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Wallacia Park, Park Road Wallacia, Crematorium

Air Quality Impact Assessment

Addressee(s): Catholic Metropolitan Cemeteries Trust

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Quality Control

Study	Status	Prepared by	Checked by	Authorised by
INTRODUCTION	Final	Northstar Air Quality	GCG, ML	M. Doyle
THE PROPOSAL	Final	Northstar Air Quality	GCG, ML	M. Doyle
LEGISLATION, REGULATION AND GUIDANCE	Final	Northstar Air Quality	GCG, ML	M. Doyle
EXISTING CONDITIONS	Final	Northstar Air Quality	GCG, ML	M. Doyle
METHODOLOGY	Final	Northstar Air Quality	GCG, ML	M. Doyle
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MITIGATION AND MONITORING	Final	Northstar Air Quality	GCG, ML	M. Doyle
CONCLUSION	Final	Northstar Air Quality	GCG, ML	M. Doyle

Report Status

Northstar References		Report Status	Report Reference	Version
Year	Job Number	(Draft: Final)	(R*x*)	(V*x*)
18	1014	F	R1	V3
Based upon the above, the specific reference for this version of the report is:				18.1014.FR1V3

Final Authority

This report must by regarded as draft until the above study components have been each marked as final, and the document has been signed and dated below.

G. Graham 2 November 2017

NON-TECHNICAL SUMMARY

Catholic Metropolitan Cemeteries Trust has engaged Northstar Air Quality Pty Ltd to perform an air quality impact assessment for a proposed cemetery and crematorium (the Proposal) to be located at 13-15 Park Road, Wallacia NSW (the Proposal site).

This air quality impact assessment forms part of the Statement of Environmental Effects prepared to accompany the development application for the Proposal to Penrith City Council.

The air quality impact assessment presents an assessment of the impacts of the Proposal upon the surrounding area, to demonstrate compliance with the Protection of the Environment Operations (Clean Air) Regulation 2002, and in accordance with the Approved Methods for the Modelling and Assessment of Air Quality in NSW.

The air quality impact assessment presents an assessment of the impacts of the proposed operation of the cemetery, including two (2) cremators at the Proposal site. To ensure that an assessment of potential worst-case (i.e. maximum cremation rate) has been considered in conjunction with potential worst-case weather conditions, an assumption that both cremators would be operational for 24 hours per day, 365 days per year has been adopted. Although highly conservative, the assessment has been presented to provide confidence that the operations can be performed with no exceedances of the relevant air quality criteria.

The air quality impact assessment demonstrates that with the appropriate and proposed air pollution control systems, the Proposal complies with the in-stack emission limits, as specified under Schedule 6 of the POEO (Clean Air) Regulation (2010), and the Australian Cemeteries & Crematoria Association code of practice. Additionally, the United Kingdom Department for Environment Food and Rural Affairs Process Guidance (PG) Note 5/2 has been referenced in regard to emission limits for crematoria and Best Available Technology.

The relevant air quality impact criteria have been referenced from the National Environment Protection (Ambient Air Quality) Measure and NSW EPA (2017) Approved Methods for the Modelling and Assessment of Air Quality in NSW. The results of the assessment of the potential impacts of the Proposal site operation upon the surrounding environment indicate that even without the inclusion of emissions controls, all air quality criteria adopted are predicted to be achieved. With the operation of the proposed air pollution control systems, the impacts are correspondingly significantly lower and demonstrate compliance with all relevant air quality standards, accounting for existing 'background' air quality.

Detail is provided within the report as to the method for air pollution control, how this meets best practice and any ongoing monitoring requirements to ensure the ongoing efficacy of those control measures.

It is respectfully concluded that the results of the air quality impact assessment indicate that Development Consent for the Proposal should not be rejected on the grounds of air quality.

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Units Used in the Report

All units presented in the report follow the International System of Units (SI) conventions, unless derived from references using non-SI units. In this report, units formed by the division of SI and non-SI units are expressed as a negative exponent, and do not use the solidus (/) symbol. For example:

- 50 micrograms per cubic metre is presented as 50 $\mu g \cdot m^{-3}$ and not 50 µg/m^3; and,
- 0.2 kilograms per hectare per hour is presented as 0.2 $kg \cdot ha^{-1} \cdot hr^{-1}$ and not 0.2 kg/ha/hr.

Common Abbreviations

Abbreviation	Term
ABS	Australian Bureau of Statistics
AHD	Australian height datum
AQIA	air quality impact assessment
AQMS	air quality monitoring station
BoM	Bureau of Meteorology
CO	carbon monoxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EETM	emission estimation technique manual
EPA	Environmental Protection Authority
K	kelvin (-273°C = 0 K, ± 1°C = ± 1 K)
kW	kilowatt
$mg \cdot m^{-3}$	milligram per cubic metre of air
$mg \cdot Nm^{-3}$	milligram per normalised cubic metre of air (at standard temperature and pressure)
$\mu g \cdot m^{-3}$	microgram per cubic metre of air
NCAA	National Clean Air Agreement
NEPM	National Environment Protection Measure
NO	nitric oxide
NO_X	oxides of nitrogen
NO_2	nitrogen dioxide
O_3	ozone
OEH	NSW Office of Environment and Heritage
Pa	Pascals
PCDD/DF	polychlorinated dibenzo-*p*-dioxins and furans

Abbreviation	Term
PM	particulate matter
PM_{10}	particulate matter with an aerodynamic diameter of 10 µm or less
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 µm or less
SEE	Statement of Environmental Effects
SO_X	oxides of sulphur
SO_2	sulphur dioxide
STP	standard temperature and pressure (273.15 K, 101.3 kPa)
TAPM	The Air Pollution Model
TSP	total suspended particulates
US EPA	United States Environmental Protection Agency
VOC	volatile organic compound

1. INTRODUCTION

Catholic Metropolitan Cemeteries Trust has engaged Northstar Air Quality Pty Ltd (Northstar) to perform an air quality impact assessment (AQIA) for a proposed cemetery and crematorium (the Proposal) to be located at 13-15 Park Road, Wallacia NSW (Lot 2 of Deposited Plan [DP] 1108408) (the Proposal site).

This AQIA forms part of the Statement of Environmental Effects (SEE) prepared to accompany the development application for the Proposal to Penrith City Council (PCC).

The AQIA presents an assessment of the impacts of the Proposal upon the surrounding area, using dispersion modelling techniques. The incremental change in air quality in the area surrounding the site is presented in addition to an assessment of compliance with relevant ambient and in-stack air quality criteria.

1.1 Assessment Requirements

No specific assessment requirements have been provided by PCC regarding the AQIA. To allow assessment of the level of risk associated with a Proposal in terms of air quality, the NSW Environment Protection Authority (EPA) provide a general list of requirements, and those broad requirements have been adopted as part of this assessment. These broad requirements are reproduced in Table 1 and have been given due consideration within the performance of this assessment. The section of the report where each general requirement has been addressed is provided in Table 1.

Table 1 NSW Environment Protection Authority general requirements for an AQIA

Issue	Requirement	Addressed
The Project	• Identify all sources of air emissions from the development.	Section 2.3
	• Provide details of the project that are essential for predicting and assessing air impacts including:	
	– The quantities and physio-chemical parameters (eg concentration, moisture content, bulk density, particle sizes etc) of materials to be used, transported, produced or stored	Section 5.2, Appendix C
	– An outline of procedures for handling, transport, production and storage	Section 2
	– The management of solid, liquid and gaseous waste streams with potential for significant air impacts.	Section 2

Issue	Requirement	Addressed
The Location	• Describe the topography and surrounding land uses. Provide details of the exact locations of dwellings, schools and hospitals. Where appropriate provide a perspective view of the study area such as the terrain file used in dispersion models. • Describe surrounding buildings that may affect plume dispersion. • Provide and analyse site representative data on the following meteorological parameters: – Temperature and humidity – Rainfall, evaporation and cloud cover – Wind speed and direction – Atmospheric stability class – Mixing height – Katabatic air drainage – Air re-circulation	Section 4.1, Section 4.3 N/A Section 4.4, Appendix B
The Environmental Issues	Describe baseline conditions • Provide a description of existing air quality and meteorology, using existing information and site representative ambient monitoring data. Assess impacts • Identify all pollutants of concern and estimate emissions by quantity (and size for particles), source and discharge point. • Estimate the resulting ground level concentrations of all pollutants. Where necessary (eg potentially significant impacts and complex terrain effects), use an appropriate dispersion model to estimate ambient pollutant concentrations. Discuss choice of model and parameters with the EPA. • Describe the effects and significance of pollutant concentration on the environment, human health, amenity and regional ambient air quality standards or goals. • Describe the contribution that the development will make to regional and global pollution, particularly in sensitive locations. Describe management and mitigation measures • Outline specifications of pollution control equipment (including manufacturer's performance guarantees where available) and management protocols for both point and fugitive emissions. Where possible, this should include cleaner production processes.	Section 4.2 Section 4.4 Section 2.3 Section 5 Section 6 Section 6 Section 6 Section 7

Further to the above, the policies, guidelines and plans which have been referenced during the performance of the AQIA include:

- Protection of the Environment Operations (Clean Air) Regulation 2002.
- Approved Methods for the Modelling and Assessment of Air Quality in NSW (NSW EPA, 2017)
- Approved Methods for the Sampling and Analysis of Air Pollutants in NSW (DEC, 2006).

2. THE PROPOSAL

The following provides a description of the Proposal and the emissions of air pollutants which would be anticipated as a result of the activities being performed at the Proposal site.

2.1 Proposal Background

Catholic Metropolitan Cemeteries Trust proposes to develop a cemetery and crematorium to be located at 13-15 Park Road, Wallacia NSW.

The proposed development has been described elsewhere in the DA submission. For the purposes of assessing air quality impacts, a conservative approach has been adopted which is based on comparable start-up cremation rates for the Rookwood Crematorium as supplied by the client. In this regard, the rates assessed *do not* reflect the proposed rates for the proposed Wallacia facility, which will be secondary to the dominant cemetery use.

Two cremators are proposed to be installed. For the purposes of this AQIA only, and using the Rookwood Crematorium emission benchmarks, we have assumed a worst-case hourly emission rate from both cremators and applied that as a constant emission rate on a 24/7 (24 hours per day, 365 days per year) basis. This has been performed to ensure that the AQIA accounts for worst case emissions coinciding with worst-case meteorological conditions, and significantly over-estimates the proposed daily and annual cremation rates. The assumed daily and annual emission rates used in the AQIA are therefore substantially higher than that proposed for the subject site.

The operating hours of the cemetery would be as follows:

- for visitation opening and closing hours will be within sunrise to sunset seven days a week; and
- The operating hours of the cemetery will be 7.00am until 5.00pm Monday to Friday and 7.00am until 12.00pm on Saturday.

The cremators will be constructed from refractory (heat resistant) bricks and typically fuelled by natural gas. Cremators generally comprise two combustion chambers (a primary combustion chamber and secondary combustion chamber) and a cooling tray, although some cremators operate with three combustion chambers and cooling tray). Each combustion chamber is fitted with a burner. Upon start-up, the primary and secondary combustion chambers are sequentially pre-heated to achieve the required operating temperatures. Once the temperature in the secondary chamber reaches 300°C – 800°C (after a preheating by the support fuel at 850°C), the primary chamber is heated to a temperature of 300°C – 800°C.

Cremation begins immediately once the coffin is inserted into the first chamber and only one coffin is ever placed inside the chamber at any one time. Coffin handles are generally burnt with the coffin however some handles can hamper the cremation process and are often removed prior to cremation. If the coffin handles are removed prior to cremation, they are typically buried within the grounds of the crematorium.

When operating, the combustion gases from the primary combustion chamber are then drawn into the compartmentalised secondary combustion chamber, which is heated with afterburners and supplied with secondary air to complete combustion. The secondary chamber has a residence time for the gases of 1 – 2 seconds.

The time taken to cremate will depend on many factors including body mass, bone density and the materials from which the coffin is manufactured, however the average time for an adult cremation is 90 minutes at a temperature between 800°C and 1,000°C (NPI, 2011).

Although it is unlikely that both cremators would be operational constantly, for the purposes of this assessment and to compare the potential maximum impacts on the surrounding environment against short term criteria (≤1 hour, refer Section 3.2), a scenario which reflects constant cremation in both cremators across an entire year has been developed (i.e. cremations in each cremator for all 8,760 hours to allow assessment against all meteorological conditions).

This scenario results in an assumed annual cremation rate of 4,224 across both cremators (eight per day per cremator, 44 per week per cremator over 48 weeks per year, allowing for maintenance). This is significantly more than the proposed annual cremation rate of 350 to 750 but is required to allow assessment of the potential coincidence between maximum hourly cremation and worst-case meteorology.

2.2 Environmental Setting

The Proposal site is to be located at 13-15 Park Road, Wallacia NSW (Lot 2 of Deposited Plan [DP] 1108408) (the Proposal site). The location of the Proposal site in a regional and local context is presented in Figure 1 and Figure 2, respectively.

The Proposal site is immediately surrounded by land zoned as R5 (large lot residential), E3 (environmental management), RU5 (village), and RU1 (primary production) (refer Section 4.1.1 for more detailed information). It is located at the northern end of the village of Wallacia and is located on the site of the current Wallacia Panthers golf course.

There are a number of residential properties and a school within close proximity to the Proposal site boundary (within 50 metres[m]). Warragamba Dam (Australia's largest urban water supply dam) is located within 5 kilometres (km) of the Proposal site. Further details of these sensitive receptor locations are provided in Section 4.1.

Figure 1 Regional project setting

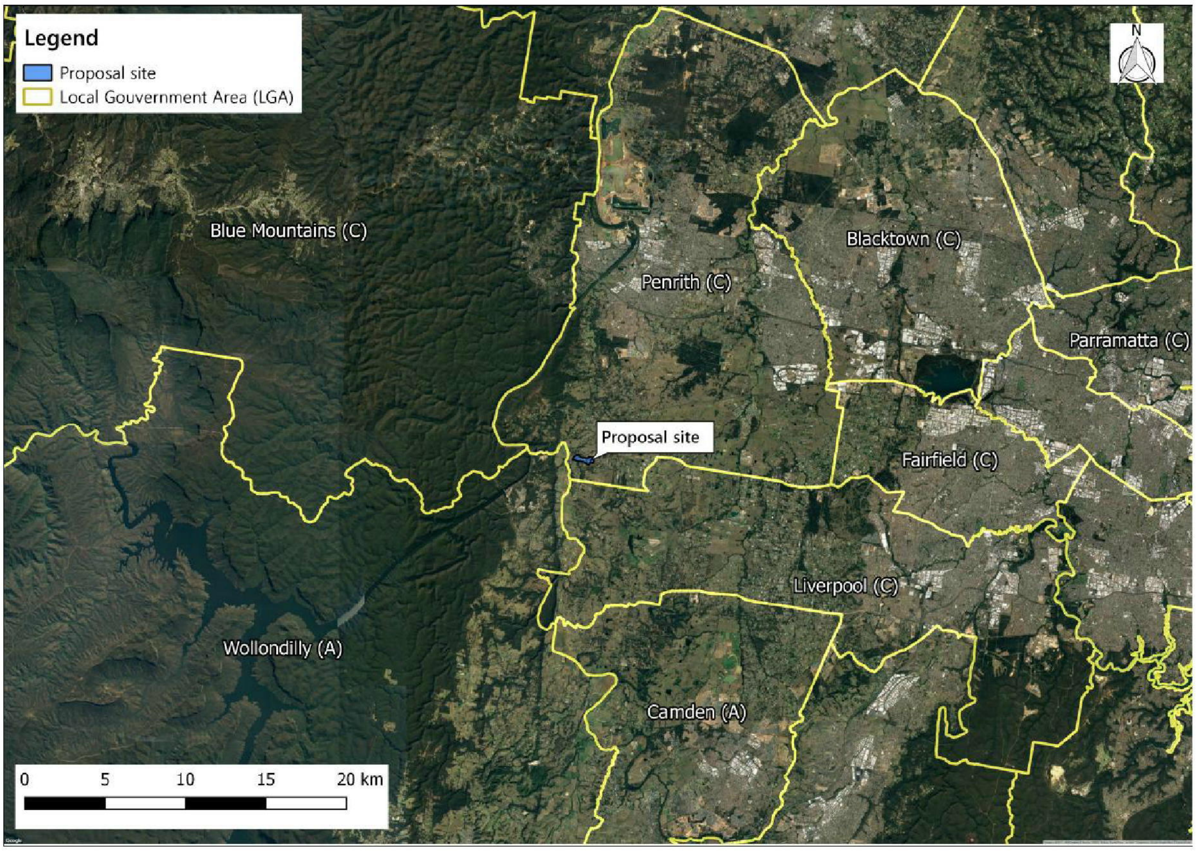
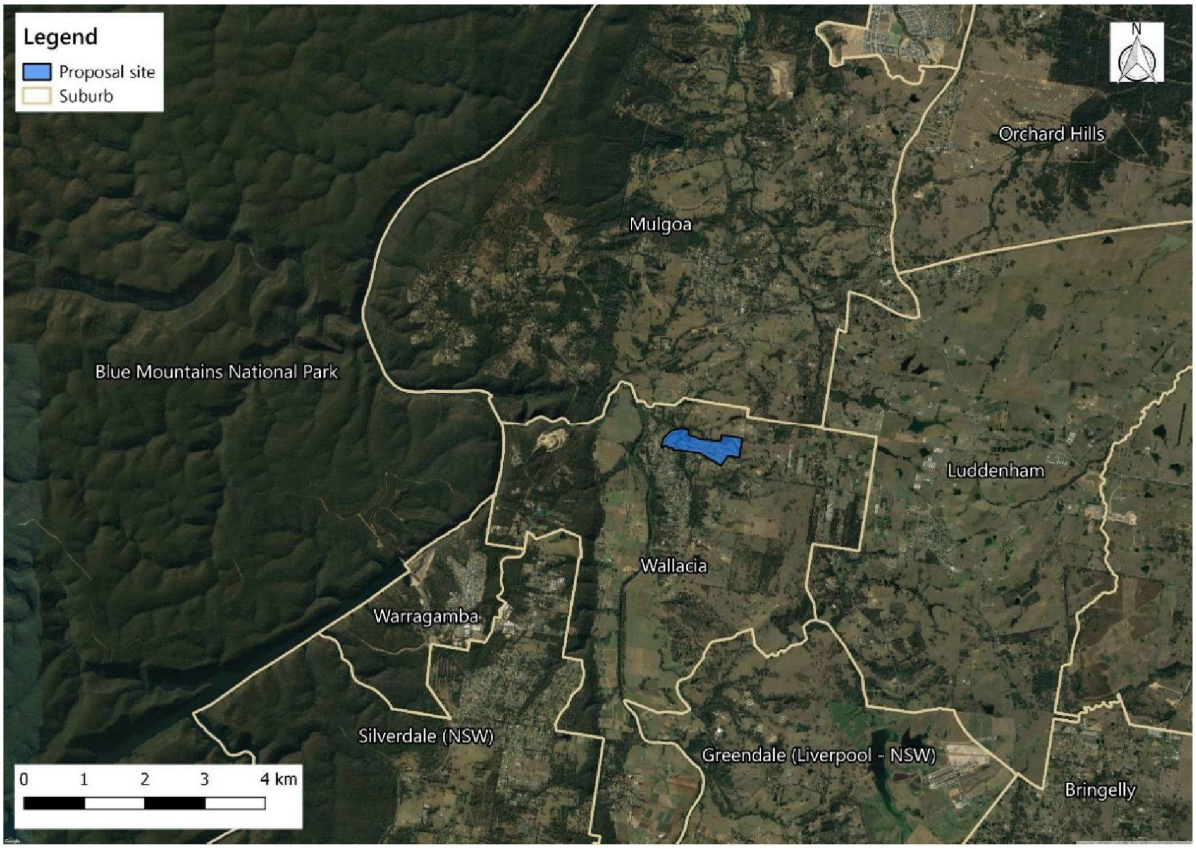


Figure 2 Local project setting



2.3 Identified Potential for Emissions to Air

The cremation process can result in the emission of pollutants to air with these being identified through review of various guidance documents, including:

- National Pollutant Inventory (NPI) Emission Estimation Technique Manual for Crematoria (NPI, 2011);
- Australian Cemeteries and Crematoria Association (ACCA) Environmental Guidelines for Crematoria and Cremators (ACCA, 2009); and
- UK Department of Environment, Food and Rural Affairs (DEFRA) Process Guidance Note PG5/2 (12) Statutory Guidance for Crematoria (DEFRA, 2012).

After review of these guidance documents, it has been established that the emissions from the cremation process may include:

- Carbon monoxide (CO);
- Oxides of nitrogen (NO_X);
- Sulphur dioxide (SO_2);
- Particulate matter (PM_{10} and $PM_{2.5}$);
- Volatile organic compounds (VOCs);
- Polychlorinated dioxins and furans (PCDD/PCDFs);
- Polycyclic aromatic hydrocarbons (PAHs);
- Heavy metals including antimony (Sb), arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se) and zinc (Zn).
- Hydrogen chloride (HCl); and
- Hydrogen fluoride (HF).

The pollutant composition and emission rates may vary depending on the fuel composition, fuel consumption, cremator design and operation and the emission and pollution control devices in use (NPI, 2011).

