PROPOSED SATELLITE GOLD ROASTER

KALGOORLIE, WESTERN AUSTRALIA
NORTH KALGURLI MINING LTD

Report and Recommendations of the Environmental Protection Authority

Environmental Protection Authority
Perth, Western Australia
Bulletin 327 April 1988

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North Kalgurli Mines Limited

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SUMMARY AND RECOMMENDATIONS

North Kalgurli Mining Ltd proposes to construct and operate a new concentrate roasting facility 17 km north north-west of the Kalgoorlie Town Centre.

The proposed roaster would be required to treat approximately 190 000 tonnes per annum of concentrate. This would result in the production of 16 000 kg/hr of sulphur dioxide. A concentrate containing typically 27% iron, 33% sulphur and 35 gram per tonne of gold, would be piped as a slurry to the roaster from the proposed Fimiston Plant. The slurry would then be fed into the fluidized bed roaster. The dry calcined product would be repulped for pumping, pre-leached with sodium cyanide, and then run through a carbon absorption circuit. The waste would be pumped to the tailings dam. The gold-loaded carbon would be transported to the proposed Fimiston Plant for recovery of the gold.

The Environmental Protection Authority determined that the project's potential for environmental impact required it to be formally assessed under Part IV of the Environmental Protection Act 1986. The Authority decided that a Public Environmental Report was required to assess the proposal.

The major environmental issues associated with the proposal are the effect of the roaster on the air quality in the Kalgoorlie-Boulder residential area and the effect of sulphur dioxide on vegetation around the site. The Environmental Protection Authority has noted that there will be some loss of vegetation in the immediate vicinity of the roaster. However, the proposal would result in the closure of an existing roaster in town and thus a general improvement of the air quality in the Kalgoorlie-Boulder residential area would result, despite an overall increase in emissions in the Eastern Goldfield region.

The Authority has noted that a 180M stack could accommodate some increase in roasting capacity. However, any significant increases would be viewed in the light of improving the air quality in the Kalgoorlie-Boulder residential area. A condition of environmental acceptability of a significant increase in capacity of the new gold roaster above 2 million tonnes per year of ore would be the closure of another roaster in town. Similarly significant expansion above 4 milliaon tonnes per year would require the closure of both remaining roasters in town.

Accordingly the Authority has concluded that the proposal is environmentally acceptable, and has made the following recommendations.

RECOMMENDATION 1

The Environmental Protection Authority has concluded that the proposal is environmentally acceptable and recommends that it could proceed subject to the EPA's Recommendation in this Report and the Proponent abiding by the environmental commitments in the Public Environmental Report (see Appendix A).

RECOMMENDATION 2

The Environmental Protection Authority recommends that the proponent design and implement a sulphur dioxide monitoring and control programme to the satisfaction of the EPA prior to commissioning.

RECOMMENDATION 3

The Environmental Protection Authority recommends that the proponent refers to the Authority any proposal to expand the operation above 2 million tonnes of ore per year.

RECOMMENDATION 4

The Environmental Protection Authority recommends that a roaster zone be created, which excludes other activities and that a buffer area around the roaster zone be zoned non-residential.

RECOMMENDATION 5

The Environmental Protection Authority recommends that the proponent design and implement a vegetation monitoring programme to the satisfaction of the EPA prior to commissioning.

RECOMMENDATION 6

The Environmental Protection Authority recommends that the Paringa Roaster be decommissioned within two months of the final commissioning of the Satellite Roaster.

1. INTRODUCTION

North Kalgurli Mines Limited (NKML) is a major gold producer in the Golden Mile at Kalgoorlie. NKML currently operates two gold roaster on its Fimiston leases, increased production from both surface and underground working, and increased production of sulphide ore require extra roasting capacity. NKML plans to construct a new concentrate roasting facility 17 km north north-west of the Kalgoorlie Town Centre (Figure 1).

The Environmental Protection Authority discussed the proposal and decided that a Public Environmental Report would be required to assess the project under Part IV of the Environmental Protection Authority 1986.

2. PROJECT DESCRIPTION

The proposed roaster would be required to treat approximately 190 000 tonnes per annum of concentrate (based on 2 million tonnes of ore). This would result in the production of 16 000 kg/hr of sulphur dioxide.

Primary-ore processing would be undertaken at the proposed Fimiston Plant, located east of Kalgoorlie. The ore would be crushed, ground and then fed into a floatation circuit, where the gold bearing iron sulphide mineral (pyrite) would be collected in a concentrate, typically containing:

- 27% iron;
- 33% sulphur; and
- 35 grams per tonne gold.

The pyrite concentrate would be piped as a thickened slurry in a single underground pipeline to the roaster.

Two concentrate storage tanks with a combined capacity of approximately 1 300 000 litres would hold 2 days of the roaster concentrate feed requirements. The concentrate would pass from the storage tanks to two pyrite slurry feed tanks, each of 100 000 litre capacity. The slurry would then be fed to the fluidized bed roaster. The slurry would consist of finely-ground particles. Air would blown into the bottom of roaster, through a sieve plate. The air would supply the oxygen required to convert the iron sulphide to iron oxide and sulphur dioxide. This reaction would provide the heat to maintain the fluidized bed at 650°C. The SO_2 rich roaster off gases would pass through cyclones (to remove calcine solids), be cooled to 350°C in an evaporative cooling chamber, pass through a bank of electrostatic precipitators to remove particulate and then discharged to the atmosphere via a stack. The dry calcined product would be quenched with saline water and then repulped to a suitable density for pumping.

Pre-leaching would be carried out in mechanically agitated tanks using sodium cyanide. After pre-leaching the slurry would be advanced to the carbon adsorption circuit. Each stage would consist of a mechanical agitated tank equipped with a carbon retaining screen. The slurry would flow between stages by gravity. The activated carbon would be advanced from stage to stage by pumping the carbon with a small amount of slurry counter-current to the main slurry flow.

The gold ladened carbon would be recovered from the first adsorption stage on an external screen. It would be washed to remove ore-fines and then transported to the Fimiston Plant for the recovery of the gold. The reactivated barren carbon would be returned to the roaster facility and re-introduced to the bottom stage of the adsorption circuit.

3. EXISTING ENVIRONMENT

3:1 GEOLOGY

The proposed site is in the Eastern Goldfield Province of the Yilgarn Block. The area is predominantly mafic and ultramafic igneous rocks.

The land surface is generally around 350 m above sea level. The terrain is dominated by sand plains and low hills. The area in the immediate vicinity of the proposed gold roaster is predominantly flat and generally low-lying and is part of the lake country immediately north of Kalgoorlie. The soils are typically neutral red-earths in the plain area and calcareous loams and brown earths in the more hilly portions. Saline soils dominate around the salt lakes. The soils of the project site are transitional between the loams of the hills and the saline soils of playa lakes.

3.2 CLIMATE

The climate of Kalgoorlie area is classified as semi-desert mediterranean and is characterised by warm winters and hot summers.

The average annual rainfall is 255 mm with a slight predominance of winter falls. The mean daily maximum temperatures ranges from 16.7^{o}C in July to 33.7^{o}C in January. The mean daily minimum temperatures ranges from 5^{o}C in July to 18.3^{o}C in January. The prevailing winds of autumn and summer are north easterly to south easterly. Spring winds are variable and winter winds are predominantly westerly to northerly at 11-30 km/hr.

3.3 HYDROLOGY

Low rainfall and highly porous sand soil result in the most of the drainage of the area being internal. After heavy intense falls streams will flow. These streams are ephemerel and are either absorbed internally or drained into clay or silt pans.

Good quality groundwater in appreciable quantities is rare. The majority of the groundwater is hypersaline but some bores are used for stock water. The water supply for the roaster would be obtained from the Gidji borefield located 5 km south-west of the roaster site. The water contains 170 000 mg/litre total dissolved solids.

3.4 VEGETATION

The proposed gold roaster site lies within the Coolgardie Botanical District's Coolgardie Vegetation System. The vegetation of the project areas has been described as sclerophyll woodland. The woodland is dominated by salmon gum often in association with other eucalyptus and with an understorey dominated by bluebush (Maireana scolifaleo). In some areas, such as north-west of the roaster site, Eucalyptus lesoufii, a mallee is the dominant species, in the north-east Eucalyptus transcontinentalis is the dominant species.

3.5 FAUNA

The fauna associated with the habitat are likely to be widespread, and occur over extensive areas in the Coolgardie Botanical District. Rare species in the broader Kalgoorlie area tend to be associated with heavy vegetation rock out crops, sand dunes and fresh water wetlands, none of which are represented in the project area. Some gazetted bird species may occur within the project area such as:

- Peregrine Falcon;
- Grey Falcon;
- Major Mitchell Cockatoo;
- Naretha Bluebonnet; and
- Crested Shrike-tit.

Most of these species range widely over Western Australia and it is unlikely that they will be affected by the project.

There are two gazetted pythons that may possibly occur on the roaster site:

- Woma; and
- Carpet python.

Most of the mammals occurring in the vicinity of the gold roaster are both common and widespread within the area. The Bilby (Macrotis lagotis), which is categorised a "C" - a specie of considerably reduced range since European settlement, may occur within the Kalgoorlie area. It is preferred habitat is hummock grasslands and acacia scrubland with spinifex and tussock grasses, and so it is unlikely that the Bilby would occur in the project area.

3.6 ABORIGINAL HERITAGE

There are no registered aboriginal sites in the immediate vicinity of the roaster. The proponent has also consulted with local aboriginal groups.

4. ENVIRONMENTAL IMPACTS

The major environmental issues associated with the proposed satellite roaster is the effect of the roaster on the air quality in Kalgoorlie-Boulder residential area and the effect of sulphur dioxide on vegetation around the roaster site.

The roaster would be located 17 km north north-west of the Kalgoorlie town centre to reduce the sulphur dioxide impact on the town. The site was chosen because north north-west direction has a low frequency of winds and also north north-west winds occur very rarely during stable conditions. Stable conditions can lead to fumigation events, which can cause very high sulphur dioxide concentrations in town.

The proponent has undertaken an extensive modelling exercise to determine the concentration of sulphur dioxide at various sites in and around Kalgoorlie using various stack heights. The Pollution Control Division of the Environmental Protection Authority has reviewed the proponent's modelling and conducted extensive modelling of its own on the proposal (see Appendix B).

The proponent indicated that a 120 m stack would achieve acceptable sulphur dioxide ground level concentration in the Kalgoorlie-Boulder residential area. However, Pollution Control Division considers, that due to an error in the stability categories used, the proponents model under predicts ground level concentration of sulphur dioxide at large distances from the source. Pollution Control Division modelling indicated that a stack in excess of 150 m would be required.

It should be noted that the modelling does not allow for fumigation events and available data indicates that the proposed Satellite Roaster may encounter fumigation conditions on an average of ten days a year. These fumigation events could lead to very high levels in town.

NKML has since informed that Authority that it intends to build a 180 m stack. This would achieve acceptable ground level concentrations of sulphur dioxide in the Kalgoorlie-Boulder residential area.

The Authority has noted that a 180 m stack could accommodate some increase in roasting capacity. However, any significant increase of throughput would be viewed in the light of improving air quality in the Kalgoorlie-Boulder residential area. The roasters in town have much smaller capacities than the proposed satellite roaster. Due to their proximity to the residential areas their impact on the air quality of Kalgoorlie-Boulder residential area is much larger than that from the proposed satellite roaster.

A condition of environmental acceptability of a significant increase in capacity of the roaster above 2 million tonnes per year of ore would be the closing of another roaster in town. Similarly significant expansion above 4 million tonnes per year would require the closure of both remaining roasters in town.

RECOMMENDATION 1

The Environmental Protection Authority has concluded that the proposal is environmentally acceptable and recommends that it could proceed subject to the EPA's Recommendation in this Report and the Proponent abiding by the environmental commitments in the Public Environmental Report (see Appendix A).

RECOMMENDATION 2

The Environmental Protection Authority recommends that the proponent design and implement a sulphur dioxide monitoring and control programme to the satisfaction of the EPA prior to commissioning.

RECOMMENDATION 3

The Environmental Protection Authority recommends that the proponent refers to the Authority any proposal to expand the operation above 2 million tonnes of ore per year.

To prevent a reoccurrence of the situation in Kalgoorlie and Boulder where residential areas are adjacent to mining area.

RECOMMENDATION 4

The Environmental Protection Authority recommends that a roaster zone be created, which excludes other activities and that a buffer area around the roaster zone be zoned non-residential.

The sulphur dioxide emission would also have an effect on the vegetation in the area surrounding the Satellite Roaster. The EPA engaged a consultant to investigate the effect of sulphur dioxide emissions on the vegetation in the gold field region (Appendix C). This report in conjunction with the modelling conducted by Pollution Control Division (Appendix B) indicated that significant vegetation damage was likely to occur in areas subject to hourly average ground level concentration sulphur dioxide in excess of 3 000 $\mu g/m^3$.

The proponent has made a commitment to establish a vegetation monitoring programme to assess damage caused by sulphur dioxide.

RECOMMENDATION 5

The Environmental Protection Authority recommends that the proponent design and implement a vegetation monitoring programme to the satisfaction of the EPA prior to commissioning.

All of the modelling data produced by both the proponent and the EPA has been based on the assumption that the Paringa Roaster will be closed down on commissioning of the Satellite Roaster. If both were allowed to run in conjunction the air quality in the Kalgoorlie Boulder residential area would deteriorate.

RECOMMENDATION 6

The Environmental Protection Authority recommends that the Paringa Roaster be decommissioned within two months of the final commissioning of the Satellite Roaster.

