

# **Application for a Variation to Environmental Permit AP3136UA**

Supporting Information for Introduction of a Reliquefaction Plant

Dragon LNG Limited

24 July 2015

Final

9Y1920/ AP3136AU/RP/Variation





**HASKONINGDHV UK LIMITED  
INDUSTRY, ENERGY & MINING**

9th Floor, Manchester One  
Portland Street  
Manchester M1 3LF  
United Kingdom  
+44 161 236 1018 Telephone  
+44 161 236 1014 Fax  
info@manchester.royalhaskoning.com E-mail  
www.royalhaskoningdhv.com Internet

Document title Application for a Variation to Environmental Permit AP3136UA  
Supporting Information for Introduction of Reliquefaction Plant  
Document short title Permit Variation Supporting Information  
Status V2 Final  
Date 24 July 2015  
Project name Reliquefaction Plant Project  
Project number 9Y1920  
Client Dragon LNG Limited  
Reference 9Y1920/AP3136AU/RP/Variation

Drafted by John Drabble, Royal HaskoningDHV  
Checked by Paul Howells, Dragon LNG Limited  
Date/initials check .....  
Approved by John Drabble, Royal HaskoningDHV  
Date/initials approval .....

## CONTENTS

	Page
NON TECHNICAL SUMMARY	1
1 ACTIVITIES BEING APPLIED TO VARY	6
1.1 Reliquefaction Plant	6
1.2 Water Discharge Variations	6
1.3 Pre-Application Consultation	6
1.4 Substantial Change Consideration	6
2 EMISSIONS TO AIR, WATER AND LAND	12
2.1 Reliquefaction Plant	12
2.2 Water Discharge Variations	13
3 OPERATING TECHNIQUES	16
3.1 Reliquefaction Plant	16
3.2 Water Discharge Variations	21
4 MONITORING	22
4.1 Reliquefaction Plant	22
4.2 Water Discharge Variations	22
5 ENVIRONMENTAL IMPACT ASSESSMENT	23
5.1 Air Emissions Impact Assessment	23
5.2 Noise Emissions Impact Assessment	24
5.3 Water Discharges Impact Assessment	24
6 RESOURCE EFFICIENCY	25
APPENDIX I	27
Table A1 AGI Pond Effluent Sampling Summary April – September 2014	28
Table A2 Effluent Pond Water Sampling Analytical Methods	29
Figure A2 AGI Pond Effluent Sampling Position E1	30
APPENDIX II	31
ATMOSPHERIC DISPERSION MODELLING REPORT	31
APPENDIX III	32
NOISE IMPACT ASSESSMENT REPORT	32
APPENDIX IV	33
H1 ASSESSMENT	33

## NON TECHNICAL SUMMARY

This application to Natural Resources Wales (NRW) seeks to vary the Environmental Permit reference AP3136AU, originally granted to Dragon LNG Limited, Waterston, Milford Haven, Pembrokeshire SA73 1DR, on 10 December 2007.

The main purpose of the activities regulated under this existing Permit at the Waterson facility is to offload marine vessels of Liquefied Natural Gas (LNG), store the LNG and on demand to convert the liquid to a gaseous form for onward transmission in the UK gas pipeline network. The present Dragon LNG Terminal features two LNG storage tanks, which each are capable of accommodating approximately 160,000m<sup>3</sup> of LNG. The facility is a critical part of the UK energy supply infrastructure, being a major import point for gas received as a cryogenic liquid by marine tanker from suppliers around the world.

The equipment at the facility can be summarised as

- LNG Storage Tanks (each maximum capacity 165,000m<sup>3</sup>)
- Gas Turbines (each 20.1MW thermal input)
- Waste Heat Boilers (each 29.4MW thermal input)
- 1 Condensing Steam Turbine (20MW electrical power input)
- Submerged Combustion Vaporisers (28MW thermal input each)
- Common collection basin for recirculation of water from the submerged combustion vaporisers
- Stack Heat Recovery Unit
- Boiler Feed Water De-aerator
- 1 Emergency Flare

Dragon LNG Limited proposes to install a new process unit to reliquefy gas which evaporates from the two existing LNG storage tanks. The gas is presently burned on a gas turbine power plant or injected into the outlet pipeline from the LNG Terminal.

Gas send-out demand from the terminal varies throughout the year depending on several factors including weather conditions, price competitiveness and input into the gas national transmission system from other sources of gas supply. As a result of variation in demand the terminal operates between two extremes of maximum gas send-out to zero gas send-out. In the case of zero send-out the LNG storage tanks are subject to heat gain from the surroundings and there is a small but finite evaporation of the LNG from the tanks, referred to as 'boil-off gas'. It is necessary to have a means of managing the gas which evaporates in order to maintain the appropriate level of pressure within the tanks and avoid venting to atmosphere.

LNG evaporation also increases when LNG is being offloaded from marine tanker vessels but this is already managed within the present operating procedure, and LNG is not offloaded during zero send-out periods.

The present method to usefully recover energy within the gas evaporating from the storage tanks gas is to burn it on a small gas turbine combined heat and power plant (the 'Cogen Plant') and provide electrical power and process heating. Alternatively, if the Cogen plant is not available then the gas can be burned on the flare, or in extreme situations it can be vented from the LNG tank pressure relief valves; however, both the flaring and venting alternatives are undesirable from an environmental and economic perspective and are an occasional and unfavoured option.

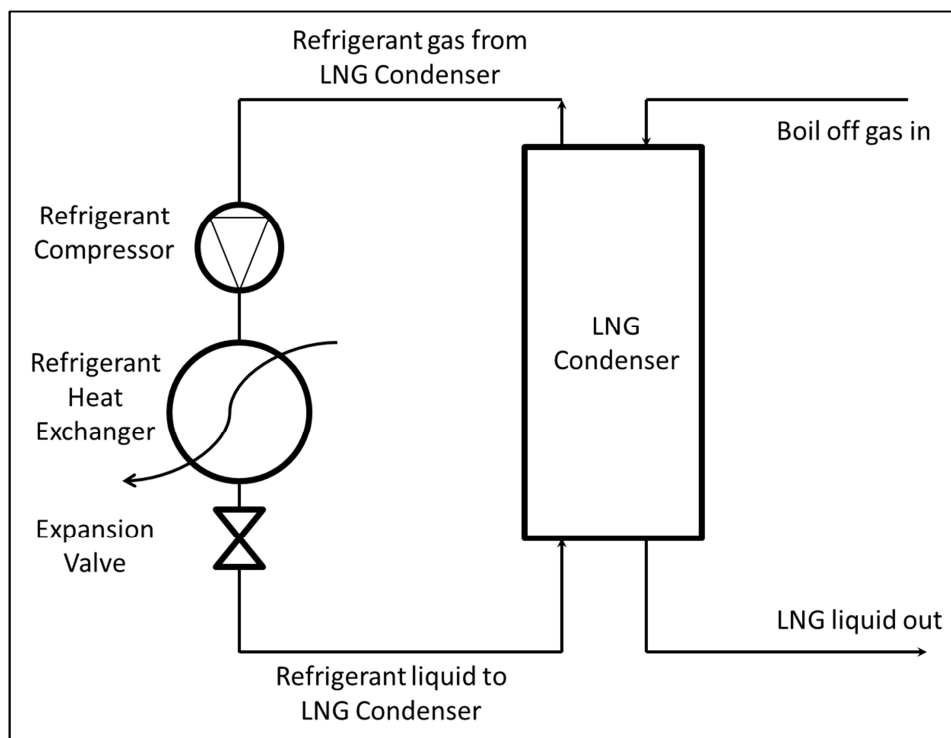
The case of zero send-out places limitations on the Cogen Plant and at times it is not possible to achieve economical operation when there is no requirement for process heating. Thus, Dragon wishes to install an alternative solution to deal with boil-off gas evaporating from the LNG storage tanks.

### *The Reliquefaction Plant*

As an alternative to consuming gas in the Cogen Plan an option is to reliquefy the gas and return it to the storage tank. This requires a specialised process unit to cool the boil-off gas evaporating from the LNG tanks so that it condenses back to a liquid, which can be pumped back to the storage tanks.

A nitrogen refrigerant will be employed as a heat transfer medium to cool the boil-off gas to a temperature of approximately  $-162^{\circ}\text{C}$ , where it re-condenses to a liquid, which will then be pumped back into the main LNG tanks. The boil-off gas/LNG condensate circuit and refrigerant circuits will both operate on a closed cycle, thus there will be no emissions to atmosphere.

A diagrammatic representation is shown in Figure 1.



**Figure 1 Boil-Off Gas Reliquefaction Process**

The main attributes and benefits of the Reliquefaction Plant are:

- there will be no gas emissions to atmosphere;
- there will be no emissions to water;
- LNG boil-off gas will be recovered which would otherwise be burned on the Cogen Plant;
- Combustion emissions such as carbon dioxide and air pollutants such as oxides of nitrogen (NO<sub>x</sub>) and unburned hydrocarbons arising from the present Cogen plant will be eliminated when the plant is not operated.
- There will be a saving in water resources and treatment costs when the Cogen Plant is not operated;
- The inventory within the tanks will not diminish or deteriorate in specification.

#### *Planning Permission*

Following a screening request submitted by Dragon LNG on 14 August 2013, a Screening Opinion was provided by Pembrokeshire County Council (PCC) on 4 September 2013, confirming that a statutory EIA for the Reliquefaction Plant development was not required (PCC reference SC/0339/13).

A Planning Application was subsequently submitted to PCC (PCC reference 14/0107/PA), and Planning Permission for the Reliquefaction Plant was granted on 29 July 2014.

#### *Hazardous Substances Consent<sup>1</sup>*

The Health & Safety Executive (HSE) responded to the PCC consultation during the planning application procedures. The Dragon LNG facility and the adjacent SEM Logistics facility each has a Hazardous Substances Consent, and the development will be within the Inner Consultation Zones of each. The consultation response was that HSE 'does not advise against', based on the 'not normally occupied' criterion set out in para 10 of Circular SPC/Tech/Gen/43.

The existing Hazardous Substances Consent Approval is in the name of Petroplus Tankstorage (Milford Haven) Limited, reference 03/0003/HS, dated March 2004. Given that the Reliquefaction Plant will occupy an area of land adjacent to but outside the 2004 red line demarcating the 'gasification area', PCC required an application to amend the Consent. An Application has been submitted to PCC (March 2015), describing the relevant changes as follows:

*Continuation of the storage of liquefied natural gas in accordance with the inventory consented by reason of Hazardous Substance Consent (reference 03/0003/HS and dated March 2004) but to now include adjacent land accommodating a Reliquefaction Plant (approved by reason of planning permission reference 14/0107/PA, dated 29 July 2014).*

---

<sup>1</sup> *Planning (Hazardous Substances) Regulations 1992 [SI 1992 No. 656 Schedule 2]; and The Planning (Hazardous Substances) (Amendment) (Wales) Regulations 2010. WSI 2010 No. 450 (W.48)*

### *Other Variation Application Aspects*

This permit variation application also seeks to amend and clarify other minor aspects of the existing permit, in relation to water discharges associated with the general operation of the terminal and unconnected to the operation of the Reliquefaction Plant. The first three (1-3 below) of these changes were discussed and agreed at a pre-application meeting with NRW on 15 December 2014; 2 further minor changes to text in the existing Permit (4 and 5 below) were discussed in a later pre-application meeting on 18 June 2015. These changes are summarised as:

1. Discharge of fire-fighting foam effluent to the Haven. The COMAH Regulations require a fire fighting system to be in operation within the terminal and for it to be tested on a monthly basis. As a consequence, approximately 50 litres of a 3% solution of 'Expandol' currently reaches an impounding basin, and the proposal is for this volume of solution to be discharged to the Milford Haven waterway. Details are provided in Section 2.2 of this application supporting document.
2. Firewater Pond Effluent. An overflow from rainwater, SCV overflow, and process water passes to the neighbouring SEM Logistics reservoir (capacity approximately 5,000m<sup>3</sup>) and to its effluent treatment plant. Condition 7.1.2 of the existing permit sets out limits on this discharge for oil, suspended solids, pH and total oxidised nitrogen, with a sampling frequency 'once mid-way through any particular transfer', and the concentration values reported as 'flow-weighted averages of all transfers in any given calendar month'. As the release is intermittent and not a continuous direct discharge, a composite flow check according to this sampling and reporting requirement is not practicable. Proposals are submitted for a weekly sample to be collected, during periods when there is some measurable flow, and for the concentration limits to be compared with an average of all weekly sampling results. Details are provided in Section 2.2 of this application supporting document.
3. Rainwater discharge from the storage tanks, which is essentially clean uncontaminated rainwater but ultimately is released to the Haven, and which due to a historical drainage re-routing around the tanks is not currently consented. A monthly sampling programme is carried out and results are reported on a 6-monthly basis to NRW, so this application variation seeks only to include the sampling position, analytical parameters and laboratory testing methods as a variation to the permit. Details are provided in Section 2.2 of this application supporting document.
4. Permit AP3136UA/V001 states at section 7.1.2:

*Transfers from the installation to the neighbouring SEM Tank storage Milford Haven West reservoir shall be subject to the sampling frequency and emission limits stated in Table 7.1.2.*

The Issue is that the emission points E2(A) and E2(B) do not discharge to the west reservoir, but to the east reservoir. The suggested Condition amendment is:

*Transfers from the installation to the neighbouring SEM Tank storage Milford Haven ~~West-reservoirs~~ shall be subject to the sampling frequency and emission limits stated in Table 7.1.2.*

5. Permit AP3136UA/V001 states at section 2.10.5:

*The additional process monitoring identified for the Secondary Heat Recovery Unit, the three Waste Heat Boilers and the two Auxiliary Boilers referred to in section 2.10.2.7 of the Application shall be undertaken and the records kept in accordance with condition 3 of this permit.*

The issue is that the two auxiliary boilers referred to do not exist and never have. The suggested Condition amendment is:

*The additional process monitoring identified for the Secondary Heat Recovery Unit, and the three Waste Heat Boilers ~~and the two Auxiliary Boilers~~ referred to in section 2.10.2.7 of the Application shall be undertaken and the records kept in accordance with condition 3 of this permit.*

## 1 ACTIVITIES BEING APPLIED TO VARY

### 1.1 Reliquefaction Plant

The activities operated by Dragon LNG fall under Section 1.1, Part A(1), paragraph (a) of Schedule 1, Part 2 to the Environmental Permitting (England and Wales) Regulations 2010 (SI 2010 No. 675), as amended, described as 'burning any fuel in an appliance with a rated thermal input of 50 or more megawatts'. The stack heat recovery unit and LNG storage are unlisted directly associated activities to the combustion activities.

The variation being sought does not change these activities or add any regulated activity. The Reliquefaction Plant will be part of the LNG storage system.

### 1.2 Water Discharge Variations

The amendments being sought which are unrelated to the Reliquefaction Plant are all existing and do not change the listed activities or add any regulated activity.

### 1.3 Pre-Application Consultation

Pre-application consultation meetings with NRW were held on 16 October 2014, 15 December 2014 and 18 June 2015.

### 1.4 Substantial Change Consideration

This application is made on the basis that the Variation does not constitute a substantial change. The relevant technical guidance considered was RGN8<sup>2</sup>, which provides guidance on changes in operation ("changes which may have an effect on the environment"), to facilities regulated under the Environmental Permitting (England and Wales) Regulations 2010 (the 'Regulations'). It describes how Natural Resources Wales (NRW) evaluates the significance of a proposed change in operation and whether it is a 'substantial change', which in turn dictates the detail required in the application submission and the associated fee.

#### Definitions

Paragraph 5(5) of Schedule 5 to the Regulations defines a "change in operation" in connection with public participation for installations as: "a change in the nature or functioning, or an extension, of an installation which may have consequences for the environment". The EA / NRW Guidance states that:

- *A change in the nature of an installation (facility) is a change in relation to the activities carried out in the installation (facility);*

---

<sup>2</sup> *Environmental Permitting Regulations (England and Wales) 2010. Regulatory Guidance Series, No RGN 8. Substantial changes in operation at installations, mining waste facilities and other facilities involving solvents and combustion (version 3.0 March 2011).*

- A change in the functioning of an installation (facility) is a change in how the activities are carried out (that is a change in the techniques used to carry out the activities, for example a waste management plan) or a change in the output of the installation (facility);
- An extension of an installation (facility) is a physical extension affecting the capacity of the installation (facility) to carry out the activities;
- A substantial change is a change in operation of installations or mining waste facilities, which (in the opinion of the regulator) may have significant negative effects on human beings or the environment.

The general definition of substantial change in paragraph 5 of Part 1 of Schedule 5 EPR states that a substantial change is a change in operation which in the regulators' opinion "may have significant negative effects on human beings or the environment". The Reliquefaction Plant and minor changes to water discharge arrangements are clearly a 'change' in the functioning of the facility. The Guidance Note includes a series of 'Practical Tests' for determining significant negative effects; these have been set out alongside a statement relating to the Reliquefaction Plant<sup>3</sup>, in **Table 1**.

**Table 1 RGN8 Practical Tests for Substantial Change**

	<b>Practical Test and summary definitions</b>	<b>RP and other permit amendment aspects</b>
<b>A1</b>	<p><b>Release of Polluting Substances</b> A proposed change should be assessed firstly in terms of the likely environmental impact of <i>individual substances</i> released to individual media. If a significant negative effect can be identified in terms of any individual substance then the change should be deemed to be substantial. If it cannot, then the assessment should move on to consider the <i>overall impact</i> on the environment from the proposed change. If the impact of each individual substance in individual media is only small, but collectively there is an overall significant negative impact, then the proposal should be deemed to be a substantial change.</p>	<p>Consideration of the air, water and land emissions associated with the RP would show no effect and ultimately a positive effect on air emissions. The consideration is also of the administrative changes brought about by water discharge releases, which NRW requested be part of this permit variation procedure. See below.</p>
<b>A2</b>	<p><b>Ambient concentrations of polluting substances as a result of releases.</b> Technical Guidance Note H1 provides a methodology for screening out of substances that are released in such small quantities that the risk of an impact could be considered insignificant. The relevant criteria consider the long term Process Contribution (PC) and the Predicted Environmental Concentration (PEC), as both short term and long term effects.</p>	<p>Dispersion modelling has shown that under the defined 'normal' and 'peak' operational scenarios, during the 6-month tandem operation and post-6-month RP only, the change will be less than the relevant criteria.</p>

<sup>3</sup> Note on Permit Variation Application and 'Substantial Change', 17 March 2015, reference 9Y1920/EP/NN3\_substantial change

	<b>Practical Test and summary definitions</b>	<b>RP and other permit amendment aspects</b>
<b>A3</b>	<p><b>Releases of Substances to groundwater</b> For hazardous substances, any change that could result in the input of hazardous substances to groundwater that would not attract an exclusion under Article 6.3 of the Groundwater Directive should be considered a substantial change. Releases of non-hazardous pollutants to groundwater “are assessed for substantial changes on a case-by-case basis” and “having regard to the general principles and guidance” in the RGN8 document.</p>	<p>No significant change to groundwater releases as a consequence of the RP. Other permit amendments are</p> <ul style="list-style-type: none"> <li>- firewater test discharge of 50l/month;</li> <li>- Firewater Pond Effluent testing regime; and</li> <li>- correction to rainwater discharge from tanks</li> </ul> <p>which not to have significant effects.</p>
<b>A4</b>	<p><b>Accumulation of substances in the environment</b> Environmental and bio-accumulation potential. Environmental accumulation should be considered over a 10-year period of operation, except in the case of heavy metals which should be considered over the whole likely lifetime of the installation (assuming a minimum of 10 years, or 30 years if the lifetime is unknown).</p>	<p>No releases with bio-accumulation potential.</p>
<b>A5</b>	<p><b>Releases of substances with no reference standards – the Precautionary Principle</b> Where the unquantified (but more than purely hypothetical) risks to human health or the environment arising from the release of a particular substance warrant it, we will take a precautionary approach and treat any increase in releases as a substantial change.</p>	<p>Not applicable</p>
<b>A6</b>	<p><b>Energy Efficiency and Releases of Greenhouse Gases</b> Energy efficiency of itself is unlikely to be an issue that would give rise to considerations of substantial change. However, releases of greenhouse gases arising from an installation would need to be considered to see if the proposed modification is a substantial change. A surrogate level of 150,000 tonnes CO<sub>2</sub>/year at which the CO<sub>2</sub> release should be deemed substantial is suggested.</p>	<p>No additional GHG releases. Changes in CO<sub>2</sub> releases with cogen shutdown and RP energy use will be beneficial; 6-month in tandem operation will be well below the 150,000 tonne threshold.</p>
<b>A7</b>	<p><b>Releases of substances that deplete the ozone layer</b> Additional releases of CFCs or HCFCs (in any year of operation)</p>	<p>Not applicable</p>

	<b>Practical Test and summary definitions</b>	<b>RP and other permit amendment aspects</b>
<b>A8</b>	<p><b>Releases of substances causing formation of ozone at low level</b> Photochemical Ozone Creation Potential (POCP) criteria are listed and if the (change in) release rate exceeds an equivalent of 2% of the ozone EPAQS standard, the change is normally considered as substantial.</p>	No additional hydrocarbon releases so no increase in POCP emissions.
<b>A9</b>	<p><b>Effects of releases on visual amenity</b> Visual amenity of the installation itself will not usually be an issue for the regulation of IPPC installations. However, the visual effects of polluting emissions, such as the appearance of any dispersed plume, will be relevant. A discharge to surface waters should be assessed for substantial change, eg a discharge which could cause a change in colour in the water on an increase in the colour concentration.</p>	No plume or any additional discharges during in-tandem operation and beneficial change after RP shutdown. No coloured releases to surface water.
<b>A10</b>	<p><b>Odours</b> Consideration should be given to any proposed increase in the mass release of an odorous substance that would be likely to lead to a higher level of exposure (duration, frequency and/or concentration) to odour at sensitive receptors or other defined points.</p>	No change in release of any odorous substance
<b>A11</b>	<p><b>Increased likelihood or consequences of accidents</b> Consideration of risks associated with foreseeable but unplanned events that could occur. Increases in inventories of toxic chemicals, or additional tanker loading/unloading activities, could also lead to increased accidental release hazards and risks. Similarly, changes to waste types may lead to different risks and/or hazards.</p>	Gas inventory unchanged, no material change in risk; Hazid and Hazop studies are completed, and a summary is provided in the application.
<b>A12</b>	<p><b>Increases in production of waste</b> A proposed modification might result in an increase in waste materials for disposal or recovery. A proposal leading to a significant increase in the quantity of waste consigned for waste disposal when it was previously recovered would constitute a substantial change.</p>	No material change in waste production
<b>A13</b>	<p><b>Heat</b> Substantial change tests for controlled fresh</p>	No changes as a consequence of the RP; amendments to water

	<b>Practical Test and summary definitions</b>	<b>RP and other permit amendment aspects</b>
	<p>surface waters in consideration of the temperature differences between the point downstream of a thermal discharge and the unaffected temperature (the upstream temperature); 3°C / 1.5°C depending on sensitivity; maximum temperature at the point downstream of a thermal discharge is 28°C / 21.5°C; Any thermal effect that would constitute 20% or more of the allowed temperature difference, result in the temperature difference exceeding the appropriate limit or take the temperature above the permitted maximum, would be considered a substantial change.</p>	<p>discharges will not bring about any temperature changes.</p>
<b>A14</b>	<p><b>Noise and Vibration</b> The change must be determined at the appropriate noise sensitive receptor; there might be a substantial change if: i) a different sensitive receptor would be exposed to a noise level which is likely to give reasonable cause for annoyance; ii) an existing noise sensitive receptor is likely to experience a 5dB or more increase in the Rating Level; or iii) the L<sub>Amax</sub>, is likely to exceed 60dB at the façade of a room regularly used for sleeping.</p>	<p>Criteria not exceeded according to the noise impact modelling assessment undertaken.</p>
<b>A15</b>	<p><b>Effects on sensitive receptors</b> Specific attention will be required to address particularly sensitive environmental receptors. For example, in assessing a proposed modification, consideration should be given to the impact on SACs, cSACs and SPAs, Ramsars, SSSIs, local sites designated for nature conservation purposes and Nitrate Vulnerable Zones. The guidance also refers to other EIA and Habitats Regulations / Appropriate Assessment criteria.</p>	<p>Not applicable (designated sites in the Haven covered above).</p>
<b>A16</b>	<p><b>Environmental Impact Assessment</b> Where a change requires an EIA, as required principally by the Town and Country Planning (Environmental Impact Assessment) (England &amp; Wales) Regulations 1999. Government guidance on these Regulations is provided in DETR Circular 02/99.</p>	<p>Regulations and guidance have now changed but PCC was formally consulted on an EIA Screening Opinion, and the Reliquefaction Plant development was screened out.</p>

NRW accepted the above criteria and agreed that under the above definitions the introduction of the Reliquefaction Plant and the proposed minor changes to water discharge arrangements do not constitute a substantial change to the facility's activities, and this application represents a 'standard variation'<sup>4</sup>.

---

<sup>4</sup> *Agreed and confirmed by email on 7 May 2015.*

## 2 EMISSIONS TO AIR, WATER AND LAND

### 2.1 Reliquefaction Plant

The Reliquefaction Plant itself is an enclosed gas condensing system, with an enclosed nitrogen refrigerant serving as the heat transfer medium, and so there will be no additional direct emissions to atmosphere. The introduction of the Reliquefaction Plant will have implications for the operation of the Cogen Plant and associated SCVs, and these emissions are described in this application.

In respect of emissions to atmosphere, the current operations and releases from the Cogen Plant and SCVs were last assessed by a detailed atmospheric dispersion modelling study in 2011. This was a validation study, to determine the dispersion and off-site effects of measured stack emissions, as opposed to those based on limits and assessed in the original permit application<sup>5</sup>. The findings were submitted to the Environment Agency Wales to demonstrate compliance with condition 9.1.1 of the Environmental Permit (Reference AP3136UA), which states:

*“The Operator shall submit to the Agency a post commissioning report for the installation. The report shall include a comparison of process and emissions performance compared with the design assumptions in the application. The report shall also include air dispersion modelling results based on actual measured emissions from the release points under normal and maximum conditions (6 months after commissioning).”*

In pre-application discussions NRW agreed that this represented a baseline situation on which to consider the potential effects of the introduction of the Reliquefaction Plant.

However, several aspects of the dispersion modelling study have changed since this 2011 study, summarised below.

- The 2011 validation Study had utilised meteorological dispersion conditions represented by 2005 data, in order to provide a direct comparison with modelled predictions included in the original application. This study applied a more recent dataset, also covering a 5-year period of 2010-2014;
- Defra background pollutant mapping concentration data have been updated since the 2011 study, and the latest available pollutant concentrations were applied<sup>6</sup>;
- The same 11 residential receptor locations as had been selected in the 2011 study were used, but an additional 5 locations were also considered; and
- Ecological receptor locations were also considered, to determine potential effects on the critical load and levels at the Milford Haven Waterway SSSI and the Pembrokeshire Marine SAC.

The Reliquefaction Plant will be commissioned and brought in to operation alongside the Cogen Plant, in order to optimise its operation whilst retaining the ability to send boil-off gas to the Cogen Plant. It is expected that this in-tandem operation will exist for a period of 3-6 months, after which the Cogen Plant will be shut down. Thus a series of

---

<sup>5</sup> Royal HaskoningDHV (2011) Validation Report on Dispersion Modelling at Dragon LNG, Post Commissioning Appraisal, reference 9W4349/R001/301690/.

<sup>6</sup> DEFRA (2014) Air Pollution Background Concentration Maps: A User Guide, June 2014.

operational scenarios were developed with Dragon LNG and in consultation with NRW to describe the interim and long term future activities, and these are set out in **Table 2**.

Scenario	Gas sendout mode	Normal/Peak Operation	Plant Operating	Time period
<b>RP and Cogen operating in tandem (3-6 months)</b>				
A1	Sendout	Normal operation	Cogen and 2 SCVs	6 months
RP + Cogen	Sendout	Peak operation	Cogen and 6 SCVs	6 months
A2	Zero Sendout	Normal and peak operation	Cogen and 0 SCVs	6 months
RP + Cogen				
<b>Post 6 month commissioning, RP only, Cogen shutdown</b>				
B1	Sendout	Normal operation	2 SCVs	6 months
RP only	Sendout	Peak operation	6 SCVs	6 months
	Sendout	Normal operation	2 SCVs	12 months
	Sendout	Peak operation	6 SCVs	12 months
B2	Zero Sendout	Normal operation	0 SCVs	12 months
RP only				

**Table 2. Reliquefaction Plant (RP) and Cogen operational scenarios.**

Scenario B1 under normal and peak operation was modelled over a 6-month period to enable comparison with Scenario A1, and was also modelled over a full 12-month period to represent the future operational conditions.

To account for seasonal variation, initial model tests were undertaken to determine the periods within the year that resulted in the highest pollutant concentrations. Q3 and Q4 were found to result in the most conservative estimation of pollutant concentrations at receptor locations, therefore meteorological data from July to December were used in all 6-month model scenarios.

Operation of the Reliquefaction Plant during the 3-6 month commissioning period and during full future implementation will have no direct emissions to water or to land.

## 2.2 Water Discharge Variations

One of the five minor permit variations being sought which are unrelated to the introduction of the Reliquefaction Plant will give rise to additional discharges to water; the other two are variations are administrative changes and relate to current emissions which will not change.

1. The proposed discharge of fire-fighting foam effluent to the Haven will comprise approximately 50 litres/month of a 3% solution of 'Expandol', a fire-fighting foam concentrate supplied by Angus Fire, product code 160-05. The MSDS shows that the product is a blend of 2-butoxyethanol, lauric acid, alkanolamide sulphosuccinate and sodium lauryl ether sulphate. The product is formulated to be biodegradable and none of the component substances shows bio-accumulation potential.

2. Firewater Pond Effluent. Condition 7.1.2 of the existing permit sets out limits on the firewater pond effluent discharge for oil, suspended solids, pH and total oxidised nitrogen, with a sampling frequency 'once mid-way through any particular transfer', and the concentration values reported as 'flow-weighted averages of all transfers in any given calendar month'. As the release is intermittent and not a continuous direct discharge, a composite flow check according to this sampling and reporting requirement is not practicable. Furthermore, the relatively minor discharge feeds to the SEM reservoir which has a capacity of approximately 5,000m<sup>3</sup>, and from there to its effluent treatment plant.

A summary of the hourly flow monitoring data is presented in **Table 3** and shows that over 2013 and 2014, there was a zero flow for around 25% of the year, and for more than 60% of the hours in the second half of 2014 during a particularly dry period. The flow was below 0.5m<sup>3</sup>/h for a further 25% of the year or more (other than July-December 2014, when the flow was below this value including zero-flow hours for some 70% of this period).

	Jan-Jul 2013	Jul-Dec 2013	Jan-Jul 2014	Jul-Dec 2014
	Hourly flow, m <sup>3</sup>			
<b>No. hours</b>	4391	4413	4340	4416
<b>No. hours zero flow</b>	1045	1123	1247	2718
<b>percentage hours zero</b>	23.8	25.4	28.7	61.5
<b>Average flow*, m3</b>	1.37	1.8	1.6	2.8
<b>95%ile flow*, m3</b>	4.7	5.4	5.0	9.4
<b>90%ile flow*, m3</b>	3.4	3.7	3.8	6.4
<b>No. hours &lt;0.5 (%*)</b>	1113 (25.4%)	1130 (25.6%)	1210 (27.9%)	379 (8.6%)

**Table 3 Firewater pond flow rate summary statistics 2013-2014**

The proposal is for a weekly sample to be collected, during periods when there is some measurable flow, and for the concentration limits to be compared with an average of all weekly sampling results. Where the flow is greater than a *de minimus* value, results would be reported to NRW on a monthly basis and all overflows would be reported.

Due to the extended periods when insufficient rain or other process releases do not allow a sample to be collected in any single week, and a *de minimus* flow is proposed, below which the reporting regime would be exempted. The proposal is for this to be 0.5m<sup>3</sup>/h, and that when this flow is recorded over a continuous period of 24 hours in any week, the sampling results would be reported to NRW.

3. Rainwater discharge from around the storage tanks is essentially clean uncontaminated rainwater but ultimately is released to the Haven, and due to a

historical drainage re-routing around the tanks, is not included as a discharge point in the current permit.

A monthly sampling programme is carried out and results are reported on a 6-monthly basis to NRW, so this application variation seeks only to include the sampling position, analytical parameters and laboratory testing methods as a variation to the permit.

Details of the latest 6-monthly (April – September 2014) analytical results and laboratory test methods are provided in **Appendix I**.

The sampling point is proposed to be allocated the description / identifier E1, and the sampling point is shown in **Figure A2**.

The proposed amendments 4 and 5 are minor changes to the text of Conditions 7.1.2 and 2.10.5 which seek only to correct and clarify existing operations and have no implication for discharges.

### 3 OPERATING TECHNIQUES

#### 3.1 Reliquefaction Plant

The Reliquefaction Plant design and operation will be managed in accordance with all existing Dragon LNG protocols, procedures, and management systems<sup>7</sup>, and full HAZID and HAZOP studies have been undertaken<sup>8</sup>.

Reliquefaction will be accomplished by condensing the Boil off Gas (BOG) at a pressure of typically 8.6 bara, using nitrogen gas as refrigerant.

The reliquefaction plant consists of one unit based on a closed nitrogen refrigeration cycle without redundancy. The plant is designed for automatic capacity control from 27% to 100%. The nitrogen cycle can be operated in standby mode. In this mode the plant is kept cold by using minimum electrical power. The system basically consists of two parts:

- Nitrogen Cycle
- Auxiliaries

The Reliquefaction Plant capacity will be 11.177 tonne/h including flash gas.

#### **BOG Cycle**

The BOG cycle will be supplied at approx. 8.6 bara and a temperature of -10°C to 43°C into the reliquefaction system.

The BOG will be pre-cooled in the upper part of the cryogenic heat exchanger and condensed in the bottom of it. LNG from the heat exchanger will be returned to the storage tanks, utilising the differential pressure between the separator and the storage tank, via a temperature control valve. The liquid can also be returned by the use of the LNG transfer pump.

The BOG cycle consists of a plate-fin cryogenic exchanger, pump and valves.

#### **Nitrogen Cycle**

The refrigeration capacity will be produced by a compression-expansion cycle. Nitrogen gas with a pressure of approximately 7,5 bara will be compressed to about 35 bara in a 3-stage centrifugal compressor. The Nitrogen gas will be cooled by aircoolers after each stage of compression.

In the cryogenic heat exchanger the Nitrogen will firstly be pre-cooled to about -117°C. It will then be expanded to a pressure of approximately 8 bara and -168°C. Nitrogen will then be routed to the “cold” section at the bottom of the cryogenic heat exchanger where it will cool and reliquefy the boil-off gas.

---

<sup>7</sup> Environment Agency (2013) *How to comply with your environmental permit. Document 433\_11 (Version 6 - June 2013)*

<sup>8</sup> DNV (2014) *Dragon LNG Reliquefaction HAZID and HAZOP Report, Document Reference 18T8B31-1*

The nitrogen pass will continue up through the heat exchanger to the “warm” part of the cryogenic heat exchanger before it is returned to the suction side of the 3-stage compressor.

