DETAILED AIR QUALITY MODELLING STUDY

FINAL REPORT

ISLE OF WIGHT COUNCIL

January 2005

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FABER MAUNSELL

TABLE OF CONTENTS

1 INTRODUCTION

1. Introduction

FaberMaunsell was commissioned by the Isle of Wight Council to undertake a detailed air quality modelling study. This assessment forms part of the second round of the local authority review and assessment process.

The aim of this study was to determine whether there are any locations that are likely to fail to meet the UK National Air Quality Objectives. Following the Stage 1 Review and Assessment, no Air Quality Management Areas (AQMAs) were designated on the Isle of Wight. However, the Updating and Screening Assessment [Ref 1] conducted at the start of the second stage indicated that the objectives relating to two of the pollutants of concern, benzene and sulphur dioxide, may not be met. This assessment continues the investigation of benzene and sulphur dioxide pollution at several locations on the Isle of Wight.

2 LITERATURE REVIEW

2. Literature Review

2.1. Overview of Recent Air Quality Legislation and Policy

The provisions of Part IV of the Environment Act 1995 establish a national framework for air quality management, which requires all local authorities in England, Scotland and Wales to conduct local air quality reviews. Section 82(1) of the Act requires these reviews to include an assessment of the current air quality in the area and the predicted air quality in future years. Should the reviews indicate that the standards prescribed in the National Air Quality Strategy (NAQS) [Ref 2] and the 'Air Quality (England) (Amendment) Regulations 2002' [Ref 3] will not be met, the local authority is required to designate an Air Quality Management Area (AQMA). Action must then be taken at a local level to ensure that air quality in the area improves. This process is known as 'local air quality management'.

2.2. National Air Quality Objectives

The NAQS identifies eight ambient air pollutants that have the potential to cause harm to human health. These pollutants are associated with local air quality problems, with the exception of ozone, which is instead considered to be a regional problem. The Air Quality Regulations set standards for the seven pollutants that are associated with local air quality. These objectives aim to reduce the health impacts of the pollutants to negligible levels.

The standards stated in the Air Quality Regulations are listed in Appendix B. The new and revised objectives for benzene, carbon monoxide and suspended particulate matter (PM_{10}), as detailed in the 'Air Quality (England)(Amendment) Regulations 2002', are included.

2.3. The Phased Approach to Review and Assessment

The second round of the review and assessment process has been split into two phases: an Updating and Screening Assessment, and a Detailed Assessment.

The first phase, the Updating and Screening Assessment, has been designed to review the changes in air quality issues that have occurred within each local authority since the first round of review and assessment. Therefore, it should cover:

- new monitoring data
- new objectives
- new sources of pollution
- significant changes to existing sources of pollution.

These changes are assessed using appropriate screening methods.

The Updating and Screening Assessment also re-examines locations and sources, e.g. road junctions, bus stations, domestic burning, fugitive sources, etc., that have been highlighted as issues during the previous round of review and assessment.

Where the Updating and Screening Assessment has identified a risk that an air quality objective may be exceeded, the local authority must undertake a Detailed Assessment. The aim of this assessment is to determine with as much certainty as is possible whether or not an air quality objective will be exceeded. If an exceedence is predicted, the local authority should designate an AQMA to cover the area of the exceedence.

2.4. The Isle of Wight Council's Updating and Screening Assessment

The Isle of Wight Council completed their Updating and Screening Assessment in 2003 [Ref 1]. This study concluded that no further assessments were required for carbon monoxide, 1,3-butadiene, lead, nitrogen dioxide and PM_{10}. However, the report determined that exceedences of the objectives relating to benzene and sulphur dioxide were possible as significant sources of these two pollutants were identified. The sources of concern were a fuel storage depot in East Cowes, and ferries operating in East Cowes, Yarmouth and Fishbourne ports. The Updating and Screening Assessment concluded that detailed assessments of benzene and sulphur dioxide should be conducted.

3 POLLUTANTS OF CONCERN

3. Pollutants of Concern

3.1. Sulphur Dioxide

3.1.1. National Air Quality Objectives

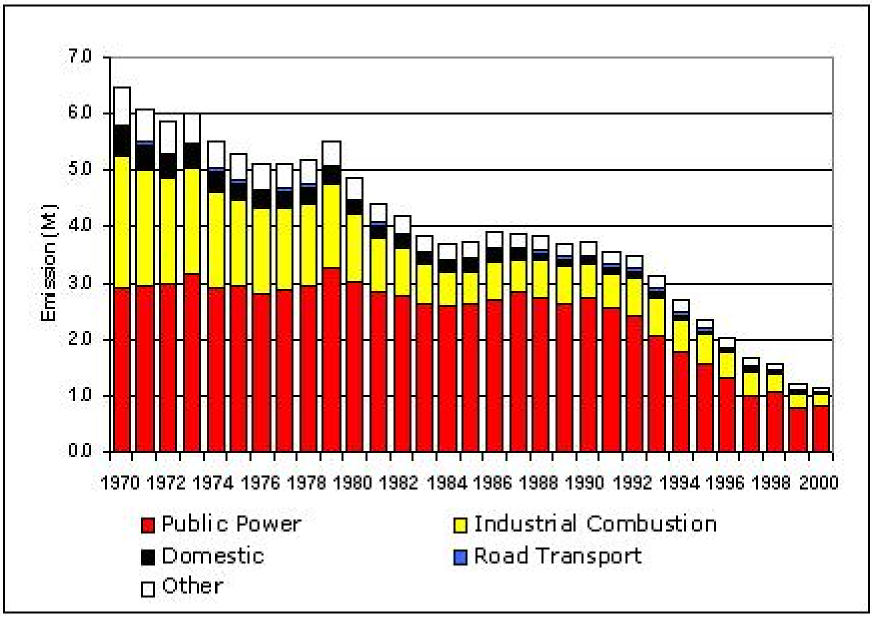
The Government and the Devolved Administrations have adopted a 15-minute mean of 266 µg/m^3 as an air quality standard for sulphur dioxide (SO_2), with an objective for the standard not to be exceeded more than 35 times in a year by the end of 2005. Additional objectives have also been set which are equivalent to the EU limit values specified in the First Air Quality Daughter Directive. These are for a 1-hour mean objective of 350 µg/m^3, to be exceeded no more than 24 times per year, and a 24-hour objective of 125 µg/m^3, to be exceeded no more than 3 times per year, to be achieved by the end of 2004.

3.1.2. UK Emissions

The principal source of SO_2 in the United Kingdom is power stations burning fossil fuels that contain sulphur [Ref 4]. In 2000, this source accounted for more than 71% of total emissions. There were also considerable emissions from other industrial combustion sources. Domestic sources only accounted for 4% of emissions, although it should be noted that this source could have significant local impacts. Road transport accounted for less than 1% of emissions.

Figure 1 illustrates the reduction in total emissions that has occurred in the UK between 1970 and 2000 [Ref 5]. The downward trend is mainly a result of the decline in coal burning in power stations, and industrial and domestic combustion processes. As a result of this reduction, ambient concentrations of SO_2 in the UK have also decreased steadily.

Figure 1 National Trend of SO_2 Emissions (MT/yr) (1970 – 2000)



In recent years, the SO_2 objectives have only been exceeded at one site in Belfast [Ref 4]. This exceedence was associated with domestic coal burning, which is still widespread in the area. Following the first round of review and assessment, a small number of sites where exceedences were likely were identified, and therefore, several AQMAs were declared. These exceedences relate to emissions from coal-fired boilers, domestic coal burning and shipping at a major port.

3.1.3. Health Impacts

SO_2 in ambient air can affect human health, particularly in those suffering from asthma and chronic lung disease [Ref 6]. Even moderate concentrations may result in a fall in lung function in asthmatics. Tightness in the chest and coughing occurs at higher levels, and the lung function of asthmatics may be impaired to the extent that medical help is required. Sulphur dioxide pollution is considered more harmful when particulate and other pollution concentrations are high.

Emissions of SO_2 to the atmosphere also adversely affect the environment. SO_2 combines with water vapour to produce acid rain, which damages vegetation, watercourses, soils and buildings. SO_2 can also form particulate matter, and is involved in processes that influence global climate change.

3.1.4. Local SO_2 Monitoring

Levels of SO_2 are not monitored on the Isle of Wight. However, monitoring is conducted in the nearby cities of Portsmouth, Southampton and Bournemouth [Ref 6]. The 2003 annual mean measurements and the number of exceedences of the 15-minute mean are listed in Table 1. The 99.9th percentiles of the 15-minute mean measurements are also listed (see section 5.1for an explanation of this statistic). It can be seen that there were no exceedences at the three monitoring locations during 2003.

