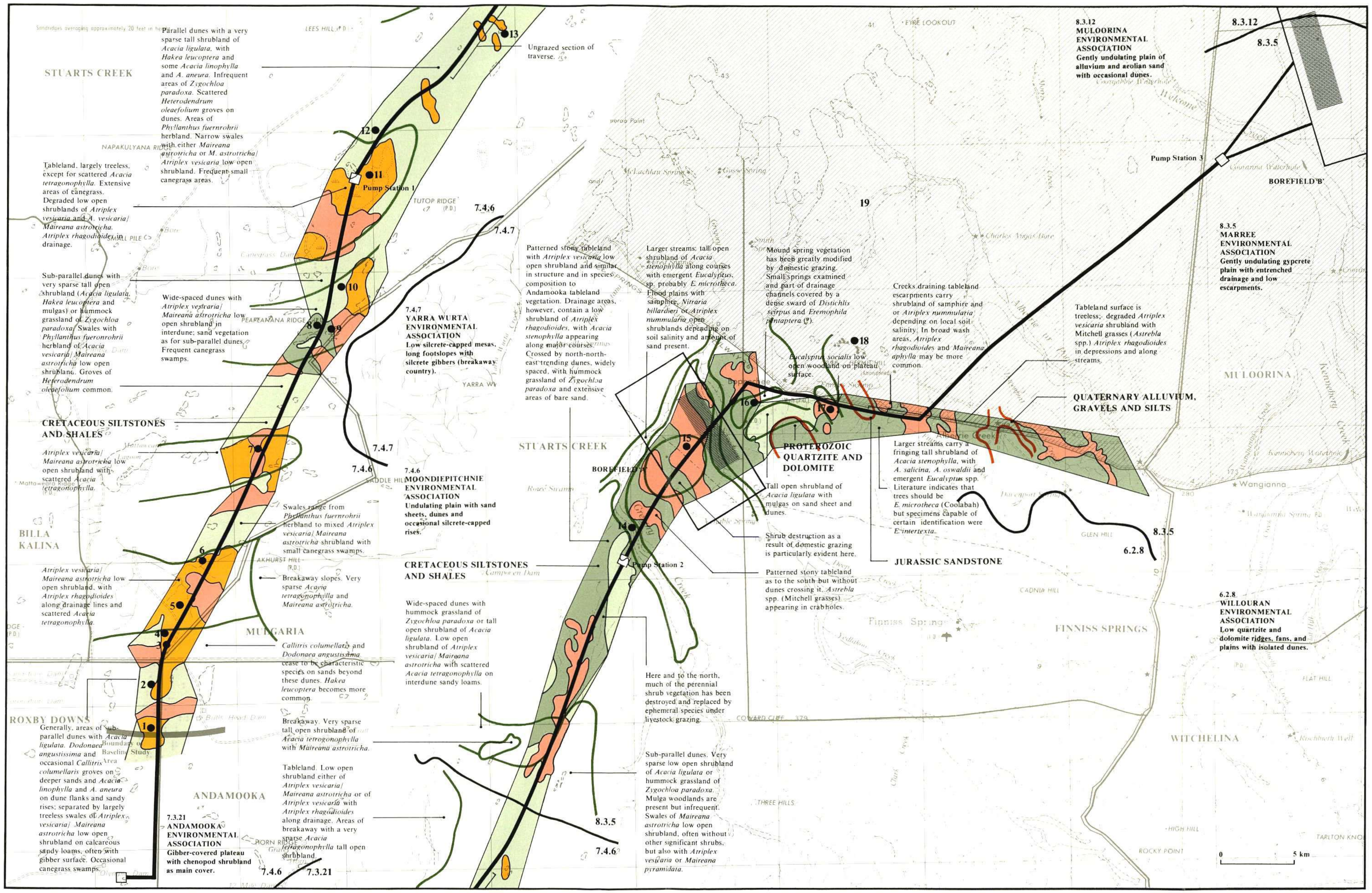


Figure 10.7
PIPELINE CORRIDOR

grey siltstones. In the area of the sand spreads, the siltstones are close to the surface, while within the broader internal drainage depressions containing canegrass swamps occasional outcrops on steeper escarpment slopes can be seen. Within swales it is possible that shale lies between 0.5 and 1.5 m from the surface.

West to east along the old railway line, the route traverses many erosional surfaces associated with the major creeks flowing north into Lake Eyre South. The rocks throughout this area are predominantly Cretaceous siltstones and shales overlying Jurassic sandstones. Small inlets of Proterozoic quartzite and dolomite outcrop in the vicinity of Hermit Hill and to the south of the railway trackbed. These older rocks are more resistant to erosion than the Cretaceous shales and, along with remnants of the tertiary siliceous capping, form prominent features in the region.

In general, gentle gradients exist along the length of the pipeline corridor. From Olympic Dam to the Dog Fence (a distance of 16 km), the series of east-west trending sand ridges are superimposed over the approximately north-south trending low siliceous ridges on the tableland surface. Within the swales, the drainage is internal into claypans or the occasional doline in the underlying Andamooka Limestone. Along this part of the route the country is very similar to that within and around the Project Area.

North of the Dog Fence, the undulations in the tableland surface gradually disappear and the drainage is more continuous along the swales into much larger swamps. On the Cretaceous siltstones these swamps support thick canegrass cover. Saline lakes or claypans are rare. Large areas of the tableland surface containing gibber and red-brown clayey soils are exposed. Approximately 26 km north of the Dog Fence is a pronounced feature, Peapeanana Ridge, which has been sharply dissected to the east by the Yarra Wurta Creek. The route selected for the pipeline corridor specifically avoids the Yarra Wurta escarpments. The tableland surface in this highland area is broadly undulating and contains many large canegrass swamps. The dune density decreases markedly, with many dunes cascading into the Yarra Wurta escarpment area, from where they are being washed into the northern parts of Lake Torrens.

North of the Yarra Wurta breakaway country, the dunes change direction in a broad arc to a northerly trend, which continues to the catchment areas of the Gregory and Screechowl Creeks approximately 40 km to the north. The dunes in this area are more strictly oriented and more uniformly spread than those in the Olympic Dam area. They show more bare sand areas and blowouts, and appear less stable than those to the south. The soil profiles of the ridges and swales are similar to those described in the Baseline Study Area.

Along the western margins of the major canegrass swamps, there is rock outcropping which appears to be a form of ferruginized sandstone. This material possibly forms most of the gibbers of the low lying area.

North of Canegrass Dam, at the start of the wide belt of almost northerly trending sand ridges, pronounced instability has been noted. Sand movement is to the north, where it disappears into the catchment areas of Lake Eyre South.

Approximately 25 km south of Bopeechee, the sand dunes become more flattened and thin sand spreads occur over the tableland surface. The tableland becomes dissected, with numerous tributaries of Gregory Creek eventually flowing into a wide braided channel in a broad depression, trending north-westerly across the corridor. From Gregory Creek to the railway line, the route cuts across the margin of the dissected escarpments of Screechowl Creek, the lower part of this country containing a number of mound springs and seepages.

The soils of the escarpment slopes, which are deeply eroded, consist of shallow brown and grey cracking clays. The underlying siltstone, which is exposed in many parts, consists of a weak highly-weathered rock. Recent erosion has occurred in many parts, cutting through the residual clays to the underlying siltstone.

From Bopeechee to Borefield B the route crosses a number of major creeks, including the Alberrie, Finniss, Davenport and Welcome Creeks. The creeks vary from locally narrow incised channels in the siltstone enlarging to broader, flatter, braided channels north towards Lake Eyre South. They all flow into Lake Eyre South, and carry large volumes of water and sediment in the rare times of flood. The road along the railway line becomes impassable during periods of heavy rain.

The landform consists of continually recurring escarpment slopes and eroded footslopes of the tableland surface. The soil cover is generally shallow to skeletal, being mainly residual red-brown and grey cracking clays on the siltstone mass, which is weak and highly jointed.

The most resistant rock formations in the area are the silcrete capping of the old Tertiary land surface which occurs just north of the Alberrie Creek crossing, and the Jurassic sandstone on the southern side of the Finniss Creek crossing. These rocks and the associated topography have influenced the routes of the railway line and road.

Terrain pattern mapping

Terrain pattern mapping has been carried out at a scale of 1:40,000 throughout the length of the corridor to Alberrie Creek. The pattern descriptions used are similar to those used for the Study Area (Section 3.2), with slight modifications and with the addition of two underlying geological regimes: Jurassic sandstone (coded J) and Proterozoic quartzite and dolomite (coded Pb).

The description of terrain pattern K2 which was previously described (Section 3.2) as moderately steep escarpment slopes of the southern tableland surface, has been modified to include the more complex northern escarpment slopes which contain erosion channels and tributaries of the major creeks. The slopes can also be much flatter but still show evidence of surface run-off into the K3 pattern delineating the major drainage lines. Some slight changes are also necessary to the description of the K3 pattern. In the Study Area this pattern refers mainly to broad drainage depressions lying within the tableland surface and associated with canegrass swamps. This description still applies in the southern part of the corridor where the tableland surface has similar characteristics. In the northern part, however, the drainage is also into broad, braided creek channels as well as into some narrow incised channels, and these drainage lines are also designated as pattern K3 in the mapping for the northern corridor.

For clarity, the terrain pattern mapping has been consolidated on Figure 10.7 to indicate the following terrain features:

- tableland surfaces (pattern K1)
- drainage depressions and dissection slopes (patterns K3 and K2 south of Beltana Dam)
- drainage channels and escarpment slopes (patterns K3, Q3, K2, Pb2 and J2 north of Beltana Dam)
- dune fields (patterns K4, K5 and K6).

Vegetation description

For much of its length, the corridor will cross dune fields of the Moondiepitchnie environmental association (Laut et al. 1977). As discussed above, the major physical variation within this association is a change in dune orientation from about north-east/south-west near Olympic Dam to north/south beyond Canegrass Dam. The primary characteristic of the northern dune field is the alternation of the dunes of recent siliceous sands with interdune corridors in which the underlying tableland surface is exposed. This spatial rhythm in landform is accompanied by an alternation of woodland or tall shrubland with an ephemeral understorey on sands, and low chenopod shrubland on the more structured interdune soils. Section 3.4.1 describes a series of vegetation sequences corresponding to the various dune and swale patterns, and these relationships between the main character species and the landform cycle are summarized in Table 10.2.

Table 10.2 Character species in dune fields

Character species	Structure	Landform	
Atriplex vesicaria (saltbush) and Maireana astrotricha (low bluebush)	Low open shrubland	Interdune corridor	Broader interdune areas with transported soils, partial gibber cover. Also in tableland bordering dunes. Jessup (1951) recognizes several soil types with the character species. (M. astrotricha tends to dominate in the more northerly parts of the dune fields. This is not a result of stocking, as it also occurs in ungrazed areas.)
Maireana astrotricha sometimes with M. georgei but lacking saltbush	Low open shrubland		
Atriplex vesicaria often with Aizoon quadrifidum (iceplant)	Low open shrubland		Narrower interdune areas, clayey sands.
Acacia aneura (mulga) and A. linophylla (grey or sandhill mulga)	Tall open shrubland/ low open woodland	Dune-interdune	Dune flanks; shallow sand over clay soils (A. aneura); low dune ridges.
Phyllanthus fuernrohrii	Herbland		Deflation areas and sandy rises. Found in northern parts of dune fields in areas occupied elsewhere by Atriplex.
Callitris columellaris (native pine)	Low open woodland	Dune: increasing sand mobility	Deep sands; dune ridges. Uncommon along corridor north of the Dog Fence.
Acacia ligulata (sandhill wattle/ Dodonaea angustissima (hopbush) with A. linophylla	Tall open shrubland		A. linophylla on dune flanks, others on dune tops associated with blowouts
Zygochloa paradoxa (sandhill canegrass)	Hummock grassland		Deep sands.

Dunefields: Vegetations on deep and shallow sands respectively, fall within Jessup's (1951) Acacia linophylla/A. ramulosa association and A. aneura/A. brachystachya association, with some areas also within Jessup's Zygochloa paradoxa association. These broad associations, however, obscure a number of variations in the composition of the plant cover, although the variations have considerable bearing on landscape stability (Table 10.2). Hence, reference is made to character species or species combinations rather than the formally defined plant associations.

Character species of dunes change significantly along the corridor. Native pine (Callitris columellaris) woodland, a common vegetation component on deep sands on Roxby Downs Station and further south, is absent along the corridor to the north of the Dog Fence. Sandhill mulga (Acacia linophylla) decreases in importance as a dune species while sandhill wattle (A. ligulata) increases, to the point where sandhill mulga is not seen for considerable distances along the traverse of the corridor. Other species also show changes in relative importance. The hopbush (Dodonaea angustissima), characteristic of less stable sand areas about Olympic Dam, also disappears to the north, while the needlebush (Hakea leucoptera) becomes much more common. The mulga (Acacia aneura) woodlands common on shallow sands and lower dune flanks on Roxby Downs are frequently replaced to the north by a very sparse cover of the low herbaceous perennial Phyllanthus fuernrohrii.

There appears to be a steady decrease in dune stability along the corridor. Relatively well vegetated and stabilized sandhill mulga dunes give way to dunes characterized by sandhill wattle and hopbush, with extensive blowouts, which in turn give way to dunes on which the slight perennial cover is almost solely provided by sandhill wattle, with scattered needlebush and bullock bush (Heterodendrum oleaefolium). The incidence and extent of sandhill canegrass (Zygochloa paradoxa) also increases. These areas generally have a very high level of sand movement. Towards the northern extremities of the dune fields there are dunes which are almost, or entirely, devoid of any perennial vegetation.

The components of the interdune vegetation are influenced largely by the degree of exposure of the underlying tableland surfaces. Primary variations in occurrence of character species are given in Table 10.2. The most common swale vegetation in the south of the traverse is a mixed saltbush/low bluebush (Atriplex vesicaria/Maireana astrotricha) low open shrubland, but swales on the northern part of the traverse frequently carry a low open shrubland of low bluebush, without saltbush present.

Western myall (Acacia papyrocarpa), frequent in swales south of Olympic Dam and characteristic of much of the plains country between Olympic Dam and Port Augusta, occurs only near the start of the corridor, and does not even extend to the area at which mapping commences in Figure 10.7.

Tablelands: Most of the corridor beyond the dune fields crosses stony tablelands largely within the Marree environmental association of Laut et al. (1977). Jessup (1951) defined and mapped a variety of plant associations for tableland areas of the type which will be crossed by the corridor. From south to north, in order, these are:

- Atriplex vesicaria/Sclerolaena (Bassia) species occurring north of the Dog Fence to about the latitude of Canegrass Dam;

- Atriplex vesicaria/Ixiolaena leptolepis about the latitude of Canegrass Dam;

- Atriplex rhagodioides on open plateau surfaces along the northern parts of the corridor.

The first two associations were closely related in floristic composition and soil requirements. They were found on tableland soils derived from Cretaceous shale and showing patterning of gibber-paved shelf areas separating vegetated gilgais or crabholes. The main feature Jessup used to distinguish these associations was the degree of patterning present. The more pronounced patterning within the A. vesicaria/Ixiolaena association is of the level found on the Andamooka and Arcoona Plateaux. It was found to be almost impossible to distinguish between the two associations along the traverse, particularly where the combination of heavy grazing and drought had removed most of the vegetation; hence, stony tableland in Figure 10.7 was mapped by reference to the main species present (see also Table 10.3). The boundaries for the associations set by Jessup and simplified by Specht (1972) were found to be incorrect. The Atriplex vesicaria/Maireana astrotricha associations of swales and low stony rises extend almost to Gregory Creek, including most of the areas mapped by Jessup as Atriplex/Bassia.

The Atriplex rhagodioides association is properly a vegetation of drainage rather than of tableland surfaces. Mapping by Jessup and Specht of the area south of Lake Eyre to Marree as A. rhagodioides gives a misleading picture of the frequency of occurrence of this vegetation. Tableland surfaces here generally carry either an Atriplex vesicaria patterned shrubland with frequent Mitchell grasses (Astrebla spp.) or, where grazing has had major influences, cottonbush (Maireana aphylla) or ephemeral Atriplex and Sclerolaena species with the Mitchell grasses.

The corridor route avoids large areas of breakaway country, in particular the Yarra Wurta environmental association, although small escarpments occur within the area mapped on Figure 10.7. These generally support a very sparse tall shrub cover of dead finish (Acacia tetragonophylla) with a very scattered understorey of low bluebush (Maireana astrotricha) on skeletal soils.

Table 10.3 Character species of tablelands and slopes

Character species	Structure	Landform
Atriplex vesicaria (saltbush) and Sclerolaena species	Low open shrubland	Patterned stony tableland with gilgai formation, similar to that of the Andamooka plateau.
Atriplex vesicaria and Astrebla (Mitchell grasses) or degraded to Maireana aphylla (cottonbush)	Low open shrubland	Patterned stony tableland with gilgai formation: Marree tableland
Atriplex vesicaria and A. rhagodioides (silver saltbush)	Low open shrubland	Undulating plateau surface with numerous drainage depressions not sufficiently marked for individual mapping.
Maireana astrotricha (low bluebush) and Acacia tetragonophylla	Low open shrubland with scattered tall shrubs	Breakaway slopes, small hills.

Note: Primary combinations only are given. Most combinations of character shrubs occur on tablelands within the Study Area.

Drainage areas: The third major suite of vegetation types is associated with drainage. Drainage within dune fields tends to be localized, generally with claypans or canegrass (Eragrostis australasica) swamps as terminal drainage features. Section 3.4 provides more detail of the variation in vegetation associated with local drainage than is given in Table 10.4. Two distinctive and uncommon drainage vegetations are found within the dune field traversed by the pipeline corridor and are discussed further below.

A series of plant communities occur along incised drainage channels on the northern tablelands, with character species depending on the degree of stream definition, frequency and salinity of stream flows (Table 10.4). At one extreme, broad washes carry a low open shrubland of silver saltbush (Atriplex rhagodioides) while, at the other, well defined water courses with frequent flows may contain fringing tall shrubland of Acacia stenophylla and Eucalyptus woodland. Large water courses such as Gregory Creek may contain a range of drainage vegetation along courses and across the flood plain (Figure 10.7). Old man saltbush (Atriplex nummularia) first appears at this creek. It is most common in water courses along the Alice Springs to Port Augusta railway section of the corridor.

Degree of alteration of vegetative cover: Grazing influences vary from light, at the start of the corridor route, to severe over most of the northern tablelands. The major influence played by pastoral activity in altering the landscape is recognized by Laut et al. (1977) who classify the environmental units along the corridor route as 'degraded natural'. This impact of grazing upon the vegetation of the region has been further compounded by rabbits. Hence, although the plant cover is native vegetation, in most cases it is far from pristine.

Table 10.4 Character species of drainage

Character species	Structure	Landform	
Eragrostis australasica (canegrass) + Muehlenbeckia cunninghamii (lignum)	Tall grassland	Drainage depressions	Canegrass swamps.
Melaleuca glomerata (tea tree) and possibly M. pauperiflora, M. uncinata	Low open woodland		Fringes of non-saline swamps in dune field.
Atriplex rhagodioides (silver saltbush)	Low open shrubland	Drainage channels: increasing degree of definition and size of streams	Broad, poorly defined washes; floodplains of larger streams.
Nitraria billardieri (nitre- or dillon-bush)	Open shrubland		Fringes of floodplains of larger streams, on saline soils.
Halosarcia indica subsp. leiostachya (samphire)	Low open shrubland		Saline streams and flood-outs.
Atriplex nummularia (old man saltbush)	Open shrubland		Main cover of floodplains and smaller streams.
Acacia stenophylla	Tall shrubland		Well defined major stream courses.
A. stenophylla/Eucalyptus spp. (E. microtheca and E. intertexta)	Tall shrubland to low open woodland		Largest streams with frequent freshwater flows

The tableland shrublands along that section of the route utilizing the trackbed of the Alice Springs to Port Augusta railway have been particularly severely degraded, a consequence of long pastoral occupation resulting from the ready availability of spring water.

Part of the dune field on the route provides an exception, showing no sign of present or past domestic grazing (Figure 10.7 Site 13). One obvious feature of the shrubland of swales in this area is the very high density of Maireana georgei, a perennial shrub which generally survives only at low densities under grazing.

Uncommon vegetation of the region: There are few areas along the corridor route containing vegetation which is not well represented throughout the region.

Within Roxby Downs Station, there are several dolines into the Andamooka Limestone. These contain localized open scrubs of mulga and other tall shrub or tree species, and give the densest vegetation cover in the region. As well as being relatively uncommon occurrences, they each occupy a very limited area. The corridor route will not directly affect any of these features.

Three kilometres north of the Bulls Head Vermin Gate, the route crosses a patch of Sarcostemma australe (Figure 10.7 Site 3), little more than 500 m in diameter, which is the only stand of this unusual plant along the vehicle traverse of the pipeline corridor. The track laid for line surveying has removed several individuals. Sarcostemma australe is widely distributed through the north-west pastoral area, but its pattern of distribution is of small colonies isolated by many kilometres from their nearest neighbours (Fatchen 1982).

The corridor skirts the one main occurrence of tea tree found along the traverse, in dunes fringing freshwater swamps (Figure 10.7 Sites 9 and 10). In this instance, the species present is Melaleuca glomerata, in contrast to the tea tree areas to the south and about the Arcoona Plateau, which were found to be M. pauperiflora and M. uncinata.

Unusual vegetation is associated with mound springs and gypseous hills at Bopeechee (Figure 10.7 Site 16). The springs themselves and part of their drainage are covered by a sward of saltwater couch (Distichlis distichophylla) and Scirpus, with numerous individuals of Myoporum refractum. The low dissected gypseous hills carry the sparse Acacia/Maireana cover associated with skeletal soils of breakaway areas, but Scirpus is also present, as well as the only occurrences of some other shrub species (e.g. Maireana appressa). A suite of species considerably different from that of the surrounding tableland could be expected to appear in these areas during growth periods. The corridor alignment was sited to specifically avoid this area.

The one other unusual vegetation is a red mallee (Eucalyptus socialis) stand on a plateau surface along the Port Augusta to Alice Springs railway (Figure 10.7 Site 17). This is the only occurrence of both the species and the structural formation within the limits of observation. Corridor development will not impinge on this vegetation.

Archaeology

The pipeline corridor from Olympic Dam to Bopeechee has been surveyed for archaeological sites. A vehicle traverse of the corridor route was undertaken, with every blowout occurring within 25 m of the pegged centreline on the crests or flanks of dunes being examined for archaeological materials. Where dunes abutted pronounced claypans, the eroded shorelines and flanks of the dunes were examined, and where rock types suitable for flaking occurred in the swales these were also examined for evidence of quarrying or knapping. Both summary and analytical recording methods were used to describe archaeological sites located during the survey (Section 5.1).

The survey recorded fifty-three sites, of which forty-eight were campsites (many with knapping floors) and five were quarries with knapping floors. In all respects, the nature, frequency, and distribution of the sites were very similar to those recorded in the Study Area (Section 5.1). All but two of the sites occurred in the dune fields of the Moondiepitchnie environmental association, and the two sites on the gypcrete plain of the Marree environmental association were both located in areas with a local sand cover.

Five of the sites recorded are considered to be richer and more diverse than the others and worthy of further investigation. These sites have not been recorded in great detail nor has any attempt been made to salvage or excavate the materials they contain. One of the sites is in the vicinity of a known mythological site.

Land use

The borefield corridor route traverses pastoral lands for its entire length. Stations which will either be crossed by the corridor or contain borefields include:

- Roxby Downs
- Stuarts Creek
- Finniss Springs
- Muloorina.

As with the transmission line corridor, easements for the various borefield works will be negotiated in accordance with the provisions of Clauses 13(17) and 31 of the Indenture Agreement. Should both pipelines be buried for their entire length, livestock movements will not be restricted and alienation of grazing lands will not occur. If the pipeline from Borefield B is constructed above ground, stock and vehicle crossings will be provided where appropriate.

Sites of geological significance

No sites of geological significance occur within the immediate vicinity of the pipeline corridor or of the borefields.

Features of special environmental or heritage significance

The Far North Planning Area Development Plan has identified a number of features of special or environmental significance which should not be destroyed or lessened in value by any development until a management plan has been prepared (Section 4.1.10). One such feature is Hermit Hill mound springs (Figure 10.7 Site 18). However, as these springs are 4 km from that section of the corridor which uses the old railway line between Bopeechee and Alberrie Creek sidings, they will not suffer direct impact from construction works associated with the pipeline corridor.

The corridor from Alberrie Creek siding to Borefield B, and Borefield B itself, lie within the 2,100,000 ha feature listed in the Register of the National Estate as 'Lake Eyre and environs' (Figure 10.7 Site 19). This area is of geomorphological interest in being partly below sea level and for its shore line and lake bed features. Palaeogeographically, its history as a freshwater lake which has changed to a salt lake is of scientific interest. Of hydrological interest are its rare great flooding events, while the mineral deposits in its bed and its geological form are also of interest (Australian Heritage Commission 1981). However, neither the pipeline corridor nor the surface developments related to Borefield B will detract from these features.

Tourism and recreation

The pipeline corridor crosses one of the tree-lined water courses of the Lake Eyre Basin (Gregory Creek, Figure 10.7 Site 14) which is considered to have some tourist and recreation significance (Section 4.1.8).

Airfields

There are no authorized landing areas or licensed aerodromes in the immediate vicinity of the pipeline corridor.

10.2.4 Environmental impact of the pipeline corridor

Terrain impacts and mitigation

The terrain features present in the pipeline corridor are of a similar type to those in the transmission line corridor (i.e. tableland surfaces, dissection slopes, drainage depressions and stream channels, and dune fields). Therefore, the same general considerations apply with respect to potential terrain impacts and appropriate mitigation measures as those which are discussed in Section 10.1.4. Additional factors specific to the pipeline corridor requiring consideration relate to particular locations along the corridor route and to the trenching operations for pipe laying. To avoid repetition of the general considerations, only these additional factors are discussed below.

Specific locality considerations

A number of specific localities are shown on the annotated map (Figure 10.7) where the potential impacts for the relevant terrain features indicated in Table 10.5 could occur. These localities are:

- immediately north of Olympic Dam, where the corridor crosses two small canegrass swamps and a depressed swale area which may hold water during wet periods (Sites 1 and 2);

Table 10.5 Potential impacts at terrain pattern level

Terrain pattern	Broad description	Potential impacts of pipeline corridor
K1	Tableland surface	Disturbance of soil by movement of plant and vehicles around pole sites and along trench alignments. Interception and concentration of surface flows. Rutting of surface by construction traffic in wet weather, leading to erosion on sloping surfaces. Creation of weak depressions due to slow consolidation of soil along pipe trenches, leading to erosion by water.
K2	Dissection slopes and escarpment slopes (including breakaway areas)	Disturbance of soil by movement of plant and vehicles around pole sites and along trench alignments. Interception of stream flows. Channelling of flows alongside embankments or trench depressions. Scarring and erosion of surfaces caused by difficult working conditions during construction. Alteration to sediment movement patterns. Possible scour around concrete structures.
K3 and Q3	Drainage depressions (including canegrass swamps and claypans) and stream channels (including drainage lines)	Disturbance of soil by movement of plant and vehicles around pole sites and along trench alignments. Alteration to areas of swamps due to embankment construction. Accelerated erosion due to structures within creek channels. Disturbance of wet surfaces.
K4 and K5	Dune fields	Disturbance of soil by movement of plant and vehicles around pole sites and along trench alignments. Removal of vegetation with increased sand movement. Alteration to sand movements due to creation of stabilized channels (effectively, blowouts) through dune ridges.

- immediately north of the Dog Fence, where the corridor traverses pattern K3, cutting across the direction of general drainage to the north-west (Site 4);

- immediately north of this drainage pattern, where the corridor crosses two large areas of pattern K2 where there are a number of minor creek channels (Sites 5 and 6). While the potential for minor scouring exists, it is considered that the mitigation techniques to be adopted (Section 10.1.4) will prevent this from occurring;

- south-west of Brumby Dam, where the corridor passes along the eastern margin of weakly dissected drainage slopes (Site 7). Again, it is considered that the mitigation techniques to be adopted will prevent scouring;

- in the Peapeanana Ridge area, where the corridor skirts a claypan to the east along an unstable transverse dune (Site 8); and prior to this where it cuts across pattern K3 where there is extensive drainage to the east;

- north of Canegrass Dam, where the route traverses many kilometres of pattern K3 with drainage to the east into a very large canegrass swamp (Site 11). On the western edge of this pattern rock outcrop occurs;

- north of the large canegrass swamp, where the rope-like appearance of the sand dunes, lack of vegetation, and numerous blowouts indicate an area of instability (Site 12);

- at Gregory Creek (Site 14) and Screechowl Creek, where major creek crossings are required;

- between Gregory Creek (Site 14) and Screechowl Creek where the route generally crosses tableland surface (Site 15), although one low drainage depression running near New Year's Gift Bore will need to be crossed;

- along the railway line, where the additional impact of pipeline construction is expected to be minimal, and will be further reduced by the existence of the access road.

Specific considerations relating to trenching operations:

- **Tableland surface - terrain pattern K1:** Where the pipeline is buried, the required construction of trenches across a tableland surface can initiate erosion. This can occur if trenches are overfilled and diversion of water results, or if trenches are underfilled or the filling compacts below ground surface level and channelling of water results. As a consequence, it is intended to adopt the following mitigation measures:

  - ensuring that all back-fill material in trenches is properly compacted;
  - providing an erosion resistant cover to trenches in any sloping tableland areas.

- **Dissection slopes - terrain pattern K2:** Being sloping surfaces formed by erosion and therefore potentially unstable, the same mitigation measures will be adopted in relation to trenching operations on dissection slopes as those mentioned above for tableland surfaces in terrain pattern K1.

- **Dune fields - terrain patterns K4 and K5:** South of Canegrass Dam, there are east-west trending dunes perpendicular to the pipeline corridor, which will allow dune crossings to be made at the most favourable angle. This will reduce the likelihood of wind-blown sands collecting on the access road, although stabilization of disturbed areas will still be required. North of Canegrass Dam, the dune direction changes to almost north-south and it has been possible to keep the pipeline corridor route within a swale area for almost its full length. A reduction in density and variation in the types of vegetation in this area, together with increased areas of bare sand, indicates a lower dune stability in this section. Therefore, where the pipeline corridor is parallel to dune ridges, potentially unstable sand dunes will be avoided where practicable, particularly those areas of denser sand accumulations on the margins of drainage depressions and upwind of dune ridges. The preferred arrangement of services within these sections will be to locate the transmission line towards the bottom of the swale, with the road near the lower footslopes of the dune ridges and the pipe trenches above the road.

Vegetation impacts and mitigation

The main impacts will be some loss of vegetation and the initiation of some erosion due to the construction of the service road (including the excavation of borrow material) and the laying of the pipeline. Off-road vehicle movement associated with corridor construction and with bore sinking may extend these impacts beyond the immediate corridor. In addition, as the service road will improve access to areas along the pipeline corridor, there is also potential for indirect impacts resulting from increased public usage.

Development impact will be least significant along the former railway alignment, where existing service routes will be used. Within the dune fields, the impact of corridor development will generally not be significant in more than a local sense, given the area occupied by equivalent landscapes within the region. The level of degradation of vegetation caused by grazing, combined with the regional extent of the tableland vegetations, means that the vegetation impacts will not be significant. It is also expected that erosion problems arising from development will be minimized by the adoption of the mitigation measures outlined below.

The impacts and mitigation measures in relation to vegetation are discussed under the following headings:

- Uncommon vegetation in the vicinity of the corridor
- Protected plants
- Rehabilitation of disturbed areas
- Erosion control in dune fields
- Erosion control on tablelands.

Uncommon vegetation in the vicinity of the corridor: There are only three instances in the immediate vicinity of the corridor where vegetation of some regional significance occurs:

- Sarcostemma australe (Figure 10.7) has only an isolated and restricted occurrence in the area, and the one known stand of this species along the traverse will be bisected and up to 10% of the individuals destroyed. While this impact is considered significant, the diversion of the corridor is not felt to be warranted as a surveying track already runs through the stand. However, no other development (such as installation of additional facilities or removal of material) will occur in this area outside the confines of the corridor, and construction and operations activity will be confined to the corridor right-of-way to avoid further damage.

- There are two stands of Melaleuca glomerata fringing swamps (Figure 10.7) which would be affected if development activity occurred beyond the corridor width. Again, construction and operations activity will be confined to the corridor right-of-way to avoid damage to these woodlands.

- The corridor will cross an ungrazed dune field (Figure 10.7) which is a rarity in the pastoral zone. However, a major and very long route diversion would be required if this were to be avoided, and this is not considered to be warranted. The area directly affected by the corridor will be small in relation to the total extent of this unstocked area and, with the erosion controls proposed below, the impact will be minimized.

Protected plants: The following species, protected under the South Australian National Parks and Wildlife Act, 1972-1980, occur along the proposed northern corridor:

- Heterodendrum oleaefolium (bullock bush)
- Pittosporum phylliraeoides (native pittosporum)
- Eremophila longifolia (emu bush)
- Clianthus formosus (Sturt pea).

Drought conditions prevented observation of the Sturt pea. From the few specimens found, the species is expected to be widespread and abundant in dune fields along the proposed route, and any impact resulting from the construction of the corridor will not be significant. Occurrences of the other three species within 50 m of the surveyed route from Olympic Dam to Bopeechee have been noted in Fatchen (1982).

Bullock bush is a common and characteristic species on dune flanks throughout dune field areas (Section 3.4.2). Some 190 bushes were counted along the corridor traverse, of which eleven had already been removed to assist line surveying and pegging. While the species was not found on every dune crossed, its distribution along the traverse was widespread, and therefore the loss of some individuals will not be significant.

Native pittosporum is uncommon but widespread on tableland areas, often associated with small water courses. Thirty-nine individuals were noted in eleven occurrences, a number of which contained one or two adults and several juveniles. Again, the rate of occurrence of the species along the traverse indicates a widespread distribution, and hence losses likely during construction should not have major significance.

Emu bush is undoubtedly rare in the country traversed. Only three occurrences were noted, all in dune fields and two within 5 km of each other. The species would appear to be more frequent further south, in the area covered by the baseline survey. While more stands would be expected in the large adjacent areas of similar dune field, the small, localized sample on the traverse suggests that stands would be very few and far between. Accordingly, removal of the specimens from the corridor might be seen as a significant impact on a rare species. However, as the specimens are towards the edge of the corridor, it may be possible during construction to modify alignments slightly to avoid the removal of these individuals. Given this possibility, and the fact that the species is widespread elsewhere in the north-west of South Australia, the impact on this species is considered acceptable.

Rehabilitation: The following measures will be adopted to rehabilitate areas disturbed during the construction of the water supply facilities:

- Profiles of borrow pits and other disturbed areas will be rounded.

- Top soil and other loose material will be respread.

- Light contour ripping of disturbed surfaces will be carried out to create seed traps and to reduce surface wind velocity.

- Trenches and back-fill will be compacted and profiles shaped to prevent water erosion.

- Certain areas will be watered once, to assist the establishment of vegetative cover.

Erosion control in dune fields: In the selection of the pipeline corridor route, one of the primary aims has been to avoid wherever possible areas prone to drift (particularly areas mapped as Zygochloa paradoxa or as bare sand), and especially to avoid running the corridor along the top of dune ridges.

The degree of vegetation cover, and therefore dune stability (Section 3.4.3), varies considerably along the corridor route. Between Olympic Dam and Bopeechee, however, there is a gradual reduction in the amount of perennial cover (and in species diversity as well) and the potential for sand drift increases accordingly.

Over the dune field segments of the pipeline corridor, adoption of the terrain mitigation measures outlined previously (particularly the forming of the road, limiting construction and operations vehicle traffic to formed roads in dune sections, ensuring that tracks cross dunes more or less perpendicularly to the dune trend, and that development avoids the more sensitive dune areas) will minimize any erosion resulting from vegetation removal.

Roads will be provided with sufficient water barring and run-off distribution to avoid initiating gully or sheet erosion, while drainage systems will be designed to avoid the transference of surface water from one local swale catchment to another. Compaction measures will ensure that filled trenches will not present a lower surface than the surrounding ground. In swales, active rehabilitation measures such as ripping or pitting may be necessary to reduce possible water erosion and to aid the re-establishment of perennial vegetation.

