



Tarmac

Tarmac Cement Plant - Aberthaw

Carbon Monoxide Dispersion Modelling Report

October 2016



Move Forward with Confidence



DOCUMENT CONTROL SHEET

Issue/Revision	Issue 1
Remarks	Draft for comment
Date	October 2016
Submitted to	David Shenton
Prepared by	Max Nancarrow (Consultant)
Signature	
Approved by	Jamie Clayton (Senior Consultant)
Signature	
Project number	6392203

Disclaimer

This Report was completed by Bureau Veritas on the basis of a defined programme of work and terms and conditions agreed with the Client. Bureau Veritas' confirms that in preparing this Report it has exercised all reasonable skill and care taking into account the project objectives, the agreed scope of works, prevailing site conditions and the degree of manpower and resources allocated to the project.

Bureau Veritas accepts no responsibility to any parties whatsoever, following the issue of the Report, for any matters arising outside the agreed scope of the works.

This Report is issued in confidence to the Client and Bureau Veritas has no responsibility to any third parties to whom this Report may be circulated, in part or in full, and any such parties rely on the contents of the report solely at their own risk.

Unless specifically assigned or transferred within the terms of the agreement, the consultant asserts and retains all Copyright, and other Intellectual Property Rights, in and over the Report and its contents.

Any questions or matters arising from this Report should be addressed in the first instance to the Project Manager.

TABLE OF CONTENTS

Executive Summary	3
1 Introduction	4
1.1 Scope	4
1.2 Report Structure	4
2 Policy, Legislation and Guidance	6
2.1 UK Air Quality Standards and Objectives	6
2.2 Local Air Quality Management (LAQM)	7
2.3 Environmental Permitting Regulations (EPR)	7
3 Assessment Methodology	10
3.1 Dispersion Model	10
3.2 Pollutants Assessed	10
3.3 Modelled Scenarios	10
3.4 Emission Sources	10
3.5 Terrain	11
3.6 Surrounding Buildings	12
3.7 Coastal Dispersion	13
3.8 Meteorological Data	13
3.9 Surface Roughness	16
3.10 Assessment Criteria for Human Receptors	16
3.11 Grids and Specific Receptors	16
4 Baseline Conditions	18
4.1 Site Location	18
4.2 Background Pollutant Concentrations	19
5 Predicted Impacts	20
5.1 ELV 1	20
5.2 ELV 2	22
6 Conclusions	24

List of Figures

Figure 1 - Terrain Data Input to the ADMS 5.1 Model	12
Figure 2 - Buildings and Stacks included in the Dispersion Modelling	13
Figure 3 - 2011 Wind Rose	15
Figure 4 - 2012 Wind Rose	15
Figure 5 - 2014 Wind Rose	15
Figure 6 - 2013 Wind Rose	15
Figure 7 - 2015 Wind Rose	15
Figure 8 – Specific Receptors Representative of Public Exposure within 10km of the Site	17
Figure 9 – Aberthaw Cement Works Location	18
Figure A1. 1 - 1-hour mean CO concentration (mg/m ³) isopleth at ELV 1.....	25
Figure A1. 2 - 8-hour running mean CO concentration (mg/m ³) isopleth at ELV 1	26
Figure A1. 3 - 1-hour mean CO concentration (mg/m ³) isopleth at ELV 2.....	27
Figure A1. 4 - 8-hour running mean CO concentration (mg/m ³) isopleth at ELV 2	28

List of Tables

Table 1 – CO Air Quality Strategy Objective (England and Wales).....	7
Table 2 – CO Environmental Assessment Level	7
Table 3 – Stack Parameters used for Dispersion Modelling	11
Table 4 - Building Inputs to the ADMS 5.1 Model	12
Table 5 - Quality Check on Meteorological Data - Cardiff Airport (Rhoose).....	14
Table 6 - Determination of Worst-Case Meteorological Year	20
Table 7 - Predicted CO impacts under ELV 1.....	21
Table 8 - Predicted CO impacts under ELV 2.....	23
Table A2. 1 - Background CO (mg/m ³) concentrations used in Assessment	29

Executive Summary

Bureau Veritas has been appointed by Tarmac UK to undertake detailed atmospheric dispersion modelling, assessing impacts to human health from Carbon Monoxide (CO) emissions from the Aberthaw cement works in South Wales.

The dispersion modelling undertaken as part of this assessment largely follows the same model set up and methodology as the modelling undertaken by Bureau Veritas for the Aberthaw site in 2011, with any differences detailed in this report. This report can therefore be considered an addendum to, and read in conjunction with, the previous report entitled “*LCUK Air Dispersion Modelling – Aberthaw Works (Final)*”.

The methodology for this assessment followed UK best-practice guidelines for dispersion modelling. It has been based on the ADMS 5.1 dispersion model, used to predict ground pollutant concentrations due to atmospheric dispersion of the main emission sources from the cement works.

Dispersion modelling of CO emissions has been undertaken at the following Emission Limit Values (ELVs):

- 1,000 mg/Nm³ (ELV 1); and
- 1,500 mg/Nm³ (ELV 2).

For ELV 1, maximum predicted CO PECs are well below both the 1-hour mean EAL, at a maximum of 0.8% of the objective, and for the maximum daily running 8-hour mean AQS objective, at a maximum of 2.1% of the objective.

For ELV 2, maximum predicted CO PECs are well below both the 1-hour mean EAL, at a maximum of 0.8% of the objective, and for the maximum daily running 8-hour mean AQS objective, at a maximum of 2.3% of the objective.

Following the significance criteria specified in Environment Agency (EA) Environmental Permitting Regulations (EPR) Guidance⁷ all impacts of CO emissions from the Aberthaw Cement works kiln stack for ELV 1 and 2 are therefore considered to be not significant.

1 Introduction

In 2011, Bureau Veritas UK Ltd (Bureau Veritas) undertook detailed atmospheric dispersion modelling of air pollutant emissions from the Aberthaw cement works in South Wales. The assessment focused on the implications of potential revisions to emissions limits that would be implemented for the site in 2013, following transposition into UK regulations of the new European Industrial Emissions Directive (IED) (IPPC recast), which came into force in January 2011.

Predicted maximum nitrogen oxide (NO_x), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ammonia (NH_3) and particulate (PM_{10} and $\text{PM}_{2.5}$) concentrations were found to be well below the relevant air quality standards (for the protection of human health and/or vegetation) at all receptors relevant for public exposure or representative of sensitive ecosystems considered in the assessment. Full details can be found in the 2011 modelling report "*LCUK Air Dispersion Modelling – Aberthaw Works (Final)*"¹.

Following discussions with the Environment Agency (EA), Tarmac UK is considering the possible amendment of the Aberthaw site's Emission Limit Value (ELV) for carbon monoxide (CO). Impacts from CO were not considered in the previous assessment, as there is no specified ELV in the Cement BREF².

Bureau Veritas have therefore been appointed by Tarmac UK to undertake detailed atmospheric dispersion modelling, assessing impacts to human health from Carbon Monoxide (CO) emissions from the Aberthaw cement works in South Wales.

All processes are Part A(1) regulated under the Environment Agency (England and Wales) (EA).

1.1 Scope

This report focuses on the Aberthaw cement works site in the Vale of Glamorgan, South Wales. The local ambient air quality impacts of emissions of CO (in relation to human health, against the relevant ambient air quality standards and objectives) have been investigated in this assessment:

Dispersion modelling of CO emissions is required at the following Emission Limit Values (ELVs):

- 1,000 mg/Nm^3 ; and
- 1,500 mg/Nm^3 .

The dispersion modelling undertaken as part of this assessment largely follows the same model set up and methodology as the modelling undertaken by Bureau Veritas for the Aberthaw site in 2011¹, with any differences detailed in this report. This report can therefore be considered an addendum to, and read in conjunction with, the previous report¹.

1.2 Report Structure

The report structure is as follows:

- Section 2 presents the legislation and guidance related to air quality assessments of cement production sites;
- Section 3 provides the methodology upon which this assessment is based, including a description of the emissions to air from the stack;

¹ Bureau Veritas (2011). *LCUK Air Dispersion Modelling – Aberthaw Works*

² European Commission (May 2010) – Reference Document on Best Available Techniques in the Cement, Lime and Magnesium Oxide Manufacturing Industries

- Section 4 describes the local environment;
- Section 5 presents the dispersion modelling results and the assessment; and
- Section 6 presents the conclusions of the assessment.

2 Policy, Legislation and Guidance

2.1 UK Air Quality Standards and Objectives

The national Air Quality Strategy (AQS)³ for the UK, last reviewed and published in 2007, provides the over-arching strategic framework for air quality in the UK and contains national air quality standards and objectives established by Government and Devolved Administrations to protect both human health and vegetation (ecosystems). The significance of existing and future pollutant levels can be assessed against these air quality standards and objectives.

The air quality objectives incorporated in the AQS (see Table 1) are based on standards defined in the Air Quality Standards Regulations (Wales)⁴, which came into force on the 11th June 2010 and superseded previous statutory instruments. These standards are derived from the legally binding Limit Values prescribed in the following EU Directives, required to be transposed into national legislation by Member States:

- Directive 2008/50/EC⁵, (the “CAFE” Directive) on ambient air quality and cleaner air for Europe; and
- Directive 2004/107/EC⁶ (the Fourth Directive) relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air.

