

AIR QUALITY AND ODOUR IMPACT ASSESSMENT OF AN ESTATE CONTAINING NOXIOUS AND OFFENSIVE INDUSTRY

Andrew Balch, Andrew Wiebe, Alex Schloss, Andrew Vernon, Christine Killip and Simon Welchman
Katestone 5/259 Coronation Drive, Milton QLD, 4064, Australia

Abstract

The Narangba Industrial Estate, located approximately 35 km north of Brisbane, is a designated hazardous and noxious industry site with greater than 70 individual enterprises ranging from leather tanning, hot dip galvanising, liquid and solid waste treatment, swimming pool, inorganic chemical, organic/inorganic fertiliser and aquaculture feed production. In 2005, a fire at a chemical manufacturing facility in the estate prompted the Queensland Government to commission an investigation into the risk to public health associated with air contaminants emitted by industrial activities operating in the NIE. People in the surrounding communities have complained to regulatory authorities about odour and health concerns that they associated with activities within the estate. This paper discusses the objectives, methods and findings of the air quality and odour impact assessments of 11 businesses in the NIE, including the assessment of 153 individual hazardous air pollutants and odours from 25 individual sources. Key air pollutants were identified using a hazard index approach and assessed for the cumulative impact of all sources monitored in the estate. The assessment found that the air quality criteria for all air pollutants were met at all sensitive places beyond the NIE boundary with the exception of three substances emitted by three individual businesses. The predicted ground-level concentrations of these three substances were highly sensitive to assumptions made in the calculation of the emission rates, and the impact was likely to be over-estimated. While standard methods were employed for the study, several issues were identified including the assessment of pollutants with an emission rate based on a concentration at the test method limit of detection, identification and monitoring of sources during routine operations, emission variability during routine operations and emission variability due to non-continuous, batch or cyclical production processes.

Keywords: Health, nuisance, air quality, air toxics, odour, dispersion modelling, impact assessment.

1. Introduction

The Narangba Industrial Estate (NIE) is situated 35 kilometres north of Brisbane and was established in the late 1960s as a suitable location for the operation of hazardous, noxious and offensive industrial activities. The NIE comprises in excess of 70 businesses.

Businesses perform a wide variety of industrial activities including:

- Chemical manufacturing such as pesticides, herbicides and oil blending for engine products
- Tanning including sheepskin, kangaroo and cow hide
- Solid, liquid and regulated waste treatment and disposal
- Aquaculture feed manufacturing
- Organic/inorganic fertilizer manufacturing
- Green waste composting
- Hot dip galvanizing
- Hot mix asphalt production
- Concrete batching
- Swimming pool and other fibreglass product manufacturing
- Chemical timber treatment
- Treatment of quarantined imported products by irradiation
- Distribution warehousing

Moreton Bay Regional Council (MBRC) and the Department of Environment and Resource Management (DERM) license industry at the NIE.

2. Background

The NIE is situated on both sides of the Bruce Highway north of Brisbane and close to rail infrastructure (see Figure 1). At its inception in the 1960s the location of the estate provided an appropriate separation distance to the local community that comprised mainly of semi-rural acreage landholdings. In 2011, the NIE finds itself in one of southeast Queensland's key growth corridors, with the density of dwellings in the area increasing significantly and residential subdivisions dispersed between the rural lots around the edge of the NIE boundary. The separation distance between the NIE and community is now as little as about 100 m at the northeast and western boundaries. One of the largest community developments in the region is the North Lakes Estate, which is approximately 800 m from the estate's southern boundary.

In recent years, the local community has raised concerns about the potential impact of emissions from NIE industries on the health of residents. The primary focus of community concerns has been regarding emissions of air toxics and odours, with the MBRC and DERM receiving complaints from the community about odours associated with several activities.

In August 2005, a fire in a chemical manufacturing facility at the NIE prompted the Queensland Government to commission a Health Impact Assessment (HIA) to investigate the potential risk to public health associated with air contaminants emitted by industrial activities at the NIE. The authors were part of a specialist air quality assessment team led by Queensland Health (QLD Health) that was commissioned to investigate the source of emissions to air associated with activities at the NIE and to assess their impacts to air quality in terms of human health. The air quality impact assessment was a key component in the issue identification process for the Health Risk Assessment (HRA).

A Community Reference Group (CRG) was formed by the Queensland Government to oversee the development of the HIA and to make recommendations in response to its findings. The CRG comprised 17 representatives from local business, industry, local and state governments and the community. The CRG also recommended that an odour impact assessment be carried out in concert with the air quality impact assessment.