Erosion control on tableland: The Olympic Dam to Bopeechee sector of the pipeline corridor runs over gently sloping tableland surfaces. Near Bopeechee, where there is a series of saline water courses and a deeply gullied tableland escarpment, soil erosion is already pronounced, and road construction and pipeline installation in this area would be likely to accelerate this process. As a consequence, this area has been avoided completely by routing the line to cross the almost flat plateau surface to the west (Figure 10.7). The adoption of this route was also considered necessary to avoid occasioning any further physical damage to vegetation and habitat associated with springs than that which has already resulted from pastoral and tourist activity.

It will be necessary for the pipeline corridor to cross tableland escarpments where alternative routes are not available. Along the abandoned railway these will present few problems, as the existing trackbed will be used. However, in the case of other escarpment crossings, protection against water erosion will be needed. This will be achieved by ensuring that construction does not take place directly down the fall line of an escarpment without the provision of protective water diversion works. The access road, in particular, will be provided with frequent water barring.

Elsewhere, undulating plateau surfaces are still prone to water erosion (Graetz and Tongway 1979). While on parts of the tablelands north of Olympic Dam there is reasonable natural erosion protection provided by both vegetation and the gibber pavements, much of the tableland along the pipeline corridor has had the vegetation cover reduced by overgrazing, leaving the gibber surface as the main erosion protection. Wherever possible therefore, this gibber cover will be left undisturbed. The main precautions against unnecessary impacts will be the construction of a formed road with water barring, care in the filling of trenches, and the limitation of off-road movement of construction and operations vehicles. Trench surfaces may require capping to prevent the dispersible clay soils from washing out and the trenches from gullying. However, development will avoid drainage areas wherever practicable.

Archaeological impacts and mitigation

The fifty-three archaeological sites found in the survey of the pipeline corridor occur at or near the surface. The construction of the service road and pipelines, plus the erection of transmission poles, will destroy or damage any site occurring in the area of activity. However, of these fifty-three sites, forty-eight are not considered to be unique in any way or of sufficient importance to warrant more detailed recording or salvage work than that already undertaken. No particular effort will therefore be made to avoid these sites.

It is considered that the current descriptions of the other five richer and more diverse sites found in the archaeological survey do not provide sufficient information upon which to estimate their scientific value. It is thus intended to undertake further recording work at these sites, supplemented by sample collections of materials where appropriate. If this additional work establishes the scientific importance of any of these sites, the corridor (or any facilities in the corridor) will be relocated or specifically designed where practicable to avoid damage to the site and to obviate the need for salvage work.

Visual amenity

The most obvious visual elements within the pipeline corridor will be the 22.5 m high transmission poles and (if it is above ground) the pipeline from Borefield B. While these elements will detract from the visual amenity of the region for travellers on the service road and on that section of the Marree to Oodnadatta road between Bopeechee and Alberrie Creek, it is considered that this is outweighed by the benefits afforded by containing all development within a narrow corridor.

Off-road vehicles

The sole purpose of the road within the corridor is to service construction and to provide access for operation and maintenance of the pipeline and borefields. In order to minimize environmental impact, off-road movement of construction and operations vehicles will be limited. However, the Joint Venturers cannot control the use of the road by the public or off-road movement by these vehicles, although this will be deterred by the raised formation.

Tourist potential

As indicated, an allowance had been made in the selection of corridor width to permit the expansion of the service road to 12 m, although this is not envisaged by the Joint Venturers as part of the Project development. The potential therefore exists for the State to upgrade the road in this manner, which could improve the region's tourist potential. This would effectively establish a ring route with better than average road conditions linking Port Augusta, Woomera, Olympic Dam, Marree, Leigh Creek, Hawker and Quorn, providing good access to tourist attractions such as the Olympic Dam Project, Andamooka, the Lake Eyre Basin, the Breakaway escarpment, the mound springs, and Strangways Springs repeater station.

10.3 BOREFIELDS DEVELOPMENT

10.3.1 Water supply provisions

Water for the Project will be drawn from two borefields, Borefield A and Borefield B, which will be developed in the Great Artesian Basin at the locations shown on Figure 10.7. Borefield A, located 100 km north-east of Olympic Dam, will consist of approximately five bores spaced at intervals of 1,000 to 1,500 m. Normally, four of the bores will operate at any given time (the remainder being on stand-by) at an abstraction rate of 6 ML/d. Buried pipelines will act as collectors to bring water from the bores to the forwarding pump station (Pump Station No. 2). Borefield B, located a further 50 km north-east of Borefield A, will consist of seven to ten bores, of which two to three will normally be on stand-by. Water from these bores will also be piped to a forwarding pump station (Pump Station No. 3 in Figure 10.7). The abstraction rate from Borefield B will be 27 ML/d.

The water supply from these borefields will be developed in accordance with the requirements of Clause 13 of the Indenture Agreement. The State will grant a Special Water Licence or Licences, under which the Joint Venturers may draw underground water from borefields to satisfy all or part of the Project water requirements. This Licence will be subject to a number of conditions, including:

- the installation and maintenance of a monitoring system, approved by the State, which will provide data on total water quantities withdrawn, water pressures and levels, and water qualities;

- the provision of an annual report to the State, defining aquifer response to water production, the ability of the resource to maintain the supply, a strategy for future water production and management, and the need for further development of, or use of, additional water sources. This annual report is intended to provide one of the mechanisms by which the State will be able to ensure that the resource is used responsibly.

The Special Water Licence may commence prior to, but will subsequently run concurrently with, the Special Mining Lease. The Minister of Water Resources has the right to restrict the abstraction of water by the Joint Venturers (at ninety-six hours' notice in an emergency) if it is believed that there is a reasonable possibility of a complete or partial failure of the water supply.

The Indenture Agreement makes provision for the use of other water supplies where practicable. Under Clause 13(4), the State will make available at Port Augusta up to 9 ML/d of potable water, should the Joint Venturers elect to construct a pipeline from Port Augusta to Olympic Dam. If this supply of water is not being utilized by 31 December 1993 (or there is not by then a reasonable expectation that the supply will be utilized), the State has the right to make available the unused part of the supply to other consumers. The right to develop local surface water supplies where practicable is also provided to the Joint Venturers by Clause 13(10) of the Indenture Agreement. Clause 13(11) requires the Joint Venturers to design, construct and operate the Project in such a manner that as much water as possible is recycled, while Clause 13(15) obliges the Joint Venturers to ensure the most efficient usage of all water resources.

10.3.2 Borefields investigation programme

At the time of writing, the Joint Venturers had undertaken the following works as part of the investigation programme associated with borefield development in the Great Artesian Basin:

- a survey of all existing bores in and surrounding the borefields to measure flow rates and to compile available information. Detailed hydrogeological data is generally lacking, as previous bores were not logged and seldom penetrated the full depth of the aquifers;

- a preliminary survey of mound springs in the area;

- electrical resistivity and seismic refraction investigations to determine depths to bedrock and to locate sites for test drilling;

- the drilling of five test holes in Borefield A and two test holes in Borefield B. These holes were drilled, cased, cemented and completed according to regulations governing the drilling of holes in the Great Artesian Basin. Although the majority of these holes are capable of supplying water, their long-term use will probably be as monitoring bores to assess the effect of pumping from the borefields;

- geophysical and geological logging of these bores;
- long-term and short-term flow tests on the bores to obtain hydraulic parameters (transmissivity) of the aquifers;
- computer modelling to predict the effect of pumping, based on existing data and that obtained from the investigation programme.

Future work will include the refining of the computer model and the testing and monitoring of the proposed borefields to further refine predictions.

10.3.3 Environmental factors

The environmental factors relevant to the assessment of impact of these borefields relate to one of the following:

- the Great Artesian Basin
- hydrogeology of the borefields
- the mound springs
- Aboriginal sites.

Great Artesian Basin

The Great Artesian Basin is an extensive sedimentary basin (1.74 million km^2 in area) which covers parts of the Northern Territory, Queensland, New South Wales, and South Australia. The South Australian portion of the Basin covers an area of about 310,000 km^2 (about 18% of the Basin's total area). The Basin consists of a multi-layered sandstone aquifer system, separated and overlain by confining beds which, although they have a low permeability, do allow some vertical movement of water from the system.

The major recharge areas occur along the Basin's eastern margin, where the aquifers outcrop along the western slope of the Great Dividing Range in Queensland and New South Wales. The movement of groundwater is from these recharge areas to the south-western, western and southern margins of the Basin. Recharge in South Australia is thought to be negligible. The potentiometric surface of the main aquifers (i.e. the height to which water will rise in a bore tapping the aquifer) is still above ground level in most locations, thereby providing artesian flows from bores.

Prior to development, the Basin was in a natural steady state condition, with an equilibrium between recharge and discharge, the latter occurring via springs, vertical leakage and some lateral outflow. Since its discovery in 1880, however, the Basin has been extensively developed for pastoral purposes, with approximately 4,700 bores having been drilled to tap this water resource. Artificial discharge from bores reached a peak of approximately 2,000 ML/d in the late 1910s to early 1920s. Development of the Basin caused a reduction in aquifer water pressure and a resultant reduction in individual bore discharge, vertical leakage, and spring discharge, which is continuing today. This general reduction in water pressure and the consequent steepening of hydraulic gradients has allowed additional recharge water to enter the system. The current recharge rate is estimated at about 2% of the amount of water available for recharge (Habermehl 1980). As a result, a new state of equilibrium has almost been reached between the total recharge and discharge rates. A greater yield of water could therefore be sustained in the longer term, the effects of which would be:

- a steepening of the hydraulic gradient, which would in turn increase the recharge rate and the flow rate through the aquifers;

- a reduction in potentiometric head throughout the Basin, which would result in a progressive reduction of flows from all outlets until a new state of equilibrium was reached.

Consequently, if this resource were to be developed to its full potential, the flow rates of existing bores and springs would be progressively diminished. However, proper management of Basin development would enable flow rates from bores to be maintained at levels sufficient to sustain existing uses. The relevant published statistics relating to recharge and discharge both for the Great Artesian Basin as a whole and for the South Australian portion are summarized in Table 10.6.

Table 10.6 Recharge and discharge statistics for the Great Artesian Basin

	South Australian portion	Entire Basin
No. of flowing bores in 1970	150	3,100
Total estimated recharge (ML/d)	-	3,100
Discharge:		
bores (ML/d)	210	1,500
springs (ML/d)	80	200
vertical leakage (ML/d)	250	1,400
Total (ML/d)	540	3,100
Effectively used (ML/d)*	<20	<150
Bore discharge wasted (ML/d)**	>190	>1,350

* Water used for domestic purposes and stock watering.
** Water lost by evaporation or seepage into shallow sediments.

Source: Shepherd 1978; Habermehl 1980; Seidel 1980.

The greater part of the water discharged by vertical leakage is lost to shallow sediments and through evapotranspiration. Of the bore discharge, more than 90 to 95% is wasted through seepage, transpiration and evaporation associated with the distribution of water by open earth drains, many of which are tens of kilometres in length (Shepherd 1978; Habermehl 1980).

The water within the Basin generally has a salinity of 500 to 1,500 mg/L (total dissolved solids) with salinity increasing near the discharge margins. The dissolved salts are dominated by sodium bicarbonate, and the water is generally unsuitable for irrigation due to the high sodium content and high residual alkalinity. The water in the Basin to the north-west of the borefields has a high sulphate content and is therefore corrosive in nature as well as being difficult to treat to provide a potable supply.

Hydrogeology of the borefields

Borefield A: Initial investigation work has been carried out in the vicinity of Borefield A, which is on a southerly extension of the Great Artesian Basin proper. The main aquifer in the area of this borefield is the Cadna-owie Formation, a fine to medium grained sandstone with quartz and lithic grains averaging 0.5 to 1.0 mm in diameter. The Formation is characterized by pyritic bands near the top, and contains lignite and shell bands. Where intersected by drilling in the borefield, it is approximately 15 m thick and underlain by white kaolin clays with sands, which in turn are underlain by weathered bedrock. The Formation is subject to lateral facies changes and lensing.

The Cadna-owie Formation outcrops in places to the south and the east of the borefield (Figure 10.8) and has been intersected at shallow depth beneath the alluvium at Stuart Creek to the west, and at Finniss Springs to the east. In the centre of the borefield it occurs at about 40 to 70 m depth and is overlain by the Bulldog Shale. The aquifer is semi-confined, with the Bulldog Shale acting as the confining bed. Bores intersecting the aquifer in a strip approximately 5 km wide to the south of the Marree to Oodnadatta road provide artesian flow. The potentiometric surface at New Year's Gift Bore is 21 m above ground level, while at the investigation bore GAB 1 it is 17 m above ground level.

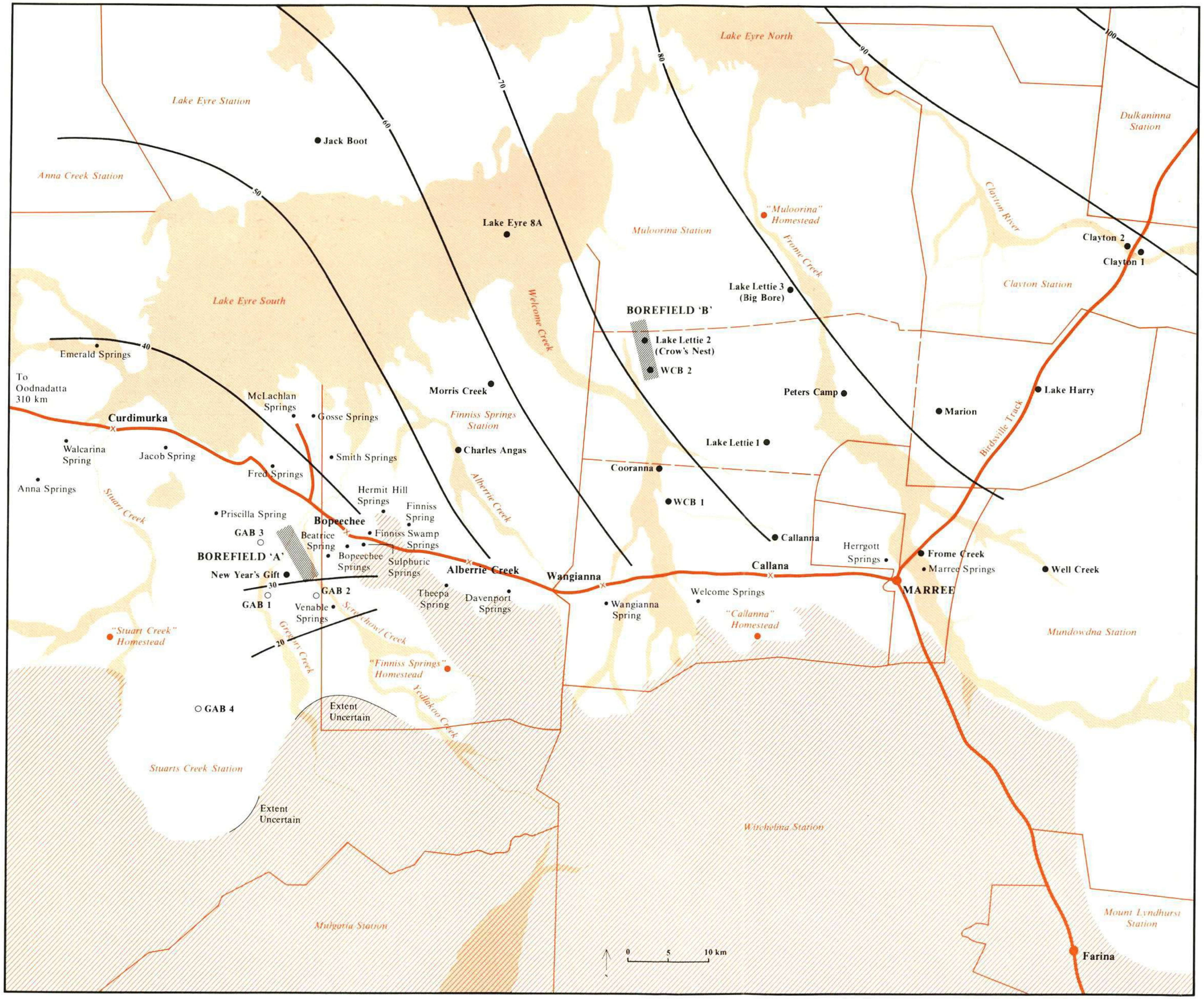
Groundwater flows into Borefield A mainly in a southerly direction from the Great Artesian Basin proper. There is a possibility that some recharge occurs around the southern and eastern margins of the borefield where aquifer pressure falls below surface elevation. Preliminary results indicate a north to south hydraulic gradient of 1.5×10^{-3} (refer to Figure 10.8 for existing potentiometric contours).

As indicated by Table 10.7, groundwater quality in Borefield A is variable, but generally of a higher salinity than in the Great Artesian Basin proper. The water in the northern and central portion of the borefield is similar to Great Artesian Basin waters, ranging in salinity from about 1,700 mg/L near the Oodnadatta to Marree road to 2,700 mg/L at the investigation bore GAB 1. The temperature of the water is approximately 25^{o}C. At Venable Springs and near Finniss Springs homestead (Figure 10.8), the salinity increases to between 3,000 and 4,000 mg/L. To the south and the west, salinities are much higher and can be in excess of 30,000 mg/L. In addition to this increase in salinity near the margins, the relative sulphate content increases due to the effect of gypseous clays and soils and/or weathering of pyrite in the aquifer. The water from this borefield will be of suitable quality for process water, but will require treatment to reduce salinity and fluoride content for potable use.

Table 10.7 Ground water quality - bores in the vicinity of Borefield A

Parameter	Beatrice	Curdimurka	GAB 1	GAB 2	New Year's Gift	Venable
Calcium (mg/L)	18	15.5	20	21	16.5	34
Magnesium (mg/L)	26	13	17	17	18	35
Sodium (mg/L)	835	930	1,100	1,020	830	1,250
Potassium (mg/L)	20	18.5	17	18	19	19
Iron (mg/L)	-	0.3	-	1.09	0.05	-
Bicarbonate (mg/L)	985	1,088	1,150	1,300	979	1,100
Sulphate (mg/L)	142	50	190	130	130	360
Chlorine (mg/L)	750	877	1,000	880	731	135
Fluorine (mg/L)	3.2	2.2	2.6	4.2	3.0	0.7
Silica (mg/L)	-	19.0	24.4	12	24.5	24.4
Nitrate (mg/L)	1	1	-	-	1	-
Phosphate (mg/L)	0.07	0.01	-	-	0.05	-
Total dissolved solids (mg/L)	2,279	2,439	2,700	2,465	2,227	3,700
pH	7.1	7.9	7.6	8.0	7.7	7.7
Electrical conductivity	3,652	4,086	6,000	4,970	3,734	7,150
Radium-226 (mBq/L)	-	-	-	-	63	-
Total hardness	152	93	120	120	115	230

Figure 10.8
BOREFIELDS, EXISTING DEVELOPMENT



Borefield B: Investigations, including seismic traverses and the drilling of two test bores (WCB1 and WCB2), have recently been completed. The results show that the depth to bedrock gradually increases from approximately 100 m near the Marree to Oodnadatta road to approximately 380 m at Crow's Nest Bore. The main aquifer (probably the Algebuckina Sandstone) lies directly on the bedrock. The thickness of this aquifer intersected in WCB1 and WCB2 is only 5 to 6 m, which is less than the thickness of the aquifer at Crow's Nest Bore. Flow rates and transmissivities at the two investigation bores are correspondingly smaller than at Crow's Nest Bore (a transmissivity of 65 m^3/d.m for WCB1 compared with an estimated transmissivity of 100 m^3/d.m for Crow's Nest). As in Borefield A, the aquifers are semi-confined, with the Bulldog Shale acting as the confining bed.

The potentiometric head ranges from 20 m above ground level at WCB1 to 57 m above ground level at WCB2. A shallow saline aquifer between 50 and 80 m in depth was also intersected in WCB2. The head in this shallow aquifer was 8 m below ground level.

Table 10.8 summarizes the groundwater quality in Borefield B. The salinity of the main aquifer ranges from 1,400 mg/L in the north to 1,800 mg/L in the south. The temperature of the water at the borehead increases in a northerly direction from approximately 30°C near the margins to 55°C to the north. The salinity of the water in the shallow aquifer in WCB2 is approximately 25,000 mg/L.

Table 10.8 Groundwater quality - bores in the vicinity of Borefield B

Parameter	Callana	Charles Angas	Cooranna	Lake Lettie No. 1	Lake Lettie No. 2 (Crow's Nest)	Lake Lettie No. 3 (Big Bore)	Peters Camp	Morris Creek
Calcium (mg/L)	9.7	11.4	7	7	3	3	5.7	11.4
Magnesium (mg/L)	7.0	11.5	3	3	3	4	0.4	5.8
Sodium (mg/L)	699	653	579	538	608	556	520	686
Potassium (mg/L)	-	-	-	-	-	-	5.1	-
Iron (mg/L)	-	-	-	-	-	-	-	-
Bicarbonate (mg/L)	1,123	1,043	1,151	1,055	1,098	1,064	1,027	1,026
Sulphate (mg/L)	20.2	27	30	34	16	28	5	32.8
Chlorine (mg/L)	448	435	222	211	100	233	234	475
Fluorine (mg/L)	3.4	3.1	3.8	3.6	3.8	4.0	3.7	3.2
Silica (mg/L)	-	-	-	-	-	0.20	-	-
Nitrate (mg/L)	1	1	1	1	1	1	Present	Present
Phosphate (mg/L)	-	-	-	-	-	-	-	-
Total dissolved solids (mg/L)	1,600	1,650	1,407	1,313	1,470	1,348	1,276	1,950
pH	8.1	7.5	7.9	8.0	8.1	8.1	8.0	-
Electrical conductivity	-	4,000	3,900	-	4,300	4,000	-	-
Radium-226 (mBq/L)	-	-	-	-	26	-	-	-
Total hardness	24	66	43	29	19	24	30	51

From the results obtained to date, it appears that the main aquifer is thicker, and hence more transmissive, both north of and along an approximate line drawn between Crow's Nest and Big Bore. Regional potentiometric contours indicate less transmissive sediments south and west of this line.

Current bore and spring discharges: As noted earlier, only a small amount of the current discharge from bores and springs is effectively utilized. In addition to this, the development of the Great Artesian Basin has led to reductions in the discharges from bores and springs. In 1978, the Department of Mines commenced a bore rehabilitation programme aimed at minimizing the wastage from existing bores, and this programme is continuing.

The existing data on spring and bore discharges between Marree and Coward Springs (Cobb 1975; Denniss and Fennell 1980; Safta and Denniss 1979) has been collated and supplemented with additional data to provide the estimates of bore discharges shown in Table 10.9. Although some bores have been rehabilitated since 1978, a number still have uncontrolled flows.

Table 10.9 Current bore discharges

Bore	1978		1981	
	Flow (kL/d)	Remarks	Flow (kL/d)	Remarks
Borefield A area:				
New Year's Gift	1,364	Uncontrolled flow	>1,000	Controlled flow
Bopeechee	35	Uncontrolled flow	26	Uncontrolled flow
Beatrice	129	Uncontrolled flow	26	Uncontrolled flow
Venable	409	Uncontrolled flow	173	Controlled flow
Borefield B area:				
Charles Angas	455	Uncontrolled flow	86	Uncontrolled flow
Cooranna	Good	Uncontrolled flow	26	Controlled flow
Big Bore (Lake Lettie No. 3)	6,137	Uncontrolled flow	6,900 (approx)	Uncontrolled flow
Crow's Nest (Lake Lettie No. 2)	6,819	Uncontrolled flow	860	Controlled flow
Morris Creek	1,818	Uncontrolled flow	2,000	Uncontrolled flow
Lake Lettie No. 1	136	Controlled flow	0	Controlled flow
Callana	43	Controlled flow	43*	Controlled flow
Peters Camp	†	†	130	Controlled flow
Marion	†	†	1,700	Controlled flow
Total	>17,345		13,000 approx.**	

* Yield assumed from previous survey.

** Based on various authorities' estimates, probably less than 1,000 kL/d of this water is used for domestic purposes or livestock watering.

† Not measured.

Table 10.10 provides estimates of mound spring discharges in the area surveyed. These estimates have been more difficult to make as, in many instances, flows occur as small seepage areas, and it is possible that the estimates understate the actual flow. Only those springs in the Hermit Hill complex which were covered in the previous studies are documented in the table. Currently, the total amount of water flowing from bores and springs within approximately 50 km of the borefields is at least 14 ML/d.

Vertical leakage: In addition to the two forms of discharge discussed above, vertical leakage occurs from the aquifers through the confining bed as the water is forced upwards by the potentiometric head.

The estimated rate of vertical leakage is about 20 mL/m^2.d, which is equivalent to a rainfall of about 7.3 mm/a. This water either mixes with generally saline groundwaters close to the surface or is quickly lost by evaporation. Because of this, it cannot be utilized by surface vegetation as a water source.

Table 10.10 Current spring discharges

Spring	1974 Flows and estimates of evapotranspiration (kL/d)	1981 Flows only (kL/d)
Welcome	130*	130
Wangianna**	0	0
Davenport	85	50
Theepa	0*	0
Venable**	85	85
Coward †	85	85
The Bubbler †	650	170
Blanche Cup †	20	20*
Strangways †	<10*	<10
Mount Hamilton Ruin †	0*	0
Horse** †	10	10
Anna	0	0
Walcarina	85	85*
Jacob	0*	0
Priscilla**	25	20
Fred	40	20
Smith**	25	10
Gosse	200	20
McLachlan	?	?
Finniss Swamp	350	350*
Beatrice**	130	25
Bopeechee**	130	25
Sulphuric	0*	0
Hermit Hill complex		
East Finniss**	25	10
West Finniss	85	10
Humphries**	20	10
Total	2,190	1,045

* Yield assumed from previous or later survey.
** Bore or well adjacent to spring.
† Springs to the west of the area shown on Figure 10.8.

Estimation of the vertical leakage rate requires a knowledge of:

- the thickness of the Bulldog Shale
- the vertical permeability
- the potentiometric surface elevation
- the surface elevation.

The vertical permeability of the Bulldog Shale has not been accurately established; however, the minimum value adopted by the Bureau of Mineral Resources for the GABHYD model is 10^{-4} m/d (Seidel 1980). The elevation of the potentiometric surface above ground level has been measured at 17 to 21 m in Borefield A; in Borefield B, regional potentiometric contours and surface contours indicate that such heads would probably range between 20 and 45 m in the 15 km wide strip to the north of the Oodnadatta to Marree road. Based on the assumptions that:

- average shale thickness is 125 m
- shale vertical permeability is 1 x 10^{-4} m/d
- average head above ground level is 20 to 30 m,

it has been calculated that the vertical leakage is of the order of 16 to 24 kL/d.km^2. The section along the margins of the Basin for which the above assumptions are likely to be valid covers an area of approximately 2,000 km^2. On this basis, the indications are that upward leakage is currently between 32 and 48 ML/d. Vertical leakage will also occur in the deeper sections of the Basin further to the north. In these sections, although the difference between potentiometric head and surface level is higher, there is also a greater thickness of shale. While a reduced vertical leakage per unit area would be expected, the large area involved would make the total vertical leakage significant.

The general conclusion of the survey has been that the total discharge from springs, bores, and vertical leakage in the vicinity of the borefields near the southern margin of the Great Artesian Basin is at least of the order of 46 to 62 ML/d.

Mound springs

Mound springs and seepages are natural outlets of water from the Great Artesian Basin. The springs, which often have a mound-like structure, occur along the margins of the Basin or along fault lines in areas where the aquifer cover sediments are thin. Notable concentrations of springs occur around Cloncurry, Hughenden and Cunnamulla in Queensland, north of Bourke and White Cliffs in New South Wales, and in an arc from Lake Frome to north of Oodnadatta in South Australia. The locations of the mound springs occurring within South Australia are shown on Figure 10.9. Both the original Port Augusta to Alice Springs railway and the Overland Telegraph line were located along the principal line of springs from Marree to Oodnadatta, as these springs represented the only permanent sources of water throughout the major portion of this section of these routes. The early pastoralists in the region were also dependent on the mound springs for water. In many instances, the springs were fenced, and troughs were used to supply the water discharged to stock. Following the introduction of bores, the mound springs became secondary sources of water, and the fences and troughs which had initially protected them from stock fell into disrepair. Stock then gained access to the vegetation associated with the springs and the resultant trampling and grazing led to their rapid degradation.

The flow of water from mound springs has declined significantly since the springs were first described in the literature. This decrease in flow has been attributed mainly to the decline in water pressures resulting from the sinking of bores and the consequent increase in discharge from the Basin. Generally, the springs are not in pristine condition. Often bores have been drilled either in the spring, or close to it, reducing discharge rates and initiating erosion of the mounds (e.g. Venable Bore). The introduction of cattle and rabbits, and the presence of settlers and tourists in the area have generated further pressures which have resulted in the degradation of many of these springs.

A number of these mound springs are considered to be of scientific, historical, archaeological and anthropological significance (SADE 1979); however, the available information on the South Australian mound springs is generally widely dispersed. In 1979, the Department for the Environment carried out a review of the relevant literature and initiated field surveys. Although a general report has been released, the work is yet to be completed (SADE 1979). The Nature Conservation Society has undertaken an ecological survey of some of the bores and springs in the Coward Springs-Strangways Springs area (Figure 4.2). Although the results of this survey have yet to be published, a preliminary draft of the report has been made available to the EIS consultant. While this survey was generally not concentrated in the area influenced by the borefields, the data obtained provides an indication of the issues likely to be relevant to the assessment of the impact of the borefields.

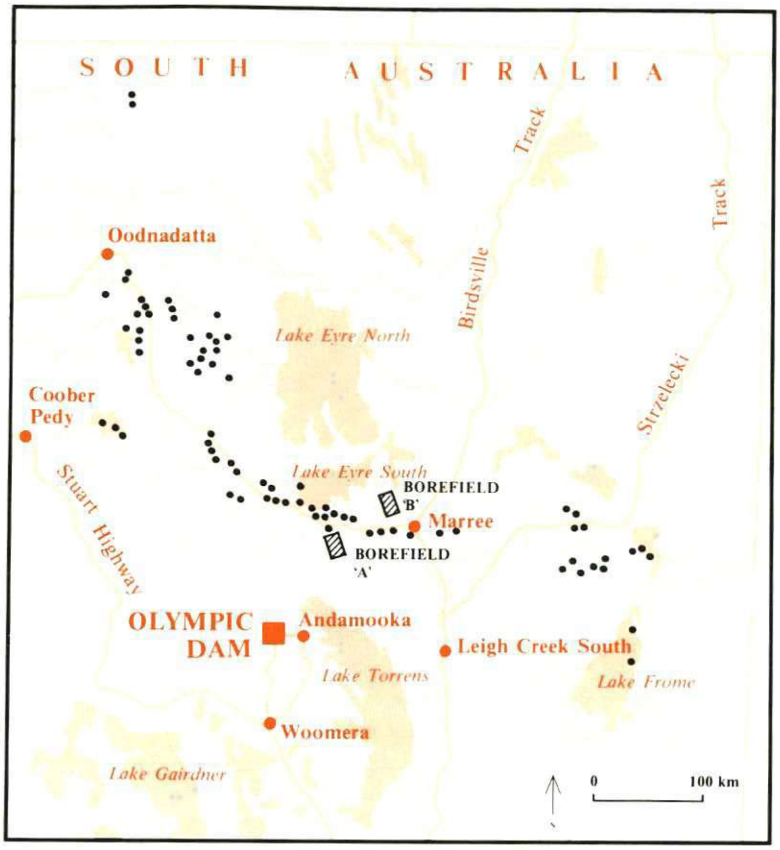


Figure 10.9
LOCATIONS OF SOUTH AUSTRALIAN MOUND SPRINGS

Geomorphology: A geomorphological study, undertaken as part of the Nature Conservation Society survey, has concluded that the mound springs form one of five geomorphic units. The highest and oldest surface form was considered to be a silcrete-capped plateau, mesa and butte assemblage of landforms. This is flanked by an extensive pediment surface cut across Cretaceous shales and siltstones, and gypsum. Another surface of low relief is provided by an extensive gypsum deposit, partially covered with claypans and sand dunes. The lowest and youngest unit is formed by the flood plains and Lake Eyre surrounds, with the mound springs representing the fifth unit punctuating the lower surfaces.

Mound springs are so named because of their tendency to exhibit mound or hummock shapes. The size, height and shape of the mound varies considerably with the composition of the groundwater, its location and the duration of flow. The interpreted structure of a typical mound spring is depicted schematically in Figure 10.10(a) (Williams and Holmes 1976) while typical external features can be seen in Figure 10.10(b) which shows Finniss Spring. It is presumed that the important features of their construction are the lines of structural weakness such as fault lines and fractured rock through which artesian waters escape from the confined aquifers, and the accumulation of sediments and precipitates in the mound.

Formation of mound springs: Early theories on the formation of these mound springs ranged from their origin in volcanic activity to their possession of erosion resistant qualities which left them as prominences above the surrounding landscape. Work undertaken in more recent times has suggested that the mounds are the result of a build-up of calcium carbonate as tufa or travertine which precipitates out of the artesian waters when carbon dioxide is released and the pH carbonate-bicarbonate equilibrium is disturbed. While it would appear that some mounds have formed in this manner, drilling on other mound springs revealed that these consisted of clay and sand derived from the Lower Cretaceous sediments. In these instances, it is hypothesized that artesian waters originating within or below these sediments have transported the clay and sand to the surface where subsequent evaporation of the water has caused their deposition in the form of a mound surrounding the discharge point (SADE 1979).

The mound springs have been classified into the following four categories on the basis of age and geomorphological characteristics (Nature Conservation Society, unpublished):

- extinct
- active
- waning
- non-active.

The term 'extinct' has been used to describe the Pleistocene mounds formed by artesian springs which were active at a time when a higher hydrostatic head of water existed in the Great Artesian Basin. These landforms have remained as remnants of an older erosion surface, rising prominently above the present surface on which the Recent mound springs are located. Two examples of this landform which occur to the west of the area shown on Figure 10.8 are Beresford Hill and Hamilton Hill.

Active mound springs have been described as Recent mound springs from which the water discharges via the vent to overflow channels, and hence to local salinas or swamp areas. The distinguishing characteristic of these springs is the presence of a body of water or overflow channels. Often the mounds are not well developed. The following springs shown on Figure 10.8 are considered to be active:

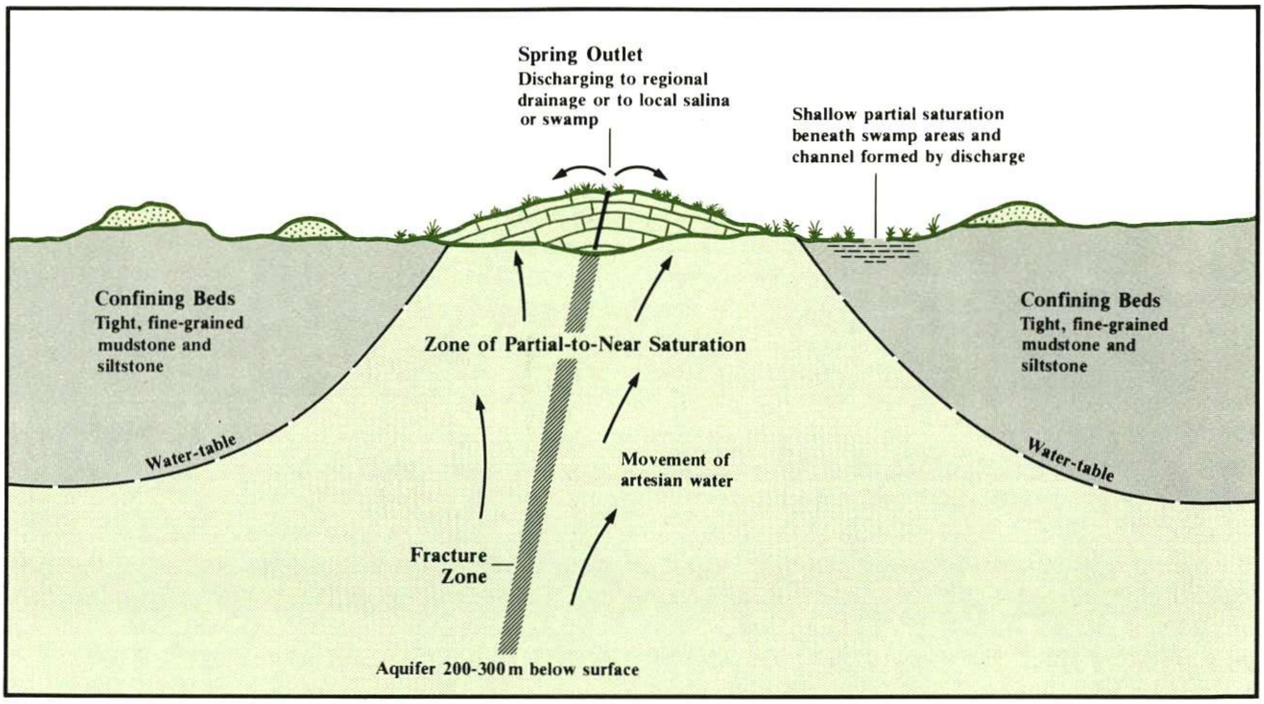
- Hermit Hill
- Welcome
- Finniss
- Davenport (portion of complex)
- Gosse
- Anna.