Table 1 Regional SO_2 Monitoring Data, 2003

Location	Analyser	Site type	Annual mean /µg/m^3	No. of exceedences of the 15-min mean	99.9th percentile of 15-min mean measurements /µg/m^3
Portsmouth	Automatic	UB	6	0	48.0
Southampton Centre	Automatic	UC	6	0	67.1
Bournemouth	Automatic	UB	3	0	35.9

Notes: UB – urban background; UC – urban centre.

3.2. Benzene

3.2.1. National Air Quality Objectives

The Government and the Devolved Administrations have adopted a running annual mean concentration of 16.25 µg/m^3 as the air quality standard for benzene, with an objective for the standard to be achieved by the end of 2003. However, in light of health advice from EPAQS and the Department of Health's Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment (COC) to reduce concentrations of benzene in the air to as low a level as possible, additional tighter objectives have also been set. The additional objective is for an annual mean of 5 µg/m^3 to be achieved by the end of 2010 in England and Wales. In Scotland and Northern Ireland, a running annual mean of 3.25 µg/m^3 has been adopted as an additional objective, to be achieved by the end of 2010.

The second Air Quality Daughter Directive also sets a limit value for benzene, which has been transposed into UK legislation. The Directive includes an annual mean of 5 µg/m^3 to be achieved by 1 January 2010.

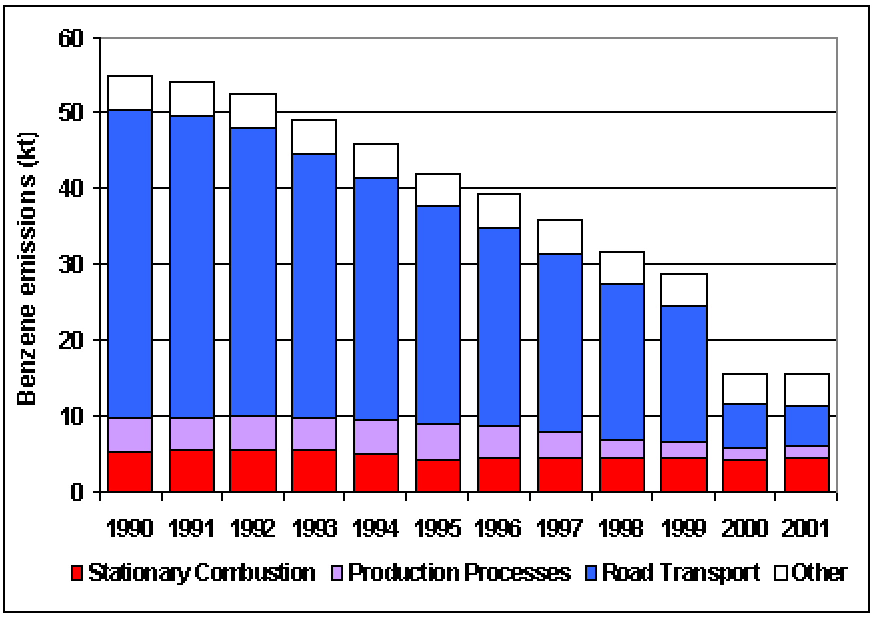
3.2.2. UK Emissions

The main sources of benzene emissions in the UK are motor vehicle exhausts, petrol refining and distribution, and uncontrolled emissions from petrol station forecourts without vapour recovery systems [Ref 4].

Figure 2 illustrates the reduction in total emissions that has occurred in the UK between 1990 and 2001 [Ref 5]. The decrease is the result of various policy measures, for example, the introduction of cars equipped with catalytic converters in 1991, and a reduction in the maximum percentage of benzene permitted in petrol from 5% to 1% in 2000. The use of vapour recovery systems at petrol storage and distribution facilities has also contributed to the decline. Emissions will continue to fall in future years as measures such as the European Auto-Oil programme, which controls emissions from cars and light duty vehicles, come into effect.

Benzene levels observed at UK national network sites have also decreased in recent years, and the measured running annual mean concentrations have been significantly below the 2003 objective of 16.25 μg/m^3. National forecasts of benzene concentrations suggest that the 2010 objectives will also be met at all urban background and most roadside locations. These conclusions are supported by the results of the first round of review and assessment: no AQMAs were declared on the basis of the 2003 objective, but current exceedences of the 2010 objectives were identified at locations in close proximity to industrial sites and busy roads. Emissions from petrol stations have also been highlighted as an area of future concern.

Figure 2 National Trend of Benzene Emissions (MT/yr) (1990 – 2001)



3.2.3. Health Impacts

Benzene is a member of a class of air pollutants called volatile organic compounds (VOCs). The possible chronic health effects of exposure to high levels of VOCs include cancer, central nervous system disorders, liver and kidney damage, reproductive disorders and birth defects [Ref 6]. Benzene, in particular, has been linked to leukaemia: studies have shown that long-term exposure to significant concentrations causes a small, but definite, increase in risk of developing certain forms of the disease [Ref 7].

3.2.4. Local Benzene Monitoring

Benzene concentrations are not monitored on the Isle of Wight. However, monitoring is conducted in the nearby cities of Portsmouth, Southampton and Bournemouth [Ref 6], see Table 2. It can be seen that there were no exceedences of either the 2003 or 2010 air quality objectives at the three monitoring locations during 2003.

Table 2 Regional Benzene Monitoring Data, 2003

Location	Analyser	Site type	Annual mean /μg/m^3
Portsmouth	Automatic	UB	1.3
Southampton Centre	Automatic	UC	2.1
Bournemouth	Automatic	UB	1.0

Notes: UB – urban background; UC – urban centre.

4 MODELLING METHODOLOGY

4. Modelling Methodology

4.1. AAQuIRE

The AAQuIRE 6.1 regional air quality model was used to predict concentrations of SO_2 and benzene for the base year (2004) and future air quality objective years, namely 2005 for SO_2 and 2010 for benzene.

The AAQuIRE regional dispersion model was developed by FaberMaunsell and has been used widely for the past 12 years. The model uses the dispersion algorithms, CALINE4 and AERMOD, which have been independently and extensively validated. A more detailed description of the AAQuIRE dispersion model is included in Appendix C.

There are 4 main categories of air pollutant sources: road traffic sources; industrial sources (Part A and B processes); diffuse sources (e.g. domestic heating); and mobile sources (e.g. airports, rail and shipping). This study involved an assessment of emissions from mobile sources (ferries operating in East Cowes, Yarmouth and Fishbourne ports) and industrial sources (the fuel storage depot in East Cowes). Contributions from the other pollutant sources were amalgamated into the background concentration (see Section 4.4).

The modelling procedure calculated the SO_2 and benzene concentrations at a Cartesian grid of receptors that covered the study areas. The receptors were evenly spaced at 20-metre intervals to ensure that a high level of spatial resolution was obtained. The results produced allowed the generation of pollutant concentration contours.

4.2. Mobile Source Data

AAQuIRE was used to model SO_2 concentrations arising from emissions from ferries operating in East Cowes, Yarmouth and Fishbourne ports. Two types of ferry activity were modelled, namely hotelling and cruising. Hotelling is when the ferry is stationary in a berth in between journeys, with either the main or auxiliary engines operating. It was not necessary to model any manoeuvring activities as ferries are designed to move in and out of their berths quickly. Hotelling was modelled in AAQuIRE as point sources located in the berths and cruising was modelled as a series of area sources that ran along the ferry routes. See Appendix D for the locations of these sources.

The model requires emission rates of pollutants from both the point and area sources. These rates were calculated from information provided by the Isle of Wight Council, Red Funnel and Wightlink, and reports prepared by the European Commission[Ref 8] and the US Environmental Protection Agency[Ref 9]. See Appendix E for details of the calculations necessary.

The model also requires the height and diameter of the ferry's funnel, and the exit velocity and temperature of the gas stream. The funnel height was estimated to be 30 m, and the remaining information was sourced from a report by the Scientifics Air and Emissions Testing Group[Ref 10]. See Appendix F for the complete source dataset.

4.3. Industrial Source Data

AAQuIRE was also used to model benzene emissions from a petrol storage depot operated by Dominion Oils in East Cowes. Emissions data for a vapour recovery unit (VRU) at the depot were provided by the Isle of Wight Council. This unit was modelled as a point source: see Appendix D for the VRU location and Appendix F for the source dataset. Fugitive emissions of benzene from the storage depot were not included in the model as data were not available.