Although odour has the potential to be emitted from the cremation process, (DEFRA, 2012) states that odour emissions are prevented by good combustion and the operation of a secondary combustion zone. Modern cremators include as standard a primary and secondary combustion zone and if cremation equipment is operating efficiently, then no odours should be emitted (ACCA, 2009).

3. LEGISLATION, REGULATION AND GUIDANCE

Legislation, regulation and guidance relating to air quality resulting from the operation of crematoria fall into two categories;

- In-stack emission limits: limits on the emission of pollutants at the point of emission; and,
- Ambient air quality criteria: standards and goals associated with the impact of those emissions within the wider environment.

Compliance with in-stack emission limits does not necessarily result in compliance with ambient criteria as the in-stack emission limits do not take into account site specific features such as meteorology, topography and background air quality. Emission limits do reflect reasonably available technology and good environmental practice, proper and efficient operation and protect the health and amenity of the surrounding community (NSW EPA, 2017). Where emissions of certain pollutants of concern associated with crematoria are not regulated by Australian state or federal bodies, examination of emission limits from other jurisdictions specific to crematoria have been referenced.

Full details of the emission limits and ambient air quality criteria adopted as part of this assessment are presented in the following sections (Section 3.1 and Section 3.2, respectively). Section 3.3 provides a discussion of Best Available Techniques (BAT) in crematoria emission reduction and outlines the features of the Proposal which will meet those benchmarks.

3.1 In-Stack Emission Limits

3.1.1 Protection of the Environment (Operations) Act 1997 (NSW)

Crematoria are a non-scheduled activity under the *Protection of the Environment (Operations)* (POEO) *Act* (1997) and are therefore required to meet the requirements of Schedule 6 of the POEO (Clean Air) Regulation (2010). These requirements only cover emissions of solid particles and smoke although for all premises (including non-scheduled premises) the POEO Act (1997) (section 128) provides requirements that the occupiers of any premises must perform any activity, or operate any plant to prevent or minimise air pollution, including odour.

The requirements of the POEO (Clean Air) Regulation (2010) for non-scheduled premises are presented in Table 2. Only the requirements for Group C plant are presented (relevant to development after 1 September 2005).

Table 2 Standards of concentration for non-scheduled premises (POEO [Clean Air] Regulation 2010)

Air impurity	Activity or plant	Group	Concentration	Reference conditions
Solid particles	Any activity or plant (except as listed below)	C	100 mg·m^{-3}	Dry, STP, 3% O_2
Smoke	Any activity or plant in connection with which liquid or gaseous fuel is burnt	A, B or C	Ringelmann 1 or 20% opacity	Gas stream temperature above dew point. Path length corrected to stack exit diameter as per CEM-1

Note: Averaging period of 1 hour for solid particles (total) and 6 minutes (rolling) for smoke opacity

3.1.2 Australian Cemeteries & Crematoria Association

The Australian Cemeteries & Crematoria Association (ACCA) has initiated a code of practice to encourage members to develop a commitment to being environmentally conscious by taking measures to control emissions of pollutants to air and to lessen the visible impact of the industry (ACCA, 2009). The guideline provides emission standards for crematorium furnace facilities which are reproduced in **Table 3** (converted to mg·m^{-3}).

Table 3 Emission standards for crematorium furnace facilities (ACCA, 2009)

Air emission	Current[a] clean air regulations (mg·m^{-3})	Future clean air regulations (mg·m^{-3})	Reference conditions	Notes
Combustion particles	450	250	Dry, STP, 7% O_2, 12 CO_2	
Carbon monoxide	-	150	Dry, STP, 7% O_2	
Nitrogen oxides	2,500	500		As NO_2
Chlorine and compounds [c]	200	200		
Acid gases	400	200		As HCl
Fluorine and compounds	100	50		As HF
Total organic compounds	-	226		As hexane
Heavy metals	20	10		Total [b] (incl Cd, Cr, Ni, Co, As and Hg)
Mercury	-	3		
Lead	-	10		
Cadmium	-	3		

Note: **(a)** Current in 2009 **(b)** Cd = cadmium, Cr = chromium, Ni = nickel, Co = cobalt, As = arsenic, Hg = mercury
(c) Not included in emission factors (NPI, 2011)

Additional guidance is provided by the ACCA which outlines further suggestions which may assist in reducing in the prevention of air emissions. These suggestions are presented in **Section 3.3**.

3.1.3 Department for Environment Food and Rural Affairs (UK)

The United Kingdom Department for Environment Food and Rural Affairs (DEFRA) has produced Process Guidance (PG) Note 5/2 (12) which outlines statutory guidance for crematoria operating in the UK (DEFRA, 2012) and provides guidance on Best Available Techniques (BAT) for regulators and operators.

Although not statutory guidance within Australia, the guidance has been referenced as it provides useful information on the in-stack emission limits which can be achieved through the implementation of BAT. As previously described, the POEO Act (1997) (section 128) provides requirements that the occupiers of any premises must perform any activity, or operate any plant to prevent or minimise air pollution, including odour and therefore the operation of the crematorium with due consideration of BAT is required.

Section 4 of (DEFRA, 2012) outlines the in-stack emission limits which are achievable using BAT (described further in **Section 3.3**). These limits are presented in full in **Appendix A** for both unabated and abated cremators, with a summary presented in **Table 4**. It is noted that (DEFRA, 2012) indicates that 50% of UK cremations were required to be carried out in plants fitted with abatement. The operation of cremators without abatement in NSW would not meet the requirements of the POEO Act (1997) and therefore, the concentration limits associated with abated plant have been taken forward for further assessment. It is noted that an assessment of unabated plant has also been examined to demonstrate the level of control which will be achieved at the Proposal site.

Table 4 Emission limits for unabated and abated cremators (DEFRA, 2012)

Substance	Unabated Concentration limits ($mg \cdot m^{-3}$)[(a)]	Abated Concentration limits ($mg \cdot m^{-3}$)[(a)]
Mercury	-	0.05
Hydrogen chloride (excluding particulate matter)	200	30
Total particulate matter	160	20
Carbon monoxide	200	100
Organic compounds (excluding particulate matter) expressed as carbon	20	20
PCDD/DF	-	0.1 $ng \cdot m^{-3}$

Note: **(a):** Reference conditions: Dry, 273.15 K, 101.3 kPa, 11% O2, dry gas

3.1.4 Summary

A summary of the in-stack emission limits outlined in **Section 3.1.1** (NSW Government) **Section 3.1.2** (Australian Cemeteries & Crematoria Association) and **Section 3.1.3** (UK DEFRA) are presented in **Table 5**.

Although only the requirements of the POEO (Clean Air) Regulation 2010 are applicable to non-scheduled premises in NSW, the POEO Act requires that operation of plant and equipment should be performed to minimise air pollution. Therefore, the most stringent in-stack limits have been adopted as part of this assessment (highlighted in green in **Table 5**).

A comparison of these in-stack emission limits with the predicted emissions concentrations resulting from the operation of the proposed crematorium is presented in **Section 6.1**.

A summary of the emissions abatement equipment required to meet these limits is also outlined in **Section 3.3** and a discussion of how this meets BAT is provided.

Table 5 Summary of emission limits for crematoria

Substance	POEO (Clean Air) Regulations 2010	ACCA (2009)	DEFRA (2012) (abated)
	Concentration limits ($mg{\cdot}m^{-3}$)		
Mercury	-	3	0.05
Hydrogen chloride (excluding particulate matter)	-	200	30
Total particulate matter	100	250	20
Carbon monoxide	-	150	100
Organic compounds (excluding particulate matter) expressed as carbon	-	226	20
PCDD/F	-	-	0.1 $ng{\cdot}m^{-3}$
Nitrogen oxides	-	500	-
Fluorine and compounds (as HF)	-	50	-
Heavy metals[(a)]	-	10	-
Lead	-	10	-
Cadmium	-	3	-
Reference conditions	Dry, 273 K, 101.3 kPa, 3% O_2	Dry, 273 K, 101.325 kPa, 7% O_2 Dry, 273 K, 101.325 kPa, 7% O_2, 12% CO_2 (for particulate matter)	273.1 K,101.3 kPa, 11% O_2 v/v, dry gas

Note **(a):** Total incl Cd, Cr, Ni, Co, As and Hg

3.2 Ambient Air Quality Criteria

3.2.1 Federal Air Quality Standards

National Environment Protection (Ambient Air Quality) Measure

The *National Environment Protection (Ambient Air Quality) Measure* (Ambient Air Quality NEPM) was promulgated in July 1998 and established ambient air quality standards for six key pollutants across Australia, and provides a standard method for monitoring and reporting on air quality. Air quality standards and performance monitoring goals for the six key air pollutants include:

- Carbon monoxide (CO);
- Lead (Pb);
- Nitrogen dioxide (NO_2);
- Particles (particulate matter with an aerodynamic equivalent diameter of 10 microns (µm) or less (PM_{10});
- Photochemical oxidants, as ozone (O_3); and,
- Sulphur dioxide (SO_2).

The Ambient Air Quality NEPM was varied in July 2003 to include advisory reporting standards for fine particulate matter with an aerodynamic equivalent diameter of 2.5 microns (µm) or less ($PM_{2.5}$) and in February 2016 (NEPC, 2016), introducing varied standards for PM_{10} and $PM_{2.5}$. The air quality standards and goals as set out in the (revised) Ambient Air Quality NEPM for the pollutants considered within this assessment are presented in Table 6.

Table 6 National Environment Protection (Ambient Air Quality) Measure standards and goals

Pollutant [(a)]	Averaging period	Criterion		Allowable exceedances per year
		ppm	$\mu g{\cdot}m^{-3(a,b)}$	
Carbon monoxide (CO)	8 hours	9.0	11.25 $mg{\cdot}m^{-3}$	1 day a year
Nitrogen dioxide (NO_2)	1 hour	0.12	246	1 day a year
	1 year	0.03	61.5	None
Sulphur dioxide (SO_2)	1 hour	0.2	572	1 day a year
	1 day	0.08	228.8	1 day a year
	1 year	0.02	57.2	None
Lead (Pb)	1 year	-	0.5	None
Particulates (as PM_{10})	1 day	-	50	None
	1 year	-	25	None
Particulates (as $PM_{2.5}$)	1 day	-	25	None

Pollutant[a]	Averaging period	Criterion		Allowable exceedances per year
		ppm	µg·m$^{-3(a,b)}$	
	1 year	-	8	None

Note (a) Criteria for ozone not relevant to the assessment and not shown

(b) converted at 0°C using conversion factors in Table 12.1 of the Approved Methods (NSW EPA, 2017)

National Clean Air Agreement

The National Clean Air Agreement (NCAA) was agreed by Australia's Environment Ministers on 15 December 2015. The NCAA establishes a framework and work plans for the development and implementation of various policies aimed at improving air quality across Australia.

Regarding air quality standards with relevance to this report, the Initial Work Plan sets an objective to vary the Ambient Air Quality NEPM regarding PM_{10} and $PM_{2.5}$ standards.

Of relevance to the standards adopted as the relevant benchmarks for the performance of the Proposal, the previous standards were augmented by an annual average PM_{10} concentration standard of 25 µg·m^{-3}, and the advisory reporting standards for $PM_{2.5}$ considered as standards. It is further likely that the 24-hour average PM_{10} concentration standard will be made more stringent from the current value of 50 µg·m^{-3} in time, although it is currently not possible to determine the revised standard for that metric.

3.2.2 NSW Air Quality Standards

State air quality guidelines adopted by the NSW EPA are published in the *'Approved Methods for the Modelling and Assessment of Air Quality in NSW'* (the Approved Methods (NSW EPA, 2017)) which has been consulted during the preparation of this assessment report.

The Approved Methods lists the statutory methods that are to be used to model and assess emissions of criteria air pollutants from stationary sources in NSW. Section 7.1 of the Approved Methods clearly outlines the impact assessment criteria for the Proposal.

The criteria listed in the Approved Methods are derived from a range of sources (including NHMRC, NEPC, DoE and WHO).

The criteria specified in the Approved Methods are the defining ambient air quality criteria for NSW. The standards adopted to protect members of the community from health impacts in NSW are presented in Table 7.

Table 7 NSW EPA air quality standards and goals

Pollutant [a]	Averaging period	Criterion		Notes
		µg·m^{-3} [b]		
Sulphur dioxide (SO_2)	10 minutes	712		
	1 hour	570		
	24 hours	228		
	Annual	60		
Nitrogen dioxide (NO_2)	1 hour	246		Numerically equivalent to the AAQ NEPM [c] standards and goals (Table 6).
	Annual	62		
Lead	Annual	0.5		
Particulates (as PM_{10})	24 hours	50		
	1 year	25		
Particulates (as $PM_{2.5}$)	24 hours	25		
	1 year	8		
Total Suspended Particulates (as TSP)	1 year	90		
		g·m^{-2}·month^{-1}	g·m^{-2}·month^{-1}	
Deposited dust	1 year	2 [d]	4 [e]	Assessed as insoluble solids as defined by AS 3580.10.1
		ppm	mg·m^{-3}	
Carbon monoxide (CO)	15 minutes	87	100	
	1 hour	25	30	
	8 hours	9	10	
		µg·m^{-3} [f]	µg·m^{-3} [g]	
Hydrogen fluoride	90 days	0.5	0.25	
	30 days	0.84	0.4	
	7 days	1.7	0.8	
	24 hours	2.9	1.5	

Notes: (a): Criteria for ozone not relevant to the assessment and not shown
(b): micrograms per cubic metre of air
(c): National Environment Protection (Ambient Air Quality) Measure
(d): Maximum increase in deposited dust level
(e): Maximum total deposited dust level
(f): General land use, which includes all areas other than specialised land use
(e): Specialised land use, which includes all areas with vegetation sensitive to fluoride such as grape vines and stone fruits

Additional air quality criteria are provided by NSW EPA for individual toxic air pollutants in section 7.2 of the Approved Methods (NSW EPA, 2017). NSW EPA states that these principal toxic air pollutants must be minimised to the maximum extent achievable which relates to the adoption of BAT (refer **Section 3.3**) and the adoption of the most stringent in-stack emission limits for the crematorium (refer **Section 3.1**).

However, that is not to say that the case for emitting up to the emission limits is proposed, just that the most stringent in-stack emission limits have been used to assess performance and compliance with the relevant air quality criteria.

The impact assessment criteria for the principal toxic air pollutants of relevance to the Proposal are presented in **Table 8**. Pollutants of relevance have been identified through examination of (NPI, 2011), (ACCA, 2009) and (DEFRA, 2012) (refer **Section 2.3**) and the in-stack concentration limits as presented in **Section 3.1**.

It is noted that cobalt and selenium are emitted from crematoria (NPI, 2011), although no specific criteria are in force in NSW. Cobalt has been assessed as part of total 'heavy metals' in the in-stack emissions assessment.

Within the Approved Methods (NSW EPA, 2017), a criterion for acetaldehyde is not included within the relevant tables for toxic air pollutants, but rather odorous air pollutants. The potential for impacts of acetaldehyde on the surrounding environment have been considered with respect to odour.

Table 8 NSW EPA air quality standards and goals – principal toxic air pollutants

Substance	Averaging period	Impact assessment criteria ($mg \cdot m^{-3}$)[(a)]
Mercury (organic)	1 hour	0.00018
Mercury (inorganic)	1 hour	0.0018
Polycyclic aromatic hydrocarbons (PAH) (as benzo[a]pyrene)	1 hour	0.0004
TVOC (assessed as benzene)	1 hour	0.029
Arsenic & compounds	1 hour	0.00009
Beryllium & compounds	1 hour	0.000004
Cadmium & compounds	1 hour	0.000018
Chromium III & compounds	1 hour	0.009
Chromium VI & compounds	1 hour	0.00009
Chlorine & compounds	1 hour	0.05
Copper & compounds (as copper fumes)	1 hour	0.0037
Formaldehyde	1 hour	0.02
Hydrochloric acid (HCl)	1 hour	0.14
Nickel & compounds	1 hour	0.00018
PCDD/DF	1 hour	2.0E–09
Acetaldehyde (assessed for impact upon odour only)[(b)]	1 hour	0.042
Antimony & compounds	1 hour	0.009
Zinc & compounds (zinc chloride fumes)	1 hour	0.018
Zinc & compounds (zinc oxide fumes)	1 hour	0.09

Note: (a): Gas volumes are expressed at 25°C (298 K) and at an absolute pressure of 1 atmosphere (101.325 kPa)

(b): Acetaldehyde has been included within the assessment as a marker for odour rather than toxicity.

3.3 Emission Control

As previously discussed, compliance with the in-stack emission limits and ambient air quality criteria is not necessarily sufficient to meet the requirements of the POEO Act (1997) (refer Section 3.1.1). Section 128 of the POEO Act (1997) provides requirements that the occupiers of any premises must perform any activity, or operate any plant to prevent or minimise air pollution, including odour:

128 Standards of air impurities not to be exceeded

(1) The occupier of any premises must not carry on any activity, or operate any plant, in or on the premises in such a manner as to cause or permit the emission at any point specified in or determined in accordance with the regulations of air impurities in excess of:

(a) the standard of concentration and the rate, or

(b) the standard of concentration or the rate,

prescribed by the regulations in respect of any such activity or any such plant.

*(1A) Subsection (1) applies only to emissions (**point source emissions**) released from a chimney, stack, pipe, vent or other similar kind of opening or release point.*

(2) The occupier of any premises must carry on any activity, or operate any plant, in or on the premises by such practicable means as may be necessary to prevent or minimise air pollution if:

(a) in the case of point source emissions—neither a standard of concentration nor a rate has been prescribed for the emissions for the purposes of subsection (1), or

(b) the emissions are not point source emissions.

(3) A person who contravenes this section is guilty of an offence.

Best Available Techniques (BAT) to minimise air pollution and odour from crematoria are outlined within the NPI Emission Estimation Technique Manual (EETM) for Crematoria (NPI, 2011), the Australian Cemeteries and Crematoria Association Environmental Guidelines document (ACCA, 2009) and within the UK DEFRA Process Guidance Note for Crematoria (DEFRA, 2012). As outlined within the NPI Emission Estimation Technique Manual (EETM) for Crematoria (NPI, 2011), a number of control techniques are available to reduce emissions from crematoria. These can be broadly categorised as:

- Process Control
  - Adjustment of combustion parameters to ensure complete combustion
  - Measurement of temperature, opacity, carbon monoxide and oxygen
- Pollutant Removal
  - Wet Scrubbing
    - Collection of combustion gases
  - Baghouses
    - Collection of particulate material (requires a cooling system)
  - Catalytic Filters
    - Filters to reduce emissions of mercury (and dioxin and nitrogen dioxide)

3.3.1 Process Control

Provisions (DEFRA, 2012) and suggestions (ACCA, 2009) relating to the control of combustion temperature, residence time and oxygen content of cremations are summarised in Table 9. There are slight inconsistencies in the two documents although the Proposal will be designed and operated to meet the more stringent provisions which will act to minimise emissions as highlighted in green in Table 9.

The process controls indicated in Table 9 (i.e. efficient cremator operation) should result in no visible smoke or odours being emitted from the cremator stack.

Table 9 Process emission requirements

Parameter	Provision [a]	
	(DEFRA, 2012)	(ACCA, 2009)
Temperature	• Minimum of 1073 K (800°C) in the secondary combustion chamber • Minimum of 1123 K (850°C) in the secondary combustion chamber when operating under emergency conditions without abatement	• Main chamber temperature of between 923 K (650°C) and 1173 K (900°C) • Main chamber optimum insertion and operation temperature at 1033 K (760°C) • At initial insertion and throughout cremation, secondary chamber should be maintained at a minimum of 1123 K (850°C)
Residence time	2 seconds residence time (minimum) in the secondary combustion chamber	1.5 seconds at 1123 K (850°C) is sufficient
Oxygen content	At the end of the secondary combustion chamber: • Measured wet or dry, minimum average 6% and minimum 3%	Air supplied at the inlet or into the secondary chamber to provide a level of oxygen not less than 6%

Note: (a): All parameters to be measured continuously

Further to the controls outlined above, air emissions may be significantly reduced through the following measures, implementable at the crematorium (ACCA, 2009):

- Removal of PVC plastics which may produce hazardous emissions such as dioxins and furan (PCDD/DF) and polychlorinated biphenyls (PCBs);
- Removal of metal fittings on caskets where possible; and,
- Removal of mementos or artefacts which may be liable to explode (batteries etc.).

Further measures to reduce emissions may be implemented by funeral directors, such as the construction of caskets and use of paints, although this is largely out of the control of the crematorium.

3.3.2 Pollutant Removal

The abatement provisions in the UK DEFRA process guidance note (DEFRA, 2012) is based on an abatement system of cool, capture and collect. Hot exhaust gases are cooled using, for example water tube coolers. Injecting dry lime or sodium bicarbonate and activated carbon into the gas stream captures pollutants. A dry filter captures the particulate matter and a reduction of between 90% to 98% in mercury concentrations is expected (DEFRA, 2012).

The NPI Emission Estimation Technique Manual (EETM) for Crematoria (NPI, 2011) outlines control efficiencies for various forms of mercury control as:

- Wet Scrubbers 55%-65%
- Wet scrubbers with conditioning agent 76%-82%
- Sprays absorbers and fabric filter (limestone) 44%-52%
- Spray absorbers and fabric filter (absorbent) 87%-94%
- ESP or fabric filter with carbon injection 50%-90%
- EP or fabric filter and polishing wet scrubber 85%

As outlined above, dry scrubbing/filtration is BAT for crematoria in the UK. In addition to reducing mercury emissions by 90% to 98% (DEFRA, 2012), dioxin and furan emissions may also be reduced, and particulate matter and other metals may be typically reduced by more than 90% (PEL, 2013).