Waning mound springs represent the immediate past generation of Recent mound springs, which are characterized by a decrease in activity, possibly due to the overall lowering of water pressure in the Great Artesian Basin. The mounds are well developed, but are beginning to disintegrate due to weathering, and water is present only as seepage which occurs near, or at the base of, the mounds. The following springs shown on Figure 10.8 are considered to be waning:

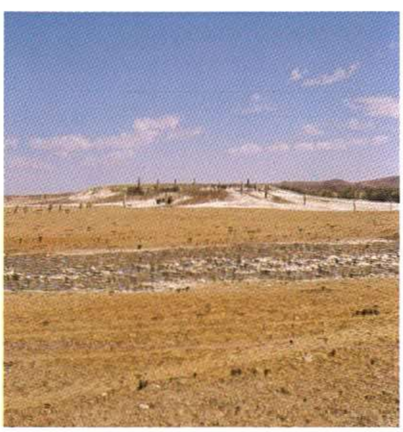
- Wangianna
- Davenport (portion of complex)
- Beatrice
- Fred
- Priscilla
- Walcarina
- Jacob.

The non-active mound springs represent the oldest of the Recent mound springs which, since the cessation of flow, have suffered severe weathering and erosion and appear to have a geologically short existence. The depth of travertine is shallow compared with the extinct Pleistocene mound springs, and it is likely that the Recent mound springs are ephemeral landforms which will disappear before the extinct mounds. Venable Springs is the only spring in the area shown on Figure 10.8 which is considered non-active.

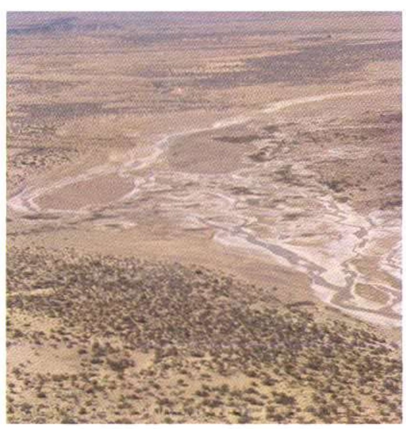
Hermit Hill mound spring complex: An extensive mound spring complex, Hermit Hill, occurs within the area which will be influenced by the borefields. An oblique aerial



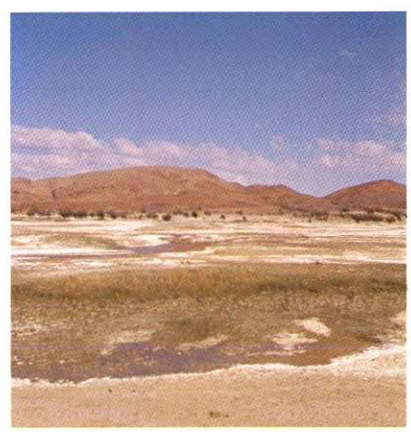
a Interpreted structure of a typical mound spring. (Source: Williams and Holmes 1976).



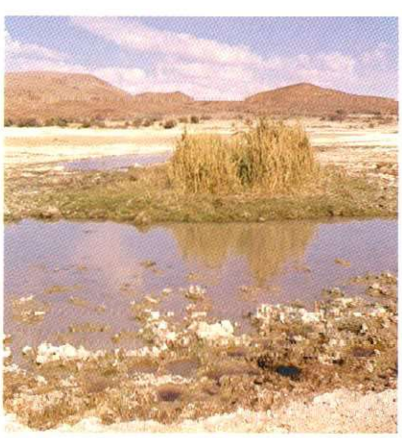
b Typical mound spring (Finniss Spring).



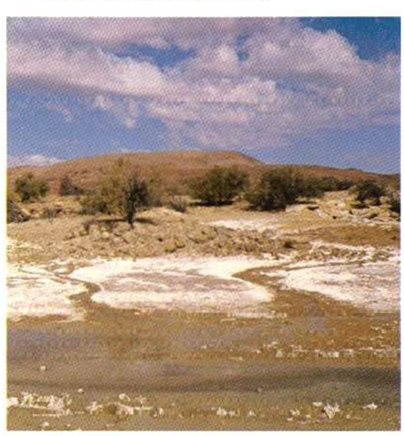
c Aerial oblique of Hermit Hill mound spring complex showing extent of stream channels and salinas.



d Low vegetated waning mound spring within braided stream channel at base of Hermit Hill.



e Low mound spring in Hermit Hill mound springs complex with rushes, reeds and salt tolerant grasses on spring outlet.



f Seepages and chemical precipitates near base of Hermit Hill.

g Stock damage to mound spring in Hermit Hill complex.

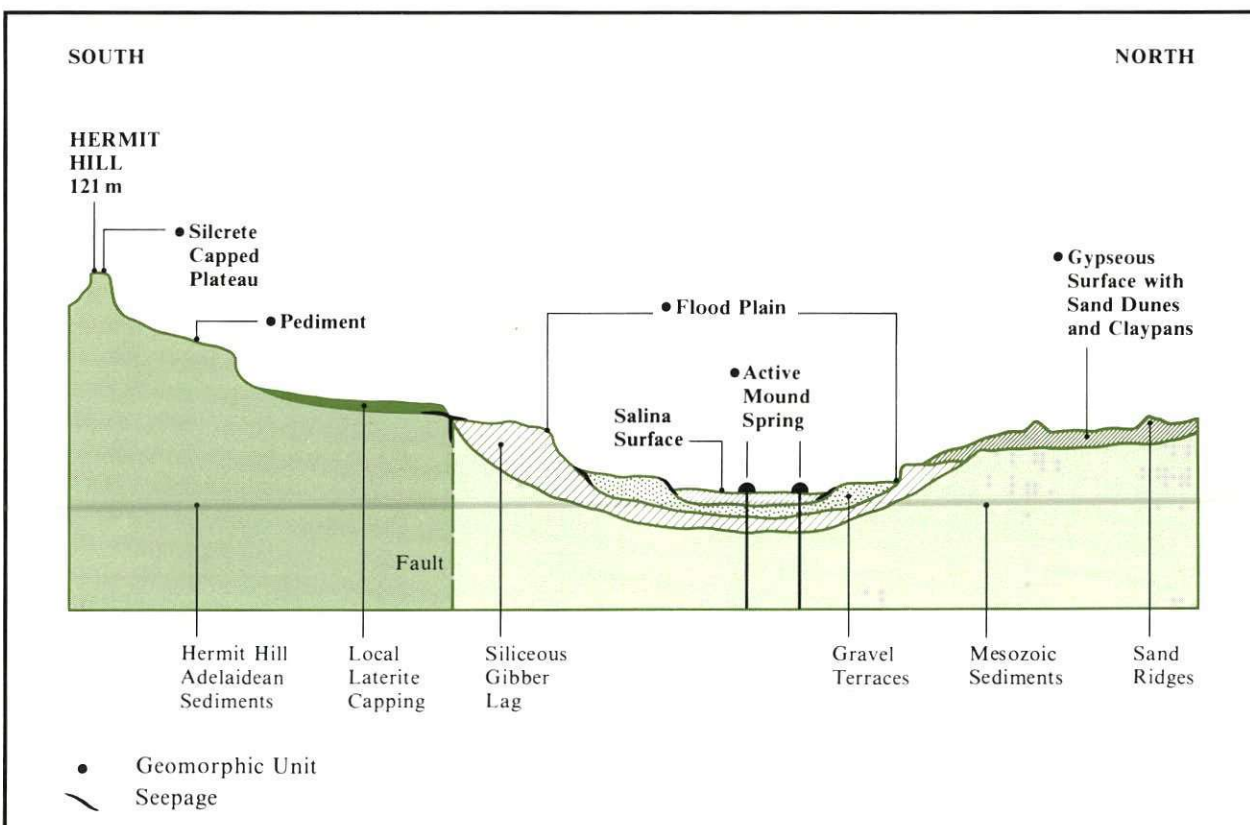
Figure 10.10
ILLUSTRATIONS OF MOUND SPRINGS

photograph of the spring complex, which occurs over a 3 km section at the northern base of Hermit Hill along a wide braided stream channel, is shown in Figure 10.10(c). A schematic north-south cross-section describing geomorphic units and probable origin of the seepages is shown in Figure 10.11.

The springs have two distinct forms. The first type are low vegetated mounds up to 2 m high, consisting of light grey gypsiferous and carbonate silt mixed with aeolian sand and layers of black saturated organic silt near the surface. Drainage from these mounds is via channels to locally lower swampy areas in the stream bed (Figure 10.10(d)). Prominent plant species present on the degraded mounds include rushes (Juncus spp.) and (Typhya domengenesis), and reeds (Phragmites australis), with salt tolerant grasses (Distichlis distichlophylla) (Figure 10.10(e)) fringing channels. The second type are seepages from fractures in the rocky flanks of Hermit Hill at their contact with the flood plain gravels. These seepages extend up to 10 m in elevation above the creek bed, and generally occur along the courses and edges of the steep tributary gullies on the hillside (Figures 10.10(f) and 10.11).

A salt encrustation currently covers most of the mounds, seepages, and some of the low vegetation within the creek channels, and undoubtedly builds up over extended dry periods. It is likely that the infrequent rainfall events causing stream flow would periodically flush these salts into and down the stream bed, ultimately to Lake Eyre.

Trampling, fouling and close cropping of vegetation by cattle has considerably degraded the area (Figure 10.10(g)).



Source: Adapted from Nature Conservation Society (unpublished)

Figure 10.11

HERMIT HILL MOUND SPRINGS, SCHEMATIC CROSS-SECTION

Vegetation: A survey undertaken as part of the Nature Conservation Society study of the vegetation associated with a number of bores and springs indicated that a number of species were confined to the mound springs. In the area shown on Figure 10.8 only one spring complex was surveyed, i.e. Hermit Hill Springs, which was characterized by examples of Gahnia trifida (cutting grass), Machaerina juncea, Eriocaulon carsoni (button grass), and peat remnants in a reasonable state.

The finding of the above three species was considered to be of significance, as they are widely disjunct from any previous collections, and can be interpreted either as examples of botanical relics of a former wetter age surviving in these special niches, or as examples of long distance dispersal of species now confined to the southern higher rainfall districts. Of particular interest was the discovery of Eriocaulon carsoni, as it is known only from two prior records in New South Wales and South Australia and had previously not been recorded anywhere this century. This plant is considered to be rare, with occurrences probably confined to springs. The Nature Conservation Society is of the opinion that efforts should be made to conserve this plant. The peats were also considered to be of interest, having the potential to hold the history of vegetational change in the area in the form of pollen (Nature Conservation Society, unpublished).

The survey also concluded that some semi-aquatic plants are able to colonize the bores. Other species are more often confined to the springs, while some species (in particular the three mentioned above) are strictly confined to the springs. The vegetation associated with existing flowing bores was not seen as being equivalent to that of the mound springs in botanical composition or in the presence of peats. The protection of mound springs from livestock movements could be expected to result in increased plant cover, particularly reeds and rushes.

Fauna: The Nature Conservation Society study included a number of surveys of fauna. A survey of terrestrial invertebrates indicated that there is a relatively abundant arthropod fauna around the springs. The species found were generally characteristic of warm humid sites with little evidence that any were restricted to the springs.

While no data is available for the Hermit Hill Springs, a survey of the limnology of mound springs to the west of the area shown on Figure 10.8 concluded that they supported a unique aquatic fauna. The organisms making up this fauna were an undescribed genus of cypridid ostracod, the phreatoicid Phreatomerus latipes, four undescribed species of hydrobiid gastropods, an unidentified amphipod, and the gobiid teleost Chlamydogobuis eremius. For the most part, these organisms are without resistant stages in their life cycle and, although widespread in the immediate area, have limited powers of dispersal. As a consequence, they are vulnerable to any deterioration of their environment. Many springs in the area studied have been degraded as aquatic habitats by the activities of stock. For example, grazing has reduced or eliminated macrophytes, which are important as habitat for a host of invertebrates which, in turn, provide a food source for larger organisms. The indications are that macrophytes provide the major source of primary biomass production in the springs as well as being important in oxygenation. However, decreasing flow rates have reduced pool size, while the trampling of edges has resulted in fouling, rendering many of the springs unsuitable for fish and planktonic organisms. Changes in the aquatic plant community resulting in masses of filamentous algae, due possibly to organic pollution, could be expected to cause oxygen depletion under certain conditions.

The limnology survey also concluded that the fencing of springs to prevent stock access would decrease organic pollution and allow the re-establishment of a natural, balanced macrophyte community. The capping of existing bores could increase spring flow rates, which would in turn increase pool depth, thereby providing the potential for recolonization by fish and microcrustacea. However, a dramatic increase in flow rate might be detrimental, reducing the retention time of pools to a point where the turnover time of planktonic organisms might be insufficent to maintain the population (Nature Conservation Society, unpublished).

A survey of reptiles and amphibians indicated that the presence of free water from the springs and bores has had little effect on the species composition or population density of any reptiles in the study area (Nature Conservation Society, unpublished).

The bores and springs were considered to be important in providing watering points for larger mammals such as the Dingo (Canis familiaris dingo), the Red Kangaroo (Macropus rufus) and the Euro (Macropus robustus) which were observed during the Nature Conservation survey. However, the study concluded that there was a general paucity of mammal species closely associated with the mound springs.

Conservation and heritage significance: The Department for the Environment (1979) considers the mound springs to be 'a unique feature of the arid landscape in the north-east corner of this State', and believes there is 'a strong case' for their conservation. These springs have featured in the mythology and daily life of the Aborigines who have lived in their vicinity, as well as being of historical, scientific and tourist interest.

As detailed in Section 4.1.10, the Far North Planning Area Development Plan includes five mound spring complexes as features proposed for consideration as areas of special environmental significance, one of which (Hermit Hill Springs) occurs in the area shown on Figure 10.8. The Nature Conservation Society study has concluded that the springs are ecologically fragile, and are currently subject to detrimental development pressures. The Society has therefore recommended the protection of some of the large spring complexes and the listing in the Register of the National Estate of eight springs or spring complexes. Again, Hermit Hill Springs is the only one of these occurring in the area shown on Figure 10.8.

Aboriginal sites

Anthropological sites: Aboriginal sites with mythological significance were identified in the general area of the proposed borefield development and pipeline route. Identification was based upon information gathered during previous field trips in the general area with a number of Aboriginal informants, and upon results of a trip which personnel of the Joint Venturers undertook with two Aboriginal informants specifically to locate and accurately record sites in the area of interest. Details of the site locations and their mythological linkages have been provided in a confidential report to the Heritage Conservation Branch of the Department of Environment and Planning.

Much of the mythology is directly related to the mound springs, which represented a reliable water source to Aboriginal people. Other sites are prominent hills, waterholes, creeks, ochre sites, quarries and meeting grounds.

One series of sites is associated with the Wiljaru (a secondary initiation ceremony) and with the travels of totemic ancestors (e.g. the turkey, bell bird and eaglehawk). Some sites where Wiljaru ceremonies were performed were 'forbidden ground', because sacred ceremonial objects were stored there.

Another series of sites is associated with the travels of the Ancestral Two Men who introduced stone knives instead of fire for circumcision. Other sites are related to ceremonies which form the background to initiation. There are also travelling myths such as the Urumbala (Section 5.2.4) and Kangaroo History.

The locations of the borefields and pipeline corridor are far enough away that there is no likelihood of direct damage to any known mythological site. However, as noted in Section 5.2.6, improved accessibility and increased population in the region must increase the probability of damage to sites. Also, within the cone of depression of the borefields there is a possibility that drawdown will affect some mound springs or seeps associated with mythological sites.

Archaeological sites: Concurrently with the anthropological field survey, a preliminary survey of archaeological features associated with mythological sites was also undertaken. The following types of sites were found in the general region of the borefields, although none will be directly affected by development of the borefields:

- Ochre sites: two sites were found with exposed red pigmented clays which were a source of ochre for local Aboriginal people, and three other sites are known to exist in the area.

- Stone quarries: one large orthoquartzite quarry was found as well as another smaller one. The larger site shows clear evidence of the processes used to extract the quarried material, and is considered to be of regional significance. It is located some 30 km from the borefield corridor.

- Rock engravings: rock engravings were associated with several of the ceremonial and mythological sites, many of the engravings including grooves and tracks of animals associated with mythological song series and the Wiljaru ceremonies.

- Stone arrangements: stone arrangements were associated with two of the mythological sites.

- Meeting ground: a site known as a traditional meeting place and exchange centre for Aboriginal groups of the region contained an extensive camping area with a number of hearth deposits.

- Surface exposure of artefacts: camp sites and artefacts scatters were evident in the vicinity of many of the mythological sites. Also found was an 'oven' site with a concentration of large carbonate nodules associated with hearth deposits.

A separate confidential report on these sites has been submitted to the Heritage Conservation Branch of the Department of Environment and Planning. Certain of the sites warrant some form of protection, but as they are located in areas beyond the control of the Joint Venturers such protective measures would need to be implemented by public authorities.

10.3.4 Impact on regional water resources

Great Artesian Basin

A computer model has been used to predict the effects of pumping from the two borefields, based on the data obtained from the initial investigation discussed in Section 10.3.2. Further investigation and monitoring during the operation of the borefields will be used to progressively update model data.

The model assumes that, initially, pumping will take water from storage and produce a lowering of the potentiometric surface around the borefield (i.e. form a cone of depression), which will reduce the vertical leakage in the area. However, some of the water originally lost to the system through vertical leakage will be captured by the borefield, and the cone of depression will expand only until the borefield yield is balanced by the reduction in vertical leakage and the reduction in flow from the bores and springs in the affected area. (Refer to Section 10.3.3 for discussion of the manner in which groundwater is lost from the aquifer.) At this stage a new equilibrium will have been reached, following which drawdowns and potentiometric heads will remain relatively constant. Only regional Basin-wide changes resulting from other developments would then have an effect on this balance.

Although the upward leakage per square metre of surface is small, the large areas involved mean that total leakage accounts for the discharge of significant volumes of groundwater (Table 10.6). To predict the effect of pumping, a conservative model which provides for this vertical leakage but not for the current discharges from bores and springs has been adopted.

The following hydraulic parameters derived from initial investigations have been used in the model:

- transmissivity - 105 m^3 /d.m (Borefield A)
  - 40 to 100 m^3 /d.m (Borefield B)
- storage coefficient - 1×10^{-4}
- vertical permeability - 1×10^{-4} m/d
- boundaries - outcropping or shallow bedrock as shown in Figure 10.8.

The model does tend to simplify the hydraulic nature of the area. It is recognized that there are changes in hydraulic parameters over the area; however, the parameters used reflect the current available data.

The combined effect of pumping both borefields simultaneously and the predicted potentiometric contours and drawdowns after four years' pumping are shown on Figure 10.12. The four year data can be regarded as the equilibrium state for the borefields development proposed, as the model has predicted that at this time the reduction in vertical leakage will equal the pumping rate. Although the model accounts for a reduction in leakage, it does not account for the reduction in discharge from other outlets which will further reduce the predicted effect of pumping on the potentiometric surface.

The required yield from the two borefields is 33 ML/d. It was indicated in Section 10.3.3 that current discharges from the area along the southern margins of the Great Artesian Basin are of the order of 46 to 62 ML/d. As a first approximation, which assumes that the reduction in current discharges will approximate the pumping rate, it can be expected that, on the whole, current discharges will be reduced by a maximum of 50 to 70%. The effect of pumping will be more marked in the close vicinity of the borefields and less marked further afield. The reduction in discharge from any bore or spring, or in vertical leakage, will theoretically be proportional to the drawdown at that point compared with the current head above ground level.

Existing bores

The estimated reduction in flow from the various bores in the area shown on Figures 10.8 and 10.12 is given in Table 10.11. The current head above ground level cannot be measured in many cases, where there is either an uncontrolled flow or a corroded casing; consequently, estimates of current heads have been made using the regional potentiometric contours on Figure 10.8. Table 10.11 indicates that the reductions in bore discharge will range from less than 10 to 100%. The greatest impact will be on Venable and New Year's Gift Bores in Borefield A and on Crow's Nest Bore in Borefield B.

However, with the exception of these localized impacts, the aquifer as a water resource will not be adversely affected. The estimated current outflow from the area is in excess of the required yield, and the pumped water will be balanced by the imposed reduction in other discharges, especially upward leakage through the overlying shale.

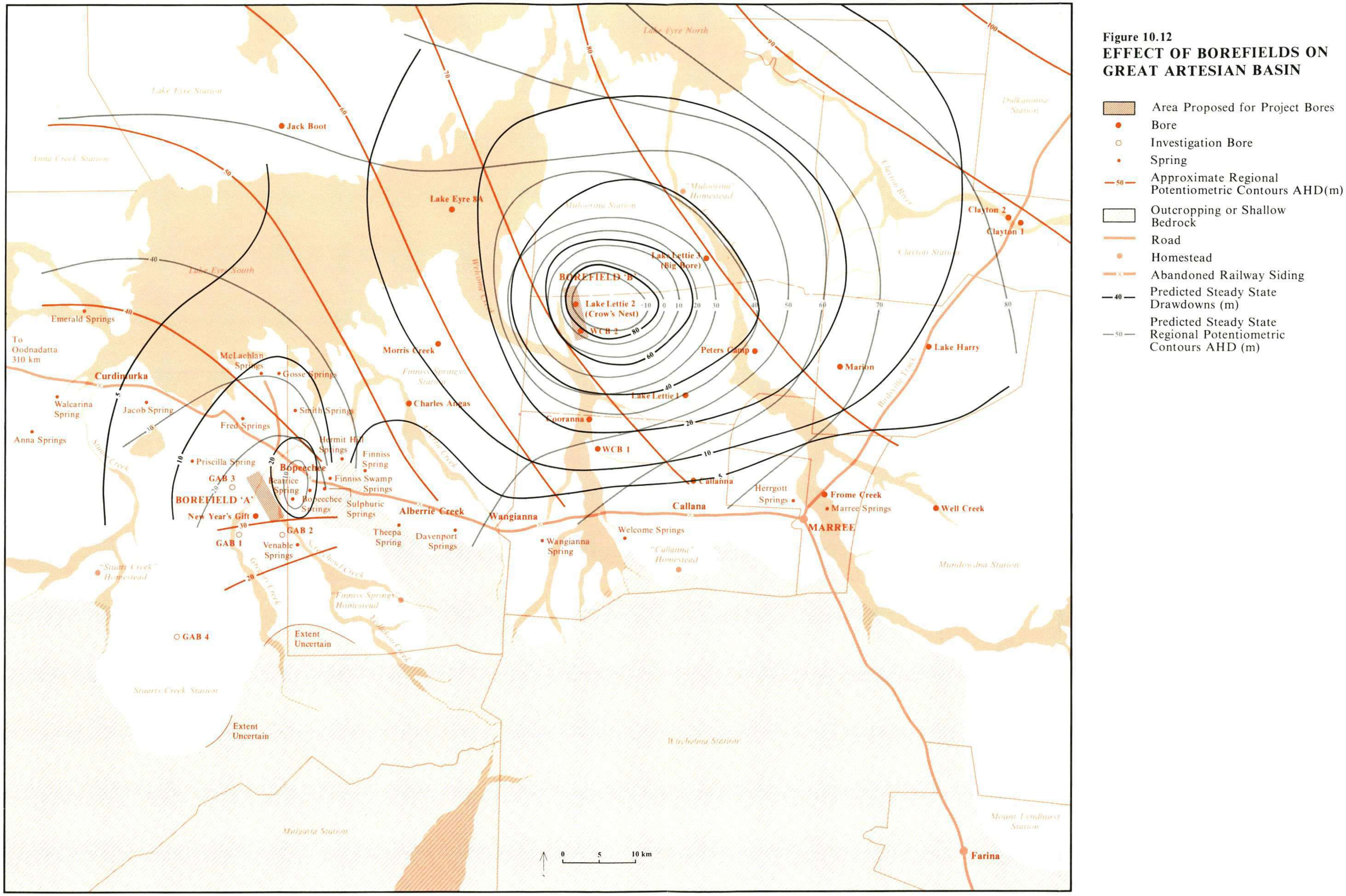


Figure 10.12
EFFECT OF BOREFIELDS ON GREAT ARTESIAN BASIN

Table 10.11 Estimates of reduction in bore discharge

Bore	Present head (approximate m above ground level)	Reduction in head (m)	Reduction in artesian flow (%)
Borefield A:			
Venable	15	15	100
Bopeechee	25	20	80
Beatrice	25	20	80
New Year's Gift	25	20	80
Curdimurka	30	4	13
Borefield B:			
Charles Angas	45	8	18
Morris Creek	50	15	30
Cooranna	50	30	60
Crow's Nest	70	70	100
Big Bore	70	40	57

Water quality is not expected to be measurably affected by the borefields development. The maximum imposed gradient near the margins of the Basin, which will tend to draw poorer quality water towards the borefields, will be of the order of 1×10^{-3}. If a porosity of 0.1 and a hydraulic conductivity of 5 m/d is assumed, then the groundwater velocity will be approximately 18 m/a. The Joint Venturers will monitor a series of bores at or near the margins of the Basin as part of the ongoing data collection. This will form part of the borefields management programme, which will ensure that no unacceptable effects upon water quality occur.

The town of Marree draws water from the Great Artesian Basin, but borefield pumping will not significantly affect this supply. The reduction in head at Marree will be about 5 m, compared with an available head of about 100 m. However, it is thought that the aquifer tapped at Marree is higher in the Cretaceous sequences and is not in direct hydraulic connection with the borefields aquifers. If this is the case then the effect will be much less than the 5% reduction in flow predicted.

Vertical leakage

Pumping from the borefields will cause a reduction in the rate of vertical leakage which will vary with the distance from the borefields. The rate of leakage will be reduced by close to 100% in the immediate vicinity of the borefields, and by progressively lesser amounts towards the edge of the cone of depression. As indicated in Section 10.3.3, this will have no effect on surface vegetation as vertical leakage is not a water source for vegetation.

10.3.5 Impact on mound springs

None of the construction or operational activities associated with the pipeline corridor or the borefields will take place in the immediate vicinity of any of the mound springs. There will therefore be no direct physical impact upon any mound spring.

Using the computer model prediction of drawdowns shown on Figure 10.12, the reduction in flow from springs has been estimated in a similar manner to that discussed for bores in Section 10.3.3. Table 10.12 indicates the estimated reduction in flow from the springs shown on Figure 10.12.

Table 10.12 Estimates of reduction in spring discharge

Spring	Present head (approximate m above ground level)	Reduction in head (m)	Reduction in discharge (%)
Borefield A:			
Priscilla	20	20	100
Gosse	40	10	25
McLachlan	40	10	25
Smith	40	10	25
Hermit Hill	30	5-10	17-33
Borefield B:			
Davenport	30	3	10
Wangianna	30	3	10
Welcome	30	3	10

Of the eight spring complexes which the Nature Conservation Society has recommended for inclusion in the Register of the National Estate, only Hermit Hill Springs will be affected by the operation of the borefields. The discharge from these springs will be reduced by between 17 and 33%. The remaining seven springs or spring complexes are to the west of the area shown on Figure 10.12 and therefore will not be significantly affected by the drawdown.

Insufficient data is currently available to enable a proper assessment to be made of the effect which such a reduction in discharge would have on the ecology of the Hermit Hill Springs. It can be expected that the flow reduction will result in a reduction in the vegetated area which can be sustained around the low mounds as well as a reduction in the maximum elevation at which seepages take place. However this will be subject to further study, as outlined in the following section.

10.3.6 Mitigation measures

The current level of knowledge on the ecology of mound springs does not allow a full range of mitigation measures to be specified at this time. Studies relevant to this task, which at the time of writing had either been completed or were in the process of being undertaken, included:

- hydrogeological investigations
- anthropological and archaeological research
- review of the Nature Conservation Society study
- general field monitoring trips.

The development of the borefields will be subject to the controls of Clause 13 of the Indenture Agreement outlined in Section 10.3.1. In particular, Clauses 13(8)(a) and (b) require the Joint Venturers to design, install and maintain a monitoring system approved by the State and to provide results of this monitoring programme in an annual report to the State. This management programme will be designed to ensure that the resource is not adversely affected.

Clauses 13(13)(a) and (b) of the Indenture Agreement protect the rights of existing users within the designated area (i.e. that area agreed upon by the Joint Venturers and the State as being the area wherein the potentiometric drawdown, due to pumping over a thirty-year period, will exceed a predetermined amount presently set at 5 m). Should the supplies of existing users be restricted below that necessary for the proper management and development of the existing land use, the Joint Venturers are obliged, under these clauses, to make alternative supplies available or to make other suitable arrangements with the users. These alternative supplies could be provided by piping from the new production bores.

In 1978, the Department of Mines initiated a programme of bore rehabilitation aimed at minimizing the present wastage of water from uncontrolled bores. This programme is continuing. If all the uncontrolled bores in the area shown on Figures 10.8 and 10.12 were rehabilitated and the flow restricted to an estimated beneficial use rate of approximately 10% of current flows (Section 10.3.3), a saving of water in the aquifer system of approximately 11.7 ML/d would occur. If the existing bores were managed in this manner, the pumping effects predicted in Sections 10.3.4 and 10.3.5 would be reduced by about 35%.

To develop specific measures for the mitigation of any impact upon the mound springs, the Joint Venturers will undertake the following programme:

- establish, in consultation with the Department of Environment and Planning, which springs require study;

- undertake a range of environmental studies related to these springs, including vegetation, limnology, fauna and avifauna. These studies will gather baseline data, assess the impact of the borefield development and recommend any necessary mitigation measures;

- develop and implement measures to protect and conserve significant mound springs in conjunction with the Department of Environment and Planning's ongoing mound spring survey and the current rehabilitation and bore capping programme of the Department of Mines and Energy. Such joint measures might include the provision of alternative water supplies to springs, the restoration of troughs and fences to exclude stock, and the rehabilitation and capping of bores. Certain of these measures could be implemented as a continuation or an extension of existing government programmes, and as such would not be the responsibility of the Joint Venturers.

10.4 TRANSPORTATION

The Joint Venturers will make use of the existing transportation infrastructure (i.e. roads, railways, ports and air services) in moving goods and people to and from Olympic Dam. The existing networks are described, together with the predicted Project use of each type of network and any upgrading of facilities which this may require.

10.4.1 Railways

The area studied is serviced by two railway lines (Figure 10.1):

- Port Augusta to Kalgoorlie (the Trans Australia Railway)
- Port Augusta to Marree.

The rail facilities nearest to the Olympic Dam Project are at Pimba (on the Port Augusta to Kalgoorlie line), from where a spur line owned by the Commonwealth Government extends to Woomera West. From Pimba, direct standard gauge rail access is available to Port Augusta, Whyalla, Perth and Sydney. The majority of rail tonnage moves westwards across Australia, with a considerable amount of empty rolling stock moving eastwards.

Australian National is currently constructing a standard gauge link from Crystal Brook to Adelaide, which will provide direct access from Pimba to Adelaide and Port Adelaide. This work is scheduled for completion during this year. There are no firm plans to replace the current broad gauge link between Adelaide and Melbourne with standard gauge. However, the current Crystal Brook to Adelaide gauge standardization project does include a bogie exchange facility at Dry Creek.

Consideration is being given by the Joint Venturers to the construction of a standard gauge rail spur from Woomera or Pimba to Olympic Dam, which would provide direct standard gauge rail access to the Trans Australia Railway and to Port Adelaide. However, such a decision will not be made until after an economic and technical review has been undertaken. A separate transportation study, undertaken as part of the enquiry into the current status and future development of the central part of South Australia, has also concluded that this system would be the most appropriate for the movement of materials associated with the Project (Iron Triangle Study Group 1982). This system could also provide the nearby pastoralists with more rapid and cheaper access to stock markets in Adelaide.

Corridor provision from the plant area to south of the town site has been made for such a line (Figure 2.1), although a route from Pimba to the town has not been selected.

Approximately 450,000 t/a of resource inputs are required for the Project, and this amount, together with about 153,000 t/a of product, would be transported by rail if this rail spur were to be provided. Approximately two trains per day would be required to transport these materials. The Iron Triangle Study Group concluded that the bulk goods transport requirements for even the most optimistic development scenario (which includes the Olympic Dam Project at 200,000 t/a of product) could be adequately handled by the rest of the existing or currently planned network (ITS 1982).

10.4.2 Roads

Figure 10.1 indicates the new alignment of the Stuart Highway and the distribution of the following categories of roads in the region (SAHD 1978):

- Primary roads: these are generally major routes carrying relatively heavy traffic; they have the greatest proportion of sealed surface and formed and sheeted surface, and usually receive the highest maintenance effort.

- Secondary roads: these usually provide the major link to or between primary roads; they carry relatively less traffic, and receive a lower level of maintenance effort.

- Major tracks: these unformed tracks provide access for pastoral activities; they carry relatively low levels of traffic, and receive a low level of maintenance effort, on a selective basis.

The Joint Venturers have constructed an 8 m wide gravelled road from Olympic Dam to connect with the Andamooka to Woomera road at Phillip Ponds. This provides an all-weather road connection from the Project site to the Stuart Highway at Pimba and from there to Port Augusta. This roadway will be progressively upgraded and sealed by the Highways Department.

The staged construction of the Stuart Highway along a new alignment between Pimba and the Northern Territory border commenced in 1979. It is expected that, by November 1982, the new highway will be sealed as far as Gosses (except for 36 km between Woomera and Glendambo). The construction works for the entire route are scheduled for completion in 1987.

Traffic flows on selected roads, based on twelve-hour and twenty-four-hour counts, were undertaken by the Highways Department in 1980, prior to the completion of the sealing of the Pimba to Port Augusta section of the Stuart Highway and the construction of the Phillip Ponds to Olympic Dam road. These figures are similar to the traffic flow predictions for 1981 shown on Figure 10.13, which were provided by the Highways Department as part of the EIS for the Stuart Highway realignment. Figure 10.13 also shows the predicted traffic flows in the area studied, following the completion of the Stuart Highway realignment and taking no account of the influence of the Olympic Dam Project (SAHD 1978). In particular, traffic volumes on the Stuart Highway at Wirrappa were expected to reach an annual average daily traffic rate (AADT) of 750 in 2006.

If the rail link is provided, the major source of any further increase in road traffic will be the day-to-day activities of the population of Olympic Dam. Estimates of the likely increase in such traffic are influenced by many factors, many of which are difficult to quantify (such as the level of tourist activity, and the frequency with which Olympic Dam residents will travel to Adelaide). However, on the basis of previous predictions for Woomera (SAHD 1978) and estimates of the percentage of materials which will be moved by road, predictions of the likely traffic volumes in 2006 have been prepared. These are compared with the previous SAHD predictions on Figure 10.13. The indications are that traffic generated by Olympic Dam on the Stuart Highway will add a further 150 to 200 AADT, an increase of 20 to 27%. However, this increased total traffic volume (900 to 950 AADT) will not exceed the highway's capacity (SAHD 1978; NAASRA 1976).

If the rail link is not provided, then approximately 120 trucks would be needed to transport resources to the Project and to transport product out. This would represent a minor increase in present traffic through Port Augusta, which is presently about 13,100 vehicles per day, including 700 (5.4%) commercial vehicles.

