Cambridge
Environmental
Research
Consultants

Air Quality Modelling for St Neots

Final report

Prepared for
Huntingdonshire District Council

11th August 2017

CERC

Report Information

CERC Job Number:	FM1129
Job Title:	Air quality modelling for St Neots
Prepared for:	Huntingdonshire District Council
Report Status:	Final
Report Reference:	FM1129/Hunts/R2/17
Issue Date:	11th August 2017
Author(s):	Catheryn Price, Matthew Williams
Reviewer(s):	Sarah Strickland

Issue	Date	Comments
1	07/08/17	Draft
2	11/08/17	Final

Contents

1 Summary

Part of the centre of St Neots is currently an Air Quality Management Area (AQMA). The AQMA was declared in 2005, due to concentrations of nitrogen dioxide (NO_2) exceeding the national air quality objectives. This AQMA initially comprised a small area of the High Street around a single junction, and was subsequently extended slightly to cover approximately 500 metres along the High Street, including the junctions of Huntingdon Street/Church Street and New Street.

In recent years, measured concentrations in St Neots have been decreasing and, since 2010, diffusion tube monitoring in the AQMA has not shown any exceedences of the air quality objective. Cambridge Environmental Research Consultants Ltd (CERC) were commissioned by Huntingdonshire District Council (the Council) to carry out modelling to determine whether or not the air quality objectives are likely to be exceeded in the St Neots AQMA, to support the possible revoking of the AQMA.

Air quality modelling was carried out using the ADMS-Urban dispersion model. The modelling used traffic data from Department for Transport and Cambridgeshire County Council, together with transport assessments for local planning applications. These were used with emission factors published by Defra, which were adjusted to take into account evidence of real-world driving emissions. The modelling also included emissions from Little Barford Power Station and other sources, taken from the National Atmospheric Emissions Inventory.

Concentrations were calculated at the locations of diffusion tubes in St Neots and the measured and modelled concentrations compared to verify the suitability of the model input data and assumptions. The modelled concentrations generally show very good agreement, with modelled annual average NO_2 concentrations at five of the seven monitoring sites within 10% of the measured values. In particular, at the two monitoring sites within the AQMA, the modelled concentrations were within 1% and 3% of the measured values, respectively. The model setup can therefore be considered appropriate for the modelled area.

Exceedences of the objective value for annual average NO_2 concentrations are predicted along sections of the High Street. However, all of these exceedences occur at locations where there is no relevant exposure over the averaging time of a year, so the annual average air quality objective does not apply. Concentrations at the building facades, where the annual average objective is relevant, are all below 40 $\mu g/m^3$.

To take into account uncertainty in the modelling, a value of 36 $\mu g/m^3$ is sometimes also considered. The only building façade location at which the modelled concentration exceeds 36 $\mu g/m^3$ is outside the Thomas Morris office, where it reaches 39 $\mu g/m^3$.

Exceedences of the objective value for hourly average concentrations are only predicted in the centre of the New Street and Huntingdon Street junctions, i.e. not in areas where the public would be expected to have regular access.

2 Introduction

Part of the centre of St Neots is currently an Air Quality Management Area (AQMA). The AQMA was declared in 2005, due to concentrations of nitrogen dioxide (NO_2) exceeding the national air quality objectives. This AQMA initially comprised a small area of the High Street around a single junction, and was subsequently extended slightly to cover approximately 500 metres along the High Street, including the junctions of Huntingdon Street/Church Street and New Street.

In recent years, measured concentrations in St Neots have been decreasing and, since 2010, diffusion tube monitoring in the AQMA has not shown any exceedences of the air quality objective. Cambridge Environmental Research Consultants Ltd (CERC) were commissioned by Huntingdonshire District Council (the Council) to carry out modelling to determine whether or not the air quality objectives are likely to be exceeded in the St Neots AQMA, to support the possible revoking of the AQMA.

This report describes the data used and assumptions made in the assessment, and presents the model results. The air quality objectives with which the calculated concentrations are compared are presented in Section 3. The location and extent of the AQMA is described in Section 4, with measured concentrations presented in Section 5. The model setup and source data are described in Sections 6 and 7, respectively, with the modelled concentrations presented in Section 8. A discussion of the results is provided in Section 9.

3 Air quality standards

The Air Quality Strategy for England, Scotland, Wales and Northern Ireland, Working Together for Clean Air, January 2000, defines Air Quality Objective values for NO_2 to be achieved by 2005. These objectives are the subject of Statutory Instrument 2000 No. 928, *The Air Quality (England) Regulations 2000*, which came into force on 6th April 2000.

In the more recent document *The Air Quality Strategy for England, Scotland, Wales and Northern Ireland,* July 2007, PM_{10} objectives to be achieved by 2010 have been removed and an objective for $PM_{2.5}$ has been added. The NO_2 objectives are unchanged.

The UK Air Quality Objectives for NO_2 are presented in Table 3.1.

Table 3.1: Air Quality Objectives

	Value ($\mu g/m^3$)	Description of standard	Date to be achieved
NO_2	200	Hourly mean not to be exceeded more than 18 times a year (modelled as 99.79th percentile)	31-12-2005
	40	Annual average	31-12-2005

The short-term standards considered are specified in terms of the number of times during a year that a concentration measured over a short period of time is permitted to exceed a specified value. For example, the concentration of NO_2 measured as the average value recorded over a one-hour period is permitted to exceed the concentration of $200\mu g/m^3$ up to 18 times per year. Any more exceedences than this during a one-year period would represent a breach of the objective.

It is convenient to model objectives of this form in terms of the equivalent percentile concentration value. A percentile is the concentration below which lie a specified percentage of concentration measurements. For example, consider the 98th percentile of one-hour concentrations over a year. Taking all of the 8760 one-hour concentration values that occur in a year, the 98th percentile value is the concentration below which 98% of those concentrations lie. Or, in other words, it is the concentration exceeded by 2% (100 – 98) of those hours, that is, 175 hours per year.

Taking the NO_2 objective considered above, allowing 18 exceedences of hourly mean concentrations per year is equivalent to not exceeding for 8742 hours or for 99.79% of the year. This is therefore equivalent to the 99.79th percentile value.

Table 3.2 gives examples from the Defra TG(16) guidance of where the air quality objectives should apply.

Table 3.2: Examples of where the air quality objectives should apply

Averaging period	**Objectives should apply at:**	**Objectives should generally not apply at:**
Annual average	All locations where members of the public might be regularly exposed. Building facades of residential properties, schools, hospitals, care homes etc	Building facades of offices or other places of work where members of the public do not have regular access. Hotels, unless people live there as their permanent residence. Gardens of residential properties Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.
Hourly average	All locations where the annual mean and: Hotels Gardens of residential properties Kerbside sites (for example pavements of busy shopping streets). Those parts of car parks, bus stations and railway stations etc. Which are not fully enclosed, where members of the public might reasonably be expected to spend one hour or longer.	Kerbside sites where the public would not be expected to have regular access.

