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RENISON LIMITED

Environmental Impact Statement for a Thermal Upgrading Plant

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ENVIRONMENTAL IMPACT STATEMENT FOR THERMAL UPGRADING PLANT, RENISON, TASMANIA

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18/19 - 9 - 1981

ACKNOWLEDGEMENTS

Croft and Associates of Newcastle NSW and J. Stephens of Hobart, Tasmania were appointed joint environmental consultants in 1981.

J. Stephens was responsible for the preparation of the preliminary statement of environmental factors submitted to the Department of the Environment in May, 1981 and has contributed data on the existing environment and details of local fauna and flora used in this document.

Croft and Associates are responsible for the environmental studies reported herein and the preparation of this Environmental Impact Statement. Dr. P. Zib, of Croft and Associates, has provided the necessary technical direction and atmospheric emission analysis and strategy with major contributions being provided by the following study team; M. Pollington (existing environment), K.W. Perry (visual aspects), J.W. Wiggers (social studies), M.R. Morris (soil studies), I. Finney (water quality), A. Martin (flora and fauna) and A. Nicholls (graphic design).

Overall control and supervision has been provided by D.J. Debney, Group Project Manager, Renison Gold Fields Consolidated Limited.

J.W. Mitchell, General Manager and other staff of Renison Limited including I.W. Wood (Chief Project Engineer), R. Winby (Metallurgical Superintendant) and A. Taylor (Chief Surveyor), have supplied details of the existing operation and other on-site data as well as reviewing this document in its draft stages.

Bergbau and Huettenkombinat "Albert Funk" of Freiberg East Germany have provided all thermal upgrading process and environmental data under a Licence Agreement with Renison Limited.

KHD Humboldt Wedag of Cologne West Germany have been responsible for the thermal upgrading process engineering upon which the project is based.

John Holland (Engineering) Pty Limited of Melbourne, Victoria have been responsible for the detail engineering (excluding the thermal upgrading process) and the major cost estimates.

1. SUMMARY AND REVIEW OF PROPOSAL

THE PROPOSAL

Renison Limited proposes to construct a pyrometallurgical upgrading plant to improve tin recovery and product grade from the existing tin mine and concentrating plant at Renison Bell.

This Environmental Impact Statement has been prepared to allow the assessment of the environmental impact of the proposed development and describes the ongoing environmental implications.

HISTORICAL DEVELOPMENTS

Alluvial tin deposits were discovered in western Tasmania around 1890 and mined between 1907 and 1922. In 1936, following the discovery of an economic means of working the sulphide ore, underground mining at Renison Bell commenced.

Subsequent improvements in ore reserves resulted in Renison's existing concentrator being commissioned in 1966 with a throughput capacity of 350,000 tpa of ore. However, subsequent expansions of the plant have resulted in the throughput capacity of 850,000 tpa of ore being achieved by 1981. Concurrent with the development of the concentrator has been steady improvement in the metallurgical understanding of the ore types mined and processed. As a consequence, some significant metallurgical developments have already been achieved including cassiterite froth flotation in 1968, heavy media separation in 1975 and acid leaching in 1977.

Investigations into the various means of further metallurgical improvements have indicated that the next logical development, to significantly improve the tin recovery, is production of a lower grade concentrate which is then thermally upgraded into a "premium" grade smelter feed material.

THE PROCESS

The thermal upgrading process pyrometallurgically upgrades low grade tin concentrate to a high grade tin oxide in a specially designed furnace. During the operation the tin contained in the low grade concentrate is volatilised as tin sulphide and subsequently oxidised to tin oxide and precipitated as a fine powder together with some minor contaminants. After collection the high grade tin oxide powder is sold for smelting outside Tasmania.

The only waste product is a granulated slag that has potential use for roadbuilding as it is hard, durable and inert.

Exhaust gas emissions of environmental significance are produced by the process.

The proposed process is a batch operation scheduled on a 24 hour day, 7 day week basis.

SETTING

The location of the proposed plant site is 2km north of the existing concentrator at Renison Bell on the West Coast of Tasmania. The plant site is on land currently held by Renison Limited under their consolidated Mining Lease. The regional setting of the proposal is shown in Plate 1.1.

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Plate 1.1 Regional Setting of the Proposal

THE PLANT

The thermal upgrading furnace has been designed in accordance with the technical specifications and engineering details obtained under a Licence Agreement. Detailed process engineering has been carried out by an international organisation well experienced in the technology.

The low grade concentrate feed to the thermal upgrading plant is produced in Renison Limited's existing concentrator and pumped in slurry form to the proposed plant. Other raw materials, comprising coke, quartz and limestone are combined with the low grade concentrate and fed in carefully metered proportions into the furnace.

Operation of the thermal upgrading plant will result in a reduction in the quantity of concentrates transported from Renison Bell and some complementary changes in the operation of the existing concentrator and leach plant will result.

Electricity reticulation will be provided from an existing substation at the concentrator complex. Demand will be increased by 3MW.

All water required will be drawn from the existing Argent Dam utilising Renison Limited's existing water supply system.

ENVIRONMENTAL SAFEGUARDS AND CONTROLS

The proposal involves a number of safeguards and controls designed to minimise the impact of the project on the environment.

Atmospheric Emissions

During the pyrometallurgical process a proportion of impurities will enter the gas stream and will eventually report in the collected product powder or be emitted to the atmosphere. The waste gas will carry residual amounts of sulphur dioxide, fluorine and arsenic. The volume and the composition of the waste gas will vary during the various stages of the furnace cycle.

A disposal strategy is proposed based upon the use of a 100 metre high stack to reduce the ground level concentrations of the pollutants. Many years of experience with tall stacks in Australia and overseas has demonstrated the effectiveness of this approach in similar situations.

The height of the stack was designed to take account of the site location in order to obtain safe ambient concentration levels near the ground. The design calculations included separate analyses with respect to human health and to vegetation responses for a range of exposure times. A relationship between sulphur dioxide and fluoride effects on vegetation was established with a specific reference to Australian native species and used to determine the stack height. The design height was shown to be safe with respect to concentration levels related to public health.

The proposed tall stack strategy was shown to be justified by a variety of environmental, safety and economic factors. An unconditional compliance with ambient air quality objectives in Tasmania and with ambient air quality standards worldwide will be achieved. No country in the world could be identified in which the emission from the proposed plant would violate the allowable limits on ground concentration levels.

A detailed monitoring programme will be implemented to document the environmental acceptability of the development and to serve as an additional safeguard. The provision of space for gas cleaning equipment was included in the final plans should its installation prove necessary in the light of the results.

The process emissions will be monitored by taking regular samples of the waste gas from the stack. The samples will be collected by grab sampling once a month and analysed for the concentrations of sulphur dioxide, fluorine and arsenic. A detailed sampling procedure will be developed to document the variations in the composition of the waste gas during the different stages of the furnace cycle. At least one full cycle will be monitored every month.

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An ambient air monitoring programme will provide the necessary data for establishing the existing levels of sulphur dioxide in the vicinity of the township of Rosebery (8km distant). A continuous sulphur dioxide recorder will be installed prior to the commencement of the operations and will remain permanently at the Rosebery site to monitor any changes in the sulphur dioxide levels following the commencement of thermal upgrading operations at the proposed plant.

A second sulphur dioxide recorder of similar design will be available to monitor ground level concentrations in locations corresponding to the area of expected touch-down of the plume from the stack.

A regular soil sampling programme will monitor any changes in the soil arsenic content over the long-term period.

A vegetation sampling programme will be developed to determine existing levels of fluoride, sulphate and arsenic in representative vegetation species in the vicinity of the proposal prior to development.

After the commencement of operations the programme will be used to determine if any observed increases in the concentrations of fluoride, sulphate and arsenic in vegetation are adversely affecting the plant species and if so to what degree and in what localities.

The meteorological programme will continue to build up a representative set of climatological data. The records shall be instrumental in detecting any abnormal dispersion patterns around the plant.

Liquid Emissions

A factor in the selection of the process and subsequent plant design has been the need to minimise adverse impacts on water quality. Removal of contaminants from the stack gases, prior to emission to the atmosphere, would create significant problems with regard to the volumes and quality of liquid effluents requiring further treatment. The proposed disposal strategy overcomes these problems and only a small volume of wastewaters will be produced.

A water quality sampling programme will be implemented, after the thermal upgrading plant becomes operational, to monitor any changes in the quality of water.

Solid Waste

The granulated slag will be stockpiled on Renison Limited's lease in a inconspicuous area.

Visual Safeguards

Buildings and structures will be designed to a common style and constructed using materials to ensure resultant site unity. The buildings will be clad with dark brown, profiled sheeting to minimise discolouration and glare.

The stack will be constructed from reinforced concrete and will be finished in its natural light grey colour to minimise silhouetting effects.

A revegetation programme will be implemented to ensure that all disturbed areas within the site boundaries are successfully rehabilitated.

The revegetation programme will comprise replanting of small native seedlings lifted from adjacent dense forested areas. This technique has proven successful in revegetation trials undertaken on the adjacent tailings dam walls.

Other methods including the planting of nursery-raised tree and shrub seedlings, conventional planting of stabilising grasses and hydromulching will be used if necessary.

Prior to the commencement of the revegetation programme all land disturbed during the construction phase will be graded to form harmonious levels with the surrounding landform, ensuring that drainage is not impeded. Head catch drains will be constructed above all cuttings and embankments to prevent excessive erosion.

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IMPACT ASSESSMENT

The potential impact of the proposed development was determined by detailed investigations both in field and in laboratory. As a result of the safeguards incorporated in the proposal the impact of the thermal upgrading plant on the environment will be minimal.

Air Quality

The mean annual levels of sulphur dioxide, fluorine and arsenic will not be increased significantly. Public health, wildlife and vegetation will not be endangered by the atmospheric emissions.

Soils

The sulphur dioxide emissions are not expected to have any significant impact on soils in the area.

Fluoride will not have any direct effect on plant health through absorption from soil. Soluble arsenic compounds will not reach the safe limit for domestic water supplies and aquatic life.

Water Quality

Domestic wastewater will be treated in a package sewerage treatment plant prior to disposal. All stormwater and wastewater will be channelled to a settling dam to remove suspended solids prior to discharge. Levels of soluble contaminants in groundwater, mainly fluoride and sulphate, will not increase significantly.

Flora and Fauna

It is not expected that emissions will have any adverse overall impact on vegetation or wildlife. The atmospheric emission disposal strategy was designed with the specific aim to protect flora and fauna.

Noise

Noise levels due to the plant will be attenuated to approximately 28 dB(A) at the nearest residences, which is considerably less than the measured background noise levels of 38 dB(A).

Transportation
No impact on traffic volumes on either the Murchison or Bass Highways is anticipated.

SOCIAL AND ECONOMIC ASPECTS

Construction Phase
The construction phase will provide employment opportunity for 55 people at Renison Bell over a period of 21 months. It is expected that about 50 percent of the total project cost will be spent within Tasmania.

Operation Phase
The proposal will provide an additional 39 employment positions. It is Renison's intention to employ married persons to reduce the existing high proportion of single male employees. An additional 121 people are expected to take up residence in the area as a result of the proposal. The estimated population growth represents a 7 percent increase on the 1981 population of Zeehan town.

Renison's policy of providing accommodation for its workers in Zeehan will continue. A variety of options concerning the type and proportions of the accommodation are under consideration.

The medical and educational facilities currently available in Zeehan will be sufficient to accommodate the increase in population.

It is estimated that significantly more than $1 million will be paid as wages and salaries as a result of the proposal. Additional income, created in the local and state economies, is estimated at a similar level and will be distributed throughout Tasmania.

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CONCLUSION

This document has been prepared for Renison Limited to support its proposal to build and operate a thermal upgrading plant at Renison Bell.

The proposed technology incorporates highly effective equipment and methodology to produce a high grade tin smelter feed efficiently and safely.

A variety of safeguards were included in the proposal to ensure that the operation of the plant will have only a minimal impact on the natural environment.

The establishment of the plant at Renison Bell is seen to be beneficial to the region and to the state of Tasmania as a whole.

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SECTION 2

INTRODUCTION

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2.1 THE PROPONENT

The proponent is Renison Limited herein after referred to as Renison.

Renison operates a tin mine and concentrating plant at Renison Bell in western Tasmania which is believed to be the world's largest underground tin producer.

Renison is wholly owned by Renison Goldfields Consolidated Limited together with other listed Australian companies, including the Mount Lyell Mining and Railway Company Limited and Associated Minerals Consolidated Limited. Renison Goldfields Consolidated Limited is 51% Australian owned and 49% owned by Consolidated Gold Fields PLC, a major mining and investment Group based in London.

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2.2 BACKGROUND

Alluvial tin deposits were discovered in western Tasmania by George Renison Bell and mined between 1907 and 1922. In 1936, following the discovery of an economic means of working the underground sulphide ore, Renison Associated Tin Mines N.L. was formed and began production. In 1960 Renison Limited was formed to acquire the assets of the No Liability company. Effective control of Renison had been acquired in 1958 by Mount Lyell Mining and Railway Company Limited which, in 1976, sold this interest to its shareholders whereupon Renison Limited became a direct subsidiary of Consolidated Gold Fields Australia Limited. In 1981 Renison Goldfields Consolidated Limited was formed as part of the restructuring of the Consolidated Gold Fields Australia Group of Companies and the existing Group companies became wholly owned subsidiaries of the newly formed Company.

Renison's existing concentrator was commissioned in 1966 with a throughput capacity of 350,000 tpa of ore. However, subsequent expansions of the plant have resulted in the throughput capacity of 850,000 tpa of ore being achieved by 1981. Concurrent with the development of the concentrator has been steady improvement in the metallurgical understanding of the ore types mined and processed. As a consequence, some significant metallurgical developments have already been achieved including cassiterite froth flotation in 1968, heavy media separation in 1975 and acid leaching in 1977.

At present Renison achieves a tin recovery of around 70% and a concentrate grade of about 50% tin. Investigations into the various means of improving tin recovery and maintaining a saleable grade of product have indicated that the only practical option to significantly improve the tin recovery is to produce a lower grade concentrate which is then upgraded pyrometallurgically into a "premium" grade smelter feed material. This strategy will result in the maximum practicable tin recovery and achieve the maximum practicable concentrate value.

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By 1979, a review of the various pyrometallurgical upgrading processes developed for tin concentrates had been completed and in 1980 a 100 tonne batch of Renison concentrates was successfully tested in the selected plant. As a result of these tests a Licence Agreement has been executed by Renison and it is proposed to construct a concentrate upgrading plant in accordance with the technical specifications and engineering design obtained under that Licence Agreement. All process data reported in this document is based on confidential information extracted from the Licence Documentation.

2.3 PROCEDURAL ASPECTS

The proposed thermal upgrading plant comprises a "scheduled premises" as defined in the Environment Protection Act 1973 (Tasmania) and, as such, will require that a Licence be granted by the Director of Environmental Control prior to commencing operation.

The thermal upgrading plant is proposed to be constructed within Renison's existing consolidated Mine Lease which in turn is located within the Zeehan Municipal Commission's boundaries. As a consequence, approval to construct and/or operate the proposed plant must also be granted by the Director of Mines and the Zeehan Municipal Commission.

This Environmental Impact Statement has been prepared on behalf of Renison by Croft and Associates in accordance with the Department of the Environment's published Guidelines and Procedures for Environmental Impact Studies and will be submitted to support:

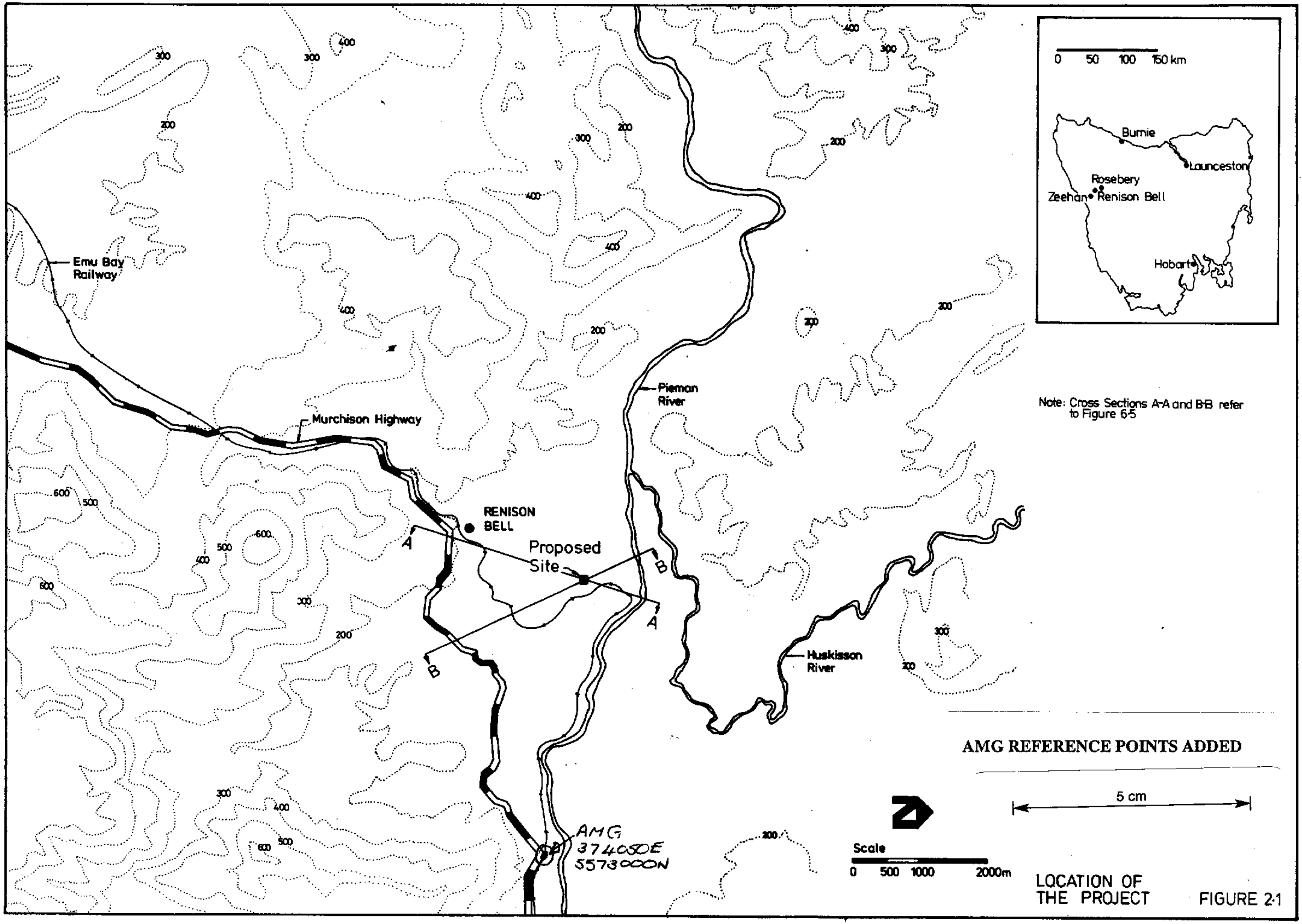
* an application to the Director of Environmental Control for a Licence to operate the proposed plant as required by the Environment Protection Act 1973,
* an application to the Director of Mines for approval to construct/operate the proposed plant, and
* an application to the Zeehan Municipal Commission for approval to construct the proposed plant.

2.4 LOCATION OF PROPOSED PLANT

2.4.1 Proposed Location

The location of the proposed plant is at Renison Bell on the West Coast of Tasmania as shown in Figure 2.1. The plant site as shown in Figure 2.2 is on land currently held by Renison under their consolidated Mining Lease. Access to the site will be through their existing mine facilities adjacent to the Murchison Highway, between the townships of Zeehan and Rosebery. Plate 2.1 shows the aerial view of the site location.

The proposed site is about 185m above sea level in a location remote from any substantial population centre. The nearest settlement is at Renison Bell (2km south). The nearest townships are Rosebery (8km east) and Zeehan (14km south-east).



LOCATION OF THE PROJECT

FIGURE 2·1

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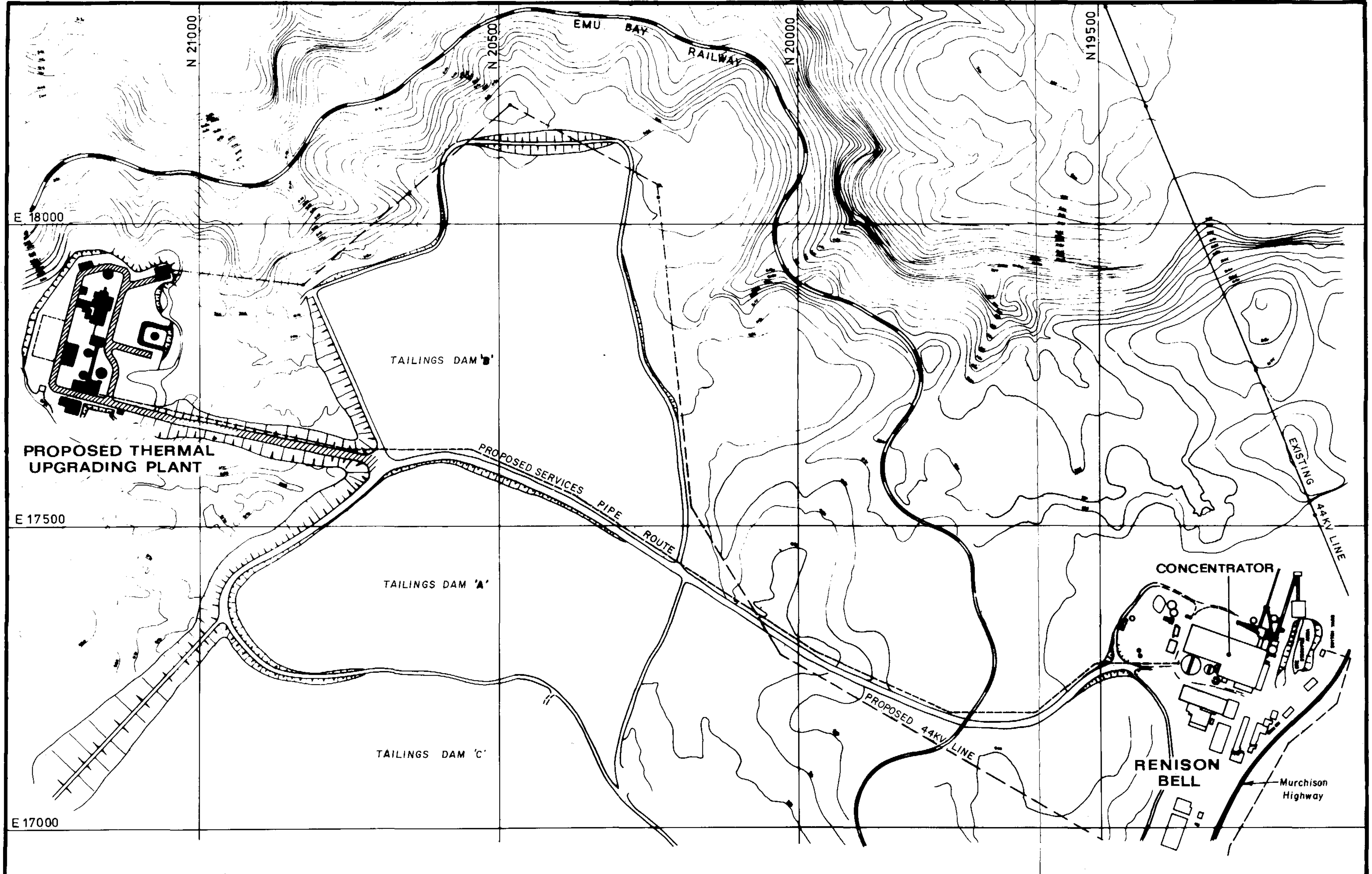

THERMAL UPGRADING PLANT
AREA LAYOUT

FIGURE 2·2

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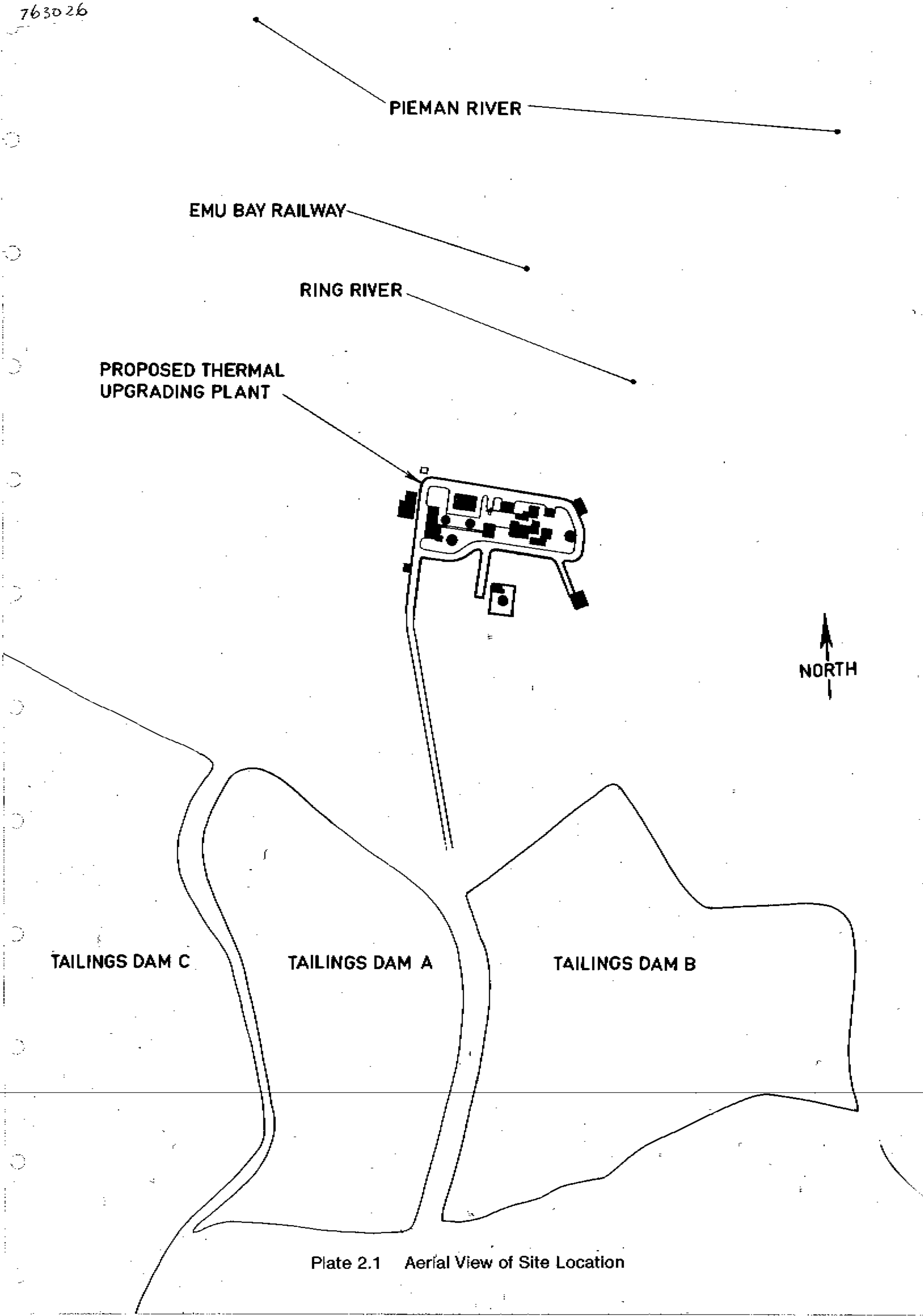

Plate 2.1 Aerial View of Site Location


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Plate 2.1 Aerial View of Site Location

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2.4.2 Alternative Locations

A number of potential sites for the proposed plant were considered during the feasibility study programme. As a result two optional sites were seen to exist, both on the Renison mining lease, comprising the proposed site and an initially preferred site located about 1 km from the Concentrator. The initially preferred site possessed clear cost advantages through being already cleared and levelled and being much closer to the Concentrator and other existing facilities. The proximity of the site to hills and the high terrain situated in the upwind direction of the prevailing winds was likely to result in a significant reduction in the effectiveness of waste gas dispersal. As a consequence, the initially preferred option was discarded in favour of the proposed site on environmental grounds.

SECTION 3

DESCRIPTION OF THE PROPOSAL

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3.1 THERMAL UPGRADING PROCESS

The thermal upgrading process pyrometallurgically upgrades low grade tin concentrate to a high grade tin oxide as shown in Figure 3.1. During the operation the tin contained in the low grade concentrate is volatilized as gaseous tin sulphide which is subsequently oxidised to tin oxide and precipitated with some minor contaminants, as a fine powder.

The process is a batch operation with a furnace cycle time of 4 hours 20 minutes comprising smelting, sulphidizing, volatilization and tapping phases.

During the initial smelting phase the feedstock is melted and some tin is volatilized as gaseous tin sulphide due to reaction between the tin and any sulphur contained in the concentrate. However, the bulk of the tin volatilization takes place during the subsequent phases following reaction between the sulphur contained in the sulphidizing agent (pyrrhotite) and the tin in the concentrate.

Oxidizing air is introduced into the gas stream in the upper part of the furnace converting the gaseous tin sulphide to a fine powder of tin oxide which is carried along in a stream of gases including newly formed sulphur dioxide. This gas stream is then cooled in two stages, initially by the injection of water at the top of the furnace and finally by a gas cooling unit involving the generation of steam from the waste heat. Gas temperatures and humidity are carefully controlled to avoid the creation of serious corrosion conditions.

The cooled gas/solid stream then passes through an electrostatic precipitator which collects the tin oxide product leaving the gases to be emitted to the atmosphere. During the volatilization phase a proportion of other impurities present in the feedstock, such as fluorine and arsenic, will enter the gas stream and will eventually report in either the product or the exhaust gases emitted to atmosphere.

During the final phase of the cycle about 75% of the end slag is removed leaving a molten residue in the furnace to facilitate melting of the next charge of feedstock.

Process heat is provided by fuel oil injected into the furnace through specially designed tuyeres.

The distribution of the most significant elements in the product, furnace slag and waste gases is summarised in Table 3.1.

TABLE 3.1

DISTRIBUTION OF TIN, SULPHUR, ARSENIC AND FLUORINE

ELEMENT	PRODUCT/WASTE	ANNUAL QUANTITY OF ELEMENT (Tonnes)
TIN	Slag Product Waste Gas	27 3031 Nil
SULPHUR	Slag Product Waste Gas	808 68 1785
ARSENIC	Slag Product Waste Gas	1.4 67.9 30.0
FLUORINE	Slag Product Waste Gas	13.5 13.6 92.9

The plant will operate on a 24 hour day, 7 day week basis. After allowing for mechanical availability and the inevitable operating delays an average of 1496 batches per year will be processed producing about 4500 tonnes of product and 27,000 tonnes of slag per year. The chemical composition of the slag is given in Table 3.2.

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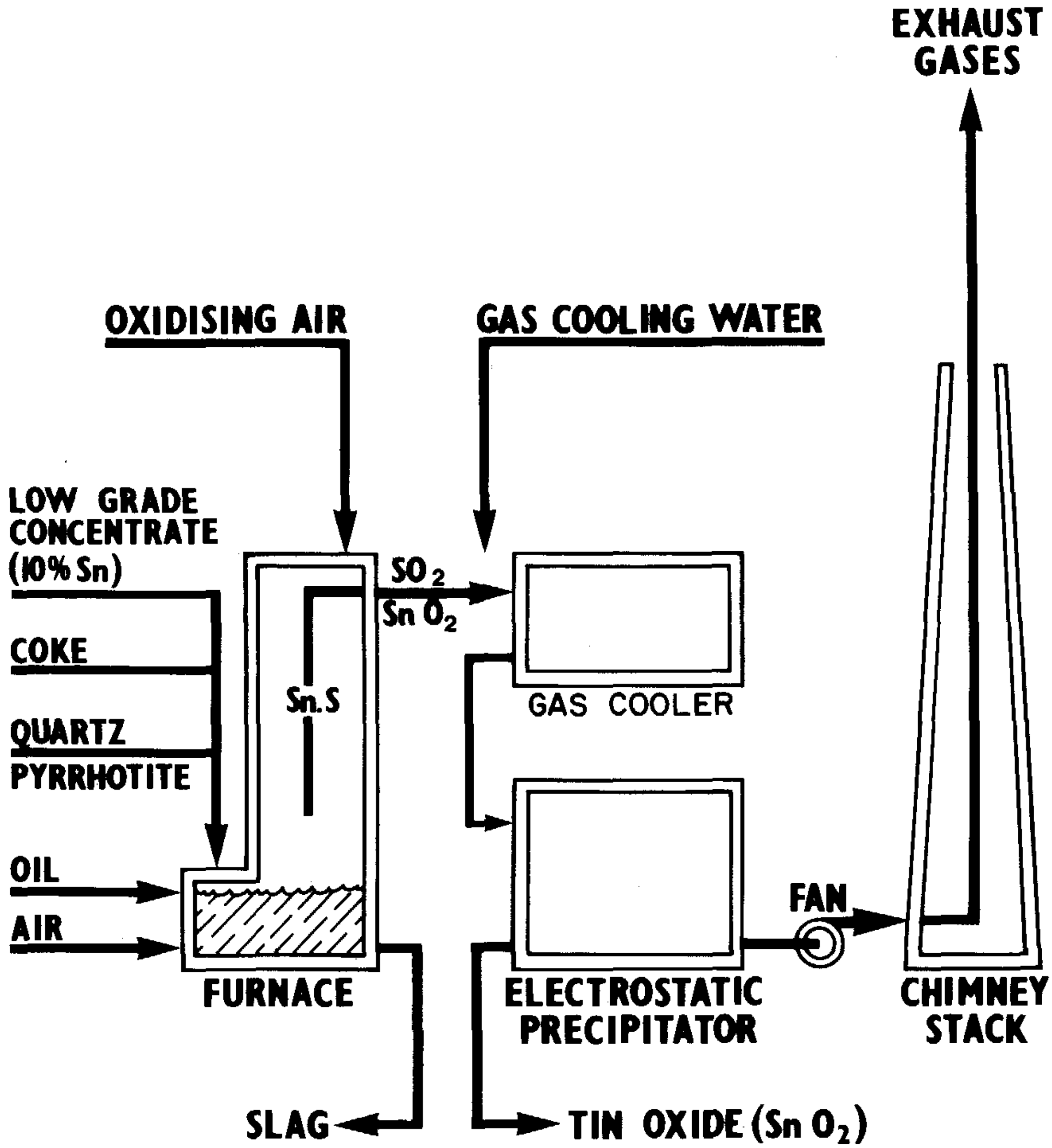


THERMAL UPGRADING PROCESS FIGURE 3·1

TABLE 3.2

SLAG COMPOSITION

Element/Compound	% (by weight)
Sn	0.10
As	0.005
F	< 0.05
S	< 3.00
FeO, Fe_2O_3	40.77
SiO_2	35.73
Al_2O_3	7.71
CaO	1.76
MgO	7.02
MnO	3.33
rest (WO_3 + K_2O + Na_2O)	> 0.53

The waste gas produced will vary over the furnace cycle in both quantity and composition. Examples of the gas volumes and composition at four different sampling times during the furnace cycle of 260 minutes are presented in Table 3.3.

TABLE 3.3

WASTE GAS EMISSIONS

Sampling time (minutes)	120	140	160	240
Volume (Nm^3/h)	42,300	45,440	24,670	24,670
SO_2 (%)	0.37	0.94	1.09	0.37
H_2O (%)	24.01	24.13	22.68	20.59
CO_2 (%)	11.15	10.41	9.36	9.59
N_2 (%)	60.80	60.90	63.28	64.86
O_2 (%)	3.66	3.62	3.59	4.64
F (grams/Nm^3)	0.59	0.55	0.09	0.03
As (grams/Nm^3)	0.15	0.14	0.26	0.03

Detailed examination of sulphur dioxide, fluorine and arsenic emissions is presented in Section 3.4.

3.2 PLANT LAYOUT AND OPERATION

3.2.1 Thermal Upgrading Plant

The proposed plant layout is shown in Figure 3.2 and in Plate 3.1. Low grade concentrate will be pumped from the concentrator as a slurry to a thickener located adjacent to the raw materials storage area. The underflow will then be pumped to filters via a feed tank. The filter cake will be discharged onto belt conveyors and sent either to a covered stockpile or storage bins. Clarified water will be returned to the concentrator for use as process water.

Other raw materials will be stored in bulk on covered concrete slabs (capable of holding more than one week's process requirements) or in storage bins with a minimum capacity of 3 days operating consumption.

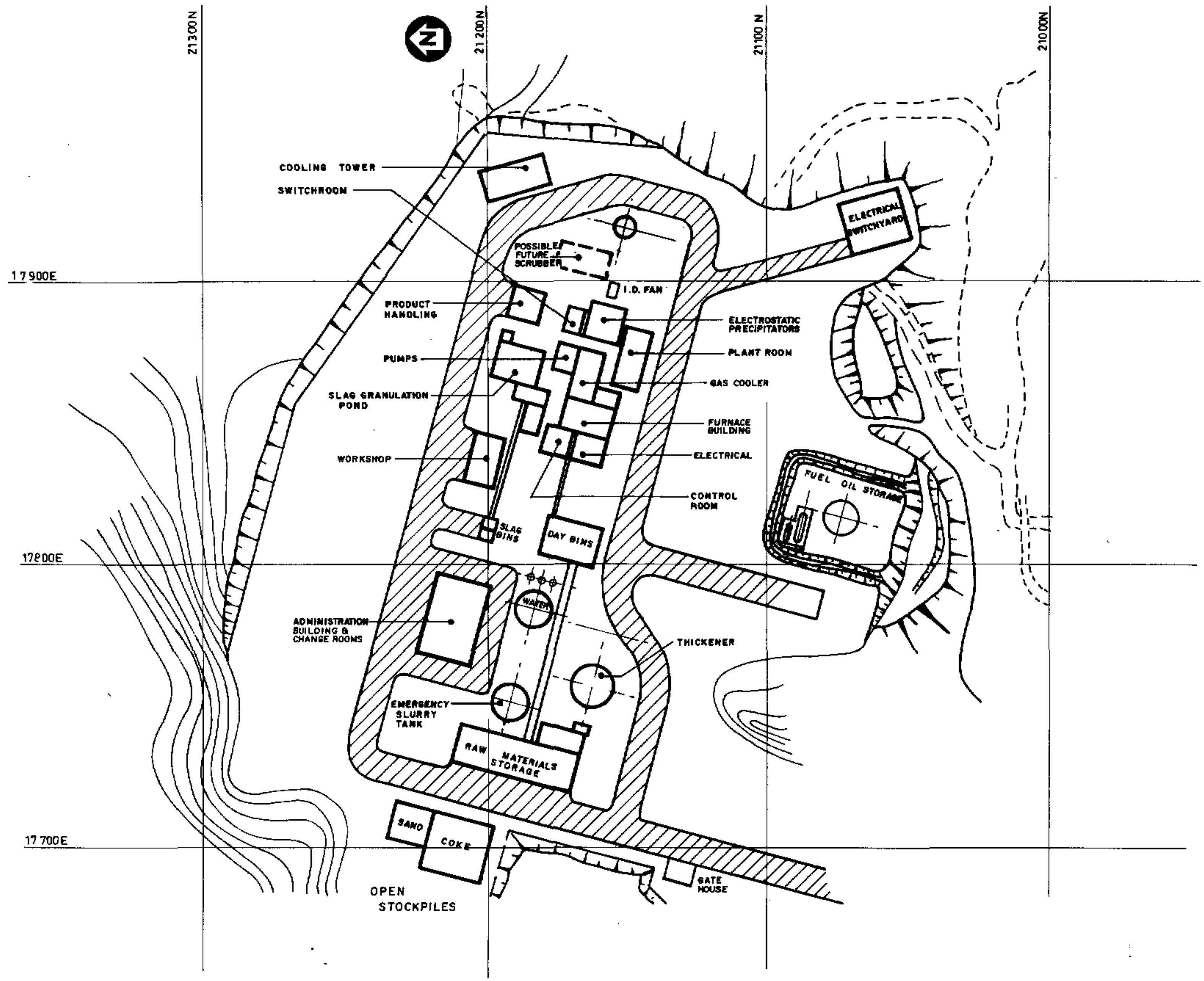
Coke for emergency use will be stored in an open stockpile.

An emergency open stockpile of sand of around 100 tonnes will be provided.

Pyrrhotite will be trucked to a storage slab or day bin from the concentrator.

In addition, day storage bins will be provided for limestone, which may be required as a slagging additive, and for slag (for use during re-firing of the furnace).

Heavy fuel oil will be delivered to a storage tank, from which it will be pumped to an elevated day tank for gravity supply to burner pumps. Both tanks are fitted with steam coils to maintain the oil at 55°C. In addition, a light oil storage tank will be provided. All of these storage tanks will be located remote from the main plant in a suitably bunded area.