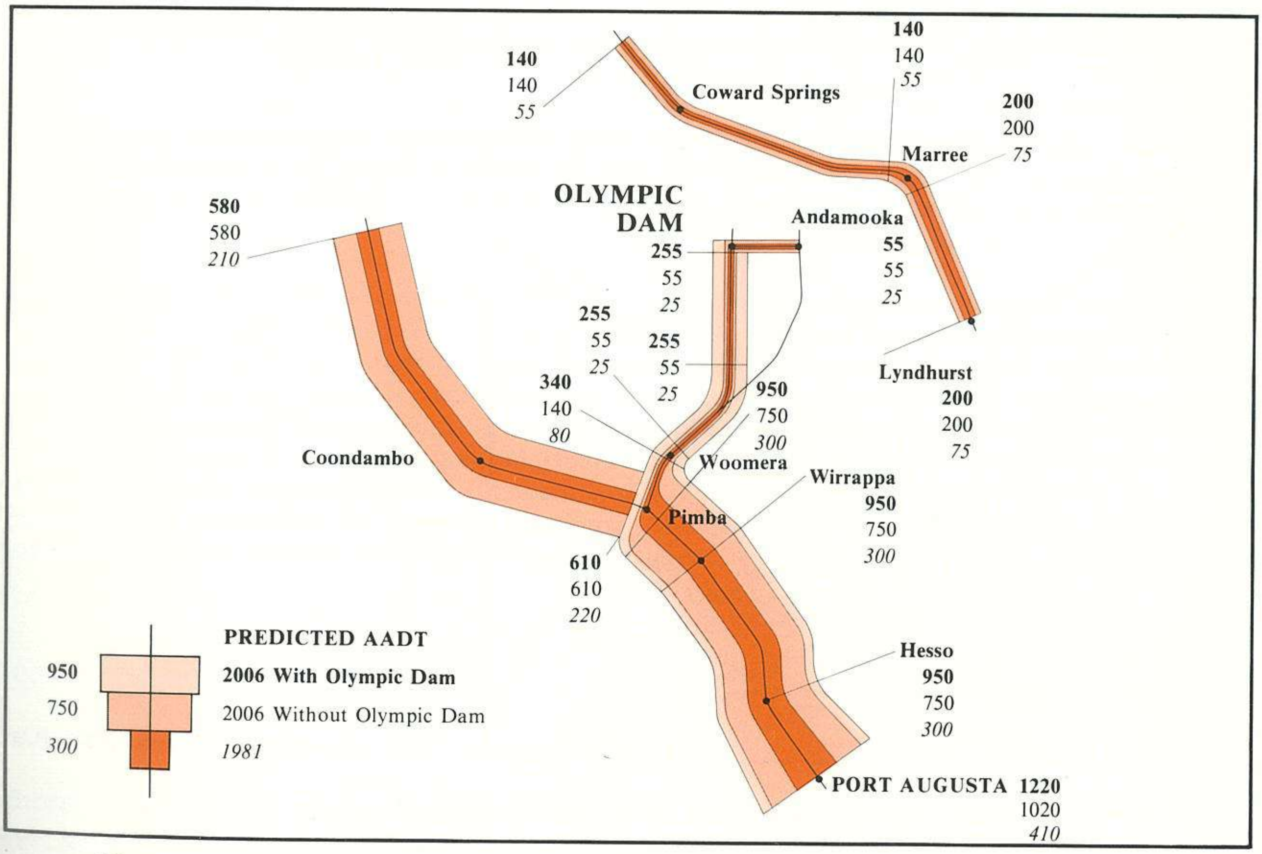


Figure 10.13
CURRENT AND PREDICTED ROAD TRAFFIC VOLUMES

10.4.3 Ports

The types and amounts of materials related to the Project which will need to be imported or exported indicate the need for a sea link. Of the twelve South Australian deep sea ports handling interstate and overseas cargo (Figure 10.14), only Port Adelaide meets the desired criteria, namely:

- good road and rail facilities
- adequate storage facilities
- roll-on roll-off berths
- container handling facilities
- adequate depth of water for fully laden vessels carrying bulk cargoes
- sufficient berth availability.

However, it is considered that some upgrading of bulk unloading facilities for handling of sulphur and pyrolusite at Port Adelaide may be desirable. Clause 17 of the Indenture Agreement requires the Joint Venturers to provide any additional facilities required at ports within South Australia to facilitate the conduct of their operations, and to pay all charges levied by port authorities at State-owned ports. In the last few years there has been a decline in the quantity of cargo passing through Port Adelaide, and the port authorities could be expected to welcome an opportunity to increase the usage of the port.

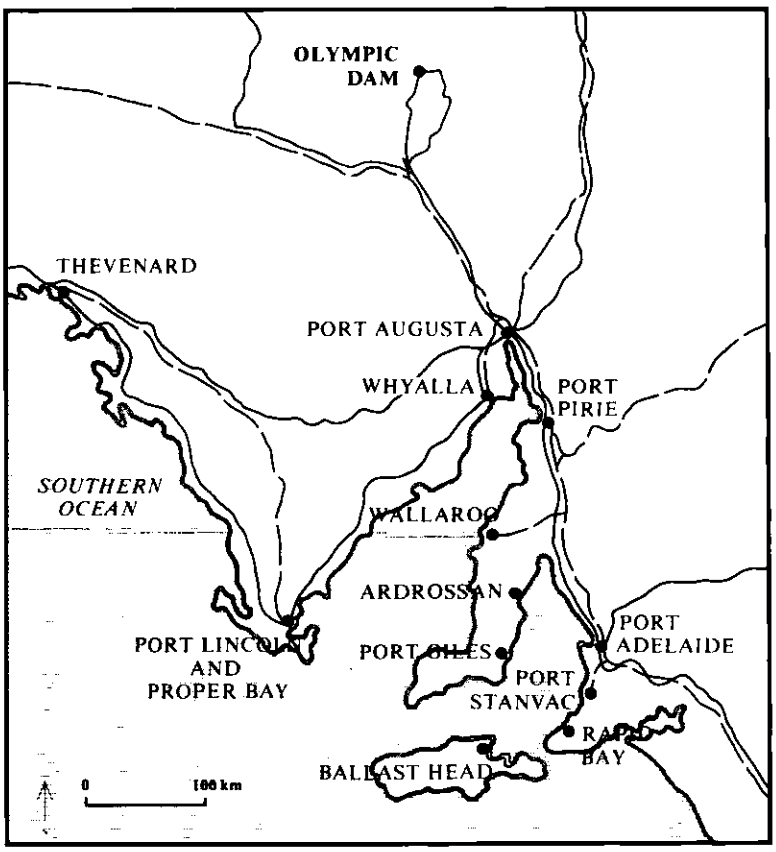


Figure 10.14
SOUTH AUSTRALIAN SEA PORTS

Railway
Road

10.4.4 Airfields

The Olympic Dam village is serviced by a 1,600 x 90 m compacted gravel airstrip on alignment 07/25 which complies with Department of Transport, Australia, standards for licensing.

Other airfields in the region (Figure 10.1) include:

- An airfield at Port Augusta with two runways suitable for daylight use by regular public transport aircraft. This is also the base for the Royal Flying Doctor Service.

- A licensed airfield at Woomera, with a sealed runway capable of accommodating most commercial aircraft. Two other runways have been abandoned.

- Authorized landing areas at Mount Gunson, Marree and Andamooka (which has two).

PAGAS Airlines operates fourteen return services per week to Port Augusta, two return services per week to Mount Gunson, one return service per week to Andamooka and one service per week to Marree. Woomera is serviced by five return air services per week, while Olympic Dam village is serviced by six return air services per week. The Woomera and Olympic Dam services are operated by Opal Air Pty Ltd. Charter flights to Olympic Dam are scheduled by Roxby Management Services for the movement of Project personnel and contractors, and the airstrip is also used regularly by the Royal Flying Doctor Service aircraft.

There are four restricted air spaces, associated with operation of the Woomera testing facilities, in the area studied. The extent of these is shown on Figure 10.1. The restricted air spaces R239A and R242 apply to all heights at all times and are currently closed. R238 and R243 apply to all heights at all times and are currently open, but can be closed at any time by a Notice to Airmen (NOTAM). An increase in RAAF activity is expected in the Woomera area, and this may result in the occasional closure of R238 and R243.

The existing Olympic Dam airstrip will serve the Project during construction. However, greatly increased traffic will necessitate the provision of a light runway seal and the installation of strip lighting to ensure all-weather use and to cater for emergency night operations.

In the longer term, it is probable that the town population and Project activity will necessitate a higher standard of strip suited to medium sized jet aircraft. The preferable direction of such a strip is north-south. Additional width, length and pavement strengths would be required, as well as expanded terminal facilities, which could not reasonably be provided at the existing site. The new site, the location of which is shown on Figure 2.1, is considerably closer to the town and will be better suited to the ultimate Project requirements. Clause 15 of the Indenture Agreement allows the Joint Venturers to construct (in conjunction with the municipality and with the Minister's consent) a sealed airstrip with associated facilities.

10.5 TELECOMMUNICATIONS

10.5.1 Current system

There are presently two exchanges in the area studied. Olympic Dam has seven radio link exchange lines to the Andamooka automatic exchange, which is connected to the automatic exchange at Woomera. This exchange is linked into the national telecommunications network through the Woomera Manual Assist Switchboard. In general, the connections between the various exchanges are cable connections, although there are small lengths of aerial line connection and some radio links.

Telecom Australia plans to convert all existing telephone services to automatic operation with STD and ISD access and to extend this service to more remote areas not currently served. The aerial trunk route north of Marree will not be maintained now that the Marree to Alice Springs railway line has been closed (SADEP 1982).

10.5.2 Town telecommunications system

A decision has yet to be made about the means by which the public exchange in the Olympic Dam town will be connected into the national telecommunications network. At the time of writing, it appeared probable that this would be a microwave link from Woomera to Olympic Dam, which would require the installation of one or two towers between these two points and another tower in the town. The exact location of the towers could only be defined following detailed studies, and it is expected that Telecom Australia will be the proponent for the installation of this link.

10.5.3 Project telecommunications system

The present Project communication system includes a forty-eight extension PABX utilizing five of the exchange lines to Andamooka. The remaining two lines are connected to public telephones in the village. The PABX extensions serve the offices, Whenan Shaft area (both surface and underground), core farm, single quarters and housing area. A two-way radio system serves selected vehicles, with long-range sets used for remote areas such as the borefields.

The existing PABX will be replaced with a unit capable of serving an increased number of exchange lines and extensions. It is anticipated that exchange lines will be connected directly to the town exchange (in lieu of Andamooka). All cabling will be underground.

CHAPTER ELEVEN

Social Effects and Town Design

SUMMARY

To operate and maintain the Olympic Dam Project at a production level of 150,000 tonnes per annum of copper will require a permanent on-site workforce of approximately 2,400 people, with a further 700 supporting workers in government and service industries. This workforce and its dependants are expected to give rise to a total population of some 8,000 people by the fourth year of operation of the Project, subsequently rising to 9,000 people at the production capacity contemplated. It is the Joint Venturers' intention to develop a permanent, comfortable and stable living environment in a new town at Olympic Dam, to be built some 10 kilometres south of the operations area. Although initial development will be carried out by the Joint Venturers under the provisions of the Indenture Agreement, the town will, from its inception, be an 'open town' administered by a municipality.

The forecast structure of the workforce will give the town in its initial years many of the social characteristics observed in other mining towns, such as a significant proportion of shift workers, the predominance of one employer, higher median incomes, and a largely male workforce. Initially, the population of the town is expected to have high percentages of larger than average sized families, and of people aged from twenty to forty. There will also be more young children but noticeably fewer teenagers and elderly people than in established towns. Possibly a quarter of the population of Olympic Dam may be overseas-born. However, this demographic structure will change as the town matures.

The majority of the married workforce is expected to have a preference for detached houses with gardens, with approximately 1,600 houses being required by the fourth year of production. In addition, accommodation for 800 single workers will be provided in units or flats, while caravan park facilities will be provided for a further 150 families. The climatic characteristics of Olympic Dam will influence housing design, and an adequate water supply will be required to sustain grassed areas and vegetation which are important in mitigating the effects of the climate, and in contributing to the creation of a pleasant town environment.

Social, cultural and recreational facilities will be provided to a level appropriate to a town of 9,000 people, with due regard to its location. Facilities will include three pre-schools, three primary schools, one high school, a library, a hospital, State and local government service and administration centres, commercial facilities, and a wide range of opportunities for passive and active recreation. Certain of these will be funded by the

State Government under the provisions of the Indenture Agreement. The special needs of a rapidly growing and relatively isolated community will be catered for, with community welfare facilities and support services being directed particularly towards the needs of young families, and the encouragement of the development of self-help groups.

In the conceptual design of the town, particular attention has been paid to the effects of climate, and to the preservation of vegetation and sand dunes at the town site. The layout of the town will facilitate ease of access to the main centre and to local centres, while maintaining privacy and safety for residents. In anticipation that the town may continue to develop for a variety of reasons, sufficient land has been reserved at the town site to accommodate an ultimate population of 30,000.

11.1 STUDY APPROACH

11.1.1 Joint Venturers' policy

While much of the initial development of the town will be guided by the Joint Venturers' policies, it will eventually assume the diversity and characteristics of a mature and permanent town. Employees will be encouraged to settle permanently and, in accordance with the Indenture Agreement, community facilities will be provided to a standard comparable with similar towns elsewhere in Australia. The Joint Venturers will fund most of the cost of initial construction, while the State Government will fund certain community facilities. The Joint Venturers wish to encourage a diversity of building styles and commercial life in the town, and from its inception Olympic Dam will be an 'open town' administered by a municipality, as provided for in the Indenture Agreement.

The Joint Venturers are experienced in the planning, development and operation of towns in environments similar to that of Olympic Dam. These include the towns of Kambalda and Leinster in Western Australia, where the Joint Venturers' policies of providing high standards of services, accommodation, facilities, and amenity in a well planned and attractive environment can be seen in operation. A policy of retaining existing trees and vegetation to the maximum extent possible has been well demonstrated at Kambalda and Leinster and is also being followed at Olympic Dam. Kambalda, developed in the late 1960s by Western Mining Corporation, was one of the first examples of such an approach. As a basis for the planning of the town at Olympic Dam, the Joint Venturers' experience is complemented by research findings and by evaluation of the planning, architecture, and community lifestyles in a number of new mining towns which have been carried out over the last decade by the CSIRO's Remote Communities Environment Unit and Division of Building Research.

Overall, it is intended that the quality of the living environment in the town should be high, to ensure that the Project can attract and retain a competent workforce. The Joint Venturers will also encourage the employment of married people, as this has been shown to increase population stability. A high standard of family housing, long-stay caravan accommodation and permanent accommodation for single employees will all be provided in the town. The short-term construction workforce will be accommodated separately in an expansion of the existing village facilities, some 7 km from the town area. Adequate water supplies will be available to give residents the option of establishing and maintaining lawns, gardens and shade trees. However, the adoption of garden styles which allow for the low rainfall characteristics of the region will be encouraged by the Joint Venturers.

The town is forecast to reach a size of some 8,000 people by the fourth year after production commences. Subsequent slower growth is expected to result in an ultimate population of about 9,000 at the production capacity contemplated. As such, the town will be the largest in South Australia north of Port Augusta and, in time, is likely to attract a number of regional service functions, thereby contributing to the diversification of the employment structure. The town location and other decisions have been influenced by the possibility that the population could expand in the longer term to 30,000 people. However, at present there is no basis for projecting the town's population beyond that proposed in this chapter.

11.1.2 Approach to town studies

Information, proposed policies, and concepts outlined in this chapter are based on data from the following sources:

- forecasts of the proposed Project workforce developed by the Joint Venturers and based on their experience in related operations;
- analyses of the workforce characteristics and population structures of other mining towns in Australia, notably Kambalda and Paraburdoo (Western Australia), and Moranbah (Queensland);
- published research by the CSIRO's Remote Communities Environment Unit and Division of Building Research, Victoria;
- standards of social facility provision adopted by the relevant State Government departments;
- the provisions of the Indenture Agreement;
- detailed environmental studies of the town site.

Planning studies for the development of the town at Olympic Dam and consideration of its social effects were carried out in two phases. Firstly, an assessment was made of alternative town sites (Chapter 2), utilizing the then available environmental baseline data. Following the selection of the preferred site, the second phase of the work involved two streams: the prediction of workforce structure, population forecasts and social facility requirements and, parallel to this, the development of a concept plan for the preferred site, supported by more detailed studies into specific planning and engineering issues in order to confirm its feasibility.

In presenting the results of these studies, the existing facilities at Olympic Dam and their role as the Project develops are first described, as well as the concerns expressed by Andamooka residents. The numbers and structure of the on-site workforce are then presented, with a discussion of the social implications of this type of workforce structure. As a basis for predicting the likely demographic characteristics of the Olympic Dam population, the demography of comparable Australian mining towns is then reviewed. This is followed by a discussion of housing requirements.

The social facility requirements in relation to the size of the town population and the special needs of a community of this type are then outlined. The conceptual town plan is presented, illustrating how the housing and social facility requirements have been incorporated with town planning and servicing requirements, as well as with the environmental characteristics of the site. Finally, the approach to municipal management and administration is discussed.

11.1.3 Existing population, employment, and social facilities

There are currently about 180 people employed at the Olympic Dam site, with the majority being engaged in the sinking of the exploration shaft and exploration drilling. The total population, including dependants, is approximately 250. About fifty primary and secondary school children are taken by bus daily to the Andamooka Special Rural School located 30 km to the east. Limited use is also made of the commercial facilities at Woomera.

Accommodation at the existing village comprises:

- single quarters accommodation for approximately 160 people
- a caravan park with en-suite facilities for thirty-six caravans
- sixteen houses.

The social and recreational facilities at the village include:

- a swimming pool
- squash courts, tennis courts and oval
- an indoor sports building and theatre
- television
- a wet canteen
- a supermarket
- a medical and first aid centre
- a BMX cycle track.

The village is serviced by scheduled and chartered air services and by a twice-weekly passenger bus service to Adelaide.

11.1.4 Role of the existing village

During the construction period, Joint Venturers' on-site personnel and any long-term contractors will be progressively moved from the existing village as soon as sufficient accommodation can be made available in the town. It is intended that all new permanent employees arriving on site will also be accommodated in the new town, although some employees may necessarily have to be accommodated in caravans for short periods while waiting for housing to become available. However, this situation is only likely to occur during the initial stages if difficulties arise in matching the on-site workforce build-up with the rate of house completion.

The existing single quarters accommodation village will be expanded for use as the construction contractors' village. The existing houses and caravan park will also be utilized by construction workforce staff, and the social and recreational facilities presently available in the village will be expanded to meet the increased demand.

The construction village will continue to be used during the early years of production, until all necessary accommodation is available in the town. Following this, the single quarters and caravan accommodation in the village will be dismantled, the existing housing will be relocated to the town, and the village area will then be rehabilitated.

11.1.5 Concerns of Andamooka residents

The principal existing community which will be potentially most affected by the establishment of the town at Olympic Dam is Andamooka, whose residents have expressed their concerns with respect to the Olympic Dam Project in a submission to the South Australian House of Assembly Select Committee on the Indenture Ratification Bill. The residents' greatest concern was not the development of the Project itself, which they welcomed; but rather the possibility that greater government administration, controls and taxes would be imposed as an indirect result of the Project. Andamooka has no local government, but there is an annually elected Progress Association. Andamooka is considered unique by its residents who choose to live there not only because of the opal mining, but also because they enjoy a relatively free and uninhibited lifestyle and do not wish to see this change.

Andamooka residents sought a general upgrading of services (such as power and water supplies, roads, and airstrip), the retention of the existing school and, in the event of the town becoming an attraction to Olympic Dam residents, the appointment of an additional police officer. However, these requests involve action by government authorities rather than by the Joint Venturers.

11.2 WORKFORCE PROJECTIONS

11.2.1 Project workforce

The estimated direct Project workforce comprises both Joint Venturers' employees and employees of contractors employed by the Joint Venturers (Table 11.1). For a Project construction period of four years and a production level of 150,000 t/a of copper, the direct Project workforce is forecast to rise to a peak of about 3,300 workers in the year prior to the start of production, and will stabilize at around 2,400 when the mine is at full production. The Joint Venturers' workforce is forecast to rise to about 800 at the start of the year prior to production, then to increase sharply to 1,800 at the start of production, stabilizing at around 2,200 at full production. Contractor employment is forecast to rise quickly to around 2,500 during the construction period and then to fall to approximately 250 during the first few years of production.

Table 11.1 Estimated total Project and non-Project workforce at Olympic Dam

Workforce category	Construction years*					Production years*			
	Pre-committal	-4	-3	-2	-1	+1	+2	+3	+4
Joint Venturers' workforce**	90	90	290	530	820	1,820	2,020	2,120	2,180
Contractors and visitors	100	100	1,000	2,500	2,500	1,000	250	250	250
Subtotal direct Project workforce	190	190	1,290	3,030	3,320	2,820	2,270	2,370	2,430
Non-Project workforce †	10	10	100	200	400	600	650	680	700
Total	200	200	1,390	3,230	3,720	3,420	2,920	3,050	3,130

* Numbers refer to the start of the year.
** Rounded from Table 12.11.
† Determined after estimating the population resulting from settlement of the direct Project workforce.

The population will expand rapidly during the construction period due to the influx of construction workers and their families. However, because of the temporary nature of employment associated with construction contracts, this period is likely to be characterized by a relatively high turnover of labour.

Table 11.1 also shows the estimated number of consequential non-Project jobs rising to around 400 in the year prior to the start of production and increasing to approximately 700 by the fourth year of production. The following section describes the forecast distribution of these jobs between industry sectors. The total workforce forecast for Olympic Dam during the period of construction and the early production years is also set out in Table 11.1. This total workforce (comprising both the direct Project and the consequential non-Project workforce) is forecast to peak at around 3,700 in the year prior to the start of production. Details of the forecast skill structure of the direct Project workforce are presented in Chapter 12.

11.2.2 Non-Project workforce

The consequential non-Project workforce will be employed by the private and public sectors to provide services to the Project and to the town population. The number of these jobs likely to be generated, based on the direct Project workforce and the resulting population, is predicted to reach about 700 in production year 4, representing approximately 22% of the total forecast workforce. These estimates may be confirmed by reference to other Australian mining towns, although their accuracy will be affected by the ultimate level of private industrial and commercial development in the town. Possible distribution between major industry categories is shown in Table 11.2.

Table 11.2 Estimated non-Project workforce by industry category at Olympic Dam*

Industry category	Construction years					Production years			
	Pre-committal	-4	-3	-2	-1	+1	+2	+3	+4
Manufacturing	-	-	-	6	15	24	26	26	26
Electricity, gas and water	-	-	3	3	5	6	7	8	8
Construction	-	-	-	10	29	40	45	45	45
Wholesale and retail	-	-	14	30	55	74	85	88	88
Transport	-	-	10	16	39	52	54	55	55
Communications	-	-	3	3	6	7	9	11	13
Finance	-	-	2	4	15	17	20	22	23
Public administration	5	5	19	27	49	56	57	59	60
Education and community services	-	-	28	50	80	148	164	183	204
Entertainment	1	1	17	45	93	146	151	151	146
Other	4	4	4	6	14	30	32	32	32
Total	10	10	100	200	400	600	650	680	700

* Estimates for individual categories, based on structure evident in other Australian mining towns, are approximate.

Table 11.3 gives an approximate indication of the employment structure for the forecast total Olympic Dam workforce in Australian Bureau of Statistics' industry categories, and combines the Joint Venturers', contractors' and consequential non-Project workforce components described in Tables 11.1 and 11.2. The table shows the expected dominance of mining and construction employment during the early years of the town's development, although in time the service employment sectors probably would continue to develop beyond the 22% predicted in year 4. To provide a comparison, the employment structures of three existing mining towns (Paraburdoo, Kambalda and Moranbah) are also presented. These figures show that the forecast situation at Olympic Dam at production year 4 is similar to the employment structures of the other towns recorded at the 1976 Census, when they were at comparable stages of town development.

11.2.4 Social implications of forecast workforce structure

Given the forecast structure of the workforce at Olympic Dam, it is anticipated that many of the social characteristics observed in other mining towns will be evident, particularly in the formative years of the town. However, as the town develops, the observable differences from other similar sized towns in Australia will lessen. Social considerations in relation to the employment structure of the town include:

- **Shift work:** The continuous operation of the Project will require a proportion of the workforce to be rostered on a shift basis. While shift work offers financial advantages and other benefits, some employees may experience personal or social difficulties because it could isolate them from family, friends or community activities. However, there is a wider acceptance of shift work within mining communities than elsewhere, and as a result these problems are expected to be less pronounced at Olympic Dam than for non-mining communities.

Table 11.3 **Industry of employed population: existing mining towns* (1976), and forecast Olympic Dam**

Industry category	Paraburdoo WA %	Moranbah Qld %	Kambalda WA %	Olympic Dam forecast in production year 4 %
Agriculture	0.2	0.1	0.1	-
Mining	57.1	60.2	71.5**	69.6
Manufacturing	0.2	2.9	1.2	0.8
Electricity, gas, water	0.3	0.7	3.6**	0.3
Construction	2.1	9.1	2.0	9.4
Wholesale and retail trade	3.6	7.5	5.4	2.8
Transport and storage	1.0	0.7	0.8	1.8
Communications	0.3	0.5	0.5	0.4
Finance	1.8	2.8	2.0	0.7
Public administration	0.1	0.4	0.5	1.9
Community services	5.6	5.1	6.4	6.5
Entertainment	7.2	2.8	2.0	4.7
Other and not stated	20.4	7.3	4.1	1.0
Total †	100.0	100.0	100.0	100.0

* The approximate ages of towns at the 1976 Census were: Paraburdoo six years, Moranbah six years, Kambalda ten years.

** Original census data adjusted according to advice from the Australian Bureau of Statistics.

† Totals may not add due to rounding.

Source: Australian Bureau of Statistics, 1976 Census.

- **Single employer dominance:** The predominance of one employer in the town has the potential to allow work related issues to assume a disproportionate status. The establishment of the town as an independent municipality (Section 11.7) and the housing policies of the Joint Venturers (Section 11.4.3) are intended to offset this effect.

- **Higher income:** The workforce structure in mining towns leads to a higher median income for employees than is usual in urban areas, as illustrated by the following statistics for median annual income from the 1976 Census:

  - Paraburdoo: $10,800
  - Moranbah: $11,200
  - Kambalda: $ 8,700
  - Adelaide: $ 6,800.

  Additional financial benefits also arise from the increased likelihood of shift work and overtime, the zone area income tax allowance available, and the opportunity to either purchase or rent a house under favourable terms. The anticipation of such overall financial benefits is expected to attract a suitable workforce to Olympic Dam.

- **Predominantly male workforce:** Mining activity generally involves a greater number of jobs traditionally performed by men (Table 11.4). There is generally a higher percentage of both married and single male employment in mining towns than in urban areas, while single female employment in mining towns is relatively low.

- **Employment for women:** In the initial stages of the Project's development, opportunities for female employment may be limited. However, it is a policy of the Joint Venturers to afford equal opportunity to all people with appropriate skills, and therefore attempts will be made to provide employment opportunities for women. In practice, this will mean that initially most Project employment opportunities for women will be in administrative positions, although consideration will also be given to their employment in non-administrative positions. As the town develops, service and public sector employment is forecast to expand and broaden the employment base of the town thereby increasing opportunities for female employment. For those who are unable to find suitable employment with either the Joint Venturers, government or private employers, programmes aimed at providing a wide range of recreational and personal development opportunities will be developed and made available.

- **Employment for school leavers:** While lack of employment opportunities for school leavers is not likely to be a problem in the early years of Olympic Dam's development (given the expected youthful population structure of the town), this could change later. However, experience at Kambalda has demonstrated that it is possible to retain people of school leaving age by providing employment opportunities through apprenticeship and job training schemes. Such schemes will be introduced by the Joint Venturers at Olympic Dam.

Table 11.4 Sex and marital status of the workforce: existing mining towns (1976) and Adelaide

Location	Male			Female		
	Married %	Single* %	Total %	Married %	Single* %	Total %
Paraburdoo (WA)	43.7	33.1	76.8	18.9	4.2	23.1
Moranbah (Qld)	66.9	14.8	81.7	12.4	5.9	18.3
Kambalda (WA)	55.4	24.8	80.2	15.1	4.7	19.8
Adelaide Statistical Division	44.1	18.6	62.7	23.1	14.2	37.3

* Single includes those never married, permanently separated, divorced and widowed.

11.3 CHARACTERISTICS OF PREDICTED POPULATION

The demographic characteristics of the town population are important in determining the demand for commercial, educational, medical, welfare and entertainment facilities. As Olympic Dam is expected to demographically resemble other mining towns in Western Australia and in Queensland in their formative years, the forecasts for Olympic Dam have been estimated after examination of data for Kambalda, Paraburdoo and Moranbah recorded at the 1976 Census. Data from the 1981 Census was not available at the time of writing.

11.3.1 Age-sex structure

The age-sex structure of the town will change as the initial residents age and the town matures. To give an indication of Olympic Dam's population structure during the early production years, Figure 11.1 compares the age-sex structures of Paraburdoo, Moranbah and Kambalda with the Adelaide Statistical Division. This figure illustrates the marked differences between the age-sex structures of recently established mining towns and that of a large, established metropolitan area. Compared with the Adelaide Statistical Division shown in this figure, the age-sex structures of the newly established mining towns exhibit the following features:

- A considerably higher proportion of the population is aged either nine years or under (around 30%) compared with Adelaide (around 17%). Attention will therefore be given to the provision of appropriate health, welfare, education and other facilities for young children, especially in the initial years of the town's development.

- A noticeably lower proportion is aged between ten and nineteen years in Paraburdoo and Moranbah (around 10%) compared with Adelaide (18%), although Kambalda shows a similar proportion to Adelaide in this age group. At Olympic Dam the situation is expected to more closely parallel that at Kambalda.

- There are higher proportions in the twenty to forty year age group (around 40 to 50%) than in Adelaide (29%). These proportions reflect the principal workforce age groups and coincide with the early to middle years of family formation. The town design and community facilities will initially reflect the needs of this age group, but will have the flexibility to adapt to changing age structure requirements as the town matures.

- There is a significantly lower proportion aged over forty years in the mining towns (10 to 15%) compared with Adelaide (35%). Community facilities planned for Olympic Dam will help to compensate for the lack of informal support functions, such as child minding, often performed in established communities by this age group.

- More males than females are found in the adult age groups in mining towns (59% male) compared with Adelaide (49%). This demographic imbalance has resulted in social problems in other new mining towns. In order to ameliorate this imbalance, the Joint Venturers intend to:

  - develop employment recruitment programmes aimed at female representation in the Project workforce;

  - integrate single status and family accommodation in the residential areas of the town;

  - provide recreational facilities and support the development of a range of recreation and community programmes.

The forecast age-sex structure for Olympic Dam at production year 4 (shown in Table 11.5) generally reflects the same features evident in these other new mining towns. Of the three mining towns selected for comparison, Kambalda has been chosen as the basis for projection of the Olympic Dam population for the following reasons:

- Kambalda is based on an underground mining operation with significant process-related employment.

- There is closer correlation between the Joint Venturers' policies at Olympic Dam and those at Kambalda than with the other towns.

- Olympic Dam in production year 4 is likely to be at a similar stage of town development as Kambalda was in 1976, and the forecast age-sex structure is based on this assumption.

Table 11.5 Forecast age-sex structure, Olympic Dam (production year 4)*

Age group	Male		Female		Total	
	Number	(%)	Number	(%)	Number	(%)
0 - 4	632	(8.0)	521	(6.6)	1,153	(14.6)
5 - 9	553	(7.0)	506	(6.4)	1,059	(13.4)
Subtotal 0 - 9	1,185	(15.0)	1,027	(13.0)	2,212	(28.0)
10 - 14	410	(5.2)	435	(5.5)	845	(10.7)
15 - 19	276	(3.5)	269	(3.4)	545	(6.9)
Subtotal 10 - 19	686	(8.7)	704	(8.9)	1,390	(17.6)
20 - 24	482	(6.1)	403	(5.1)	885	(11.2)
25 - 29	569	(7.2)	466	(5.9)	1,035	(13.1)
30 - 34	403	(5.1)	316	(4.0)	719	(9.1)
35 - 39	356	(4.5)	221	(2.8)	577	(7.3)
Subtotal 20 - 39	1,810	(22.9)	1,406	(17.8)	3,216	(40.7)
40 - 44	221	(2.8)	103	(1.3)	324	(4.1)
45 - 49	190	(2.4)	126	(1.6)	316	(4.0)
50 - 54	134	(1.7)	71	(0.9)	205	(2.6)
55 - 59	87	(1.1)	47	(0.6)	134	(1.7)
60 - 64	39	(0.5)	24	(0.3)	63	(0.8)
65 - 69	8	(0.1)	8	(0.1)	16	(0.2)
70 - 74	8	(0.1)	16	(0.2)	24	(0.3)
75+	-	-	-	-	-	-
Subtotal 40+	687	(8.7)	395	(5.0)	1,082	(13.7)
Total	4,368	(55.3)	3,532	(44.7)	7,900	(100.0)

* Based on Kambalda, 1976, Australian Bureau of Statistics census data.

11.3.2 Marital status

Table 11.6 shows the marital status of the population in three mining towns and in the Adelaide Statistical Division in 1976. It is noteworthy that the percentage of married people in mining towns is greater than for Adelaide, while the percentage of single women is less.

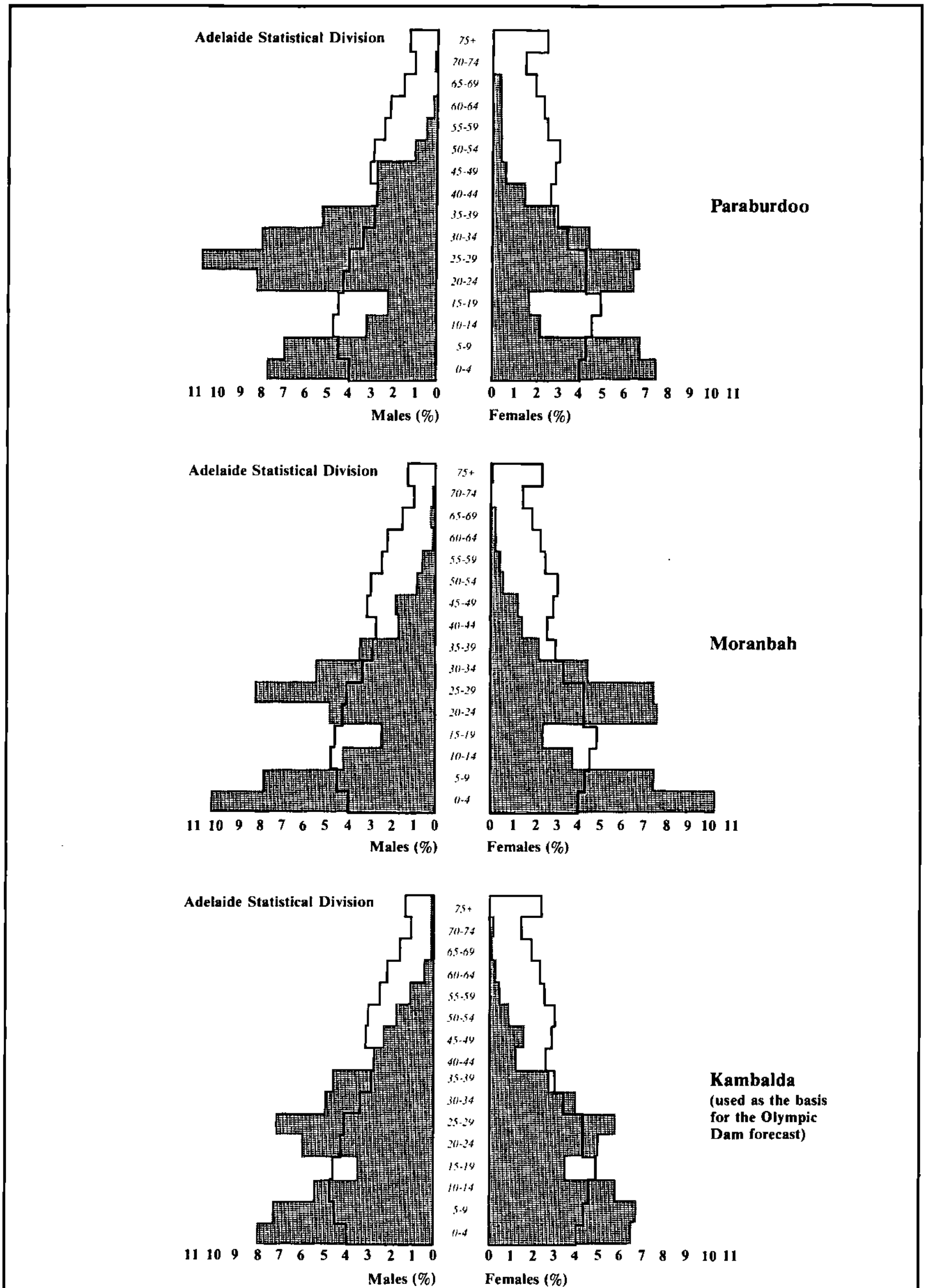


Figure 11.1
POPULATION AGE-SEX STRUCTURE

Table 11.6 **Marital status of the population older than fifteen in selected mining towns and Adelaide**

Location	Married			Single		
	Male %	Female %	Total %	Male %	Female %	Total %
Paraburdoo (WA)	35.7	31.5	67.2	27.6	5.2	32.8
Moranbah (Qld)	41.1	41.1	82.2	10.5	7.3	17.8
Kambalda (WA)	38.6	34.8	73.4	18.8	7.7	26.5
Adelaide (SA)	31.6	31.9	63.5	16.8	19.7	36.5

Source: Australian Bureau of Statistics, 1976 Census.

