Cumulative impacts of oxides of nitrogen emissions from existing and proposed industries, Burrup Peninsula

Section 16(e) report and recommendations of the Environmental Protection Authority

Environmental Protection Authority
Perth, Western Australia
Bulletin 1124
January 2004

ISBN. 0 7307 6760 4
ISSN. 1030 - 0120

Summary and recommendations

This report provides the Environmental Protection Authority's (EPA's) advice and recommendations to the Minister for the Environment in response to a request from the Minister to provide advice under Section 16(e) of the *Environmental Protection Act 1986* (the Act). Advice was requested on the impact of cumulative air emissions, particularly oxides of nitrogen (NO_X), on the Burrup Peninsula environment and on whether a review of conditions previously issued should be undertaken under Section 46 of the Act. However, the EPA has not considered the potential effects of NO_x on the integrity of Aboriginal Rock Art on the Burrup Peninsula. There is an expert committee which has been established by the Department of Industry and Resources and reporting to the Minister for State Development which is specifically considering the issue.

Section 16(e) of the Act requires the EPA to advise the Minister on any matter which the Minister may refer to it for advice, including the environmental protection aspects of any proposal or scheme, and on the evaluation of information relating thereto. Section 46(1) of the Act states that the Minister may request the Authority to inquire into and report on whether or not conditions or procedures relating to the implementation of a proposal should be changed.

The reason for the request for advice was the announcement by Woodside Energy Ltd in March 2003 that it had underestimated the emission of NO_X from its on-shore gas processing plant on the Burrup. Recent environmental assessments of industrial proposals on the Burrup by the EPA have been based on cumulative modelling data using substantially lower NO_x emissions than those reported in March 2003. Cumulative modelling work has been redone by Woodside to confirm that cumulative NO_X emissions from its plant and the previously assessed industrial proposals do not pose a threat to human health or have a significant impact on the natural and historical values of the Burrup Peninsula.

In particular, this report:

a) reviews the modelling results and assesses the effect the increased estimates in NO_x emissions have on predicted future air quality;
b) examines the potential impacts to human health from NO_x and ozone (O_3);
c) reviews the potential impacts to the terrestrial environment from changes in air quality due to NO_x and ozone;
d) considers the terrestrial environmental impact of NO_x in conjunction with oxides of sulphur as acid gas, and the potential of NO_x in conjunction with ammonia and urea to cause nutrient enrichment of soil and water;
e) focuses on the impact of NO_x on the terrestrial environment as the industrial areas adjoin the Conservation, Heritage and Recreational Area. Although there will be deposition of atmospheric NO_x into the marine environment, the potential impacts of this deposition have not been considered in detail in this report; and

f) provides a summary of predicted ground level concentrations for other air pollutants at Dampier and Karratha and the maximum in the region, compared to relevant National Environment Protection Measure levels, in Appendix 2.

Conclusion

Three modelling studies have been considered in this report. The three studies provide predictions of regional and local air quality for existing and proposed industries on the Burrup. The modelling studies are not directly comparable but account for different physical processes influencing emissions and provide a range of results within which it is expected that the actual ground level concentrations will fall. All models predict that National Environment Protection Measure (NEPM) health-based standards will be met at population centres. However in order to confirm the modelled predictions, the EPA recommends that air quality monitoring be undertaken co-operatively by those industries operating on the Burrup. Monitoring should be carried out in consultation and agreement with the Department of the Environment.

Previous monitoring of air quality in 1999 showed no exceedences of NEPM standards for NO_2, O_3, and SO_2 at any of the monitoring sites at Dampier, Karratha, or King Bay (EPA 2002d). Therefore there is no health concern relating to the current levels of these pollutants.

There is limited information on the effects of air pollutants on the vegetation, soils, rockpools and rock art of the Burrup. The increased estimate of NO_x emissions from the Woodside plant results in an increased level of risk that parts of the Burrup may suffer adverse environmental impact. In order to obtain more information on the potential impact of NO_x on vegetation it is suggested that the monitoring work being carried out as part of the Burrup Rock Art Study could be extended to address environmental changes that could impact on vegetation. Although there will be deposition of atmospheric NO_x into the marine environment, the potential impacts of this deposition have not been considered in detail in this report. The effects of emissions on rock art are being investigated by the Burrup Rock Art Monitoring Management Committee and therefore are not considered in this report.

It is important for proponents to monitor for early warning signs of impacts from emissions and have contingency plans for corrective action relevant to their operations. The EPA also encourages the formation of a Burrup Industrial Council for the overall management of environmental impacts on the Burrup, as previously mooted in the assessments carried out for the Burrup Fertilisers Ammonia Plant, the Methanex Methanol complex, Liquigaz Methanol Plant and the Dampier Nitrogen Ammonia-Urea plant. It is also important to employ best practicable measures as defined in EPA Guidance Statement No 55 (EPA 2003) to minimise emissions and environmental impacts as a precautionary measure against environmental damage and to allow space in the airshed if other industries seek to establish in the same area. It is possible that future air emissions from the proposed Maitland Estate may also contribute pollutants to the airshed on the Burrup.

The EPA considers that based on the air modelling studies, it is not necessary to alter any conditions pertaining to EPA assessments already carried out on proposed industry on the Burrup because all completed assessments already contain sufficiently stringent conditions to manage air quality issues.

Additional studies on the impacts of air emissions on bio-physical receptors on the Burrup are, however, recommended.

Recommendations

The EPA submits the following recommendations to the Minister for the Environment:

1. All existing and future proponents be required to employ best practicable measures to reduce their air emissions and to minimise the risk of environmental impact;
2. Future emission stacks be sited and designed to reduce impacts on nearby terrain;
3. Industries operating on the Burrup carry out monitoring for early warning signs of impacts that can be attributed to their particular activities where these can be identified and prepare contingency plans relevant to their operations;
4. A Burrup Industrial Council, as previously mooted in recent assessments of proposals on the Burrup, be set up to carry out monitoring for air quality and cumulative impacts from the operations of all industries (where impacts due to individual industries cannot be identified) funded by those industries operating in the air shed;
5. Research should be carried out to investigate the potential effect of air pollutants and nutrients on Burrup vegetation and consideration should be given to extending the Burrup Rock Art Study to include this; and
6. Research should be undertaken into identifying sensitive organisms or fundamental parameters that may serve as early warning indicators of impending loss of biological diversity on the Burrup and establishing trigger levels for management action.

Contents

Tables

Figures

Appendices

1. Introduction and background

This report provides the Environmental Protection Authority's (EPA's) advice and recommendations to the Minister for the Environment in response to a request from the Minister to provide advice under Section 16(e) of the *Environmental Protection Act 1986* (the Act). Advice was requested on the impact of cumulative air emissions, particularly oxides of nitrogen (NO_X), on the Burrup Peninsula environment and on whether a review of conditions previously issued should be undertaken under Section 46 of the Act. However, the EPA has not considered the potential effects of NO_x on the integrity of Aboriginal Rock Art on the Burrup Peninsula. There is an expert committee which has been established by the Department of Industry and Resources and reporting to the Minister for State Development which is specifically considering the issue.

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In particular, this report:

a) reviews the modelling results and assesses the effect the increased estimates in NO_x emissions have on predicted future air quality;
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f) provides a summary of predicted ground level concentrations for other air pollutants at Dampier and Karratha and the maximum in the region, compared to relevant National Environment Protection Measure levels, in Appendix 2.

2. Sources and quantities of air pollutants

Existing industrial sources of air pollutants on the Burrup are Woodside's on-shore gas processing plant, the Hamersley Iron power station and shipping using the Dampier Port. The main emissions from these sources are NO_x and volatile organic compounds (VOC's) and to a lesser extent, oxides of sulphur (SO_x) and particulates. Ozone (O_3), another air pollutant, is formed by the reaction of NO_x and VOC's in the presence of sunlight. The development of proposed industries on the Burrup will add further emissions of NO_x, SO_x, particulates and VOC's and also urea and ammonia.

The correction of Woodside's NO_x emission figure will affect the predicted cumulative ground level concentrations of NO_x and ozone from Woodside and proposed industries. Emissions of other pollutants and their predicted cumulative concentrations will not be affected.

Estimates of emissions from existing industries and proposed industries with environmental approval are shown in Tables 1 and 2. The NO_x estimates for Woodside emissions are conservative figures and actual annual emissions are likely to be lower.

