London City Airport

London City Airport master plan

Air Quality Assessment

Final | April 2019

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 261746-04

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Executive Summary

Ove Arup & Partners Ltd (Arup) was commissioned by London City Airport to prepare an air quality assessment to inform the draft master plan for consultation. A local air quality emissions inventory was compiled and used as input to the ADMS-Airport dispersion model to calculate air pollutant concentrations at human receptors.

The airport is located in the London Borough of Newham. In 2018, there were 80,668 air traffic movements (ATMs) and 4.8 million passengers. In 2035, it is predicted that there will be 151,500 ATMs and 11mppa. The 2035 fleet mix is forecast to include around 75% of next generation aircraft which are more fuel efficient than the comparable existing aircraft fleet.

Air quality concentrations

Air quality monitoring data undertaken by London City Airport in 2018 and previous years shows that air quality in the vicinity of the airport meet the UK air quality objectives for nitrogen dioxide (NO_2) and particulate matter (PM_{10} and $PM_{2.5}$). Modelling of the current scenario also predicted that pollutant concentrations near to the Airport meet the UK objectives.

Current measures being rolled out at the airport include:

- use of a gas-fired Combined Heat and Power (CHP) systems to suit the airport’s base load profiles and photovoltaic panels on the terminal building roof;
- provision of ultra-low NOx boilers and CHP systems that include 95% catalytic reduction of emissions;
- installation of fixed electrical ground power (FEGP) on all new and reconfigured stands as part of the City Airport Development Programme (CADP);
- an airport-wide strategy for expanding the use of low emission and electric vehicles; requiring all vehicles issued with a new Airside Vehicle Permit to comply with the latest vehicle emissions standards for road vehicles (Euro Standards); and controlling Auxiliary Power Units (APU) ground running and engine testing and undertaking routine emissions testing for airside vehicles.

The dispersion modelling of the current baseline scenario and growth to 151,000 ATMs by 2035 took into account all relevant local sources of emissions: aircraft on the ground and aloft, other on-airport sources, road traffic, energy sources. Emissions from sources outside the local area were taken into account through the background pollutant concentrations. The assessment started in 2018 and used the latest year for which data were available, 2017.

The highest predicted annual mean NO_2 and PM_{10} concentrations in 2017 were at R40 Royals Business Park Hotel (34.3µg/m^3 and 17.9µg/m^3 respectively) The highest predicted annual mean $PM_{2.5}$ concentrations were at R40 at Royals Business Park Hotel and R1 at Camel Road/Hartmann Road (11.6µg/m^3).

In 2035 the maximum predicted concentrations are predicted to decrease. The highest predicted annual mean NO_2 concentration was at R2 Camel Road/Parker Street (21.6µg/m^3) and the highest predicted annual mean PM_{10} concentration is at R40 at Royals Business Park Hotel (16.8µg/m^3). The highest annual mean $PM_{2.5}$ concentration is predicted at four sites (R2 at Camel Road/Parker Street, R8 at Albert Road/Woolwich Manor Way, R26 at Felixstowe Court, R40 at Royals Business Park Hotel) with a concentration of 10.4µg/m^3.

While growth to 151,000 ATMs by 2035 would lead to increased aircraft activity, concentrations of NO_2, PM_{10} and $PM_{2.5}$ are predicted to decrease and would therefore remain below the UK's air quality objectives. The decrease in concentrations is due to the predicted decrease in road traffic emissions due to tighter emissions regulations and in background concentrations to 2035.

Further initiatives to improve air quality in 2035 would include:

- working with airlines to encourage improvements in aircraft performance and so reduce emissions;
- provision of Fixed Electrical Ground Power on all future stands;
- ensuring all vehicles owned by the airport will be ULEZ compliant by December 2020;
- ensuring all airside vehicles with a permanent vehicle pass will be electric (or zero emissions) or use renewable fuels by 2030; and
- 300 parking spaces (1 in 5) with electric charging points by 2035 with provision for electric charging or zero emission vehicles on all other spaces.

Abbreviations

AADT	Annual Average Daily Traffic
APU	Auxiliary Power Unit
AQMA	Air Quality Management Area
ATMs	Air traffic movements
CADP	City Airport Development Programme
CERC	Cambridge Environmental Research Consultants
DfT	Department for Transport
EA	Environment Agency
EDMS	Emissions and Dispersion Modelling System
EEA	European Economic Area
EFT	Emissions Factor Toolkit
FEGP	Fixed Electrical Ground Power
FOCA	Swiss Federal Office for Civil Association
FOI	Swedish Defence Research Agency
GPU	Ground Power Unit
GSE	Ground Support Equipment
HGV	Heavy Goods Vehicle
ICAO	International Civil Aviation Organization
LTO	Landing and Take-off
MCAT	Modelling Category
mppa	Million passengers per annum
$\mu g/m^3$	Micrograms per cubic metre
NAEI	National Atmospheric Emissions Inventory
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NOx	Oxides of Nitrogen (NO and NO_2)
NPPF	National Planning Policy Framework
NRMM	Non-Road Mobile Machinery
OS	Ordnance Survey
$PM_{2.5}$	Airborne particulate matter passing a sampling inlet with a 50% efficiency cut off at 2.5µm aerodynamic diameter and which transmits particles of below this size
PM_{10}	Airborne particulate matter passing a sampling inlet with a 50% efficiency cut off at 10µm aerodynamic diameter and which transmits particles of below this size
pNO_2	Primary NO_2
ppb	Parts per billion
PSDH	Project for Sustainable Development of Heathrow

1 Introduction

Ove Arup & Partners Ltd (Arup) was commissioned by London City Airport to prepare an air quality assessment to inform the draft masterplan. The airport is located in the London Borough of Newham. In 2017 there were 80,668 air traffic movements (ATMs) and 4.8 million passengers per annum (mppa), where as in 2035 there is predicted to be 151,500 ATMs and 11mppa.

The air quality model covers all sources contributing to air concentrations of the key pollutants, such as the aircraft and all activity on the airport, traffic on the surrounding highway network, car parks and the background pollutant concentrations due to emission sources outside the local area.

This report describes the relevant legislation, policy and guidance, the methodology used and the baseline conditions in section 2 to section 5. The dispersion modelling in section 6 before concluding.

2 Air quality legislation

2.1 European Air Quality Management

In 1996 the European Commission published the Air Quality Framework Directive on ambient air quality assessment and management (96/62/EC)[1]. This Directive defined the policy framework for 12 air pollutants known to have harmful effects on human health and the environment.

Limit values (*pollutant concentrations not to be exceeded by a certain date*) for each specified pollutant were set through a series of Daughter Directives: Directive 1999/30/EC (the 1st Daughter Directive)[2] for NO_2 and PM_{10} (amongst other pollutants); Directive 2000/69/EC (the 2nd Daughter Directive)[3] for benzene and carbon monoxide; Directive 2002/3/EC (the 3rd Daughter Directive)[4] for ozone; and Directive 2004/107/EC (the 4th Daughter Directive)[5] for certain toxic heavy metals and polycyclic aromatic hydrocarbons.

In May 2008 the Directive 2008/50/EC[6] on ambient air quality and cleaner air for Europe came into force. This Directive consolidates the Air Quality Framework Directive and Daughter Directives 1 to 3, makes provision for extended compliance deadlines for NO_2 and PM_{10} and introduces standards for $PM_{2.5}$. The Directive was transposed into national legislation in England by the Air Quality Standards Regulations 2010[7]. The Secretary of State for the Environment has the duty of ensuring compliance with the air quality limit values.

