Dŵr Cymru
Welsh Water

Afan WwTW Advanced Digestion

CHP Air Quality Modelling

October 2009

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1 Introduction

Afan WwTW serves a total population equivalent (PE) of just under 150,000. Wastewater flows are received and treated from Margam, Port Talbot and the surrounding district. A major upgrade is planned for the works:

- Replacement of an existing sludge treatment centre (sludge is currently treated by a thermal drying process) with an advanced digestion (AD) process.

Advanced Digestion (AD) is a treatment process which produces an enhanced treated sludge and recovers large amounts of gas which will be converted to electrical energy in CHP (Combined Heat and Power) plants

This study assesses the air quality impact from the combustion of the gas produced by the enhanced digestion process. Gas will be variously combusted within two CHP (combined heat and power units). The heat produced by the CHP units will be used in the advanced digestion process, with additional heat provided by natural gas combustion in two composite boilers. The modelling has been used to predict:

- Concentrations of carbon monoxide, sulphur dioxide and nitrogen dioxide at the nearest receptors to the site.
- Compare the above results against relevant Air Quality Standards.

The dispersion modelling has been undertaken using the US EPA Aermod package. The results of this study are reported below. The modelling has considered two scenarios:

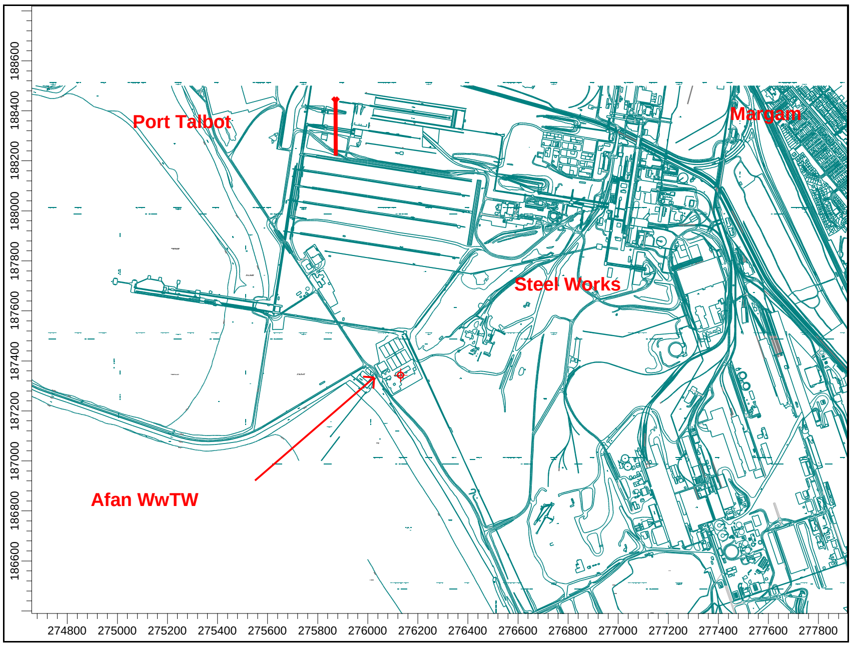
- Both CHP units (combusting biogas) and one boiler (combusting natural gas) operating at 100% output.
- Two boilers (combusting natural gas) at 100% output.

In practice both the above, extreme, scenarios are unlikely to occur but represent the worse possible cases with respect to emissions.

1.1 Afan WwTW

Afan WwTW is located at Grid Reference SS276132, 187342 on the east edge of Swansea Bay, within the Port Talbot Steel Works Complex. The outskirts of Margam are between 1700 to 1800m to the east of the WwTW boundary and Port Talbot approximately 2km to the north.

The new advanced digestion process will be built within the existing WwTW site. The location is shown below as Figure 1. The area shown below is all included within the modelled domain.



1.2 Pollutants and Air Quality Guidelines

The pollutants listed below have been considered within this assessment:

- Nitrogen Dioxide
- Sulphur Dioxide
- Carbon Monoxide

The modelled results for these pollutants have been compared against the Air Quality Standards published by the UK Environment Agency Air Quality Modelling and Assessment Unit (2007):

Nitrogen Dioxide:

Hourly mean 200ug/m^3 (max exceedences 18 per Year)
Annual Mean 40ug/m^3

Sulphur Dioxide:

Hourly mean 350ug/m^3 (max exceedences 24 per Year)
24-hour Mean 125ug/m^3 (max exceedences 3 per Year)

Carbon Monoxide:

Running 8-Hourly mean 10mg/m^3

PM_{10}

24-hour Mean 50ug/m^3 (max exceedences 7 per Year)
Annual Mean 40ug/m^3

1.3 Ambient/Background Levels

Neath Port Talbot Council currently have in place an Air Quality Management Area (AQMA) for the Taibach, Margam Area for particulate PM_{10}. The area included with the AQMA is bordered by the M4 to the east and the main railway line to the west. The area extends to the southern edge of Part Talbot and as far south to the area of Junction 39 on the M4. The associated Action Plan area includes the above AQMA but extends further west to include the steel works complex. There is also concern regarding Nitrogen Dioxide NO_2 along Water Street Port Talbot (B4286 linking the A48 to the A4241) where historically NO_2 concentrations have been very close to air quality standard limits.

Data from a detailed assessment of NO_2 undertaken by Neath Port Talbot Council and published in April 2007 reported mean annual NO_2 levels of 17.2ug/m^3 (24.2ug/m^3) at Rice Street, Port Talbot and 18.1ug/m^3 (14.9ug/m^3) at College Green, Margam. Figures in brackets represent prediction values for 2010. The Council also operates a NO_2 continuous monitoring station at Groeswen Hospital, Margam: mean annual results of 18ug/m^3 were reported for this station for early 2008.

The 2006 Air Quality Report, published by Neath Port Talbot Council, indicates that the highest hourly SO_2 level was 122ug/m^3 and that the highest daily average 37ug/m^3 for the Borough. The highest eight hourly mean CO concentration was 3.6mg/m^3 (3600ug/$m^{3)}$. None of these values breach air quality standards.

The average for hourly measurements for PM_{10} for the Port Talbot Area (PT4) for 2008 is 28.7ug/m^3.

1.4 Modelling Set Up and Protocol

Aermod (as supplied by Lakes Environmental) an updated derivative of ISCST 3 (industrial source complex short term) model has been employed. This model is widely used and is adopted by the US EPA, as the principal model for air dispersion modelling, and is widely employed within the UK: its use is also accepted by the UK Environment Agency.

From review of a site layout drawing and data collected during from the site a source file for the site was constructed, this in simple terms tells the model the geographical location and dimensions of all the sources that need to be considered. The source file also contains pollutant emission rates for each source; these are discussed in more detail below.

1.5 Stack Configuration & Emission Parameters

The proposals have been reviewed for potential emissions to air. The only identified significant emissions are two CHP (combined heat and power units) and two boilers that will combust the biogas generated by the enhanced digestion process to generate electricity and heat. Each CHP and boiler will have separate stacks. The location of the stacks is shown in Figure 2 below.