4.4. Background Concentrations

A large number of small sources of air pollutants exist, which individually may not be significant, but collectively, over a large area, need to be considered in the modelling process. The UK National Air Quality Information Archive[Ref 6] provides estimates of background SO_2 and benzene concentrations nationwide, with a spatial resolution of 1 km^2. The background concentrations applied to the model are listed in Table 3. The concentrations for future years were determined by following the method outlined in Defra's Technical Guidance note, LAQM.TG(03)[Ref 4].

Table 3 Background Concentrations

Study area	SO_2/µg/m^3	Benzene/µg/m^3	
	2004/2005	2004	2010
Yarmouth	1.9		
East Cowes	2.1	0.24	0.21
Fishbourne	1.9		

Notes: the background concentrations of SO_2 in 2004 and 2005 are identical according to the guidance in LAQM.TG(03); the background concentrations applied to the Yarmouth, East Cowes and Fishbourne models are those listed for the 1-km squares centred on grid references (436500, 88500), (447500, 91500) and (455500, 88500) respectively.

4.5. Meteorological Data

After consultation with the Meteorological Office, a meteorological data set was compiled using data from the nearest suitable station: Bournemouth. Windroses from the most recent years available were analysed and the most typical year (1998) was selected. The windrose for Bournemouth is presented in Appendix G, along with further details of the methodology used.

4.6. Model Verification

Model verification involves comparing the model results with local monitoring data in order to assess the errors associated with the model, and if necessary, correct the model results. However, as SO_2 and benzene are not monitored on the Isle of Wight, it was not possible to perform such a verification. Instead, the model results were compared with the regional monitoring data described in section 3 in order to provide an indication of the model performance.

5 RESULTS

5. Results

5.1. SO_2 Results

The model results of the SO_2 studies of East Cowes, Fishbourne and Yarmouth are presented as concentration contour plots in Figures 3, 4 and 5 in Appendix A. The concentrations depicted in the plots are the 99.9th percentile of the 15-minute mean SO_2 concentrations predicted to occur. This percentile allows a comparison with the most stringent air quality standard for SO_2: the 15-minute mean objective of 266 µg/m^3 not to be exceeded more than 35 times a year. Thus, a predicted concentration below 266 µg/m^3 indicates that neither the 15-minute mean, nor the other, less stringent objectives for SO_2, will be exceeded.

It can be seen that the predicted concentrations for all three areas are well below the SO_2 15-minute mean objective.

The highest concentrations (up to 89 µg/m^3) are predicted to occur in East Cowes, to the north-east of the ferry berth. East Cowes is expected to experience the highest levels, despite having the lowest number of ship movements of the three ports, because the ferries hotel for the longest period of time.

Fishbourne is predicted to experience 15-minute mean concentrations that are lower than those at East Cowes, with the highest concentrations (up to 76 µg/m^3) occurring out at sea. SO_2 concentrations are lower inland because the Fishbourne ferries hotel for a short period of time with the main engines switched off.

The lowest concentrations (up to 47 µg/m^3) are predicted to occur in Yarmouth. The ferries that operate out of this port have the smallest engines of the three ports studied and hotel for the shortest period of time.

5.2. Benzene Results

The annual mean benzene concentrations predicted to occur in East Cowes in 2004 and 2010 are presented in Figures 6 and 7 in Appendix A. It can be seen that the air quality standards for benzene for both 2003 (an annual mean of 16.25 µg/m^3) and 2010 (an annual mean of 5 µg/m^3) are predicted to be easily met. It can also be seen that the background concentrations of benzene used in the modelling process comprise the vast majority of the predicted concentrations and that emissions from the vapour recovery unit contribute very little.

As discussed in section 4.3, fugitive emissions of benzene at the petrol storage depot were not included in the model as data were not available. However, it should be noted that such emissions are possible and will lead to higher concentrations of benzene than those predicted by the model. These emissions may be of importance, particularly as sensitive receptors, namely a new housing development at East Cowes Marina, are sited within 40 m of the storage depot [Ref 1].

5.3. Verification of Model Results

As described in section 4.6, the model results were compared with regional monitoring data in order to provide an indication of the model performance.

With regard to the SO_2 studies, the model results are in broad agreement with the monitoring data listed in Table 1 in that the model predicted no exceedences of the 15-minute mean objective, and that the predicted concentrations are comparable to the 99.9th percentile of the 15-minute mean measurements.

With regard to the benzene study, it is possible that the model may be under predicting annual mean benzene concentrations, as the measurements taken in Portsmouth, Southampton and Bournemouth are higher (see Table 2). However, these cities are obviously much bigger and are likely to have many more sources of benzene than East Cowes.

5.4. Model Error

It is possible to account for the degree of random error in dispersion model results according to guidance provided by the NSCA [Ref 14].

'Stock U Values' allow the standard deviation of the model (SDM) to be calculated. The Stock U Value (U) for the SO_2 15-minute mean objective is 0.5 and the value for the annual mean benzene objective is between 0.1 and 0.3. The SDM can be calculated according to:

SDM = U x Co

where Co is the air quality objective. Thus:

$SDM_{(SO2\ 15\text{-minute mean})} = 0.5 \times 266 = 133\ \mu g/m^3$
$SDM_{(benzene\ annual\ mean,\ 2003)} = 0.2 \times 16.25 = 3.25\ \mu g/m^3$
$SDM_{(benzene\ annual\ mean,\ 2010)} = 0.2 \times 5 = 1\ \mu g/m^3$.

The SDM allows areas to be identified where it is possible that an air quality objective may be breached. If the predicted concentration plus the SDM is greater than the objective, then an exceedence is possible.

Taking the above SDM values into account, possible exceedences of the SO_2 and benzene objectives are not likely.

6 SUMMARY AND CONCLUSIONS

6. Summary and Conclusions

FaberMaunsell was commissioned by the Isle of Wight Council to undertake a detailed modelling study of SO_2 concentrations arising from emissions from ferries in East Cowes, Fishbourne and Yarmouth ports, and benzene concentrations arising from emissions from a petrol storage depot in East Cowes. The SO_2 model was run for 2004/2005 and the benzene model was run for 2003 and 2010.

The assessment was performed using the AAQuIRE 6.1 regional dispersion model, which has been independently and extensively validated, and widely used for the past 12 years. Emissions and meteorological data, and background concentrations of the two pollutants of concern were input to the model to produce pollutant concentration plots for the required years.

The results of the SO_2 study indicate that the 15-minute mean objective will not be exceeded in East Cowes, Fishbourne and Yarmouth in 2004/2005. Indeed, the highest predicted concentration (89 $\mu g/m^3$ in East Cowes) was well below the objective. Predicted concentrations in Fishbourne were lower than those predicted to occur in East Cowes, and the concentrations in Yarmouth were lower still.

The annual mean benzene concentrations predicted to occur in East Cowes in 2004 and 2010 are also well below both the 2003 and 2010 air quality standards for benzene. It was determined that emissions from the vapour recovery unit contribute very little to the predicted concentrations. The lack of data regarding fugitive emissions was identified as an issue, particularly as a new housing development is sited within 40 m of the petrol storage depot.

The model results were compared qualitatively with regional monitoring data in order to provide an indication of the model performance. The SO_2 results were in broad agreement with the monitoring data but the benzene results were lower, indicating that the model may be under predicting annual mean benzene concentrations.