Table 1: Existing industrial sources

	NO_X (t/a)	**SO_2 (t/a)**
Woodside Gas Processing Plant[1]	11 241	176
Hamersley Iron Power Station[1]	360	62
Shipping[2]	989	807

Sources:
1 CSIRO 2003
2 SKM 2003b

Table 2: Proposed industrial sources with environmental approval

	NO_x (t/a)	**SO_2 (t/a)**	**Ammonia(t/a)**	**Urea(t/a)**
Woodside with the addition of Trains 4 & 5[1]	13 000	460	n/a	n/a
Burrup Fertilizers Plant[1]	527	0.6	n/a	n/a
Liquigaz* Methanol Plant[1]	422	4	n/a	n/a
Methanex Methanol Complex[1]	1766	n/a	n/a	n/a
Dampier Nitrogen Ammonia-Urea Plant[2]	747	8.4	800	300
Shipping, existing and future[3]	1494	1002	n/a	n/a

n/a - *not applicable* ** previously Australian Methanol Company Pty Ltd and GTL Resources PLC*
Sources
1 CSIRO 2003
2 EPA 2002c
3 SKM 2003b

3. Description of air modelling

Three studies were undertaken to predict ground level concentrations and deposition of various air pollutants. These are:

1. Modelling by the CSIRO for Woodside using the model TAPM on different sized grids (CSIRO 2003);

2. Modelling by SKM for Woodside using AUSPLUME and DISPMOD models (SKM 2003a); and

3. Modelling by SKM for the Office of Major Projects using TAPM and CALPUFF models (SKM 2003b).

1. CSIRO studies for Woodside using the model TAPM on different sized grids

TAPM is a 3-dimensional model that predicts space and time-varying local-scale meteorology and dispersion of air contaminants emitted from various sources. As TAPM allows wind and turbulence fields to vary in 3 dimensions it is well suited to regional dispersion of air pollutants especially in areas where the meteorology is complex, such as the Burrup Peninsula. It also has photochemistry capabilities and can simulate the complex chemical transformations involved in the production of photochemical smog. However, its near source application is potentially limited by grid resolution and therefore Gaussian plume models such as AUSPLUME and DISPMOD were recommended to supplement near-source modelling.

A commitment to further modelling was made during the assessment of Woodside's Trains 4 and 5 to confirm initial air modelling predictions. In addition to Woodside's new trains, cumulative emissions from other proposals with environmental approval, have been modelled. The pollutants modelled were nitrogen dioxide (NO_2), ozone, particulates with a diameter of less than 10 microns (PM_{10}), SO_2, and the hydrocarbons benzene, toluene and xylene. As well as ground level concentrations, information on the deposition of NOx and SOx, identification of deposition regions and annual deposition rates was also obtained. The model included local biogenic and area source emissions, in addition to industrial and shipping sources and gives the most comprehensive picture of expected pollutant distribution.

Comparison with measured pollutant concentrations have shown that the TAPM model predicts NO_X and NO_2 at Dampier well, with good prediction of the average and extreme concentrations. Some minor underestimation of the extreme NO_X and minor overestimation of the extreme NO_2 has occurred. The predictions of O_3 at Dampier are very close to the observations for all concentration levels. The results at King Bay show that NO_X and NO_2 are predicted well, although there is a general overestimation of the average and lower percentiles of NO_X, and a general overestimation of NO_2 for all concentration levels. These results give confidence in the use of TAPM to predict the pollution concentrations in the Burrup Peninsula region for nitrogen oxides and ozone.

2. SKM studies for Woodside using AUSPLUME and DISPMOD models.

The models AUSPLUME and DISPMOD were employed to identify near-source concentration peaks of NO_X and NO_2 on the Burrup and as a point of comparison with the TAPM modelling. AUSPLUME is a standard Gaussian-plume based air quality dispersion model, which is widely accepted and used for regulatory purposes within Australia. DISPMOD is a Gaussian plume based air quality model for coastal regions and was designed to simulate the downward fumigation of an elevated plume as it intersects a growing thermal internal boundary layer within onshore flow (CSIRO, DEP 2001). AUSPLUME and DISPMOD were used by proponents of recently assessed proposals and hence provide information consistent with that previously used in the EPA's assessment decisions.

The sources of emissions considered were the existing sources, included flaring emissions from Woodside and shipping emissions (not included in DISPMOD due to the limitations of the model), and industrial proposals with environmental approval on the Burrup Peninsula, but excluding the Syntroleum proposal which is unlikely to proceed.

AUSPLUME and DISPMOD modelling results presented here cannot be compared with observations as the current modelling also includes emissions from proposed industries.

3. SKM studies for the Office of Major Projects using TAPM and CALPUFF models.

This modelling was undertaken primarily to gain an understanding of the impact of industrial emissions on Burrup rock engravings. Modelling included the existing sources of the Woodside On-Shore Treatment Plant, Hamersley Iron Power Station and shipping and the potential future sources of Methanex, Liquigaz, Burrup Fertilisers, Dampier Nitrogen, Japan DME, and two other theoretical industries, on Hamersley Iron land, equivalent to Japan DME and Dampier Nitrogen.

As the sources included Japan DME and two hypothetical industries that have not been assessed by the EPA, this modelling could be considered a worst case future scenario. Results from the TAPM study have been included for this reason and because the study provides information on deposition of air emissions not available from other studies.

The modelling carried out by SKM using CALPUFF showed that CALPUFF underpredicts both NO_X and NO_2, while the TAPM modelling showed good agreement with observed NO_X concentrations (but tended to overpredict NO_2 concentrations when compared with previously measured concentrations). The results obtained from CALPUFF have not been included in this report since the model has been shown to underpredict and therefore may need further modification for conditions on the Burrup.

Comparison of models

The three sets of modelling are not directly comparable. All have considered different sources. The models are also different in design and are able to account for different physical processes. Due to the complex meteorology on the Burrup it was considered that no one model could adequately account for all dispersive processes or adequately

resolve near source plumes. However, overall the modelling provides a range within which ground level concentrations are expected to fall. It should be noted that all modelling is for steady state operation, allowing for a maximum value of emissions, but does not include unusual occurrences such as plant start up or emergency releases. These situations would only occur for a small amount of time, however.

4. Results

4.1 Human Health Impacts

a) Nitrogen Dioxide (NO_2)

Tables 3 and 4 summarise the predicted maximum 1-hour and annual averaged concentrations of NO_2 in parts per billion (ppb). All three modelling studies, which include future industry sources, predict that the NO_2 levels at Dampier and Karratha will be below the National Environment Protection Measure (NEPM) level recommended for the protection of human health. Results for Hearson Cove, where available, are also included for information.

Table 3: Predicted NO_2 maximum 1-hour averaged concentrations (ppb)

Predicted NO_2 maximum 1-hour concentrations (ppb)				
	Anywhere on grid	Dampier	Karratha	Hearson Cove
CSIRO TAPM	138	34	50	45
SKM AUSPLUME	89	22	24	31
SKM DISPMOD	94	22	31	55
SKM TAPM	82	59	60	70
NEPM standard	**120**	**120**	**120**	**120**

Table 4: Predicted NO_2 maximum annual averaged concentrations (ppb)

Predicted NO_2 maximum annual concentrations (ppb)				
	Anywhere on grid	Dampier	Karratha	Hearson Cove
CSIRO TAPM	3.9	2.2	1.3	n/a
SKM AUSPLUME	19	1.5	0.5	2.7
SKM DISPMOD	4.4	0.9	0.5	3.1
SKM. TAPM	n/a	2.5	1.5	n/a
NEPM standard	**30**	**30**	**30**	**30**

n/a: not available

Table 3 shows that the CSIRO TAPM modelling predicts an exceedence of the NEPM standard in an area of the grid (see Figure 1). This is probably due to a single fumigation event resulting from the break up of a nocturnal inversion. There is debate as to whether the resulting high ground level concentrations are realistic or an artefact of the model. However the NEPM is intended to apply to where people live and the modelled exceedence does not occur at the towns of Dampier or Karratha.

It should be noted that the TAPM modelling done by the CSIRO and SKM used different minimum grid resolutions, different sources of emissions and that the CSIRO modelling included buoyancy enhancement of plumes. The SKM TAPM modelling included possible future industries which have not been assessed by the EPA and represents a "worst case" scenario. The results from the two sets of modelling are not directly comparable.

The EPA therefore concludes that the NEPM standard for NO_2 is unlikely to be exceeded at the residential areas of Dampier or Karratha even if the proposed industries (Burrup Fertilisers, Methanex, Dampier Nitrogen and Liquigaz) proceed. This is the same conclusion that the EPA reached in the assessment of the individual proposals.

b) Ozone (O_3)

Table 5 shows the maximum predicted ground level concentrations of ozone with existing and proposed industries. The predictions are from the TAPM modelling study carried out by the CSIRO (see Figure 2).

Table 5: Predicted O_3 maximum concentrations (ppb)