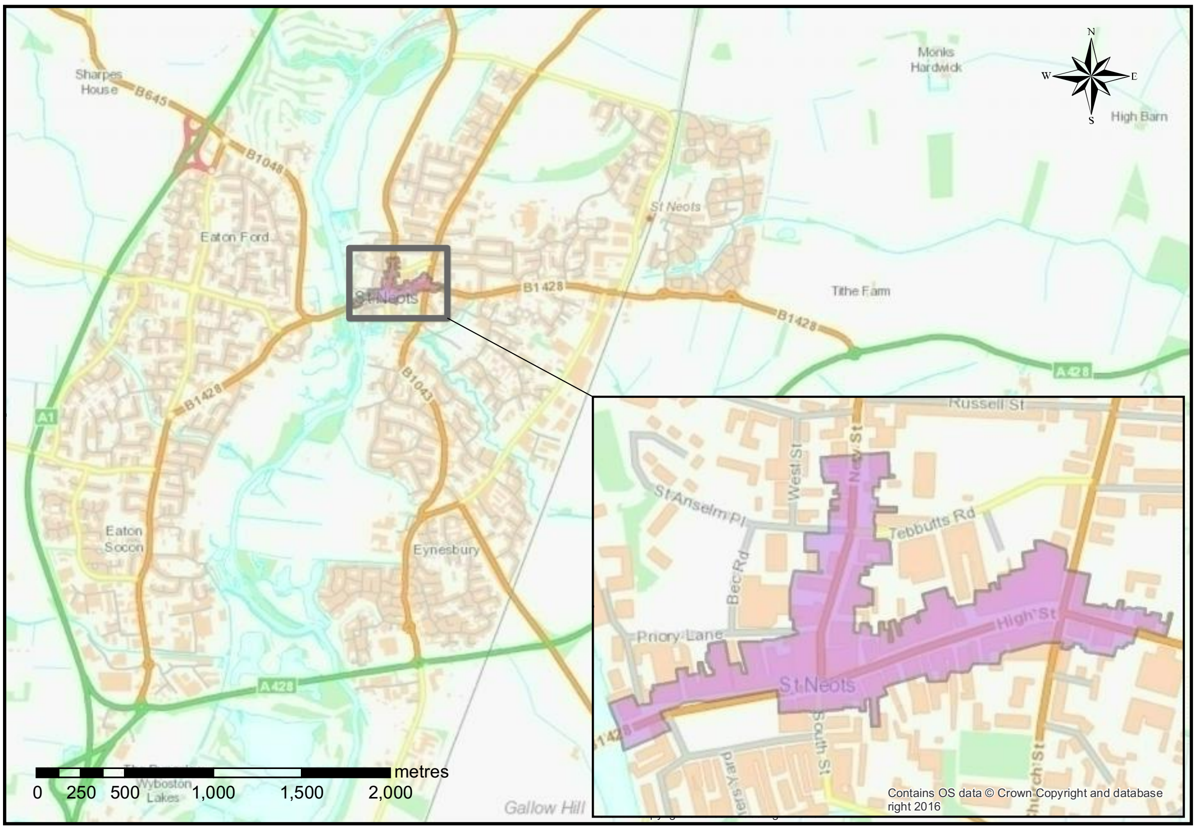
4 Air Quality Management Area

The total AQMA area is around 40,000 m^2, or 4 hectares. It comprises the entirety of the High Street, which is a busy shopping street around 500 m in length, plus several junctions. The junction with New Street/South Street is included, plus around 220 m of New Street, north of the High Street, incorporating the junction with Tan Yard and Tebbutts Road.

The junction with Huntingdon Street/Cambridge Street/Church Street is also included in the AQMA, plus around 100 m of Cambridge Street, to the east of the High Street. At the far west of the High Street, the road becomes St Neots Road. The stretches of road within the AQMA all form street canyons.

The location of the AQMA within St Neots, and its extent, are shown in Figure 4.1

Figure 4.1: The location of the St Neots AQMA



5 Measured concentrations

Although there are no automatic monitoring sites in or around St Neots, there are seven passive diffusion tubes in the area, for the measurement of NO_2. The details of these diffusion tubes are shown in Table 5.1 and the locations are shown in Figure 5.1.

Table 5.1: Diffusion tube information and concentrations for 2015

Site Name	Location	x, y location (m)	Height (m)	Site Type	In AQMA?	Distance to kerb (m) of nearest road	Worst-case location?
St Neots 1	Avenue Rd	518925, 260503	3	Urban background	N	1	N
St Neots 2	Harland Rd	518489, 260871	3	Urban background	N	1	N
St Neots 3	High St (Post Office)	518323, 260263	3	Kerbside	Y	1	Y
St Neots 4	High St (Traffic lts)	518433, 260321	3	Kerbside	Y	1	Y
St Neots 5	The Paddocks	517869, 260132	3	Kerbside	N	1	N
Eynesbury	17 Arundel Crescent	518424, 258566	3	Suburban	N	17	Y
Eaton Socon	5 Duchess Close	516370, 259514	3	Suburban	N	24 (to trunk rd)	N