Figure 2: Discharge Stack Location

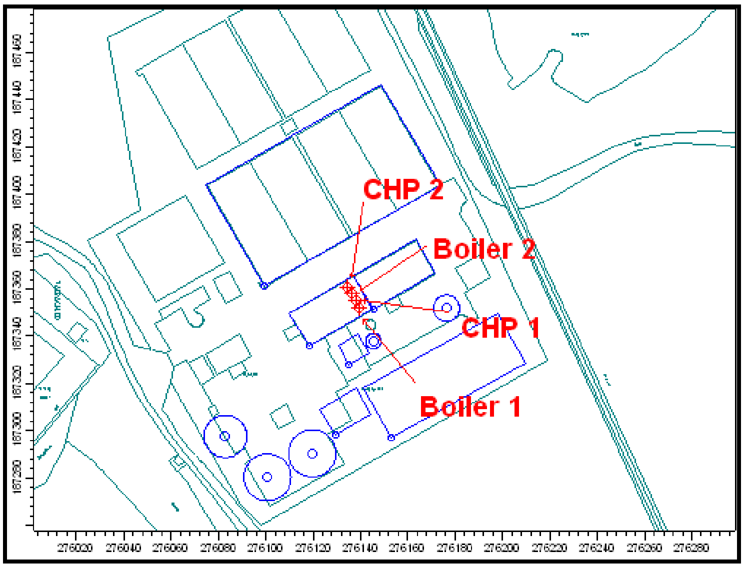
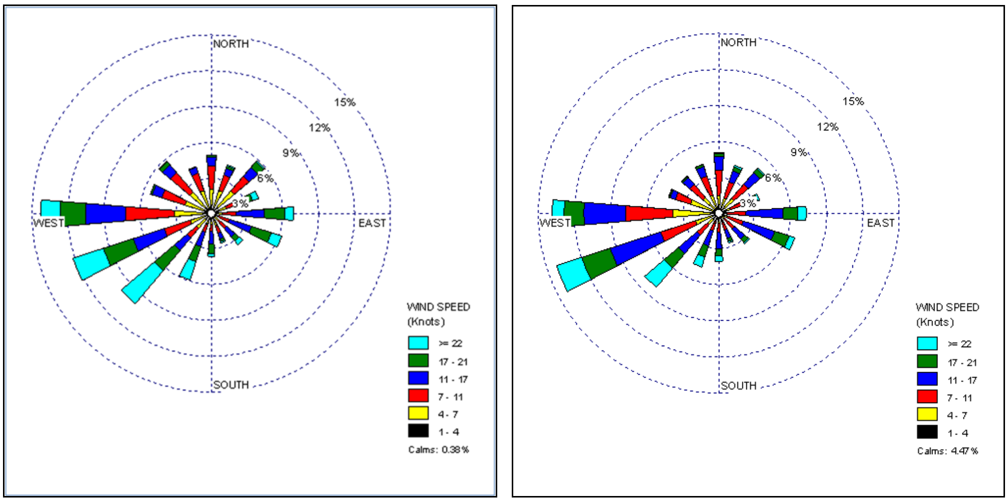


Figure 2 shows the discharge stacks to be located through the roof of the existing sludge dryer building (that will be reutilised within the advanced digestion scheme). Each stack will discharge at a height of 24.5m, the CHP Flues will be 400mm diameter and the boiler flues will be of 550mm diameter. The drier building is 19.5m tall at the highest point.

1.6 Meteorological Data

The model requires hourly averaged values for wind speed, wind direction and height of the mixing layer. Two sets of meteorological data, held by DCWW, for the years 2004 to 2006 and 1994 to 1995 recorded at the Mumbles Met Station have been employed. Data from The Mumbles, approximately 8 kilometres to the south west, across Swansea Bay, was selected following informal advice from Trinity Consultants. The wind rose for The Mumbles for the years to 2004 to 2006 and 1994 to 1995 are shown below. This indicates that the predominant winds are from the west and south west and that the wind roses for the two sets of data are in fact very similar.

Figure 3: Mumbles Wind Rose 2003 to 2004 & 1993 to 1995



The met data has been formatted using annual averages as follows (these values have been calculated based upon an assessment of surrounding land use):

For all wind directions Albedo 0.19
For all wind directions Bowen 0.88
Roughness Length:

Sector	Roughness Length
150 to 330°	0.0001
100 to 150°	0.0725
330 to 100°	1

1.7 Receptors & Treatment of Terrain

The second component is the receptor file; this is a set of graphical coordinates surrounding the site where the model predicts hourly averaged concentrations. Although the site lies on the coastal edge of a flat plain, the file generated for Afan includes digital terrain data to account for the raised terrain (hills) east of the site. The model has been adjusted to take account of tanks and structures surrounding the discharge stacks (see below). A 10km square receptor grid, centred upon the site, has been entered into the model. This is to ensure that the model includes for the possibility that plumes for the stacks may ground on the high terrain east of the site.

1.8 Building Downwash

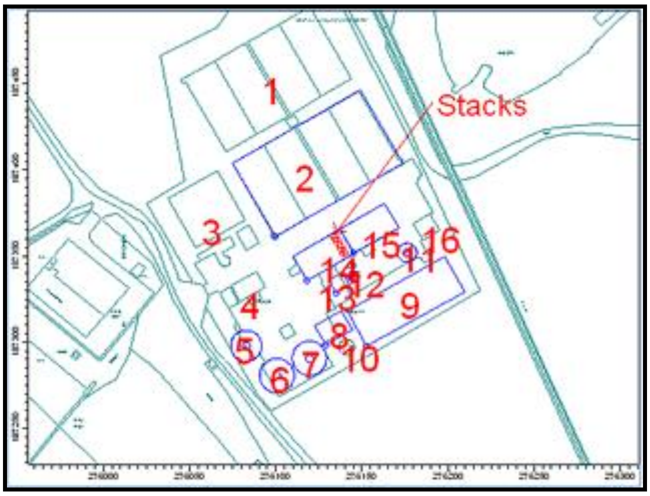
Building downwash is the result of airflow over large obstacles, such as buildings, that are close to a point of emission. The plume from the source enters the wake zone created by the airflow around the building. The wake zone, sometimes called the "cavity", is a zone on the leeward side of a building that is isolated from the main air stream. Within this zone air recirculates and the exhaust emitted from the stack becomes "trapped". Therefore both the trajectory and the turbulence of a plume that would normally be expected to disperse emissions are likely to be restricted. Pollutant concentrations immediately downwind of the plume will be greater than without the presence of the building. With increasing distance from the release point it becomes more difficult to predict the impact of buildings at given locations.

Downwash effects for Afan have been included; in general terms buildings impact upon dispersion when a stack is located with five building lengths downwind and two building lengths upstream of the structure in question. To escape downwash effects from a particular building the US EPA suggests that the stack height should be at least 2.5 times the height of the building creating the downwash effect.