11.3.3 Household size

Household and family size reflect the age-sex structure and marital status of a population, and the forecast distribution of family size can indicate the size range of houses necessary. Generally, mining towns have larger family sizes and higher house occupancy rates than major metropolitan areas. Table 11.7, which shows the distribution of family size and average household size at Paraburdoo, Kambalda and Moranbah, indicates that approximately two-thirds of families in these towns are comprised of between three and five people. When applied to Olympic Dam, the average household size is expected to be 4.1 people as in Kambalda, with the result that the majority of houses will have three to four bedrooms.

Table 11.7 **Distribution of family size and average household size in selected mining towns and Adelaide**

Number in family	Paraburdoo (WA) %	Moranbah (Qld) %	Kambalda (WA) %	Adelaide (SA) (%)
1	5.8	4.0	7.9	19.8
2	21.2	13.9	15.4	29.1
3	17.4	19.1	15.4	17.0
4	31.3	33.8	27.9	19.0
5	15.8	16.8	20.0	9.7
6	5.8	8.3	9.1	3.7
7	1.9	2.4	3.1	1.1
8 or more	0.8	1.7	1.2	0.6
Average occupancy rate*	3.6	3.9	3.8	2.9
Average occupancy excluding single person households	3.8	4.0	4.1	3.4

* Persons per private occupied dwelling only.
Source: Australian Bureau of Statistics, 1976 Census.

11.3.4 Ethnic composition

Research (Brealey and Newton 1980) has indicated that in the early 1970s an average of 30% of all residents in recently established Australian mining towns were foreign-born.

The ethnic composition of the 1976 Kambalda population indicates that approximately 75% were Australian-born, while 15% were born in English-speaking countries, and 10% in other countries. These figures are comparable with Adelaide where in 1976, 72% were Australian born, 16% born in English-speaking countries, and 12% in other countries.

Changes in national migration policies make it difficult to estimate the future ethnic composition of the population at Olympic Dam. However, if the experience of Kambalda is a guide, possibly a quarter of the population of Olympic Dam may have no close family ties within Australia, and almost half of the non-Australian born population may come from non-English speaking countries. Kambalda has not experienced any significant social difficulties arising from the ethnic composition of its population.

11.4 POPULATION AND HOUSING PROJECTIONS

11.4.1 Methodology

The methodology adopted for determining housing and population projections is illustrated diagrammatically in Figure 11.2.

Estimates of the accommodation requirements for the direct Project workforce (those directly employed by the Joint Venturers and by contractors) were based on the Joint Venturers' housing policy and demonstrated demand for accommodation types in other mining towns. For employees of the Joint Venturers, the number of married heads of households was estimated to reach 66% of the total in the long term. These were allocated house or caravan accommodation. The remainder of this workforce was then classified into those who were dependants of heads of households (and who therefore would not require separate accommodation), and those of single status (who were allocated single quarters). A similar exercise was then conducted for the contractors likely to be associated with the Project in the long term. It was assumed that 40% of these would require married accommodation, with the remainder in single quarters.

From the accommodation requirements, the total population relating directly to Project activities was calculated. Population multipliers of 4.1 persons per house and 3 persons per caravan were used to estimate the population in these types of accommodation. To this was added the number in single quarters, in order to provide an estimate of the total population associated with the direct Project workforce. The additional consequential non-Project workforce (engaged in service, commercial and administrative functions to support the population associated with the direct Project workforce) was then estimated. The accommodation requirements of the non-Project workforce and the total population associated with this workforce were calculated in a manner similar to that used for the Project workforce. The estimate of the total town population is therefore the sum of the population associated with the direct Project workforce and with the non-Project workforce. The estimated distribution of this total population between types of accommodation is set out in Table 11.8.

11.4.2 Results of forecasts

Table 11.9 sets out the forecast population based on the above methodology, and shows that, after committal, the population is forecast to increase rapidly to about 5,550 people during the four-year construction period. The second and third years of the construction phase show the largest forecast population increments, due to the substantial increase in the construction workforce. Although not shown directly by the total population estimates, the year prior to production will see considerable population movement, with most of the contractor workforce (who had been housed in the construction village) leaving, and the Joint Venturers' workforce increasing substantially

Table 11.8 Estimated distribution of workforce between types of accommodation

Category	Construction years					Production years			
	Pre-committal	-4	-3	-2	-1	+1	+2	+3	+4
Project:									
Senior staff									
Houses	6	6	13	24	30	51	54	60	65
Staff									
Houses	8	10	32	70	120	220	230	250	254
Single quarters	11	11	26	47	55	77	67	73	72
Dependants*	2	2	6	13	20	20	32	35	37
Award									
Houses	-	-	55	130	270	720	860	950	1,060
Caravans	10	10	30	60	60	60	60	60	60
Single quarters	46	44	110	160	223	572	625	592	528
Dependants*	7	7	18	26	42	100	92	100	104
Subtotal Project	90	90	290	530	820	1,820	2,020	2,120	2,180
Contractors:									
Houses	4	4	10	30	30	40	50	50	50
Caravans	20	20	50	100	100	100	50	50	50
Single quarters	70	70	350	350	350	350	140	140	140
Contractors' village	-	-	580	2,000	2,000	500	-	-	-
Dependants*	6	6	10	20	20	10	10	10	10
Subtotal contractors	100	100	1,000	2,500	2,500	1,000	250	250	250
Non-Project:									
Houses	1	2	10	40	100	160	170	180	190
Caravans	-	-	10	30	40	40	40	40	40
Single quarters	-	-	30	40	60	70	70	70	70
Dependants*	9	8	50	90	200	330	370	390	400
Subtotal non-Project	10	10	100	200	400	600	650	680	700
Total workforce	200	200	1,390	3,230	3,720	3,420	2,920	3,050	3,130

* Dependent workers do not require separate housing.

Table 11.9 Estimated population and housing, Olympic Dam

Dwelling	Construction years					Production years			
	Pre-committal	-4	-3	-2	-1	+1	+2	+3	+4
Number of houses	19	22	120	294	550	1,191	1,364	1,490	1,619
Subtotal housed population*	78	90	492	1,205	2,255	4,883	5,592	6,109	6,638
Number of caravans	30	30	90	190	200	200	150	150	150
Subtotal caravan population**	90	90	270	570	600	600	450	450	450
Number of single quarters†:									
In town	-	-	200	300	390	800	800	800	810
In village	130	130	900	2,300	2,300	770	100	80	-
Total forecast population:	298	310	1,862	4,375	5,545	7,053	6,942	7,439	7,898
In town	-	-	862	1,875	3,045	6,153	6,842	7,349	7,898
In village	298	310	1,000	2,500	2,500	900	100	90	-

* Number of houses x 4.1 and rounded.
** Number of caravans x 3.0.
† Numbers rounded from Table 11.8.

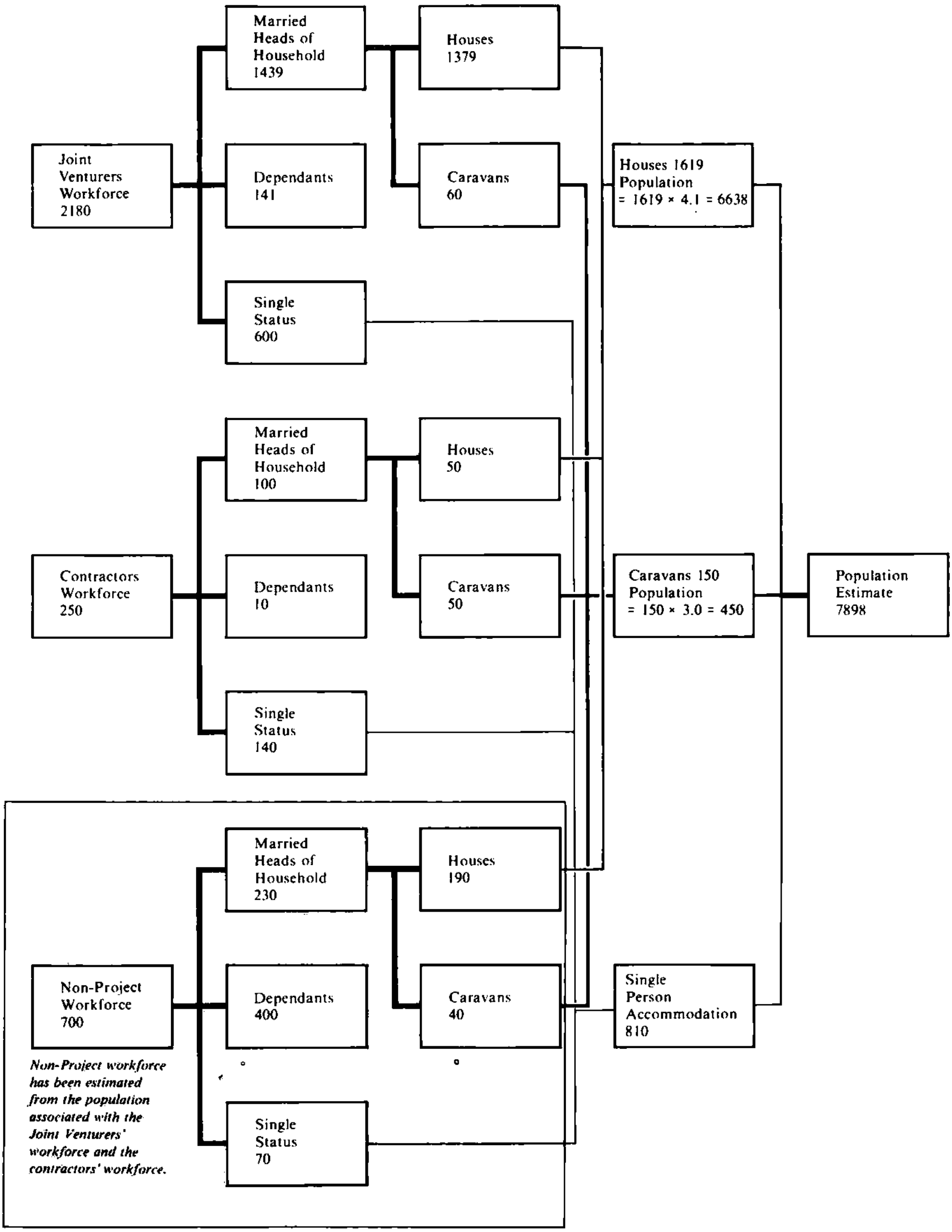


Figure 11.2
POPULATION HOUSING AND PROJECTION METHODOLOGY (NUMBERS ARE FOR PRODUCTION YEAR +4)

(Table 11.1). At the start of production the permanent population in the town will almost double. Thereafter, the growth rate will slow down considerably, although beyond production year 4 the population will continue to grow as a result of natural increase, the immigration of family groups, and the expansion of the town's service sectors. Assuming that the Project workforce remains fairly constant, a rate of increase in the town population of between 2 and 4% per annum could be expected.

The projected population figure of approximately 7,900 is based on the steady state Project workforce at a production level of 150,000 t/a of copper. Evidence from other mining towns in their early stages of development (Brealey and Newton 1980) indicates that higher than average population turnover was experienced in the early years, as some people found the work or lifestyle not to their preference. However, changing economic circumstances in recent years may have served to reduce this effect.

The distribution of accommodation types shown in Table 11.9 assumes that, by production year 4, approximately 6% of the total population will live in caravans, 10% in single person accommodation, and the remaining 84% in houses. During the earlier construction phase of the Project, the proportion living in single person accommodation will be considerably higher because of the greater proportion of people of single status.

Table 11.9 also shows the distribution of the population between the town and the village area. The construction camp in the village area will expand to accommodate a peak of 2,500 in the final construction year (year -1) and will rapidly taper off after that time. By the fourth year of production in the schedule of development assumed in this Draft EIS, there will be no-one housed in the village area. The town for the permanent workforce is expected to grow from a population of 862 in the second year of construction (year -3) to 7,898 in the fourth year of production (year +4). However these are necessarily estimates, and the Joint Venturers' workforce numbers and accommodation provisions will be reviewed at least annually throughout the development of the Project, with forward programmes being amended and modified on the basis of these findings.

The estimated distribution of the combined direct Project and consequential non-Project workforce between married, single and dependent workers is shown in Table 11.10. Married heads of households are forecast to be the largest group (57% of the workforce by year 4). Single status workers are forecast to comprise 26% of the workforce, with the remainder made up of dependent spouses and children (17%).

Table 11.10 Estimated number of married, single and dependent workers in forecast total Olympic Dam workforce

Employee status	Construction years					Production years			
	Pre-committal	-4	-3	-2	-1	+1	+2	+3	+4
Married heads of households*	49	52	210	484	750	1,391	1,514	1,640	1,769
Working dependants	24	23	84	149	282	460	504	535	551
Single	127	125	1,096	2,597	2,688	1,569	902	875	810
Total employed	200	200	1,390	3,230	3,720	3,420	2,920	3,050	3,130

* Assuming all house and caravan occupants are families.

The results of the population projections by workforce category and by accommodation type are shown diagrammatically in Figures 11.3 and 11.4.

11.4.3 Accommodation

The distribution of different types of accommodation in the town will be directly influenced by:

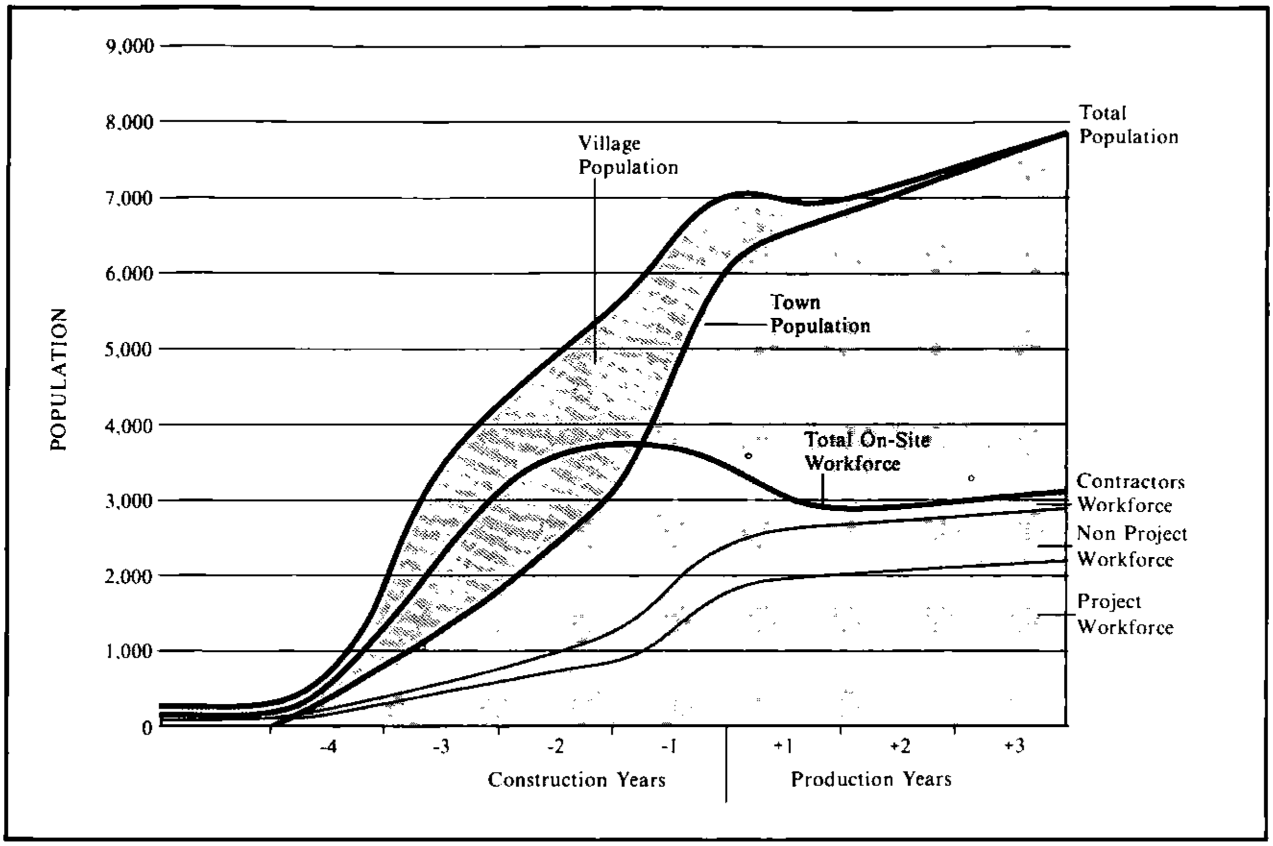


Figure 11.3
ESTIMATED POPULATION BY WORKFORCE CATEGORY

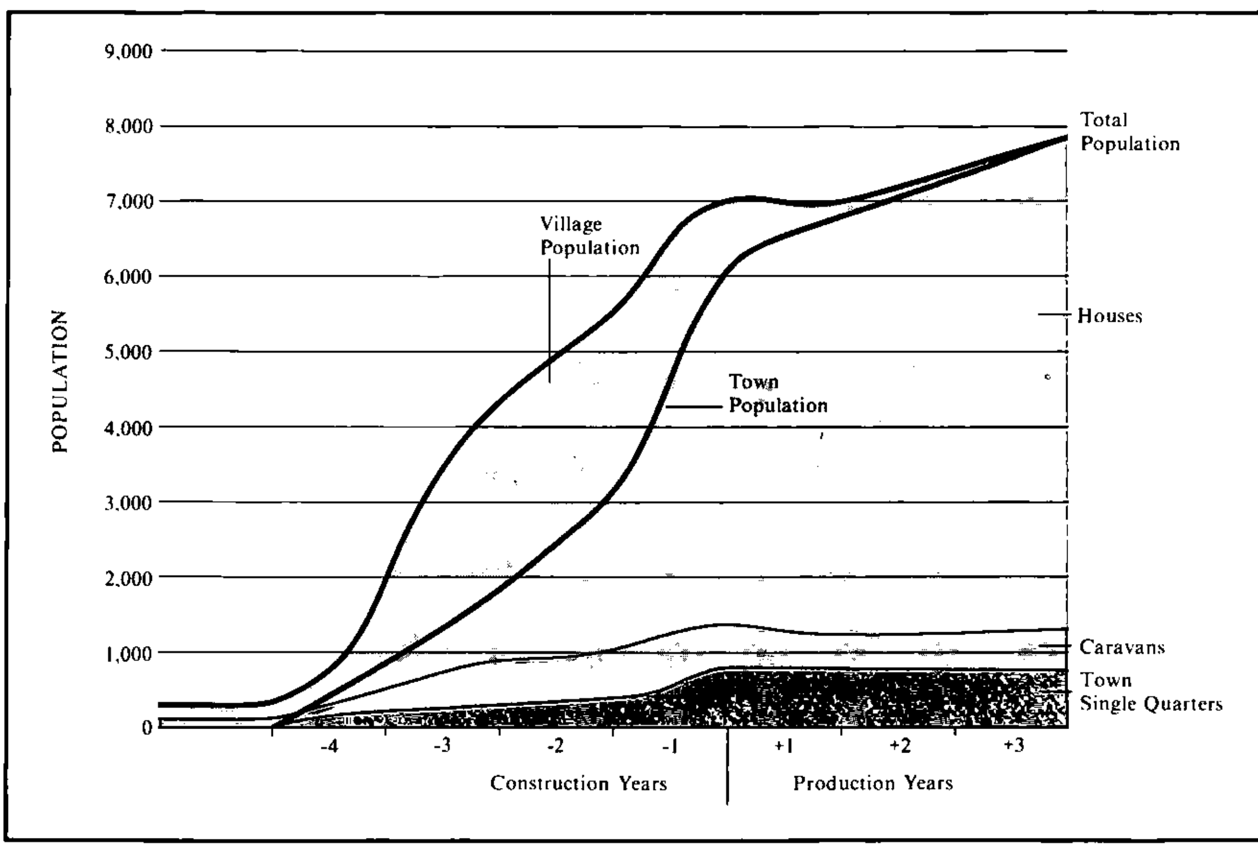


Figure 11.4
ESTIMATED POPULATION BY ACCOMMODATION TYPE

- the Joint Venturers' policy on the provision of accommodation for the Project workforce;
- the policies of the State Government and the municipality on the housing of their employees;
- the open town concept where individual preferences can be expressed through privately developed housing.

Construction workforce: A separate village will be provided for the construction workforce, 7 km from the town. This separation is considered desirable because of the different social characteristics of the construction and production workforces. The construction village facilities will be an extension of the existing single quarters at Olympic Dam, which consist of blocks of about ten rooms with shared ablution facilities, as well as central dining and recreation facilities.

Single person accommodation in the town: A flexible accommodation policy for single status production employees will be considered and, where appropriate, single accommodation will be integrated with other housing throughout the town.

In the past, single workers in mining towns, particularly men, have been stereotyped as an homogeneous group and have often been accommodated in physically isolated quarters not conducive to encouraging permanent residence. Research (Gribbin and Thomson 1979) has shown that the single status sector of a mining workforce has particular characteristics which need to be taken into account in the provision of accommodation, and the following modes will be considered for use in the long term at Olympic Dam:

- **Single room accommodation:** In planning single room accommodation, the optimum groupings of units for sharing of common facilities will be based on usage patterns. Lounge facilities could be shared by between six and eight people for example, while recreational facilities could be shared among a larger number. This would permit self-grouping on the basis of common interests and lifestyles. It is envisaged that the accommodation units would be centred on the dining and recreational facilities, in a manner similar to that of the existing village facilities. An example of this type of accommodation at Leinster is shown in Figure 11.5(a) and (b).
- **Self-contained flats:** This type of accommodation provides self-contained facilities for one or more people. The flats could be located in small groups with a common outdoor area.
- **House-sharing:** This form of accommodation for single workers may be appropriate as the town develops.

Married worker housing provision

Experience in other new mining towns and research (Brealey and Newton 1978) have shown that the majority of the married workforce (70 to 80%) has a preference for houses located on blocks of land of sufficient size to allow the development of lawns, gardens and shade trees. However, as a proportion of residents may prefer medium density housing, a limited number of two-bedroom units may be provided as the town develops.

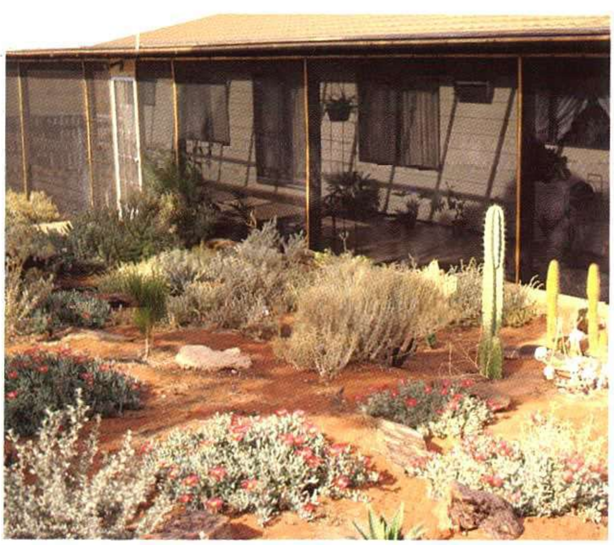
Good, comfortable housing in a pleasant physical and social environment is an important consideration in attracting and retaining a stable workforce. Figure 11.5(c) and (d) shows typical housing at Kambalda, where these principles have been applied. It is the Joint Venturers' intention to provide such an environment at Olympic Dam, with particular attention being given to house siting, and to the retention and augmentation of existing vegetation. This policy is already in operation at the existing Olympic Dam village as the examples shown in Figure 11.5(e) and (f) demonstrate.

a Single accommodation at Leinster

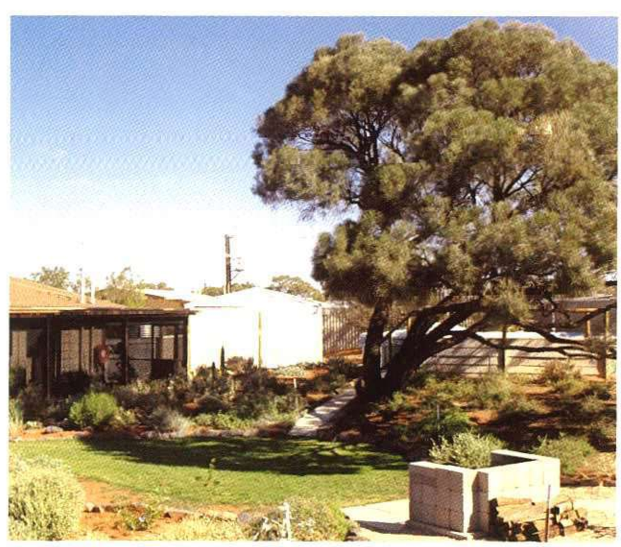
b Single accommodation at Leinster

c Typical housing at Kambalda

d Typical housing at Kambalda



e Existing housing at Olympic Dam



f Existing housing at Olympic Dam

Figure 11.5
TYPICAL ACCOMMODATION

The Joint Venturers wish to encourage home ownership among employees, and will consider instituting policies such as price maintenance and buy back provisions for home purchases.

Caravan park accommodation

Caravan park accommodation will be provided for the minor proportion of the workforce expected to show a preference for this type of accommodation. The reasons for this preference are likely to include:

- a desire for a more mobile and flexible lifestyle
- an unwillingness to make a commitment to the cost of furnishing a house and maintaining a garden.

It is expected that the majority of caravan dwellers will be short-term residents, staying in the caravan park for less than eighteen months. However, a smaller proportion, particularly those with children, will become longer-term members of the workforce and may progress to housing accommodation.

Current caravan park practice is to provide en-suite ablution facilities for each site. This overcomes the major problems of maintenance and cleanliness associated with shared ablution facilities, and permits the option of creating a number of smaller parks throughout the town rather than one large park. Caravan parks in the town will be sited within easy pedestrian access to schools and other community facilities. It is anticipated that private entrepreneurs will provide some of the caravan park facilities, particularly to cater for non-Project and tourist demand.

11.5 SOCIAL FACILITY REQUIREMENTS

The social, cultural and recreational facilities to be established at Olympic Dam are expected to incorporate the range of services and facilities which would be found in most towns with a population of 9,000 people, having due regard to the location of Olympic Dam. The responsibility for the funding of these facilities will be shared by the Joint Venturers and the State as defined in the Indenture Agreement. The scope and requirements for those facilities normally provided by State Government departments and authorities have been determined after consultation with State and other relevant authorities. Municipal requirements have been assessed by comparison with established municipalities, taking into account the particular circumstances which apply, and these requirements have been agreed upon with the State Government. The normal range of Commonwealth Government services can also be expected to be established as the town develops. It is anticipated that the open town concept will encourage private entrepreneurs to provide additional facilities.

11.5.1 Public services

Education

The estimated population of 9,000 will require three pre-schools, three primary schools and one high school. The primary schools and pre-schools will be located within the neighbourhoods which they serve, while the high school will be centrally located. In the early years of the town, high school students could use existing facilities at Andamooka (Section 4.1.5) or Woomera (Section 4.1.6). The pre-school centres will consist of one or more units, with facilities in each for a group of up to twenty-five children. Each unit will be capable of accommodating two such groups each day. Each primary school will have a maximum enrolment of 600 pupils and will consist of appropriate teaching spaces, administration area, shaded or covered play areas, amenities block and tuckshop. The high school will be able to cater for up to 800 pupils, and in addition to general teaching spaces will have special areas for maths/science, music and home economics, a library, administration block, staff facilities and a senior student lecture theatre. It is envisaged that these high school facilities will also be made available for Technical and Further Education classes. All necessary pre-school, primary and secondary school facilities will be funded and operated by the State Government pursuant to Clauses 22(2)(e), (f) and (g) of the Indenture Agreement, and will be included in the building programme for the town in accordance with Indenture Agreement provisions. A library to be included in the municipal facilities will be funded by the State Government pursuant to Clause 22(2)(j) of the Indenture Agreement.

Health and welfare

A hospital will be established which will contain general, maternity and childrens' sections, a casualty department, labour ward, operating theatre, out-patients' department, diagnostic X-ray unit and physiotherapy department. The hospital will be funded by the State Government in accordance with Clause 22(2)(h) of the Indenture Agreement. Prior to its establishment, the nearest medical facilities with this range of services will be in Woomera.

In addition to the hospital, a medical and dental centre will be established in the town centre, and will also include maternity and child care facilities and family planning services. This centre will be funded by the State Government pursuant to Clause 22(2)(i) of the Indenture Agreement. Higher order medical and dental services will be available in Adelaide.

An ambulance centre, vehicle, and associated equipment will be funded by the State Government in accordance with Clause 22(2)(q) of the Indenture Agreement. It is assumed that this service will be operated on a subscription basis by the St John Council for South Australia Incorporated, and will be supplemented by access to the Flying Doctor service for patient transfers to and from Adelaide.

Police and law

The State Government will fund a police station, lock-up and accommodation for the required police personnel and support staff, in accordance with Clause 22(2)(c) of the Indenture Agreement. This clause also includes the provision for State funding of a court house, which will be administered by a magistrate and staff.

Fire services

A two-bay fire station equipped with a fire tender and an additional pump and trailer unit will be funded by the State Government pursuant to Clause 22(2)(n) of the Indenture Agreement. It is expected that the fire service will be administered by a full-time officer assisted by part-time staff or volunteers.

11.5.2 Commercial facilities

Shops

It is expected that a range of commercial facilities will become established within the town centre and neighbourhood areas. The conceptual land use budget makes provision for a town centre which can develop with the growth of population. A two-level retail hierarchy is proposed, with the town centre catering for weekly shopping trips and comparison shopping for items such as clothes and household appliances, while the neighbourhood centres will mainly provide convenience goods such as milk, bread, and grocery items.

As town development proceeds, it is expected that free market forces will ensure the conditions necessary to maintain competitive pricing for day-to-day purchases. In the first years of development, it may be necessary for the Joint Venturers to provide premises on favourable terms to encourage operators of commercial facilities to establish at Olympic Dam. Appropriately zoned and serviced land will be made available to entrepreneurs for purchase, and the rate at which other commercial and service oriented businesses develop will depend largely on the involvement of these private entrepreneurs, as would be the case in any growing town.

Hotels

Sites for hotels, taverns and licensed clubs are planned for the town. These facilities will develop in response to demand, and will be subject to normal licensing and town planning procedures. The Joint Venturers will probably provide the facilities necessary for the early population. It is envisaged that accommodation for tourists and other visitors will be developed by private entrepreneurs in association with some of the licensed facilities within the town.

Offices

State Government and municipal offices will be funded by the State Government as specified in the Indenture Agreement (Clause 22(2)(j) and (o)). It is assumed that premises for banks, businesses, professional services, Australia Post, TAB, and other commercial and Commonwealth Government services will be established.

11.5.3 Community welfare facilities and services

The demographic study of mining towns in Western Australia and Queensland suggests that the population during the formative years of the town will comprise a high proportion of young married couples, and a significant number of women with young children. Although the Joint Venturers' policy is to encourage female employment, these opportunities will be necessarily limited. The usual difficulties experienced during the early stages of family formation may also be exacerbated for some families in Olympic Dam because of the lack of extended families (especially grandparents) or long-time friends to provide support.

Although moving to a new, isolated mining town can be an exciting and rewarding experience for many people, settling-in can present a potentially stressful situation. Olympic Dam is not as isolated as some new mining towns in Western Australia; however it is remote in relation to settlement patterns in south-eastern Australia, the area from which many of the incoming residents are expected to come. Research (Brealey and Newton 1980) indicates that, while economic and physical considerations (particularly high incomes and allowances, and a good standard of housing) are important factors in attracting people to remote centres, they are not necessarily significant in the retention of people there. A characteristic of new mining communities in Australia has been their high population turnover, especially in the early years of town development. Other possible family-life related issues include the normal stresses associated with shift work and changes in marital relationships. Therefore, in order to establish and develop a stable and permanent population, attention will be paid to the physical and social well-being of the Olympic Dam residents, with special emphasis being given to the provision of social and recreational facilities for families and, in particular, for mothers with young children. These facilities will include kindergartens, pre-schools, day care centres and child minding facilities. It is anticipated that these formal support services will be complemented by the evolution of self-help groups such as the Nursing Mothers'

Association or local babysitting clubs to compensate, to some extent, for isolation from family and friends.

A number of religious denominations may wish to establish churches in the town, and it is possible that a church school might be established if a need is perceived. The Indenture Agreement (Clause 22(2)(m)) provides for the funding of premises for the creative, performing and visual arts for use by community groups. The establishment of this range of facilities will help to encourage a sense of belonging and local community spirit. Government social and community officers will play an important role in encouraging the participation of women and families in the development of the Olympic Dam community, and it is envisaged that a variety of community groups will also develop with the growth of the permanent population, reflecting the community's particular interests or needs.

11.5.4 Recreational facilities

The Indenture Agreement and conceptual planning for the town provides for a range of active and passive recreational demands to be met. The active recreational facilities to be funded under the provisions of Clauses 22(2)(k) and (l) include an Olympic standard swimming pool complex and other sporting facilities such as playing fields. Tennis, squash and basketball courts are allowed for in the land use budget, together with a lawn bowls club, a golf course, and ovals for football and cricket.

Sites have been set aside for a showground and a racecourse, which could be used by a variety of local clubs for large scale functions. Some land outside the presently envisaged municipal boundaries, i.e. the town site and buffer zone, may need to be provided for those recreational activities which may cause nuisance to residents or environmental damage. These may include a rifle range, car racing, or trail bike riding, all of which will need to be under municipal control.

It could be expected that residents of Olympic Dam will, in time, identify and patronize a number of locations in the region seen to be attractive places for picnics or other outdoor passive recreation activities. Where these sites are not presently used or managed for recreational purposes, the State Government will need to monitor emerging recreation patterns in the region and develop appropriate management procedures to ensure that undue adverse environmental impacts are controlled.

11.6 TOWN DESIGN FOR PROPOSED DEVELOPMENT

11.6.1 General development and design philosophy

The broad development and design philosophies adopted in the conceptual planning of the town are described briefly below. The general conceptual layout of the town is outlined in Figure 11.6 which shows the road hierarchy, location of residential areas, the town centre and other facilities, as well as the relationship of the town to the plant site.

Subdivision and house design

Climatic extremes and the relative isolation will require sensitive town planning and house design, and climatic factors will have a major influence on subdivision layouts, design and orientation of housing, and policies for the maintenance of existing vegetation.

The morphology of the proposed town site, with its pronounced pattern of sand dunes and swales, is an important environmental feature. The swale areas can more readily accommodate development, as once dune areas are disturbed they have the potential for sand movement.

The street layout will adopt a hierarchy of roads designed to facilitate the flow of vehicles, while minimizing vehicle/pedestrian conflict and eliminating through-traffic in residential areas. The principal streets will be aligned to minimize intersection with dunes, and the concept plan envisages that, where appropriate, well vegetated dunes will be preserved as restricted access open space protected by the rear fences of the subdivision areas.

Commercial centres and community facilities

It is intended that, from inception, the town centre will provide the principal focus of the new town, and at the planned development size of around 9,000 people most of the population will live within 2 km of this centre. The growth of facilities and services will keep pace with the community's requirements, with smaller neighbourhood multi-purpose centres developing to complement the level of services offered in the town centre. These neighbourhood centres will probably comprise a cluster of commercial and community facilities including shops, a pre-school and a primary school.