7 REFERENCES

7. References

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Appendix A Model Results

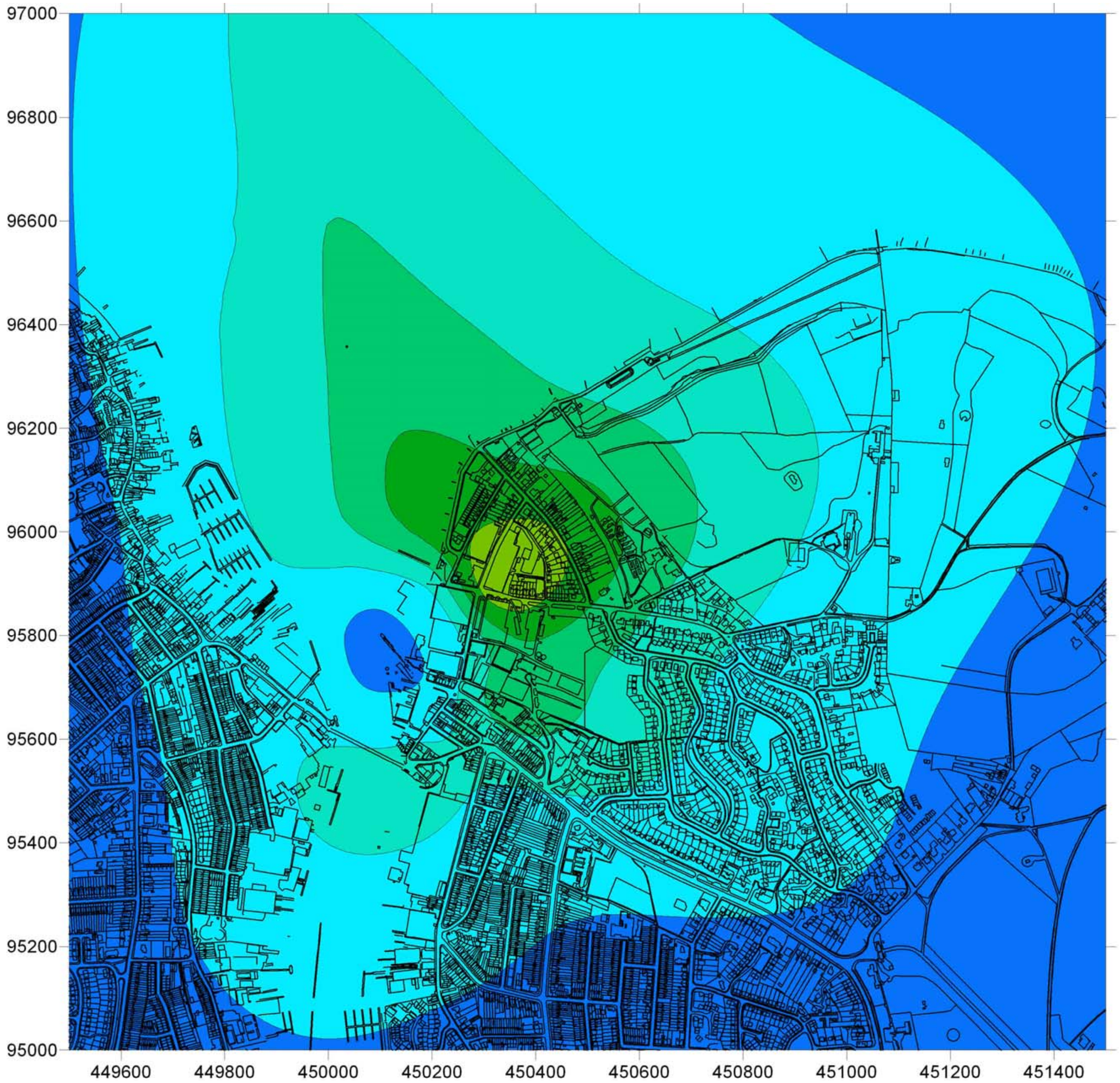
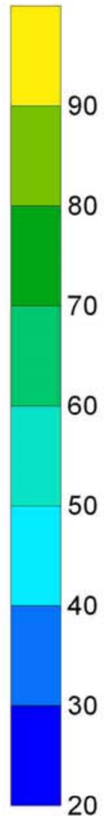
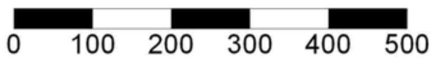


Figure 3: 99.9th Percentile of 15-Minute Mean SO_2 Concentrations ($\mu g/m^3$), East Cowes 2004/2005





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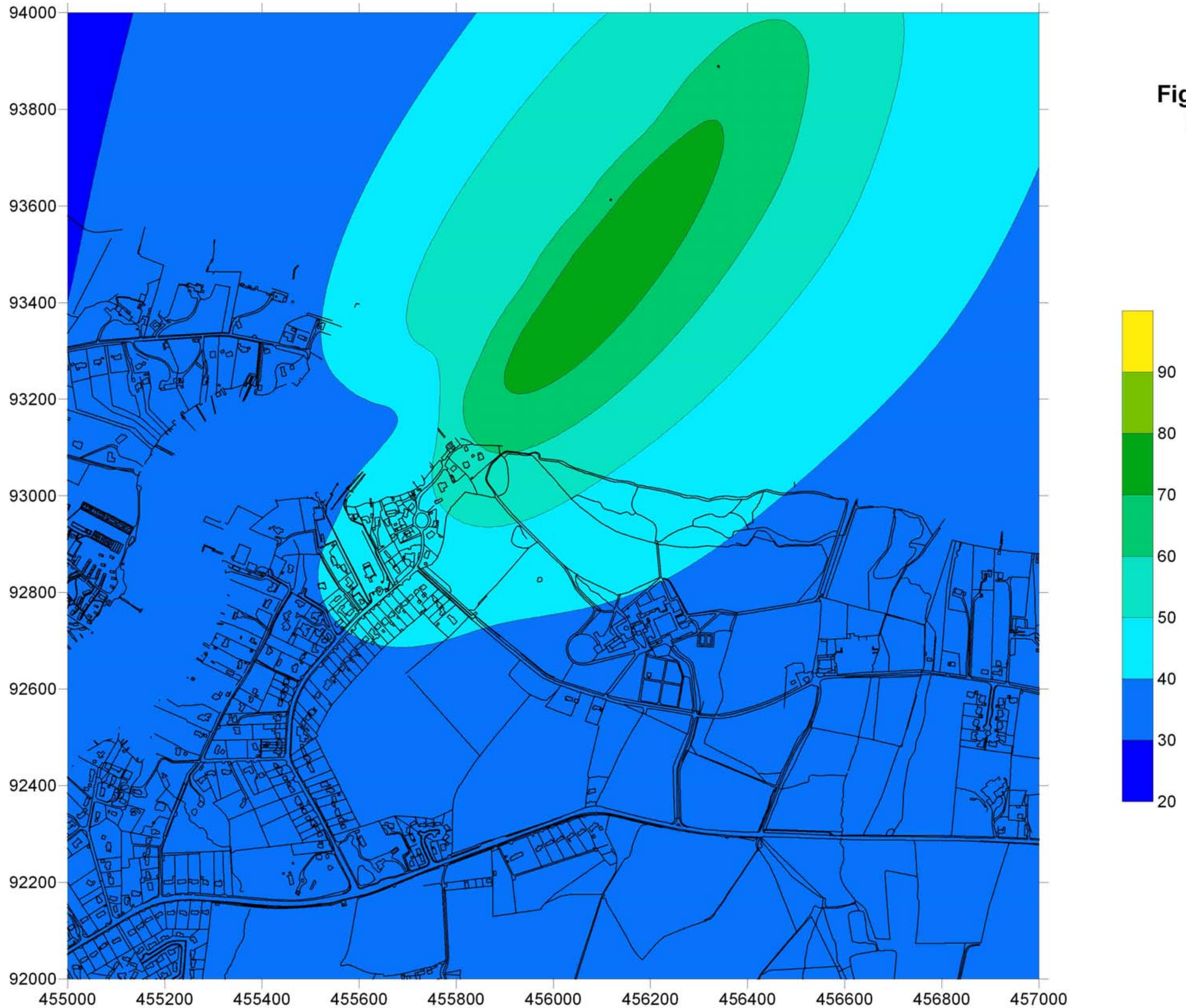

Figure 4: 99.9th Percentile of 15-Minute Mean SO_2 Concentrations ($\mu g/m^3$), Fishbourne 2004/2005