The BPIP utility within Aermod has been employed to generate a downwash file for inclusion in the Afan Model. This file has considered the existing/proposed structures listed below (these are indicated within Figure 4):

Number on Fig 4	Structure Name	Projected Building	Height	5L	Distance to nearest	Considered in
		Width (m)	(m)	(m)	Stack (m)	Downwash Model
1	SBR North	80	4	20	80	No
2	SBR South	80	4	20	18	Yes
3	Storm Tank	33	3	15	53	No
4	Admin Building	11.5	5	25	45	No
5	Gas Holder	18	16	80	70	Yes
6	Digester 1	20	23	100	75	Yes
7	Digester 2	20	23	100	54	Yes
8	Cambi Plant	20	8.5	42.5	34	Yes
9	Sludge dewatering Building	63	17m/10m	77.5	26	Yes
10	Digested Sludge Tank	9	10.5	45	51	No
11	Liquor Balancing Tank	11	11	55	31	Yes
12	Cake Silo	6.5	16	32.5	11	Yes
13	Cake Reception	13	7	35	11	Yes
14	Existing Drier Building	15.7	19.5	78.5	0	Yes
15	Existing Dewatering Building	15.7	15.5	78.5	4	Yes
16	SAS Tank	10	4	20	50	No

Figure 4: Structures considered for downwash calculations



1.9 Sensitivity Analysis

The model has been run using data from the met recording station at Mumbles approximately 8 kilometres to the south west. The Mumbles Station is the nearest station and an exposed coastal site as per to the study site. The nearest alternative met stations are airfields at St Athan and Rhoose (Cardiff Airport), over 40 kilometres to the south east. Both sites are significantly further away from the site and further inland. Five yearly sets of met data have been individually run within the model and the worse case results (the year of meteorological data that produces the highest ground level concentrations) compared against air quality standards.

Two scenarios have been run within the model:

- Both CHP units (combusting biogas) and one boiler (combusting natural gas) operating at 100% output.
- Two boilers (combusting natural gas) at 100% output.

In practice both the above, extreme, scenarios are unlikely to occur but represent the worse possible cases with respect to emissions. Therefore the results of the model are regarded as conservative.

Sulphur dioxide (SO_2) emission rates have been calculated on the assumption that the hydrogen sulphide (H_2S) concentration of the biogas will 1000ppm, in practice the CHP engines will not operate at a concentration in excess of 500ppm: therefore the input SO_2 emission rates are conservative.

A rural dispersion coefficient has been specified within the model.

2 Dispersion Modelling Results

2.1 Source Emission Rate Estimates

Estimates of pollutant emission for site, using data supplied by the scheme designers, were compiled into a source file. The source file tells the model the geographical location and height, physical dimensions and estimated emission rate for each source. Table 3 contains the stack parameters) and Table 4 the estimates for the two Scenarios.

Table 3: Summary of stack parameters

	NB (mm)	Stack height (m)	Actual flow (Am^3/hr)	Actual flow (Am^3/s)	Efflux m/s	Temperature ^oK
CHP 1	400	24	10870	3.02	24.04	453
CHP 2	400	24	10870	3.02	24.04	453
Boiler 1	550	24	7525	2.09	8.80	503
Boiler 2	550	24	7525	2.09	8.80	503

Table 4: Summary of Pollutant Emissions for each Scenario

Scenario 1: 2 CHP at full fire & 1 Boiler at Full Fire				
	NO_x g/s	SO_2 g/s	CO g/s	PM_{10} g/s
CHP 1	0.64	0.433	1.408	0.061
CHP2	0.64	0.433	1.408	0.061
Boiler 1	0.166	0.156	0.073	0.03
Scenario 2: 2 Boilers at full fire combusting natural gas				
	NO_x g/s	SO_2 g/s	CO g/s	PM_{10} g/s
Boiler 1	0.166	0.156	0.073	0.03
Boiler 2	0.166	0.156	0.073	0.03

3 Results & Interpretation

3.1 Interpretation – General

The results of the modelling are presented in the form of contours; the contours do not necessarily represent an average condition, but indicate the worst-case possible for the area surrounding the site as defined by the meteorological data. The emission rate, height and location of the source, topography of the locality and the met data determine the shape of the contours. The predicted ground level concentrations are above background concentrations and only relate to emission originating from the CHP and Boiler stacks.

3.2 Results – Afan

As Scenario 1 produced much higher results than Scenario 2, contour plots are presented for the met data year that produced the highest ground level concentrations for all pollutants for Scenario 1 only. In accordance with guidance, published by the UK Environment Agency Air Quality Modelling and Assessment Unit (noxno2conv2005_1233043.pdf), it has been assumed that 35% of short-term and 70% of long-term average NO_x emissions are converted to NO_2. These scaling factors have been employed to generate the contour plots and results presented below.

Note: Met Data in a format suitable for atmospheric dispersion modelling is not available in less than mean hourly observations and hence the model cannot predict 15 minute mean values. However the Environment Agency proposes a scaling factor, that can be employed if required, of 1.34 to convert hourly averages to 15 minute averages (Horizontal Guidance Note H1).

3.3 Maximum Ground Level Concentrations

The maximum ground level concentrations are predicted close to the WwTW within rough ground (and an area of no public access) belonging to the Steel Works Complex for all pollutants. Whilst these results are very localised and not representative of any wider impact they are included as they allow comparison of the different scenarios and between met data years. Maximum GLC results for each pollutant and scenario are presented in Tables 5 to 7. These maximum values are typically less than 20% of the respective air quality standards.

Table 5: Maximum Ground Level Concentrations NO_2 Predictions

	Scenario 1		**Scenario 2**	
	Hourly ug/m^3	Annual ug/m^3	Hourly ug/m^3	Annual ug/m^3
1994	34.9	7.68	9.34	1.99
1995	34.5	6.72	9.2	1.75
2004	34.3	8.16	9.4	2.07
2005	33.5	5.72	9.04	1.46
2006	33.9	7.57	9.28	1.92
Limit	**200**	**40**	**200**	**40**

Table 6: Maximum Ground Level Concentrations SO_2 Predictions

	Scenario 1		**Scenario 2**	
	Hourly ug/m^3	24 Hourly ug/m^3	Hourly ug/m^3	24 Hourly ug/m^3
1994	69.4	31.4	24.4	10.5
1995	68.9	33.7	24.1	11.1
2004	69.4	37.5	24.9	12.6
2005	66.9	30.3	23.8	9.7
2006	68.2	29.6	24.04	10.02
Limit	**350**	**125**	**350**	**125**

Table 7: Maximum Ground Level Concentrations CO Predictions

	Scenario 1	**Scenario 2**
	8 Hourly ug/m^3	8 Hourly ug/m^3
1994	145.7	8.29
1995	133.9	7.95
2004	156.5	9.06
2005	149.2	8.51
2006	134.8	7.9
Limit	**10000**	**10000**