Figure 5.1: Locations of NO_2 diffusion tubes

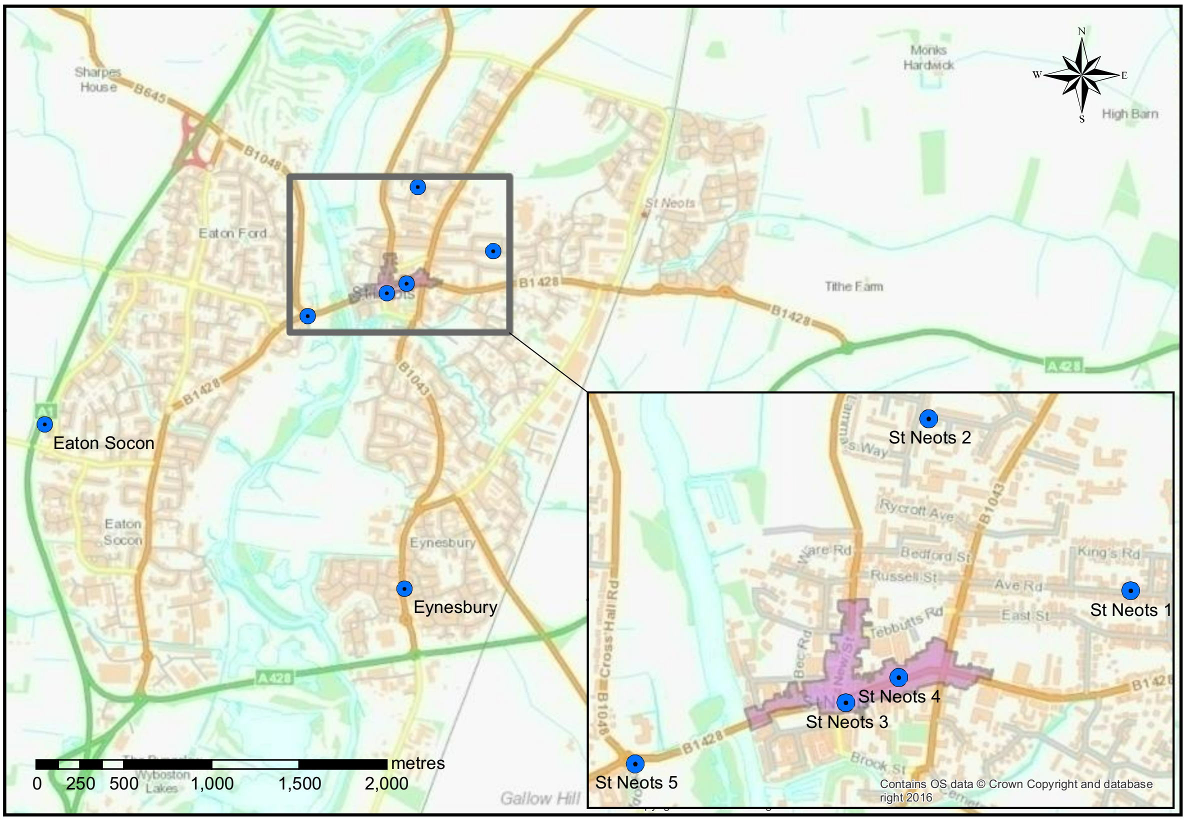
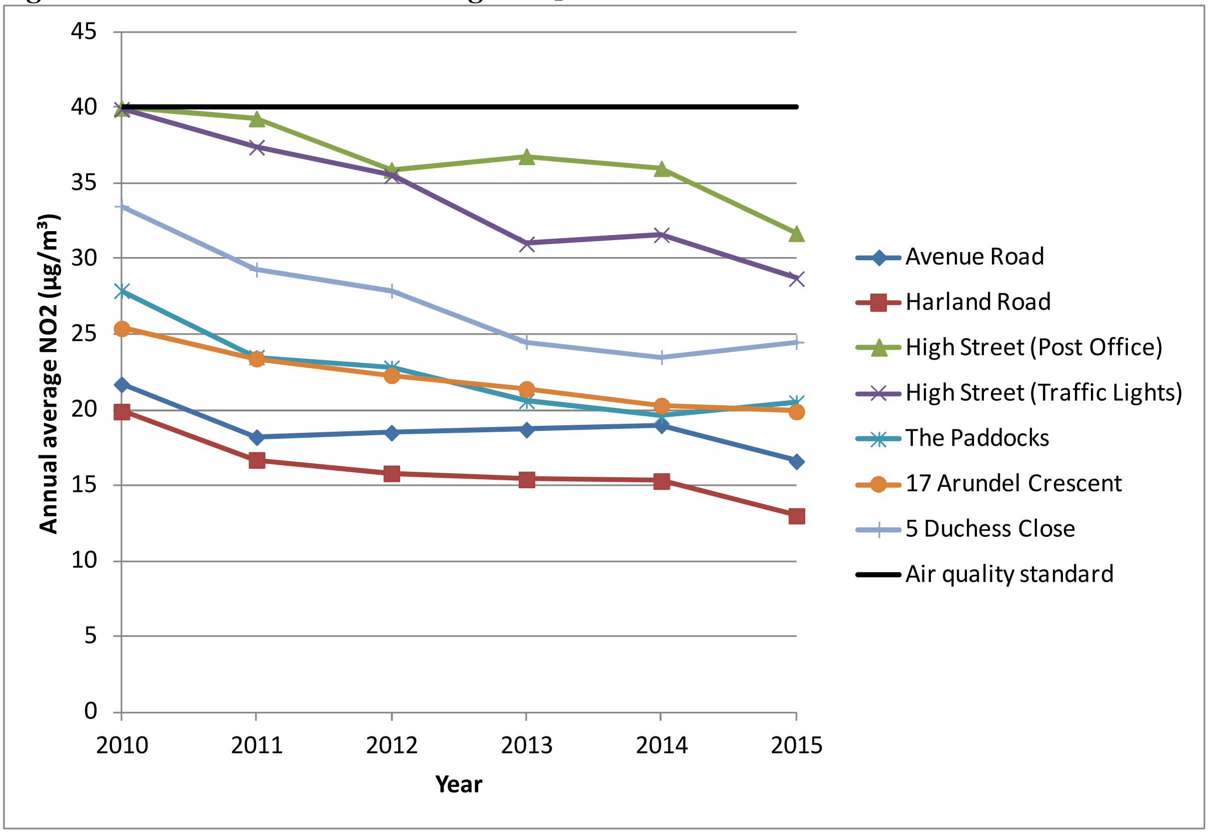


Table 5.2 shows measured concentrations for 2010 to 2015 and the applied bias adjustment factors for each year. Figure 5.2 shows the trends in measured concentrations compared to the air quality objective of 40 µg/m³.

Table 5.2: Diffusion tube locations and heights used for the modelling

Site Name	Location	2010	2011	2012	2013	2014	2015
Bias adjustment factors		0.82	0.85	0.84	0.79	0.82	0.81
St Neots 1	Avenue Road	21.7	18.2	18.5	18.7	19.0	16.6
St Neots 2	Harland Road	19.9	16.7	15.8	15.4	15.3	13.0
St Neots 3	High Street (Post Office)	40.0	39.3	35.9	36.8	36.0	31.7
St Neots 4	High Street (Traffic lights)	39.9	37.4	35.5	31.0	31.6	28.7
St Neots 5	The Paddocks	27.9	23.5	22.8	20.6	19.6	20.5
Eynesbury	17 Arundel Crescent	25.4	23.4	22.3	21.4	20.3	19.9
Eaton Socon	5 Duchess Close	33.5	29.3	27.9	24.5	23.5	24.5

Figure 5.2: Measured annual average NO_2 concentrations in St Neots



6 Model setup

6.1 Modelling software

Modelling of pollutant concentrations was carried out using the ADMS-Urban model (version 4.1.1)[1]. ADMS-Urban is an advanced dispersion model which is widely used by UK local authorities for the assessment of air quality as part of the Local Air Quality Management process.

6.2 Surface roughness

A parameter called the surface roughness length is used in the model to characterise the area in terms of the effects it will have on wind speed and turbulence, which are key factors in the modelling. The modelling used a roughness length of 0.5 m, which represents relatively open, less built-up, urban areas.

The difference in land use at the meteorological site compared to the modelled area was taken into account, by entering a different surface roughness for the meteorological site. See Section 6.4 for further details.

6.3 Monin-Obukhov length

In urban areas a significant amount of heat is absorbed and re-emitted by buildings and other vegetation-free urban surfaces, which means that the area will tend to warmer than surrounding rural areas, particularly at night. This is known as the urban heat island and its effect is to prevent the atmosphere from becoming very stable. In general, the larger the area the more heat is generated and the stronger the effect.