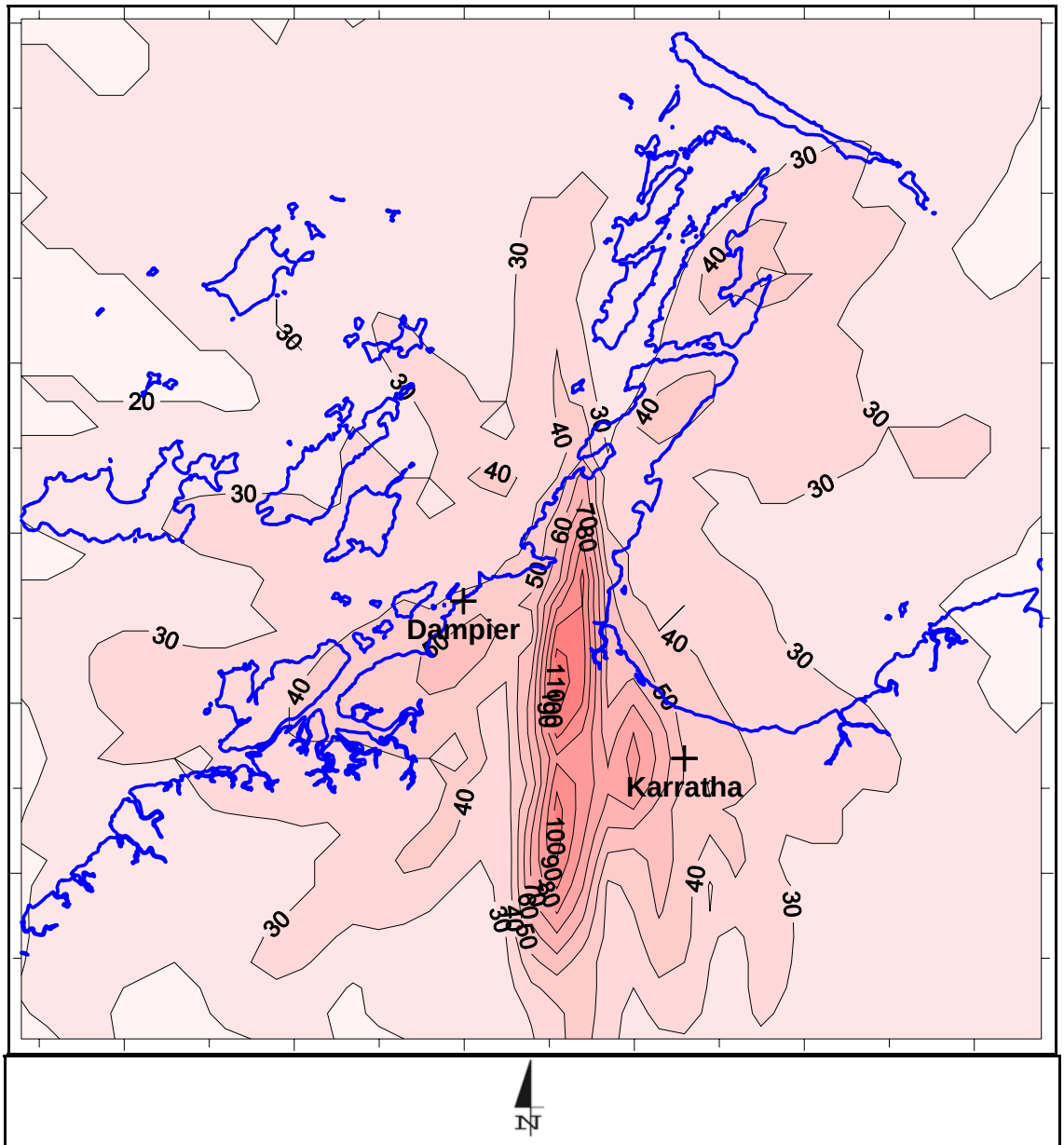
Predicted O_3 maximum concentrations (ppb)			
	Anywhere on grid	Dampier	Karratha
1-hour average	80	45	51
NEPM standard	**100**	**100**	**100**
4-hour average	58	43	45
NEPM standard	**80**	**80**	**80**

Source:CSIRO 2003

Results show that O_3 concentrations over the modelled area are predicted to be within the NEPM standards. Therefore the EPA concludes that the NEPM standard is unlikely to be exceeded at the residential areas of Dampier and Karratha even if the proposed industries proceed.

c) Other air pollutants

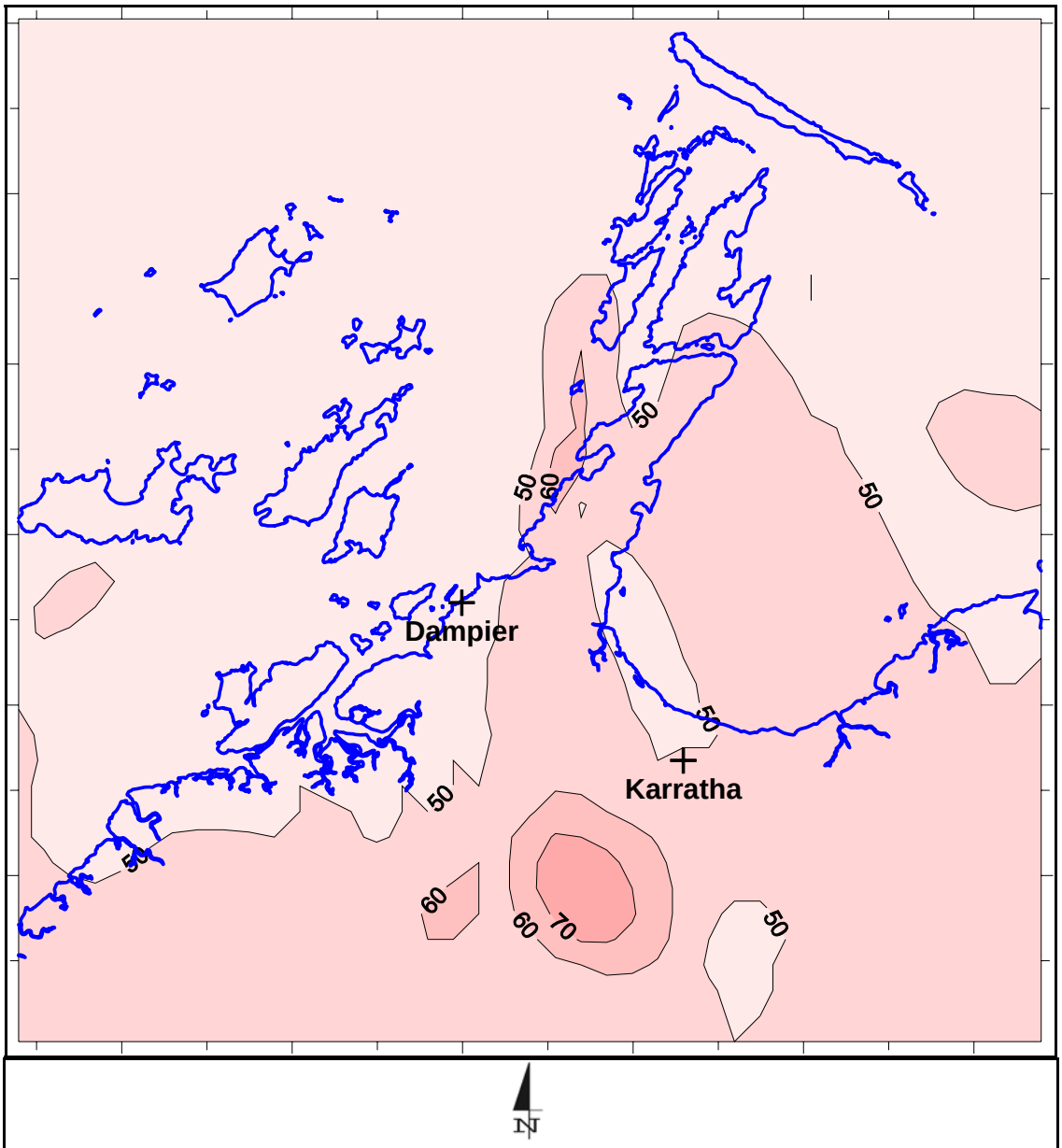
It should be noted that the TAPM modelling undertaken by the CSIRO for Woodside has predicted that over the region ground level concentrations of benzene, toluene and xylene (VOCs of health concern) will be well below the National Environment Protection Measure Draft Air Toxics investigation levels. Concentrations of particulates with a diameter of less than 10 microns (PM_{10}), (excluding PM_{10} in background dust) and SO_2 due to Woodside operations plus proposed industries will also be below the relevant National Environment Protection Measure levels (see Appendix 2)**.**



(not to scale)

Reproduced from "Woodside LNG Expansion Project – Modelling Existing and Proposed Emissions on the Burrup Peninsula using TAPM." P J Hurley, W L Physick, M E Cope & M S Borgas, CSIRO October 2003.

Figure 1: TAPM Maximum 1-hour-averaged NO_2 (ppb) on the 1.5-km spaced pollution grid for Scenario 4 (existing plus assessed industrial projects).



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Reproduced from "Woodside LNG Expansion Project – Modelling Existing and Proposed Emissions on the Burrup Peninsula using TAPM." P J Hurley, W L Physick, M E Cope & M S Borgas, CSIRO October 2003.

Figure 2: TAPM Maximum 1-hour-averaged O_3 (ppb) on the 1.5-km spaced pollution grid for Scenario 4 (existing plus assessed industrial projects).

4.2 Terrestrial Environmental Impacts

a) Air Quality (NO, NO_2 and O_3)

Table 6 shows the maximum predicted ground level concentrations of NO_x (NO and NO_2) from AUSPLUME, DISPMOD and the CSIRO TAPM studies, for 1-hour, 24-hour and annual averages. The table also shows the World Health Organisation (WHO) suggested critical levels for short-term (24-hour average) and long-term (annual average) exposures recommended for the protection of vegetation.

Table 6 Predicted NO_x maximum concentrations (ppb)

Predicted NO_x maximum concentrations (ppb)			
	1-hour average	**24-hour average**	**Annual average**
AUSPLUME[1]	272	85	18.6
DISPMOD[1]	290	47	4.4
CSIRO TAPM[2]	n/a	30	n/a
WHO critical level guideline for vegetation	**-**	**36.5**	**14.6**

n/a not available
Source:
1. SKM 2003a and 24-hour averages supplied separately
2. Additional information provided by CSIRO (pers com)

The error in the estimation of NO_x emissions from the Woodside plant has resulted in the underprediction of the maximum concentrations of NO_x that may occur on the Burrup. Predictions of maximum ozone levels have decreased in current modelling work due to the under estimation of NO_x emissions and the refinement of model parameters.