The Nitrogen Cycle will consist of one 3-stage centrifugal compressor, one expander, three air cooled gas coolers and one plate-fin cryogenic exchanger.

### **BOG Compressors**

The purpose of the BOG compressors will be to maintain a set storage tank pressure. The BOG compressor capacity will depend on the deviation from storage tank set point. If the tank pressure is increasing, the BOG compressor will increase capacity, i.e. flow loading additional cylinders.

The reliquefaction plant will liquefy BOG that is not sent out to external consumers such as electrical generation. The capacity controller of the reliquefaction plant will minimize split off to recondenser, i.e. will adjust capacity so that the split off to recondenser is as small as possible. At the same time, the pressure control valve will maintain BOG compressor discharge pressure. When the pressure control valve approaches 0% open, the reliquefaction system will decrease capacity which will increase opening of the pressure control valve thus maintaining control of BOG compressor discharge pressure.

### **Cryogenic Heat Exchanger - Cold Box**

The cold box has three passes:

- Pass 1 – The BOG flowing downwards will be de-superheated and condensed
- Pass 2 – The warm high pressure nitrogen flowing downwards will be pre-cooled
- Pass 3 – The cold nitrogen flowing upwards will cool the BOG (pass 1) and nitrogen (pass 2)

The temperature in the cold box will be lowest at the bottom (typically -163°C) and highest at the top (slightly above the cooling air temperature). It is important that the temperature difference between the various passes is not larger than the specified mechanical design limits for the cold box. The cold box safety features are designed such that if the temperatures exceed the design parameters, the cold box will be protected.

The cold box temperature will be allowed to change at a maximum rate of 1°C per minute. This limit will be built into the controller for the expander bypass valve. This will protect the cold box temperature from changing quicker than ROC (rate of change).

### **Nitrogen refrigeration system (R-loop)**

The purpose of the system is to provide the refrigeration to liquefy boil off gas. Capacity of the loop will be by inventory control, i.e. letting nitrogen in or out from the R-loop based on required capacity.

Nitrogen gas with a maximum pressure of approximately 7,5 bara will be compressed to about 35 bara in a 3-stage centrifugal compressor. The gas will be cooled by air coolers after each stage.

In the cryogenic heat exchanger the Nitrogen will be pre-cooled to about -117°C and then expanded to a pressure of about 8 bara out of the expander. The gas will leave the expander at about -168°C and will then be introduced into the “cold” part of the cryogenic heat exchanger where it will cool and reliquefies the boil-off gas.

The nitrogen will then make another pass through the “warm” part of the cryogenic heat exchanger before being returned to the suction side of the 3-stage compressor. The Nitrogen Cycle will consist of one 3-stage centrifugal compressor, one expander, three air coolers and the plate-fin cryogenic exchanger.

Other process controls will be as follows:

- BOG Compressor discharge pressure control
- N2 Comander Safety Controllers
- Motor current limit controller
- Surge controller
- Pressure ratio controller
- Comander 3rd stage differential pressure controller
- Discharge pressure limit controller
- Hand indicating controller
- Expander outlet temperature limit controller
- Hand indicating controller expander inlet nozzles
- Cold box temperature change rate protection

## **N2 supply system**

The purpose of the N2 supply system will be to supply N2 to the N2 reservoir to replenish N2 leakages from N2 comander seals. The booster compressor will also operate during the unloading of the R-loop (reducing refrigeration capacity). The N2 supply system comprises the following items:

- One Drier
- Two N2 booster compressor
- One Oil separator systems
- One Nitrogen reservoir

## **Control System Configuration**

The reliquefaction system control will be a stand-alone system with its own local operator station with a keyboard and display placed in the electric motor room. The system will be connected to the IAS for the total plant. This means that plant data such as field measuring points, sequence status, trends etc. will be presented to the IAS and the plant can be controlled either from the storage control room or from the local operator station.

The control system will be self-diagnostic and if any part of the control system becomes defective, the rest of the system will not suffer any malfunction and continue to safely operate the equipment and process. The control system will be designed for automatic control of all process variables, in order for the plant to maintain the storage tank pressure within acceptable limits under all operating conditions.

### **Plant operation – Operating modes**

The BOG compressors will maintain a constant storage tank pressure, and a maximum amount of BOG will be reliquefied and the least possible is recycled to the recondenser.

If the storage tank pressure is increasing, the BOG compressor will increase capacity. The result of this is an increased BOG compressor discharge pressure.

### **Options Appraisal**

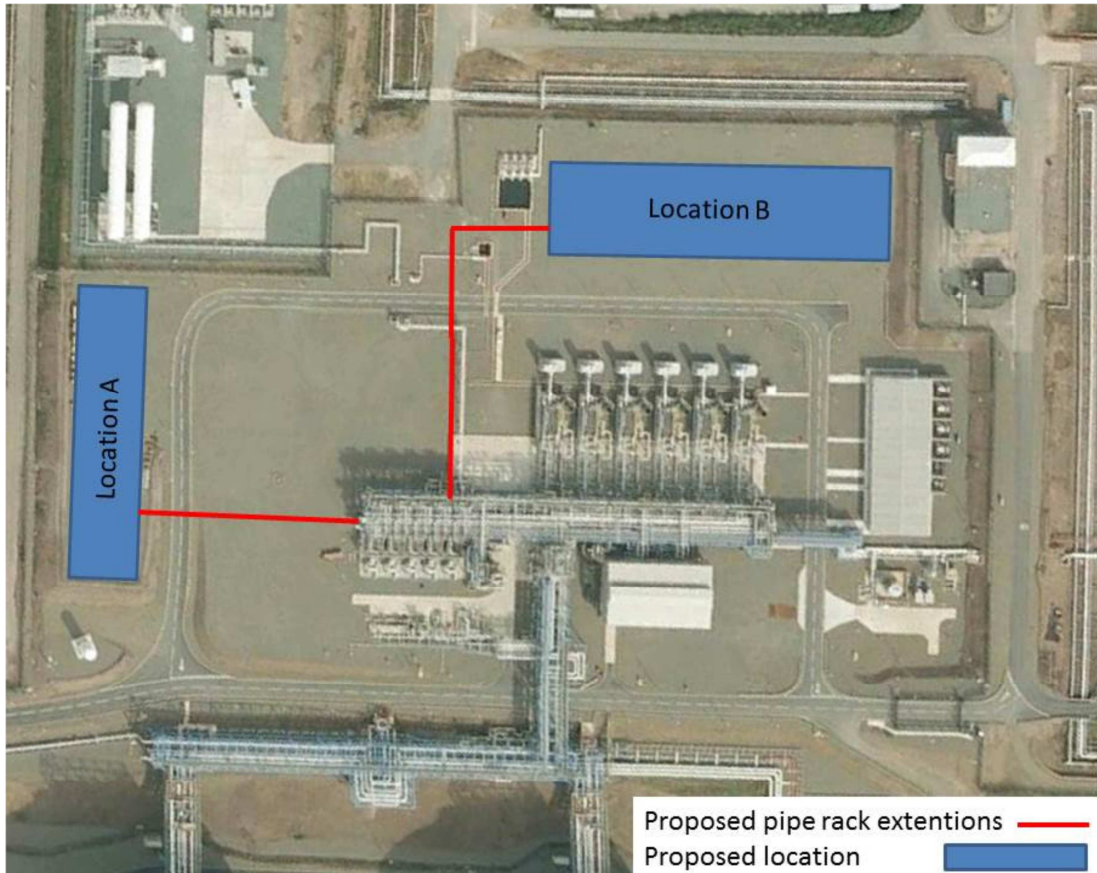
In respect of the plant design, the refrigerant technology was considered in the early design stage as either nitrogen or single mixed refrigerants (SMR), and the closed loop nitrogen refrigeration cycle option was selected for moving forward into the Hazid / Hazop study. The refrigeration compressors and pumping systems will be driven by air cooled electric motors. Heat rejected from the refrigeration circuit would be dissipated to atmosphere as warm air by the use of air blast coolers. All compressors and fans would be specified and / or attenuated so as not to significantly affect the noise environment beyond the site boundary.

The inert gas storage and closed refrigerant system will present no material potential environmental effects. Selection of the nitrogen technology is an inherently safer option (safer by design) than use of the SMR technology because it does not introduce additional hazardous substances which have the potential to increase the overall residual risk on site.

A plant location study was undertaken which considered the following criteria:

- Technical: (available plot size, construction access and site security, utilities and drainage connections, arrangements for linkages to existing as process plant);
- Operability: consideration of the facility operations with the main plant post-commissioning;
- Constructability: construction and laydown areas, safety and segregation of construction activities;
- Cost: preliminary review; and
- Risk: incident risk consequence comparison.

One potential location was not considered in detail as the plot size was insufficient and constrained by underground HV power cables. Locations 'A' and 'B' were taken forward for the study, and these are indicated in Figure 2.



**Figure 2 Location Study Plots A and B.**

The construction vehicle routing within the site would not be materially different for the two location options, and off-site vehicle movements and therefore community considerations would be no different. Location B was selected as the preferred location, primarily given the inherent safety of the area as it is not within the pool fire hazard contours from SEM tank 10, and its relatively simple connections to fire water, power and LNG spill drain.

These safety and environmental protection measures were therefore inherent considerations in the site location decision.

### **Environmental Benefit**

The project concept is to recover and recirculate boil-off gases and this will reduce gas combustion emissions and save water resources and treatment costs when the Cogen plant is not operated. Once operational, there will be no emissions to air, an insignificant noise effect, no associated within-site or off-site traffic movements, and no visual profile when viewed from outside the Terminal site. The project therefore offers an enhanced sustainability aspect for what will be a significant investment, with some environmental benefit and few disbenefits once operational.

The relevant conditions in the existing permit relating to management techniques and control and operating techniques (sections 2.1 – 2.3) will continue to apply and will be complied with.

### 3.2 Water Discharge Variations

The permit variation being sought due to amendments to the water discharge and sampling regime do not change any control techniques and activities will be managed in accordance with all existing Dragon LNG protocols, procedures, and management systems

1. The collection of approximately 50 litres of firefighting foam solution in the impounding basin results from monthly testing drills required by the COMAH Safety Plan and this activity is unchanged. The variation seeks only to discharge this 50litres of 3% solution to the Haven. The product is formulated to be biodegradable and none of the component substances shows bio-accumulation potential. There are no other proposed changes to the management techniques or controls, and the fire-fighting testing is a mandatory procedure under COMAH. The Material Safety Data Sheet (MSDS) and Fire Fighting Foam Laboratory Test Reports have been submitted to NRW<sup>9</sup>.
2. Firewater Pond Effluent. There are no proposed changes to the effluent management or controls; the existing activity of the collected effluent and its discharge to the SEM facility is not being changed. The proposed variation seeks only to rationalise the monitoring and reporting regime, and the principles of this change were agreed in pre-application consultation with NRW.
3. Rainwater discharge from around the storage tanks is essentially clean uncontaminated rainwater but ultimately is released to the Haven, and due to a historical drainage re-routing around the tanks, is not included as a discharge point in the current permit. The management and controls are not being changed, and monthly monitoring is already undertaken and reported. Details of the sampling position, analytical parameters and laboratory testing methods are provided in **Appendix I**.

The proposed amendments 4 and 5 are minor changes to the text of Conditions 7.1.2 and 2.10.5 which seek only to correct and clarify existing operations and have no implication for discharges.

---

<sup>9</sup> *Dragon LNG letter to NRW 4 March 2015, enclosing MSDS, lab test reports and excerpt from COMAH Safety Report. Laboratory Test references NFPA 11, 2010 Ed, clause 11.6.4; and BS 5306, s6.1, clause 15.1.*

## 4 MONITORING

### 4.1 Reliquefaction Plant

There are no proposed changes to the monitoring regime for the period of construction, commissioning and first 3-6 month operation of the Reliquefaction Plant, when the Cogen Plant will continue to operate in accordance with the existing permit conditions. Therefore the required continuous, quarterly and 6-monthly spot sampling of nitrogen oxides, particulate matter and carbon monoxide from the listed emission point sources will continue, in accordance with the schedule set out in Table 6.1.2 of the permit. The Reliquefaction Plant will not introduce any other emission to air, water or land, and no additional monitoring is proposed. A commissioning plan for the Reliquefaction Plant will be produced which will consider any additional monitoring requirements during that period, and this will be issued to NRW.

A noise impact assessment has been undertaken (see section 5.1) which concluded that there will be no significant noise effect at a range of residential receptor locations, when the Reliquefaction Plant is operated in tandem with the Cogen, and a net benefit when the Cogen is closed down.

A noise verification monitoring survey will be undertaken within 12 months of the Reliquefaction Plant being fully commissioned and operating in replacement of the Cogen. The survey would be in accordance with the main procedural requirements as set out in Condition 1.1.3(e) of the exiting permit, and would follow the relevant technical guidance in H3<sup>10</sup> and BS4142.

### 4.2 Water Discharge Variations

The permit variation being sought in respect of the water discharge changes encompass monitoring procedures for the firewater pond effluent and rainwater discharge point. There are no proposals to monitor the monthly release of fire-fighting foam, but any future changes as might be required by revision to the COMAH Safety Plan which would change the nature or release volume of the solution would be notified to NRW.

Monitoring of the firewater pond effluent will continue on a weekly basis, where there is sufficient flow to allow samples to be collected. The monitoring technique will not change and will continue to follow the existing permit condition 7, except in that the proposed sampling frequency in 7.1.2 would be weekly, and reporting would be as an average of all weekly sampling results in any given calendar month. Proposals for a *de minimus* threshold below which no reporting would be required are set out in section 2.2 of this application.

Details of the sampling position, analytical parameters and laboratory testing methods for the monthly rainwater discharge monitoring regime are provided in **Appendix I**.

---

<sup>10</sup> Environment Agency (2004). *Environmental Permitting: H3 Part 2 noise assessment and control*

## 5 ENVIRONMENTAL IMPACT ASSESSMENT

### 5.1 Air Emissions Impact Assessment

A description of the atmospheric emissions modelling study undertaken to support this application is provided at Section 2.1, and the full report and modelling results are presented at **Appendix II**.

The modelled scenarios represented the future periods when the Reliquefaction Plant will be commissioned and brought in to operation alongside the Cogen Plant, within an expected in-tandem operational period of 3-6 months, and the period afterwards when the Cogen Plant will be shut down (see **Table 2**).

Operation of the Reliquefaction Plant itself during the 3-6 month commissioning period and during full future implementation will have no direct emissions. The impact assessment therefore considered the existing Cogen and SCV emissions, and under these future scenarios.

#### **Modelling Study Summary**

The US EPA AERMOD dispersion model was used with five years (2010–2014) of hourly sequential meteorological data from the Milford Haven recording station. The model calculations accounted for the effect of local buildings and terrain on plume dispersion.

The modelled Process Contributions (PCs) and Predicted Environmental Concentrations (PECs) for nitrogen oxides (NO<sub>x</sub>) and carbon monoxide (CO) were all below the relevant respective air quality Objectives at all the representative human receptor locations considered in the assessment.

A habitat assessment was also undertaken to consider the impact of the scenarios assessed with regard to critical level and critical load values. The results of the critical level assessment showed that all predicted PECs were below the relevant NO<sub>x</sub> annual mean and 24 hour mean critical levels of 30µg.m<sup>-3</sup> and 75µg.m<sup>-3</sup>. The critical load assessment predicted that process contributions to nutrient nitrogen and acid deposition would not have a significant impact at Milford Haven Waterway SSSI and Pembrokeshire Marine SAC designations.

A conservative assessment was undertaken as the results reflect maximum predicted values over 5 years of representative dispersion conditions, assuming continuous emissions throughout the year for the time periods considered in the scenarios assessed.

When the Cogen Plant is shut down there will be no associated emissions and an overall air emissions benefit.

## 5.2 Noise Emissions Impact Assessment

A noise impact assessment has been undertaken<sup>11</sup> which considered the noise environment at five selected residential receptor locations, each representing a property within 2 km of the site. The assessment followed the approach set out in BS4142, establishing a baseline noise level and determining the effect with the addition of the Reliquefaction Plant as a new noise source, and also the scenario when the Cogen would be shut down. The full report is provided at **Appendix III**.

When the Cogen and Reliquefaction Plant will be in operation simultaneously, there was predicted to be no adverse impact compared to the noise environment with the Cogen operating alone. Noise levels at each of the five residential receiver locations are predicted to be lower when the Reliquefaction Plant replaces Cogen, with noise levels at selected receptor properties on Main Road predicted to reduce by 9dB. The variation in activities will therefore be neutral during the commissioning and initial in-tandem operation of the Reliquefaction Plant, and will give rise to a net benefit in the long term.

## 5.3 Water Discharges Impact Assessment

For two of the proposed changes, revision of the firewater pond effluent monitoring regime and the introduction of a rainwater discharge monitoring point, there are no operational changes and no associated environmental impact. The proposal to release 50 litres per month of a 3% dilute solution of fire-fighting test foam into the Haven will give rise to a negligible environmental effect and no change to the temperature regime in the waterway.

---

<sup>11</sup> *Xodus Group (2014) Update of noise model for proposed new re-liquefaction plant. L-300017-S05-TECH-001*

## 6 RESOURCE EFFICIENCY

Without the Cogen Plant in operation, the site is limited to a maximum of 26MW of power. In gas send-out mode, the Reliquefaction Plant will be on stand-by and will consume approximately 3MW. The sendout rate will determine the number of SCVs in service, all controlled with fuel gas. In zero send out periods, the LNG plant is in circulation mode, with no SCVs in service and no sendout to the national grid. The Reliquefaction Plant will be in full operational mode; the rate of energy consumption will be dependent on the amount of Boil of Gas produced from the terminal, which will be dependent on the composition of the stock in the storage tanks at that time, but at peak rate will consume 9.5MW, at which time the Terminal will be consuming approximately 4.5 – 5.5MW.

Therefore when the facility is in zero send out mode, the overall consumption will be approximately 15MW of power, and when in send out mode, consumption will be between 10 – 26MW depending on the sendout nomination from the customers.

Using the Defra GHG conversion factor for carbon reporting of LNG fuel gas (gross CV) of 0.184973 kgCO<sub>2</sub>e/kWh, the Reliquefaction Plant, when operating fully in standby or peak mode, would be associated with the release of 4.9 – 15.5 tonnes CO<sub>2</sub>e per year.

## **Appendices**

<b>Appendix I</b>	<b>Firewater Pond Effluent Sampling</b>
<b>Appendix II</b>	<b>Atmospheric Dispersion Modelling Report</b>
<b>Appendix III</b>	<b>Noise Impact Assessment Report</b>
<b>Appendix IV</b>	<b>H1 Assessment</b>

## **APPENDIX I**

### **Firewater Pond Effluent Sampling Summary and Analytical Methods**

**Table A1 AGI Pond Effluent Sampling Summary April – September 2014**

depth, sample type, date, sample time,			Effluent pit, water	Effluent pit, water	Effluent pit, water	Effluent pit, water	Effluent pit, water	Effluent pit, water
date received, SDG Ref, lab sample,			30/4/2014 140503-4	03/05/2014 140503-4	28/6/2014 140503-4	2/08/2014 140503-4	30/08/2014 140503-4	01/10/2014 140503-4
lab sample No, AGS Reference.			9234621	9370032	9234621	9523265	9731587	9894633
<b>Component</b>	<b>LOD/UNITS</b>	<b>METHOD*</b>	<b>April</b>	<b>May</b>	<b>June</b>	<b>July</b>	<b>August</b>	<b>September</b>
suspended solids	<2 mg/L	TM022	6	4.5	6	6	10.5	<2
BOD unfiltered	<1 mg/L	TM045	<1	2.08	3.17	4.17	<1	<1
ammoniacal nitrogen	<0.2 mg/L	TM099	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
COD unfiltered	<7 mg/L	TM107	9.04	14.5	13.1	23.5	<7	<7
aluminium	<2.9 µg/L	TM152	2.97	<2.9	<2.9	<2.9	<2.9	<2.9
cadmium	<0.1 µg/L	TM152	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
chromium	<0.22 µg/L	TM152	1.42	1.12	2.07	0.793	1.98	0.58
copper	<0.85 µg/L	TM152	<0.85	<0.85	<0.85	<0.85	1.14	0.855
lead	<0.02 µg/L	TM152	0.044	<0.02	<0.02	<0.02	<0.02	<0.02
nickel	<0.15 µg/L	TM152	0.256	0.586	0.605	0.633	0.431	0.699
zinc	<0.41 µg/L	TM152	2.45	<0.41	0.677	1.25	2.25	0.72
mercury	<0.01 µg/L	TM183	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate NO2	<0.05 µg/L	TM184	<0.05	<0.05	<0.05	<0.05	0.074	<0.05
Nitrate NO3	<0.3 mg/L	TM184	3.45	3.56	<0.3	<0.3	3.35	0.62
Iron	<0.019 mg/L	TM228	<0.019	<0.019	<0.019	<0.019	<0.019	<0.019
TPH / Oil + Greases	1 mg/L	TM235	<1	<1	<1	<1	<1	<1
pH	<1 pH UNITS	TM256	8.04	8.03	8.02	7.81	7.94	8.01

\*see Table A2 for specified analytical methods.

**Table A2 Effluent Pond Water Sampling Analytical Methods**

Method Number	Reference	Description
TM022	Method 2540D, AWWA/APHA, 20th Ed., 1999 / BS 2690: Part120 1981;BS EN 872	Determination of total suspended solids in waters
TM045	MEWAM BOD5 2nd Ed.HMSO 1988 / Method 5210B, AWWA/APHA, 20th Ed., 1999; SCA Blue Book 130	Determination of BOD5 (ATU) Filtered by Oxygen Meter on liquids
TM099	BS 2690: Part 7:1968 / BS 6068: Part2.11:1984	Determination of Ammonium in Water Samples using the Kone Analyser
TM107	ISO 6060-1989	Determination of Chemical Oxygen Demand using COD Dr Lange Kit
TM152	Method 3125B, AWWA/APHA, 20th Ed., 1999	Analysis of Aqueous Samples by ICP-MS
TM183	BS EN 23506:2002, (BS 6068-2.74:2002) ISBN 0 580 38924 3	Determination of Trace Level Mercury in Waters and Leachates by PSA Cold Vapour Atomic Fluorescence Spectrometry
TM184	EPA Methods 325.1 & 325.2,	The Determination of Anions in Aqueous Matrices using the Kone Spectrophotometric Analysers
TM228	US EPA Method 6010B	Determination of Major Cations in Water by iCap 6500 Duo ICP-OES
TM235	The Determination of Hydrocarbon Oils in Waters by Solvent Extraction, Infra red Absorption and Gravimetry 1983, HMSO, London	Determination of Total Petroleum Hydrocarbons (TPH) in Waters By Infra-Red Spectroscopy
TM256	The measurement of Electrical Conductivity and the Laboratory determination of pH Value of Natural, Treated and Wastewaters. HMSO, 1978. ISBN 011 751428 4.	Determination of pH in Water and Leachate using the GLpH pH Meter

<sup>1</sup> Applies to Solid samples only. DRY indicates samples have been dried at 35°C. NA = not applicable.

**Figure A2    AGI Pond Effluent Sampling Position E1**

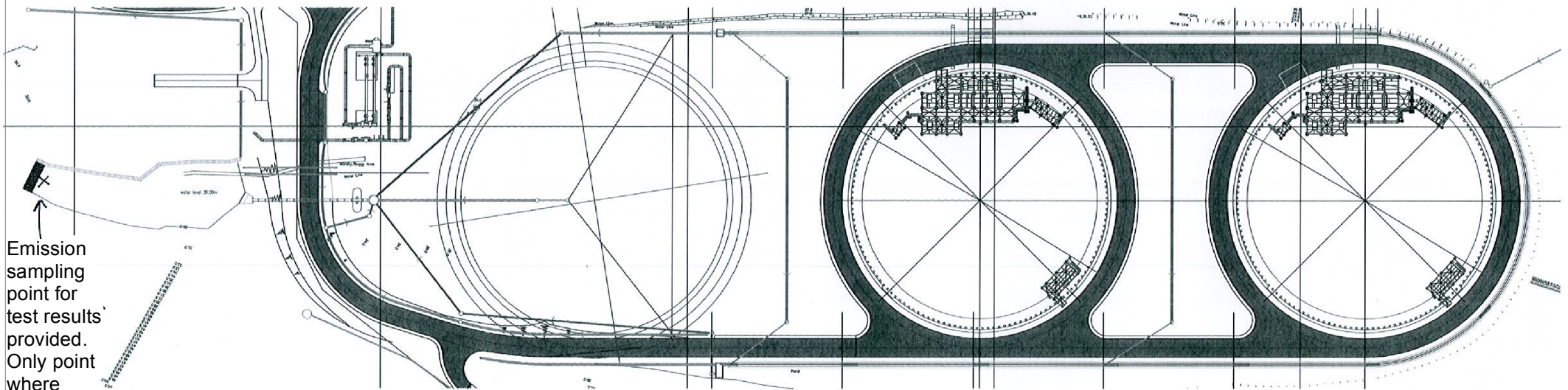
## APPENDIX II    ATMOSPHERIC DISPERSION MODELLING REPORT



## APPENDIX III NOISE IMPACT ASSESSMENT REPORT



## APPENDIX IV H1 ASSESSMENT



Emission sampling point for test results provided. Only point where access is safe.

*Title*

AGI Pond Effluent Sampling Position E1

*Date*

24/07/2015

*Scale*

Not to Scale

*Figure*

Permit Application 9Y1920 Figure A2

*Checked by*

EH/JD

*Number*

V1





# Reliquefaction Plant at Dragon LNG

9Y1920/03/RP/v1.0

Air Dispersion Modelling Report

**Document title:** Reliquefaction Plant at Dragon LNG  
**Status:** Final  
**Date:** 20 March 2015  
**Project name:** Reliquefaction Plant, Dragon LNG  
**Project number:** 9Y1920  
**Client:** Dragon LNG Limited

**Reference:** 9Y1920/03/RP/v1.0  
**Drafted by:** Claire Meddings  
**Checked by:** John Drabble  
**Date / initials check:** 20 March 2015  
**Approved by:** John Drabble  
**Date / initials approval:** 20 March 2015

**Checklist:** In accordance with Environment Agency (2011) H1 Annex F, version 2.2 – Air Emissions.

Item	✓	Reason for omission
Location map	✓	
Site plan	✓	
List of pollutants modelled and relevant air quality guidelines	✓	
Details of modelled scenarios	✓	
Details of relevant ambient concentrations used	✓	
Model description and justification	✓	
Special model treatments used	✓	
Table of emission parameters used	✓	
Details of modelled domain and receptors	✓	
Details of meteorological data used (including origin) and justification	✓	
Details of terrain treatment	✓	
Details of building treatment	✓	
Sensitivity analysis	✓	
Assessment of impacts	✓	
Model input files		Available on request

<b>1</b>	<b>Introduction .....</b>	<b>4</b>
1.1	Introduction .....	5
1.2	Site Location .....	5
1.3	Site Proposals .....	5
<b>2</b>	<b>Air Quality Guidelines.....</b>	<b>6</b>
2.1	Air Quality Standards and Objectives.....	7
2.2	Critical Levels.....	7
2.3	Critical Loads.....	7
<b>3</b>	<b>Methodology.....</b>	<b>9</b>
3.1	Consultation .....	10
3.2	Air Dispersion Modelling.....	10
3.2.1	Model Scenarios.....	10
3.2.2	Model Emission Parameters .....	10
3.2.3	Meteorological Data .....	11
3.2.4	Seasonal Variation .....	11
3.2.5	Terrain Data .....	11
3.2.6	Treatment of Buildings .....	12
3.2.7	Background Pollutant Concentrations .....	13
3.2.8	Human Receptor Locations.....	13
3.2.9	Cartesian Receptor Grid Parameters .....	14
3.3	Ecological Receptor Locations .....	15
<b>4</b>	<b>Assessment Results.....</b>	<b>16</b>
4.1	Human Receptors .....	17
4.2	Ecological Receptors.....	18
4.2.1	Critical Level Assessment .....	18
4.2.2	Critical Load Assessment.....	19
<b>5</b>	<b>Conclusions .....</b>	<b>22</b>
5.1	Conclusions.....	23

## Appendices

<b>Appendix A1</b>	Technical Appendix
<b>Appendix A</b>	Figures
	Figure 1 Site Location Plan
	Figure 2 Terrain Contours Included in the Dispersion Model
	Figure 3 Buildings Considered in the Dispersion Model
	Figure 4 Human Receptor Location Plan
<b>Appendix B</b>	Human Receptor Results
<b>Appendix C</b>	Contour Plots
<b>Appendix D</b>	Critical Level Assessment Results
<b>Appendix E</b>	Critical Load Assessment Results



**Royal  
HaskoningDHV**  
*Enhancing Society Together*

# 1 Introduction

# Introduction

## 1.1 Introduction

Royal HaskoningDHV was commissioned by Dragon LNG Ltd to undertake an air dispersion modelling assessment to support an Environmental Permit variation application.

A comparison between current emissions resulting from the following scenarios was undertaken:

- Operation of the Cogeneration (Cogen) Plant;
- Operation of both the Cogen Plant and the proposed Reliquefaction Plant simultaneously during a commissioning and in-tandem operational period; and
- Operation of the proposed Reliquefaction Plant only.

Emissions of oxides of nitrogen (NO<sub>x</sub>) and carbon monoxide (CO) were modelled in the assessment and ground level concentrations at identified receptor locations were predicted.

## 1.2 Site Location

The site is located on the northern shore of the Milford Haven waterway. A location plan of the site is provided in **Figure 1 of Appendix A**.

## 1.3 Site Proposals

Dragon LNG Limited proposes to install a new process unit to reliquefy gas which evaporates from the two existing liquefied natural gas (LNG) storage tanks at its LNG Terminal at Waterston, Milford Haven.

The present Dragon LNG Terminal features two LNG storage tanks, which each are capable of accommodating approximately 160,000m<sup>3</sup> of LNG. Gas send-out demand from the terminal varies throughout the year depending on several factors including weather conditions, price competitiveness and input into the gas national transmission system from other sources of gas supply. As a result of variation in demand the Dragon Terminal operates between two extremes of maximum gas send-out to zero gas send-out. In the case of zero send-out the LNG storage tanks are subject to heat gain from the surroundings and there is a small but finite evaporation of the LNG from the tanks, this is referred to as "boil-off gas". It is necessary to have a means of managing the gas which evaporates in order to maintain the appropriate level of pressure within the tanks and avoid venting to atmosphere.

The present method to usefully recover energy within the gas evaporating from the storage tanks gas is to burn it on a small gas turbine combined heat and power plant (the Cogen Plant) and provide electrical power and process heating. The case of zero send-out places limitations on the Cogen Plant and at times it is not possible to achieve economical operation when there is no requirement for process heating.

As an alternative to consuming gas in the Cogen Plant, it is proposed to reliquefy the gas and return it to the storage tanks. A nitrogen refrigerant will be employed as a heat transfer medium to cool the boil-off gas to a temperature of approximately -162°C, where it re-condenses to a liquid, which will then be pumped back into the main LNG tanks. The boil-off gas/LNG condensate circuit and refrigerant circuits will both operate on a closed cycle, thus there will be no emissions to atmosphere from the Reliquefaction Plant itself.



**Royal  
HaskoningDHV**  
*Enhancing Society Together*

## 2 Air Quality Guidelines

## Air Quality Objectives

### 2.1 Air Quality Standards and Objectives

Dispersion modelling was undertaken to quantify ground level pollutant concentrations based on emissions monitoring data of NO<sub>x</sub> and CO from the Cogen Plant and Submerged Combustion Vaporisers (SCVs). The AERMOD model provided the ground level Process Contribution (PC) which was added to the ambient pollutant background concentration, to provide a Predicted Environmental Concentration (PEC) at each considered receptor location. The PC and PEC values were then compared to the relevant air quality Objectives<sup>1</sup> (AQOs) as detailed in **Table 1**.

**Table 1: Relevant Air Quality Objectives**

Pollutant	Averaging Period	Limit Value
Nitrogen Dioxide	One hour, calendar year	200µg.m <sup>-3</sup> , not to be exceeded more than 18 times a year
	Calendar year	40µg.m <sup>-3</sup>
Carbon Monoxide	Maximum daily eight hour mean	10mg.m <sup>-3</sup> ,

### 2.2 Critical Levels

Critical levels are provided for the protection of vegetation and ecosystems. The critical levels for those pollutants considered in the assessment are detailed in **Table 2**.

**Table 2: Critical Levels for Pollutants Considered in the Assessment**

Pollutant	Concentration (µg.m <sup>-3</sup> )	Measured As
Oxides of Nitrogen (NO <sub>x</sub> )	30	Annual Mean
	75	Daily Mean

### 2.3 Critical Loads

Critical loads for habitat sites in the UK are published by the Centre for Ecology and Hydrology<sup>2</sup>. These are the maximum levels of acid and nutrient nitrogen that can be tolerated without harm to the most sensitive features of these habitat sites. The critical loads for the nature conservation sites considered in this assessment are detailed in **Table 3**.

**Table 3: Critical Load Values for Designated Ecological Sites Considered in the Assessment**

Designation	Habitat	Nutrient Nitrogen	Acidity	
		kg/ha.yr	MinCLminN	MinCLmaxN
Milford Haven Waterway SSSI	Calcerous Grassland	10	0.856	4.856
	Inland Rock Outcrop and Scree Habitats	5	0.178	0.711
	Calaminarian Grasslands	No Data	0.856	4.856
	Inland Rock	No Data	0.178	0.711

<sup>1</sup> Air Quality Standards (Wales) Regulations 2010. Welsh Statutory Instruments 2010 No.1433 (W.126) Environmental Protection, Wales.

<sup>2</sup> Centre for Ecology & Hydrology (CEH), critical load dataset, accessed via [www.apis.ac.uk](http://www.apis.ac.uk).

## Air Quality Objectives

Designation	Habitat	Nutrient Nitrogen	Acidity	
		kg/ha.yr	MinCLminN	MinCLmaxN
	Lowland Beech and Yew Woodland	5	0.142	1.175
	Limestone Pavements	5	No Data	No Data
	Coastal Sand Dunes	8	0.223	0.756
	Upland Heathland	10	0.499	1.299
	Lowland Heathland	10	0.499	1.299
	Upland Flushes Fens and Swamps	10	0.223	0.756
	Lowland Fens and Swamps	10	0.223	0.756
	Marshy Grassland	No Data	0.223	0.756
	Neutral Grassland	20	0.223	0.756
Pembrokeshire Marine SAC*	Estuaries	20	-	-
	Coastal Lagoon	20	-	-
	Atlantic Salt Marshes	20	-	-
	Supralittoral Rock	10	-	-

\* No critical load values available on APIS for acidity within the Pembrokeshire Marine SAC



**Royal  
HaskoningDHV**  
*Enhancing Society Together*

## 3 Methodology

## Methodology

### 3.1 Consultation

The proposed dispersion modelling approach was discussed with Natural Resources Wales (NRW) during two pre-application meetings on 16 October 2014 and 15 December 2014. The approach to the air dispersion modelling and scenarios to be modelled were agreed during these meetings.