The CAFE Directive is the result of the Clean Air for Europe (CAFE) programme, initiated in the late 1990s to draw together previous directives (with exception of the Fourth Daughter Directive) into a single EU Directive on air quality.

The AQS objectives for the protection of human health are prescribed for ten pollutants: hydrocarbons (benzene and 1,3-butadiene); carbon monoxide; lead; nitrogen dioxide; sulphur dioxide; particulates (PM₁₀ and PM_{2.5}); ozone and Polycyclic Aromatic Hydrocarbons. The locations where these AQS objectives apply are defined in the AQS as locations outside buildings or other natural or man-made structures above or below ground where members of the public are regularly present and might reasonably be expected to be exposed to pollutant concentrations over the relevant averaging period of the AQS objective. Typically these include residential properties, schools and care homes for longer period (i.e. annual mean) pollutant objectives and high streets for short-term (i.e. 1-hour) pollutant objectives.

The AQS objectives for the protection of vegetation and ecosystems are prescribed for three pollutants: nitrogen oxides, sulphur dioxide and ozone. These objectives are based on a Critical Level approach, further. The locations where these AQS objectives apply are defined as locations:

- more than 20km from an agglomeration (of more than 250,000 inhabitants);
- more than 5km away from industrial sources regulated under Part A of the Environment Act 1990 (and/or Part A1 sites under the PPC regulations), motorways and built up areas of more than 5,000 people

Since none of these pollutants are considered as part of this assessment, it is not necessary to demonstrate compliance against these objectives.

³ The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (2007), Published by Defra in partnership with the Scottish Government, Welsh Assembly Government and Department of the Environment Northern Ireland

⁴ The Air Quality Standards (Wales) Regulations 2010, Statutory Instrument No 1433 (W.126), The Stationary Office Limited

⁵ Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe

⁶ Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air

Table 1 provides the national Air Quality Strategy (AQS)³ Air Quality Objective (AQO) for CO for the protection of human health.

Table 1 – CO Air Quality Strategy Objective (England and Wales)

Pollutant	Objective		Date to be Achieved By
	Concentration	Measured As	
Carbon monoxide (CO)	10.0 mg/m ³	Maximum daily running 8-hour mean	31/12/2003

Environment Agency (EA) Environmental Permitting Regulations (EPR) Guidance defines short-term and long-term Environmental Assessment Levels (EALs)⁷. These EALs are based upon AQS objectives, Critical Levels (for the protection of ecosystems), World Health Organisation (WHO) guidelines, recommendations of the Government's Expert Panel on Air Quality Standards (EPAQS), or Occupational Exposure Standards (OES) / Maximum Exposure Levels (MEL), commonly used to assess the impacts of pollutants with no associated AQS objectives. Table 2 provides details of applicable the 1-hour mean CO EAL⁸.

Table 2 – CO Environmental Assessment Level

Pollutant	Environmental Assessment Level	
	Concentration	Measured As
Carbon monoxide (CO)	30.0 mg/m ³	1-hour mean

In this assessment, model predicted CO concentrations have been compared against both the maximum daily running 8-hour mean AQO and the 1-hour mean EAL.

2.2 Local Air Quality Management (LAQM)

As established by the Environment Act 1995 Part IV, all local authorities in the UK are under a statutory duty to undertake an air quality assessment within their area to determine whether they are likely to meet the air quality objectives set down by Government for a number of pollutants. The process of Review and Assessment of air quality undertaken by local authorities is set out under the Local Air Quality Management (LAQM) regime. Where the results of the Review and Assessment process highlight that problems in the attainment of health-based objectives for air quality will arise, the local authority is required to declare an AQMA – a geographic area defined by high levels of pollution and exceedences of health-based standards.

Information available on Defra's AQMA website⁹ shows that approximately 258 UK local authorities have declared one or more AQMAs. The vast majority of AQMAs has been declared for exceedences of the NO₂ and PM₁₀ AQS objectives, due to pollution from road transport emissions. To date, there have been no AQMAs declared in the Vale of Glamorgan, where Aberthaw cement works is located.

2.3 Environmental Permitting Regulations (EPR)

The Environmental Permitting Regulations (England and Wales)¹⁰ which came into force on 6 April 2010 (replacing the 2007 Regulations), provide a single regulatory framework transposing EU Directives into UK legislation, by defining the permitting and compliance system for industry and

⁷ Environment Agency (2016) Guidance: Air emissions risk assessment for your environmental permit, Available at: <https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit>

⁸ Environmental standards for air emissions (2016) Available at: <https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit#environmental-standards-for-air-emissions>

⁹ <http://aqma.defra.gov.uk/>

¹⁰ The Environmental Permitting Regulations (England and Wales) 2010, Statutory Instrument No 675, The Stationary Office Limited

regulators. Industrial activities considered to be potentially the most polluting – Part A(1) processes – require an Environmental Permit issued by the Environment Agency (EA), the regulator for England and Wales. Lafarge Aberthaw cement works site is classed as a Part A(1) process under these regulations.

2.3.1 Emission Limit Values (ELVs)

Emission Limit Values (ELV) to air are set out by the regulator in the Environmental Permit as permit conditions. Although ELVs are based on limit values prescribed in the relevant EU Directives (IPPC, WID, LCPD), they can be different from site to site due to a variety of site-specific factors such as geographical location, mineralogy variations and local environmental conditions, but also technical and economic considerations.

2.3.1.1 The Industrial Emissions Directive

The Industrial Emissions Directive (2010/75/EU)¹¹ came into force on 6 January 2011. The IED is a recast of the IPPC Directive, which also has an impact on 6 other existing EU Directives, namely:

- the Large Combustion Plant Directive (LCPD)¹²;
- the Waste Incineration Directive (WID)¹³;
- the Solvent Emissions Directive (SED)¹⁴; and
- the three existing Directives on Titanium Dioxide on:
 - o disposal (78/176/EEC)¹⁵,
 - o monitoring and surveillance (82/883/EEC)¹⁶; and
 - o programs for the reduction of pollution (92/112/EEC)¹⁷.

The introduction of the IED results in a number of substantial changes, including new emission performance values (EPV) associated with the use of Best Available Techniques (BAT) that may lead to more stringent ELVs being stipulated in Environmental Permits.

2.3.2 Environmental Assessment Levels (EALs)

Environment Agency (EA) Environmental Permitting Regulations (EPR) Guidance defines short-term and long-term Environmental Assessment Levels (EALs)⁷. These EALs are based upon AQS objectives, Critical Levels (for the protection of ecosystems), World Health Organisation (WHO) guidelines, recommendations of the Government's Expert Panel on Air Quality Standards (EPAQS), or Occupational Exposure Standards (OES) / Maximum Exposure Levels (MEL), commonly used to assess the impacts of pollutants with no associated AQS objectives.

¹¹ Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast)

¹² Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants

¹³ Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste

¹⁴ Council Directive 1999/13/EC of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations

¹⁵ Council Directive 78/176/EEC of 20 February 1978 on waste from the titanium dioxide industry

¹⁶ Council Directive 82/883/EEC of 3 December 1982 on procedures for the surveillance and monitoring of environments concerned by waste from the titanium dioxide industry

¹⁷ Council Directive 92/112/EEC of 15 December 1992 on procedures for harmonizing the programmes for the reduction and eventual elimination of pollution caused by waste from the titanium dioxide industry

For this assessment, modelled pollutant concentrations have been compared against the relevant EAL wherever applicable.

2.3.3 Significance

(EA) Environmental Permitting Regulations (EPR) Guidance⁷ stipulates that for a site to be deemed not to have a significant impact on the local environment, the process contributions must meet both of the following criteria; the short-term PC must be less than 10% of the short-term environmental standard and the long-term PC must be less than 1% of the long-term environmental standard.

For this assessment, these criteria are applied.

3 Assessment Methodology

3.1 Dispersion Model

Detailed dispersion modelling of pollutant emission sources has been carried out using the ADMS 5.1 model¹⁸, using the most up-to-date version of the model at the time of this study (v5.1).

The ADMS model is a 'new-generation' air dispersion model, which has been widely validated for industrial point sources, and is accepted as being 'fit-for-purpose' for environmental impact assessments of stack releases. It is regularly tested against other dispersion models by the Environment Agency's (EA) Air Quality Modelling and Assessment Unit (AQMAU), and is recognised as being suitable for environmental impact assessments. The model incorporates the latest understanding of boundary layer meteorology and air flows in complex terrain.

3.2 Pollutants Assessed

This assessment focuses on carbon monoxide (CO) emitted from the kiln stack at the Aberthaw cement works. All other key air pollutants emitted by the Aberthaw cement works are assessed in the 2011 Bureau Veritas assessment¹, and the conclusions for these pollutants are considered to remain valid.

Carbon monoxide arises from incomplete fuel-combustion. The principal source of CO emissions in the UK is from petrol vehicles, accounting for 54% of total UK emissions in 2008¹⁹, with industrial, commercial and residential combustion sources contributing the significant majority of the remainder. CO emissions in the UK have decreased substantially over recent decades, with the decrease attributed to significant reductions in emissions from road transport, iron and steel production and the domestic sector²⁰.

The toxicity of CO results in it binding avidly to haemoglobin and thus reducing the oxygen-carrying capacity of the blood. In very high doses, the restriction of oxygen to the brain and heart can be fatal. At lower concentrations, CO can affect higher cerebral function, heart function and exercise capacity. It is also of concern due to its role in tropospheric ozone formation.