4. EXISTING CONDITIONS

4.1 Surrounding Land Sensitivity

4.1.1 Discrete Receptor Locations

Air quality assessments typically use a desk-top mapping study to identify 'discrete receptor locations', which are intended to represent a selection of locations that may be susceptible to changes in air quality. In broad terms, the identification of sensitive receptors refers to places at which humans may be present for a period representative of the averaging period for the pollutant being assessed (see Section 3.2). Typically, these locations are identified as residential properties although other sensitive land uses may include schools, medical centres, places of employment, recreational areas or ecologically sensitive locations.

It is important to note that the selection of discrete receptor locations is not intended to represent a fully inclusive selection of all sensitive receptors across the study area. The location selected should be considered to be representative of its location, and may be reasonably assumed to be representative of the immediate environs. In some instances, several viable receptor locations may be identified in a small area, for example a school neighbouring a medical centre. In this instance, the receptor closest to the potential sources to be modelled would generally be selected and would be used to assess the risk to other sensitive land uses in the area. It is further noted that in addition to the identified 'discrete' receptor locations, the entire modelling area is gridded with 'uniform' receptor locations (see Section 4.1.2) that are used to plot out the predicted impacts and furthermore, 200 additional receptors at 20 m spacing have been placed around the perimeter of the Proposal site (see Section 4.1.3) and as such the accidental non-inclusion of a location sensitive to changes in air quality does not render the AQIA invalid, or otherwise incapable of assessing those potential risks.

To ensure that the selection of discrete receptors for the AQIA are reflective of the locations in which the population of the area surrounding the Proposal site reside, population density data has been examined. Population density data based on the 2016 census have been obtained from the Australian Bureau of Statistics (ABS) for a 1 square kilometre (km^2) grid, covering mainland Australia (ABS, 2017). Using a Geographical Information System (GIS), the locations of sensitive receptor locations have been confirmed with reference to their population densities. For clarity, the ABS use the following categories to analyse population density (persons·km^{-2}):

- Very high >8,000
- High >5,000
- Medium >2,000
- Low >500
- Very low <500
- No population 0

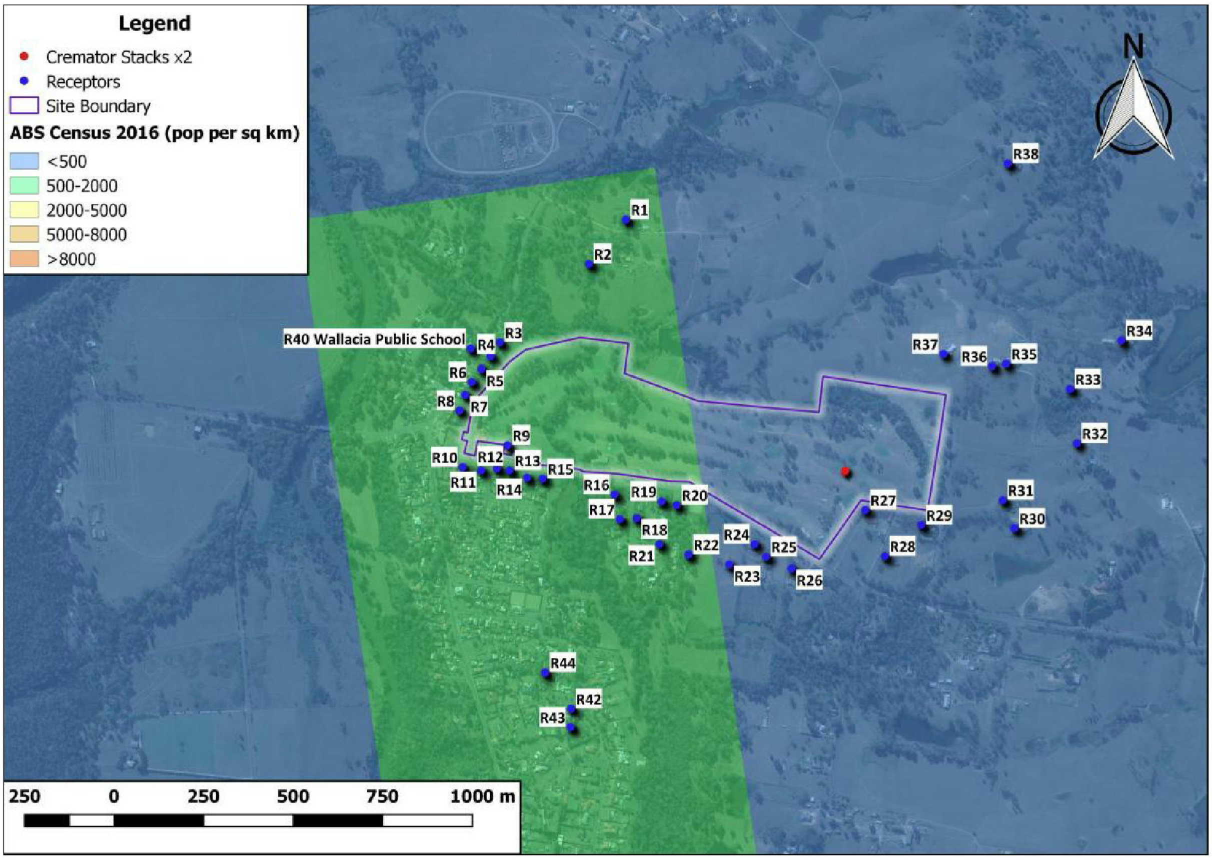
Using ABS data in a GIS, the population density of the area immediately surrounding the Proposal site are presented in Figure 3. The Proposal site is located in an area of low (>500 and <2000 persons·km $^{-2}$) to very low population (<500 persons·km $^{-2}$).

A number of residential locations and an educational receptor location have been identified and these receptors adopted for use within this AQIA are presented in Table 10. Figure 3 identifies that the receptors selected are located at points of the compass which correspond to areas of population which are observed surrounding the site and are therefore appropriate.

Knowledge of the behaviour of emissions associated with buoyant emissions sources (such as emissions stacks with significantly higher than ambient temperatures) indicates that maximum ground level impacts may be experienced at distances away from the site boundary. An initial dispersion modelling assessment for the Proposal operation indicated that the maximum short term (≤1 hour) impacts associated with the Proposal were likely to be experienced within Wallacia village. Three receptors (R42, R43 and R44 on Figure 3) have been included as discrete receptors to reflect those maximum impacts.

The nearest identified school to the Proposal site is Wallacia Public School located at a distance of over 1 km from the crematorium. This particularly sensitive receptor location has been specifically included within the assessment.

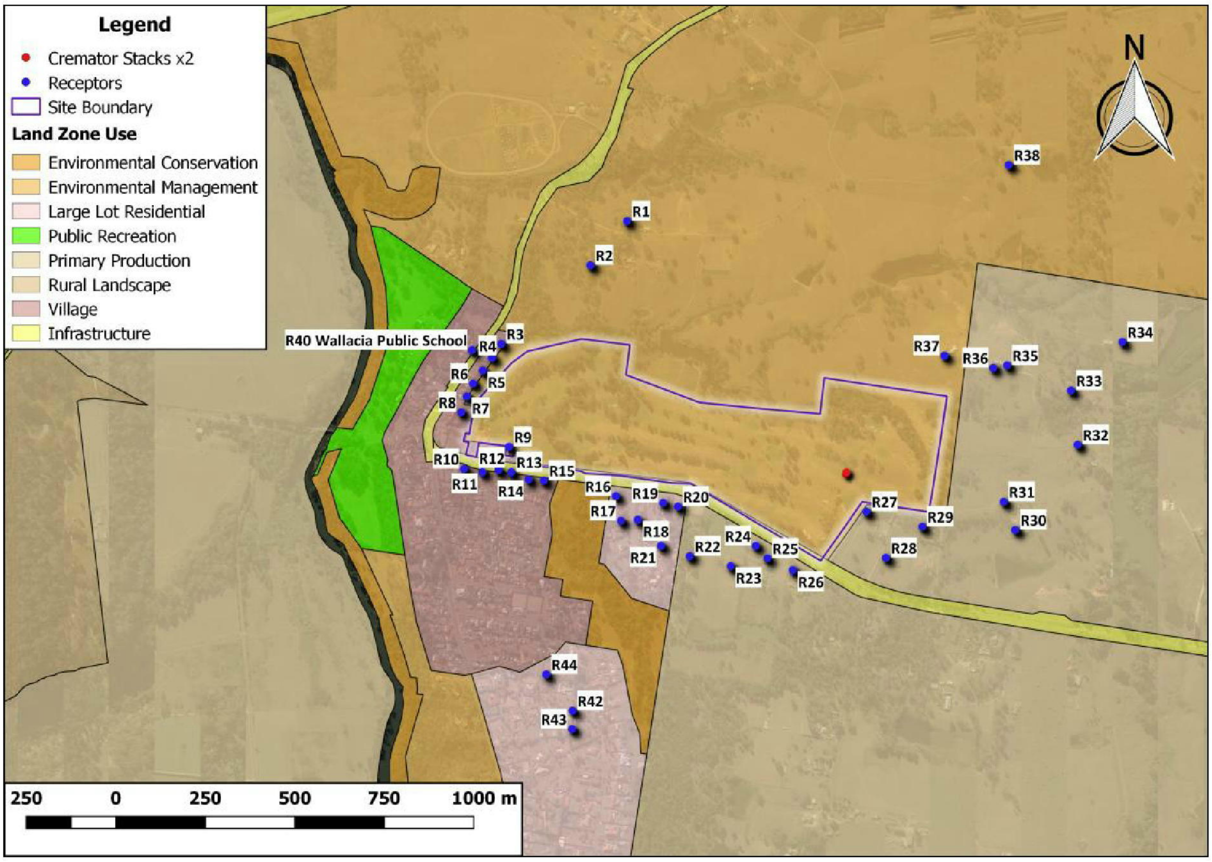
Figure 3 Population density and sensitive receptors surrounding the Proposal site



Note: R41 (Warragamba Dam) not shown

The land use zoning surrounding the Proposal site is presented in **Figure 4**.

Figure 4 Land use zoning and sensitive receptors surrounding the Proposal site



Note: R41 (Warragamba Dam) not shown. Colours taken from the Department of Planning and Environment template

Table 10 represents the discrete receptor locations that have been identified as part of this study (see **Figure 3**). The table is not intended to represent a definitive list of sensitive land uses, but a cross section of available locations that are used to characterise larger areas, or selected as they represent more sensitive locations which may represent people who are more susceptible to changes in air pollution than the general population.

Table 10 Discrete sensitive receptor locations used in the study

Rec.	Address	Land use	Land use zone	Location (m, Australian Map Grid, zone 56)	
				Easting	Northing
R1	1504-1508 Mulgoa Road, Wallacia	Resi.	Env. Man.	282,276	6,250,876
R2	1534 Mulgoa Road, Wallacia	Resi.	Env. Man.	282,176	6,250,751
R3	1562 Mulgoa Road, Wallacia	Resi.	Village	281,932	6,250,527
R4	1568 Mulgoa Road, Wallacia	Resi.	Village	281,907	6,250,488
R5	1574-1576 Mulgoa Road, Wallacia	Resi.	Village	281,882	6,250,452

Rec.	Address	Land use	Land use zone	Location (m, Australian Map Grid, zone 56)	
				Easting	Northing
R6	1508 Mulgoa Road, Wallacia	Resi.	Village	281,856	6,250,415
R7	1586 Mulgoa Road, Wallacia	Resi.	Village	281,839	6,250,379
R8	1590-1594 Mulgoa Road, Wallacia	Resi.	Village	281,824	6,250,335
R9	25 Park Road, Wallacia	Resi.	Village	281,960	6,250,242
R10	2 Park Road, Wallacia	Resi.	Village	281,836	6,250,178
R11	18 Park Road, Wallacia	Resi.	Village	281,888	6,250,170
R12	22 Park Road, Wallacia	Resi.	Infrastructure	281,932	6,250,177
R13	26 Park Road, Wallacia	Resi.	Infrastructure	281,968	6,250,172
R14	32 Park Road Wallacia	Resi.	Village	282,017	6,250,153
R15	36 Park Road, Wallacia	Resi.	Village	282,060	6,250,151
R16	11 Montelimar Place, Wallacia	Resi.	Large Lot Resi.	282,262	6,250,112
R17	10 Montelimar Place, Wallacia	Resi.	Large Lot Resi.	282,278	6,250,044
R18	2 Montelimar Place, Wallacia	Resi.	Large Lot Resi.	282,325	6,250,048
R19	68 Park Road, Wallacia	Resi.	Large Lot Resi.	282,394	6,250,096
R20	72 Park Road, Wallacia	Resi.	Large Lot Resi.	282,436	6,250,087
R21	3 Montelimar Place, Wallacia	Resi.	Large Lot Resi.	282,391	6,249,977
R22	76 Park Road, Wallacia	Resi.	Primary Production	282,472	6,249,950
R23	82 Park Road, Wallacia	Resi.	Primary Production	282,587	6,249,925
R24	90 Park Road, Wallacia	Resi.	Primary Production	282,656	6,249,983
R25	90 Park Road, Wallacia	Resi.	Primary Production	282,689	6,249,949
R26	1-9 James Street, Wallacia	Resi.	Primary Production	282,761	6,249,918
R27	115 Park Road, Wallacia	Resi.	Primary Production	282,963	6,250,085
R28	127 Park Road Wallacia	Resi.	Primary Production	283,020	6,249,958
R29	137 Park Road, Wallacia	Resi.	Primary Production	283,120	6,250,047
R30	151 Park Road, Wallacia	Resi.	Primary Production	283,380	6,250,044
R31	151 Park Road, Wallacia	Resi.	Primary Production	283,346	6,250,121
R32	217 Park Road, Wallacia	Resi.	Primary Production	283,549	6,250,284
R33	219 Park Road, Wallacia	Resi.	Primary Production	283,527	6,250,434
R34	221 Park Road, Wallacia	Resi.	Primary Production	283,667	6,250,572
R35	149 Park Road, Wallacia	Resi.	Primary Production	283,347	6,250,500
R36	149 Park Road, Wallacia	Resi.	Primary Production	283,308	6,250,492

Rec.	Address	Land use	Land use zone	Location (m, Australian Map Grid, zone 56)	
				Easting	Northing
R37	147 Park Road, Wallacia	Resi.	Env. Man.	283,171	6,250,523
R38	1404-1438 Mulgoa Road, Wallacia	Resi.	Env. Man.	283,339	6,251,056
R39	33 Square Dam Road, Mulgoa	Resi.	Env. Man.	283,178	6,251,517
R40	Wallacia Public School	School	Village	281,851	6,250,508
R41	Warragamba Dam	Utility	Infrastructure	277,905	6,248,000
R42	21-27 Davenport Drive, Wallacia	Resi.	Large Lot Resi.	282,154	6,249,514
R43	29 Davenport Drive, Wallacia	Resi.	Large Lot Resi.	282,514	6,249,463
R44	18-20 Davenport Drive, Wallacia	Resi.	Large Lot Resi.	282,079	6,249,613

4.1.2 Uniform Receptor Locations

Additional to the sensitive receptors identified in **Section 4.1.1**, a grid of uniform receptor locations has been used in the AQIA to allow presentation of contour plots of predicted impacts.

4.1.3 Boundary Receptor Locations

Additional to the sensitive receptors identified in **Section 4.1.1** and the grid of uniform receptor locations discussed in **Section 4.1.2**, 200 receptors have been placed along the boundary of the Proposal site at 20 m intervals to identify the maximum predicted concentration at any site boundary.

4.2 Air Quality

The air quality experienced at any location will be a result of emissions generated by natural and anthropogenic sources on a variety of scales (local, regional and global). The relative contributions of sources at each of these scales to the air quality at a location will vary based on a wide number of factors including the type, location, proximity and strength of the emission source(s), prevailing meteorology, land uses and other factors affecting the emission, dispersion and fate of those pollutants.

When assessing the potential impact of any particular source of emissions on the air quality at a location, the impact of all other sources of an individual pollutant should also be assessed. This 'background' air quality will vary depending on the pollutants to be assessed, and can often be characterised by using representative air quality monitoring data.

In the case of many of the pollutants anticipated to be emitted as part of the Proposal operation (refer Section 2.3), routine air quality monitoring to determine their concentration in the environment surrounding the Proposal site is not performed. Monitoring of ambient air quality is largely driven by the presence of proximal sources of pollutants and given the largely rural nature of the area surrounding the Proposal site, air quality monitoring for any of the pollutants emitted by the Proposal is not performed in the immediate area.

Air quality monitoring is performed by the NSW Office of Environment and Heritage (OEH) at Bringelly air quality monitoring station (AQMS), which is located at distance of approximately 12 km from the Proposal site. Pollutants of relevance to the Proposal monitored at the Bringelly AQMS include:

- Oxides of nitrogen (NO_X);
- Particulate matter (PM_{10}); and
- Sulphur dioxide (SO_2).

NOX, carbon monoxide (CO) and particles (as PM_{10} and $PM_{2.5}$) are measured at the Camden AQMS (located approximately 25 km from the Proposal site).

A summary of the maximum measured concentrations of CO, NO_2, SO_2, PM_{10} and $PM_{2.5}$ as measured at those AQMS is presented in Table 11, as derived from National Environment Protection Measure (NEPM) monitoring summaries for NSW. Where data is not available (either not measured or not available at the relevant averaging period), this is indicated in the table.

As shown in Table 11, concentrations of all pollutants across all relevant averaging periods are generally well below criteria, except for PM_{10} and $PM_{2.5}$. Concentrations of these pollutants are shown to be elevated in certain years, which is generally due to regional bushfire and/or dust storm events. For the purposes of this assessment, those years in which exceedances of the PM_{10} and $PM_{2.5}$ criteria have been experienced have been discounted from further assessment. The maximum (non-exceeding) concentration from all five years of monitoring data has been selected for use as representative background. Given the minor incremental impacts (especially relating to particulate matter), this is considered to be appropriate.

Concentrations of TSP are not measured by the NSW OEH at any AQMS surrounding the Proposal site. A detailed discussion of the relationship between TSP and PM_{10} concentrations in the Newcastle and Illawarra regions is presented in (SLR Consulting Australia Pty Ltd, 2016). Although no analysis is available for the Sydney region, the analysis concludes that the derivation of a broad TSP:PM_{10} ratio of 2.4 : 1 (i.e. PM_{10} represents 41% of TSP) is appropriate, based on data collected in those regions between 1996 and 2011. In the absence of any more specific information, this ratio has been adopted within this AQIA. Adopting the maximum measured annual average PM_{10} concentration in the most recent year of monitoring (15.8 $\mu g \cdot m^{-3}$ at Bringelly, 2015) and the ratio of 2.4 : 1, a background annual average TSP concentration of 37.9 $\mu g \cdot m^{-3}$ has been derived.

Table 11 Background air quality

Pollutant	Ave. period	Criterion	Bringelly AQMS					Camden AQMS				
		$\mu g \cdot m^{-3}$	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Sulphur dioxide (SO_2)	10 min	712										-
	1 hr	570	31.5	42.9	31.5	25.7	20.0					
	24 hr	228	5.7	5.7	5.7	8.6	2.9					
	Ann.	60	0.0	0.0	0.0	0.0	0.0					
Nitrogen dioxide (NO_2)	1 hr	246	59.5	77.9	75.8	51.2	55.3		45.1	73.8	65.6	53.3
	Ann.	62	10.2	10.2	10.2	8.2	8.2		10.2	8.2	8.2	8.2
PM_{10}	24 hr	50	86.0	40.1	97.2	42.6	57.0		35.6	97.5	41.4	62.4
	Ann.	25	15.9	15.7	17.0	16.6	15.8		20.1	15.4	15.6	13.9
$PM_{2.5}$	24 hr	25							19.5	61.9	18.5	25.0
	Ann.	8								6.5	6.3	6.2
Pollutant	Ave. period	$mg \cdot m^{-3}$	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Carbon monoxide (CO)	15 min	100										
	1 hr	30										
	8 hr	10							0.4	2.4	0.8	0.6

Similarly, no dust deposition data is available for the area surrounding the Proposal site. The incremental impact criterion of 2 $g \cdot m^{-2} \cdot month^{-1}$ as outlined within the Approved Methods has been adopted which effectively provides a background deposition level of 2 $g \cdot m^{-2} \cdot month^{-1}$ (the total allowable deposition being 4 $g \cdot m^{-2} \cdot month^{-1}$).

Volatile organic compounds (VOCs), polychlorinated dioxins and furans (PCDD/PCDF), polycyclic aromatic hydrocarbons (PAHs), hydrogen chloride (HCl), hydrogen fluoride (HF) and heavy metals are not measured routinely within NSW, given their low concentrations. For the purposes of this assessment, the concentrations of these pollutants have been assumed to be negligible which is considered to be a reasonable assumption.

The AQIA has been performed to assess the contribution of the Proposal to the air quality of the surrounding area. A full discussion of how the Proposal impacts upon the air quality of the area is presented in Section 6.