NO_x in air may have a direct effect on vegetation by uptake through plant stomata. Studies on Australian vegetation have shown that NO_X can result in reduction in biomass of the *Eucalyptus* species studied (Murray et al, 1991). Both NO and NO_2 were found to be toxic to growth in the species studied, with simultaneous exposure to NO_x and SO_2 also having a detrimental effect on growth. Studies have also shown that although arid zone vegetation demonstrates adaptations to reduce gaseous exchange and moisture loss, it is still vulnerable to NO_X exposure (Calquhoun et al. 1984, El Kiey & Ormerod 1987, quoted in URS 2002).

Air quality guidelines for Europe for impacts on vegetation (World Health Organisation, 2000) suggest 36.5 ppb (75µg/m^3) for NO_X (NO + NO_2) as a 24 hour mean as a critical level for short term exposures. For long term effects 14.6ppb (30µg/m^3) of NO_X as an annual mean may be appropriate. Whether these guidelines are appropriate for vegetation found on the Burrup has not been determined.

CSIRO modelling of NO_X concentrations for existing and proposed industry show a maximum 24-hour average of 30ppb occurring in the vicinity of Hearson Cove (Figure 3). This is below the WHO critical level of 36.5ppb for short-term exposures.

AUSPLUME and DISPMOD modelling of NO_X was carried out for the cumulative emissions of existing sources plus the proposed Woodside expansion, Liquigaz, Burrup Fertilisers, Methanex and Dampier Nitrogen plants to identify local peaks. Both these models are considered to give conservative results.

AUSPLUME predicts a maximum 24-hour average of 85ppb at the Woodside plant, with the WHO 24-hour guideline value exceeded up to 2 km from the plant and on the hills to the north east (Figure 4). However, it is thought that AUSPLUME may over state building wake effects on the Woodside plant. The annual average is predicted to be a maximum of 18.6ppb on the Woodside site, which also exceeds the long-term WHO exposure guideline, but the average falls below the guideline value outside of the site.

DISPMOD predicts a maximum 24-hour average of 47ppb, exceeding the European short-term exposure critical level, to the east and south of the Woodside plant (Figure 5). The annual average is predicted to be a maximum of 4.4 ppb which is well below the WHO long-term exposure guideline.

As a point of comparison the 2002 maximum 24-hour average for NO_X in Hope Valley was 32ppb and annual average of 7ppb. At Queens Building in central Perth, where vehicle emissions are the main source of NO_X, the maximum 24-hour average during 2002 was 179ppb, with an annual average of 76ppb.

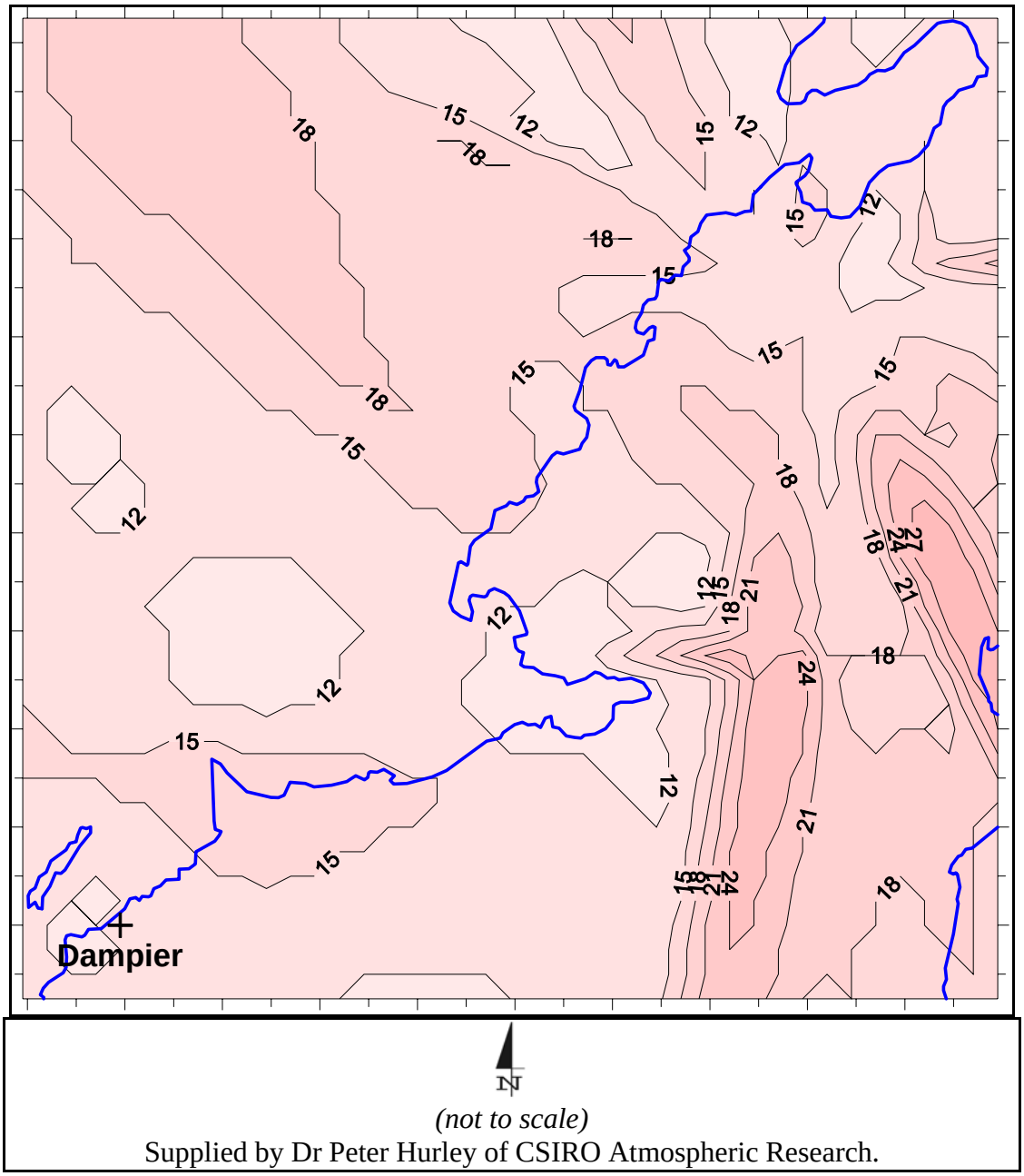
The modelling indicates that there is the potential for NO_x emissions to have an impact on vegetation on the Burrup due to short-term exposure to high NO_x levels. The modelling is not conclusive and monitoring of 24-hour averages at the predicted maxima sites is needed to confirm the model predictions. Woodside's corrected estimate of the plant's NO_x emissions increases the risk of adverse impact to the environment.

Ozone may also cause leaf damage and physiological changes in plants (Driscoll, et al). The effects of ozone on Burrup vegetation have not been studied in detail. Ozone exposure guidelines are difficult to set as impacts result from cumulative exposure. The United Nations Economic Commission for Europe has adopted a critical level for ozone for semi-natural vegetation of 3 000 ppb.hour cumulative seasonal exposure above 40 ppb during daylight hours (Ashmore, 2002). Further investigations of ozone levels are required to determine if these have the potential to impact vegetation.

No information is available for any impacts of the change in air quality due to NO_x and O_3 on fauna.

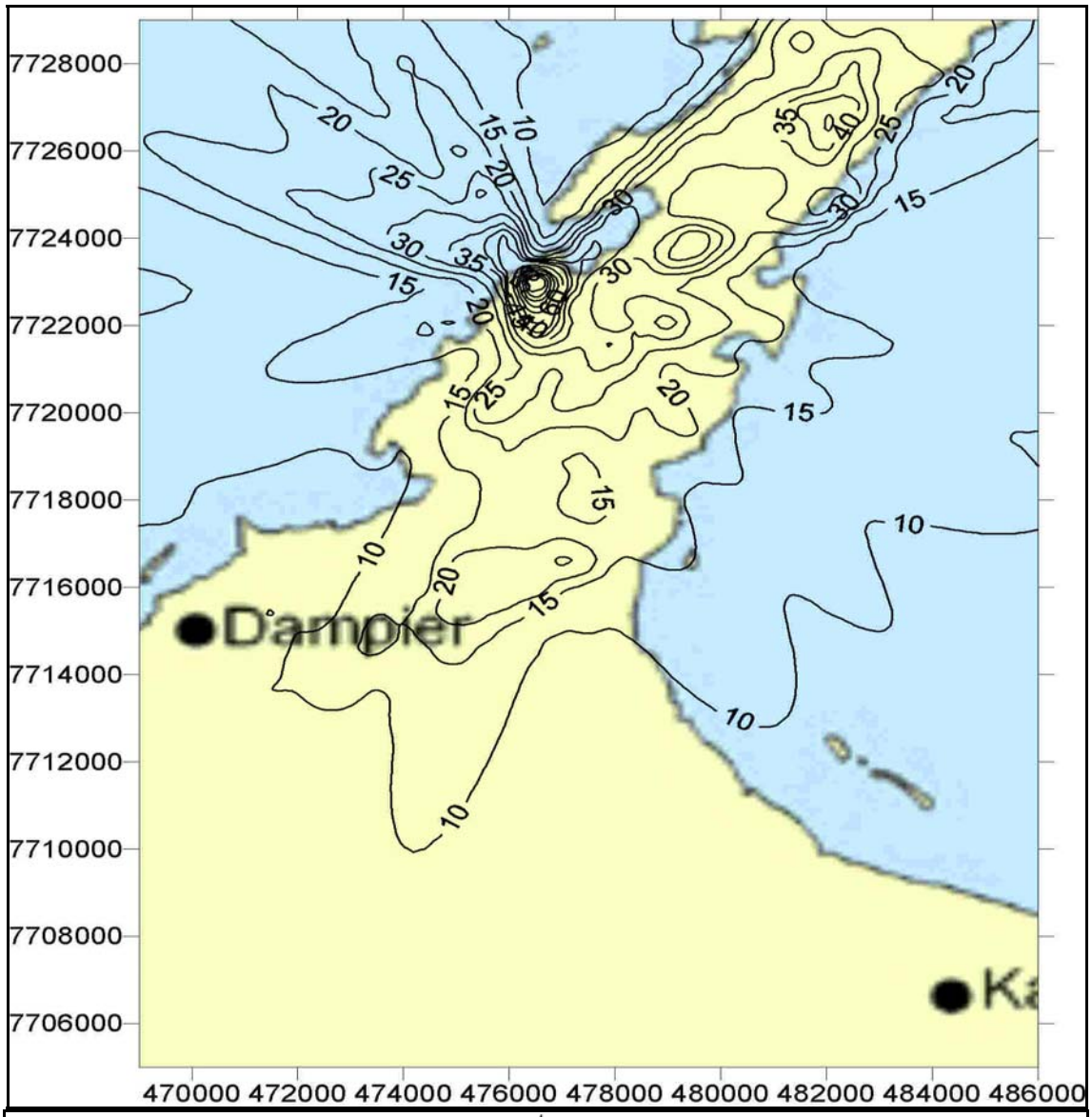
Predictions of whether the level of NO_x and O_3 will have an adverse impact on the vegetation or fauna of the Burrup are hampered by:

i) a lack of knowledge of the susceptibility of Burrup vegetation;
ii) a lack of knowledge of the interaction and synergistic effect of NO_x with other pollutants such as O_3, SO_2 and ammonia (NH_3);
iii) inconsistency of concentration levels predicted by different models; and
iv) lack of knowledge of air quality impacts on fauna.



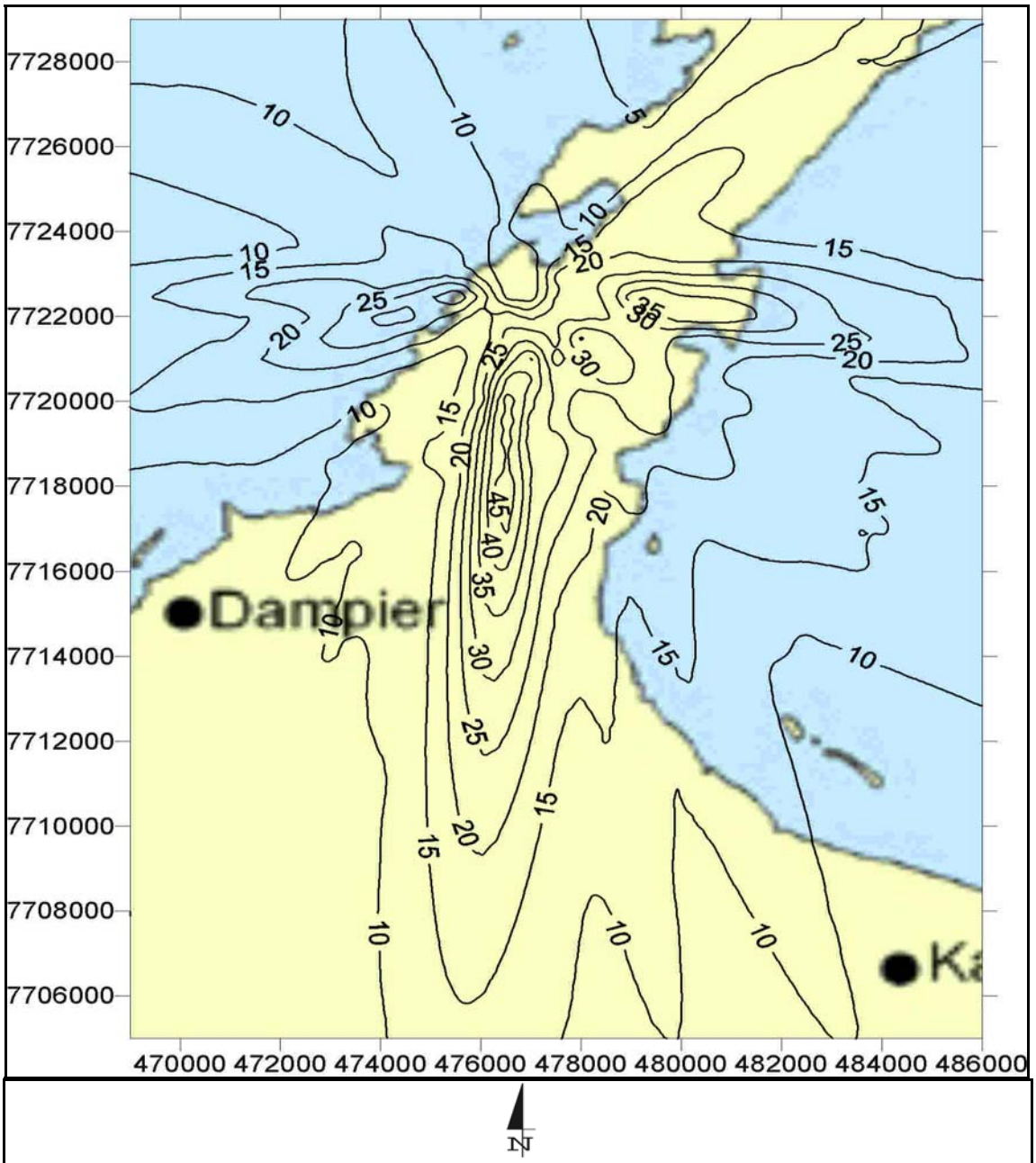
(not to scale)
Supplied by Dr Peter Hurley of CSIRO Atmospheric Research.

Figure 3: TAPM Maximum 24 hour-averaged NO_X (ppb) on the 0.25-km spaced pollution grid for Scenario 4 (existing plus assessed industrial projects).



(not to scale)
Reproduced from "Cumulative Oxides of Nitrogen Emissions on the Burrup" by SKM.

Figure 4: ***AUSPLUME Maximum 24-hour averaged NO_X (ppb) (existing plus assessed industrial projects)***



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Reproduced from "Cumulative Oxides of Nitrogen Emissions on the Burrup" by SKM.

Figure 5: DISPMOD Maximum 24-hour averaged NO_X (ppb) (existing plus assessed industrial projects)