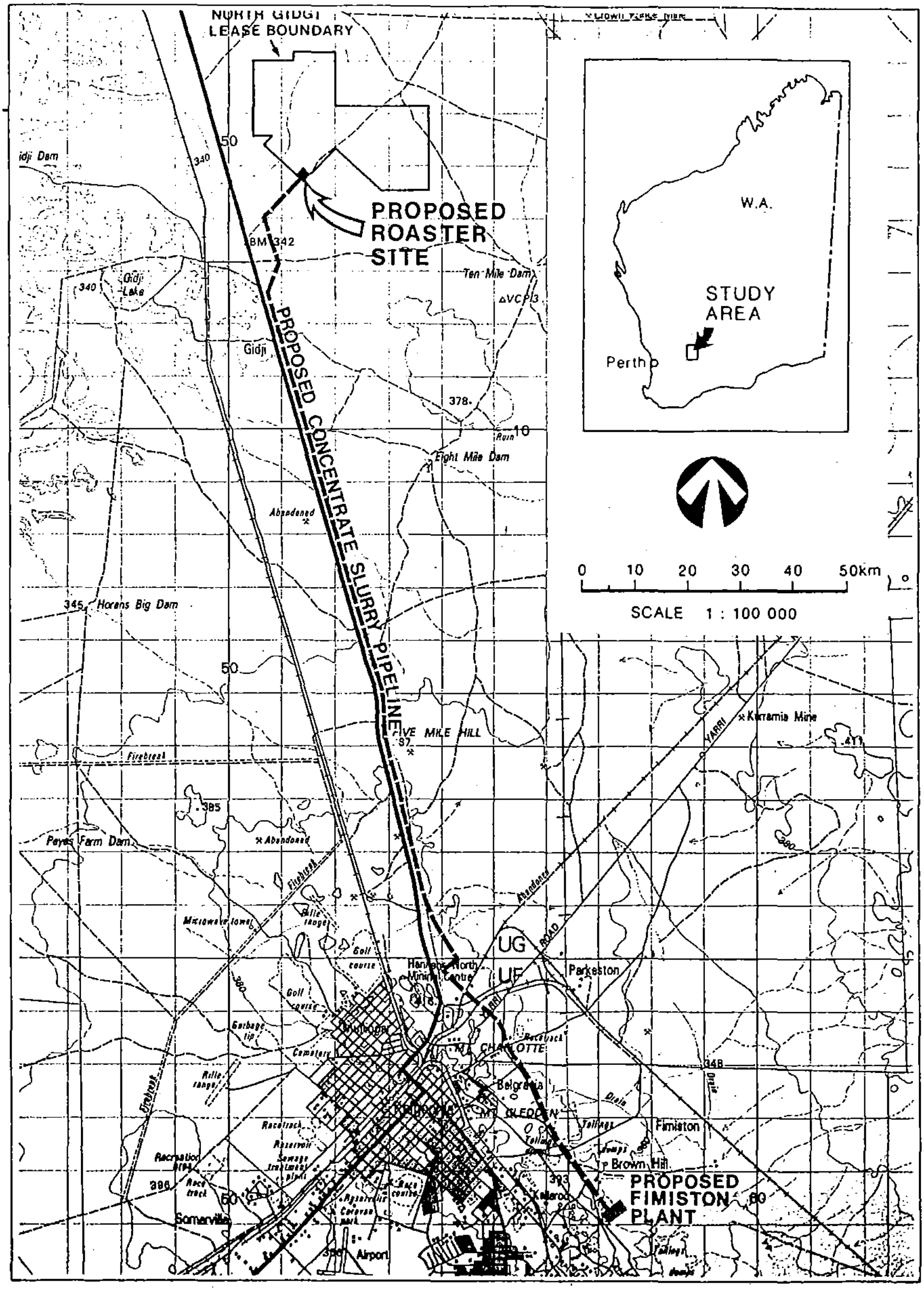
Other environmental impacts also require consideration.

No rare species of fauna appear likely to occur in the vicinity of the roaster site. The tailings areas would be fenced to prevent access by larger fauna, and bird use of the pond would be monitored.

On completion of the project the proponent will rehabilitate the tailings disposal area, by revegetation. Rehabilitation of the project area after decommissioning would include revegetating roads and track and other compacted and cleared lands.

5. CONCLUSION

The Environmental Protection Authority has concluded that the proposal would be environmentally acceptable. The Authority has noted that there will be some vegetation loss in the immediate vicinity of the roaster. The Satellite roaster, however, would result in the closure of one of the roasters in town and this will lead to an improvement of air quality in the Kalgoorlie-Boulder residential area. This is consistent with the EPA philosophy to reduce sulphur dioxide levels in the residential area.



LOCALITY PLAN

APPENDIX A

ENVIRONMENTAL COMMITMENTS

- Air Quality

  NKML would plan and implement a sulphur dioxide management and control procedure similar to that currently in place with its existing roasting facilities. A new continuous sulphur dioxide monitor would be installed and operated by NKML in the northern outskirts of Kalgoorlie. Regular reports would be provided to the EPA.

- Flora and Fauna

  Efforts would be made to preserve vegetation and stands of trees during project construction. Fire management procedures would be implemented. A programme for monitoring the environmental impacts of sulphur dioxide on vegetation would also be implemented and regular reports would be provided to the EPA. The tailings area would be securely fenced off to prevent access by larger fauna. Avifaunal use of the pond would be monitored and appropriate management action taken as required.

- Rehabilitation

  The proponent plans to rehabilitate the tailings disposal area by revegetation to produce an artificial landform in keeping with it surroundings, and supporting similar vegetation. Rehabilitation of the project site after decommissioning would include revegetation of roads and tracks, hardstand areas, and other compacted and cleared ground.

- Safety Measures and Controls

  Safety measures and controls would include full compliance with all relevant Acts and Regulations, as well as a comprehensive operator programme.

- Management of Dangerous Goods

  All government regulations related to the storage and handling of dangerous goods would be observed.

In summary, the satellite gold roaster project would represent an important development in the Kalgoorlie Boulder area in terms of ensuring future viability of the gold producing region, while achieving air quality objectives for the residential areas.

There are no known environmental or social impacts of the project which would likely be significant or unmanageable. The proponent would implement various management programmes designed to monitor and mitigate the effects of the operation. Given the nature of the existing environment, the project as described herein, and these management programmes, the project should produce significant benefits to the region and the State without significant adverse environmental impacts.

APPENDIX B

SUMMARY OF THE AIR QUALITY ASSESSMENT OF THE PROPOSED SATELLITE GOLD ROASTER

1.0 Introduction

The following is a brief summary report of the assessment of the air quality impact of the proposed satellite gold roaster. It provides details of the studies undertaken by the proponent and the subsequent assessment studies conducted by the E.P.A..

2.0 Review of Sulphur Dioxide modelling in the PER.

Dames and Moore (1987) reported on the air pollution impact of the proposed satellite gold roaster. The meteorological and emissions information were obtained from the following sources:

i) Bureau of Meteorology:
- Historical records of meteorological data including wind speed, wind direction and surface temperature.
- Morning radiosonde profiles.

ii) Environmental Protection Authority:
- Meteorological data from the Kalgoorlie Technical School site.
- Sulphur Dioxide data from the Kalgoorlie Technical School, Kalgoorlie Regional Hospital and the South Boulder Primary School.

iii) Kalgoorlie Mining Companies
- Rate of emission of sulphur dioxide from the three existing gold roasters. For each roaster these data were supplied in the form of:
  - daily throughput of ore
  - average percentage sulphur content of the ore for the day
  - times when the roaster was not in operation.

The data supplied by the E.P.A. were summarised into a file of hourly averages from the ten minute data. Wind roses were then produced and as expected these agreed with those produced by the E.P.A..

A stability analysis was undertaken using the MST approach as outlined by Mitchell (1982). It would appear that Dames and Moore (1987) have made an error in correcting the measured sigma theta (standard deviation of wind direction) to account for surface roughness when classifying the stability classes by using the inverse of the appropriate factor. This would result in a shift towards instability over all classes. As the maximum concentrations tend to occur under unstable conditions this error would probably have resulted in the prediction of slightly excessive concentrations close to the source. However the same error will tend to cause under-prediction of concentrations at large distances, eg. around the Kalgoorlie/Boulder townships. This source of error will be discussed later.

The Gaussian dispersion model which Dames and Moore used is known as ISCST and is a modified version of a model from the USEPA-approved UNIMAP series. ISCST is extensively used in eastern Australia by various regulatory authorities.

The model uses widely accepted theory but is limited by the following factors:

i) Stability is classified into classes, rather than a continuous classification scheme, with an associated loss of accuracy.
ii) Modelling of the plume penetration of elevated inversions is treated in a simplistic manner.

Dames and Moore performed a validation study of the models' performance based on the actual 1984 roaster emissions data and the measured sulphur dioxide concentrations at all three sites operated by the E. P. A.. This validation study contained a few shortcomings, the major ones being:

i) the major source of sulphur dioxide in the Kalgoorlie area, the Kalgoorlie Nickel Smelter, was not included in the modelling validation.
ii) A three month period was not modelled due to missing emissions data.

The comparison of predicted and measured results was conducted by comparing the maximum results for the various averaging periods under consideration. Generally the comparison indicated that the model was under-predicting the concentrations of sulphur dioxide at both the Technical School and the Hospital. Only the annual and maximum hourly concentration was over-predicted at the Hospital. It is difficult to interpret these results in view of the above-mentioned shortcomings.

From the results of this validation study Dames and Moore (1987) concluded that ISCST predicted concentrations of sulphur dioxide which were typical of the measured values.

The impact of the proposed 2 mtpa (million tonne per annum) roaster, located 15 kilometres north of Kalgoorlie, was then modelled. Various stack heights were considered and a height of 120 metres was chosen. This choice was made because Dames and Moore felt that, no matter what the stack height, it would not be possible to protect the vegetation in close proximity to the roaster from exposure to high levels of sulphur dioxide. Additionally a stack height of 120 metres resulted in levels below 700 ug/m**3 within the Kalgoorlie/Boulder townsites.

It is pertinent to note at this point that Gaussian dispersion models tend to under-predict ground level concentrations at large distances from the stack by shifting the plume centreline over large lateral distances from one timestep to the next (ie. due to a shift in wind direction). The only means of avoiding this "pseudo dispersion" is to match the model timestep to the plume travel time at the downwind distance of interest, and this is often impractical. Accordingly, hourly averages of ground level concentrations in Kalgoorlie from the proposed roaster emissions may tend to be under-predicted, given the combination of 15 kilometres distance and a 1 hour timestep. In addition to the above point it should also be noted that the results of Gaussian modelling over distances greater than 10 to 15 kilometres should be used with caution. Therefore, although the modelling of the proposed satellite roaster indicated that, under normal conditions, it would not cause any ground level concentrations over 700 ug/m**3 within the Kalgoorlie/Boulder residential areas this result should be viewed with caution.

Finally, the proposed scenario of the satellite roaster operating in conjunction with the Croesus and Oroya gold roasters was modelled. Not surprisingly this indicated that the air quality within Kalgoorlie would be improved relative to the existing situation. However, this modelling did not include the Kalgoorlie Nickel Smelter, which would lead to an under-prediction of the actual situation. Additionally it appears as if there may be plans to operate the Paringa gold roaster for up to 2 years after commissioning the satellite roaster. If this is the case then the modelling should have included Paringa, with the net result being a degradation of the air quality within the Kalgoorlie area.

The problem of plume fumigation was addressed by Dames and Moore (1987) using the approach of Deardorff and Willis (1982). The resultant fumigation concentration was predicted to be 2800 ug/m**3 for an hourly average. The dismissal of these events by Dames and Moore was inadequate, being mainly based on a comparison with the maximum predicted hourly concentration close to the source under limited mixing conditions. For a remote source, the maximum concentration under limited mixing will occur within 2 kilometres of the source, whereas the fumigation concentration has been predicted to occur 15 kilometres away. Under normal dispersion conditions, including limited mixing, the maximum predicted hourly concentration at the edge of the Kalgoorlie residential area was approximately 600 ug/m**3. This is nearly five times lower than the predicted fumigation concentration.

Dames and Moore's treatment of the effects of the high levels of sulphur dioxide on the vegetation around the proposed satellite roaster was virtually non existent, other than an unsubstantiated statement that no significant damage due to sulphur dioxide is anticipated.

In summary the study conducted by Dames and Moore (1987) has been done using standard modelling approaches. Despite some errors/shortcomings in the methods and discussions of results the study provides a reasonable basis for assessment by the E.P.A..

3.0 E.P.A. Investigation of Sulphur Dioxide Concentrations

The E.P.A. has conducted a detailed study of the meteorology at Kalgoorlie and the air quality impact of the proposed satellite gold roaster in order to evaluate the work conducted by Dames and Moore (1987). The data sources used were the same as those used by Dames and Moore, except that 1985 was used for modelling rather than 1984 in order to obtain a more complete data set.

Models which were initially developed during the Kwinana Air Modelling Study (KAMS) (D.C.E. 1982) were used to process the available data to produce a file of ten minute averages of parameters, including mixing height, Monin-Obukhov length (ie. atmospheric stability), friction velocity, wind speed, wind direction and air temperature. For daytime hours the mixing height model also calculated the well mixed layer temperature and the temperature step at the top of this layer.

The results from these models were checked using a number of different approaches. The stability results were compared to the results of five other methods, and in most cases these were found to be in reasonable agreement, with strong agreement in the areas expected. The major deviation from this agreement was observed with the stability distribution resulting from the MST classification scheme. It was observed that the MST approach predicted a lot more neutral conditions and less unstable conditions than any other approach. The reasons for this are unclear. The previously mentioned error in Dames and Moores' analysis is superimposed on the MST method.

The modelled mixing heights were compared to those measured by an acoustic sounder between the 23 October and the 11 November 1985. Generally it was shown that the growth of the daytime well mixed layer was well simulated. Deviations from this good agreement occurred on days when the morning radiosonde profile was not available, and a standard profile had to be used.

From this analysis it was concluded that the data file produced by these models provided a realistic, best available description of the meteorological conditions that exist at Kalgoorlie.

The dispersion model used by the E.P.A. is known as DISPMOD and is a Gaussian dispersion model which was developed during KAMS. The model has undergone several stages of development since this time and has been kept up to date with the state of knowledge.

The model output was checked by comparing the predicted results to the measured results for each of the three monitoring sites for various averaging times (see Table 1).

	Hospital		Tech. School *		Boulder	
	Predicted	Observed	Predicted	Observed	Predicted	Observed
Annual average Concentration (ug/m**3)	44.6	34.5	81.1	83.1	81.2	68.5
Number of hours > 700 ug/m**3	179	136	349	248	258	188
Number of hours > 1000 ug/m**3	84	85	175	128	110	101
Number of hours > 1400 ug/m**3	33	44	51	46	26	31
Number of hours > 2000 ug/m**3	2	16	8	10	3	3

Table 1: Comparison of predicted and measured concentration statistics at the three monitoring sites.
* The Technical School monitor was only in service for 61.2 percent of the year.

In most cases it was seen that the model performed in a satisfactory nature, predicting reasonable agreement with the observed annual concentration and the number of hours over 700, 1000 and 1400 ug/m**3 at each site. The model did, however, under-predict the number of hours where

2000 ug/m**3 was exceeded at the Kalgoorlie Regional Hospital. Most of these measured events occurred at night, under stable conditions and appear to be the result of the effects of the slime dumps on plume dispersion. At this stage DISPMOD does not account for this type of enhanced dispersion, and as it will not be a feature of the dispersion of the plume from the satellite roaster it has not been pursued.