4.3 Topography

The elevation of the Proposal site is approximately 45 m to 65 m Australian Height Datum (AHD). A 3-dimensional representation of the topography surrounding the project site is presented in **Figure 5**. Significant topography can be seen to the west of the Proposal site which marks the western edge of the Sydney basin, the edge of the Blue Mountains National Park and the Burragorang State Conservation Area, which houses Warragamba Dam (identified as a specific discrete receptor in the assessment [refer **Table 10**]).

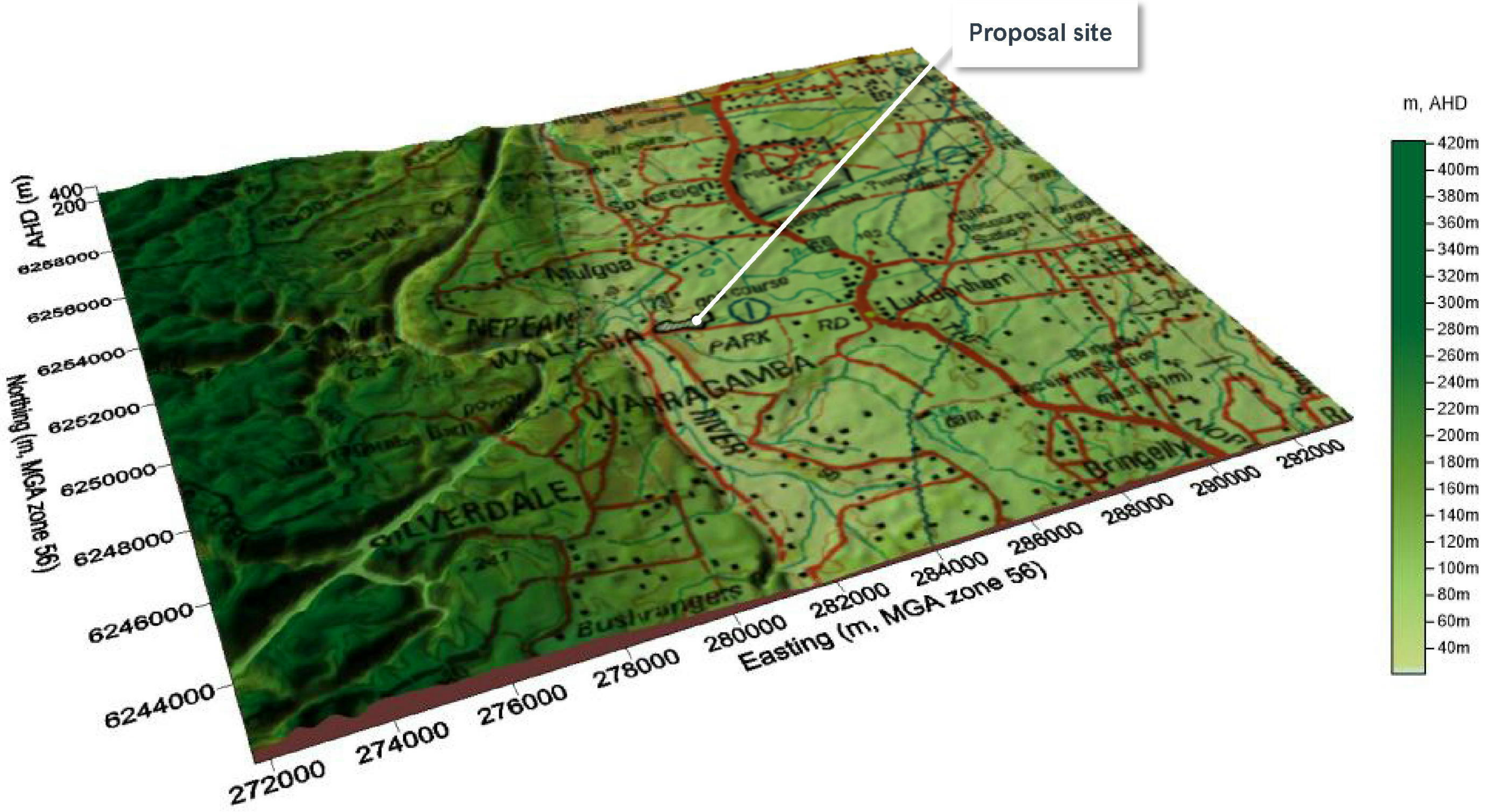
4.4 Meteorology

The meteorology experienced within an area can govern the generation (in the case of wind dependent emission sources), dispersion, transport and eventual fate of pollutants in the atmosphere. The meteorological conditions surrounding the Proposal site have been characterised using data collected by the Australian Government Bureau of Meteorology (BoM) at a number of surrounding Automatic Weather Stations (AWS).

To provide a characterisation of the meteorology which would be expected at the Proposal site, a meteorological modelling exercise has been performed.

A summary of the inputs and outputs of the meteorological modelling assessment, including validation, is presented in **Appendix B**.

Figure 5 3-dimensional representation of topography surrounding Proposal site



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5. METHODOLOGY

5.1 Dispersion Modelling

A dispersion modelling assessment has been performed using the NSW EPA approved CALPUFF atmospheric dispersion model. The modelling has been performed in CALPUFF 3-dimensional (3-D) mode. Although the distances between the sensitive receptors and emissions sources are relatively small, the complicated terrain in the area, especially to the west of the Proposal site, and the buoyancy and vertical velocity associated with the emission sources, a detailed assessment using a 3-dimensional (3-D) meteorological dataset is warranted.

An assessment of the impacts of the operation of activities at the Proposal site has been performed which characterises the worst-case day-to-day operation of the Proposal, approximating maximum operational characteristics which are appropriate to assess against shorter term (≤1-hour, 24-hour) criteria. This scenario will overstate the impacts associated with impacts associated with longer-term averaging periods.

The modelling scenarios provide an indication of the air quality impacts of the operation of activities at the Proposal site. Added to these impacts are background air quality concentrations (where available and discussed in Section 4.2) which represent the air quality which may be expected within the area surrounding the Proposal site, without the impacts of the Proposal itself.

The following provides a description of the determination of appropriate emissions of air pollutants resulting from the operation of the project.

5.2 Emissions Estimation

The estimation of emissions from a process is typically performed using direct measurement or through the application of factors which appropriately represent the processes under assessment. This assessment has adopted emission factors for cremation contained within the National Pollutant Inventory Emission Estimation Technique Manual (EETM) for Crematoria (NPI, 2011) to represent the emission of pollutants resulting from the operation of the cremators at the Proposal site as described in Section 2.3.

Appendix B of the NPI EETM for Crematoria lists a number of emission factors which are presented in Table 12.

Table 12 Emission factors for cremation (uncontrolled) (NPI, 2011)

Substance	Emission factor (kg·cremation^{-1})
Mercury and compounds	1.55×10^{-3}
Carbon monoxide	1.00×10^{-1}
Fluoride and compounds	1.46×10^{-3}
Oxides of nitrogen	5.22×10^{-1}
Particulate matter PM_{10}	3.86×10^{-2}
Particulate matter $PM_{2.5}$	3.47×10^{-2}
Polycyclic aromatic hydrocarbons	2.60×10^{-5}
Sulphur dioxide	7.39×10^{-2}
Total volatile organic compounds	1.02×10^{-1}
Arsenic and compounds	1.36×10^{-5}
Beryllium and compounds	6.21×10^{-7}
Cadmium and compounds	5.03×10^{-6}
Chromium III and compounds	1.36×10^{-5}
Chromium VI and compounds	6.12×10^{-6}
Copper and compounds	1.24×10^{-5}
Formaldehyde	1.54×10^{-5}
Hydrochloric acid	3.27×10^{-2}
Lead and compounds	3.00×10^{-5}
Nickel & compounds	1.73×10^{-5}
Polychlorinated dioxins and furans	4.90×10^{-9}
Acetaldehyde	5.90×10^{-5}
Antimony and compounds	1.37×10^{-5}
Cobalt and compounds[a,b]	7.94×10^{-7}
Selenium and compounds[a]	1.98×10^{-5}
Zinc and compounds	1.60×10^{-4}

Note: **(a):** Pollutants emitted but no criteria in NSW

(b): Cobalt assessed as total heavy metals (ACCA, 2009), refer **Table 5**

No specific stack parameters are currently available for the proposed crematorium. However, average stack parameters across nine crematoria within NSW which responded to a NSW EPA survey regarding emission characteristics in support of the generation of the Greater Metropolitan Region (GMR) Air Emissions Inventory for NSW, 2008 Calendar Year (NSW EPA, 2012) were:

- Stack height 8 m
- Stack diameter 0.7 m
- Exit velocity 15.4 $m \cdot s^{-1}$
- Exit temperature 635 K

The variables outlined above result in a volumetric flow rate ($m^3 \cdot s^{-1}$) (exit velocity [$m \cdot s^{-1}$] x stack area [m^2]) of 5.9 $Am^3 \cdot s^{-1}$ (at stack exhaust conditions). Please note that the prefix 'A' is used throughout this report to clearly represent units at actual exhaust conditions (e.g. $Am^3 \cdot s^{-1}$) as opposed to normalised conditions ($Nm^3 \cdot s^{-1}$).

The Australian Cemeteries and Crematoria Association recommend that the stack outlet from a cremator should be designed to allow for volumetric flow rates of at least 8 $Am^3 \cdot s^{-1}$ (ACCA, 2009). ACCA also states that the stack must be no less than 3 m above the peak of the roof.

To achieve the volumetric flow rates recommended by the ACCA, the stack diameter and exit velocity adopted in the generation of the NSW GMR Emissions Inventory (NSW EPA, 2012) can be marginally increased to 0.8 m stack diameter and 16 $m \cdot s^{-1}$ exit velocity (8.0 $Am^3 \cdot s^{-1}$). For the purposes of this assessment, the following stack parameters have been adopted.

- Stack height 8 m (minimum of 3 m above roof peak per (ACCA, 2009) guidelines)
- Stack diameter 0.8 m
- Exit velocity 16 $m \cdot s^{-1}$
- Volumetric flow rate 8.0 $Am^3 \cdot s^{-1}$
- Exit temperature 635 K
- Oxygen content 10%
- Moisture content 18%
- Pressure 101.325 kPa

The oxygen and moisture content and pressure are all required to allow calculation of the in-stack emission concentrations and comparison with the limits as outlined in Section 3.1. These variables are currently unknown but have been assumed based on sourced stack emission testing data for a crematorium (Facultatieve Technologies UK Ltd, 2014) and are considered to be appropriate for the current assessment.

Based on the anticipated cremation rate of one per 90 minutes per cremator (maximum of six to seven per 10-hour day per cremator), the anticipated hourly emission rate (per cremator) is presented in Table 13, along with the calculated in-stack emission concentration at actual stack conditions (assessment of these in-stack concentrations against the relevant criteria is presented in Section 6.1).

For clarity, the operating hours of the cemetery are as described in Section 2.1. For the modelling assessment it has been assumed that the cremators are both operating daily (365 days per year), 24 hours per day. It is considered that this is a highly conservative assumption.

Table 13 Emission rates for cremation (uncontrolled) (NPI, 2011)

Substance	Emission rate (kg·hr^{-1}·cremator^{-1})	In-stack emission concentration (mg·Am^{-3})
Mercury and compounds	1.03×10^{-3}	3.57×10^{-2}
Carbon monoxide	6.67×10^{-2}	2.30
Fluoride and compounds	9.73×10^{-4}	3.36×10^{-2}
Oxides of nitrogen	3.48×10^{-1}	12.02
Particulate matter PM_{10}	2.57×10^{-2}	8.89×10^{-1}
Particulate matter $PM_{2.5}$	2.31×10^{-2}	7.99×10^{-1}
Polycyclic aromatic hydrocarbons	1.73×10^{-5}	5.99×10^{-4}
Sulphur dioxide	4.93×10^{-2}	1.70
Total volatile organic compounds	6.80×10^{-2}	2.35
Arsenic and compounds	9.07×10^{-6}	3.13×10^{-4}
Beryllium and compounds	4.14×10^{-7}	1.43×10^{-5}
Cadmium and compounds	3.35×10^{-6}	1.16×10^{-4}
Chromium III and compounds	9.07×10^{-6}	3.13×10^{-4}
Chromium VI and compounds	4.08×10^{-6}	1.41×10^{-4}
Copper and compounds	8.27×10^{-6}	2.86×10^{-4}
Formaldehyde	1.03×10^{-5}	3.55×10^{-4}
Hydrochloric acid	2.18×10^{-2}	7.53×10^{-1}
Lead and compounds	2.00×10^{-5}	6.91×10^{-4}
Nickel & compounds	1.15×10^{-5}	3.98×10^{-4}
Polychlorinated dioxins and furans	3.27×10^{-9}	1.13×10^{-7}
Acetaldehyde	3.93×10^{-5}	1.36×10^{-3}
Antimony and compounds	9.13×10^{-6}	3.15×10^{-4}
Cobalt and compounds[a,b]	5.29×10^{-7}	1.83×10^{-5}
Selenium and compounds[a]	1.32×10^{-5}	4.56×10^{-4}
Zinc and compounds	1.07×10^{-4}	3.68×10^{-3}
Heavy metals[c]	2.97×10^{-4}	3.70×10^{-2}

Note: **(a)**: Pollutants emitted but no criteria in NSW

(b): Cobalt assessed as total heavy metals (ACCA, 2009), refer **Table 5**

(c): Total incl Cd, Cr, Ni, Co, As and Hg for assessment against (ACCA, 2009) criterion

As previously stated, Best Available Techniques (BAT) are required to be implemented to minimise pollutant emissions in accordance with the POEO Act (1997). The control measures to be adopted would include dry scrubbing/filtration which is BAT in the UK to reduce mercury, other heavy metals and particulate emissions. Wet scrubbing is not recommended by the ACCA due to cost and 'additional problems' (ACCA, 2009) assumed to be the disposal of waste liquid. ACCA does state that modern and well-maintained cremators do not normally require wet scrubbers.

The control efficiency afforded by the use of such a dry scrubber/filtration unit is stated as being between 87% (spray absorbers and fabric filter [absorbent]), (NPI, 2011) and 98% (DEFRA, 2012) for mercury emissions with dioxin and furan emissions also reduced and particulate matter and other metals typically reduced by more than 90% (PEL, 2013). For the purposes of this assessment, the control efficiency for all controlled pollutants which may be achieved through the installation of a dry scrubber/filtration unit has been assumed to be 90%. The actual control efficiency (especially for mercury) is likely to be higher, but in the interests of conservatism, a lower value has been selected for assessment purposes.

Other process controls outlined in **Table 9** will also act to reduce emissions of pollutants including carbon monoxide and nitrogen dioxide although the efficiency afforded by these process controls is not quantifiable.

Table 14 presents the control efficiency afforded by the installation and operation of a dry scrubber/filtration unit on each cremator, and how it would act to reduce emissions of each emitted pollutant (refer **Table 12**).

Table 14 Emission control measures for crematoria

Substance	Control method	Control efficiency (%)
Mercury and compounds	Spray absorbers and fabric filter (absorbent)	90%
Carbon monoxide	Temperature and oxygen control	-
Fluoride and compounds	-	-
Oxides of nitrogen	Temperature and oxygen control	-
Particulate matter PM_{10}	Spray absorbers and fabric filter (absorbent)	90%
Particulate matter $PM_{2.5}$		
Polycyclic aromatic hydrocarbons (PAHs)	-	-
Sulphur dioxide	-	-
Total volatile organic compounds (Total VOCs)	-	-
Arsenic and compounds	Spray absorbers and fabric filter (absorbent)	90%
Beryllium and compounds		
Cadmium and compounds		
Chromium III and compounds		
Chromium VI and compounds		
Copper and compounds		
Formaldehyde	-	-
Hydrochloric Acid (HCl)	-	-
Lead and compounds	Spray absorbers and fabric filter (absorbent)	90%
Nickel & compounds		
Polychlorinated dioxins and furans (PCDFs)		
Acetaldehyde	-	-
Antimony and compounds	Spray absorbers and fabric filter (absorbent)	90%
Cobalt and compounds[a,b]		
Selenium and compounds[a]		
Zinc and compounds		
Heavy metals[c]		

Note: **(a)**: Pollutants emitted but no criteria in NSW

(b): Cobalt assessed as total heavy metals (ACCA, 2009), refer **Table 5**

(c): Total incl Cd, Cr, Ni, Co, As and Hg for assessment against (ACCA, 2009) criterion only

6. AIR QUALITY IMPACT ASSESSMENT

The assessment of air quality associated with the Proposal includes an assessment of in-stack emissions (Section 6.1), and the impact of those emissions on the surrounding environment (Section 6.2).

The assessment has been performed to demonstrate the impacts of the crematorium operation associated with both uncontrolled and controlled emissions.

Importantly, the inclusion of control measures is not driven by non-compliance with the relevant criteria (in-stack or ambient). Control measures have been applied to ensure that emissions are minimised in accordance with the POEO Act (1997) and their inclusion is integral to the operation of the Proposal. Operation of the Proposal in an uncontrolled manner will not be performed, but the impacts associated with uncontrolled emissions are presented to allow transparency in the likely impacts on the surrounding community, should emissions control failure occur. Continual monitoring of cremator operation would ensure that any failure in the process would result in shut-down and therefore uncontrolled emission to the environment is not anticipated to occur in any event.

For clarity, the assessment associated with uncontrolled emissions is solely provided within this report to demonstrate:

- the impact of the applied control measures in minimising emissions from the crematorium; and
- the impact of uncontrolled emissions on the environment, should any unplanned failure in control measures eventuate.

6.1 Assessment of In-Stack Concentrations

Presented in Table 15 is the assessment of the calculated in-stack emission concentrations compared against the relevant criteria, previously discussed in detail in Section 3.1. The results are presented for a cremator operating with, and without control measures (specifically a dry scrubber/filtration unit [refer Section 5.2]).

The results indicate that without appropriate control, emissions of mercury and dioxins and furans have the potential to exceed the most stringent in-stack emission limits adopted (DEFRA, 2012). However, the inclusion of the control measures proposed will act to ensure that all criteria adopted are achieved.

Once again, it is stressed that the crematorium will not operate without the control measures being operational.

Table 15 Assessment against in-stack emission limits

Substance	In-stack criterion (mg·m⁻³)	Source	Ref. cond.	Uncontrolled (mg·m⁻³)	Uncontrolled % of criterion	Controlled (mg·m⁻³)	Controlled % of criterion
Mercury	0.05	(DEFRA, 2012)	273.1 K, 101.3 kPa, 11% O_2 v/v, dry gas	0.09	177.9%	0.009	17.8%
Hydrogen chloride (excluding particulate matter)	30			1.88	6.3%	1.88	6.3%
Total particulate matter	20			1.99	9.9%	0.199	0.9%
Carbon monoxide	100			5.74	5.7%	5.74	5.7%
Organic compounds (excluding particulate matter) expressed as carbon	20			5.85	29.3%	5.85	29.3%
Dioxins and furans	0.1 ng·m⁻³			0.28 ng·m⁻³	281.3%	0.028 ng·m⁻³	28.1%
Nitrogen oxides	500	(ACCA, 2009)	Dry, 273 K, 101.325 kPa, 7% O_2	42.1	8.4%	42.1	8.4%
Fluorine and compounds (as HF)	50			0.118	0.2%	0.118	0.2%
Heavy metals[(a)]	10			0.129	1.3%	0.013	0.1%
Lead	10			0.002	0.02%	0.0002	0.002%
Cadmium	3			0.0004	0.01%	0.0004	0.001%

Note (a): Total incl Cd, Cr, Ni, Co, As and Hg

6.2 Ambient Air Quality Assessment

Presented in Table 16 and Table 17 are the results of the assessment of incremental impacts associated with the operation of the crematorium on the surrounding environment. A full list of results at each of the discrete receptors is presented in Appendix C.

The time resolution of dispersion modelling is defined by the hourly limitation of the meteorology, which uses hourly averaged data.

To derive predictions of sub-hourly concentrations from the maximum 1-hour average prediction, the following Power Law adjustment has been applied[1]:

[1] http://www.epa.vic.gov.au/~/media/Publications/1551.pdf

$$C_{p,t} = C_{p,60}\left[\frac{60}{t}\right]^{0.2}$$

Where:

$C_{p,t}$ = concentration of pollutant (p) at averaging time (mins) (t)

$C_{p,60}$ = concentration of pollutant (p) at modelled averaging time (60 mins)

t = time (mins)

The results are presented as the percentage of the criterion predicted at each discrete receptor location and the location on the Proposal site boundary at which the maximum concentration is predicted (which varies according to the averaging period under examination).

Results are presented for uncontrolled and controlled emissions, although it is noted that control measures as discussed in Section 3.3 will be included as part of the Proposal operation. The results are presented in this manner to provide information as to the potential impact should the efficacy of those control measures be compromised.

As outlined in Table 14, some pollutants are not affected by the control measures proposed to be adopted, or the efficacy of the control measures proposed cannot be quantified, and therefore the controlled/uncontrolled impacts are numerically identical.

Results presented in Table 16 indicate that the Proposal can be operated with minimal incremental impact upon the surrounding environment, either with or without emissions controls in place. Of the pollutants presented in Table 16, impacts of NO_X are predicted to be greatest when compared to the relevant criterion, with impacts predicted to be approximately 24% of the 1-hour maximum NO_2 criterion. It should be noted that the assessment has assumed that 100% of the emitted NO_X is converted to NO_2, which is a conservative assumption.