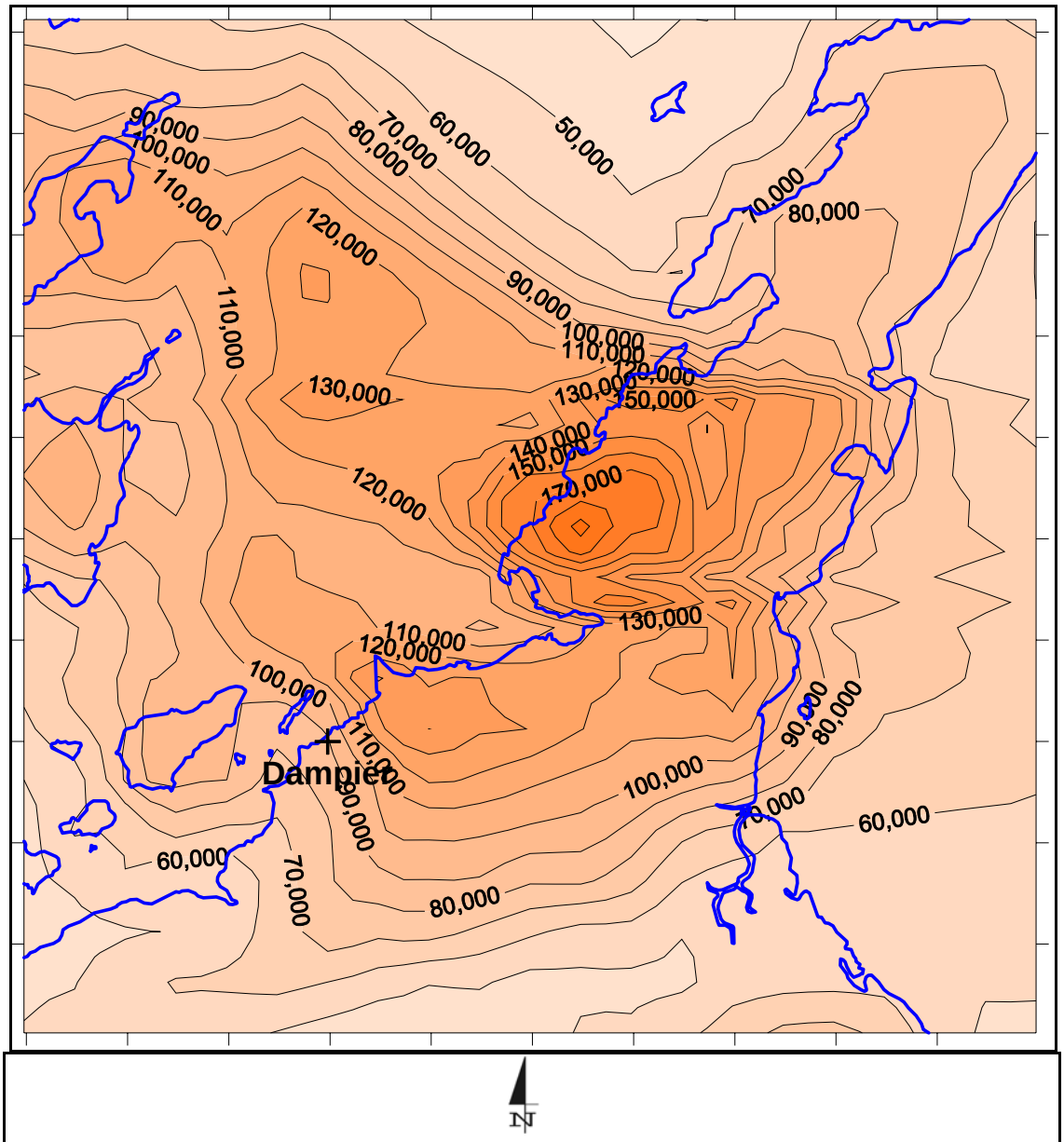
b) Deposition of Acid Gases

NO_x (as NO_2) and SO_2 are classed as acid gases as they combine with water to form acid solutions. This can occur in the atmosphere to form acid rain or acidic gases. Gases and particulates can also be deposited or absorbed on surfaces as dry deposition. These gases and particulates can then react with moisture to produce acids. A very significant feature of the climate of the Burrup is persistent ambient, maritime moisture as dew, which attenuates the arid environment. It is a key point of difference with the hinterland, which otherwise shares the same likelihood of cyclonic rain. Dew is a key phenomenon and this combined with condensation surfaces provided by the major rock outcrops is likely to be the key to the survival of biota on the peninsula (N Casson, *pers comm*). This humidity and condensation will also act to dissolve NO_x and SO_x, causing acid precipitation that may impact vegetation and surface water. Terrestrial aqueous systems and fauna on the Burrup could be at risk due to acidification of run-off and rockpools. Concern has also been expressed for molluscs such as snails, which may be vulnerable to acid attack. Acidification of soil is also possible in the long term. The erosion of rock surfaces by acid is also possible resulting in damage to the ancient rock art found on the Burrup.

European studies (Ashenden, 2002) have shown that some plant species show visible injury when exposed to wet acid precipitation below pH 3.4. Acid precipitation may either depress growth because of the toxic effects of acidity or stimulate growth due to fertilisation. Studies indicate that some species of crop may be affected by pH in the range of 3.5-4.5. Exposure to acid precipitation may also alter root:shoot ratios. Effects on plant reproduction may be found in the pH range of 2.5 – 5.6. There is some evidence that sulphuric acid has more impact on vegetation than nitric acid. Changes in algal communities have been noted in acidified lakes with pH of less than 5 (Harriman R, et al, 2002). In general the effects of acid on vegetation is very species dependent and results from other species cannot be extrapolated to vegetation on the Burrup.

The CSIRO modelling has estimated the dry deposition of NO_x and SO_2 in the region and over the Burrup land area from existing and proposed industries (Figures 6 & 7). Cumulatively the modelling predicts a maximum deposition of 1.94 kilogram per hectare per annum (kg/ha/a) of NO_2 (or 0.59 kg/ha/a of nitrogen) over land and approximately 1.0kg/ha/a of SO_2 over land. However the report notes deposition values have a large uncertainty as surface resistances used in deposition formulations for most species in air pollution models have a large uncertainty. The study also does not take into account wet deposition or deposition in dew formation.

SKM in its TAPM modelling also modelled deposition of NO_2 and SO_2 from cumulative emissions of existing and proposed industries, including hypothetical industries. Deposition of NO_2 was predicted to be up to 2.1kg/ha/a and SO_2 up to 2.6kg/ha/a over land. The report found that the highest depositions of NO_2 occurred near the Woodside plant in a general westward and eastward direction. For SO_2 the highest depositions occurred over water near the Port.

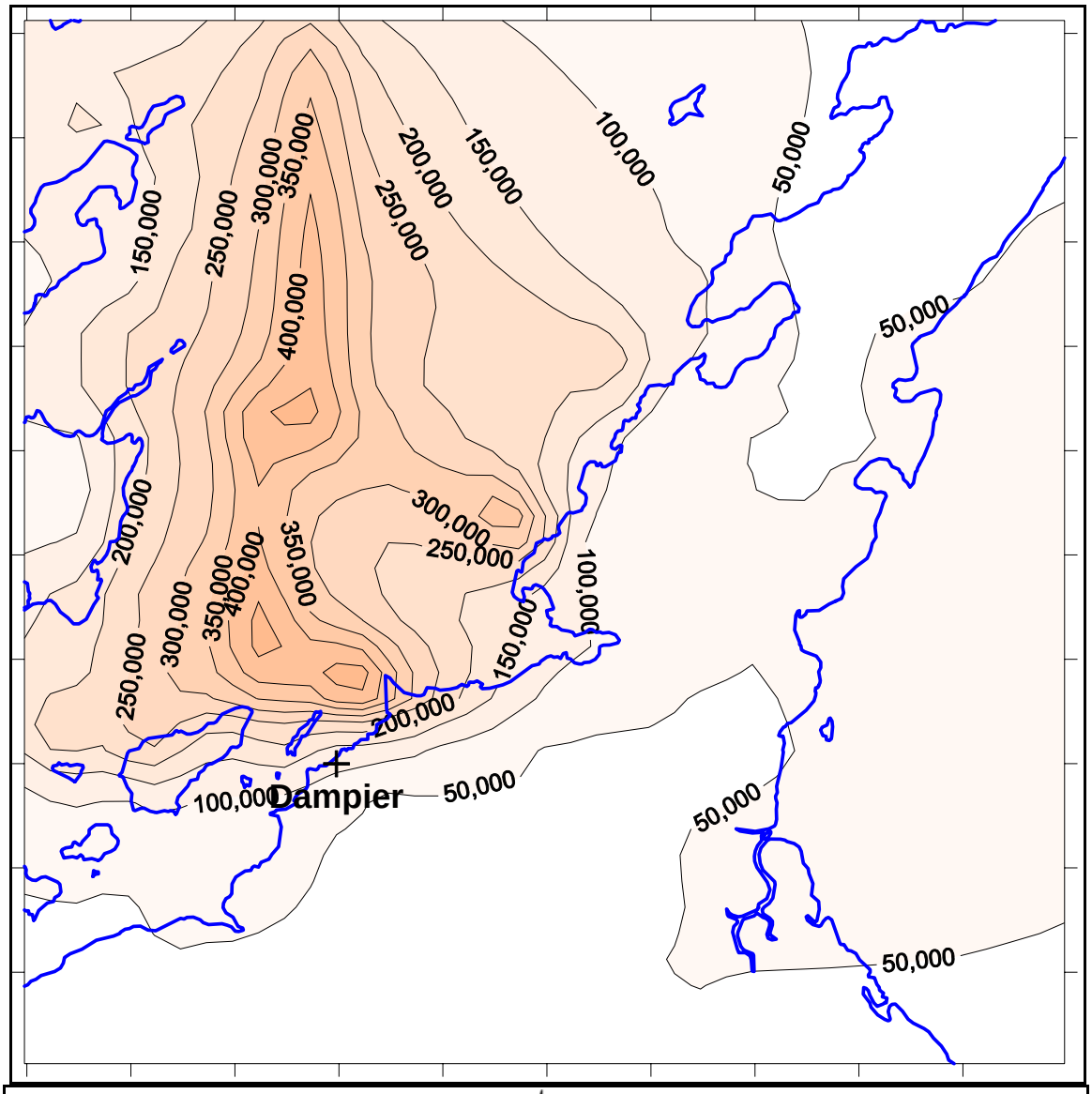


(not to scale)

*** 100 000 µg m^{-2} = 1 kg/ha**

Reproduced from "Woodside LNG Expansion Project – Modelling Existing and Proposed Emissions on the Burrup Peninsula using TAPM." P J Hurley, W L Physick, M E Cope & M S Borgas, CSIRO October 2003.

Figure 6: TAPM Annual dry deposition (µg m^{-2})* of NO_X on the 0.5-km spaced pollution grid for Scenario 4 (existing plus assessed industrial projects).



(not to scale)

*** 100 000 µg m^{-2} = 1 kg/ha**

Reproduced from "Woodside LNG Expansion Project – Modelling Existing and Proposed Emissions on the Burrup Peninsula using TAPM." P J Hurley, W L Physick, M E Cope & M S Borgas, CSIRO October 2003.

Figure 7: TAPM Annual dry deposition (µg m^{-2})* of SO_2 on the 0.5-km spaced pollution grid for Scenario 4 (existing plus assessed industrial projects).

The modelling indicates that there will be deposition of acid gases as a result of industrial activities. Whether the deposition will be sufficient to affect vegetation or fauna on the Burrup is not known. Monitoring of the pH of wet deposition, i.e. dew and rainfall, may provide some data to predict whether impacts are likely or not. The Burrup Rock Art committee is undertaking a study to examine the effects of air pollutants on rock art. It is suggested that this study is extended to consider the effects of pollutants on vegetation.