One of the model results that will be used to assess the impact of the satellite roaster is the maximum hourly concentration. It is therefore useful to obtain an indication of the performance of DISPMOD in predicting these levels. Table 2 presents the maximum hourly concentration measured at each monitoring site, compared to the highest and the 9-th highest hour predicted by the model.

Site	Measured Hourly (ug/m**3)		Predicted Hourly (ug/m**3)	
	All data	Daytime	Maximum	9th Highest
Kal. Reg. Hosp.	3528	2465	3373	1683
Kal. Tech. Sch.*	2526	2310	4409	1963
Sth. Boulder	2723	2176	4819	1619

Table 2: Comparison of the predicted and measured maximum hourly concentrations.
* The Technical School monitor was only in service for 61.2 percent of the year.

The 9-th highest hourly concentration represents the 99.9 percentile of all hourly predictions and is generally used to represent the likely maximum hourly concentration from the modelling results. By choosing the 99.9 percentile value, inconsistencies in the input meteorological data that may produce unrealistically high concentrations can be ignored. From the measured data it is apparent that the 99.9 percentile under-predicts the actual maximum hourly concentration. All of the measured maximum concentrations occurred during the night and, as stated previously, DISPMOD does not account for these enhanced dispersion conditions. The maximum hourly daytime concentrations measured at each monitoring station were in closer agreement with the 99.9 percentile, although the measured value was still higher than the predicted value. DISPMOD does not account for fumigation conditions that could lead to the observed elevated levels in the early morning. It would appear therefore that the 99.9 percentile actually under-predicts the maximum hourly concentrations measured under the conditions that are modelled.

Essentially the comparison studies indicated that DISPMOD performed in a reasonable manner although it did highlight some phenomena that are not modelled. Of these phenomena, fumigation is possibly the most important in terms of the satellite roaster.

The effect of the satellite roaster was evaluated by modelling the following scenarios for a number of different stack heights:

i) satellite roaster operating in isolation
ii) satellite roaster operating in conjunction with the existing sources without Paringa (Gold Resources).

Three grid sizes were used in order to optimise the outputs:

i) A 10 kilometre by 10 kilometre grid with a 500 metre grid interval. This was used to provide relatively fine scale resolution of the area close to the proposed satellite roaster.

ii) A 28.5 kilometre by 18 kilometre grid with a 1500 metre grid interval. This was used to provide an indication of the effects of the satellite roaster over an area including the Kalgoorlie/Boulder townsites.

iii) A 10 kilometre by 9 kilometre grid with a 500 metre grid interval. This grid was used to provide relatively fine scale resolution of the effects of the satellite roaster within the Kalgoorlie/Boulder residential areas.

The results and discussions of the modelling runs will be presented in Section 5.0.

The E.P.A. has also investigated the likely concentrations that could result from a fumigation event caused by the satellite roaster. The method was checked by comparing the predicted concentrations with those observed during an actual fumigation of the Kalgoorlie Nickel Smelter plume. It would appear that under fumigation conditions the satellite gold roaster could cause hourly concentrations of around 3000 ug/m**3 in Kalgoorlie which is very close to Dames and Moore's prediction. Considering the proposed location of the satellite roaster and four years of meteorological data (1/1/84 - 31/12/87), it has been estimated that the proposed roaster could cause fumigation in Kalgoorlie on an average of 10 days per year. (A day was classified as a possible fumigation day when the wind direction was from a single sector mid-way between the north and north-north-west sectors for at least two hours continuously between 0500 and 1000 hours.) It may be possible to control these fumigation events by using a predictive shutdown strategy. The use of taller stacks is not a cost effective measure to reduce fumigation concentrations.

4.0 Assessment Criteria

4.1 Human Exposure

Sulphur dioxide within the Kalgoorlie/Boulder residential areas is soon to be controlled by an Environmental Protection Policy (EPP) which is described in E.P.A. Bulletin Number 315 (1987). The EPP aims to protect the following beneficial uses within the policy area:

"(a) all human activity and occupation within a mining town setting, including residential, recreation, education, employment and other occupational engagement;

(b) operation of existing gold roasting and nickel smelting industries with the associated emission of sulphur dioxide gas into the atmosphere and dispersion of these emissions in and around the policy area."

New sources are not covered by the EPP but the E.P.A. is "strongly committed to seeking improvements in the air quality at Kalgoorlie, as and when opportunities arise. This involves seeking to minimise any further degradation of air quality due to the operations of any future developments and the encouragement of any future initiatives to reduce the existing emissions of sulphur dioxide in the vicinity of the policy area." New sources will be assessed under Part IV of the Environmental Protection Act, 1986 and "will be expected to meet more stringent controls on sulphur dioxide impact."

In June 1987, the National Health and Medical Research Council (NHMRC) adopted the following goals:

annual mean of 60 ug/m**3
hourly mean of 700 ug/m**3
10 minute mean of 1400 ug/m**3.

These represent the maximum desired levels, and are expressed at 0 degree Celsius and 1013 hectapascals.

Dames and Moore have addressed the 1 hour goal in their assessment.

A large remote source such as the satellite gold roaster should, under most conditions, be able to restrict the resultant ground level concentrations in residential areas to these levels using appropriate stack design at an appropriate location. As indicated earlier, the likely levels of sulphur dioxide which may result from fumigation conditions would be far more difficult to restrict below the NHMRC goals. A predictive shutdown strategy could prevent most of these fumigation events, but occasionally conditions may be such that a predictive approach would not work (eg. when there is a large shear (shift) in wind direction with height). It is therefore considered necessary and reasonable to allow a number of exceedences of the ten minute and hourly goals within a calendar year.

The available data indicates that the proposed satellite roaster may encounter fumigation conditions on a average of 10 days a year and may encounter several more days per year where there is a potential for elevated concentrations to occur in residential areas. It is reasonable to expect that some of these events could be controlled through a shutdown strategy, so it is recommended that, as a design criteria, the satellite roaster be allowed to cause the hourly goal of 700 ug/m**3 to be exceeded in any residential area on up to five separate days within a calendar year. This exceedence allowance is an initial guess at what is achievable; future experience with a control strategy could lead to this number being varied. A separate design goal for 10 minute concentrations is not warranted for this project.

4.2 Vegetation Exposure

The E.P.A. contracted Dr. Frank Murray from Murdoch University to investigate the likely impacts of sulphur dioxide on the vegetation surrounding the proposed satellite roaster in February 1988.

Initially an investigation of vegetation around the Kalgoorlie Nickel Smelter was conducted in an effort to determine the effect that this source has had. Dr. Murray's findings indicated that there were areas of considerable vegetation damage up to 2 kilometres from the smelter. Further to this, leaf sulphur content analysis indicated that the levels were capable of causing chronic injury within 3 to 5 kilometres from the stack in a north west direction. The limited sampling programme indicated that most of the significant vegetation injury was found to the north west of the Nickel Smelter.

The dispersion model DISPMOD was used to predict the 99.9 percentile hourly concentrations over a fine scale grid surrounding the Nickel Smelter. Figure 1 shows the results of this run. These results can be used in conjunction with the results of the vegetation survey to determine an hourly concentration that is likely to cause vegetation damage. At a distance of 5 kilometres north west of the Smelter the 99.9 percentile hourly concentration was 2500 ug/m**3. Similarly at a distance of 2 kilometres south a concentration of 3500 ug/m**3 was predicted. Using these results a conservative hourly concentration of 3000 ug/m**3 has been selected as being representative of the level likely to cause vegetation damage.

The choice of a short term exposure criterion (ie. hourly) rather than long term (ie. annual) was made in view of the pattern of observed vegetation damage which is correlated better with the pattern of modelled hourly values than that of modelled annual values. One possible reason put forward by Dr. Murray was that in general most areas would experience low sulphur dioxide concentrations, with occasional high short term exposure. "Consequently the vegetation is exposed to intermittent acute fumigations, with relatively long periods in which the vegetation may detoxify and recover." (Murray, 1988).

5.0 Impact Assessment

5.1 Selection of Stack Height

The proposed satellite roaster was modelled in isolation as discussed in Section 3.0. For each stack height considered (120, 150 and 180 metres) DISPMOD was run 2 times, for the following reasons. As indicated in Section 2.0 the choice of the model timestep can have an influence on the predicted concentrations of sulphur dioxide. Just as it is necessary to have a large timestep when travel times are large, small timesteps are necessary for small travel times. Consequently the two runs were conducted using a timestep of 30 minutes for the short range and 60 minutes for the estimation of concentrations within the policy area (where the policy area is used as a convenient representation of the Kalgoorlie/Boulder residential areas). When the windspeed is less than 4 metres per second the 60 minute timestep will still not be large enough to enable the plume to traverse 15 kilometres. Although this is not completely satisfactory, the use of a larger timestep (say two hours) would require substantial extrapolation of the model dispersion parameters which could introduce even larger errors in the predicted concentrations.

The results from DISPMOD have been summarised in Tables 3 and 4 for the three stack heights under consideration.

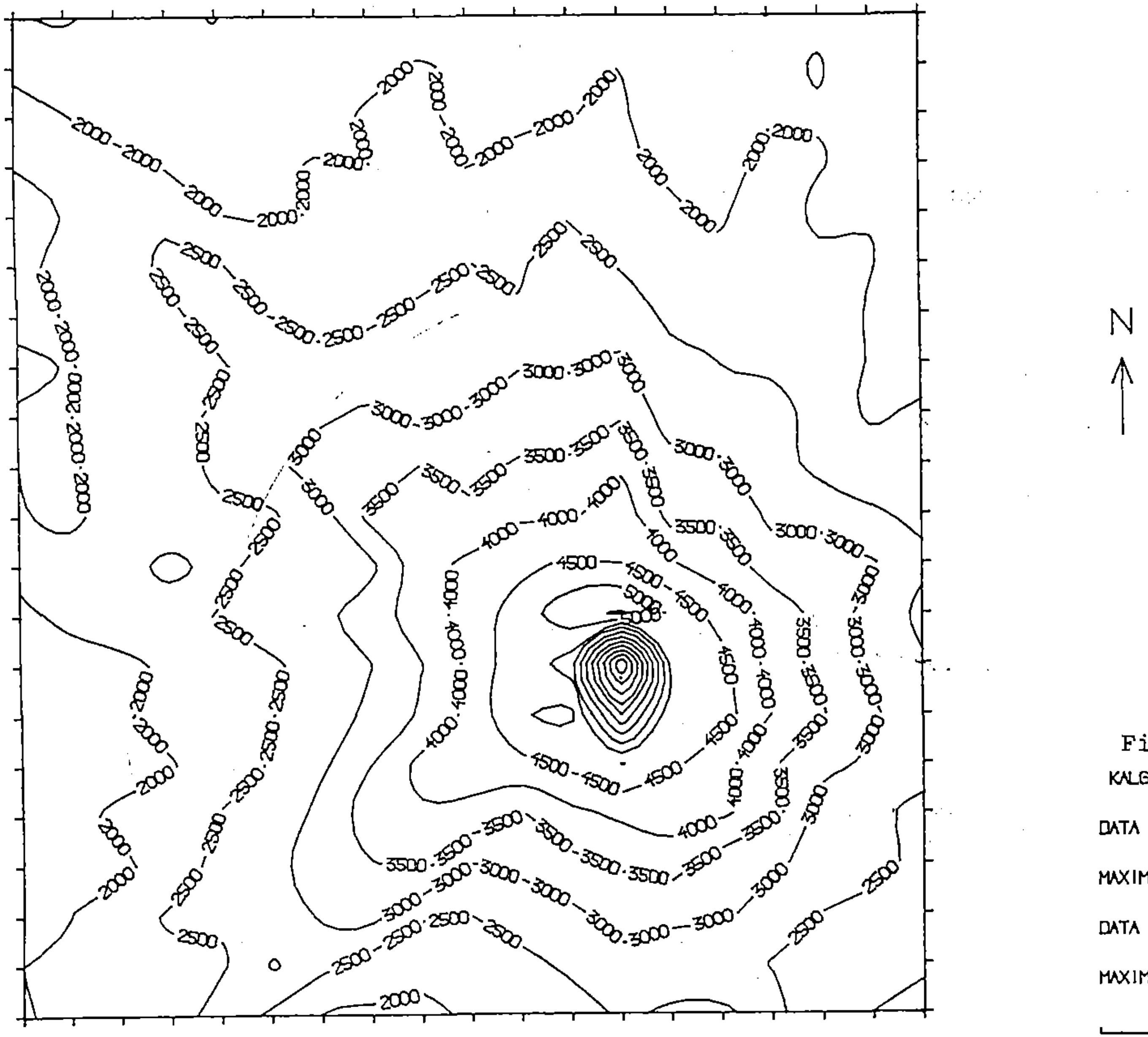


Figure 1:

KALGOORLIE – KNS IN ISOLATION – 500 M GRID

DATA PERIOD: 1 185 TO 311285

MAXIMUM HOURLY CONC. (99.9 PERCENT)

DATA RECOVERY: 100.0%

MAXIMUM RECEPTOR VALUE: 5565.0

SCALE: 2.0 KM

	Stack Height		
	120	150	180
Maximum Hourly 99.9 percentile (ug/m**3)	4840	3803	3127
Maximum distance to 3000 ug/m**3 99.9 percentile (km)	1.7	1.2	0.7
Average distance to 3000 ug/m**3 99.9 percentile (km)	1.4	1.1	0.6

Table 3: Near field summarised outputs from DISPMOD for the short range grid with the remote Roaster operating in isolation .

	Stack Height		
	120	150	180
Maximum Hourly 99.9 percentile (ug/m**3)	780	713	622
Maximum Number of hours over 700 ug/m**3	13	9	6
Maximum Number of hours over 1000 ug/m**3	3	1	0
Maximum Number of hours over 1400 ug/m**3	1	1	0
Maximum Number of hours over 2000 ug/m**3	0	0	0

Table 4: Summarised output from DISPMOD for the Environmental Protection Policy area with the satellite roaster operating in isolation.

The results predicted by DISPMOD within the policy area are greater than those predicted by Dames and Moore; this is thought to be the mainly due to the error in the stability analysis as discussed in Section 2.0. Further to this, the scheme used by Dames and Moore to predict mixing height would tend to result in an under-prediction of ground level concentrations within the policy area.