Public transport

The distance between the town and the operations area is relatively short, and is likely to encourage the use both of buses and private transport to and from work. Buses operated by private contractors will be available between the town and the mine site to cater for each shift, and may be available for normal public transport services during the remainder of the day.

11.6.2 Conceptual town plan

The development of the conceptual town plan has required balanced consideration of the following design objectives:

- provision of usable allotments, at an acceptable cost, upon which it is possible to locate suitably oriented facilities;
- provision for the social facilities outlined in Section 11.5;
- provision of a hierarchical road layout, which enables ready access to all facilities, facilitates the flow of vehicles, minimizes vehicle/pedestrian conflict and eliminates through-traffic from residential areas;
- economic provision of services;
- location of residential areas within 2 km of the town centre;
- creation of an aesthetically pleasing physical environment;
- establishment of the town centre as the commercial, social and cultural focus;
- siting of development on swale areas as a general rule;
- minimization of development on sand ridges, in particular the avoidance of development on dune ridges sensitive to disturbance or likely to present sand drift problems;
- avoidance of development on drainage depressions;
- maintenance of existing vegetation, particularly myall groves, mulga, and canegrass swamps and ensuring that significant vegetation has an adequate water supply;
- prevention of flood damage.

Figure 11.6
CONCEPTUAL TOWN LAYOUT

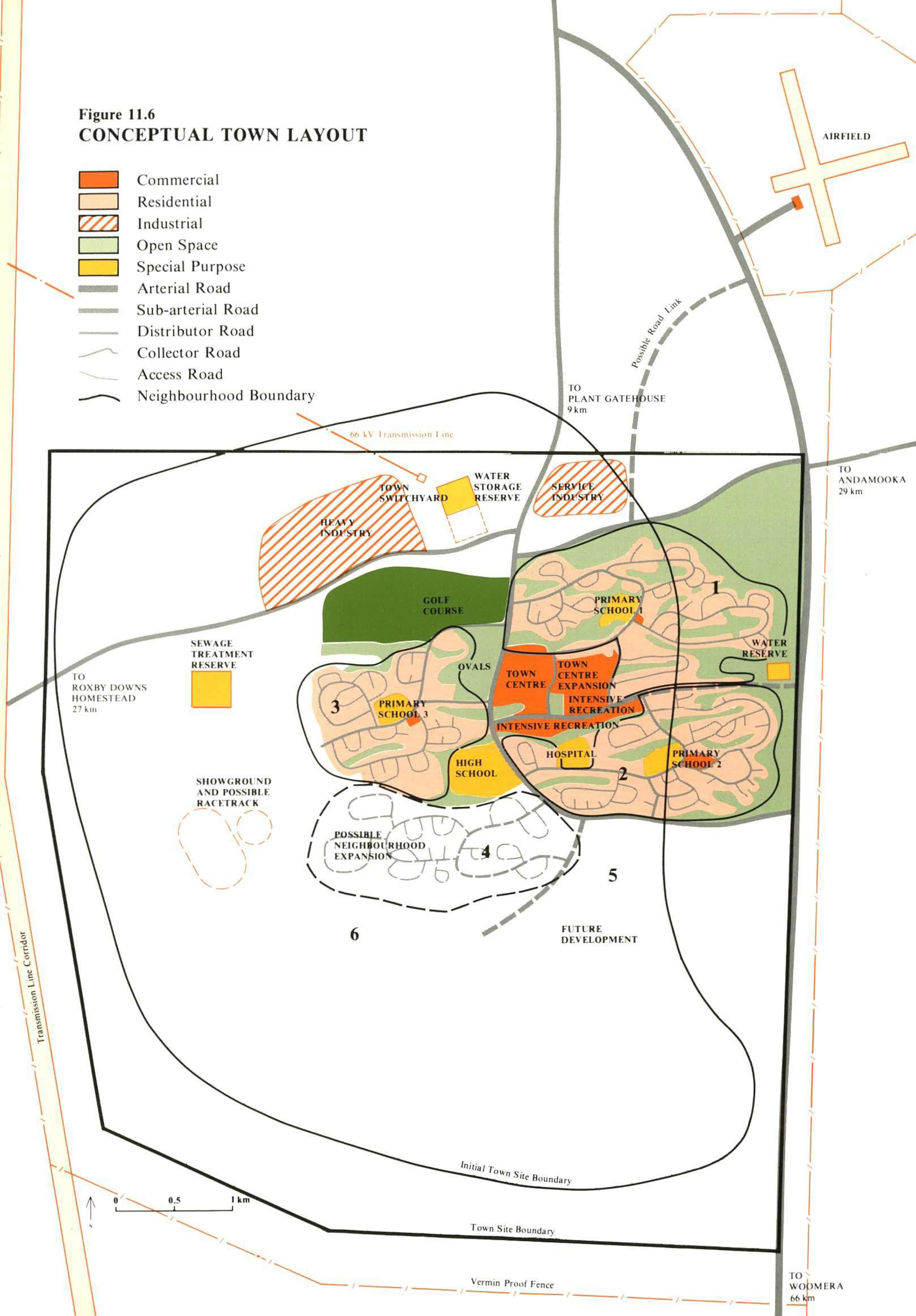


Figure 11.7, illustrating the balance achieved between the town plan and the various environmental factors, depicts the following:

. existing dune ridges, some of which would need to be modified by development;

. native pine groves and sandhill wattle/hopbush woodland (which are indicative of dune fields sensitive to disturbance or likely to present sand drift problems);

. myall groves which have significant amenity value, and in which residential areas have been located;

. canegrass and mulga swamps (which are of some conservation significance).

The conceptual town plan is a broad-scale representation of the manner in which the town will be developed. Many of the design considerations (e.g. retention of mulga swamps, prevention of flooding, avoidance of myall trees) discussed above are more relevant to detailed subdivisional design which is discussed in Section 11.6.7. However, it can be seen from Figure 11.7 that at the broad scale the town plan has been influenced by the environmental factors. A free form approach to the design of the street layout has been adopted. Generally, sub-arterial and distributor roads are located within the swales, with a minimum number of dune crossings (with the notable exception of the north-south sub-arterial road which runs through the centre of the town and provides ready access to the town centre). Dune ridges and areas of significant vegetation have been incorporated where practicable into parkland and recreation areas. However, modification of some dunes will be required.

11.6.3 Land use budget

Table 11.11 lists the land budget appropriate to a town with a population of 9,000 people, based on planning and development standards used in mining towns recently developed in Queensland and Western Australia. This table shows that approximately 896 ha of land would be required for a population of 9,000 people. Based on these standards, the overall density of the town would be about 10 persons per hectare, and the density of the residential areas would be approximately 34 persons per hectare.

The history of the development of such towns as Mount Isa, Broken Hill and Kalgoorlie suggests that a maximum population of approximately 30,000 should be allowed for in the conceptual land use planning. Table 11.11 also shows the approximate area required for a population of this size.

The boundary of the area initially considered suitable for town development is shown in Figure 11.6. Of the 3,100 ha of land within this boundary, 970 ha are considered unsuitable for residential development, thereby leaving 2,130 ha of suitable land. The unsuitable land comprises dune ridges (700 ha), depressions (200 ha), claypans (40 ha) and gibbered swales (30 ha). The total land use budget of 2,384 ha can readily be accommodated within the initial town site boundary, as the land considered unsuited to building development can provide much of the 403 ha required for open space, while some of the depressions can be reclaimed by filling or drainage and used for recreation, car parks and storage areas. It should be noted that the current town site boundary encompasses a larger area than the initial town site.

11.6.4 Road hierachy

The conceptual road layout and hierarchy are shown in Figure 11.6, while road functions and standards are summarized in Table 11.12.

Figure 11.7
CONCEPTUAL TOWN LAYOUT, ENVIRONMENTAL FACTORS

Table 11.11 Land use allocation in conceptual plan

Land use	For 9,000 population (ha)	For possible future 30,000 population (ha)
Residential:		
Low density (9 allotments per hectare)	250	833
Medium density (flats/multiple dwellings)	9	20
Caravan parks	7	12
Hotels, motels	7	16
Subtotal residential	273	881
Non-residential:		
Commercial	6	20
Industrial	24	80
Schools	80	150
Community services	22	30
Landfill	195	648
Recreation	144	172
Open space	152	403
Subtotal non-residential	623	1,503
Total	896	2,384

In Moranbah, where the traffic situation is likely to be similar to that anticipated for Olympic Dam, each housing allotment generates six trips per day. In applying such a parameter to the analysis of the street network, allowance must be made for the proportion of shift workers living at Olympic Dam. In such a situation, four or more peak hour flows are expected to occur each day: at the beginning and end of shifts and school activities.

The objective of street design has been to provide ease of access and to maintain safety and privacy in residential neighbourhoods. Where appropriate, off-road links will be provided for cyclists and pedestrians, to facilitate access to schools and shops. Provision will be made in the road width for on-street parking, and verge widths will be the minimum consistent with the need for installation of services and planting of shade trees.

Table 11.12 Design aims and criteria for roads and streets

Road type and function	Maximum traffic flow (AADT)*	Reserve width** (m)	Pavement width** (m)
Arterial	20,000	40	2 x 7.5
Sub-arterial	10,000	30	10
Distributor	3,000	20	11
Collector	1,000	20	9
Access	250	15	7

* Annual average daily traffic.
** Subject to final design considerations and consultation with appropriate authorities.

11.6.5 Open space and reserves

Approximately 20% of the developed area of the town has been reserved as open space and/or parkland (Figure 11.6). This is a relatively generous proportion by accepted town planning standards (the Planning and Development Act 1966-1981 requires a provision of 12.5%), and should produce an impression of spaciousness. Access to some open space areas will need to be restricted in order to protect vegetation. However, this will be reviewed in the light of early experience, to ensure that effective management and control can be achieved without undue restriction of residents' activities. A substantial proportion of the open space will comprise existing well vegetated dunes, which will provide visual structure to the town and separation between areas of development.

11.6.6 Services

The town will be fully serviced in accordance with current municipal engineering standards. Headworks will include:

- the distributor road system
- water supply service basins and pressurization pumps
- sewerage outfall mains and treatment works
- electrical high voltage distribution and transformers
- solid waste disposal facilities.

Reticulated services will include:

- sealed roads and streets
- water supply and fire services
- sewerage network
- stormwater collection and disposal
- electricity supply and street lighting.

Pursuant to the Indenture Agreement, the municipality or the relevant government authority will operate and maintain these infrastructure facilities from the date of completion. At that time, the ownership of these facilities (with certain exceptions specified in the Indenture Agreement) will be transferred at no cost from the Joint Venturers to either the municipality or the appropriate State instrumentality.

Water supply and fire services

Under Clause 13(3) of the Indenture Agreement, the Joint Venturers will be responsible for providing a potable water supply to the town, appropriate to a level of production at the mine site of 150,000 t/a of copper. Sufficient water of acceptable quality will be available to satisfy the following minimum consumption demands:

- an average daily consumption of 650 L/capita, plus open space irrigation usage
- a mean daily consumption in the month of maximum demand of 845 L/capita
- a maximum daily consumption of 1,170 L/capita.

Based on these supply requirements, the total water consumption for a town of 9,000 people would approximate:

- an average daily consumption of 5.8 ML plus open space irrigation
- a mean daily consumption in the month of maximum demand of 6.3 ML
- a maximum daily consumption of 10.53 ML
- an annual demand of 2,135 ML.

These levels are adequate for normal urban use with additional allowance for climatic conditions, and can be compared with the average daily consumptions for the nearby cities of Port Pirie, Port Augusta and Whyalla. In 1976 and 1980, average daily consumption in these three cities varied between 450 and 600 L/capita.

The town supply will be pumped and pressurized from the main potable water supply storage located near the town, as shown on Figure 11.6 (see also Figures 2.1 and 2.22). This surface storage will cater for seasonal fluctuations in demand and provide a reserve against supply interruptions, while a suitably sized elevated service basin will assist in maintaining adequate pressure through the reticulation system in the event of pump failure, and at times of peak demand. Water will be distributed to the various residential, commercial and industrial allotments by mains which will generally be located in road reserves. Fire hydrants will be provided. Water supply, design and installation will be to Engineering and Water Supply Department (E&WS) standards, and water quality will meet the appropriate standards of the South Australian Health Commission.

Water for recreation and grassed areas will be from mains, supplemented by water reclaimed from sewage and water harvested from stormwater flows. This latter supply will be used when available, with minimum retention periods to reduce evaporation losses or stagnation.

Sewerage reticulation and sewage treatment

Under the Indenture Agreement (Clause 21(2)(c)), the Joint Venturers are responsible for the installation of the sewerage reticulation and sewage disposal system, while the municipality or the relevant government authority will be responsible for the subsequent operation of the system. The town will be provided with a conventional sewerage scheme installed to E&WS standards. Drains from the various residential, commercial and industrial buildings will be connected to sewers which will gravitate to pumping stations located at the low points of the various catchments. From there, the sewage will be pumped to a sewage treatment plant (or plants) located on the western or north-western edge of the town (Figure 11.6).

An oxidation ditch plant is likely to be used for the treatment of the sewage and is expected to be capable of producing an effluent to meet the following standards:

- BOD (five days) 20 mg/L
- suspended solids 30 mg/L.

The effluent from the treatment plant will be pumped to an earthen storage for later use in the irrigation of the golf course or parks. All effluent used will be fully chlorinated to conform to standards set by the South Australian Health Commission.

Stormwater drainage and disposal

The stormwater drainage system will be designed to provide hydrologic characteristics similar to those existing in the natural catchments. Wherever practicable, existing drainage paths, catchments and pondage areas will be maintained.

Stormwater flow will be principally in street channels, with a limited underground drainage system towards the low points of catchments. Rainfall and run-off design will be generally in accordance with recognized standards. In residential areas it is intended to design the stormwater drainage system for a recurrence interval of five years, and in industrial and commercial areas for a recurrence interval of ten years. Run-off in excess of the design flows will be accommodated by ponding onto the street pavements, which will be set at a lower level than the surrounding allotments to allow them to channel and pond excess flows when the underground drainage system surcharges.

The town site is characterized by closed drainage catchments of various sizes. These closed catchments result from the intersection of the westerly sloping corridors between the predominant east-west trending sand dunes with a series of low north-south trending ridges. Where practicable, surface water run-off will be harvested and used for supplementary watering of playing fields and parks. The stormwater run-off from individual catchments will be discharged into excavated pondages or natural depressions within the catchments or, where practicable, piped or drained along streets and channels to a terminal storage basin in a lower catchment. Where discharge is totally within the catchment and into natural drainage depressions, the run-off will pond to a shallow depth for eventual loss by evaporation, infiltration and transpiration. In those cases where additional storage capacity is required within the catchment, the excavated storage will be sized to accommodate the run-off from the majority of storms with some ponding back onto road formation in the extreme rainfall events. The stored water will be used for local irrigation.

Where piping through to lower catchments is practicable, some provision for excavated detention pondages will be made at the pipe entry to accommodate flood peaks and to allow for surcharging of the discharge pipeline. The terminal storages in the lower catchments (generally to the west or north-west) will be excavated to greater depths to minimize evaporation losses, and to provide for longer-term storage for general irrigation use.

Electricity supply

The supply of electricity to the town will be the responsibility of the Joint Venturers pursuant to Clause 18(13) of the Indenture Agreement, but distribution and operation of the electricity supply within the town will be the responsibility of the municipality or other agreed power distribution authority. All relevant standards of the Electricity Trust of South Australia will be met.

A 66 kV electric power supply will be provided to the town switchyard from the main switchyard adjacent to the plant (Figure 2.1). High voltage power will be distributed through the town via 11 kV or 3.3 kV overhead high tension lines. The high tension supply will be transformed to low voltage for consumer services and street lighting. Underground reticulation of electricity is contemplated, although this will be subject to detailed assessment at the time of development.

Street lighting to accepted standards will be installed by the Joint Venturers, with subsequent operation and maintenance being the responsibility of the municipality. These will be mounted on free-standing poles or from electricity reticulation poles.

Telecommunications

Agreement will be sought with Telecom for the provision of a telecommunications network to, and in, the town. Telephone installations in the town and the mine will be linked to the town exchange via underground cables. The permanent trunk system is likely to be established from Woomera, probably by microwave, to connect the town exchange to the national telecommunications network.

Solid waste disposal

The collection and disposal of solid wastes generated by town residents will be the responsibility of the municipality. These wastes will probably be disposed of in a sanitary landfill, a process which involves the controlled excavation and filling of land with refuse which is then regularly covered with soil. The locations and operation of the disposal facilities will be undertaken with reference to the South Australian Waste Management Commission Act, 1979.

Gas supply

Gas will not be reticulated in the town, and any requirement will be satisfied by liquefied petroleum gas. Cylinders will be available for domestic use, and town use will be substantial enough to ensure the availability of bulk supply to major users.

Solar water heating

At the time of commencement of town development, the Joint Venturers will review the use of solar hot water heaters in the light of technical developments and cost relativities.

11.6.7 Typical subdivision design

A typical subdivision within the conceptual town plan has been examined in greater detail to ensure that an efficient and environmentally sensitive provision of allotments can be achieved. Figure 11.8 indicates the layout within the typical subdivision, together with areas of significant vegetation, dune ridges, stormwater detention or storage basins, and drainage catchments. It is evident from the examination that it is possible to create an economic subdivision while minimizing both development on dune ridges and the clearance of significant vegetation, each of which have environmental and aesthetic functions. While the typical subdivision layout should not be seen as a final design decision for this section of the town layout, it does indicate the flexible design approach which will be taken to subdivision layout and road hierarchy, and illustrates the types of works which will be undertaken.

Development is generally not on dune ridges, although in some instances requirements relating to drainage, traffic engineering, access or land use make it necessary to cross, modify or reprofile dune ridges (Figure 11.8). To achieve an economical proportion of land for development within the town site it will be necessary to develop some sandy areas which have the potential for movement. The development itself (structures, driveways, lawns and gardens) will effectively stabilize most of the areas involved and any adjacent bare areas will also be stabilized by mulching, revegetation or armouring.

The typical subdivision layout indicates that the maintenance of drainage-related vegetation of conservation significance (mulga and canegrass swamps) has been achieved by incorporating them into stormwater detention or storage basins. In general, development has avoided the native pine and sandhill wattle/hopbush areas (which are indicators of sand movement) and the myall woodlands (which are of amenity value). However, in some instances where drainage, traffic engineering, access, or land use requirements make it necessary to remove some of this vegetation, replanting will be undertaken on road verges. The siting and design of houses and their associated services will take account of the need to minimize the removal of trees during construction. Unstable dune ridges, and dune ridges with a degraded vegative cover, will be stabilized where necessary by revegetation, mulching or armouring.

The stormwater drainage system for the typical subdivision shown in Figure 11.8 incorporates the three types of storage or detention basins. Catchment 1 is served by a natural drainage depression which will act as a storage basin. Hydrologic modelling of this catchment in both the 'natural' and the 'developed' state has indicated that subdivisional development will result in a slightly greater depth of inundation from substantial storms, i.e. rainfall up to 75 mm. For extreme storms, however, the depth of inundation for the developed catchment is similar to that for the natural catchment. The ponding from storms in excess of 50 mm could be sufficient to cause water to enter the lowest adjacent residential areas. In the final subdivision design, therefore, the floor levels selected for houses will be at least 300 mm higher than the ponding level for a 200 mm storm, and it may also prove necessary to selectively fill portions of the adjacent residential land.

Catchment 3 is served by a storage basin formed by enlarging an existing drainage depression. Catchments 2, 4, 5 and 6 are served by detention basins excavated in the lower portion of the catchment, while Catchment 7 is served by a natural drainage depression acting as a detention basin. Conservative first order calculations indicate that basin capacities of 4,000 to 7,000 m^3 will be required within the town. These calculations have been based on a 200 mm storm which is well in excess of the 1 in 100 year recurrence interval 72 hour duration storm of 99 mm (Institution of Engineers, Australia, 1977). Basin volumes of the above order are readily attainable within the catchments of the town site, and consequently a stormwater drainage system based on storage and detention basins is considered feasible. A system of this type also provides the opportunity to ensure that a satisfactory water supply to some areas of significant vegetation is maintained.

11.6.8 House design

Housing and associated outdoor living areas will be designed and sited to mitigate the adverse effects of heat and wind, and to maximize convenience, amenity and privacy. Although the temperature is higher than that of Adelaide, the climate at Olympic Dam is not uncomfortably hot. Table 11.13 compares effective temperature and relative strain indices of climatic discomfort for a number of areas in Australia (including Woomera). These provide a guide to the climatic conditions at Olympic Dam, which are comparable to Ceduna and Mildura; Olympic Dam experiences only about half the number of heat discomfort days as Alice Springs.

Table 11.13 Indicators of climatic discomfort

Location	Period of record	Effective temperature*			Relative Strain Index**	
		Cold discomfort (days/annum)	Comfort (days/annum)	Heat discomfort (days/annum)	Heat discomfort (days/annum)	High heat discomfort (days/annum)
Adelaide	1955-72	128	234	3	7	1
Alice Springs	1955-67	39	300	26	50	4
Ceduna	1955-71	77	279	9	16	3
Marble Bar	1957-71	0	220	145	173	69
Mildura	1946-72	95	258	12	19	3
Woomera	1954-72	73	279	13	25	3

* Effective temperature with respect to any environmental combination of temperature, humidity, and wind, is defined as the temperature of still, saturated air in which a normally clothed sedentary worker would feel the same level of comfort or discomfort. Cold discomfort is defined as the average number of days per year when the effective temperature at 1500 hours is lower than 15°C, comfort is when this is between 15 and 27°C, while heat discomfort occurs when the temperature is higher than 27°C.

** Relative strain index (RSI) is defined as the ratio between the amount of perspiration which must be evaporated from the skin to maintain thermal equilibrium and the maximum amount of evaporation which can occur under particular conditions. RSI at 1500 hours greater than 0.3 indicates heat discomfort, while 0.4 indicates high heat discomfort.

Source: Commonwealth of Australia (1973).

The design of any building for a hot dry climate is influenced significantly by the effects of air movement. Heat gain in houses at Olympic Dam will be inhibited by locating windows to prevent direct intrusion of sun, and by the use of internal and external shading, such as louvres, verandahs, pergolas and vegetation. It is intended to provide an

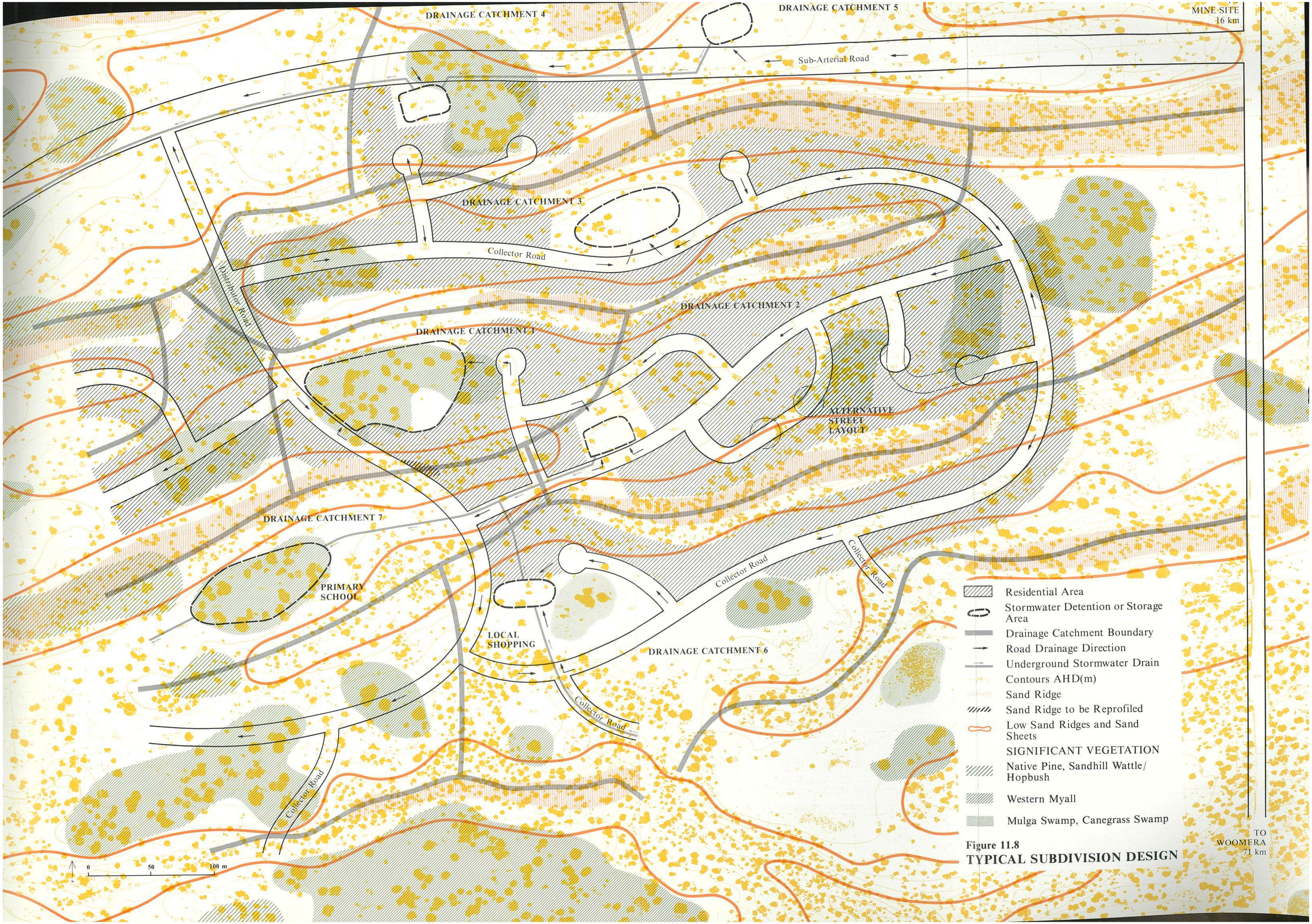


Figure 11.8
TYPICAL SUBDIVISION DESIGN

ample water supply to sustain external grassed areas and vegetation, which are considered important in reducing heat loads on buildings, in reducing the effects of wind and dust, and in providing cooler and more pleasant outdoor conditions (Saini 1969).

The main factors in determining the design and orientation of buildings are glare reduction and the prevention of the entry of direct summer sunlight and dust. It is therefore intended to place the long axes of houses on a general east-west orientation and to have reasonably wide overhangs where practicable.

Although final decisions have not been made about the building materials to be used, the reduction of heat build-up and thermal storage will influence the types of building construction to be selected. Table 11.14 summarizes the principles which will be adopted in the design of housing at Olympic Dam.

Table 11.14 Housing and accommodation design principles

Element	Principle
Walls	Insulated frame construction. Heavyweight construction desirable for living rooms, dining rooms, and kitchens, where practicable.
Partitions	Frame construction, sheeted with materials to reduce noise transmission.
Roofs	Cladding and pitch to be selected primarily for weather resistance.
Ceilings	Ceilings to be insulated and fixed clear of roof to permit roof space to be ventilated.
Floors	Concrete on ground or compressed sheet asbestos on framing. Under-floor spaces, if any, to be enclosed.
Windows	Located to minimize summer solar penetration yet facilitate cross-ventilation for evening cooling. Casements, top-hung sashes, double-hung sashes or horizontal sliding windows all capable of being closed tightly. Double glazing to be considered where high air-conditioning loads occur.
Thermal insulation	Desirable to provide insulation to external walls, and between rooms and ceilings.
Shade	Walls to be shaded by eaves of sufficient width to prevent or minimize penetration by direct summer sunlight, or by pergolas, vegetation, or trellis-work; alternatively, windows to be shaded with shutters or blinds, preferably externally.
Surface treatment	Paint or base material should be of lightest practicable colour.
Air-conditioning	Construction to allow for ducted or wall mounted air-conditioning.

11.7 MUNICIPAL MANAGEMENT

11.7.1 Local government

Olympic Dam will be administered by a municipality, unlike 'closed' (company/government-owned) towns such as Leigh Creek and until recently Woomera, where the company or government agency administers the town. The establishment of the municipality is outlined in Clause 23 of the Indenture Agreement. Under this Agreement, the boundaries of the municipality are to be agreed by the Joint Venturers and the Minister, but will exclude the area subject to the Special Mining Lease.

Following the passage of the Indenture Agreement, the State Government has appointed a town development officer to act as its adviser and to liaise with the Joint Venturers in municipal and town matters. From the date of the Joint Venturers' commitment to the Project, a municipality will be created. This will be administered by an Administrator for five years from the commencement of commercial production, unless otherwise agreed upon by the Joint Venturers and the Minister. (The time at which commercial production is deemed to commence is defined in Clause 1 of the Indenture Agreement.) The administrator will exercise all the powers and discharge the functions of the municipality in relation to the operation of the town during this period. Thereafter, councillors will be elected in the normal fashion.

The Joint Venturers have responsibility for the first stages of town development. The works and facilities to be initially constructed by the Joint Venturers and transferred without cost to the State or municipality include:

- public roads and lighting
- drainage works
- the sewerage reticulation system and treatment works
- the potable water reticulation system and works
- the electricity reticulation system (but not the Joint Venturers' electricity generating and distribution equipment)
- garbage disposal facilities.

11.7.2 Land tenure and planning control

The land tenure provisions for the town site are set out in Clause 24 of the Indenture Agreement. An area of land sufficient for town development will be dedicated by the Government for that purpose and the fee simple estate of portions of this land will be progressively granted to the Joint Venturers for town development purposes.

Land within the town will be available for purchase, at the cost of development, for any purpose consistent with municipal planning and zoning requirements. The location and nature of all developments will be broadly controlled by zoning of the various areas in accordance with the town concept plan, which will be progressively detailed and modified by future planning.

The Special Buffer Zone around the town will be leased to the municipality pursuant to Clause 25 of the Indenture Agreement. No development in this zone will take place and access will be restricted. The Joint Venturers have the right to construct and operate within this area any transportation services required for the operation of the Project.

It is not possible to comment upon the effect, if any, of the Planning Act 1982, since the principles of development control which will be incorporated in the development plan are not yet known. However, Clause 21(2) of the Indenture Agreement places the responsibility for all planning within the town site upon the Joint Venturers, who have prepared the conceptual town plan shown in Figure 11.6. Clause 6 of the Indenture Agreement also requires the Joint Venturers to provide details of town site development to the Minister at the time at which a Project Notice is given.

11.7.3 Financing

The operation of town services such as garbage disposal, recreational facilities and street maintenance will be the responsibility of the municipality. Water supply, sewerage services, and electricity supply will be operated either by the municipality or by the relevant statutory authority. The municipality will collect revenue from the levying of rates and user charges, and will operate under the normal local government regulations with regard to grants and borrowings.

In order to assist the municipality in the formative years, Clause 29(3) of the Indenture Agreement requires that, during the period of the Administrator's appointment, the level of rates to be levied by the municipality shall be agreed upon by the Joint Venturers and the municipality. The Joint Venturers and the State, pursuant to Clause 29(3)(b) of the Indenture Agreement, will also meet (on an equal basis) any shortfall in expenditure over revenue in the approved municipal budget during this period. The Joint Venturers will, in each financial year after the Administrator's tenure, contribute an amount of up to $150,000 to the revenue of the municipality. That contribution will be indexed from 1982 in accordance with the CPI, and pro-rated on the basis of a population of 9,000 directly associated with the Joint Venturers' operations or with the necessary ancillary service population.

11.7.4 Development timing

The timing and staging of construction of the town at Olympic Dam will be determined following the final feasibility study, subsequent negotiation between the Joint Venturers and the State Government, and assessment of the accommodation needs of the population generated by the Project development.

While the conceptual planning for the town envisages a population of 9,000 people, factors which may lead to unforeseen growth in excess of this estimate include the following:

- The town could become the base for a workforce engaged on future mining projects in the region.

- The Project workforce may expand as a result of changes in work conditions or scope of the Project.

- The town may attract additional population because of its status as a regional centre.

However, the concept plan is sufficiently flexible to cope with unforeseen expansion, as the total town site area has the capacity to accommodate 30,000 people.

CHAPTER TWELVE

Economic Effects

SUMMARY

The Olympic Dam Project will generate a significant increase in economic activity in South Australia. The $1,400 million construction expenditure (which excludes interest and is expressed in December 1981 dollars) is estimated to increase economic output in the South Australian economy by between $233 million and $638 million each year during the four-year construction period. Once in production at the proposed capacity, the annual Project expenditure of $117 million on goods and services is predicted to increase South Australian economic production by between $88 million and $213 million. The Project will broaden and strengthen the State's economic base, and is expected to add between 32 and 43% to the State's present level of export income.

During the construction phase, the Project is forecast to generate an average of approximately 9,300 to 18,600 jobs, while the production phase is estimated to generate between 5,700 and 8,300 jobs. However, the total number of new jobs generated in South Australia will depend ultimately on the ability of the economies of the State and the Northern Region to meet the Project's demands for goods and services. Clause 12 of the Indenture Agreement obliges the Joint Venturers, subject to normal commercial considerations, to utilize South Australian labour and materials as far as practicable.

The Project will contribute considerable royalty and payroll tax revenue to the State Government. Royalties from the Project have been calculated to average between $18 million and $28 million per year, while payroll tax payments are estimated at about $2.4 million for each year of production. Corporate taxation and personal income tax paid by the on-site construction and production workforce will contribute a significant amount to the Federal Treasury, while the Project's indirect and induced economic effects could increase payroll and personal income tax receipts to between three and seven times that derived from the directly employed workforce.

12.1 EXISTING ECONOMIC STRUCTURE

The economic effects of the Olympic Dam Project will be felt throughout the South Australian and national economies. However, the most significant effect, in relative terms, will be felt locally and in South Australia's Northern Region. This chapter discusses the results of investigations into the Project's economic impacts on the following three regions (Figure 12.1):

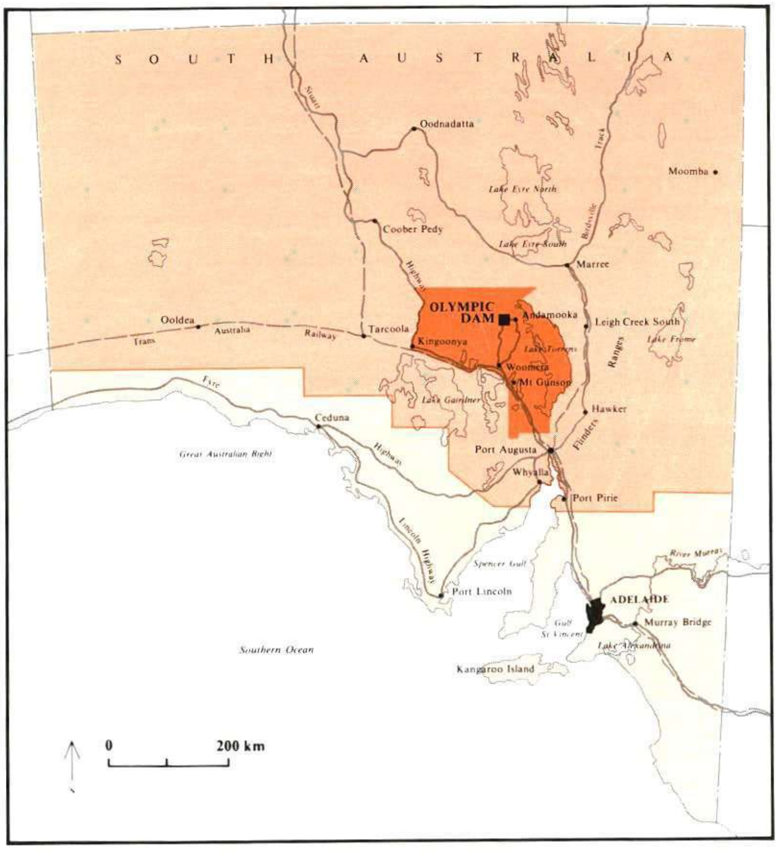


Figure 12.1
ECONOMIC STUDY REGIONS

Local Region
Northern Region

- **the Local Region:** which comprises the Project Area and the towns of Andamooka, Woomera and Mount Gunson (the statistical boundary of which is defined by eight census districts of the Far North statistical subdivision);

- **the Northern Region:** which comprises the area from the Iron Triangle cities of Port Pirie, Port Augusta and Whyalla in the south to the South Australian border in the north. This includes the Far North statistical subdivision, other unincorporated areas, and the local government areas of:

  - Port Augusta
  - Port Pirie
  - Hallett
  - Peterborough
  - Orroroo
  - Port Germein
  - Carrieton
  - Wilmington
  - Hawker
  - Kanyaka-Quorn
  - Whyalla;

- **the State Region:** which comprises the whole of South Australia and its economy.