### 3.2 Air Dispersion Modelling

Emissions of oxides of nitrogen (NO<sub>x</sub>) and carbon monoxide (CO) were modelled using AERMOD (Lakes Environmental model version 8.8.9). AERMOD is a quantitative dispersion model based on the Gaussian theory of plume dispersion and is widely used in the UK for regulatory and assessment purposes. It uses all input data (stack parameters, the terrain, hourly sequential meteorological data and building locations and configurations) to calculate dispersion and resulting ground level pollutant concentrations.

The air dispersion modelling assessment was undertaken in accordance with Environment Agency guidance<sup>3</sup>.

#### 3.2.1 Model Scenarios

The scenarios considered in the assessment are detailed in **Table 4**.

**Table 4: Model Scenarios Considered**

Scenario	Sendout	Normal/Peak Operation	Plant Operating	Time period
Scenario A1	Sendout	Normal operation	Cogen and 2 SCVs	6 month period
Scenario A1	Sendout	Peak operation	Cogen and 6 SCVs	6 month period
Scenario A2	Zero Sendout	Normal and peak operation	Cogen and 0 SCVs	6 month period
Scenario B1	Sendout	Normal operation	2 SCVs	6 month period
Scenario B1	Sendout	Peak operation	6 SCVs	6 month period
Scenario B1	Sendout	Normal operation	2 SCVs	12 month period
Scenario B1	Sendout	Peak operation	6 SCVs	12 month period
Scenario B2	Zero Sendout	Normal operation	0 SCVs	12 month period

Scenario B2 was not modelled as this scenario represents the Cogen Plant being shut down and the Reliquefaction Plant running at zero sendout. During zero sendout no SCVs are required and therefore there are no associated emissions to air.

#### 3.2.2 Model Emission Parameters

The emission parameters used in the assessment for the Cogen Plant and SCVs were obtained from the Validation Report<sup>4</sup>. The emission parameters utilised in the dispersion modelling are detailed in **Table 5**.

<sup>3</sup> Environment Agency (2011) H1 Annex F, version 2.2 – Air Emissions.

<sup>4</sup> Royal HaskoningDHV (01 February 2011) Validation Report on Dispersion Modelling at Dragon LNG, Post Commissioning Appraisal, reference 9W4349/R001/301690/King.

## Methodology

Table 5: Emission Parameters Utilised in the Dispersion Model

Source	Release Height (m)	Stack Diameter (m)	Volumetric Flow Rate (Nm <sup>-3</sup> .s <sup>-1</sup> )	Temp (K)	Mass Release (g.s <sup>-1</sup> )	Exit Velocity (m.sec <sup>-1</sup> ) at Discharge Temp	Measured Pollutant Concentration (mg.m <sup>-3</sup> )
Cogeneration Plant Main Stack	92	2.80	75.80	406	NOx 4.6 CO 3.1	18.30	NOx 69 CO 37.5
Submerged Combustion Vapourisers (SCVs)	15	0.68	7.34	288	NOx 0.45 CO 0.26 <sup>1</sup>	21.30	NOx 61 CO 33 <sup>2</sup>

<sup>1</sup> Average NOx and CO mass release rates over all six SCVs

<sup>2</sup> Average NOx and CO emission concentrations over all six SCVs

### 3.2.3 Meteorological Data

Meteorological data from Milford Haven recording station were used in the air dispersion modelling. This is the closest and most representative station to the site location and was used to provide consistency with the Validation Report on Dispersion Modelling at Dragon LNG. Five years (2010 – 2014) of hourly sequential meteorological data from the Milford Haven recording station were used in the dispersion model.

The meteorological data were processed to make their interaction with the land surface representative of the site. The parameters used to process the meteorological data were consistent with the Validation report, and are detailed in **Table 6**.

Table 6: Buildings included in the AERMOD Model

Sector	Sector Degrees (°)	Land use	Albedo	Bowen Ratio	Surface Roughness
1	90 - 270	Water	0.14	0.45	0.001
2	270 - 90	Cultivated Grassland	0.28	0.75	0.0725

### 3.2.4 Seasonal Variation

Initial model tests were undertaken to determine the periods within the year that resulted in the highest pollutant concentrations. Q3 and Q4 were found to result in the most conservative estimation of pollutant concentrations at receptor locations, therefore meteorological data from July to December were used in all 6-month model scenarios.

### 3.2.5 Terrain Data

To represent the influence of terrain elevations on dispersion, a digital elevation file was used in the AERMOD model setup. Shuttle Radar Topography Mission (SRTM3) elevation data was extrapolated from the WebGIS website<sup>5</sup> and incorporated into the modelling assessment.

For both the receptors and grid points, the recommended Lakes Inverse Distance interpolation was used. This function interpolates the neighbouring points using inverse distance to obtain the elevation at the desired point. The terrain

<sup>5</sup> SRTM3 terrain data obtained from WebGIS <http://www.webgis.com/srtm3.html>

## Methodology

elevations used in the dispersion model are presented in **Figure 2 of Appendix A.**

### 3.2.6 Treatment of Buildings

Building dimensions were taken from the site plan and elevation drawings and the Building Profile Input Programme (BPIP) algorithm was used to calculate building downwash parameters within AERMOD. The configuration of the buildings included in the model set-up is presented in **Figure 3 of Appendix A.**

Building height details were determined from site drawings. Full details of the buildings included in the model are provided in **Table 7.**

**Table 7: Buildings included in the AERMOD Model**

Building Description	Building Height (m)	Building Description	Building Height (m)
LNG Tank 1	26.25	Tank 103	12.88
LNG Tank 2	26.25	Tank 104	12.88
Tank 706	17.40	Tank 105	12.88
Tank 705	12.88	Tank 402	12.88
Tank 704	12.88	Tank 403	12.88
Tank 604	13.26	Tank 506	9.20
Tank 876	9.90	Tank 401	13.28
Tank 10	14.47	Tank 400	13.28
Tank 703	14.95	Tank 508	10.90
Tank 702	14.95	Tank 511	10.90
Tank 603	13.28	Tank 312	12.88
Tank 875	9.90	Tank 311	12.88
Tank 602	12.88	Tank 306	9.00
Tank 607	12.88	Tank 305	9.00
Tank 606	12.88	Tank 310	12.88
Tank 605	12.88	Tank 304	12.88
Tank 601	12.88	Tank 309	9.00
Tank 600	12.88	Tank 303	9.00
Tank 220	9.90	Tank 302	9.00
Tank 221	9.90	Tank 308	9.00
Tank 222	9.90	Tank 307	9.00
Tank 223	9.90	Tank 301	9.00
Tank 224	9.90	Tank 300	9.00
Tank 225	9.90	Tank 507	11.70

## Methodology

Building Description	Building Height (m)	Building Description	Building Height (m)
Tank 226	9.90	Tank 502	11.70
Tank 201	1.00	Tank 501	11.70
Tank 200	1.00	Tank 500	11.70
Tank 202	13.28	Tank 504	11.70
Tank 203	13.28	Tank 505	11.70
Tank 204	13.28	Tank 9	14.47
Tank 205	13.28	Tank 11	14.47
Tank 206	9.00	Tank 12	7.50
Tank 114	9.00	Tank 8	9.00
Tank 115	9.00	Tank 7	9.00
Tank 110	13.28	Tank 6	9.00
Tank 111	13.28	Tank 5	9.00
Tank 112	13.28	Tank 1	9.00
Tank 113	13.28	Tank 2	9.00
Tank 100	12.88	Tank 3	9.00
Tank 101	12.88	Tank 4	9.00
Tank 102	12.88	Nitrogen Plant 1	18.78
Nitrogen Plant 2	18.78	Cogen Plant	8.50
Preliquefaction Plant	3.80		

### 3.2.7 Background Pollutant Concentrations

Background air pollutant concentrations corresponding to the 1km x 1km grid squares covering the study area were obtained from the LAQM support tools provided by Defra for use in air quality assessments. Background concentrations for the base year (2014) were obtained to establish baseline NO<sub>x</sub> and NO<sub>2</sub> concentrations at the receptor locations identified. Background concentrations for 2011 were obtained to establish baseline CO concentrations as this is the latest year for which mapped background concentrations are available.

### 3.2.8 Human Receptor Locations

Sixteen receptor locations were included in the dispersion model, including the same 11 receptor locations that were previously used in the Validation Report, for consistency, plus an additional 5 locations to further inform the understanding of potential local effects. These receptor locations are detailed in **Table 8** and shown on **Figure 4** of **Appendix A**.

## Methodology

**Table 8: Model Receptor Locations**

Receptor		Grid Reference	
R1	Waterston	193816	205760
R2	Neyland	195929	205318
R3	Milford Haven	191138	206098
R4	Pembroke Dock	195732	203486
R5	Rosemarket	195281	208371
R6	Scoveston	193693	206981
R7	Steynton	191805	207638
R8	The Daugleddau	197350	211450
R9	Littlewick Point to Brunel Quay	193966	204293
R10	Milford Haven South	194539	202913
R11	Pembroke River	194639	202060
R12	2, Alban Crescent, Waterston	193718	205422
R13	Hazel Hill House, Llanstadwell	194253	204999
R14	10, Lighthouse Drive, Llanstadwell	194498	204539
R15	Castle Hall Lode, Blackbridge	191891	205752
R16	The Glen, Milford Haven	192903	205741

### 3.2.9 Cartesian Receptor Grid Parameters

A 12 x 11km uniform Cartesian receptor grid with a resolution of 500m was included in the dispersion model to cover human receptor locations. Embedded within that grid was a fine Cartesian receptor grid, measuring 2.5km x 3km with a resolution of 100m. Both grids were centered on the site. The Cartesian receptor grids are detailed in **Table 9**.

**Table 9: Cartesian Receptor Grid Parameters – Human Receptors**

Parameter	Grid 1		Grid 2	
	Easting	Northing	Easting	Northing
Centre Grid Coordinates	193447	205217	193447	205217
No. of Points	25	23	26	31
Spacing (m)	500	500	100	100
Length (m)	12,000	11,000	2,500	3,000
Total Receptors	575		806	

## Methodology

### 3.3 Ecological Receptor Locations

In accordance with H1 Annex F methodology<sup>3</sup>, a screening assessment was undertaken to consider designated ecological sites located within proximity to the LNG Terminal. The designated ecological sites considered were:

- Milford Haven Waterway SSSI – located approximately 15m in a southerly direction from the LNG Terminal site boundary.
- Pembrokeshire Marine SAC – located approximately 15m in a southerly direction from the LNG Terminal site boundary.

An additional three receptor grids were included in the dispersion model, to cover the Pembrokeshire Marine SAC and Milford Haven Waterway SSSI. Details of the ecological receptor grids are presented in **Table 10**.

**Table 10: Cartesian Receptor Grid Parameters – Designated Ecological Sites**

Parameter	Grid 3		Grid 4		Grid 5	
	Easting	Northing	Easting	Northing	Easting	Northing
South-west Grid Coordinates	188348	203036	193576	201262	195918	205940
No. of Points	201	51	26	31	21	25
Spacing (m)	50	50	100	100	50	50
Length (m)	10,000	2,500	4,700	1,700	1,000	1,200
Total Receptors	10,251		3,325		525	



**Royal  
HaskoningDHV**  
*Enhancing Society Together*

## 4 Assessment Results

## Assessment Results

### 4.1 Human Receptors

The outputs of the AERMOD model provided the ground level PC which was added to the ambient pollutant background concentration, detailed in **Table 7**, to provide a PEC at each receptor location assessed. The PC and PEC concentrations as a percentage of the relevant air quality Objective (AQO) were then determined for each receptor. This approach is in accordance with Environment Agency Guidance Note H1<sup>3</sup>.

The Environment Agency Air Quality Modelling and Assessment Unit (AQMAU) has made recommendations regarding the conversion rates for NO<sub>x</sub> to NO<sub>2</sub>:

- Step 1. Screening/Worst Case Scenario:
  - 50% and 100% of the modelled values should be used for short-term and long term average concentrations respectively. If PEC exceeds the relevant air quality objective then proceed to step 2.
- Step 2. Worst Case Scenario:
  - 35% for short term and 70% for long term average concentration should be considered. If PEC exceeds the relevant air quality objective then proceed to step 3.
- Step 3. Case Specific Scenario:
  - Operators are asked to justify their use of percentages lower than 35% for short term and 70% for long term in their application reports.

In accordance with these recommendations, the short term (1 hour) and long term (annual mean) concentrations of NO<sub>2</sub> were derived from the predicted NO<sub>x</sub> concentrations using the following approach: 35% of NO<sub>x</sub> to NO<sub>2</sub> for short term and 70% of NO<sub>x</sub> to NO<sub>2</sub> for long term average concentrations.

The full assessment results are provided in **Appendix B**. Contour plots showing the modelled concentrations as isopleths are provided in **Appendix C**. **Tables 11 – 13** detail the modelled pollutant concentrations for each scenario for those receptors predicted to experience the highest PEC value. The year shown is the meteorological data year (2010 – 2014) in which the receptor experiences the highest PEC value.

**Table 11: 1 Hour NO<sub>2</sub> 99.8th Percentile Concentrations for the Receptor Predicted to Experience the Highest PEC Value**

Scenario	Month Run Period (Months)	Receptor	Year	PEC	PEC/AQO
				µg.m <sup>-3</sup>	%
A1 Normal	6	R9	2010	57.99	28.99
A1 Peak	6	R9	2010	59.23	29.62
A2 Normal	6	R9	2010	57.79	28.89
A2 Peak	6	R9	2010	57.79	28.89
B1 Normal	6	R9	2010	57.95	28.97
B1 Peak	6	R9	2010	59.21	29.61
B1 Normal	12	R9	2013	58.01	29.00
B1 Peak	12	R9	2013	59.40	29.70

Receptor R9 was predicted to experience the highest 1 hour NO<sub>2</sub> PEC values for all scenarios considered. The predicted PCs and PECs were all 'well below' the relevant air quality Objective of 200µg.m<sup>-3</sup>.

**Table 12: Annual Mean NO<sub>2</sub> Concentrations for the Receptor Predicted to Experience the Highest PEC Value**

## Assessment Results

Scenario	Month Run Period (Months)	Receptor	Year	PEC	PEC/AQO
				$\mu\text{g.m}^{-3}$	%
A1 Normal	6	R9	2010	28.70	71.75
A1 Peak	6	R9	2010 and 2014	28.75	71.87
A2 Normal	6	R9	2011	28.68	71.69
A2 Peak	6	R9	2011	28.68	71.69
B1 Normal	6	R9	2010, 2012 and 2014	28.69	71.73
B1 Peak	6	R9	2010 and 2014	28.74	71.85
B1 Normal	12	R9	2010, 2012 and 2014	28.71	71.77
B1 Peak	12	R9	2010	28.80	71.99

Receptor R9 was predicted to experience the highest annual mean NO<sub>2</sub> PEC values for all scenarios considered. The predicted PCs and PECs were all 'well below' the relevant air quality Objective of 40 $\mu\text{g.m}^{-3}$ .

**Table 13: 8 Hour CO Concentrations for the Receptor Predicted to Experience the Highest PEC Value**

Scenario	Month Run Period (Months)	Receptor	Year	PEC	PEC/AQO
				$\text{mg.m}^{-3}$	%
A1 Normal	6	R2	2012	3.19	3.19
A1 Peak	6	R2	2012	3.20	3.20
A2 Normal	6	R2	2012 and 2014	3.19	3.19
A2 Peak	6	R2	2012 and 2014	3.19	3.19
B1 Normal	6	R2	2010	3.19	3.19
B1 Peak	6	R2	2010	3.20	3.20
B1 Normal	12	R2	2011	3.19	3.19
B1 Peak	12	R2	2011	3.21	3.21

Receptor R2 was predicted to experience the highest 8 hour CO PEC values for all scenarios considered. The predicted PCs and PECs were all 'well below' the relevant air quality Objective of 10 $\text{mg.m}^{-3}$ .

## 4.2 Ecological Receptors

### 4.2.1 Critical Level Assessment

The full results of the critical level assessment are provided in **Appendix D**. The maximum modelled PCs for each considered nature conservation site are detailed in **Table 14**. The predicted PC was then added to the background pollutant concentration to provide the PEC. Background pollutant concentrations for use in the assessment were obtained from the Defra background maps. **Table 14** provides a summary of the highest predicted PC for each designated site considered, for each scenario assessed. Both the Pembrokeshire Marine SAC and Milford Haven

## Assessment Results

Waterway SSSI have the same designation boundary. The highest predicted concentration for both designated sites are therefore the same.

**Table 14: Critical Level Assessment Results**

Habitat	Scenario	Background NOx	Highest Predicted PC	PEC	PC/AQO	PEC/AQO
		( $\mu\text{g.m}^{-3}$ )	( $\mu\text{g.m}^{-3}$ )	( $\mu\text{g.m}^{-3}$ )	(%)	(%)
<b><i>NOx Annual Mean Critical Level Assessment</i></b>						
SSSI & SAC	A1 Normal	28.80	0.06	28.86	0.20	96.21
SSSI & SAC	A1 Peak	28.80	0.15	28.95	0.49	96.50
SSSI & SAC	A2 Normal and Peak	28.80	0.03	28.83	0.10	96.11
SSSI & SAC	B1 Normal 6 Months	28.80	0.05	28.85	0.15	96.16
SSSI & SAC	B1 Peak 6 Months	28.80	0.14	28.94	0.48	96.49
SSSI & SAC	B1 Normal 12 Months	28.80	0.09	28.89	0.28	96.29
SSSI & SAC	B1 Peak 12 Months	28.80	0.25	29.05	0.83	96.84
<b><i>NOx 24-Hour Mean Critical Level Assessment</i></b>						
SSSI & SAC	A1 Normal	28.80	1.32	58.92	1.76	78.57
SSSI & SAC	A1 Peak	28.80	3.27	60.87	4.36	81.17
SSSI & SAC	A2 Normal and Peak	28.80	0.60	58.20	0.79	77.60
SSSI & SAC	B1 Normal 6 Months	28.80	1.02	58.62	1.37	78.17
SSSI & SAC	B1 Peak 6 Months	28.80	3.14	60.74	4.19	81.00
SSSI & SAC	B1 Normal 12 Months	28.80	1.24	58.84	1.66	78.47
SSSI & SAC	B1 Peak 12 Months	28.80	3.51	61.11	4.68	81.49

As shown in Table 14, the existing background NOx concentration is approaching the NOx annual mean critical level of  $30\mu\text{g.m}^{-3}$ . The predicted PCs were all less than  $0.15\mu\text{g.m}^{-3}$  are therefore when added to the background to provide the PECs, the concentrations did not exceed the annual mean NOx critical level.

Predicted 24 hour NOx PCs were all below  $3.51\mu\text{g.m}^{-3}$ . When added to the background concentration to provide the PEC, all concentrations were less than the 24 hour mean critical level for NOx of  $75\mu\text{g.m}^{-3}$ .

### 4.2.2 Critical Load Assessment

The highest process contribution for each nature conservation site assessed was identified and the ground level deposition of nutrient nitrogen calculated. The full results of the critical load assessment are provided in **Appendix E**. The highest predicted nutrient nitrogen and acid deposition rates for each considered nature conservation site are detailed in **Table 15**. Where a critical load range was provided as the benchmark, the most demanding value was applied to provide a conservative assessment. Modelled NOx concentrations were converted to NO<sub>2</sub> using a conversion

## Assessment Results

of NO<sub>x</sub> to NO<sub>2</sub> of 35% short term and 70% long term as detailed in **Section 4.1**, and corrected for nitrogen as N. Acidity values were not available from APIS and therefore acid deposition could not be considered for all habitats identified.

**Table 15: Critical Load Assessment Results**

Designation	Feature	Scenario	Highest Predicted NN Deposition Rate	Maximum Modelled NN Deposition Rate	Highest Predicted Acid Deposition Rate	Maximum Modelled Acid Deposition Rate
			(kgN.Ha-yr <sup>-1</sup> )	(% Critical Load)	(kgN.Ha-yr <sup>-1</sup> )	(% Critical Load)
SSSI	Inland Rock Outcrop and Scree	A1 Normal	0.0062	0.12	0.0004	0.25
	Lowland Beech and Yew Woodland		0.0124	0.25	0.0008	0.31
	Limestone Pavements		0.0062	0.12	-	-
SAC	Supralittoral Rock		0.0062	0.12	-	-
SSSI	Inland Rock Outcrop and Scree	A1 Peak	0.0148	0.30	0.0010	0.60
	Lowland Beech and Yew Woodland		0.0298	0.60	0.0021	0.75
	Limestone Pavements		0.0149	0.30	-	-
SAC	Supralittoral Rock		0.0149	0.30	-	-
SSSI	Inland Rock Outcrop and Scree	A2 Normal and Peak	0.0031	0.06	0.0002	0.12
	Lowland Beech and Yew Woodland		0.0061	0.12	0.0004	0.16
	Limestone Pavements		0.0031	0.06	-	-
SAC	Supralittoral Rock		0.0031	0.06	-	-
SSSI	Inland Rock Outcrop and Scree	B1 Normal 6 Months	0.0044	0.09	0.0003	0.18
	Lowland Beech and Yew Woodland		0.0089	0.18	0.0006	0.22
	Limestone Pavements		0.0044	0.09	-	-
SAC	Supralittoral Rock		0.0044	0.09	-	-
SSSI	Inland Rock Outcrop and Scree	B1 Peak 6 Months	0.0144	0.29	0.0010	0.58
	Lowland Beech and Yew Woodland		0.0288	0.58	0.0021	0.73
	Limestone Pavements		0.0144	0.29	-	-
SAC	Supralittoral Rock		0.0144	0.29	-	-
SSSI	Inland Rock Outcrop and Scree	B1 Normal 12 Months	0.0086	0.17	0.0006	0.34
	Lowland Beech and Yew Woodland		0.0171	0.34	0.0012	0.43

## Assessment Results

Designation	Feature	Scenario	Highest Predicted NN Deposition Rate	Maximum Modelled NN Deposition Rate	Highest Predicted Acid Deposition Rate	Maximum Modelled Acid Deposition Rate
			(kgN.Ha-yr <sup>-1</sup> )	(% Critical Load)	(kgN.Ha-yr <sup>-1</sup> )	(% Critical Load)
	Limestone Pavements		0.0086	0.17	-	-
SAC	Supralittoral Rock		0.0086	0.17	-	-
SSSI	Inland Rock Outcrop and Scree	B1 Peak 12 Months	0.0251	0.50	0.0018	1.01
	Lowland Beech and Yew Woodland		0.0503	1.01	0.0036	1.27
	Limestone Pavements		0.0251	0.50	-	-
SAC	Supralittoral Rock		0.0251	0.50	-	-

Nutrient nitrogen and acid deposition within the SSSI and SAC for all scenarios considered was predicted to be lower than the most stringent value for each critical load. The deposition rates were predicted to be less than 1% of the critical loads with the exception of the B1 Peak 12 Month scenario, in which the 1% criterion was marginally exceeded. However, the B1 Peak 12 Month scenario assumes that sendout, with 6 SCVs are operating, will occur continually for a 12 month period, which is a very conservative assumption and will not materialise in practice. The predicted concentrations for this scenario are therefore considered to be very robust. Additionally, the assessment undertaken was conservative in the following respects:

- Meteorological dispersion conditions were considered for a five year period and the maximum pollutant concentration and levels were reported for all parameters;
- Where a benchmark range for nutrient nitrogen deposition is provided, the lower value within that range, i.e. the most stringent standard, was assumed; and
- A continuous emission scenario was modelled assuming stack emissions 24 hours a day, 7 days a week, over the scenario time frame (6 or 12 months) which in reality would not occur.

The assessment therefore concluded that the impact of nutrient nitrogen and acid deposition, from the scenarios considered, would not be significant.



**Royal  
HaskoningDHV**  
*Enhancing Society Together*

## 5 Conclusions

## Conclusions

### 5.1 Conclusions

Detailed dispersion modelling was undertaken to consider NO<sub>x</sub> and CO emissions from the Cogen Plant and SCVs, an in-tandem operational period with both the Cogen and Reliquefaction Plant operating, and the operation of the Reliquefaction Plant only. The proposed Reliquefaction Plant itself will not result in any additional pollutant emissions to air.

The US EPA AERMOD dispersion model was used with five years (2010–2014) of hourly sequential meteorological data from the Milford Haven recording station. The model calculations accounted for the effect of local buildings and terrain on plume dispersion.

The modelled Process Contributions (PCs) and Predicted Environmental Concentrations (PECs) for the considered pollutants were all below the relevant respective air quality Objectives at all the representative human receptor locations considered in the assessment.

A habitat assessment was also undertaken to consider the impact of the scenarios assessed with regard to critical level and critical load values.

The results of the critical level assessment showed that all predicted PECs were below the relevant NO<sub>x</sub> annual mean and 24 hour mean critical levels of 30µg.m<sup>-3</sup> and 75µg.m<sup>-3</sup>. The critical load assessment predicted that process contributions to nutrient nitrogen and acid deposition would not have a significant impact at Milford Haven Waterway SSSI and Pembrokeshire Marine SAC designations.

A conservative assessment was undertaken as the results reflect maximum predicted values over 5 years of representative dispersion conditions, assuming continuous emissions throughout the year (i.e. 24 hours a day, 7 days a week) for the time periods considered in the scenarios assessed.



**Royal  
HaskoningDHV**  
*Enhancing Society Together*

## **Appendix A1: Technical Appendix**

## Appendix A1: Technical Appendix

### 1.1 Introduction

Emissions of NO<sub>x</sub> and CO in all scenarios were modelled using AERMOD (Lakes Environmental model version 8.8.9). AERMOD is a quantitative dispersion model based on the Gaussian theory of plume dispersion and is widely used in the UK for regulatory and assessment purposes. It uses all input data (stack parameters, the terrain, hourly sequential meteorological data and buildings location and configuration) to calculate dispersion and resulting ground level pollutant concentrations.

### 1.2 Meteorological Data

Meteorological data from Milford Haven recording station were used in the air dispersion modelling. This is the closest and most representative station to the site location and was used to provide consistency with the Validation Report on Dispersion Modelling at Dragon LNG. Five years (2010 – 2014) of hourly sequential meteorological data from the Milford Haven recording station were therefore used in the dispersion model.

The meteorological data were processed to make their interaction with the land surface representative of the site. The parameters used to process the meteorological data were consistent with the Validation report, which are detailed in **Table A1**.

**Table A1: Buildings included in the AERMOD Model**

Sector	Sector Degrees (°)	Land use	Albedo	Bowen Ratio	Surface Roughness
1	90 - 270	Water	0.14	0.45	0.001
2	270 - 90	Cultivated Grassland	0.28	0.75	0.0725

#### 1.2.1 Seasonal Variation

Initial model tests were undertaken to determine the periods within the year that resulted in the highest pollutant concentrations. Q3 and Q4 were found to result in the most conservative estimation of pollutant concentrations at receptor locations, therefore meteorological data from July to December were used in all 6-month model scenarios.

### 1.3 Terrain Data

To represent the influence of terrain elevations on dispersion, a digital elevation file was used in the AERMOD model setup. Shuttle Radar Topography Mission (SRTM3) elevation data was extrapolated from the WebGIS website<sup>1</sup> and incorporated into the modelling assessment.

For both the receptors and grid points, the recommended Lakes Inverse Distance interpolation was used. This function interpolates the neighbouring points using inverse distance to obtain the elevation at the desired point. The terrain elevations used in the dispersion model are presented in **Figure A1**.

<sup>1</sup> SRTM3 terrain data obtained from WebGIS <http://www.webgis.com/srtm3.html>

## Appendix A1: Technical Appendix

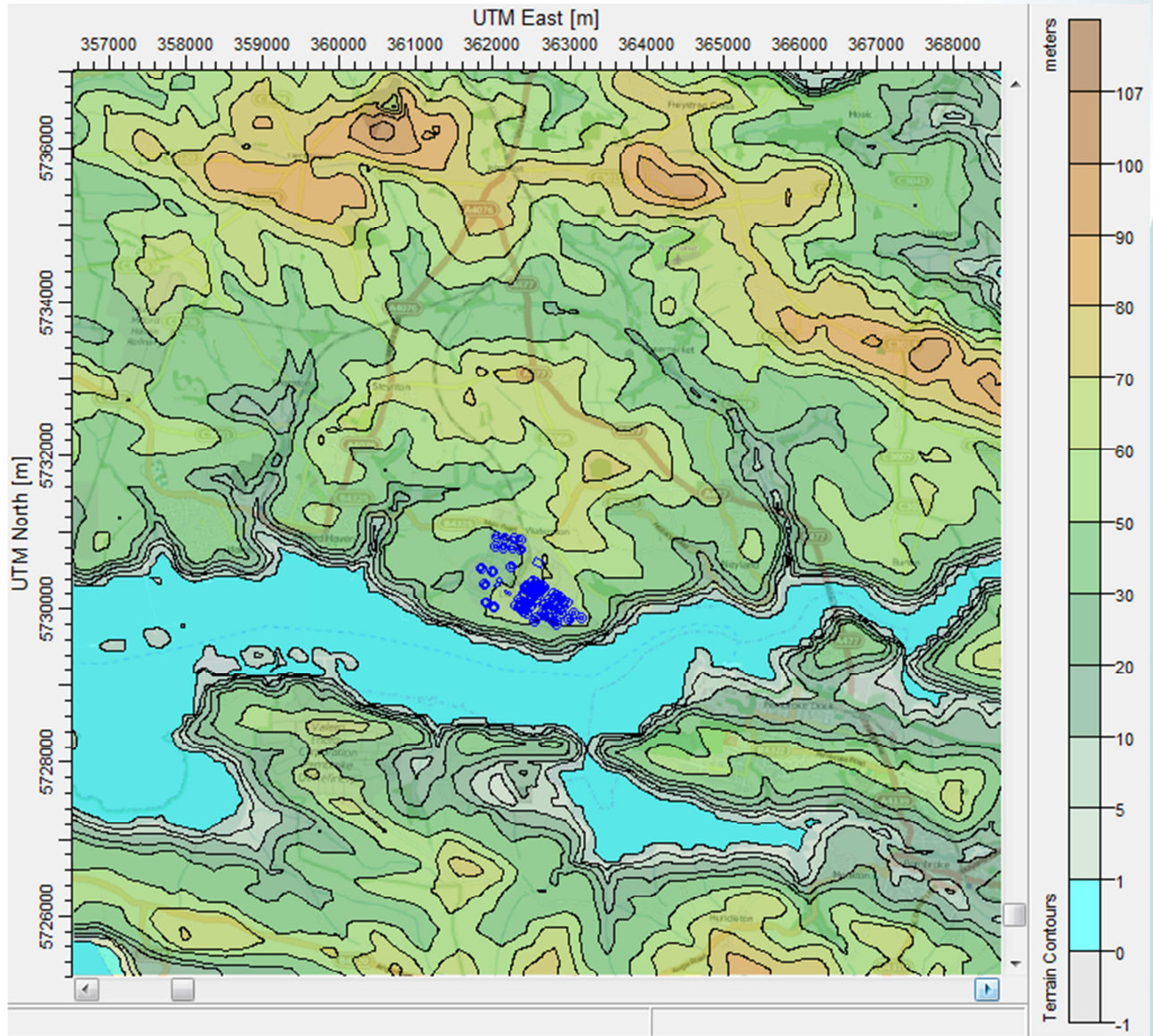
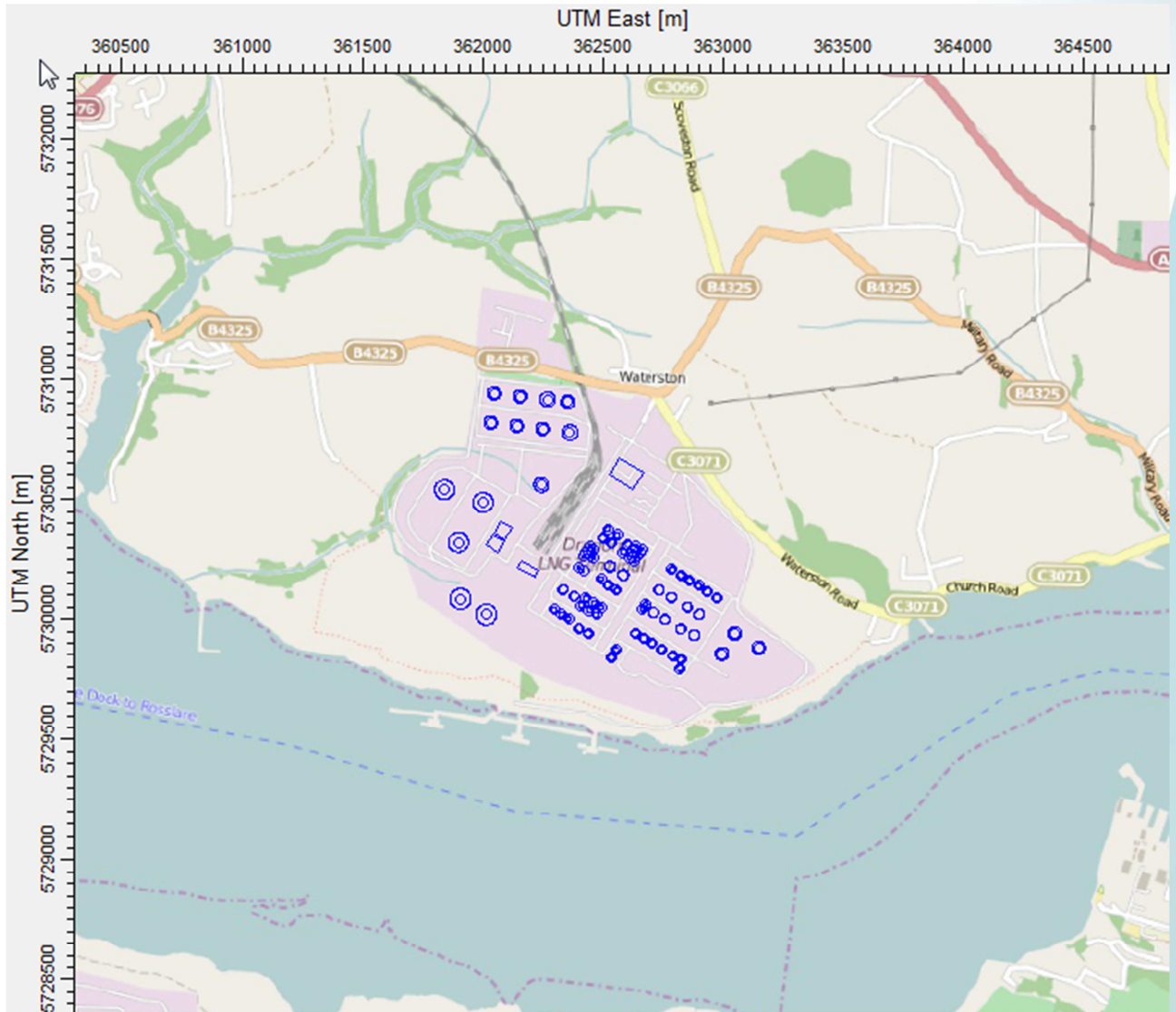


Figure A1: Terrain Contours Included in the Dispersion Model

### 1.4 Treatment of Buildings

Building dimensions were taken from the site plan and elevation drawings and the Building Profile Input Programme (BPIP) algorithm was used to calculate building downwash parameters within AERMOD. The configuration of the buildings included in the model set-up is presented in **Figure A2**.