5.2 Impact on Existing Air Quality

The satellite roaster will lead to an improvement of the air quality within the policy area due to the decommissioning of the Paringa Gold Roaster as indicated in Table 7. Note that if the Paringa roaster remains on line after the proposed roaster is commissioned, the air quality will be degraded during that period. This Table shows the percentage improvement between the existing and the proposed (satellite roaster with a 150 metre stack and Paringa decomissioned) emissions scenarios in and around the policy area for the hourly 99.9 percentile concentrations. As can been seen there is a noticeable improvement in air quality over most of the policy area. Similarly the results indicate a decrease in hours over 700, 1000, 1400 and 2000 ug/m**3. There are a few negative numbers in the bottom right of the Table; these indicate that the predicted concentrations have actually increased in these areas, as a result of the plume from the proposed satellite roaster mixing with the plumes from the remaining roasters on the edge of the policy area. These conditions will rarely occur and, as can be seen from the Table, are outside of the policy area.

6.0 Monitoring

It is recommended that the proponent monitors ground level concentrations of sulphur dioxide on the northern edge of the policy area as discussed within the PER. The selection of a suitable site and monitoring equipment should be approved by the E.P.A..

It is recommended that the proponent undertake a vegetation monitoring programme in the areas around the proposed site. The programme should be designed in consultation with, and approved by, the E.P.A..

7.0 Conclusions

The modelling study conducted by Dames and Moore has provided an adequate basis for assessment. Errors identified in their analysis would lead to an under-prediction of concentrations within the Kalgoorlie/Boulder residential areas; consequently their recommendation of a 120 metre stack height must be reviewed.

The NHMRC goal for sulphur dioxide of 700 ug/m**3 over 1 hour, as addressed by Dames and Moore, is considered appropriate for residential areas impacted by this project. It is recommended that an appropriate design criterion for impact on residential areas is 700 ug/m**3 to be exceeded on up to five separate days in a calendar year. The exceedence allowance takes account of the likelihood of plume fumigation incidents over the townships which may not always be prevented by a shutdown strategy. Experience with a control strategy could lead to a different exceedence allowance being chosen for an air quality objective. A second criterion for environmental impact has also been adopted here, namely 3000 ug/m**3 for 1 hour, above which damage to native vegetation may be expected.

Analysis of alternative stack heights relative to the above criteria indicates that 150 metres is the minimum acceptable height. This height is required to limit the hourly 99.9 percentile concentrations in residential areas to less than 700 ug/m**3 (with an exception at one locality), and to limit vegetation impact to approximately 4 square kilometres. There is no

7.	10.	11.	15.	17.	12.	16.	11.	14.	17.	12.	3.	15.	15.	11.	22.	13.	13.	9.
6.	3.	14.	12.	18.	19.	15.	16.	14.	20.	13.	4.	25.	10.	13.	23.	14.	13.	8.
5.	2.	11.	6.	20.	15.	18.	13.	20.	18.	17.	12.	9.	17.	17.	24.	6.	12.	5.
2.	2.	3.	16.	16.	21.	19.	13.	15.	20.	15.	12.	8.	17.	14.	21.	7.	14.	5.
1.	0.	0.	6.	15.	17.	24.	12.	11.	23.	13.	18.	20.	20.	12.	26.	7.	10.	5.
13.	1.	0.	6.	15.	20.	22.	9.	13.	14.	21.	17.	24.	12.	12.	21.	1.	10.	6.
13.	4.	0.	3.	10.	15.	23.	19.	17.	18.	19.	16.	22.	10.	17.	7.	12.	7.	2.
4.	5.	3.	6.	5.	4.	22.	26.	23.	20.	23.	24.	22.	23.	26.	17.	13.	7.	0.
0.	0.	2.	0.	4.	6.	15.	18.	17.	25.	25.	15.	20.	14.	14.	24.	15.	1.	5.
9.	16.	6.	4.	1.	10.	13.	20.	9.	15.	22.	18.	14.	4.	22.	21.	4.	0.	1.
0.	0.	5.	0.	1.	4.	16.	15.	9.	16.	11.	18.	12.	0.	25.	16.	19.	11.	3.
0.	4.	0.	0.	1.	0.	0.	3.	9.	10.	6.	10.	12.	12.	28.	33.	8.	0.	0.
3.	0.	0.	0.	0.	0.	1.	0.	0.	9.	0.	3.	5.	-4.	29.	38.	0.	0.	0.
5.	15.	10.	5.	3.	2.	9.	7.	3.	4.	6.	7.	5.	8.	8.	9.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.	2.	3.	0.	3.	7.
0.	0.	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	6.	-3.	7.
0.	0.	0.	0.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	1.	-8.	-3.
4.	0.	0.	1.	0.	0.	0.	0.	0.	0.	6.	0.	0.	0.	0.	6.	0.	-1.	-2.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	0.	0.	13.	0.	-11.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	7.	-10.

Table 7: Percentage difference between the existing and the proposed emission scenarios (The line represents the approximate distorted boundary of the policy area).

These results indicate that there are graduated benefits to be gained by increasing the stack height. For example, by increasing the stack height from 120 to 150 metres, the benefits are:

i) Decrease in the average area likely to suffer vegetation damage from approximately 6.2 to 3.8 square kilometres.
ii) A 21 percent decrease in the predicted hourly 99.9 percentile concentration.
iii) Better protection of the policy area by decreasing the number of hours when 700 ug/m**3 and 1000 ug/m**3 are exceeded.
iv) The maximum hourly 99.9 percentile is closer to the desired level of 700 ug/m**3 within the policy area.

Similar benefits can be listed when considering an increase to a 180 metre stack.

The analysis presented in Table 4 does not present a full picture of the improvement in air quality within the policy area gained by increasing the stack height to 150 metres. Further analyses of the model runs for the 120 and 150 metre stacks are presented in Tables 5 and 6. These tables show the hourly 99.9 percentile concentrations over the policy area for a 120 and 150 metre stack respectively. Comparison of the values reveals a more favourable picture for the 150 metre stack, with virtually all values below 700 ug/m**3 and significantly lower than those for a 120 metre stack. Similar trends can be observed in the number of hours over 700, 1000, 1400 and 2000 ug/m**3 as well as the annual average.

In practice there will be very little interaction of the plumes from the proposed and existing sources. Hence it is valid to set the stack height from the results of modelling the proposed roaster in isolation.

Fumigation events from the proposed satellite roaster within the Kalgoorlie/Boulder residential areas could, as indicated previously, cause very high hourly ground level concentrations of sulphur dioxide. Increasing stack height is not an effective means of overcoming this problem and therefore alternative methods to control these events (eg a predictive shutdown strategy) must be investigated.

The above discussion and results would indicate that a 2 mtpa satellite roaster operating with a 120 metre stack would have great difficulty in reaching the suggested design criterion, as recommended in Section 4.1. However, it would appear that the same roaster with a 150 metre stack would be able to meet the criterion with negligible exceptions. In addition to this, a 150 metre stack would reduce the area of vegetation likely to be injured by exposure to sulphur dioxide to 3.8 square kilometres, which is considered acceptable. As a 150 metre stack will achieve the desired levels of protection of both the residential areas and the vegetation surrounding the roaster, there appears to be little point in considering a 180 metre stack at this stage. Therefore the remainder of the discussion will consider the satellite roaster with a 150 metre stack.

893.	725.	742.	753.	752.	720.	679.	600.	659.	726.	754.	765.	701.	814.	878.	849.	779.	712.	639.
826.	714.	731.	729.	733.	719.	684.	590.	619.	698.	747.	767.	682.	810.	837.	839.	820.	705.	705.
780.	695.	717.	709.	727.	699.	689.	578.	574.	696.	751.	742.	676.	711.	788.	835.	830.	719.	690.
713.	698.	704.	696.	715.	695.	691.	579.	543.	675.	721.	715.	680.	685.	800.	819.	783.	769.	677.
670.	683.	700.	672.	732.	699.	692.	579.	530.	660.	689.	688.	711.	669.	779.	784.	788.	796.	674.
657.	665.	692.	677.	715.	701.	692.	581.	531.	643.	672.	661.	704.	653.	704.	745.	774.	800.	713.
661.	671.	686.	686.	716.	696.	677.	578.	509.	616.	662.	676.	687.	621.	668.	770.	765.	760.	754.
677.	674.	671.	678.	716.	690.	663.	578.	505.	600.	692.	684.	667.	618.	616.	743.	738.	749.	772.
657.	669.	657.	664.	700.	684.	649.	569.	489.	586.	697.	684.	647.	648.	614.	711.	733.	732.	768.
667.	669.	647.	669.	703.	677.	641.	563.	472.	566.	672.	664.	632.	651.	613.	657.	735.	719.	741.
666.	650.	625.	674.	707.	670.	632.	554.	461.	546.	645.	650.	649.	639.	613.	593.	726.	698.	699.
644.	640.	612.	659.	697.	663.	624.	550.	463.	526.	618.	632.	639.	625.	575.	567.	683.	708.	690.
633.	630.	605.	646.	687.	656.	616.	557.	463.	514.	577.	616.	653.	637.	586.	568.	656.	695.	679.
628.	644.	601.	644.	677.	649.	616.	554.	442.	527.	545.	606.	660.	596.	606.	569.	608.	726.	668.
632.	618.	614.	642.	667.	642.	620.	550.	419.	500.	533.	604.	659.	577.	597.	576.	557.	666.	673.
629.	597.	613.	626.	656.	635.	611.	547.	422.	473.	510.	595.	635.	588.	587.	565.	526.	637.	663.
623.	592.	604.	622.	644.	628.	601.	542.	429.	447.	490.	596.	598.	603.	616.	530.	529.	601.	685.
615.	575.	594.	622.	631.	620.	592.	537.	436.	441.	492.	574.	562.	614.	599.	552.	525.	578.	651.
598.	555.	584.	622.	618.	610.	583.	531.	442.	450.	478.	550.	572.	620.	622.	561.	537.	522.	614.
589.	549.	591.	621.	605.	600.	575.	526.	448.	446.	478.	510.	545.	625.	630.	553.	537.	491.	592.
578.	547.	593.	616.	592.	595.	567.	521.	449.	453.	502.	476.	534.	625.	624.	583.	517.	496.	569.

Table 5: Predicted hourly 99.9 percentile concentration resulting from emissions from a 120 metre stack for the proposed roaster in isolation. (The line represents the approximate distorted boundary of the policy area).

745.	673.	656.	671.	648.	579.	538.	465.	532.	624.	631.	590.	625.	609.	576.	665.	609.	578.	542.
744.	643.	649.	648.	630.	562.	518.	458.	522.	629.	604.	611.	526.	618.	531.	643.	616.	570.	563.
713.	626.	640.	624.	612.	545.	520.	451.	503.	593.	603.	626.	581.	619.	578.	595.	614.	578.	557.
659.	610.	629.	600.	595.	529.	521.	460.	483.	550.	604.	619.	581.	608.	611.	535.	659.	581.	540.
601.	612.	617.	577.	580.	515.	505.	442.	464.	547.	596.	594.	611.	581.	578.	523.	620.	607.	569.
613.	581.	614.	555.	565.	501.	516.	444.	438.	539.	590.	591.	593.	555.	591.	570.	557.	625.	546.
549.	582.	598.	541.	556.	488.	508.	445.	425.	527.	584.	579.	597.	539.	566.	572.	526.	616.	595.
551.	585.	580.	531.	563.	486.	496.	445.	407.	514.	575.	565.	578.	558.	560.	567.	493.	574.	614.
551.	585.	566.	523.	562.	485.	484.	444.	403.	499.	550.	573.	560.	544.	507.	559.	540.	524.	613.
530.	574.	556.	515.	549.	484.	472.	453.	413.	470.	515.	550.	541.	556.	505.	544.	538.	502.	594.
533.	560.	547.	524.	537.	478.	469.	455.	408.	440.	525.	525.	531.	557.	515.	522.	535.	485.	551.
531.	545.	535.	529.	529.	479.	471.	458.	404.	422.	507.	514.	516.	543.	493.	495.	530.	472.	520.
535.	528.	518.	531.	512.	474.	473.	453.	400.	396.	516.	511.	499.	528.	491.	493.	523.	508.	506.
534.	512.	514.	510.	501.	473.	474.	444.	395.	411.	498.	507.	507.	513.	515.	482.	501.	507.	477.
531.	506.	510.	500.	508.	470.	474.	436.	392.	408.	493.	502.	514.	498.	523.	484.	486.	504.	478.
527.	500.	503.	502.	518.	468.	475.	437.	380.	392.	470.	488.	496.	491.	512.	469.	488.	499.	482.
522.	498.	497.	503.	507.	467.	474.	441.	379.	378.	447.	500.	480.	477.	500.	458.	483.	485.	491.
510.	496.	489.	504.	492.	466.	474.	444.	380.	363.	436.	505.	484.	451.	488.	472.	471.	471.	499.
498.	491.	488.	503.	477.	465.	473.	445.	376.	349.	424.	487.	487.	463.	476.	492.	460.	455.	477.
489.	480.	482.	502.	463.	462.	471.	435.	373.	351.	413.	473.	469.	471.	463.	484.	445.	457.	473.
483.	474.	482.	500.	452.	460.	466.	432.	369.	337.	401.	456.	451.	470.	451.	475.	431.	458.	444.

Table 6: Predicted hourly 99.9 percentile concentration resulting from emissions from a 150 metre stack for the proposed roaster in isolation. (The line represents the approximate distorted boundary of the policy area).

factor of safety in these calculations and, in fact, it is possible that the model under-predicts concentrations at these distances, for reasons described in the text. In view of the above and in view of the likely fumigation incidents it is recommended that the proponent will need to develop a shutdown strategy, although it is thought that such a strategy will not need to be invoked on a frequent basis.

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APPENDIX C

Effects of projected sulphur dioxide levels on plant communities in the vicinity of the proposed Satellite Gold Roaster, Kalgoorlie.

A report to the Environmental Protection Authority

February 1988

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INTRODUCTION

A Satellite Gold Roaster has been proposed at a site located 17 km NNW of the Kalgoorlie town centre. The emissions from the proposed development include up to 16 tonnes of SO_2 per hour, or 140,000 tonnes of SO_2 per year. These emissions represent a large rate of SO_2 discharge, comprising about 6% of total Australian emissions of SO_2. When the proposed Satellite Gold Roaster is considered with other SO_2 sources in the Kalgoorlie area, the rate of discharge of SO_2 will be about 20-25% of total Australian emissions, exceeding the SO_2 emissions of many of the small industrialised European countries.

The stack height proposed in the Public Environmental Report for the Satellite Gold Roaster is 120 m, which is predicted to result in maximum ground level concentrations of SO_2 in excess of 6000 $\mu g\ m^{-3}$ as a 1-hour average, at a distance of about 1-2 km from the stack.