2.2 Environment Act 1995

Part IV of the Environment Act 1995[8] places a duty on the Secretary of State for the Environment to develop, implement and maintain an Air Quality Strategy with the aim of reducing atmospheric emissions and improving air quality. The *Air Quality Strategy for England, Scotland, Wales and Northern Ireland*[9] (NAQS) provides the framework for ensuring compliance with the air quality limit values based on a combination of international, national and local measures to reduce emissions and improve air quality. This includes the statutory duty, also under Part IV of the Environment Act 1995, for local authorities to undergo a process of local

[1] Directive 96/62/EC of 27 September 1996 on ambient air quality assessment and management
[2] Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air
[3] Directive 2000/69/EC of the European Parliament and of the Council of 16 November 2000 relating to limit values for benzene and carbon monoxide in ambient air
[4] Directive 2002/3/EC of the European Parliament and of the Council of 12 February 2002 relating to ozone in ambient air
[5] Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air
[6] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe
[7] The Air Quality Standards Regulations 2010, SI 2010/1001
[8] Environment Act 1995, Chapter 25, Part IV Air Quality
[9] The Air Quality Strategy for England, Scotland, Wales and Northern Ireland, Volume 1, July 2007

air quality management and declare Air Quality Management Areas (AQMA) where necessary.

2.3 Air Quality Standards

The air quality limit values set by the European legislation have been transposed into national law (as the UK air quality objectives). Some pollutants have standards expressed as annual average (long-term) concentrations due to the chronic way in which they affect health or the natural environment (i.e. effects occur after a prolonged period of exposure to elevated concentrations) and others have standards expressed as 24-hour, 1-hour or 15-minute (short-term) average concentrations due to the acute way in which they affect health or the natural environment (i.e. after a relatively short period of exposure). Some pollutants have standards expressed in terms of both long-term and short-term concentrations.

In this assessment, the term 'air quality standard' has been used to refer to both the UK objectives and European limit values. Table 1 sets out the air quality standards for the pollutants of most relevance to this study (NOx, NO_2, PM_{10} and $PM_{2.5}$). Other pollutants have been screened out of this air quality assessment, since they are not likely to cause exceedances of their respective standards.

Table 1: Air quality standards

Pollutant	**Averaging period**	**Air quality standard**
Human health		
Nitrogen Dioxide (NO_2)	Annual mean	40µg/m^3
	1-hour mean	200µg/m^3 [1]
Particulate Matter (PM_{10})	Annual mean	40µg/m^3
	24-hour mean	50µg/m^3 [2]
[1] not to be exceeded more than 18 times a year (99.79th percentile)		
[2] not to be exceeded more than 35 times a year (90.41st percentile)		

3 Policy and guidance

3.1 National

3.1.1 Aviation Policy Framework (2013)

The Aviation Policy Framework[10] reinstates the Government's commitment to achieve full compliance with European air quality standards. It also states that the policy in relation to air quality is to "seek improved international standards to reduce emissions from aircraft and vehicles". It further identifies road transport as the main source of pollution around airports, as emissions from aircraft fall off significantly from the runway.

3.1.2 Aviation 2050 – the future of UK aviation

The consultation outcome of the first stage in developing the new aviation strategy outlines six objectives[11]. One of which states "to support growth while tackling environmental impacts". It proposes to achieve this by reviewing the latest government policy and guidance, examine the suitability of the existing framework, and "explore setting…aviation specific air quality targets".

This subsequently led to the draft Aviation 2050 strategy[12] which includes policy detail for the six objectives outlined. It identifies three main sources of pollutants which arise in relation to the aviation industry. This includes airborne aircraft, airside operations and surface access, which refers to transportation to and from the airport, and is recognised as the primary source affecting air quality. It highlights the need for "making best use of existing runways" and sustainable growth of the sector. The strategy highlights the need, at a national level, for improved monitoring of UFPs to improve the understanding of aviation's impact on local air quality and proposes that all major airports should develop air quality plans to manage emissions.

3.1.3 UK Clean Air strategy

The UK Clean Air strategy[13] states that *"the biggest domestic impact of aircraft is during take-off and landing (1% of total NOx and SO_2 national emissions)"*, but notably airports also *"generate significant land journeys by passengers, workers and freight transport"*. The strategy states that the Government will work with stakeholders of the aviation industry to implement the Aviation 2050 strategy.

[10] Department for Transport (2013) Aviation Policy Framework

[11] Department for Transport (2018) Beyond the horizon, The future of UK aviation, Making best use of existing runways, Department for Transport, June 2018, ISBN: 978-1-84864-206-5

[12] Department for Transport (2018) Aviation 2050 – the future of UK aviation

[13] Department for Environment and Rural Affairs (2019) UK Clean Air Strategy

3.1.4 Local Air Quality Management Policy Guidance (2009)

LAQM (PG16) [14] provides guidance on the links between air quality and the land-use planning system. The accompanying technical guidance, Technical Guidance (TG16)[15], although designed to support local authorities in carrying out their duties to review and assess air quality in their area contains general advice on dispersion modelling assessments of air quality impacts.

3.2 Local

3.2.1 The London Borough of Newham

The LBN's Local Plan (2018)[16] discusses air quality.

In the Sustainability and Climate Change theme, policy SC5 Air Quality, the following strategic principals, spatial strategy and design and technical criteria are outlined:

> *"1. Strategic Principals:*
>
> *a. All development should be at least Air Quality Neutral, supporting a net decrease in specified pollutants and making design, access, energy, and management decisions that minimise air pollution generation and exposure at demolition, construction, and operation stage; and*
>
> *b. Development will support implementation of Newham's Air Quality Action Plan, ensuring identified actions and mitigation are incorporated where relevant.*
>
> *2. Spatial Strategy:*
>
> *a. Development along major roads or in other locations that experience air quality exceedances1 should be configured to improve the dispersal of identified pollutants and reduce exposure without compromising SP7 objectives; and*
>
> *b. Development close to navigable waterways should maximise use of waterborne freight and waste movement during construction and operation.*
>
> *3. Design and technical criteria:*
>
> *a. Air quality neutrality should be demonstrated using methodologies set out by the London Plan and related guidance;*
>
> *b. All Major development should detail how it aligns with the Mayor of London's Control of Dust & Emissions during Construction & Demolition SPG2 or subsequent updates;*

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[14] Department for Environment and Rural Affairs 2016) Local Air Quality Management Policy Guidance, PG16

[15] Department for Environment and Rural Affairs (2016) Local Air Quality Management Technical Guidance, TG16

[16] London Borough of Newham (2018) Newham Local Plan 2018

c. Waste facilities and other dust and emissions-generating uses should be fully enclosed or provide an equivalent level of environmental protection with respect to air emissions;

d. Developments should only deploy combustion-based energy sources (including CHP, biomass boilers, and wood-burning stoves) as a last resort; those that do should demonstrate use of low-emission plant and post process mitigation/treatment where necessary to avoid an increase in controlled pollutants; and

e. Developments likely to generate any significant traffic, and hence air quality impacts, on the A12 and A406 (whether alone or in combination with other development) which pass within 200m of the Epping Forest SAC will need to undertake an assessment of impact on the SAC as part of the HRA."