3.3 Modelled Scenarios

Dispersion modelling of CO emissions is required at the following Emission Limit Values (ELVs):

- 1,000 mg/Nm³ (ELV 1); and
- 1,500 mg/Nm³ (ELV 2).

Constant and continuous hourly emission rates have been assumed for both scenarios.

3.4 Emission Sources

The main source of emissions at the cement works is the kiln stack, which releases pollutants generated from the combustion of kiln fuel. All other sources modelled in the 2011 Bureau Veritas assessment¹ are not combustion sources and so will not emit significant amounts of CO.

The location of the kiln stack included in this assessment is illustrated in Figure 2. Stack parameters used in the assessment are summarised in Table 3.

¹⁸ ADMS5.1 Atmospheric Dispersion Modelling System, User Guide, CERC, May 2015

¹⁹ AEA: UK Emissions Inventory Team (August 2010) – UK Emissions of Air Pollutants 1970 to 2008

²⁰ NAEI "Pollutant Information: Carbon Monoxide" [online]. Available at
http://naei.defra.gov.uk/overview/pollutants?pollutant_id=4

The same stack parameters (temperature, flow rate, etc.) have been assumed for both scenarios; only the pollutant mass emission rates differ from one scenario to the other. Details of emission rates used are also summarised in Table 3.

Table 3 – Stack Parameters used for Dispersion Modelling

Source	Kiln Stack (A1)
X Coordinate (m)	303076
Y Coordinate (m)	167447
Height (m)	100.6
Diameter (m)	2.34
Actual Flow Rate (m ³ /s)	74.04
Exit Temperature (°C)	161.5
Exhaust Moisture Content as kg H ₂ O/kg dry gas (%)	10.73
Exhaust O ₂ Content (%)	10.04
CO Emission Rate ELV 1 (g/s)	41.4
CO Emission Rate ELV 2 (g/s)	62.1

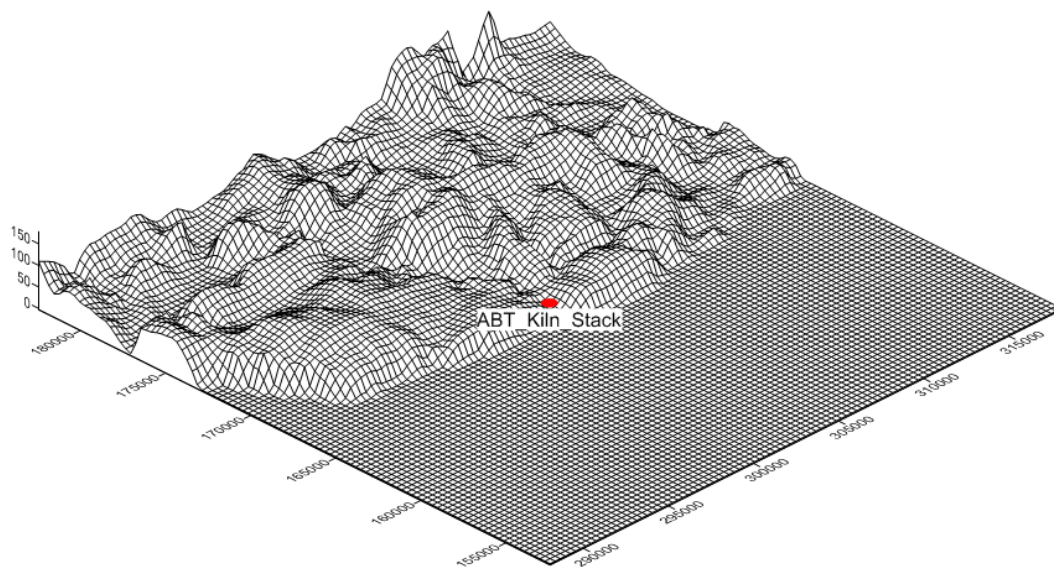
3.5 Terrain

Complex terrain can have a significant effect on the dispersion of a stack plume. As a result, pollutant concentrations at ground level may be higher or lower than on a flat area, depending on the topography. This effect can be taken into account by the dispersion model.

Although the topography around the works is relatively flat, the terrain module operated within ADMS 5.1 has been used to generate a high resolution terrain file. Topographical data for the surrounding area has been obtained from OS Open Data²¹, covering an area of approximately 2 km × 2 km centred on the cement works. The area covered by their terrain file has been reduced when compared to the previous modelling¹ to allow for greater resolution of the terrain file over a smaller modelled area. The resulting terrain grid is shown below in Figure 1.

²¹ OS Landform Panorama DTM terrain tiles

Figure 1 - Terrain Data Input to the ADMS 5.1 Model



3.6 Surrounding Buildings

Buildings can have a significant effect on the dispersion of pollutants, particularly if they are at least 30-40% of the height of the pollutant release. If tall buildings are close to a stack, the plume can be entrained in the cavity zone downwind of the building. This can lead to higher ground concentrations near the stack than would be expected and can affect the dispersion of pollutants in the atmosphere. The downwash effects can be taken into account by the ADMS 5.1 dispersion modelling.

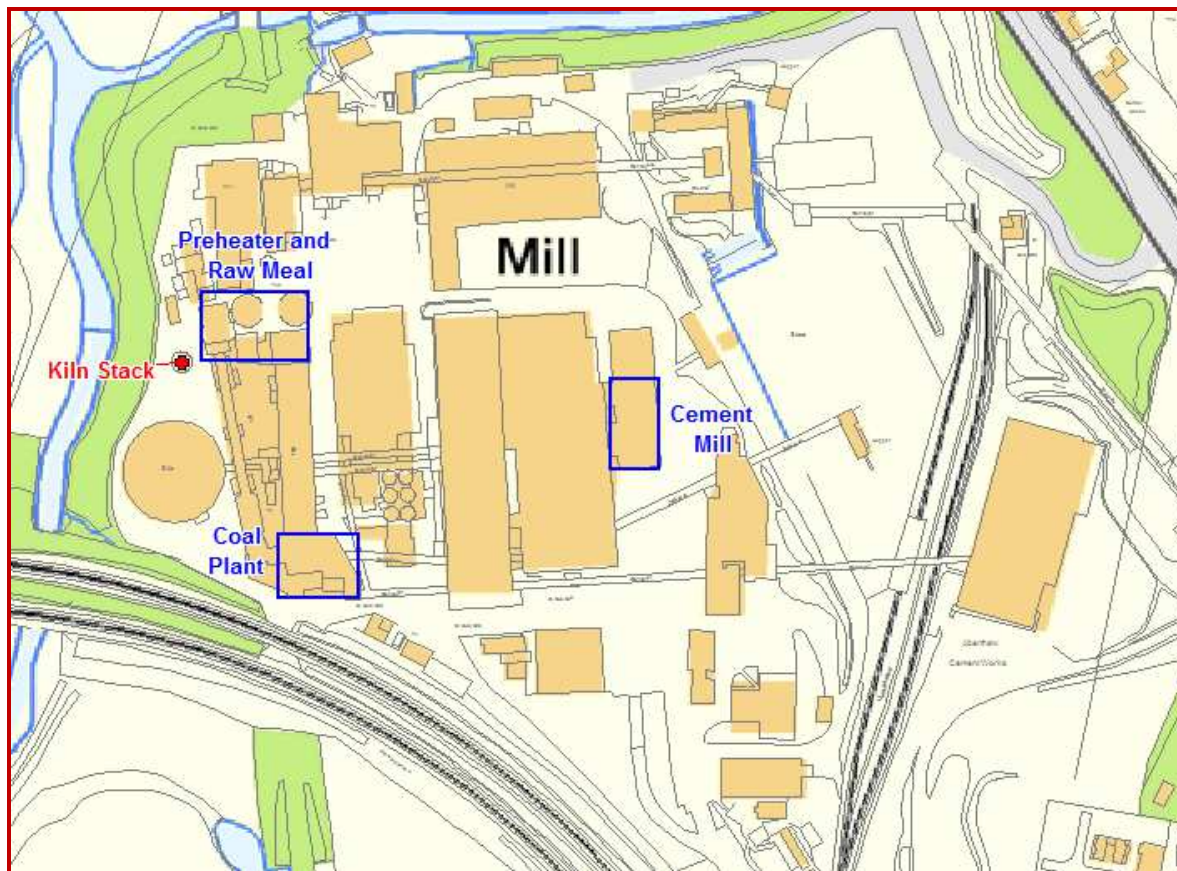
The inclusion of buildings within the model can lead to significant increase in predicted ground concentrations as plume dispersion is hindered by the presence of buildings and plume grounding occurs closer to the site than would otherwise be expected.

For this assessment, downwash effects were taken into account for the dominant buildings in the vicinity of the sources, by setting up 3 sets of "grouped" buildings in the dispersion model (see Figure 2 and Table 4). The building inputs to the model are somewhat larger than their actual size (as indicated on site plans) in order to ensure a conservative approach, allowing for smaller buildings and the complex configuration of other structures on site (which cannot be included individually into the model set-up).