Table 8: Maximum Ground Level Concentrations PM_{10} Predictions

	Scenario 1		**Scenario 2**	
	Annual ug/m^3	24 Hourly ug/m^3	Annual ug/m^3	24 Hourly ug/m^3
1994	1.16	4.25	0.51	1.92
1995	1.01	4.47	0.45	2.03
2004	1.23	5.16	0.54	2.18
2005	0.86	3.93	0.38	1.62
2006	1.14	4.11	0.5	1.82
Limit	**40**	**50**	**40**	**150**

3.4 Predictions at Nearest Points of Interest

Review of the contour plots (Section 4) indicate that the highest ground level concentrations are predicted close to the WwTW site boundary or in rough ground within the steel works complex. To illustrate the impact of the scheme upon the wider area, predicted concentrations for three locations have been considered further:

- West edge of Margam and within the AQMA (Princes Street Area, NGR 277687, 188222, approximately 1.8km to the north east)
- Eglwys Nunydd SSSI (NGR 278624, 185291, approximately 3.5km to the south east)
- Kenfig Burrows SSSI (NGR 279446, 183195, approximately 5.5km to the south, south east)

The highest results from Scenario 1 for each location (taken from the met data year giving the highest GLC) are given in Table 9 below. Following the guidance given in TG08, annual mean predictions have been added to annual mean background concentrations. Hourly NO_2 predictions have been added to twice the annual mean background concentrations:

Table 9: Model Pollutant Predictions at Points of Interest

Location	NO_2 Annual	NO_2 Hourly	SO_2 15min	SO_2 Hourly	SO_2 24Hr	CO
	ug/m^3	ug/m^3	ug/m^3	ug/m^3	ug/m^3	ug/m^3
Max GLC	8.16	34.9	93.00	69.4	37.5	156.5
Princes St Margam	0.14	1.97	6.03	4.5	1.01	7.27
Background	14.9	29.8	163.48	122	37	3600
Eglwys Nunydd	0.05	1.6	4.69	3.5	0.51	8.53
Background	20.5	41	163.48	122	37	3600
Kenfig Burrows	0.02	0.83	2.28	1.7	0.3	2.7
Background	10.8	29.8	163.48	122	37	3600
EQS	**40**	**200**	**266**	**350**	**125**	**10000**

Notes Table 9:

- Annual NO_2 prediction added directly to predicted 2010 values (www.airquality.co.uk) for Kenfig and Eglwys Nunydd. For Margam value taken from Neath Port Talbot Council predicted values for 2010 at College Green, Margam

- SO_2 and CO background values taken from highest recorded Neath Port Talbot Council results in 2006
- Margam SO_2 and CO values employed for Eglwys Nunydd & Kenfig
- Hourly NO_2 background values have been added to twice the annual mean concentration
- For Hourly SO_2, daily SO_2 and eight hourly CO (2006 Air Quality Report) the highest recorded values from NPT Council data have been added to the process contribution

The highest 24 hourly PM_{10} result for Princes Street, Margam is 0.05ug/m^3, 0.03ug/m^3 for Eglwys Nunydd and 0.02ug/m^3 for Kenfig Burrows. The highest predicted annual PM_{10} results are 0.02ug/m^3 for Princes Street Margam, 0.01ug/m^3 for Eglwys Nunydd and less than 0.01ug/m^3 for Kenfig Burrows.

3.5 Interpretation of Results

In Table 10 predicted values for each location have been added to background values to produce a total future concentration. Predicted PM_{10} concentrations from the AD Scheme at all three locations are less than 0.15% of the respective EQS.

Table 10: Total Future Pollutant Predictions at Points of Interest

Location	**NO_2 Annual**	**NO_2 Hourly**	**SO_2 15min**	**SO_2 Hourly**	**SO_2 24Hr**	**CO**
	ug/m^3	**ug/m^3**	**ug/m^3**	**ug/m^3**	**ug/m^3**	**ug/ m^3**
EQS	**40**	**200**	**266**	**350**	**125**	**10000**
Princes St Margam	**15**	**32**	**170**	**127**	**38**	**3607**
TC % less than EQS	62	84	36	64	70	64
% PC is of EQS	0.35	1.0	2.3	1.3	0.8	0.1
Eglwys Nunydd	**20.55**	**42.6**	**168.2**	**125.5**	**37.5**	**3609**
TC % less than EQS	49	78.7	36.8	64.1	70.0	63.9
% PC is of EQS	0.125	0.8	1.8	1.0	0.4	0.1
Kenfig Burrows	**10.82**	**30.6**	**165.8**	**123.7**	**37.3**	**3603**
TC % less than EQS	73	84.7	37.7	64.7	70.2	64.0
% PC is of EQS	0.05	0.4	0.9	0.5	0.2	0.0

Notes Table 10:

- TC = Total future predicted concentration
- PC = Process concentration (model prediction)
- EQS = Environmental Quality Standard

In Table 11 the impact of emissions from the site upon the two SSSIs identified above is considered. The methodology from H1 Part 2 to screen out emissions to air that are insignificant when deposited to land has been employed for

PC Ground = (PCair x DV x 3 x 86400) / 1000

(DV = Deposition velocity. Values of 0.0015 and 0.012 have been employed for NO_2 and SO_2 respectively)

Table 11: Evaluation of model predictions upon SSSIs

	PCair NO_2	**PCairSO_2**	
Eglwys Nunydd	0.05	0.03	Annual Average
Kenfig Burrows	0.02	0.01	Annual Average
Deposition Velocity	0.0015	0.012	m/s
PC Ground	**0.0194**	**0.1047**	mg/m2/day
(Eglwys Nunydd)	0.0071	0.0382	kg/ha/yr
Min Critical Load 2010	1.04	0.82	kg/ha/yr
% PC of Min Critical Load	0.68	4.66	
PC Ground	**0.0077**	**0.0419**	mg/m2/day
(Kenfig Burrows)	0.0028	0.0153	kg/ha/yr
Min Critical Load 2010	1.04	0.82	kg/ha/yr
% PC of Min Critical Load	0.27	1.86	

Note: The minimum critical loads for Kenfig for 2010 have been taken from the APIS website. As no values are given by APIS for Eglwys Nunydd, it has been assumed that are the same as for Kenfig.

3.6 Discussion of Results

When the predicted results at Princes Street (the western edge of Margam and the AQMA, and the nearest residential area/ area if general public access to the WwTW) are reviewed against air quality standards (Tables 8 to 10): the results for all pollutants (NO_2, SO_2, PM_{10} and CO) are less than 2.5% of the respective National Air Quality Standards. In fact as the remainder of the AQMA and surrounding residential areas are further downwind from the WwTW, predicted ground level concentrations resulting from the CHP units associated with the advanced digestion process will be even less.