PLANT LAYOUT FIGURE 3·2

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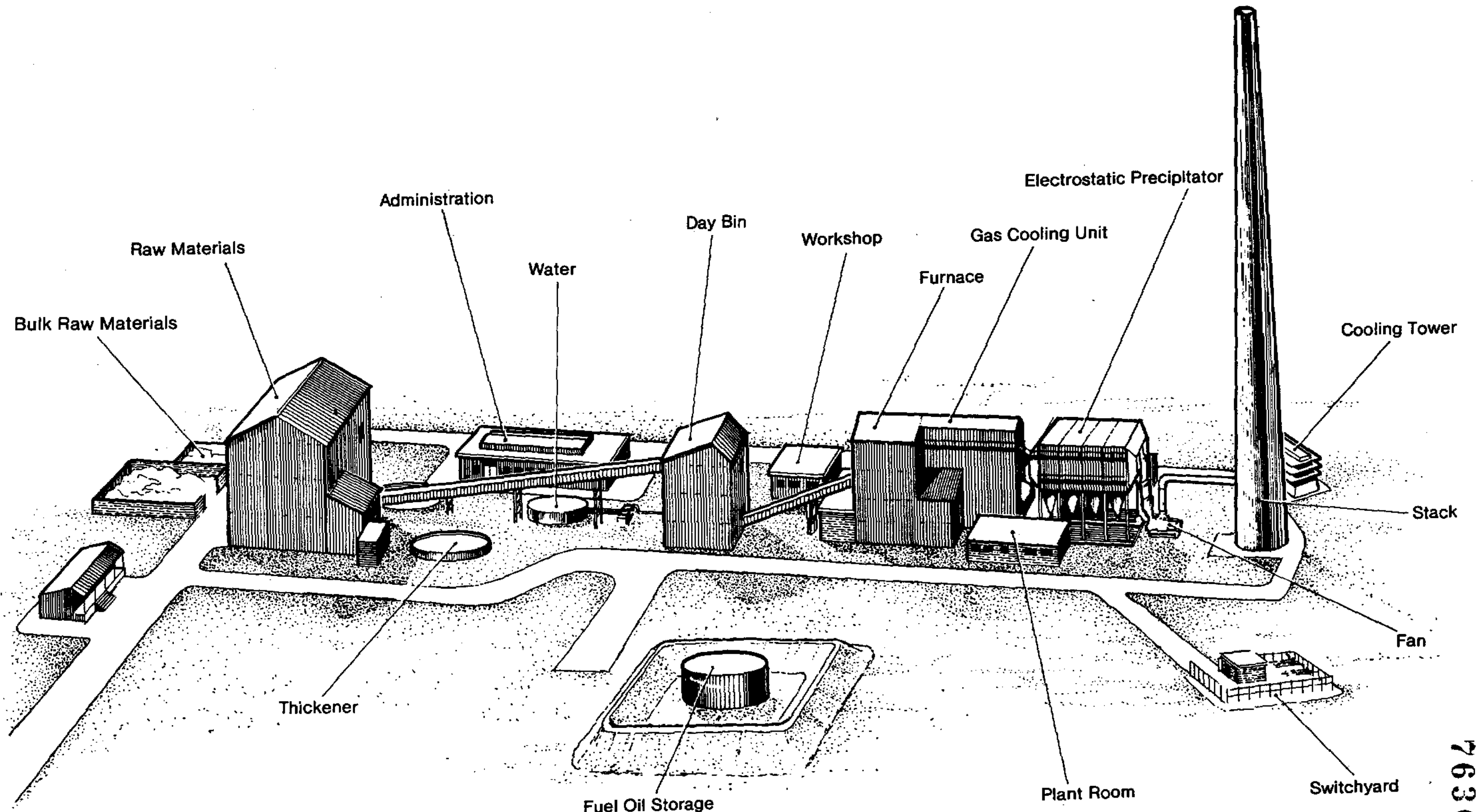

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Plate 3.1 Artists Impression of the Proposed Thermal Upgrading Plant

Furnace feed materials will be extracted from their respective day storage bins via belt weigh feeders and delivered to the furnace at predetermined rates. Prior to charging to the furnace, the feed concentrate will be pelletized by the addition of water in a pelletizing drum.

Steam generated during the process by the gas cooling operation will not be sufficient for economic utilization in turbines. Consequently, the steam not used for primary air preheating and fuel oil heating will be condensed before return to the gas cooling unit. Investigations are still proceeding to ascertain whether more of this heat energy can be economically employed within the process.

Dust accumulating within the waste gas cooling unit will contain iron oxide and silica as well as tin oxide. It will be extracted by a drag-chain conveyor and discharged into a storage bin, from where it will be either returned to the furnace or blended with the product, depending on its tin content.

The cooled gas will then pass through an electrostatic precipitator before emission to the atmosphere via a tall insulated stack. Provision has been made in the plant layout for space to accommodate a future gas scrubbing unit, adjacent to the stack, which would be constructed should the monitoring programme (described in Section 7.5) prove this to be necessary.

The dust collected in the precipitator will be conveyed to a storage bin by drag chain conveyor, pelletized and loaded into "Bulka" bags of 2 tonne capacity for eventual trucking from the site to the port of Burnie.

Slag will be tapped from the furnace at the end of each operating cycle and granulated with water sprays. The inert granulated material will then be sluiced into a collection pit for subsequent disposal and the decanted water from this operation recycled.

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As shown in Figure 3.3 the raw materials storage slabs, day bins and furnace are each enclosed in substantial buildings ranging from about 6 to 9 metres high. A roof structure will be erected over the gas cooling unit leaving the operating platforms partially exposed to the weather. All material handling conveyors will be enclosed against the weather.

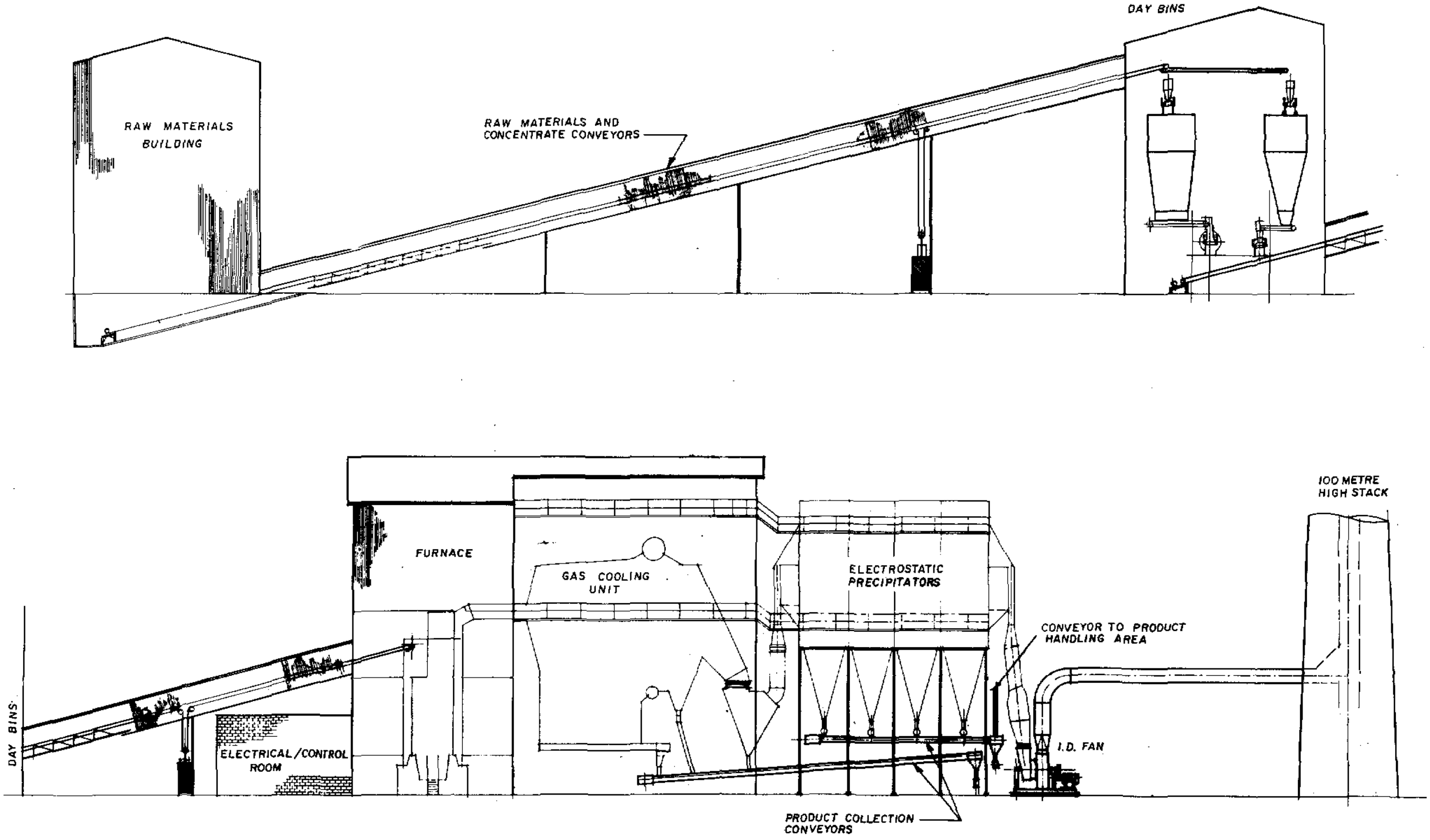
3.2.2 Existing Concentrator

As a consequence of constructing the thermal upgrading plant the existing Concentrator will require modification in order to produce the low grade concentrate to be thermally upgraded. These modifications do not involve any change in existing process technology and will result in a reduced quantity of tailings for disposal. However, changes in concentrate handling will be required as the low grade concentrate will be collected as a slurry and pumped to the Thermal Upgrading Plant. The high grade gravity concentrate will be bagged and handled as at present.

A major change to the operation of the leach plant will also occur. High grade concentrates will continue to be leached, prior to bagging for sale, but the low grade concentrates will be diverted to the thermal upgrading plant. This will result in the usage of sulphuric acid falling from the present rate of over 5,000 tpa to less than 1,000 tpa, and the neutralizing lime requirement will reduce proportionally from over 3,500 tpa.

3.3 FACILITIES AND SERVICES

The proposed thermal upgrading plant will be constructed on the Renison mining lease as an extension to the existing plant and facilities. As a consequence, the existing services and internal roads will be extended to accommodate the new plant.



ELEVATION OF PRINCPAL BUILDINGS FIGURE 3·3

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3.3.1 Site Access

Materials delivered to Renison Bell will normally be delivered by road, via the Bass and Murchison Highways, from Burnie or Devonport on the North West Coast. All product is trucked to Burnie for shipping along the same route.

From the "Port and Rail" area at Burnie, the feeder roads lead almost directly to the Bass Highway. Some 8 km westwards along this Highway, a left-hand turn leads into the Murchison Highway at Somerset. This 8 km stretch runs through a continuously "built-up" area comprising variously residential, commercial and light industry zones.

The route from Devonport to Burnie is also along the Bass Highway, for some 52 km. This road is mostly wide, but heavily trafficked.

The distance from the commencement of the Murchison Highway to Renison Bell is 139 km; this road runs approximately southwards to Tullah, and shortly thereafter veers westwards to Renison. Most of the route is through bushland or pine plantations; the main (but small) townships encountered along the way are Yolla, Tullah and Rosebery.

All of these roads are sealed, mostly to National Highway standards. The Murchison Highway presents a mixture of straight runs and sharp corners (some of which are adequately signposted), and there is a particularly narrow section of twisting road for about 11 km between the hamlets of Oonah and Parrawe as the Highway runs into and out of the Hellyer Gorge.

Internal roads are, in the main, surfaced with a waste material from the concentrating operation and are not bitumen sealed.

3.3.2 Material Supplies

Imported coke will be conveyed from the Burnie Wharves to the site in open containers of approximate capacity 14½ dry tonnes. It will be of nominal size range 5 to 25 mm (maximum of 10% less than 5 mm) and contain about 10% moisture. The coke requirement will be fulfilled by the delivery of one container each day for 5 days per week.

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Fuel oil will be delivered from Devonport in tanker loads at the average rate of 10 tanker loads per week (two per day, 5 days per week).

The low grade tin concentrates to be processed will be pumped to the plant from the existing concentrator via a pipeline as a slurry in water.

Pyrrhotite will be trucked from the concentrator via internal roads.

The thermal upgrading plant product will be transported by road to Burnie wharves in 20 tonne lots (2 tonne Bulka bags by 10 bags per load) together with the high grade concentrates produced by the concentrator. A total of about 10,000 tonnes of combined product will be transported from Renison Bell each year. This comprises a reduction in tonnage of about 25% below the quantity of lower grade concentrates alternatively produced without the thermal upgrading plant.

3.3.3 Power Supplies

Power will be transmitted via a 44 KV overhead line from the switchyard at the mine site to the thermal upgrading plant switchyard where it is transformed to 6.6KV.

The transmission line route, shown in Figure 2.2, will lie within the Renison mining lease. At points where the Murchison Highway and Emu Bay Railway are crossed, clearances approved by the HEC, Department of Main Roads and Emu Bay Railway will be observed.

The thermal upgrading plant will increase Renison's maximum power demand by 3MW and consume about 15 million KWH per year.

3.3.4 Water Supplies

Water will be drawn from the Argent Dam, which has adequate capacity to supply the relatively small requirements of the thermal upgrading process, as well as the supplies to the concentrator. The existing pipeline from this dam to Renison Bell will be adequate.

Raw water will be piped approximately 2km from the concentrator to the new plant site through a 200 mm (approx.) pipeline as shown in Figure 2.2. The process water requirements for the thermal upgrading plant are relatively small. The main water usage will be to make up evaporative cooling losses, plus that continuously supplied for gas cooling and conditioning. Relatively minor quantities of water will be used for feed and product pelletizing and changehouse amenities. The bulk of the cooling and granulation water will be recycled.

Raw water, containing some organic matter and a little hardness, will be used as slag granulation water makeup, firefighting, pelletizing of feed concentrates and product, cooling of the gas stream by injection of water and cooling water supply for condensers. Recirculated cooling water will be treated as required to avoid surface deposition and fouling.

Potable water, produced on-site by sand-filtering raw water, is to be used for changehouse amenities, drinking supplies and as make-up water for gas cooling unit and furnace cooling system. Makeup water to the gas cooling unit and furnace cooling system will also be demineralised.

3.4 WASTE PRODUCTS

3.4.1 Emissions to the Air

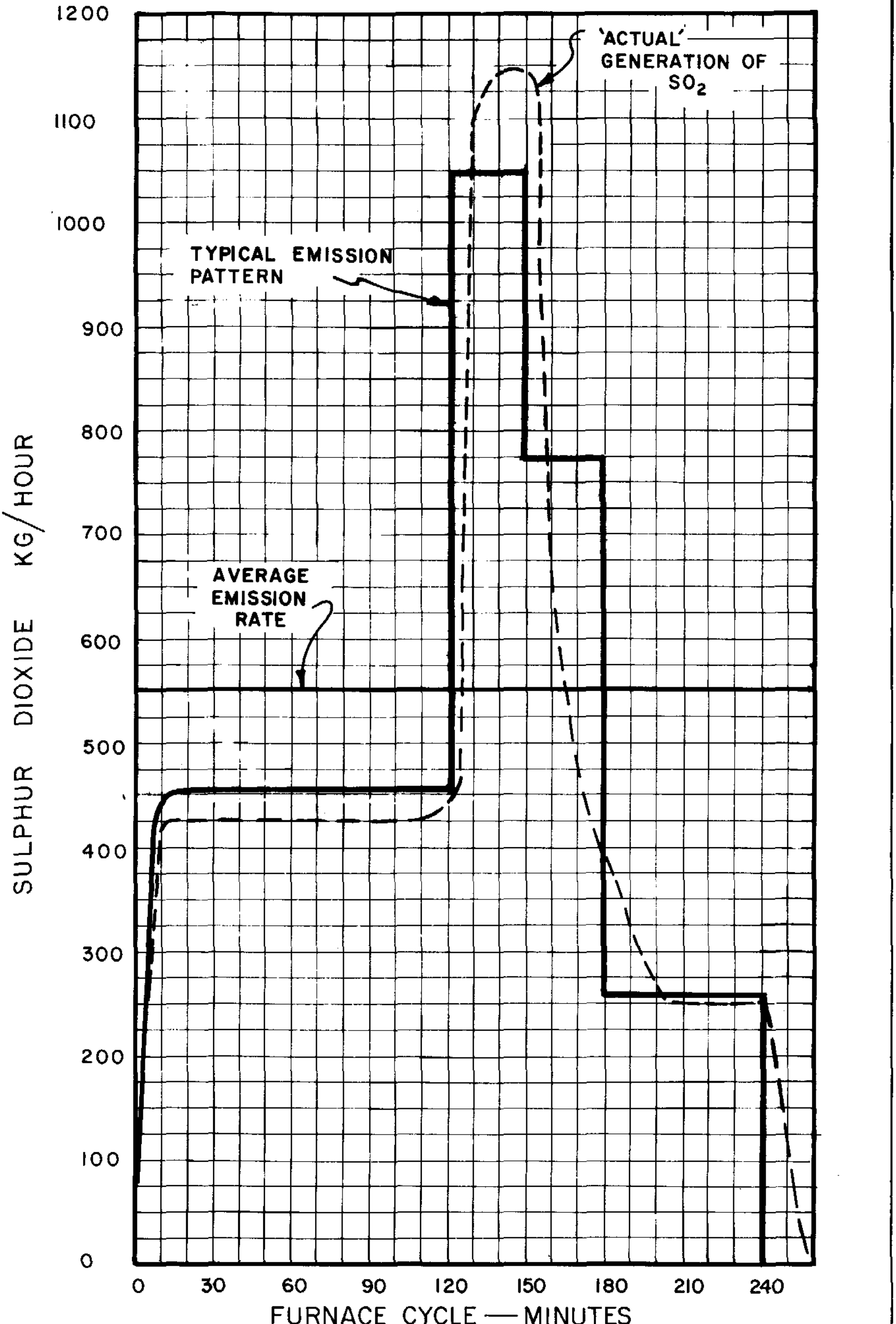
During the thermal upgrading process impurities will be released into the gas stream and carried to the furnace outlet. The volume and the composition of the waste gas will vary during the different stages of the process cycle in a manner shown earlier in Table 3.3. The emissions of residual sulphur dioxide, fluorine and arsenic are considered to be of environmental concern. A detailed analysis of the emission patterns with respect to these three pollutants follows.

First, the emission pattern during the typical furnace cycle is analysed. The peak emission rate of each pollutant over the total cycle period of 260 minutes is identified. Based upon an average number of 1496 cycles expected in one year the average annual emission rate is then determined. Likewise, a mean emission rate per cycle is calculated for the use in the dispersion analysis presented later in Section 5.

Sulphur Dioxide

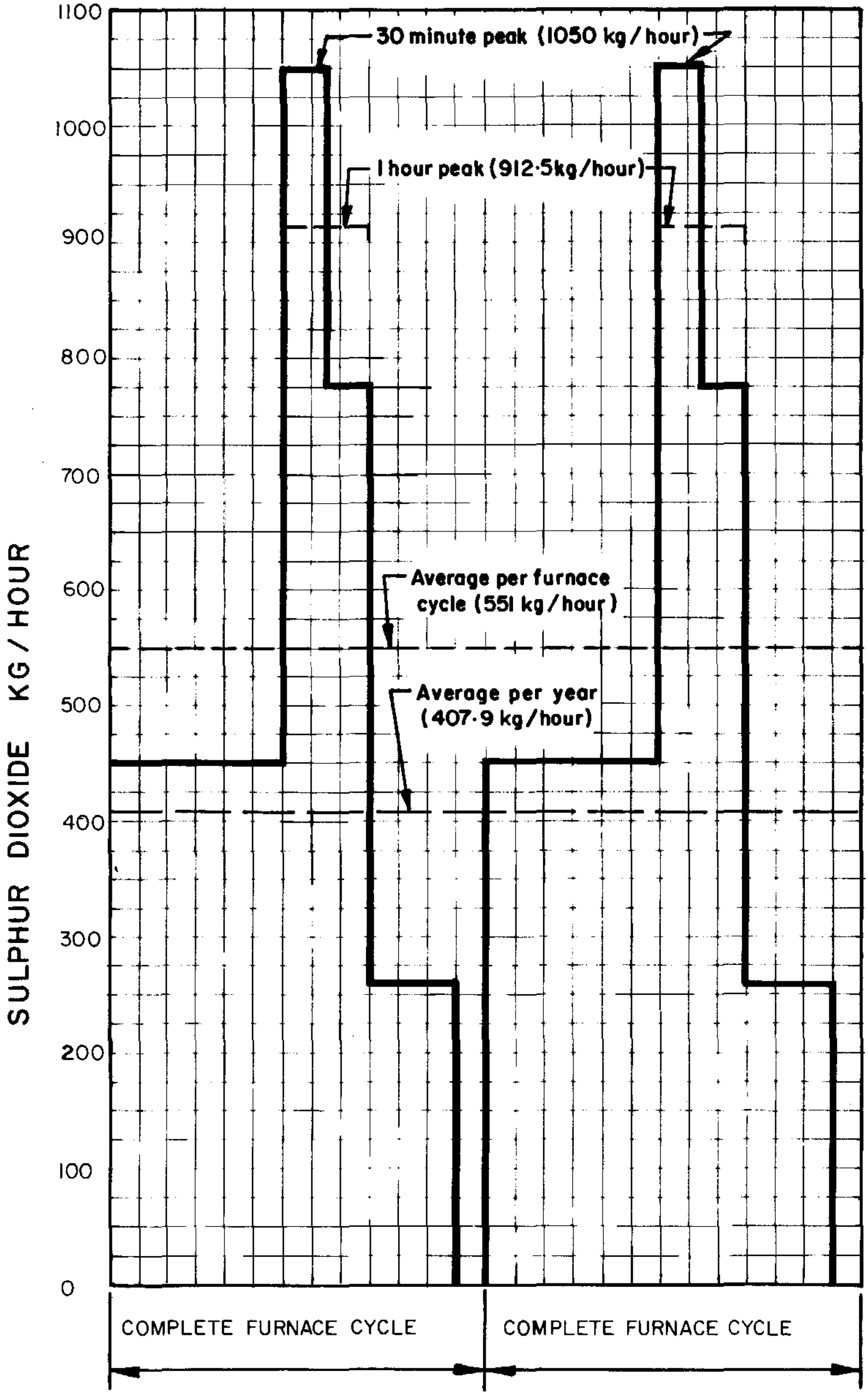
Figure 3.4 shows the typical emission pattern of sulphur dioxide during one furnace cycle. The pattern was obtained by simplifying the theoretical curve of SO_2 generation shown by the broken line.

An average emission rate of 551 kg of sulphur dioxide per hour is indicated with respect to one cycle. The curve expresses the variation in the mass rate of sulphur dioxide released from the furnace and includes the changes in the volume rate and in the concentration of sulphur dioxide in the waste gas. The emission pattern due to multiple cycles is illustrated in Figure 3.5. A 30-minute peak rate of 1050 kg/hour will occur between the 120 and 150 minute mark of each cycle followed by an emission rate of 775 kg/hour lasting for the next 30 minutes giving a 60 minute peak emission rate of 912.5 kg/hour. The variations in the mass rate of sulphur dioxide released from the furnace during the cycle are due to changes in the waste gas volumes and the addition of sulphidizing agent.



MASS RATE OF SULPHUR DIOXIDE EMITTED BY THE FURNACE FOR A SINGLE CYCLE

FIGURE 3·4



MASS RATE OF SULPHUR DIOXIDE EMITTED BY THE FURNACE FOR MULTIPLE CYCLES FIGURE 3·5

The average value of the mass emission rate per year is required to project the long-term effect of sulphur dioxide on the environment in Section 6. The average rate per year was calculated as 407.9 kg/hour.

For comparison, the average emission rates of sulphur dioxide from typical coal-fired power generation plants exceed 2000 kg/hour (Stern, 1977). Large modern power plants emit sulphur dioxide at a constant rate of 8000 kg/hour and more. Similar levels of sulphur dioxide emissions are associated with the operation of large smelters of nonferrous metals.

Fluorine

The variation in the concentration of fluorine in the waste gas is illustrated in Figure 3.6. A peak concentration of 590 mg/Nm^3 will occur in the first 120 minutes of the operating cycle followed by a reduction to 550 mg/Nm^3 for the next 30 minutes. A sharp reduction to below 100 mg/Nm^3 will occur at 150 minutes followed by a more gradual reduction in the fluorine concentrations for the remainder of the cycle.

The corresponding mass rate of fluorine emissions is shown in Figure 3.7 for multiple cycles of the furnace. A constant mass rate of about 25 kg/hour will be experienced for the initial 150 minutes due to a slight increase in waste gas volume between the 120 and 150 minute mark. The average cycle emission rate is 14.4 kg/hour and the average annual emission rate 10.6 kg/hour.

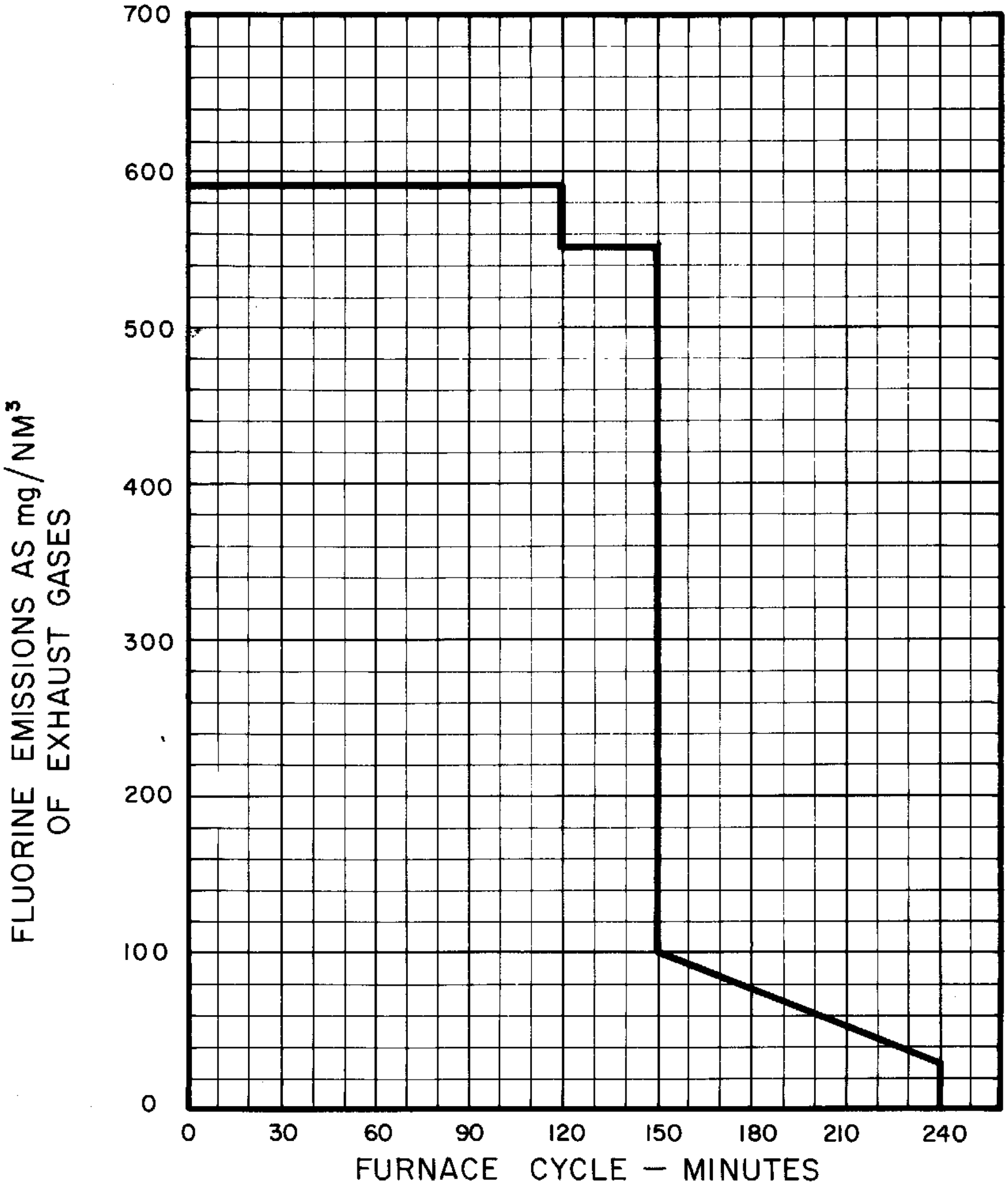
A modern aluminium smelter operation normally results in the emission rate of total fluorine of about two to three times of the annual emission expected at Renison. Owing to the potroom design of aluminium smelters, most of the fluorine emissions are released at the roof level. The design of the thermal upgrading furnace, on the other hand, enables the collection of waste gases and their collective disposal. As a consequence, the environmental effects of fluorine in the vicinity of the thermal upgrading plant can be minimised well below the level indicated by the comparative emission rates.

Arsenic

Figure 3.8 indicates the variation in the concentration of arsenic in the waste gas. The initial concentration of 150 mg/Nm^3 remains unchanged for the first 120 minutes of the cycle and is followed by a slight reduction to 140 mg/Nm^3 during the next 30 minutes. At the 150 minute mark the waste gas volume is reduced substantially and a peak concentration of 260 mg/Nm^3 occurs for the next 30 minutes followed by a sharp reduction to 30 mg/Nm^3. Owing to the variations in waste gas volume over the cycle the mass emission rate of arsenic, shown in Figure 3.9, is expected to remain constant for most of the cycle duration. The peak plateau of 6.4 kg/hour is followed by a sharp drop in arsenic emissions at a later stage of the process. The average emission rate per cycle is 4.63 kg/hour and the average annual emission rate 3.4 kg/hour.

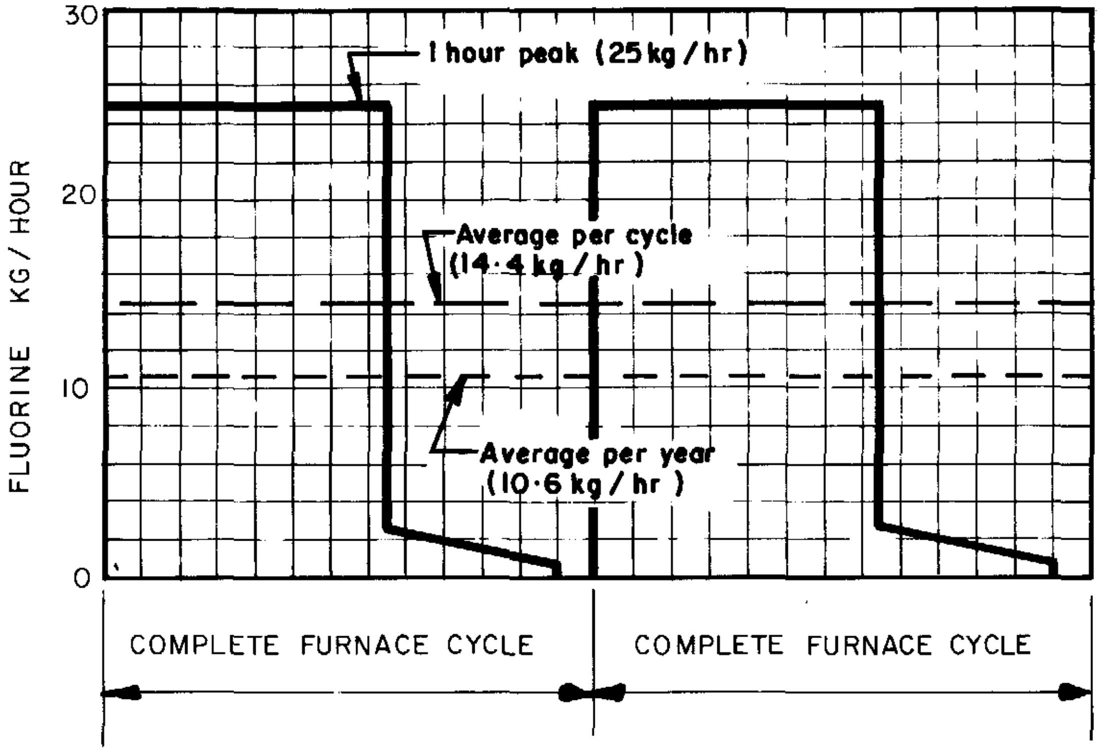
The expected emission rates of arsenic compare very favourably with the emission rates from a number of nonferrous metallurgical operations especially copper smelting (Stern, 1977). Electrolytic copper refining operations were shown to result in typical stack concentrations of about 20 ppm of highly toxic arsine AsH_3 (Stern, 1977).

The arsenic emissions described in this document have been conservatively estimated, by the process Licensor, to amount to 30.2% of the total arsenic in the feed. Table 3.1 presented earlier shows that 1.4% of the arsenic remains in the slag and the remaining 68.4% precipitated with the product. However, while the estimated emissions are acknowledged to be realistic, evidence from other sources indicates that the arsenic contained in the waste gas emissions may prove to be less than 1/5 of that predicted by the Licensor.

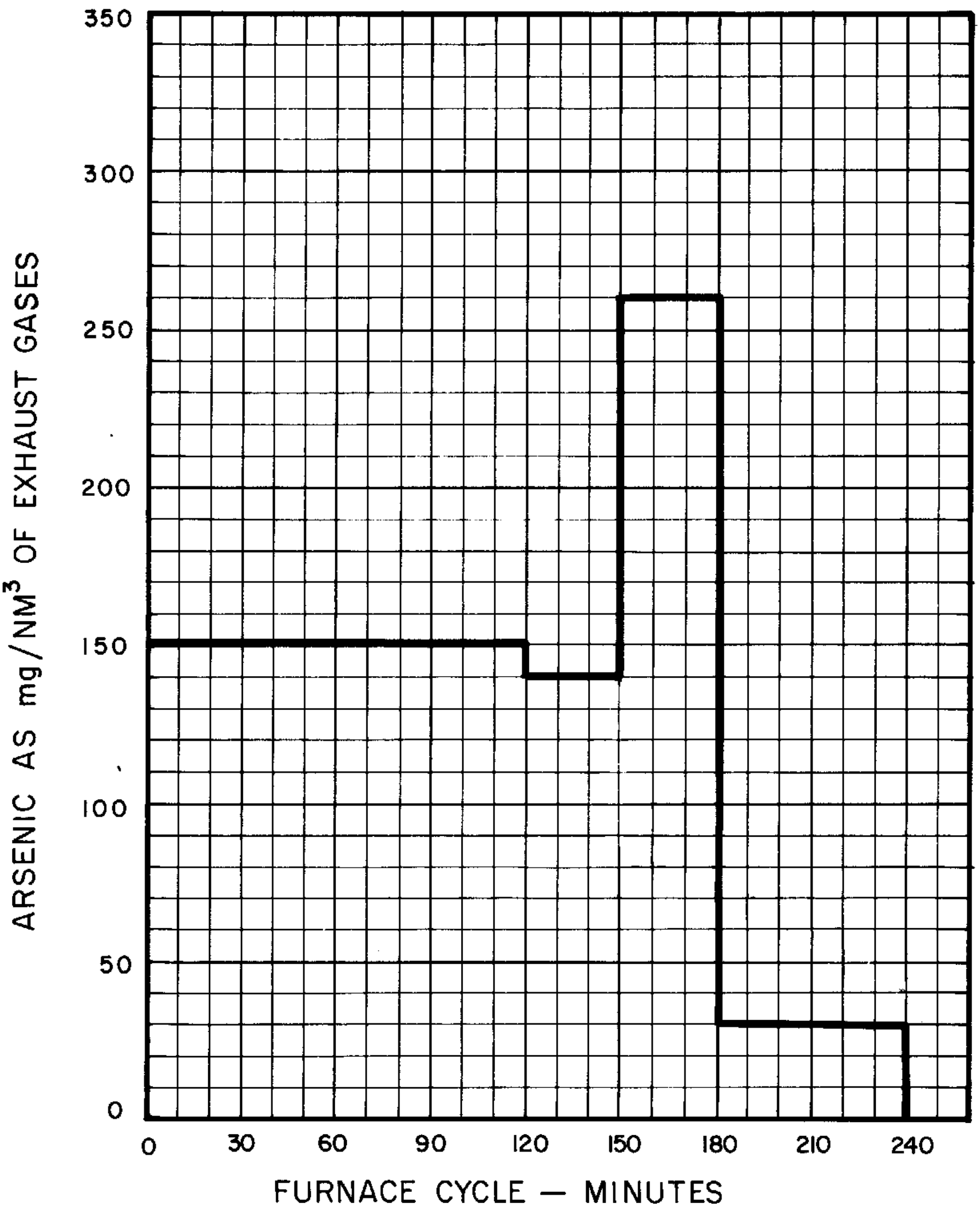


CONCENTRATION OF FLUORINE
IN THE WASTE GAS
FOR A SINGLE CYCLONE

FIGURE 3·6

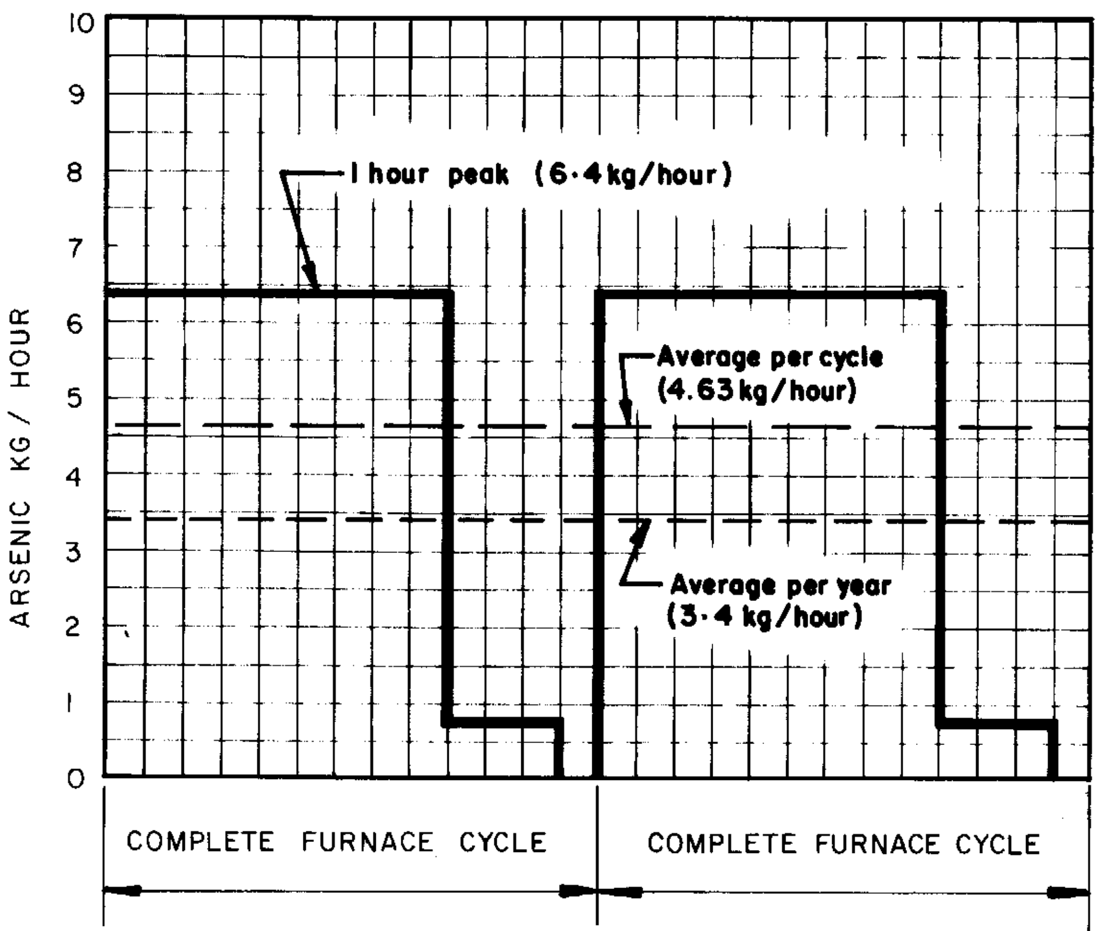


MASS RATE OF FLUORINE
EMITTED BY THE FURNACE
FOR MULTIPLE CYCLES FIGURE 3·7



CONCENTRATION OF ARSENIC
IN THE WASTE GAS
FOR A SINGLE CYCLE

FIGURE 3·8



MASS RATE OF ARSENIC
EMITTED BY THE FURNACE
FOR MULTIPLE CYCLES

FIGURE 3·9

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Dust

Dust may be liberated from the following sources:

- movement of transports along unsealed internal roads,
- windage from raw materials delivery and storage,
- windage or losses from conveyors and transfer points,
- stack emissions.

Dust emissions with the waste gases will be at a very low level - around 3 mg/Nm^3 - and will be carefully monitored to avoid loss of product. Virtually no dust will result from raw materials and product handling during the process.

Water Vapour

Water vapour will be released to the atmosphere from the following sources

- evaporative water coolers,
- slag granulation,
- stack emissions.