Table 4 - Building Inputs to the ADMS 5.1 Model

ID	Building Description	OS Grid Coordinate Centre- point of Building		Height (m)	Length (m)	Width (m)
		X	Y			
1	Preheater and Raw Meal	303106	167461	55	43	29
2	Cement Mill	303259	167422	25	37	20
3	Coal Plant	303131	167365	35	33	26.5

Figure 2 - Buildings and Stacks included in the Dispersion Modelling



3.7 Coastal Dispersion

The dispersion of exhaust stack emissions from the cement works is likely to be affected by buildings, terrain and the coastal nature of the site. The coastline option within ADMS 5.1 aims to take into account the differences in the development of a convective internal boundary layer between the sea and on the land, where the boundary layer height increases on land during the day and may trap a plume within it when further inland (leading to higher concentrations as the plume is brought towards the ground). However, the coastline module within ADMS 5.1 cannot be run in conjunction with terrain or buildings. Moreover, the coastline module has not been validated against field data, whilst building wake effects have been subject to validation, based on various experiments. Sensitivity testing indicates that the effect of onsite buildings on plume dispersion is not negligible; therefore, it was deemed more important to include buildings in the model in order to account for the building wake effect appropriately.

3.8 Meteorological Data

Dispersion of pollutant emissions is dependent upon the prevailing meteorological conditions at the time of release. Hourly sequential meteorological data has been used in the assessment.

The source of meteorological data used within this dispersion modelling assessment is taken from a synoptic observing station providing the parameters required by dispersion models. In this case, the site at Cardiff Airport (Rhoose) has been utilised.

To ensure worst-case met conditions are applied, sensitivity testing of five years' worth of met data has been undertaken. The wind roses for the meteorological data from 2011 to 2015 are shown in Figure 3 to Figure 7, where the dominant westerly winds can be identified.

A check on the data quality of the dataset is summarised in Table 5. It is recommended in LAQM.TG(16) that the meteorological data file be tested within a dispersion model to confirm the number of missing hours and calm hours that cannot be used by the dispersion model. This is important when considering predictions of high percentiles and the number of exceedences. LAQM.TG(16) recommends that meteorological data should only be used if the percentage of usable hours is greater than 75%, and preferably 90%.

The availability of usable hours of meteorological data fulfils the minimum requirements for dispersion modelling as advised in best-practice guidance²² for all years.

Table 5 - Quality Check on Meteorological Data - Cardiff Airport (Rhoose)

ADMS Meteorological Input Data	2011	2012	2013	2014	2015
Total Met lines	8760	8784	8760	8760	8760
Number of hourly meteorological lines used	8670	8678	8679	8658	8692
Number of meteorological lines with calm conditions	73	58	53	59	10
Number of meteorological lines with inadequate data	8	45	22	25	33
Number of non-calm meteorological lines with wind speeds (at 10 m height) less than 0.75 m/s	9	3	6	18	25

²² Defra Technical Guidance LAQM.TG(16), 2016

Figure 3 - 2011 Wind Rose

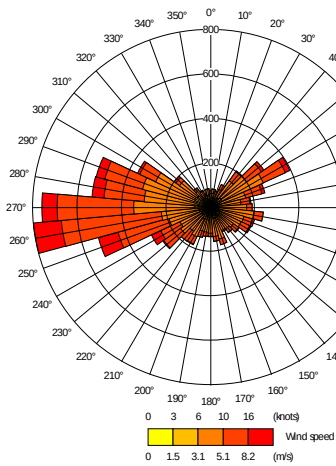


Figure 4 - 2012 Wind Rose

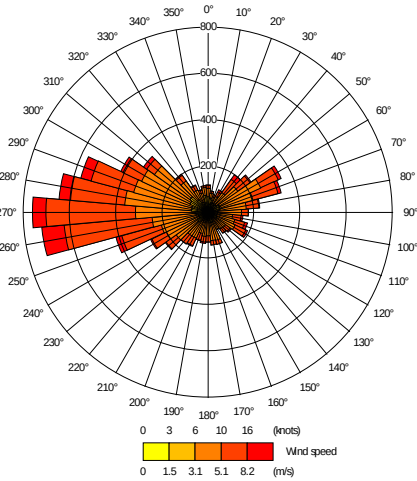


Figure 6 - 2013 Wind Rose

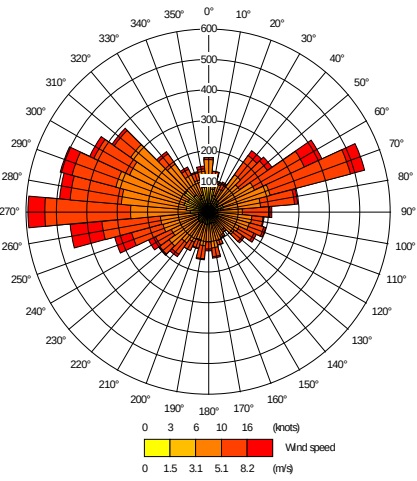


Figure 5 - 2014 Wind Rose

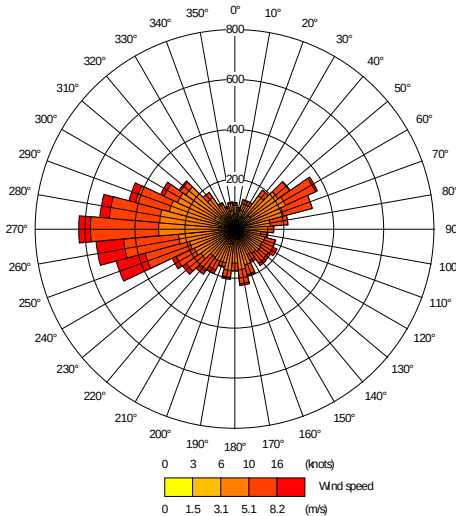
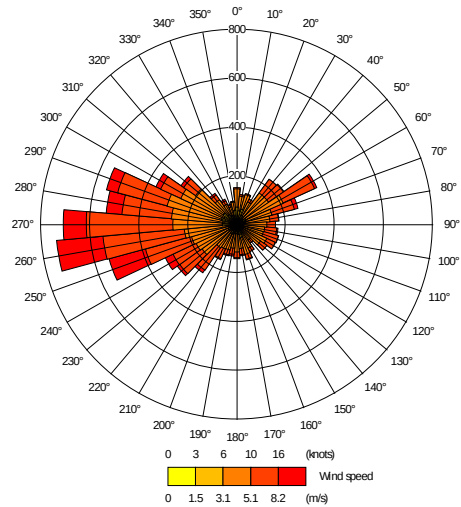


Figure 7 - 2015 Wind Rose



3.9 Surface Roughness

Together with terrain elevation, surface roughness length is another important variable in dispersion models, used to characterise the surface conditions. This parameter can have a significant impact on atmospheric turbulence near the ground and therefore on pollutant dispersion.

A surface roughness of 0.5m has been assumed throughout the model domain, which was considered appropriate for the area as representative of the rural character of the site surroundings (with some local features causing additional turbulence). This figure was chosen as opposed to a roughness length 0.3m, typically representative of a more homogenous agricultural area, or a higher roughness length of 1m often used to represent a small town with numerous buildings and/or woodlands. Sensitivity tests using these figures were carried out, and showed that, compared to the selected roughness length of 0.5m, the change in pollutant concentrations would be overall within the range of $\pm 5\%$ (based on results at all sensitive receptors considered in the assessment), which is not considered significant.

3.10 Assessment Criteria for Human Receptors

CO concentrations have been predicted at ground level at receptors representative of public exposure, i.e. residential properties, farms and other sensitive locations.

Background concentrations, which include the contribution of other sources of pollution not considered in the modelling – such as road traffic, domestic sources and other industrial processes at the local, regional and national level – have been added to the Process Contribution (PC) from the kiln to calculate the total concentration, or Predicted Environmental Concentration (PEC), of CO. These PECs have then been compared against the relevant QO and EAL for CO, as detailed in Table 1 and Table 2 respectively.

As both the 1-hour mean and 8-hour rolling mean criteria are relevant to human receptors only, CO emissions to ecological receptors are not considered in this assessment.

3.11 Grids and Specific Receptors

A regularly spaced grid covering the area around the site has been included in the model, along with a large number of identified specific human receptor locations such as residential buildings. A description of the grid and sensitive receptors is provided below.

3.11.1 Grids

A grid of receptors has been considered, covering an area of 2km x 2km, centered on the cement works, with a resolution of 20m, in order to provide more detailed results in the vicinity of the site.

3.11.2 Specific Receptors for Human Health

Concentrations have been predicted at 42 specific receptor locations, representative of residential properties in the surrounding villages or isolated farms / properties within a radius of 10km from the site. The location of these receptors are shown in Figure 8. The height of all specific receptors has been assumed to be 1.5m to represent inhalation exposure.