0 100 200 300 400 500

Scale: 1:10000 at A3

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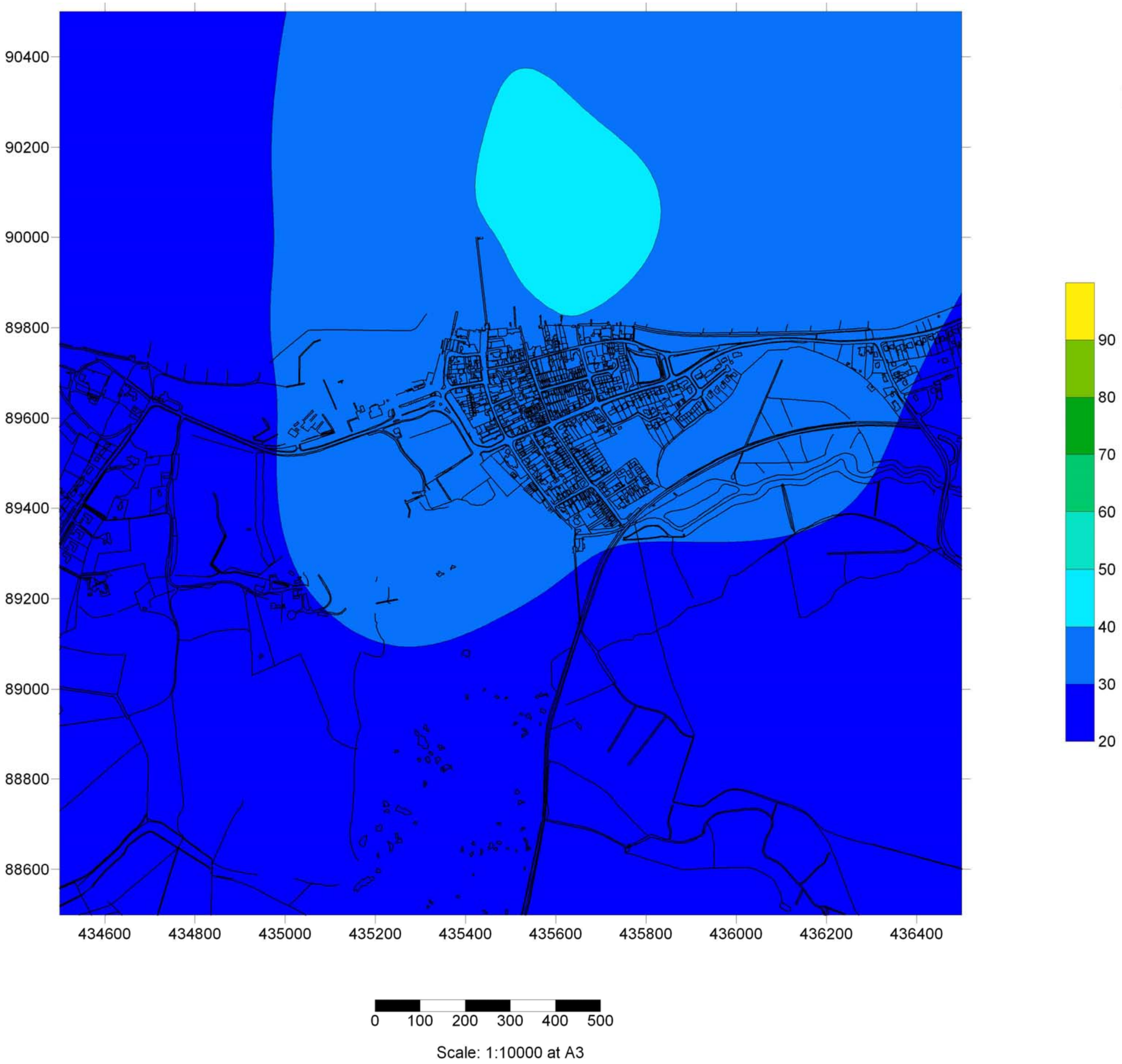

Figure 5: 99.9th Percentile of 15-Minute Mean SO_2 Concentrations ($\mu g/m^3$), Yarmouth 2004/2005

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Figure 6: Annual Mean Benzene Concentrations ($\mu g/m^3$), East Cowes 2004