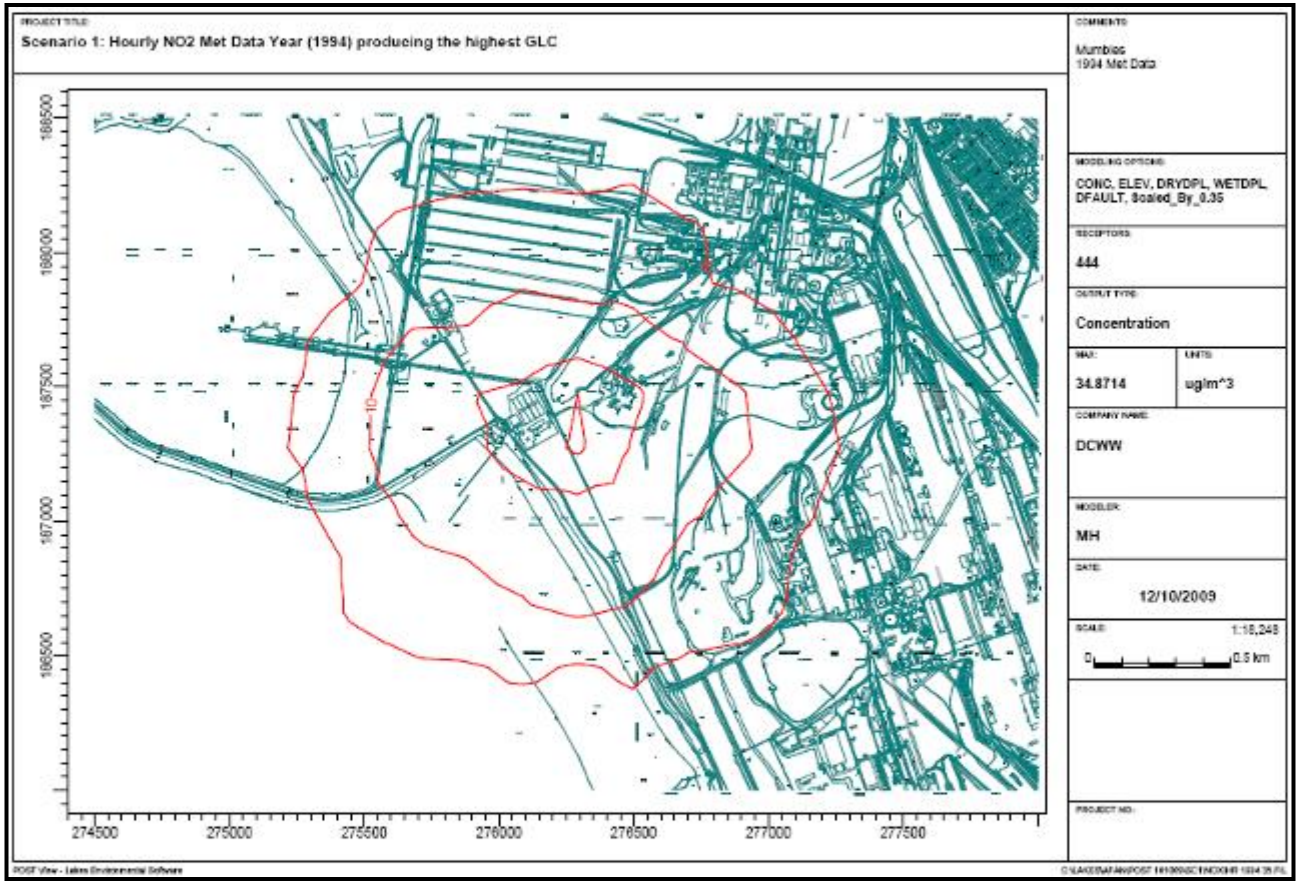
Although the majority of NO_2 recorded within the existing AQMA is attributed to traffic congestion or industrial activity, it seems likely that some of the estimated NO_2 background concentrations within the areas surrounding the works may well be attributable to existing combustion sources within the WwTW. That is, the existing gas fired combustion process contained within the sludge drying process. Therefore at least a small quantity of the existing background concentrations of NO_2, SO_2 PM_{10} and CO will include a contribution from the combustion process at the site that will be replaced by the advanced digestion scheme.

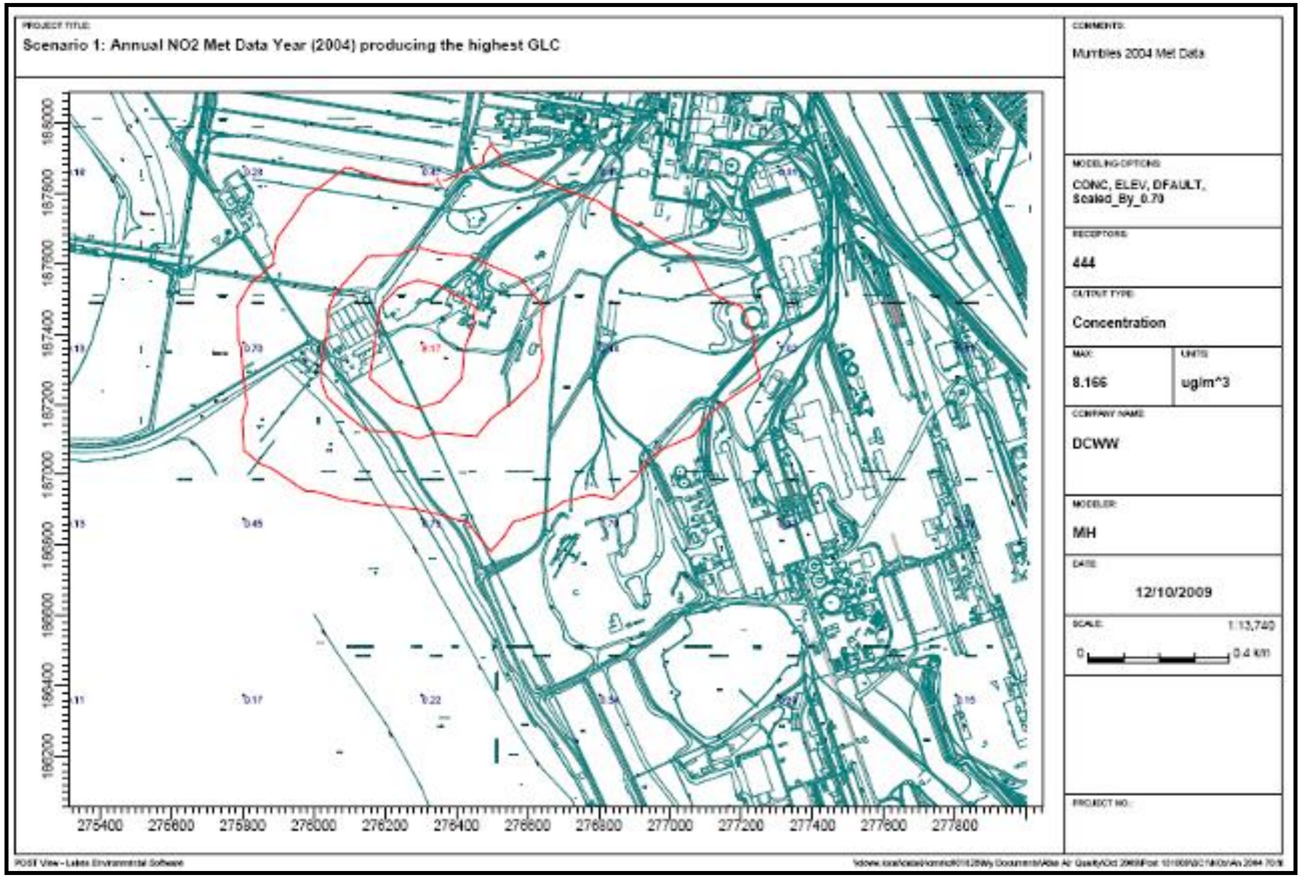
Therefore for all the pollutants modelled no national air quality standards are predicted to be exceeded, even with the two worse case scenarios considered within this study.