Figure 8 – Specific Receptors Representative of Public Exposure within 10km of the Site



4 Baseline Conditions

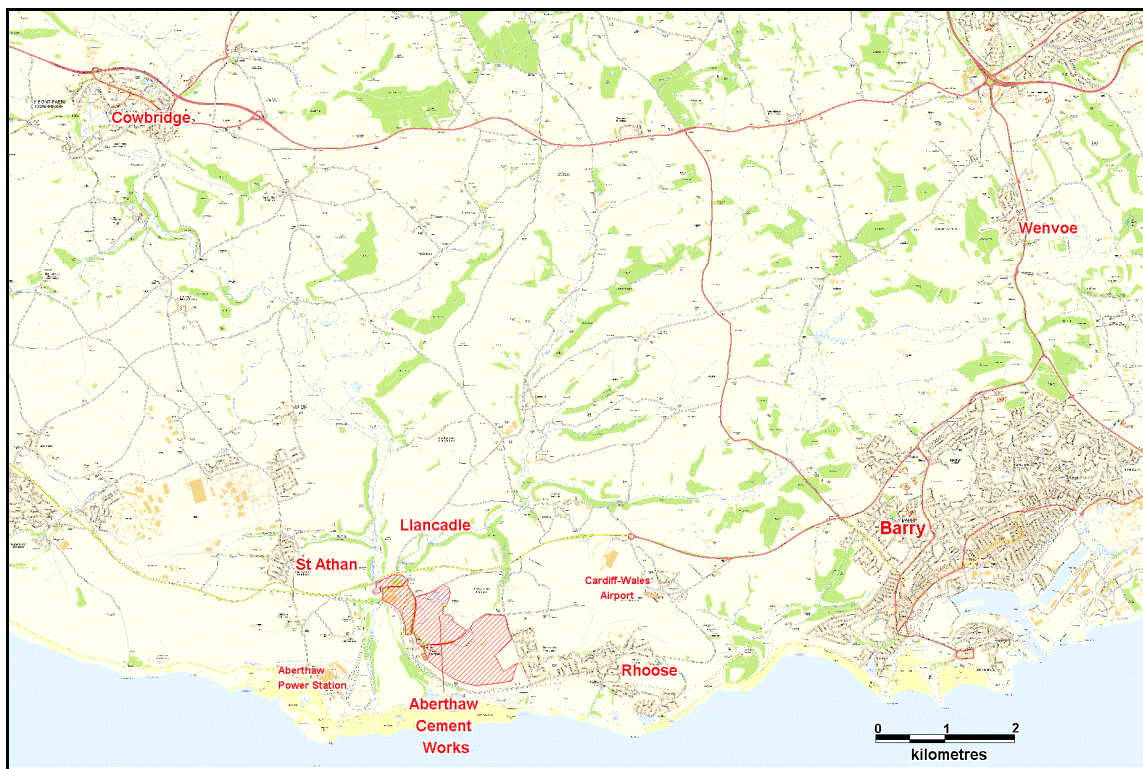
4.1 Site Location

Aberthaw cement works is located in the Vale of Glamorgan in South Wales, 15km southwest of Cardiff and 8km west of the town of Barry. The site immediate surroundings are predominantly rural in character, surrounded by the villages of Aberthaw (within 1km south of the site), Rhoose (2km southeast), Llancadle (1km north), and St Athan and Gileston (1.5km west of the site). Cardiff International Airport lies 3km east of the site, while Aberthaw Power Station is situated 1km southwest of the works, on the coastline. Barry is also a major trading port, including steelworks, scrapyard, and coal and aggregate handling and storage.

There are a number of isolated properties within 10km of the works, which have been taken into account in this assessment. Further information on nearby sensitive receptors taken into account in the assessment is provided in Section 3.11 below.

The site location and surroundings are shown in Figure 9.

Figure 9 – Aberthaw Cement Works Location



4.2 Background Pollutant Concentrations

The dispersion model has been used to predict the contribution of the exhaust stack emissions, or Process Contribution (PC), to ambient air concentrations. Existing background concentrations have then been added to the Process Contribution in order to report total pollutant concentrations, or Predicted Environmental Concentration (PEC) at specific locations and on the grid of receptors. In order to determine background concentration levels, local monitoring sites and the UK background maps have been considered.

In order to obtain background CO concentration levels, the 2001-based modelled maps of background pollutant concentrations (available from the Local Air Quality Management Support (LAQM) website²³), have been utilised, adjusted for the assessment year²⁴. Background maps are available at a 1km² resolution for the whole of the UK. The background annual mean CO concentration used for this assessment is summarised in Appendix 2, expressed as mg/m³. For comparison with the short-term objectives for CO, twice the annual mean background has been assumed as short-term background concentration, in accordance with the EA's EPR Guidance⁷.

²³ <http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html>

²⁴ Following methodology in Background Concentration Maps User Guide October 2016, <http://laqm.defra.gov.uk/documents/2013-based-background-maps-user-guide-v2.1.pdf>

5 Predicted Impacts

Results are presented for the meteorological year resulting in the highest concentrations at one of the assessed receptor locations, as a worst case assumption. The worst-case meteorological year was determined for the 8-hour running mean concentrations at the worst-case receptor location, based on process contributions from the Tarmac cement plant operating for the entire year at ELV 1. Therefore, the data in Table 6 are used to determine the worst-case meteorological year.

Table 6 - Determination of Worst-Case Meteorological Year

Year	Predicted Process Contributions ($\mu\text{g}/\text{m}^3$)
	Maximum CO 8-hour running mean
2011	47.8
2012	48.9
2013	49.2
2014	43.3
2015	44.9

Notes: These concentrations are based on the maximum process contribution at the worst-case receptor location.

From the above predicted ground level concentrations, it can be seen that 2013 meteorological data produces the highest predicted concentrations. Therefore, as a worst case assumption, results using 2013 data are reported in the following sections.

The dispersion model assumes pollutants are released continuously during each hour of the year and no adjustment has been made for likely hours of operation.

The short-term impacts are derived from the specific hours of meteorological data producing the highest potential ground level concentrations. It is considered unlikely that operation of the plant will coincide with these 'worst-case' meteorological conditions and actual values are expected to be significantly lower than that predicted by this assessment.

5.1 ELV 1

Table 7 details the predicted CO process contributions (PCs) and predicted environmental concentrations (PECs) assuming operation at ELV 1, or $1,000 \text{ mg}/\text{Nm}^3$. The maximum 1-hour and maximum daily running 8-hour mean PCs have been added to twice the annual mean CO background concentration in order to estimate the PECs, as recommended in the EPR Guidance⁷.

The maximum PC to the 1-hour mean EAL is $0.06 \text{ mg}/\text{m}^3$, predicted at receptors 1, 3, 4 and 6, all within 1km of the stack. As a percentage of the 1-hour mean EAL, this PC equates to 0.2%. When combined with background concentrations, the maximum PEC is $0.23 \text{ mg}/\text{m}^3$, predicted at receptor 38, some 8.6km from the stack. This represents a maximum of 0.8% of the 1-hour mean EAL. The impact of CO emissions at ELV 1 from the Aberthaw Cement works Kiln stack in respect of the 1-hour mean EAL are therefore considered not significant.

The maximum PC to the 8-hour rolling mean AQS objective is $0.05 \text{ mg}/\text{m}^3$, predicted at receptors 3 and 4, within 600m of the stack. As a percentage of the 8-hour rolling mean AQS objective, this PC equates to 0.5%. When combined with background concentrations, the maximum PEC is $0.21 \text{ mg}/\text{m}^3$, predicted at receptors 3, 4, 34, 38 and 42 at varying distances from the stack. This represents a maximum of 2.1% of the 8-hour rolling mean AQS objective. The impact of CO emissions at ELV 1 from the Aberthaw Cement works Kiln stack in respect of the 8-hour rolling mean AQS objective are therefore considered not significant.

1-hour and 8-hour running mean CO concentrations isopleths, modelled on a $2 \text{ km} \times 2 \text{ km}$ grid for ELV 1, are presented in Appendix 1.