It is shown that impacts at the Proposal boundary are often lower than those experienced at receptor locations away from the boundary. As previously discussed, the buoyant nature of the emissions can result in grounding of the plume away from the site, with the plume essentially 'looping' over the boundary. Initial dispersion modelling identified the locations of potential maximum impact (R42, R43 and R44, on Devonport Drive) which have then been specifically included within the modelling assessment. The results in Table 16 can therefore be viewed as the maximum predicted impacts within the modelling domain.

A contour plot of the predicted maximum 1-hour NO_X (as NO_2) concentration (increment only) can be viewed in Figure 6 which confirms the area of maximum impact and the appropriate coverage of the receptors. The impacts associated with NOX (as NO_2) are identical for both the uncontrolled and controlled emission scenarios.

Addition of the available air quality monitoring data as described in **Section 4.2** results in no exceedances of the relevant criteria. These results are presented in **Table 18** for pollutants and averaging periods with appropriate and available background data (refer **Section 4.2**). Results are presented for the maximum impact across the modelling domain (boundary and receptors) and for controlled emissions only.

Results presented in **Table 17** show that criteria for all pollutants within that table are predicted to be achieved. Impacts of mercury are shown to be close to the organic mercury criterion without the inclusion of emissions control (95.5% of the criterion). However, as stated previously, mercury abatement is proposed for the operation of the Proposal and therefore the 90% reduction in emissions would result in a maximum impact at the receptors (and within the modelling domain) of <10% of the 1 hour maximum mercury (organic) criterion.

It should be noted that the emission of mercury has been assumed to be 100% organic (for comparison against the more stringent organic mercury criterion) and simultaneously 100% inorganic (for comparison against the inorganic mercury criterion). In reality, emissions of mercury may be either elemental, or organic/inorganic with a study of Japanese crematoria finding that 29% of the emitted mercury was of the organic/inorganic form with the remainder elemental mercury (M. Takaoka, 2010). The predicted impacts associated with mercury can therefore be viewed as conservative.

Similarly, zinc emissions were assumed to be simultaneously in the form of zinc chloride fumes and zinc oxide fumes for conservative assessment against the relevant criteria.

A contour plot of the predicted maximum 1-hour mercury (organic) concentration (increment only) associated with the uncontrolled and controlled scenarios can be viewed in **Figure 7**and **Figure 8** which confirms the area of maximum impact and the appropriate coverage of the receptors.

No background air quality data is available for the pollutants assessed in **Table 17** and the background concentrations of those pollutants has been assumed to be negligible.

Acetaldehyde has been included within the assessment as a marker for odour. Predicted impacts are shown to represent <0.1% of the relevant criterion which indicates that odour is likely to be an insignificant issue.

Impacts have been specifically assessed at the site of Warragamba Dam to provide information relating to the likely pollutant concentrations at that location, given its importance as the main water supply for Sydney. It is stressed that this is not a health impact assessment, or a full assessment of the likely deposition of heavy metals etc to water. It is provided to demonstrate the minimal impacts and the achievement of all air quality criteria at that location. It is demonstrated that impacts of toxic air pollutants (refer **Table 8**) resulting from the Proposal operation are predicted to contribute less than 1.5% of the relevant criteria at Warragamba Dam. For criteria air pollutants (refer **Table 7**), emissions from the Proposal operation are predicted to contribute <1% of the relevant criteria at Warragamba Dam.

Table 16 Dispersion modelling predictions - NSW EPA air quality standards and goals - increment

Pollutant	Averaging Period	Criterion (µg·m^{-3})	% of criterion at Receptors		% of criterion at Boundary	
			U[(a)]	C[(a)]	U	C
Sulphur dioxide (SO_2)	10 minutes	712	1.6	1.6	0.9	0.9
	1 hour	570	1.4	1.4	0.8	0.8
	24 hours	228	0.3	0.3	0.2	0.2
	Annual	60	0.1	0.1	<0.1	<0.1
Nitrogen dioxide (NO_2)[(b)]	1 hour	246	23.5	23.5	13.0	13.0
	Annual	62	0.4	0.4	0.3	0.3
Lead (Pb)	Annual	0.5	<0.1	<0.1	0.0	0.0
Particulates (as PM_{10})	24 hours	50	0.7	0.1	0.4	0.0
	Annual	25	0.1	<0.1	0.1	0.1
Particulates (as PM_{10})	24 hours	25	1.3	0.1	0.8	0.1
	Annual	8	0.2	<0.1	0.1	0.0
Particulates (as TSP)	Annual	90	<0.1	<0.1	<0.1	<0.1
Hydrogen fluoride (HF)[(c)]	90 days	0.25	0.5	0.5	0.3	0.3
	30 days	0.4	0.4	0.4	0.2	0.2
	7 days	0.8	0.4	0.4	0.3	0.3
	24 hours	1.5	0.8	0.8	0.5	0.5
Pollutant	**Averaging Period**	**g·m^{-2}·month^{-1}**	**U[(a)]**	**C[(a)]**	**U**	**C**
Deposited dust	Annual	2	<0.1	<0.1	<0.1	<0.1
Pollutant	**Averaging Period**	**mg·m^{-3}**	**U[(a)]**	**C[(a)]**	**U**	**C**
Carbon monoxide (CO)	15 minutes	100	<0.1	<0.1	<0.1	<0.1
	1 hour	30	<0.1	<0.1	<0.1	<0.1
	8 hours	10	<0.1	<0.1	<0.1	<0.1

Note: (a) U = Uncontrolled, C = Controlled

(b) 100% conversion from NO_X to NO_2 assumed

(c) most stringent of the HF criteria (specialised land use) assessed

Table 17 Dispersion modelling predictions – principal toxic air pollutants

Substance	Averaging Period	Impact assessment criteria ($mg{\cdot}m^{-3}$)	% of criterion at Receptors		% of criterion at Boundary	
			U(a)	C(a)	U	C
Mercury (organic)	1 hour	0.00018	95.5	9.6	52.8	5.3
Mercury (inorganic)	1 hour	0.0018	9.6	1.0	5.3	0.5
Polycyclic aromatic hydrocarbons (as benzo[a]pyrene)	1 hour	0.0004	0.7	0.7	0.4	0.4
TVOC (assessed as benzene)	1 hour	0.029	39.0	39.0	21.5	21.5
Arsenic & compounds	1 hour	0.00009	1.7	0.2	0.9	0.1
Beryllium & compounds	1 hour	0.000004	1.7	0.2	1.0	0.1
Cadmium & compounds	1 hour	0.000018	3.1	0.3	1.7	0.2
Chromium III & compounds	1 hour	0.009	<0.1	<0.1	<0.1	<0.1
Chromium VI & compounds	1 hour	0.00009	0.8	0.1	0.4	0.0
Copper & compounds (as copper fumes)	1 hour	0.0037	<0.1	<0.1	<0.1	<0.1
Formaldehyde	1 hour	0.02	<0.1	<0.1	<0.1	<0.1
Hydrochloric acid	1 hour	0.14	2.6	2.6	1.4	1.4
Nickel & compounds	1 hour	0.00018	1.1	0.1	0.6	0.1
Dioxins and furans	1 hour	2.0E–09	27.2	2.7	15.0	1.5
Acetaldehyde (assessed for impact upon odour only)	1 hour	0.042	<0.1	<0.1	<0.1	<0.1
Antimony & compounds	1 hour	0.009	<0.1	<0.1	<0.1	<0.1
Zinc & compounds (zinc chloride fumes)	1 hour	0.018	0.1	<0.1	0.1	<0.1
Zinc & compounds (zinc oxide fumes)	1 hour	0.09	<0.1	<0.1	<0.1	<0.1

Note: **(a)** U = Uncontrolled, C = Controlled

(b) most stringent of the HF criteria (specialised land use) assessed against

Table 18 Dispersion modelling predictions - NSW EPA air quality standards and goals - cumulative

Pollutant	Averaging Period	Criterion ($\mu g \cdot m^{-3}$)	% of criterion at Receptors
			U[a]
Sulphur dioxide (SO_2)	1 hour	570	9.0
	24 hours	228	4.0
	Annual	60	<0.1
Nitrogen dioxide (NO_2)[b]	1 hour	246	55.2
	Annual	62	16.9
Particulates (as PM_{10})	24 hours	50	85.3
	Annual	25	80.4
Particulates (as PM_{10})	24 hours	25	78.1
	Annual	8	81.3
Particulates (as TSP)	Annual	90	42.1
Pollutant	**Averaging Period**	**$mg \cdot m^{-3}$**	
Carbon monoxide (CO)	8 hours	10	24.1

Note: (a) U = Uncontrolled

(b) 100% conversion from NO_X to NO_2 assumed

Figure 6 Predicted maximum 1-hour NOX (as NO2) concentrations

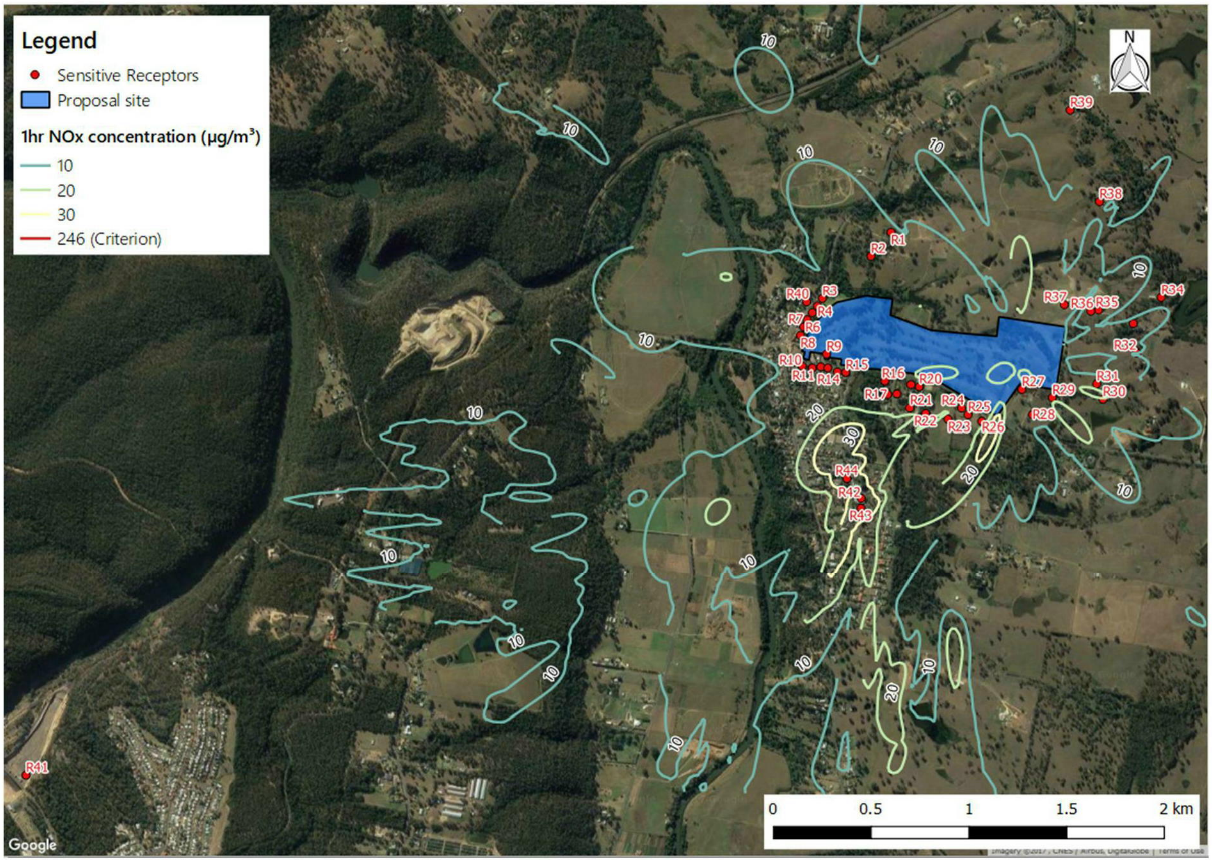


Figure 7 Predicted maximum 1-hour mercury (organic) concentration (increment only) – Uncontrolled scenario

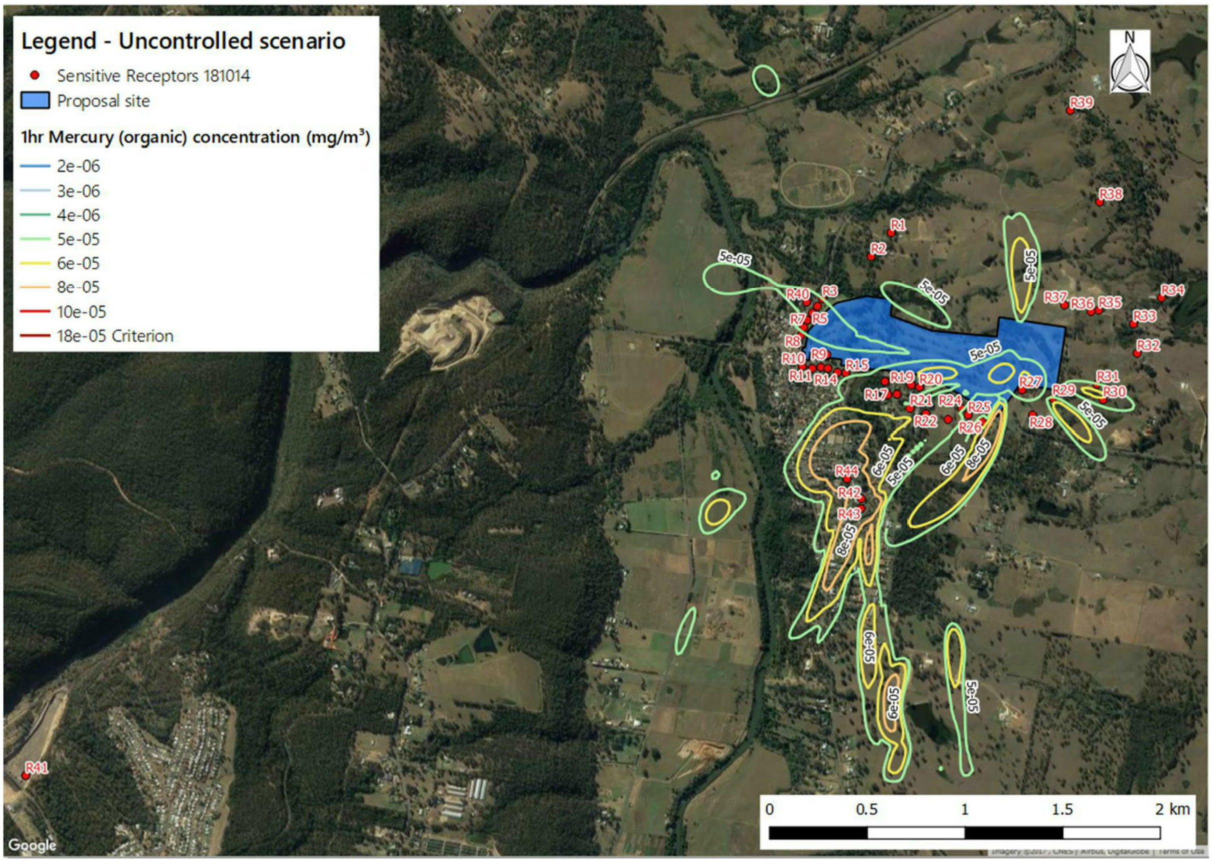
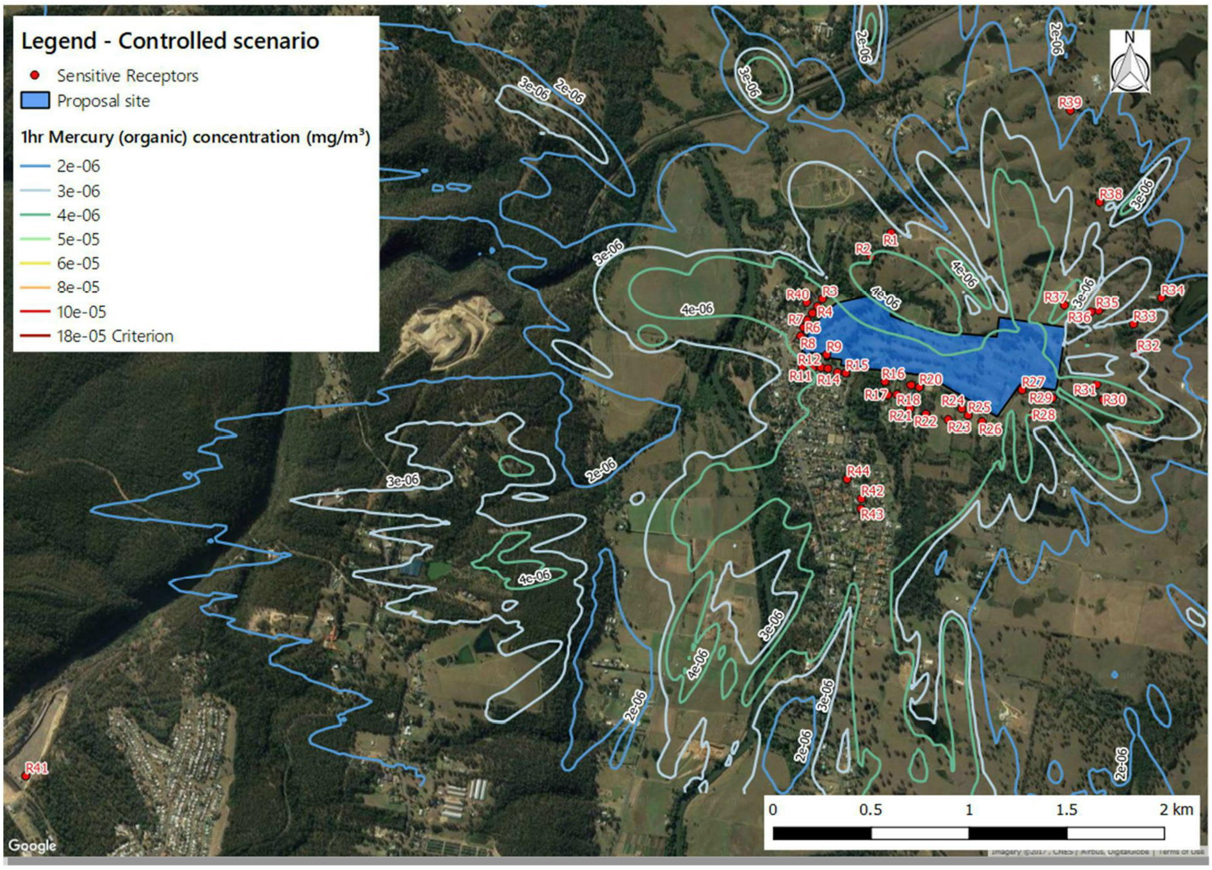


Figure 8 Predicted maximum 1-hour mercury (organic) concentration (increment only) – Controlled scenario



7. MITIGATION AND MONITORING

The assessment of the in-stack concentrations and ambient air quality both indicate that the inclusion of emission controls is required to meet the most stringent in-stack emission limits or ensure that ambient air quality criteria are not at risk of being exceeded.

The assessment indicates:

- Exceedance of the most stringent in-stack criterion for mercury and PCDD/DF without emission controls BUT achievement of those limits with appropriate air pollution control.

- Achievement of all ambient air quality criterion assessed BUT concentrations of mercury approaching the criterion should emissions controls not be included.

Emissions controls will be included as part of the crematorium operation and therefore, in-stack emission limits are demonstrated to be achieved and ambient air quality criteria demonstrated to easily meet the relevant criteria. In addition, regular or continuous monitoring of several parameters should be performed to ensure that the cremators are operating in accordance with manufacturer's recommendations.

The emissions control proposed is a dry scrubber/filtration unit which is Best Available Technology, as described in Section 3.3 and Section 5.2.

With regard to ongoing monitoring, the monitoring requirements of (DEFRA, 2012) for abated cremators would be adhered to which are outlined in full in Appendix A and summarised below in Table 19 and Table 20.

It is considered that monitoring to this standard would ensure that emissions are kept at or below those assumed within this AQIA.