In the ADMS-Urban model, the stability of the atmosphere is represented by the Monin-Obukhov length parameter, which has the dimension of length. In very stable conditions it has a positive value of between 2 m and 20 m. The effect of the urban heat island is that, in stable conditions the Monin-Obukhov length will never fall below some minimum value; the larger the urban area, the larger the minimum value. As the St Neots urban area is compact and surrounded by rural areas, a minimum Monin-Obukhov length of 30 m was used in the modelling, which is generally intended to represent small towns with populations of less than around 50,000 inhabitants.

[1] http://cerc.co.uk/environmental-software/ADMS-Urban-model.html

6.4 Meteorological data

A year of hourly sequential meteorological data measured at the Bedford site in 2015 was used for the modelling. The measurement site is located approximately 13 km to the west of the St Neots AQMA. Table 6.1 shows the proportion of useable data and Table 6.2 summarises the data used in the modelling. A surface roughness of 0.2 m was used for the meteorological site.

Table 6.1: Hours of meteorological data used

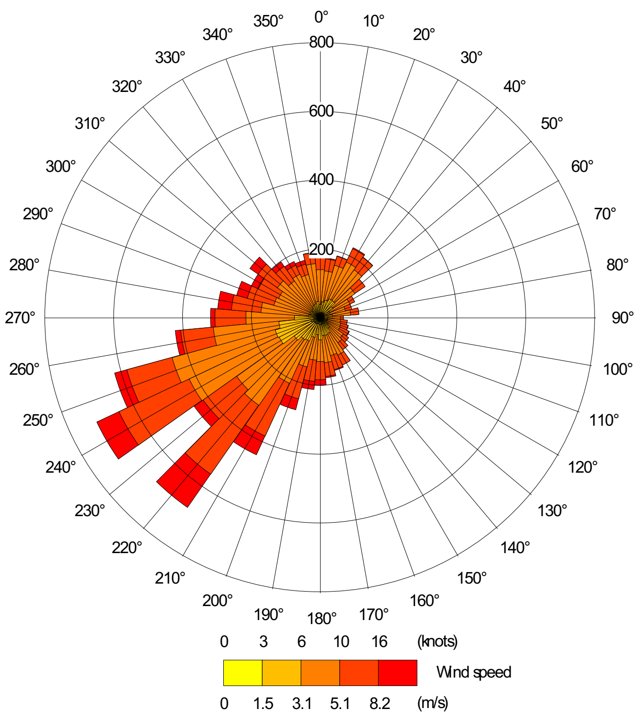
Total number of hours used	8655
Percentage of hours used	98.8

Table 6.2: Summary of meteorological data

	Minimum	Maximum	Mean
Temperature (°C)	-5.5	33.3	10.4
Wind speed (m/s)	0.0	16.5	4.7
Cloud cover (oktas)	0	8	4.8

The ADMS meteorological pre-processor, written by the Met Office, uses the data provided to calculate the parameters required by the program. Figure 6.1 shows a wind rose for the Bedford site, giving the frequency of occurrence of wind from different directions for a number of wind speed ranges.

Figure 6.1: Wind rose for Bedford, 2015



6.5 Background data

A proportion of the emitted nitrogen oxides (NO_x) from the modelled sources will be in the form of nitrogen dioxide (NO_2) and a further proportion will be converted to NO_2 during the time spent in the atmosphere. In order to calculate the conversion of nitric oxide (NO) to NO_2, the ADMS-Urban chemistry module was used in the modelling. The NO_x chemistry calculations in ADMS-Urban take into account emissions and background concentrations of NO_x, NO_2, volatile organic compounds (VOCs) and ozone (O_3). See Appendix A for further information about the NO_x chemistry used in ADMS-Urban.

For the inclusion of NO_x chemistry, and to allow for ambient concentrations of NO_x and NO_2, hourly average background concentrations of NO_x, NO_2 and ozone were input to the model. These data were taken from the rural site at Wicken Fen, downloaded from the National Air Quality Information Archive.[2] Wicken Fen is situated around 40 km to the east of St Neots.

Some statistics calculated from the background data are shown in Table 3.3, to give an idea of the typical concentrations.

Table 3.3: Summary of 2015 background data used in the modelling (µg/m^3)

	Annual average	99.79th percentile of hourly average
NO_2	7.3	43.9
NO_x	9.1	64.3
O_3	54.4	n/a

6.6 Street canyons

The presence of buildings either side of a road can introduce street canyon effects that result in pollutants becoming trapped, leading to increased pollutant concentrations. Street canyon effects were taken into account using the ADMS Advanced Canyon option, which makes use of detailed information for roadside buildings. Street canyon parameters were calculated using building outline data were taken from Ordnance Survey Open Map Local data[3] and height data from the Environment Agency LIDAR data[4].

[2] http://www.airquality.co.uk/archive/data_and_statistics.php
[3] https://www.ordnancesurvey.co.uk/opendatadownload/products.html
[4] http://environment.data.gov.uk/ds/survey/index.jsp#/survey