The potential impact of acid deposition is difficult to predict as:

i) most of the research that has been done in this area has been carried out in Europe and there is little information relating to the arid type climate and vegetation and fauna found on the Burrup;
ii) the synergistic action of NO_x and SO_2 is difficult to estimate;
iii) the likelihood of soil acidification depends on the acid buffering capacity of the soil which has not been investigated on the Burrup. European standards for impacts to vegetation from soil acidification are based on the ratio of base cations to aluminium in the soil which has not been examined on the Burrup;
iv) there is as yet little knowledge of the impact of acid deposition on rock art under the climatic conditions of the Burrup.

c) Nutrient enrichment due to Oxides of Nitrogen (NO and NO_2) in combination with Ammonia (NH_3) and Urea

i) Terrestrial environment

The higher estimate of NO_x emissions from the Woodside plant will increase the amount of nitrogen expected to be available in the environment from the existing and proposed industrial developments.

Much of the Australian flora has adapted to low levels of nitrogen, phosphorus and other nutrients and therefore may be vulnerable to nutrient enrichment. Nutrient enrichment of the soil and change in plant species distribution, abundance and diversity are the most likely outcomes of the addition of surplus nitrogen to the environment. Excess nutrients may favour the growth of weeds and introduced species. Another important impact may be on mycorrhizal associations i.e. symbiotic associations between plant roots and fungi. Little research has been carried out in Australia specifically on atmospheric deposition of nitrogen. Fertiliser trials in Australia (reported in Campbell, 2002) found changes in species composition, but relate to applications of fertiliser which contains other elements besides nitrogen, such as phosphorus and potassium. Rockpools may also be affected disproportionately by nutrient deposition (Campbell 2002).

European studies suggest a critical load of 5-10 kg nitrogen/ha/a for shallow soft-water lakes (Cunha, et al, 2002). In Europe, increased deposition of reactive nitrogen has been linked with changes in a wide range of natural and semi-natural ecosystems, most notably the conversion of heathland to acid grassland, shifts in community composition in calcareous grasslands and changes in the nutrient dynamics of forest systems (Cunha, et al, 2002). Recommended deposition guidelines for vulnerable ecosystems are 5-10kg/ha/a (heath, bogs and cryptogams) and 10-20kg/ha/a for

forests in European and North American publications (WHO 2000), but these guidelines may not be appropriate for Burrup vegetation.

Nitrogen deposition occurs naturally due to nitrogen emissions from vegetation. The CSIRO has measured total nitrogen deposition rates in a clean environment near Darwin of approximately 1.4 kg nitrogen/ha/a, with a 30% fluctuation range (Gillett, *pers comm*.). Loss of nitrogen from terrestrial systems also occurs through denitrification in soil.

Various modelling reports have provided estimated figures for the terrestrial deposition of nitrogen from different sources:

i) from the dry deposition of NO_x of 0.59kg nitrogen/ha/a (CSIRO 2003);
ii) from urea deposition of approximately 1kg nitrogen/ha/a (URS 2002);
iii) from ammonia of 3.3kg nitrogen/ha/a (based on the SKM 2003a report which includes a second source of ammonia from a theoretical project which has not been proposed yet).

The concentrations of nitrogen from the different pollutants will peak in different areas depending on the source and no cumulative estimate is available. From the above results, it appears that industrial sources will not add more than 5kg/ha/a to nitrogen deposition on the Burrup, but the accuracy of the predictions is uncertain and deposition in dew has not been estimated. In comparison, total wet and dry deposition of nitrogen in Europe mostly from NO_x and ammonia emissions, ranges from 7-80 kg nitrogen/ha/a (Green, et al, 1998) and in the UK averages 17 kg nitrogen/ha/a. (Cunha, et al, 2002). The expected deposition is therefore low in comparison to European levels but above the natural fluctuation levels of background deposition.

Prediction of the impact of nutrient enrichment on Burrup terrestrial systems is difficult as:

i) no combined estimates of all nitrogen deposition for the Burrup have been modelled;
ii) the effect of wet deposition in dew has not been investigated;
iii) European standards may not be applicable for the protection of Burrup species; and
iv) the accuracy of modelled deposition rates is uncertain.

ii) Marine environment

The revised estimate of Woodside's NO_x emissions will also increase the deposition of nutrients to the marine environment and mangrove communities. Nutrient enrichment in the marine environment can cause stimulation of phytoplankton and epiphyte growth, change in species composition and increases in macroalgae. Besides deposition, there will also be direct discharge of nutrients through the Water Corporation's brine discharge pipeline and from sewage treatment at the Woodside plant. The Water Corporation will monitor for potential nutrient enrichment around their outfall.

d) Addressing potential environmental impacts

In recent assessments the EPA has recognised that emissions from industries on the Burrup have the potential to cause environmental degradation. The EPA has therefore

recommended rigorous conditions be imposed or sought commitments designed to reduce the potential for environmental impacts and to detect and address any impact that may occur.

These precautions include:

i) emphasising the necessity to keep emissions as low as practicable on the Burrup;
ii) recommendation for the review of stack positions and parameters to reduce local impacts of air emissions (EPA 2002a);
iii) the monitoring of vegetation and rock pools, which may be the most environmentally sensitive systems, and the development of contingency plans, should adverse impacts be detected (EPA 2002b,c);
iv) proponent commitments to weed management plans to minimise the spread of introduced species on the Burrup that may benefit from higher nutrient levels (EPA 2001. EPA 2002 a,b,c);
v) the formation of a local Industries Council to undertake joint investigation and ongoing management of the cumulative impacts of gaseous emissions (EPA 2001, EPA 2002 a,b,c); and
vi) the investigation of the impacts of industrial emissions on the rock art of the Burrup. This is currently being addressed by the Office of Major Projects on behalf of the WA Government which has commenced a four year study to establish a baseline for petroglyph condition and investigate potential threats to them from air emissions on the Burrup.

The EPA considers that these measures are appropriate to protect the environmental values of the Burrup and does not believe that environmental conditions need to be changed for any of the assessed proposals due to the correction of Woodside's NO_x emissions figure. The EPA notes that the proposals assessed recently are relatively small contributors to the total NO_x emissions on the Burrup.

For future proposals, the EPA believes similar conditions and commitments should apply and further recommends:

i) research should be carried out to investigate the potential effect of air pollutants and nutrients on Burrup vegetation and consideration should be given to extending the Burrup Rock Art Study to include this;
ii) research should be undertaken into identifying sensitive organisms or fundamental parameters that may serve as early warning indicators of impending loss of biological diversity on the Burrup and establishing trigger levels for management action;
iii) industries operating on the Burrup carry out monitoring for early warning signs of impacts that can be attributed to their particular activities where these can be identified and prepare contingency plans relevant to their operations; and
iv) a Burrup Industrial Council, as previously mooted in recent assessments of proposals on the Burrup, be set up to carry out monitoring for air quality and cumulative impacts from the operations of all industries (where impacts due to individual industries cannot be identified), funded by those industries operating in the air shed.

5. Conclusions

Three modelling studies have been considered in this report. The three studies provide predictions of regional and local air quality for existing and proposed industries on the Burrup. The modelling studies are not directly comparable but account for different physical processes influencing emissions and provide a range of results within which it is expected that the actual ground level concentrations will fall. All models predict that National Environment Protection Measure (NEPM) health-based standards will be met at population centres. However in order to confirm the modelled predictions, the EPA recommends that air quality monitoring be undertaken co-operatively by those industries operating on the Burrup. Monitoring should be carried out in consultation and agreement with the Department of the Environment.

Previous monitoring of air quality in 1999 showed no exceedences of NEPM standards for NO_2, O_3, and SO_2 at any of the monitoring sites at Dampier, Karratha, or King Bay (EPA 2002d). Therefore there is no health concern relating to the current levels of these pollutants.

There is limited information on the effects of air pollutants on the vegetation, soils, rockpools and rock art of the Burrup. The increased estimate of NO_x emissions from the Woodside plant results in an increased level of risk that parts of the Burrup may suffer adverse environmental impact. In order to obtain more information on the potential impact of NO_x on vegetation it is suggested that the monitoring work being carried out as part of the Burrup Rock Art Study, could be extended to address environmental changes that could impact on vegetation. Although there will be deposition of atmospheric NO_x into the marine environment, the potential impacts of this deposition have not been considered in detail in this report. The effects of emissions on rock art are being investigated by the Burrup Rock Art Monitoring Management Committee and therefore are not considered in this report.

It is important for proponents to monitor for early warning signs of impacts from emissions and have contingency plans for corrective action relevant to their operations. The EPA also encourages the formation of a Burrup Industrial Council, as previously mooted in the assessments carried out for the Burrup Fertilisers Ammonia Plant, the Methanex Methanol complex, Liquigaz Methanol Plant and the Dampier Nitrogen Ammonia-Urea plant, for the overall management of environmental impacts on the Burrup. It is also important to employ best practicable measures as defined in EPA Guidance Statement No 55 (EPA 2003) to minimise emissions and environmental impacts as a precautionary measure against environmental damage and to allow space in the airshed if other industries seek to establish in the same area. It is possible that future air emissions from the proposed Maitland Estate may also contribute pollutants to the airshed on the Burrup.

The EPA considers that based on the air modelling studies, it is not necessary to alter any conditions pertaining to EPA assessments already carried out on proposed industry on the Burrup because all completed assessments already contain sufficiently stringent conditions to manage air quality issues.