These policy notes were reflected on while writing this air quality assessment.

3.2.2 The Royal Borough of Greenwich

The Royal Greenwich Local Plan[17] was adopted in July 2014. It sets out a strategy to guide developments over the period to 2028. Policy E(c) addressing air pollution states:

"Development proposals with the potential to result in any significant impact on air quality will be resisted unless measures to minimise the impact of air pollutants are included. Such planning applications should be accompanied by an assessment of the likely impact of the development on air quality.

All new developments with a floor space greater than 500sqm or residential developments of 10 or more units are required to reduce carbon dioxide (CO_2), particulate matter (PM_{10}) and nitrogen dioxide (NO_2) emissions from transport through the use of measures such as those set out in DEFRA guidance 'Low Emissions Strategies: using the planning system to reduce transport emissions Good Practice Guidance -January 2010'."

3.3 Other relevant policy and guidance

3.3.1 ICAO Airport Air Quality Manual (2011)

ICAO has published a manual for assessing air quality at airports.[18] This document describes the methods for calculating emissions during different operating modes of the aircraft, as well as different sources of air pollution found at airports.

[17]Royal Borough of Greenwich (2014) Royal Greenwich Local Plan: Core Strategy with Detailed Policies
[18] ICAO (2011) Airport Air Quality Manual

4 Methodology

This section describes the methodology used to create the emissions inventory and to undertake the dispersion modelling for air. Further details of the methodology are given in Appendices A to F.

The assessment started in 2018 and used the latest year for which data were available, 2017.

The use of 2017 as the baseline year will not affect the future predictions as a verification has been carried out using a compatible set of data for the baseline: aircraft and airport activity data, traffic activity data, emissions factors, background concentrations and meteorology. The verified concentrations have been used in the calculation of the future concentrations. Use of 2018 as the baseline year would not make a material difference.

4.1 Assessment years and scenarios

The following assessment years and scenarios have been included in the air quality assessment:

- 2017 baseline year
- 2035 future year

Table 2 presents the passenger numbers and aircraft movements for the assessment years and scenarios.

Table 2: Assessment years and scenarios

Scenario	Million passengers per annum (mppa)	Air traffic movements (ATMs)
2017 baseline year	4.5	80,299
2035 future year	11.0	151,500

4.2 Data sources

The following data sources have been used to inform the assessment:

- Monitoring reports for the London Borough of Newham and the Royal Borough of Greenwich[19,20, 21]
- Monitoring report for London City Airport[22,23];

[19] London Borough of Newham (2017) Annual Status Report 2016
[20] London Borough of Newham (2017) NO2 diffusion sample report – bias corrected summary
[21] Royal Borough of Greenwich (2018) Royal Greenwich Annual Status Report
[22] Air Quality Consultants (2018) Air Quality Monitoring Strategy: Annual Report 2017
[23] London City Airport 2018 Annual Performance Report, Annex 7, London City Airport, Air Quality Monitoring Strategy: Annual Report 2018, March 2019

- The UK Air Information Resource website[24];
- Aircraft fleet and airside operational data from London City Airport (e.g. detailed annual flight record, airside vehicles and fuel usage, engine testing records, fuel usage for the fire training ground and transaction data for car parks);
- The ICAO aircraft engine emissions databank[25];
- The ICAO airport air quality manual document no. 9889[18];
- The International Air Transport Association (IATA) long-term traffic and emission forecasts[26];
- The Emissions and Dispersion Modelling System (EDMS) software[27];
- The Aviation Environmental Design Tool (AEDT)[28];
- The Swedish Defence Research Agency (FOI) database for turboprop engine emissions (used with permission)[29];
- The Swiss Federal Office for Civil Association (FOCA) database for piston engine emissions[30];
- The Project for Sustainable Development of Heathrow (PSDH) methodology[31];
- The Emissions Inventory Toolkit (EMIT)[32];
- The European Environment Agency EMEP/EEA air pollutant emissions inventory guidebook[33];
- The National Atmospheric Emissions Inventory (NAEI)[34]; and
- The updated environmental statement of the City Airport Development Programme (CADP)[35].

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[24] http://uk-air.defra.gov.uk/

[25] https://www.easa.europa.eu/document-library/icao-aircraft-engine-emissions-databank (version 25a of 28/05/2018)

[26] IATA (2014) HKIA long-term traffic and emission forecast: Emission Forecasting Report Version 3

[27] https://www.faa.gov/about/office_org/headquarters_offices/apl/research/models/edms_model/

[28] https://aedt.faa.gov/

[29] https://www.foi.se/en/our-knowledge/aeronautics-and-air-combat-simulation/fois-confidential-database-for-turboprop-engine-emissions.html

[30] https://www.bazl.admin.ch/bazl/de/home/fachleute/regulation-und-grundlagen/umwelt/schadstoffemissionen/triebwerkemissionen.html

[31] Department for Transport (2007) Project for the Sustainable Development of Heathrow, Report of the Air Quality Technical Papers

[32] https://www.cerc.co.uk/environmental-software/EMIT-tool.html

[33] European Environment Agency (2016) EMEP/EEA air pollutant emission inventory guidebook 2016

[34] http://naei.defra.gov.uk/

[35] London City Airport (2015) City Airport Development Programme – Updated Environmental Statement (September 2015)

4.3 Study area and sensitive receptors

The study area for this assessment has been defined as a 6km x 3km domain centred on the airport to account for sources of emissions at the airport, the highway network and the surrounding domestic and commercial land uses.

Sensitive human receptors are defined as those residential properties, schools, hospitals or care homes that are likely to experience a change in pollutant concentrations. The receptors have been chosen to be indicative rather than exhaustive. Where appropriate, receptors at height have been selected to account for blocks of flats.

There are sensitive human receptors in all directions around the airport. A total of 56 representative receptors close to the airport and/or road junctions in the study area (eight educational establishments, one healthcare facilities and 47 residential dwellings) were selected for inclusion in the assessment. Appendix A presents details of the human receptors sensitive to air quality and their location in the study area. There are no sensitive ecological receptors within 1km of the airport.

Concentrations at receptors outside the study area, at greater distances from the airport, will be lower than those at the modelled receptors due to the greater distance from the ground-based airport sources and their greater distance from aircraft aloft. Away from the immediate vicinity of the airport the greatest contributor to concentrations is usually road traffic.

4.4 Methodology for compilation of emissions inventory

An inventory of NOx, primary NO_2 (pNO_2)[36], PM_{10} and $PM_{2.5}$ emissions was compiled for the following pollution sources:

- Aircraft main engines in the landing and take-off (LTO) cycle;
- Aircraft auxiliary power units (APUs), while in use on the ground;
- Ground support equipment (GSE), namely airside vehicles which handle aircraft turn-arounds, load and unload baggage and cargo, and conduct inspections and essential maintenance of airfield infrastructure, particularly the runway which is in constant use;
- Other airport sources, including car parks, airport heating plant, ground power units and the fire training ground; and
- Road vehicles using the local and strategic highway network around the airport.