The concentration would normally be expected to result in death or at least severe damage to vegetation, on the basis of studies and field experience with crops, forests, and native vegetation of mesic humid areas. A very limited number of studies suggest that the native vegetation of arid areas of the USA is generally much more resistant to SO_2 than native vegetation of humid areas.

Although the drought-resistant perennial vegetation of arid areas of the USA generally appears to be tolerant of SO_2, the drought-avoiding annual species, which germinate only when adequate soil water is available, generally appear to be less tolerant of SO_2 exposure than the perennials.

The location of the proposed Satellite Gold Roaster is within the same botanical district as the Kalgoorlie Nickel Smelter. In addition the predicted maximum ground level SO_2 concentration are very similar to measured maximum ground level SO_2 concentrations around the Kalgoorlie Nickel Smelter. Consequently an evaluation of the effects of SO_2 on vegetation around the Kalgoorlie Nickel

Smelter was considered to be a useful guide to the prediction of SO_2 impact on the vegetation around the proposed Satellite Gold Roaster.

Many of the issues raised in this report are more thoroughly discussed in a companion report to the EPA entitled, "Effects of SO_2 on plant communities around the Kalgoorlie Nickel Smelter and the Windarra Nickel/Gold Smelter".

Impact of SO_2 on vegetation around the Kalgoorlie Nickel Smelter.

Injury to vegetation attributable to SO_2 is largely confined to the area within 2 km of the smelter stack. At the time of inspection (February 1988) the area of vegetation injured by SO_2 was extended in a NW direction but vegetation injury occurred only very close to the stack in the SW and NE directions. In the worst affected areas there was considerable damage and death to the trees and shrubs, especially Eucalyptus and Acacia species, although there were considerable differences in relative tolerance between species. Very severe injury was only found to the NW of the smelter, and much of the area within 2 km of the stack was only slightly injured, or had no injury attributable to SO_2.

Leaf sulphur analysis of vegetation collected from around the smelter showed that accumulation of leaf sulphur to levels capable of inducing chronic injury occurred to a distance of 3-5 km in a NW direction but normal background levels were close to the smelter in other directions. A survey conducted during a cooler, wetter period of the year may have produced slightly different results.

Assessment

It seems likely that the projected SO_2 concentrations from the Satellite Gold Roaster as proposed and modelled, will cause injury to vegetation within about 2 km of the stack. Injury to vegetation beyond 2 km is likely to be isolated in area and slight in intensity. Within about 2 km of the stack, effects will predominantly occur in a NW direction, and injury in SW and NE directions is likely to be slight. In the most severely impacted areas within about 2 km NW of the stack, trees and shrubs, most noticeably <u>Eucalyptus</u> and <u>Acacia</u>, are likely to die or be severely injured by SO_2. In less heavily impacted areas there will be foliar injury, loss of vigour and reproductive capacity and predisposition to the effects of some other stresses and diseases. Over a long period of time the composition of the plant community will change, as less tolerant species are replaced with more tolerant species, and taller exposed trees and shrubs are replaced with shorter, less-exposed shrubs. However, over most of the area within about 5 km of the proposed development, effects of SO_2 on vegetation are likely to be negligible or absent.

APPENDIX D

SUMMARY AND REVIEW OF SUBMISSIONS

Four public and several governmental submissions were received on the Public Environment Report for the Satellite Gold Roaster.

The major issue of concern was the sulphur dioxide levels to be discharged from the stack. A variety of points were subject to submission and should be further addressed by the proponent.

i) The proponent states that sulphur dioxide scrubbers are not economically viable. Further details are required to support this statement;

ii) Several submissions were concerned about the location of the roaster and suggested it should be south, adjacent to the Nickel smelter. Concern was expressed about the effects on the northern suburbs, and on the near by pastoral stations;

iii) The effect on a water body known as King of the West Lakes was not discussed and requires further information;

iv) One submission suggested that the stack be built at this stage to allow an increase in height, if sulphur dioxide levels in Kalgoorlie were excessive;

v) Concern was expressed about the lack of information on the toxicity of sulphur dioxide for both humans and plant life;

vi) There was one submission suggesting that sulphur dioxide levels should be measured by a third party ie. the EPA;

vii) Several submissions suggested extra monitoring should occur at both the pastoral station, King of the West Lakes and in Kalgoorlie;

viii) Concern was expressed over the effect of sulphur dioxide on vegetation; and

ix) Concern was also expressed about fumigation events.

Other concerns were also expressed about the project.

Two submissions expressed concern that a survey of aboriginal sites of ethnographic significance was not undertaken. The proponent should contact relevant aboriginal groups to investigate this.

Several submissions were concerned that the levels of heavy metals in the plume and in the calcined product were not presented. The proponent should provide details of these levels.

One submission said that there was no justification for the choice of model and that the meteorological date was insufficient.

Another submission expressed concern that expansion of the roasting facility was not discussed.

APPENDIX E

SATELLITE GOLD ROASTER
PUBLIC ENVIRONMENTAL REPORT
RESPONSE TO SUBMISSIONS
for
North Kalgurli Mines Ltd

Dames & Moore

Dames & Moore Job No. 16037-004-071
8 March 1988

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SATELLITE GOLD ROASTER

PUBLIC ENVIRONMENTAL REPORT

RESPONSE TO SUBMISSIONS

for

North Kalgurli Mines Ltd.

1.0 INTRODUCTION

North Kalgurli Mines Ltd (NKML) plans to construct and operate a satellite gold roaster facility in the Kalgoorlie area. In December, 1987, NKML made available for public review a Public Environmental Report (PER) for this project in accordance with the provisions of the Environmental Protection Act (1987).

The PER was subject to an eight week public review period, from 16th December, 1987 to 10th February, 1988. Four public and several governmental submissions were received by the Environmental Protection Authority (EPA), and a summary of these submissions was forwarded to the Proponent.

This document responds to matters raised in the various submissions. The major issues of concern are associated with the sulphur dioxide to be discharged from the roaster stack. Section 2 of this report responds to the various concerns that have been raised with respect to sulphur dioxide, and Section 3 addresses the remaining issues.

2.0 SULPHUR DIOXIDE

2.1 ALTERNATIVES TO SULPHUR DIOXIDE EMISSIONS

One of the issues raised was whether scrubbers could be used to recover sulphur dioxide, as an alternative to direct emission to the atmosphere.

The PER in Section 3.1.2 page 9 concluded that sulphur dioxide removal via lime absorption would be uneconomic due to the high operating costs required to import the large quantities of lime, and to dispose of the large quantities of slurry by-product. Further details of the feasibility of using scrubbers are discussed below:-

- While the capital cost of a limestone absorber circuit is relatively low, the operating cost of running the scrubber would be approximately $12M a year. Most of this operating cost would be the cost of the lime consumed in scrubbing the sulphur dioxide.

- o In addition to considering lime, local deposits of limestone and magnesite were considered, and testwork was conducted to assess their suitability for scrubbing sulphur dioxide. In general, both these rocks were poor scrubbers of sulphur dioxide, and the size of the scrubbing plant and volume of material required would be prohibitive.

- o It was considered that the problems of disposal of the waste products from the scrubbing operation would present a major pollution problem in their own right. Gypsum would also accumulate in circuit water and would create major plant operational difficulties.

- o The use of water to scrub sulphur dioxide from the gas stream was also considered, but was found not to be feasible due to the large volumes of water required and problems of water neutralisation.

The PER in Section 3.1.2 addressed several alternative sulphur dioxide recovery processes in addition to lime absorption scrubbers (production of sulphuric acid and production of elemental sulphur), and further details of these studies are presented below.

The alternative of recovering sulphur dioxide from the roaster stack gases to produce sulphuric acid was quickly eliminated in favour of elemental sulphur production, for the following reasons:

- o Elemental sulphur could be more readily stored, allowing the cyclic nature of the sulphur market to be accomodated.

- o Elemental sulphur represented one third the weight of sulphuric acid per equivalent sulphur unit. Transport would be much cheaper due to less weight.

- o Elemental sulphur could be readily transported in conventional transportation units.

- o Elemental sulphur was more marketable than sulphuric acid.

A reducing agent is required to produce elemental sulphur, and available technology uses natural gas as a reductant. The production of elemental sulphur also generates significant cooling loads which require substantial amounts of cooling water. The costs of supplying cooling water, together with the costs of transporting natural gas, would make the production of elemental sulphur uneconomic at this point in time.

The capital costs of a plant to generate elemental sulphur, including the associated scheme water demands, are estimated to exceed $50 million. It is estimated that operating costs would be recovered from the proceeds of elemental sulphur sales (at mid 1987 values).

The Proponent continues to evaluate the elemental sulphur alternative, and has done nothing to preclude the recovery of sulphur from the roaster off gases. Should a natural gas pipeline be constructed to Kalgoorlie, and should technology be developed to lower the cost of industrial quantities of fresh water in the Kalgoorlie area, then production of elemental sulphur could become an attractive alternative, if proved to be commercially viable.

2.2 LOCATION OF THE ROASTER

Several submissions were concerned about the proposed location of the roaster and suggested that it should be located to the south, adjacent to the Kalgoorie Nickel Smelter. Concern was expressed about the effects on the northern suburbs of the Kalgoorlie-Boulder urban area, and on the nearby pastoral stations.

The proposed location for the roaster is at North Gidji, approximately 17km to the north of Kalgoorlie Town Centre. Prior to the selection of the North Gidji site, NKML also had considered their Jubilee mine site to the south of Kalgoorlie, but had discarded that alternative due to its location with respect to the surrounding populated areas of Coolgardie, Kambalda and Kalgoorlie-Boulder. Its centralised position would have meant that prevailing winds would have carried the roaster plume towards populated areas a large percentage of time. A site near the Kalgoorlie Nickel Smelter was also considered and rejected as the cumulative effect of sulphur dioxide from the roaster and from existing industries would have yielded an undesirable and unnecessary concentration of sulphur dioxide discharge in one area.

Serious consideration of the North Gidji site was based on preliminary advice from the Pollution Control Division of the EPA, according to the following rationale:

i) The EPA suggested that the site be located remotely from the Kalgoorlie-Boulder residential areas with the intent of minimising the cumulative impact of the proposed roaster and the other existing sources of pollution in the Eastern Goldfields region.

ii) Analysis of prevailing winds and other meteorological parameters by the EPA indicated that the north to north-westerly direction would have the lowest percentage of low wind speeds (ie: those most conducive to high ground-level concentrations). This direction also would have the advantage of having a low percentage occurrence of winds that would blow the plume in the direction of Kalgoorlie and Boulder (only 5% of the time on an annual basis).

Subsequently, an extensive plume dispersion modelling study, which was conducted as part of the PER, confirmed that the proposed site is close to optimum in terms of minimising air pollution in Kalgoorlie-Boulder. The study also indicated that air quality in the Kalgoorlie-Boulder residential areas, including the northern suburbs, would be generally improved by installing the roaster at the remote location, and shutting down the Paringa roaster close to town.

Although air quality at Kanowna (the only inhabited pastoral station within 15km of the stack) would decline with the installation of the roaster, it would still be comparable to the air quality which would be experienced in the residential areas of Kalgoorlie-Boulder as a result of this proposal. It should be emphasised that the permanent population of Kanowna is extremely low - comprising several caretakers and seasonal workers.

2.3 KING OF THE WEST LAKE

Some submissions queried the effect on a local water body known as King of the West Lake.

Neither the Kalgoorlie Mines Department, the Pastoral Board, nor the Kalgoorlie Town Council are aware of any official or gazetted recreational activities associated with this lake, although the area is well known to local inhabitants.

According to the Shire of Boulder, King of the West Lake is located on privately owned land about 25 km north of Kalgoorlie Town Centre (about 8 km north of the proposed stack). This is an ephemeral water system comprised of a string of lakes which are usually dry, due to the low rainfall and high evaporation rates of the Eastern Goldfields Region. The unusually consistent rainfall of 1987 enabled the lakes to suport such recreational activities as water skiing, yachting, swimming, and duck shooting. Last year was the first time in over a decade that the lakes were filled with water.

The proposed roaster is not expected to impair the informal recreational use of The King of the West Lake. Although the air quality in the vicinity of the lake will decline with the installation of the roaster, the anticipated ground-level concentrations are expected to be comparable to the levels which would be experienced within the residential areas of Kalgoorlie as a result of this proposal. The lake is located to the north of the proposed roaster, and the frequencies of winds from the south are low over all seasons, and just over 5% during the summer season, when recreational use would be highest.

The visual appearance of this area should not be impaired since, according to the vegetation survey referred to in Section 2.8 of this document, sulphur dioxide effects on vegetation are unlikely to be observable beyond 7km from the stack.

2.4 CONTINGENCIES TO CONTROL SULPHUR DIOXIDE EMISSIONS

Some of the submissions were concerned about what measures NKML would take if the sulphur dioxide levels in Kalgoorlie were to exceed the guidelines specified in the Draft Environmental Protection Policy for the Control of Sulphur Dioxide in the Air Environment of the Kalgoorlie-Boulder Residential Areas (EPP). One submission suggested that the stack be built at this stage to allow an increase in stack height at some future date, should sulphur dioxide levels in Kalgoorlie become excessive.

Raising the stack height would not be economically feasible, since it would require major plant shut-down during heightening. The proposed roaster location has been chosen so that there will be an improvement in air quality in the Kalgoorlie-Boulder area, in spite of the significant expansion of roasting capacity. This improvement will be obtained by retirement of the Paringa roasting facility from the immediate Kalgoorlie-Boulder area.

NKML has considerable experience in roaster operation in the Kalgoorlie-Boulder area, and has played a major role in the development of the Environmental Protection Policy for Kalgoorlie-Boulder through its involvement in the Gold Roaster Task Force. NKML is fully aware of its responsibilities under the EPP and will take action as appropriate to control pollution in the Kalgoorlie-Boulder area. NKML's current strategy to monitor sulphur dioxide levels and shut down its roaster operations in Kalgoorlie-Boulder are detailed in Appendix C of the PER.

2.5 TOXICITY OF SULPHUR DIOXIDE

Concern was expressed about the lack of information on the toxicity of sulphur dioxide to both human and plant life.

The effects of sulphur dioxide on human health are illustrated in Figure 1, as adapted from the World Health Organisation's "Manual on Urban Air Quality Management."

Refer to Section 2.8 for more information on the toxic effects of sulphur dioxide on plant life.