Table 19 Ongoing monitoring requirements - pollutants

Substance	Concentration limits	Type of monitoring	Monitoring frequency
Mercury	50 micrograms·m^{-3}	Periodic monitoring	Annual
Hydrogen chloride (excluding particulate matter)	30 mg·m^{-3} hourly average	Periodic monitoring	Annual
Total particulate matter	20 mg·m^{-3} hourly average	Filter leak monitor • Provide visual alarms and record levels and alarms • Set reference levels on commissioning (i.e. set levels at which alarms will activate) Plus • Instrument health check - i.e. service according to manufacturer's instructions Plus Periodic monitoring • Set reference levels for continuous emission monitor (CEM) (i.e. set levels at which alarms will activate)	Continuous Plus Annual Plus Every 3 years
Carbon monoxide	• 100 mg·m^{-3} reported as 2 x 30-minute averages	Qualitative monitoring • Record data at 15 second intervals or less • Provide visual alarms and record alarm events Plus Periodic test • Validation of continuous emissions monitor (CEM) output through comparison with periodic test results	Continuous Plus Annual
Organic compounds (excluding particulate matter) expressed as carbon	20 mg·m^{-3} averaged over an hour of cremation	Periodic monitoring	Annual

Substance	Concentration limits	Type of monitoring	Monitoring frequency
PCDD/DF	0.1 nanogram·m^{-3} as I-TEQ	Periodic monitoring • Continuous monitoring of any temperature, oxygen and flow parameters that apply during the dioxin tests should be required by the permit • Interlock to prevent cremator loading unless those parameters are met	Upon commissioning of new or replacement cremators
Particulate matter	50 mg·m^{-3} with no correction for oxygen concentration or water vapour	Gross filter failure detection	Testing at commissioning

Note: 'Periodic monitoring' should be determined with Council and EPA, and may consider the UK Environment Agency monitoring guidance M2, which advises that "*the choice of a suitable averaging period is strongly influenced by the expected short-term variability in emission levels and whether peaks are important*". Also "*the averaging time for manual techniques is often constrained by the need for a sampling run of appropriate duration ... because manual techniques have an associated analytical end-method stage (e.g. weighing of particulate samples) for which a sufficient mass of pollutant must be sampled to achieve an adequate limit of detection (LOD)...*". For these reasons, regulators are advised to ensure that those undertaking monitoring liaise with the relevant analytical laboratory to determine the detection limit of the analytical method in order to obtain an estimate of the expected concentration of the monitored substance in the stack gas and calculate the sampling time required to ensure that the LOD of the sampling method is met. In any case it is not expected that the duration of sampling runs will be less than 30 minutes or longer than 8 hours

Table 20 Ongoing monitoring requirements – operational parameters

Parameter	Combustion Provision	Type of monitoring	Monitoring frequency
Temperature	• Minimum of 1073 K (800°C) in the secondary combustion chamber • Minimum of 1123 K (850°C) in the secondary combustion chamber when operating under emergency conditions without abatement measuring point should be at the last measuring thermocouple	• Measure at the exit of the secondary combustion zone (measuring point should be at the last measuring thermocouple) • Automatically record temperatures • Visual alarm when temperature falls below 1073 K (800°C) • Record alarm activations • Interlock to prevent cremator loading below 800°C	Continuous
Residence time	2 seconds residence time (minimum) in the secondary combustion chamber without correction for temperature, oxygen or water vapour	Measurement and calculation of the volume rate of the flue gases throughout the cremation cycle at the cremator exit.	Upon commissioning of new or replacement cremators
Oxygen	At the end of the secondary combustion chamber: • measured wet or dry, minimum average 6% and minimum 3%	• Record of concentration at outlet of secondary combustion zone · • Visual alarm and record activations • During discontinuous tests, continuous reference oxygen measurements should be at the same sampling location as the parameters tested	Continuous

8. CONCLUSION

Catholic Metropolitan Cemeteries Trust has engaged Northstar Air Quality Pty Ltd to perform an air quality impact assessment (AQIA) for a proposed cemetery and crematorium to be located at 13-15 Park Road, Wallacia NSW (the Proposal site).

The AQIA presents an assessment of the impacts of the proposed operation of two cremators at the Proposal site. To ensure that an assessment of potential worst-case (i.e. maximum cremation rate) has been considered in conjunction with potential worst-case weather conditions, an assumption that both cremators would be operational for the period 6 am to 6 pm daily has been adopted. Although highly conservative, the assessment has been presented to provide confidence that the operations can be performed with no exceedances of the relevant air quality criteria.

Legislation, regulation and guidance relating to air quality resulting from the operation of crematoria fall into two categories;

- In-stack emission limits: limits on the emission of pollutants at the point of emission; and,
- Ambient air quality criteria: standards and goals associated with the impact of those emissions within the wider environment.

The impacts of the crematorium operation on both aspects have been assessed.

Compliance with the in-stack emission limits and ambient air quality criteria is not necessarily sufficient to meet the requirements of the *Protection of the Environment (Operations)* (POEO) *Act* (1997) which provides requirements that the occupiers of any premises must perform any activity, or operate any plant to prevent or minimise air pollution, including odour.

Emissions controls will be included as part of the crematorium operation which would constitute a dry scrubber/filtration unit which is Best Available Technology and result in at least 90% reduction in a number of pollutant emissions, including mercury.

8.1 In-stack Emission Limits

A review of NSW, Australian and UK legislation and guidance has been performed, with the most stringent in-stack emission limits across all jurisdictions adopted for this assessment.

Potential exceedances of the in-stack criteria (for mercury and dioxins and furans) are predicted without the inclusion of emission control.

However, with the inclusion of proposed emissions controls no exceedances of those criteria are predicted.

8.2 Ambient Air Quality Criteria

The results of the assessment of the potential impacts of the Proposal site operation upon the surrounding environment indicate that even without the inclusion of emissions controls, all air quality criteria adopted are predicted to be achieved.

Even with the inclusion of existing (background) air quality data, achievement of all relevant criteria is predicted.

The predictions presented cover the area of maximum predicted impact, being Davenport Drive, Wallacia.

8.3 Mitigation and Monitoring

The assessment indicates that the inclusion of mitigation measures is not necessarily required to meet the ambient air quality criteria. However, it is stressed that the POEO Act (1997) requires the inclusion of these controls. Detail is provided within the report as to the method for emission control, how this meets best practice and any ongoing monitoring requirements to ensure the ongoing efficacy of those control measures.

The results of the air quality impact assessment indicate that the granting of Development Consent for the Proposal should not be rejected on the grounds of air quality.

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APPENDIX A

In-Stack Emission Limits

Table A1 Unabated cremators – emission limits, monitoring and other provisions (DEFRA, 2012)

Row	Substance	Mass emission limits per cremator (Note 1 & Note 3)	Concentration limits (Note 3)	Type of monitoring	Monitoring frequency
1	Hydrogen chloride (excluding particulate matter)	300 g an hour	200 mg·m^{-3} averaged over an hour	Periodic monitoring	Annual
2	Total particulate matter from cremator (Note 2)	• 120 g an hour for 95% of cremations; and • 240 g an hour for all cremations	• 80 mg·m^{-3} averaged over an hour for 95% of cremations; and • 160 mg·m^{-3} averaged over an hour for all cremations	Qualitative monitoring (Note 2) • Provide visual alarms and record levels and alarms Plus • Instrument health check - i.e. a service according to manufacturer's instructions Plus Periodic monitoring • Use results to set reference levels for continuous emissions monitor (CEM) i.e. configure outputs and set reference levels at which alarms will activate	Continuous Plus Annual Plus Annual
3	Carbon monoxide	• 150 g in the first hour of cremation for 95% of cremations; and • 300 g in the first hour of cremation for all cremations	• 100 mg·m^{-3} averaged over the first hour for 95% of cremations; and • 200 mg·m^{-3} averaged over the first hour for all cremations	Qualitative monitoring • Record data at 15 second intervals or less • Provide visual alarms and record alarm events Plus Instrument health check - i.e. service according to manufacturer's instructions	Continuous Plus Annual

Row	Substance	Mass emission limits per cremator (Note 1 & Note 3)	Concentration limits (Note 3)	Type of monitoring	Monitoring frequency
				Plus Periodic monitoring • Validation of continuous emissions monitor (CEM) output through comparison with periodic test results	Plus Annual
4	Organic compounds (excluding particulate matter) expressed as carbon	30 g an hour	20 mg·m^{-3} averaged over an hour of cremation	Periodic monitoring	Annual
If the combustion provisions in Rows 7 - 9 are not met, then the dioxin emission limit and monitoring provision in Row 5 should be applied					
5	PCDD/F	4.5 micrograms as ITEQ per 3 cremations (minimum sampling period 6 hours)	1 nanogram·m^{-3} as ITEQ	Periodic monitoring • Continuous monitoring of any temperature, oxygen and flow parameters that apply during the dioxin tests should be required by the permit • Interlock to prevent cremator loading unless those parameters are met	Upon commissioning of new or replacement cremators
Concentration limits from cremated remains reduction plant (cremulators) venting externally are given in Row 6					
6	Particulate matter	n/a	50 mg·m^{-3} with no correction for oxygen concentration or water vapour	Gross filter failure detection • Instrument health check - i.e. service according to manufacturer's instructions	Testing at commissioning Service interval as specified by

Row	Substance	Mass emission limits per cremator (Note 1 & Note 3)	Concentration limits (Note 3)	Type of monitoring	Monitoring frequency
					manufacturer
If the combustion provisions in Rows 7 - 9 are not met, then the dioxin emission limit and monitoring provision in Row 5 should be applied					

Row	Parameter	Combustion Provision	Type of monitoring	Monitoring frequency
7	Temperature	Minimum of 1123 K (850°C)	• Measure at the exit of the secondary combustion zone (measuring point should be at the last measuring thermocouple) • Automatically record temperatures • Visual alarm when temperature falls below 1123K • Record alarm activations • Interlock to prevent cremator loading to operate when temperature and combustion provisions in Rows 7 – 9 are not met	Continuous
8	Residence time	2 seconds residence time (minimum) in the secondary combustion chamber without correction for temperature, oxygen or water vapour	Measurement and calculation of the volume rate of the flue gases throughout the cremation cycle at the cremator exit.	Upon commissioning of new or replacement cremators
9	Oxygen	At the end of the secondary combustion chamber: ·	• Monitor and record of concentration at outlet of secondary combustion zone · • Visual alarm and record activations ·	Continuous

Row	Parameter	Combustion Provision	Type of monitoring	Monitoring frequency
		• measured wet or dry, minimum average 6% and minimum 3%	• During discontinuous tests, continuous reference oxygen measurements should be at the same sampling location as the parameters tested	

Note 1 - the mass of emissions per hour are calculated from the measured values from 2 minutes to 62 minutes after the close of coffin loading.

Note 2 - in this table, the term "qualitative" monitoring refers to those particulate continuous emissions monitors (CEM) where the instrument response should be correlated to the results of multiple isokinetic gravimetric samples according to the standard reference method (SRM) which is typically EN-13284-1.

Note 3 – for unabated cremators, the operator chooses whether the mass or the concentration limits apply and the Regulator should then specify those limits in the permit. When calculating mass emissions, the cremator should multiply the flow rate at that moment by the concentration at that moment.

Table A2 Abated cremators – emission limits, monitoring and other provisions (DEFRA, 2012)

Row	Substance	Mass emission limits per cremator	Concentration limits	Type of monitoring	Monitoring frequency
1	Mercury	n/a	50 micrograms·m^{-3}	Periodic monitoring (Note 1)	Annual
2	Hydrogen chloride (excluding particulate matter)	n/a	30 mg·m^{-3} hourly average	Periodic monitoring	Annual
3	Total particulate matter	n/a	20 mg·m^{-3} hourly average	Filter leak monitor • Provide visual alarms and record levels and alarms • Set reference levels on commissioning (i.e. set levels at which alarms will activate) Plus • Instrument health check - i.e. service according to manufacturer's instructions Plus Periodic monitoring • Set reference levels for continuous emission monitor (CEM) (i.e. set levels at which alarms will activate)	Continuous Plus Annual Plus Every 3 years
For abated crematoria with a "multiple cremators/single abatement plant" configuration, the provisions of Row 4a apply. For abated crematoria with a "single cremator/single abatement plant" configuration, the provisions of either Row 4a OR Row 4b can apply but should be specified to the regulator at the earliest opportunity.					

Row	Substance	Mass emission limits per cremator	Concentration limits	Type of monitoring	Monitoring frequency
4a	Carbon monoxide	n/a	• 100 $mg{\cdot}m^{-3}$ reported as 2 x 30-minute averages	Qualitative monitoring • Record data at 15 second intervals or less • Provide visual alarms and record alarm events Plus Periodic test • Validation of continuous emissions monitor (CEM) output through comparison with periodic test results	Continuous Plus Annual
4b	Carbon monoxide	• 150 g in the first hour of cremation for 95% of cremations; and • 300 g in the first hour of cremation for all cremations	n/a	Qualitative monitoring • Record data at 15 second intervals or less • Provide visual alarms and record alarm events Plus Instrument health check - i.e. service according to manufacturer's instructions Plus Periodic monitoring • Validation of continuous emissions monitor (CEM) output through comparison with periodic test results	Continuous Plus Annual Plus Annual

Row	Substance	Mass emission limits per cremator	Concentration limits	Type of monitoring	Monitoring frequency
5	Organic compounds (excluding particulate matter) expressed as carbon	n/a	20 mg·m^{-3} averaged over an hour of cremation	Periodic monitoring	Annual
If the combustion provisions in Rows 8 - 10 are *not* met, then the dioxin emission limit and monitoring provision in Row 6 should be applied					
6	PCDD/F	n/a	0.1 nanogram·m^{-3} as ITEQ	Periodic monitoring • Continuous monitoring of any temperature, oxygen and flow parameters that apply during the dioxin tests should be required by the permit • Interlock to prevent cremator loading unless those parameters are met	Upon commissioning of new or replacement cremators
Concentration limits from cremated remains reduction plant (cremulators) venting externally are given in Row 7					
7	Particulate matter	n/a	50 mg·m^{-3} with no correction for oxygen concentration or water vapour	Gross filter failure detection	Testing at commissioning
If the combustion provisions in Rows 8 - 10 are *not* met, then the dioxin emission limit and monitoring provision in Row 6 should be applied					

Row	Parameter	Combustion Provision	Type of monitoring	Monitoring frequency
8	Temperature	• Minimum of 1073 K (800°C) in the secondary combustion chamber • Minimum of 1123K (850°C) in the secondary combustion chamber when operating under emergency conditions without abatement measuring point should be at the last measuring thermocouple	• Measure at the exit of the secondary combustion zone (measuring point should be at the last measuring thermocouple) • Automatically record temperatures • Visual alarm when temperature falls below 1073K (800°C) • Record alarm activations • Interlock to prevent cremator loading below 800°C	Continuous
9	Residence time	2 seconds residence time (minimum) in the secondary combustion chamber without correction for temperature, oxygen or water vapour	Measurement and calculation of the volume rate of the flue gases throughout the cremation cycle at the cremator exit.	Upon commissioning of new or replacement cremators
10	Oxygen	At the end of the secondary combustion chamber: · • measured wet or dry, minimum average 6% and minimum 3%	• Record of concentration at outlet of secondary combustion zone · • Visual alarm and record activations · • During discontinuous tests, continuous reference oxygen measurements should be at the same sampling location as the parameters tested	Continuous

Note 1 – the Environment Agency monitoring guidance, M2, advises that "the choice of a suitable averaging period is strongly influenced by the expected short-term variability in emission levels and whether peaks are important". Also "the averaging time for manual techniques is often constrained by the need for a sampling run of appropriate duration … because manual techniques have an associated analytical end-method stage (e.g. weighing of particulate samples) for which a sufficient mass of pollutant must be sampled to achieve an adequate limit of detection (LOD)… ". For these reasons, regulators are advised to ensure that those undertaking monitoring liaise with the relevant analytical laboratory to determine the detection limit of the analytical method in order to obtain an estimate of the expected concentration of the monitored substance in the stack gas and calculate the sampling time required to ensure that the LOD of the sampling method is met. In any case it is not expected that the duration of sampling runs will be less than 30 minutes or longer than 8 hours

APPENDIX B

Meteorological Data Analysis

A summary of the relevant monitoring sites is provided in Table B1.

Table B1 Details of the meteorological monitoring surrounding the project site

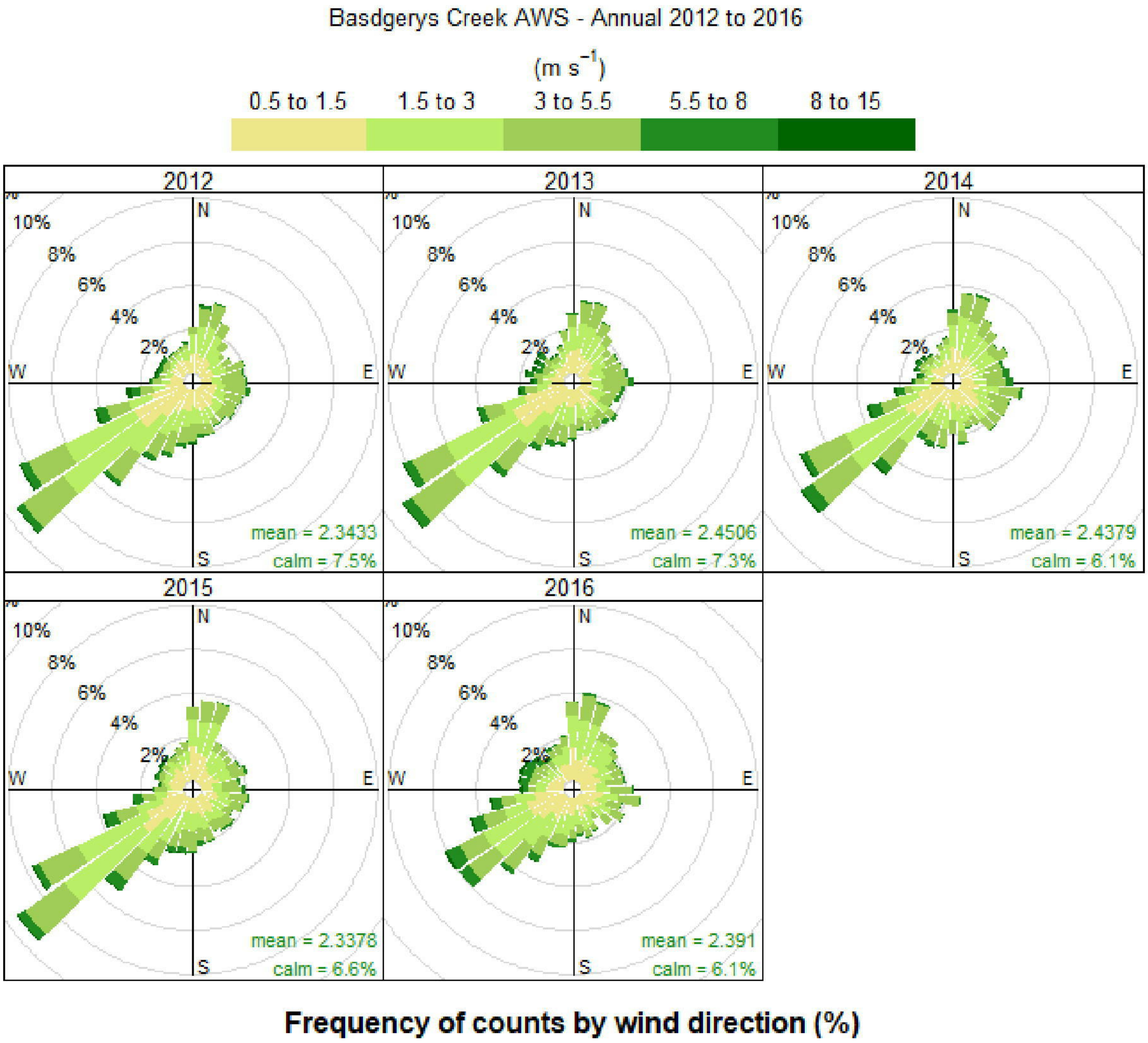
Site Name	Approximate Location (Latitude, Longitude)	
	˚S	˚E
Badgerys Creek AWS – Station # 67108	33.90	150.72

Meteorological conditions at Badgerys Creek AWS have been examined to determine a 'typical' or representative dataset for use in dispersion modelling. Annual wind roses for the most recent years of data (2012 to 2016) are presented in Figure B1.

The wind roses indicate that from 2012 to 2016, winds at Badgerys Creek AWS show a predominant south-westerly wind direction with a northerly component also evident.

The majority of wind speeds experienced at the Badgerys Creek AWS between 2012 and 2016 are generally in the range 0.5 metres per second ($m \cdot s^{-1}$) to 3.0 $m \cdot s^{-1}$ with the highest wind speeds (greater than 8 $m \cdot s^{-1}$) occurring from a south westerly direction. Winds of this speed are rare and occur during 1.1% of the observed hours during the years. Calm winds (< 0.5 $m \cdot s^{-1}$) occur for less than 7.5% of hours across the years.

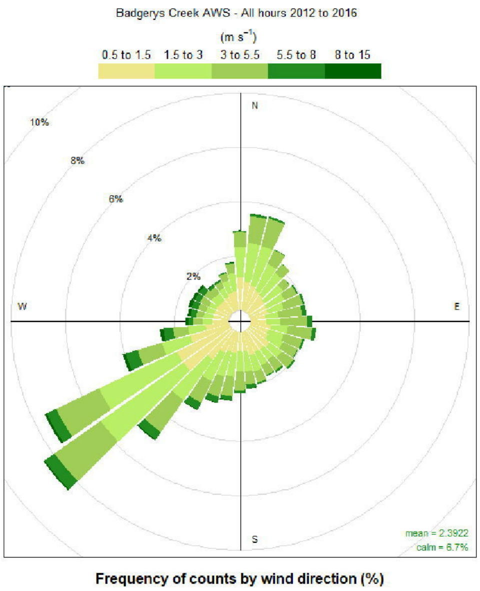
Figure B1 Annual wind roses 2012 to 2016, Badgerys Creek AWS



The distribution of winds in year 2016 was considered to be slightly atypical when compared to the previous years (2012-2015), and 2015 was selected as the most recent year with a broadly typical profile. Presented in **Figure B2** are the annual wind rose for the 2012 to 2016 period and the year 2015 and in **Figure B3** the annual wind speed distribution for Badgerys Creek AWS. These figures indicate that the distribution of wind speed and direction in 2015 is very similar to that experienced across the longer-term period.