4.4.1 Aircraft emissions during the LTO cycle

ICAO defines the LTO cycle as the emissions associated with aircraft operations up to a height of 3,000ft. Emissions from aircraft were calculated using fleet data

[36] Primary NO_2 refers to the proportion of NOx that is emitted as NO_2.

provided by London City Airport, consisting of annual aircraft movements recorded in 2017. The fleet data was used to build the emissions inventory for all modes of the LTO cycle: taxiing; hold; take-off roll; initial climb; climb out; approach; and landing.

Aircraft emissions were calculated up to a height of 3,000ft. However, ground level concentrations are not significantly affected by aircraft emissions at altitudes above approximately 500m. Therefore, the dispersion modelling assessment has been undertaken up to a height of 457.2m (1,500ft).

The detailed aircraft movement data was used to identify the main types of aircraft that used the airport in 2017. These were merged into categories of similar aircraft types, relating to short/long haul and narrow/wide body aircraft, and number and type of engines (Table 3). For each modelling category (MCAT), a representative aircraft type was selected and information on their engines obtained using an in-house aircraft fleet database and online resources[37]. Emissions were calculated for the top engines and aircraft types within each MCAT. Further details on the engine variants used for each category are presented in Appendix B.

Table 3: Aircraft modelling categories

MCAT	Description
1	Turboprop engine aircraft (DHC Dash 8 type)
2	Turboprop engine aircraft (Saab 2000 type)
3	Narrow body, short to medium range aircraft (Airbus A318)
4	Regional jets, short to medium range (Embraer 190/ 170 type)
5	Regional jet, short to medium range (Airbus A220)
6	Regional jets, short to medium range aircraft with four engines (British Aerospace jets)
7	Narrow body, short to medium range aircraft (Airbus A320NEO)
8	Regional jet, short to medium range (Embraer 190-E2)

Turbofan engine emission factors of NOx and fuel consumption rates were taken from the ICAO aircraft engine emissions databank[25] or for MCAT 8 calculated using the product specification produced by MTU Aero Engines[38]. Emissions of pNO_2 were derived using the fractions described in the PDSH methodology. PM_{10} emissions were derived from the smoke number following the methodology described in the ICAO airport air quality manual (Document No. 9889). In relation to $PM_{2.5}$ emissions, the EMEP/EEA guidebook[33] states that "it is reasonable to assume that for aircraft, the particulate matter emissions can be considered as $PM_{2.5}$". Therefore, it was assumed that all particulate matter emissions from aircraft engines were in the $PM_{2.5}$ fraction.

For aircraft with turboprop engines, emission factors and fuel rates were taken from the FOI confidential database[29]. For aircraft with piston engines, emission factors and fuel rates were taken from the FOCA database[30]. For a representative aircraft

[37] https://www.planespotters.net/
[38] https://www.mtu.de/fileadmin/EN/7_News_Media/2_Media/Brochures/Engines/PW1000G.pdf

in each MCAT, Bickerdike Allen Partners used the AEDT[28] to provide information on the speeds and angles for the modes of take-off, climb, approach and landing This was used to derive horizontal distance and time in mode for take-off, initial climb, climb out and approach. Further details on the emission factors and assumptions for each LTO mode are presented in Appendix B.

The detailed fleet data for 2017 was further used to derive the runway utilisation for this year, which is presented in Table 4. Diurnal profiles derived from the detailed hourly 2017 data, were applied to all the aircraft departures and arrivals (Appendix D).

Table 4: Runway use in 2017

Runway	ATMs	ATMs (% of total)
09	20,878	26
27	59,421	74

4.4.2 Auxiliary power units (APUs)

APUs were modelled at the stands and were represented as volume sources in the model. Emission rates of NOx and PM_{10} were obtained from the EDMS software[27] and IATA's long-term traffic and emission forecast[26]. The emission rates are detailed in Appendix B.

The Airside Operating Instructions (AOI 07)[39] on aircraft noise specifies that FEGP or ground power units (GPUs) should be used wherever possible and APUs should be shut down as soon as practicable following arrival and must not be restarted until 10mins prior to leaving the stand. The updated environmental statement of the CADP[35] states that the APU running times on arrival range from one to five minutes. The assessment in the CADP therefore used a total APU running time of 13mins, which has been used in the assessment of the baseline scenario.

APUs are also allowed to operate when conditioning of the cabin is required due to outside temperatures (below 5°C or above 20°C). These operations due to temperature are recorded by Air Traffic Control (ATC). A schedule of these APU operations have been provided by London City Airport and the emissions from them were included in the baseline scenario.

The airport provided fixed electrical ground power (FEGP) at stands 1 to 10 and 15 in 2017. For the future scenario, it has been assumed that the FEGP will be available at all stands and there will not be a need to run APU for 10mins prior to leaving the stands. It is assumed that ground power units (GPUs) will only be used for aircraft at the jet centre. However, the APU may still be required on arrival. Therefore, an APU running time of 3mins was used in the 2035 future scenario.

[39] London City Airport (2016) Airside Operating Instruction – AOI 07 Aircraft Noise & Maintenance

4.4.3 Other airport sources

Aircraft engine testing

Aircraft engines are tested at the airport at the stands (a figure of the airfield is included in Appendix B). Ground idle runs are completed at all stands and high-power runs are completed at stands 10 and 24. The engine tests were included in the model as volume sources with a height of 5m. Detailed data on the engine tests was provided by London City Airport for 2017 and this is presented in Appendix B.

Fire training ground

The fire training ground is located to the west of the airport. The training ground is operated by London City Airport's fire services for training purposes, using red diesel, propane and wood as the combustion fuels. Emission factors were taken from the NAEI. The fuel use from the operation of this facility was provided by London City Airport and is presented in Appendix B.

Ground support equipment (GSE)

GSE at the airport includes a range of different vehicles, such as belt-loaders, tugs, towers, hydraulic lift platforms and de-icing units. Data for airside vehicles at the airport was provided by London City Airport, consisting of a record of all permitted vehicles for airside access, total number of airside vehicles operating at the airport and total fuel used in 2017. Details for this source are presented in Appendix B.

For the emissions calculations, GSE was split into road vehicles and non-road mobile machinery (NRMM). From the record of licenced vehicles, it was derived that 20% of GSE (that was not noted as electric) is NRMM and 80% road vehicles. The roads vehicles were further split into cars (12%), light goods vehicles (LGVs) (43%), buses and heavy goods vehicles (HGVs) (44%). It was assumed that all NRMM on the airport comply with Stage IIIA emission standards and that road vehicle GSE comply with Euro 4/IV emission standards. It was further assumed that all GSE use diesel fuel.

Emissions of NOx, PM_{10} and $PM_{2.5}$ were taken from the EMEP/EEA air pollutant emissions inventory[33] for NRMM and road vehicle GSE. LGVs were selected to be light duty vehicles N1(II)/N1(III), buses and HGVs were selected to be rigid 12-14t vehicles. For the NRMM, emissions of pNO_2 were assumed to be the urban traffic UK fleet average for 2017 (28%) and 2035 (25%), taken from the NAEI[34]. For road vehicle GSE, emissions of pNO_2 were taken for each type of vehicle and Euro standard, i.e. 42% for Euro 4 diesel cars (any engine size), 46% for LGVs and 10% for buses and HGVs, taken from NAEI[34].