Estimates of make-up water requirements indicate that total water vapour emissions will average about 60 tonnes per day from the stack and about 80 tonnes per day from the evaporative water coolers. The water vapour emitted during slag granulation is estimated to be about 36 tonnes per day.

3.4.2 Liquid Effluents

The bulk of the water discharged from the site will be stormwater. However, a small quantity of process wastewater will be generated from raw water treatment, recirculating water bleedoff, washdowns and domestic sources.

Domestic wastewater will be treated in a package sewerage treatment plant prior to disposal.

All stormwater and wastewaters will be channelled to an adjacent settling dam designed to provide a pond large enough for settlement of suspended solids. The total area draining into the proposed settling dam is about 250,000 square metres which will result in an annual rainfall collection of about 600,000 cubic metres of stormwater.

The outflow from this dam will not carry any measurable pollution arising from the thermal upgrading plant operation. However, the outflow will be monitored for quality prior to discharge into the Pieman River.

3.4.3 Solid Waste

The only waste solids from the process will be approximately 100 tonne per day of granulated slag with the composition given in Table 3.2. This slag is environmentally inert, as it is a glassy material comprising mostly oxides of silicon and iron. Trace metals such as tin, zinc, lead, bismuth, arsenic and antimony are held as inert stable oxides within the glassy matrix.

Although this material has a number of potential uses, ranging from permeable fill or mine backfill to road paving, none of these options are likely to be implemented in the short term. As a consequence, it is proposed to stockpile the granulated slag in a cleared and levelled area immediately south of Tailings Dam 'C'. This will permit a stockpile 200m by 300m in plan with a height of less than 0.5m for each years operation. In the event that this stockpile area is utilised for the assumed life of the thermal upgrading (about 20 years) a stockpile height of about 10m will result.

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SECTION 4

DESCRIPTION OF THE EXISTING ENVIRONMENT

TABLE OF CONTENTS

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4.1 TOPOGRAPHY AND GENERAL FEATURES

The proposed site lies in the Argent River Valley, approximately three kilometres from its confluence with the Pieman River. Topography is shown in Figure 4.1.

The surrounding area is marked by considerable variation in relief, with steep slopes and narrow river valleys. In the immediate vicinity of the site relief ranges up to 400m but a maximum height in excess of 1200m is attained 15km to the east. Relief is much more subdued in a small area to the north of the site, between Renison Bell and the Pieman River, and to the southwest, between Commonwealth Hill and Zeehan.

The area in the vicinity of the proposed site comprises mainly tall closed rainforest in the river valleys, with the slopes frequently modified by fire and logging over many decades.

In the immediate surrounds, the Emu Bay railway line to the east is the apparent source of frequent fires that have spread southwards or westwards up the steep slopes of the Pieman River and Ring River valleys, significantly opening out the ground cover where bracken, Acacia scrubland or eucalypt-dominated open forest present a mosaic pattern depending on the fire frequency and the period since the last major fire (Plates 4.1, 4.2, 4.3, 4.4).

Northwards are the Pieman and Huskisson Rivers, beyond which the land is relatively undisturbed, (except by the eastwest Pieman Dam (HEC) road five kilometres to the north of the site) with the valleys and gullies typically supporting tall closed rainforest dominated by myrtle-beech, and the drier ridgelines exhibiting tall emergent eucalypts above a less tall rainforest canopy (Plates 4.5, 4.6, 4.7). Flatter areas with poorly drained acid soils are characterised by low button grass zones (sedgeland).

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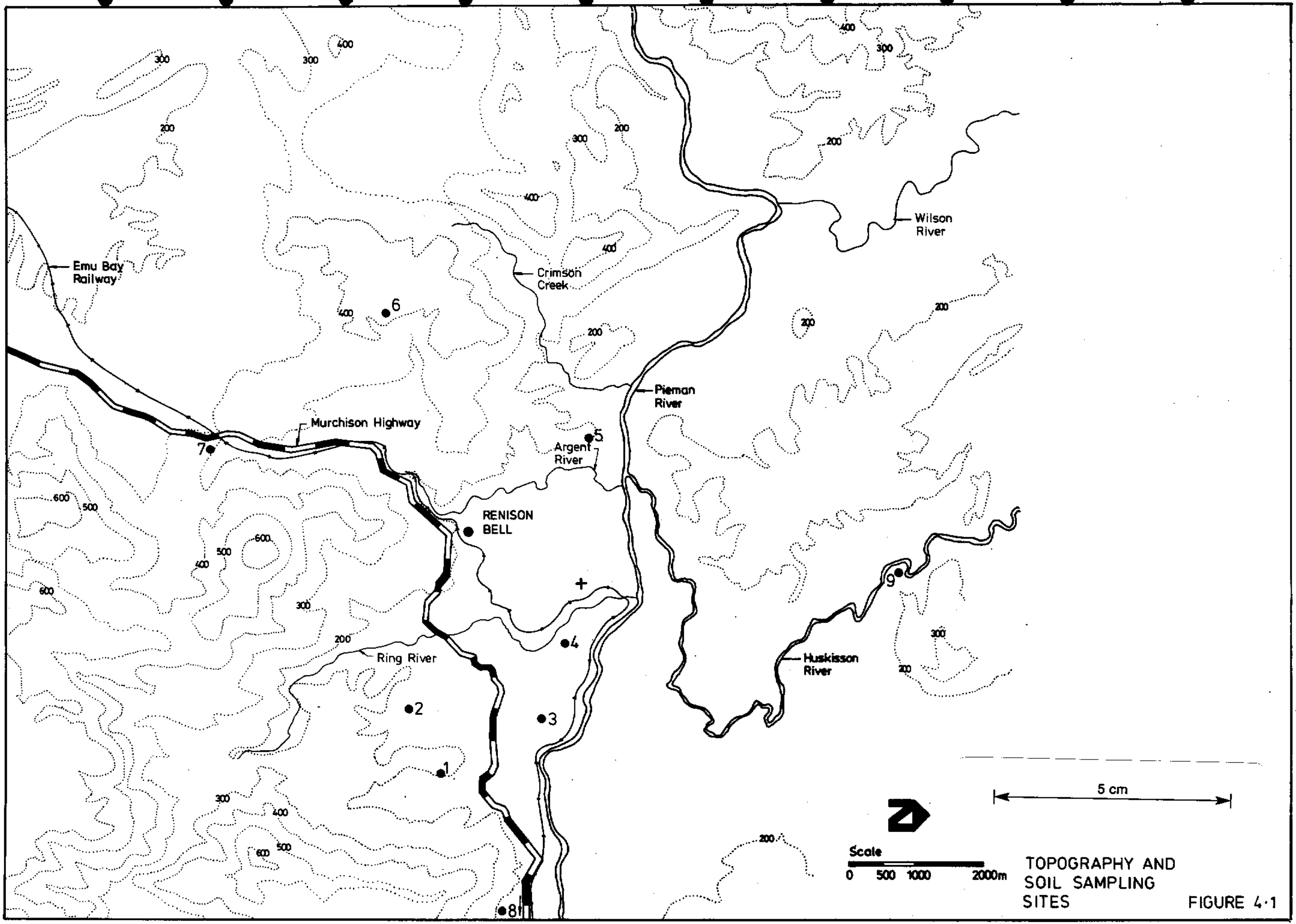
Eastwards in the direction of the mining township of Rosebery, much of the land has been alienated by the construction of the Murchison Highway and by mining exploration tracks cutting to both the north and south of this Highway. This is a mixture of sedgeland, scrubland, open eucalypt forest and regenerating rainforest, with a relatively thin strip of undisturbed rainforest bordering the Highway. The western outskirts of Rosebery (over 6km away) can just be seen, looking eastwards from the edge of the flatland adjacent to the proposed plantsite.

About three kilometres to the south, across the Murchison Highway, is a divergent area of higher ground, with Dreadnought Hill at its northernmost 'apex'. Much of this area was formerly rainforest, but has been severely alienated by frequent fires and intensive surface activity associated with mining and exploration. The Colebrook and Exe Creek valleys, roughly southeast of the site, are mainly tall closed rainforest (Plate 4.8) with some past disturbance shown by patches of regenerating eucalyptus forest (Plate 4.9). Further southwards again, looking towards Montezuma Falls and Godkin Ridge, the country is largely unbroken rainforest, merging into sparser alpine country as the land rises to a series of prominent eastwest ridges (Plate 4.10).

The environment of the lower lands is aggressive with regard to self-rehabilitation, and narrow tracks such as tramways are rapidly overgrown, especially where openings in the canopy are relatively minor. The species Acacia mucronata and A. melanoxylon are especially aggressive in this sense, recolonising to such an extent on more open ground that the boundary zones of mining operating areas need frequent re-clearing to maintain their viability. This former species is also reappearing in the devastated areas around Queenstown (to the south). Miners' huts and even small towns have 'disappeared' into the bushland, to be rediscovered decades later by explorers hacking through dense and apparently undisturbed rainforest.



TOPOGRAPHY AND SOIL SAMPLING SITES

FIGURE 4·1

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Plate 4.1 View North Across the Pieman River

Plate 4.2 Burn From Railway Up Pieman River Bank - View North

Plate 4.3 Burn From Railway Up Pieman River Bank - View Northwest

Plate 4.4 Burn From Railway Up Ring River Bank - View Northeast

Plate 4.6 View Northeast From the Site

Plate 4.5 View North Across the Pieman River From Near the Site

Plate 4.7 Pieman River Crossing at Rapids - View North

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Plate 4.8 Tall Closed Rainforest

Plate 4.9 Disturbed Rainforest Showing Patches of Regenerating Eucalyptus Forest

Plate 4.10 Rainforest

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Fire appears to be the greatest threat to the auto-rehabilitation process. 'Spot' fires are largely contained within very small areas in a closed wetforest ecosystem, and as with man made tracks the damage is rapidly repaired. However, with increased fire frequency, nutrients are reduced, the canopy is opened up, the forest floor dries out, the ground species are exposed to excessive light and the environment becomes unsuited to the regeneration of most rainforest species. Fire requiring species intrude. Such areas revert to open-forest (eucalypt), scrubland (tea-tree or wattle) or bracken, in increasing order of fire frequency.

The ecosystem of the highlands is much more sensitive to damage, and rehabilitation is slow, mainly because of the harsher climate, more exposed situation and thinner and poorer soils.

4.2 GEOLOGY

The area in the immediate vicinity of the site is comprised mainly of Tertiary gravels (predominantly glacial) with zones of undifferentiated Middle Cambrian argillites and tuffs. This general structure extends east and west to northwest along the line of the Pieman River Valley.

In the Colebrook Creek - Exe Creek area to the southeast Upper Cambrian fossiliferous shales and mudstones, cut by occasional narrow (mainly south-north) bands of intrusives such as Upper Cambrian serpentinites, occur.

To the north of the Pieman River, extensive areas of Tertiary gravels are interspersed with more limited zones of Upper Cambrian shales and mudstones and Upper Cambrian serpentinites.

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West and southwest of the plant site, towards Crimson Creek, there are relatively large zones of Lower Cambrian sandstones and shales, and some siltstones.

To the south, in the Dreadnought Hill area, argillites, cherts and conglomerates, carbonates, shales, sandstones and siltstones occur.

4.3 SOILS

4.3.1 Introduction

A sampling programme has been initiated in order to monitor possible changes in pH or accumulations of arsenic, sulphate or fluorides in soils in the vicinity of the proposal. This section describes the sampling procedure and the sites sampled, the methods by which the samples were analysed and the results of the analyses. Conclusions concerning the ambient concentrations of these substances are drawn.

4.3.2 The Sampling Procedure

Ten soil samples were collected from 9 sites shown in Figure 4.1. The criteria considered in the selection of sites included provision of a reasonable distribution of sites around the proposal and representation of the major vegetation communities and the major soil types as inferred from the surface geology. In practice accessibility also proved a factor in site selection.

Samples were collected from the surface at each site with a further sample taken from 10 to 20cm depth at site 4.

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4.3.3 The Sampling Sites

Table 4.1 shows the characteristics of each of the 9 sites shown in Figure 4.1.

TABLE 4.1

CHARACTERISTICS OF THE SOIL SAMPLING SITES

Site	Vegetation Community	Soil Parent Material
1	Nothofagus forest	Crimson Creek Formation
2	Eucalypt forest	Serpentinite & pyroxenite
3	Sedgeland heath	Moraine
4	Eucalypt forest	Moraine
5	Nothofagus forest	Fluvioglacial & lacustrine deposits
6	Nothofagus forest	Oonah Quartzites
7	Woody heath	Serpentinite & pyroxenite
8	Eucalypt scrub	Volcanics
9	Nothofagus forest	Conglomerate/limestone

4.3.4 Soil Analysis Methods

Saturated extracts of samples were analysed for pH, sulphate and arsenic. Soil pH was measured by calibrated meter. Sulphate was determined gravimetrically and arsenic by atomic absorption spectrophotometry. Fluoride was determined as total Fluoride by the fusion method of McQuaker and Gurney (1977).

4.3.5 Analysis Results

Table 4.2 presents the results of the analyses.

TABLE 4.2

SOIL ANALYSIS RESULTS

Site	Sample Depth (cm)	Saturated Moisture Content (%)	pH (sat)	Sulphate	Arsenic	Fluoride
				μg/g	μg/g x 10^{-3}	μg/g
1	0-10	60.78	3.93	213	6.7	108
2	0-10	86.81	5.59	104	19.1	132
3	0-15	389.90*	4.29	19	35.1	176
4	0-10	66.16	4.84	218	23.2	164
4	10-20	70.97	4.95	70	5.7	324
5	0-15	94.65	4.01	93	4.7	172
6	0-10	76.36	4.26	108	6.1	96
7	0-20	73.35	5.40	98	2.9	191
8	0-15	39.73	4.57	192	5.2	432
9	0-10	53.54	3.67	100	3.7	119

Oven dry basis.

* An organic soil will retain 2 to 4 times its dry weight of moisture (**Brady, 1974**).

i. pH

In keeping with the high average rainfall of the region all samples are strongly acid. On sites that are freely drained this indicates the leaching of bases from soil profiles, while on poorly drained, boggy sites it is caused by the accumulation and decay of organic material under predominantly anaerobic conditions. Nutrient stress due to the relative unavailability of elements such as nitrogen and phosphorus at such low soil pH may be a characteristic of the soils and vegetation communities of the region.

ii. Sulphates

Sulphate concentrations are low. The major factors limiting the accumulation of sulphate are the high average rainfall and solubility of the sulphate ion which lead to the leaching of water soluble sulphate from the soil. Appreciable amounts of sulphate can be adsorbed on soil colloids however, contributing greatly to sulphate retention. The adsorption capacity of soils varies considerably, being primarily dependent on the pH, clay content and nature of clay minerals. Sulphate adsorption is greater in soils which have low pH and are high in iron and aluminium oxides. It is readily reversible, the amount of sulphate adsorbed being dependent also on the concentration of sulphate in solution. The major natural source of soil sulphate in the area is through the biochemical mineralization of organic sulphur by aerobic bacteria. The very low value determined at site 3 is symptomatic of an anaerobic environment typical in the acid peat soil sampled. Under these anaerobic conditions soil sulphate tends to be biochemically reduced to the lower oxidation state hydrogen sulphide (H_2S).

iii. Arsenic

Water soluble arsenic levels are low. Arsenic demonstrates a very similar chemical behaviour in soils to that of phosphorus (**Haan and Zwerman, 1976**). As such, most of the arsenic content in soils is immobilised, being either adsorbed on the oxides and hydroxides of aluminium and iron and on clay minerals or precipitated as aluminium or iron arsenates. Because of this strong fixation arsenic accumulation is usually confined to the top 10 cm of the soil profile and only a minute fraction remains soluble, moving with leaching water at very low concentrations.

iv. Fluoride

Total fluoride levels are moderate to low for the soil types of the area. The major natural factors determining total fluoride content are the nature of the soil parent material and the extent of weathering of soil minerals. Significant non-natural sources can include superphosphate fertilisers which are generally 1-3 percent fluoride, insecticides and industrial atmosphere emissions, however these are unlikely to be significant contributors to the present levels found in the soils of this area.

Soil fluoride occurs in a range of forms. A small proportion is water soluble, usually in concentrations of less than 3 μg/g. In this form it is highly mobile, being available to plants or readily leached from the soil profile to groundwaters. Larsen and Widdowson (1971) found that for any pH there appeared to be an upper limit to the solubility of soil fluoride and that this limit was lowest at a pH of 6.

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Fluoride is also adsorbed by soil material, the degree of adsoprtion being dependent on the clay content, amorphous aluminium content and soil pH. The amount adsorbed is also dependent on the concentration of fluoride and other anions in solution. The adsorption process is readily reversible and a lowering in the concentration of soluble fluoride in the soil solution will lead to replacement by desorption. Larsen and Widdowson, using a resin extraction method, found that for 100 U.K. soils the labile soil fluoride levels were fairly evenly distributed around a mean of approximately 20 μg/g. Omueti and Jones (1977) found fluoride adsorption was strongly pH dependent with maximum adsorption occurring between pH 5.5 and 6.5.

The third and usually major pool of soil fluoride is that chemically bound in soil minerals. This form is relatively inert, being released very slowly through chemical weathering. The clay minerals muscovite, biotite and hornblende are major sources of soil fluoride (**Robinson and Edgington, 1946**), and in general soils with a high clay content exhibit much higher concentrations of total fluoride than sandy soils.

4.4 HYDROLOGY

4.4.1 Drainage Patterns

The main watercourse in the district is the Pieman River, which flows east to west past the plant site and immediately to the north of it.

The Murchison and Mackintosh Rivers combine at a point near Tullah to become the Pieman River. As the Pieman flows towards the sea, it is fed, in turn, by the Huskisson, Wilson, Stanley, White, Savage and Donaldson Rivers, as well as by many lesser streams.

In the near area under investigation, the Ring River flows into the Pieman from the south at a point near the proposed plant site. This watercourse receives runoff and clarified overflow water from Renison's tails dam 'B', 'anti-pollution' catch-all dam and 'crusher' dams.

Less than two kilometres downstream the Argent River enters the Pieman from the south and the Huskisson River enters from the north. The impoundment of the Argent River near Renison Bell provides the water supply for Renison and also for the proposed plant. Between the dam and its confluence with the Pieman River, the Argent River receives runoff water from abandoned mine workings, and from tailings areas 'A' and 'C'.

The Pieman River is gauged at a point above the Heemskirk River, 17 km west of Renison. Records are available from 1955 to the present. The average annual monthly flow is 135 cumecs, with the instantaneous range being from 4.5 cumecs to 2619 cumecs.

4.4.2 Surface Water Quality

Two sets of data are available for assessment of the quality of the waters of the streams and rivers in the region.

One set gives hitherto unpublished analytical results of up to 15 individual spot samples taken at random times since 1974 from the Mackintosh, Murchison, Pieman and Ring Rivers. These were not related to one another, or to relative flowrates, and are listed in Table 4.3 in terms of concentration ranges to provide an 'order of magnitude' determination of existing contaminant levels.

TABLE 4.3
SURFACE WATER ANALYTICAL RESULTS

Mackintosh River at Highway Crossing	pH	mg/L									
		Ca	Na	Zn	Cl	Mn	Cu	SO_4	Mg	TDS	F
Prior to damming	4.2-7.0	1.4-9.0	2-5	0-0.4	10	Nil	Nil	0-3	1	40-85	0.3
After damming (low-flow)	-	10-27	8	0-0.4	10	Nil	Nil	24-32	4-10	140-180	0.3

Murchison River at Highway Crossing	pH	mg/L									
		Ca	Na	Zn	Cl	Mn	Cu	SO_4	Mg	TDS	F
	4.1-6.9	0.6-2.5	2-4	0.1	5-11	0.1	Nil	0-2	0.5-1.7	37-70	0.3

Pieman River	pH	mg/L									
		Ca	Na	Zn	Cl	Mn	Cu	SO_4	Mg	TDS	F
At Rosebery, prior to damming Mackintosh	4.5-5.7	2-5	-	0.1	6-11	0.1	-	2-8	0.7-1.2	50-70	<0.3-0.3
At Rosebery after damming Mackintosh (one result only)	6.8	13	-	-	-	-	-	36	3	110	-
At the crossing downstream from Renison	4.3-5.4	3-6	4-7	0.1-0.3	7-11	0.1	-	2-10	1.5-2.0	60-90	0.3

Ring River at Highway Crossing	pH	mg/L									
		Ca	Na	Zn	Cl	Mn	Cu	SO_4	Mg	TDS	F
	3.7-6.3	2-4	5-8	3-8	-	1-2	to 0.1	20-40	2-3	70-120	0.3

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The second set of results is derived from a survey of the Ring, Argent and Pieman Rivers, conducted on 19th April, 1979. Twenty-one sampling points were defined, and analyses were carried out for Fe, Mn, Cu, Zn, Na, Ca, Mg, Cl, SO_4 and As. The purpose of this investigation was to derive the contribution of Renison concentrator effluents to the contaminant load of the watercourses in the area.

Results are given in Table 4.4, and the sampling points are illustrated in Figure 4.2. The 'base' Pieman River water quality is indicated by sample No. 16. The effect of the entry of the Ring River (which carries some of the Renison wastewater) into the Pieman was to increase the concentration of iron (0.5-1.0 mg/L), of manganese (less than 0.5 to 0.5 mg/L), of copper (less than 0.02 to 0.2 mg/L), of zinc (0.20 to 0.60 mg/L) and (marginally) of sulphate (14 to 19 mg/L). The entry of the Argent River into the Pieman increased the concentration of iron (to 2.0 mg/L), of calcium (from 8 to 12 mg/L), of magnesium (from 3.6 to 5.2 mg/L) and of sulphate (to 38 mg/L).

During this survey, the flowrates of the various streams were estimated from some values supplied by the Hydro-Electric Commission, relative catchment areas and mass balances. The catchment areas used to allocate flowrates were:-

Mackintosh	22%
Murchison	33%
Ring	2%
Argent	2%
Huskisson	22%
Wilson	12%
Stanley	3%
Small Streams	4%
Pieman at Heemskirk	100%

TABLE 4.4

SURFACE WATER ANALYTICAL RESULTS (mg/L) - 19TH APRIL 1979

SAMPLE NO.	SPL. TIME	FLOW L/MIN	Fe	Mn	Cu	Zn	Na	Ca	Mg	Cl	SO_4	As
1	1300		1.0	<0.5	<0.02	0.03	8.8	3.5	4.2	12.4	5	
2	1300		9.0	<0.5	0.02	0.19	8.5	3.5	5.7	12.4	31	
3	1400		20.0	2.0	<0.02	0.15	18.0	68.0	26.0	15.2	250	0.17
4	1400		0.5	0.5	<0.02	0.52	5.8	8.0	3.6	6.5	17	
5	1400		2.0	0.5	<0.02	0.54	6.1	12.0	5.2	7.5	38	0.02
6A	1400		7.5	7.5	<0.02	0.08	32.5	280.0	92.0	19.5	1053	
7	1100		1.5	2.0	0.08	7.70	11.0	8.0	7.0	11.2	47	0.01
8	1200		2.5	2.0	0.08	6.80	11.3	16.0	13.0	12.2	66	
9	1200		5.0	2.5	0.06	6.00	14.3	30.0	20.0	13.0	119	
10	1130		26.0	8.0	<0.02	0.10	29.0	142.0	72.0	24.8	614	
11	1100	710	3.0	7.0	<0.02	0.07	26.6	146.0	54.0	22.4	570	0.04
12	1100		445.0	26.5	0.08	0.76	18.0	98.0	122.0	24.4	1715	
13	1100	1510	3.5	5.0	0.02	0.11	20.1	85.0	54.0	24.0	294	0.14
14	1200	56	14.5	5.0	0.03	0.04	53.3	480.0	96.0	33.0	1632	0.11
15	1200		3.5	2.5	0.04	6.30	12.5	30.0	15.0	14.0	90	0.01
16	1200		0.5	<0.5	<0.02	0.20	6.3	8.0	3.6	8.2	14	0.01
17E	1200		1.0	0.5	0.02	0.60	7.0	8.5	4.0	8.7	19	
17F	1300	500	0.5	1.0	<0.02	0.01	65.5	585.0	103.0	47	1743	0.63
18	1300		300.0	24.0	0.05	0.15	29.4	365.0	62.0	12.2	2381	
19	1300		16.0	13.0	<0.02	0.04	33.8	243.0	68.0	21.8	943	
20	1300		115.0	35.0	<0.02	0.21	23.6	262.0	73.0	17.6	1766	

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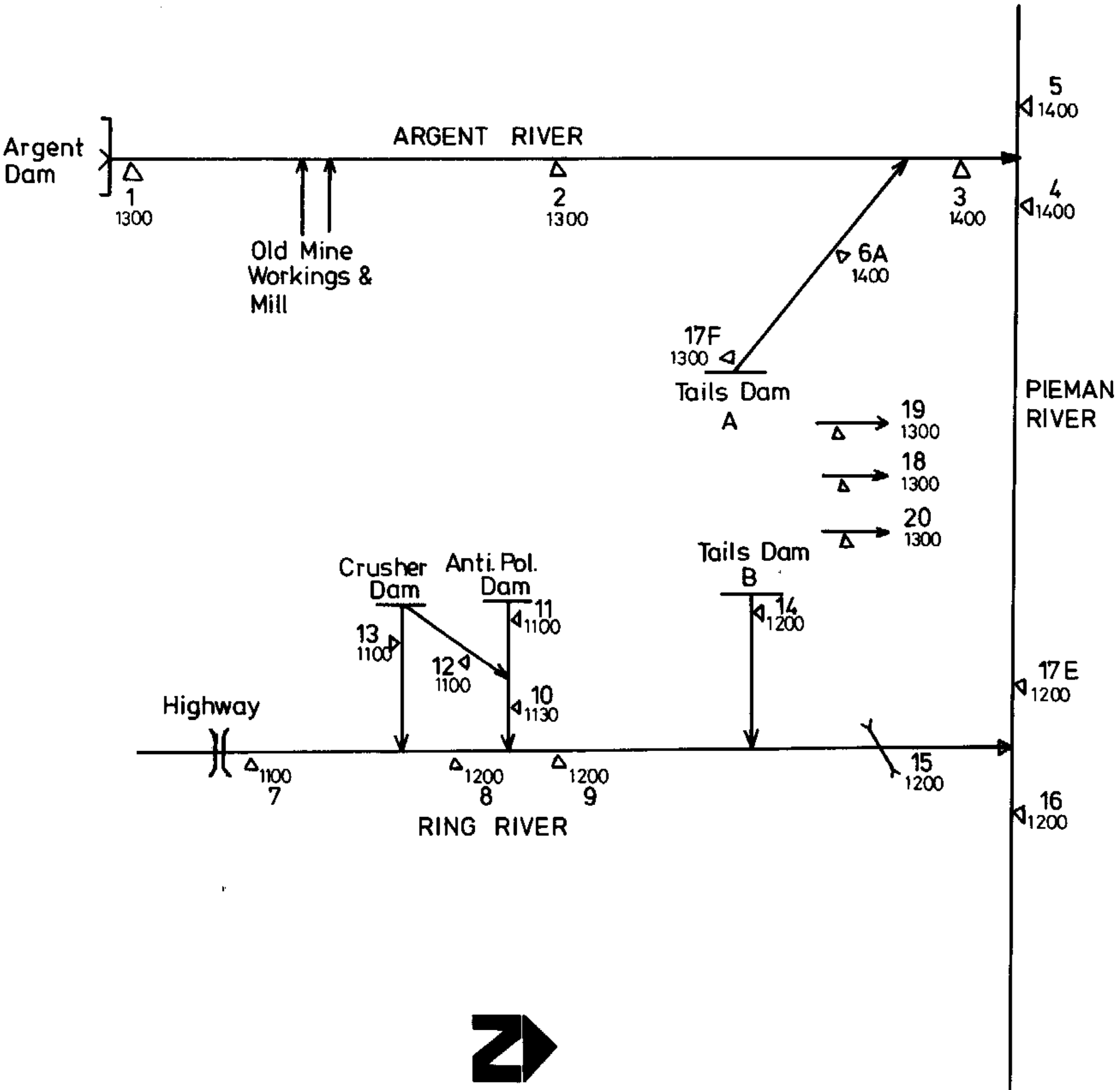

WATER SAMPLING POINTS AND TIMES

FIGURE 4·2

The Murchison River flowrate was given as 7 cumecs during the period. The Pieman flowrate downstream from Renison (at the Argent Road crossing) would have been approximately 12.4 cumecs, that for the Argent River about 0.9 cumecs (including Renison discharges) and that for the Ring River about 0.3 cumecs (also including Renison discharges). The Pieman River flowrate upstream of Renison was estimated at 11.2 cumecs, and downstream near Heemskirk at around 26 cumecs.

To summarise these two sets of data, it is apparent that the general rivers system is one of low contamination by heavy metals, fluoride and arsenic. Sulphate is present, stemming both from current operations at Rosebery and Renison, and from the leaching of oxidised sulphidic ores exposed by (mostly abandoned) mining operations carried out in the district over many decades. The waters generally tend towards acidity due to sulphate contamination and also due to the leaching of organic acids from the peaty soils near the sources of many of the streams. This acidic tendency is common to most Tasmanian West Coast surface waters. Flowrates are extremely variable, and at times of low flow (for example, when the survey was carried out) overall contamination levels would be relatively large. It is notable that the Pieman River water quality is changing subsequent to the damming of the Mackintosh River, and will change again as segments of the Pieman River hydro-electric scheme are phased in. The Pieman River will become a narrow lake at the conclusion of this scheme, and the final quality of the ponded water may not be predicted with any confidence.

Clarified tailings from the Renison settling dams overflow to the river system at a typical flowrate of 2 to 3 kL/min. Routine weekly analysis of these effluents has been carried out for some years. Table 4.5 shows typical analyses of effluent prior to the installation of the acid leaching plant at the concentrator in 1977 and after the leach plant was fully operational.

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TABLE 4.5

TYPICAL ANALYSES OF RENISON SETTLING DAM EFFLUENTS

(mg/L)

	pH	Solids	As	F	Cl	SO_4	Fe	Mn	Cu	Zn	Pb	Ca
(a)	4	15	0.1	5	20	900	60	15	0.1	0.5	0.02	300
(b)	4.5	10	0.01	7	20	1500	6	8	0.1	0.5	0.02	400

(a) Prior to the installation of the acid leaching plant at the concentrator in 1977.
(b) After rate of addition of neutralising lime established and the tailings dam conditions stabilised.

A possible effect of a significant reduction in leach plant operation might be to reduce the sulphate in the wastewater, but at the same time to increase the iron and manganese concentration at the tailings dam overflow.

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4.5 CLIMATIC ASPECTS

Meteorological parameters are currently being continuously monitored at a position close to the site (on 'B' dam wall Latitude S41° 46' 57.75" Longitude E145° 26' 29.44") by a mechanical weather station. The station has been recording wind speed and direction, ambient air temperature, relative humidity and precipitation continuously since September 1981. The data available to date are presented in Appendix 1. The brief duration of the monitoring programme does not allow the derivation of long-term averages as yet. Historical data available from the Bureau of Meteorology were used to document the climatalogical aspects of the region. The site specific measurements at Renison Bell confirm the regional characteristics particularly the dominance of southwesterly winds at the site. The measurements provide not only a site specific information but also a greater degree of detail and accuracy than the historical data on the regional basis. As a consequence, the Bureau of Meteorology has adopted the results of the monitoring as regional indicators. The role of the meteorological monitoring in the overall monitoring programme will be discussed in Section 7.

Rainfall

The Bureau of Meteorology has reported rainfall at Renison Bell on a monthly basis. From these records, a summary of average, highest and lowest rainfall for each month over the period 1911 to 1981 is given in Table 4.6.

TABLE 4.6

RAINFALL, RENISON BELL, 1911-1981

(mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Average	127	94	135	198	215	223	249	242	228	195	177	150	2252
High	409	251	293	389	594	399	536	518	479	373	384	361	2939
Low	14	11	46	6	47	55	64	92	78	75	62	25	1825

The most readily accessible data on short term rainfall is from the pluviograph site at Queenstown. For a 1 in 10 year return period, the rainfall intensity for various duration storms is given in Table 4.7.

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TABLE 4.7

1 IN 10 YEAR RAINFALL INTENSITIES

Time (Hours)	Rainfall (mm/h)
0.25	46
0.50	32
0.75	26
1.0	22

Source: Rainfall and Runoff, Institution of Engineers Aust., 1977.

Temperature

Temperature data available for Zeehan (State School) between 1969 and 1978 are summarised in Table 4.8

TABLE 4.8

TEMPERATURE, ZEEHAN, 1969-1978

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mean Daily Maxima °C												
Average	20.6	21.8	19.2	16.4	13.8	11.7	10.9	11.6	12.8	15.0	16.8	18.1
High	23.4	24.2	21.6	17.9	15.0	12.8	11.9	12.7	14.0	16.5	18.3	20.7
Low	18.2	19.0	16.9	15.1	13.0	10.7	10.2	10.3	11.0	13.6	15.8	15.8
Mean Daily Minima °C												
Average	9.7	10.3	8.7	7.6	5.5	2.9	3.5	3.5	4.4	5.5	7.0	8.6
High	10.4	12.5	10.1	8.0	7.3	4.1	4.9	4.3	5.9	6.6	8.6	9.7
Low	8.7	7.8	7.5	7.0	3.9	1.0	2.8	2.6	2.6	4.6	6.1	7.6
Highest °C	36.4	36.6	31.9	32.3	21.6	17.7	19.8	19.5	25.1	27.3	31.5	34.2
Lowest °C	1.5	1.8	-0.4	-1.1	-4.9	-4.8	-4.7	-4.4	-3.6	-2.3	-0.8	1.8

Wind

Summary percentage analyses are given for Zeehan Post Office 1962-1967 and Zeehan State School 1969-1977 in Tables 4.9 and 4.10. Each entry in the tables represents the number of occurrences during the period expressed as a percentage of the total number of observations.

The wind speed categories in Table 4.10 were rearranged in a format required by the air quality dispersion model used later on. The corresponding windrose for Zeehan State School is shown in Figure 4.3.

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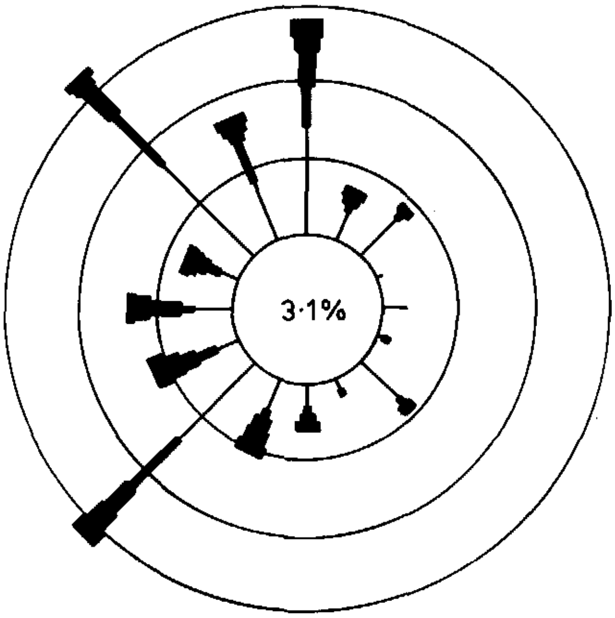

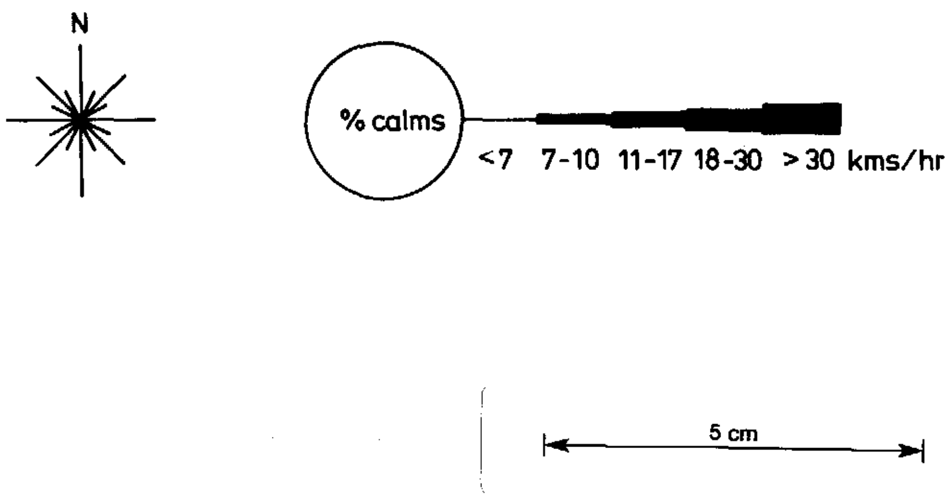

WINDROSE: ZEEHAN STATE SCHOOL

FIGURE 4·3

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TABLE 4.9

WIND SPEED (km/h) AND DIRECTION,
ZEEHAN POST OFFICE, 1962-1967

Direction/ Speed		1-5	6-12	13-19	20-28	29-38	39-49	50 and over	Total
Calm	8.3								8.3
NNE		0.3	0.3	0.3	0.1	0.1	0.1		1.0
NE		1.7	2.3	1.6	0.8	0.3	0.2		6.9
ENE		0.2	0.2	0.2		0.1			0.6
E		0.7	0.6	0.6	0.1				2.1
ESE		0.1	0.2	0.1					0.4
SE		2.0	4.6	2.3	0.9	0.4	0.1		10.2
SSE		0.3	0.4	0.3	0.1				1.1
S		0.8	1.7	0.7	0.5	0.3	0.1		4.0
SSW		0.1	0.5	0.4	0.2	0.1	0.1		1.4
SW		2.5	5.7	3.4	1.7	0.6	0.3		14.2
WSW		0.1	0.1	0.1			0.1		0.3
W		1.4	2.3	1.4	0.4	0.3	0.1	0.1	6.0
WNW		0.2	0.7	0.5	0.2	0.4	0.1		2.0
NW		5.5	10.7	6.0	3.0	2.4	1.4	0.4	29.3
NNW		0.7	1.4	0.5	0.3	0.3	0.2		3.4
N		2.0	3.1	1.7	0.6	0.6	0.4	0.2	8.6
Totals	8.3	18.6	34.7	20.0	9.0	5.7	3.1	0.7	100.0

TABLE 4.10

WIND SPEED (km/h) AND DIRECTION
ZEEHAN STATE SCHOOL, 1969-1977

Direction/ Speed		<7	7-10	11-17	18-30	30	Total
Calm	3.1						3.1
NNE		1.8	0.5	0.6	0.4	0.1	3.4
NE		3.5	0.7	0.6			4.8
ENE		0.3	0.1				0.4
E		1.5	0.2				1.7
ESE		0.4	0.4	0.2			1.0
SE		3.7	0.3	0.5		0.1	4.6
SSE		0.4	0.5	0.1		0.1	1.1
S		1.5	0.3	0.7	0.4		2.9
SSW		2.0	0.7	0.9	0.8	0.5	4.9
SW		7.1	4.7	2.0	1.5	1.0	16.3
WSW		1.5	1.3	1.1	1.1	0.9	5.9
W		2.7	0.9	2.0	1.2	0.7	7.5
WNW		1.0	1.0	0.7	0.5	0.6	3.8
NW		8.6	4.4	2.3	0.6	0.6	16.5
NNW		4.1	3.0	0.6	0.5	0.4	8.6
N		7.1	2.7	2.4	0.6	0.7	13.5
Totals	3.1	47.2	21.7	14.7	7.6	5.7	100.0

4.6 AMBIENT SOUND LEVELS

The noise environment of the district is dominated by the 'ribbon' source of road noise associated with traffic along the Murchison Highway, especially during the daytime.

At the residential area nearest the plant site - Renison Bell - some additional continuous noise can be heard from the Renison concentrator operations. Further afield - for example, near Colebrook Creek - a continuous whine can be heard from the Renison mine ventilation fans. Further afield again - for example at Rosebery - a continuous 'rumble' is audible from the E.Z. mining and concentrating operations.

Measurements were carried out on 19th January 1982, at a position near the plant site during the afternoon, near the Renison Bell Hotel late in the afternoon and at night, and in west Rosebery at night. The instruments employed were a Bruel and Kjaer Type 2204 Precision Sound Level Meter, and a Rion LR-04 Recorder. Calibrations were carried out in the standard manner before and after each measurement run. The recorder was set to 1 mm/s chart speed, and 'fast' writing response. The weather was clear and fine, with slight breeze. Cloud cover ranged between 5/10 and 9/10, the temperature range was 24°C (day) to 15°C (night) and the pressure was 739 to 734 mm Hg.

The results for the measuring position near the plant site indicate a 'quiet' daytime background (L_{90}) to be close to 40 dB(A). Noise from mobile equipment operating some distance away was often audible, usually to around 44 dB(A). The concentrator (1.7 km away) was not audible.

Late afternoon noise and night time noise at the Renison Bell Hotel were similar in characteristics, dominated by traffic (less frequent at night) and the operating 'rumble' of the concentrator complex nearby. Quiet background levels (L_{90}) were 38.5 dB(A) in both cases.