## Appendix A1: Technical Appendix



**Figure A2: Buildings Considered in the Dispersion Model**

Building height details were determined from site drawings. Full details of the buildings included in the model are provided in **Table A2**.

**Table A2: Buildings included in the AERMOD Model**

Building Description	Building Height (m)	Building Description	Building Height (m)
LNG Tank 1	26.25	Tank 103	12.88
LNG Tank 2	26.25	Tank 104	12.88
Tank 706	17.40	Tank 105	12.88
Tank 705	12.88	Tank 402	12.88

## Appendix A1: Technical Appendix

Building Description	Building Height (m)	Building Description	Building Height (m)
Tank 704	12.88	Tank 403	12.88
Tank 604	13.26	Tank 506	9.20
Tank 876	9.90	Tank 401	13.28
Tank 10	14.47	Tank 400	13.28
Tank 703	14.95	Tank 508	10.90
Tank 702	14.95	Tank 511	10.90
Tank 603	13.28	Tank 312	12.88
Tank 875	9.90	Tank 311	12.88
Tank 602	12.88	Tank 306	9.00
Tank 607	12.88	Tank 305	9.00
Tank 606	12.88	Tank 310	12.88
Tank 605	12.88	Tank 304	12.88
Tank 601	12.88	Tank 309	9.00
Tank 600	12.88	Tank 303	9.00
Tank 220	9.90	Tank 302	9.00
Tank 221	9.90	Tank 308	9.00
Tank 222	9.90	Tank 307	9.00
Tank 223	9.90	Tank 301	9.00
Tank 224	9.90	Tank 300	9.00
Tank 225	9.90	Tank 507	11.70
Tank 226	9.90	Tank 502	11.70
Tank 201	1.00	Tank 501	11.70
Tank 200	1.00	Tank 500	11.70
Tank 202	13.28	Tank 504	11.70
Tank 203	13.28	Tank 505	11.70
Tank 204	13.28	Tank 9	14.47
Tank 205	13.28	Tank 11	14.47
Tank 206	9.00	Tank 12	7.50
Tank 114	9.00	Tank 8	9.00
Tank 115	9.00	Tank 7	9.00
Tank 110	13.28	Tank 6	9.00

## Appendix A1: Technical Appendix

Building Description	Building Height (m)	Building Description	Building Height (m)
Tank 111	13.28	Tank 5	9.00
Tank 112	13.28	Tank 1	9.00
Tank 113	13.28	Tank 2	9.00
Tank 100	12.88	Tank 3	9.00
Tank 101	12.88	Tank 4	9.00
Tank 102	12.88	Nitrogen Plant 1	18.78
Nitrogen Plant 2	18.78	Cogen Plant	8.50
Preliquification Plant	3.80		

### 1.5 Model Scenarios

The following scenarios were considered in the assessment:

- A1 normal operation – 6 month period;
- A1 peak operation – 6 month period;
- A2 normal and peak operation – 6 month period;
- B1 normal operation – 6 month period;
- B1 peak operation – 6 month period;
- B1 normal operation – 12 month period; and
- B1 peak operation – 12 month period.

The emission parameters utilised in the dispersion modelling are detailed in **Table A3**.

**Table A3: Emission Parameters Utilised in the Dispersion Model**

Source	Release Height (m)	Stack Diameter (m)	Volumetric Flow Rate (Nm <sup>3</sup> .s <sup>-1</sup> )	Temp (K)	Mass Release (g.s <sup>-1</sup> )	Exit Velocity (m.sec <sup>-1</sup> ) at Discharge Temp	Measured Pollutant Concentration (mg.m <sup>-3</sup> )
Cogeneration Plant Main Stack	92	2.80	75.80	406	NOx (4.6) CO (3.1)	18.30	NOx 69 CO 37.5
Submerged Combustion Vapourisers (SCVs)	15	0.68	7.34	288	NOx (0.45) CO (0.26) <sup>1</sup>	21.30	NOx 61 CO 33 <sup>2</sup>

<sup>1</sup> These are the average mass release rates for NOx and CO over all six SCVs

<sup>2</sup> Note that these are the average NOx and CO emission concentrations over all six SCVs

## Appendix A1: Technical Appendix

### 1.6 Model Receptor Locations

Fifteen receptor locations were included in the dispersion model. The same receptor locations that were previously used were selected in previous modelling examples at the site. These receptor locations are detailed in **Table A4**.

**Table A4: Model Receptor Locations**

Receptor		Grid Reference	
R1	Waterston	193816	205760
R2	Neyland	195929	205318
R3	Milford Haven	191138	206098
R4	Pembroke Dock	195732	203486
R5	Rosemarket	195281	208371
R6	Scoveston	193693	206981
R7	Steynton	191805	207638
R8	The Daugleddau	197350	211450
R9	Littlewick Point to Brunel Quay	193966	204293
R10	Milford Haven South	194539	202913
R11	Pembroke River	194639	202060
R12	2, Alban Crescent, Waterston	193718	205422
R13	Hazel Hill House, Llanstadwell	194253	204999
R14	10, Lighthouse Drive, Llanstadwell	194498	204539
R15	Castle Hall Lode, Blackbridge	191891	205752
R16	The Glen, Milford Haven	192903	205741

### 1.7 Cartesian Receptor Grid Parameters

A 12 x 11km uniform Cartesian receptor grid with a resolution of 500m was included in the dispersion model to cover human receptor locations. Embedded within that grid was a fine Cartesian receptor grid, measuring 2.5km x 3km with a resolution of 100m. Both grids were centered on the site. The Cartesian receptor grids are detailed in **Table A5**.

**Table A5: Cartesian Receptor Grid Parameters – Human Receptors**

Parameter	Grid 1		Grid 2	
	Easting	Northing	Easting	Northing
Centre Grid Coordinates	193447	205217	193447	205217
No. of Points	25	23	26	31
Spacing (m)	500	500	100	100

## Appendix A1: Technical Appendix

Length (m)	12,000	11,000	2,500	3,000
Total Receptors	575		806	

An additional three receptor grids were included in the dispersion model, to cover the Pembrokeshire Marine SAC and Milford Haven Waterway SSSI. Details of the ecological receptor grids are presented in **Table A6**.

**Table A6: Cartesian Receptor Grid Parameters – Designated Ecological Sites**

Parameter	Grid 3		Grid 4		Grid 5	
	Easting	Northing	Easting	Northing	Easting	Northing
South-west Grid Coordinates	188348	203036	193576	201262	195918	205940
No. of Points	201	51	26	31	21	25
Spacing (m)	50	50	100	100	50	50
Length (m)	10,000	2,500	4,700	1,700	1,000	1,200
Total Receptors	10,251		3,325		525	



**Royal  
HaskoningDHV**  
*Enhancing Society Together*

## **Appendix A: Figures**



**Key:**

— LNG Boundary

**ABERDAUGLEDDAU / MILFORD HAVEN**

**Title**  
Site Location Plan

**Project**  
9Y1920 Air Dispersion Modelling

**Client**  
Dragon LNG

**Date**  
23/03/2015

**Scale**  
1:25000

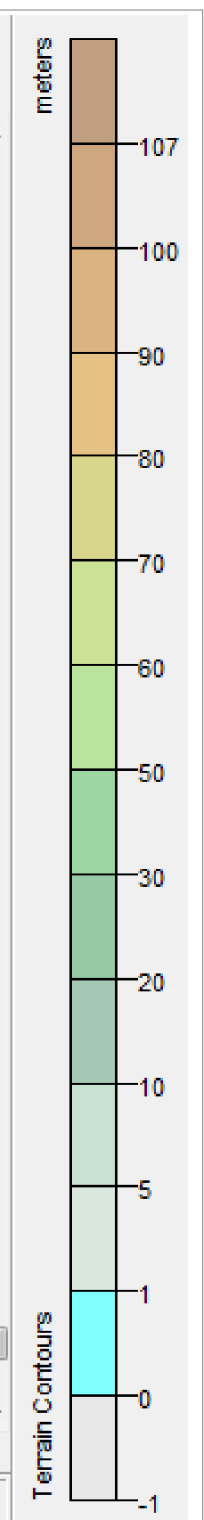
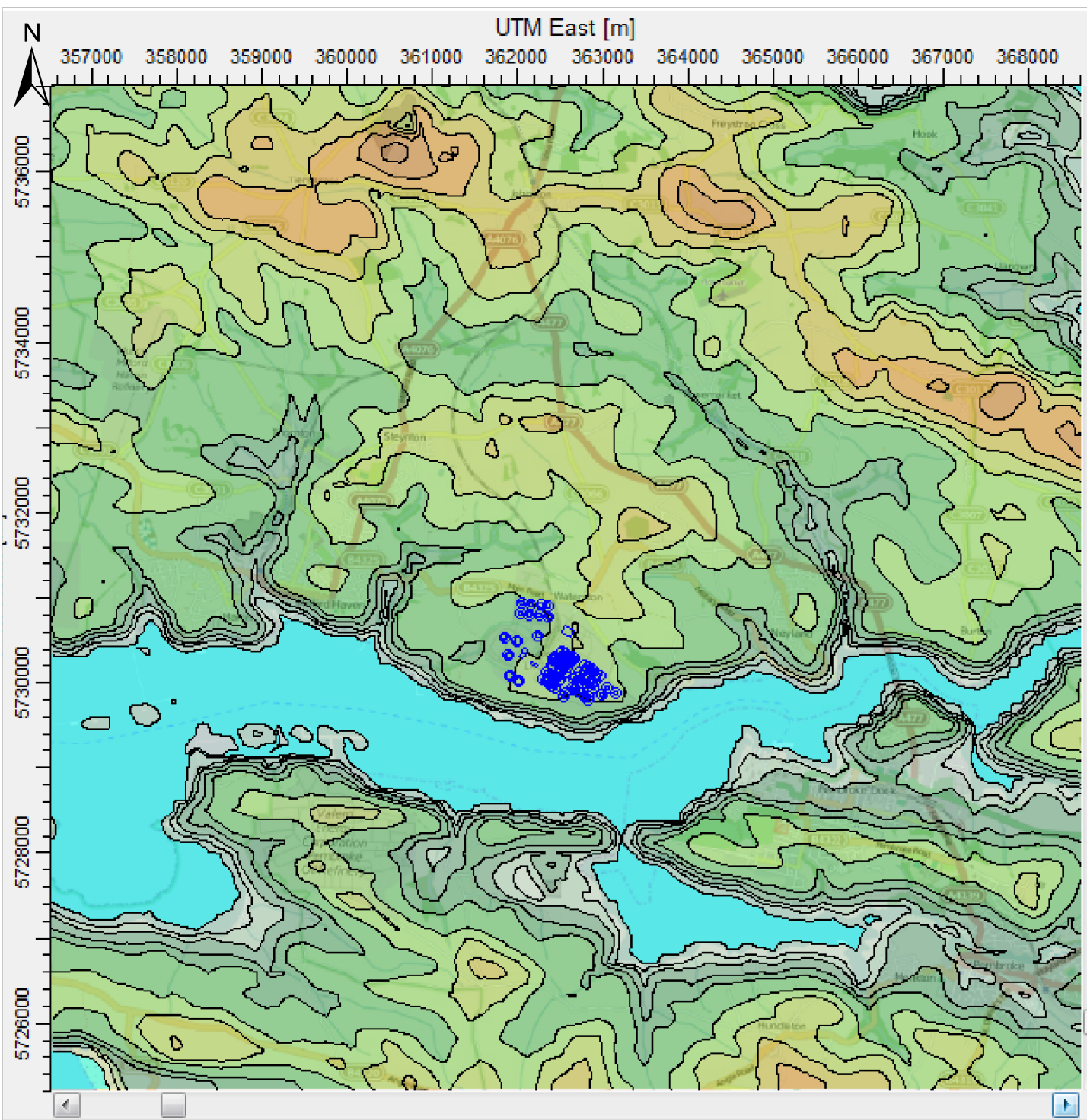
**Figure**  
Figure 1

**Checked by**  
JD

**Number**  
V1



**Royal HaskoningDHV**  
Enhancing Society Together



*Title*  
Terrain Contours Included in the Dispersion Model

*Project*  
Dragon LNG Terminal Reliquefaction Plant

*Client*  
Dragon LNG Limited

*Date*  
23/03/2015

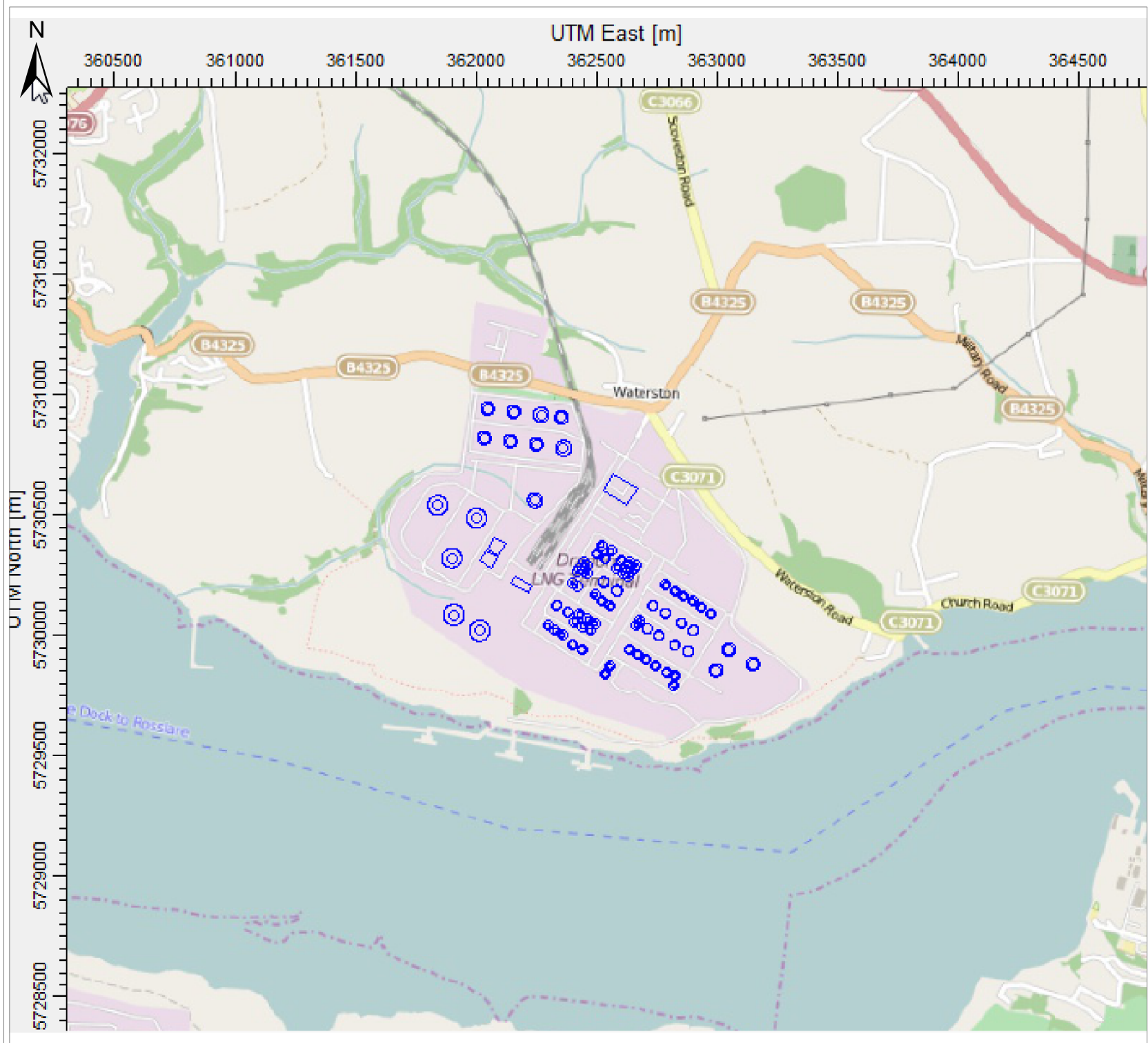
*Scale*  
N/A

*Figure*  
Figure 2

*Checked by*  
JD

*Number*  
V1





*Title*  
Buildings Considered in the Dispersion Model

*Project*  
Dragon LNG Terminal Reliquefaction Plant

*Client*  
Dragon LNG Limited

*Date*  
23/03/2015

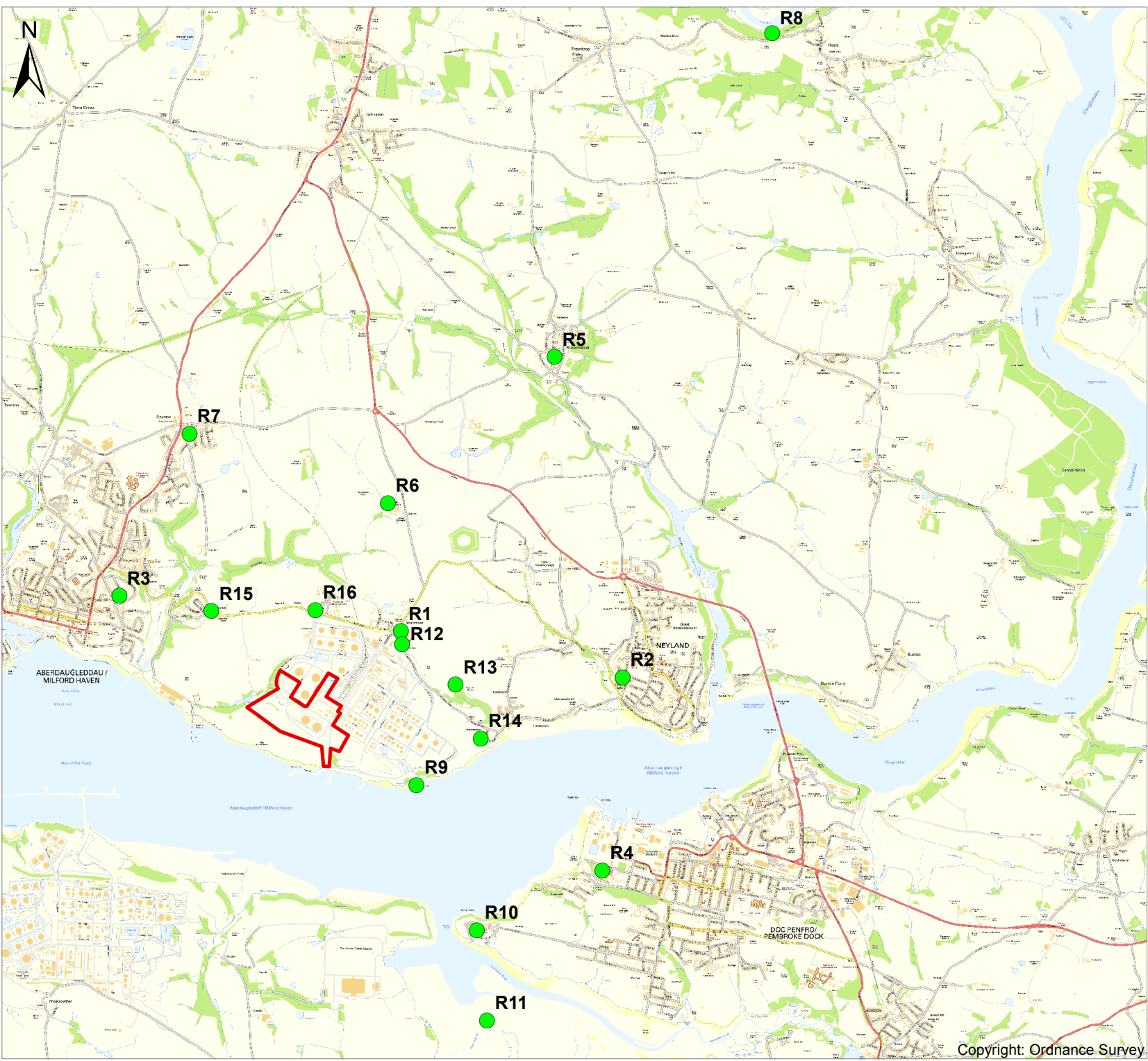
*Scale*  
N/A

*Figure*  
Figure 3

*Checked by*  
JD

*Number*  
V1





**Key:**

- LNG Boundary
- Human Receptors

**Title**  
Human Receptor Location Plan

**Project**  
9Y1920 Air Dispersion Modelling

**Client**  
Dragon LNG

**Date**  
23/03/2015

**Scale**  
1:50000

**Figure**  
Figure 1

**Checked by**  
JD

**Number**  
V1





**Royal  
HaskoningDHV**  
*Enhancing Society Together*

## **Appendix B: Human Receptor Results**

**A1 Normal Scenario**

**NO<sub>2</sub> 1 Hour 99.8<sup>th</sup> Percentile**

Receptor	2014 NO <sub>2</sub> Background Concentration	2010					2011					2012					2013					2014				
		PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO
		µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
R1	20.10	3.13	1.10	41.30	1.57	20.65	3.08	1.08	41.28	1.54	20.64	2.73	0.95	41.16	1.36	20.58	3.16	1.11	41.31	1.58	20.65	2.89	1.01	41.21	1.45	20.61
R2	12.24	1.54	0.54	25.02	0.77	12.51	1.53	0.53	25.02	0.76	12.51	1.60	0.56	25.04	0.80	12.52	1.72	0.60	25.09	0.86	12.54	1.39	0.49	24.97	0.70	12.49
R3	19.77	1.56	0.55	40.09	0.78	20.04	1.39	0.49	40.03	0.70	20.02	1.44	0.51	40.05	0.72	20.02	1.68	0.59	40.13	0.84	20.06	1.90	0.67	40.21	0.95	20.10
R4	10.87	1.14	0.40	22.14	0.57	11.07	1.01	0.35	22.09	0.51	11.05	1.10	0.38	22.12	0.55	11.06	1.07	0.38	22.11	0.54	11.06	1.02	0.36	22.09	0.51	11.05
R5	9.59	1.52	0.53	19.71	0.76	9.86	1.37	0.48	19.66	0.68	9.83	1.28	0.45	19.63	0.64	9.82	1.28	0.45	19.63	0.64	9.81	1.31	0.46	19.64	0.65	9.82
R6	13.98	1.81	0.63	28.59	0.90	14.30	1.85	0.65	28.61	0.93	14.30	1.57	0.55	28.51	0.79	14.26	1.81	0.63	28.59	0.91	14.30	1.73	0.61	28.57	0.86	14.28
R7	13.56	0.92	0.32	27.45	0.46	13.72	1.25	0.44	27.56	0.63	13.78	1.13	0.40	27.52	0.57	13.76	1.01	0.35	27.48	0.51	13.74	1.10	0.39	27.51	0.55	13.75
R8	7.34	1.03	0.36	15.04	0.51	7.52	0.93	0.32	15.00	0.46	7.50	0.71	0.25	14.93	0.35	7.46	0.72	0.25	14.93	0.36	7.47	0.79	0.28	14.95	0.39	7.48
R9	28.67	1.86	0.65	57.99	0.93	28.99	1.79	0.63	57.96	0.89	28.98	1.74	0.61	57.94	0.87	28.97	1.76	0.61	57.95	0.88	28.98	1.69	0.59	57.93	0.85	28.96
R10	10.22	1.23	0.43	20.86	0.61	10.43	1.11	0.39	20.82	0.55	10.41	1.07	0.38	20.81	0.54	10.40	1.08	0.38	20.81	0.54	10.40	1.10	0.39	20.82	0.55	10.41
R11	10.22	1.03	0.36	20.79	0.51	10.39	0.88	0.31	20.74	0.44	10.37	0.77	0.27	20.70	0.38	10.35	0.89	0.31	20.74	0.44	10.37	0.89	0.31	20.74	0.44	10.37
R12	20.10	3.30	1.16	41.36	1.65	20.68	3.00	1.05	41.25	1.50	20.63	2.82	0.99	41.19	1.41	20.59	3.12	1.09	41.30	1.56	20.65	3.23	1.13	41.33	1.62	20.67
R13	15.42	2.54	0.89	31.73	1.27	15.87	2.86	1.00	31.84	1.43	15.92	2.90	1.02	31.86	1.45	15.93	2.98	1.04	31.89	1.49	15.94	2.54	0.89	31.73	1.27	15.87
R14	16.75	1.88	0.66	34.16	0.94	17.08	1.69	0.59	34.09	0.84	17.04	1.80	0.63	34.13	0.90	17.06	1.81	0.64	34.13	0.91	17.07	1.77	0.62	34.12	0.88	17.06
R15	21.28	1.71	0.60	43.15	0.85	21.58	2.04	0.72	43.27	1.02	21.64	2.36	0.83	43.38	1.18	21.69	2.16	0.76	43.31	1.08	21.66	1.87	0.65	43.21	0.93	21.60
R16	20.10	2.61	0.91	41.12	1.30	20.56	3.01	1.05	41.26	1.51	20.63	1.80	0.63	40.83	0.90	20.42	2.30	0.80	41.01	1.15	20.50	2.36	0.83	41.03	1.18	20.51

**NO<sub>2</sub> Annual Mean**

Receptor	2014 NO <sub>2</sub> Background Concentration	2010					2011					2012					2013					2014				
		PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO
		µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
R1	20.10	0.05	0.03	20.13	0.12	50.34	0.04	0.03	20.13	0.11	50.33	0.04	0.03	20.13	0.11	50.33	0.04	0.03	20.13	0.11	50.33	0.04	0.03	20.13	0.10	50.33
R2	12.24	0.04	0.03	12.27	0.10	30.68	0.06	0.04	12.28	0.14	30.70	0.05	0.03	12.28	0.12	30.69	0.04	0.03	12.27	0.11	30.68	0.04	0.03	12.27	0.10	30.67
R3	19.77	0.02	0.01	19.79	0.05	49.46	0.01	0.01	19.78	0.03	49.45	0.01	0.01	19.78	0.03	49.45	0.02	0.02	19.79	0.06	49.47	0.03	0.02	19.79	0.07	49.48
R4	10.87	0.03	0.02	10.89	0.08	27.23	0.03	0.02	10.89	0.07	27.23	0.03	0.02	10.89	0.08	27.23	0.03	0.02	10.89	0.06	27.22	0.03	0.02	10.89	0.07	27.22
R5	9.59	0.02	0.02	9.61	0.06	24.02	0.02	0.02	9.61	0.06	24.02	0.02	0.01	9.60	0.05	24.01	0.02	0.02	9.61	0.06	24.02	0.02	0.01	9.60	0.04	24.01
R6	13.98	0.03	0.02	14.00	0.07	35.00	0.02	0.02	14.00	0.06	34.99	0.03	0.02	14.00	0.06	34.99	0.03	0.02	14.00	0.07	35.00	0.02	0.02	14.00	0.06	34.99
R7	13.56	0.01	0.01	13.57	0.02	33.92	0.01	0.01	13.57	0.03	33.93	0.01	0.01	13.57	0.02	33.92	0.01	0.01	13.57	0.02	33.92	0.01	0.01	13.57	0.02	33.92
R8	7.34	0.01	0.01	7.35	0.03	18.37	0.01	0.01	7.35	0.03	18.37	0.01	0.01	7.35	0.02	18.37	0.01	0.01	7.35	0.03	18.37	0.01	0.01	7.35	0.02	18.37
R9	28.67	0.05	0.03	28.70	0.12	71.75	0.04	0.03	28.70	0.10	71.74	0.04	0.03	28.70	0.11	71.74	0.04	0.03	28.69	0.09	71.74	0.04	0.03	28.70	0.11	71.75
R10	10.22	0.03	0.02	10.23	0.06	25.58	0.02	0.02	10.23	0.06	25.58	0.02	0.01	10.23	0.05	25.57	0.03	0.02	10.23	0.06	25.58	0.02	0.02	10.23	0.06	25.58
R11	10.22	0.02	0.01	10.23	0.04	25.57	0.02	0.01	10.23	0.04	25.57	0.01	0.01	10.23	0.04	25.56	0.02	0.01	10.23	0.05	25.57	0.02	0.01	10.23	0.04	25.57
R12	20.10	0.05	0.03	20.14	0.12	50.34	0.04	0.03	20.13	0.11	50.33	0.04	0.03	20.13	0.11	50.33	0.05	0.03	20.14	0.12	50.34	0.05	0.03	20.13	0.11	50.33
R13	15.42	0.07	0.05	15.47	0.19	38.68	0.07	0.05	15.47	0.19	38.68	0.08	0.05	15.47	0.19	38.69	0.08	0.05	15.47	0.19	38.69	0.06	0.05	15.47	0.16	38.67
R14	16.75	0.05	0.03	16.78	0.12	41.96	0.06	0.04	16.79	0.16	41.98	0.06	0.04	16.79	0.15	41.97	0.05	0.03	16.78	0.12	41.95	0.05	0.03	16.78	0.12	41.95
R15	21.28	0.02	0.01	21.29	0.05	53.23	0.02	0.01	21.29	0.05	53.23	0.02	0.01	21.29	0.05	53.23	0.03	0.02	21.30	0.07	53.25	0.03	0.02	21.30	0.07	53.24
R16	20.10	0.03	0.02	20.12	0.07	50.30	0.03	0.02	20.12	0.07	50.31	0.02	0.01	20.11	0.04	50.28	0.03	0.02	20.12	0.06	50.30	0.02	0.02	20.12	0.06	50.30

**CO 8 Hour Mean**

Receptor	2001 CO Background Concentration	2010				2011				2012				2013				2014			
		PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO
		mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%
R1	0.150	0.0013	0.3013	0.01	3.01	0.0011	0.3011	0.01	3.01	0.0021	0.3021	0.02	3.02	0.0014	0.3014	0.01	3.01	0.0015	0.3015	0.01	3.01
R2	0.159	0.0009	0.3189	0.01	3.19	0.0008	0.3188	0.01	3.19	0.0010	0.3190	0.01	3.19	0.0008	0.3188	0.01	3.19	0.0009	0.3189	0.01	3.19
R3	0.155	0.0008	0.3108	0.01	3.11	0.0010	0.3110	0.01	3.11	0.0008	0.3108	0.01	3.11	0.0007	0.3107	0.01	3.11	0.0010	0.3110	0.01	3.11
R4	0.159	0.0006	0.3186	0.01	3.19	0.0005	0.3185	0.00	3.18	0.0006	0.3186	0.01	3.19	0.0005	0.3185	0.00	3.18	0.0006	0.3186	0.01	3.19
R5	0.154	0.0007	0.3087	0.01	3.09	0.0009	0.3089	0.01	3.09	0.0009	0.3089	0.01	3.09	0.0010	0.3090	0.01	3.09	0.0006	0.3086	0.01	3.09
R6	0.152	0.0006	0.3046	0.01	3.05	0.0010	0.3050	0.01	3.05	0.0007	0.3047	0.01	3.05	0.0010	0.3050	0.01	3.05	0.0007	0.3047	0.01	3.05
R7	0.157	0.0005	0.3145	0.00	3.14	0.0005	0.3145	0.00	3.14	0.0005	0.3145	0.00	3.14	0.0006	0.3146	0.01	3.15	0.0004	0.3144	0.00	3.14
R8	0.151	0.0004	0.3024	0.00	3.02	0.0006	0.3026	0.01	3.03	0.0005	0.3025	0.00	3.02	0.0006	0.3026	0.01	3.03	0.0003	0.3023	0.00	3.02
R9	0.150	0.0010	0.3010	0.01	3.01	0.0009	0.3009	0.01	3.01	0.0008	0.3008	0.01	3.01	0.0008	0.300						

**A1 Peak Scenario**

**NO<sub>2</sub> 1 Hour 99.8<sup>th</sup> Percentile**

Receptor	2014 NO <sub>2</sub> Background Concentration	2010					2011					2012					2013					2014				
		PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO
		µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
R1	20.10	9.47	3.31	43.52	4.73	21.76	9.27	3.24	43.45	4.63	21.72	7.94	2.78	42.98	3.97	21.49	9.11	3.19	43.39	4.56	21.70	8.59	3.01	43.21	4.29	21.60
R2	12.24	3.14	1.10	25.58	1.57	12.79	3.28	1.15	25.63	1.64	12.82	3.56	1.24	25.73	1.78	12.86	3.95	1.38	25.87	1.97	12.93	3.10	1.09	25.57	1.55	12.79
R3	19.77	3.00	1.05	40.59	1.50	20.30	3.39	1.19	40.73	1.69	20.36	3.20	1.12	40.66	1.60	20.33	3.90	1.36	40.91	1.95	20.45	4.30	1.50	41.05	2.15	20.52
R4	10.87	2.85	1.00	22.73	1.42	11.37	2.13	0.75	22.49	1.07	11.24	2.44	0.86	22.59	1.22	11.30	2.64	0.92	22.66	1.32	11.33	2.37	0.83	22.57	1.19	11.28
R5	9.59	2.74	0.96	20.14	1.37	10.07	2.28	0.80	19.98	1.14	9.99	2.08	0.73	19.91	1.04	9.95	2.07	0.73	19.91	1.04	9.95	2.29	0.80	19.98	1.14	9.99
R6	13.98	4.19	1.47	29.43	2.09	14.71	3.85	1.35	29.31	1.92	14.65	3.69	1.29	29.25	1.85	14.63	4.73	1.66	29.62	2.37	14.81	4.35	1.52	29.48	2.18	14.74
R7	13.56	1.46	0.51	27.64	0.73	13.82	2.07	0.72	27.85	1.03	13.92	1.68	0.59	27.71	0.84	13.86	1.54	0.54	27.66	0.77	13.83	1.76	0.61	27.74	0.88	13.87
R8	7.34	1.79	0.63	15.31	0.90	7.65	1.48	0.52	15.20	0.74	7.60	1.18	0.41	15.09	0.59	7.55	1.31	0.46	15.14	0.66	7.57	1.36	0.48	15.15	0.68	7.58
R9	28.67	5.42	1.90	59.23	2.71	29.62	4.71	1.65	58.98	2.35	29.49	4.88	1.71	59.04	2.44	29.52	4.85	1.70	59.04	2.43	29.52	4.77	1.67	59.01	2.38	29.50
R10	10.22	2.73	0.96	21.39	1.37	10.69	2.38	0.83	21.26	1.19	10.63	2.21	0.77	21.20	1.10	10.60	2.84	0.99	21.42	1.42	10.71	2.39	0.84	21.27	1.19	10.63
R11	10.22	2.23	0.78	21.21	1.12	10.61	1.90	0.66	21.09	0.95	10.55	1.81	0.63	21.06	0.91	10.53	2.26	0.79	21.22	1.13	10.61	2.21	0.77	21.20	1.10	10.60
R12	20.10	10.27	3.59	43.80	5.13	21.90	8.67	3.04	43.24	4.34	21.62	8.87	3.10	43.31	4.43	21.65	9.32	3.26	43.46	4.66	21.73	9.74	3.41	43.61	4.87	21.81
R13	15.42	7.26	2.54	33.38	3.63	16.69	8.21	2.87	33.72	4.11	16.86	7.92	2.77	33.61	3.96	16.81	8.95	3.13	33.98	4.48	16.99	7.71	2.70	33.54	3.86	16.77
R14	16.75	3.39	1.19	34.68	1.69	17.34	3.82	1.34	34.83	1.91	17.42	3.69	1.29	34.79	1.84	17.39	3.81	1.34	34.83	1.91	17.42	3.79	1.33	34.82	1.90	17.41
R15	21.28	4.23	1.48	44.04	2.11	22.02	5.59	1.96	44.51	2.79	22.26	5.87	2.05	44.61	2.94	22.31	5.32	1.86	44.42	2.66	22.21	4.68	1.64	44.19	2.34	22.10
R16	20.10	7.31	2.56	42.76	3.65	21.38	8.34	2.92	43.12	4.17	21.56	4.58	1.60	41.81	2.29	20.90	6.82	2.39	42.59	3.41	21.29	5.92	2.07	42.28	2.96	21.14