SO_2 depositions are predicted to be a 4.66% contributor to minimum critical load for Eglwys Nunydd, however as SO_2 emissions are considered to be over-estimated and hence conservative (see section 1.9) this result is not considered significant.

4 Contour Plots

4.1 Contour Plots NO_2

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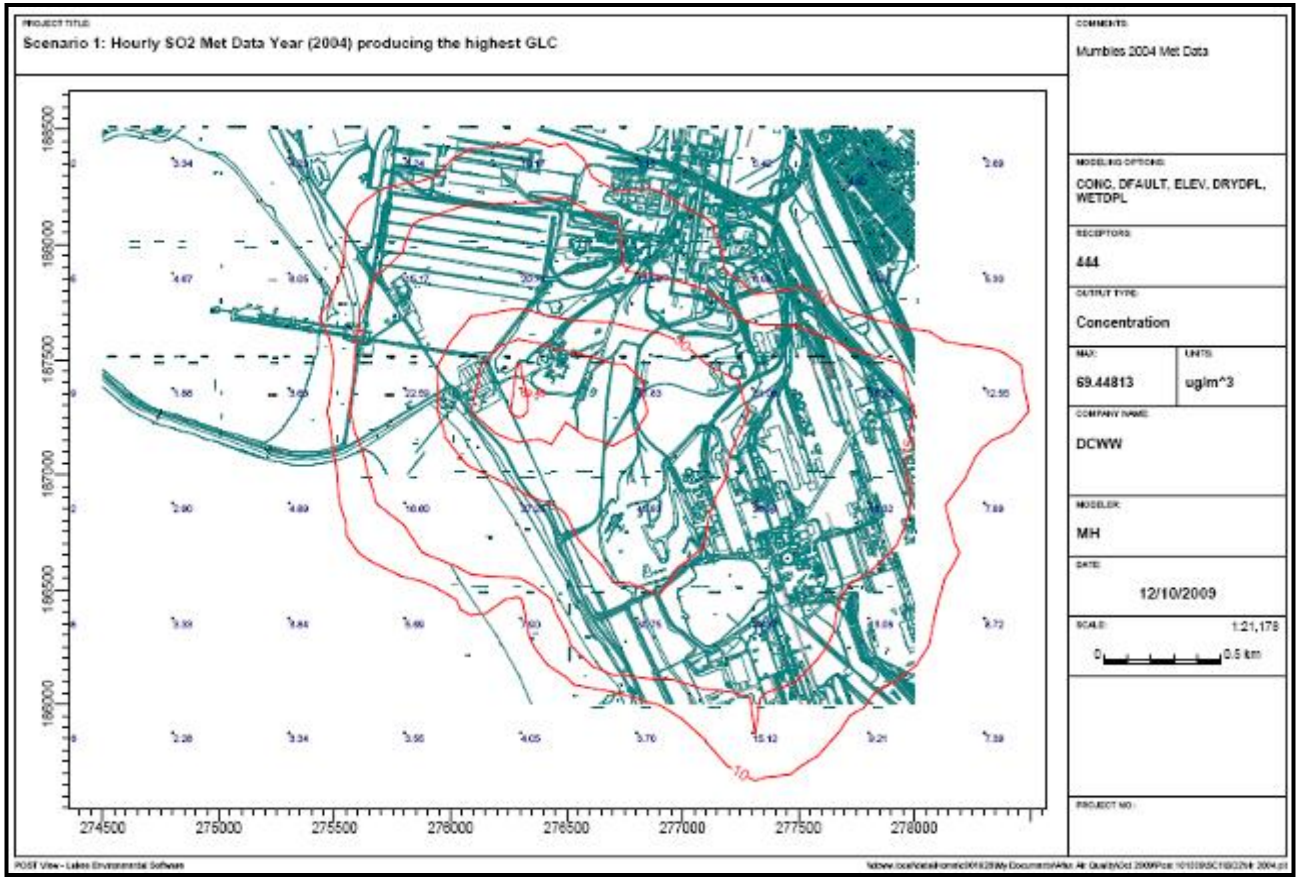
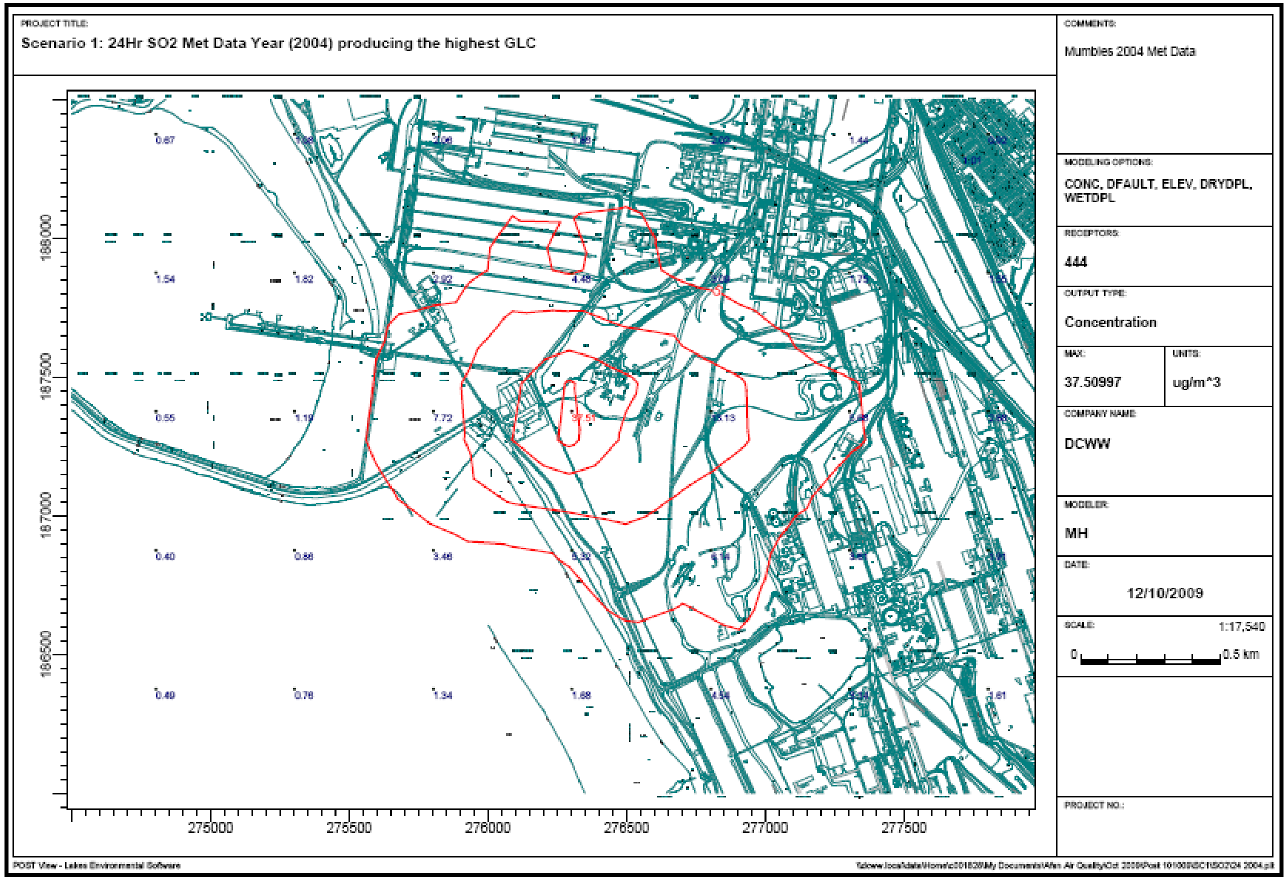
POST View - Lakes Environmental Software