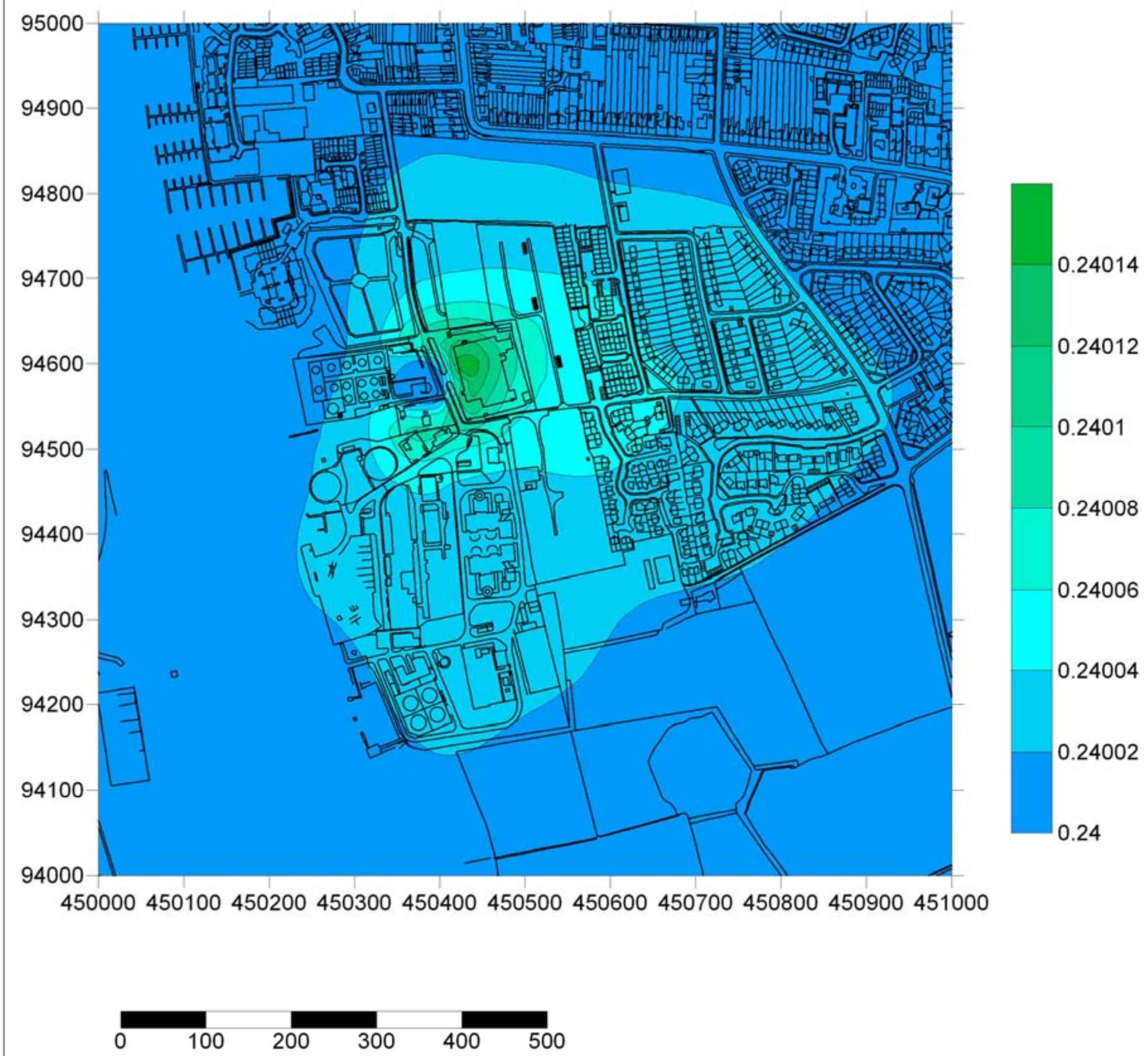

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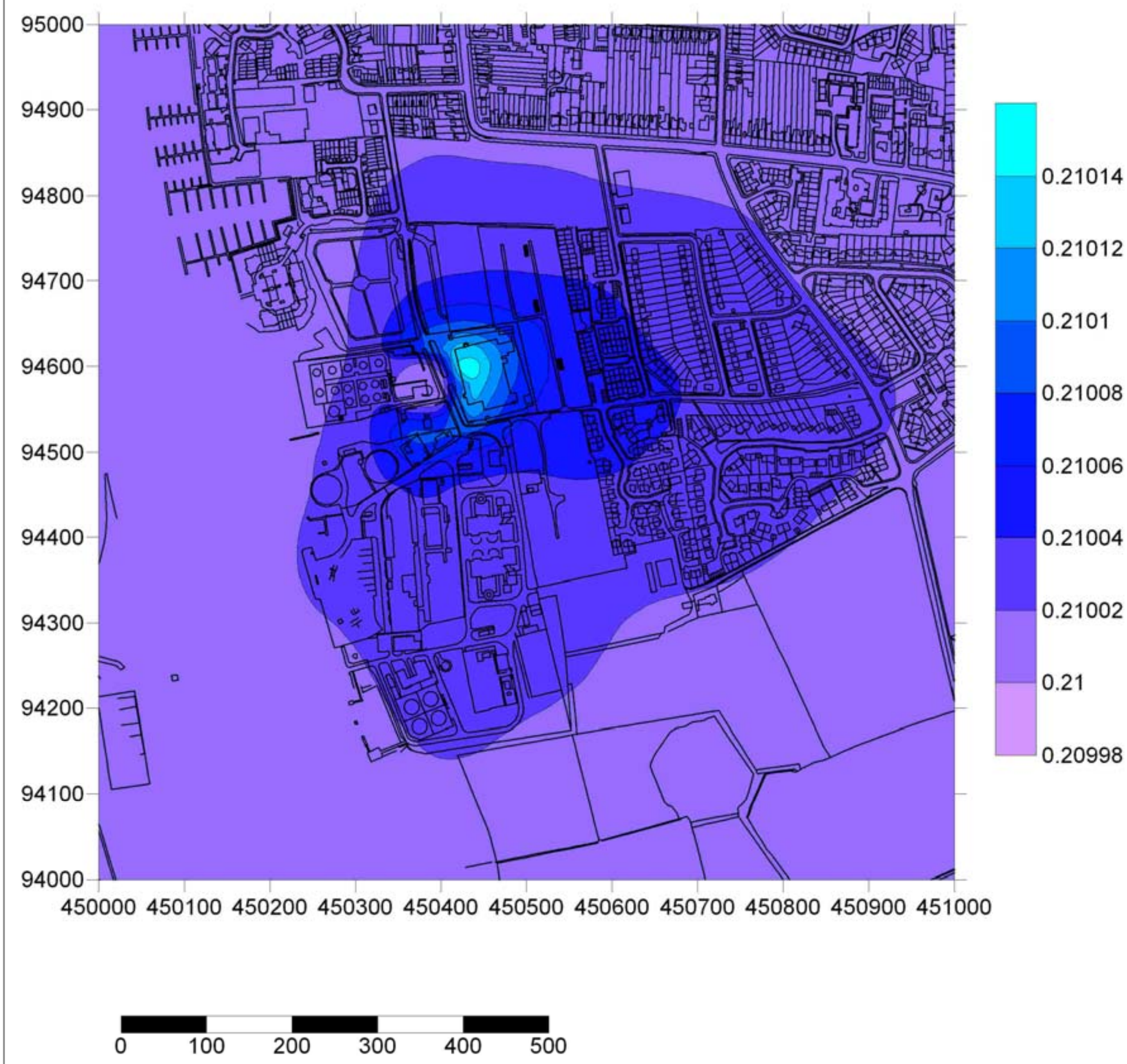
Figure 7: Annual Mean Benzene Concentrations ($\mu g/m^3$), East Cowes 2010



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Appendix B UK National Air Quality Objectives

Table 4 UK Air Quality Objectives set in Regulations

Pollutant	Applies	Objective		Compliance	EU Objectives	
		Concentration	Measured as		Concentration	Date
Benzene	All UK	16.25 µg/m^3 (5 ppb)	Running annual mean	Dec 31, 2003	5 µg/m^3	2010
	England & Wales	5 µg/m^3 (1.5 ppb)	Annual mean	Dec 31, 2003		
	Scotland	3.25 µg/m^3 (1 ppb)		Dec 31, 2010		
1,3-Butadiene	All UK	2.25 µg/m^3 (1 ppb)	Running annual mean	Dec 31, 2010	n/a	n/a
Carbon monoxide	All UK	10 mg/m^3 (8.6 ppm)	Maximum daily running 8 hour mean	Dec 31, 2003	10 mg/m^3	2005
Lead	All UK	0.5 µg/m^3	Annual mean	Dec 31, 2004	0.5 µg/m^3	2005
		0.25 µg/m^3	Annual mean	Dec 31, 2008		
Nitrogen dioxide	All UK	200 µg/m^3 (105 ppb)	1 hour, 18 exceedences	Dec 31, 2005	200 µg/m^3 (18 exceedences)	2010
		40 µg/m^3 (21 ppb)	Annual mean	Dec 31, 2005	40 µg/m^3	2010
Particles (PM_{10}) (gravimetric)	All UK	50 µg/m^3	24hr mean, 35 exceedences	Dec 31, 2004	50 µg/m^3	2005
		40 µg/m^3	Annual mean	Dec 31, 2004	40 µg/m^3	2005
	Scotland	50 µg/m^3	24hr mean, 7 exceedences	Dec 31, 2010	40 µg/m^3	2010
		18 µg/m^3	Annual mean	Dec 31, 2010	20 µg/m^3	2010
Sulphur dioxide	All UK	350 µg/m^3 (132 ppb)	1 hour, 24 exceedences	Dec 31, 2004	350 µg/m^3 (24 exceedences)	2005
		125 µg/m^3 (47 ppb)	24 hour mean, 3 exceedences	Dec 31, 2004	125 µg/m^3 (18 exceedences)	2005
		266 µg/m^3 (100 ppb)	15 min mean, 35 exceedences	Dec 31, 2005	n/a	n/a

Table 5 UK Air Quality Objectives not set in Regulations

Pollutant	Applies	Objective		Compliance	Notes
		Concentration	Measured as		
Polycyclic aromatic hydrocarbons (PAHs)	All UK	0.25 ng/m^3	Annual mean	Dec 31, 2010	To be set in future regulations, 2005.
Ozone	All UK	100 µg/m^3	8 hour mean, 10 exceedences	Dec 31, 2005	Ozone is a national rather then local authority problem.
Particles (PM_{10}) (gravimetric)	London	50 µg/m^3 (provisional)	24 hour mean, 10 exceedences	Dec 31, 2010	These particle objectives may be set in regulations once the EU has decided its new limit value.
		23 µg/m^3 (provisional)	Annual mean	Dec 31, 2010	
		20 µg/m^3 (provisional)	Annual mean	Dec 31, 2015	
	Rest of England & Wales	50 µg/m^3 (provisional)	24 hour mean, 7 exceedences	Dec 31, 2010	
		20 µg/m^3 (provisional)	Annual mean	Dec 31, 2010	
Nitrogen oxides	All UK	30 µg/m^3 (16 ppb)	Annual mean	Dec 31, 2000	Vegetative based directives kept out of regulations as national problem. Targets have been met.
Sulphur dioxide	All UK	20 µg/m^3 (8 ppb)	Annual mean	Dec 31, 2000	
		20 µg/m^3 (8 ppb)	Winter mean (October – March)	Dec 31, 2000	

Appendix C AAQuIRE Description

The AAQuIRE 6.1 software is a system that predicts Ambient Air Quality in Regional Environments and comprises a regional air quality model and statistical package.

AAQuIRE was developed by FaberMaunsell Ltd to meet three requirements in predictive air quality studies. The first requirement was an immediate need for a system that produced results that could be interpreted easily by non-air quality specialists to allow for proper informed inclusion of air quality issues in wider fora, the main example being to allow consideration of air quality issues in planning processes. This was achieved by allowing results to be generated over a sufficiently large study area, and at an appropriate resolution, for the issue being considered. The results are also presented in a relevant format, which is normally a statistic directly comparable with an air quality criterion or set of measured data being considered. For example, the UKNAQS PM_{10} 24-hour objective level of 50 µg/m_3 is expressed as a 90th percentile of hourly means. AAQuIRE can also produce results directly comparable with all ambient air quality standards, including:

- the annual average objective for nitrogen dioxide of 40 µg/m^3
- the 90th percentile of 24-hour means for PM_{10} of 50 µg/m^3
- the 99.9th percentile of 15-minute means for sulphur dioxide of 266 µg/m^3
- the nitrogen dioxide 1-hour mean objective of 200 µg/m^3, not to be exceeded more than 18 times a year.

The second requirement was for a system to be based, initially, on existing and well-accepted and validated dispersion models. This has two advantages. The primary one is that it avoids the need to prove a new model against the accepted models and therefore enhances acceptability. The second advantage is that when appropriate new models are developed they can be included in AAQuIRE and be compared directly with the existing models, and sets of measured data, using the most appropriate statistics.

The final primary requirement for AAQuIRE was a consideration of quality assurance and control. An important aspect of modelling is proper record keeping ensuring repeatability of results. This is achieved within AAQuIRE by a set of log files, which record all aspects of a study and allow model runs to be easily repeated.

The ways in which AAQuIRE and the models currently available within it operate are discussed below.

The operation of AAQuIRE can be divided into five main stages. These are:

- the preparation of the input data
- the generation of model input files
- dispersion modelling
- the statistical treatment of dispersion modelling results
- the presentation of results.