It is concluded that conditions in 2015 may be considered to provide a suitably representative dataset for use in dispersion modelling.

Figure B2 Annual wind roses 2012 to 2016, and 2015 Badgerys Creek AWS



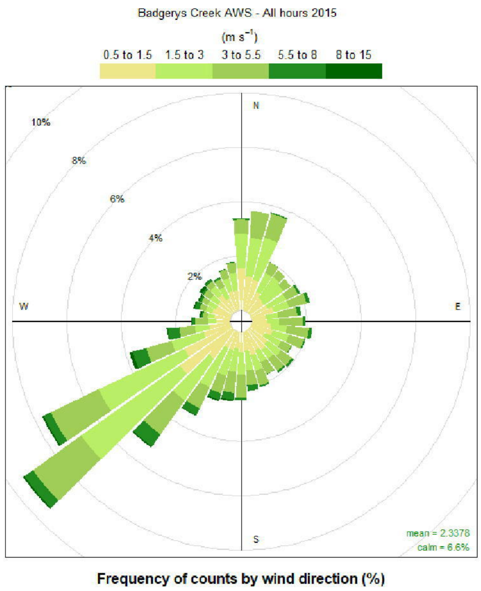
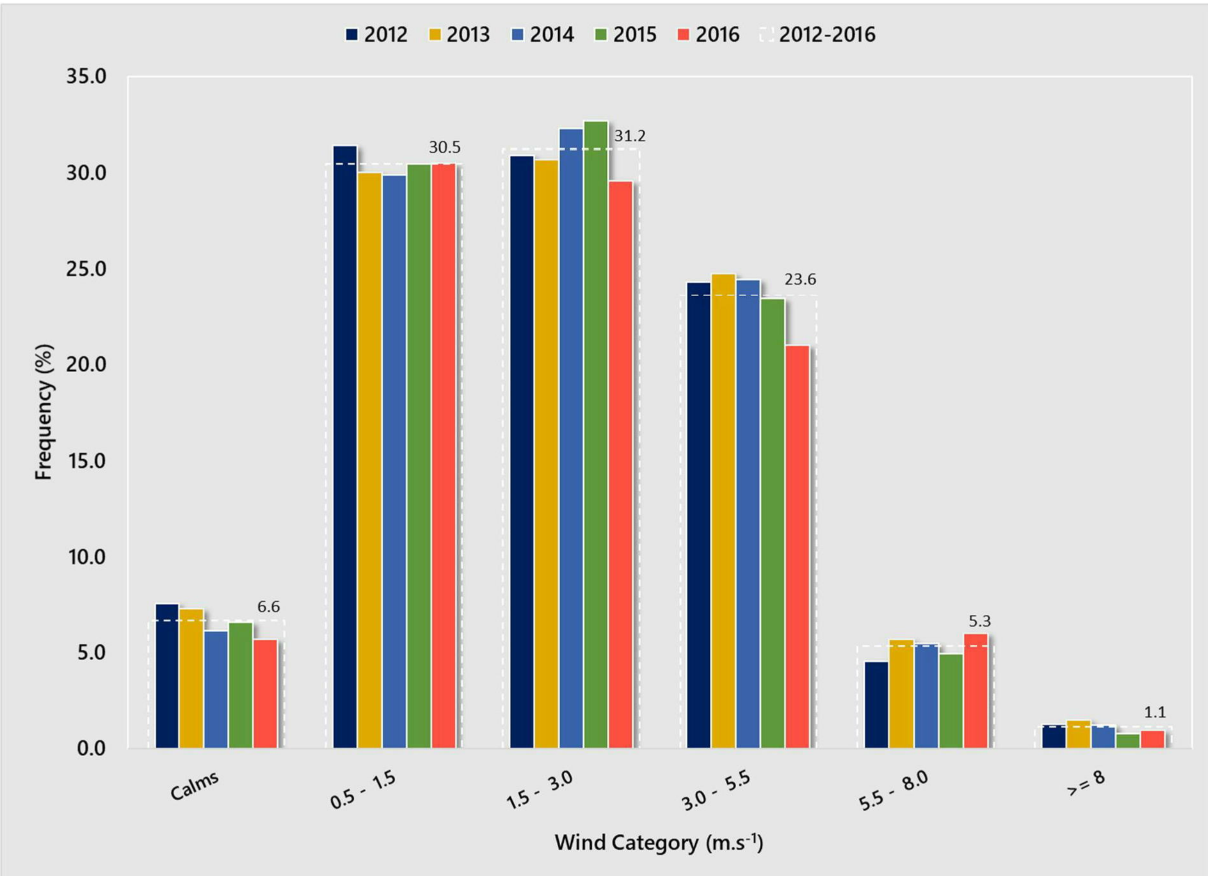


Figure B3 Annual wind speed distribution Badgerys Creek AWS



Meteorological Processing

The BoM data adequately covers the issues of data quality assurance, however it is limited by its location compared to the project site. To address these uncertainties, a multi-phased assessment of the meteorological data has been performed.

In absence of any measured onsite meteorological data, site representative meteorological data for this project was generated using the TAPM meteorological model in a format suitable for using in the CALPUFF dispersion model (refer **Section 5.1**).

Meteorological modelling using The Air Pollution Model (TAPM, v 4.0.5) has been performed to predict the meteorological parameters required for CALPUFF. TAPM, developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) is a prognostic model which may be used to predict three-dimensional meteorological data and air pollution concentrations.

TAPM predicts wind speed and direction, temperature, pressure, water vapour, cloud, rain water and turbulence. The program allows the user to generate synthetic observations by referencing databases (covering terrain, vegetation and soil type, sea surface temperature and synoptic scale meteorological analyses) which are subsequently used in the model input to generate site-specific hourly meteorological observations at user-defined levels within the atmosphere.

CALMET is a meteorological model that develops wind and temperature fields on a three-dimensional gridded modelling domain. Associated two-dimensional fields such as mixing height, surface characteristics, and dispersion properties are also included in the file produced by CALMET. The interpolated wind field is then modified within the model to account for the influences of topography, as well as differential heating and surface roughness associated with different land uses across the modelling domain. These modifications are applied to the winds at each grid point to develop a final wind field and thus the final wind field reflects the influences of local topography and current land uses.

The parameters used in TAPM and CALMET modelling are presented in **Table B2** .

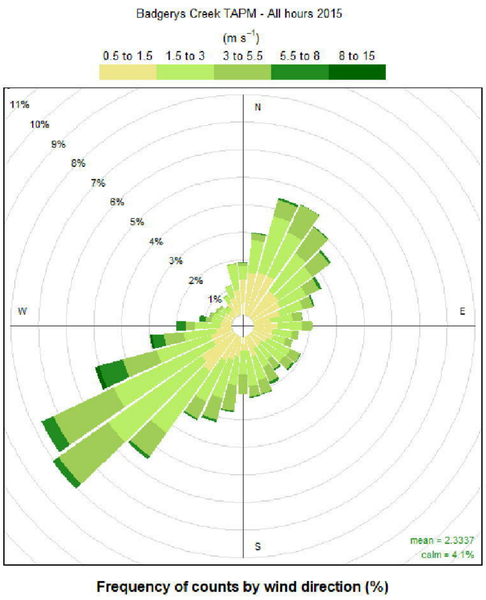
Table B2 Meteorological parameters used for this study (TAPM v 4.0.5)

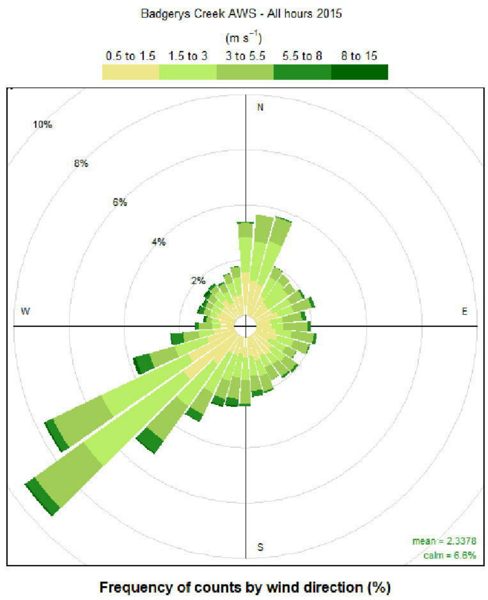
TAPM v 4.0.5	
Modelling period	1 January 2015 to 31 December 2015
Centre of analysis	282,904 mE, 6,250,188 mN (UTM Coordinates)
Number of grid points	40 × 40 × 25
Number of grids (spacing)	4 (30 km, 10 km, 3 km, 1 km)
Terrain	AUSLIG 9 second DEM
Data assimilation	-
CALMET	
Modelling period	1 January 2015 to 31 December 2015
Centre of analysis	282,904 mE, 6,250,188 mN (UTM Coordinates)
Meteorological grid domain (resolution)	0.1 km x 100 x 100
Vertical resolution (cell heights)	10 (0 m, 20 m, 40 m, 80 m, 160 m, 320 m, 640 m, 1200 m, 2000 m, 3000 m, 4000 m)
Data assimilation	No-obs approach using TAPM – 3D.DAT file

A comparison of the TAPM generated meteorological data, and that observed at the Badgerys Creek AWS is presented in **Figure B4**. These data generally compare well which provides confidence that the meteorological conditions modelled as part of this assessment are appropriate.

Figure B4 Modelled and observed meteorological data – Badgerys Creek AWS, 2015

TAPM generated windrose	Observations at Badgerys Creek AWS



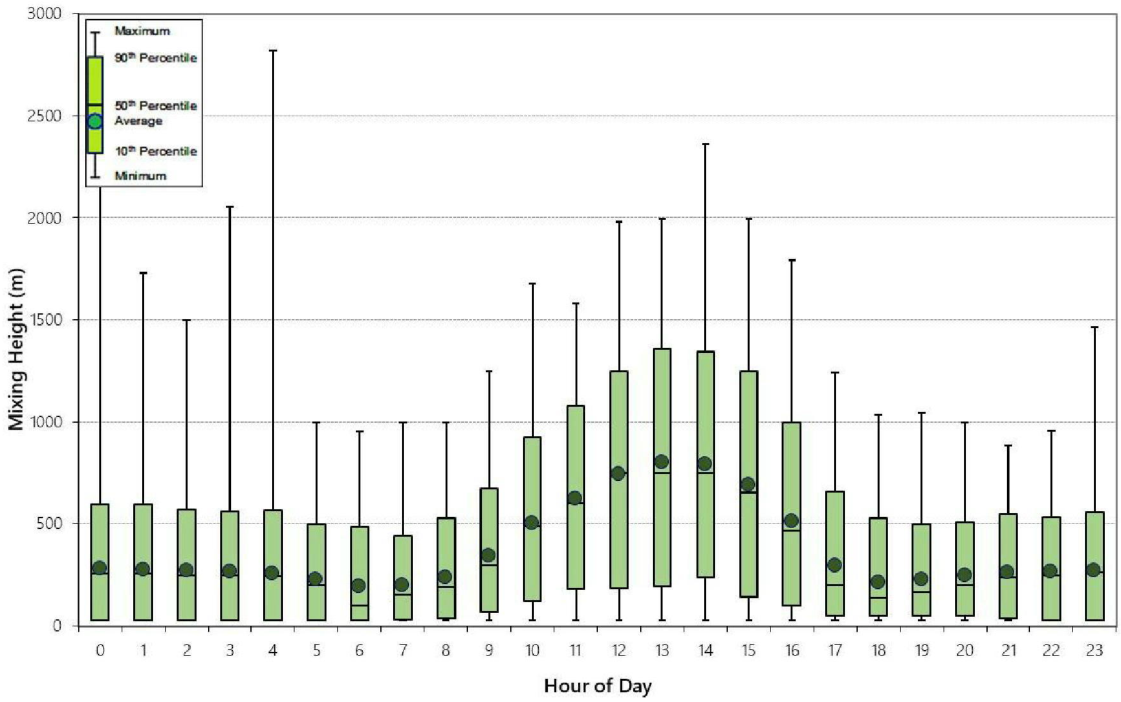


As generally required by the NSW EPA (refer **Section 1.1**) the following provides a summary of the modelled meteorological dataset. Given the nature of the pollutant emission sources at the project site, detailed discussion of the humidity, evaporation, cloud cover, katabatic air drainage and air recirulation potential of the project site has not been provided. Details of the predictions of wind speed and direction, mixing height and temperature at the project site are provided below.

Diurnal variations in maximum and average mixing heights predicted by TAPM at the project site during 2015 period are illustrated in **Figure B5**.

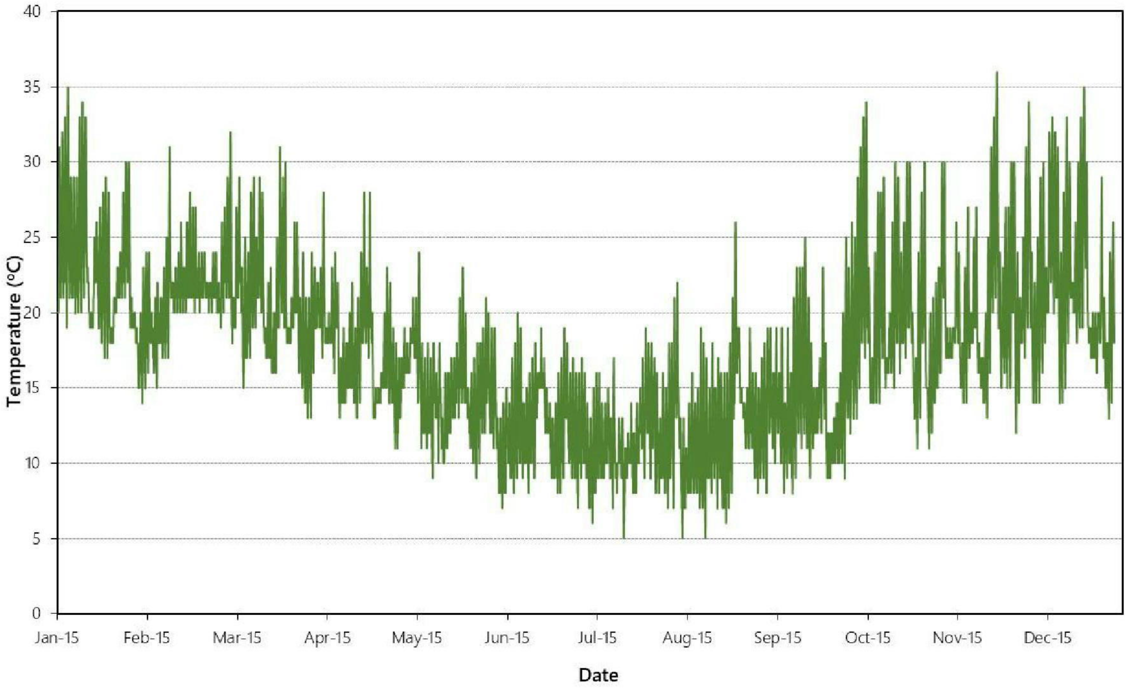
As expected, an increase in mixing height during the morning is apparent, arising due to the onset of vertical mixing following sunrise. Maximum mixing heights occur in the mid to late afternoon, due to the dissipation of ground based temperature inversions and growth of the convective mixing layer.

Figure B5 Predicted mixing height – Proposal site 2015



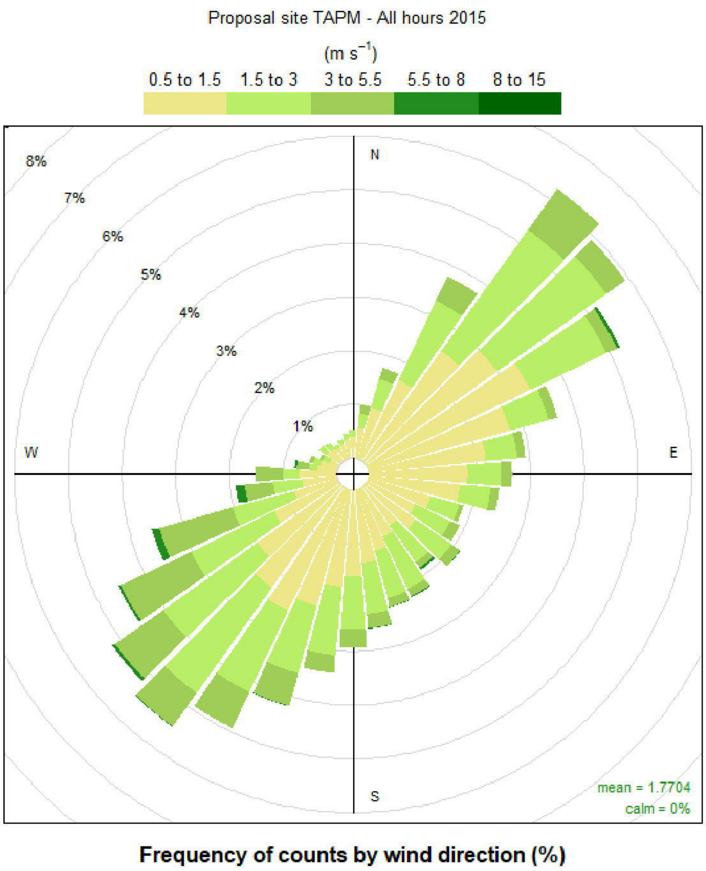
The modelled temperature variations predicted at the project site during 2015 are presented in **Figure B6**. The maximum temperature of 36°C was predicted on 20 November 2015 and the minimum temperature of 5°C was predicted on July and August 2015.

Figure B6 Predicted temperature – Proposal site 2015



The modelled wind speed and direction at the project site during 2015 are presented in **Figure B7**.

Figure B7 Predicted wind speed and direction – project site 2015



APPENDIX C

Dispersion Modelling Results – Increment at Receptors

Table A3 Incremental impacts at Receptors – Principal toxic air pollutants (1 of 2)

	Mercury (organic)	Mercury (inorganic)	Polycyclic aromatic hydrocarbons (PAH) (as benzo[a]pyrene)	TVOC (assessed as benzene)	Arsenic & compounds	Beryllium & compounds	Cadmium & compounds	Chromium III & compounds	Chromium VI & compounds
Ave. Period.	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr
Criterion ($mg \cdot m^{-3}$)	1.80E-04	1.80E-03	4.00E-04	2.90E-02	9.00E-05	4.00E-06	1.80E-05	9.00E-03	9.00E-05
R1	3.32E-06	3.32E-06	5.48E-07	2.15E-03	2.91E-08	1.33E-09	1.08E-08	2.91E-08	1.31E-08
R2	3.99E-06	3.99E-06	6.60E-07	2.59E-03	3.51E-08	1.60E-09	1.30E-08	3.51E-08	1.58E-08
R3	4.90E-06	4.90E-06	8.03E-07	3.15E-03	4.30E-08	1.96E-09	1.59E-08	4.30E-08	1.94E-08
R4	5.44E-06	5.44E-06	8.90E-07	3.49E-03	4.77E-08	2.18E-09	1.77E-08	4.77E-08	2.15E-08
R5	5.50E-06	5.50E-06	9.20E-07	3.61E-03	4.83E-08	2.20E-09	1.79E-08	4.83E-08	2.17E-08
R6	5.23E-06	5.23E-06	8.47E-07	3.32E-03	4.59E-08	2.09E-09	1.70E-08	4.59E-08	2.06E-08
R7	5.25E-06	5.25E-06	8.50E-07	3.33E-03	4.61E-08	2.10E-09	1.70E-08	4.61E-08	2.07E-08
R8	4.64E-06	4.64E-06	7.51E-07	2.95E-03	4.07E-08	1.86E-09	1.51E-08	4.07E-08	1.83E-08
R9	4.33E-06	4.33E-06	7.10E-07	2.79E-03	3.80E-08	1.74E-09	1.41E-08	3.80E-08	1.71E-08
R10	3.76E-06	3.76E-06	6.15E-07	2.41E-03	3.30E-08	1.51E-09	1.22E-08	3.30E-08	1.49E-08
R11	4.05E-06	4.05E-06	6.64E-07	2.60E-03	3.56E-08	1.62E-09	1.32E-08	3.56E-08	1.60E-08
R12	4.35E-06	4.35E-06	7.13E-07	2.80E-03	3.82E-08	1.74E-09	1.41E-08	3.82E-08	1.72E-08
R13	4.46E-06	4.46E-06	7.33E-07	2.87E-03	3.91E-08	1.79E-09	1.45E-08	3.91E-08	1.76E-08
R14	4.55E-06	4.55E-06	7.45E-07	2.92E-03	3.99E-08	1.82E-09	1.48E-08	3.99E-08	1.79E-08
R15	4.71E-06	4.71E-06	7.71E-07	3.02E-03	4.13E-08	1.89E-09	1.53E-08	4.13E-08	1.86E-08
R16	5.49E-06	5.49E-06	9.11E-07	3.57E-03	4.82E-08	2.20E-09	1.78E-08	4.82E-08	2.17E-08
R17	5.78E-06	5.78E-06	9.59E-07	3.76E-03	5.07E-08	2.32E-09	1.88E-08	5.07E-08	2.28E-08
R18	5.67E-06	5.67E-06	9.43E-07	3.70E-03	4.98E-08	2.27E-09	1.84E-08	4.98E-08	2.24E-08
R19	5.66E-06	5.66E-06	9.43E-07	3.70E-03	4.96E-08	2.27E-09	1.84E-08	4.96E-08	2.23E-08