3. Impact Assessment Methodology

3.1. Assessment approach

The impact assessment approach included various field and desktop studies to identify air emissions associated with NIE industries and assess their impact on the surrounding environment. Studies included:

- Ambient air quality monitoring program
- Field ambient odour assessment
- Identification of NIE activities likely to generate air emissions
- Consultation with key selected NIE businesses including site investigations and engagement of management to provide information on industrial process, emission sources and air pollutant mix
- Identification and characterisation of air emission sources and potential air pollutant mix
- Selection of sources of air toxics and odour for inclusion in the air sampling program
- Identification of process variability and normal operations
- Sampling and testing of air toxics and odour from sources at the NIE
- Emission calculation
- Meteorological and air dispersion modelling
- Selection of air quality assessment criteria
- Air quality and odour impact assessment

The field odour assessment study, ambient air quality monitoring and source emissions sampling and testing programs for air toxics and odour were carried out by other independent consultants in the air quality assessment team and consequently, their methods and findings are not presented in this paper. The source emission test results were used as input into the dispersion modelling study.

3.2. Identification of emission sources and air pollutants for impact assessment

A detailed process was undertaken to identify the key industrial activities to include in the emissions monitoring program and impact assessment. A qualitative review of each industrial activity at the NIE was carried out by the air quality assessment team and potential air emission sources identified. The review comprised site inspections, consultation with company management, environmental protection licence conditions and identification of emission sources and air pollutants using resources such as the National Pollutant Industry Emission Estimation Technique Handbooks and the United States Environmental Protection Agency's AP-42.

This process resulted in 11 businesses and 25 emission sources being identified for the emissions

monitoring program and the air quality and odour impact assessments. Sources included short wake-affected vertical stacks and roof vents, horizontal building wall vents and ducts, solid stockpiles, ponds and open tanks, fugitive emissions from open buildings and biofilters. The review of potential air pollutants that could be released from each of the sources identified 153 individual air toxics for inclusion in the air quality assessment. The industrial activities and air pollutant groups assessed are summarised in Table 1.

Table 1: Industrial activities and air pollutants assessed

Activity	Air pollutants
Manufacture of pesticides and herbicides	Metals, metalloids, reduced sulfur compounds, volatile organic compounds, pesticides and poly-chlorinated biphenyls
Hazardous waste treatment and management	Poly-chlorinated biphenyls, organochlorine pesticides, dioxins and furans and volatile organic compounds
Solid waste handling and green waste composting, storage and distribution	Odour
Wastewater and oily water recycling	Odour
Treatment, recycling and management of waste oil and other chemicals in liquid and solid form	Oxides of nitrogen, carbon monoxide, polycyclic aromatic hydrocarbons, metals and metalloids, volatile organic compounds and odour
Hot dip galvanising of steel fabrications	PM ₁₀ , total suspended particulates, metals and metalloids, ammonia, hydrogen chloride, ammonium chloride and odour
Kangaroo and cow hide tanning for leather production	Volatile organic compounds and odour
Fertilizer manufacturing and handling using organic and inorganic raw materials	Odour
Manufacturing of aqua culture feed and pet food	PM ₁₀ , odour
Swimming pool manufacturing	Styrene and odour
Sheepskin tanning for manufacture of sheepskin products	Odour

3.3. Dispersion modelling

3.3.1. Modelling methodology

The following approach was adopted for the dispersion modelling:

- Analysis of the regional meteorology based on observations from the Bureau of Meteorology (BoM) monitoring stations at Brisbane Airport

and Redcliffe, the DERM monitoring station at Deception Bay and the DERM automatic weather station (AWS) set up at the NIE during the chemical fire site remediation works between October 2006 – September 2007.

- Analysis of the inter-annual variability of regional wind direction, wind speed and temperature.
- Selection of a representative year for the meteorological simulation - 2008.
- Modelling of the regional meteorology using TAPMv4. TAPM land use and coastline data was refined using aerial images and vegetation maps obtained from the DERM.
- Wind fields for the BoM monitoring station at Brisbane Airport assimilated into the model.
- Further refinement of the meteorology in the Narangba, Deception Bay, Dakabin, Burpengary and North Lakes areas using CALMET. This included the input of local terrain (sourced from MBRC) and land use information into the model at a grid resolution of 50 metres.
- Modelling of plume dispersion associated with emissions using the CALPUFF air dispersion model.
- Prediction of ground-level concentrations of air pollutants and odour in the local area at a resolution of 50 metres. Predictions were also made at 16 sensitive receptor locations, identified by Queensland Health.