2.6 SULPHUR DIOXIDE MONITORING

One submission suggested that sulphur dioxide levels should be measured by a third party, ie: the EPA. The EPA has been operating air quality monitoring stations in Kalgoorlie since 1982. Under the proposed EPP, the responsibility for the daily monitoring logistics has been taken on by the operating companies. The monitoring procedures will comply with EPA requirements, and will be subject to EPA review.

2.7 ADDITIONAL MONITORING STATIONS

Several submissions suggested that additional sulphur dioxide monitoring should be done at Kanowna (the only pastoral station permanently occupied in the area) the King of the West Lake and Kalgoorlie.

The EPA currently operates sulphur dioxide monitoring stations at the Kalgoorlie Regional Hospital, the Kalgoorlie Technical School, and the South Boulder Primary School. In addition to the three existing monitors, NKML has already agreed to the provision of two additional monitoring stations in Kalgoorlie-Boulder under the requirements of the EPP, as well as one extra monitoring station on the northern outskirts of Kalgoorlie, at a location agreeable to the EPA, associated with licensing of the roasting facility proposed in the PER.

It is NKML's view that further additional monitors are not justified at Kanowna or King of the West Lake, for the combined permanent population of these areas is minimal, comprising several caretakers and seasonal workers.

2.8 SULPHUR DIOXIDE EFFECTS ON VEGETATION

Some concern was expressed over the effect of sulphur dioxide on vegetation.

It is understood that the EPA has recently received the results of a study commissioned to investigate the effects of sulphur dioxide on vegetation in the Eastern Goldfields (including the areas around the Kalgoorlie Nickel Smelter). Similar vegetation effects may be anticipated at the roaster site to those recently observed around the nickel smelter, for the following reasons:-

- the peak ground-level concentrations of sulphur dioxide due to the operation of the nickel smelter are understood to be of the same order of magnitude as those projected for the development described in the PER; and

- the vegetation around the nickel smelter is essentially comparable to that at the satellite roaster site.

The effects noted around the nickel smelter have been observed up to a radius of 6km to 7km, although more substantial damage is noted within 2km of the stack. It is understood that even in the most affected areas, regeneration of at least some species is taking place.

2.9 FUMIGATION EVENTS

Some of the submissions expressed concern about fumigation events.

This section will describe some of the general characteristics of the fumigation phenomena, and relate these specifically to the proposed roaster:-

- Fumigation events in continental areas, such as the Kalgoorlie area, occur when the slowly dispersing plume emitted under stable night-time conditions is intercepted by a developing turbulent convective layer, which is produced when the sun warms the ground during the morning. Under these night-time conditions, the plume undergoes only a small amount of plume rise and horizontal and vertical dispersion. When the convective layer reaches the plume height in the morning, the initial mixing is primarily in the vertical direction, and ground-level concentrations can be high. However, once the convective layer has grown to well past the height of the plume, then horizontal dispersion can also assist in reducing concentrations and ground-level concentrations will be lower.

- The absolute frequency of fumigation events, without respect to location, is probably fairly high. However, the frequency at any particular downwind location is likely to be low, because the fumigation would occur over a large range of downwind distances and directions. Fumigation conditions generally occur under the breakdown of stable conditions with low wind speeds. These occur more often in winter than in summer, but could occur at any time of the year.

- The duration of the maximum ground-level concentration caused by the fumigation is inherently short, from a few minutes to 20 or 45 minutes, depending on the height of the stack and the buoyancy of the plume.

The PER (Section 6.1.1 page 36) estimated that the frequency of fumigation events over Kalgoorlie is expected to be very low, less than 5% per annum. This is because the windrose diagrams (Figure 5 of the PER) indicate that, on an annual basis, the winds from the north-north-west would blow the roaster plume over Kalgoorlie less than 5% of the time, and only some of those plumes would encounter the stable conditions conducive to fumigation events.

3.0 OTHER ISSUES

3.1 ABORIGINAL HERITAGE

Two submissions expressed concern that a survey of Aboriginal sites of ethnographic significance had not been undertaken for the PER.

Archaeological and ethnographic surveys of the roaster site and the slurry pipeline route have now been completed, including liaison with Aboriginal bodies recommended by the Western Australian Museum.

No Aboriginal sites have been found in areas that will be affected by the project, and the Aboriginal bodies and individuals that have been contacted (including those recommended by the West Australian Museum) have no objections to the project.

3.2 HEAVY METALS

Several submissions were concerned that the levels of heavy metals in the plume and calcined product were not presented.

Calculations have indicated that, even under worst case assumptions, the concentrations of heavy metals in the stack emissions would be within the guidelines of the NHMRC. The PER (in Section 6.1.3 page 38) concluded that, as the roaster would be operating under oxidising conditions with a relatively low roasting temperature, there would be no significant volatilisation of heavy metals, which would remain locked in the calcine. This conclusion was based on previous experience with similar roaster technology, further supplemented with a semi-quantitative analysis of batch samples of calcine and concentrate (Table 1) taken from a Kalgoorlie area roaster.

It should be emphasised that direct estimates of volatilisation cannot be made from Table 1, since:-

i) the available analytical instruments are not sensitive enough, and
ii) the analyses of calcine and concentrate samples are difficult to correlate due to the large circulating mass in the roaster.

TABLE 1

SEMI-QUANTITATIVE ANALYSIS OF CONCENTRATE AND CALCINE

HEAVY METALS CONTENT (ppm)

ELEMENT	DOLERITE		BASALT	
	Concentrate	Calcine	Concentrate	Calcine
Arsenic (As)	240	602	110	420
Lead (Pb)	< 20	40	< 20	39
Cadmium (Cd)	< 2	3	< 2	< 2
Tellurium (Te)	54	23	42	23
Antimony (Sb)	19	22	12	28

Examination of the chemistry of arsenic, antimony, cadmium, lead and tellurium, as well as their possible oxide and sulphide compound formations, suggests that the only doubtful element is arsenic. The other metals and their compounds should remain in solid or liquid form throughout the roasting process, and should not be emitted from the stack (other than incorporated into the particulates).

The proposed roaster will be of the circulating fluidised bed type, whereas the roasters currently operating in the Kalgoorlie area are of the static fluidised bed type. The velocities of gas and materials are higher in a circulating roaster and therefore there is a significantly reduced possiblity of localised pockets of dead material occuring in the bed. It is in such pockets that reducing rather than oxidising conditions may occur. In other words, a circulating roaster ensures a more uniform roast in an oxidising atmosphere; conditions which are not suitable for the release of arsenic.

The arsenic is likely to be found in the concentrate as arsenopyrite (FeAsS). Since the satellite roaster will be operating under oxidising conditions at a temperature of 650°C, it is estimated that the major part of the arsenic in the feed concentrate would remain fixed in the calcine as ferrous arsenate ($FeAsO_4$). A minor percentage may oxidise to form arsenic trioxide (As_2O_3), which sublimates at 193°C to form a gas. Based on previous experience at other roasting installations overseas, less than 10% of the arsenic might be expected to oxidise to As_2O_3, and the more probable range would be 4-6% oxidation.

Arsenic will leave the stack in both gaseous (arsenic trioxide As_2O_3) and particulate form. The PER stated that the arsenic trioxide would be unlikely to exceed 4 ppm, which is equivalent to less than 13 mg/Nm^3. Expressed as elemental arsenic, this would be 3.0 ppm, equivalent to less than 10 mg/Nm^3. In the interim, revised estimates indicate an arsenic level of 3.1 ppm or 3.6 mg/Nm^3. Both estimates were based on the following methodology:-

1. Assuming a concentrate formed from equal mixtures of doleritic and basaltic ore, the average arsenic concentration would be 175 ppm (from Table 1). Based on a 6% oxidation rate, the estimated amount of arsenic in the gas exhausted from the roaster would be:

$$0.06 \times 24{,}000 \text{ kg/hr} \times \frac{175}{1{,}000{,}000} = 0.25 \text{ kg/hr}$$

Based on a total stack gas flow of 81,000 kg/hr (69,000 Nm^3/hr), the estimated concentration of arsenic in the stack gas would be:

$$\frac{0.25 \text{ kg/hr}}{81{,}000 \text{ kg/hr}} \times 1{,}000{,}000 = 3.1 \text{ ppm}$$

This is equivalent to $\frac{0.25 \text{ kg/hr}}{69{,}000 \text{ Nm}^3\text{/hr}} \times 1{,}000{,}000 = 3.6 \text{ mg/Nm}^3$

Sensitivity analysis results (Table 2) illustrate the effect of different ore composition and oxidation rates on the concentration of arsenic in the stack gas. Even under worst case assumptions, the concentration of arsenic in the stack gas is comfortably within the NHMRC Guidelines of 10 mg/Nm^3.

TABLE 2

SENSITIVITY ANALYSIS

ORE COMPOSITION	ARSENIC CONCENTRATION	OXIDATION TO As_2O_3 6%		10%	
Basalt/Dolerite	ppm	ppm	mg/Nm^3	ppm	mg/Nm^3
0% / 100%	240	4.3	5.1	7.1	8.4
50% /50%	175	3.1	3.6	5.2	6.1
100% / 0%	110	2.0	2.3	3.3	3.8

2. In addition to the arsenic trioxide, one can assume that the dust loading after the precipitator contains heavy metals in a similar proportion to that determined from the analysis of the calcine. Assuming the value for arsenic in calcine formed from equal mixtures of doleritic and basaltic ore (511 ppm), and given the precipitator emission rate of 100mg/Nm^3, the concentration of arsenic in the exhaust stack can be calculated as follows:

$$\frac{511}{1,000,000} \times 100 \text{ mg/Nm}^3 = 0.051 \text{ mg/Nm}^3$$

Similarly, one can estimate the concentrations for lead (0.004 mg/Nm^3), cadmium (0.0002 mg/Nm^3), antimony (0.002 mg/Nm^3) and tellurium (0.002 mg/Nm^3). The cumulative concentration of these five heavy metals would be in the order of 0.06 mg/Nm^3, which is insignificant.

3.3 PLUME DISPERSION MODEL

One submission said that there was no justification for the choice of model and that the meteorological data was insufficient.

The treatment of the meteorological data and the choice of dispersion model were discussed with the EPA Pollution Control Branch at various decision points during the plume dispersion study to ensure compliance with EPA Pollution Control requirements. Full justification is given in Sections 3.0 and 5.1 of the Supporting Document to the PER, and is summarised below.

The Victorian Environment Protection Authority's (VEPA) version of the Short-Term Industrial Source Complex Model (ISC-ST) was used to predict the ground-level concentrations of sulphur dioxide emissions, for the following reasons:-

- The model is an advanced Gaussian dispersion model which can be tailored to account for the influence of terrain, building-wake effects, and the wide range of meteorological conditions which effect dispersion.

- Several other regulatory agencies in Australia make use of this version of the model to evaluate air pollution impacts and to determine appropriate stack heights for licensing purposes.

- Validation studies comparing predicted ground-level concentrations with actual measured concentrations confirmed that the model would give a useful indication of the likely air quality.

The best available data from the project area was used in the dispersion model:

- Surface meteorological data was available from the EPA's meteorological station at the Kalgoorlie Technical School, comprising wind speed, wind direction, the standard deviation of horizontal wind direction fluctuations (sigma-theta), temperature and solar radiation. Data at 10 minute intervals were available from January 1984 to December 1986.

- Upper-air data were available from routine Bureau of Meteorology radiosonde ascents made from the Kalgoorlie airport, and profiles were available from intensive studies conducted by the EPA, comprising measurements of wet and dry bulb temperature, and wind speed and wind direction over variable height intervals.

3.4 EXPANSION PLANS

One submission expressed concern that expansion of the roasting facility was not discussed.

The project as described in the PER is viable and is the one for which approval is currently being sought. Any subsequent proposal to expand production above the levels given in the PER will be referred to the EPA for approval.

4.0 CONCLUSIONS

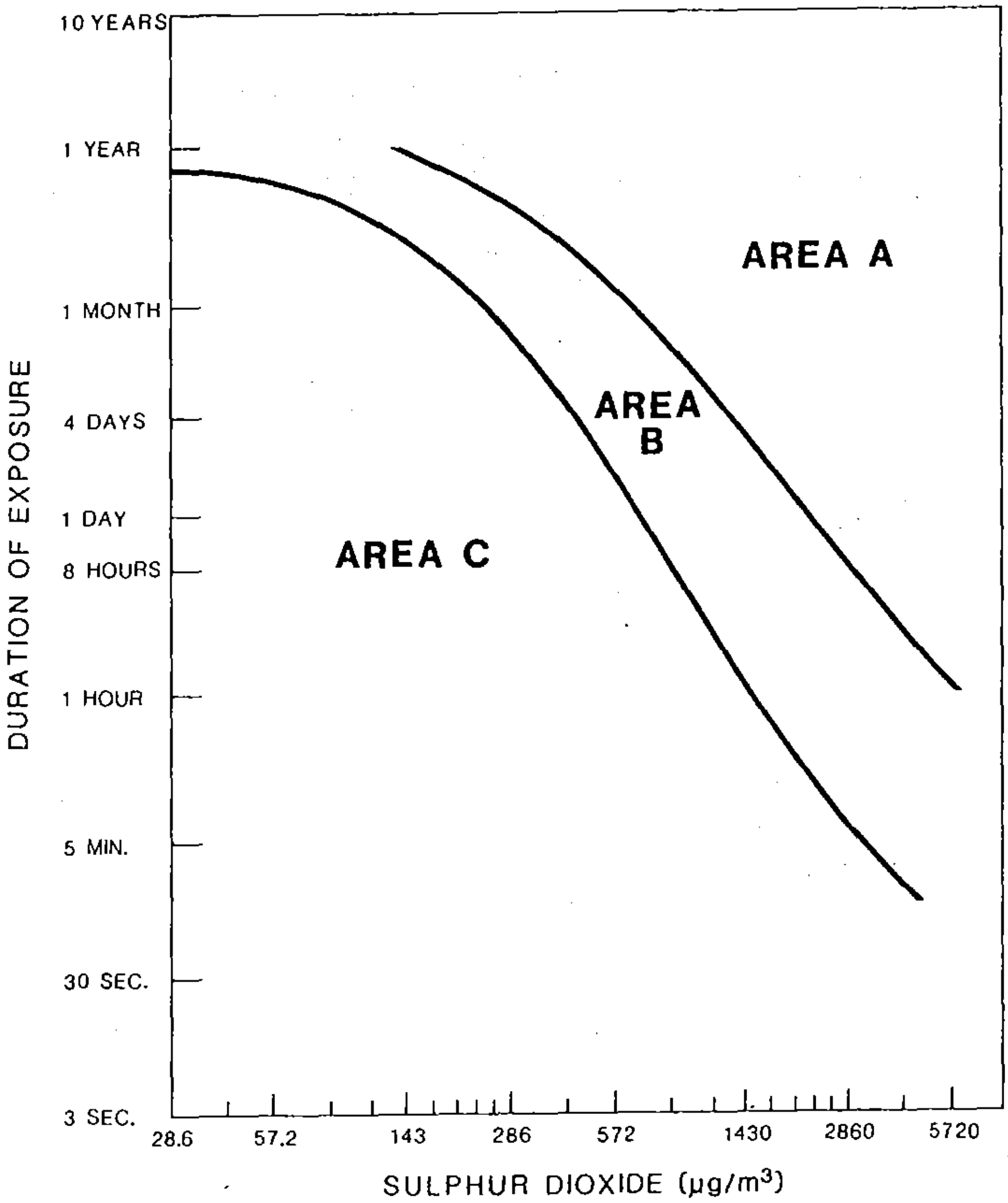
Analysis and consideration of submissions made by the public and by Government departments has not changed any of the main findings of the PER, which were:-

- The satellite roaster proposal would represent an important development in the Kalgoorlie-Boulder area in terms of ensuring future viability of the gold producing region, while assisting in the achievement of air quality objectives for the residential areas.