	Mercury (organic)	Mercury (inorganic)	Polycyclic aromatic hydrocarbons (PAH) (as benzo[a]pyrene)	TVOC (assessed as benzene)	Arsenic & compounds	Beryllium & compounds	Cadmium & compounds	Chromium III & compounds	Chromium VI & compounds
Ave. Period.	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr
Criterion (mg·m^{-3})	1.80E-04	1.80E-03	4.00E-04	2.90E-02	9.00E-05	4.00E-06	1.80E-05	9.00E-03	9.00E-05
R20	5.63E-06	5.63E-06	9.40E-07	3.69E-03	4.94E-08	2.26E-09	1.83E-08	4.94E-08	2.22E-08
R21	5.45E-06	5.45E-06	9.08E-07	3.56E-03	4.78E-08	2.18E-09	1.77E-08	4.78E-08	2.15E-08
R22	5.72E-06	5.72E-06	9.55E-07	3.74E-03	5.02E-08	2.29E-09	1.85E-08	5.02E-08	2.26E-08
R23	5.42E-06	5.42E-06	9.05E-07	3.55E-03	4.76E-08	2.17E-09	1.76E-08	4.76E-08	2.14E-08
R24	5.41E-06	5.41E-06	9.04E-07	3.55E-03	4.75E-08	2.17E-09	1.76E-08	4.75E-08	2.14E-08
R25	4.61E-06	4.61E-06	7.69E-07	3.02E-03	4.05E-08	1.85E-09	1.50E-08	4.05E-08	1.82E-08
R26	5.50E-06	5.50E-06	9.22E-07	3.62E-03	4.83E-08	2.21E-09	1.79E-08	4.83E-08	2.17E-08
R27	5.66E-06	5.66E-06	9.41E-07	3.69E-03	4.97E-08	2.27E-09	1.84E-08	4.97E-08	2.24E-08
R28	3.97E-06	3.97E-06	6.59E-07	2.58E-03	3.49E-08	1.59E-09	1.29E-08	3.49E-08	1.57E-08
R29	5.28E-06	5.28E-06	8.84E-07	3.47E-03	4.63E-08	2.11E-09	1.71E-08	4.63E-08	2.08E-08
R30	5.91E-06	5.91E-06	9.88E-07	3.87E-03	5.18E-08	2.37E-09	1.92E-08	5.18E-08	2.33E-08
R31	5.13E-06	5.13E-06	8.58E-07	3.37E-03	4.50E-08	2.05E-09	1.66E-08	4.50E-08	2.02E-08
R32	2.88E-06	2.88E-06	4.83E-07	1.89E-03	2.53E-08	1.15E-09	9.35E-09	2.53E-08	1.14E-08
R33	3.23E-06	3.23E-06	5.38E-07	2.11E-03	2.84E-08	1.29E-09	1.05E-08	2.84E-08	1.28E-08
R34	2.59E-06	2.59E-06	4.30E-07	1.69E-03	2.27E-08	1.04E-09	8.40E-09	2.27E-08	1.02E-08
R35	3.64E-06	3.64E-06	6.07E-07	2.38E-03	3.19E-08	1.46E-09	1.18E-08	3.19E-08	1.44E-08
R36	3.48E-06	3.48E-06	5.81E-07	2.28E-03	3.06E-08	1.40E-09	1.13E-08	3.06E-08	1.38E-08
R37	4.44E-06	4.44E-06	7.44E-07	2.92E-03	3.90E-08	1.78E-09	1.44E-08	3.90E-08	1.75E-08
R38	2.74E-06	2.74E-06	4.63E-07	1.82E-03	2.40E-08	1.10E-09	8.89E-09	2.40E-08	1.08E-08
R39	1.63E-06	1.63E-06	2.71E-07	1.07E-03	1.43E-08	6.54E-10	5.29E-09	1.43E-08	6.44E-09
R40	5.45E-06	5.45E-06	8.69E-07	3.41E-03	4.78E-08	2.18E-09	1.77E-08	4.78E-08	2.15E-08

	Mercury (organic)	Mercury (inorganic)	Polycyclic aromatic hydrocarbons (PAH) (as benzo[a]pyrene)	TVOC (assessed as benzene)	Arsenic & compounds	Beryllium & compounds	Cadmium & compounds	Chromium III & compounds	Chromium VI & compounds
Ave. Period.	**1 hr**	**1 hr**	**1 hr**	**1 hr**	**1 hr**	**1 hr**	**1 hr**	**1 hr**	**1 hr**
Criterion ($mg \cdot m^{-3}$)	**1.80E-04**	**1.80E-03**	**4.00E-04**	**2.90E-02**	**9.00E-05**	**4.00E-06**	**1.80E-05**	**9.00E-03**	**9.00E-05**
R41	5.63E-07	5.63E-07	8.98E-08	3.52E-04	4.94E-09	2.26E-10	1.83E-09	4.94E-09	2.22E-09
R42	1.72E-05	1.72E-05	2.88E-06	1.13E-02	1.51E-07	6.89E-09	5.58E-08	1.51E-07	6.79E-08
R43	1.18E-05	1.18E-05	1.97E-06	7.74E-03	1.03E-07	4.72E-09	3.82E-08	1.03E-07	4.65E-08
R44	1.17E-05	1.17E-05	2.06E-06	8.07E-03	1.02E-07	4.68E-09	3.79E-08	1.02E-07	4.61E-08
Max at boundary	9.50E-06	9.50E-06	1.59E-06	6.24E-03	8.33E-08	3.81E-09	3.08E-08	8.33E-08	3.75E-08

Table A4 Incremental impacts at Receptors – Principal toxic air pollutants (2 of 2)

	Copper & compounds (as copper fumes)	Formaldehyde	Hydrochloric Acid (HCl)	Nickel & compounds	PCDD/DF	Acetaldehyde (assessed for impact upon odour only)	Antimony & compounds	Zinc & compounds (zinc chloride fumes)	Zinc & compounds (zinc oxide fumes)
Ave. Period.	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr
Criterion (mg·m^{-3})	3.70E-03	2.00E-02	1.40E-01	1.80E-04	2.00E-09	4.20E-02	9.00E-03	1.80E-02	9.00E-02
R1	2.66E-08	3.25E-07	6.90E-04	3.70E-08	1.05E-11	1.24E-06	2.93E-08	3.37E-07	3.37E-07
R2	3.20E-08	3.91E-07	8.30E-04	4.46E-08	1.26E-11	1.50E-06	3.53E-08	4.06E-07	4.06E-07
R3	3.92E-08	4.75E-07	1.01E-03	5.47E-08	1.55E-11	1.82E-06	4.33E-08	4.94E-07	4.94E-07
R4	4.35E-08	5.27E-07	1.12E-03	6.07E-08	1.72E-11	2.02E-06	4.81E-08	5.48E-07	5.48E-07
R5	4.40E-08	5.45E-07	1.16E-03	6.14E-08	1.74E-11	2.09E-06	4.86E-08	5.66E-07	5.66E-07
R6	4.18E-08	5.01E-07	1.06E-03	5.83E-08	1.65E-11	1.92E-06	4.62E-08	5.21E-07	5.21E-07
R7	4.20E-08	5.04E-07	1.07E-03	5.86E-08	1.66E-11	1.93E-06	4.64E-08	5.23E-07	5.23E-07
R8	3.71E-08	4.45E-07	9.45E-04	5.18E-08	1.47E-11	1.70E-06	4.10E-08	4.62E-07	4.62E-07
R9	3.46E-08	4.20E-07	8.93E-04	4.83E-08	1.37E-11	1.61E-06	3.83E-08	4.37E-07	4.37E-07
R10	3.01E-08	3.64E-07	7.73E-04	4.20E-08	1.19E-11	1.39E-06	3.33E-08	3.78E-07	3.78E-07
R11	3.24E-08	3.93E-07	8.34E-04	4.52E-08	1.28E-11	1.51E-06	3.58E-08	4.08E-07	4.08E-07
R12	3.48E-08	4.23E-07	8.97E-04	4.86E-08	1.38E-11	1.62E-06	3.85E-08	4.39E-07	4.39E-07
R13	3.57E-08	4.34E-07	9.22E-04	4.98E-08	1.41E-11	1.66E-06	3.94E-08	4.51E-07	4.51E-07
R14	3.64E-08	4.41E-07	9.37E-04	5.07E-08	1.44E-11	1.69E-06	4.02E-08	4.58E-07	4.58E-07
R15	3.77E-08	4.56E-07	9.69E-04	5.26E-08	1.49E-11	1.75E-06	4.16E-08	4.74E-07	4.74E-07
R16	4.39E-08	5.39E-07	1.15E-03	6.13E-08	1.74E-11	2.07E-06	4.85E-08	5.60E-07	5.60E-07
R17	4.62E-08	5.68E-07	1.21E-03	6.45E-08	1.83E-11	2.18E-06	5.11E-08	5.90E-07	5.90E-07
R18	4.54E-08	5.59E-07	1.19E-03	6.33E-08	1.79E-11	2.14E-06	5.01E-08	5.81E-07	5.81E-07
R19	4.53E-08	5.59E-07	1.19E-03	6.31E-08	1.79E-11	2.14E-06	5.00E-08	5.80E-07	5.80E-07
R20	4.50E-08	5.57E-07	1.18E-03	6.28E-08	1.78E-11	2.13E-06	4.98E-08	5.78E-07	5.78E-07
R21	4.36E-08	5.38E-07	1.14E-03	6.09E-08	1.72E-11	2.06E-06	4.82E-08	5.59E-07	5.59E-07

	Copper & compounds (as copper fumes)	Formaldehyde	Hydrochloric Acid (HCl)	Nickel & compounds	PCDD/DF	Acetaldehyde (assessed for impact upon odour only)	Antimony & compounds	Zinc & compounds (zinc chloride fumes)	Zinc & compounds (zinc oxide fumes)
Ave. Period.	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr
Criterion (mg·m^{-3})	3.70E-03	2.00E-02	1.40E-01	1.80E-04	2.00E-09	4.20E-02	9.00E-03	1.80E-02	9.00E-02
R22	4.57E-08	5.65E-07	1.20E-03	6.38E-08	1.81E-11	2.17E-06	5.05E-08	5.87E-07	5.87E-07
R23	4.34E-08	5.36E-07	1.14E-03	6.05E-08	1.71E-11	2.05E-06	4.79E-08	5.57E-07	5.57E-07
R24	4.33E-08	5.36E-07	1.14E-03	6.04E-08	1.71E-11	2.05E-06	4.78E-08	5.57E-07	5.57E-07
R25	3.69E-08	4.55E-07	9.67E-04	5.15E-08	1.46E-11	1.74E-06	4.08E-08	4.73E-07	4.73E-07
R26	4.40E-08	5.46E-07	1.16E-03	6.14E-08	1.74E-11	2.09E-06	4.87E-08	5.67E-07	5.67E-07
R27	4.53E-08	5.58E-07	1.18E-03	6.32E-08	1.79E-11	2.14E-06	5.00E-08	5.79E-07	5.79E-07
R28	3.18E-08	3.90E-07	8.28E-04	4.43E-08	1.26E-11	1.49E-06	3.51E-08	4.05E-07	4.05E-07
R29	4.22E-08	5.24E-07	1.11E-03	5.89E-08	1.67E-11	2.01E-06	4.66E-08	5.44E-07	5.44E-07
R30	4.73E-08	5.85E-07	1.24E-03	6.60E-08	1.87E-11	2.24E-06	5.22E-08	6.08E-07	6.08E-07
R31	4.10E-08	5.08E-07	1.08E-03	5.72E-08	1.62E-11	1.95E-06	4.53E-08	5.28E-07	5.28E-07
R32	2.31E-08	2.86E-07	6.07E-04	3.22E-08	9.11E-12	1.10E-06	2.55E-08	2.97E-07	2.97E-07
R33	2.59E-08	3.19E-07	6.77E-04	3.61E-08	1.02E-11	1.22E-06	2.86E-08	3.31E-07	3.31E-07
R34	2.07E-08	2.55E-07	5.41E-04	2.89E-08	8.18E-12	9.76E-07	2.29E-08	2.65E-07	2.65E-07
R35	2.91E-08	3.59E-07	7.63E-04	4.06E-08	1.15E-11	1.38E-06	3.21E-08	3.73E-07	3.73E-07
R36	2.79E-08	3.44E-07	7.31E-04	3.89E-08	1.10E-11	1.32E-06	3.08E-08	3.58E-07	3.58E-07
R37	3.56E-08	4.41E-07	9.36E-04	4.96E-08	1.40E-11	1.69E-06	3.93E-08	4.58E-07	4.58E-07
R38	2.19E-08	2.74E-07	5.82E-04	3.06E-08	8.66E-12	1.05E-06	2.42E-08	2.85E-07	2.85E-07
R39	1.31E-08	1.61E-07	3.41E-04	1.82E-08	5.16E-12	6.16E-07	1.44E-08	1.67E-07	1.67E-07
R40	4.36E-08	5.15E-07	1.09E-03	6.08E-08	1.72E-11	1.97E-06	4.82E-08	5.35E-07	5.35E-07
R41	4.51E-09	5.32E-08	1.13E-04	6.29E-09	1.78E-12	2.04E-07	4.98E-09	5.53E-08	5.53E-08
R42	1.38E-07	1.71E-06	3.62E-03	1.92E-07	5.44E-11	6.54E-06	1.52E-07	1.77E-06	1.77E-06
R43	9.42E-08	1.17E-06	2.48E-03	1.31E-07	3.72E-11	4.48E-06	1.04E-07	1.21E-06	1.21E-06
R44	9.34E-08	1.22E-06	2.59E-03	1.30E-07	3.69E-11	4.67E-06	1.03E-07	1.27E-06	1.27E-06

	Copper & compounds (as copper fumes)	Formaldehyde	Hydrochloric Acid (HCl)	Nickel & compounds	PCDD/DF	Acetaldehyde (assessed for impact upon odour only)	Antimony & compounds	Zinc & compounds (zinc chloride fumes)	Zinc & compounds (zinc oxide fumes)
Ave. Period.	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr	1 hr
Criterion ($mg{\cdot}m^{-3}$)	3.70E-03	2.00E-02	1.40E-01	1.80E-04	2.00E-09	4.20E-02	9.00E-03	1.80E-02	9.00E-02
Max at boundary	7.60E-08	9.43E-07	2.00E-03	1.06E-07	3.00E-11	3.61E-06	8.39E-08	9.79E-07	9.79E-07

Table A5 Incremental impacts at Receptors – Criteria air pollutants (1 of 2)

	SO_2				CO			NO_2	
Ave. Period.	10min	1hr	24hr	Annual	15min	1hr	8hr	1hr	Annual
Criterion	712	570	228	60	100	30	10	246	62
	µg·m^{-3}				mg·m^{-3}			µg·m^{-3}	
R1	2.2	1.6	0.1	< 0.1	< 0.1	< 0.1	< 0.1	11.0	0.1
R2	2.7	1.9	0.1	< 0.1	< 0.1	< 0.1	< 0.1	13.2	0.1
R3	3.3	2.3	0.1	< 0.1	< 0.1	< 0.1	< 0.1	16.1	0.1
R4	3.6	2.5	0.1	< 0.1	< 0.1	< 0.1	< 0.1	17.9	0.1
R5	3.7	2.6	0.2	< 0.1	< 0.1	< 0.1	< 0.1	18.5	0.1
R6	3.4	2.4	0.2	< 0.1	< 0.1	< 0.1	< 0.1	17.0	0.1
R7	3.5	2.4	0.2	< 0.1	< 0.1	< 0.1	< 0.1	17.1	0.1
R8	3.1	2.1	0.2	< 0.1	< 0.1	< 0.1	< 0.1	15.1	0.1
R9	2.9	2.0	0.2	< 0.1	< 0.1	< 0.1	< 0.1	14.3	0.1
R10	2.5	1.7	0.2	< 0.1	< 0.1	< 0.1	< 0.1	12.3	0.1
R11	2.7	1.9	0.2	< 0.1	< 0.1	< 0.1	< 0.1	13.3	0.1
R12	2.9	2.0	0.2	< 0.1	< 0.1	< 0.1	< 0.1	14.3	0.1
R13	3.0	2.1	0.2	< 0.1	< 0.1	< 0.1	< 0.1	14.7	0.1
R14	3.0	2.1	0.2	< 0.1	< 0.1	< 0.1	< 0.1	15.0	0.1
R15	3.1	2.2	0.2	< 0.1	< 0.1	< 0.1	< 0.1	15.5	0.1
R16	3.7	2.6	0.2	< 0.1	< 0.1	< 0.1	< 0.1	18.3	0.1
R17	3.9	2.7	0.3	< 0.1	< 0.1	< 0.1	< 0.1	19.3	0.1
R18	3.8	2.7	0.3	< 0.1	< 0.1	< 0.1	< 0.1	18.9	0.1
R19	3.8	2.7	0.3	< 0.1	< 0.1	< 0.1	< 0.1	18.9	0.1
R20	3.8	2.7	0.3	< 0.1	< 0.1	< 0.1	< 0.1	18.9	0.1
R21	3.7	2.6	0.3	< 0.1	< 0.1	< 0.1	< 0.1	18.2	0.2
R22	3.9	2.7	0.3	< 0.1	< 0.1	< 0.1	< 0.1	19.2	0.2
R23	3.7	2.6	0.3	< 0.1	< 0.1	< 0.1	< 0.1	18.2	0.2
R24	3.7	2.6	0.2	< 0.1	< 0.1	< 0.1	< 0.1	18.2	0.2

	SO_2				CO			NO_2	
Ave. Period.	10min	1hr	24hr	Annual	15min	1hr	8hr	1hr	Annual
Criterion	712	570	228	60	100	30	10	246	62
	µg·m^{-3}				mg·m^{-3}			µg·m^{-3}	
R25	3.1	2.2	0.3	<0.1	<0.1	<0.1	<0.1	15.4	0.2
R26	3.7	2.6	0.2	<0.1	<0.1	<0.1	<0.1	18.5	0.1
R27	3.8	2.7	0.2	<0.1	<0.1	<0.1	<0.1	18.9	0.0
R28	2.7	1.9	0.1	<0.1	<0.1	<0.1	<0.1	13.2	0.0
R29	3.6	2.5	0.1	<0.1	<0.1	<0.1	<0.1	17.8	0.0
R30	4.0	2.8	0.2	<0.1	<0.1	<0.1	<0.1	19.8	0.0
R31	3.5	2.4	0.4	<0.1	<0.1	<0.1	<0.1	17.2	0.1
R32	2.0	1.4	0.4	<0.1	<0.1	<0.1	<0.1	9.7	0.1
R33	2.2	1.5	0.5	<0.1	<0.1	<0.1	<0.1	10.8	0.2
R34	1.7	1.2	0.4	<0.1	<0.1	<0.1	<0.1	8.6	0.2
R35	2.5	1.7	0.4	<0.1	<0.1	<0.1	<0.1	12.2	0.2
R36	2.4	1.7	0.4	<0.1	<0.1	<0.1	<0.1	11.7	0.2
R37	3.0	2.1	0.3	<0.1	<0.1	<0.1	<0.1	14.9	0.1
R38	1.9	1.3	0.3	<0.1	<0.1	<0.1	<0.1	9.3	0.1
R39	1.1	0.8	0.2	<0.1	<0.1	<0.1	<0.1	5.5	0.1
R40	3.5	2.5	0.1	<0.1	<0.1	<0.1	<0.1	17.5	0.1
R41	0.4	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	1.8	0.0
R42	11.7	8.2	0.6	<0.1	<0.1	<0.1	<0.1	57.9	0.2
R43	8.0	5.6	0.6	<0.1	<0.1	<0.1	<0.1	39.6	0.2
R44	8.4	5.8	0.6	<0.1	<0.1	<0.1	<0.1	41.3	0.2
Max at boundary	6.5	4.5	0.4	<0.1	<0.1	<0.1	<0.1	31.9	0.2

Table A6 Incremental impacts at Receptors – Criteria air pollutants (2 of 2)

	PM_{10}		$PM_{2.5}$		TSP	Dust Dep.n	HF			
Ave. Period.	24hr	Annual	24hr	Annual	Annual	Annual	24hr	7d	30d	90d
Criterion	50	25	25	8	90	2	1.5	0.8	0.4	0.25
	µg·m^{-3}		µg·m^{-3}		µg·m^{-3}	g·m^{-2}·month^{-1}	µg·m^{-3}			
R1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R7	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R8	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R9	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R11	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R13	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R14	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R16	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R17	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R18	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R19	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R20	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R21	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R23	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R24	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

	PM $_{10}$		PM $_{2.5}$		TSP	Dust Dep.n	HF			
Ave. Period.	24hr	Annual	24hr	Annual	Annual	Annual	24hr	7d	30d	90d
Criterion	50	25	25	8	90	2	1.5	0.8	0.4	0.25
	$\mu g \cdot m^{-3}$		$\mu g \cdot m^{-3}$		$\mu g \cdot m^{-3}$	$g \cdot m^{-2} \cdot month^{-1}$	$\mu g \cdot m^{-3}$			
R25	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R26	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R27	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R28	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R29	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R31	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R32	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R33	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R34	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R35	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R36	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R37	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R38	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R39	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R40	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R41	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R42	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R43	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
R44	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Max at boundary	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1