3.3.2. Model evaluation

Meteorological and air quality monitoring is not carried out within the extent of the modelling domain. The nearest DERM meteorological and air quality monitoring station is situated at Deception Bay with winds strongly influenced by its coastal position in a similar way to the BoM monitoring station at Redcliffe. During the remediation of the NIE site affected by the chemical plant fire, between October 2007 and September 2007, DERM operated an AWS. The monitor was situated adjacent to the remediation site and, due to local terrain and land use, was found to be representative of the local area within the centre of the NIE rather than the regional wind fields across the entire NIE and the broader community. Consequently, the data was not found to be suitable for assimilation into the meteorological model but more suited to an evaluation of the model's performance.

The performance of the modelling system was evaluated in two ways. The first step was an evaluation of TAPM's performance in simulating regional meteorology. TAPM was run with and without the assimilation of Brisbane Airport observations and the correlations between the predicted and observed distributions of wind speed

and direction (including U and V vector components) and temperature were analysed. The analysis indicated that TAPM performed reasonably well, and while improved by the data assimilation, the model tended to over-predict the frequency of winds less than 4 m/s and under-predict winds greater than 4 m/s.

For air quality impact assessment, the maximum or ninth highest (100th or 99.9th percentile) predicted 1-hour average concentration is assessed against the air quality objective. For odour assessment (Queensland odour guideline), the 44th highest concentration (99.5th percentile) is compared to the guideline. It was important for the model to be able to predict the type of conditions that are conducive to causing impacts and the frequency of the conditions for more than just the highest 1-hour average. Consequently, the second evaluation step was to compare the frequency of occurrence of the conducive meteorological conditions with the frequency of those conditions occurring at the DERM AWS situated near the centre of the NIE. While the modelling was not conducted for the same period as the AWS was operating, the analysis of the winds in the region indicated that there was little inter-annual variability for the period.

For this evaluation, meteorological conditions during hours when the 1-hour average ground-level odour concentrations were predicted to be greater than 1 ou at sensitive places were analysed. The time of day, wind speed and wind direction were then used as filters and the frequency of the meteorological conditions were correlated with the AWS data. The analysis found that, on average, the model tended to slightly over-predict the frequency of meteorological conditions likely to generate a ground-level odour concentration greater than one odour unit at sensitive places.

3.4. Impact assessment

The following approach was adopted for the impact assessment:

- Where more than one emission test was conducted, the highest emission rate was used in the impact assessment.
- The emission monitoring reports were used to calculate air pollutant emission rates based on the following:
 - i. The measured concentration that is greater than the test Method Limit of Detection (MLOD).
 - ii. The concentration that is equal to the test MLOD. Where the source concentration of an air pollutant was not monitored at a concentration greater than the MLOD, the value of the MLOD has been used to calculate the emission rate. This provides for a conservative worst case approach as the

concentration will be between zero and the MLOD.

- iii. The volume flow that is based on a continuous and consistent air velocity from the source that is greater than the limit of detection of the measurement instrument.
 - iv. The volume flow that is based on an intermittent and variable air velocity from the source such as fugitive emissions from a building where the velocity through openings is below the limit of detection (LOD) of the measurement instrument. In the case of a velocity monitored below the instrument LOD, the use of the LOD value in the emission rate calculations will provide for a conservative worst case assessment.
- Due to the large number of sources and air pollutants monitored in the study and the large number of pollutants monitored below the MLOD, an air pollutant importance hierarchy was developed. The hierarchy was based on ranking the air pollutants by the ratio of the emission rate to air quality standard for each source. Notwithstanding the hierarchy, the independent health risk assessor and CRG requested that all air pollutants be modelled including substances that were not measured above the MLOD.
 - The model was run to predict ground-level concentrations of odour and all air pollutants monitored across the modelling grid and at sensitive receptor locations for every hour of the year.
 - The study focussed on potential incremental impacts of NIE emissions on local air quality and therefore background levels were not assessed.
 - The assessment of odour impacts has been made on an individual facility basis, however, where appropriate, sources of odorous emissions from a facility with a different odour character have also been assessed on an individual basis. Each industry had a unique odour emissions character and consequently it was assumed that there were no cumulative affects.
 - An assessment of the cumulative impacts of key pollutants of interest identified by QLD Health was made, based on all NIE emission sources that emit the substance.
 - The assessment of ground-level concentrations of individual air pollutants and odour was carried out across the model domain at all areas beyond the NIE boundary and at the 16 sensitive places identified by QLD Health. The dispersion model grid was set up to incorporate the sensitive receptor locations.