The first step in operating AAQuIRE is to prepare the input data. Data are needed on:

- meteorological data expressed as occurrence frequencies for specified combinations of wind speed, direction, stability and boundary layer height
- road system layout and associated traffic data within and immediately surrounding the study area
- industrial stack locations and parameters
- grid of model prediction locations (receptors)

for the year and pollutant to be modelled. The modelling is always carried out to give annual average results from which appropriate shorter period concentrations can be derived.

The second stage is the generation of the model input files required for the study. All the data collated in the first stage can be easily input into AAQuIRE, using the worksheets, drop down boxes and click boxes in the Data Manager section of the software. Data from spreadsheets can be easily pasted into worksheets, so that any complicated procedures required for data manipulation can be achieved before entry into AAQuIRE. Several diurnal and seasonal profiles can be defined for each separate source. The relevant meteorological data can also be specified at this stage.

The third stage is executing the models. The study area will usually be divided up into manageable grids and run separately using the Run Manager in AAQuIRE. The results from the separate files can be combined at a later stage. Pollutant concentrations are determined for each receptor point and each meteorological category and are subsequently combined.

The fourth stage is the statistical processing of the raw dispersion results to produce results in the relevant averaging period. Traffic sources and industrial sources can be combined at this stage provided the same receptor grid has been used for both. Background concentrations should also be incorporated at this stage.

The final stage is presentation of results. Currently the result files from the statistical interpretation are formatted to be used directly by the SURFER package produced by Golden Software Inc. Alternative formats are available to permit interfacing with other software packages. On previous projects the results have been imported into a GIS (e.g. ArcView and Map Info).

Currently AAQuIRE uses the CALINE4 model for the dispersion of road-traffic emissions and AERMOD for all other sources. Both these models are fully validated and have been extensively used worldwide. These are relatively complex models designed for detailed studies of local areas, which are used within AAQuIRE for both local and larger scale studies. This is considered necessary because of the frequent importance of local effects, such as traffic junctions, in properly assessing ‘regional’ effects. The modelling uncertainty for AAQuIRE is approximately ± 20%, which is well within the recommendations in technical guidance note LAQM.TG(03) [Ref 4].

Appendix D Source Locations

Figure 3 The Locations of the Area and Point Sources included in the East Cowes Model

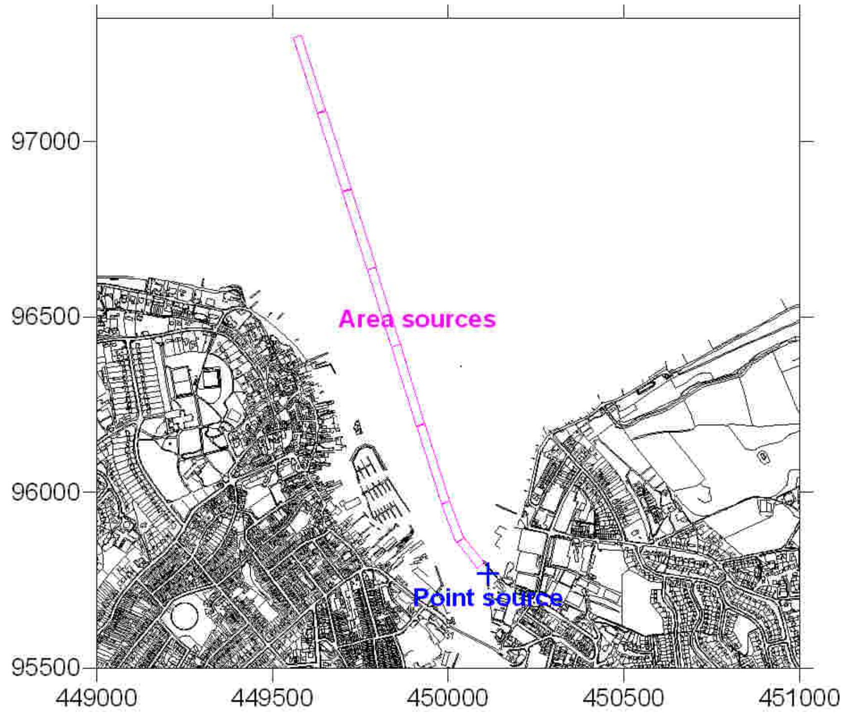


Figure 4 The Locations of the Area and Point Sources included in the Yarmouth Model

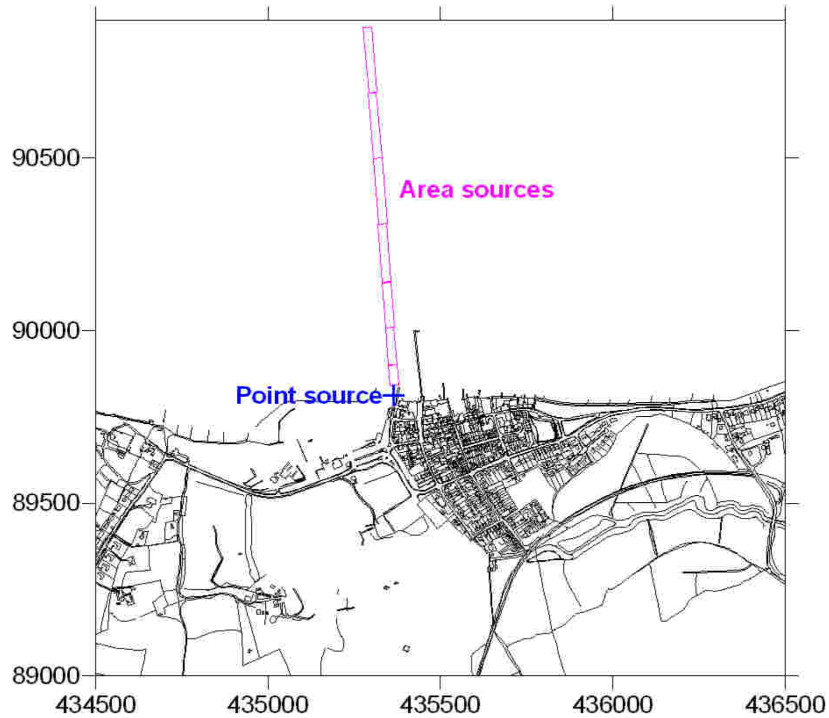


Figure 5 The Locations of the Area and Point Sources included in the Fishbourne Model

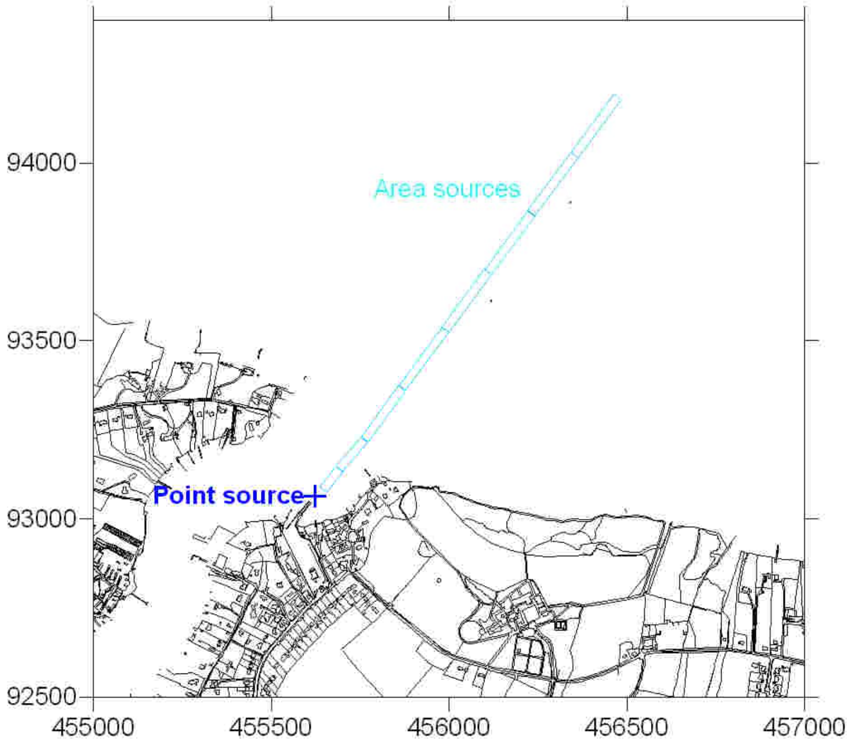
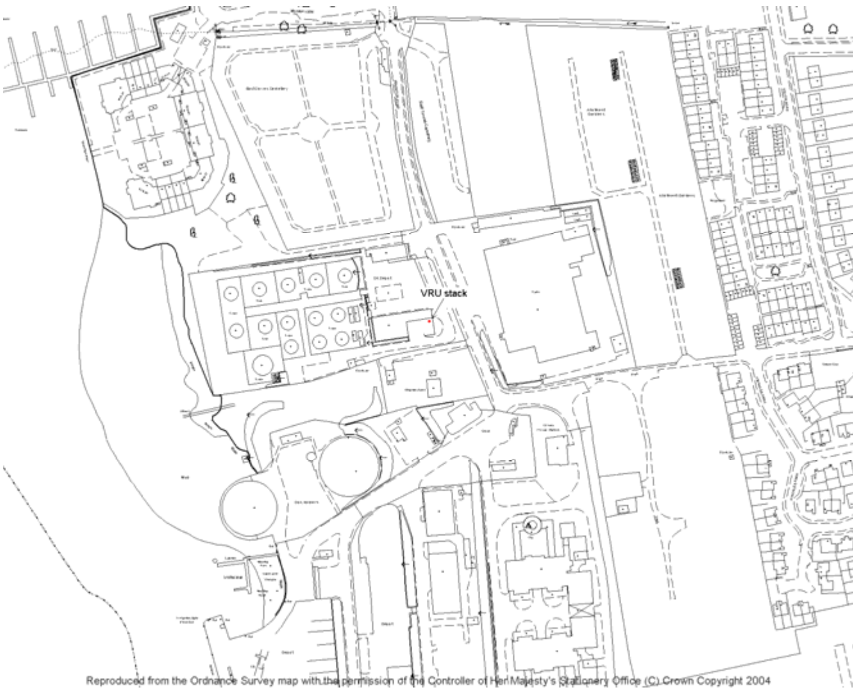