An average fuel consumption of 12.3mpg (23.0 litres per 100km) was used for buses and HGVs, taken from the Department for Transport (DfT) fuel consumption statistical data[40]. For the cars and LGVs, an average fuel consumption of 25.9mpg and 19mpg, respectively, (10.9 and 14.9 litres per 100km respectively) was used, taken from the DfT energy and environment data tables[41]. Vehicles were assumed

[40] Department for Transport (2016), Fuel consumption statistical data set ENV01,
[41] https://www.gov.uk/government/statistical-data-sets/energy-and-environment-data-tables-env

to travel with a speed of 10mph (16kph), which is the speed limit for the apron roadways (as specified in AOI 12[42]).

GSE emissions were distributed spatially on the aprons of the airport, based on the stand usage for 2017.

Ground power units (GPUs)

GPUs are used at the airport to provide power to an aircraft while at stand, where FEGP is not provided or not working. Data for the fuel used by GPUs was provided by London City Airport and emissions were distributed spatially on the aprons, similar to GSE. Further details are provided in Appendix B.

Energy centre

The airport has one energy centre at the terminal in the 2017 scenario and will have the additional Eastern Energy Centre (EEC) in the future 2035 scenario. The model parameters and emissions for both centres have been taken from data sheets provided in the CADP environmental assessment that accompanied that planning application[35]. The energy centres and boilers were represented in the model as point sources. Details are presented in Appendix B.

4.4.4 Road vehicles

Highway network

Traffic data for the study area was obtained from traffic counts by the DfT and Arup transport. The data was in the form of 24-hour annual average daily traffic (AADT) flows with HGV percentage. The source of traffic data, AADT flows and location of road links included in the assessment are presented in Appendix C.

Emissions were calculated using Defra's Emissions Factor Toolkit (EFT) (version 8.0.1)[43]. The percentage of primary NO_2 emissions was taken from the NAEI[34]. Speeds were taken from the ITO website[44] and speeds were also reduced to 20kph near to junctions and at roundabouts following the Defra TG16 guidance.

Car parks

Information on car park movements was provided by London City Airport in the form of the daily transaction at car park machines and staff permits. Emissions were calculated in accordance with the Cambridge Environmental Research Consultants (CERC) note on modelling car parks[45].

Emission factors for vehicles were taken from Defra's EFT (version 8.0.1), while cold start emissions were taken from the NAEI database[34]. The percentage of primary NO_2 emissions was also taken from the NAEI. A speed of 5kph was assumed at all car parks. The vehicle flows and location of the car parks included in the assessment are presented in Appendix C.

[42] London City Airport (2016) Airside Operating Instruction – AOI 12 Control of Vehicles Airside
[43] https://laqm.defra.gov.uk/review-and-assessment/tools/emissions-factors-toolkit.html
[44] http://product.itoworld.com/map/
[45] CERC (2004) Modelling car parks

4.4.5 Industrial sources

For completeness the Tate and Lyle factory emissions to the south of the airport have been included within the model. The stack has been modelled as a point source, the model parameters and emissions have been taken from the CADP environmental assessment that accompanied that planning application [35].

Appendix D presents a summary of the emissions inventory created as input to the air quality model and Appendix F lists the assumptions and limitations.

4.5 Methodology for air quality dispersion modelling

4.5.1 NOx to NO_2 conversion

The model predicts roadside NOx concentrations, which comprise principally nitric oxide (NO) and primary NO_2 (i.e. NO_2 that is emitted directly from the aircraft or vehicle exhaust). The emitted NO reacts with oxidants in the air (mainly ozone) to form more NO_2 (known as secondary NO_2). Since only NO_2 has been associated with effects on human health, the air quality standards for the protection of human health are based on NO_2 rather than NOx or NO. Thus, a suitable NOx to NO_2 conversion needs to be applied to the modelled NOx concentrations.

The method taken for this conversion in the assessment follows the approach described by Clapp and Jenkin[46,47], which takes account of the proportion of primary NO_2 in the balance between NO and NO_2 and derives total NO_2 concentrations as a function of distance from major sources. The method requires a value for the regional background oxidant, which was taken to be 33.5ppb in 2008 and was projected to increase by +0.1ppb/year for future years, i.e. 34.4ppb in 2017 and 36.2ppb in 2035.

4.5.2 Model verification

Model verification refers to the comparison of modelled pollutant concentrations with measured concentrations at the same points to assess the performance of the model and determine an adjustment factor, if one is required. Defra's TG16 guidance[15] provides advice on model verification, which is used for the modelling of road networks for highways assessments, local air quality management and other local modelling of roads. Should the model results for NO_2 be largely within ±25% of the measured values and there is no systematic over or under-prediction of concentrations, then the Defra TG16 guidance[15] advises that no adjustment is necessary. If this is not the case, then the modelled values are adjusted based on the observed relationship between modelled and measured NOx concentrations to provide better agreement.

[46] Clapp and Jenkin (2001) Analysis of the relationship between ambient levels of O3, NO2 and NO as a function of NOx in the UK, Atmospheric Environment 35, 6391-6405
[47] Jenkin (2004) Analysis of sources and portioning of oxidant in the UK – Part 1: the NOx-dependence of annual mean concentrations of nitrogen dioxide and ozone

Modelled results may not compare as well at some locations for various reasons, including:

- Errors/uncertainties in model input data (e.g. height of monitoring sites);
- Model setup (including missing road sources on roundabouts);
- Neglect of local effects (including barrier effect from walls and hedges; car parks); and
- Uncertainty in monitoring data, notably diffusion tubes (e.g. low data capture).

The above factors were investigated as part of the model verification process to minimise the uncertainties as far as practicable. Details of the model verification are presented in Appendix E.

5 Baseline air quality conditions

This section describes the environmental conditions that exist in the study area in the baseline assessment year.

The assessment started in 2018 and used as baseline the latest year for which a full, compatible set of data was available at the time, 2017: aircraft and airport activity data, traffic activity data, emissions factors, background concentrations and meteorology.

The air quality around the airport is influenced mainly by vehicle emissions from the surrounding road network and car parks, with the Connaught Bridge, A112 and A1020 being key sources of pollution. The emissions from aircraft, related activities and on-airport facilities have a localised impact with the concentrations of these sources being largely confined to within the boundary of the airport.

5.1 Local air quality management

The Environment Act 1995[8] requires local authorities to review and assess air quality with respect to the objectives for the pollutants specified in the National Air Quality Strategy. Historically local authorities were required to carry out an Updating and Screening Assessment (USA) of their area every three years. If the USA identifies potential hotspot areas likely to exceed air quality objectives, then a Detailed Assessment of those areas would be required. Where objectives were not predicted to be met, local authorities must declare the area as an Air Quality Management Area (AQMA). In addition, local authorities were required to produce an Air Quality Action Plan (AQAP) which includes measures to improve air quality in the AQMA. However, this approach has now been streamlined and local authorities are required to submit a single Annual Status Report (ASR) to Defra by 30th June each year.

As part of the review and assessment process the Royal Borough of Greenwich in 2001 declared the whole borough as an AQMA. This is due to exceedances of the annual mean objective for NO_2 and the daily mean objective for PM_{10}. The primary source for the Royal Borough of Greenwich are transport and industrial source. The London Borough of Newham in 2002 declared the main roads within the borough as an AQMA (Newham AQMA) due to road traffic. However, consultation with the London Borough of Newham Environmental Health Officer indicated that the declaration of a borough wide AQMA is imminent for 2019. Figure 1 shows the declared AQMAs.