- An assessment of each air pollutant has been made against the air quality objectives and standards identified for the study. Where available, the Queensland Environmental Protection (Air) Policy 2008 (Air EPP 2008) has been used as the primary source. Other sources of air quality standards include the DECC (2005), TCEQ (2009) and DEFRA (2009).
- For air pollutants assessed on the basis of a 1-hour average, the highest (100th percentile) concentration is compared to the Air EPP (2008) objectives and TCEQ (2009) guidelines, while the ninth highest (99.9th percentile) is compared to the DECC (2005) criteria in line with the accepted method. For averaging periods of eight hours, one day and one week, the maximum value is compared with the objective, while the annual average is the average of all of the hourly predictions for the year modelled.
- A time series analysis has been carried out to investigate the frequency of the impacts that exceed the criteria.
- For odour, the assessment has been made in accordance with the Queensland odour guideline of 2.5 odour units for the 99.5th percentile, 1-hour average (EPA 2004). However, a further analysis has been carried out to investigate the frequency of predicted odour impacts above the odour detection threshold of one odour unit (based on an hourly average). This assessment has been carried out at receptors where an impact above 1 ou is predicted.

3.5. Treatment of air pollutants monitored above and below the MLOD concentration

The monitoring of emission sources with air pollutants found to be at concentrations below the MLOD provided a degree of uncertainty in the assessment findings. Consequently, the assessment findings were divided into two groups:

1. Group 1 air pollutants: Assessment of the predicted ground-level concentrations of air pollutants with a measured source concentration that was greater than the MLOD.
2. Group 2 air pollutants: Assessment of the predicted ground-level concentrations of air pollutants that were not found at a concentration greater than the MLOD. The assessment has been carried out for an emission rate based on the source concentration that is equal to the MLOD.

4. Interpretation of Assessment Findings

4.1. Results

The air quality impact assessment found that ground-level concentrations of all Group 1 air pollutants were predicted to meet the Air EPP (2008) objectives and air quality standards for all other jurisdictions identified for the assessment at all sensitive places. The assessment also found that ground-level concentrations of all Group 2 pollutants were predicted to meet the objectives and standards with the exception of:

- Beryllium, when assessed against the DECC (2005) 1-hour average health-based criteria – associated with the hot dip galvanising process
- Methyl mercaptan, when assessed against the DECC (2005) 1-hour average odour-based criteria – associated with pesticide and herbicide manufacturing
- Styrene, when assessed against the Air EPP (2008) 1-hour average odour-based criteria – associated with swimming pool manufacturing
- Odour was not predicted to exceed the Queensland odour guideline at any sensitive place due to emissions from any source or based on cumulative impacts associated with any single facility. However, odour from the swimming pool, organic/inorganic fertiliser and aquaculture feed manufacturers was predicted to occur at some sensitive places from time to time.

4.2. Discussion of results

As identified above, the only predicted impacts that were found above any air quality criteria were associated with uncertainty in the emission characterisation.

Beryllium and methyl mercaptan were not measured at concentrations greater than the MLOD. The dispersion modelling found that beryllium impacts above the air quality criteria were predicted beyond the NIE boundary including the nearest sensitive receptor, located within 100 m of the western boundary of the NIE.

Methyl mercaptan impacts above the criteria were predicted across the majority of the model domain. While concurrent odour monitoring was not carried out on this source, the predicted impacts were considered a significant over-estimation due to the lack of observed and community reported odour impact associated with a methyl mercaptan odour character.

Styrene was measured in a stack dispersing particulate filtered air emissions collected from within the main production building and in fugitive emissions released from the building through

openings. The impact assessment found the primary source contributions were associated with the building fugitive emissions. However, the volume flow from the main building was based on an estimate of the air velocity, as the velocity was highly variable and tended to be less than the measurement instrument LOD. Consequently, the model predictions were considered an over-estimate. Notwithstanding this, the odour assessment, based on odour emission rates with the same volume flow from the main building, found the odour guideline was predicted to be met at all sensitive places. The air quality assessment also found that the Air EPP (2008) 7-day average health-based objective was predicted to be met at all sensitive places.