Table 7 - Predicted CO impacts under ELV 1

Receptor Name	Distance to Main Stack (m)	Direction	Maximum CO 1-hr Mean				Maximum CO 8-hr Rolling Mean			
			PC	PC % of EAL	PEC	PEC % of EAL	PC	PC % of AQO	PEC	PEC % of AQO
1	377	NNE	0.06	0.2%	0.22	0.7%	0.02	0.2%	0.18	1.8%
2	385	NNE	0.05	0.2%	0.22	0.7%	0.03	0.3%	0.19	1.9%
3	497	WSW	0.06	0.2%	0.22	0.7%	0.05	0.5%	0.21	2.1%
4	599	WSW	0.06	0.2%	0.22	0.7%	0.05	0.5%	0.21	2.1%
5	702	SSE	0.05	0.2%	0.21	0.7%	0.02	0.2%	0.18	1.8%
6	767	WSW	0.06	0.2%	0.21	0.7%	0.04	0.4%	0.20	2.0%
7	1012	NNE	0.05	0.2%	0.21	0.7%	0.03	0.3%	0.20	2.0%
8	1024	SSE	0.05	0.2%	0.21	0.7%	0.02	0.2%	0.18	1.8%
9	1139	NNW	0.04	0.1%	0.20	0.7%	0.02	0.2%	0.18	1.8%
10	1188	WNW	0.04	0.1%	0.20	0.7%	0.03	0.3%	0.19	1.9%
11	1231	WSW	0.04	0.1%	0.20	0.7%	0.04	0.4%	0.20	2.0%
12	1596	ESE	0.03	0.1%	0.19	0.6%	0.02	0.2%	0.18	1.8%
13	1740	ENE	0.03	0.1%	0.19	0.6%	0.02	0.2%	0.19	1.9%
14	1887	ESE	0.03	0.1%	0.19	0.6%	0.02	0.2%	0.18	1.8%
15	2022	NNW	0.04	0.1%	0.21	0.7%	0.01	0.1%	0.18	1.8%
16	2204	WNW	0.03	0.1%	0.19	0.6%	0.02	0.2%	0.18	1.8%
17	2380	ESE	0.03	0.1%	0.20	0.7%	0.01	0.1%	0.18	1.8%
18	2645	ENE	0.04	0.1%	0.21	0.7%	0.01	0.1%	0.18	1.8%
19	2889	NNE	0.03	0.1%	0.20	0.7%	0.01	0.1%	0.18	1.8%
20	3226	NNE	0.04	0.1%	0.20	0.7%	0.01	0.1%	0.18	1.8%
21	4130	ESE	0.02	0.1%	0.19	0.6%	0.01	0.1%	0.18	1.8%
22	4544	WNW	0.02	0.1%	0.18	0.6%	0.01	0.1%	0.17	1.7%
23	4683	ESE	0.02	0.1%	0.19	0.6%	0.01	0.1%	0.18	1.8%
24	4835	ENE	0.02	0.1%	0.20	0.7%	0.01	0.1%	0.18	1.8%
25	4933	NNW	0.02	0.1%	0.18	0.6%	0.01	0.1%	0.17	1.7%
26	5053	NNE	0.02	0.1%	0.19	0.6%	0.01	0.1%	0.18	1.8%
27	6047	ESE	0.02	0.1%	0.20	0.7%	<0.01	<0.1%	0.19	1.9%
28	6449	NNW	0.01	<0.1%	0.18	0.6%	<0.01	<0.1%	0.17	1.7%
29	6899	WNW	0.02	0.1%	0.18	0.6%	<0.01	<0.1%	0.16	1.6%
30	7099	ENE	0.01	<0.1%	0.21	0.7%	0.01	0.1%	0.20	2.0%
31	7196	NNW	0.01	<0.1%	0.18	0.6%	<0.01	<0.1%	0.18	1.8%
32	7280	ESE	0.01	<0.1%	0.20	0.7%	<0.01	<0.1%	0.19	1.9%
33	7353	NNE	0.01	<0.1%	0.20	0.7%	<0.01	<0.1%	0.19	1.9%
34	7705	ENE	0.01	<0.1%	0.22	0.7%	<0.01	<0.1%	0.21	2.1%
35	7843	NNW	0.01	<0.1%	0.19	0.6%	<0.01	<0.1%	0.19	1.9%
36	7886	NNE	0.02	0.1%	0.20	0.7%	<0.01	<0.1%	0.19	1.9%
37	8612	NNW	0.02	0.1%	0.20	0.7%	0.01	0.1%	0.19	1.9%
38	8676	NNE	0.02	0.1%	0.23	0.8%	<0.01	<0.1%	0.21	2.1%
39	8926	WNW	0.01	<0.1%	0.17	0.6%	<0.01	<0.1%	0.16	1.6%
40	9115	WNW	0.01	<0.1%	0.15	0.5%	<0.01	<0.1%	0.15	1.5%
41	9556	WNW	0.01	<0.1%	0.18	0.6%	<0.01	<0.1%	0.17	1.7%
42	10180	ENE	0.01	<0.1%	0.22	0.7%	<0.01	<0.1%	0.21	2.1%
AQS Objective			30				10			

5.2 ELV 2

Table 8 details the predicted CO process contributions (PCs) and predicted environmental concentrations (PECs) assuming operation at ELV 2, or 1,500 mg/Nm³. The maximum 1-hour and maximum daily running 8-hour mean PCs have been added to twice the annual mean CO background concentration in order to estimate the PECs, as recommended in the EPR H1 Guidance⁷.

The maximum PC to the 1-hour mean EAL is 0.09mg/m³, predicted at receptors 3 and 4, within 600m of the stack. As a percentage of the 1-hour mean EAL, this PC equates to 0.3%. When combined with background concentrations, the maximum PEC is 0.25 mg/m³, predicted at receptors 1, 3 and 4, within 600m of the stack. This represents a maximum of 0.8% of the 1-hour mean EAL. The impact of CO emissions at ELV 2 from the Aberthaw Cement works Kiln stack in respect of the 1-hour mean EAL are therefore considered not significant.

The maximum PC to the 8-hour rolling mean AQS objective is 0.07mg/m³, predicted at receptors 3, 4 and 6, within 800m of the stack. As a percentage of the 8-hour rolling mean AQS objective, this PC equates to 0.7%. When combined with background concentrations, the maximum PEC is 0.23 mg/m³, predicted at receptors 3 and 4, within 600m of the stack. This represents a maximum of 2.3% of the 8-hour rolling mean AQS objective. The impact of CO emissions at ELV 2 from the Aberthaw Cement works Kiln stack in respect of the 8-hour rolling mean AQS objective are therefore considered not significant.

1-hour and 8-hour running mean CO concentrations isopleths, modelled on a 2km x 2km grid for ELV 2, are presented in Appendix 1.

Table 8 - Predicted CO impacts under ELV 2

Receptor Name	Distance to Main Stack (m)	Direction	Maximum CO 1-hr Mean				Maximum CO 8-hr Rolling Mean			
			PC	PC % of EAL	PEC	PEC % of EAL	PC	PC % of AQO	PEC	PEC % of AQO
1	377	NNE	0.08	0.3%	0.25	0.8%	0.03	0.3%	0.20	2.0%
2	385	NNE	0.08	0.3%	0.24	0.8%	0.04	0.4%	0.20	2.0%
3	497	WSW	0.09	0.3%	0.25	0.8%	0.07	0.7%	0.23	2.3%
4	599	WSW	0.09	0.3%	0.25	0.8%	0.07	0.7%	0.23	2.3%
5	702	SSE	0.07	0.2%	0.23	0.8%	0.03	0.3%	0.19	1.9%
6	767	WSW	0.08	0.3%	0.24	0.8%	0.07	0.7%	0.22	2.2%
7	1012	NNE	0.07	0.2%	0.24	0.8%	0.04	0.4%	0.21	2.1%
8	1024	SSE	0.07	0.2%	0.23	0.8%	0.03	0.3%	0.19	1.9%
9	1139	NNW	0.06	0.2%	0.22	0.7%	0.03	0.3%	0.19	1.9%
10	1188	WNW	0.05	0.2%	0.21	0.7%	0.04	0.4%	0.20	2.0%
11	1231	WSW	0.06	0.2%	0.22	0.7%	0.05	0.5%	0.21	2.1%
12	1596	ESE	0.04	0.1%	0.20	0.7%	0.03	0.3%	0.19	1.9%
13	1740	ENE	0.04	0.1%	0.21	0.7%	0.03	0.3%	0.20	2.0%
14	1887	ESE	0.04	0.1%	0.21	0.7%	0.02	0.2%	0.18	1.8%
15	2022	NNW	0.07	0.2%	0.23	0.8%	0.02	0.2%	0.19	1.9%
16	2204	WNW	0.05	0.2%	0.21	0.7%	0.02	0.2%	0.19	1.9%
17	2380	ESE	0.05	0.2%	0.21	0.7%	0.02	0.2%	0.18	1.8%
18	2645	ENE	0.06	0.2%	0.23	0.8%	0.02	0.2%	0.19	1.9%
19	2889	NNE	0.04	0.1%	0.21	0.7%	0.02	0.2%	0.18	1.8%
20	3226	NNE	0.05	0.2%	0.22	0.7%	0.01	0.1%	0.18	1.8%
21	4130	ESE	0.03	0.1%	0.20	0.7%	0.01	0.1%	0.18	1.8%
22	4544	WNW	0.03	0.1%	0.19	0.6%	0.01	0.1%	0.17	1.7%
23	4683	ESE	0.03	0.1%	0.20	0.7%	0.01	0.1%	0.18	1.8%
24	4835	ENE	0.03	0.1%	0.21	0.7%	0.01	0.1%	0.19	1.9%
25	4933	NNW	0.03	0.1%	0.19	0.6%	0.01	0.1%	0.17	1.7%
26	5053	NNE	0.03	0.1%	0.21	0.7%	0.01	0.1%	0.18	1.8%
27	6047	ESE	0.02	0.1%	0.21	0.7%	0.01	0.1%	0.19	1.9%
28	6449	NNW	0.02	0.1%	0.19	0.6%	0.01	0.1%	0.18	1.8%
29	6899	WNW	0.03	0.1%	0.18	0.6%	0.01	0.1%	0.16	1.6%
30	7099	ENE	0.02	0.1%	0.22	0.7%	0.01	0.1%	0.20	2.0%
31	7196	NNW	0.02	0.1%	0.19	0.6%	<0.01	<0.1%	0.18	1.8%
32	7280	ESE	0.02	0.1%	0.21	0.7%	0.01	0.1%	0.19	1.9%
33	7353	NNE	0.02	0.1%	0.20	0.7%	<0.01	<0.1%	0.19	1.9%
34	7705	ENE	0.02	0.1%	0.22	0.7%	0.01	0.1%	0.21	2.1%
35	7843	NNW	0.02	0.1%	0.20	0.7%	0.01	0.1%	0.19	1.9%
36	7886	NNE	0.03	0.1%	0.21	0.7%	0.01	0.1%	0.19	1.9%
37	8612	NNW	0.03	0.1%	0.22	0.7%	0.01	0.1%	0.19	1.9%
38	8676	NNE	0.03	0.1%	0.24	0.8%	0.01	0.1%	0.22	2.2%
39	8926	WNW	0.01	<0.1%	0.17	0.6%	<0.01	<0.1%	0.16	1.6%
40	9115	WNW	0.01	<0.1%	0.16	0.5%	<0.01	<0.1%	0.15	1.5%
41	9556	WNW	0.01	<0.1%	0.18	0.6%	<0.01	<0.1%	0.17	1.7%
42	10180	ENE	0.01	<0.1%	0.22	0.7%	<0.01	<0.1%	0.21	2.1%
AQS Objective			30				10			

6 Conclusions

Bureau Veritas has been appointed by Tarmac UK to undertake detailed atmospheric dispersion modelling of carbon monoxide (CO) emissions from the Aberthaw cement works in South Wales.