5.2 Air quality monitoring information

Monitoring of NO_2 and PM_{10} concentrations is currently carried out by the local authorities within the London Borough of Newham and the Royal Borough of Greenwich, and London City Airport itself. In total there are four continuous monitoring sites and 21 diffusion tube sites within the study area. Table 5 presents details and monitoring data for these sites for the past four years, while their locations are presented in Figure 2 and Figure 3.

It can be observed that across the study area, pollutant concentrations are below the relevant air quality standards at sites. There is one monitoring site which shows an exceedance of the annual mean NO_2 standard in 2017; GW 49 in the Royal Borough in Greenwich.

Figure 1: Air Quality Management Area (AQMA)

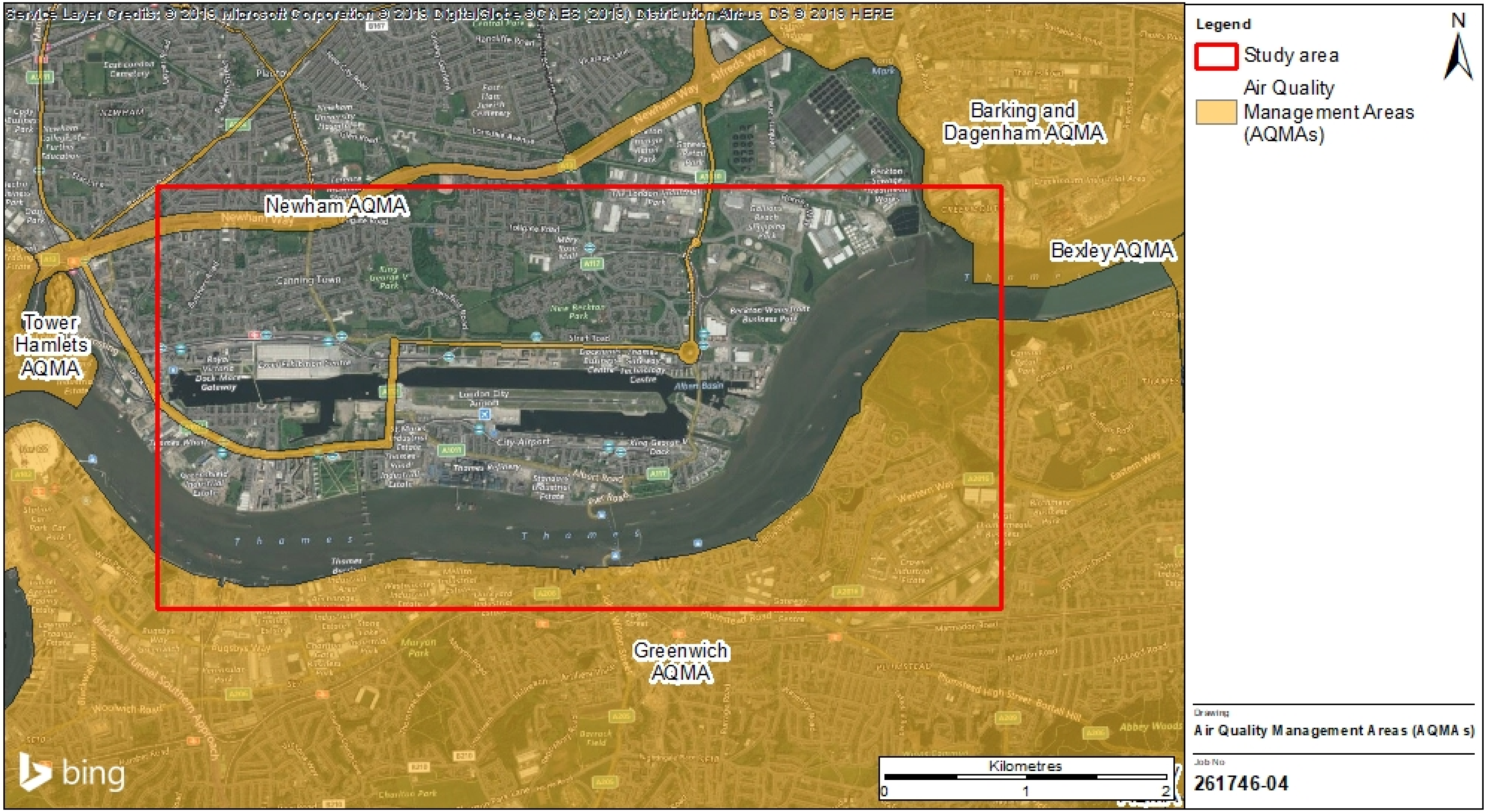


Table 5: Local air quality monitoring in the study area

ID	Site	OS coordinates		Operator	Location type	Distance to kerb (m)	2014	2015	2016	2017	2018
		X	Y								
NO_2 concentrations (µg/m^3) – Continuous monitors											
NM 3	Wren Close	539889	181469	London Borough of Newham	Background	n/a	34.0	30.0	33.0	30.0	n/a[c]
GN 2	Millennium Village	540169	178999	Royal Borough of Greenwich	Background	n/a	36.0	28.0	30.0	n/a	n/a
LCA CAH	City Aviation House	542527	180203	London City Airport	Airport	17.0[a]	n/a	29.6	27.8	28.5	29.2
LCA ND	Newham Dockside	542298	180709	London City Airport	Airport	157.0[a]	n/a	25.8	29.0	26.0	24.7
NO_2 concentrations (µg/m^3) – Diffusion tubes											
NM 11	City Airport	542583	180201	London Borough of Newham	Roadside	5.0	37.0	32.0	37.0	38.0	n/a[c]
NM 12	Galleons Roundabout	543762	180784	London Borough of Newham	Roadside	9.5	34.8	34.0	37.0	38.0	n/a[c]
GW 49	Woolwich High St	543472	179217	Royal Borough of Greenwich	Roadside	1.0	**44.6**	**44.2**	**54.8**	**58.1**	n/a[c]
GW 52	Woolwich High St	542842	179108	Royal Borough of Greenwich	Roadside	1.5	**43.9**	39.6	39.0	39.2	n/a[c]
GW 61	Millennium Village (Triplicate co-located site)	544086	178882	Royal Borough of Greenwich	Background	16.9	35.2	30.5	32.1	28.1	n/a[c]
LCY 1	Parker Street	542154	180288	London City Airport	Airport	28.6[a]	28.1	29.1	28.3	24.7	27.9
LCY 2	Camel Road, adjacent to nearest property on Hartmann Street	541965	180299	London City Airport	Airport	15.6[a]	26.5	31.3	31.2	28.0	28.8
LCY 3	Silvertown Quay	541589	180373	London City Airport	Airport	47.3[a]	29.7	29.3	29.5	34.2	n/a[c]
LCY 4	To east end of Newham Dockside	542271	180708	London City Airport	Airport	159.5[a]	32.2	30.6	30.4	30.2	26.2
LCY 5	Straight Road	542847	180914	London City Airport	Airport	27.4[a]	29.2	27.8	26.2	24.3	24.3