Additional studies on the impacts of air emissions on bio-physical receptors on the Burrup are, however, recommended.

6. Other Advice

It is apparent that the major industrial sources of NO_X emissions on the Burrup Peninsula are Woodside's gas turbines in Trains 1, 2 and 3. These were assessed by the EPA prior to the *Environmental Protection Act 1986*. Therefore there are no Ministerial conditions relating to the original gas processing plant. However these trains are licensed under Part V of the *Environmental Protection Act 1986*.

The older turbines in use at the Woodside site have poorer thermal efficiency (21%) and produce more NO_x than modern turbines. These older turbines do not have low NO_x burners or any NO_x reduction control currently. The new turbines to be installed on Trains 4 and 5 have increased efficiency and low NO_x burners**.** Consequently NO_x emissions by comparison are far lower. Emissions could be reduced further by using combined cycle turbines for base load power generation thereby improving efficiency and reducing the amount of gas burnt.

Should there be the necessity to reduce NO_x emissions due to unacceptable environmental impacts occurring in the future or to create space in the airshed, reduced emissions limits could be placed on Woodside through the Part V licensing process. Progressive upgrading by Woodside of old equipment should also be encouraged. It is recommended that ongoing monitoring of air quality and environmental impacts should also be required as part of Woodside's operations.

The EPA has been advised that Woodside is intending to reduce NO_x emissions from Train 1, 2 and 3 turbines through the installation of low NO_x liners. This programme will commence in 2004 and be completed by 2008. It is anticipated that a minimum reduction in NO_x emissions of 25% can be achieved when the programme is fully implemented. This will need to be confirmed through monitoring of emissions. This will assist in lowering the risk to the terrestrial environment from NO_x emissions. However, as the level at which NO_x will impact on the terrestrial environment is not known, it cannot be concluded that the reduction will be sufficient to ensure that there is no impact on the terrestrial environment.

7. Recommendations

It is recommended:

1. All existing and future proponents be required to employ best practicable measures to reduce their air emissions and to minimise the risk of environmental impact;
2. Future emission stacks be sited and designed to reduce impacts on nearby terrain;
3. Industries operating on the Burrup carry out monitoring for early warning signs of impacts that can be attributed to their particular activities where these can be identified and prepare contingency plans relevant to their operations;
5. A Burrup Industrial Council, as previously mooted in recent assessments of proposals on the Burrup, be set up to carry out monitoring for air quality and cumulative impacts from the operations of all industries (where impacts due to individual industries cannot be identified) funded by those industries operating in the air shed;

5. Research should be carried out to investigate the potential effect of air pollutants and nutrients on Burrup vegetation and consideration should be given to extending the Burrup Rock Art Study to include this; and
6. Research should be undertaken into identifying sensitive organisms or fundamental parameters that may serve as early warning indicators of impending loss of biological diversity on the Burrup and establishing trigger levels for management action.

Appendix 1

References

Ashenden T W 2002 *Effects of wet deposited acidity*, published in *Air Pollution and Plant Life*, second edition, edited by J N B Bell and M Treshow, 2002, John Wiley & Sons, Ltd

Ashmore M R 2002 *Effects of oxidants at the whole plant and community level*, published in *Air Pollution and Plant Life*, second edition, edited by J N B Bell and M Treshow, 2002, John Wiley & Sons, Ltd

Campbell 2002 *Proposed Urea Plant on the Burrup Peninsula, Effects on Vegetation of Predicted Urea Deposition Rates*, R Campbell, URS Supplement to 1998 CER, Technical Appendices, May 2002

CSIRO, DEP 2001 *An Evaluation of Air Quality Models for the Pilbara Region*, William Physick and Adrian Blockley, CSIRO Atmospheric Research and Department of Environmental Protection, June 2001

CSIRO 2003 *Woodside LNG Expansion Project – Modelling Existing and Proposed Emissions on the Burrup Peninsula using TAPM*, P J Hurley, W L Physick, M E Cope & M S Borgas, CSIRO October 2003

Cunha A, Power S A, Ashmore M R, Green P R S, Haworth B J and Bobbink R *Whole Ecosystem Nitrogen Manipulation: An Updated Review*, JNCC Report No 331, December 2002

Driscoll C, Whitall D, Aber J, Boyer E, Castro M, Cronan C, Goodale C, Groffman P, Hopkinson C, Lambert K, Lawrence G and Olinger S *Nitrogen Pollution*, Environment Vol 45 No 7, September 2003, Heldref Publications

EPA 2001 *Ammonia Plant, Burrup Peninsula*, Environmental Protection Authority Bulletin 1036, December 2001

EPA 2002a *Methanex Complex, Burrup Peninsula*, Environmental Protection Authority Bulletin 1077, November 2002

EPA 2002b *Methanol Plant and Product Export, Burrup Peninsula*, Environmental Protection Authority Bulletin 1075, November 2002

EPA 2002c *Ammonia-Urea Plant, Burrup Peninsula*, Environmental Protection Authority Bulletin 1065, September 2002

EPA 2002d *Monitoring of Ambient Air Quality and Meteorology during the Pilbara Air Quality Study*, Environmental Protection Authority Technical Series 113, September 2002

EPA 2003 Guidance for the Assessment of Environmental Factors, Environmental Protection Authority Draft Guidance Statement No 55, March 2003

Green P R S, Ashmore M R, Power S A and Bobbink R *Whole ecosystem nitrogen manipulation: review study*, English Nature Science Series, English Nature, Peterborough, 1998

Harriman R, Battarbee R W and Monteith D T *Effects of acidic deposition on aquatic ecosystems,* published in *Air Pollution and Plant Life*, second edition, edited by J N B Bell and M Treshow, 2002, John Wiley & Sons, Ltd

Krupa S V *Effects of atmospheric ammonia (NH_4) on terrestrial vegetation: a review*, Environmental Pollution 124, 2003, Elsevier Science Ltd

Murray F, Clarke K, Wilson S, Monk R *Development of Secondary Ambient Air Quality Criteria for SO_2 and NO_x, School of Biological and Environmental Sciences*, Murdoch University, February 1991

SKM 2003a *Cumulative Oxides of Nitrogen Emissions on the Burrup*, Sinclair Knight Mertz, October 2003

SKM 2003b *Burrup Rock Art, Atmospheric Modelling – Concentrations and Depositions*, prepared for Department of Industry and Resources by Sinclair Knight Mertz, June 2003

URS 2002a *Supplement to 1998 Consultative Environmental Review*, Prepared for Plenty River Corporation Limited, URS May 2002

URS 2002b *Supplement to 1998 Consultative Environmental Review, Technical Appendices,* Prepared for Plenty River Corporation Limited, URS May 2002

World Health Organisation (2000) *Air quality guidelines for Europe* Second Edition, World Health Organisation regional publications, European Series, Number 91

Appendix 2

Summary of the air quality outcomes for Dampier and Karratha townships and maxima anywhere on the grid, based on the emission scenario existing + all proposed industries (Methanex, Burrup Fertilisers, Dampier Nitrogen and GTL Liquigaz).

Dampier	**NO_2 (ppb)**	**SO_2 (ppb)**	**O_3 (ppb)**	**PM_{10} ($\mu g\ m^{-3}$)**	**Benzene ($\mu g\ m^{-3}$)**	**Toluene ($\mu g\ m^{-3}$)**	**Xylene ($\mu g\ m^{-3}$)**
1-hour (max)	34 (**120**)	7 (**200**)	45 (**100**)	-	-	-	-
4-hour (max)	-	-	43 (**80**)	-	-	-	-
1-day (max)	-	2 (**80**)	-	13 (**50**)	-	4 (**7540**)	2 (**868**)
Annual (avg)	2.2 (**30**)	0.5 (**20**)	-	-	0.2 (**9.6**)	-	-

Karratha	**NO_2 (ppb)**	**SO_2 (ppb)**	**O_3 (ppb)**	**PM_{10} ($\mu g\ m^{-3}$)**	**Benzene ($\mu g\ m^{-3}$)**	**Toluene ($\mu g\ m^{-3}$)**	**Xylene ($\mu g\ m^{-3}$)**
1-hour (max)	50 (**120**)	3 (**200**)	51 (**100**)	-	-	-	-
4-hour (max)	-	-	45 (**80**)	-	-	-	-
1-day (max)	-	1 (**80**)	-	7 (**50**)	-	5 (**7540**)	3 (**868**)
Annual (avg)	1.3 (**30**)	0.1 (**20**)	-	-	0.3 (**9.6**)	-	-

Reproduced from CSIRO 2003

Anywhere on grid	**NO_2 (ppb)**	**SO_2 (ppb)**	**O_3 (ppb)**	**PM_{10} ($\mu g\ m^{-3}$)**	**Benzene ($\mu g\ m^{-3}$)**	**Toluene ($\mu g\ m^{-3}$)**	**Xylene ($\mu g\ m^{-3}$)**
1-hour (max)	138 (**120**)	20 (**200**)	80 (**100**)	-	131	235	133
4-hour (max)	-	-	58 (**80**)	-	-	-	-
1-day (max)	-	5 (**80**)	-	40 (**50**)	10	19 (**7540**)	10 (**868**)
Annual (avg)	3.9 (**30**)	1.4 (**20**)	-	-	0.8 (**9.6**)	1.4	0.8

Figures from CSIRO 2003
(**NEPM levels shown in brackets**).