- There are no known environmental impacts of the proposal which would likely be significant or unmanageable.

- The Proponent will implement various management programmes designed to monitor and mitigate the effects of the operation.

FIGURE



A Range of concentrations and exposure times in which deaths have been reported in excess of normal expectation.

B Range of concentrations and exposure times in which significant health effects have been reported.

C Range of concentrations and exposure times in which health effects are suspected.

EFFECTS OF SULPHUR DIOXIDE ON HEALTH

Adapted from: The Manual on Urban Air Quality Management
WHO Regional Publication, European Series, 1976.

Figure 1
Dames & Moore

A reducing agent is required to produce elemental sulphur, and available technology uses natural gas as a reductant. The production of elemental sulphur also generates significant cooling loads which require substantial amounts of cooling water. The costs of supplying cooling water, together with the costs of transporting natural gas, would make the production of elemental sulphur uneconomic at this point in time.

The capital costs of a plant to generate elemental sulphur, including the associated scheme water demands, are estimated to exceed $50 million. It is estimated that operating costs would be recovered from the proceeds of elemental sulphur sales (at mid 1987 values).

The Proponent continues to evaluate the elemental sulphur alternative, and has done nothing to preclude the recovery of sulphur from the roaster off gases. Should a natural gas pipeline be constructed to Kalgoorlie, and should technology be developed to lower the cost of industrial quantities of fresh water in the Kalgoorlie area, then production of elemental sulphur could become an attractive alternative, if proved to be commercially viable.

2.2 LOCATION OF THE ROASTER

Several submissions were concerned about the proposed location of the roaster and suggested that it should be located to the south, adjacent to the Kalgoorie Nickel Smelter. Concern was expressed about the effects on the northern suburbs of the Kalgoorlie-Boulder urban area, and on the nearby pastoral stations.

The proposed location for the roaster is at North Gidji, approximately 17km to the north of Kalgoorlie Town Centre. Prior to the selection of the North Gidji site, NKML also had considered their Jubilee mine site to the south of Kalgoorlie, but had discarded that alternative due to its location with respect to the surrounding populated areas of Coolgardie, Kambalda and Kalgoorlie-Boulder. Its centralised position would have meant that prevailing winds would have carried the roaster plume towards populated areas a large percentage of time. A site near the Kalgoorlie Nickel Smelter was also considered and rejected as the cumulative effect of sulphur dioxide from the roaster and from existing industries would have yielded an undesirable and unnecessary concentration of sulphur dioxide discharge in one area.

Serious consideration of the North Gidji site was based on preliminary advice from the Pollution Control Division of the EPA, according to the following rationale:

i) The EPA suggested that the site be located remotely from the Kalgoorlie-Boulder residential areas with the intent of minimising the cumulative impact of the proposed roaster and the other existing sources of pollution in the Eastern Goldfields region.

ii) Analysis of prevailing winds and other meteorological parameters by the EPA indicated that the north to north-westerly direction would have the lowest percentage of low wind speeds (ie: those most conducive to high ground-level concentrations). This direction also would have the advantage of having a low percentage occurrence of winds that would blow the plume in the direction of Kalgoorlie and Boulder (only 5% of the time on an annual basis).

Subsequently, an extensive plume dispersion modelling study, which was conducted as part of the PER, confirmed that the proposed site is close to optimum in terms of minimising air pollution in Kalgoorlie-Boulder. The study also indicated that air quality in the Kalgoorlie-Boulder residential areas, including the northern suburbs, would be generally improved by installing the roaster at the remote location, and shutting down the Paringa roaster close to town.

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2.3 KING OF THE WEST LAKE

Some submissions queried the effect on a local water body known as King of the West Lake.

Neither the Kalgoorlie Mines Department, the Pastoral Board, nor the Kalgoorlie Town Council are aware of any official or gazetted recreational activities associated with this lake, although the area is well known to local inhabitants.

According to the Shire of Boulder, King of the West Lake is located on privately owned land about 25 km north of Kalgoorlie Town Centre (about 8 km north of the proposed stack). This is an ephemeral water system comprised of a string of lakes which are usually dry, due to the low rainfall and high evaporation rates of the Eastern Goldfields Region. The unusually consistent rainfall of 1987 enabled the lakes to suport such recreational activities as water skiing, yachting, swimming, and duck shooting. Last year was the first time in over a decade that the lakes were filled with water.

The proposed roaster is not expected to impair the informal recreational use of The King of the West Lake. Although the air quality in the vicinity of the lake will decline with the installation of the roaster, the anticipated ground-level concentrations are expected to be comparable to the levels which would be experienced within the residential areas of Kalgoorlie as a result of this proposal. The lake is located to the north of the proposed roaster, and the frequencies of winds from the south are low over all seasons, and just over 5% during the summer season, when recreational use would be highest.

The visual appearance of this area should not be impaired since, according to the vegetation survey referred to in Section 2.8 of this document, sulphur dioxide effects on vegetation are unlikely to be observable beyond 7km from the stack.

2.4 CONTINGENCIES TO CONTROL SULPHUR DIOXIDE EMISSIONS

Some of the submissions were concerned about what measures NKML would take if the sulphur dioxide levels in Kalgoorlie were to exceed the guidelines specified in the Draft Environmental Protection Policy for the Control of Sulphur Dioxide in the Air Environment of the Kalgoorlie-Boulder Residential Areas (EPP). One submission suggested that the stack be built at this stage to allow an increase in stack height at some future date, should sulphur dioxide levels in Kalgoorlie become excessive.

Raising the stack height would not be economically feasible, since it would require major plant shut-down during heightening. The proposed roaster location has been chosen so that there will be an improvement in air quality in the Kalgoorlie-Boulder area, in spite of the significant expansion of roasting capacity. This improvement will be obtained by retirement of the Paringa roasting facility from the immediate Kalgoorlie-Boulder area.

NKML has considerable experience in roaster operation in the Kalgoorlie-Boulder area, and has played a major role in the development of the Environmental Protection Policy for Kalgoorlie-Boulder through its involvement in the Gold Roaster Task Force. NKML is fully aware of its responsibilities under the EPP and will take action as appropriate to control pollution in the Kalgoorlie-Boulder area. NKML's current strategy to monitor sulphur dioxide levels and shut down its roaster operations in Kalgoorlie-Boulder are detailed in Appendix C of the PER.

2.5 TOXICITY OF SULPHUR DIOXIDE

Concern was expressed about the lack of information on the toxicity of sulphur dioxide to both human and plant life.

The effects of sulphur dioxide on human health are illustrated in Figure 1, as adapted from the World Health Organisation's "Manual on Urban Air Quality Management."

Refer to Section 2.8 for more information on the toxic effects of sulphur dioxide on plant life.

2.6 SULPHUR DIOXIDE MONITORING

One submission suggested that sulphur dioxide levels should be measured by a third party, ie: the EPA. The EPA has been operating air quality monitoring stations in Kalgoorlie since 1982. Under the proposed EPP, the responsibility for the daily monitoring logistics has been taken on by the operating companies. The monitoring procedures will comply with EPA requirements, and will be subject to EPA review.

2.7 ADDITIONAL MONITORING STATIONS

Several submissions suggested that additional sulphur dioxide monitoring should be done at Kanowna (the only pastoral station permanently occupied in the area) the King of the West Lake and Kalgoorlie.

The EPA currently operates sulphur dioxide monitoring stations at the Kalgoorlie Regional Hospital, the Kalgoorlie Technical School, and the South Boulder Primary School. In addition to the three existing monitors, NKML has already agreed to the provision of two additional monitoring stations in Kalgoorlie-Boulder under the requirements of the EPP, as well as one extra monitoring station on the northern outskirts of Kalgoorlie, at a location agreeable to the EPA, associated with licensing of the roasting facility proposed in the PER.

It is NKML's view that further additional monitors are not justified at Kanowna or King of the West Lake, for the combined permanent population of these areas is minimal, comprising several caretakers and seasonal workers.

2.8 SULPHUR DIOXIDE EFFECTS ON VEGETATION

Some concern was expressed over the effect of sulphur dioxide on vegetation.

It is understood that the EPA has recently received the results of a study commissioned to investigate the effects of sulphur dioxide on vegetation in the Eastern Goldfields (including the areas around the Kalgoorlie Nickel Smelter). Similar vegetation effects may be anticipated at the roaster site to those recently observed around the nickel smelter, for the following reasons:-

- the peak ground-level concentrations of sulphur dioxide due to the operation of the nickel smelter are understood to be of the same order of magnitude as those projected for the development described in the PER; and

- the vegetation around the nickel smelter is essentially comparable to that at the satellite roaster site.

The effects noted around the nickel smelter have been observed up to a radius of 6km to 7km, although more substantial damage is noted within 2km of the stack. It is understood that even in the most affected areas, regeneration of at least some species is taking place.

2.9 FUMIGATION EVENTS

Some of the submissions expressed concern about fumigation events.

This section will describe some of the general characteristics of the fumigation phenomena, and relate these specifically to the proposed roaster:-

- Fumigation events in continental areas, such as the Kalgoorlie area, occur when the slowly dispersing plume emitted under stable night-time conditions is intercepted by a developing turbulent convective layer, which is produced when the sun warms the ground during the morning. Under these night-time conditions, the plume undergoes only a small amount of plume rise and horizontal and vertical dispersion. When the convective layer reaches the plume height in the morning, the initial mixing is primarily in the vertical direction, and ground-level concentrations can be high. However, once the convective layer has grown to well past the height of the plume, then horizontal dispersion can also assist in reducing concentrations and ground-level concentrations will be lower.

- The absolute frequency of fumigation events, without respect to location, is probably fairly high. However, the frequency at any particular downwind location is likely to be low, because the fumigation would occur over a large range of downwind distances and directions. Fumigation conditions generally occur under the breakdown of stable conditions with low wind speeds. These occur more often in winter than in summer, but could occur at any time of the year.

- The duration of the maximum ground-level concentration caused by the fumigation is inherently short, from a few minutes to 20 or 45 minutes, depending on the height of the stack and the buoyancy of the plume.

The PER (Section 6.1.1 page 36) estimated that the frequency of fumigation events over Kalgoorlie is expected to be very low, less than 5% per annum. This is because the windrose diagrams (Figure 5 of the PER) indicate that, on an annual basis, the winds from the north-north-west would blow the roaster plume over Kalgoorlie less than 5% of the time, and only some of those plumes would encounter the stable conditions conducive to fumigation events.

3.0 OTHER ISSUES

3.1 ABORIGINAL HERITAGE

Two submissions expressed concern that a survey of Aboriginal sites of ethnographic significance had not been undertaken for the PER.

Archaeological and ethnographic surveys of the roaster site and the slurry pipeline route have now been completed, including liaison with Aboriginal bodies recommended by the Western Australian Museum.

No Aboriginal sites have been found in areas that will be affected by the project, and the Aboriginal bodies and individuals that have been contacted (including those recommended by the West Australian Museum) have no objections to the project.

3.2 HEAVY METALS

Several submissions were concerned that the levels of heavy metals in the plume and calcined product were not presented.

Calculations have indicated that, even under worst case assumptions, the concentrations of heavy metals in the stack emissions would be within the guidelines of the NHMRC. The PER (in Section 6.1.3 page 38) concluded that, as the roaster would be operating under oxidising conditions with a relatively low roasting temperature, there would be no significant volatilisation of heavy metals, which would remain locked in the calcine. This conclusion was based on previous experience with similar roaster technology, further supplemented with a semi-quantitative analysis of batch samples of calcine and concentrate (Table 1) taken from a Kalgoorlie area roaster.

It should be emphasised that direct estimates of volatilisation cannot be made from Table 1, since:-

i) the available analytical instruments are not sensitive enough, and
ii) the analyses of calcine and concentrate samples are difficult to correlate due to the large circulating mass in the roaster.

TABLE 1

SEMI-QUANTITATIVE ANALYSIS OF CONCENTRATE AND CALCINE

HEAVY METALS CONTENT (ppm)

ELEMENT	DOLERITE		BASALT	
	Concentrate	Calcine	Concentrate	Calcine
Arsenic (As)	240	602	110	420
Lead (Pb)	< 20	40	< 20	39
Cadmium (Cd)	< 2	3	< 2	< 2
Tellurium (Te)	54	23	42	23
Antimony (Sb)	19	22	12	28

Examination of the chemistry of arsenic, antimony, cadmium, lead and tellurium, as well as their possible oxide and sulphide compound formations, suggests that the only doubtful element is arsenic. The other metals and their compounds should remain in solid or liquid form throughout the roasting process, and should not be emitted from the stack (other than incorporated into the particulates).

The proposed roaster will be of the circulating fluidised bed type, whereas the roasters currently operating in the Kalgoorlie area are of the static fluidised bed type. The velocities of gas and materials are higher in a circulating roaster and therefore there is a significantly reduced possiblity of localised pockets of dead material occuring in the bed. It is in such pockets that reducing rather than oxidising conditions may occur. In other words, a circulating roaster ensures a more uniform roast in an oxidising atmosphere; conditions which are not suitable for the release of arsenic.