4.2 Contour Plots SO_2

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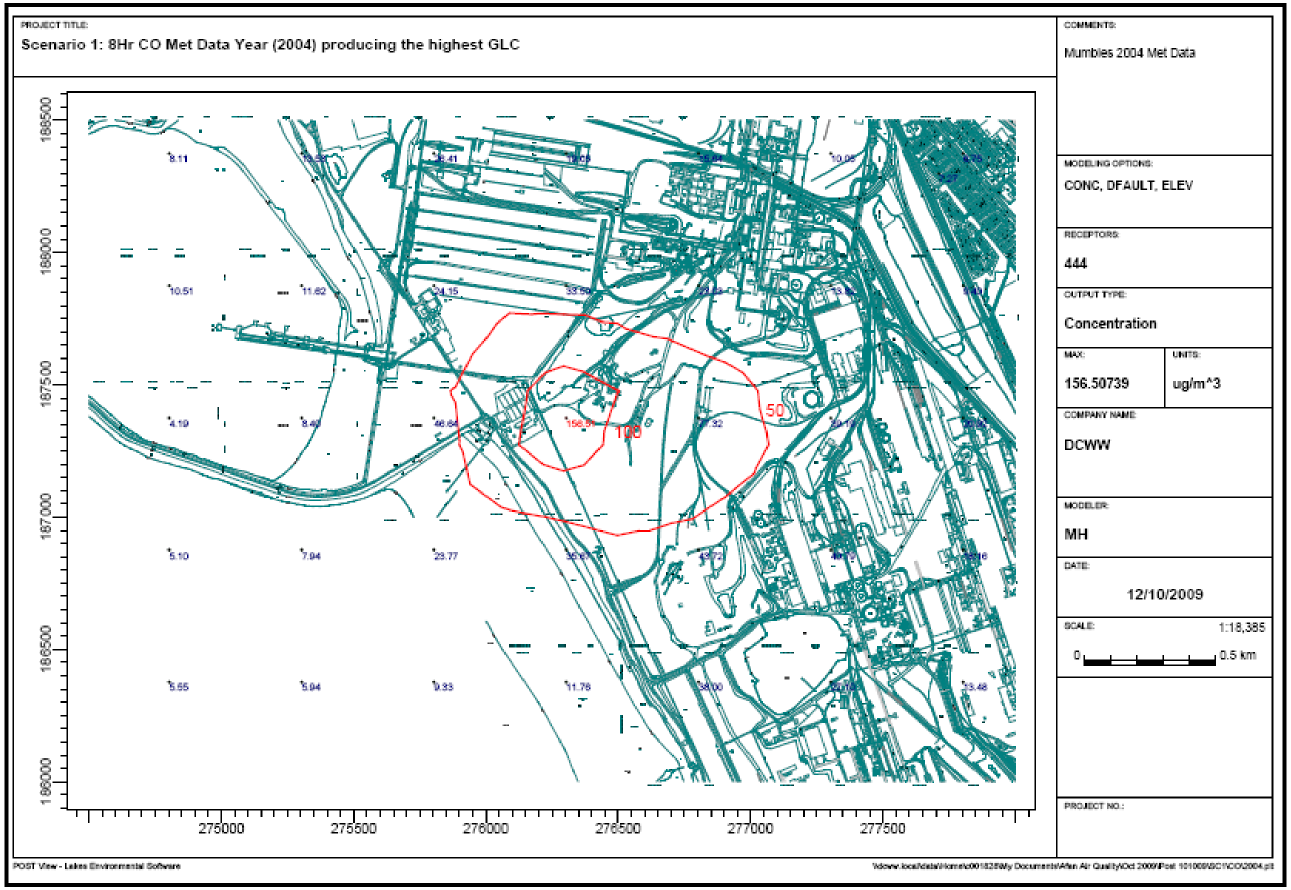
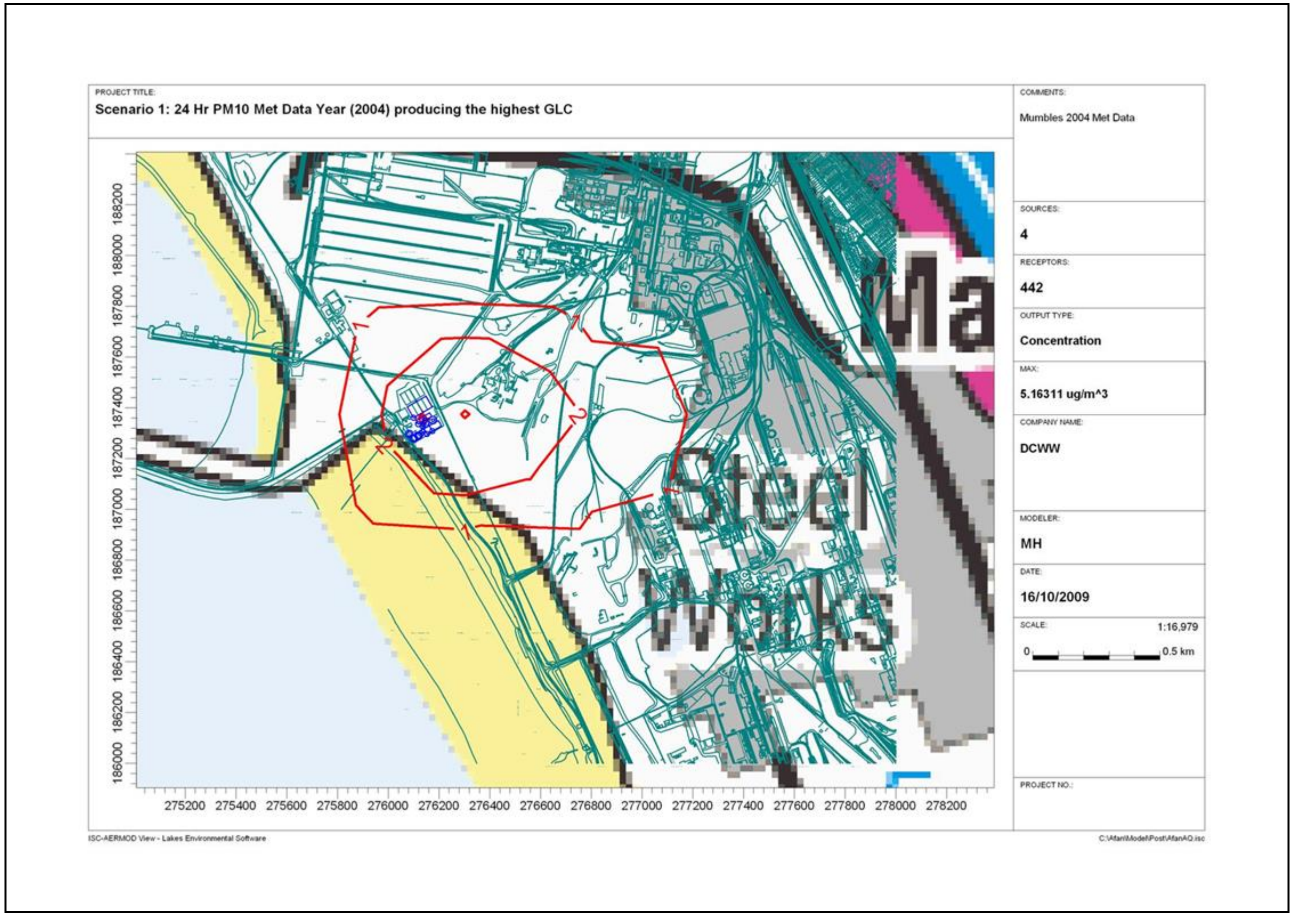
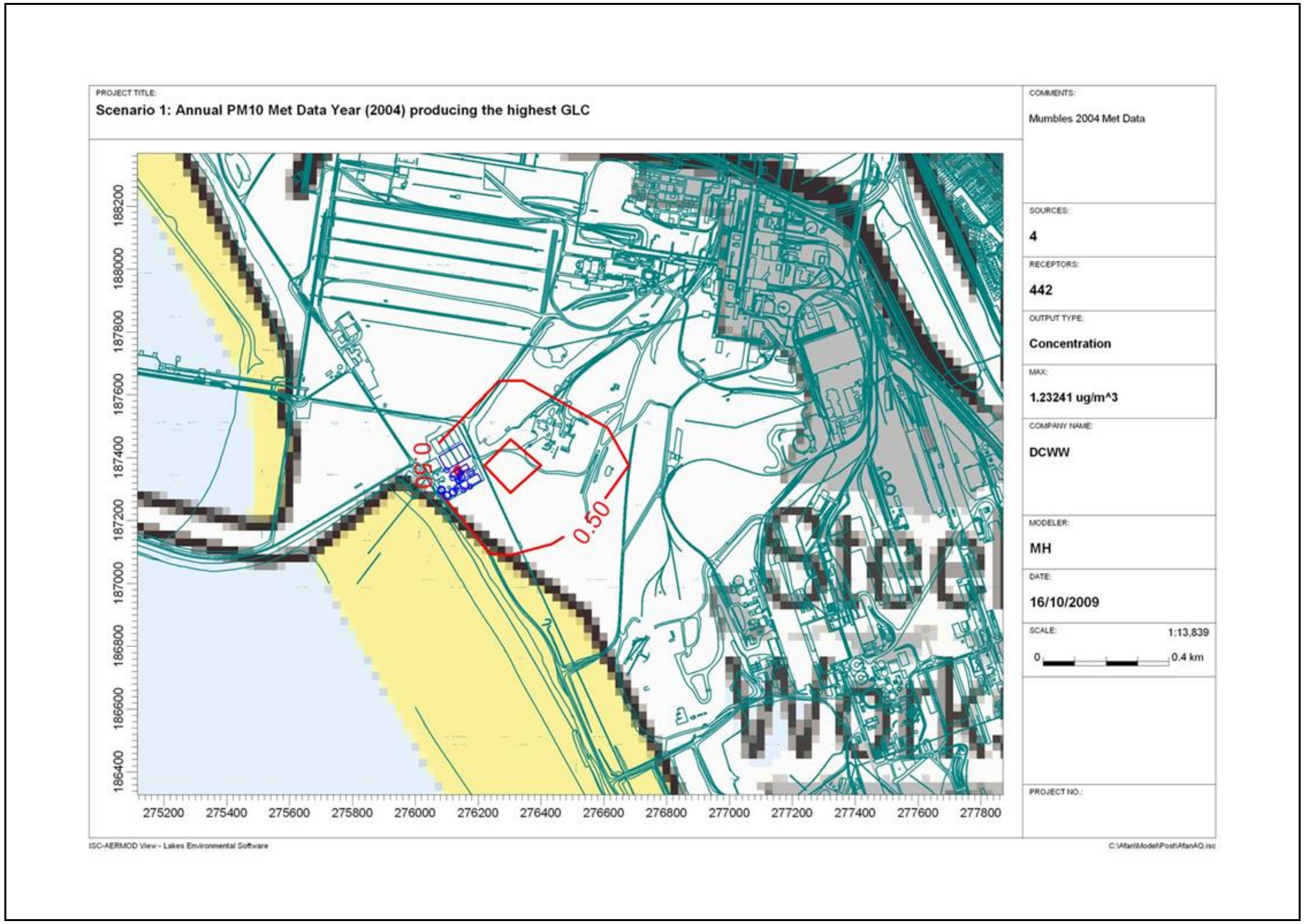
POST View - Lakes Environmental Software

4.3 Contour Plots CO



4.4 Contour Plots PM_{10}




PROJECT TITLE:
Scenario 1: Annual PM10 Met Data Year (2004) producing the highest GLC
COMMENTS:
Mumbles 2004 Met Data
SOURCES:
4
RECEPTORS:
442
OUTPUT TYPE:
Concentration
MAX:
1.23241 ug/m^3
COMPANY NAME:
DCWW
MODELER:
MH
DATE:
16/10/2009
SCALE:
1:13,839
0
0.4 km
PROJECT NO.:
0.50
Steel
Works
188200
188000
187800
187600
187400
187200
187000
186800
186600
186400
275200
275400
275600
275800
276000
276200
276400
276600
276800
277000
277200
277400
277600
277800
ISC-AERMOD View - Lakes Environmental Software
C:\Afan\Model\Post\AfanAQ.isc