**NO<sub>2</sub> Annual Mean**

Receptor	2014 NO <sub>2</sub> Background Concentration	2010					2011					2012					2013					2014				
		PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO
		µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
R1	20.10	0.13	0.09	20.19	0.33	50.48	0.12	0.08	20.19	0.30	50.46	0.12	0.08	20.18	0.29	50.46	0.12	0.09	20.19	0.31	50.47	0.11	0.08	20.18	0.28	50.45
R2	12.24	0.07	0.05	12.29	0.19	30.74	0.10	0.07	12.31	0.25	30.78	0.09	0.06	12.30	0.22	30.76	0.08	0.06	12.30	0.21	30.75	0.07	0.05	12.29	0.19	30.74
R3	19.77	0.04	0.03	19.80	0.10	49.50	0.03	0.02	19.79	0.07	49.48	0.03	0.02	19.79	0.08	49.48	0.05	0.04	19.81	0.13	49.52	0.06	0.04	19.81	0.14	49.53
R4	10.87	0.06	0.04	10.91	0.15	27.28	0.07	0.05	10.92	0.17	27.29	0.06	0.04	10.91	0.16	27.28	0.05	0.04	10.91	0.13	27.27	0.06	0.04	10.91	0.14	27.27
R5	9.59	0.04	0.03	9.62	0.10	24.05	0.04	0.03	9.62	0.10	24.05	0.03	0.02	9.61	0.08	24.03	0.04	0.03	9.62	0.09	24.04	0.03	0.02	9.61	0.07	24.03
R6	13.98	0.06	0.04	14.02	0.15	35.05	0.05	0.04	14.02	0.13	35.04	0.06	0.04	14.02	0.14	35.05	0.07	0.05	14.03	0.17	35.07	0.05	0.04	14.02	0.13	35.04
R7	13.56	0.01	0.01	13.57	0.04	33.93	0.02	0.01	13.58	0.05	33.94	0.01	0.01	13.57	0.03	33.93	0.01	0.01	13.57	0.04	33.93	0.02	0.01	13.57	0.04	33.93
R8	7.34	0.02	0.02	7.36	0.06	18.39	0.02	0.02	7.35	0.05	18.39	0.02	0.01	7.35	0.04	18.38	0.02	0.01	7.35	0.05	18.38	0.02	0.01	7.35	0.04	18.38
R9	28.67	0.11	0.08	28.75	0.28	71.87	0.10	0.07	28.74	0.24	71.84	0.11	0.07	28.74	0.27	71.86	0.09	0.06	28.73	0.23	71.83	0.11	0.08	28.75	0.28	71.87
R10	10.22	0.05	0.04	10.25	0.13	25.63	0.05	0.04	10.25	0.13	25.63	0.04	0.03	10.24	0.10	25.61	0.06	0.04	10.25	0.14	25.64	0.05	0.03	10.25	0.12	25.62
R11	10.22	0.03	0.02	10.24	0.09	25.60	0.03	0.02	10.24	0.08	25.59	0.03	0.02	10.24	0.07	25.59	0.04	0.03	10.25	0.11	25.62	0.03	0.02	10.24	0.08	25.60
R12	20.10	0.14	0.10	20.20	0.35	50.50	0.12	0.08	20.19	0.30	50.46	0.12	0.09	20.19	0.31	50.47	0.14	0.09	20.20	0.34	50.49	0.13	0.09	20.19	0.33	50.48
R13	15.42	0.19	0.13	15.55	0.47	38.88	0.19	0.13	15.55	0.46	38.88	0.19	0.13	15.56	0.48	38.89	0.20	0.14	15.56	0.49	38.90	0.17	0.12	15.54	0.44	38.86
R14	16.75	0.10	0.07	16.82	0.25	42.04	0.16	0.11	16.86	0.41	42.16	0.13	0.09	16.84	0.34	42.11	0.11	0.08	16.82	0.27	42.06	0.11	0.07	16.82	0.26	42.05
R15	21.28	0.04	0.03	21.31	0.10	53.27	0.05	0.03	21.31	0.12	53.28	0.05	0.03	21.31	0.12	53.28	0.06	0.05	21.32	0.16	53.31	0.06	0.04	21.32	0.14	53.30
R16	20.10	0.07	0.05	20.15	0.17	50.37	0.07	0.05	20.15	0.18	50.38	0.04	0.03	20.13	0.09	50.32	0.06	0.04	20.14	0.14	50.35	0.06	0.04	20.14	0.14	50.35

**CO 8 Hour Mean**

Receptor	2014 CO Background Concentration	2010				2011				2012				2013				2014			
		PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO
		mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%
R1	0.150	0.0039	0.3039	0.04	3.04	0.0034	0.3034	0.03	3.03	0.0056	0.3056	0.06	3.06	0.0042	0.3042	0.04	3.04	0.0044	0.3044	0.04	3.04
R2	0.159	0.0021	0.3201	0.02	3.20	0.0012	0.3192	0.01	3.19	0.0019	0.3199	0.02	3.20	0.0016	0.3196	0.02	3.20	0.0018	0.3198	0.02	3.20
R3	0.155	0.0013	0.3113	0.01	3.11	0.0025	0.3125	0.02	3.12	0.0016	0.3116	0.02	3.12	0.0016	0.3116	0.02	3.12	0.0020	0.3120	0.02	3.12
R4	0.159	0.0013	0.3193	0.01	3.19	0.0010	0.3190	0.01	3.19	0.0009	0.3189	0.01	3.19	0.0011	0.3191	0.01	3.19	0.0012	0.3192	0.01	3.19
R5	0.154	0.0011	0.3091	0.01	3.09	0.0016	0.3096	0.02	3.10	0.0019	0.3099	0.02	3.10	0.0016	0.3096	0.02	3.10	0.0009	0.3089	0.01	3.09
R6	0.152	0.0017	0.3057	0.02	3.06	0.0019	0.3059	0.02	3.06	0.0018	0.3058	0.02	3.06	0.0020	0.3060	0.02	3.06	0.0017	0.3057	0.02	3.06
R7	0.157	0.0009	0.3149	0.01	3.15	0.0007	0.3147	0.01	3.15	0.0007	0.3147	0.01	3.15	0.0007	0.3147	0.01	3.15	0.0006	0.3146	0.01	3.15
R8	0.151	0.0007	0.3027	0.01	3.03	0.0009	0.3029	0.01	3.03	0.0010	0.3030	0.01	3.03	0.0011	0.3031	0.01	3.03	0.0006	0.3026	0.01	3.03
R9	0.150	0.0023	0.3023	0.02	3.02	0.0020	0.3020	0.02	3.02	0.0023	0.3023	0.02	3.02	0.0017	0.3017	0.02					

**A2 Normal and Peak Scenario**

**NO<sub>2</sub> 1 Hour 99.8<sup>th</sup> Percentile**

Receptor	2014 NO <sub>2</sub> Background Concentration	2010					2011					2012					2013					2014				
		PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO
		µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
R1	20.10	0.61	0.21	40.42	0.31	20.21	1.04	0.36	40.57	0.52	20.28	0.57	0.20	40.40	0.28	20.20	0.76	0.27	40.47	0.38	20.23	0.48	0.17	40.37	0.24	20.19
R2	12.24	1.12	0.39	24.88	0.56	12.44	1.12	0.39	24.88	0.56	12.44	1.16	0.41	24.89	0.58	12.44	1.13	0.40	24.88	0.57	12.44	1.13	0.39	24.88	0.56	12.44
R3	19.77	1.19	0.42	39.96	0.59	19.98	0.58	0.20	39.75	0.29	19.87	0.83	0.29	39.83	0.42	19.92	1.08	0.38	39.92	0.54	19.96	1.15	0.40	39.95	0.58	19.97
R4	10.87	0.94	0.33	22.07	0.47	11.03	0.80	0.28	22.02	0.40	11.01	0.94	0.33	22.07	0.47	11.03	0.87	0.31	22.04	0.44	11.02	0.82	0.29	22.03	0.41	11.01
R5	9.59	1.08	0.38	19.56	0.54	9.78	1.03	0.36	19.54	0.51	9.77	0.90	0.32	19.50	0.45	9.75	0.98	0.34	19.53	0.49	9.76	0.96	0.34	19.52	0.48	9.76
R6	13.98	1.00	0.35	28.31	0.50	14.16	1.10	0.38	28.34	0.55	14.17	0.90	0.32	28.28	0.45	14.14	0.95	0.33	28.29	0.48	14.15	0.96	0.34	28.30	0.48	14.15
R7	13.56	0.59	0.20	27.33	0.29	13.66	1.03	0.36	27.48	0.51	13.74	0.92	0.32	27.44	0.46	13.72	0.83	0.29	27.41	0.41	13.71	0.85	0.30	27.42	0.42	13.71
R8	7.34	0.76	0.27	14.94	0.38	7.47	0.71	0.25	14.93	0.35	7.46	0.51	0.18	14.86	0.25	7.43	0.52	0.18	14.86	0.26	7.43	0.57	0.20	14.88	0.29	7.44
R9	28.67	1.23	0.43	57.77	0.62	28.88	1.30	0.45	57.79	0.65	28.89	1.16	0.41	57.74	0.58	28.87	1.14	0.40	57.73	0.57	28.87	1.03	0.36	57.70	0.51	28.85
R10	10.22	0.91	0.32	20.75	0.45	10.37	0.91	0.32	20.75	0.45	10.37	0.83	0.29	20.72	0.42	10.36	0.90	0.31	20.75	0.45	10.37	0.84	0.29	20.72	0.42	10.36
R11	10.22	0.75	0.26	20.70	0.38	10.35	0.67	0.24	20.67	0.34	10.33	0.60	0.21	20.64	0.30	10.32	0.65	0.23	20.66	0.32	10.33	0.67	0.23	20.67	0.33	10.33
R12	20.10	0.44	0.15	40.36	0.22	20.18	1.00	0.35	40.55	0.50	20.28	0.35	0.12	40.32	0.17	20.16	0.58	0.20	40.41	0.29	20.20	0.32	0.11	40.31	0.16	20.16
R13	15.42	1.53	0.53	31.38	0.76	15.69	1.43	0.50	31.34	0.71	15.67	1.35	0.47	31.32	0.68	15.66	1.45	0.51	31.35	0.72	15.67	0.98	0.34	31.18	0.49	15.59
R14	16.75	1.62	0.57	34.06	0.81	17.03	1.27	0.44	33.94	0.63	16.97	1.53	0.54	34.03	0.77	17.02	1.46	0.51	34.01	0.73	17.00	1.52	0.53	34.03	0.76	17.01
R15	21.28	1.22	0.43	42.98	0.61	21.49	0.83	0.29	42.85	0.42	21.42	0.75	0.26	42.82	0.37	21.41	1.30	0.45	43.01	0.65	21.50	1.26	0.44	43.00	0.63	21.50
R16	20.10	0.79	0.28	40.48	0.40	20.24	1.31	0.46	40.66	0.65	20.33	0.66	0.23	40.44	0.33	20.22	1.22	0.43	40.63	0.61	20.32	0.82	0.29	40.49	0.41	20.25

**NO<sub>2</sub> Annual Mean**

Receptor	2014 NO <sub>2</sub> Background Concentration	2010					2011					2012					2013					2014				
		PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO
		µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
R1	20.10	0.00	0.00	20.10	0.01	50.26	0.01	0.00	20.11	0.02	50.27	0.00	0.00	20.10	0.01	50.26	0.01	0.00	20.11	0.01	50.26	0.00	0.00	20.10	0.01	50.26
R2	12.24	0.02	0.02	12.26	0.06	30.65	0.03	0.02	12.27	0.09	30.66	0.03	0.02	12.26	0.07	30.65	0.02	0.02	12.26	0.06	30.65	0.02	0.02	12.26	0.05	30.64
R3	19.77	0.01	0.01	19.78	0.03	49.45	0.00	0.00	19.77	0.01	49.44	0.01	0.00	19.78	0.01	49.44	0.01	0.01	19.78	0.02	49.44	0.01	0.01	19.78	0.03	49.45
R4	10.87	0.02	0.01	10.88	0.04	27.20	0.01	0.01	10.88	0.03	27.19	0.01	0.01	10.88	0.04	27.20	0.01	0.01	10.88	0.03	27.19	0.01	0.01	10.88	0.03	27.20
R5	9.59	0.02	0.01	9.60	0.04	24.00	0.02	0.01	9.60	0.04	24.00	0.01	0.01	9.60	0.03	24.00	0.01	0.01	9.60	0.04	24.00	0.01	0.01	9.60	0.03	24.00
R6	13.98	0.01	0.01	13.99	0.03	34.97	0.01	0.01	13.99	0.02	34.97	0.01	0.01	13.99	0.02	34.96	0.01	0.01	13.99	0.02	34.97	0.01	0.01	13.99	0.02	34.97
R7	13.56	0.00	0.00	13.57	0.01	33.91	0.01	0.01	13.57	0.02	33.92	0.01	0.00	13.57	0.02	33.92	0.01	0.00	13.57	0.02	33.92	0.01	0.00	13.57	0.02	33.92
R8	7.34	0.01	0.01	7.35	0.02	18.36	0.01	0.01	7.35	0.02	18.36	0.01	0.00	7.34	0.01	18.36	0.01	0.01	7.34	0.02	18.36	0.01	0.00	7.34	0.02	18.36
R9	28.67	0.01	0.01	28.68	0.03	71.69	0.01	0.01	28.68	0.03	71.69	0.01	0.01	28.68	0.02	71.69	0.01	0.01	28.68	0.03	71.69	0.01	0.01	28.68	0.03	71.69
R10	10.22	0.01	0.01	10.22	0.03	25.56	0.01	0.01	10.22	0.03	25.56	0.01	0.01	10.22	0.02	25.55	0.01	0.01	10.22	0.02	25.56	0.01	0.01	10.22	0.02	25.56
R11	10.22	0.01	0.01	10.22	0.02	25.55	0.01	0.00	10.22	0.02	25.55	0.01	0.00	10.22	0.02	25.55	0.01	0.01	10.22	0.02	25.55	0.01	0.00	10.22	0.02	25.55
R12	20.10	0.00	0.00	20.10	0.01	50.26	0.01	0.00	20.11	0.01	50.26	0.00	0.00	20.10	0.01	50.26	0.00	0.00	20.10	0.01	50.26	0.00	0.00	20.10	0.01	50.26
R13	15.42	0.02	0.01	15.43	0.05	38.59	0.02	0.01	15.43	0.04	38.58	0.02	0.01	15.43	0.04	38.58	0.02	0.01	15.43	0.04	38.58	0.01	0.01	15.43	0.03	38.57
R14	16.75	0.03	0.02	16.77	0.06	41.91	0.01	0.01	16.76	0.04	41.90	0.02	0.01	16.76	0.05	41.91	0.02	0.01	16.76	0.05	41.90	0.02	0.01	16.76	0.05	41.90
R15	21.28	0.01	0.01	21.29	0.03	53.21	0.01	0.00	21.28	0.01	53.20	0.01	0.00	21.28	0.01	53.20	0.01	0.01	21.29	0.03	53.21	0.01	0.01	21.29	0.03	53.22
R16	20.10	0.01	0.00	20.11	0.01	50.26	0.01	0.01	20.11	0.02	50.27	0.00	0.00	20.10	0.01	50.26	0.01	0.01	20.11	0.02	50.27	0.01	0.00	20.11	0.02	50.26

**CO 8 Hour Mean**

Receptor	2001 CO Background Concentration	2010				2011				2012				2013				2014			
		PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO
		mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%
R1	0.150	0.0005	0.3005	0.00	3.00	0.0005	0.3005	0.01	3.01	0.0005	0.3005	0.00	3.00	0.0005	0.3005	0.00	3.00	0.0003	0.3003	0.00	3.00
R2	0.159	0.0005	0.3185	0.01	3.19	0.0006	0.3186	0.01	3.19	0.0007	0.3187	0.01	3.19	0.0007	0.3187	0.01	3.19	0.0007	0.3187	0.01	3.19
R3	0.155	0.0006	0.3106	0.01	3.11	0.0004	0.3104	0.00	3.10	0.0004	0.3104	0.00	3.10	0.0004	0.3104	0.00	3.10	0.0006	0.3106	0.01	3.11
R4	0.159	0.0005	0.3185	0.00	3.18	0.0004	0.3184	0.00	3.18	0.0005	0.3185	0.01	3.19	0.0004	0.3184	0.00	3.18	0.0005	0.3185	0.00	3.18
R5	0.154	0.0005	0.3085	0.01	3.09	0.0005	0.3085	0.01	3.09	0.0006	0.3086	0.01	3.09	0.0006	0.3086	0.01	3.09	0.0004	0.3084	0.00	3.08
R6	0.152	0.0004	0.3044	0.00	3.04	0.0007	0.3047	0.01	3.05	0.0005	0.3045	0.00	3.04	0.0007	0.3047	0.01	3.05	0.0004	0.3044	0.00	3.04
R7	0.157	0.0003	0.3143	0.00	3.14	0.0005	0.3145	0.00	3.14	0.0004	0.3144	0.00	3.14	0.0005	0.3145	0.00	3.14	0.0003	0.3143	0.00	3.14
R8	0.151	0.0003	0.3023	0.00	3.02	0.0004	0.3024	0.00	3.02	0.0003	0.3023	0.00	3.02	0.0004	0.3024	0.00	3.02	0.0003	0.3023	0.00	3.02
R9	0.150	0.0007	0.3007	0.01	3.01	0.0007	0.3007	0.01	3.01	0.0006	0.3006	0.01	3.01	0.0007	0.3007	0.01	3.01	0.0005	0.3005	0.01	

**B1 Normal 6 Month Scenario**

**NO<sub>2</sub> 1 Hour 99.8<sup>th</sup> Percentile**

Receptor	2014 NO <sub>2</sub> Background Concentration	2010					2011					2012					2013					2014				
		PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO
		µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
R1	20.10	3.11	1.09	41.29	1.55	20.65	2.96	1.03	41.24	1.48	20.62	2.68	0.94	41.14	1.34	20.57	3.09	1.08	41.28	1.54	20.64	2.89	1.01	41.21	1.44	20.61
R2	12.24	0.93	0.32	24.81	0.46	12.40	1.03	0.36	24.84	0.51	12.42	1.13	0.39	24.88	0.56	12.44	1.17	0.41	24.90	0.59	12.45	0.89	0.31	24.80	0.45	12.40
R3	19.77	0.88	0.31	39.85	0.44	19.93	1.05	0.37	39.91	0.53	19.96	1.03	0.36	39.90	0.52	19.95	1.24	0.43	39.98	0.62	19.99	1.30	0.46	40.00	0.65	20.00
R4	10.87	0.93	0.33	22.07	0.47	11.03	0.71	0.25	21.99	0.36	10.99	0.81	0.28	22.02	0.40	11.01	0.88	0.31	22.05	0.44	11.02	0.74	0.26	22.00	0.37	11.00
R5	9.59	0.60	0.21	19.39	0.30	9.70	0.54	0.19	19.37	0.27	9.68	0.48	0.17	19.35	0.24	9.67	0.48	0.17	19.35	0.24	9.67	0.49	0.17	19.35	0.25	9.68
R6	13.98	1.33	0.47	28.43	0.67	14.21	1.34	0.47	28.43	0.67	14.21	1.17	0.41	28.37	0.59	14.19	1.47	0.52	28.48	0.74	14.24	1.34	0.47	28.43	0.67	14.22
R7	13.56	0.36	0.13	27.25	0.18	13.63	0.55	0.19	27.32	0.28	13.66	0.33	0.11	27.24	0.16	13.62	0.29	0.10	27.22	0.14	13.61	0.40	0.14	27.26	0.20	13.63
R8	7.34	0.39	0.14	14.82	0.20	7.41	0.38	0.13	14.81	0.19	7.41	0.37	0.13	14.81	0.18	7.40	0.34	0.12	14.80	0.17	7.40	0.33	0.12	14.79	0.17	7.40
R9	28.67	1.75	0.61	57.95	0.88	28.97	1.53	0.53	57.87	0.76	28.94	1.61	0.56	57.90	0.80	28.95	1.61	0.56	57.90	0.81	28.95	1.55	0.54	57.88	0.77	28.94
R10	10.22	0.81	0.28	20.72	0.41	10.36	0.77	0.27	20.70	0.38	10.35	0.69	0.24	20.67	0.34	10.34	0.94	0.33	20.76	0.47	10.38	0.77	0.27	20.70	0.38	10.35
R11	10.22	0.69	0.24	20.67	0.34	10.34	0.60	0.21	20.64	0.30	10.32	0.59	0.21	20.64	0.30	10.32	0.72	0.25	20.68	0.36	10.34	0.69	0.24	20.67	0.34	10.34
R12	20.10	3.30	1.16	41.36	1.65	20.68	2.88	1.01	41.21	1.44	20.61	2.81	0.98	41.19	1.40	20.59	3.12	1.09	41.30	1.56	20.65	3.23	1.13	41.33	1.62	20.67
R13	15.42	2.52	0.88	31.72	1.26	15.86	2.75	0.96	31.80	1.37	15.90	2.77	0.97	31.81	1.39	15.91	2.96	1.04	31.88	1.48	15.94	2.50	0.87	31.72	1.25	15.86
R14	16.75	1.08	0.38	33.87	0.54	16.94	1.22	0.43	33.92	0.61	16.96	1.19	0.42	33.91	0.59	16.96	1.21	0.42	33.92	0.60	16.96	1.24	0.44	33.93	0.62	16.97
R15	21.28	1.28	0.45	43.00	0.64	21.50	1.84	0.64	43.20	0.92	21.60	1.92	0.67	43.23	0.96	21.61	1.63	0.57	43.12	0.81	21.56	1.52	0.53	43.09	0.76	21.54
R16	20.10	2.55	0.89	41.09	1.27	20.55	2.65	0.93	41.13	1.33	20.57	1.53	0.53	40.74	0.76	20.37	2.25	0.79	40.99	1.13	20.50	2.18	0.76	40.97	1.09	20.48

**NO<sub>2</sub> Annual Mean**

Receptor	2014 NO <sub>2</sub> Background Concentration	2010					2011					2012					2013					2014				
		PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO
		µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
R1	20.10	0.04	0.03	20.13	0.10	50.33	0.04	0.03	20.13	0.09	50.32	0.04	0.03	20.13	0.10	50.32	0.04	0.03	20.13	0.10	50.32	0.04	0.03	20.13	0.09	50.32
R2	12.24	0.02	0.01	12.25	0.04	30.63	0.02	0.02	12.26	0.05	30.64	0.02	0.01	12.26	0.05	30.64	0.02	0.01	12.26	0.05	30.64	0.02	0.01	12.25	0.04	30.64
R3	19.77	0.01	0.01	19.78	0.02	49.45	0.01	0.01	19.78	0.02	49.44	0.01	0.01	19.78	0.02	49.44	0.01	0.01	19.78	0.04	49.45	0.02	0.01	19.78	0.04	49.46
R4	10.87	0.01	0.01	10.88	0.04	27.20	0.02	0.01	10.88	0.05	27.21	0.02	0.01	10.88	0.04	27.20	0.01	0.01	10.88	0.04	27.20	0.01	0.01	10.88	0.04	27.20
R5	9.59	0.01	0.01	9.60	0.02	23.99	0.01	0.01	9.60	0.02	23.99	0.01	0.00	9.60	0.02	23.99	0.01	0.01	9.60	0.02	23.99	0.01	0.00	9.60	0.02	23.99
R6	13.98	0.02	0.01	13.99	0.04	34.98	0.02	0.01	13.99	0.04	34.98	0.02	0.01	13.99	0.04	34.98	0.02	0.01	13.99	0.05	34.98	0.01	0.01	13.99	0.04	34.98
R7	13.56	0.00	0.00	13.56	0.01	33.91	0.00	0.00	13.56	0.01	33.91	0.00	0.00	13.56	0.01	33.91	0.00	0.00	13.56	0.01	33.91	0.00	0.00	13.56	0.01	33.91
R8	7.34	0.00	0.00	7.34	0.01	18.36	0.00	0.00	7.34	0.01	18.36	0.00	0.00	7.34	0.01	18.36	0.00	0.00	7.34	0.01	18.36	0.00	0.00	7.34	0.01	18.35
R9	28.67	0.03	0.02	28.69	0.08	71.73	0.03	0.02	28.69	0.07	71.72	0.03	0.02	28.69	0.08	71.73	0.03	0.02	28.69	0.07	71.72	0.03	0.02	28.69	0.08	71.73
R10	10.22	0.01	0.01	10.23	0.03	25.56	0.01	0.01	10.23	0.04	25.56	0.01	0.01	10.22	0.03	25.56	0.02	0.01	10.23	0.04	25.57	0.01	0.01	10.22	0.03	25.56
R11	10.22	0.01	0.01	10.22	0.02	25.55	0.01	0.01	10.22	0.02	25.55	0.01	0.01	10.22	0.02	25.55	0.01	0.01	10.22	0.03	25.56	0.01	0.01	10.22	0.02	25.55
R12	20.10	0.05	0.03	20.13	0.11	50.33	0.04	0.03	20.13	0.09	50.32	0.04	0.03	20.13	0.10	50.32	0.04	0.03	20.13	0.11	50.33	0.04	0.03	20.13	0.11	50.33
R13	15.42	0.06	0.04	15.46	0.14	38.65	0.06	0.04	15.46	0.14	38.65	0.06	0.04	15.46	0.15	38.66	0.06	0.04	15.46	0.15	38.66	0.05	0.04	15.46	0.14	38.65
R14	16.75	0.02	0.02	16.77	0.06	41.91	0.05	0.03	16.78	0.12	41.96	0.04	0.03	16.77	0.09	41.94	0.03	0.02	16.77	0.07	41.92	0.03	0.02	16.77	0.07	41.92
R15	21.28	0.01	0.01	21.28	0.03	53.21	0.02	0.01	21.29	0.04	53.22	0.02	0.01	21.29	0.04	53.22	0.02	0.01	21.29	0.05	53.23	0.02	0.01	21.29	0.04	53.22
R16	20.10	0.02	0.02	20.12	0.06	50.29	0.02	0.02	20.12	0.05	50.29	0.01	0.01	20.11	0.03	50.27	0.02	0.01	20.11	0.04	50.28	0.02	0.01	20.11	0.04	50.28

**CO 8 Hour Mean**

Receptor	2001 CO Background Concentration	2010				2011				2012				2013				2014			
		PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO
		mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%
R1	0.150	0.0013	0.3013	0.01	3.01	0.0011	0.3011	0.01	3.01	0.0021	0.3021	0.02	3.02	0.0014	0.3014	0.01	3.01	0.0014	0.3014	0.01	3.01
R2	0.159	0.0006	0.3186	0.01	3.19	0.0003	0.3183	0.00	3.18	0.0005	0.3185	0.01	3.19	0.0005	0.3185	0.00	3.18	0.0006	0.3186	0.01	3.19
R3	0.155	0.0004	0.3104	0.00	3.10	0.0008	0.3108	0.01	3.11	0.0004	0.3104	0.00	3.10	0.0005	0.3105	0.00	3.10	0.0006	0.3106	0.01	3.11
R4	0.159	0.0004	0.3184	0.00	3.18	0.0003	0.3183	0.00	3.18	0.0003	0.3183	0.00	3.18	0.0004	0.3184	0.00	3.18	0.0003	0.3183	0.00	3.18
R5	0.154	0.0003	0.3083	0.00	3.08	0.0004	0.3084	0.00	3.08	0.0005	0.3085	0.00	3.08	0.0003	0.3083	0.00	3.08	0.0002	0.3082	0.00	3.08
R6	0.152	0.0006	0.3046	0.01	3.05	0.0006	0.3046	0.01	3.05	0.0006	0.3046	0.01	3.05	0.0006	0.3046	0.01	3.05	0.0006	0.3046	0.01	3.05
R7	0.157	0.0002	0.3142	0.00	3.14	0.0002	0.3142	0.00	3.14	0.0001	0.3141	0.00	3.14	0.0002	0.3142	0.00	3.14	0.0001	0.3141	0.00	3.14
R8	0.151	0.0002	0.3022	0.00	3.02	0.0002	0.3022	0.00	3.02	0.0003	0.3023	0.00	3.02	0.0003	0.3023	0.00	3.02	0.0001	0.3021	0.00	3.02
R9	0.150	0.0007	0.3007	0.01	3.01	0.0007	0.3007	0.01	3.01	0.0008	0.3008	0.01	3.01	0.0006	0.3006	0.01	3.01	0.0007	0.3007	0.0	

**B1 Peak Scenario 6 Month**

**NO<sub>2</sub> 1 Hour 99.8<sup>th</sup> Percentile**

Receptor	2014 NO <sub>2</sub> Background Concentration	2010					2011					2012					2013					2014				
		PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO
		µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
R1	20.10	9.44	3.30	43.51	4.72	21.75	9.26	3.24	43.44	4.63	21.72	7.94	2.78	42.98	3.97	21.49	9.05	3.17	43.37	4.52	21.68	8.59	3.01	43.21	4.29	21.60
R2	12.24	2.80	0.98	25.47	1.40	12.73	3.15	1.10	25.59	1.57	12.79	3.37	1.18	25.66	1.69	12.83	3.45	1.21	25.69	1.72	12.85	2.73	0.96	25.44	1.37	12.72
R3	19.77	2.59	0.91	40.45	1.29	20.22	3.11	1.09	40.63	1.55	20.31	3.06	1.07	40.61	1.53	20.31	3.65	1.28	40.82	1.82	20.41	3.82	1.34	40.88	1.91	20.44
R4	10.87	2.78	0.97	22.71	1.39	11.36	2.13	0.75	22.48	1.07	11.24	2.41	0.84	22.58	1.20	11.29	2.61	0.91	22.65	1.30	11.33	2.23	0.78	22.52	1.11	11.26
R5	9.59	1.87	0.66	19.84	0.94	9.92	1.63	0.57	19.75	0.82	9.88	1.40	0.49	19.67	0.70	9.84	1.45	0.51	19.69	0.73	9.84	1.42	0.50	19.68	0.71	9.84
R6	13.98	3.79	1.33	29.29	1.90	14.64	3.81	1.33	29.29	1.90	14.65	3.55	1.24	29.20	1.78	14.60	4.59	1.61	29.57	2.29	14.78	3.98	1.39	29.35	1.99	14.68
R7	13.56	1.08	0.38	27.50	0.54	13.75	1.63	0.57	27.69	0.82	13.85	1.00	0.35	27.48	0.50	13.74	0.84	0.29	27.42	0.42	13.71	1.17	0.41	27.53	0.58	13.77
R8	7.34	1.16	0.41	15.09	0.58	7.54	1.11	0.39	15.07	0.56	7.53	1.07	0.37	15.05	0.53	7.53	0.99	0.35	15.02	0.49	7.51	0.98	0.34	15.02	0.49	7.51
R9	28.67	5.36	1.88	59.21	2.68	29.61	4.69	1.64	58.98	2.34	29.49	4.87	1.71	59.04	2.44	29.52	4.85	1.70	59.04	2.43	29.52	4.71	1.65	58.99	2.36	29.49
R10	10.22	2.42	0.85	21.28	1.21	10.64	2.29	0.80	21.23	1.15	10.62	2.03	0.71	21.14	1.02	10.57	2.79	0.98	21.41	1.40	10.70	2.34	0.82	21.25	1.17	10.63
R11	10.22	2.04	0.71	21.14	1.02	10.57	1.79	0.63	21.06	0.89	10.53	1.77	0.62	21.05	0.89	10.53	2.15	0.75	21.18	1.08	10.59	2.06	0.72	21.15	1.03	10.58
R12	20.10	10.26	3.59	43.79	5.13	21.90	8.67	3.04	43.24	4.34	21.62	8.87	3.10	43.31	4.43	21.65	9.32	3.26	43.46	4.66	21.73	9.73	3.41	43.61	4.87	21.80
R13	15.42	7.26	2.54	33.38	3.63	16.69	8.21	2.87	33.72	4.11	16.86	7.90	2.77	33.61	3.95	16.80	8.95	3.13	33.98	4.48	16.99	7.71	2.70	33.54	3.86	16.77
R14	16.75	3.34	1.17	34.66	1.67	17.33	3.71	1.30	34.79	1.85	17.40	3.65	1.28	34.77	1.82	17.39	3.74	1.31	34.81	1.87	17.40	3.78	1.32	34.82	1.89	17.41
R15	21.28	3.80	1.33	43.88	1.90	21.94	5.43	1.90	44.46	2.72	22.23	5.65	1.98	44.53	2.83	22.27	4.91	1.72	44.27	2.45	22.14	4.53	1.59	44.14	2.27	22.07
R16	20.10	7.31	2.56	42.76	3.65	21.38	8.34	2.92	43.12	4.17	21.56	4.35	1.52	41.73	2.18	20.86	6.82	2.39	42.59	3.41	21.29	5.91	2.07	42.27	2.96	21.14