7 Source data

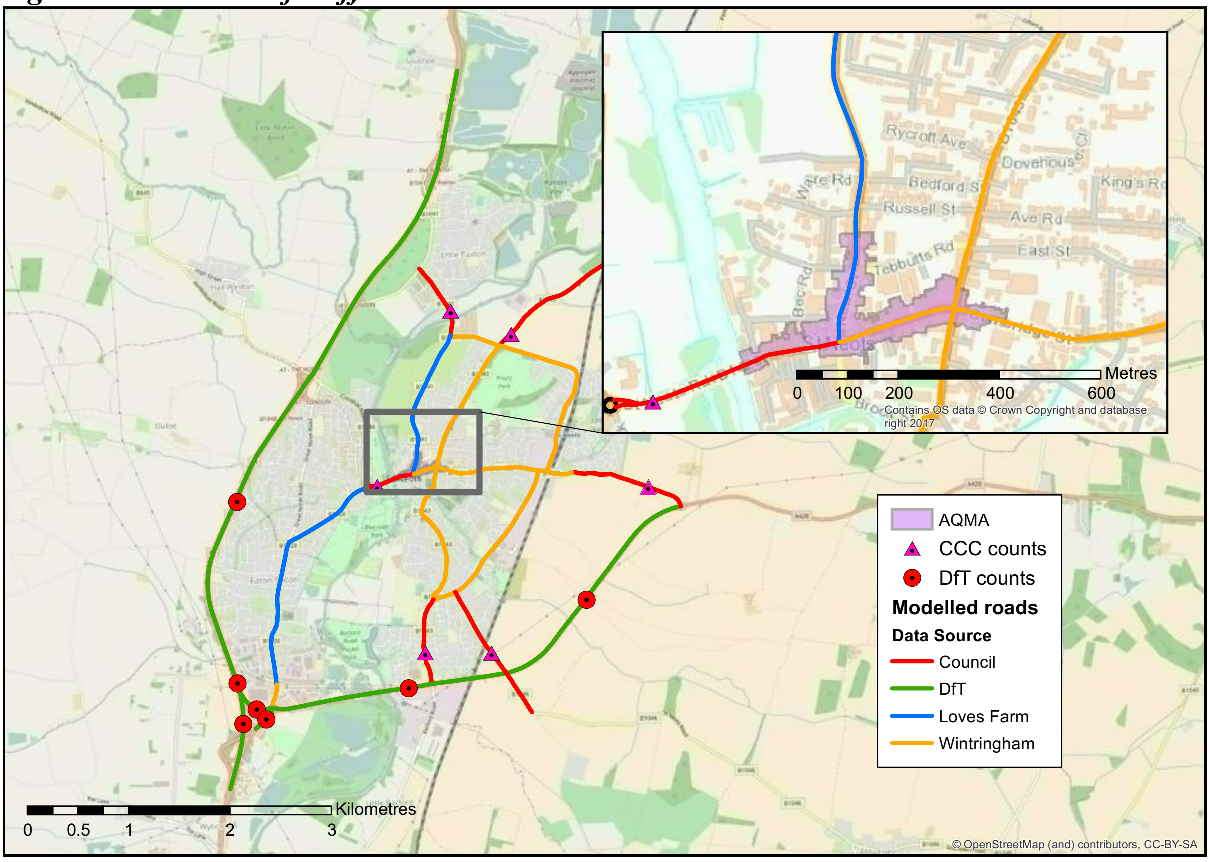
7.1 Road traffic

Traffic data were available from the following sources, listed in order of preference:

- Department for Transport (DfT) traffic counts
- Cambridgeshire County Council traffic counts
- Transport assessments for planning applications at Loves Farm and Wintringham Park

Figure 7.1 shows the source of traffic data for each of the modelled roads.

Figure 7.1: Sources of traffic data



7.1.1 DfT traffic data

Traffic counts for major roads are available from the DfT.[5] These comprise counts for motorcycles, cars, buses and coaches, light goods vehicles (LGV), three categories of rigid heavy goods vehicles (HGV), and three categories of articulated HGVs for 2015.

[5] http://www.dft.gov.uk/traffic-counts/area.php?region=East+of+England&la=Cambridgeshire

7.1.2 Cambridgeshire County Council traffic data

Traffic counts for other major roads in the city are available from the Cambridgeshire County Council website.[6] These data comprise counts of motorcycles, cars, LGVs, buses and HGVs for 2015. These are 12-hour counts which were converted to 24 hour by factors in the Cambridgeshire County Council 2015 Traffic Monitoring Report[7].

7.1.3 Transport Assessments

For roads where no DfT or County Council data were available, data were taken from planning application transport assessments. The two planning applications referred to were:

- the proposed residential development at Loves Farm East; and
- the mixed-use development at Wintringham Park.

7.1.4 Traffic speeds

Traffic speeds for all roads in Cambridge were taken from previous air quality modelling carried out for the city. These were refined by reducing speeds close to junctions and in congested areas; in particular the High Street was modelled with an average speed of 20 km/hr.

7.1.5 Emission factors

Traffic emissions of NO_x and NO_2 were calculated from traffic flows using NAEI 2014 emission factors based on Euro vehicle emissions categories. The emissions calculations used the vehicle fleet composition published by the DfT.

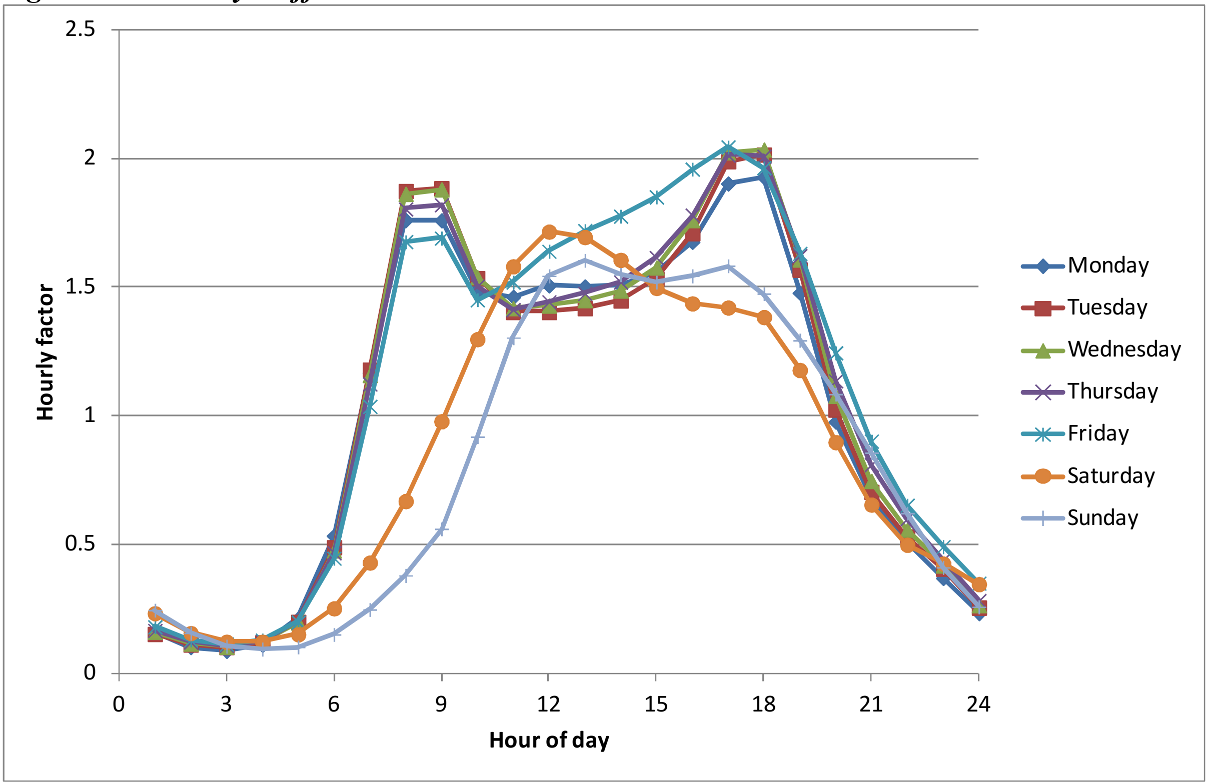
The NAEI 2014 emission factors include speed-emissions data for NO_x based on the COPERT 4 version 10 software tool[8]. The emissions data include primary NO_2 emission factors for each vehicle type resulting in accurate road-by-road NO_x and NO_2 emission rates. Note that there is large uncertainty surrounding the current emissions estimates of NO_x from all vehicle types, in particular diesel vehicles, in these factors; refer to for example an AQEG report from 2007[9] and a Defra report from 2011[10]. In order to address this discrepancy, the NO_x emission factors were modified based on recently published Remote Sensing Data (RSD)[11] for vehicle NO_x emissions in London. Scaling factors were applied to each vehicle category and Euro standard.