The arsenic is likely to be found in the concentrate as arsenopyrite (FeAsS). Since the satellite roaster will be operating under oxidising conditions at a temperature of 650^{o}C, it is estimated that the major part of the arsenic in the feed concentrate would remain fixed in the calcine as ferrous arsenate ($FeAsO_4$). A minor percentage may oxidise to form arsenic trioxide (As_2O_3), which sublimates at 193^{o}C to form a gas. Based on previous experience at other roasting installations overseas, less than 10% of the arsenic might be expected to oxidise to As_2O_3, and the more probable range would be 4-6% oxidation.

Arsenic will leave the stack in both gaseous (arsenic trioxide As_2O_3) and particulate form. The PER stated that the arsenic trioxide would be unlikely to exceed 4 ppm, which is equivalent to less than 13 mg/Nm^3. Expressed as elemental arsenic, this would be 3.0 ppm, equivalent to less than 10 mg/Nm^3. In the interim, revised estimates indicate an arsenic level of 3.1 ppm or 3.6 mg/Nm^3. Both estimates were based on the following methodology:-

1. Assuming a concentrate formed from equal mixtures of doleritic and basaltic ore, the average arsenic concentration would be 175 ppm (from Table 1). Based on a 6% oxidation rate, the estimated amount of arsenic in the gas exhausted from the roaster would be:

$$0.06 \times 24{,}000 \text{ kg/hr} \times \frac{175}{1{,}000{,}000} = 0.25 \text{ kg/hr}$$

Based on a total stack gas flow of 81,000 kg/hr (69,000 Nm^3/hr), the estimated concentration of arsenic in the stack gas would be:

$$\frac{0.25 \text{ kg/hr}}{81{,}000 \text{ kg/hr}} \times 1{,}000{,}000 = 3.1 \text{ ppm}$$

This is equivalent to $$\frac{0.25 \text{ kg/hr}}{69{,}000 \text{ Nm}^3\text{/hr}} \times 1{,}000{,}000 = 3.6 \text{ mg/Nm}^3$$

Sensitivity analysis results (Table 2) illustrate the effect of different ore composition and oxidation rates on the concentration of arsenic in the stack gas. Even under worst case assumptions, the concentration of arsenic in the stack gas is comfortably within the NHMRC Guidelines of 10 mg/Nm^3.

TABLE 2

SENSITIVITY ANALYSIS

ORE COMPOSITION	ARSENIC CONCENTRATION	OXIDATION TO As_2O_3 6%		10%	
Basalt/Dolerite	ppm	ppm	mg/Nm^3	ppm	mg/Nm^3
0% / 100%	240	4.3	5.1	7.1	8.4
50% /50%	175	3.1	3.6	5.2	6.1
100% / 0%	110	2.0	2.3	3.3	3.8

2. In addition to the arsenic trioxide, one can assume that the dust loading after the precipitator contains heavy metals in a similar proportion to that determined from the analysis of the calcine. Assuming the value for arsenic in calcine formed from equal mixtures of doleritic and basaltic ore (511 ppm), and given the precipitator emission rate of 100mg/Nm^3, the concentration of arsenic in the exhaust stack can be calculated as follows:

$$\frac{511}{1,000,000} \times 100 \text{ mg/Nm}^3 = 0.051 \text{ mg/Nm}^3$$

Similarly, one can estimate the concentrations for lead (0.004 mg/Nm^3), cadmium (0.0002 mg/Nm^3), antimony (0.002 mg/Nm^3) and tellurium (0.002 mg/Nm^3). The cumulative concentration of these five heavy metals would be in the order of 0.06 mg/Nm^3, which is insignificant.

3.3 PLUME DISPERSION MODEL

One submission said that there was no justification for the choice of model and that the meteorological data was insufficient.

The treatment of the meteorological data and the choice of dispersion model were discussed with the EPA Pollution Control Branch at various decision points during the plume dispersion study to ensure compliance with EPA Pollution Control requirements. Full justification is given in Sections 3.0 and 5.1 of the Supporting Document to the PER, and is summarised below.

The Victorian Environment Protection Authority's (VEPA) version of the Short-Term Industrial Source Complex Model (ISC-ST) was used to predict the ground-level concentrations of sulphur dioxide emissions, for the following reasons:-

- The model is an advanced Gaussian dispersion model which can be tailored to account for the influence of terrain, building-wake effects, and the wide range of meteorological conditions which effect dispersion.

- Several other regulatory agencies in Australia make use of this version of the model to evaluate air pollution impacts and to determine appropriate stack heights for licensing purposes.

- Validation studies comparing predicted ground-level concentrations with actual measured concentrations confirmed that the model would give a useful indication of the likely air quality.

The best available data from the project area was used in the dispersion model:

- Surface meteorological data was available from the EPA's meteorological station at the Kalgoorlie Technical School, comprising wind speed, wind direction, the standard deviation of horizontal wind direction fluctuations (sigma-theta), temperature and solar radiation. Data at 10 minute intervals were available from January 1984 to December 1986.

- Upper-air data were available from routine Bureau of Meteorology radiosonde ascents made from the Kalgoorlie airport, and profiles were available from intensive studies conducted by the EPA, comprising measurements of wet and dry bulb temperature, and wind speed and wind direction over variable height intervals.

3.4 EXPANSION PLANS

One submission expressed concern that expansion of the roasting facility was not discussed.

The project as described in the PER is viable and is the one for which approval is currently being sought. Any subsequent proposal to expand production above the levels given in the PER will be referred to the EPA for approval.

4.0 CONCLUSIONS

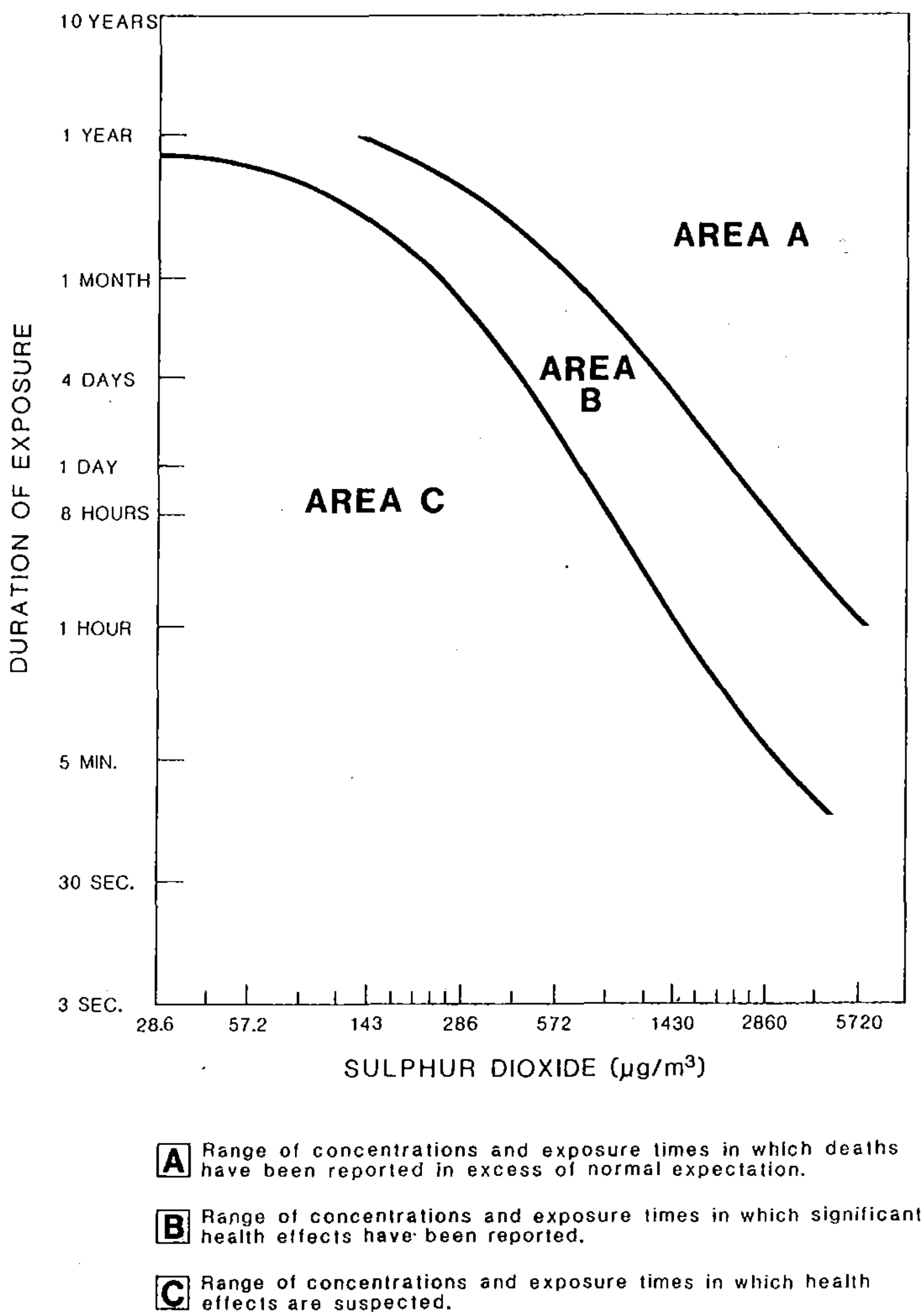
Analysis and consideration of submissions made by the public and by Government departments has not changed any of the main findings of the PER, which were:-

- The satellite roaster proposal would represent an important development in the Kalgoorlie-Boulder area in terms of ensuring future viability of the gold producing region, while assisting in the achievement of air quality objectives for the residential areas.

- There are no known environmental impacts of the proposal which would likely be significant or unmanageable.

- The Proponent will implement various management programmes designed to monitor and mitigate the effects of the operation.

FIGURE



EFFECTS OF SULPHUR DIOXIDE ON HEALTH

Adapted from: The Manual on Urban Air Quality Management
WHO Regional Publication, European Series, 1976.

Figure 1
Dames & Moore

SUMMARY AND REVIEW OF SUBMISSIONS

Four public and several governmental submissions were received on the Public Environment Report for the Satellite Gold Roaster.

The major issue of concern was the sulphur dioxide levels to be discharged from the stack. A variety of points were subject to submission and should be further addressed by the proponent.

i) The proponent states that sulphur dioxide scrubbers are not economically viable. Further details are required to support this statement;

ii) Several submissions were concerned about the location of the roaster and suggested it should be south, adjacent to the Nickel smelter. Concern was expressed about the effects on the northern suburbs, and on the near by pastoral stations;

iii) The effect on a water body known as King of the West Lakes was not discussed and requires further information;

iv) One submission suggested that the stack be built at this stage to allow an increase in height, if sulphur dioxide levels in Kalgoorlie were excessive;

v) Concern was expressed about the lack of information on the toxicity of sulphur dioxide for both humans and plant life;

vi) There was one submission suggesting that sulphur dioxide levels should be measured by a third party ie. the EPA;

vii) Several submissions suggested extra monitoring should occur at both the pastoral station, King of the West Lakes and in Kalgoorlie;

viii) Concern was expressed over the effect of sulphur dioxide on vegetation; and

ix) Concern was also expressed about fumigation events.

Other concerns were also expressed about the project.

Two submissions expressed concern that a survey of aboriginal sites of ethnographic significance was not undertaken. The proponent should contact relevant aboriginal groups to investigate this.

Several submissions were concerned that the levels of heavy metals in the plume and in the calcined product were not presented. The proponent should provide details of these levels.

One submission said that there was no justification for the choice of model and that the meteorological date was insufficient.

Another submission expressed concern that expansion of the roasting facility was not discussed.

SATELLITE GOLD ROASTER
PUBLIC ENVIRONMENTAL REPORT
RESPONSE TO SUBMISSIONS
for
North Kalgurli Mines Ltd

Dames & Moore

Dames & Moore Job No. 16037-004-071
8 March 1988

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SATELLITE GOLD ROASTER
PUBLIC ENVIRONMENTAL REPORT
RESPONSE TO SUBMISSIONS
for
North Kalgurli Mines Ltd.

1.0 INTRODUCTION

North Kalgurli Mines Ltd (NKML) plans to construct and operate a satellite gold roaster facility in the Kalgoorlie area. In December, 1987, NKML made available for public review a Public Environmental Report (PER) for this project in accordance with the provisions of the Environmental Protection Act (1987).

The PER was subject to an eight week public review period, from 16th December, 1987 to 10th February, 1988. Four public and several governmental submissions were received by the Environmental Protection Authority (EPA), and a summary of these submissions was forwarded to the Proponent.

This document responds to matters raised in the various submissions. The major issues of concern are associated with the sulphur dioxide to be discharged from the roaster stack. Section 2 of this report responds to the various concerns that have been raised with respect to sulphur dioxide, and Section 3 addresses the remaining issues.

2.0 SULPHUR DIOXIDE

2.1 ALTERNATIVES TO SULPHUR DIOXIDE EMISSIONS

One of the issues raised was whether scrubbers could be used to recover sulphur dioxide, as an alternative to direct emission to the atmosphere.

The PER in Section 3.1.2 page 9 concluded that sulphur dioxide removal via lime absorption would be uneconomic due to the high operating costs required to import the large quantities of lime, and to dispose of the large quantities of slurry by-product. Further details of the feasibility of using scrubbers are discussed below:-

- While the capital cost of a limestone absorber circuit is relatively low, the operating cost of running the scrubber would be approximately $12M a year. Most of this operating cost would be the cost of the lime consumed in scrubbing the sulphur dioxide.

- In addition to considering lime, local deposits of limestone and magnesite were considered, and testwork was conducted to assess their suitability for scrubbing sulphur dioxide. In general, both these rocks were poor scrubbers of sulphur dioxide, and the size of the scrubbing plant and volume of material required would be prohibitive.

- It was considered that the problems of disposal of the waste products from the scrubbing operation would present a major pollution problem in their own right. Gypsum would also accumulate in circuit water and would create major plant operational difficulties.

- The use of water to scrub sulphur dioxide from the gas stream was also considered, but was found not to be feasible due to the large volumes of water required and problems of water neutralisation.

The PER in Section 3.1.2 addressed several alternative sulphur dioxide recovery processes in addition to lime absorption scrubbers (production of sulphuric acid and production of elemental sulphur), and further details of these studies are presented below.

The alternative of recovering sulphur dioxide from the roaster stack gases to produce sulphuric acid was quickly eliminated in favour of elemental sulphur production, for the following reasons:

- Elemental sulphur could be more readily stored, allowing the cyclic nature of the sulphur market to be accomodated.

- Elemental sulphur represented one third the weight of sulphuric acid per equivalent sulphur unit. Transport would be much cheaper due to less weight.

- Elemental sulphur could be readily transported in conventional transportation units.

- Elemental sulphur was more marketable than sulphuric acid.