**NO<sub>2</sub> Annual Mean**

Receptor	2014 NO <sub>2</sub> Background Concentration	2010					2011					2012					2013					2014				
		PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO
		µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
R1	20.10	0.13	0.09	20.19	0.32	50.47	0.11	0.08	20.18	0.28	50.45	0.11	0.08	20.18	0.28	50.45	0.12	0.08	20.18	0.30	50.46	0.11	0.08	20.18	0.28	50.45
R2	12.24	0.05	0.04	12.28	0.13	30.69	0.06	0.05	12.29	0.16	30.72	0.06	0.04	12.29	0.15	30.71	0.06	0.04	12.28	0.14	30.71	0.05	0.04	12.28	0.13	30.70
R3	19.77	0.03	0.02	19.79	0.07	49.48	0.02	0.02	19.79	0.06	49.47	0.02	0.02	19.79	0.06	49.47	0.04	0.03	19.80	0.10	49.50	0.05	0.03	19.80	0.12	49.51
R4	10.87	0.04	0.03	10.90	0.11	27.25	0.05	0.04	10.91	0.14	27.27	0.05	0.03	10.90	0.12	27.26	0.04	0.03	10.90	0.11	27.25	0.04	0.03	10.90	0.11	27.25
R5	9.59	0.03	0.02	9.61	0.06	24.02	0.02	0.02	9.61	0.06	24.02	0.02	0.01	9.60	0.05	24.01	0.02	0.02	9.61	0.05	24.02	0.02	0.01	9.60	0.05	24.01
R6	13.98	0.05	0.03	14.01	0.12	35.04	0.04	0.03	14.01	0.11	35.03	0.05	0.03	14.01	0.12	35.04	0.06	0.04	14.02	0.14	35.05	0.04	0.03	14.01	0.11	35.03
R7	13.56	0.01	0.01	13.57	0.02	33.92	0.01	0.01	13.57	0.03	33.93	0.01	0.01	13.57	0.02	33.92	0.01	0.01	13.57	0.02	33.92	0.01	0.01	13.57	0.02	33.92
R8	7.34	0.01	0.01	7.35	0.03	18.37	0.01	0.01	7.35	0.03	18.37	0.01	0.01	7.35	0.03	18.37	0.01	0.01	7.35	0.03	18.37	0.01	0.01	7.35	0.03	18.37
R9	28.67	0.10	0.07	28.74	0.25	71.85	0.08	0.06	28.73	0.21	71.82	0.10	0.07	28.74	0.24	71.84	0.08	0.05	28.72	0.20	71.81	0.10	0.07	28.74	0.25	71.85
R10	10.22	0.04	0.03	10.24	0.10	25.61	0.04	0.03	10.24	0.11	25.61	0.03	0.02	10.24	0.08	25.60	0.05	0.03	10.25	0.11	25.62	0.04	0.03	10.24	0.10	25.61
R11	10.22	0.03	0.02	10.23	0.07	25.59	0.03	0.02	10.23	0.06	25.58	0.02	0.02	10.23	0.06	25.58	0.04	0.03	10.24	0.09	25.60	0.03	0.02	10.23	0.07	25.59
R12	20.10	0.14	0.10	20.20	0.34	50.49	0.11	0.08	20.18	0.28	50.45	0.12	0.09	20.19	0.31	50.47	0.13	0.09	20.19	0.33	50.48	0.13	0.09	20.19	0.32	50.48
R13	15.42	0.17	0.12	15.54	0.42	38.85	0.17	0.12	15.54	0.42	38.85	0.17	0.12	15.54	0.44	38.86	0.18	0.13	15.55	0.45	38.87	0.16	0.11	15.54	0.41	38.84
R14	16.75	0.07	0.05	16.80	0.18	42.00	0.15	0.10	16.85	0.37	42.13	0.11	0.08	16.83	0.29	42.07	0.09	0.06	16.81	0.23	42.03	0.09	0.06	16.81	0.21	42.02
R15	21.28	0.03	0.02	21.30	0.07	53.25	0.04	0.03	21.31	0.11	53.27	0.04	0.03	21.31	0.11	53.27	0.05	0.04	21.32	0.13	53.29	0.04	0.03	21.31	0.11	53.27
R16	20.10	0.06	0.04	20.15	0.16	50.37	0.06	0.04	20.15	0.16	50.36	0.03	0.02	20.12	0.08	50.31	0.05	0.03	20.14	0.12	50.34	0.05	0.03	20.14	0.12	50.34

**CO 8 Hour Mean**

Receptor	2001 CO Background Concentration	2010				2011				2012				2013				2014			
		PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO
		mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%
R1	0.150	0.0039	0.3039	0.04	3.04	0.0034	0.3034	0.03	3.03	0.0056	0.3056	0.06	3.06	0.0042	0.3042	0.04	3.04	0.0043	0.3043	0.04	3.04
R2	0.159	0.0018	0.3198	0.02	3.20	0.0010	0.3190	0.01	3.19	0.0016	0.3196	0.02	3.20	0.0014	0.3194	0.01	3.19	0.0017	0.3197	0.02	3.20
R3	0.155	0.0012	0.3112	0.01	3.11	0.0022	0.3122	0.02	3.12	0.0011	0.3111	0.01	3.11	0.0014	0.3114	0.01	3.11	0.0017	0.3117	0.02	3.12
R4	0.159	0.0012	0.3192	0.01	3.19	0.0009	0.3189	0.01	3.19	0.0008	0.3188	0.01	3.19	0.0011	0.3191	0.01	3.19	0.0010	0.3190	0.01	3.19
R5	0.154	0.0008	0.3088	0.01	3.09	0.0011	0.3091	0.01	3.09	0.0015	0.3095	0.01	3.09	0.0010	0.3090	0.01	3.09	0.0006	0.3086	0.01	3.09
R6	0.152	0.0017	0.3057	0.02	3.06	0.0017	0.3057	0.02	3.06	0.0018	0.3058	0.02	3.06	0.0019	0.3059	0.02	3.06	0.0017	0.3057	0.02	3.06
R7	0.157	0.0006	0.3146	0.01	3.15	0.0005	0.3145	0.00	3.14	0.0004	0.3144	0.00	3.14	0.0005	0.3145	0.01	3.15	0.0004	0.3144	0.00	3.14
R8	0.151	0.0005	0.3025	0.00	3.02	0.0005	0.3025	0.01	3.03	0.0008	0.3028	0.01	3.03	0.0007	0.3027	0.01	3.03	0.0004	0.3024	0.00	3.02
R9	0.150	0.0021	0.3021	0.02	3.02	0.0020	0.3020	0.02	3.02	0.0023	0.3023	0.02	3.02	0.0017	0.3017	0.02	3.02	0.0021	0.3021	0	

**B1 Normal Scenario 12 Month**

**NO<sub>2</sub> 1 Hour 99.8<sup>th</sup> Percentile**

Receptor	2014 NO <sub>2</sub> Background Concentration µg.m <sup>-3</sup>	2010					2011					2012					2013					2014				
		PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO
		µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
R1	20.10	3.16	1.11	41.31	1.58	20.65	3.16	1.10	41.31	1.58	20.65	3.03	1.06	41.26	1.51	20.63	3.19	1.12	41.32	1.60	20.66	3.19	1.12	41.32	1.60	20.66
R2	12.24	1.32	0.46	24.95	0.66	12.47	1.28	0.45	24.93	0.64	12.47	1.33	0.47	24.95	0.67	12.48	1.40	0.49	24.97	0.70	12.49	1.21	0.42	24.91	0.60	12.45
R3	19.77	1.28	0.45	39.99	0.64	19.99	1.56	0.55	40.09	0.78	20.05	2.30	0.80	40.35	1.15	20.17	1.42	0.50	40.04	0.71	20.02	1.73	0.61	40.15	0.87	20.07
R4	10.87	0.93	0.33	22.07	0.47	11.03	0.82	0.29	22.03	0.41	11.01	0.87	0.30	22.04	0.43	11.02	0.92	0.32	22.06	0.46	11.03	0.84	0.29	22.03	0.42	11.02
R5	9.59	0.62	0.22	19.40	0.31	9.70	0.68	0.24	19.42	0.34	9.71	0.58	0.20	19.39	0.29	9.69	0.55	0.19	19.38	0.28	9.69	0.67	0.24	19.42	0.34	9.71
R6	13.98	1.77	0.62	28.58	0.89	14.29	1.70	0.60	28.56	0.85	14.28	1.57	0.55	28.51	0.79	14.26	1.68	0.59	28.55	0.84	14.27	1.56	0.55	28.51	0.78	14.25
R7	13.56	0.67	0.23	27.36	0.33	13.68	0.63	0.22	27.35	0.32	13.67	0.71	0.25	27.37	0.35	13.69	0.54	0.19	27.31	0.27	13.66	0.73	0.25	27.38	0.36	13.69
R8	7.34	0.41	0.14	14.82	0.20	7.41	0.41	0.14	14.82	0.21	7.41	0.39	0.14	14.81	0.19	7.41	0.43	0.15	14.83	0.22	7.41	0.44	0.15	14.83	0.22	7.42
R9	28.67	1.90	0.66	58.00	0.95	29.00	1.83	0.64	57.98	0.91	28.99	1.78	0.62	57.96	0.89	28.98	1.92	0.67	58.01	0.96	29.00	1.83	0.64	57.98	0.91	28.99
R10	10.22	0.97	0.34	20.77	0.49	10.39	0.86	0.30	20.73	0.43	10.37	0.85	0.30	20.73	0.43	10.36	0.98	0.34	20.77	0.49	10.39	0.91	0.32	20.75	0.45	10.37
R11	10.22	0.75	0.26	20.69	0.38	10.35	0.68	0.24	20.67	0.34	10.34	0.72	0.25	20.68	0.36	10.34	0.77	0.27	20.70	0.38	10.35	0.80	0.28	20.71	0.40	10.35
R12	20.10	3.46	1.21	41.41	1.73	20.71	3.38	1.18	41.38	1.69	20.69	3.29	1.15	41.36	1.65	20.68	3.39	1.19	41.39	1.70	20.70	3.47	1.21	41.42	1.73	20.71
R13	15.42	2.91	1.02	31.86	1.45	15.93	3.04	1.06	31.91	1.52	15.95	3.01	1.06	31.90	1.51	15.95	3.37	1.18	32.02	1.69	16.01	2.86	1.00	31.84	1.43	15.92
R14	16.75	1.33	0.47	33.96	0.66	16.98	1.35	0.47	33.97	0.68	16.98	1.54	0.54	34.04	0.77	17.02	1.38	0.48	33.98	0.69	16.99	1.46	0.51	34.01	0.73	17.00
R15	21.28	1.73	0.61	43.16	0.87	21.58	2.11	0.74	43.30	1.06	21.65	2.59	0.91	43.46	1.29	21.73	2.02	0.71	43.26	1.01	21.63	1.78	0.62	43.18	0.89	21.59
R16	20.10	2.86	1.00	41.21	1.43	20.60	2.92	1.02	41.23	1.46	20.61	2.53	0.89	41.09	1.26	20.54	2.51	0.88	41.08	1.25	20.54	2.88	1.01	41.21	1.44	20.61

**NO<sub>2</sub> Annual Mean**

Receptor	2014 NO <sub>2</sub> Background Concentration µg.m <sup>-3</sup>	2010					2011					2012					2013					2014				
		PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NOx	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO
		µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
R1	20.10	0.07	0.05	20.15	0.17	50.37	0.07	0.05	20.15	0.17	50.37	0.07	0.05	20.15	0.17	50.38	0.06	0.04	20.14	0.15	50.36	0.06	0.04	20.15	0.16	50.37
R2	12.24	0.03	0.02	12.26	0.07	30.65	0.04	0.03	12.27	0.10	30.68	0.04	0.03	12.27	0.10	30.67	0.03	0.02	12.27	0.08	30.66	0.04	0.03	12.27	0.09	30.67
R3	19.77	0.02	0.02	19.79	0.05	49.47	0.03	0.02	19.79	0.07	49.48	0.03	0.02	19.79	0.08	49.48	0.03	0.02	19.79	0.08	49.49	0.03	0.02	19.79	0.08	49.49
R4	10.87	0.02	0.02	10.88	0.05	27.21	0.03	0.02	10.89	0.06	27.22	0.03	0.02	10.89	0.07	27.22	0.02	0.02	10.89	0.06	27.22	0.03	0.02	10.89	0.06	27.22
R5	9.59	0.01	0.01	9.60	0.03	24.00	0.01	0.01	9.60	0.04	24.00	0.01	0.01	9.60	0.03	24.00	0.01	0.01	9.60	0.03	24.00	0.01	0.01	9.60	0.03	24.00
R6	13.98	0.03	0.02	14.00	0.08	35.01	0.03	0.02	14.00	0.08	35.00	0.03	0.02	14.00	0.07	35.00	0.03	0.02	14.00	0.08	35.00	0.04	0.03	14.01	0.10	35.02
R7	13.56	0.01	0.01	13.57	0.02	33.92	0.01	0.00	13.57	0.02	33.92	0.01	0.00	13.57	0.02	33.92	0.01	0.00	13.57	0.01	33.91	0.01	0.01	13.57	0.02	33.92
R8	7.34	0.01	0.00	7.34	0.02	18.36	0.01	0.01	7.34	0.02	18.36	0.01	0.00	7.34	0.02	18.36	0.01	0.00	7.34	0.02	18.36	0.01	0.01	7.34	0.02	18.36
R9	28.67	0.06	0.04	28.71	0.15	71.77	0.05	0.03	28.70	0.11	71.75	0.06	0.04	28.71	0.14	71.77	0.05	0.03	28.70	0.12	71.75	0.06	0.04	28.71	0.14	71.77
R10	10.22	0.03	0.02	10.23	0.07	25.59	0.02	0.02	10.23	0.06	25.58	0.03	0.02	10.23	0.07	25.59	0.03	0.02	10.23	0.06	25.58	0.02	0.01	10.23	0.05	25.57
R11	10.22	0.02	0.01	10.23	0.05	25.57	0.01	0.01	10.23	0.04	25.56	0.02	0.01	10.23	0.05	25.57	0.02	0.01	10.23	0.05	25.57	0.01	0.01	10.22	0.03	25.56
R12	20.10	0.08	0.05	20.16	0.19	50.39	0.07	0.05	20.15	0.17	50.37	0.07	0.05	20.15	0.19	50.38	0.07	0.05	20.15	0.18	50.38	0.07	0.05	20.15	0.18	50.38
R13	15.42	0.09	0.06	15.48	0.22	38.71	0.12	0.08	15.51	0.30	38.76	0.11	0.08	15.50	0.27	38.75	0.10	0.07	15.49	0.26	38.74	0.11	0.08	15.50	0.27	38.75
R14	16.75	0.04	0.03	16.78	0.10	41.94	0.08	0.06	16.80	0.20	42.01	0.08	0.05	16.80	0.20	42.01	0.05	0.04	16.78	0.13	41.96	0.05	0.04	16.79	0.14	41.97
R15	21.28	0.02	0.02	21.29	0.06	53.24	0.04	0.03	21.31	0.11	53.27	0.05	0.03	21.31	0.12	53.28	0.04	0.03	21.30	0.10	53.26	0.04	0.02	21.30	0.09	53.26
R16	20.10	0.04	0.03	20.13	0.11	50.33	0.04	0.03	20.13	0.10	50.32	0.03	0.02	20.12	0.07	50.30	0.03	0.02	20.12	0.07	50.30	0.04	0.03	20.13	0.10	50.32

**CO 8 Hour Mean**

Receptor	2014 CO Background Concentration mg.m <sup>-3</sup>	2010				2011				2012				2013				2014			
		PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO
		mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%
R1	0.150	0.0013	0.3013	0.01	3.01	0.0011	0.3011	0.01	3.01	0.0021	0.3021	0.02	3.02	0.0014	0.3014	0.01	3.01	0.0014	0.3014	0.01	3.01
R2	0.159	0.0006	0.3186	0.01	3.19	0.0010	0.3190	0.01	3.19	0.0005	0.3185	0.01	3.19	0.0005	0.3185	0.01	3.19	0.0006	0.3186	0.01	3.19
R3	0.155	0.0005	0.3105	0.00	3.10	0.0008	0.3108	0.01	3.11	0.0007	0.3107	0.01	3.11	0.0005	0.3105	0.00	3.10	0.0006	0.3106	0.01	3.11
R4	0.159	0.0004	0.3184	0.00	3.18	0.0004	0.3184	0.00	3.18	0.0004	0.3184	0.00	3.18	0.0004	0.3184	0.00	3.18	0.0003	0.3183	0.00	3.18
R5	0.154	0.0003	0.3083	0.00	3.08	0.0004	0.3084	0.00	3.08	0.0005	0.3085	0.00	3.08	0.0003	0.3083	0.00	3.08	0.0003	0.3083	0.00	3.08
R6	0.152	0.0006	0.3046	0.01	3.05	0.0007	0.3047	0.01	3.05	0.0008	0.3048	0.01	3.05	0.0006	0.3046	0.01	3.05	0.0006	0.3046	0.01	3.05
R7	0.157	0.0004	0.3144	0.00	3.14	0.0002	0.3142	0.00	3.14	0.0002	0.3142	0.00	3.14	0.0002	0.3142	0.00	3.14	0.0003	0.3143	0.00	3.14
R8	0.151	0.0002	0.3022	0.00	3.02	0.0002	0.3022	0.00	3.02	0.0003	0.3023	0.00	3.02	0.0003	0.3023	0.00	3.02	0.0002	0.3022	0.00	3.02
R9	0.150	0.0007	0.3007	0.01	3.01	0.0007	0.3007	0.01	3.01	0.0008	0.3008										

**B1 Peak Scenario 12 Month**

**NO<sub>2</sub> 1 Hour 99.8<sup>th</sup> Percentile**

Receptor	2014 NO <sub>2</sub> Background Concentration	2010					2011					2012					2013					2014				
		PC NO <sub>x</sub>	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NO <sub>x</sub>	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NO <sub>x</sub>	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NO <sub>x</sub>	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NO <sub>x</sub>	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO
		µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
R1	20.10	9.77	3.42	43.62	4.88	21.81	9.44	3.30	43.51	4.72	21.75	8.74	3.06	43.26	4.37	21.63	9.49	3.32	43.52	4.74	21.76	9.31	3.26	43.46	4.65	21.73
R2	12.24	3.97	1.39	25.87	1.99	12.94	3.92	1.37	25.86	1.96	12.93	4.10	1.44	25.92	2.05	12.96	4.13	1.44	25.93	2.06	12.96	3.55	1.24	25.73	1.78	12.86
R3	19.77	3.78	1.32	40.87	1.89	20.43	4.63	1.62	41.16	2.32	20.58	6.83	2.39	41.94	3.42	20.97	4.19	1.47	41.01	2.09	20.50	5.12	1.79	41.33	2.56	20.67
R4	10.87	2.78	0.97	22.71	1.39	11.36	2.43	0.85	22.59	1.21	11.29	2.57	0.90	22.64	1.28	11.32	2.73	0.96	22.69	1.37	11.35	2.51	0.88	22.62	1.26	11.31
R5	9.59	1.93	0.68	19.86	0.97	9.93	2.07	0.72	19.91	1.03	9.95	1.71	0.60	19.78	0.86	9.89	1.74	0.61	19.79	0.87	9.90	2.02	0.71	19.89	1.01	9.94
R6	13.98	5.03	1.76	29.72	2.51	14.86	4.91	1.72	29.68	2.46	14.84	4.69	1.64	29.60	2.35	14.80	5.07	1.78	29.74	2.54	14.87	4.66	1.63	29.59	2.33	14.80
R7	13.56	2.00	0.70	27.83	1.00	13.91	1.94	0.68	27.80	0.97	13.90	2.09	0.73	27.86	1.04	13.93	1.62	0.57	27.69	0.81	13.85	2.21	0.77	27.90	1.10	13.95
R8	7.34	1.21	0.42	15.10	0.60	7.55	1.23	0.43	15.11	0.61	7.55	1.15	0.40	15.08	0.58	7.54	1.28	0.45	15.13	0.64	7.56	1.28	0.45	15.13	0.64	7.56
R9	28.67	5.79	2.02	59.36	2.89	29.68	5.62	1.97	59.30	2.81	29.65	5.44	1.90	59.24	2.72	29.62	5.90	2.06	59.40	2.95	29.70	5.59	1.96	59.29	2.80	29.65
R10	10.22	2.88	1.01	21.44	1.44	10.72	2.53	0.88	21.32	1.26	10.66	2.52	0.88	21.31	1.26	10.66	2.87	1.01	21.44	1.44	10.72	2.69	0.94	21.37	1.35	10.69
R11	10.22	2.22	0.78	21.21	1.11	10.60	2.03	0.71	21.14	1.01	10.57	2.16	0.76	21.19	1.08	10.59	2.30	0.81	21.24	1.15	10.62	2.35	0.82	21.25	1.17	10.63
R12	20.10	10.53	3.69	43.89	5.27	21.94	10.05	3.52	43.72	5.03	21.86	9.77	3.42	43.62	4.88	21.81	10.03	3.51	43.71	5.02	21.86	10.55	3.69	43.90	5.28	21.95
R13	15.42	8.49	2.97	33.82	4.25	16.91	9.22	3.23	34.07	4.61	17.04	9.14	3.20	34.04	4.57	17.02	9.68	3.39	34.23	4.84	17.11	8.54	2.99	33.83	4.27	16.92
R14	16.75	3.97	1.39	34.89	1.98	17.44	4.14	1.45	34.94	2.07	17.47	4.69	1.64	35.14	2.35	17.57	4.08	1.43	34.93	2.04	17.46	4.51	1.58	35.07	2.25	17.54
R15	21.28	5.12	1.79	44.35	2.56	22.17	6.19	2.17	44.72	3.09	22.36	7.60	2.66	45.21	3.80	22.61	5.96	2.09	44.64	2.98	22.32	5.23	1.83	44.39	2.61	22.19
R16	20.10	8.04	2.82	43.02	4.02	21.51	8.63	3.02	43.22	4.32	21.61	7.86	2.75	42.96	3.93	21.48	7.44	2.61	42.81	3.72	21.40	8.45	2.96	43.16	4.22	21.58

**NO<sub>2</sub> Annual Mean**

Receptor	2014 NO <sub>2</sub> Background Concentration	2010					2011					2012					2013					2014				
		PC NO <sub>x</sub>	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NO <sub>x</sub>	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NO <sub>x</sub>	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NO <sub>x</sub>	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO	PC NO <sub>x</sub>	PC NO <sub>2</sub>	PEC NO <sub>2</sub>	PC/AQO	PEC/AQO
		µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
R1	20.10	0.21	0.15	20.25	0.52	50.62	0.20	0.14	20.24	0.51	50.61	0.21	0.14	20.25	0.51	50.61	0.18	0.13	20.23	0.45	50.57	0.19	0.13	20.23	0.47	50.58
R2	12.24	0.08	0.06	12.30	0.20	30.74	0.12	0.09	12.33	0.31	30.82	0.12	0.08	12.32	0.29	30.81	0.10	0.07	12.31	0.25	30.78	0.11	0.08	12.32	0.27	30.80
R3	19.77	0.06	0.04	19.82	0.16	49.54	0.08	0.05	19.83	0.20	49.57	0.09	0.06	19.84	0.23	49.59	0.10	0.07	19.84	0.24	49.60	0.10	0.07	19.84	0.24	49.60
R4	10.87	0.07	0.05	10.92	0.16	27.29	0.08	0.05	10.92	0.19	27.31	0.08	0.06	10.93	0.20	27.31	0.07	0.05	10.92	0.18	27.30	0.08	0.05	10.92	0.19	27.30
R5	9.59	0.04	0.03	9.62	0.09	24.04	0.04	0.03	9.62	0.11	24.05	0.04	0.03	9.62	0.09	24.04	0.03	0.02	9.61	0.09	24.04	0.04	0.03	9.62	0.10	24.05
R6	13.98	0.10	0.07	14.05	0.24	35.12	0.09	0.06	14.04	0.22	35.11	0.08	0.06	14.04	0.21	35.10	0.09	0.06	14.04	0.23	35.11	0.11	0.08	14.06	0.28	35.15
R7	13.56	0.02	0.02	13.58	0.06	33.95	0.02	0.01	13.58	0.05	33.94	0.02	0.01	13.58	0.05	33.94	0.02	0.01	13.57	0.04	33.93	0.02	0.02	13.58	0.06	33.95
R8	7.34	0.02	0.01	7.35	0.05	18.38	0.02	0.02	7.36	0.06	18.39	0.02	0.01	7.35	0.05	18.38	0.02	0.01	7.35	0.05	18.38	0.02	0.02	7.36	0.06	18.39
R9	28.67	0.18	0.13	28.80	0.45	71.99	0.14	0.10	28.76	0.34	71.91	0.17	0.12	28.79	0.44	71.98	0.14	0.10	28.77	0.36	71.92	0.17	0.12	28.78	0.42	71.96
R10	10.22	0.08	0.06	10.27	0.20	25.68	0.07	0.05	10.26	0.17	25.66	0.08	0.06	10.27	0.20	25.68	0.08	0.05	10.27	0.19	25.67	0.06	0.04	10.26	0.15	25.64
R11	10.22	0.06	0.04	10.25	0.14	25.64	0.04	0.03	10.25	0.11	25.62	0.06	0.04	10.26	0.15	25.64	0.06	0.04	10.26	0.15	25.64	0.04	0.03	10.24	0.10	25.61
R12	20.10	0.23	0.16	20.26	0.57	50.65	0.21	0.15	20.25	0.52	50.62	0.22	0.16	20.26	0.56	50.65	0.21	0.15	20.25	0.52	50.62	0.22	0.15	20.25	0.54	50.63
R13	15.42	0.27	0.19	15.61	0.68	39.03	0.36	0.25	15.67	0.89	39.18	0.33	0.23	15.65	0.81	39.12	0.31	0.22	15.64	0.78	39.10	0.33	0.23	15.65	0.83	39.14
R14	16.75	0.12	0.08	16.83	0.29	42.07	0.24	0.17	16.92	0.61	42.29	0.24	0.17	16.91	0.59	42.29	0.16	0.11	16.86	0.39	42.15	0.17	0.12	16.86	0.41	42.16
R15	21.28	0.07	0.05	21.33	0.17	53.32	0.13	0.09	21.37	0.32	53.42	0.14	0.10	21.38	0.36	53.45	0.11	0.08	21.36	0.28	53.39	0.10	0.07	21.35	0.26	53.38
R16	20.10	0.13	0.09	20.19	0.32	50.48	0.11	0.08	20.18	0.29	50.45	0.08	0.05	20.16	0.19	50.39	0.08	0.05	20.15	0.19	50.39	0.11	0.08	20.18	0.29	50.45

**CO 8 Hour Mean**

Receptor	2014 CO Background Concentration	2010				2011				2012				2013				2014			
		PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO	PC	PEC	PC/AQO	PEC/AQO
		mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%	mg.m <sup>-3</sup>	mg.m <sup>-3</sup>	%	%
R1	0.150	0.0039	0.3039	0.04	3.04	0.0034	0.3034	0.03	3.03	0.0056	0.3056	0.06	3.06	0.0042	0.3042	0.04	3.04	0.0043	0.3043	0.04	3.04
R2	0.159	0.0018	0.3198	0.02	3.20	0.0030	0.3210	0.03	3.21	0.0016	0.3196	0.02	3.20	0.0016	0.3196	0.02	3.20	0.0017	0.3197	0.02	3.20
R3	0.155	0.0012	0.3112	0.01	3.11	0.0022	0.3122	0.02	3.12	0.0022	0.3122	0.02	3.12	0.0014	0.3114	0.01	3.11	0.0019	0.3119	0.02	3.12
R4	0.159	0.0012	0.3192	0.01	3.19	0.0011	0.3191	0.01	3.19	0.0012	0.3192	0.01	3.19	0.0011	0.3191	0.01	3.19	0.0010	0.3190	0.01	3.19
R5	0.154	0.0008	0.3088	0.01	3.09	0.0011	0.3091	0.01	3.09	0.0015	0.3095	0.01	3.09	0.0010	0.3090	0.01	3.09	0.0009	0.3089	0.01	3.09
R6	0.152	0.0017	0.3057	0.02	3.06	0.0019	0.3059	0.02	3.06	0.0024	0.3064	0.02	3.06	0.0019	0.3059	0.02	3.06	0.0019	0.3059	0.02	3.06
R7	0.157	0.0006	0.3146	0.01	3.15	0.0005	0.3145	0.00	3.14	0.0006	0.3146	0.01	3.15	0.0006	0.3146	0.01	3.15	0.0010	0.3150	0.01	3.15
R8	0.151	0.0005	0.3025	0.00	3.02	0.0005	0.3025	0.01	3.03	0.0008	0.3028	0.01	3.03	0.0007	0.3027	0.01	3.03	0.0005	0.3025	0.01	3.03
R9	0.150	0.0021	0.3021	0.02	3.02	0.0020	0.3020	0.02	3.02	0.0023	0.3023	0.02	3.02	0.0021	0.3021						

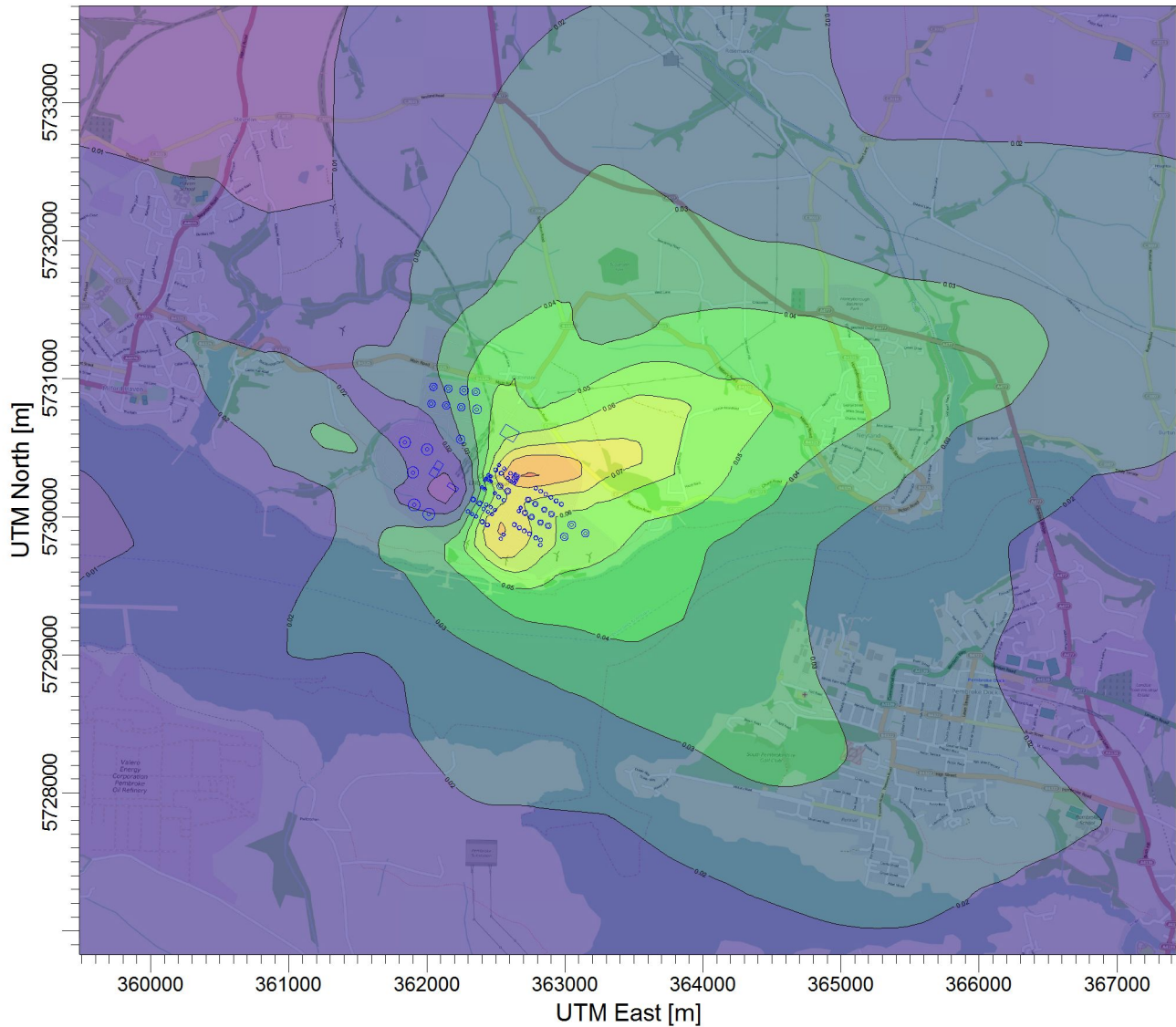


**Royal  
HaskoningDHV**  
*Enhancing Society Together*

## **Appendix C: Contour Plots**

PROJECT TITLE:

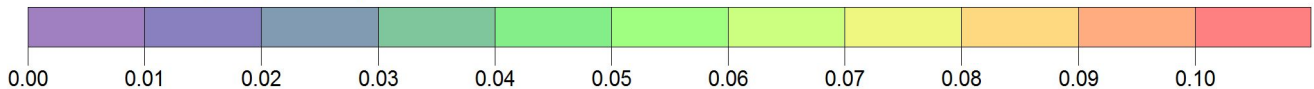
**A1 Normal Scenario: NOx Annual Mean (2010)**



PLOT FILE OF ANNUAL VALUES FOR SOURCE GROUP: ALL

ug/m<sup>3</sup>

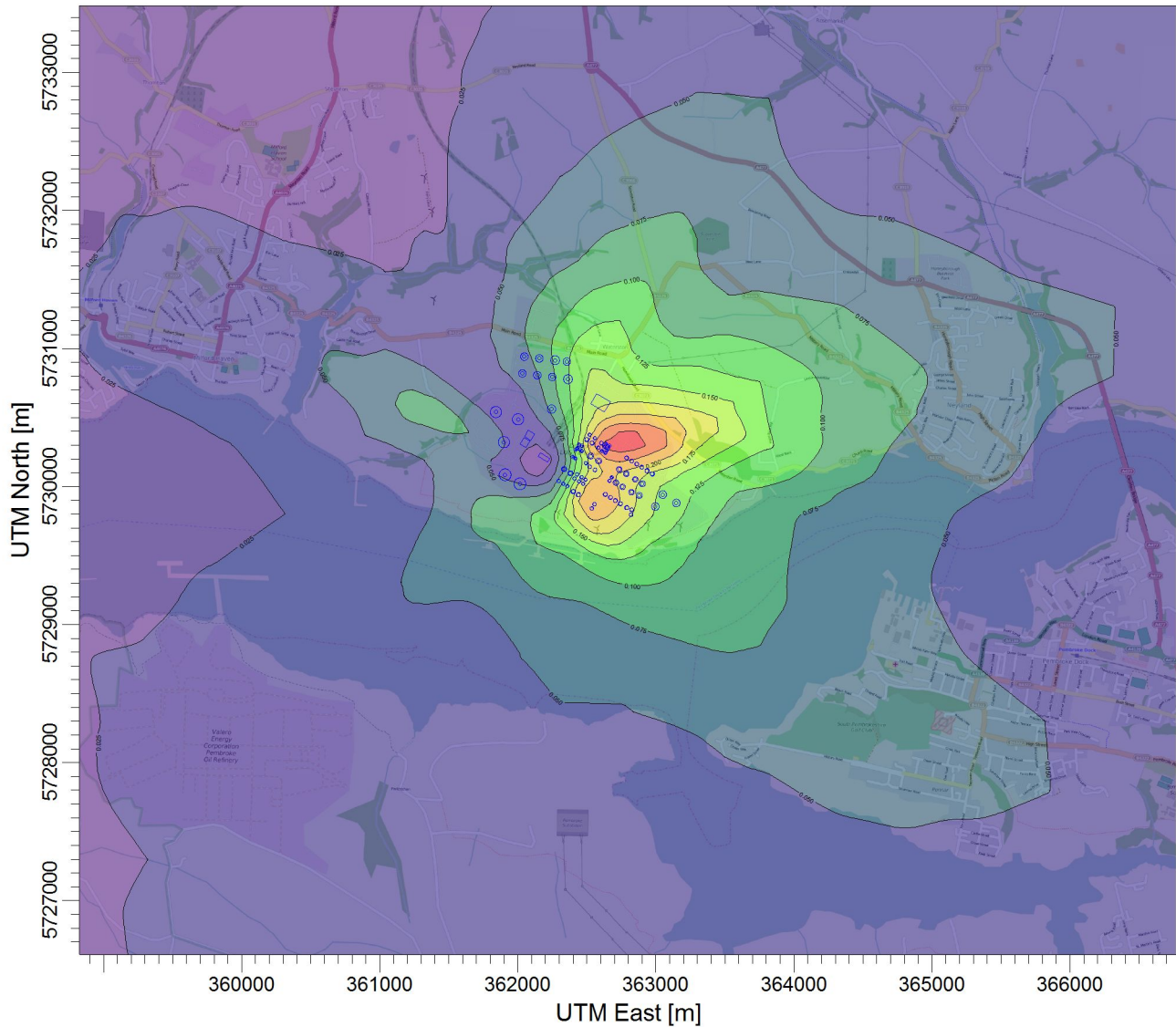
Max: 0.09 [ug/m<sup>3</sup>] at (362735.49, 5730297.07)