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In West Rosebery (Somerset Street), the night time noise pattern was relatively consistent, usually varying only between 40.5 and 42 dB(A), with the occasional higher levels being due to domestic noise, or (briefly) traffic passing along the Highway. The 'rumble' of the E.Z. concentrator located nearby was audible throughout.

4.7 FLORA

Floral associations within the near region (up to 6 km from the site) were investigated by ground survey within the limits of ready accessibility. Subsequent reviews on a somewhat broader basis were carried out by stereo observation of colour aerial photographs, where the crown characteristics were matched with those zones that had been closely examined to derive species inventories and floral associations.

The initial area considered forms a rough oval oriented WNW to ESE, some 12 km long by 4 km wide, centred around the plant site and approximately bisected on its long axis by the Pieman River. The results of this survey are detailed in Appendix 2.

In broad terms, the majority of the area examined comprises tall closed rainforest, especially in the river valleys, dominated by **Nothofagus cunninghamii** (Myrtle-beech), with secondary species **Eucryphia lucida** (Leatherwood), **Atherosperma moschatum** (Sassafras), **Anodopetalum biglandulosum** (Horizontal), and **Acacia melanoxylon** (Blackwood) or A. **dealbata** (Silver Wattle) often occurring near the forest perimeters. Along the ridgelines, tall emergent **Eucalyptus delegatensis** and E. **obliqua** are often seen above the lower closed canopy of the rainforest, sometimes merging with limited stands of E. **nitida** .

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Where man's activities are evident, tracks, clearings and logging operations have opened out the forest, and **Eucalytpus** or **Acacia** species tend to dominate, sometimes in almost pure stands. By far the most apparent effects of human activity are those changes occasioned by wildfires. Where fires have been relatively infrequent, regrowth **Eucalytpus** or **Acacia** species are noted, below which rainforest species assume progressively greater prominence proportional to the time since the last fire. Where fires are more frequent **Melaleuca** and/or **Leptospermum** species may dominate in dense scrubland. Where fires have been very frequent, the fire corridors are dominated by **Pteridium esculentum** (Bracken) with some **Pomaderris apetala**, **Acacia verticillata** and **Cassinia aculeata** as secondary species.

Thus, a mosaic of differing floral associations is present in the region, ranging from low closed fern communities through scrub and semi-open forest to tall closed rainforest, depending on the intensity of the human impact on the basically temperate rainforest environment.

Also of some note are areas of sedgeland ('Buttongrass') occurring sporadically on flat, acid and poorly-drained ground. The flora in such zones comprise a closed **Restio** /sedge heath community, commonly about one-half metre tall. On the peripheries, a tall closed scrub community forms the transition between heathland and forest.

Colour aerial photographs covering an area approximately 17 km north to south and 13 km west to east (centred roughly on the plant site) clearly show that the floral associations examined in detail on the ground are essentially repeated throughout the district. As a rough guide to the vegetative characteristics of this area, seven 'basic' associates are defined:

* Rainforest
* **Restio** /Sedgeland
* **Eucalyptus** species over scrub
* **Eucalyptus** forest, or **Eucalyptus** thickly overtopping rainforest

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* Scrub
* Alienated land
* Severely burnt-over land, which may revert to either buttongrass or bracken depending on the topography.

The areas broadly fitting these definitions are shown in Figure 4.4. It should be noted that there is considerable variation and overlap of floral associations within these broad definitions; for example, 'rainforest' encompasses only only **Nothofagus** forest, but also rainforest regrowth, stands of **Acacia** species surrounded by rainforest and **Eucalyptus** species overtopping rainforest. Because this figure is intended to provide a broad overview of the district, transition zones from one association to another, and floral zones of limited extent are not shown. Nevertheless, the figure does provide an idea of the relative areas of forests, scrub, sedgeland and alienated land within the area under investigation.

Plant species of interest or importance recorded in the area are:

* **Dacrydium franklinii** (Huon Pine) - this species has a limited distribution, being restricted to the west and southwest of Tasmania along or near rivers (**Hall, et al, 1970**). It is regarded by a number of groups and individuals as a rare and threatened species in need of protection but is not included in the list of rare or threatened Australian plants (**Leigh et al, 1981**). Its habitat in the study area is the Pieman River area.

* **Eucryphia lucida** (Leatherwood) - This is a fairly common species in the rainforests of the area and is important for honey production.

* **Phyllocladus aspleniifolius** (Celery-top Pine) is another timber species occurring in the more remote areas.

* **Ctenopteris heterophylla** (A fern) is an uncommon species but is not considered as rare or threatened (**Leigh et al, 1981**).

* **Acacia melanoxylon** (Blackwood). This is a commercial timber species logged from the Crimson Creek area and used for sawlogs.

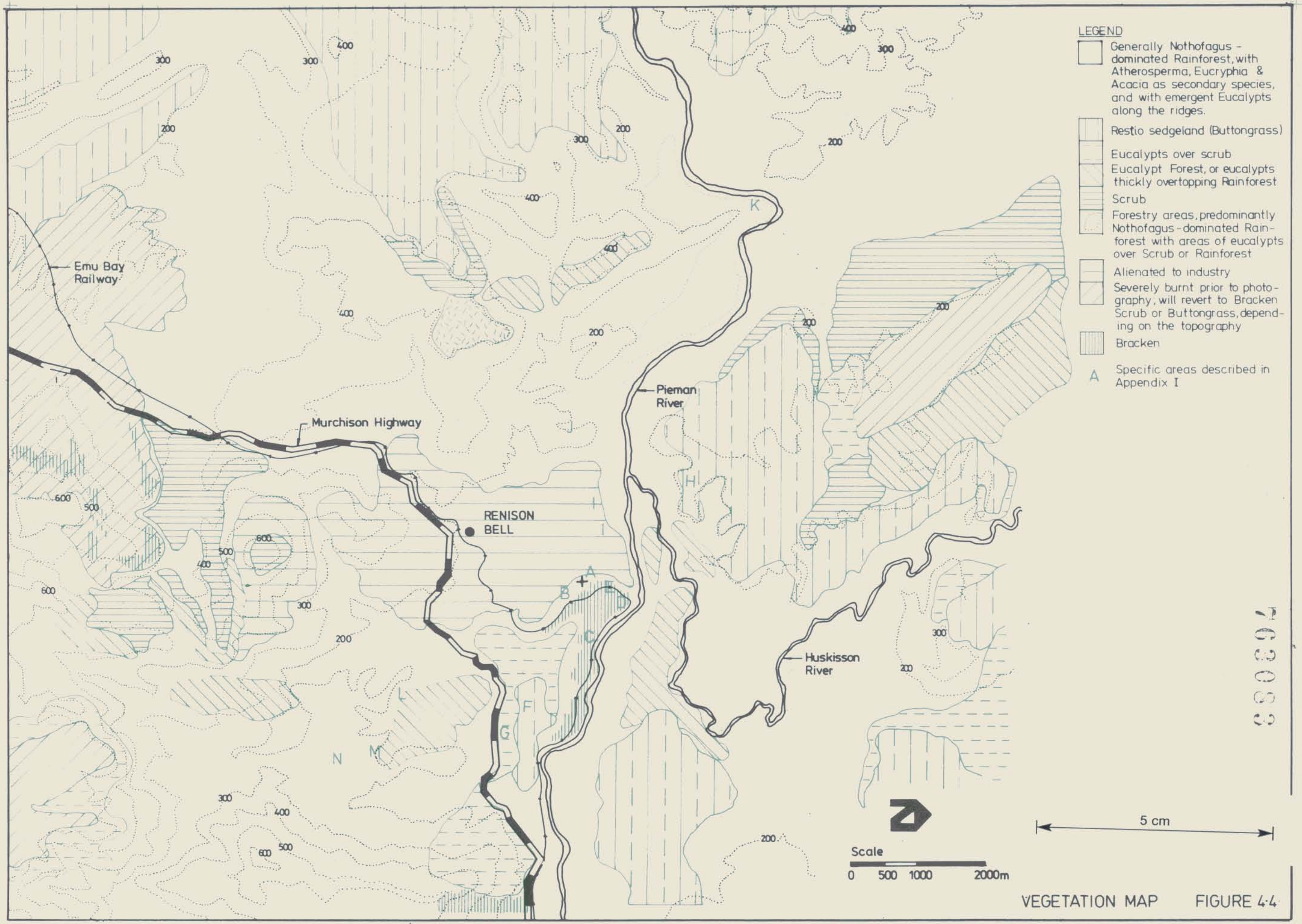
* **Eucalyptus obliqua** (Messmate Stringybark) and **Nothofagus cunninghamii** (Myrtle-beech) are also commercial timber species in the area and are used for sawlogs and pulp.

* **Acacia dealbata** (Silver Wattle) may also be used as a timber species.

4.8 FAUNA

A detailed physical survey of the fauna of the area surrounding the site has not been carried out. During investigation of the surrounds, there occurred casual sightings of a small number of birds and once of a Black Tiger Snake, and the droppings of Tasmanian Devil were observed on two occasions.

Because the habitat is largely temperate rainforest, interspersed with relatively minor zones of mixed wet forest, it is known from other detailed studies that relatively few species of fauna prefer, or are confined to, this essentially hostile environment.



VEGETATION MAP FIGURE 4·4

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It is therefore considered appropriate to summarise those faunal species known to inhabit or visit this general habitat structure, as below. In this context, it is important to note that, of the State's total area of 2,763,700ha, some 463,800ha is classified as temperate rainforest; the habitat structure under investigation is thus common within the State, especially in the western regions.

4.8.1 Birds

Rainforest avifauna is somewhat depauperate compared with drier eastern parts of the State; the essentially closed-canopy situation represents a relatively hostile environment to most bird species due to a general lack of soft food and difficulty of access to invertebrate food. All species found in the Closed-forest habitat are also found in Open-forest areas. Species known or expected to occur in the vicinity of the site are listed in Table 4.11.

Of the two rosellas recorded in Tasmania, the very common endemic Green Rosella is sometimes recorded in rainforest or mixed forest. The Blue-winged Parrot is common in Tasmania, and occupies a wide variety of habitats, including mixed forests, nesting high in emergent eucalypts. The Yellow-tailed Black Cockatoo is common and adaptable and is often sighted in temperate rainforest. The Mush Lorikeet is found in a variety of habitats, which includes mixed forest, as its food comprises mainly Eucalyptus nectar.

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TABLE 4.11

BIRDS KNOWN OR EXPECTED TO OCCUR IN THE VICINITY OF THE SITE

Scientific Name	Common Name (in order of mention)
Platycercus caledonicus	* Green Rosella
Neophema chrysostoma	Blue-winged Parrot
Calyptorhynchus xanthanotus	Yellow-tailed Black Cockatoo
Glossopsitta concinna	Mush Lorikeet
Ninox novaeseelandiae	Spotted Owl
Podargus strigoides	Tawny Frogmouth
Aegotheles cristatus	Owlet-nightjar
Ceyx azureus	*Azure Kingfisher
Turdus merula	Common Blackbird
Zoothera dauma	Scaly Thrush
Petroica rodinogaster	Pink Robin
Rhipidura fuliginosa	Grey Fantail
Pachycephala olivacea	Olive Whistler
Pachycephala pectoralis	Golden Whistler
Sericornis magnus	* Scrubtit
Acanthiza ewingii	* Tasmanian Thornbill
Sericornis humilis	* White-browed Scrubwren
Phylidonyris pyrrhoptera	Crescent Honeyeater
Lichenostomus flavicollis	* Yellow-throated Honeyeater
Acanthorphynchus tenuirostris	Eastern Spinebill
Strepera fuliginosa	* Black Currawong
Phaps elegans	Brush Bronzewing

* endemic

Owls and similar species feed on insects and small invertebrates, and require tree holes for nesting. Because of their nocturnal habits, little is known of their preferred habitat; however, it is possible that the common Spotted Owl, the Tawny Frogmouth and the uncommonly-sighted Owlet-nightjar may occur in mixed forest habitats, especially where nearby areas are at the regenerative stage after disturbance.

The azure Kingfisher is a rare and sedentary Tasmanian subspecies, and is not well distributed throughout the State, occurring along rivers of the north-west and south. It excavates holes in soft river banks for breeding, and is probably to be found along the relatively undisturbed banks of the major watercourses in the area. In the region under review, the habitat of this species is at risk, as a result of the proposed ponding of the main drainage channels, resulting from the Pieman River Hydro-Electric Scheme.

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The introduced Common Blackbird is known to occasionally penetrate temperate rainforest areas, where it may compete with the native Scaly Thrush. The latter species is common and sedentary in rainforest, preferring damp gullies for nesting.

Most flycatchers and fantails are birds of the dry forest and open woodland although the nomadic Pink Robin favours wet forests for breeding, the very common, migratory Grey Fantail is sometimes found in rainforest habitat, the Olive Whistler is common and sedentary in wet forests as well as tea-tree scrub, and the Golden Whistler is seen on rare occasions in rainforest environments.

The warblers, wrens and allies are small, mainly insectivorous birds, and some may be found in the dense undergrowth and canopy layers of wet forest, especially when there are more open, cleared areas nearby. The endemic Scrubtit prefers cold, wet habitats such as fern gullies, where it nests in the dead fronds of **Dicksonia antarctica** (Man-fern). Of the State's three thornbills, the common Tasmanian Thornbill is endemic and restricted to the wetter forests. The White-browed Scrubwren is also common and sedentary in rainforest, as well as in more open forest, swamps and scrub.

The Crescent Honeyeater is common and nomadic, occurring in rainforest as well as a wide variety of other habitats. The Yellow-throated Honeyeater is known to sometimes visit rainforest, although it is much more common in drier forests. The Eastern Spinebill is common and nomadic in rainforest, dry forest and coastal scrub.

The Black Currawong is common and nomadic, occurring mostly in sub-alpine rainforest and sclerophyll forest.

Of the pigeons and doves, only the Brush Bronzewing favours the heavier forests, but is seldom seen in Closed-forest habitat.

None of the species discussed above are rare or threatened, except perhaps the Azure Kingfisher.

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4.8.2 Mammals

A low level of mammal activity is a feature of the dense wet forests of the Tasmanian west. However, it is notable that several species are apparently largely confined to temperate rainforest and mixed forest habitat. Species known or expected to occur in the vicinity of the site are listed in Table 4.12.

The Eastern Pigmy Possum occurs in south-eastern Australia, but nowhere is it known to be common. In Tasmania, it occurs predominantly in rainforest areas.

The Tasmanian distribution of the Dusky Antechinus is confined principally to the temperate rainforest.

The favoured habitat of the Tiger Cat is rainforest and adjacent bushland. Its distribution is patchy, but it is commonly found in the west and northwest of the State.

The Long-tailed Rat occurs only in Tasmania, where it is common in the rainforests, especially in the western region, rarely being found in any other habitat.

The Sugar Glider is an introduced species, now common and widely distributed in Tasmania, being seen in most forested areas including sub-alpine rainforest, and living in the upper branches of tall trees.

The Common Ringtail is common and widely distributed in a range of habitats including forest, scrub and argricultural areas. The Brushtailed Possum is also common to most habitat types.

The Common Wombat (Tasmanian subspecies) is widely distributed and plentiful, and has been sighted in Closed-forest situations, although being a grazing animal it prefers more open localities near pastures.

The Tasmanian Devil, now confined to Tasmania, is commonly found in all forest habitats, as well as scrubland.

763088

The White-footed Dunnart appears to be widely distributed in Tasmania, but is relatively rarely sighted; it lives in a variety of habitats from coastal heathland to sub-alpine rainforest.

The Pademelon is plentiful and widely distributed in Tasmania, its favoured habitat being thick scrub or densely vegetated gullies, where it finds good cover and seclusion.

The Echidna has occasionally been sighted in dense forestland, but is much more common in drier areas.

The Platypus is widely distributed and common in most water catchments, creeks and rivers from the highlands to the sea. The Water Rat is also common along the drainage systems. The habitat of both of these species in the area under survey will be subject to modification as the result of damming the Pieman River.

The Eastern Swamp-rat is common and widespread, occurring in rainforest, coastal swamps and heathland, and sedgeland.

TABLE 4.12

MAMMALS KNOWN OR EXPECTED TO OCCUR IN THE VICINITY OF THE SITE

Scientific Name	Common Name (in order of mention)
Cercartetus nanus	Eastern Pigmy Possum
Antechinus swainsonii	Dusky Antechinus
Dasyurus maculatus	Tiger Cat
Pseudomys higginsi	Long-tailed Rat
Petaurus breviceps	Sugar Glider
Pseudocheirus peregrinus	Common Ringtail
Trichosurus vulpecula	Brush-tailed Possum
Vombatus ursinus	Common Wombat
Sarcophilus harrisii	Tasmanian Devil
Sminthopsis leucopus	White-footed Dunnart
Thylogale billardierii	Pademelon
Tachyglossus aculeatus	Echidna
Ornithorhynchus anatinus	Platypus
Hydromys chrysogaster	Water Rat
Rattus lutreolus	Eastern Swamp-rat

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4.8.3 Amphibians

Tasmania has only ten species of amphibians, the habitat of four of which includes either temperate rainforest or mixed wet forest. These are:

* The Tasmanian Tree-frog (largely confined to the southwest region of the State)
* The Brown Tree-frog
* The Common Eastern Froglet, and
* The Southern Toadlet.

The Tasmanian Tree-frog is the only species of the four not found outside the State.

4.8.4 Reptiles

There are thirteen species of lizards in Tasmania, and only three of snakes. Closed wet forest is not a preferred habitat for any of the reptile species, as these animals prefer open areas for basking. The opening-out of the forest by man's activities in limited areas in the vicinity of Renison Bell has probably provided small zones of adequate habitat for -

* the Blotched Blue-tongued Lizard
* the Metallic Skink, and
* the Black Tiger Snake.

These three species of reptiles are widely distributed.

763090

4.9 VISUAL ASPECTS

The subregional landscape is rugged, densely forested and highly dissected with steep slopes and narrow river valleys. The marked variation in topographic relief in conjunction with the dense vegetation limits views to foreground distance zones*. Views to the middleground and background distance zones are limited to glimpses from selected vantage points on the Murchison Highway and other minor roads. Views from Renison Bell to the proposed site are screened by local topography. The site is not visible from the towns of Zeehan and Rosebery.

To the east, Mount Murchison forms the background skyline with densely forested ridges in the middleground distance zone. The form and colour associated with these features are strong visual elements within the middleground and background landscape. Texture, colour, line and species diversity have the greatest impact on the visual character in foreground views where detail is readily observed. Panoramic views over the Pieman River to the northeast may be obtained from vantage points near the site.

The site for the proposed development is adjacent to old borrow areas and has been largely cleared of forest vegetation to carry out the necessary soil investigations. Consequently the scenic status of the site has been rated as moderate to low.

* Distance Zones:

Foreground	0 to 300 - 400 m
Middleground	400 m to 1-1.5 km
Background	1.5 km to infinity

4.10 LAND USE

The area around the site is Crown Land, the majority of which is dedicated to mining and exploration activities. The land use is shown in Figure 4.5.

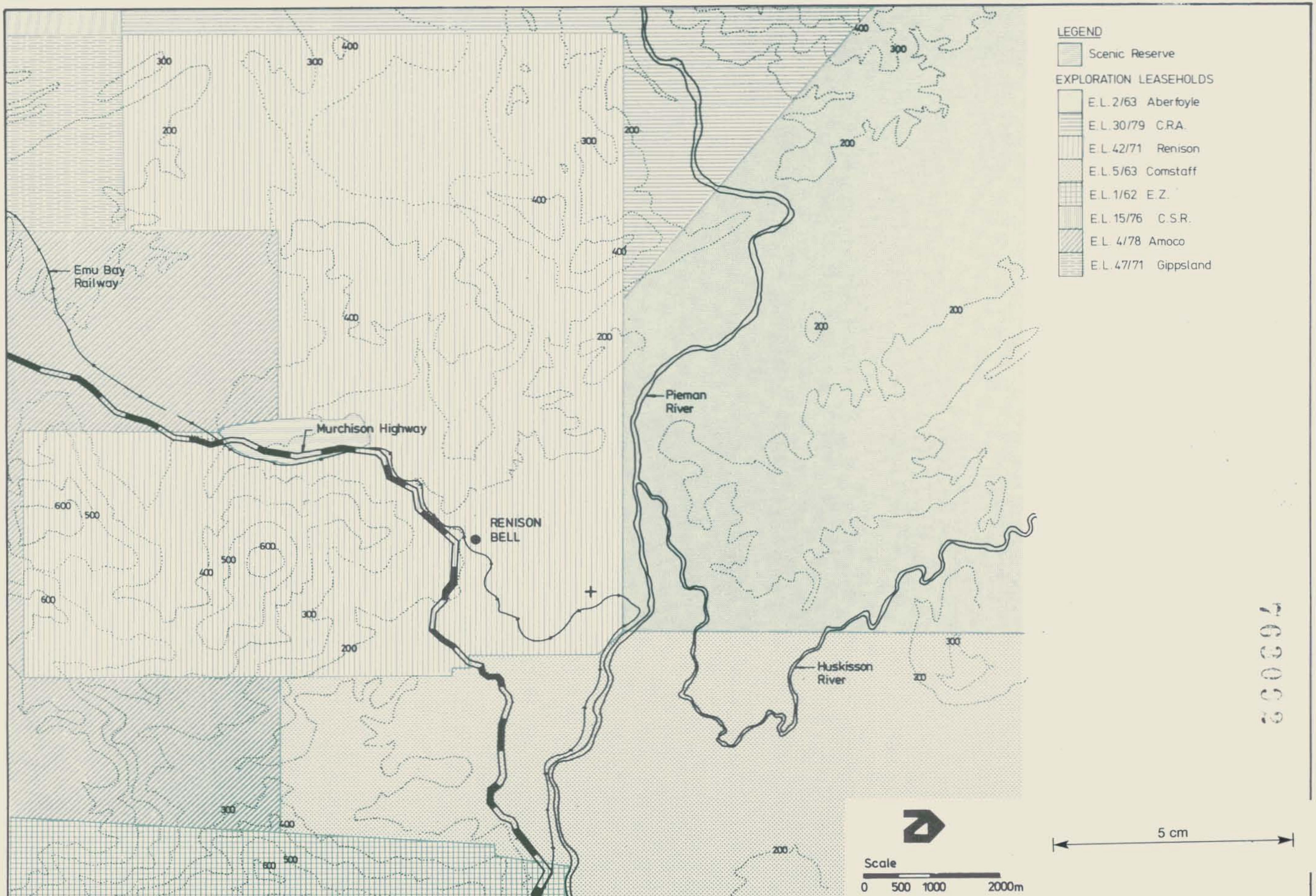
The land immediately to the south and west of the site is alienated to existing Renison operations, comprising tailings dams and access roads interspersed with small pockets of vestigial disturbed wet forest often comprising typical rainforest species (Plates 4.11, 4.12). The existing concentrator complex is approximately 2 km away in this direction, adjacent to the Murchison Highway. Only about 700m to the west of the concentrator is the small settlement of Renison Bell.

The Renison Consolidated Mining Lease (near the northeast corner of which is the proposed site) extends southwards from the Pieman River to Commonwealth Hill (a N-S distance of 6.2 km) and eastwards from the Argent Dam to Colebrook Creek (a variable W-E distance of from 2.5 to 3.5 km). Renison also holds further mineral exploration leases to the south and to the west of the Consolidated Lease; the southernmost boundary of the south lease is 9.0 km from the proposed plant site.

Northwards from the Pieman River, a large area of land is under exploration leasehold to Aberfoyle Ltd.

Eastwards of the Renison lease is an exploration lease held by Comstaff Pty. Ltd., which in turn abuts the extensive Electrolytic Zinc Co. leasehold areas to the east, which are centred around Rosebery.

The southern Renison exploration lease is adjoined on its eastern, southern and western boundaries by an extensive exploration lease held by C.S.R., which extends southwards of the abandoned mining village of Dundas (near Zeehan).



LAND USE MAP FIGURE 4·5

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Plate 4.11 View West at the Site

Plate 4.13 View Showing the Relatively Undisturbed State of the Pieman River Valley

Plate 4.12 View South at the Site

Plate 4.14 View Showing the Relatively Undisturbed State of the Pieman River Valley

Throughout the entire region, mining and exploration has taken place since last century, and such activities are still frequent as the area is highly mineralised. Major underground mining operations occur at Renison (tin), at Rosebery (zinc and lead), and at Williamsford (zinc and lead) which is about 8 km southeast of the site.

Other mining, both surface and underground, has occurred or is occurring at Farrell (11 km to the northeast), Tullah (15 km east-north-east), Razorback (10 km to the south) and Zeehan. Small abandoned workings are numerous, and abandoned tramways (mostly overgrown) meander throughout much of the region.

The Murchison Highway is a prominent feature of this district, and not only affords transportation through the West Coast region from Queenstown in the south to Burnie in the north, but also offers a well-paved scenic route for holiday makers and tourists.

Roughly paralleling this road is the privately operated Emu Bay Railway line, which is now used for the bulk transportation of copper concentrates to the wharves at Burnie.

Permanent rivers and streams abound in the region, but the main drainage channel in the near area is the Pieman River, which is to be impounded and will back up to flood the steep valley through which this river presently runs. Thus a new 'land use' in the near future will be water storage for hydro-electricity generation. One further possible land use occasioned by this water storage might be water recreational pursuits; access to the narrow lake could be gained from the Murchison Highway via the Argent road, which presently leads to the Pieman River, west of Renison Bell.

Two narrow 'Scenic Reserves' have been proclaimed in the region, both relating to land bordering the Murchison Highway. One is approximately 2 km long and south of the Argent Dam, and the other is about 3 km long approximately midway between Renison Bell and Rosebery. These reserves relate largely to strips of dense rainforest bordering the Highway.

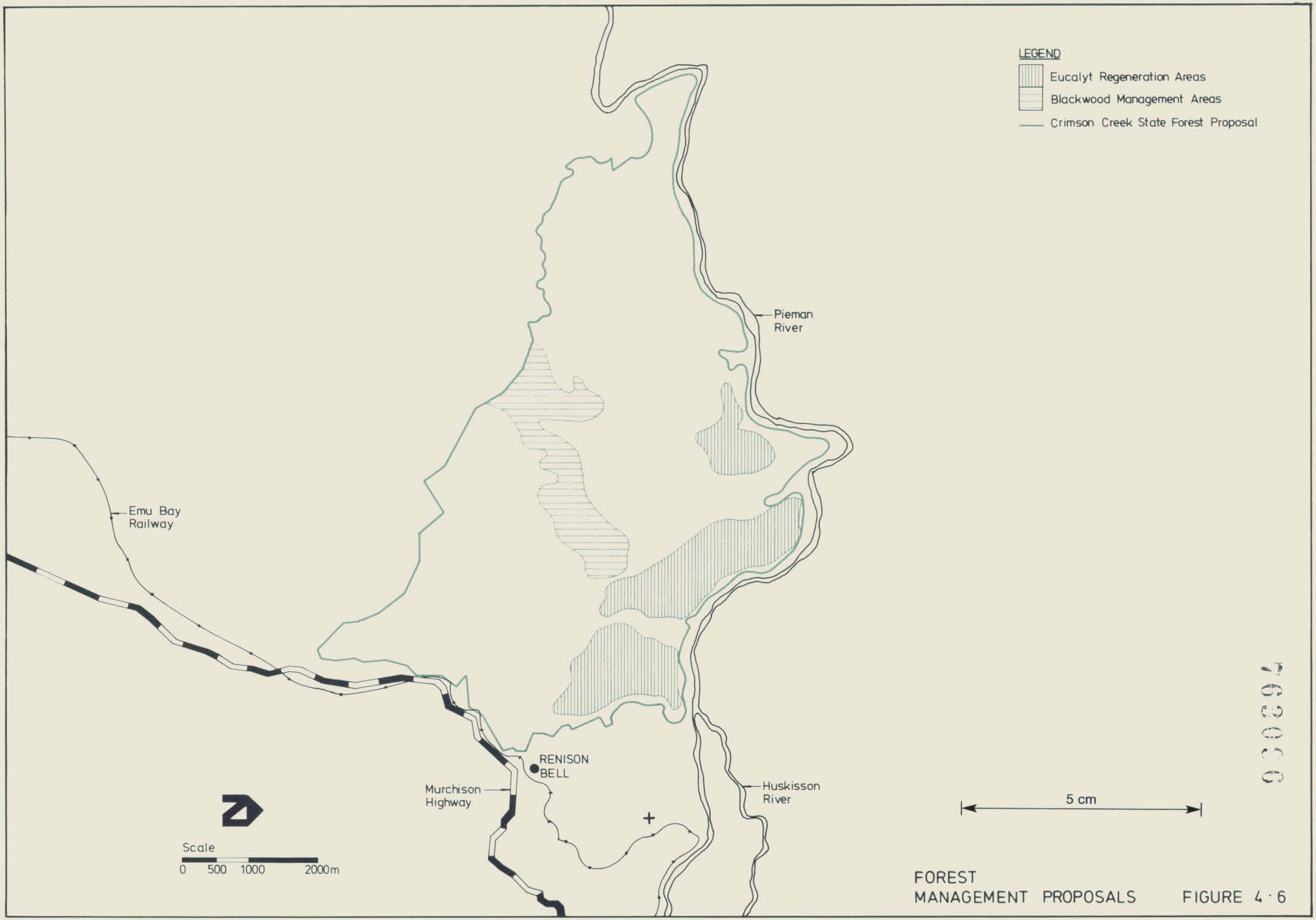
763095

Westward of the site, the former rainforest has been extensively cut over by past and present timber-getting activities and the country ranges from regenerating rainforest (near the Argent River) to clearfelled coupe (near Success Creek and down to the Pieman River). The Pieman River valley itself is as yet relatively undisturbed (Plates 4.7, 4.13 and 4.14), but this narrow valley will be inundated as a result of the Pieman River hydro-electric scheme.

The State Forestry Commission has drafted a proposal to dedicate approximately 3300 ha of land to the west of the Argent River as the 'Crimson Creek State Forest'. The broad objectives of this plan include forest management, the provision of timber and pulpwood, regeneration of native species and other - perhaps recreational - purposes. This area has long been used as a source of timber, without any clear management; if the proposal is ultimately adopted, the Commission hopes to establish three Eucalypt regeneration areas and one Blackwood management area (stands of Blackwood-Acacia melanoxylon - have been established along the line of an abandoned miners' tramway) within the boundaries of the proposed State Forest. The proposed boundaries and management areas are shown in Figure 4.6.

Bee-keeping is an important activity along roads and tracks in the forested areas, particularly for the production of leatherwood honey.

The nearest boundary of the 'South-west Conservation Area' is about 14 km to the east of the proposed plant site. This Conservation Area, the Cradle Mountain National Park and the recently proclaimed Wild Rivers National Park are shown on Figure 4.7



FOREST MANAGEMENT PROPOSALS FIGURE 4·6

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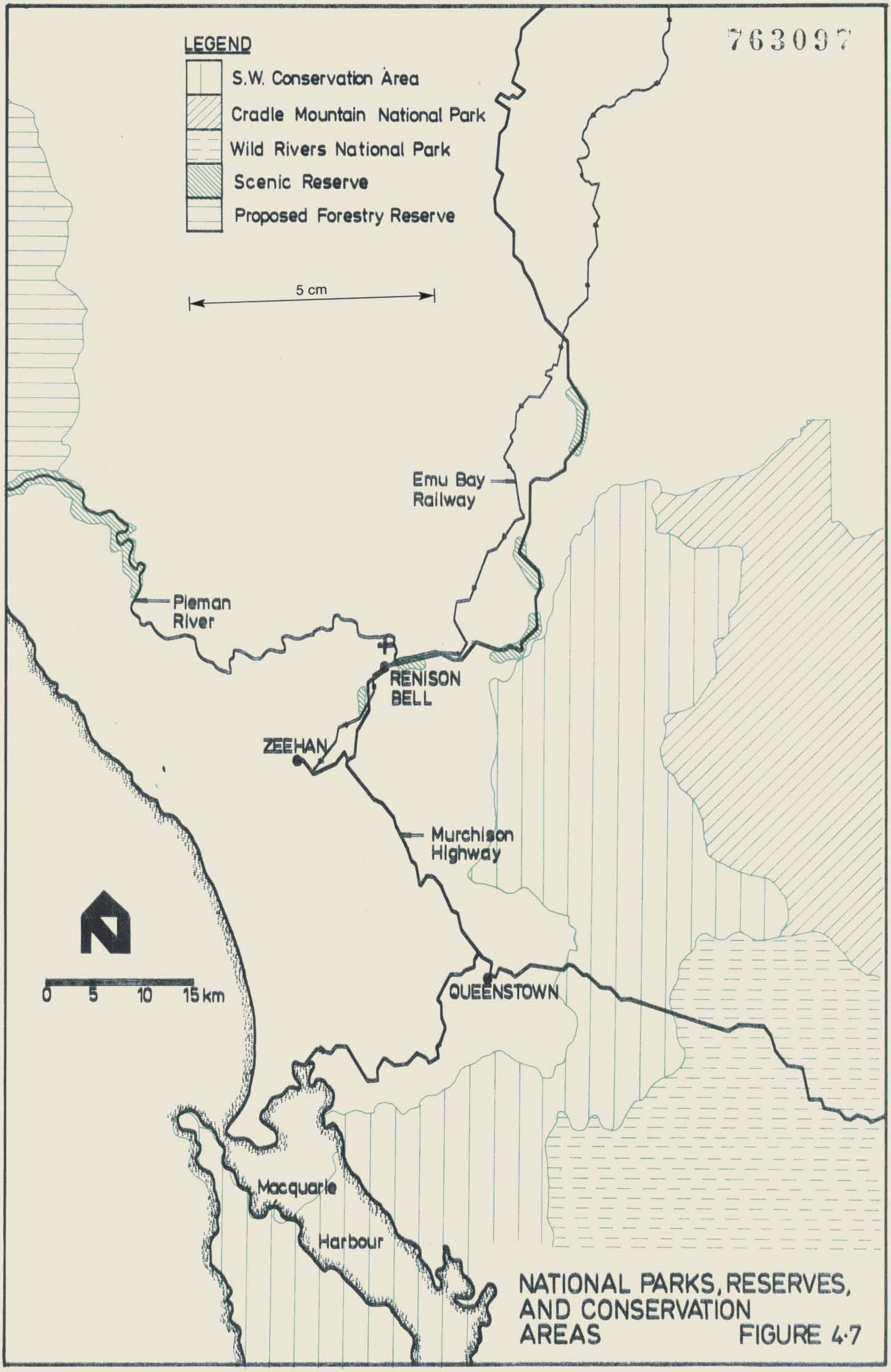

NATIONAL PARKS, RESERVES, AND CONSERVATION AREAS

FIGURE 4·7

763098

4.11 SOCIO-ECONOMIC ENVIRONMENT

4.11.1 Demographic Characteristics

At the time of preparation, only preliminary 1981 Census information was available for inclusion in this study. This information is included where possible. In those areas where 1981 statistics are not available analysis is based upon 1976 Census data.

Population Growth

Details of population growth in the town of Zeehan, Zeehan local government area (LGA) and Tasmania are presented in Table 4.13.

Between 1961 and 1976 the town of Zeehan has experienced a significant reversal of a previously declining population. This reversal was primarily attributed to the development by the Renison Company of the Renison Bell tin deposits in the mid 1960's. The population of Zeehan increased by 130 per cent between 1961-76, an average annual increase of 8.7 per cent.

TABLE 4.13

POPULATION GROWTH ZEEHAN URBAN AREA, LOCAL GOVERNMENT AREA AND TASMANIA, 1961-81

Area	1961	1966	% Change 1961-66	1971	% Change 1966-71	1976	% Change 1971-76	1981	% Change 1976-81
Zeehan (town)	780	1115	43.0	1471	32.0	1793	22.0	1750	-2.4
Zeehan (LGA)	3191	3489	9.0	4369	25.0	5220	19.0	6722	28.8
Tasmania	350340	371436	6.0	390413	5.0	407360	4.0	427300	4.9

In addition to the reversal of local population trends, the rate of growth in Zeehan's population to 1976 represented a significant departure from the growth patterns of the state as a whole. Between 1961-76 the population of Tasmania increased by 15 per cent, representing an average annual increase of 1.1 percent relative to the 8.7 per cent found at the local level.

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Tasmania as a whole consistently exhibited a lower growth rate than the national average. This occurred largely as a result of an extensive outmigration of residents which has served to reduce any possible gains from a higher than average birth rate.

Based upon the preliminary 1981 Census data the population of Zeehan town not only failed to maintain its previous rate of growth but also experienced a net decline of 2.4%. The absence of any additional Census data precludes proper explanation of the reversal, but it has been coincidental with a reduction in average family size in Renison housing.

Age Structure

At the 1976 census, Tasmania's population exhibited a more youthful population than that of Australia. In particular, the State had a greater proportion of residents in the 0-19 age grouping.

The age structure of Zeehan, shown in Table 4.14 indicates that an even greater proportion of residents fall in the 0-10 and 20-34 years age group. In addition there is a distinctive absence of residents greater than 35 years of age.

TABLE 4.14

AGE STRUCTURE ZEEHAN URBAN AREA AND TASMANIA, 1976

(%)

Age	Zeehan (town)	Tasmania
0.4	16.0	9.0
5-9	13.3	9.7
10-14	9.1	10.0
15-19	5.8	9.6
20-24	12.7	8.1
25-29	14.6	8.1
30-34	8.5	6.5
35-39	4.7	5.8
40-44	3.9	5.1
45-49	3.4	5.3
50-54	1.6	5.4
55-59	2.3	4.6
60-64	1.7	4.2
65+	2.4	8.6

763100

The particular age structure of Zeehan reflects the close relationship the population has with the mining industry. The requirement by the industry for labour to be largely obtained by inmigration results in a predominance of new residents being in the 25-45 year age group. This pattern is similar to one found at the national level in which 82 percent of people changing their place of residence are between 15 and 45 years of age (**ABS, 1980**). The association of this age group with family development can be considered to account in part for the high proportion of 0-10 year olds in Zeehan.

A relative absence of residents greater than 35 years of age reflects the inability of Zeehan to retain its employees for extended periods of time and as they near the end of their working lives. Such a characteristic is consistent with other urban centres on the west coast associated with the mining industry (**Lee, 1977**).

Sex, Marital and Nationality Characteristics

The population of Zeehan has, along with other mining centres on Tasmania's west coast, a significantly lower proportion of females than the state as a whole. With the renewal of mining activity since the 1960's this historical pattern has been accentuated. In addition to a predominace of males, Table 4.15 indicates that a large proportion of Zeehan's population is single.

The distinctive demographic characteristics result in part from the need by the mining industry to import labour to the area. In addition to the influences of the mining industry, it is considered that the relative isolation and small size of Zeehan, together with a low level of service provision also contributes to the area's particular demographic pattern.

763101

Despite the existence of demographic imbalances in Zeehan's population, evidence from other longer established mining communities indicates that such imbalances are reduced to a certain extent following the initial development phase. However, in the case of sex ratios in particular, differences between the local and State populations continue to exist.

TABLE 4.15

SEX, BIRTHPLACE AND MARITAL STATUS, ZEEHAN, AND TASMANIA 1976

(%)

Area	Sex		Birthplace		Marital Status	
	Male	Female	Australia	Overseas	Married	Other
Zeehan (town)	54.6	45.4	89.8	10.2	43.1	56.9
Tasmania	50.0	50.0	87.4	12.6	46.1	53.9

Employment and Economic Base

The significance of mining in Zeehan's economy is made apparent by the employment structure shown in Tables 4.16 and 4.17. Fifty nine per cent of the towns' workforce is employed in this industry.

Apart from mining, few alternative employment opportunities are available in Zeehan. In particular, as Table 4.16 indicates, relative to the State very few opportunities exist in tertiary industries. As a consequence a relative lack of professional, administrative, clerical, retail and service positions limits the ability of residents to obtain employment in an industry other than mining.

A census of manufacturing industry conducted by the **Australian Bureau of Statistics (1979-80)** found 3 establshments operating in Zeehan LGA. A similar survey of agriculture found that this activity was limited to 6 establishments in the western sub division. The narrow employment structure is reflected in the lower workforce participation rates shown in Table 4.18. These rates indicate that whilst male rates are high, those for females are low. It is assumed that this relative lack of employment opportunities contributes to a loss of residents, particularly of 15-25 year olds, and acts as a disincentive for new residents to remain in the area.

763102

TABLE 4.16

EMPLOYMENT BY INDUSTRY, ZEEHAN AND TASMANIA, 1976

(%)

Industry	Zeehan	Tasmania
Agriculture	0.6	7.8
Mining	59.2	2.6
Manufacturing	0.5	16.9
Electricity etc.	0.6	1.9
Construction	4.5	7.7
Wholesale/retail	7.8	17.8
Transport	0.1	5.0
Communication	0.6	1.9
Finance	0.7	6.0
Public Administration	2.6	4.7
Community Services	5.6	15.0
Entertainment	6.8	5.8
Others	10.4	7.0

TABLE 4.17

EMPLOYMENT STRUCTURE BY OCCUPATION ZEEHAN AND TASMANIA, 1976

(%)

Occupation	Zeehan	Tasmania
Professional	12.2	12.6
Administrative	2.6	5.8
Clerical	7.5	14.6
Sales Workers	3.1	7.7
Farmers	1.5	8.1
Miners	29.0	1.3
Transport	3.0	5.3
Process Workers	25.4	30.2
Service	6.1	8.5
Armed Services	0.0	0.2
Others	9.6	5.6

Tasmania's employment structure as a whole is characterised by a regional specialisation in particular industries. The major industries of the state, agriculture and mining, reflect this pattern with the latter being concentrated in the west. In the past decade these two industries have exhibited significant declines in their level of employment. The growth and development of the Renison mining operations has therefore contributed significantly to employment opportunities in an otherwise declining industry.