12.1.1 The economy of the Local Region

Population and settlement in the Local Region

The Local Region's present population is small, and its principal urban centres have been declining, due mainly to the contraction of defence operations at Woomera and, to a lesser extent, to the decline of the opal mining industry at Andamooka. Table 12.1 shows the Local Region's population as determined from the 1971, 1976 and 1981 Census returns. The strong population growth recorded for the rest of the region largely reflects the impact of two mining developments: the establishment of the Mount Gunson copper mine between 1971 and 1976, and the Olympic Dam village between 1976 and 1981. The population of the pastoral areas has remained steady.

Table 12.1 Population change in the Local Region and in South Australia, 1971-81

Location	1971	Annual average change 1971-76 (%)	1976	Annual average change 1976-81 (%)	1981
Andamooka	683	(-9.3)	420	(-0.9)	402
Woomera	4,082	(-6.2)	2,958	(-10.9)	1,658*
Rest of region (inc. Pimba)	310	(10.7)	516	(11.7)	896
Subtotal region	5,075	(-5.2)	3,894	(-5.4)	2,956
South Australia	1,185,300	(1.3)	1,261,600	(0.4)	1,285,000

* This does not include US nationals.
Source: Australian Bureau of Statistics, 1971, 1976, 1981 Census data.

The history of the settlements in the area (Woomera, Andamooka, Mount Gunson and Pimba) and their current functions are discussed in Chapter 4. The effects of the Project on land use associated with Roxby Downs, Purple Downs, Andamooka, Arcoona, Parakylia, Billa Kalina, Stuarts Creek, Finniss Springs and Muloorina Stations are discussed in Chapters 4 and 10.

Employment in the Local Region

Labour force: Table 12.2 shows the labour force and participation rates for the Local Region and for South Australia as recorded in the two most recently available census results.

Table 12.2 Regional labour force: numbers and participation rates*

	Andamooka	Woomera	Rest of region	Subtotal	South Australia ('000)
1971 Male Number (%)	238 (72.6)	1,586 (86.5)	109 (86.5)	1,933 (84.9)	343 (83.1)
1971 Female Number (%)	55 (31.8)	447 (45.0)	21 (36.7)	523 (42.0)	170 (40.0)
1971 Total Number (%)	293 (58.5)	2,033 (71.9)	130 (70.9)	2,456 (69.9)	513 (61.2)
1976 Male Number (%)	129 (60.6)	1,095 (90.3)	232 (96.3)	1,456 (87.3)	359 (79.6)
1976 Female Number (%)	55 (47.8)	419 (50.0)	44 (39.3)	518 (48.6)	208 (44.8)
1976 Total Number (%)	184 (56.1)	1,514 (73.8)	276 (78.2)	1,974 (72.3)	567 (62.0)

* Labour force expressed as a percentage of the population aged fifteen years and over.
Source: Australian Bureau of Statistics.

The structure of the labour force by occupation and industry is shown in Tables 12.3 and 12.4. These tables show the dominance of defence-related employment at Woomera, and of mining and agriculture in the remainder of the Local Region. Because the labour force in the region is relatively small (around 2,000 in 1976, and presumably less now as a result of continued decline in employment at Woomera), most of the Project workforce will need to be drawn from outside the region. Lack of data prevents assessment of the number of local unemployed people whom the Project could employ; however it is likely that they could fill many positions, and workers from Andamooka are already employed on the Project.

Table 12.3 Structure of the employed labour force by occupation: Local Region and South Australia, 1976

Occupation	Andamooka %	Woomera %	Rest of Local Region %	South Australia %
Professional and technical	11.0	15.6	8.6	12.4
Administrative	1.1	1.9	2.6	6.1
Clerical	1.3	12.8	4.1	15.1
Sales	11.6	2.6	1.1	7.9
Farmers, fishermen	4.0	1.5	23.8	9.2
Miners, quarrymen	48.0	0.2	18.8	0.2
Transport, communications	4.8	5.9	4.5	4.9
Production, process workers, labourers	2.3	26.1	23.3	31.4
Service, sport, recreation	1.1	15.9	7.1	8.2
Armed forces	-	9.4	-	0.5
Other	14.8	8.1	6.1	4.1
Total employed population	100.0	100.0	100.0	100.0

Source: Australian Bureau of Statistics.

Table 12.4 Structure of the employed labour force by industry: Local Region and South Australia, 1976

Industry	Andamooka %	Woomera %	Rest of Local Region %	South Australia %
Agriculture	2.8	0.3	27.7	8.7
Mining	50.6	0.4	44.8	0.6
Manufacturing	-	0.8	3.4	20.7
Electricity, gas, water	-	-	-	1.8
Construction	-	1.5	6.4	8.1
Wholesale, retail trade	9.0	3.8	3.0	18.4
Transport and storage	2.5	3.2	4.9	4.5
Communications	3.6	3.4	0.4	1.9
Finance	-	10.8	-	6.1
Public admin., defence	2.3	51.2	-	4.1
Community services	10.5	13.8	3.0	15.3
Entertainment	2.5	3.0	-	4.7
Other	16.2	7.8	6.4	5.1
Total employed population	100.0	100.0	100.0	100.0

Source: Australian Bureau of Statistics.

Regional economic base

Grazing: Livestock grazing is the dominant land use in the region (Section 4.1.3). Generally, cattle are run north of the dog-proof fence (which traverses the northern part of the Local Region) and are shipped south to abattoirs in Adelaide while, south of the Dog Fence, holdings are usually smaller and used for sheep grazing. The station most affected by the Project will be Roxby Downs, although Purple Downs, Andamooka, Arcoona, Stuarts Creek, Finniss Springs and Muloorina Stations will also be marginally affected economically (Figure 4.2).

Mining: Opal mining, located at the Andamooka opal fields, and copper mining are important elements in the Local Region's economic base (Section 4.1.5). Australia produces 95% of the world's precious opals, the majority of which come from South Australian fields. The South Australian Department of Mines and Energy has conducted annual surveys of opal production at Coober Pedy, Andamooka, Stuart Creek and Mintabie since 1978. Table 12.5 summarizes the changes in the number of miners, capital investment and value of production for these fields over the period from 1978 to 1981. Andamooka experienced a peak in production during 1979/80, when the number of miners increased from 50 in 1978 to 125 in 1979 and 1980, while the value of opal production rose from $2.5 million in 1978 to $4.5 million in 1979. However, figures for 1981 indicate that mining activity at Andamooka has declined following the exhaustion of certain fields. Mount Gunson (servicing the open cut copper mine) and the Olympic Dam village are the only two established mining-related centres in the Local Region not based on opal mining.

Table 12.5 Estimated operations data: opal fields, South Australia, 1978-81

	1978	1979	1980	1981
Number of miners				
Coober Pedy	1,000	1,000	1,000	900
Mintabie	150	150	150	75
Andamooka	50	125	125	100
Stuart Creek	20	-	-	-
Total number of miners	1,220	1,275	1,275	1,075
Capital investment ($m)				
Coober Pedy	17.8	18.5	19.3	
Mintabie	7.8	6.1	6.1	
Andamooka	3.2	3.7	3.6	
Stuart Creek	0.1	-	-	
Total capital investment	28.9	28.3	29.0	n.a.
Value of production ($m)				
Coober Pedy	32.0	32.7	30.9	28.0
Mintabie	6.5	6.1	5.6	3.0
Andamooka	2.5	4.5	4.1	3.3
Stuart Creek	0.8	-	-	-
Total value of production	41.8	43.3	40.6	34.3

n.a. - not available.
Source: Department of Mines and Energy Surveys 1978-81.

Defence: Weapons research at Woomera has played an important role historically in the Local Region's economic base. However, this has declined in recent years following the scaling down of testing activities (Section 4.1.6). Remaining defence personnel are now primarily engaged in satellite tracking and deep space research.

Potential development in the Local Region

Non-mining developments in the Local Region depend largely on the future of defence operations at Woomera. The current population of Woomera is approximately 2,300 (including 600 US nationals), and this figure is forecast to stabilize at about 2,000. However, there is some potential for an expansion of the tourist industry in the Northern Region, which may have some benefits for Woomera.

The Stuart Shelf Joint Venturers (Western Mining Corporation Limited, BP Australia and BP Petroleum Development) are engaged in a regional exploration programme over the Stuart Shelf Area. Scout drilling has already intersected mineralization in several areas, including Acropolis which is approximately 25 km south-west of Olympic Dam. Further development could ultimately result from this programme, and from exploration being carried out by other companies in the region.

12.1.2 The Northern Region

Population in the major urban centres

The major urban centres within the Northern Region are Port Augusta, Port Pirie and Whyalla. Table 12.6 outlines the population changes in these three cities in the decade from 1971 to 1981. Port Augusta is the only one of the three centres to have grown during the last five years. For the ten years since 1971 the population of Port Pirie was almost static. The population growth recorded at Whyalla since 1971 ceased with the closure of the shipyards there in 1977. However, the Iron Triangle Study Group (ITS) found that the outward movement of population as a result of this closure has now ceased, and Whyalla's population is expected to stabilize at around 31,000 (ITS 1982).

Table 12.6 Population change: Port Augusta, Port Pirie, and Whyalla, 1971-81

Statistical district	1971	Annual average change 1971-76 (%)	1976	Annual average change 1976-81 (%)	1981
Port Augusta	13,200	(1.6)	14,300	(1.7)	15,550
Port Pirie	15,650	(-0.3)	15,450	(0.3)	15,650
Whyalla	32,550	(1.1)	34,350	(-1.9)	31,250
Total	61,400	(0.9)	64,100	(-0.5)	62,450

Source: Australian Bureau of Statistics, 1971, 1976, and 1981 Census data.

The existing economic base of the Iron Triangle cities

Port Augusta: Port Augusta's resident population of more than 15,000 is heavily dependent on the operations of Australian National and the Electricity Trust of South Australia (ETSA) power stations. Together, these two employers provide almost half the employment within the city, with 2,100 employed by Australian National and 800 by ETSA (excluding the Northern Power Station construction workforce). Increased tourism in the Flinders Ranges and in the outback area, together with transcontinental rail and road movement, has had a positive and increasing influence on the city's economy. The designation of Port Augusta as the regional centre for State Government services in the northern part of the State has also added to employment opportunities in the city (ITS 1982). A wide range of service industries in the fabricated metals, construction, and transport sectors has developed in the city to service the railway and electricity generation industries. These service industries largely consist of firms employing less than twenty people.

Port Pirie: Port Pirie is heavily dependent on two sources of employment: the lead and zinc smelter of Broken Hill Associated Smelters Pty Ltd (BHAS), and Australian National. BHAS has a production capacity of 250,000 t/a of refined lead (making it the world's largest lead smelter) as well as a capacity of 40,000 t/a of refined zinc and 70,000 t/a of sulphuric acid. Approximately 1,600 people are directly employed by the company, with a further significant proportion of the workforce being indirectly associated with the smelter operations through foundry and engineering fabrication services. A large proportion of the 670 people employed by Australian National are engaged on the bogie exchange linking the standard gauge east-west railway with the broad gauge north-south line to Adelaide. However, the bogie exchange will not be required after 1982 when the standard gauge line to Adelaide will be completed. Port Pirie is also a shipping terminal and port for fishing vessels.

Whyalla: The economic viability of Whyalla, the second largest city in South Australia, has traditionally been closely dependent on BHP, which employs approximately 6,000 people (or almost half the total town workforce). BHP operates an integrated iron and steel plant at Whyalla serving both domestic and export markets. Iron ore is mined from the Middleback Ranges, approximately 50 km west of Whyalla, at a rate of approximately 3 million t/a. Pellet production has varied between 1.6 and 1.8 million t/a. The pig iron is converted to steel in two basic oxygen furnaces with a capacity of 1.3 million t/a. A considerable proportion of the steel produced is shipped out as raw billet, or as partly processed bloom, with the remainder being converted into structural sections. Recent expansion of finishing capacity has included the commissioning of a rail production facility with capacity of up to 300,000 t/a. The company also produces raw salt from solar salt fields adjacent to the steel works and sells the entire production of about 50,000 t/a to a local firm for processing and shipment (ITS 1982). There are a number of service industries, mainly in engineering fabrication, which are highly dependent on BHP.

The structure of the Iron Triangle labour force

Table 12.7 shows the labour force and participation rates for the Iron Triangle cities. Unemployment statistics are shown in Table 12.8. The potential for the Olympic Dam Project to utilize this pool of unemployed labour is discussed in Section 12.5.

Potential development in the Northern Region

After extensive investigation into the future potential of existing activities in the Iron Triangle area and of all projected new developments, the ITS evaluated four possible scenarios for future development within the Northern Region (ITS 1982). Only those projects which are likely to commence operations by 1991 and which will have a significant impact on the area were included in this evaluation. While the inclusion of projects within a particular ITS scenario is not necessarily in accordance with the more recent forecasts of the companies or organizations involved, they represent a range of development options. Assumptions concerning the scale and timing of the Olympic Dam Project made by the ITS differ from those described in this Draft EIS, but the ITS analysis allows the economic effects of the Olympic Dam Project to be isolated and discussed separately from these other projects. However, the four scenarios which are outlined in Table 12.9 are of direct relevance in discussing the supply and demand for labour and the likely impact of the Project on the region's labour market.

Table 12.7 Labour force in Iron Triangle cities*: numbers and participation rates

Category	Port Augusta	Port Pirie	Whyalla
1971 Male			
Number	3,612	3,655	9,120
Percentage	(84.6)	(79.2)	(88.5)
1971 Female			
Number	1,238	1,369	3,102
Percentage	(32.3)	(28.2)	(33.6)
1971 Total			
Number	4,850	5,024	12,222
Percentage	(59.8)	(53.1)	(62.6)
1976 Male			
Number	3,904	3,478	9,954
Percentage	(84.6)	(79.4)	(87.0)
1976 Female			
Number	1,721	1,497	4,399
Percentage	(39.7)	(32.3)	(41.6)
1976 Total			
Number	5,625	4,975	14,353
Percentage	(62.8)	(55.2)	(65.2)

* Local Government Areas.
Source: Australian Bureau of Statistics.

Table 12.8 Registered unemployed by skill category: Iron Triangle cities, 1978 and 1980

Skill category	Port Augusta	Port Pirie	Whyalla	Total
Skilled				
1978	19	39	267	325
1980	41	30	86	157
Semi-skilled				
1978	35	36	171	242
1980	58	49	58	165
Unskilled and other				
1978	568	431	1,252	2,251
1980	591	740	1,313	2,644
Total unemployed				
1978	622	506	1,690	2,818
1980	690	819	1,457	2,966

Source: Commonwealth Employment Service.

Table 12.9 Summary of Iron Triangle Study Northern Region development scenarios

Company/project	Timing			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Olympic Dam (WMC, BPA and BPPD) copper production				
75,000 t/a	late 1990s	1991	-	-
100,000 t/a	-	-	1991	1990
200,000 t/a	-	2000	1996	1994
BHP Co. Ltd (Whyalla)				
Same level of operations at Whyalla, minor equipment additions:	all scenarios			
Additional rolling mill capacity installed by:	-	-	1986	1985
Australian National (Port Augusta, Port Pirie)				
Complete Adelaide-Crystal Brook standard gauge line and consequent reduction of employment in Port Pirie and Port Augusta:	all scenarios			
Construction of Alice Springs-Darwin railway:				
commence:	-	1984	1984	1984
complete:	-	1990	1990	1988
Broken Hill Associated Smelters (Port Pirie)				
No new investment at Port Pirie, gradual contraction until:	1991	-	-	-
Completion of 250,000 t/a Kivcet lead smelter by:	-	1986	1986	1985
Minor upgrading of zinc plant to 45,000 t/a by:	-	1986	-	-
Install major new zinc plant by:	-	-	1987	1986
Electricity Trust of South Australia (Port Augusta)				
Complete current Northern Power Station development and unit 3 by:	1988	1988	1988	1988
Complete unit 4 by:	-	-	1989	1989
Stony Point projects				
Crude oil and LPG shipping facility operational by:	1984	1984	1984	-
Petroleum refinery and LPG shipping facility operational by:	-	-	-	1988
Petrochemical plant operational by:	-	-	1987	-
Stuart Highway upgrading completed by:	1987	1987	1987	1987
CSR Ltd Mount Gunson mine				
close by:	1984	-	-	-
continue operations:	-	ongoing	ongoing	ongoing
Iron Triangle petrochemical plant operational by:	-	-	-	1987
Port Pirie uranium conversion plant operational by:	-	-	1990	1988
Port Pirie uranium enrichment plant operational by:	-	-	-	1990
Significant harbour development with bulk loading facilities:	-	-	-	ongoing
Development of alternative industries not based directly on resource projects:	-	-	-	ongoing

Source: ITS 1982.

Each scenario assumes different expectations and timing for the listed developments, reflecting varying degrees of uncertainty. The level of probability adopted in each is as follows:

- **Scenario 1:** This scenario includes only those activities which are considered as being almost certain to take place, and may be regarded as the most conservative view.

- **Scenario 2:** This scenario includes projects which are considered to have a very high probability of occurrence, and is regarded therefore as being the most likely to represent the pattern of future development. The main additions to the activities of Scenario 1 are a new lead smelter for Port Pirie, and the commencement of the Olympic Dam Project by 1990 with an annual production of 75,000 t of copper by 1991.

- **Scenario 3:** This scenario includes those projects considered to have a reasonably high possibility of proceeding if markets and other conditions are favourable. The main changes from Scenario 2 are the inclusion of a new zinc plant and a uranium conversion plant at Port Pirie, a petrochemical project at Stony Point, and an earlier commencement date (1988) for the Olympic Dam Project, with an annual production of 100,000 t of copper by 1991.

- **Scenario 4:** This scenario includes those projects which, at this stage, must be regarded as having a relatively low but still significant probability but which, given an appropriate market situation, availability of capital, and an economic environment generally conducive to such development, could realistically be expected to proceed. A more optimistic view has been taken of the time scale on some projects.

12.2 CAPITAL EXPENDITURE AND LABOUR REQUIREMENTS

12.2.1 Capital expenditure

The capital cost of the Olympic Dam Project, prior to start-up, is currently estimated at $1,400 million. This total excludes any interest capitalized during the pre-production period and is expressed in December 1981 dollars. The effect of inflation will be to increase the actual amount which will be spent. Figure 12.2 shows the expected schedule of capital expenditure during the construction period, while Table 12.10 shows the approximate division of expenditure between elements of the Project.

Table 12.10 Division of estimated capital expenditure between major Project elements

Item	Approx. expenditure (December 1981 $m)
Mine	300
Metallurgical plant	700
Infrastructure and town	400*
Total	1,400

* Excludes a further $50 million to be contributed by the State Government towards the cost of the town.

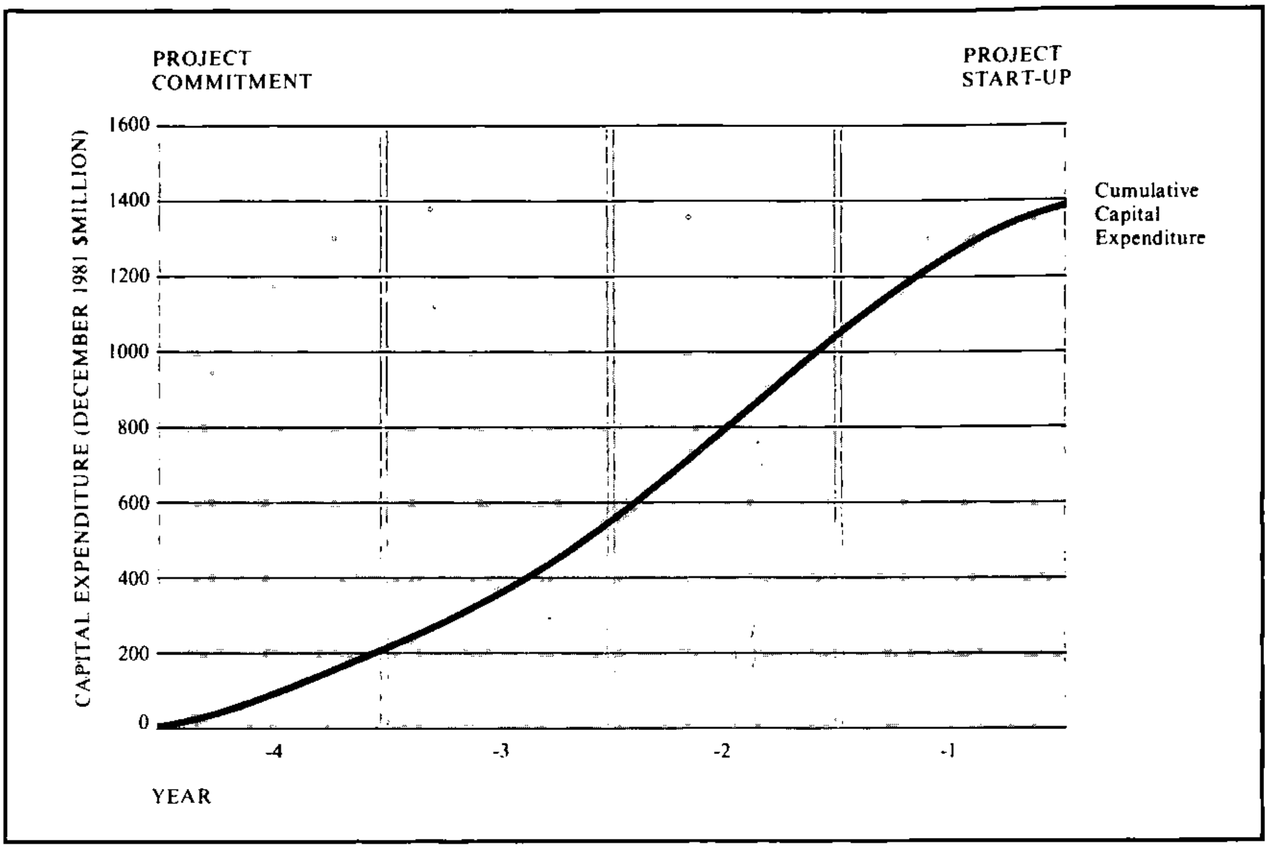


Figure 12.2
CONSTRUCTION EXPENDITURE SCHEDULE

12.2.2 Labour requirements

Approximately 180 people are presently employed at Olympic Dam, and the total population, including families, is about 250.

The development of the Project will require a substantial increase in both skilled and unskilled workers. Table 12.11 lists the forecast numbers for the construction and production workforce up to the fourth production year, after which it is assumed that Project workforce numbers will stabilize.

In Table 12.12 the forecast skill requirements of the Olympic Dam construction and production workforce are listed. The construction workforce, including contractors and Joint Venturers' personnel, will require relatively higher percentages of skilled and semi-skilled workers than the production workforce.

The metallurgical treatment plant will be operated on a continuous basis of three shifts per day, seven days per week. The mine will be worked on a five day week, with three shifts per day. The expected distribution of the production workforce between day, afternoon, and night shifts is listed in Table 12.13.

Table 12.11 Estimated Olympic Dam Project on-site construction and production workforce (numbers at start of year)

Category	Pre-committal	Construction years				Production years			
		-4	-3	-2	-1	+1	+2	+3	+4
Joint Venturers' senior staff									
Geology	3	3	3	3	3	4	4	4	4
Mining	1	1	4	6	8	12	15	20	25
Metallurgy	-	-	-	1	2	13	13	13	13
Engineering	1	1	2	4	5	10	11	12	12
Administration	1	1	2	4	6	10	10	10	10
Construction	-	-	2	6	6	2	1	1	1
Subtotal	6	6	13	24	30	51	54	60	65
Joint Venturers' staff									
Geology	9	9	12	15	20	25	30	30	30
Mining	2	6	12	30	50	80	89	89	89
Metallurgy	-	-	-	-	10	53	53	53	53
Engineering	2	2	10	20	30	54	54	60	65
Administration	6	6	20	50	70	90	100	123	123
Construction	-	-	10	15	15	15	3	3	3
Subtotal	19	23	64	130	195	317	329	358	363
Joint Venturers' award workforce									
Geology	42	40	40	40	38	38	38	40	43
Mining	2	2	100	200	300	400	540	560	575
Metallurgy	-	-	-	-	10	250	290	300	307
Engineering	7	7	50	100	200	700	720	750	773
Administration	13	13	15	20	25	44	44	44	49
Construction	-	-	10	20	20	15	3	3	3
Subtotal	64	62	215	380	593	1,447	1,635	1,697	1,750
Total Joint Venturers' workforce	89	91	292	534	818	1,815	2,018	2,115	2,178
Contractors and visitors	100	100	1,000	2,500	2,500	1,000	250	250	250
Total direct Project workforce	189	191	1,292	3,034	3,318	2,815	2,268	2,365	2,428

Table 12.12 Forecast Olympic Dam Project workforce skill requirements

Category	Construction phase*				Production phase**	
	Contractors		Total direct Project workforce			
	No.	(%)	No.	(%)	No.	(%)
Staff (and senior staff)	250	(10)	475	(14)	428	(18)
Skilled	900	(36)	1,092	(33)	695	(29)
Semi-skilled	900	(36)	1,084	(33)	560	(23)
Unskilled	450	(18)	616	(19)	556	(23)
Apprentices	-	-	51	(2)	189	(8)
Total (rounded)	2,500	(100)	3,318	(100)	2,428	(100)

* The year prior to start of production.
** Production year 4.

Table 12.13 Forecast of operation workforce on day, afternoon and night shifts, Olympic Dam Project

Category	Day shift (%)	Afternoon shift (%)	Night shift (%)
Geological	76	12	12
Mining	60	25	15
Metallurgical	60	20	20
Engineering	90	5	5
Administration	100	-	-

12.2.3 Methodology of assessment of economic impacts

The Olympic Dam Project has the potential for substantial and far reaching effects on the South Australian economy. However, the ability of South Australian industry to respond to the construction and production demands generated by the Project will determine the ultimate extent to which these benefits are realized. Two separate and independent assessments of the possible extent of these benefits are described below.

The Centre of Policy Studies (CoPS) Report

To provide a quantitative analysis of the effects of the construction and production phases of the Olympic Dam Project on output, prices, and employment within South Australia, a twenty-five sector input-output model of the South Australian economy was constructed by the Centre of Policy Studies (CoPS) at Monash University. In this CoPS report (Cooke and Trengove 1982), the economic effects were modelled using three different cases, each embodying different assumptions concerning the ability of the South Australian economy to respond to the Project's requirements. The models do not include the likely lead times or lags involved in these effects registering in the economy. In some instances the actual effects may be delayed for up to twelve months longer than those predicted below.

The cases were labelled 'optimistic', 'pessimistic' and 'probable'.

- **The optimistic case:** This adopts the standard assumptions of the static input-output model, which assumes that all inputs in production are required in fixed proportion to output and that all factor and commodity supplies are available at established prices which do not rise in response to increased demands. A limitation of the optimistic case is that, in practice, some supply bottlenecks may occur. Consequently, some demand may be switched away from locally produced commodities towards those imported from outside the region. By not allowing for this possibility, the optimistic case probably overstates the effect of the Olympic Dam Project on the South Australian economy.

- **The pessimistic case:** This case attempts to include the price effects of the supply and demand situation caused by the Project's construction and production expenditure. Assumptions are made about the ability of South Australian producers to supply various goods and services to the Project. It is assumed in this case that competition for the available scarce factors of production drives up the prices of such South Australian goods and services, leading to the substitution of imported goods from other States. This case is likely to understate the effects of the Project, because it assumes that locally produced and externally produced commodities are perfectly interchangeable, and that even the slightest pressure on prices (through supply bottlenecks) in South Australia would result in a large increase in imports.

- **The probable case:** This case is similar to the pessimistic case in attempting to take into account the capacity of the South Australian economy to supply the Project's requirements, but differs in assuming only a moderate degree of substitutability between imported and South Australian produced commodities. This factor was derived from estimates of the substitutability between Australian produced and imported commodities in the ORANI economic model of the Australian economy (Dixon et al., in press). The responsiveness of demand with respect to price (the price elasticity of demand) for exports of South Australian goods was derived from the average figure for the Australian export sectors in ORANI. The inclusion of these factors allows for some freedom of price movement as the South Australian economy adjusts to the new supply and demand balance likely to flow from the Project's requirements.

While the probable case is thought to reflect the more likely magnitude of the economic effects of the construction and production phases of the Olympic Dam Project on the South Australian economy, it should be noted that these models are not presented as precise forecasts, but rather to provide broad estimates of the likely economic effects and, as such, should be interpreted carefully in the light of the assumptions used.

An important assumption has been that relative real wages in South Australia will increase at a rate comparable with the rest of Australia. If relative wages were to increase at a greater rate, then the number of jobs generated for South Australians by the Project would be reduced. The reason lies in the cost-increasing effect on those sectors which have prices largely determined by conditions outside South Australia. These sectors would be unable to fully recover cost increases, and consequently would experience contracting output and employment. The effect of the Project on material costs is likely to be very small, but the effect of any increase in nominal wages would be much more substantial.

The Iron Triangle Study (ITS)

The ITS used the Generation of Regional Input-Output (GRIT) system of tables to simulate the output and employment effects of the Olympic Dam Project on the Northern Region and on the South Australian economy as a whole. The GRIT model adopts the usual assumptions of the standard input-output model (similar to the optimistic case described above). The ITS used data from interviews with industry groups in the Iron Triangle region to improve the accuracy of the model. Adjustments were made to the tables to allow for the temporary construction workforce spending only a proportion of its wages within the region, consequently reducing the consumption induced effects which are an important component of the total employment effects.

12.3 ECONOMIC EFFECTS OF THE CONSTRUCTION PHASE

For the purposes of evaluation using the CoPS economic models, the total construction cost of the Olympic Dam Project of $1,400 million (December 1981 dollars) was assumed to be expended at a uniform rate of $350 million per annum over a four-year construction period. However, as shown in Figure 12.2, the expenditure will actually be incurred unevenly over the construction period. The uniform figure should therefore be interpreted only as providing a guide to the average effect of the construction phase, with higher and lower levels of expenditure occurring in practice.

The economic effects of the construction phase were divided into direct and total effects on output and employment. This division allows an estimate of the proportion of the direct construction expenditure which will be spent in South Australia. The total output and employment effects include the direct, indirect and induced effects of the Project on the economy. Because they take account of the inter-industry linkages and effects of increased consumer spending, total effects are considerably larger than the direct effects.

12.3.1 Direct output and employment effects (construction phase)

The direct effects measure the economic effect on output and employment of the first round of purchases of the construction phase, valued at $350 million per annum. It is estimated that this expenditure could result in a direct increase in production in the South Australian economy of approximately $275 million per annum. This figure does not include the consequent inter-industry linkage effects.

Based on these calculations, the South Australian economy is expected to provide about 79% of the average annual construction phase requirements of the Project. These estimates are based on supply conditions in 1973/74 (the date of the industry survey data) and thus may not reflect the present position with the same degree of accuracy. However, in the absence of more current data, this proportion provides a useful guide to likely South Australian industry involvement in the construction phase. Table 12.14 lists these direct annual output effects by industry sector.

Table 12.14 Direct annual output effects by industry sector (construction)

	Industry sector categories*	Project investment purchases ($m)** (1)	Proportion from South Australian suppliers † (2)	Direct output effects ($m) (1)x(2)
11	Chemical and petrol products	1.54	0.39	0.60
12	Non-metallic mineral products	0.35	0.63	0.22
14	Fabricated metal products	46.31	0.74	34.27
15	Transport equipment	2.80	0.41	1.15
16	Other machinery and equipment	136.43	0.59	80.49
17	Other manufacturing	4.55	0.47	2.14
18	Electricity, gas, water	11.89	1.00	11.89
19	Construction	100.70	1.00	100.70
20	Wholesale and retail trade	32.02	1.00	32.02
21	Transport and communication	13.40	0.88	11.79
-	All other sectors	-	-	-
Total		350.00	0.79	275.27

* Sector numbers refer to those used in CoPS input-output model.
** 1981 dollars.
† Based on 1973/74 proportions (Butterfield 1979).

Source: CoPS 1982.

The number of jobs per million dollars of output in South Australia in 1979/80 (Table 12.15) was used to convert the direct output effects of the construction phase of the Olympic Dam Project into direct employment effects. Table 12.16 combines the direct output effects (Table 12.14) with the jobs per million dollars of output ratios (Table 12.15) to provide estimates of the direct employment effects of the Olympic Dam Project construction expenditure.

Table 12.15 Jobs per million dollars of output: South Australia, 1979/80

Industry sector categories		Estimated South Australian production 1979/80 ($m) (1)	Estimated South Australian employment 1979/80 (2)	Number of jobs per million $ of output (2)/(1)
11	Chemical and petrol products	226.4	3,000	13.25
12	Non-metallic mineral products	225.4	3,600	15.97
14	Fabricated metal products	387.2	8,800	22.73
15	Transport equipment	936.0	20,300	21.69
16	Other machinery and equipment	660.9	17,100	25.87
17	Other manufacturing	273.1	6,000	21.97
18	Electricity, gas, water	431.0	10,300	23.90
19	Construction	1,290.6	36,000	27.89
20	Wholesale and retail trade	2,595.3	114,200	44.00
21	Transport and communication	983.8	37,200	37.81
-	All other sectors	9,220.5	286,900	31.12
Total		17,230.2	543,400	31.54

Source: CoPS 1982.

Table 12.16 also shows that the South Australian component of the annual Project construction expenditure could generate approximately 7,900 direct jobs in South Australia, including construction jobs on site at Olympic Dam.

Table 12.16 Direct employment effects per annum, by industry sector (construction)

Industry sector categories		Direct output ($m)* (1)	Number of jobs per $ million of output** (2)	Direct employment (no. of jobs) (1)x(2)
11	Chemical and petrol products	0.60	13.25	8
12	Non-metallic mineral products	0.22	15.97	4
14	Fabricated metal products	34.27	22.73	779
15	Transport equipment	1.15	21.69	25
16	Other machinery and equipment	80.49	25.87	2,082
17	Other manufacturing	2.14	21.97	47
18	Electricity, gas, water	11.89	23.90	284
19	Construction	100.70	27.89	2,809
20	Wholesale and retail trade	32.02	44.00	1,409
21	Transport and communication	11.79	37.81	446
-	All other sectors	-	31.12	-
Total		275.27	28.67	7,893

* Column 3, Table 12.14.
** Column 3, Table 12.15.

Source: CoPS 1982.

12.3.2 Total output and employment effects (construction phase)

In addition to the direct effects of the construction phase, there will be indirect and induced effects. Indirect output and employment effects will occur as a result of the inter-industry linkages between the sectors of the South Australian economy. The indirect or production induced effects will occur as a result of local firms being required to supply extra goods and services to those sectors receiving direct orders for the construction of the Project. This will result in increased output and employment for most sectors of the economy over and above the direct stimulus. The consumption induced output and employment effects will occur as a result of the increased income flows and consumption arising from the wages and salaries of the greater number of directly and indirectly employed workers.

In order to compare the CoPS assessment of the economic effects with those derived from the ITS, the ITS output and Type II employment multipliers were used with the Joint Venturers' estimates of construction and production workforces. These multipliers are an indication of the likely ratio of total output and employment generated, compared with the initial direct Project output and employment. Based on a four-year construction period, a total construction expenditure of $1,400 million, and the workforce figures in Table 12.11 (total construction employment of 7,835 person years), the average expenditure per construction worker of $178,685 was derived. The CoPS study assumed an average annual construction expenditure of $350 million which, using this figure, converts to approximately 1,960 construction jobs per annum.

Table 12.17 compares the CoPS total (direct, indirect and induced) effects of the construction phase on the South Australian economy for each of these previously defined cases with output and employment effects based on the ITS output and Type II employment multipliers.

Table 12.17 Total output and employment effects (construction)

Scenario	Total output effects*		Total employment effects*	
	($m)	Change %**	Jobs	Change %**
Optimistic	638	(3.70)	18,613	(3.43)
Probable	364	(2.11)	13,798	(2.54)
Pessimistic	233	(1.35)	9,332	(1.72)
Iron Triangle Study † (for comparison)	578	(3.35)	10,780	(1.98)

* Direct, indirect and induced.