COMMENTS:	SOURCES: <b>3</b>	COMPANY NAME: <b>Royal HaskoningDHV</b>	
	RECEPTORS: <b>1397</b>	MODELER: <b>JP</b>	
	OUTPUT TYPE: <b>Concentration</b>	SCALE: 1:50,000	
	MAX: <b>0.09 ug/m<sup>3</sup></b>	DATE: <b>10/02/2015</b>	PROJECT NO.: <b>9Y1920</b>

PROJECT TITLE:

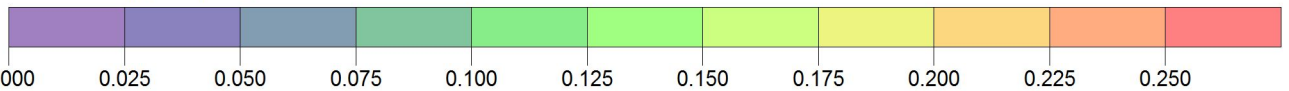
**A1 Peak Scenario: NOx Annual Mean (2010)**



PLOT FILE OF ANNUAL VALUES FOR SOURCE GROUP: ALL

ug/m<sup>3</sup>

Max: 0.269 [ug/m<sup>3</sup>] at (362735.49, 5730297.07)



COMMENTS:

SOURCES:

COMPANY NAME:

**7**

**Royal HaskoningDHV**

RECEPTORS:

MODELER:

**1397**

**JP**

OUTPUT TYPE:

SCALE:

1:50,000

**Concentration**

0 2 km

MAX:

DATE:

PROJECT NO.:

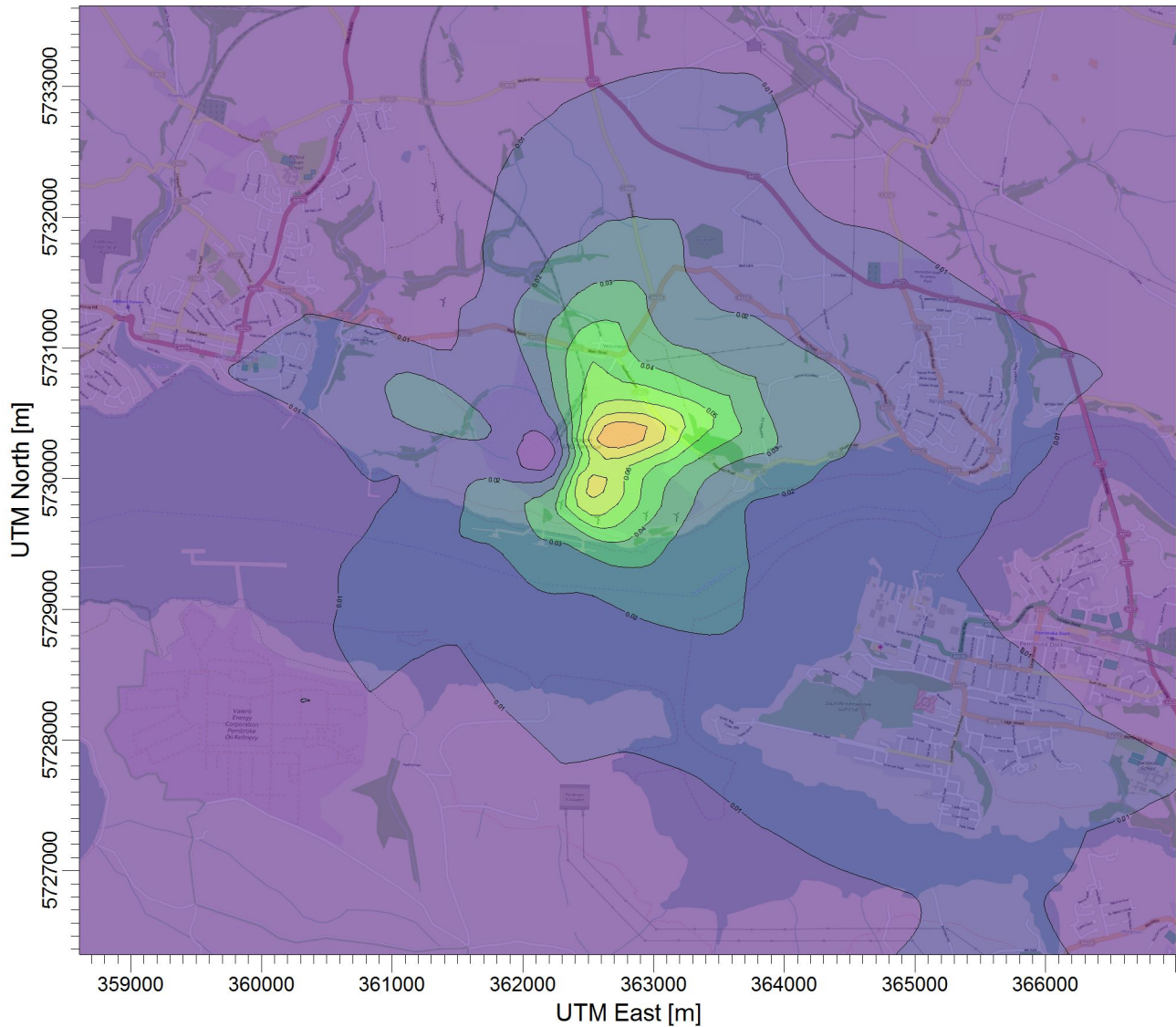
**0.269 ug/m<sup>3</sup>**

**10/02/2015**

**9Y1920**

PROJECT TITLE:

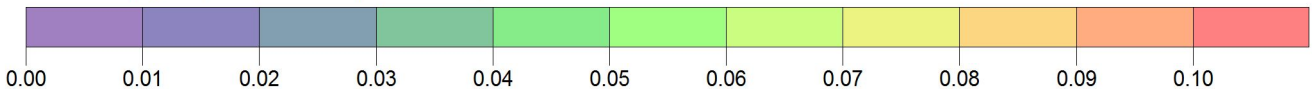
**B1 Normal Scenario: NOx Annual Mean (2010)**



PLOT FILE OF ANNUAL VALUES FOR SOURCE GROUP: ALL

ug/m<sup>3</sup>

Max: 0.09 [ug/m<sup>3</sup>] at (362735.49, 5730297.07)



COMMENTS:

SOURCES:

**2**

COMPANY NAME:

**Royal HaskoningDHV**

RECEPTORS:

**1397**

MODELER:

**JP**

OUTPUT TYPE:

**Concentration**

SCALE:

1:52,815

0 2 km

MAX:

**0.09 ug/m<sup>3</sup>**

DATE:

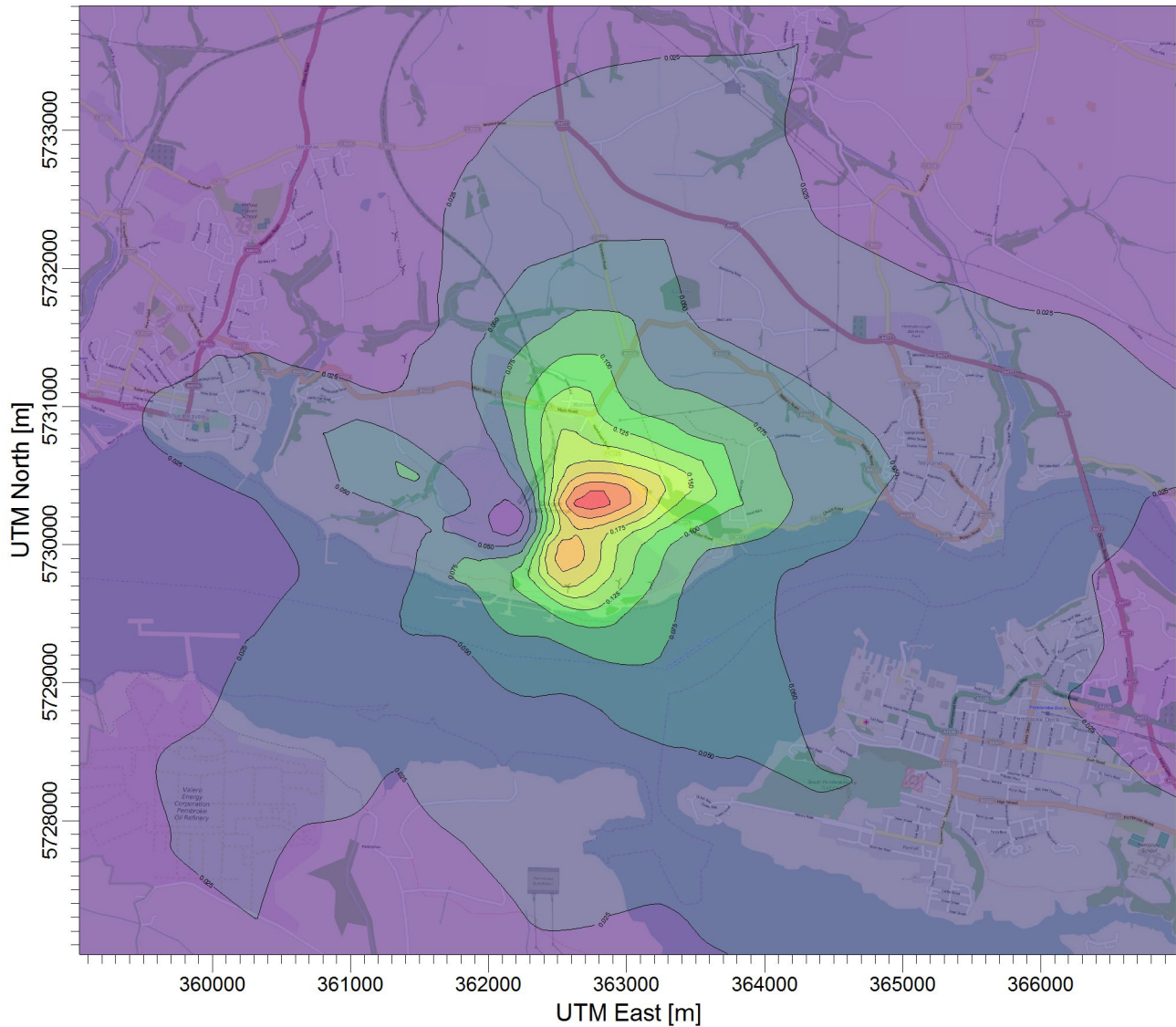
**10/02/2015**

PROJECT NO.:

**9Y1920**

PROJECT TITLE:

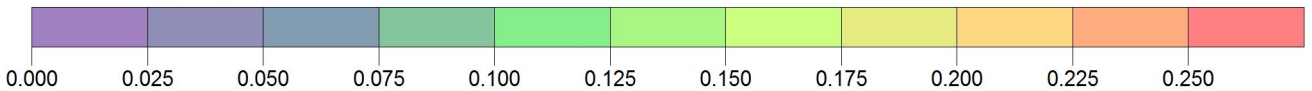
**B1 Peak Scenario: NOx Annual Mean 2010**



PLOT FILE OF ANNUAL VALUES FOR SOURCE GROUP: ALL

ug/m<sup>3</sup>

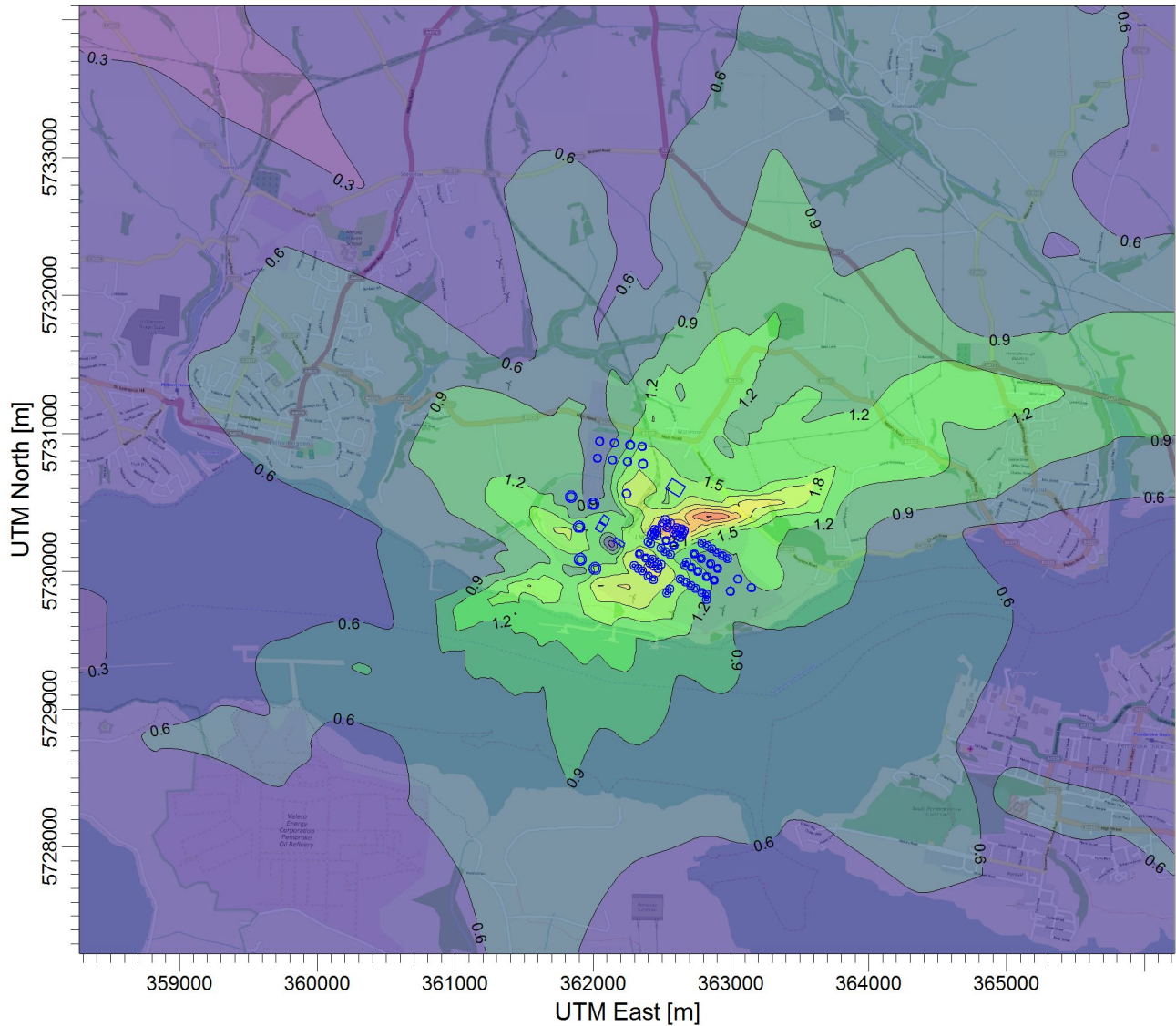
Max: 0.266 [ug/m<sup>3</sup>] at (362735.49, 5730297.07)



COMMENTS:	SOURCES: <b>6</b>	COMPANY NAME: <b>Royal HaskoningDHV</b>	
	RECEPTORS: <b>1397</b>	MODELER: <b>JP</b>	
	OUTPUT TYPE: <b>Concentration</b>	SCALE: 1:50,000	
	MAX: <b>0.266 ug/m<sup>3</sup></b>	DATE: <b>10/02/2015</b>	PROJECT NO.: <b>9Y1920</b>

PROJECT TITLE:

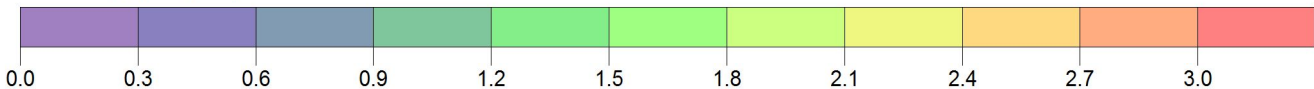
**A1 Normal Scenario: CO 8 Hour Rolling Average (2010)**



PLOT FILE OF HIGH 1ST HIGH 8-HR VALUES FOR SOURCE GROUP: ALL

ug/m<sup>3</sup>

Max: 3.0 [ug/m<sup>3</sup>] at (362835.49, 5730397.07)



COMMENTS:

SOURCES:

**3**

COMPANY NAME:

**Royal HaskoningDHV**

RECEPTORS:

**1397**

MODELER:

**JP**

OUTPUT TYPE:

**Concentration**

SCALE:

1:50,000

0 2 km

MAX:

**3.0 ug/m<sup>3</sup>**

DATE:

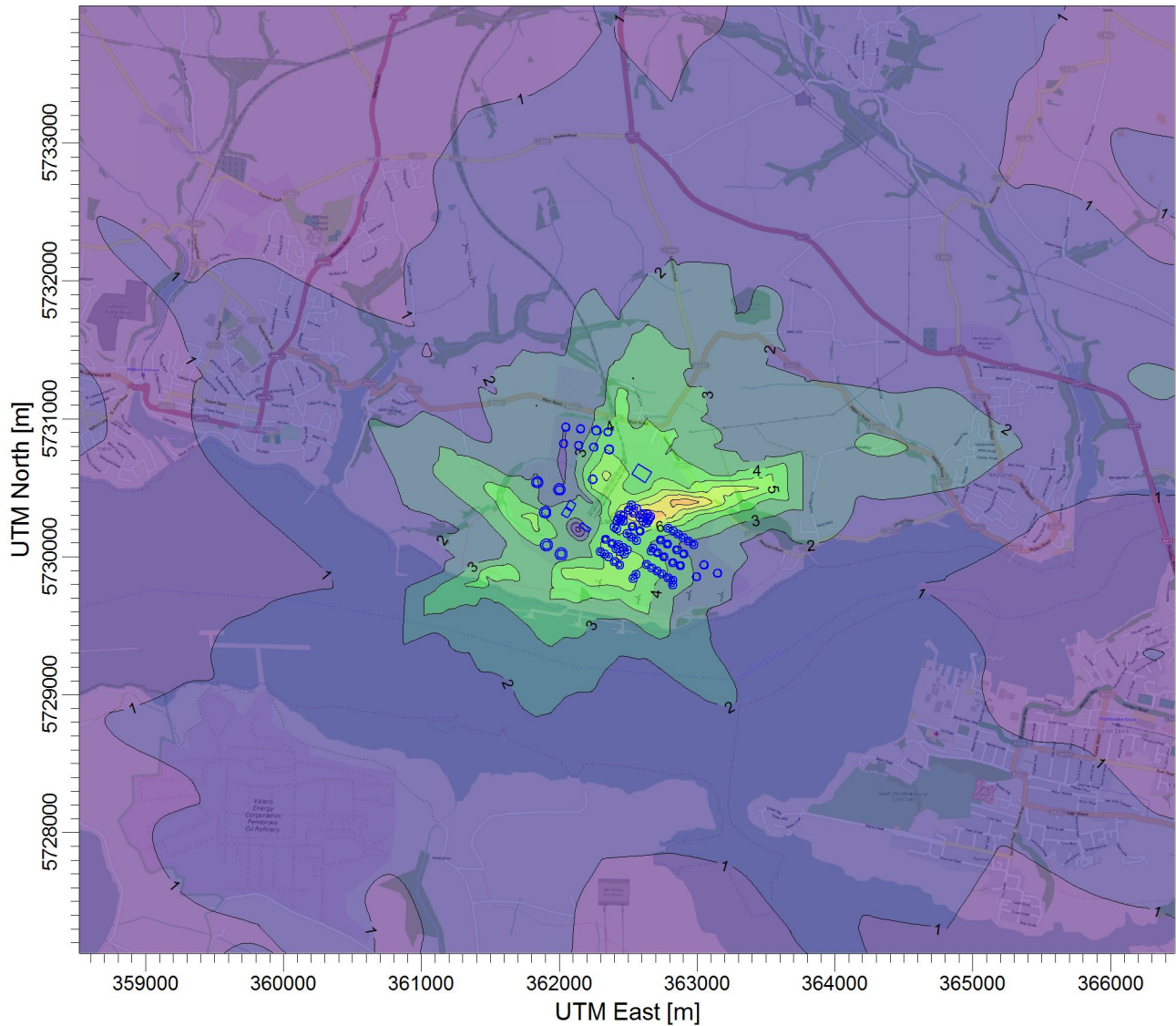
**12/02/2015**

PROJECT NO.:

**9Y1920**

PROJECT TITLE:

**A1 Peak Scenario: CO 8 Hour Rolling Average (2010)**



PLOT FILE OF HIGH 1ST HIGH 8-HR VALUES FOR SOURCE GROUP: ALL

ug/m<sup>3</sup>

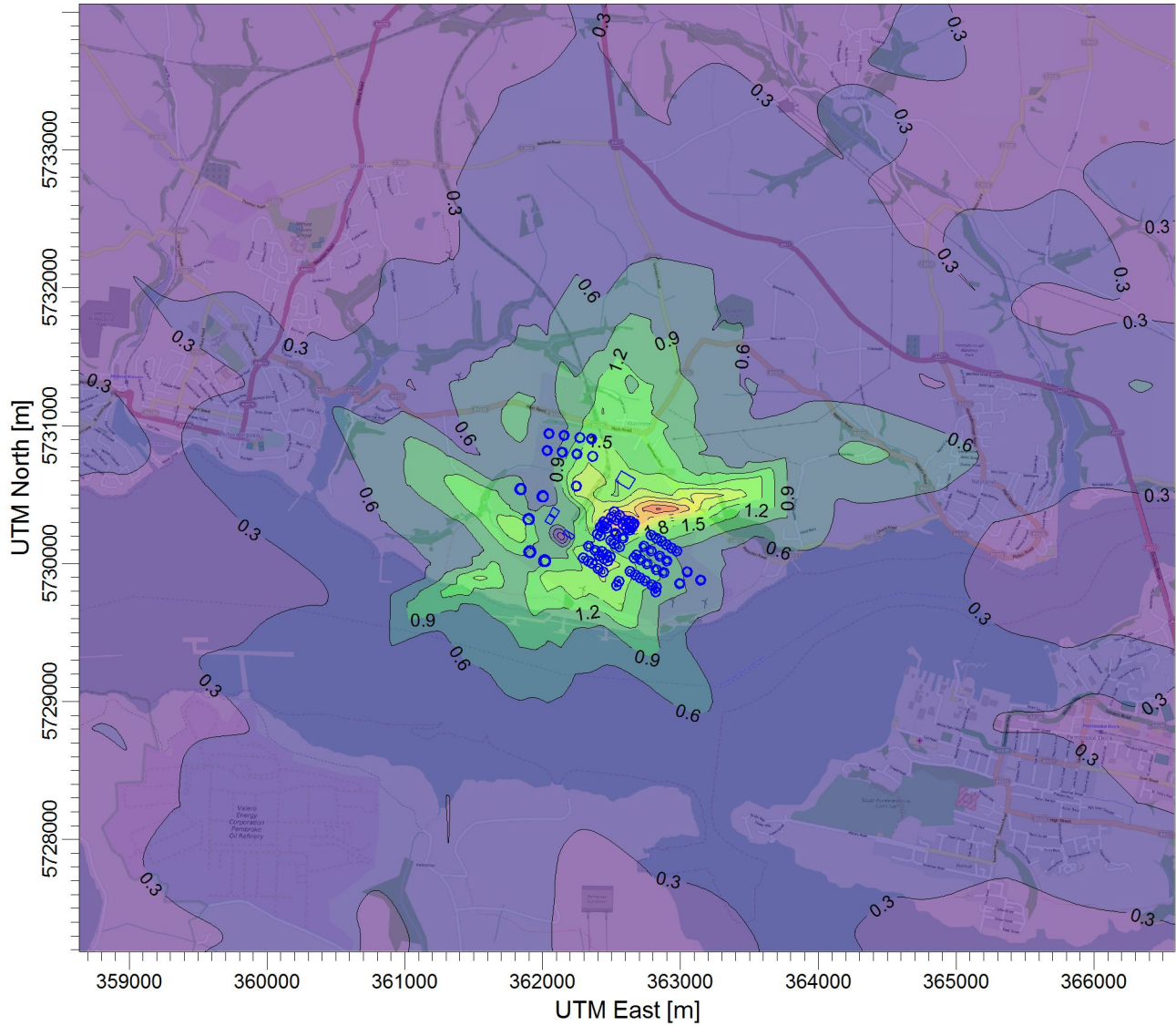
Max: 9 [ug/m<sup>3</sup>] at (362635.49, 5730297.07)



COMMENTS:	SOURCES: <b>7</b>	COMPANY NAME: <b>Royal HaskoningDHV</b>	
	RECEPTORS: <b>1397</b>	MODELER: <b>JP</b>	
	OUTPUT TYPE: <b>Concentration</b>	SCALE: 1:50,000	
	MAX: <b>9 ug/m<sup>3</sup></b>	DATE: <b>12/02/2015</b>	PROJECT NO.: <b>9Y1920</b>

PROJECT TITLE:

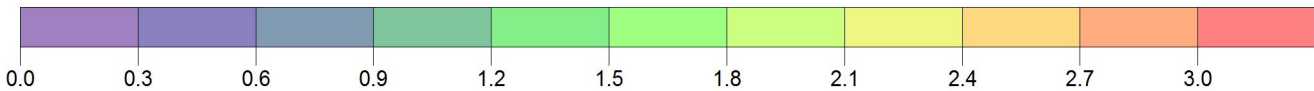
**B1 Normal Scenario: CO 8 Hour Rolling Average (2010)**



PLOT FILE OF HIGH 1ST HIGH 8-HR VALUES FOR SOURCE GROUP: ALL

ug/m<sup>3</sup>

Max: 3.0 [ug/m<sup>3</sup>] at (362835.49, 5730397.07)



COMMENTS:

SOURCES:

COMPANY NAME:

**2**

**Royal HaskoningDHV**

RECEPTORS:

MODELER:

**1397**

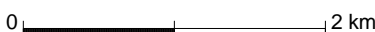
**JP**

OUTPUT TYPE:

SCALE:

1:50,000

**Concentration**

0  2 km

MAX:

DATE:

PROJECT NO.:

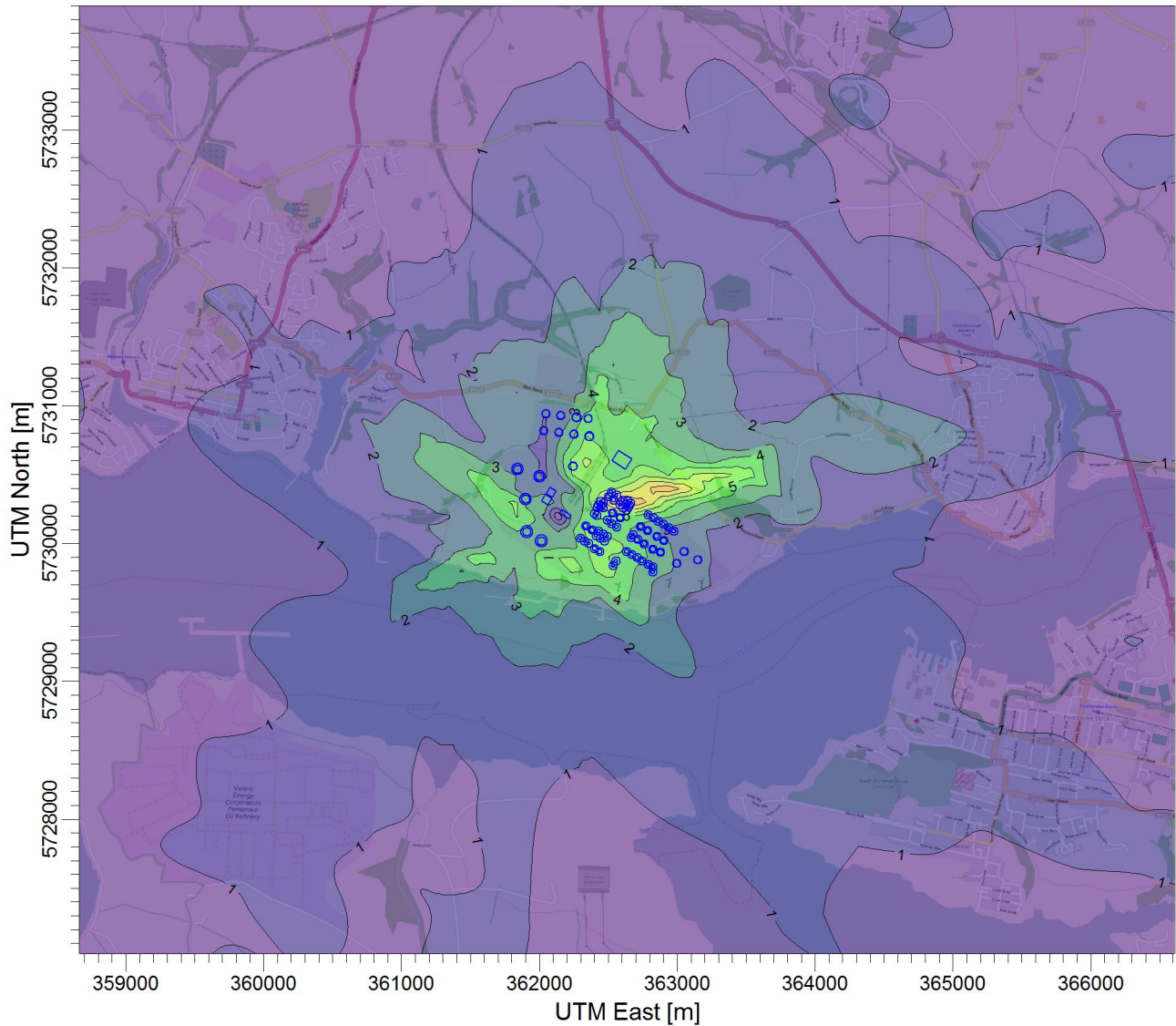
**3.0 ug/m<sup>3</sup>**

**12/02/2015**

**9Y1920**

PROJECT TITLE:

**B1 Peak Scenario: CO 8 Hour Rolling Average (2010)**




PLOT FILE OF HIGH 1ST HIGH 8-HR VALUES FOR SOURCE GROUP: ALL

ug/m<sup>3</sup>

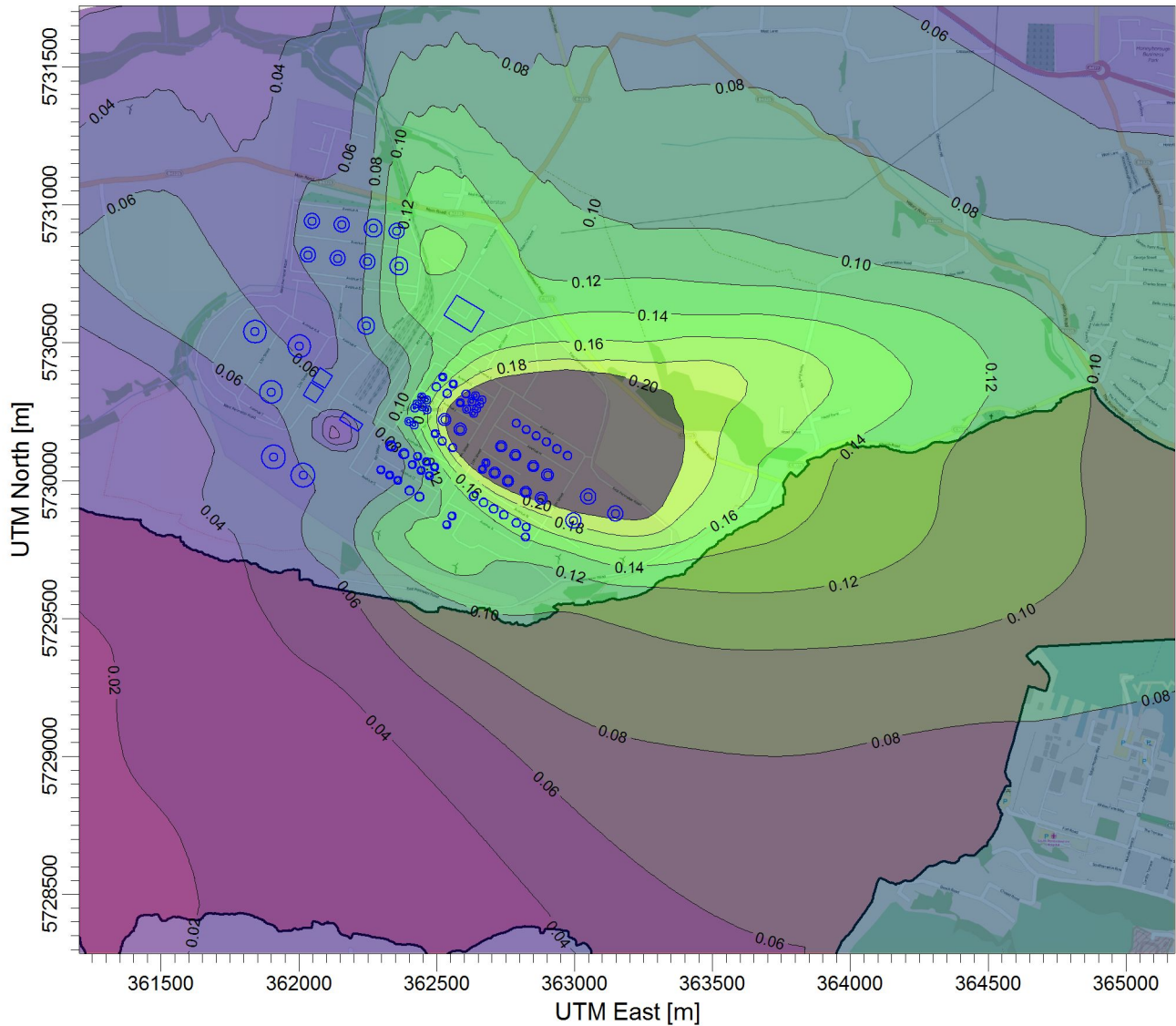
Max: 9 [ug/m<sup>3</sup>] at (362635.49, 5730297.07)



COMMENTS:	SOURCES: <b>6</b>	COMPANY NAME: <b>Royal HaskoningDHV</b>
	RECEPTORS: <b>1397</b>	MODELER: <b>JP</b>
	OUTPUT TYPE: <b>Concentration</b>	SCALE: 1:50,000 0  2 km
	MAX: <b>9 ug/m<sup>3</sup></b>	DATE: <b>12/02/2015</b>