763103

TABLE 4.18

WORKFORCE PARTICIPATION RATES[1], ZEEHAN AND TASMANIA, 1976

(%)

	Zeehan	Tasmania
Male	93.5	79.5
Female	33.3	39.6

Note 1: Participation rates are calculated by taking the number of males 15-65 years of age in the labour force as a proportion of the total number of males in this age group.

4.11.2 Employment Characteristics at Existing Operations

Labour Supply

The Company currently employs approximately 550 people.

Current labour supply patterns indicate that up to 77 percent of labour requirements are obtained from Tasmania. Of this number 27 percent are obtained from the local population.

Greater levels of inmigration into Zeehan, from both elsewhere in Tasmania and the mainland are required for tradesmen and professional positions. Up to 35 percent of tradesmen are obtained from the mainland as compared to 20 percent of non-tradesmen/operators.

Demographic Characteristics

An analysis of recent new starters at the existing operations was undertaken to determine their demographic characteristics. The analysis found that a high 57 percent of recent new starters were single. Differences were apparent between occupational groups with 48 percent of tradesmen and 61 percent of non-tradesmen being single.

A breakdown of married employees into family sizes indicates that the average number of children per married employee is 1.1. Differences between occupational groups are again apparent with tradesmen having an average of .83 children per family.

Training Programmes

Renison has undertaken a number of training programmes in an effort to maximise the number of employment opportunities available for existing local residents. Current programmes include a mill operators training scheme and an extensive apprenticeship scheme.

In an attempt to broaden the opportunities for female employment in the mining industry Renison has, in the past five years, employed females as apprentices in the metal trades. Renison has undertaken to augment its existing training programmes and is in the process of hiring additional personnel to achieve this aim.

4.11.3 Unemployment

Over the 12 month period to April 1981, Zeehan LGA had an average of 62 persons unemployed. No details of current levels are available due to the discontinuation of unemployment data collection.

The junior female category accommodated the greatest proportion of the unemployed accounting for 36 percent of the total. This reflects the limited range of employment opportunities in the area and the lack of opportunities for females in the mining industry.

Adult females contributed a low 10 percent of the total number of unemployed. The low proportion seeking employment supports the pattern of low female workforce participation rates discussed previously.

4.11.4 Community Facilities and Services

Accommodation

Dwelling characteristics of Zeehan's population at the 1976 Census are presented in Table 4.19. The figures indicate that a very high proportion of the population reside in rented accommodation. This pattern reflects the significance of housing provision by Renison Limited for its employees.

Renison currently provides accommodation for 91 percent of its employees in Zeehan on a subsidised rental basis. A variety of accommodation types are provided including both detached dwellings and single mens quarters. It is Renison's policy to provide accommodation in Zeehan for all its workers. Temporary accommodation is limited in Zeehan to 2 motels, a hotel and a caravan park.

TABLE 4.19

NATURE OF OCCUPANCY - ZEEHAN TOWN

1976

(%)

Owner/purchaser	18.2
Tenant - Public	0.5
Tenant - Private	71.2
Other	10.1

Education

The population of Zeehan is served by a state primary school and a non government infants school. Non government primary school facilities are available in Rosebery and Queenstown. There are no non government secondary facilities available on the west coast.

In 1981 approximately 90 secondary students from Zeehan were transported daily to Murray High School in Queenstown, a distance of 33 km.

Enrolments at those schools serving the Zeehan population are provided in Table 4.20.

763106

In the period 1976-81 enrolments at Zeehan primary school have shown a slight decline. However as the population of the town is relatively stable enrolments are expected to maintain their current level. Significant declines in primary enrolments are evident in other centres on the west coast such as Queenstown.

TABLE 4.20

ENROLMENTS AT SCHOOLS SERVING ZEEHAN, 1981

Primary	
Zeehan	244
St. Furseaus (Zeehan: to Year 3 only)	30
St. Josephs (Queenstown)	135
St. Josephs (Rosebery)	145
Secondary	
Murray High School (Queenstown)	432
West Coast Community College	13

Source: **Education Department**

Enrolments at Murray High School Queenstown reflect the decline of that town's population.

The west coast community college at Queenstown caters for fulltime HSC students, in addition to providing technical courses.

Medical Services

The town of Zeehan is serviced by a medical centre operated by a doctor and a clinical sister. General medical services only are provided by the centre.

Overnight care and surgery facilities are provided by Queenstown hospital. The hospital and the Zeehan Medical Centre have been upgraded in the past 15 years and are considered adequate to meet the needs of the local population.

763107

Details of services and bed numbers available at Queenstown are provided in Table 4.21. Bed occupancy rates for the hospital averaged 51 percent for the six month period to November 1981.

An ambulance service is available from Zeehan. Renison's mining operations are serviced by an additional vehicle for its own needs.

TABLE 4.21

SERVICES AND BED AVAILABILITY
QUEENSTOWN HOSPITAL

Bed Type	Number
General	19
Childrens	4
I.C.U.	3
Nursing Home	14
Obstetric	3
Total	43

Source: **Department of Health Services (1981)**

Recreational Facilities

The major recreational facilities available in Zeehan involve those required by particular sporting activities. Facilities are available for tennis, basketball, swimming, cricket, football, squash and golf.

Other than sporting activities, recreational pursuits are limited by the size of the town. The only major source of entertainment in the area is a movie theatre in Queenstown.

Provision of Services

Due to the position of Renison as the principal land owner in Zeehan, Renison provides a significant proportion of revenues received by local government through rate payments. In addition to the contribution towards the provision of services through such payments, Renison makes further annual contributions towards the maintenance of Zeehan Swimming Pool.

763108

The role of Renison as a housing developer results in it having to meet the costs of providing services to new housing areas. To the extent that such new areas may require expansion of existing services, the Company makes contributions towards the costs of such works based upon negotiations with the relevant authorities.

4.12 TRANSPORTATION

The site is linked to the Port of Burnie by the Murchison and Bass Highways and the Emu Bay Railway line.

The Department of Main Roads has carried out traffic counts on the Murchison and Bass Highways during 1981. Details are shown in Tables 4.22 and 4.23.

TABLE 4.22

TRAFFIC COUNTS, MURCHISON HIGHWAY

8am-6pm, 1981

	Mount Black (North of Rosebery) January	South of Waratah Highway Junction May
Cars	679	542
Trucks	41	70
Total Vehicles	720	612
24 hour factor	1.3	1.3
Total vehicles/24 hr	936	796

Source: **Department of Main Roads**

The difference in the number of movements of light vehicles along the Highway would be attributable to the January holiday traffic.

The number of trucks plying the route obviously varies significantly from day to day, although at the more northerly observation point there could be some passing heavy traffic associated with the mining operations at Que River, which is located just off the Murchison Highway to the south of the Waratah Highway junction.

TABLE 4.23

TRAFFIC COUNTS - MURCHISON AND BASS HIGHWAYS
JUNCTION TO BURNIE WHARVES
7am-7pm, 20TH MARCH, 1981

Light Vehicles, Inc Small Trucks	14,357
Heavy Vehicles (i.c. dual axles)	407
Total Vehicles	14,764
24 hour factor 1.2	
Total vehicles/24 hr	17,717

Source: **Department of Main Roads**

SECTION 5

DISPOSAL OF ATMOSPHERIC EMISSIONS

TABLE OF CONTENTS

763111

5. DISPOSAL OF ATMOSPHERIC EMISSIONS

The Environment Protection (Atmospheric Pollution) Regulations 1974 proclaimed under the Environment Protection Act 1973 for the State of Tasmania specify emission standards for selected pollutants released into the atmosphere. Part II of the Regulations considers installations not in operation before 1975 and determines the emission limits at the point of emission for a variety of pollutants. Whereas limits are set for sulphuric acid and sulphur trioxide emissions (from sulphuric acid plants) no emission limit at the point of release is defined for the concentration of sulphur dioxide in the discharged gas.

The Regulations do not distinguish between releases from near-ground sources and elevated stacks. The concentration of fluorine, hydrofluoric acid, and other inorganic fluorine compounds in the effluent shall not be such as to exceed the equivalent of 50 mg of hydrofluoric acid per cubic metre. The Regulations also require that the total concentration of heavy metals (including arsenic) in the waste gas emissions do not exceed 10 mg/m^3.

5.1 DISPOSAL STRATEGY

Alternative gas disposal strategies were considered in the light of the expected emission rates of sulphur dioxide, fluorine and arsenic. The two broad options were dispersal to the atmosphere via a tall stack and gas cleaning techniques.

Renison proposes to adopt a strategy in accordance with the need for a selective approach to their specific proposal. The ultimate goal of this strategy is to minimise the impact of atmospheric emissions on the environment surrounding the proposed plant.

The major component of the strategy is the use of a tall stack to disperse the emissions and so to reduce the maximum ground level concentrations. Site selection received most careful attention and was tailored to match the adopted technique. It has been documented extensively over many years that under most atmospheric conditions the maximum ground level concentrations resulting from isolated emission sources such as the thermal upgrading plant are reduced significantly by a tall stack. Hence the application of a tall stack, although sometimes challenged for its use in densely populated areas, is the most effective approach to solving the air pollution problem in this case.

In this section a detailed analysis is carried out to determine whether in the Renison Bell situation the tall stack would achieve compliance with the strictest ambient air quality objectives worldwide. The maximum ground level concentrations of the main indicators are investigated and related to the most conservative threshold values with respect to vegetation injuries and public health.

A stack height of 100 metres is proposed to ensure effective dispersal of the emissions including sulphur dioxide, hydrogen fluoride and arsenic as the indicators. Inherent in the proposal is the specification of environment protection criteria which, when applied to the stack design, would result in safe ambient concentration levels of all three indicators found near the ground in the vicinity of the project at all times. The possible combined effect of sulphur dioxide and hydrogen fluoride emissions on both the public health and the local fauna and flora is considered through the introduction of the so-called equivalent sulphur dioxide emissions. The higher potential for vegetation injury by gaseous fluoride is recognised in the scheme by using a loading factor to multiply the fluoride emissions and by adding them to the emissions of sulphur dioxide for the purpose of stack height design. The conversion factor is, at the same time, linked to a very conservative ambient air quality goal of 0.17 ppm of equivalent SO_2 emissions over a three minute averaging interval.

5.2 ENVIRONMENT PROTECTION CRITERIA

Review discussions with the Department of the Environment established the need to support the design calculation procedure by undertaking separate analyses with respect to human health and vegetation response for a range of exposure times.

The first task in the analysis was to establish the relationship between sulphur dioxide and fluoride effects on vegetation with a specific reference to Australian native vegetation. Once the relationship was known it was possible to determine the minimum stack height with respect to vegetation responses using both the equivalent sulphur dioxide and equivalent hydrogen fluoride emissions. In the final step a check was made to ensure that the ground level concentrations of sulphur dioxide and arsenic would not exceed the allowable limits for population exposure.

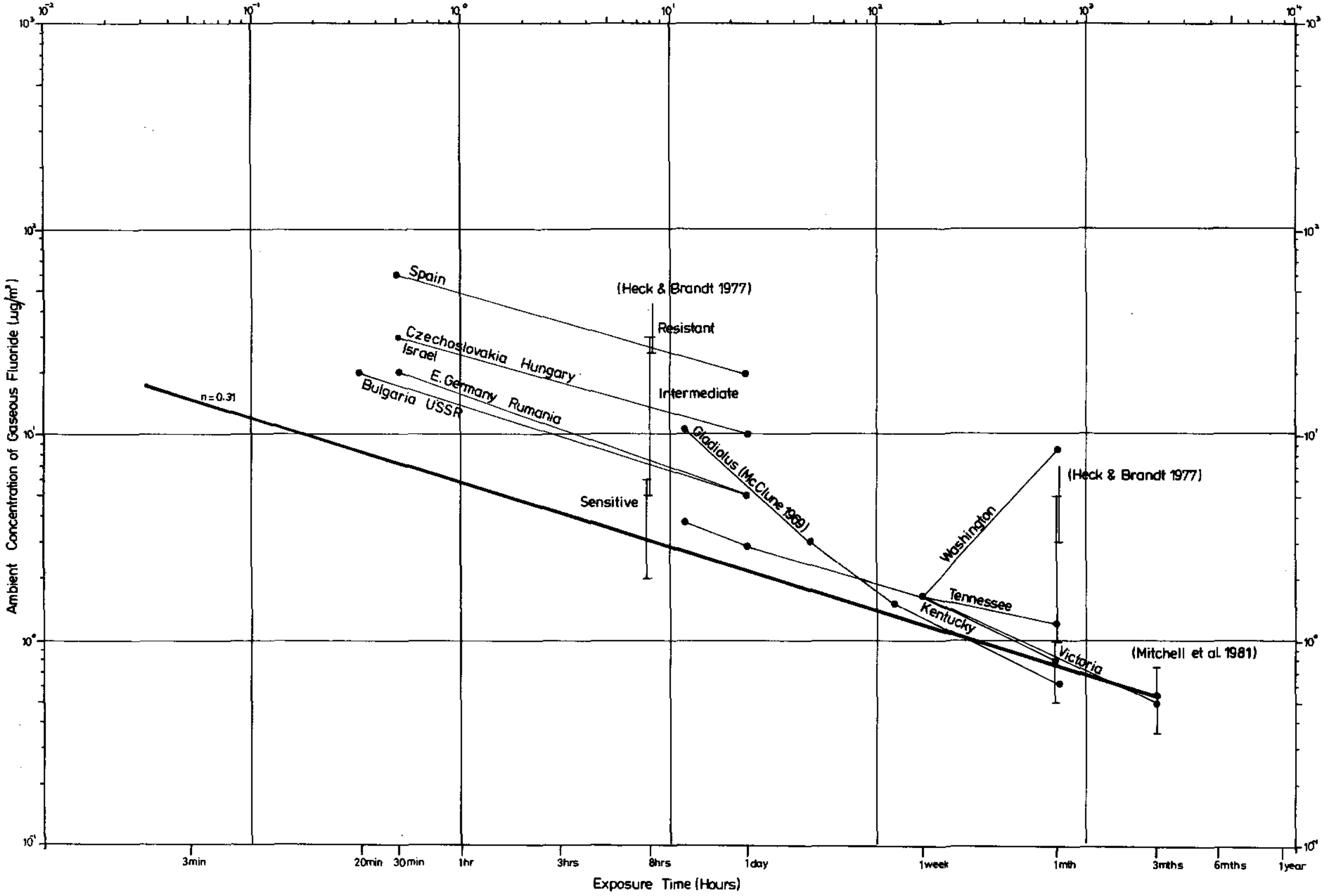
5.2.1 Effects of Fluoride on Vegetation

The fluoride in the effluent gas will be present in the gaseous form as HF with a trace of SiF_4. Different species of vegetation display a varying degree of susceptibility to gaseous fluorine compounds. Plants range from sensitive species to intermediate and resistant. A summary of the projected injury thresholds for the three groupings of vegetation and a range of exposure times was published by **Heck and Brandt (1977)** . Figure 5.1 shows three ranges of ambient gaseous fluoride concentrations that may result in a measurable effect when the plants are exposed for eight hours and one month respectively. Different plants may experience variations in their sensitivity grouping with varying exposure times as demonstrated by gladiolus. Gladiolus is sensitive to very sensitive when exposed over the period of 30 days but only moderately sensitive to exposures of the duration of 12 hours or less.

The curve in Figure 5.1 indicates the possible injury threshold of gladiolus as published by **McCune (1969)** . The response of Australian vegetation to ambient gaseous fluoride was summarised by **Mitchell et al (1981)** . Using the results of an *eight year sampling programme* in the vicinity of an aluminium smelter the authors recommended the adoption of 0.54 $\mu g/m^3$ over a three month period as the threshold value for moderate injury. The authors further stressed that the threshold represented the worst case situation and that higher levels of ambient fluoride may cause no damage at all.

Several overseas countries adopted ambient air quality objectives with respect to gaseous fluoride. The objectives are shown in Figure 5.1 for a number of European countries and, more recently, for various states in the U.S.A. Finally, the State Environment Protection Policy for Victoria reflects the trend set by the State Pollution Control Commission of N.S.W. by setting the local objective for gaseous fluoride at 0.50 $\mu g/m^3$ over a 90 days averaging period.

The data assembled in Figure 5.1 are consistent with a log-normal distribution of threshold values with respect to exposure time. Experimental evidence of vegetation response to *exposures of the order of minutes is very limited.* The sporadic information available indicates that much higher pollutant ambient concentrations may be tolerated by plants for a short duration of time. Notwithstanding, a conservative approach was adopted in the analysis to determine a safe threshold value applicable to Australian sensitive plants for the worst case situation and the three minute interval. A simple power law with the exponent of 0.31 was used to extrapolate the threshold boundary from 0.54 $\mu g/m^3$ over three months to short-term exposure times on the left of the diagram. Points above the threshold boundary represent potential damage to sensitive vegetation, points below the line represent marginal injuries or no damage at all. The conservatism of the approach adopted in the proposal is immediately evident from a comparison with the standards used overseas including the United States.



PROJECTED CONCENTRATION THRESHOLDS
OF INJURY TO VEGETATION
BY AMBIENT GASEOUS FLUORIDE

FIGURE 5.1

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5.2.2 Effects of Sulphur Dioxide on Vegetation

A similar analysis as for gaseous fluoride was carried out for sulphur dioxide. The results are again presented in a graphical form in Figure 5.2. Although generally more experimental information is available concerning plant responses to short-term exposures of sulphur dioxide than to gaseous fluoride, an extrapolation based on the simple power law is needed to determine the threshold values applicable in stack height calculations. Projected injury thresholds for the three groupings of vegetation, summarised by **Heck and Brandt (1977)** , range from 30 minutes to eight hour values. They agree well with results of comprehensive field experiments near a sulphur dioxide source in Germany (**Guderian and Stratmann, 1962**). Slight to no effect on a range of sensitive plants was found for a maximum 30 minute concentration of 3400 $\mu g/m^3$ (1.3 ppm).

O'Connor et al (1974 a,b) reported the results of numerous experiments designed to determine the susceptibility of Australian tree and shrub species to acute sulphur dioxide injury. No evidence of acute of chronic injury, premature leaf abscission, or any other abnormality was observed in sets of plants exposed to 786 $\mu g/m^3$ (0.3 ppm) of sulphur dioxide over the period of 27 hours. In later experiments the authors determined the major injury thresholds for highly sensitive species of Eucalyptus as 2620 $\mu g/m^3$ (1.0 ppm) over three hours. The corresponding value for resistant species was 7860 $\mu g/m^3$ (3.0 ppm). Consistent with the extrapolation of gaseous fluoride threshold values and reflecting the high degree of conservatism inherent in our analysis, the threshold boundary was obtained by fitting the power law (n = 0.31) through the 0.3 ppm point over a three hour interval.

5.3 MINIMUM STACK HEIGHT WITH RESPECT TO VEGETATION

The bold lines in Figures 5.1 and 5.2 provide the estimates of injury threshold values for sensitive plants in the vicinity of the proposed thermal upgrading plant. The minimum height of the discharge stack above the ground was determined as the height which will reduce the maximum ground level concentration of combined indicators below those threshold values. Three minute ambient air quality objectives were used to focus the design criteria on the worst case situation.

5.3.1 Equivalent Fluoride Exposure

The calculation procedure is based on the concept of equivalent fluoride emissions in excess of the actual fluoride emissions to accommodate the possibility of additive effects of sulphur dioxide to the fluoride exposure. The ratio of ($HF:SO_2$) = (200:1) is consistent with the threshold values in Figures 5.1 and 5.2. The peak emission rate of (HF) equivalent was then calculated as $Q_{HF} + (Q_{SO_2}/200)$ = 30.25 kg/hr. It occurs for the maximum of 30 minutes between the 120 and 150 minute mark during each charge. The other applicable emission rates of (HF) equivalent are shown in Table 5.1 along with emissions of (SO_2) equivalent.

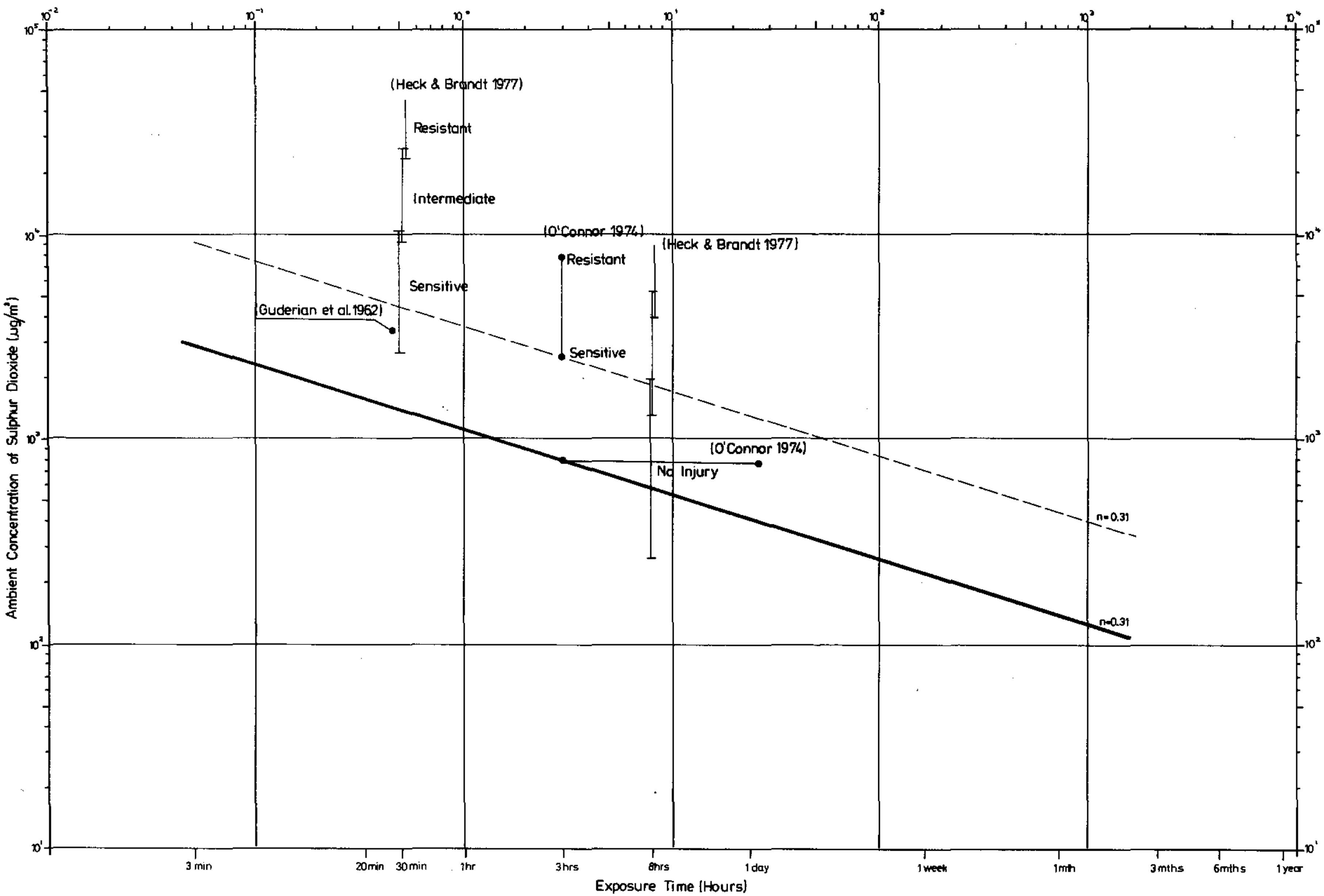
TABLE 5.1

PROJECTED COMBINED EMISSION RATES OF SULPHUR DIOXIDE AND GASEOUS FLUORIDE (kg/hr)

Time Interval	(HF) Equivalent	(SO_2) Equivalent
30 minute peak	30.25	6050
1 hour maximum	29.6	5912.5
Average per charge	17.2	3431
Average per year	12.6	2527.6

The Model

The dispersion model for the simulation of the three minute maximum ground level concentrations includes considerations of dispersive conditions associated with coning, high wind fumigation, and plume trapping and inversion break-up.



PROJECTED CONCENTRATION THRESHOLDS OF INJURY TO VEGETATION BY AMBIENT SULPHUR DIOXIDE

FIGURE 5·2

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The inversion break-up fumigation (IBF) occurs when a buoyant plume is trapped in an elevated inversion layer and the conditions below the inversion base become neutral or unstable. The IBF may also be caused by advection of air from cool to warm surfaces as from water to land in coastal areas. Higher than usual ground level concentrations are experienced at some distance downwind from the source because of the dominance of plume behaviour by buoyant rise at smaller distances. The duration of IBF is inherently short, from a few minutes in the case of smaller, less buoyant plumes to 30 to 45 minutes for very large stacks. Although the absolute frequency of IBF may be fairly high, the frequency at any particular downwind location is low because it occurs over a large range of downwind distances.

The limited mixing or plume trapping occurs when upward mixing of the plume is restricted by an elevated inversion below which strong mixing takes place. The duration of limited mixing can be quite persistent lasting possibly for several hours on days of subsidence inversion associated with anticyclones.

The high wind fumigation (HWF) occurs as a result of coning when the atmosphere is well mixed by turbulence at all heights. The maximum ground level concentration is found at a point downwind usually of the order of ten stack heights. Because the HWF is caused by coning it can persist for hours under cloudy, windy conditions.

The looping of plumes occurs with highly unstable atmospheric conditions. Large convective eddies are produced by solar heating and concentrated plume segments may reach the ground for very short time intervals. Between these intervals ground level concentrations remain very low.

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Of all four types of fumigation described above the high wind fumigation will most often be associated with the meteorological conditions prevailing in the region. The region lies within the broad band of strong westerly winds and the variation of cloud coverage on a daily and seasonal basis is not large. Surface wind measurements at all proposed sites indicate a dominant westerly component and mean velocities in the range of 2 to 5 m/s. Summer wind velocities usually fall in the top of the range, the bottom of the range is more prevalent in winter. Mean annual wind speed at Zeehan is 2.6 m/s, Queenstown 3.0 m/s, Wynyard 4.0 m/s and Stanley 4.1 m/s.

In the first stage of plume calculations a coning model was applied to neutral conditions and minimum wind speed of 2.6 m/s. As the critical wind speeds are generally low owing to the only moderate buoyancy of the plume the lowest observed wind speed was used. In the second stage the effect of fumigation processes was examined. It was found that all the maximum ground level concentrations fall within a factor of two from the coning model. The final fumigation model used to determine stack heights was defined as an envelope of individual fumigation types and related to the coning model by the factor of two.

Maximum ground level concentrations were estimated using the Pasquill-Gifford (**Turner, 1969**) dispersion coefficients and Briggs' (1975) plume rise formulae. The formulae include a combination of observational data for buoyant plumes from elevated sources. The estimates of SO_2 concentrations over a three minute interval were adjusted by using a simple power law with exponent $n = 0.2$.

Table 5.2 shows the design stack height for each set of conditions with respect to vegetation exposure to equivalent fluoride emissions.

TABLE 5.2

DESIGN STACK HEIGHT WITH RESPECT TO VEGETATION EXPOSURE TO EQUIVALENT FLUORIDE EMISSIONS

Atmospheric Conditions	Emission Rate	Design Stack Height
Coning	Average per charge	34.4 m
High wind fumigation	1 hour maximum 30 minute peak	58.4 m 59.8 m
Plume trapping	Average per charge	71.1 m

A minimum stack height of 71.1 m is required to ensure compliance with the fluoride injury threshold. The proposed height of 100 metres would include an additional and significant safeguard by reducing the concentration levels even further.

5.3.2 Equivalent Sulphur Dioxide Exposure

The calculation was repeated for equivalent sulphur dioxide emissions yielding identical design stack heights. Table 5.3 shows projected three minute concentration maxima for the proposed 100 metre stack and a buoyant plume. The maximum values in Table 5.3 compare very favourably with the projected threshold value of 3000 $\mu g/m^3$ over the three minute interval.

TABLE 5.3

MAXIMUM THREE MINUTE GLC OF EQUIVALENT SULPHUR DIOXIDE FOR A 100 METRE STACK

Atmospheric Conditions	Emission Rate	Maximum Three Minute Concentration	Injury Threshold Value
Coning	Average per charge	873 $\mu g/m^3$	
High Wind Fumigation	1 hour maximum 30 minute peak	1504 $\mu g/m^3$ 1540 $\mu g/m^3$	3000 $\mu g/m^3$
Plume Trapping	Average per charge	1746 $\mu g/m^3$	

The highest concentration experienced locally during the worst case situation is not expected to exceed 50 percent of the projected threshold value.

5.4 STACK HEIGHT WITH RESPECT TO PUBLIC HEALTH

It was shown that the proposed stack height of 100 metres would result in peak concentration levels well below the threshold limits of vegetation injury by sulphur dioxide and gaseous fluoride, both by separate and collective exposure.

Different ambient air quality objectives were applied to considerations of public health. They included sulphur dioxide and arsenic as the indicators.

5.4.1 Ambient Levels of Sulphur Dioxide

The determination of the applicable ambient standard for sulphur dioxide with respect to humans was discussed with the Department of the Environment. On the recommendation of the Department the extremely conservative value of 445 $\mu g/m^3$ (0.17 ppm) over a three minute interval was selected to check the performance of the proposed stack. The resulting maxima are shown in Table 5.4.

TABLE 5.4

MAXIMUM THREE MINUTE GLC OF SULPHUR DIOXIDE FOR A 100 METRE STACK

Atmospheric Conditions	Emission Rate	Maximum Three Minute Concentration	Ambient Standard
Coning	Average per charge	137.8 $\mu g/m^3$	
High Wind	1 hour maximum	232.2 $\mu g/m^3$	
Fumigation	30 minute peak	262.5 $\mu g/m^3$	445 $\mu g/m^3$
Plume Trapping	Average per charge	275.6 $\mu g/m^3$	

Only 60 percent of the local ambient standard is approached under the worst case conditions. A minimum height of 72.5 m would be sufficient to ensure compliance with the standard.

5.4.2 Ambient Levels of Arsenic

More than 90 percent of the arsenic emitted from the fuming plant will be in the submicron range allowing dispersion calculations to be carried out in a manner similar to gaseous pollutants. Ambient air quality standards were adopted in most European countries and used along the same lines as standards for sulphur dioxide and other major indicators. The standards are summarised in Table 5.5 indicating the lowest acceptable value of 3 $\mu g/m^3$ for short time exposure of 30 minutes. This value corresponds to 4.75 $\mu g/m^3$ (simple power law with $n = 0.2$ for plume behaviour) and 6.1 $\mu g/m^3$ ($n = 0.31$) over the three minute interval. For comparison, the industrial threshold limit to which workers may be repeatedly exposed for eight hours, day after day, in workplace is 250 $\mu g/m^3$.

TABLE 5.5

AMBIENT AIR QUALITY STANDARDS FOR ARSENIC

Bulgaria, Czechoslovakia, East Germany, USSR, Poland, Yugoslavia	3 $\mu g/m^3$ over 24 hours
Poland	2 $\mu g/m^3$ over 24 hours
Romania	1 $\mu g/m^3$ over 24 hours
Poland	5 $\mu g/m^3$ over 20 minutes
Romania	3 $\mu g/m^3$ over 30 minutes

Table 5.6 shows the estimated maximum three minute concentrations of arsenic in the vicinity of the 100 metre stack for a range of atmospheric conditions. The maximum value for the worst case did not exceed about 60 percent of the strictest ambient standard applicable.

TABLE 5.6

MAXIMUM THREE MINUTE GLC OF ARSENIC FOR A 100 METRE STACK

Atmospheric Conditions	Emission Rate	Maximum Three Minute Concentration	Ambient Standard
Coning	Average per charge	1.15 $\mu g/m^3$	
High Wind Fumigation	30 minute peak	2.95 $\mu g/m^3$	4.75 $\mu g/m^3$
Plume Trapping	Average per charge	2.3 $\mu g/m^3$	

5.5 ALTERNATIVE SOLUTIONS

Alternative solutions to the atmospheric emissions control would have to be based on the implementation of gas cleaning techniques. A high degree of removal from the effluent gas would be required in order to meet the emission limits set by the Regulations.

In the case of arsenic the excess factor is 26 and a minimum cleaning efficiency of 96.30 percent would be needed to achieve the required dilution. In the control of arsenic emissions special attention has been given to the temperature of the effluent gas since arsenic trioxide sublimes at 192°C. For this reason the exhaust fumes must be cooled prior to removing arsenic as particulates. Owing to the small particle size and the high target efficiency a series of cleaning equipment would be required including cooling flues, bag houses and electrostatic precipitators.

Wet scrubbing techniques would have to be applied to remove fluorine compounds from the gas stream. A minimum efficiency of 92.2 percent is required to compensate for the excess factor of fluorides in the effluent of 11.8. A similar type of industrial waste, which contains the fluoride in the form of HF with only small amounts of SiF_4, is produced in phosphate processing. The experience in the industry has shown that since HF has a high vapour pressure over aqueous solutions, concentrated solutions of HF cannot be obtained by scrubbing the gases with water. Consequently, copious amounts of water are required with the addition of lime or limestone creating water supply and water pollution problems as well as solid waste disposal problems as side effects.

The reduction factor applicable to emissions of sulphur dioxide would have to be determined on the basis of ground level concentrations. In relation to the efficiency of the scrubbing technique it is interesting to determine the reduction factor with respect to SO_2 ground level concentrations achieved by the 100 metre stack. The release of a unit volume of buoyant gas from a 100 metre stack and under neutral atmospheric conditions results in a maximum ground level concentration 120 times lower than the release of the same gas, but cool, from a 20 metre stack. Therefore a wet scrubbing technique with the efficiency of 99.2 percent would be required to achieve the same degree of dilution of sulphur oxides at the ground level. Most of the processes for removing sulphur oxides from waste gases involve introduction of some material into the gas stream to combine with the sulphur dioxides and convert them to a removable liquid or solid. Only two materials have normally been considered for the throwaway process, i.e. limestone and water. Of these, water has the disadvantage that sulphur dioxide is not very soluble and large volumes of water are required. Most of the emphasis had therefore been on use of limestone. Wet systems are preferred to dry systems but there are drawbacks to the wet system as well, including corrosion, pressure drop through scrubbers, growth of crystal deposits in the equipment, and cooling of the gas. Large quantities of water are required and the acidity of the scrubber effluent makes disposal a problem. Sludge disposal and relatively high power requirements for the operation of the scrubber also have to be considered.

The cost of a scrubbing installation varies widely with many factors, including type of absorbent, size of the installation, method of sludge disposal, and various site-related considerations such as the availability and cost of electric power. In view of the high cleaning efficiencies required to meet the existing Regulations the overall costs have been estimated to exceed 15% of the total plant capital cost and 20% of the annual plant operating costs.

5.6 JUSTIFICATION OF DISPOSAL STRATEGY

The proposed tall stack strategy to dispose of atmospheric emissions at the Renison site can be justified by a number of factors. The factors encompass environmental, safety and economic considerations.

5.6.1 Environmental Factors

The construction of a 100 metre stack in conjunction with the simultaneous retention of plume buoyancy would ensure the unconditional compliance with ambient air quality objectives in Tasmania and ambient air quality standards worldwide. No country in the world could be identified in which the allowable ambient levels of any of the indicators would be violated by the emission from the proposed fuming plant. In fact, the maximum ground level concentrations would reach only 50 to 60 percent of the limit. In addition, very conservative design criteria were adopted in the process of atmospheric calculations increasing the safety margin of the proposed strategy well beyond the factor of two.

It is seen as significant that the proposed strategy would result in a reduced impact on the environment compared with strict adherence to the existing regulations. Ground level concentration maxima estimated with respect to the tall stack are shown in the first column in Table 5.7. The second column indicates the corresponding values obtained when current regulations are applied, i.e., emission limits for fluorine and arsenic compounds are met and sulphur dioxide is removed from the gas to the point where it meets ambient air quality objectives when released from a 20 metre stack.

TABLE 5.7

MAXIMUM GLC ESTIMATED FOR DIFFERENT CONTROL APPROACHES

Maximum Ground Level Concentrations	Proposed Strategy	Current Regulations
Gaseous fluoride	6.7 $\mu g/m^3$	67 $\mu g/m^3$
Arsenic	2.95 $\mu g/m^3$	14 $\mu g/m^3$
Sulphur dioxide	262.5 $\mu g/m^3$	262.5 $\mu g/m^3$

Related to the reduced impact of the proposed strategy is the fact that it does not introduce water and solid waste disposal problems in addition to atmospheric emissions. Wet scrubbing control techniques, on the other hand, have the potential to present an environmental problem transformed from air to water and land.

5.6.2 Safety Factors

Tall stacks are relatively maintenance free and not subject to mechanical or electrical failures as gas cleaning equipment normally is, thus providing more dependable protection to the environment.

5.6.3 Economic Factors

The capital and operating costs inherent in installing gas cleaning equipment are high. In addition to the estimated costs of scrubber installation, the costs of the additional power requirements, equipment maintenance, and the acquisition of scrubbing materials and the disposal of scrubber wastes would have to be met.

It is unlikely that the required efficiency for the removal of sulphur dioxide from the gas could successfully be maintained on a continuous basis. Depending on the efficiency actually achieved the construction of a medium stack (50 to 60 metres) could become necessary adding a significant premium to the costs of implementing environmental safeguards.

The proposed strategy, on the other hand, would reduce waste gas disposal costs to about 20% of the capital cost and less than 10% of the annual operating costs of the gas scrubbing option.

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SECTION 6

EFFECTS OF PROPOSAL ON THE ENVIRONMENT

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6.1 EFFECTS ON TOPOGRAPHY AND DRAINAGE

The proposal will have only a minor effect on the local topography. Approximately 3 ha of land will be cleared and levelled.

Existing drainage patterns in the area will not be altered. Possible effects on the quality of water in these streams is discussed in Section 6.4.

6.2 EFFECTS OF AIR QUALITY

In developing the strategy for minimising the effect of atmospheric emissions described in Section 5 the emphasis was on projecting the local maximum ground level concentrations of major indicators over short periods of time associated with the worst case situation. It was shown that the release of effluent gases from a 100 metre stack resulted in safe short-term levels of fluoride, sulphur dioxide and arsenic which would reach the ground under adverse atmospheric conditions. The stack height was designed with respect to pollutant effects on human health and vegetation, both separately and collectively. It is expected that the peak three minute concentrations of any indicator shall not exceed 60 percent of the lowest ambient standard applicable.

The application of short-term criteria to stack height design calculations is a safe and standard procedure followed worldwide. The development of long-term climatological dispersion patterns presented here serves as a useful screening technique for determining the effect of local meteorological parameters on the long-term concentration levels around the proposed site.

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6.2.1 Dispersion of Atmospheric Pollutants

A standard Gaussian long-term dispersion model was applied to calculate ground-level values of all indicators using statistical wind summaries compiled from the data observed at the Zeehan State School.

A simplified joint frequency function of occurrence fi,j was derived for 16 wind sectors of 22.5 degrees each (j=1 to 16) and for five wind speed categories (i=1 to 5). The mean weighted speed was determined for each wind sector and used in the model equation to calculate the annual concentration levels as:

$$C = \frac{2}{\sqrt{2\pi}\ x \left(\frac{2\pi}{n}\right)} \sum_{i,j} \frac{Q\ f_{i,j}}{\bar{u}_i\ \sigma_z} \left\{ \text{Decay Term} \right\} \left\{ \text{Vertical Term} \right\}$$

Where x represents the distance downwind from the stack and Q the mass emission rate of the pollutant. The symbol n stands for the total number of wind sectors (n = 16) and σ_z describes the extent of vertical dispersion under D - stability conditions. The mean wind speed in each category is designated $\bar{u}_i$.

The model predictions allowed for buoyant plume rise (**Briggs, 1975**) and also for small plume depletion in the form of an exponential removal term. The decay factor γ used to simulate the removal of fluoride was taken as 1.0×10^{-4} sec $^{-1}$ (reference to the SPCC and other work in the Hunter Valley, New South Wales) and 2.93×10^{-5} sec $^{-1}$ for sulphur dioxide (reference to European and American experiments with long-range transport). No exponential decay was modelled for arsenic. Average neutral atmospheric stability and level terrain were assumed.

The deposition of particulate arsenic on the ground was simulated in a manner initially proposed by **Dumbault et al (1976)** and subsequently adopted in the USEPA model ISC (**USEPA, 1979**).

Particle settling was introduced into the vertical dispersion term and a ground reflection coefficient R was specified to approximate the retention or reentrainment of particles on the surface.