This report focuses on emissions of CO from the kiln stack at the Aberthaw cement works site and their impacts in relation to human health, assessed against the relevant ambient air quality objectives.

This dispersion modelling undertaken as part of this assessment largely follows the same model set up and methodology as the modelling undertaken by Bureau Veritas for the Aberthaw site in 2011¹, with any differences detailed in this report. This report should therefore be considered an addendum, and read in conjunction with, the previous report entitled "*LCUK Air Dispersion Modelling – Aberthaw Works (Final)*"¹.

The modelling considered local weather conditions, topography and site buildings, as well as existing background concentrations.

Predictions have been undertaken at series of specific receptors (residential properties) within 10km from the site boundaries to estimate the impact of pollutant concentrations on human health and compare against the relevant Air Quality Strategy objectives and Environment Assessment Levels (EALs).

Predictions on a grid of receptors have also been used to map ground level concentration isopleths (contour lines) within 1km of the site boundaries.

Dispersion modelling of CO emissions has been undertaken at the following ELVs:

- 1,000 mg/Nm³ (ELV 1); and
- 1,500 mg/Nm³ (ELV 2).

For ELV 1, maximum predicted CO PECs are well below both the 1-hour mean EAL, at a maximum of 0.8% of the objective, and for the maximum daily running 8-hour mean AQS objective, at a maximum of 2.1% of the objective.

For ELV 2, maximum predicted CO PECs are well below both the 1-hour mean EAL, at a maximum of 0.8% of the objective, and for the maximum daily running 8-hour mean AQS objective, at a maximum of 2.3% of the objective.

Following the significance criteria specified in Environment Agency (EA) Environmental Permitting Regulations (EPR) Guidance⁷ all impacts of CO emissions from the Aberthaw Cement works kiln stack for ELV 1 and 2 are therefore considered to be not significant.