PROJECT TITLE:

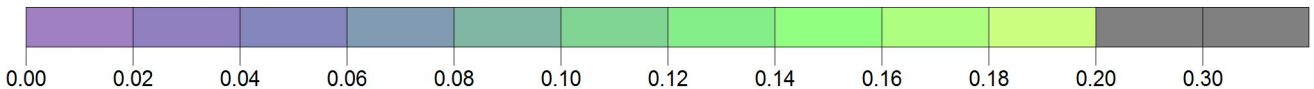
**A1 Peak Scenario: NOx Annual Mean (2011)**



PLOT FILE OF ANNUAL VALUES FOR SOURCE GROUP: ALL

ug/m<sup>3</sup>

Max: 0.28 [ug/m<sup>3</sup>] at (362868.00, 5730160.00)



COMMENTS:	SOURCES: <b>7</b>	COMPANY NAME: <b>Royal HaskoningDHV</b>	
	RECEPTORS: <b>14101</b>	MODELER: <b>JP</b>	
	OUTPUT TYPE: <b>Concentration</b>	SCALE: 1:25,000	
	MAX: <b>0.28 ug/m<sup>3</sup></b>	DATE: <b>12/02/2015</b>	PROJECT NO.: <b>9Y1920</b>



**Royal  
HaskoningDHV**  
*Enhancing Society Together*

## **Appendix D: Critical Level Assessment Results**

**NOx Critical Level Assessment for Milford Haven Waterway SSSI and Pembrokeshire Marine SAC**

Scenario	Year	NOx Annual Mean Critical Level Assessment						NOx 24-Hour Mean Critical Level Assessment					
		Grid Co-ordinates of Highest PC within SSSI/SAC		Highest Predicted PC Within SSSI/SAC	Highest Predicted PEC Within SSSI/SAC	PC/AQO	PEC/AQO	Grid Co-ordinates of Highest PC within SSSI/SAC		Highest Predicted PC Within SSSI/SAC	Highest Predicted PEC Within SSSI/SAC	PC/AQO	PEC/AQO
		x	y	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%	x	y	µg.m <sup>-3</sup>	µg.m <sup>-3</sup>	%	%
A1 Normal	2010	193667	204332	0.05	28.86	0.17	96.18	193069	204440	1.08	58.68	1.43	78.24
	2011	194875	204866	0.06	28.86	0.20	96.21	192571	204597	0.94	58.55	1.26	78.07
	2012	194875	204866	0.06	28.86	0.19	96.20	192919	204492	1.32	58.93	1.76	78.57
	2013	194824	204816	0.05	28.85	0.15	96.16	193069	204440	1.00	58.61	1.34	78.15
	2014	194118	204376	0.05	28.85	0.15	96.16	193069	204440	1.24	58.85	1.66	78.46
A1 Peak	2010	193667	204332	0.13	28.94	0.44	96.45	193119	204440	2.77	60.38	3.70	80.51
	2011	194722	204668	0.15	28.95	0.49	96.50	192969	204492	2.50	60.10	3.33	80.14
	2012	194976	204914	0.13	28.93	0.43	96.44	192869	204492	3.21	60.81	4.28	81.09
	2013	193617	204333	0.10	28.90	0.34	96.35	193069	204440	3.27	60.88	4.36	81.17
	2014	193667	204332	0.12	28.92	0.38	96.39	193069	204440	2.67	60.27	3.56	80.36
A2 Normal and Peak	2010	194722	204668	0.02	28.83	0.08	96.09	193517	204334	0.52	58.13	0.69	77.50
	2011	195829	205102	0.03	28.83	0.10	96.11	194976	204914	0.60	58.20	0.79	77.60
	2012	195829	205102	0.02	28.83	0.08	96.09	194168	204375	0.49	58.10	0.65	77.46
	2013	195829	205102	0.02	28.82	0.07	96.08	194168	204375	0.51	58.11	0.68	77.48
	2014	194622	204619	0.02	28.82	0.07	96.08	194218	204375	0.54	58.14	0.72	77.52
B1 Normal 6 Month	2010	193667	204332	0.04	28.84	0.13	96.14	193069	204440	0.83	58.44	1.11	77.92
	2011	194622	204619	0.04	28.85	0.15	96.16	192919	204492	0.81	58.41	1.07	77.88
	2012	194875	204866	0.04	28.84	0.12	96.13	192869	204492	1.02	58.63	1.37	78.17
	2013	193571	204334	0.03	28.83	0.10	96.11	193069	204440	1.00	58.61	1.34	78.15
	2014	193717	204331	0.04	28.84	0.12	96.13	192869	204492	0.89	58.49	1.18	77.99
B1 Peak 6 Month	2010	193717	204331	0.12	28.92	0.40	96.41	193069	204440	2.45	60.06	3.27	80.08
	2011	193722	204681	0.14	28.95	0.48	96.49	193069	204440	2.41	60.01	3.21	80.02
	2012	194824	204816	0.11	28.91	0.35	96.36	192869	204492	3.05	60.65	4.06	80.87
	2013	193571	204334	0.09	28.90	0.31	96.32	193069	204440	3.14	60.75	4.19	81.00
	2014	193717	204331	0.11	28.91	0.37	96.38	193069	204440	2.62	60.23	3.49	80.30
B1 Normal 12 Month	2010	193069	204440	0.09	28.89	0.28	96.29	193667	204332	0.89	58.50	1.19	78.00
	2011	194875	204866	0.07	28.87	0.24	96.25	192869	204492	0.81	58.41	1.07	77.88
	2012	194875	204866	0.07	28.87	0.24	96.25	193368	204386	1.00	58.61	1.34	78.15
	2013	193567	204333	0.06	28.86	0.19	96.20	193069	204440	1.00	58.61	1.34	78.15
	2014	193069	204440	0.06	28.87	0.21	96.22	193069	204440	1.24	58.85	1.66	78.47
B1 Peak 12 Month	2010	193069	204440	0.25	29.05	0.83	96.84	192869	204492	2.74	60.34	3.65	80.46
	2011	194824	204816	0.22	29.02	0.72	96.73	193069	204440	2.41	60.01	3.21	80.02
	2012	194824	204816	0.22	29.02	0.72	96.73	192869	204492	3.05	60.65	4.06	80.87
	2013	193617	204333	0.17	28.97	0.56	96.57	193069	204440	3.14	60.75	4.19	81.00
	2014	193069	204440	0.19	28.99	0.62	96.64	193069	204440	3.51	61.12	4.68	81.49



**Royal  
HaskoningDHV**  
*Enhancing Society Together*

## **Appendix E: Critical Load Assessment Results**

## Critical Loads for Nutrient Nitrogen and Acid Deposition

Information obtained from APIS on 02/02/2015

Lowest Critical Loads for Nutrient Nitrogen and Acid Deposition

### Milford Haven Waterway SSSI

Habitat	Nutrient Nitrogen	Acidity	
	KgN.Ha-yr <sup>-1</sup>	MinCLminN	MinCLmaxN
Calcerous Grassland	10	0.856	4.856
Inland Rock Outcrop and Scree Habitats	5	0.178	0.711
Calaminarian Grasslands	No Data	0.856	4.856
Lowland Beech and Yew Woodland	5	0.142	1.175
Limestone Pavements	5	No Data	No Data
Coastal Sand Dunes	8	0.223	0.756
Upland Heathland	10	0.499	1.299
Lowland Heathland	10	0.499	1.299
Upland Flushes Fens and Swamps	10	0.223	0.756
Lowland Fens and Swamps	10	0.223	0.756
Marshy Grassland	No Data	0.223	0.756
Neutral Grassland	20	0.223	0.756

### Pembrokeshire Marine SAC

Habitat	Nutrient Nitrogen	Acidity	
	KgN.Ha-yr <sup>-1</sup>	MinCLminN	MinCLmaxN
Estuaries	10	No Data	No Data
Coastal Lagoon	10	No Data	No Data
Atlantic Salt Marshes	10	No Data	No Data
Supralittoral Rock	5	No Data	No Data

Nutrient Nitrogen and Acid Deposition Critical Load Assessment

Scenario	Year	Max Annual Mean NOx Concentration Within SSSI/SAC µg.m <sup>-3</sup>	Grid Co-ordinates of Maximum Concentration within SSSI/SAC X Y		Milford Haven Waterway SSSI										Pembrokeshire Marine SAC	
					Inland Rock Outcrop and Scree				Lowland Beech and Yew Woodland				Limestone Pavements		Supralittoral Rock	
					Maximum Modelled NN Deposition Rate KgN.Ha-yr <sup>-1</sup> % of Critical Load		Maximum Modelled Acid Deposition Rate KgN.Ha-yr <sup>-1</sup> % of Critical Load		Maximum Modelled NN Deposition Rate KgN.Ha-yr <sup>-1</sup> % of Critical Load		Maximum Modelled Acid Deposition Rate KgN.Ha-yr <sup>-1</sup> % of Critical Load		Maximum Modelled NN Deposition Rate KgN.Ha-yr <sup>-1</sup> % of Critical Load		Maximum Modelled NN Deposition Rate KgN.Ha-yr <sup>-1</sup> % of Critical Load	
A1 Normal	2010	0.05	193667	204332	0.0053	0.11	0.0004	0.21	0.0105	0.21	0.0008	0.26	0.0053	0.11	0.0053	0.11
	2011	0.06	194875	204866	0.0062	0.12	0.0004	0.25	0.0124	0.25	0.0009	0.31	0.0062	0.12	0.0062	0.12
	2012	0.06	194875	204866	0.0057	0.12	0.0004	0.23	0.0115	0.23	0.0008	0.29	0.0057	0.12	0.0057	0.12
	2013	0.05	194824	204816	0.0045	0.09	0.0003	0.18	0.0091	0.18	0.0006	0.23	0.0045	0.09	0.0045	0.09
	2014	0.05	194118	204376	0.0046	0.09	0.0003	0.19	0.0093	0.19	0.0007	0.23	0.0046	0.09	0.0046	0.09
A1 Peak	2010	0.13	193667	204332	0.0134	0.27	0.0010	0.54	0.0267	0.53	0.0019	0.67	0.0134	0.27	0.0134	0.27
	2011	0.15	194722	204668	0.0149	0.30	0.0011	0.60	0.0298	0.60	0.0021	0.75	0.0149	0.30	0.0149	0.30
	2012	0.13	194976	204914	0.0129	0.26	0.0009	0.52	0.0258	0.52	0.0018	0.65	0.0129	0.26	0.0129	0.26
	2013	0.10	193617	204333	0.0102	0.20	0.0007	0.41	0.0204	0.41	0.0015	0.51	0.0102	0.20	0.0102	0.20
	2014	0.12	193667	204332	0.0116	0.23	0.0008	0.47	0.0232	0.47	0.0017	0.58	0.0116	0.23	0.0116	0.23
A2 Normal and Peak	2010	0.02	194722	204668	0.0025	0.05	0.0002	0.10	0.0050	0.10	0.0004	0.13	0.0025	0.05	0.0025	0.05
	2011	0.03	195829	205102	0.0031	0.06	0.0002	0.12	0.0061	0.12	0.0004	0.16	0.0031	0.06	0.0031	0.06
	2012	0.02	195829	205102	0.0025	0.05	0.0002	0.10	0.0050	0.10	0.0004	0.13	0.0025	0.05	0.0025	0.05
	2013	0.02	195829	205102	0.0020	0.04	0.0001	0.08	0.0040	0.08	0.0003	0.10	0.0020	0.04	0.0020	0.04
	2014	0.02	194622	204619	0.0020	0.04	0.0001	0.08	0.0040	0.08	0.0003	0.10	0.0020	0.04	0.0020	0.04
B1 Normal 6 Month	2010	0.04	193667	204332	0.0040	0.08	0.0003	0.16	0.0080	0.16	0.0006	0.20	0.0040	0.08	0.0040	0.08
	2011	0.04	194622	204619	0.0044	0.09	0.0003	0.18	0.0089	0.18	0.0006	0.22	0.0044	0.09	0.0044	0.09
	2012	0.04	194875	204866	0.0035	0.07	0.0003	0.14	0.0071	0.14	0.0005	0.18	0.0035	0.07	0.0035	0.07
	2013	0.03	193571	204334	0.0031	0.06	0.0002	0.12	0.0062	0.12	0.0004	0.16	0.0031	0.06	0.0031	0.06
	2014	0.04	193717	204331	0.0037	0.07	0.0003	0.15	0.0074	0.15	0.0005	0.19	0.0037	0.07	0.0037	0.07
B1 Peak 6 Month	2010	0.12	193717	204331	0.0122	0.24	0.0009	0.49	0.0244	0.49	0.0017	0.61	0.0122	0.24	0.0122	0.24
	2011	0.14	193722	204681	0.0144	0.29	0.0010	0.58	0.0288	0.58	0.0021	0.73	0.0144	0.29	0.0144	0.29
	2012	0.11	194824	204816	0.0106	0.21	0.0008	0.43	0.0212	0.42	0.0015	0.53	0.0106	0.21	0.0106	0.21
	2013	0.09	193571	204334	0.0093	0.19	0.0007	0.37	0.0186	0.37	0.0013	0.47	0.0093	0.19	0.0093	0.19
	2014	0.11	193717	204331	0.0111	0.22	0.0008	0.45	0.0223	0.45	0.0016	0.56	0.0111	0.22	0.0111	0.22
B1 Normal 12 Month	2010	0.09	193069	204440	0.0086	0.17	0.0006	0.34	0.0171	0.34	0.0012	0.43	0.0086	0.17	0.0086	0.17
	2011	0.07	194875	204866	0.0072	0.14	0.0005	0.29	0.0144	0.29	0.0010	0.36	0.0072	0.14	0.0072	0.14
	2012	0.07	194875	204866	0.0072	0.15	0.0005	0.29	0.0145	0.29	0.0010	0.36	0.0072	0.15	0.0072	0.15
	2013	0.06	193567	204333	0.0056	0.11	0.0004	0.23	0.0113	0.23	0.0008	0.28	0.0056	0.11	0.0056	0.11
	2014	0.06	193069	204440	0.0063	0.13	0.0005	0.25	0.0126	0.25	0.0009	0.32	0.0063	0.13	0.0063	0.13
B1 Peak 12 Month	2010	0.25	193069	204440	0.0251	0.50	0.0018	1.01	0.0503	1.01	0.0036	1.27	0.0251	0.50	0.0251	0.50
	2011	0.22	194824	204816	0.0218	0.44	0.0016	0.87	0.0436	0.87	0.0031	1.10	0.0218	0.44	0.0218	0.44
	2012	0.22	194824	204816	0.0218	0.44	0.0016	0.88	0.0437	0.87	0.0031	1.10	0.0218	0.44	0.0218	0.44
	2013	0.17	193617	204333	0.0170	0.34	0.0012	0.68	0.0339	0.68	0.0024	0.85	0.0170	0.34	0.0170	0.34
	2014	0.19	193069	204440	0.0189	0.38	0.0013	0.76	0.0378	0.76	0.0027	0.95	0.0189	0.38	0.0189	0.38



# Update of noise model for proposed new re-liquefaction plant

## Re-liquefaction Plant Noise Assessment

### Dragon LNG Limited

Assignment Number: L300017-S05  
Document Number: L-300017-S05-TECH-001

Xodus Group Ltd  
Kenneth Dibben House  
Enterprise Road, Southampton Science Park  
Chilworth, Southampton  
SO16 7NS  
UK

T +44 (0)207 246 2990  
E [info@xodusgroup.com](mailto:info@xodusgroup.com)  
[www.xodusgroup.com](http://www.xodusgroup.com)






Integrated Services  
**Asset Support**



# Re-liquefaction Plant Noise Assessment

## L300017-S05

**Client:** Dragon LNG Limited  
**Document Type:** Technical Note  
**Document Number:** L-300017-S05-TECH-001

R01	12/12/14	Issued for Client Review	 <small>Digitally signed by Phill Moxley DN: cn=Phill Moxley, o=The Moxley Group, ou=The Moxley Group, email=phill.moxley@moxley.com.au, c=AU Date: 2015.01.23 17:05:55 +1100</small>	 <small>Digitally signed by Simon Stephenson DN: cn=Simon Stephenson, o=Simon Stephenson Pty Ltd, ou=Simon Stephenson Pty Ltd, email=stephenson@simonstephenson.com.au, c=AU Date: 2015.01.23 17:05:55 +1100</small>	 <small>Digitally signed by Simon Stephenson DN: cn=Simon Stephenson, o=Simon Stephenson Pty Ltd, ou=Simon Stephenson Pty Ltd, email=stephenson@simonstephenson.com.au, c=AU Date: 2015.01.23 17:05:55 +1100</small>	
			ppLCP	SJS	SJS	
<b>Rev</b>	<b>Date</b>	<b>Description</b>	<b>Issued by</b>	<b>Checked by</b>	<b>Approved by</b>	<b>Client Approval</b>



## **Table of Contents**

<b><u>1</u></b>	<b><u>INTRODUCTION</u></b>	<b><u>4</u></b>
<b><u>2</u></b>	<b><u>METHODOLOGY</u></b>	<b><u>5</u></b>
2.1	Approach	5
2.2	Re-liquefaction Plant Sound Power Levels	5
2.3	Noise Modelling	5
2.4	Assessment	6
<b><u>3</u></b>	<b><u>BASELINE NOISE</u></b>	<b><u>7</u></b>
<b><u>4</u></b>	<b><u>ASSESSMENT</u></b>	<b><u>8</u></b>
4.1	BS4142 Assessment	8
4.2	Absolute Noise Level Assessment	8
4.3	Uncertainties	9
<b><u>5</u></b>	<b><u>RECOMMENDATIONS</u></b>	<b><u>10</u></b>
<b><u>6</u></b>	<b><u>CONCLUSIONS</u></b>	<b><u>11</u></b>
<b><u>APPENDIX A</u></b>	<b><u>SOUND POWER LEVELS</u></b>	<b><u>12</u></b>
<b><u>APPENDIX B</u></b>	<b><u>SITE MAP</u></b>	<b><u>13</u></b>



## 1 INTRODUCTION

Dragon LNG plans to install new re-liquefaction plant at its LNG site in Milford Haven, Pembrokeshire. The intention is that the new plant will operate instead of the existing CoGen plant, although there is a possibility that both plants could operate concurrently for a short period of time. Dragon LNG has requested Xodus Group to conduct a study of the impact that this change of equipment will have on noise levels at sensitive receivers in the community surrounding the site.

The technical note describes the methodology and results of the impact assessment due to introduction of the re-liquefaction plant to the existing environment and the eventual operation of the re-liquefaction plant alone.

In this report all sound pressure levels are quoted in dB re 20  $\mu$ Pa and sound power levels in dB re 1 pW.



## 2 METHODOLOGY

### 2.1 Approach

The objective of this study is to determine the effect of the introduction of new re-liquefaction plant at the residential receiver locations near the Dragon LNG site at Milford Haven. In order to do this, the existing acoustic model of the Dragon LNG site, including detailed modelling of the existing CoGen equipment, was utilised and the re-liquefaction plant added to the model.

### 2.2 Re-liquefaction Plant Sound Power Levels

The re-liquefaction project is at a preliminary design stage and therefore detailed specifications of equipment are not yet available. Dragon LNG has provided an equipment list and provisional layout drawing showing some equipment specification and the proposed location of the equipment.

Sound power level data used in the acoustic model was, where possible, derived from on-site measurements of similar equipment on other LNG and oil and gas sites. The sound power level of the compander enclosure, including the compander motor, was calculated based on the manufacturer's sound pressure level limit of 75 dBA at 1 m from the enclosure and the enclosure dimensions stated in the equipment list. Similarly, the sound power levels for the fin fan coolers and pumps were based on an assumed sound pressure at 1 m of 75 and 80 dBA respectively.

The equipment included in the acoustic model and the associated sound power levels are shown in Appendix A.

### 2.3 Noise Modelling

A computer-based noise model (using CadnaA software) has been developed to predict community noise levels. The detailed terrain model for the development area was based on digital mapping data from Ordnance Survey.

The source term levels (i.e. the calculated sound power levels of equipment) were entered into CadnaA to calculate the expected sound pressure levels in and around the site and in particular at the community receptors. CadnaA uses the propagation method described in CONCAWE Report No. 4/81, "The propagation of noise from petroleum and petrochemical complexes to neighbouring communities".

The ConcaWE report provides a method of calculating sound propagation outdoors in order to predict the level of environmental noise at locations from various sound sources. The document specifies an engineering method of calculating the attenuation of sound as a result of geometric divergence, direct absorption by the atmosphere, ground effects, refraction through wind gradients, reflection from surfaces and screening from obstacles etc.

Geometrical divergence relates to the way in which sound energy dissipates with distance. In general, sound decays at 6 dB per doubling of distance from a 'point' source, although this factor is modified close to the source by the source dimensions and near-field effects.

The ground interaction effect is a phase cancellation phenomenon caused by destructive interference of direct rays and those reflected by the ground. This effect is significant for a range of mid-frequencies over acoustically soft ground (e.g. grassland, ploughed fields etc.) but is less significant, and less frequency dependant over acoustically hard ground (e.g. concrete, water etc.). The actual ground profile between source and receiver may also modify this phenomenon.

Sound absorption by atmosphere involves a "real" loss mechanism in that a direct transfer of energy occurs between the acoustic wave and the constituents of the atmosphere. There are a number of different attenuation mechanisms involved concerning thermal and viscous losses and transfer of energy to nitrogen and oxygen molecules. This is a frequency dependant phenomenon, with the greatest effect occurring at high frequencies.

The model was set up assuming light winds (from source to receiver) resulting in Meteorological Category 6 for propagation from the site to the receiver locations. This is a worst case scenario and noise levels will be less than this under upwind and cross wind conditions, but it allows for comparison with measurement data obtained under conditions favourable for the propagation of sound from the site towards the receptors.

A 3D view of the noise model is shown in Figure 2.1.

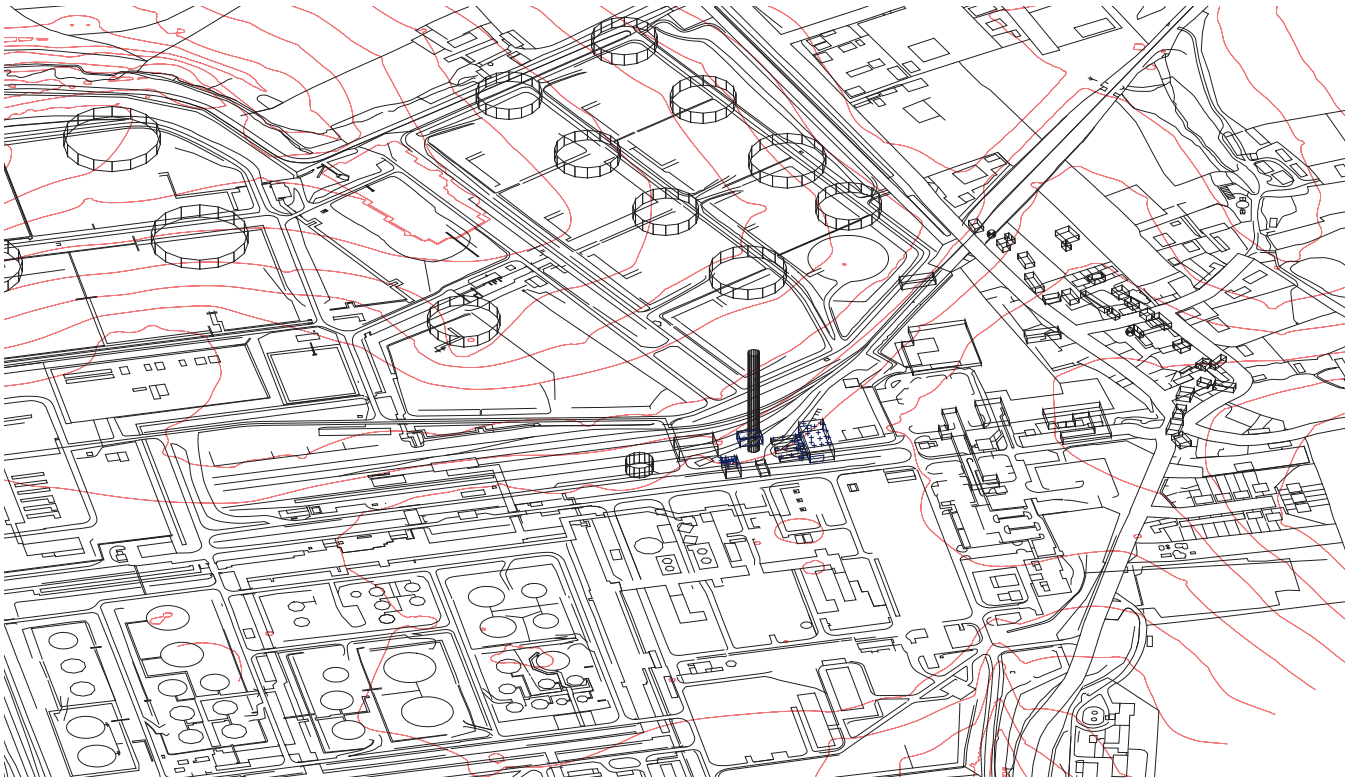


Figure 2.1 3D View of Noise Model

Sound pressure levels were predicted at five noise-sensitive receiver locations, as shown in Appendix B and listed below. These locations each represent a property within 2 km of the proposed location for the re-liquefaction plant.

The receiver locations included in the acoustic model were:

- > Venn Farm
- > Copybush
- > No.2 Main Road
- > No.20 Main Road
- > Harbour View

For each receiver location, the model considered light downwind conditions from the re-liquefaction plant to that specific receiver location.

## 2.4 Assessment

The results of the model were compared with one another and with background noise levels which have previously been measured through attended and unattended surveys.

A BS4142 assessment was undertaken to give an indication of the effect of introducing the new plant in both of these scenarios. For the purposes of the assessment, it is assumed that both the CoGen and the re-liquefaction plant operate continuously 24 hours a day.



### 3 BASELINE NOISE

In order to assess the impact of the re-liquefaction plant, it is necessary to understand the existing noise environment into which the plant is installed. It is anticipated that the re-liquefaction plant will initially operate along with the CoGen plant, before CoGen is shut down. As such, two baseline noise scenarios have been considered in this study, with and without CoGen in operation.

Background noise levels have been obtained from attended and unattended noise surveys which have been carried out at the Dragon LNG site, further details of which can be found in Xodus reports L-300017-S03-TECH-003 and L-300017-S04-TECH-001. The background and ambient noise data taken from the Dragon LNG permanent noise monitor has been analysed to extract the sound pressure levels under light downwind conditions to the Main Road properties. Data measured at the other properties was obtained under light south-easterly wind conditions. A summary of the background levels that were used for the assessment is presented below:

Receiver Location		Background noise level dB L <sub>A90</sub>		Ambient noise level dB L <sub>Aeq</sub>	
		With CoGen	Without CoGen	With CoGen	Without CoGen
1	Venn Farm	36	36**	38	38**
2	Copybush	41	40**	43	43**
3	2 Main Road*	48	40	52	42
4	20 Main Road*	48	40	52	42
5	Harbour View	32	32**	36	36**
*Data from the Dragon LNG permanent noise monitor has been used to represent typical background and ambient noise levels at the rear of the properties on Main Road (i.e. facing the Dragon LNG site).					
**Measurements of background and ambient noise during a CoGen shutdown are not available at these locations – data measured when the CoGen is operating has therefore been used as a proxy.					

Table 3.1 Baseline noise levels with and without CoGen operating



## 4 ASSESSMENT

### 4.1 BS4142 Assessment

A BS4142 assessment of the future noise levels compares the rating level with the existing background level. The rating level is the specific sound level in terms of  $L_{Aeq, T}$  plus a correction for certain acoustic features, such as tonality. It has been assumed that noise from the re-liquefaction plant will be designed such that it will not have any such features, thus the rating level is equal to the specific sound level. The BS 4142 assessment is shown in Table 4.1

Receiver Location		Background noise level dB $L_{A90}$		Specific noise level dB $L_{Aeq}$	Level Difference, dB	
		With CoGen	Without CoGen	Re-liquefaction plant	With CoGen	Without CoGen
1	Venn Farm	36	36*	32	-4	-4
2	Copybush	41	40*	40	-1	0
3	2 Main Road	48	40	36	-12	-4
4	20 Main Road	48	40	38	-10	-2
5	Harbour View	32	32*	17	-15	-15

*\*Measurements of background data during a shutdown at LNG are not available at these locations – data measured when the CoGen is operating has therefore been used as a proxy.*

Table 4.1 BS 4142 assessment for proposed new re-liquefaction plant

According to BS 4142, a level difference of around +10 dB or more is likely to be an indication of a significant adverse impact, depending on the context, whereas a difference of around +5 dB is likely to be an indication of an adverse impact. The lower the rating level is relative to the measured background sound level, the less likely it is that the specific sound source will have an adverse impact or a significant adverse impact. Where the rating level does not exceed the background sound level, this is an indication of the specific sound source having a low impact

When the CoGen plant is operating, the level difference ranges between -1 to -15 dB. With the CoGen not operating, the rating level ranges between 0 to -15 dB. This indicates that the re-liquefaction plant will not have an adverse impact on environmental noise whether the CoGen is operating or not.

### 4.2 Absolute Noise Level Assessment

BS 4142 notes that it is not just the level difference that affects the impact of industrial noise, but also the absolute level of noise.

BS 8233 has been used for many years for general guidance on acceptable noise levels in and around buildings. The standard defines 'good' and 'reasonable' interior ambient noise limits for dwellings from intrusive external noise. According to the standard, an internal noise level in bedrooms of 30 dB  $L_{Aeq}$  is classified as 'good' and 35 dB  $L_{Aeq}$  is classified as 'reasonable'. These internal noise criteria equate to external noise levels of 40 - 45 dB  $L_{Aeq}$  for good sleeping conditions (assuming 10 – 15 dBA attenuation through an open window). It should be noted that these levels are similar to those contained in World Health Organisation guidelines. The standard also suggests a desired garden and amenity area noise level of 50 dB  $L_{Aeq}$  or below and an upper limit of 55 dB  $L_{Aeq}$  for both day and night time periods.

The ambient noise level assessment is shown in Table 4.2. It is estimated that noise levels at Venn Farm and Copybush will increase slightly (by 1 to 2 dB). Given that a 3 dB change in noise is generally taken to be as the minimum noticeable change in noise level, it is unlikely that this slight increase in ambient noise will be perceptible. The noise level at properties on Main Road is expected to reduce by 10 dB when the CoGen is decommissioned, which is subjectively a halving in loudness. There will be no change in noise level for properties on Main Road when the CoGen is operating. Noise from the re-liquefaction plant will not affect the ambient noise levels at Harbour View.



Receiver Location		Baseline ambient noise level dB LAeq		Specific noise level dB LAeq	New ambient noise level, dB LAeq	
		With CoGen	Without CoGen	Re-liquefaction plant	With CoGen	Without CoGen
1	Venn Farm	38	38*	32	39	39
2	Copybush	43	43*	40	45	45
3	2 Main Road	52	42	36	52	43
4	20 Main Road	52	42	38	52	43
5	Harbour View	36	36*	17	36	36

*\*Measurements of ambient noise data during a shutdown at LNG are not available at these locations – data measured when the CoGen is operating has therefore been used as a proxy.*

**Table 4.2 Ambient noise assessment for proposed new re-liquefaction plant**

### 4.3 Uncertainties

As detailed information about the equipment is not yet available, the acoustic model of the re-liquefaction plant uses sound power levels measured on similar equipment and calculations based on assumptions (e.g. meeting an area noise level limit), rather than manufacturers data or measurements specific to the plant to be installed. Furthermore, the assessment assumes no source tonality or other acoustic features, which could potentially increase the rating level of the re-liquefaction plant sufficiently to exceed background.



## 5 RECOMMENDATIONS

In order to ensure that the potential impact from the new re-liquefaction plant is minimised, it is recommended that standard good practice noise control measures are implemented in the design from the outset. These are detailed below in general terms, although more specific recommendations will be provided once the design progresses.

### 5.1 Pipe Lagging

Depending on the type of compressor used, centrifugal and screw compressors can produce highly tonal noise which is then re-radiated via the pipework and support structures. It is therefore recommended that provision is made in the design for acoustic lagging of all suction and discharge compressor pipework. Initially, provision should be made (for weight and space) for Class B insulation according to ISO 15665, although it may be necessary to upgrade or downgrade this requirement at a later date, once manufacturer's data is received. Some manufacturers produce a combined acoustic and thermal insulation product which might be considered most suitable in this application.

### 5.2 Fin Fans

Fin fan cooler banks can often be a source of low frequency environmental noise. The sound power level of such units can vary considerably depending on the type of fan used. It is recommended that inherently low noise design fans are used for both the main cooler bank and lube oil cooler.

### 5.3 Recommended Noise Limits

Recommended sound power level limits for the plant are provided in Table 5.1, along with the equivalent sound pressure level at 1m. These are preliminary sound power level limits, which will prevent noise emissions from the development exceeding the community noise levels which have been predicted in the acoustic model. As the design progresses, the sound power limits may become more refined.

Item	Sound Power Level Limit, dBA re 1 pW	Equivalent Sound Pressure at 1m, dBA re 1 20 µPa
LNG Pump	85	76
Compander Enclosure (external)	98	75
Fin Fan Coolers	99	75
Lube Oil Pump	83	76
Lube Oil Cooler	87	79

Table 5.1 Recommended sound power level limits for new re-liquefaction plant



## 6 CONCLUSIONS

An assessment of the noise impact of installing a new re-liquefaction facility at the Dragon LNG site has been undertaken. The re-liquefaction equipment has been added to the existing Dragon LNG model in order to assess the predicted noise levels against background levels.

- > Noise levels at each of the five residential receiver locations are expected to be lower when the re-liquefaction plant replaces CoGen.
- > When CoGen and re-liquefaction are in operation simultaneously, there is not expected to be an adverse impact compared to CoGen operating alone.



## APPENDIX A SOUND POWER LEVELS

Item	Overall L <sub>w</sub> dBA	Octave band centre frequency, Hz								
		31.5	63	125	250	500	1k	2k	4k	8k
LNG Pump	85	74	75	76	78	78	81	78	74	68
Compander Enclosure	98	65	71	85	86	85	92	94	88	81
Fin Fan Coolers	99	-	89	95	99	97	94	90	83	76
Lube Oil Pump	83	81	83	78	77	76	77	77	75	68
Lube Oil Cooler	87	99	94	92	89	84	79	77	72	62
1st Stage Suction Pipework (per m)	91	41	47	53	59	65	79	86	87	77
1st Stage Discharge Pipework (per m)	92	39	45	51	57	63	77	86	88	84
2nd Stage Suction Pipework (per m)	89	36	42	48	54	60	74	84	85	76
2nd Stage Discharge Pipework (per m)	90	34	40	46	52	58	72	85	86	77

Table A1 Linear octave band and overall A-weighted sound power levels of prosed new re-liquefaction plant as assumed in the model



## APPENDIX B SITE MAP