5. Discussion of Study Approach

The following discussion outlines some of the important issues identified during the air quality and odour impact assessment study.

5.1. Size of the study

Air quality and odour studies are typically carried out to evaluate the impact of a single activity, either existing or proposed, on the receiving environment. It is rare for an entire industrial estate of more than 70 businesses to be comprehensively investigated in a single study. The approach to this study was to address the impacts associated with emissions from the entire NIE with each of the businesses investigated being evaluated both in isolation and in combination with the others. This provided for the cumulative impact assessment of important and common air pollutants and the calculation of source apportionment of individual activities.

5.2. Emissions associated with routine and non-routine production conditions

While the catalyst for the study was a non-routine event that caused an environmental impact, i.e. a fire in a chemical plant, the objective of the HRA was to evaluate the potential risk to the health of the local population due to air emissions associated with routine operations at NIE businesses. Routine operations and emission controls were investigated prior to monitoring to determine the characteristics of continuous and intermittent emission sources and appropriate times to monitor. However, it is likely that air quality and, in particular, odour impacts tend to occur due to emissions released during non-routine operating conditions. Consequently, understanding the frequency of occurrence of non-routine operations at a business and the magnitude of emissions variability due to process changes is an important part of impact assessment.

5.3. Emissions variability during routine operations

Emissions monitoring was carried out for the duration of time prescribed by the standard for the testing method and this averages out any variability in process emission rates for that time. For some sources, replicate samples were collected and the highest emission rate was used for a conservative approach to the impact assessment. Notwithstanding this, the emissions monitoring program was not designed to characterise the variability of emission rates associated with variations and anomalies in the routine production process.

5.4. Emissions variability associated with batch and cyclical production

Many of the industries in the NIE only operate during daytime hours with batch production processes, or have cyclical production schedules due to seasonal or other demand-side production drivers. Consequently, the variability in emission rates during other parts of the cycle is not known. All attempts were made to model emissions for the hours of day or seasons of the year that each activity operates.

5.5. Handling of emissions not monitored above the method limit of detection

The source emissions monitoring program found that the concentration of a significant proportion of the air pollutants tested were not detected above the MLOD. A conservative approach was adopted to model the upper range of the emission rate by using the test MLOD as the criterion for calculating the emission rate for the impact assessment. Consequently, the emission rate of the substance is between zero and the MLOD. This will result in the over-prediction of ground-level concentrations in the local area. For air pollutants emitted by two activities, this led to the prediction of impacts greater than the air quality criterion. A similar issue occurred for fugitive emissions from buildings due to the measured air velocity being below the instrument MLOD.

The study found that preliminary dispersion modelling prior to the sampling program would have been beneficial to calculate an appropriate MLOD for substances based on an air pollutant importance hierarchy. The modelling could have been used to determine the key pollutants from each source and the emission concentration required to meet the air quality objectives.

6. Conclusions

The air quality and odour impact assessment undertaken for the NIE was a successful study that delivered important outcomes for an area where

minimal information was known. The success of the study is attributed to the good communication between the study team members, the CRG and NIE businesses. The detailed planning undertaken by the study team for the study and the sampling program were also important in the study's success. The intention of this paper is to provide useful information to others attempting to undertake an assessment of this magnitude in the future.

Air quality and odour impact assessments of emissions associated with 11 businesses at the NIE were conducted to inform the HRA process. The study methodology employed standard impact assessment techniques including:

- Identification of important sources and processes during routine operating conditions
- Emissions sampling and measurement according to the relevant standards
- Dispersion modelling using regulatory models and accepted techniques, including a model performance evaluation, to predict ground-level concentrations of 153 air pollutants and odour associated with 25 emission sources
- Impact assessment against Air EPP (2008) and other national and international air quality objectives and the Queensland odour guideline

The assessment found that the air quality criteria for all air pollutants were met at all sensitive places beyond the NIE boundary, with the exception of three substances emitted by three individual businesses. However, the impacts associated with these emissions were highly sensitive to assumptions made in the calculation of their emission rates, and the impact was likely to be over-estimated.

While standard methods were employed for the study, several issues were identified. Issues included the assessment of substances with an emission rate based on a concentration at the test method limit of detection, the identification of routine operations, the monitoring of sources during routine operations, emission variability during routine operations and emission variability due to non-continuous, batch or cyclical production processes.