APPENDICES

Appendix 1 – Modelled CO Concentration Isopleths

Figure A1. 1 - 1-hour mean CO concentration (mg/m^3) isopleth at ELV 1

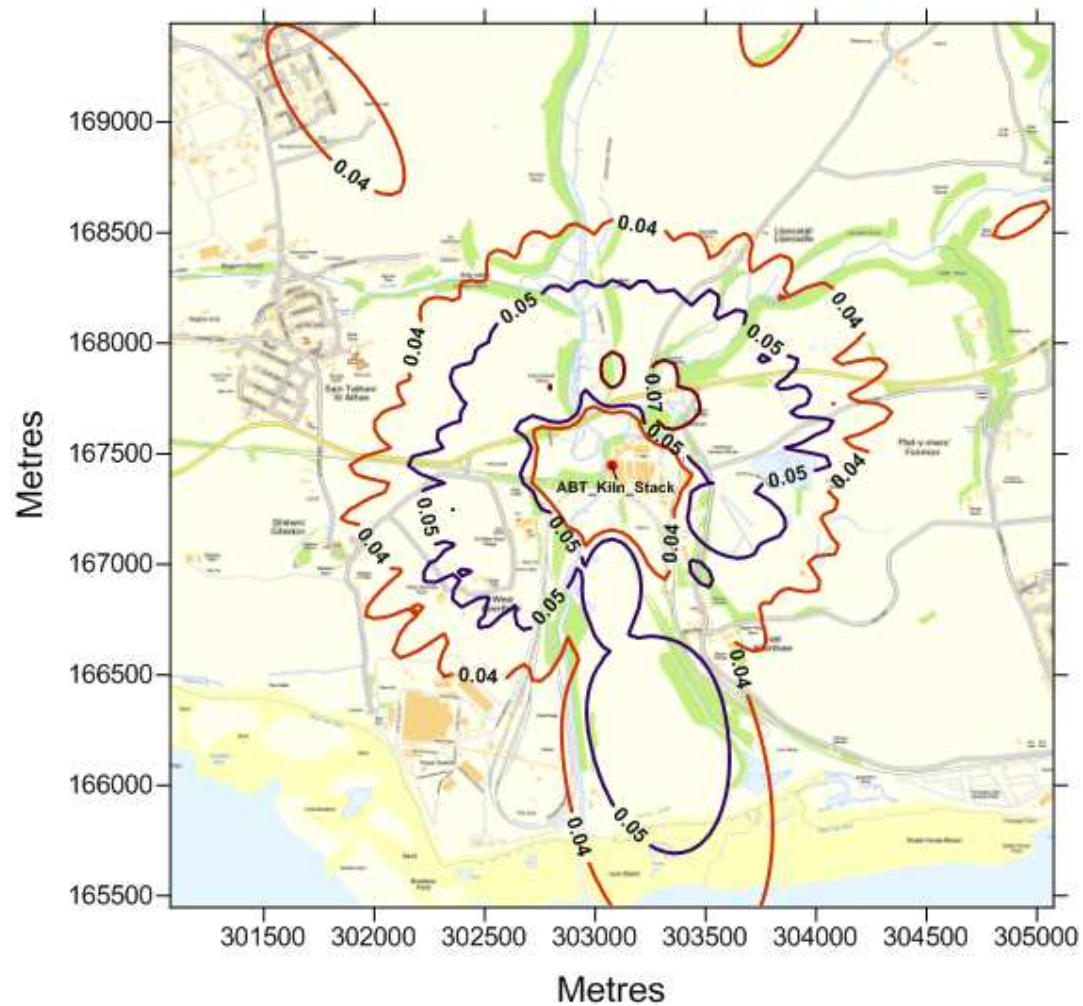


Figure A1. 2 - 8-hour running mean CO concentration (mg/m^3) isopleth at ELV 1

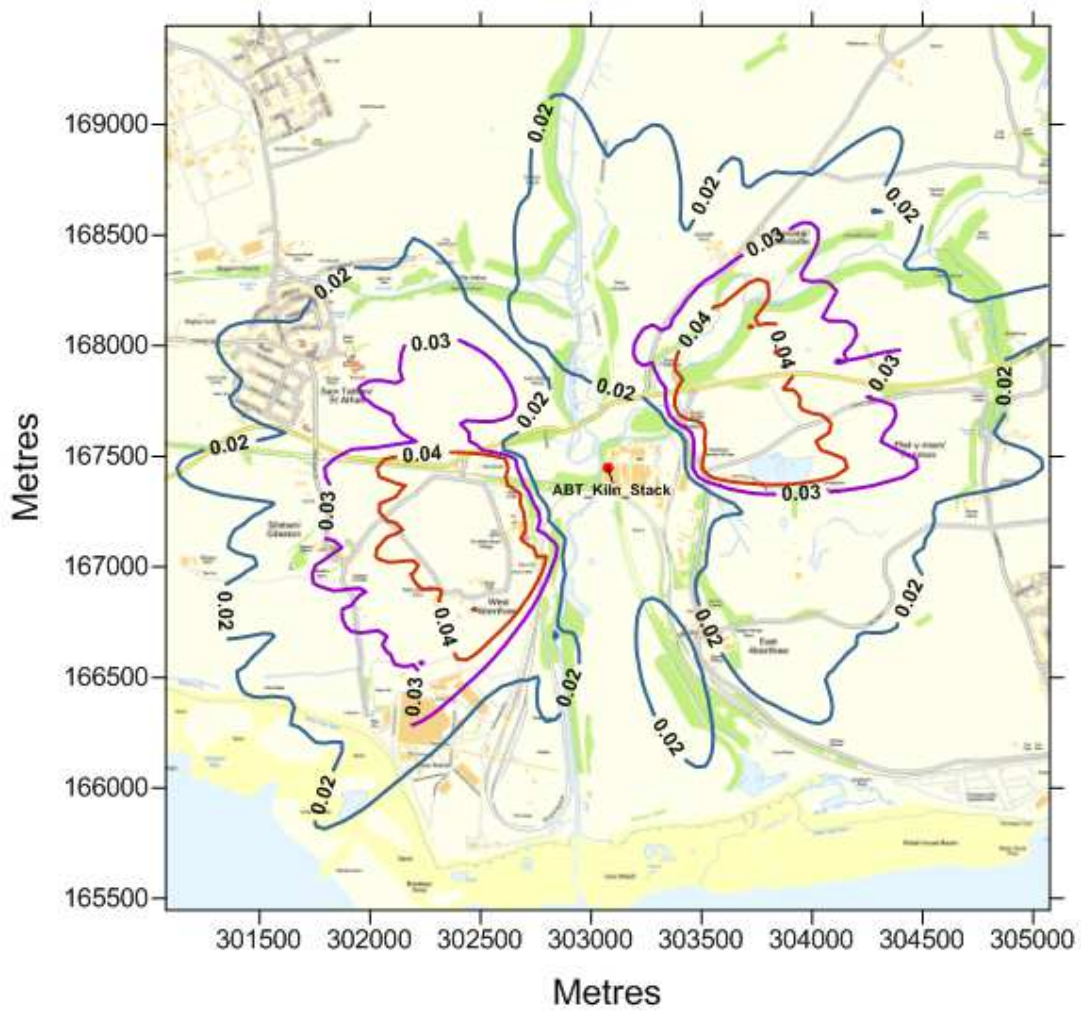


Figure A1. 3 - 1-hour mean CO concentration (mg/m^3) isopleth at ELV 2

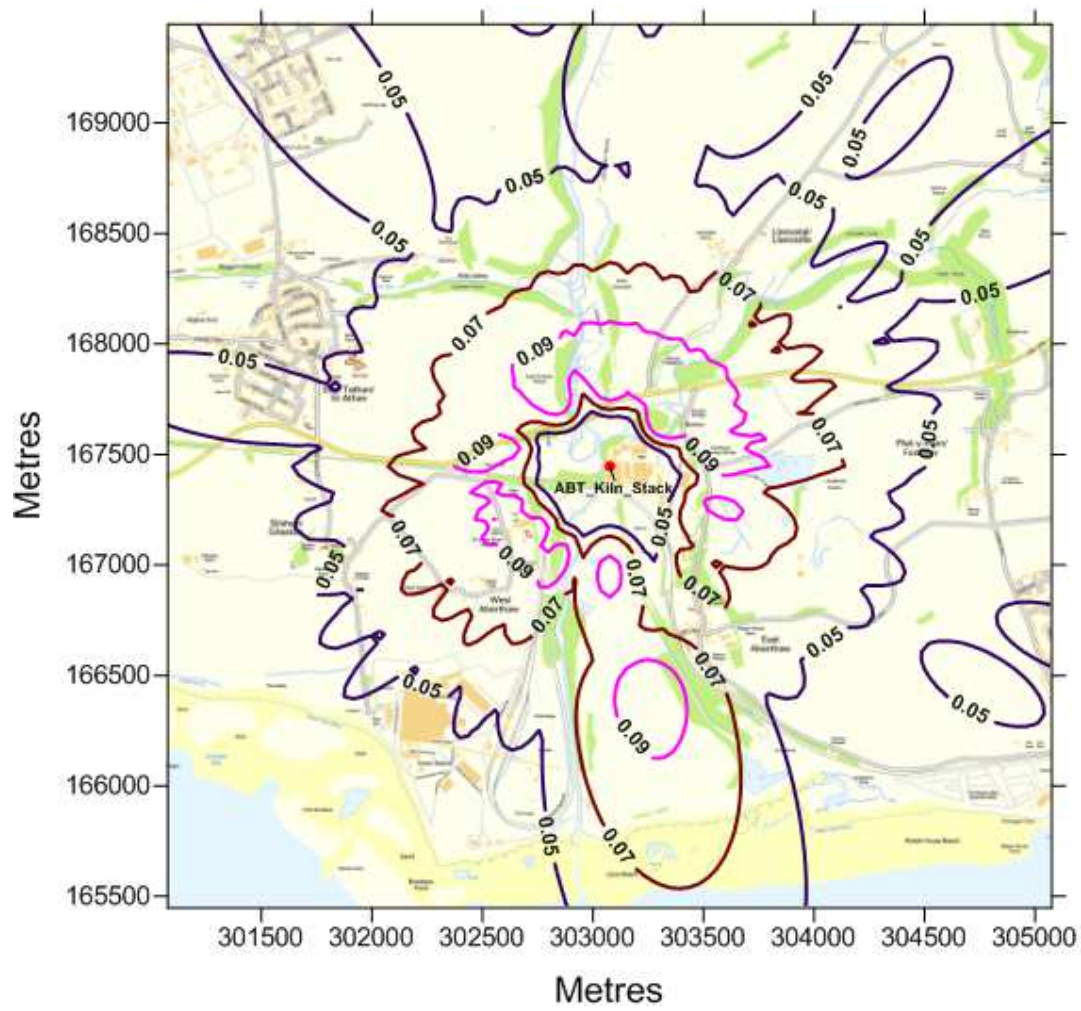
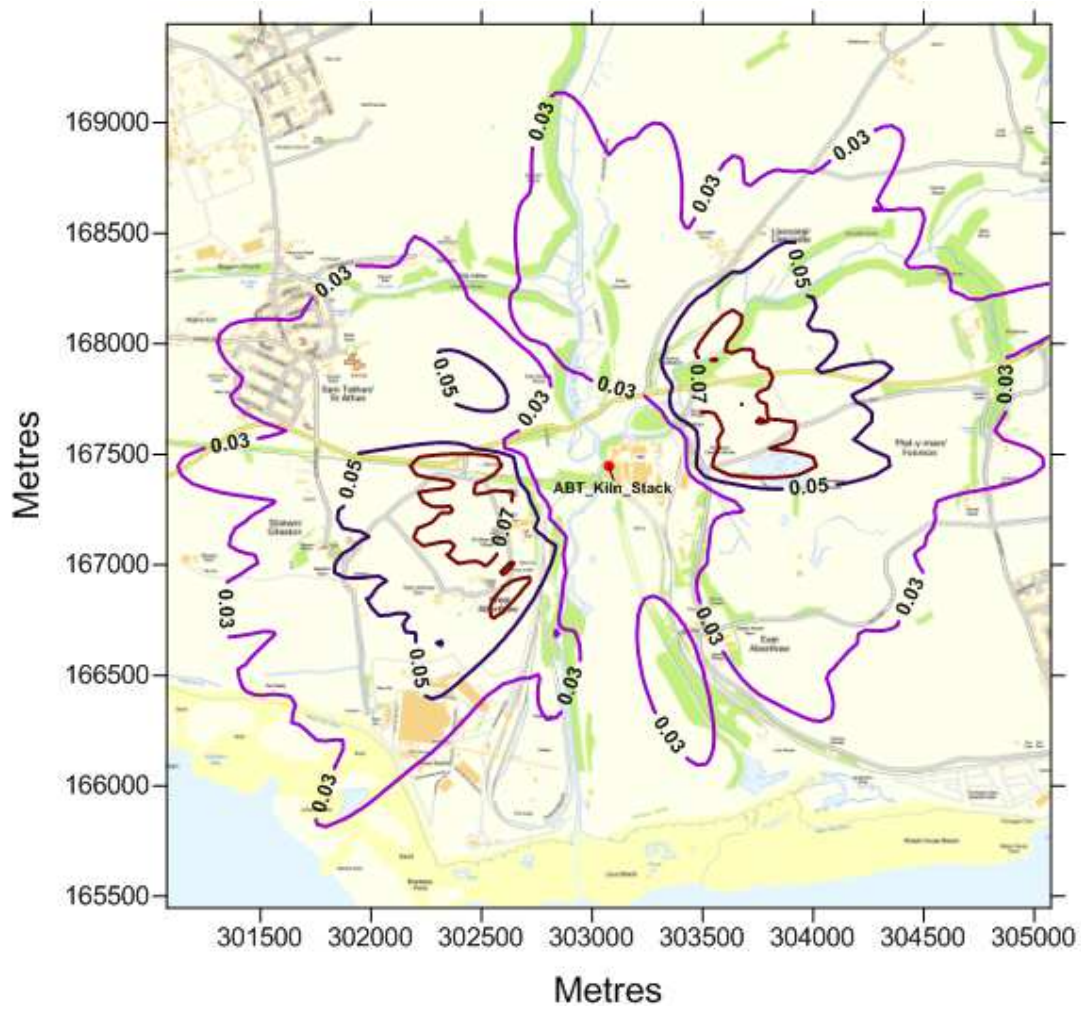


Figure A1. 4 - 8-hour running mean CO concentration (mg/m^3) isopleth at ELV 2



Appendix 2 – Background CO concentrations used in Assessment

Table A2. 1 - Background CO (mg/m³) concentrations used in Assessment

X, Y	2001-Based Annual Mean CO Concentration (mg/m ³)	Adjustment to 2013 (x 0.439)	Short Term Adjustment (x 2)
293500, 168500	0.16	0.07	0.14
295500, 172500	0.18	0.08	0.16
296500, 169500	0.18	0.08	0.16
296500, 174500	0.19	0.08	0.17
298500, 168500	0.19	0.08	0.16
299500, 172500	0.19	0.08	0.17
299500, 173500	0.20	0.09	0.17
300500, 168500	0.19	0.08	0.16
300500, 171500	0.19	0.08	0.16
301500, 167500	0.18	0.08	0.16
301500, 169500	0.19	0.08	0.17
301500, 175500	0.21	0.09	0.18
302500, 166500	0.18	0.08	0.16
302500, 167500	0.18	0.08	0.16
302500, 168500	0.19	0.08	0.17
302500, 176500	0.21	0.09	0.18
303500, 166500	0.18	0.08	0.16
303500, 167500	0.19	0.08	0.16
303500, 168500	0.19	0.08	0.17
303500, 172500	0.20	0.09	0.17
303500, 175500	0.21	0.09	0.19
304500, 166500	0.18	0.08	0.16
304500, 167500	0.19	0.08	0.16
304500, 169500	0.19	0.08	0.17
304500, 170500	0.19	0.08	0.17
305500, 166500	0.19	0.08	0.16
305500, 168500	0.19	0.09	0.17
306500, 173500	0.21	0.09	0.19
307500, 166500	0.20	0.09	0.17
307500, 169500	0.20	0.09	0.18
308500, 174500	0.24	0.10	0.21
309500, 166500*	0.21	0.09	0.19
309500, 169500	0.22	0.10	0.20
309500, 171500	0.23	0.10	0.20
310500, 166500	0.21	0.09	0.19
313500, 168500	0.24	0.10	0.21
* Background Value not available, so figure for adjacent grid square 310500, 166500 used			