ID	Site	OS coordinates		Operator	Location type	Distance to kerb (m)	2014	2015	2016	2017	2018
		X	Y								
LCY 6	Gallions Way	543712	180868	London City Airport	Airport	13.9[a]	32.3	31.2	28.8	25.7	27.2
LCY 7	Gallions Way	543662	180460	London City Airport	Airport	183.1[a]	31.9	31.4	33.9	29.4	31.1
LCY 8	Brixham Street	543120	180133	London City Airport	Airport	18.4[a]	28.2	21.1	23.4	18.8	24.6
LCY 9 (CAH)	City Aviation House (triplicate tubes)	542532	180196	London City Airport	Airport	17.0[a]	31.5	28.8	29.3	27.1	28.8
LCY 10	Jet Centre	541758	180428	London City Airport	Airport	44.0[a]	32.5	34.0	34.7	28.6	33.0
LCY 11	Eastern end of the University of East London	543549	180693	London City Airport	Airport	140.2[a]	33.1	31.3	31.7	27.8	29.6
LCY 12	South of Royal Albert Dock	542192	180561	London City Airport	Airport	291.0[a]	31.2	28.5	28.9	31.8	23.8
LCY 13	North west corner of Newham Dockside	542280	180769	London City Airport	Airport	97.6[a]	32.3	28.4	27.8	31.1	29.8
LCY 14	Western end of Newham Dockside	542070	180712	London City Airport	Airport	161.0[a]	33.7	31.1	31.9	28.9	30.9
LCY 15	Royal Albert Way	542316	180862	London City Airport	Airport	4.3[a]	32.2	26.5	30.8	23.5	28.1
LCY 18 (ND)	Newham Dockside analyser (duplicate)	542303	180707	London City Airport	Airport	159.5[a]	27.7	26.4	28.3	30.0	25.0
LCY 20	Silvertown Quay	541632	180373	London City Airport	Airport	1.0	n/a	n/a	n/a	n/a	*26.7*
PM_{10} concentrations (µg/m^3) – Continuous monitors											
NM 3	Wren Close	539889	181469	London Borough of Newham	Background	n/a	29.0	25.0	19.0	17.0[b]	n/a[c]
GN 2	Millennium Village	540169	178999	Royal Borough of Greenwich	Background	n/a	26.0	17.0	20.0	n/a	n/a
LCA CAH	City Aviation House	542527	180203	London City Airport	Airport	17.0[a]	n/a	20.3	20.3	19.2	20.0

Notes: [a] estimated from ArcGIS; n/a: data not available; bold font indicates measurement above the air quality standard (40µg/m^3); *italics* font represents low data capture (below 75%); [b] annualised and [c] local authority data not available at time of report publication

Figure 2: Local authority monitoring sites

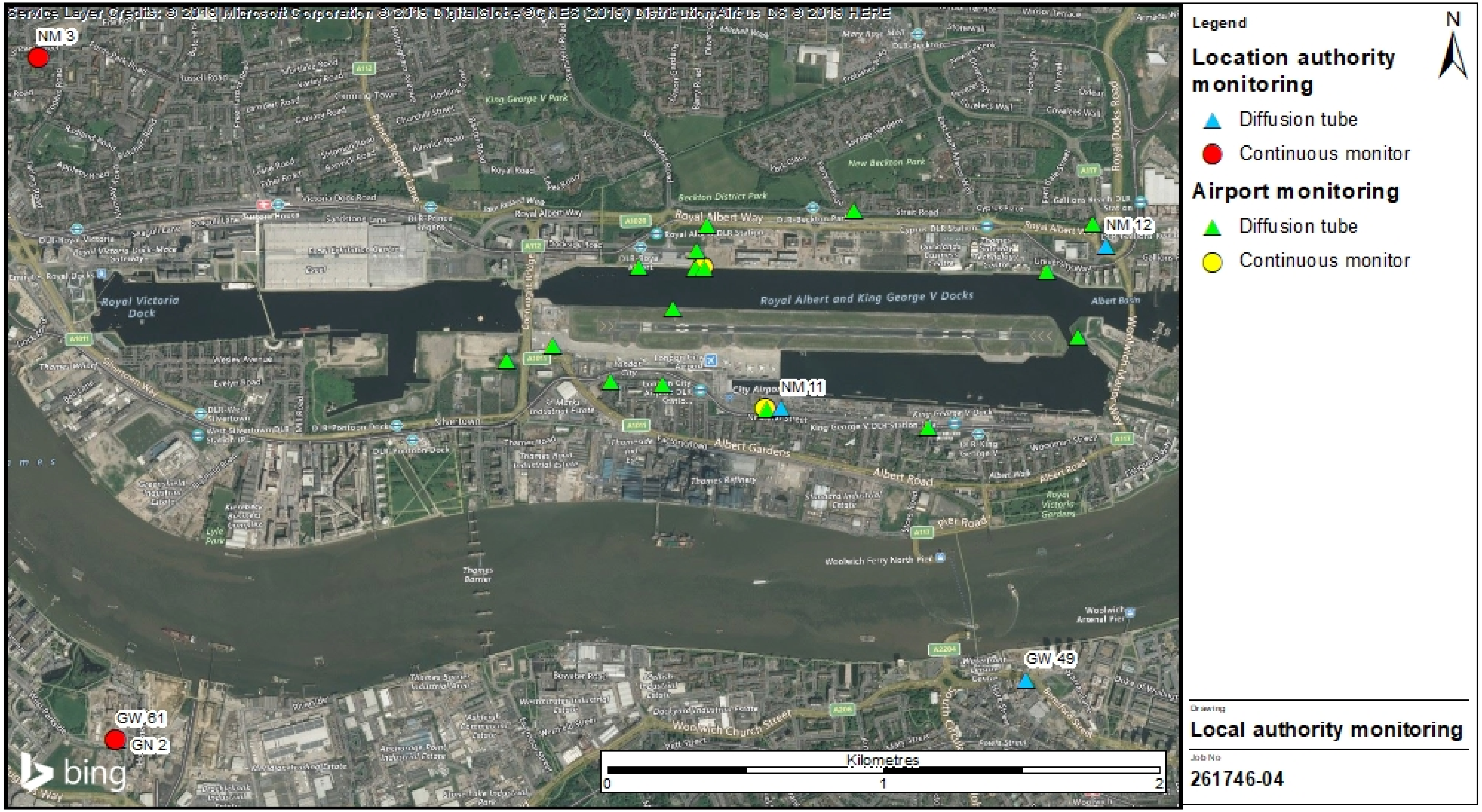


Figure 3: Airport monitoring sites

5.3 Industrial sources

To the south of the airport there is the Tate and Lyle factory, which operates gas and gas-oil boilers. This industrial source has been included within the modelling assessment for completeness.

5.4 Background pollutant concentrations

5.4.1 Baseline 2017 scenario

The Defra website includes estimated background concentrations for NO_2, NO_x, PM_{10} and $PM_{2.5}$ for each 1km by 1km OS grid square. Table 6 shows the estimated Defra background concentrations for the OS grid square containing the closest background automatic monitor Wren Close and the three OS grid squares covering the airport in 2017. The estimated Defra background concentrations are below the air quality objectives for annual mean NO_2, PM_{10} (40µg/m^3) and for $PM_{2.5}$ (25µg/m^3).