Acknowledgments

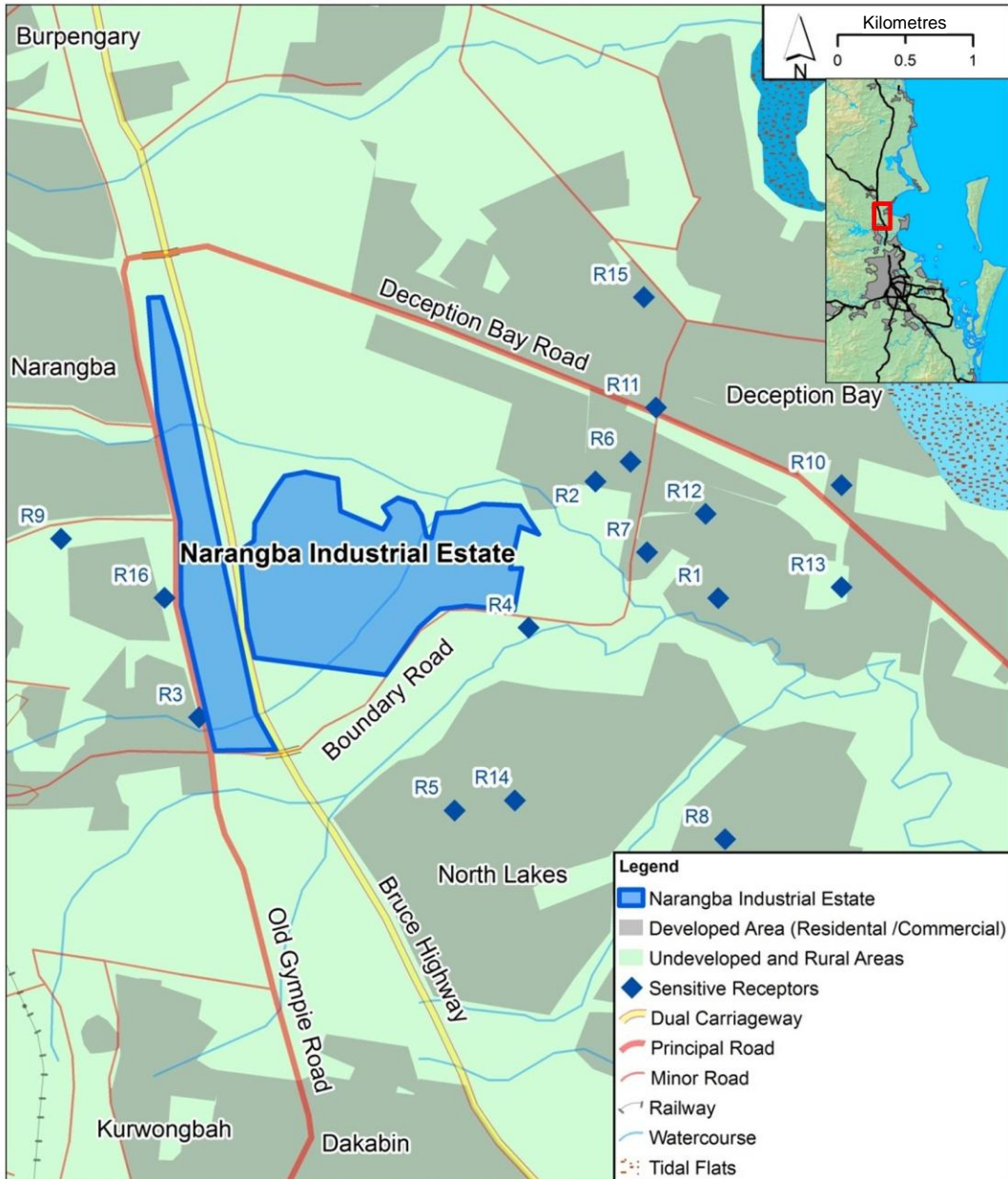
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Figure 1 Maps illustrating the assessment area and location of emission sources



Activity Location Key

- Swimming pool manufacturing
- Hot dip galvanising of steel fabrications
- Green waste composting
- Kangaroo and cow hide tanning
- Sheepskin tanning
- Treatment, recycling and management of waste oil and other chemicals
- Aqua culture feed and pet food manufacturing
- Manufacture of pesticides and herbicides
- Fertilizer manufacturing
- Hazardous waste treatment and management
- Wastewater and oily water recycling