The basic equation for the sector-averaged deposition rate D resulting from a point source of strength Q_t was

$$D = \frac{(1-R)}{\sqrt{2\pi} \times \left(\frac{2\pi}{n}\right)^2} \sum_{i,j} \frac{Q_t f_{i,j}}{\sigma_z} \left\{\text{Decay Term}\right\} \left\{\text{Vertical Term}\right\}$$

The estimated mean annual concentration and deposition levels are shown in Figures 6.1 to 6.4. The distribution of the concentrations is consistent with the occurrence at Zeehan of the prevailing winds from N, NW and SW sectors. The highest mean concentrations are found at a distance from the stack and gradually level off.

The shape of the isopleths presented in Figures 6.1 to 6.4 retains the distinct stepwise character introduced by the sector approach to the classification of wind directions. Subsequent smoothing of the isopleths would result in a more concentric pattern of the contours but also in some flattening of the predicted peaks. As the flattening effect was considered undesirable the stepwise character of the contours must be kept in mind when interpreting the figures.

6.2.2 Sulphur Dioxide Emissions

The mean annual increase in ground level concentrations of sulphur dioxide is shown in Figure 6.1. The highest mean annual increase in the concentration is expected to occur at a distance of about 5,500 metres southeast from the stack. A similar increase is predicted for the northeasterly sectors with generally lower levels in the remainder of the area. The magnitude of the increase of 6 $\mu g/m^3$ compares favourably with the USEPA ambient air quality standard of 80 $\mu g/m^3$ for the period of one year. The ambient objective recommended by the World Health Organisation for a corresponding period of time is 60 $\mu g/m^3$. As a result there will be no adverse effects on air quality from the emissions of sulphur dioxide.

Note: To convert concentrations from μg/m^3 to ppb multiply μg/m^3 by 0.382.

6.2.3 Fluoride Emissions

The locations of the maximum ground level concentrations of gaseous fluoride correspond to the areas identified in the section on sulphur dioxide. The highest value of the expected increase on a yearly basis does not exceed 0.15 μg/m^3. This value of annual ground level concentration was shown to be well below the injury thresholds identified in Section 5.

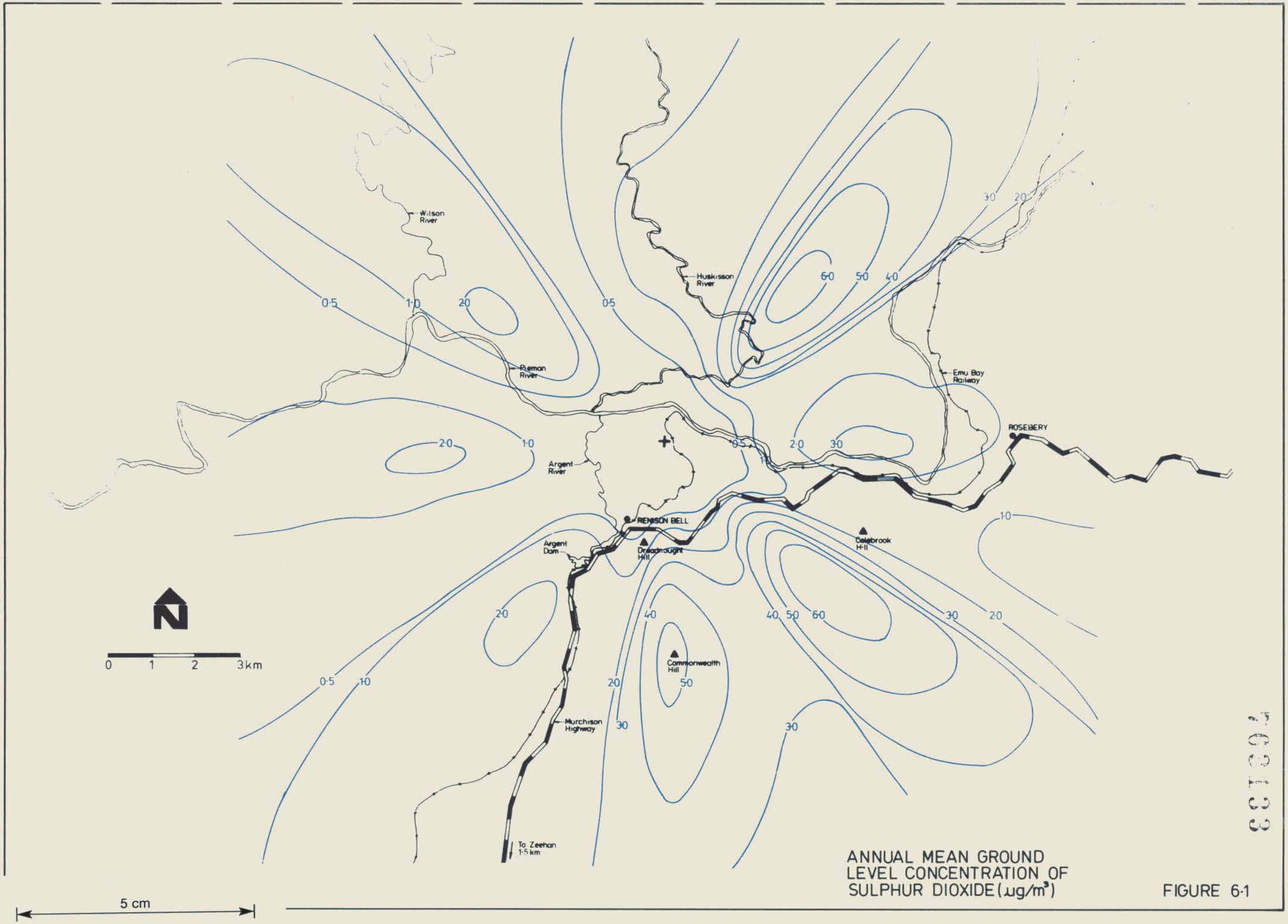
6.2.4 Arsenic Emissions

Ninety percent or more of the arsenic released from the stack will be in the submicron range. It will remain in suspension for long periods of time until the plume will be brought down by the dispersion process.

The estimated highest increase in the mean annual concentration of arsenic near the ground is 0.04 μg/m^3. The highest level permitted in a workplace in Australia is 250 μg/m^3.

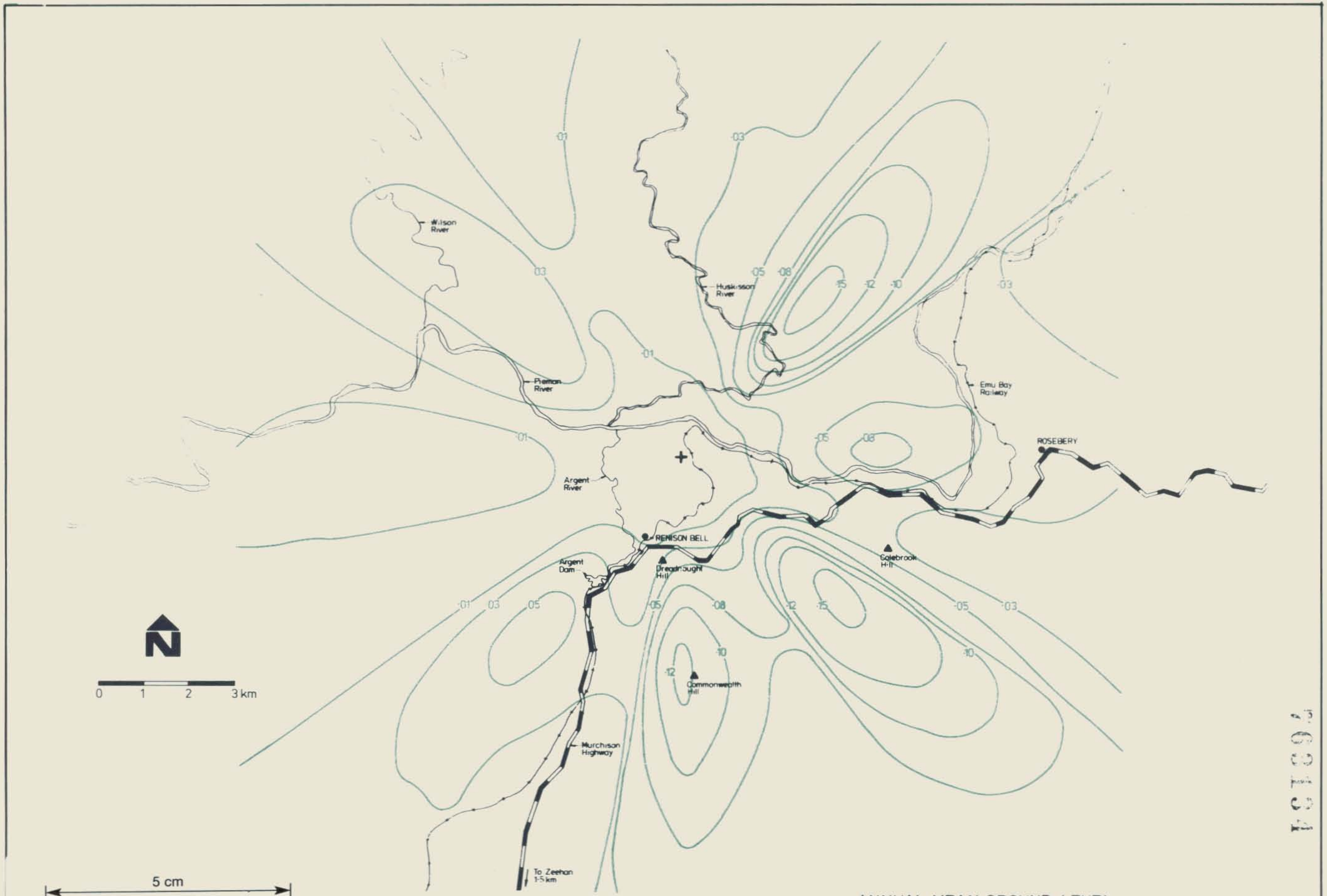
The strictest ambient air quality standard for arsenic applied overseas is 1 μg/m^3 over a 24 hour period. The value is equivalent to about 5.9 μg/m^3 allowable limit for the period of one year. In a number of countries the allowable limits are higher. A detailed discussion of ambient standards applicable to arsenic was presented in Section 5.4.2.

Arsenic associated with larger dust particles will fall out of the plume at an earlier stage and will be deposited on the ground. The distribution of particulate arsenic is shown in Figure 6.4. The highest increase in the deposition rate will be limited to 0.2 mg/m^2.mth. The effects of arsenic on soils will be discussed in Section 6.3.



ANNUAL MEAN GROUND LEVEL CONCENTRATION OF SULPHUR DIOXIDE ($\mu g/m^3$)

FIGURE 6·1



ANNUAL MEAN GROUND LEVEL CONCENTRATION OF FLUORIDE(μg/m³) FIGURE 6·2

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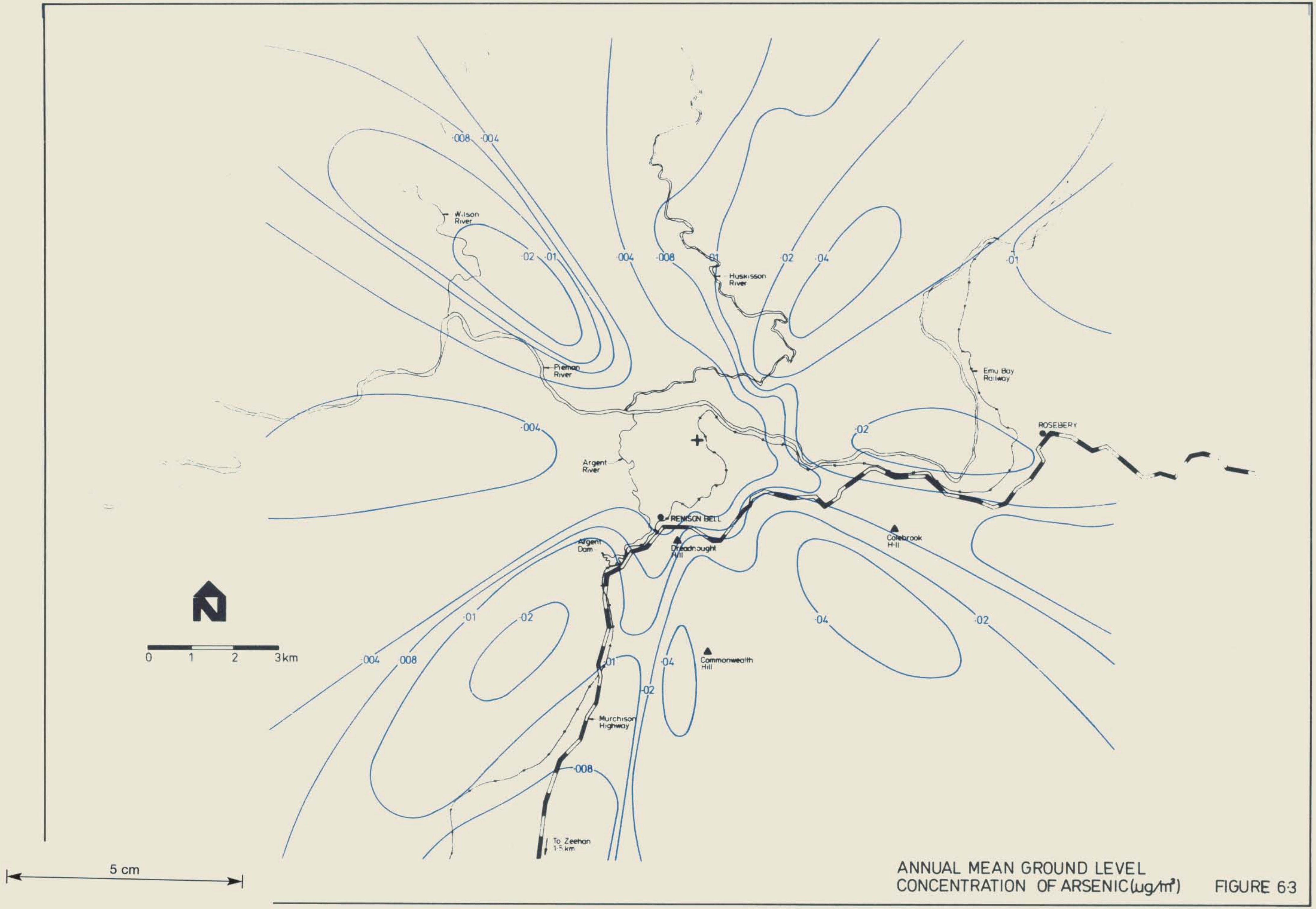

ANNUAL MEAN GROUND LEVEL
CONCENTRATION OF ARSENIC (μg/m³) FIGURE 6·3

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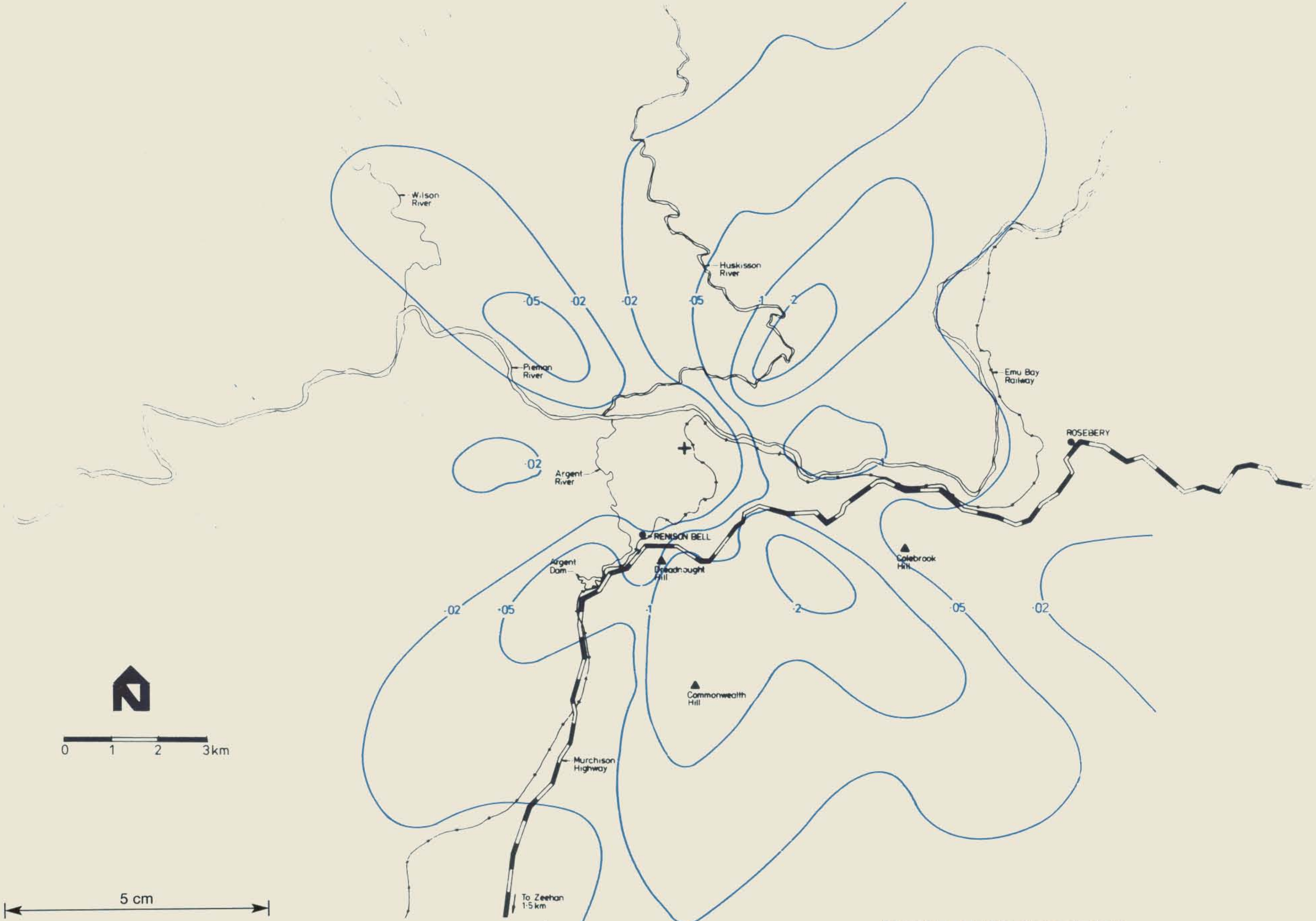

ANNUAL MEAN DEPOSITION
OF PARTICULATE ARSENIC(mg/m² mth.) FIGURE 6·4

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6.2.5 Conclusions

The analysis of the dispersion of stack emissions indicated safe levels of annual concentrations of all three gaseous pollutants as well as annual deposition rates of particulate arsenic. The dispersion patterns at Renison may differ in detail from the climatological data at Zeehan which were used in the analysis. As soon as a representative long-term information becomes available from the ongoing meteorological monitoring programme at Renison the analysis of dispersion patterns will be updated.

The predicted ground level values of pollutants resulting from the proposed Thermal Upgrading Plant will not exceed, at any time or in any location, levels that will endanger vegetation or human health.

6.3 EFFECTS ON SOILS

Gaseous emissions can cause changes in soil chemistry leading to toxicity or the immobilisation of essential elements, and can influence its physical structure.

There are three main pathways by which emissions may reach soils:

(i) by direct fumigation due to drift of the plume,
(ii) by the washing of emissions from the atmosphere and off surfaces by precipitation, and
(iii) by the death and subsequent decay of organisms which have accumulated emissions over their life spans.

The following discussion examines in turn the likely effects of the three gaseous species to be generated in the fuming process.

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6.3.1 Sulphur Dioxide Emissions

Sulphur dioxide is likely to enter soil directly in the dissolved state, and indirectly by the incorporation of organic sulphur from decaying vegetation.

The high solubility of most sulphur compounds renders the likelihood of accumulating levels toxic to either vegetation or micro organisms very slight. Similarly, it is unlikely that any other essential elements will be immobilised. Soil structure is expected to be similarly unaffected.

The sulphur dioxide emissions are not expected to have any significant impact on soils in the area.

6.3.2 Arsenic Emissions

Any arsenic reaching the soil will be rapidly immobilised either by strong adsorption onto clay minerals and oxides and hydroxides of iron and aluminium, or by precipitation as insoluble aluminium or iron arsenates.

Some immobilisation of iron and aluminium will result. It is unlikely however to lead to any deficiencies in these elements.

The very low values of soluble arsenic that may occur in soil profiles are unlikely to reach the maximum concentration of 50 μg/L recommended by **Hart (1974)** to be the safe limit for domestic water supplies and aquatic life.

6.3.3 Fluoride Emissions

Fluoride can enter the soil by each of the pathways described previously.

Due to the typically slow rates of litter decay apparent in the vegetation communities of the region and the tendency for plants to accumulate fluoride in foliage, it is probable that a significant pool of fluoride will accumulate in the decaying litter at the soil surface. Water soluble fluoride will tend to be rapidly leached from soil profiles by the consistent, high rainfall characteristic of the region.

As the amount of fluoride adsorbed by soil colloids is in part dependent on the concentration of fluoride and other ions in solution, the mechanisms of fluoride adsorption and desorption will tend to buffer fluctuation in soluble fluoride concentrations caused by protracted dry or wet weather conditions.

Oelschlager (1971) found that between 8 and 30 kg/ha/yr of fluoride was normally added to soils through superphosphate fertiliser applications to a variety of crops in the U.S. **Weinstein (1977)** and **Hansen et. al. (1958)** concluded that fluoride taken up from the soil by plants was generally very minor in relation to that absorbed directly from the atmosphere and that fluoride concentrations in soils bear little relationship to those found in plants.

Consequently, it is unlikely that fluoride will have any direct effect on plant health through adsorption from soil. If however there are existing problems of magnesium and calcium deficiency, these may be exacerbated by their immobilisation by fluoride, causing some level of nutrient stress.

6.4 EFFECTS ON WATER QUALITY

6.4.1 Surface Waters

Gaseous emissions of sulphur dioxide, arsenic and fluoride, and particulate arsenic will be dispersed over the catchments of the Ring, Argent, Pieman, Huskisson and Wilson Rivers.

The emissions may enter waters directly by absorption of gases at the surface, particulate settling, and by rainfall washing emissions from the atmosphere. A proportion of emissions contacting soil and plants may enter surface waters by more indirect pathways. Contaminated soil and plant material may be transported by surface runoff into watercourses and contaminants may be leached from these materials.

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As the airborne emissions from the thermal upgrading plant will be widely dispersed and transport of contaminants into surface waters will be variable, it is not possible to predict resultant concentrations of contaminants in watercourses. Nevertheless, the impact of the emissions can be placed in perspective by estimating the concentrations in the Pieman River if it is assumed that there is no retention of contaminants in the soil or vegetation. As an approximation of this case, contaminant concentrations were estimated for the Pieman immediately downstream of its confluence with the Huskisson River. This location was selected to represent drainage of contaminants from the tributary inflows.

Water quality data obtained by the company at the Pieman Crossing in the 1979 survey were used to estimate the background contaminant load at this location. This data together with annual average emission rates[1] and an annual average minimum monthly flow of 2570 megalitres per day[2] were used to approximate instream concentrations. Concentrations on this basis were estimated to be about 27 mg/L for sulphate, 0.26 mg/L for fluoride and 0.04 mg/L for arsenic.

The values for sulphate and arsenic are below those recommended by Hart (1974) for drinking water standards, namely 250 mg/L for sulphate and 0.05 mg/L for arsenic. The fluoride concentration is well below the accepted level of 1 mg/L of fluoride added to water for dental health purposes (Hart, 1974).

1. Annual average emission rates

sulphur dioxide	9792 kg/d
fluoride	255 kg/d
arsenic	82 kg/d

2. Flow data based on HEC records for flows at Heemskirk over the period June 1975 to December 1979. Flows in Pieman River down stream of Huskisson River based on relative flow data provided in Section 4.4.2.

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Although lower flows may occur in the Pieman due to extended dry weather periods or stream regulation by the HEC the approximation is considered representative of the worst case as it does not allow for the wider dispersion of emissions beyond the Renison area nor the immobilisation of contaminants (particularly arsenic) in sediment, soil and vegetation. In addition, low flows in the Pieman River are likely to coincide with dry weather conditions when there will be a reduction in both the quantities of contaminants deposited by rainfall and leached from the soil.

As indicated in Section 4.4.2 the water quality of the Pieman River is changing due to the construction of dams for the hydro-electric scheme. As a result, the final quality of ponded waters down-stream of the site may not be predicted with confidence. However, the consistent high rainfall in the region and the operation of hydro-electric plant in the future indicates that there should be a reasonable turnover of the ponded waters and therefore dilution and dispersion of any contaminants. Following the completion of the thermal upgrading plant it is anticipated that the contaminant concentrations in the ponded waters will only be marginally increased above the levels which would have been found under existing conditions.

6.4.2 Groundwaters

Due to the reliable supply of large quantities of surface waters in the region it is improbable that extraction of groundwaters will occur. Following the development of the thermal upgrading plant there is an increased possibility that the levels of soluble contaminants in groundwater, mainly fluoride and sulphate, will increase. With the high rainfall characteristic of the area the recharging of groundwaters will be correspondingly high and contaminant levels should not increase to levels of significance.

6.4.3 Plant Effluents

Proposed water management procedures at the thermal upgrading plant are designed to maximise the re-use of process wastewaters. Only a small volume of process wastewaters will be generated which will be directed to a catch-all dam. Similarly, stormwater from the operations area will also be channeled to this dam. Due to small volumes involved the impact of these wastewaters on water quality will be minimal.
An indirect effect of the thermal upgrading process will be a reduction in existing leach plant throughput at the Renison mill. A corresponding reduction in sulphate concentration in mill tailings will occur and concentrations in the main tailings dam overflow will decrease. This change will reduce lime additions which may cause the pH of the bulk tailings dam to be lowered to a level where the filterable iron and manganese content of the tailings water are increased. There will be no significant change in the overall rate of tailings from the concentrator.

In summary, the proposed operation may increase the concentration of manganese and iron in the tailings water and receiving waters. The effects of this change will be monitored and appropriate plant controls implemented if necessary to maintain effluent within licenced limits.

6.5 EFFECTS ON VEGETATION

6.5.1 Land Clearing

The development of the partially cleared site involves the clearing of less than 3 ha of native vegetation. This consists of predominantly **Nothofagus** - dominated rainforest as described in Appendix 1 and some eucalypts. The area involved is on the northern side of the existing development area.

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6.5.2 Emissions

The main component of the proposed strategy of disposal of atmospheric emissions was the selection of appropriate and, where doubt existed, conservative environmental criteria with the aim of protecting the environment to the maximum possible degree. On the insistence of the Department of the Environment the major emphasis during the process of determining the applicable threshold criteria was placed on the preservation of the native vegetation in the vicinity of the proposed development. The final set of threshold values was used to design the stack height for the disposal of emissions. A considerable safety margin was applied to ensure that the expected maximum pollution levels at the ground were still less than the projected thresholds.

This subsection is devoted to a discussion of the known effects of the emissions on vegetation. The information supplements the corresponding parts of Section 5 and formed the basis for setting the environment protection criteria presented there.

Sulphur Dioxide

The effect of SO_2 on plant species has been comparatively well documented, particularly with regard to overseas species. Responses of plant leaves to SO_2 in the air are highly variable and the effects may be chronic (from lower SO_2 concentrations over extended periods) or acute (from large, short-term doses). The two types of effects and responses do not necessarily directly correlate within the one species or individual (**O'Connor et al, 1974**).

Table 6.1 presents examples of known dosages causing acute and chronic effects in a number of plant species. The results show marked variations but generally very few species appear to suffer adverse, acute or chronic effects below concentrations of 1,000 - 2,000 $\mu g/m^3$. Hypersensitive species however, such as some lichens, may not occur in areas with a mean annual winter SO_2 concentration of greater than 30 $\mu g/m^3$ (**Neiboem et al, 1976**). Other sensitive species may experience hidden injury or other effects at levels between 100 and 1000 $\mu g/m^3$ (**Dochinger and Jensen, 1975; Bell and Mudd, 1976.**)

The annual average ground level concentrations of SO_2 are not expected to exceed 6.0 - 7.0 $\mu g/m^3$, which are well below any concentrations found to have had any effect on any plant species. The maximum three minute concentration of SO_2 for the worst case situation is 275.6 $\mu g/m^3$ and this is also below any short-term levels found to cause acute affects in plants. For Australian species tested, no acute or chronic effects were found in plants exposed to 786 $\mu g/m^3$ SO_2 over 27 hours (**O'Connor et al, 1974**).

Consequently it is not expected that the SO_2 emissions will cause any adverse impacts on vegetation.

Fluoride

Fluoride occurs naturally in plant leaves in industrial free areas, normal background leaf concentrations being 2-20 ppm. With increased ambient fluoride levels, fluoride tends to be accumulated in leaves, the rates of uptake and accumulation and final responses of plants differing widely amongst species and individuals. **Heck and Brandt (1977)** suggest that foliar concentration threshold levels for injury to plants may be about 15-25 ppm for some highly sensitive species and above 200 ppm for resistant species.

Owing to the variations in responses and determining factors, it is not generally possible to correlate directly ambient air concentrations and foliar fluoride levels in the plant community.

Studies of the effects on plants by various ambient fluoride levels have been conducted on both overseas and native plant species and examples of the results are presented in Table 6.1.

The ambient concentration of fluoride suggested as being the threshold for moderate injury to native vegetation by **Mitchell et. al. (1981)** is 0.54 $\mu g/m^3$ over a three month period. This level is equivalent to approximately 0.2 $\mu g/m^3$ annual average as described by **Croft (1980)** and **Doley (1980)** .

TABLE 6.1
CONCENTRATIONS OF SO_2 AND HF AND RESULTANT EFFECTS ON PLANT SPECIES

Gas	Plant Species	Sensitivity Rating	Concentration (µg/m³)	Period of Exposure	Effects	Source
SO_2	**Phaseolus vulgaris**		300	2-3 weeks	Rapid increase in enzyme capacity suggesting temporary increased pollution resistance.	Michele & Queiroz, 1981
			26200;2620;7860	2-3 weeks	Inhibition of translocation and inhibition of photosynthesis at the higher levels.	Noyes, 1980
	Poplar		13000 650	1.5;3;6 hours 6 weeks	Changes in growth, injury. Changes in growth, injury	Dochinger & Jensen, 1975
	Juvenile Pine Needles	S	1400	3 hours	Level of sensitivity.	Godzik & Linskens, 1974
	Acacia melanoxylon	HR	2620;5240;7860	6;4;4 hours	0-5%; 5-20%; 20-50% leaf tissue destroyed respectively.	O'Connor et al, 1974
	Eucalyptus obliqua	R	2620;5240;7860	6;4;4 hours	0-10%; 10-40%; 40-75% leaf tissue destroyed respectively.	O'Connor et al, 1974
	Melaleuca squarrosa	MS	2620;5240;7860	6;4;4 hours	20-40%, 40-70%, 70-100% leaf tissue destroyed respectively.	O'Connor et al, 1974
	M. squamea	ER	2620;5240;7860	6;4;4 hours	0%, 0-10%, 2-25% leaf tissue destroyed respectively.	O'Connor et al, 1974
	Banksia marginata	MS	2620;5240;7860	6;4;4 hours	20-40%; 40-70%; 70-100% leaf tissue destroyed respectively.	O'Connor et al, 1974
	Lolium perenne		343	9 weeks in summer	4% decrease in shoot dry weight for plants introduced to area. No effect on indigenous plants	Bell & Mudd in Mansfield (1976)
			191	26 weeks in winter	50% decrease in shoot dry weight for introduced plants. No effect on indigenous plants.	

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TABLE 6.1 (cont'd)

Gas	Plant Species	Sensitivity Rating	Concentration (μg/m^3)	Period of Exposure	Effects	Source
HF	Cotton	R	4	14 days	533 ppm Foliar fluoride content.	Jacobson et al, 1966 in Weinstein, 1977
	Gladiolus	S	2	9; 7 days	36 ppm; 17 ppm Foliar fluoride concentration necrosis.	Jacobson et al, 1966 in Weinstein, 1977
	Dutch Tulips (some varieties)	S	0.1-0.3	6 hours (3 x every 42 hrs)	Leaf-tip necrosis.	Wolting, 1978
	Sweet Corn	S	0.49	32 days	100% of plants showed Foliar injury symptoms.	Mandl et al, 1980
	Alfalfa	I	0.6 40	80 days 6.25 days	Foliar fluoride accumulation at 75 ppm (dry weight). Foliar fluoride accumulation at 1327 ppm dry weight	Benedict et al, 1964 in Weinstein, 1977 Guderian et al, 1969 in Weinstein, 1977
	Eucalyptus maculata	S	8.5	16 days	Incidence of chlorosis.	Bot.Dpt. Univ. of Qld. 1975
	E. obliqua	S	9.0	39 days	Visible injury.	Henry, 1979
	Banksia marginata	R	2.9 5.9;9.0	8 weeks 8 weeks	Possible visible injury. Visible injury.	Henry, 1979
	Acacia melanoxylon	MR		More than 1 year	Some visible injury around an aluminium smelter.	Doley, 1980

KEY: S - Sensitive; MS - Moderately Sensitive; I - Intermediate; MR - Moderately Resistant; R - Resistant; HR - Highly Resistant; ER - Extremely Resistent

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The expected annual average fluoride levels in the vicinity of the proposed plant fall below both the 0.5 μg/m^3 and 0.2 μg/m^3 levels. Consequently, it is expected that no significant injury would occur to the majority of plant species in the area.

The possibility of hypersensitive species occurring in the locality cannot be discounted owing to the lack of detailed knowledge of the responses of most native species to fluoride, particularly over longer periods of a year or more. Such species may be affected at levels between 0.1 μg/m^3 and 0.2 μg/m^3 as found for some crop and cultivated species (Table 6.1), by experiencing metabolic 'hidden injury' **(Doley, 1975)** . Such injury may occur at concentrations 2-5 times lower than those causing visible injury.

Figure 6.2 shows that areas to the southeast and northeast of the plant will experience the highest long-term levels. The predicted levels are below 0.16 g/m. The main vegetation types within these areas are **Nothofagus** - dominated rainforest, Eucalypts over scrub, Eucalypt Forest/Eucalypts thickly overtopping rainforest and Restio Sedgeland.

Known sensitivities of plant species occurring in these communities are given in Table 6.1. One of these, **Eucalyptus obliqua** has been listed as sensitive by **Henry (1979)** .

Topography is an important factor affecting the actual levels of fluoride experienced by the plant communities. Gullies in the vicinity of the highest exposure levels (greater than 0.1 μg/m^3) may be subject to increased fluoride concentrations under certain conditions.

The possibility of a few unknown and very sensitive species being affected, possibly mainly in terms of hidden injury, cannot be discounted.

The overall impact on vegetation from fluoride emissions is not expected to be of significance.

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Synergistic Effects of Sulphur Dioxide and Hydrogen Fluoride

Investigations have been made on the combined effects of SO_2 and HF on plant species (**Air Pollution Training Institute, 1976; Mandl, Weinstein and Keveny, 1975**). Various relationships have been found for different experiments with some adverse and some beneficial responses observed. Generally, however, any effects were found with far higher concentrations of SO_2 (e.g. 234 $\mu g/m^3$ over 23 days) than are expected to occur in the vicinity of the plant. The concurrent fluoride levels were also higher than those expected at Renison.

Synergistic effects of SO_2 and HF are not expected to be of major significance in the area.

Arsenic

Few studies appear to have been conducted on the effects of particular ambient arsenic concentrations on plant species. Arsenic levels in the foliage of most plant species are less than 5 ppm (**Williams and Whetstone, 1940**). The level of arsenic in forage considered safe for dairy cattle is 30-50 ppm.

The levels of particulate arsenic considered safe for industrial workers is 250 $\mu g/m^3$ (**Goldsmith and Friberg, 1977**) and concentrations in the vicinity of the thermal upgrading plant are 1,000 times less than this.

Generally plants absorb arsenic from the soil and the element is concentrated in the roots before accumulating in the above-ground parts. Available arsenic concentrations in the soil are not expected to increase significantly. No impact on vegetation is expected.

6.6 EFFECTS ON WILDLIFE

6.6.1 Land Clearing

The clearing of vegetation will mean a loss of those wildlife species and individuals dependent on that particular area. Since the area is small, the impact on wildlife numbers will be minor.

6.6.2 Emissions

Sulphur Dioxide

Table 6.2 presents data on ambient air concentrations known to have affected wildlife. The values are all in the order of 10 to 1000 times higher than the predicted levels around the plant.

Indirect effects on wildlife through damage to habitat by emissions are also unlikely.

The effect of the low level SO_2 emissions on bees is not known.

Fluoride

The effects of fluoride on native wildlife species are not well documented at present. Elevated levels have been found in some species around an aluminium smelter at Kurri Kurri, New South Wales (**Croft, 1980**) but the effects of such levels have not been determined.

Table 6.2 presents data of fluoride effects on wildlife. Impact has in the past been determined largely by comparison to the effects on the dairy cow, the most sensitive domestic animal. A forage level of 35 ppm which equates with the 0.3 $\mu g/m^3$ annual average isopleth has been considered to be safe (**NSW State Pollution Control Commission, 1980**). There are no areas experiencing such concentrations and no impact on wildlife is expected.

Bees are sensitive to fluoride. Since individuals may range a number of kilometres from a hive, the hives themselves need not be located within a potential zone of impact. There is the possibility that individual bees may be affected by the plant's operations.

TABLE 6.2

RECENT INCIDENTS INVOLVING THE ADVERSE EFFECTS OF SO_2, HF AND As ON VERTEBRATE WILDLIFE

(Adapted from Newman 1979 in Newman 1980)

Date	Location	Species	Pollutant(s) and Source(s)	Reported Atmospheric levels or tissue concentrations[a]	Effects	References
1965	Czechoslovakia	Small birds	Fluoride, aluminium plant	Up to 139 g/m^3 in air	Declining populations	Feriancova-Masarova & Kalivodova (1965)
1967	Ontario, Canada	White-tailed deer	Fluoride, industrial complex	Up to 7,125 ppm in bone and 1,200 ppm in water	Fluorosis	Karstad (1967)
1968	Czechoslovakia	House sparrows	Fluoride, aluminium plant	0.02 to 0.014 mg/m^3 in air	Biological concentration	Balazova & Hulchan (1969)
1969	Czechoslovakia	Red and roe deer	Arsenic, smelter	NA	Sickness and death	Hais & Masek (1969)
1971	Czechoslovakia	Hares	SO_2 and fly ash power plants and other industries	>0.15 mg SO_2/m^3 in air and 300 $t/km^2/yr$ fly ash deposition	Hypocalcemia and hypoproteinesis	Novakova & Roubal (1971), Novakova et al (1973)
1975	Montana, USA	Mule and white-tail deer	Fluoride, aluminium plant	Up to 430 ppm in vegetation	Fluorosis	Kay et al (1975)
1975	Poland	Roe deer	SO_2 and particulates, steel mill	80-450 $t/km^2/yr$ particulates	Reduced antler quality	Jop (1979)
1976	Washington, USA	Black-tailed deer	Fluoride, aluminium plant	3,900 ppm in metatarsals	Fluorosis	Newman & Yu (1976)
1977	Czechoslovakia	House martins	SO_2, particulates, fluoride, and NO_x; power plants and other industries	NA	Reduced nesting	Newman (1977); Newman & Novakova (1979)
1978	England	Field mice and voles	Fluoride, mining	Up to 7,000 ppm in bone	Biological concentration	Wright et al (1978)
1979	Washington, USA	Black-tailed deer	Fluoride, aluminium plant	Up to 90 ppm in vegetation	Browse contamination	Newman & Murphy (1979)
1979	California, USA	Deer mice	Ozone	6.6 ppm for 12 hrs in lab air	Genetic change in sensivity to ozone	Richkind (1979)

a - Tissue concentrations on dry weight basis.
b - NA - Not available
c - Tissue concentrations on wet weight basis
Note: Industrial Threshold Levels for SO_2, F and As given Goldsmith & Friberg (1977) are:
SO_2 - 1.3 mg/m^3 (5ppm)
Fluoride (as F) - 2.5 mg/m^3
Particulates - 0.25 mg/m^3
Arsenic

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Arsenic

Arsenic has been known to have a highly detrimental effect on wildlife populations in a number of instances, (**Newman, 1980**). There are few details of specific ambient air concentrations causing specific effects.

The particulate industrial threshold value for humans is 250 $\mu g/m^3$ (**Goldsmith and Friberg, 1977**) and this is well above both the estimated concentrations. This accepted level for humans and the low possibility of arsenic affecting or concentrating in plants in the area suggests that arsenic will not cause problems for wildlife.

The exception may be bees which are sensitive to arsenic. Threshold levels for injuries are unknown.

6.7 VISUAL EFFECTS

6.7.1 Short Term Effects

Site preparation and construction damage will represent a short term visual impact arising from the colour contrast of the reddish disturbed earth and the green background. Very little of this will be visible from Murchison Highway or the Pieman River.