[6] https://www.cambridgeshire.gov.uk/residents/travel-roads-and-parking/roads-and-pathways/road-traffic-data/
[7] https://ccc-live.storage.googleapis.com/upload/www.cambridgeshire.gov.uk/residents/travel-roads-and-parking/Traffic_monitoring_report_2015.pdf?inline=true
[8] http://www.emisia.com/copert/General.html
[9] Trends in primary nitrogen dioxide in the UK
[10] Trends in NO_x and NO_2 emissions and ambient measurements in the UK
[11] Carslaw, D and Rhys-Tyler, G 2013: New insights from comprehensive on-road measurements of NO_x, NO_2 and NH_3 from vehicle emission remote sensing in London, UK. *Atmos. Env.* **81** pp 339–347.

7.2 Hourly traffic variation

The variation of traffic during the day was taken into account by applying hourly factors to the average traffic flow. These data were obtained from the DfT road traffic statistics datasets[12] and are shown in Figure 7.2.

Figure 7.2: Hourly traffic variation



7.3 Industrial sources

Emissions from the Little Barford Power Station were included in the modelling using data from the UK Pollutant Release and Transfer (PRTR) data sets[13].

7.4 Other sources

Emissions for all other sources were taken from the National Atmospheric Emissions Inventory (NAEI)[14], and included in the model as grid sources with a 1-kilometre resolution.

[12] https://www.gov.uk/government/collections/road-traffic-statistics
[13] http://prtr.defra.gov.uk/facility-details?view=details&facility_id=2270&year=2014
[14] http://naei.beis.gov.uk/data/gis-mapping

8 Modelled concentrations

8.1 Model verification

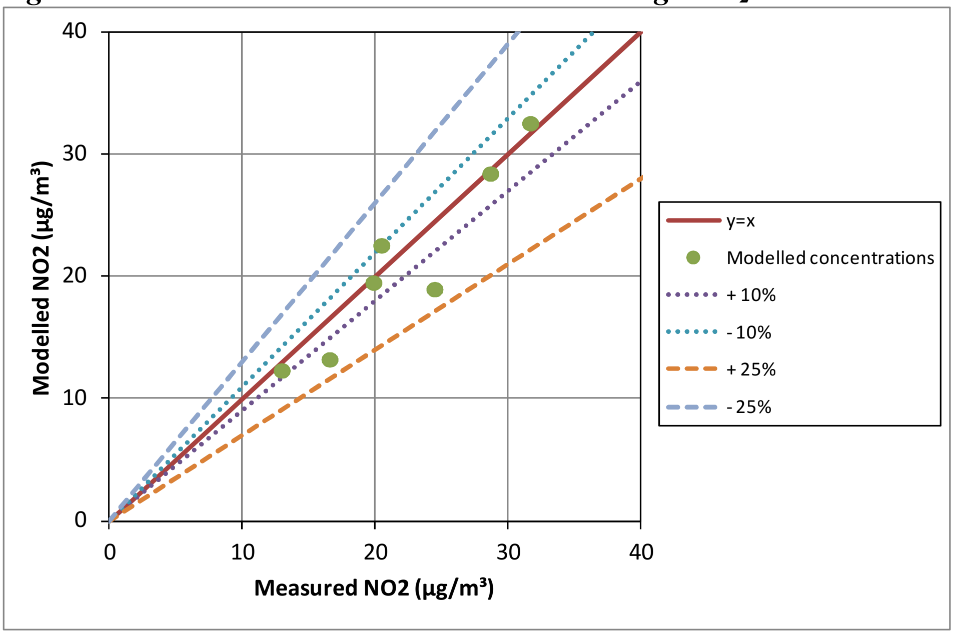
The first stage of dispersion modelling is to model a current case in order to verify that the input data and model setup are representative of the area. This was carried out by comparing the modelled concentrations of NO_2 with those measured at the dispersion tube monitoring sites described in Section 5.

Table 8.1 presents the measured and modelled annual average NO_2 concentrations at the monitoring locations for 2015, together with the modelled concentrations expressed as a percentage of the measured values. A value of 100% indicates perfect agreement between measured and modelled data, with values greater than 100% indicating that the model is over-predicting concentrations and values less than 100% showing model under-prediction. Figure 8.1 shows the same data as a scatter plot.

Table 8.1: Measured and modelled NO_2 concentrations, 2015, µg/m^3

Site name	Location	Annual average NO_2		
		Measured	Modelled	%
St Neots 1	Avenue Road	16.6	13.2	80%
St Neots 2	Harland Road	13.0	12.3	95%
St Neots 3	High Street (Post Office)	31.7	32.6	103%
St Neots 4	High Street (Traffic lights)	28.7	28.4	99%
St Neots 5	The Paddocks	20.5	22.6	110%
Eynesbury	17 Arundel Crescent	19.9	19.5	98%
Eaton Socon	5 Duchess Close	24.5	19.0	77%

Figure 8.1: Measured and modelled annual average NO_2 concentrations



The modelled annual average NO_2 concentrations show generally very good agreement. There is no consistent over or underprediction of concentrations, with five of the seven sites showing agreement within 10%. In particular, at the two sites in the AQMA, the modelled concentrations are within 1% and 3% of the measured values.

These results show that the model setup accurately predicts concentrations at urban background and roadside locations in and around St Neots, and provide confidence in model results.

8.2 Concentration contour maps

Ground level concentrations of NO_2 were calculated for the year 2015, on a regular grid of receptor points covering the AQMA with a resolution of 10 metres. In addition to this regular grid, concentrations were also calculated at additional points along the roads, inside and outside the street canyons, with an along-road resolution of 2 metres.

Figure 8.2 shows the modelled annual average NO_2 concentrations in the AQMA. Figure 8.3 shows the modelled 99.79^{th} percentile of hourly average NO_2 concentrations. In each case, areas coloured yellow and orange show exceedences of the air quality objectives, with green and blue showing areas which meet the objectives.

Exceedences of the objective value for annual average NO_2 concentrations are predicted along sections of the High Street, however, the concentrations at the building facades are all below 40 µg/m³.

Exceedences of the objective value for hourly average concentrations are only predicted in the centre of the junctions of the New Street and Huntingdon Street junctions.

Figure 8.2: Modelled annual average NO_2 concentrations (µg/m³)

Figure 8.3: Modelled 99.79th percentile of hourly average NO_2 concentrations (μg/m³)

9 Discussion

Air quality modelling was carried out using the ADMS-Urban dispersion model.

Concentrations were calculated at the locations of the diffusion tubes in St Neots and the measured and modelled concentrations compared to verify the suitability of the model input data and assumptions. The modelled concentrations generally shows very good agreement, with modelled annual average NO_2 concentrations at five of the seven monitoring sites within 10% of the measured values. In particular, at the two monitoring sites within the AQMA, the modelled concentrations were within 1% and 3% of the measured values, respectively. The model setup can therefore be considered appropriate for the modelled area.

Exceedences of the objective value for annual average NO_2 concentrations are predicted along sections of the High Street, however, these exceedences all occur at locations where the annual average air quality objective does not apply. Concentrations at the building facades, where the annual average objective does apply, are all below 40 $\mu g/m^3$.

To take into account uncertainty in the modelling, a value of 36 $\mu g/m^3$ is sometimes also considered. The only building façade location at which the modelled concentration exceeds 36 $\mu g/m^3$ is outside the Thomas Morris office, where it reaches 39 $\mu g/m^3$.