** Increase over existing South Australian level of output and employment respectively.

† Based on output multiplier of 2.1 and Type II employment multiplier of 5.5.

Source: CoPS 1982; ITS 1982.

Table 12.17 clearly shows the substantial impact which the construction phase will have on the South Australian economy. Construction at Olympic Dam is forecast to increase the total output of the South Australian economy by between $233 million (1.35%) and $638 million (3.7%) per annum over the existing level. Total employment is forecast to increase by between 9,332 (1.72%) and 18,613 (3.43%) over and above existing levels. The ITS estimates of an increase in output of $578 million (3.35%) and an increase in employment of 10,780 jobs (or 1.98%) fall within this range.

12.3.3 Price effects (construction phase)

The predicted increase in demand will slightly increase the scarcity of goods, and is therefore expected to have a very minor effect on prices within South Australia. This will be a 'one off' effect of the construction of the Project. The total predicted effect on the Consumer Price Index (CPI) of the construction phase of the Olympic Dam Project varies with each case. There is no price effect forecast in the optimistic case, while the probable case predicts a slight price rise of 0.5% in the South Australian CPI, and the pessimistic case (in terms of the level of activity) predicts a slightly lower rise of 0.33% in the CPI. This predicted lower rise reflects the assumption made in the pessimistic case that prices of traded goods are fixed outside South Australia and are therefore inflexible.

12.4 THE ECONOMIC EFFECTS OF THE PRODUCTION PHASE

12.4.1 Direct output and employment effects (production phase)

During production, the Joint Venturers estimate that, including long-term contractors, approximately 2,430 jobs will be provided on site. The average annual expenditure on outside goods and services during each year of operation is estimated to be $117 million in 1981 dollars. Table 12.18 lists the expected annual distribution of this expenditure by the South Australian industrial sector, and shows that an average of 75% of this expenditure is forecast to be paid to South Australian suppliers.

Table 12.18 Direct annual output effects (production)

	Industry sector	Purchases for production at Olympic Dam ($m)* (1)	Proportion from South Australian suppliers** (2)	Direct output effects ($m) (1)x(2)
3	Mining	8.7	0.92	8.00
11	Chemical and petrol products	21.7	0.39	8.46
12	Non-metallic mineral products	17.4	0.63	11.00
13	Basic metals	13.2	0.69	9.11
17	Other manufacturing	3.5	0.47	1.65
18	Electricity, gas, water	28.3	1.00	28.30
20	Wholesale and retail trade	2.6	1.00	2.60
21	Transport and communication	21.6	0.88	19.01
-	All other sectors	-	-	-
Total		117.0	0.75	88.13

* 1981 dollars.

** Based on 1973/74 proportions (Butterfield 1979), and excluding Northern Region sourced inputs.

Source: CoPS 1982.

Table 12.18 shows that output in South Australia could directly increase by approximately $88 million during each year of production. This figure does not include the inter-industry linkage effects of this expenditure on the economy, which are discussed more fully in the next section. It should be noted that this analysis and the estimation of multiplier effects do not include the supply of goods and services to the town, which would add significantly to the effects.

Tables 12.19 and 12.20 follow the same format as Tables 12.15 and 12.16 in order to convert the direct output increase of production into the direct employment change. Fewer sectors are involved in supplying goods and services during production at Olympic Dam than during the construction phase.

Table 12.19 Jobs per million dollars of output: South Australia, 1979/80

Industry sector		Estimated South Australian production 1979/80 ($m) (1)	Estimated South Australian employment 1979/80 (2)	Number of jobs per million $ of output (2)/(1)
3	Mining	238.7	3,100	12.99
11	Chemical and petrol products	226.4	3,000	13.25
12	Non-metallic mineral products	225.4	3,600	15.97
13	Basic metals	792.6	9,200	11.61
17	Other manufacturing	273.1	6,000	21.97
18	Electricity, gas, water	431.0	10,300	23.90
20	Wholesale and retail trade	2,595.3	114,200	44.00
21	Transport and communication	983.8	37,200	37.81
-	All other sectors	11,463.9	356,800	31.12
Total		17,230.2	543,400	31.54

Source: CoPS 1982.

Table 12.20 Direct employment effects per annum, by industry sector (production)

Industry sector		Direct output ($m) * (1)	Number of jobs per million $ of output** (2)	Direct employment (no. of jobs) (1)x(2)
3	Mining	8.00	12.99	104
11	Chemical and petrol products	8.46	13.25	112
12	Non-metallic mineral products	11.00	15.97	176
13	Basic metals	9.11	11.61	106
17	Other manufacturing	1.65	21.97	36
18	Electricity, gas, water	28.30	23.90	676
20	Wholesale and retail trade	2.60	44.00	114
21	Transport and communication	19.01	37.81	719
-	All other sectors	0.00	31.12	0
Total		88.13	23.18	2,043†

* Column 3, Table 12.18.

** Column 3, Table 12.19.

† When added to direct Project employment of 2,428, a total of 4,471 direct jobs can be attributed to the Project.

Source: CoPS 1982.

Table 12.20 combines the direct output effects listed in Table 12.18 with the jobs per million dollars of output ratios listed in Table 12.19 to provide estimates of the direct employment effects of production. Table 12.20 shows that in each year of production the Olympic Dam Project could generate approximately 4,470 direct jobs, of which approximately 2,430 would be employed directly by the Joint Venturers and long-term contractors on site and 2,040 elsewhere in South Australia.

12.4.2 Total output and employment effects (production phase)

Table 12.21 lists the total output and employment effects (direct and induced) of the production phase at Olympic Dam. These effects are lower than those recorded for the construction phase, largely due to the stronger multiplier effects associated with the construction sector. However, the economic effects of production are substantial, and the continued operation of the Project will result in a long-standing and major contribution to the economic base of the South Australian economy.

Table 12.21 Total output and employment effects (production)

Scenario	Total output effects*		Total employment effects*	
	($m)	Change %**	Jobs	Change %**
Optimistic	213	(1.2)	8,330	(1.5)
Probable	115	(0.7)	6,490	(1.2)
Pessimistic	88	(0.5)	5,700	(1.0)
Iron Triangle Study †	132	(0.8)	8,505	(1.6)

* Direct, indirect and induced.

** Increase over existing South Australian level of output and employment respectively.

† Based on output multiplier of 1.5 and Type II employment multiplier of 3.5.

Source: CoPS 1982; ITS 1982.

Table 12.21 shows that total output of the South Australian economy during production at Olympic Dam is forecast to increase by between $88 million (0.5% of the present level) and $213 million (1.2%). Total employment is forecast to increase by between 5,700 jobs (1% of the present level) and 8,330 jobs (1.5%) during production years. The ITS estimates of the output and employment effects (ITS 1982) are generally consistent with this forecast, with an estimated increase in output of $132 million (0.8%) and 8,505 jobs (1.6%).

12.4.3 Price effects (production phase)

The effect of the increased demand resulting from production at Olympic Dam is expected to be a very minor increase in prices in South Australia in the first year of production, after which the Project will become part of the general economic activity within the State.

The total effect on the CPI of Project production varies with each scenario. While there is no price effect based on the optimistic scenario, the probable scenario predicts a rise of 0.15% in the South Australian CPI, and the pessimistic scenario predicts a slightly lower rise of 0.10%.

12.5 PROJECT EFFECTS ON THE SUPPLY AND DEMAND FOR LABOUR

The ITS discusses the likely manpower requirements of the four development scenarios in the Northern Region within the context of the region's ability to supply skilled and unskilled workers (ITS 1982). This is directly relevant to the availability of workers for Olympic Dam, because the Project's manpower requirements represent a significant component of the likely manpower requirements of the Northern Region. Table 12.22 shows the Olympic Dam workforce forecast in relation to the anticipated range of total manpower requirements estimated by the ITS. The numbers show the anticipated construction and production workforces for Scenario 2 (which is assumed to represent the most likely rate of development in the ITS), and for Scenario 4 (which is the most optimistic in the ITS).

Table 12.22 Comparison of manpower requirements*

Source of estimates	Construction**	Production
ITS Scenario 2	2,300	1,790
ITS Scenario 4	4,890	4,020
Olympic Dam direct workforce †	3,320	2,430

* ITS estimates refer to Northern Region.
** Peak years only. Note that peak years vary between estimates.
† Derived from Table 12.11.

12.5.1 Direct labour requirements

Skill requirements were estimated by the ITS for each development scenario, in order to derive a broad overview of the likely demand for each skill category (ITS 1982), which was then compared with the 1976 Census count of the relevant employed workforce in the Northern Region to derive an approximate measure of the demand impact for each category of labour.

This analysis showed that, for each scenario, the principal overall requirements during construction and production are in the professional, technical and administrative areas, and in the skilled trades area. The professional, technical and administrative category represents 10 to 15% of all labour required during the construction phase of each scenario. For the production phase, the proportion is somewhat higher (around 20 to 25%) representing, according to the ITS estimate, a significant change from the 1976 workforce pattern in the region. Therefore, it may be necessary to attract from outside the Northern Region personnel suitably qualified in these fields as well as significant numbers of electrical and metal tradesmen. The relative mobility of skilled workers within Australia and from overseas, and recent studies of the Australian labour market (such as Richardson 1981) have demonstrated considerable potential flexibility in the supply of skilled labour. Given the level of unemployment within South Australia, including the Iron Triangle cities, there should be little difficulty in obtaining semi-skilled and unskilled labour from these sources.

The Joint Venturers' policy is to provide a manpower training programme. This programme will be designed to facilitate the employment of semi-skilled and unskilled labour within the region, of females where practicable, and of apprentices to a level compatible with the Project's workforce.

12.5.2 Indirect and induced labour requirements

The ITS used a similar method to estimate the manpower requirements caused by the indirect and induced flow-on effects of the forecast development in each scenario (ITS 1982).

The results suggest that, particularly during the construction phases of major projects, labour in the professional, technical and administrative areas and in the metal trades will be in high demand within the Northern Region as a result of production and consumption induced employment effects. The electrical and building trades will also be affected, although to a lesser degree. The induced labour requirements for trade skills in the region vary from 40 to 70% of the direct labour requirements for each major project, which will therefore have a significant impact on the regional labour market. The induced employment effects for the rest of the State will be spread more evenly across existing industries. The ITS does not expect to have to look outside the Northern Region for any particular area of skill. The study also suggests that potential demands for labour in the area will require continued government monitoring and adjustment of training policies where necessary.

12.6 PROJECT EFFECTS ON REGIONAL ECONOMIC BASE

12.6.1 Effects on the local economic base

A major effect of the Olympic Dam Project on the local economy will be the establishment of the new town as the major service centre within the region, replacing Woomera as the principal provider of medical, educational, retail and entertainment facilities. Improvements in access to the Iron Triangle cities and in transport services to Adelaide will also benefit the surrounding population. The wider range of employment opportunities created by the Project may help to slow the migration of people from the Local Region, as the multiplier effects of indirect employment will be felt in the towns of Andamooka and Woomera as well as within Olympic Dam.

The establishment of the Project will lead to some loss of station land, although the economic impact of the resulting loss of production will be minimal. Station owners may be affected by a minor rise in stock losses from collisions with vehicles, grazing disturbance, and theft, but these cannot be accurately evaluated at present. Chapter 4 deals with these impacts in more detail.

12.6.2 Effects on Iron Triangle cities and the Northern Region

Iron Triangle cities

There are likely to be beneficial effects on the workforce and population levels in the cities of Port Augusta, Port Pirie, and Whyalla arising from the purchase of goods and services for use in the construction and production phases of the Project. These will include, for example, the provision of transport services to carry goods to and from the site, the provision of contract maintenance services, and the off-site manufacture of equipment. The spending of wages earned by direct and indirect employees on the purchase of goods and services in these cities will in turn create further economic activity and increase employment (ITS 1982).

Port Augusta and Whyalla will experience indirect and induced flow-on effects largely through increased expenditure in the entertainment, trade, and maintenance sectors. However, these effects are not expected to cause significant economic or social problems within these cities, nor to require significant investment in new infrastructure. The flow-on effects to Port Pirie will be less, due to the smaller range of service industries in that city (ITS 1982).

Northern Region

The current total workforce in the Northern Region is approximately 37,000. Under the ITS projected development scenarios, the peak increase in this workforce ranges from 6%

in Scenario 1 to 26% in Scenario 4. The Olympic Dam Project is estimated to contribute the major share of this employment increase, averaging between 60 and 70% of the new positions created in Scenarios 3 and 4.

Employment multipliers: Iron Triangle cities and Northern Region

Table 12.23 lists the ITS estimates of the Type II employment multipliers for each location within the Northern Region likely to benefit from the Olympic Dam Project. This table shows that for every one hundred jobs created at Olympic Dam during each year of construction, twenty jobs will be created in Port Augusta, thirty jobs in Whyalla, and fifteen flow-on jobs at Olympic Dam. These jobs, together with minor job creation in other towns such as Port Pirie, Andamooka and Woomera, will result in a total of 180 jobs being created within the Northern Region for every one hundred jobs created at Olympic Dam.

Table 12.23 ITS Type II employment multipliers, Olympic Dam Project

Location	Construction	Production
Port Augusta	0.2	0.15
Whyalla	0.3	0.1
Olympic Dam*	1.15	1.3
Northern Region	1.8	1.7

* Olympic Dam town employment multiplier.
Source: ITS 1982.

For the production phase, Type II employment multipliers show that for every one hundred jobs created at Olympic Dam, fifteen jobs will be created in Port Augusta, ten jobs in Whyalla, and thirty flow-on jobs at Olympic Dam, with a total employment stimulus of 170 jobs within the Northern Region per one hundred jobs at Olympic Dam. The ITS emphasizes that these results are an indication only of the likely economic effects of the Olympic Dam Project.

Table 12.24 shows the distribution of these employment effects within the Northern Region using the multipliers in Table 12.23 and the direct employment numbers used in the CoPS study.

Table 12.24 Distribution of Olympic Dam employment effects within the Northern Region

Location of extra jobs	Construction*	Production**
Port Augusta	390	365
Whyalla	590	245
Olympic Dam	295	730
Other †	295	360
Total Northern Region	1,570	1,700

* Assumes CoPS average construction employment of 1,960 workers per annum.
** Assumes average production workforce of 2,428 workers per annum.
† Includes Port Pirie, Woomera and Andamooka.

12.7 EFFECTS ON THE STATE AND NATIONAL ECONOMIES

12.7.1 Financial implications for the State Government

The Olympic Dam taxation arrangements

The taxation arrangements for the Olympic Dam development established in the Indenture Agreement (Clause 32) are intended to provide South Australia with a stable flow of taxation revenue from the Project while ensuring that, if a particularly large surplus is generated, the State will gain a share of those additional returns. As with most other Australian resource developments, the Olympic Dam Project will generate a taxation return to the State through an ad valorem royalty (AVR) on the ex-mine value of all product at a rate of 2.5% for up to the fifth year of commercial production, and at 3.5% for the remaining period through to 2005. Thereafter, unless otherwise agreed, the rate will revert to that prevailing in the Mining Act at the time.

An AVR increases the unit cost of extracting a resource, and hence potentially reduces the extent of extraction. The Indenture Agreement recognizes the disincentive effects of the AVR upon production, and therefore the additional 1% to be applied after year 5 has been made fully rebatable against the surplus related royalty (SRR) discussed below. SRR is only paid in years of significant surplus and thus does not have the same disincentive effect upon production. If the Olympic Dam Project yields a return on funds invested in excess of the returns earned elsewhere in the Australian economy, the SRR enables the South Australian Government to gain a share of those additional returns. Should the Project earn less than this threshold rate of return, the tax returns to the Government are restricted to the AVR. The measure of the returns earned elsewhere is the ten-year Commonwealth Bond rate, with an additional 20% above that rate allowed as compensation to the Joint Venturers for risk.

The taxable income of the Project is defined by initially calculating an income figure (based on the ex-mine value) for the Project which recognizes operating costs, depreciation (at 20% declining balance), the 2.5% AVR, and an allowance for Federal corporate income tax. It is then determined whether or not this Project surplus is in excess of the threshold rate by calculating the required real return on funds employed. Escalated Project funds employed (less depreciation), plus working capital and new funds, are multiplied by 1.2 times the ten-year Commonwealth Bond rate to determine the threshold return. The 'post threshold Project surplus' is then determined by subtracting the threshold return from the Project surplus. While losses are not carried forward, the SRR is applied to a five-year running average of the post threshold Project surplus (whether positive or negative). The rate of SRR is on a sliding scale from 0 to 15% for average returns in excess of 120% of the Bond rate. Should the SRR be positive, the additional 1% AVR applicable after year 5 is rebatable against SRR payments.

State Government royalty revenue

Using two different revenue rates, the CoPS study has estimated the amount of royalties (Table 12.25) accruing to the State from the Project over a twenty-year production period:

- **Low revenue:** which uses pessimistic metal prices and gives an annual revenue of $450 million based on:-
  - copper: $1,600/t
  - uranium oxide: $25/lb
  - gold: $400/oz
  - silver: $8/oz.

- **High revenue:** which uses more optimistic metal prices and gives an annual revenue of $600 million based on:

  - copper: $2,200/t
  - uranium oxide: $40/lb
  - gold: $500/oz
  - silver: $10/oz.

Both these cases assumed the following:

- rate of growth of revenue: 12% per annum
- annual operating costs: $175 million per annum
- initial Project funds employed: $1,400 million
- new funds employed: $50 million per annum
- Bond rate: 13.1% per annum
- rate of increase of CPI: 10% per annum.

Table 12.25 Estimated royalty payments (1982 $A million)

Period	Low revenue			High revenue		
	AVR	SRR less rebatable AVR	Total	AVR	SRR less rebatable AVR	Total
Years 1-5						
Total	58.5	-	58.5	77.8	-	77.8
Annual average	11.7	-	11.7	15.6	-	15.6
Years 6-10						
Total	89.3	-	89.3	119.2	-	119.2
Annual average	17.9	-	17.9	23.8	-	23.8
Years 11-15						
Total	97.9	-	97.9	130.3	23.8	154.1
Annual average	19.6	-	19.6	26.1	4.8	30.8
Years 16-20						
Total	106.9	12.4	119.3	142.6	64.7	207.3
Annual average	21.4	2.5	23.9	28.5	12.9	41.4
First 20 years						
Total	352.6	12.4	365.0	469.9	88.5	558.4
Annual average	17.6	0.6	18.3	23.5	4.4	27.9

The CoPS study concludes that, over the first twenty years of production at a rate of 150,000 t/a of copper and associated products, the State would receive between $365 million and $558 million in royalties. This is an average of between $18 million and $28 million per annum, and represents a significant increase over the 1981/82 mineral royalty receipts to the South Australian Government, which totalled $9.9 million (ITS 1982).

The SRR component of the royalty payments is intended to provide a significant proportion of royalties only when the Joint Venturers' rate of return is greater than the general level of returns earned elsewhere. Thus in the low revenue case where metal prices are assumed to be at depressed levels, the SRR is relatively small. However, as metal prices rise, it becomes a more significant contributor, averaging $4.4 million per annum over the twenty-year period in the high revenue case.

Sensitivity testing of these assumptions by CoPS indicated that the year in which the SRR will initially be payable will be influenced mainly by the level of the long-term Bond rate, the rate of growth of revenue, metal prices, and Project operating costs. These figures should therefore be regarded as only an estimate of the possible level of royalty payments. Favourable variations in the above factors would lead to an increase in the level of royalties paid, and an earlier commencement of SRR payments.

Payroll tax receipts

The level of payroll tax payable was calculated as 5% of the estimated earnings of the direct on-site construction and production workforce in each year. The ITS study assumed an average annual wage of $30,000 for each worker during the construction phase, and $25,000 for each worker during production. Payroll tax revenue is forecast to increase from approximately $90,000 in the first construction year to an average of $2,400,000 for each year of production (1982 dollars).

This figure excludes the payroll tax resulting from increased indirect and induced employment within the Northern Region and the State. Tables 12.17 and 12.21 indicate that the total employment multiplier effect for the State is likely to range from between 5 and 10 for each on-site construction worker and between 2.5 and 3.5 for each production worker employed. The likely increase in total payroll tax payments could therefore be between three and seven times the amounts estimated for the direct production and construction phase workforces respectively.

12.7.2 Financial implications for the Commonwealth Government

The development of the Olympic Dam Project will result in increased tax revenue to the Commonwealth Government, through taxes on additional corporate and personal income and on the sale of goods and services. Increased Federal taxation revenue will also benefit South Australia by providing a larger pool of funds available for redistribution back to the State.

12.7.3 Balance of payments

Construction phase

The construction phase will have two major effects on Australia's balance of payments: through a higher level of imports to meet direct Project demands, and through increased capital inflow reflecting the overseas borrowing required to finance the Project.

Of the total construction capital expenditure of $1,400 million, it is estimated that, in line with other major Australian mining projects, approximately 85% of this expenditure will flow to Australian suppliers, with the greater proportion of this (about 79%) being expended in South Australia (Table 12.14). Equipment to a value of approximately $210 million will need to be imported during the four-year construction period. The extent to which this negative balance of payments effect is offset by the capital inflow to finance the Project will depend on the eventual Project financing structure. While this financing structure had not been determined at the time of writing, it is almost certain to require overseas investment in excess of the 15% imported component of expenditure, thus ensuring a positive contribution to the balance of payments during any construction year.

Production phase

During the production phase of the Project, about 80% of annual operating expenditure is expected to flow to Australian suppliers (75% of these being South Australian). The export earnings will greatly exceed the repayments of capital and interest on foreign loans, and the Project will therefore also have a significant positive balance of payments effect during the production phase.

In 1980/81, South Australian annual exports were $1,400 million. At the annual revenues assumed, the Olympic Dam Project would add between 32 and 43% to the State's export income.

APPENDIX ONE

Glossary

Acidic	A descriptive term applied to igneous rocks which contain more than 60% silica.
Activity	The number of disintegrations per unit time taking place in a radioactive material.
Allelopathy	The influence which one living plant exerts upon another by the release of growth retardant chemicals.
Alpha-emitter	A radioisotope which emits an alpha particle when it decays.
Alpha particle	A positively charged particle containing two protons and two neutrons which is emitted by certain radioactive material. It is identical with the nucleus of a helium atom and the least penetrating of the three forms of radiation (alpha, beta and gamma) in that it may be stopped by a sheet of paper.
Aquifer	A permeable rock formation which stores and transmits sufficient groundwater to yield quantities to wells, bores or springs.
Becquerel (Bq)	The unit of measurement of radioactive decay defined as one radioactive disintegration per second. The disintegration may occur as a result of emission of an alpha particle or a beta particle.
Beta-emitter	A radioisotope which emits a beta particle when it decays.
Beta particle	An elementary particle emitted from a nucleus during radioactive decay. It may carry a negative or a positive charge, but in common usage it is a negatively charged particle identical with an electron. Beta particles may be easily stopped by a thin sheet of metal.
Blowout	A general term for saucer shaped hollows formed by wind erosion on sand ridges and sand sheets.

Breccia	A coarse grained clastic rock composed principally of angular broken rock fragments either held together by a mineral cement or in a fine grained matrix.
Bund	An earth rock or concrete wall constructed to prevent the inflow or outflow of liquids.
Burren	A tula-adze flake rechipped on both margins and which may also be attached to a wooden handle.
Calcine	The residue derived from heating a mineral substance with air to drive off the chemically combined volatile portion of the substance and to convert the non-volatile mineral to an oxide.
Calcrete	Friable to hard calcareous material of secondary accumulation found near or on the surface, and composed largely of crusts of soluble calcium salts intermixed with gravel, sand, salt and clay.
Clastic (adj.)	Said of a rock or sediment composed principally of broken fragments derived from pre-existing rocks or minerals which have been mechanically transported.
Comminution	The process of size reduction of ore involving crushing or grinding.
Competent rock	Rock which is capable of sustaining relatively large underground openings with minimal support apart from pillars and walls left during mining.
Crabhole	See gilgai.
Cross-bedding	The arrangement of rock strata inclined at an angle to the main plane of stratification of adjacent layers and which forms in relatively shallow water environments.
Cyanidation	The process of extracting gold and silver from ore by treatment with dilute solutions of sodium or potassium cyanide.
Decay product	The product of the spontaneous radioactive decay of a nuclide. A substance such as uranium-238 decays through a sequence of steps and has associated with it many successive decay products in a decay series.
Doline	A solution feature, caused by the dissolution of carbonate rock by water. It is generally circular or oval in plan, with depth varying closely with the diameter, and is commonly funnel-shaped.
Dolomitic limestone	A limestone in which the mineral dolomite, $CaMg(CO_3)_2$, is conspicuous but calcite, $CaCO_3$, is more abundant.
Dose	The radiation energy absorbed in a unit mass of material.

Dose equivalent	The mathematical product of the absorbed dose, the quality factor, and any other specified modifying factors. The quality factor accounts for the effectiveness of energy transfer of the ionizing radiation in producing a biological detriment. Modifying factors are those which may act to modify the effect of the energy imparted to the matter.
Ecotype	Recognizable varieties of a particular plant species which have become specially adapted to certain environmental conditions.
Electrorefining	The process of dissolving a metal from an impure anode and depositing it in a more pure state at the cathode.
Evapotranspiration	Transfer of water from liquid to vapour through the combined effect of evaporation from soil and transpiration from plants.
Felsic	A term derived from feldspar, feldspathoid and silica, and applied to light-coloured igneous rocks containing an abundance of one or more of these constituents.
Flotation	The process of mineral separation by addition of reagents (collectors) in an aerated agitated slurry. The collectors attach to sulphide minerals and render the surfaces hydrophobic. Sulphide particles therefore 'attach' to air bubbles which float to the top of the flotation tank, thus effecting a separation between the non-valuable and valuable minerals.
Freeboard	The vertical distance between the design water level and the top of the containing structure.
Gamma radiation	A form of electromagnetic radiation similar to light or X-rays, distinguished by its high energy and penetrating power.
Gangue	Non-valuable minerals associated with an ore deposit.
Geosyncline	A large, generally linear trough, which has subsided deeply over a long time interval and in which thick sequences of sedimentary and volcanic rocks have accumulated.
Gilgai	Small depressions formed in arid areas which contain heavy clay soils which have repeatedly expanded and contracted with intermittent rainfall and subsequent evaporation.
Groundwater	Underground water contained within a saturated zone or rock (aquifer).
Gypcrete	A gypsum-cemented crust or rock found in some playa (q.v.) lake beachrock environments in arid climates.
Hydraulic gradient	The change in static head or hydraulic potential per unit of distance in a given direction.
Hydrocyclone	A conically shaped device which uses centrifugal force to separate particles by density or size. The coarse or heavy material is collected at the bottom of the cone (underflow), while lighter material passes through the top of the cone (overflow).

Hydrogeology	The science dealing with groundwater and its relationship with geology.
Ionizing radiation	Radiation which interacts with matter to remove electrons from (i.e. to ionize) the atoms of the material absorbing it, producing electrically charged atoms called ions.
Irradiation	Subjection to ionizing radiation.
Isotope	One of two or more forms of an atomic element having the same number of protons but a different number of neutrons. All isotopes of the same element have the same chemical properties and therefore cannot be separated by chemical means.
Konimeter	A measuring device which draws a measured volume of air through a jet, causing particles to impinge upon a coated glass surface for counting.
Lens	A body of sedimentary rock, thick in the middle and thinning towards the edges.
Lithostratigraphy	Recognition and interpretation of the physical or chemical characteristics of sedimentary rocks.
Mafic	A description of an igneous rock composed chiefly of one or more dark-coloured minerals.
Mesoscale meteorology	The study of meteorology on an intermediate scale of the order of an area 10 to 100 km^2 .
Mullock	Waste rock (generally unmineralized) which is extracted during mine development and production.
Pasquill stability classes	Classes of atmospheric stability which are indicators of the degree of turbulent mixing in the atmosphere varying from Class A (the most unstable condition, with rapid mixing) to Class F (the most stable with very limited mixing).
Perched water-table	Unconfined groundwater separated from an underlying main body of groundwater by an unsaturated zone.
Playa	A flat area or basin at the lowest part of an undrained desert basin, underlain by clays, silts, sands and commonly by soluble salts.
Polymict	A clastic sedimentary rock composed of many rock types.
Porcellanite	A light-coloured siliceous rock having the texture, dull lustre, hardness, conchoidal fracture and general appearance of unglazed porcelain.
Potentiometric surface	A hypothetical water surface representing the total head of groundwater for a particular locality and defined by the level to which water will rise in a well.
Pregnant (solution, solvent or electrolyte)	A solution containing the valuable mineral component in any of the steps in a mineral leaching and recovery operation.

Pyrolusite	Manganese dioxide (Mn O_2). The principal ore of manganese which is used as an oxidant.
Quality factor	A factor used in determining the dose equivalent which accounts for the effectiveness of energy transfer of ionizing radiation in causing biological damage.
Radon	The radioactive decay product of radium. It occurs as an inert gas. The predominant isotope, radon-222, has a half-life of 3.8 days.
Radon daughters	A term applied to the four short-lived decay products of radon gas: polonium-218, lead-214, bismuth-214 and polonium-214.
Raffinate	The aqueous leaching solution remaining after the valuable mineral, such as copper or uranium, has been removed by solvent extraction.
Raise	A mine shaft or opening excavated upwards from below.
Raise borer	A mechanical device which excavates a raise by back-reaming a small pilot hole.
Rare earth elements	A group of metals with atomic numbers from lanthanum (atomic number 57) to lutetium (71). Yttrium (39), and scandium (21), while not strictly rare earths, are generally grouped with them. Rare earth elements are not especially uncommon. They have very similar chemical and physical properties making separation of individual elements difficult.
Rip-rap	A layer of coarse rock fragments used to line or protect earthen embankments from erosion.
Rudite	A general name for consolidated sedimentary rocks composed of rounded or angular fragments which are coarser than sand.
Secular equilibrium	A condition which occurs when the activity of the decay products is equal to that of the parent in a material. It may arise when a radioactive parent is long-lived compared with its decay products and none of the decay products are removed from the material.
Semi-autogenous grinding (SAG) mill	A revolving cylindrical mill which crushes ore by cascading a combination of steel balls with the larger pieces of ore.
Sericite	A white, fine grained potassium mica, occurring in small scales and flakes as an alteration product of certain rock-forming minerals.
Shotcrete	Fine concrete applied with a pressure gun.
Sievert (Sv)	The unit of measurement of radiation dose equivalent. One sievert is equal to the product of the absorbed dose by the quality factor and any modifying factor(s). It allows a comparison of the relatively greater biological damage caused by some particles such as alpha particles and fast neutrons. For most beta and gamma radiation, one sievert is equal to an absorbed dose of one joule per kilogram.

Sigma theta	The value of the standard deviation of the wind direction over a selected time interval.
Silcrete	Surficial sand cemented into a hard mass by silica.
Solvent extraction	A separation process in which two immiscible solvents (water-based and organic-based) are brought into contact for the transfer of ore and iron components. The process is usually carried out in multiple staged countercurrent flow contactors to obtain maximum efficiency of extraction.
Steel sets	Steel structure used in underground mines to support development openings.
Stratabound	Said of a mineral deposit confined to a single stratigraphic unit.
Subaerial	A process which takes place in the open air on the land surface rather than under water or underground.
Swale	The area lying between sand ridges.
Transmissivity	The rate at which groundwater is transmitted through rock of a specific width and at a specified hydraulic gradient.
Tula (tula-adze)	A tongue shaped stone flake attached to a wooden handle used for chiselling and scraping wood.
Uranium (decay) series	A series of radionuclides produced in the decay of radioactive uranium to stable lead. The steps of interest of this series are uranium-238 to uranium-234 to thorium-230 to radium-226 to radon-222 (and its daughter products) to lead-210 to lead-206, the stable non-radioactive end product.
Understorey	The vegetative cover beneath taller trees and shrubs.
Working Level	The quantity of radon decay products (radon daughters) in one litre of air which will result in the emission by them of 130,000 million electron volts of alpha particle energy. If the radon daughters are in equilibrium with radon in the air, then 3.7 Bq of radon per litre of air is equivalent to one Working Level.
Working Level Month	A measure of the total radiation dose which would be received by someone breathing air containing radon daughters at a concentration of 1 Working Level throughout the working period of a month (170 hours).
Yellowcake	The precipitate from the uranium precipitation step consisting of a chemical compound of ammonium diuranate, ammonium sulphate, ammonia and uranyl sulphate and uranium oxide. After drying and calcining, it contains greater than 90% uranium oxide (U_3O_8) with the remainder being impurities.

Note: The Concise Oxford Dictionary may be consulted for definitions of any terms not listed in this glossary.

APPENDIX TWO

Abbreviations

Measurements

Technical units of measurement in this report are based on the International System of Units (SI) wherever possible. These technical units may be broadly grouped as prefixes and measurements. Different units are combined by a full stop (.) to differentiate units of the same exponential sign and a solidus (/) to indicate 'per'. For example, kilometres per hour is abbreviated as km/h and micrograms per cubic metre per second is abbreviated as $\mu g/m^3.s$.

The prefixes used are as follows:

M	mega	1,000,000
k	kilo	1,000
m	milli	0.001
μ	micro	0.000,001
p	pico	0.000,000,000,001

Units of measurements which have been used in this report are as follows:

a	annum
AADT	annual average daily traffic (vehicle/day)
b	bar
Bq	becquerel
d	day
dB	decibel
dBA	decibel, frequency weighting network A
dD/dt	surface dose rate
°C	degree Celsius
g	gram
h	hour
ha	hectare
Hz	hertz
J	joule
L	litre
L_{bg}	background sound power level
L_{eq}	equivalent sound power level
L_{90}	sound power level exceeded 90% of the time
$L_{bg\ calc.}$	calculated background sound power level
m	metre
MeV	million electron volts
M_L	Richter earthquake magnitude
ppb	parts per billion by volume
pphm	parts per hundred million by volume
ppm	parts per million by volume
%	per cent
s	second
Sv	sievert
t	tonne
TDS	total dissolved solids
TWA-TLV	time-weighted average threshold limit values
V	volt
W	watt
WL	Working Level
WLM	Working Level Month

Chemicals

CO_2	carbon dioxide
Cu_2S	copper sulphide
FeO	ferrous oxide
FeS	ferrous fluoride
HF	hydrogen fluoride
MnO_2	manganese dioxide
NO_2	nitrogen dioxide
Rn-222	radon-222
SO_2	sulphur dioxide
SO_3	sulphur trioxide
UF_6	uranium hexafluoride
U_3O_8	uranium oxide

Uranium decay series:

U-238	uranium-238
U-234	uranium-234
Th-230	thorium-230
Ra-226	radium-226
Pb-210	lead-210

Organizations

ARL	Australian Radiation Laboratory
AWRC	Australian Water Resources Council
CoPS	Centre of Policy Studies, Monash University
E&WS	Engineering and Water Supply Department
ETSA	Electricity Trust of South Australia
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ISO	International Standards Organization
ITS	Iron Triangle Study Group
NHMRC	National Health and Medical Research Council
RMS	Roxby Management Services Pty Ltd
WMC	Western Mining Corporation Limited

Miscellaneous

ADU	ammonium diuranate
AL	Atmospheric leaching
AVR	*Ad valorem* royalty
BOD	Biochemical oxygen demand
CCD	Countercurrent decantation
CIP	Carbon-in-pulp (process)
CPI	Consumer Price Index
EIS	Environmental impact statement
LHD	Load/haul/dump unit
PL	Pressure leaching
PLE	Pressure leaching and electrowinning
RLE	Roasting, leaching and electrowinning
SAG	Semi-autogenous grinding (mills)
SC	Smelting and converting
SRR	Surplus related royalty
SX	Solvent extraction
TLD	Thermoluminescent dosimeter
TRS	Tailings retention system
USC	Unified soil classification (system)

APPENDIX THREE

References

CHAPTER 2

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APPENDIX FOUR

Study Team

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Dr J.L. York	Senior Advisor

Technical

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R.I. Thomas	EIS compilation
J.A. Gillett	Economic and social analysis
A.D. Robertson	Economic analysis
H.M. Weston	Social assessment
Dr L. Bren	Hydrology
E.B. Pugsley	Technical review
E.R. Andrews	Technical review
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C.A. Masson	Technical review
R. Addison	Technical review
D.S. Packnett	Technical review
Dr M. Rehn	Technical review

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Dr J. White	Herpetology
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Ullman and Nolan Pty Ltd G.A. Nolan	Town planning
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