6.7.2 Long Term Effects

The proposed development is situated within an area of rugged terrain and dense forest ranging in height to a maximum of 30m. These two factors substantially reduce the likelihood of the development creating an impact when viewed from either the Murchison Highway or the proposed Lake Pieman.

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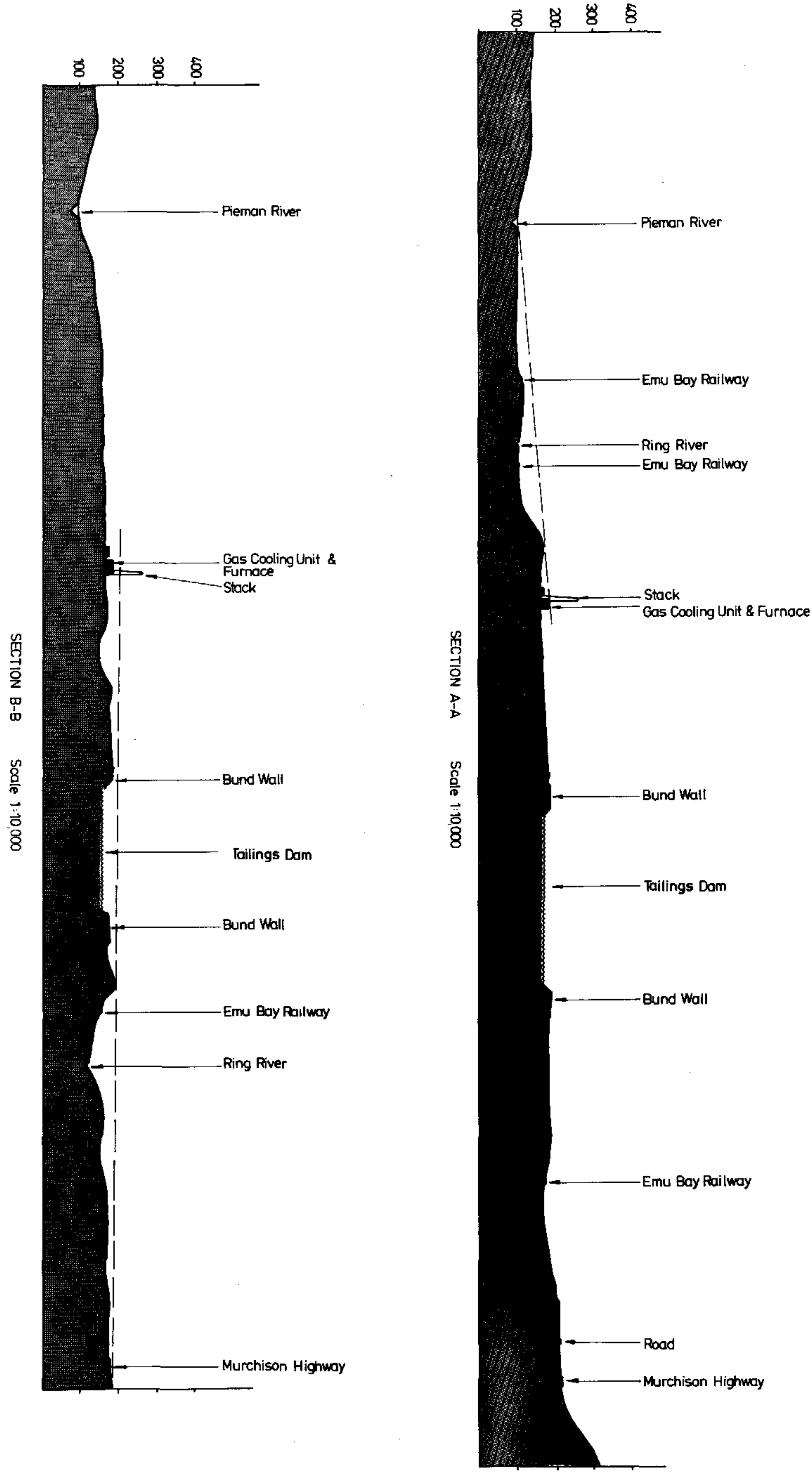
The Pieman River is situated within a deep gorge in this vicinity and with the creation of Lake Pieman it is predicted that standing water level will occur substantially below the level of adjacent banks. The confluence of the Ring and Pieman Rivers is the only position along the proposed Lake Pieman where views to the site may be possible.

Figure 6.5 comprises two typical cross sections between the Pieman River and the Murchison Highway which illustrate lines of sight to the development based upon topography. (The orientation of the cross sections is shown in Figure 2.1.) When the additional screening effects of the dense forest cover are considered, it is predicted that only the 100m high stack will be visible from either of these two viewing points.

6.8 EFFECTS ON NOISE LEVELS

Noise levels produced by the plant will be attenuated with increasing distance from the plant. This attenuation will be due mainly to sound wave divergence, ground absorption and atmospheric absorption. The attenuation due to wave divergence is roughly 6 dB (A) per doubling of distance from the plant. The effect of ground absorption on noise levels depends on the local topography (**U.K. Department of the Environment Design Bulletin No. 26, 1968**). At Renison Bell the result should be a reduction of 10 dB (A) in the plant noise levels experienced. Atmospheric absorption will reduce noise levels by at least 1 dB (A) for every kilometre the noise is propagated (**Harris, 1979**).



TYPICAL SECTIONS
INDICATING VISUAL IMPACT

FIGURE 6-5

It is anticipated that noise levels produced will generally be in the vicinity of 70 dB (A) at 60 m from the plant. The nearest privately-owned residences, at Renison Bell, are approximately 2 km away. Noise levels due to the plant will be attenuated to approximately 28 dB (A) at these residences. This is much less than the measured background noise levels of 38 dB (A). Consequently the plant operations will usually be inaudible at Renison Bell.

An occasional explosion may occur during the slag granulation process. Little is known on the noise levels generated by these explosions but the distance to the nearest houses suggests that this noise should not disturb the residents.

During the construction phase, noise levels in the vicinity of 85 dB (A) at 60 m may be produced. These levels would result from foundation preparations, drills, compressors and cranes, and a range of percussive noises associated with building operations. The resultant noise levels in Renison Bell could be as high as 43 dB (A), compared with existing background noise levels of about 38 dB(A). According to the Australian Standard 1055 "Noise Assessment in Residential Areas" (1978), noise levels no more than 5 dB (A) above existing background levels are unlikely to prove annoying. The construction operations are thus not expected to cause significant impact.

6.9 EFFECTS ON LAND USE

The proposal will have no effect on mining and mineral exploration, the dominant land use in the area. Any possible effects on forestry (the other major land use) and on beekeeping are discussed in Sections 6.5 and 6.6 respectively.

There will be a small increase in the size of Zeehan township and the area of industrial land at Renison Bell.

6.10 EFFECTS ON TRANSPORTATION

The Murchison Highway carries about 800 vehicles per day of which 11.5 percent are heavy vehicles. The Bass Highway over the section of relevance to the proposal, carries about 17,700 vehicles per day of which 2.8 percent are heavy vehicles.

Approximately 25 extra passenger vehicle movements per day will be generated between Zeehan and Renison by the project workforce.

Only one additional heavy vehicle movement per day is expected as shown in Table 6.3.

TABLE 6.3

ADDITIONAL HEAVY VEHICLE MOVEMENTS

Plant Input/Output	No. of Trucks per day
Product*	-1
Coke	1
Sand	1
Fuel Oil	2
Sulphuric Acid**	-1
Lime**	-1
	1

* Because of the increased concentration of tin resulting from the new process, total product tonnage will decrease from 14,000 tpa to 10,400 tpa.

** The fuming process will reduce the requirement for both lime and sulphuric acid by 85 percent.

It is therefore considered that the proposed project will not result in any significant impact on traffic volumes on either the Murchison or Bass Highways. While short term construction generated flows may be higher, they are not expected to create any problems.

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6.11 SOCIAL AND ECONOMIC EFFECTS

6.11.1 Construction Phase

The construction phase of the proposal will occur over a period of 21 months and employ an average of 55 employees. Total costs of the proposal will exceed $30 million.

It is estimated that 50 per cent of the capital expenditure will be spent within Tasmania. Of the remainder, approximately 33 and 17 per cent will be expended elsewhere in Australia and overseas respectively.

Employment

Five per cent of the construction labour requirements may be obtained from the local area. The lack of a local labour surplus with the appropriate skills will limit the extent to which locals may be employed. It is anticipated that 80 per cent of the total construction workforce will be obtained from Tasmania as a whole.

By the application of employment multipliers for the construction industry in Tasmania (Edwards, 1981), a further 90 positions have the potential to be created throughout the State as a consequence of the proposal.

The additional employment effects, obtained through the application of a 2.616 Type II multiplier, give an indication of the maximum number of possible positions rather than a prediction of likely employment growth.

The extent to which Type II employment effects eventuate throughout Tasmania depends on whether industries accommodate the short term increase in demand by employing more labour or by other organisational changes. It is anticipated that due to the limited and short term nature of these impacts the additional positions may not all be realised.

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Income and Output Effects

The construction phase will have a short term economic impact on the local area by creating new sources of income. The magnitude of this impact will be relatively small with the greater proportion occurring elsewhere in Tasmania rather than in the local area.

Expenditure of approximately 50 per cent of construction costs within Tasmania has the potential to increase the value of output from the state's industries. The construction capital spent in the state may increase the total output value of industry by more than $20 million through the application of a 2.376 Type II multiplier.

Population Growth

The requirement for a large proportion of construction labour to be obtained by inmigration will result in a temporary increase in the population of Zeehan. It is envisaged that the population increase will be largely limited to the construction workers themselves.

The lack of accommodation for married workers and their families, the relatively short period of construction, and demographic patterns of previous construction projects in the area indicate that few if any of the construction workforce will be accompanied by their families.

Throughout the construction phase the number of employees will vary, with a peak of 92 men occurring during the eleventh to sixteenth months. Fluctuations in the number and types of construction labour will occur as a result of changing labour requirements during various stages of construction. Impact on the local population will thus also vary according to the changing labour requirements.

Negligible population growth is expected to occur elsewhere in Tasmania due to multiplier employment effects.

Demographic Impacts

The temporary increase in Zeehan's population will involve alteration of the existing demographic structure. This alteration will result from an expected higher proportion of the construction labour force being single, male and of overseas origin.

As the population of Zeehan currently exhibits a demographic structure with a higher proportion of single males, the proposal will result in a temporary accentuation of this characteristic.

Provision of Accommodation and Community Services

The Company is analysing a variety of options concerning the provision of accommodation for the construction workforce. It is intended that accommodation be provided in Zeehan sufficient for the maximum number of construction employees. Demand for community services in Zeehan will increase as a result of the proposal. The limited number and variety of community and recreational facilities currently available in Zeehan will accentuate the effects of this increase. A lesser increase in demand for services may occur in Queenstown.

The principal area in which the additional population will create increased demand lies in the availability of recreational facilities.

6.11.2 Operations Phase

Employment

The proposal will provide an additional 39 employment positions. It is anticipated that 16 of the additional employees will be tradesmen and the remainder operators.

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Based upon past employment patterns it is expected that half of the tradesmen will be obtained from the mainland whilst almost all of the non-tradesmen will be obtained from Tasmania. Of the 30 employees estimated to be obtained from Tasmania, up to 20 may involve new residents moving to Zeehan with the remainder being obtained from existing residents.
Negligible population growth is expected to occur elsewhere in Tasmania due to multiplier employment effects.

The application of a 2.973 Type II multiplier for the Tasmanian Metallic Minerals Mining Industry (Edwards, 1981) results in a possible further 77 employment positions being created throughout Tasmania. This number represents the maximum possible order of effect.

Production induced employment effects are expected to be minimal in the local area as little of the operation's expenses will be spent in that area.

Consumption induced employment effects, based upon the increased consumption expenditure of employees will occur to some extent in the local area but will also be spread over a much wider area. A wider distribution may occur due to the limited range of services provided in the local area and the tendency for local residents to obtain some consumer goods from urban centres outside that area.

Total employment growth in the local area is estimated to primarily involve the 39 operations positions. The distribution of the additional indirect and induced employment positions over a number of centres in Tasmania will limit the extent to which such growth has a significant impact in any one centre.

Income and Output Value Impacts

Annual operating costs of the proposal at full production will be around $5 million at 1981 prices of which around 25% will be paid as wages and salaries.

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Additional income will be created in the local and state economies as a result of Type II income multiplier effects estimated at 2.114 (Edwards, 1981). Significantly more than $1 million in additional income may be generated through those means. As a very limited number of industries occur in the local area almost all of this income gain will be distributed elsewhere in Tasmania.

An economic impact on the output value of Tasmanian industries may result from expenditure made by the Company. As in the case of employment and income multiplier effects, the limited number and variety of local industries precludes the proposal having any significant impact on local industrial output.

In the case of the state as a whole a Type II output multiplier of 1.842 may increase output value to around $3 million at 1981 prices.

Population Growth

Although previous trends at Renison's operations indicate a high proportion of single male employees, it is Renison's intention to employ married persons to fill the needs of this proposal. Similarly due to the nature of these labour needs it is anticipated that almost all will be obtained through immigration.

Based upon the above factors population growth as a result of the proposal is estimated to involve an additional 121 residents. This estimate is based on the assumption that all positions will be filled through immigration, that all new employees are married and have an average of 1.1 children.

The estimated population growth represents a 7.0 percent increase on the 1981 population of Zeehan town. Renison's policy of providing accommodation for its workers in Zeehan will ensure the concentration of new residents in that centre.

Demographic Impacts

Demographic characteristics of the existing workforce indicate that a high proportion (50 per cent) of new employees are single males. As a consequence of the intention to employ married persons it is anticipated that the proposal will serve to reduce, to a degree, the existing population imbalance between sexes and between married and unmarried persons.

Due to the general youthfulness of new employees and their families it is anticipated that the proposal will contribute to a maintenance of the existing population's concentration of residents in the 0 to 10 and 20 to 25 year age groups.

IMPACT ON COMMUNITY SERVICES

Accommodation

Assuming that an additional accommodation unit is required for each of the new employees a further 39 dwelling units will be required in Zeehan. In accordance with the existing policy, these additional units will be provided by the Company. The Company is considering a variety of options concerning the type and proportions in which the accommodation will be provided.

Community Services and Facilities

The increases estimated to occur as a consequence of the proposal will result in additional demands on community services. In terms of the capacity of these services to cater for this growth it is expected that the increased demand will in part be offset by the effects of a decline in the population between 1976-81.

The increased demand for services will largely involve adult recreational facilities and health, education and recreational facilities for children.

Both the medical and educational facilities available to the population of Zeehan have the capacity to accommodate increases in population. It is considered that the relatively small increase in population will not require the provision of additional facilities in Zeehan.

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SECTION 7

ENVIRONMENT PROTECTION MEASURES

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7.1 AIR QUALITY SAFEGUARDS

7.1.1 Dust Controls

Dust may be generated by a number of activities including:

- vehicle movements along unsealed internal roads
- wind erosion of stockpiled materials
- wind losses from conveyors and transfer points
- wind erosion of exposed areas.

The road to the site will be a relatively short extension to the existing roads to the tailings dam walls. Consequently, dust from this source will not be increased significantly. Road dust is unlikely to cause environmental nuisance, because of the remoteness of the site from the public domain. The roads may be watered for dust suppression, if long periods of dry weather are experienced.

Coke and sand as delivered will be moist and will be of great enough particulate size to minimise wind-borne spreading of these materials. It is proposed that the emergency storage piles will be located in the open adjacent to the materials receival/ handling building. Manual hosing will be used to dampen the surfaces of the piles for dust suppression should any problems be experienced with wind erosion of the surface.

Pyrrhotite will be trucked to the enclosed day bin from the existing concentrator complex as required. Little loss of this material is expected either in transit or during transfer to the bin.

Limestone will likewise be held in the enclosed day bin as required. This material will be delivered in covered transports.

The belt conveyors from the raw materials building to the day bins, and from the day bins to the furnace will carry material occasionally susceptible to dusting. There is provision at the furnace feed inlet lock to collect any dust from the feed via a vacuum hood and bag filter, and return it to process.

Product handling conveyors will be fully enclosed. Provision has been made for dust collection at each of the oxide storage bins. This material will be finely divided, and for economic reasons great care will be taken to avoid its loss. From the oxide bins, the product is screw-conveyed in an enclosed conveyor to the pelletizer, and the pellets are to be bagged for sale. Virtually no dust will result from these operations.

7.1.2 Waste Gas Safeguards

The proposed tall stack strategy is seen to be competent and safe. A detailed monitoring programme is proposed to confirm the adequacy of this approach. The ultimate safeguard is that gas scrubbing equipment could be installed and the exhaust gases cleaned prior to emission if this is subsequently found to be necessary. Space for a possible future gas scrubbing unit has been provided in the plant layout. (Refer Figure 3.2.)

The dust in the exhaust gas comprises the tin oxide product and highly efficient electrostatic precipitators will be installed to collect this material. In the event that this dust collection system becomes less than highly efficient the plant would shutdown for repairs. The economic need to collect the dust from the exhaust gases is thus a significant environmental safeguard.

7.2 WATER QUALITY SAFEGUARDS

A major factor in the selection of the process and subsequent plant design has been the need to minimise adverse impacts on water quality. Removal of contaminants from the stack gases, prior to emission to the atmosphere, would create significant problems with regard to the volumes and quality of liquid effluents requiring further treatment. The proposed disposal strategy overcomes these problems and only a small volume of wastewaters will be produced.

A water quality sampling programme will be implemented after the plant becomes operational to monitor any changes in the quality of water.

7.3 NOISE CONTROLS

The dominant sources of noise from the proposed development will be slag granulation, bucket elevation of slag, pelletizers, air blowers and air compressors to furnace, product dust conveyors, induced draft fan to stack, plant air compressors, water pumps and furnace operation.

The Mines Inspection Regulations 1975 specify that 'every owner shall supply properly fitted hearing conservation equipment to every person who, during a normal working day in a mine, is subjected to a noise of a pressure level exceeding 85 decibels A scale ...'. It is a design goal to produce noise levels not exceeding 85 dB (A) in the operations area, and so not rely on hearing protection devices for employees. By housing air compressors, blowers and fans in acoustic enclosures, this goal can be achieved.

7.4 VISUAL SAFEGUARDS

7.4.1 Architectural Design

Buildings and structures will be designed to a common style and constructed using similar materials to ensure resultant site unity.

The major buildings, including the raw materials building, day bin structure, workshop, furnace building and enclosures for the gas cooling unit and electrostatic precipitator, will be clad with prefinished, dark brown, profiled steel sheeting. This colour will minimise discolouration of the sheeting by staining from industrial processes, and will ensure a minimum of glare.

The administration building will be constructed using concrete blocks, and a roof comprising dark brown steel sheeting. Small buildings and structures will be clad in the same steel sheeting, with other components being finished in matching dark brown paint.

The stack is to be constructed from reinforced concrete and will be finished in its natural light grey colour. This finish will result in minimal silhouetting effects.

7.4.2 Landscaping and Rehabilitation

It is predicted that the main source of visual impact will be the cuttings and embankments around the site and along the access road. In this regard, Renison will undertake a revegetation programme to ensure that all disturbed areas within the site boundaries are successfully rehabilitated.

The revegetation programme will comprise replanting of small native seedlings lifted from adjacent dense forested areas. This technique has proven successful in revegetation trials undertaken on the adjacent tailings dam walls. Species to be used in the programme will include those listed in Table 7.1.

TABLE 7.1

SPECIES TO BE USED IN REVEGETATION PROGRAMME

Scientific Name	Common Name	Mature Height
Acacia dealbata	Silver Wattle	10-30m
A. melanoxylon	Blackwood	25-30m
Atherosperma moschatam	Black Sassafras	20 m
Banksia marginata	Silver Banksia	6-10 m
Eucalyptus delegatonsis	Alpine Ash	45-60m
E. nitida	Shiny-leaved Peppermint	8-20 m
E. obliqua	Messmate Stringybark	45-65m
Eucryphia lucida	Leatherwood	7 m
Leptospermum scoparium	Broom Tea-Tree	3 m
Melaleuca squamea	Swamp Honey-myrtle	3 m
M. squarrosa	Scented Paper-bark	3 m
Nothofagus cunninghamii	Myrtle-beech	50 m

However, other methods including the planting of nursery-raised tree and shrub seedlings, conventional planting of stabilising grasses and hydromulching will be used if the proposed revegetation programme proves to be unsuccessful.

Prior to the commencement of the revegetation programme all land disturbed during the construction phase will be graded to form harmonious levels with the surrounding landform, ensuring that drainage is not impeded. Head catch drains will be constructed above all cuttings and embankments to prevent excessive erosion.

7.5 DESIGN OF MONITORING PROGRAMME

A comprehensive monitoring programme will be implemented to support the proposed environmental protection strategy. The programme will address the three main areas related to atmospheric pollution:

* the process emissions,
* the concentration levels in the ambient air, vegetation and soil,
* the dispersive character of the atmosphere.

The current monitoring of water quality will be continued.

7.5.1 Monitoring of Process Emissions

The process emissions will be monitored by taking regular samples of the waste gas from the stack. The samples will be collected by grab sampling once a month and analysed by sensitive instrumental techniques such as atomic absorption for the concentrations of sulphur dioxide, fluorine and arsenic. A detailed sampling procedure will be developed to document the variations in the composition of the waste gas during the different stages of the furnace cycle. At least one full cycle will be monitored every month.

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Grab sampling involves extracting a gas sample into a container which is then taken to the laboratory for analysis. A selection of suitable containers for the grab sample are available. Collection into flexible bags by pumping is suggested. The use of a sensitive analytical equipment in the laboratory would enable an accurate analysis of the sample without the need to concentrate the contaminant in an absorbent or a freeze-out trap prior to sample transport.

In addition to monitoring the composition of the waste gas, simultaneous measurements of the gas temperature and flow rate in the stack will be taken for the duration of a full furnace cycle. A standard pitot tube is suggested to measure the velocity of the waste gas in the stack. A mercury or bimetallic thermometer or thermocouples would be suitable for temperature measurements.

7.5.2 Ambient Air Surveillance

An ambient air monitoring programme will be initiated by Renison to provide the necessary data for establishing the existing levels of sulphur dioxide in the vicinity of Rosebery. It is anticipated that a continuous sulphur dioxide recorder will be installed prior to the commencement of the operations. The exact site for the recorder will be determined in consultation with the Department of the Environment but it is expected to be located between the proposed plant and the township of Rosebery closer to the latter. The continuous analog record will be available on a strip chart for analysis.

The recorder will remain permanently at the Rosebery site to monitor any changes in the sulphur dioxide levels following the commencement of thermal upgrading operations at the proposed plant.

A second sulphur dioxide recorder of similar design will be available to monitor ground level concentrations in the band corresponding to the area of expected touch-down of the plume from the stack. The location of this band was shown in Section 6 to extend from the northeasterly to the southeasterly sector at a distance of approximately 4.5 to 6km from the stack.

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In contrast to the developed instrumental techniques applicable to monitoring of sulphur dioxide in the ambient air, similar instruments for the analysis of atmospheric fluorine and arsenic compounds are still in a development stage. In the absence of reliable monitoring techniques specific to fluoride and arsenic, an alternative monitoring programme is proposed. The programme includes soil sampling with respect to arsenic and vegetation sampling with respect to fluoride and sulphur dioxide.

Finally, the proposed monitoring of the composition of the waste gas in the stack will provide information on the ratios of fluoride and arsenic to sulphur dioxide in the plume. Consequently, the measured levels of atmospheric sulphur dioxide will also indicate the probable levels of atmospheric fluoride and arsenic at the monitoring site.

7.5.3 Soil Sampling

A regular soil sampling programme will be introduced to monitor any changes in the soil arsenic content over the long-term period. Soil sampling sites will be established in the vicinity of Rosebery and samples will be collected twice a year and analysed for total arsenic. The sampling periods will be organised to coincide with the times set for vegetation sampling. One sampling period will be used to reflect dry weather conditions, probably in mid-summer. The second sampling will be undertaken during the winter season.

7.5.4 Vegetation Sampling

The proposed monitoring programme has been devised with the following objectives in mind:

i. To obtain sufficient statistical data to determine existing levels of fluoride, sulphate and arsenic in representative vegetation species in the vicinity of the proposal.

ii. To obtain sufficient statistical data at an acceptable level of accuracy to determine levels of fluoride, sulphate and arsenic in subsequent years after development.

iii. To determine if any observed increases in the concentrations of fluoride, sulphate and arsenic in vegetation are adversely affecting the plant species and if so to what degree and in what localities.

The two main parts of the programme - the field sampling and Landsat imagery interpretation - will interrelate to achieve the third objective.

Correct site selection, and the selection of suitable plant inviduals for sampling is considered to be critical to the success of the programme.

Inherent in any monitoring programme is the necessity for ongoing review and flexibility. The location of sites and sample numbers will therefore be reviewed after the initial collections period and at subsequent intervals and any necessary alterations incorporated.

Site Selection

Ten sites will be selected according to the following criteria:

* Location within areas predicted to experience the highest, moderate and lowest levels of emissions.

* Relative ease of access to the locality and the site itself.

* Correlation with soil sampling sites where possible.

* Occurrence of species required for sampling.

* Visibility of upper parts of species required for sampling facilitating sampling procedure.

Ideally, individual plants selected for sampling would be located close to existing tracks on the edges of small clearings or adjacent to the track. This would be necessary considering the terrain and impenetrable nature of much of the vegetation in the area.

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Species Selection

Five plant species are suggested for sampling, these being:

Nothofagus cunninghamii
Eucalyptus obliqua
Eucryphia lucida
Acacia melanoxylon
Melaleuca squamosa

These species are either dominant or emergent trees, of commercial significance and/or have been rated according to their sensitivity or resistance to fluoride or sulphur dioxide. The latter information is considered useful for the monitoring programme since likely responses of the species are known and therefore trends of sites exhibiting these species may be apparent at an early stage.

Owing to its widespread distribution, **Nothofagus cunninghamii** is a potentially valuable indicator species.

Sampling Procedures

Foliar samples should be collected from five individual plants of each species at each site twice per year. Preferred sampling periods would be in the driest summer month and a wet winter month. Samples will also be collected under similar weather conditions each year within the months stipulated for monitoring.

Foliage collected for analysis should be obtained from the upper layers of the plant species where any effects from atmospheric emissions would be most likely to occur. This presents practical problems in collecting samples from canopies at great heights.

Once samples are collected in the field, the leaves will be placed in plastic bags on ice and transported immediately to the laboratory.

Leaves collected will also be examined for any physical effects.

Landsat Imagery Interpretation

Interpretation of Landsat scenes covering the area around the site will be carried out on a yearly basis. This would enable continual monitoring of the health of vegetation in the area and allow any localities under stress to be determined. Subsequent field investigations could then be undertaken to determine the cause of stress and if there is any relationship with emissions.

Based upon the results of the investigations further refinements of the monitoring programme and the sampling site location may be carried out.

Landsat scenes are readily available within Australia and may be purchased at minimum costs for any given time of year. One scene should adequately cover the area of interest.

7.5.5 Meteorological Programme

A multiparameter meteorological station was established at the prospective site in September 1981. The station continuously monitors wind speed and direction, ambient temperature and relative humidity as well as rainfall. The record is analysed for hourly mean values and processed to provide information needed for the characterisation of dispersive properties and the ventilation potential of the atmosphere. The meteorological programme will continue to build up a representative set of climatological data. The records shall be instrumental in detecting any abnormal dispersion patterns around the plant.

7.5.6 Monitoring of Water Quality

The water quality monitoring programme will provide for the regular collection of water samples from the Pieman River and tributaries both upstream and downstream of the site. Tailings water leaving the on-site dams will also be sampled and the flow rate determined. The water samples collected will be analysed to determine basic water quality characteristics and the concentration of contaminants such as fluorides and trace metals.

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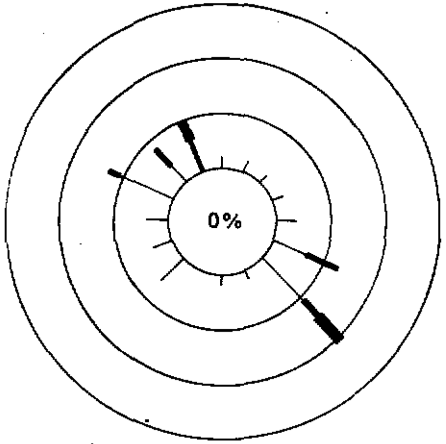
APPENDIX 1

CLIMATOLOGICAL RECORDS AT RENISON BELL
SUMMARY OF WINDROSES
SEPTEMBER 1981 TO APRIL 1982

Footnote: Detailed data reported in separate reports available from Renison Limited.



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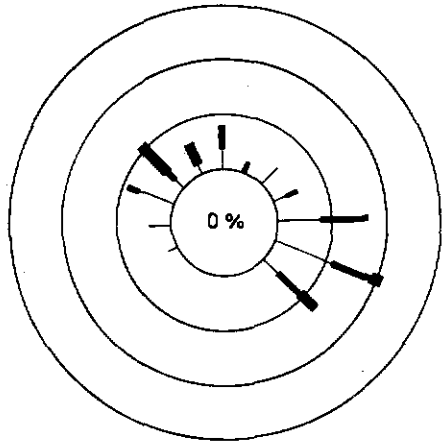

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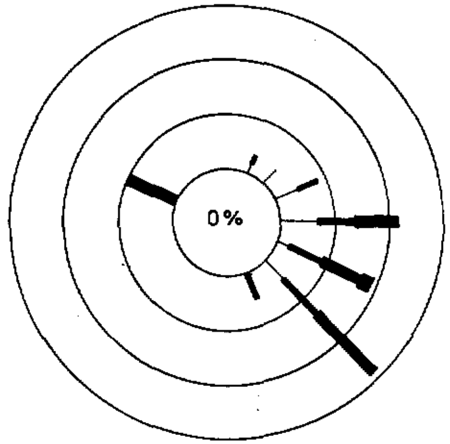

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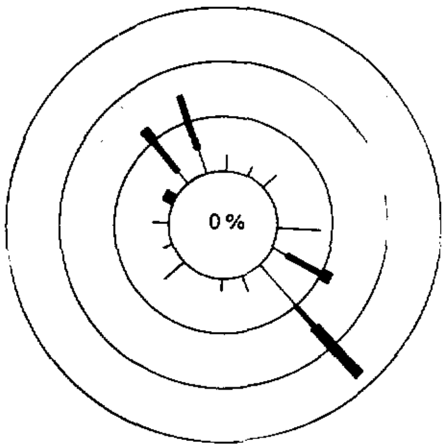

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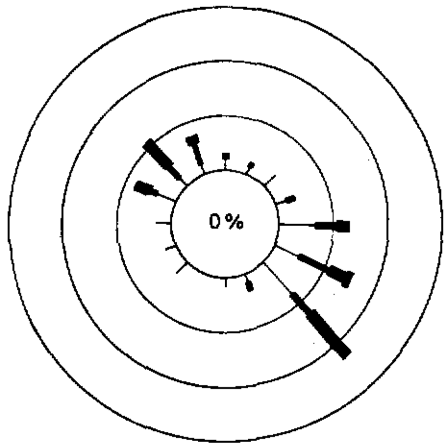

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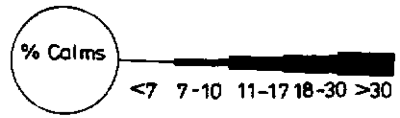
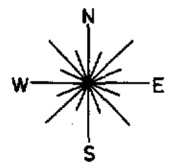
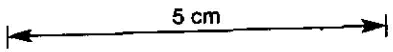


Wind Speed km/hr
Arcs represent 10% frequency intervals





Wind Roses: RENISON BELL
SEPTEMBER 1981

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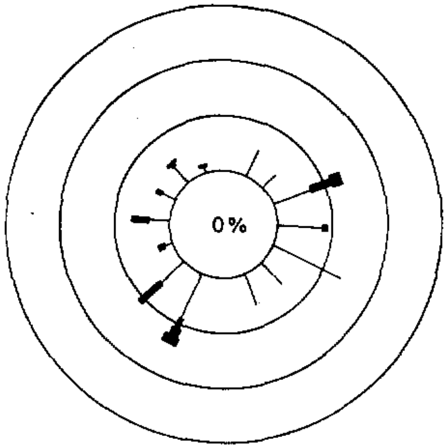

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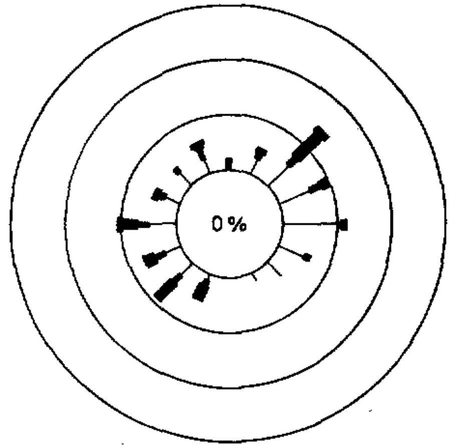

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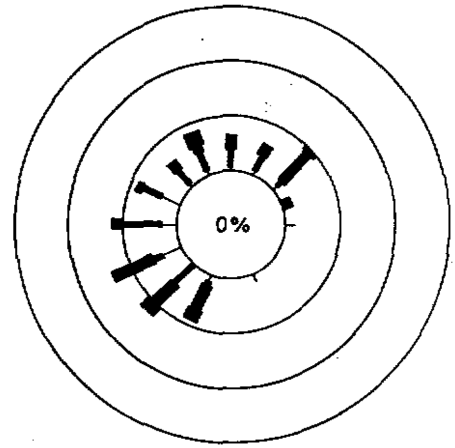

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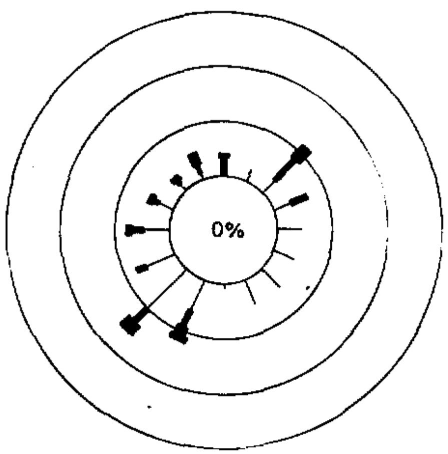

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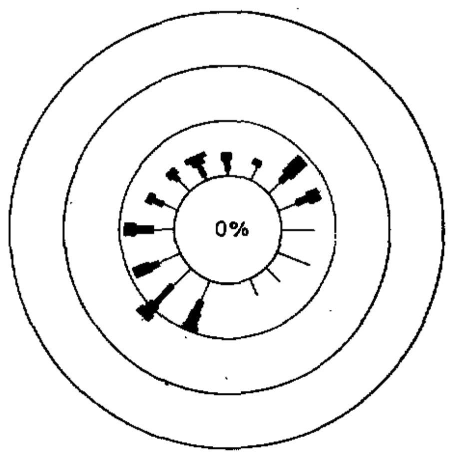

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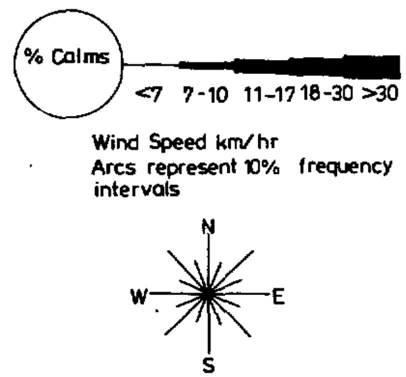

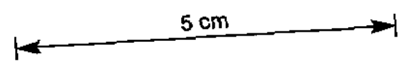

Wind Roses : RENISON BELL
OCTOBER 1981

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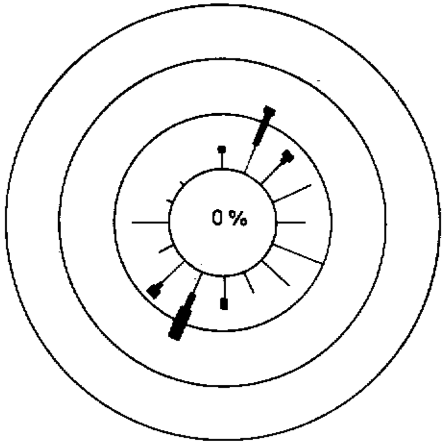

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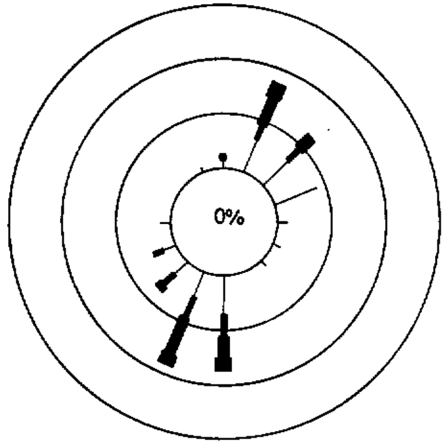

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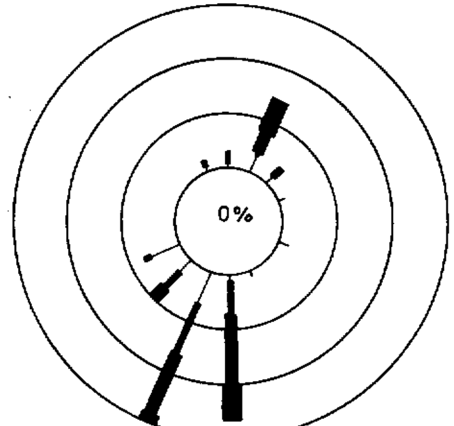

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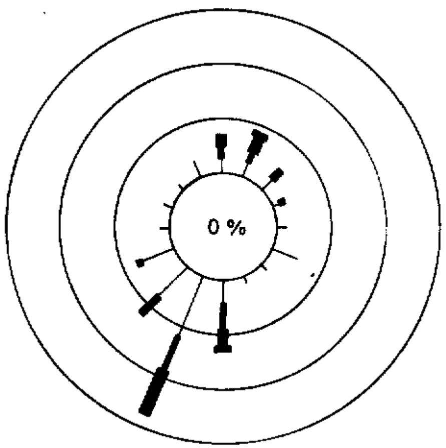

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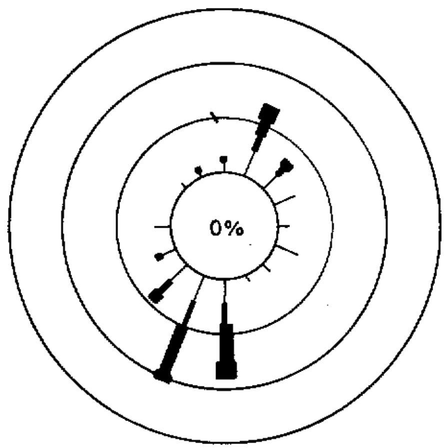

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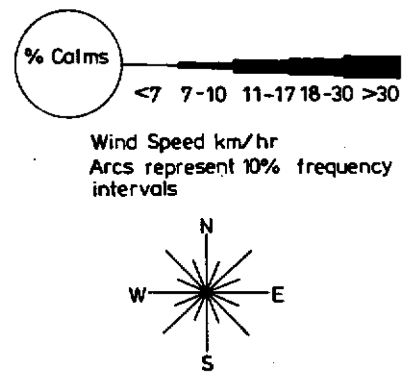
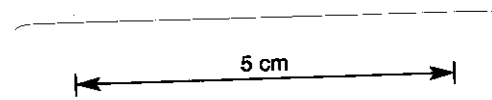
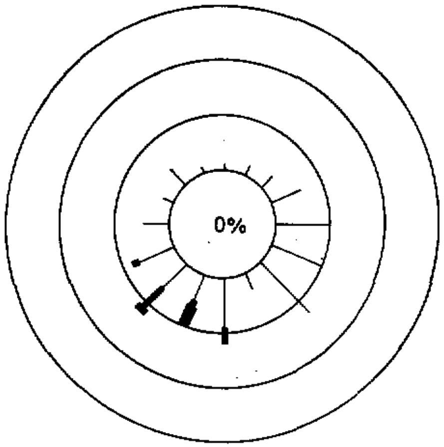




Wind Roses : RENISON BELL
NOVEMBER 1981

763182



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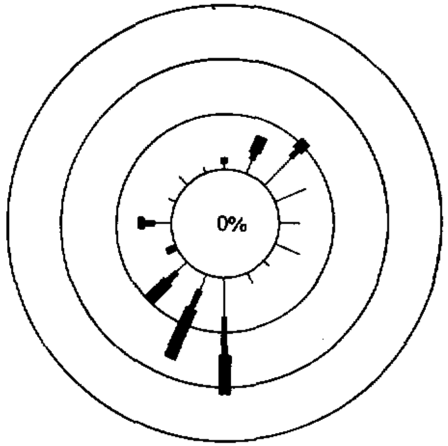