Exceedences of the objective value for hourly average concentrations are only predicted in the centre of the New Street and Huntingdon Street junctions, i.e. not in areas where the public would be expected to have regular access.

APPENDIX A: Summary of ADMS-Urban

ADMS-Urban is a practical air pollution modelling tool, which has been developed to provide detailed predictions of pollution concentrations for all sizes of study area. The model can be used to look at concentrations near a single road junction or over a region extending across the whole of a major city. ADMS-Urban has been extensively used for the Review and Assessment of Air Quality carried out by Local Authorities in the UK. The following is a summary of the capabilities and validation of ADMS-Urban. More details can be found on the CERC web site at www.cerc.co.uk.

ADMS-Urban is a development of the Atmospheric Dispersion Modelling System (ADMS), which has been developed to investigate the impacts of emissions from industrial facilities. ADMS-Urban allows full characterisation of the wide variety of emissions in urban areas, including an extensively validated road traffic emissions model. It also boasts a number of other features, which include consideration of:

- the effects of vehicle movement on the dispersion of traffic emissions;
- the behaviour of material released into street-canyons;
- the chemical reactions occurring between nitrogen oxides, ozone and Volatile Organic Compounds (VOCs);
- the pollution entering a study area from beyond its boundaries;
- the effects of complex terrain on the dispersion of pollutants; and
- the effects of a building on the dispersion of pollutants emitted nearby.

More details of these features are given below.

Studies of extensive urban areas are necessarily complex, requiring the manipulation of large amounts of data. To allow users to cope effectively with this requirement, ADMS-Urban has been designed to operate in the widely familiar PC environment, under Microsoft Windows. The manipulation of data is further facilitated by the possible integration of ADMS-Urban with a Geographical Information System (GIS) such as MapInfo or ArcGIS, and with the CERC Emissions Inventory Toolkit, EMIT.

Dispersion Modelling

ADMS-Urban uses boundary layer similarity profiles in which the boundary layer structure is characterised by the height of the boundary layer and the Monin-Obukhov length, a length scale dependent on the friction velocity and the heat flux at the ground. This has significant advantages over earlier methods in which the dispersion parameters did not vary with height within the boundary layer.

In stable and neutral conditions, dispersion is represented by a Gaussian distribution. In convective conditions, the vertical distribution takes account of the skewed structure of the vertical component of turbulence. This is necessary to reflect the fact that, under convective conditions, rising air is typically of limited spatial extent but is balanced by descending air extending over a much larger area. This leads to higher ground-level concentrations than would be given by a simple Gaussian representation.

Emissions

Emissions into the atmosphere across an urban area typically come from a wide variety of sources. There are likely to be industrial emissions from chimneys as well as emissions from road traffic and domestic heating systems. To represent the full range of emissions configurations, the explicit source types available within ADMS-Urban are:

- **Industrial points**, for which plume rise and stack downwash are included in the modelling.
- **Roads**, for which emissions are specified in terms of vehicle flows and the additional initial dispersion caused by moving vehicles is also taken into account.
- **Areas**, where a source or sources is best represented as uniformly spread over an area.
- **Volumes**, where a source or sources is best represented as uniformly spread throughout a volume.

In addition, sources can also be modelled as a regular grid of emissions. This allows the contributions of large numbers of minor sources to be efficiently included in a study while the majority of the modelling effort is used for the relatively few significant sources.

ADMS-Urban can be used in conjunction with CERC's Emissions Inventory Toolkit, EMIT, which facilitates the management and manipulation of large and complex data sets into usable emissions inventories.

Presentation of Results

For most situations ADMS-Urban is used to model the fate of emissions for a large number of different meteorological conditions. Typically, meteorological data are input for every hour during a year or for a set of conditions representing all those occurring at a given location. ADMS-Urban uses these individual results to calculate statistics for the whole data set. These are usually average values, including rolling averages, percentiles and the number of hours for which specified concentration thresholds are exceeded. This allows ADMS-Urban to be used to calculate concentrations for direct comparison with existing air quality limits, guidelines and objectives, in whatever form they are specified.

ADMS-Urban can be integrated with the ArcGIS or MapInfo GIS to facilitate both the compilation and manipulation of the emissions information required as input to the model and the interpretation and presentation of the air quality results provided.

Complex Effects - Street Canyons

ADMS-Urban includes two options for modelling the effects of street canyons:
1. The *basic* street canyon option uses the *Operational Street Pollution Model (OSPM)*[15], developed by the Danish National Environmental Research Institute (NERI). The OSPM uses a simplified flow and dispersion model to simulate the effects of the vortex that occurs within street canyons when the wind-flow above the buildings has a component perpendicular to the direction of the street. The model takes account of vehicle-induced turbulence. The model has been validated against Danish and Norwegian data.
2. The *advanced* street canyon option modifies the dispersion of pollutants from a road source according to the presence and properties of canyon walls on one or both sides of the road. It differs from the basic canyon option in the following ways:

(i) It can consider a wide range of canyon geometries, including tall canyons and asymmetric canyons;
(ii) The modelled concentrations vary with height within the canyon;
(iii) Emissions can be restricted only to the carriageway with no emissions on pedestrian areas; and
(iv) Concentrations both inside and outside a particular street canyon are affected.

Complex Effects - Chemistry

ADMS-Urban includes the *Generic Reaction Set (GRS)*[16] atmospheric chemistry scheme. The original scheme has seven reactions, including those occurring between nitrogen oxides and ozone. The remaining reactions are parameterisations of the large number of reactions involving a wide range of Volatile Organic Compounds (VOCs). In addition, an eighth reaction has been included within ADMS-Urban for the situation when high concentrations of nitric oxide (NO) can convert to nitrogen dioxide (NO_2) using molecular oxygen.

In addition to the basic GRS scheme, ADMS-Urban also includes a trajectory model[17] for use when modelling large areas. This permits the chemical conversions of the emissions and background concentrations upwind of each location to be properly taken into account.

---

[15] Hertel, O., Berkowicz, R. and Larssen, S., 1990, 'The Operational Street Pollution Model (OSPM).' *18th International meeting of NATO/CCMS on Air Pollution Modelling and its Applications.* Vancouver, Canada, pp741-749.
[16] Venkatram, A., Karamchandani, P., Pai, P. and Goldstein, R., 1994, 'The Development and Application of a Simplified Ozone Modelling System.' *Atmospheric Environment,* Vol 28, No 22, pp3665-3678.
[17] Singles, R.J., Sutton, M.A. and Weston, K.J., 1997, 'A multi-layer model to describe the atmospheric transport and deposition of ammonia in Great Britain.' In: *International Conference on Atmospheric Ammonia: Emission, Deposition and Environmental Impacts. Atmospheric Environment*, Vol 32, No 3.