Figure 6 The Location of the VRU in East Cowes



Appendix E Calculation of Emission Rates

The following methodology was used to calculate emission rates of SO_2 from the point and area sources used to describe mobile sources in the model. An example of the calculation for one of the area sources used in the Yarmouth model is provided.

1. Select the appropriate emission factors from those listed *in Quantification of emissions from ships associated with ship movements between ports in the European Community*, a report by the European Commission[Ref 8]. For example:

   Emission factor for a cruising ferry (classified as a passenger/roro cargo vessel at sea) = 9.8 g/kWh

   Note that factors in units of kg/tonne fuel are also available.

2. Determine the power ratings of the ferries and multiply by the emission factor to obtain the emission rate in g/h.

   Wightlink ferry power rating = 990 BHP = 738 kW

   Emission rate = 9.8 × 738 = 7,232 g/h

3. Calculate the time spent in the point or area source and multiply by the emission rate to determine the emissions in g.

   Cruising speed = 10 knots = 18.5km/h

   Length of area source = 0.19 km

   Time in source = 0.19/18.5 = 0.01 h

   Emissions = 0.01 × 7,232 = 72 g

4. The above emissions apply to one ferry movement. Multiply this number by the total number of movements per year to calculate the emission rate in g/yr.

   Number of ship movements per year in Yarmouth port = 23,404

   Total emissions = 23404 × 72 = 1,685,088 g/yr

Notes: 1. Emission factors for hotelling and manoeuvring activities for a wide range of ships are available. 2. The main engines may be turned off and the auxiliary engines turned on when the ferry is hotelling, in which case the power rating of the auxiliary engines must be used in step 2. 3. Ferries move more slowly nearer the berth; the correct speed must be applied in step 3.

Appendix F Source Data

Table 6 Mobile Source Data for 2004/2005

SO_2 emission factors		**Reference**
Passenger/roro cargo vessels:		8
Hotelling	11.2 g/kWh	
Cruising	9.8 g/kWh	
Engine power ratings		
Wightlink Yarmouth	Main engines 990 BHP	11
Wightlink Fishbourne	Main engines 2928 BHP Auxiliary engines (used when hotelling) 453 BHP	
Red Funnel East Cowes	Main engines 2718 HP	12
Speeds		
Yarmouth	5 knots for 0.25 nautical miles; 10 knots thereafter	11
Fishbourne	5 knots for 0.5 nautical miles; 12.5 knots thereafter	
East Cowes	5 knots for 0.6 nautical miles; 7 knots for 0.6 nautical miles, 13 knots thereafter	12
Ship movements per annum		
Yarmouth	23404	13
Fishbourne	25304	
East Cowes	14972	
Time spent hotelling		
Yarmouth	15 mins	11
Fishbourne	20 mins	
East Cowes	30 mins	12
Other details		
Funnel height	30 m	Estimated
Funnel diameter	0.37 m	10
Gas stream temperature	560 K	
Gas stream exit velocity	28.5 m/s	

Table 7 Industrial Source Data for 2003 and 2010

Parameter	
Location	450381, 94575
Stack height	10 m
Stack diameter	0.1 m
Gas steam temperature	293 K
Gas stream exit velocity	0.20 m/s
Volume emission of benzene	0.002025 g/m^3
Volume flow	50000 m^3/yr
Emission rate	3.2×10^{-6} g/s

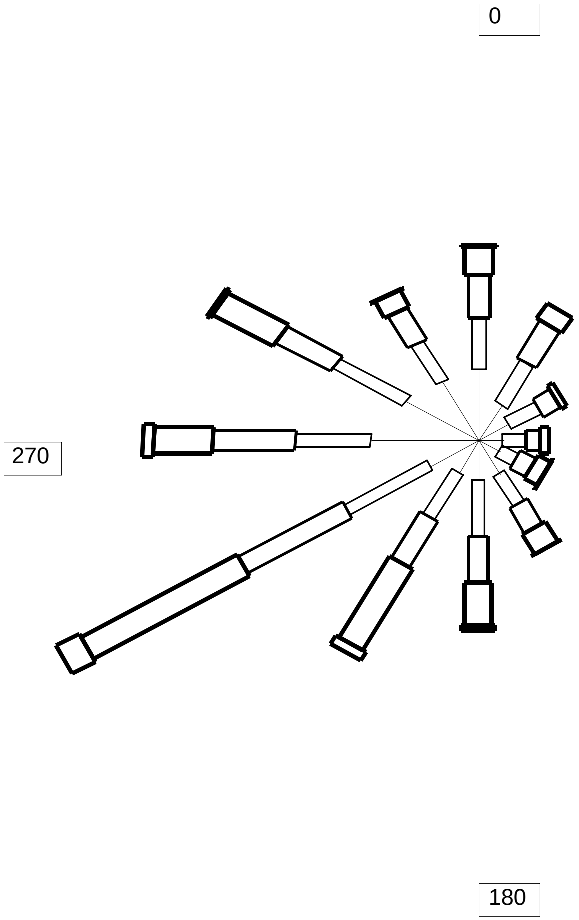
Appendix G Meteorological Data

Meteorological data measured at Bournemouth were used in this modelling study. The data consisted of the frequencies of occurrence of wind speed (0 – 2, 2 – 4, 4 – 6, 6 – 10, 10+ m/s), wind direction (30° resolution) and Pasquill stability classes. Pasquill stability classes categorise the stability of the atmosphere from A (very unstable) through D (neutral) to G (very stable).

Calm winds were distributed evenly between the wind direction sectors in the 1 m/s category. The stability classes used were C, D and E where all of the unstable classes were grouped in C and all of the stable classes in E.

The meteorological data were used to produce a wind/stability rose: see the figure on the following page. Each windrose bar is designed to illustrate three wind properties: the direction the wind is coming from; the relative number of hours the wind is from this direction; and the magnitude of the wind speeds. These data are also tabulated to show the total number of hours and the wind speed split for each wind direction sector.

Figure 7 Windrose and Data for Bournemouth, 1998



	Wind <= 2 m/s	Wind <= 4 m/s	Wind <= 6 m/s	Wind <= 10 m/s	Wind > 10 m/s
D >= 345 or D < 15	268	201	160	106	5
15 <= D < 45	155	183	161	68	
45 <= D < 75	120	119	69	23	
75 <= D < 105	84	83	52	30	
105 <= D < 135	85	62	66	49	4
135 <= D < 165	146	131	111	83	3
165 <= D < 195	154	209	173	163	21
195 <= D < 225	144	189	203	352	36
225 <= D < 255	192	334	413	622	92
255 <= D < 285	374	261	285	200	40
285 <= D < 315	284	284	222	239	14
315 <= D < 345	253	174	134	67	5
Total	2259	2230	2049	2002	220