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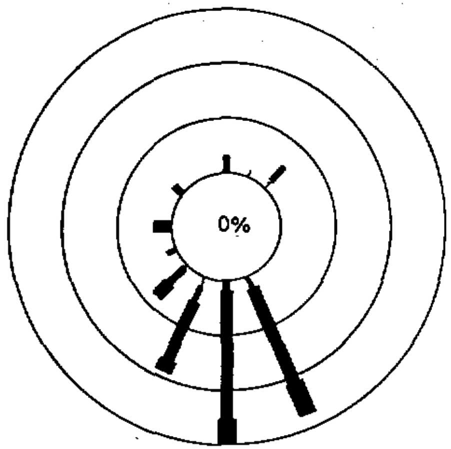

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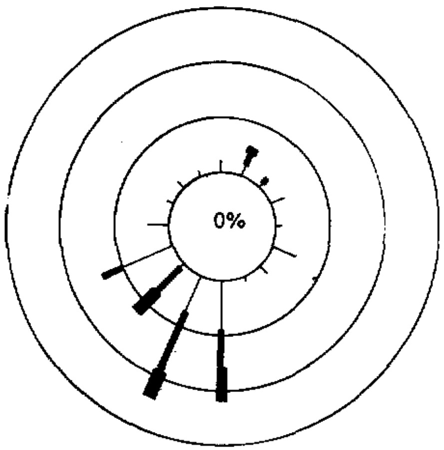

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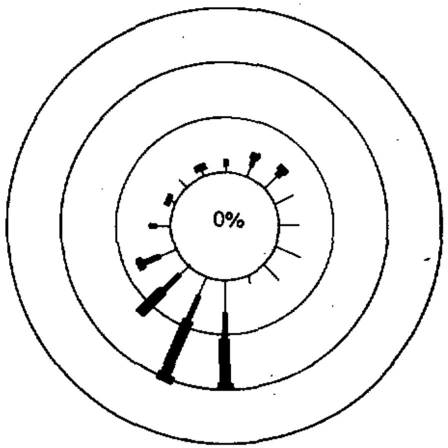

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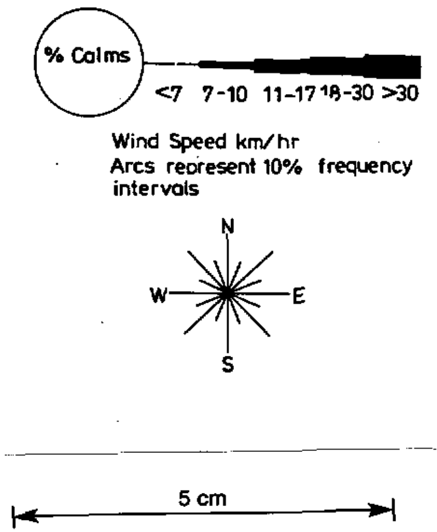
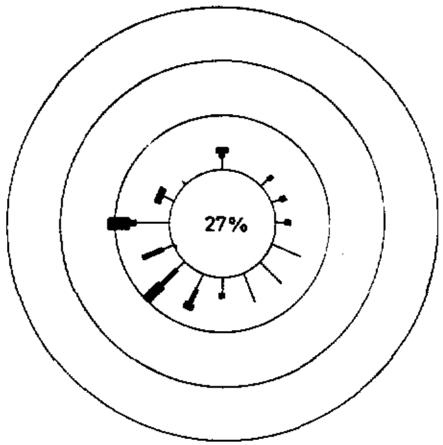


Wind Roses : RENISON
DECEMBER 1981

762183



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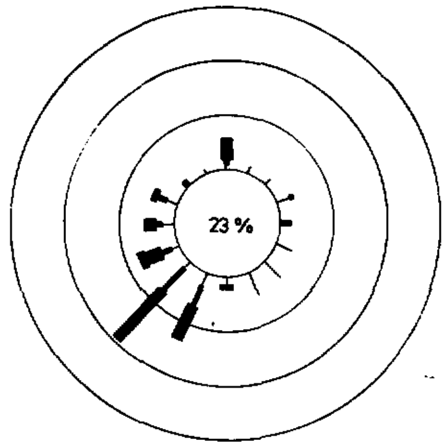

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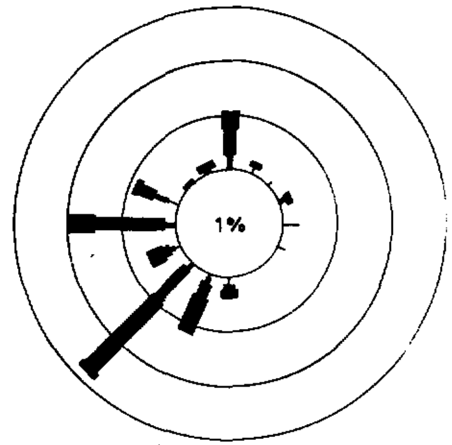

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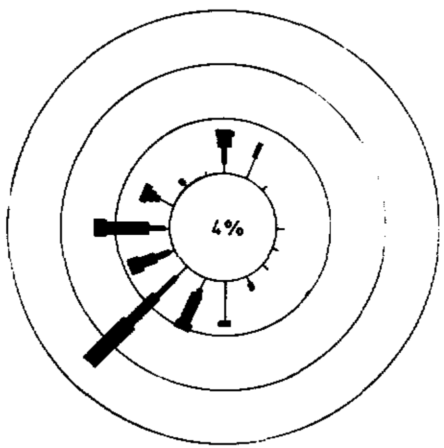

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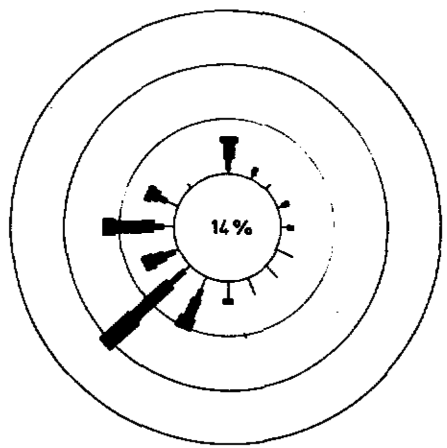

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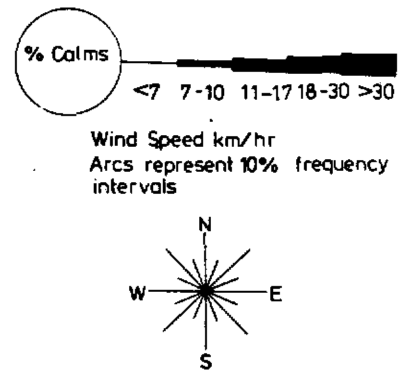

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Wind Roses : RENISON
JANUARY 1982

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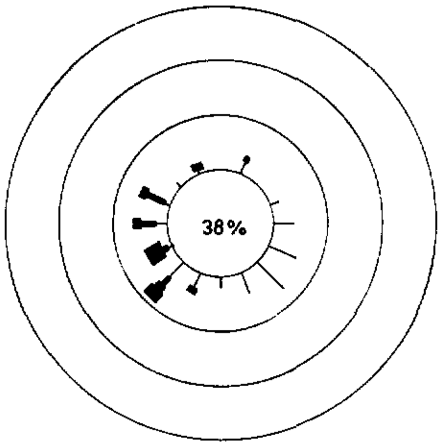

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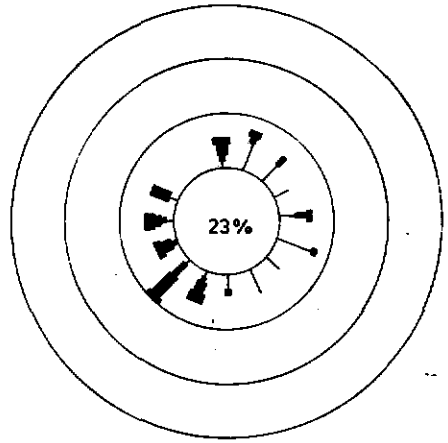

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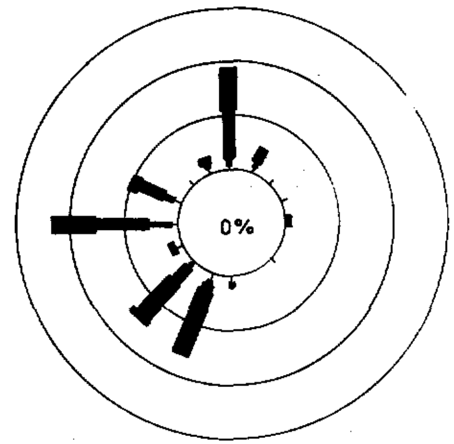

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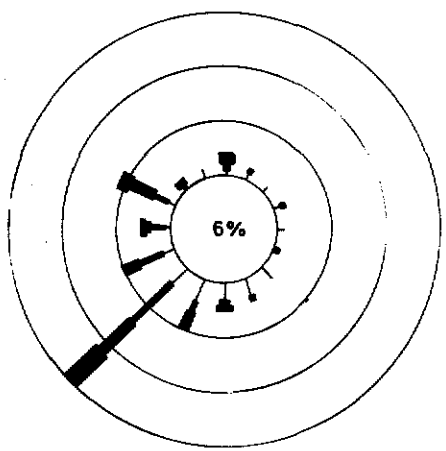

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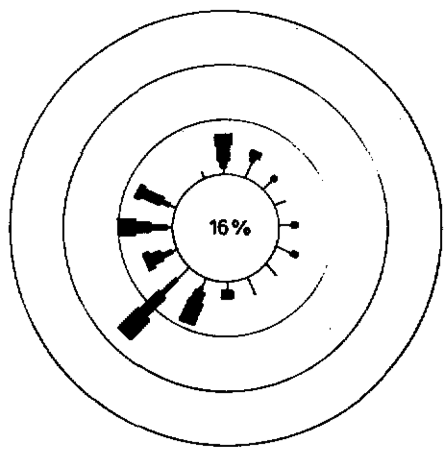

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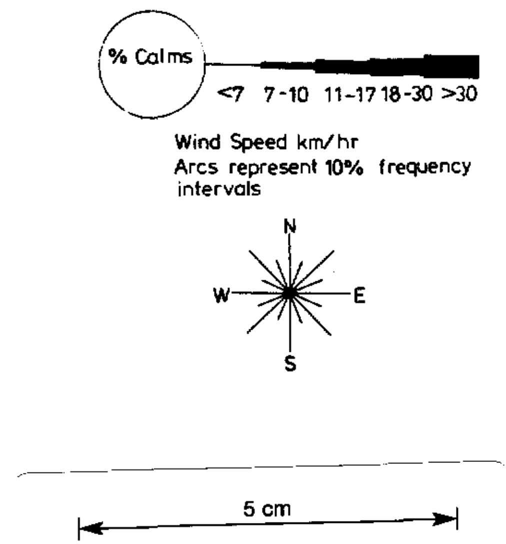
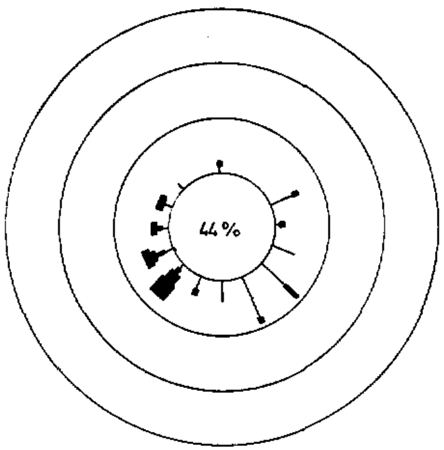


WIND ROSES : RENISON
FEBRUARY 1982

7631185



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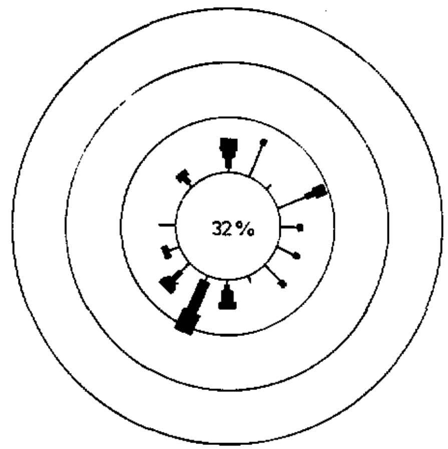

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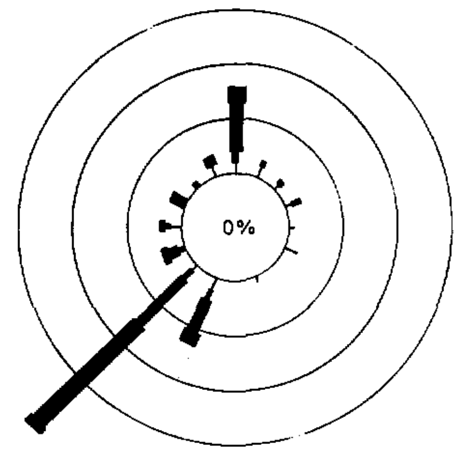

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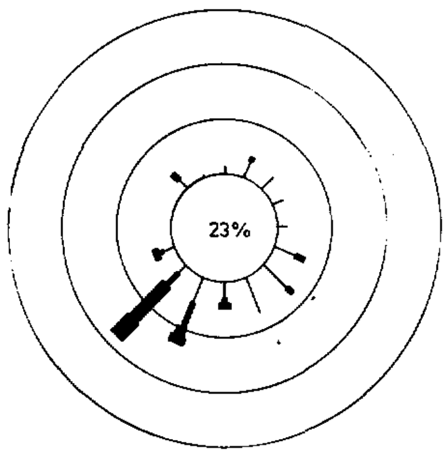

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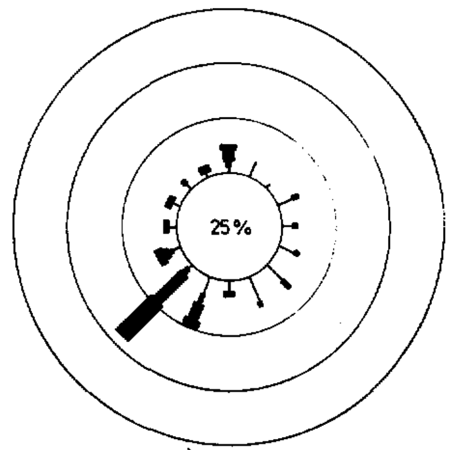

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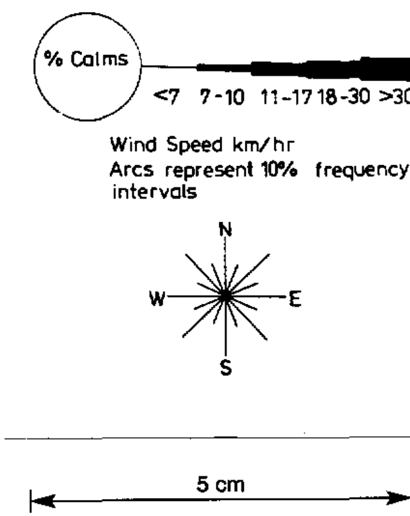

WIND ROSES : RENISON
MARCH 1982

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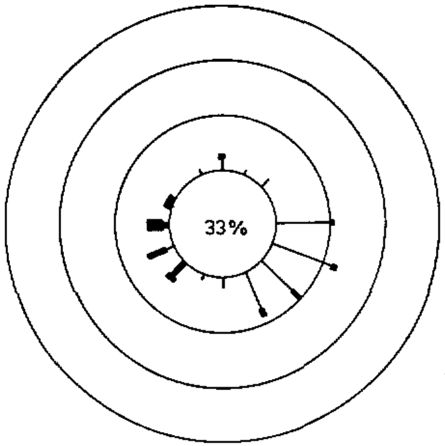

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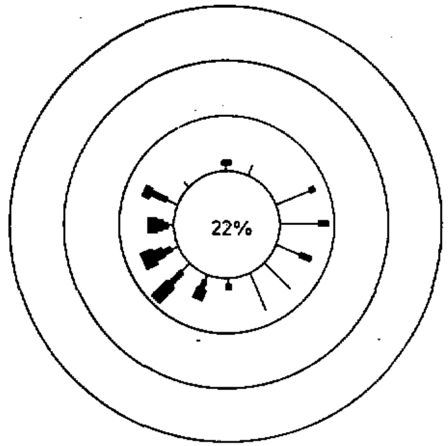

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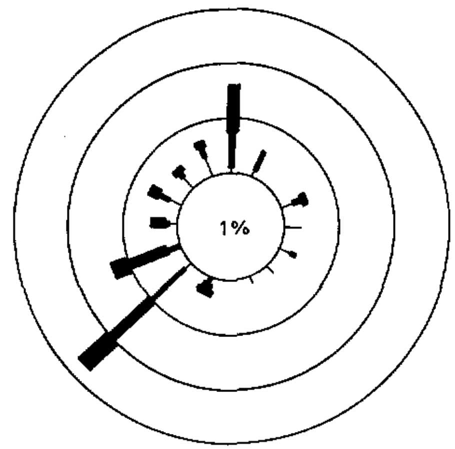

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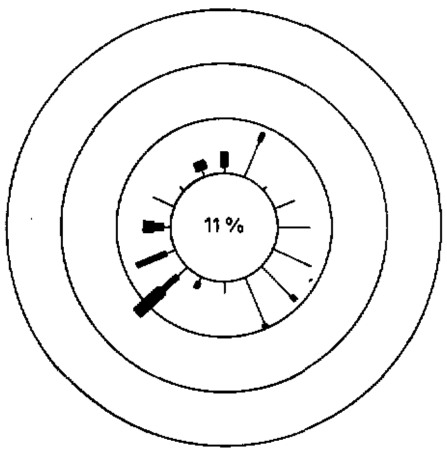

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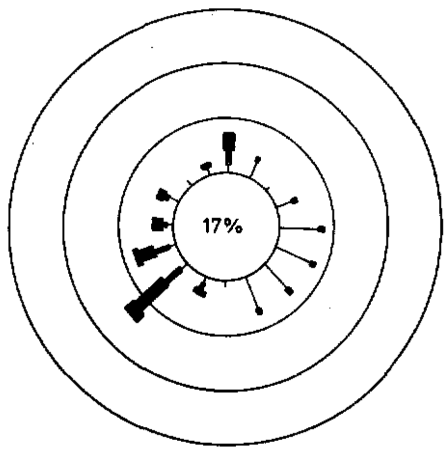

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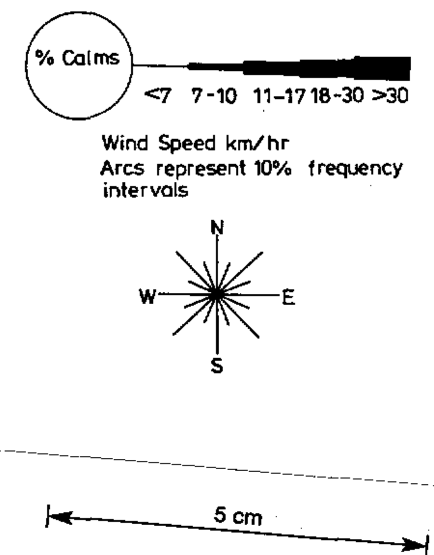

WIND ROSES: RENISON
APRIL 1982

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APPENDIX 2

BOTANICAL SURVEY OF THE RENISON AREA 18/19-9-1981

by A.M. Gray and J.R. Stephens

AREA OVERVIEW

The area round the proposed Renison site of the tin fuming plant mainly comprises tall closed rainforest in the river valleys, with frequent areas on the slopes modified by fire and logging over many decades. Largely because of the significant effects of fire frequency, the forest associations are complex, but similar to those seen elsewhere in the north-west of Tasmania.

The rainforest in the relatively undisturbed river valleys and steep gullies is dominated by mature **Nothofagus cunninghamii** (Myrtle-Beech), forming a closed canopy beneath which the most frequent species is **Dicksonia antarctica** (Man-fern), with the forest floor often dominated by **Blechnum wattsii** . Other important species occurring with the **Nothofagus** are **Eucryphia lucida** (Leatherwood), **Atherosperma moschatum** (Sassafras), **Anodopetalum biglandulosum** (Horizontal), **Cenarrhenes nitida, Pomaderris apetala** and **Phebalium squameum** . Sometimes occurring within the rainforest, and often at the forest perimeter are large **Acacia melanoxylon** (Blackwood) and **Acacia dealbata** (Silver Wattle).

Phyllocladus aspleniifolius (Celery-top Pine) occurs in significant numbers in more inaccessible rainforest associations; this species is perhaps not as frequent now as in earlier years, possibly due in part to its traditional use as pit props and railway sleepers, and currently as a prized panelling material.

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In wet areas, where the rainforest has been spotburnt and/or selectively logged in less recent times, reversion to low semi-open forest occurs, typically dominated by **Nothofagus cunninghamii** and **Eucryphia lucida** , with **Anodopetalum biglandulosum** as a prolific undershrub. Thickets of **Leptospermum scoparium** and **Trochocarpa cunninghamii** are common. **Gahnia grandis** (Cutting Grass) is frequent in openings and at the forest peripheries, with **Dicksonia antarctica** and **Blechnum wattsii** remaining the most common ground species.

In drier areas, especially along the ridges, severely damaged rainforest may be dominated by regenerating **Eucalyptus** species, notably E. **nitida** . The resultant medium-open forest demonstrates an interesting community of quite different floral association, comprising scattered **Leptospermum scoparium** and **Acacia** species (notably **A. melanoxylon** and **A. mucronata**), with the forest floor often dominated by **Bauera rubioides** and **Gahnia grandis** .

Where fires have been frequent, such as along the slopes to the south of the Emu Bay Railway track, the fire corridors are dominated by **Pteridium esculentum** (Bracken) up to 1 metre tall, with **Pomaderris apetala, Acacia verticillata** and **Cassinia aculeata** of secondary frequency. On the perimeter of these fire corridors, the low semi-open forest typically comprises **Eucalyptus delegatensis** of widely diverse age class, large **Pomaderris apetala** and frequent **Acacia dealbata** and **A. melanoxylon** . Some such areas on the drier slopes to the south of the Murchison Highway are dominated by dense **A. melanoxylon** . Commonly, patches of **Pittosporum bicolor, Phebalium squameum, Monotoca glauca** and **Coprosma quadrifida** also occur.

Of some note are areas of sedgeland, occurring sporadically on flat, acid and poorly drained ground. The floral association is described as a closed **Restio** /sedge heath community, about one-half metre tall. On the periphery, a tall-closed scrub community forms the transition zone between heathland and forest.

A number of specific areas considered typical of these varied floral associations were viewed in some detail during the survey. Vegetation descriptions of such areas may be found in the following sections of this report.

DETAIL OF SELECTED AREAS

The overall area considered forms a rough oval oriented WNW to ESE, some 12 km long by 4 km wide, centred about the proposed plant site and approximately bisected on its long axis by the Pieman River.

The Forestry Commission's forest-type map sheet "Zeehan B2" was initially used as a guide to the forest classifications of the area, but observations from the ground indicated some significant errors in the classification of the major species. Consequently, zonal matching was subsequently carried out by combining stereo analysis of crown characteristics from colour aerial photographs with "on the ground" visual observations within the limits of accessibility.

It is seen that there are, within the areas under consideration, a number of quite different floral associations, which are repeated within zones of similar soils, aspect and frequency of disturbance. Each of these associations, as seen during the current survey, and the zones where they are most probably repeated, are discussed below:-

1. The Immediate Site Surrounds

Bordering the western side of the flat, cleared site for the proposed plant is a low-to medium-closed forest, indicated by the designation A on the map, Figure 4.4. This is former rainforest severely disturbed over a long period by fires and other human activities, the main tree species being **Acacia melanoxylon, A. mucronata, Phebalium squameum, Eucalyptus delegatensis** (emergent), E. **nitida, Leptospermum scoparium** and Melaleuca **squarrosa** . Prominent shrubs are **Cassinia aculeata, Olearia Sp., Pultenaea juniperina** , and **Monotoca glauca** . **Gahnia grandis** is common on the periphery of this forest, as is the introduced **Rubus Fruticosus** . The lily **Dianella longifolia** is abundant, and the fern flora includes **Blechnum wattsii, Histiopteris incisa** and **Polystichum proliferum** .

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Other species identified within this forest association are **Epacris impressa, Comesperma volubile, Coprosma quadrifida, Senecioineariifolius, Coprosma hirtella, Oxylobium arborescens** and **Pimelea drupacea** . On the periphery are **Bauera rubioides** and **Restio tetraphyllus** .

To the west this forest merges with relatively undisturbed rainforest which is dominated by **Nothogafus cunninghamii** .

To the south of the site, designated B on the map, is a pocket of medium to tall closed rainforest with a dense canopy provided by **Nothofagus cunninghamii, Atherosperma moschatum** and **Pomaderris apetala** , below emergent, tall **Eucalyptus delegatensis** and E. **obliqua** . The main secondary tree species is **Acacia melanoxylon** , with frequent A. **dealbata** near the periphery and sporadic **A. verticillata** (mainly as seedlings). The understratum is dominated by **Dicksonia antarctica** . Smaller plants occurring mainly toward the periphery are **Coprosma, Pterostylis, Viola** and **Cladium** species, and **Acaena novae-zelandiae** . Notable ferns are **Histiopteris incisa, Microsorium diversifolium** and **Hypolepis sp.** Grass **(Poa)** , mosses and liverworts are frequent.

Directly to the north-east of the site, the land slopes steeply down to the Emu Bay Railway line, and has been affected by frequent firing (doubtless from the railway). The low (to one metre tall) resultant scrub is dominated by **Pteridum esculentum** , with regenerating **Pomaderris apetala, Cassinia aculeata** and the **Acacias A. verticillata A. dealbata** and **A. melanoxylon** growing on the fringes of the more recent fire corridors.

From point C, and toward the north-west along the railway line, this frequent fire damage on the slope from the line is more evident. On the perimeters of the fire corridors, low semi-open forest dominated by **Eucalyptus delegatensis** of various age classes is evident, with large **Pomaderris apetala, Acacia dealbata** and **A. melanoxylon** as the main sub-species. **Pittosporum bicolor, Phebalium squameum, Monotoca glauca** and **Coprosma quadrifida** also occur.

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In the area marked D, regrowth **Nothofagus cunninghamii** is growing through, and overtopping, the mainly **Leptospermum** scrub. **Phebalium squameum**, and very scattered **Atherosperma moschatum** also occur in this zone, which is bordered by **Acacia melanoxylon** and **A. dealbata**. This area is interesting, as it is indicative of the transition stage between a scrubland community following a fired rainforest, and a progression toward the rainforest climax.

The area designated E., on the north bank of the Ring River is **Nothofagus**-dominated rainforest, disturbed to a minor extent by an old tram track and more recent clearing for survey work, but escaping fire. This true rainforest association is rich in other species such as **Eucryphia lucida** and **Pomaderris apetala**, with scattered **Atherosperma moschatum** throughout. The main ground species is **Dicksonia antarctica**, considerable numbers of which are observed to be lacking the usual persisting frond-butts on the trunk, instead being clothed throughout with fine, soft, rust-coloured root hairs. Ferns noted on close inspection of this region are **Rumohra adiantiformis, Hymenophyllum australe, Grammitis billardieri, Polyphlebium venosum**, and the uncommon **Ctenopteris heterophylla**. In more open areas, the grass-like plant **Libertia pulchella** is scattered.

This dense rainforest association extends south-eastwards for several kilometres on the slopes forming the Ring River valley, and also northward to the Pieman River. In the latter direction, some decadent **Acacia dealbata** and **A. melanoxylon** are noted to occur sporadically.

Along the ridges on this zone, the closed forest is overtopped by mature **Eucalyptus obliqua** and **E. delegatensis**, merging into almost pure stands of **E. nitida**. In these better-drained areas, **Pomaderris apetala** and **Acacia melanoxylon** are important components of the sub-storey, with mature **Acacia dealbata** scattered throughout and **Phebalium squameum** occurring frequently.

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This pattern of **Nothofagus** rainforest in gullies and river valleys, merging into **Eucalyptus** -dominated forest along the ridges is seen to be common within the area under investigation, where disturbance by fire and man has been minimal.

2. To the East of the Site

In the zone to the east of the site of the proposed fuming plant, in the area bounded by the Ring River, the Pieman River and the Murchison Highway, much of the higher land has been damaged by past fires, and the intrusion of exploration tracks, transmission lines and the railway.

The closed-rainforest association is seen in the deeper, relatively undisturbed river valleys (as previously described) of the Ring River, Colebrook Creek and Exe Creek, and northwards from the Pieman River.

In the flatland marked F on the map is a closed sedgeland heath community, about one-half metre tall, comprising **Restio** species, **Epacris lanuginosa, Gymnoschoenus sphaerocephalus, Sprengelia incarnata, Bauera rubioides** and **Melaleuca squamea** . This is a stable community adapted to the boggy acid soil of the ill-drained, flat wetland. This is surrounded by a tall closed scrub community to 4 metres - the transition zone between the heathland and the regenerating rainforest which comprises much of this area. Shrubs on the periphery are **Leptospermum scoparium, Eucalyptus nitida, Acacia mucronata, Zieria aborescens, Oxylobium arborescens** and **Melaleuca squarrosa** . Low plants associated with this transition zone are **Epacris impressa, Epacris lanuginosa, Xanthosia dissecta, Xyris operculata** , and **Restio tetraphyllus** . This zone then merges into regenerating rainforest.

The surrounding rainforest and scrub has been destroyed by fire perhaps 50 years ago (judging by the height of the **E. nitida** regrowth), and rainforest species are assuming greater prominence. For example, around the point marked G on the map, the understory is largely **Phyllocladus aspleniifolius**, large **Cenarrhenes nitida** and **Anodopetalum biglandulosum**, associated with lower species comprising **Gaultheria hispida**, **Cyathodes parvifolia, Trochocarpa cunninghamii, Monotoca glauca, Billardiera longiflora, Pimelea linifolia, Dianella longifolia** (large specimens) and the fern **Sticherus tener**. Scattered grasses growing along the access track are **Microlaena tasmanica var sub-alpina**.

Drier areas between the map notations F and C alternate between medium-closed **Leptospermum - Melaleuca** scrub with some interspersed rainforest species, and reemergent rainforest after burning. Species identified in the latter zones are **Melaleuca squarrosa, Phyllocladus aspleniifolius, Anodopetalum biglandulosum, Anopterus glandulosus, Nothofagus cunninghamii, Acacia melanoxylon, Acacia dealbata, Eucalyptus nitida** and **E. delegatensis, Cenarrhenes nitida, Trochocarpa gunnii, Phebalium squameum**, and the ferns **Hymenophyllum flabellatum** and **H. rarum**.

3. <u>To the North of the Site</u>

To the north of the site (beyond the near environs dominated by the Ring River and railway track) is the Pieman River valley, and further north the Huskisson River valley. Access from the ground is not possible.

From the air it appears that the vegetative associations to the north of the Pieman River are identical to, but more extensive than, those examined and described above.

The deep river valleys support mature closed **Nothofagus** rainforest, and along the ridges the forest is overtopped by tall emergent **Eucalyptus delegatensis** and **E. obliqua**. By inference, the understory is of the same species association as seen in the undisturbed forest closer to the site.

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To the north-west, beyond the Huskisson River, the area marked H comprises a wet heathland community similar in appearance to the sedgeland examined at area F. This area is also bounded by a transition zone of dense scrub, which blends into the rainforest associations described above.

4. To the West of the Site

In the south-west quadrant, the area bounded by the Argent River (to the west) and the Murchison Highway (to the south) is alienated by mining activities at Renison, including three large tailings dams. The vegetation here is largely vestigial pockets of rainforest species.

Between the tailings dams and the Pieman River is mainly tall to medium closed **Nothofagus** rainforest with limited disturbed zones similar to the area A described above, and pockets of tall dense regrowth scrub such as seen at the points labelled I on the map. The regrowth scrub comprises etiolated **Phebalium squameum** and **Leptospermum scoparium**, with **Acacia melanoxylon, Pomaderris apetala** and the occasional **Nothofagus cunninghamii**. On the periphery of this scrub, the most prolific species are **Nothofagus** and **Leptospermum** seedlings. **Gahnia grandis** occupies canopy openings where drainage is much impeded.

On the far side of the Argent River, in the area designated J on the map the forest is largely damaged rainforest, where spot-fires and past logging operations have opened the canopy to reduce the association to a low semi-open forest. The main species are **Nothofagus cunninghamii, Eucryphia lucida, Anodopetalum biglandulosum** as a prolific undershrub, **Phebalium squameum**, tall **Leptospermum scoparium** in thickets, **Acacia melanoxylon, Acacia verticillata** (scattered and young), **Trochocarpa cunninghamii** in thickets, sporadic **Cenarrhenes nitida** (large), **Anopterus glandulosus, Agastachys odorata, Phyllocladus aspleniifolius** mainly as seedlings, **Gahnia grandis, Monotoca glauca**, with **Sprengelia incarnata** dominating the ground species. Large plants of **Restio tetraphyllus** occur in the soaks; the ferns noted include prolific **Blechnum wattsii** and **Histiopteris incisa** (bats-wing fern) in the openings and **Hymenophyllum** species on trunks, rotting stumps and logs.

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Between the areas J and K on the map, the land has recently been very severely damaged by forestry operations. Pockets of recently-disturbed rainforest cut by logging roads and clear-felled coups comprise much of this land area.

At K, access to the Pieman River allows detailed inspection of the river-bank flora and closer examination of the northern slope of the valley. At the water's edge, two species not seen elsewhere during the survey are **Dacrydium franklinii** (Huon Pine) and **Leptospermum riparium** . The valley slopes comprise medium-closed wet forest dominated by **Nothofagus cunninghamii** with emergent, tall **Eucalyptus** forest on the ridgelines. Mature E. **obliqua** is seen to be growing on the slopes nearer the river bank than further upstream. The main secondary species are **Eucryphia lucida, Phyllocladus aspleniifolius, Anodopetalum biglandulosum** and **Acacia melanoxylon** , with scattered **Acacia dealbata, A. verticillata** and **A. mucronata** ; in the drier openings on the riverbank **Pomaderris apetala** and **Phebalium squaemeum** are scattered. Again the understory is predominately **Dicksonia antarctica** , with scattered **Cenarrhenes nitida** and **Anopterus glandulosus** . Sporadic ground species include **Stylidium graminifolium** (Trigger Plant), **Sticherus tener** (Silky Fan-fern), **Lepidosperma elatior** and **Libertia pulchella** .

5. To the South of the Site

The land to the south of the site, up to the Murchison Highway (approximately 2 km) has been alienated to the Renison mining operations and the township of Renison Bell. On the southern side of the Highway is a triad of hills (Dreadnought, Stebbins and Renison Bell), which are the site of much human activity associated with the mining operations, as evidenced by a maze of access tracks and signs of past fires and clearing.

Typical of the vegetation on these hills is that on the northern slopes of Dreadnought Hill, which is a low-closed forest dominated by **Acacia melanoxylon** (to approximately 6 metres tall). The understory is comprised chiefly of **Cassinia aculeata** , with clumps of **Dicksonia antarctica** in the gullies. **Rubus fruticosus, Pteridium esculentum** and **Monotoca glauca** dominate the clearings.

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As previously indicated the steep Ring River valley is relatively undisturbed medium-closed **Nothofagus** rainforest.

East of Dreadnought Hill, **Nothofagus** rainforest borders the southern edge of the Murchison Highway in a relatively thin strip. Further south, there is a change to medium-open forest, where regenerating E. **nitida** is the dominant tree species. The area marked L on the map, is a zone of regenerating **Eucalyptus** , associated with **Leptospermum scoparium** and **Acacia mucronata** . There is prolific **Gahnia grandis** and **Bauera rubioides** , and as well **Spyridium gunnii, Notelaea ligustrina, Hakea lissosperma, Cyathodes parvifolia, Olearia phylogopappa, Banksia marginata** and **Orites diversifolia. Aristotelia peduncularis, Clematis aristata, Comesperma volubile** and Epacris **impressa** are scattered, especially toward the edges of the more disturbed areas.

Mature **Eucalyptus nitida** forest is seen on the ridges bordering Colebrook Creek.

Further south, the vegetation again merges into low-closed rainforest, as around the point M on the map. The main tree species are **Nothofagus cunninghamii, Eucryphia lucida, Phyllocladus aspleniifolius** , with **Acacia melanoxylon** and **Leptospermum scoparium** in the openings. The understory contains **Cenarrhenes nitida, Anodopetalum biglandulosum, Anopterus glandulosus, Agastachis odorata, Pimelea lindleyana, Coprosma sp. aff. quadrifida, Monotoca glauca, Trochocarpa gunnii, Pimelea drupacea, Olearia phlogopappa, Billardiera longiflora** , and **Prionotes cerinthoides** . In disturbed or open areas are **Prostanthera lasianthos, Gahnia grandis, Drimys lanceolata** and **Cyathodes sp** . The fern flora comprises **Blechnum wattsii, Hypolepis australis, Histiopteris incisa** and, sporadically in damper areas **Blechnum nudum** . The lily **Dianella longifolia** occurs frequently. A species of **Thelymitra** was noted here.

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Further south again, for example at N on the map, the vegetation cover as far as the high ground of the Godkin Ridge is tall-closed **Nothofagus** rainforest, with the understory dominated by **Anodopetalum biglandulosum, Cenarrhenes nitida** and **Atherosperma moschatum** , and the forest floor dominated by the fern species **Dicksonia antarctica** and **Blechnum wattsii** . Many of the trees have patches of **Microsorium diversifolium** climbing around the trunks. Limited areas on the drier slopes where spot fires have apparently occurred are dominated by dense **Acacia melanoxylon** . Commonly, patches of **Pittosporum bicolor, Phebalium squameum, Monotoca glauca** and **Coprosma quadrifida** also occur.

SPECIES INVENTORY

MYRTACEAE
Leptospermum scoparium
Leptospermum riparium

Melaleuca squamea
Melaleuca squarrosa

Eucalyptus obliqua
Eucalyptus delegatensis
Eucalyptus nitida

PODOCARPACEAE
Phyllocladus aspleniifolius
Dacrydium franklinii

FAGACEAE
Nothofagus cunninghamii

EUCRYPHIACEAE
Eucryphia lucida

MONIMIACEAE
Atherosperma moschatum

PROTEACEAE
Banksia marginata

Orites diversifola

Cenarrhenes nitida

Agastachys odorata

Hakea lissosperma

RHAMNACEAE
Pomaderris apetala

Spyridium gunnii

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RUTACEAE

Phebalium squameum

Zieria arborescens

OLEACEAE

Notelaea ligustrina

COMPOSITAE

Cassinia aculeata

Olearia phlogopappa

Senecio lineariifolius

LEGUMINOSAE

Acacia melanoxylon

Acacia mucronata

Acacia dealbata

Acacia verticillata

Oxylobium arborescens

Pultenaea juniperina

CUNONIACEAE

Anodopetalum biglandulosum

Bauera rubioides

ESCALLONIACEAE

Anopterus glandulosus

THYMELAEACEAE

Pimelea drupacea

Pimelea linifolia

Pimelea lindleyana

POLYGALACEAE

Comesperma volubile

RUBIACEAE

Coprosma quadrifida

Coprosma hirtella

UMBELLIFERAE

Xanthosia dissecta

STYLIDIACEAE

Stylidium graminifolium

RANUNCULACEAE

Clematis aristata

ELAEOCARPACEAE

Aristotelia peduncularis

EPACRIDACEAE

Prionotes cerinthoides

Cyathodes parvifolia

Trochocarpa cunninghamii

Trochocarpa gunnii

Monotoca glauca

Epacris impressa

Epacris lanuginosa

Sprengelia incarnata

PITTOSPORACEAE

Pittosporum bicolor

Billardiera longiflora

WINTERACEAE

Drimys lanceolata

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LABIATAE

Prostanthera lasianthos

BIOLACEAE

Viola sp.

ROSACEAE

Acaena novae-zelandiae

ERICACEAE

Gaultheria hispida

FERNS

Blechnum nudum
Blechnum wattsii
Blechnum vulcanicum
Dicksonia antarctica
Microsorium diversifolium
Hypolepis australis
Histiopteris incisa
Sticherus tener
Hymenophyllum peltatum
Hymenophyllum flabellatum
Hymenophyllum rarum
Hymenophyllum australe
Rumohra adiantiformis
Grammitis billardieri
Polyphlebium venosum
Ctenopteris heterophylla
Pteridum esculentum
Polystichum proliferum

LYCOPODIACEAE

Lycopodium laterale

MONOCOTYLEDONS

CYPERACEAE

Gymnoschoenus sphaerocephalus
Gahnia grandis
Lepidosperma elatior
Cladium sp.

LILIACEAE

Libertia pulchella

Dianella longifolia

ORCHIDACEAE

Thelymitra sp.

Pterostylis sp.

RESTIONACEAE

Restio tetraphyllus

Restio spp.

Other species of Restionaceae not identified because of lack of a definitive textbook.

GRAMINAE

Microlaena tasmanica var. sub-alpina

Poa sp.

XYRIDACEAE

Xyris operculata

JUNCACEAE

Juncus sp.

INTRODUCED SPECIES

Ulex europaeus (Gorse)

Leycesteria formosa (Elisha's Tears)

Rubus fruticosus (Blackberry)

Sarothamnum scoparius (Roadside Weed)

Genista monspessulana (Canary Broom)