Complex Effects – Terrain and Roughness

Complex terrain can have a significant impact on wind-flow and consequently on the fate of dispersing material. Primarily, terrain can deflect the wind and therefore change the route taken by dispersing material. Terrain can also increase the levels of turbulence in the atmosphere, resulting in increased dilution of material. This is of particular significance during stable conditions, under which a sharp change with height can exist between flows deflected over hills and those deflected around hills or through valleys. The height of dispersing material is therefore important in determining the route it takes. In addition, areas of reverse flow, similar in form and effect to those occurring adjacent to buildings, can occur on the downwind side of a hill. Changes in the surface roughness can also change the vertical structure of the boundary layer, affecting both the mean wind and levels of turbulence.

The ADMS-Urban Complex Terrain Module models these effects using the wind-flow model FLOWSTAR[18]. This model uses linearised analytical solutions of the momentum and continuity equations, and includes the effects of stratification on the flow. Ideally hills should have moderate slopes (up to 1 in 2 on upwind slopes and hill summits, up to 1 in 3 in hill wakes), but the model is useful even when these criteria are not met. FLOWSTAR has been extensively tested with laboratory and field data.

Complex Effects - Buildings

A building or similar large obstruction can affect dispersion in three ways:
1. It deflects the wind flow and therefore the route followed by dispersing material;
2. This deflection increases levels of turbulence, possibly enhancing dispersion; and
3. Material can become entrained in a highly turbulent, recirculating flow region or cavity on the downwind side of the building.

The third effect is of particular importance because it can bring relatively concentrated material down to ground-level near to a source. From experience, this occurs to a significant extent in more than 95% of studies for industrial facilities.

The buildings effects module in ADMS-Urban has been developed using extensive published data from scale-model studies in wind-tunnels, CFD modelling and field experiments on the dispersion of pollution from sources near large structures. It operates in the following stages:

(i) A complex of buildings is reduced to a single rectangular block with the height of the dominant building and representative streamwise and crosswind lengths.

(ii) The disturbed flow field consists of a recirculating flow region in the lee of the building with a diminishing turbulent wake downwind, as shown in Figure A1.

(iii) Concentrations within the well-mixed recirculating flow region are uniform and based upon the fraction of the release that is entrained.

(iv) Concentrations further downwind in the main wake are the sum of those from two plumes: a ground level plume from the recirculating flow region and an elevated plume from the non-entrained remainder.

[18] Carruthers D.J., Hunt J.C.R. and Weng W-S. 1988. 'A computational model of stratified turbulent airflow over hills – FLOWSTAR I.' Proceedings of Envirosoft. In: *Computer Techniques in Environmental Studies,* P. Zanetti (Ed) pp 481-492. Springer-Verlag.

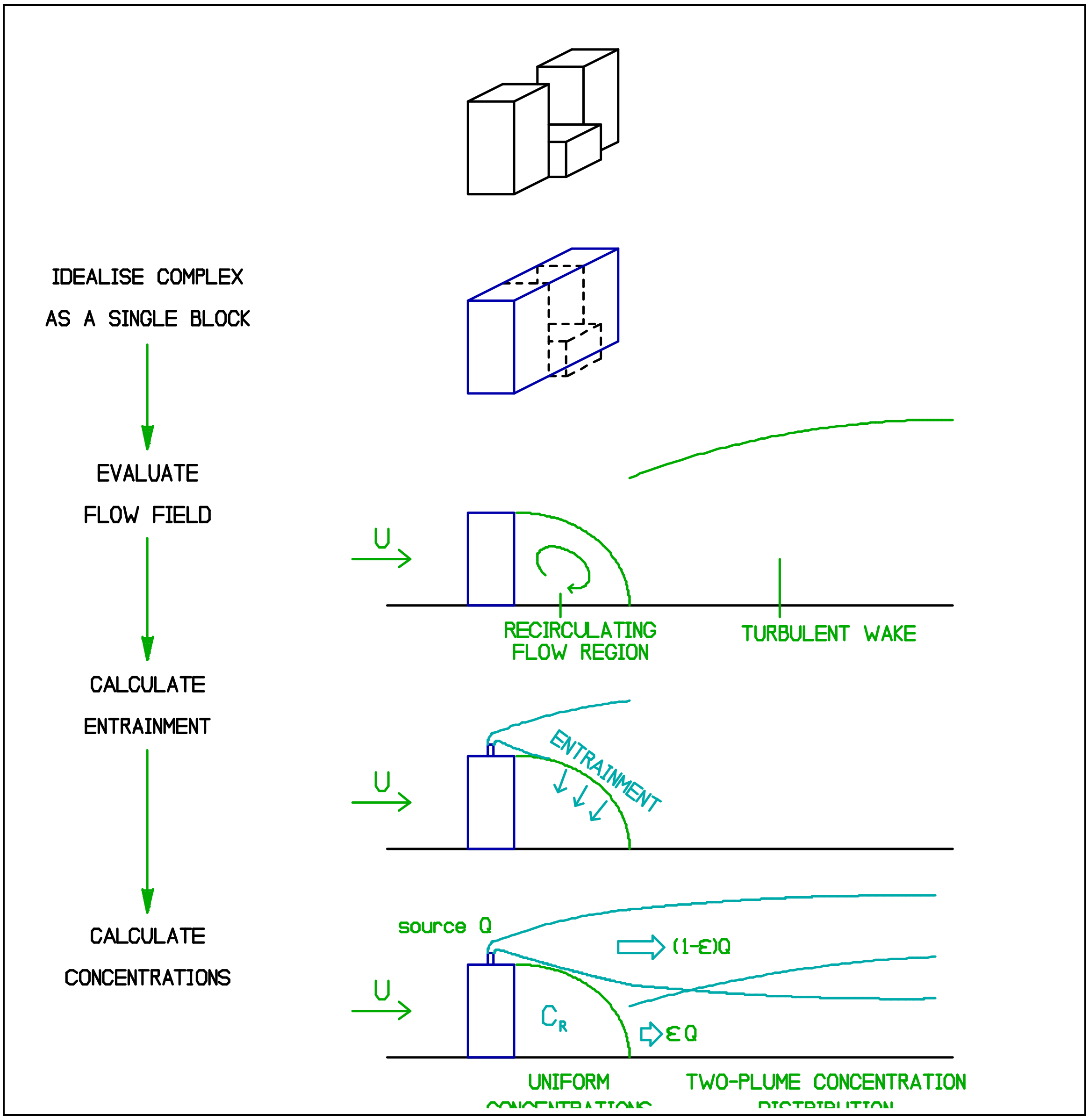


Figure A3.1: Stages in the modelling of building effects

Data Comparisons – Model Validation

ADMS-Urban is a development of the Atmospheric Dispersion Modelling System (ADMS), which is used throughout the UK by industry and the Environment Agency to model emissions from industrial sources. ADMS has been subject to extensive validation, both of individual components (e.g. point source, street canyon, building effects and meteorological pre-processor) and of its overall performance.

ADMS-Urban has been extensively tested and validated against monitoring data for large urban areas in the UK, including Central London and Birmingham, for which a large scale project was carried out on behalf of the DETR (now DEFRA).

Further details of ADMS-Urban and model validation, including a full list of references, are available from the CERC website at www.cerc.co.uk.