Table 6: Defra's estimated background pollutant concentrations in 2017

Location	**OS grid square**		**Annual mean concentrations (µg/m^3)**			
	X	**Y**	**NO_2**	**NOx**	**PM_{10}**	**$PM_{2.5}$**
Wren Close (NM 3)	539500	181500	33.4	53.2	19.4	12.1
Airport 1	541500	180500	41.0	26.8	17.5	11.3
Airport 2	542500	180500	44.2	28.3	16.8	11.0
Airport 3	543500	180500	38.2	25.2	16.8	10.9
Average of airport grid squares			**41.2**	**26.8**	**17.0**	**11.1**

The NO_2 concentration measured at the Wren Close background monitoring site in 2017 was 30.0 µg/m^3, which is lower than the estimated Defra background concentration for the same grid square (33.4 µg/m^3). Therefore, Defra background concentrations will be used in this assessment since they provide a more conservative approach. The average of the three OS grid squares covering the airport has a higher background concentration than the OS grid square containing the closest background automatic monitor, so these will be used instead.

5.4.2 Future year 2035 scenario

Table 8 shows the estimated Defra background concentrations for the OS grid square containing the closest background automatic monitor Wren Close and the three OS grid squares covering the airport in 2030. The 2030 future year backgrounds have been used in the assessment for 2035, as the 2015-based background maps produced by Defra are only provided for years up to 2030. The estimated Defra background concentrations remain below the air quality objectives for annual mean NO_2, PM_{10} (40µg/m^3) and for $PM_{2.5}$ (25µg/m^3).

Table 7: Defra's estimated background pollutant concentrations in 2030

Location	OS grid square		Annual mean concentrations (µg/m^3)			
	X	Y	NO_2	NOx	PM_{10}	$PM_{2.5}$
Airport 1	541500	180500	18.9	27.3	15.8	9.9
Airport 2	542500	180500	16.6	23.5	16.6	10.3
Airport 3	543500	180500	16.0	22.4	15.8	9.9
Average of airport grid squares			**17.1**	**24.4**	**16.1**	**10.0**

6 Air quality dispersion modelling

Appendix G presents the predicted pollutant concentrations at receptors in the study area.

6.1 Model verification

Model verification compares modelled and measured NO_2 concentrations to assess the performance of the model. From the monitoring undertaken in the study area, 12 monitoring sites were included in the model for model verification exercise. Appendix E presents the details of these sites and graphs for the performance of the model.

No adjustment factor has been applied to pollutant sources as NO_2 concentrations at sites near roads were overestimated compared to monitored concentrations. At airside locations, modelled NO_2 concentrations were between -6% and 13% of monitoring sites, in agreement with Defra recommended guidance of ±25%.

6.2 Modelled concentrations at human receptors

Appendix G presents details of the predicted pollutant concentrations at all human receptors for both assessment scenarios: 2017 baseline year and 2035 future year.

In 2017 and 2035, there were no exceedances predicted for annual mean NO_2 concentrations at any receptor location. The highest predicted annual mean NO_2 concentration was at R40 Royals Business Park Hotel (34.3µg/m^3) in 2017 and R2 Camel Road/Parker Street (21.6µg/m^3) in 2035. Also, R40 showed the largest decrease in predicted NO_2 concentrations (13.2 µg/m^3).

Furthermore, there were no exceedances predicted for annual mean PM_{10} and $PM_{2.5}$ concentrations at any receptor. The highest predicted annual mean PM_{10} concentration in both scenarios was at R40 at Royals Business Park Hotel (17.9µg/m^3 in 2017 and 16.8µg/m^3 in 2035). The highest annual mean $PM_{2.5}$ concentrations are predicted across six sites in both scenarios. The highest annual mean $PM_{2.5}$ concentration predicted in 2017 was at R40 at Royals Business Park Hotel and R1 at Camel Road/Hartmann Road (11.6µg/m^3). The highest predicted concentration in 2035 were R2 at Camel Road/Parker Street, R8 at Albert Road/Woolwich Manor Way, R26 at Felixstowe Court, R40 at Royals Business Park Hotel with a concentration of 10.4µg/m^3. Four sites (R1 at Camel Road/Hartmann Road, R4 at Newland Street (opposite entrance to LCY car park), R5 at Newland Street/Kennard Street, R16 at Drew Road/Leonard Street) showed the largest decrease in predicted PM_{10} concentrations (1.2µg/m^3). R1 at Camel Road/Hartmann Road showed the largest decrease in predicted $PM_{2.5}$ concentrations (1.3 µg/m^3).

7 Conclusions

The air quality model included emissions from all sources contributing to air concentrations of the key pollutants, such as the aircraft and all activity on the airport, traffic on the surrounding road network and car parks. Emissions from sources outside the local area were taken into account through the background pollutant concentrations.

The monitoring data undertaken by London City Airport shows that air quality in the vicinity of the airport meet the UK air quality objectives for nitrogen dioxide (NO_2) and particulate matter (PM_{10} and $PM_{2.5}$). Modelling for the current baseline (2017) also predicted that concentrations near to the Airport would meet the UK objectives.

The highest predicted annual mean NO_2 and PM_{10} concentrations in 2017 were at R40 Royals Business Park Hotel (34.3µg/m^3 and 17.9µg/m^3 respectively) The highest predicted annual mean $PM_{2.5}$ concentrations were at R40 at Royals Business Park Hotel and R1 at Camel Road/Hartmann Road (11.6µg/m^3).

In 2035, under the draft master plan scenario, the maximum predicted concentrations were predicted to decrease. The highest predicted annual mean NO_2 concentration was at R2 Camel Road/Parker Street (21.6µg/m^3) and the highest predicted annual mean PM_{10} concentration is at R40 at Royals Business Park Hotel (16.8µg/m^3). The highest annual mean $PM_{2.5}$ concentration is predicted at four sites (R2 at Camel Road/Parker Street, R8 at Albert Road/Woolwich Manor Way, R26 at Felixstowe Court, R40 at Royals Business Park Hotel) with a concentration of 10.4µg/m^3.

While growth to 151,000 ATMs by 2035 would lead to increased aircraft activity and increased emissions of NOx, PM_{10} and $PM_{2.5}$, concentration of NO_2, PM_{10} and $PM_{2.5}$ are predicted to decrease and would therefore remain below the UK's air quality objectives. The decrease in concentrations is due to the predicted decrease in road traffic emissions due to tighter emissions regulations and in background concentrations between 2017 and 2035.

Further initiatives to improve air quality in 2035 would include:

- working with airlines to encourage improvements in aircraft performance and so reduce emissions;
- provision of Fixed Electrical Ground Power on all future stands;
- ensuring all vehicles owned by the airport will be ULEZ compliant by December 2020;
- ensuring all airside vehicles with a permanent vehicle pass will be electric (or zero emissions) or use renewable fuels by 2030; and
- 300 parking spaces (1 in 5) with electric charging points by 2035 with provision for electric charging or zero emission vehicles on all other spaces.

7.1 Recommendations for additional assessment work

In the event that detailed proposals come forward in the future the air quality assessment would be updated and additional work carried out as follows:

Updating of assessment

- Gather the latest available data on all model inputs (activity and emissions factors) and if input data has changed, rerun the model with the latest data;
- A change of baseline year and hence and updating of the model verification may be required or possible; and
- Update section 5 on monitoring data with the latest data.

Additional assessment

- Based on available project information at the relevant point in the future, consider the impact of construction emissions and suitable mitigation;
- Based on available project information at the relevant point in the future, consider cumulative impacts; and
- Ensure that the approach used reflects any developments in good practice methodology emerging from air quality assessments of other UK airports.

Appendix A

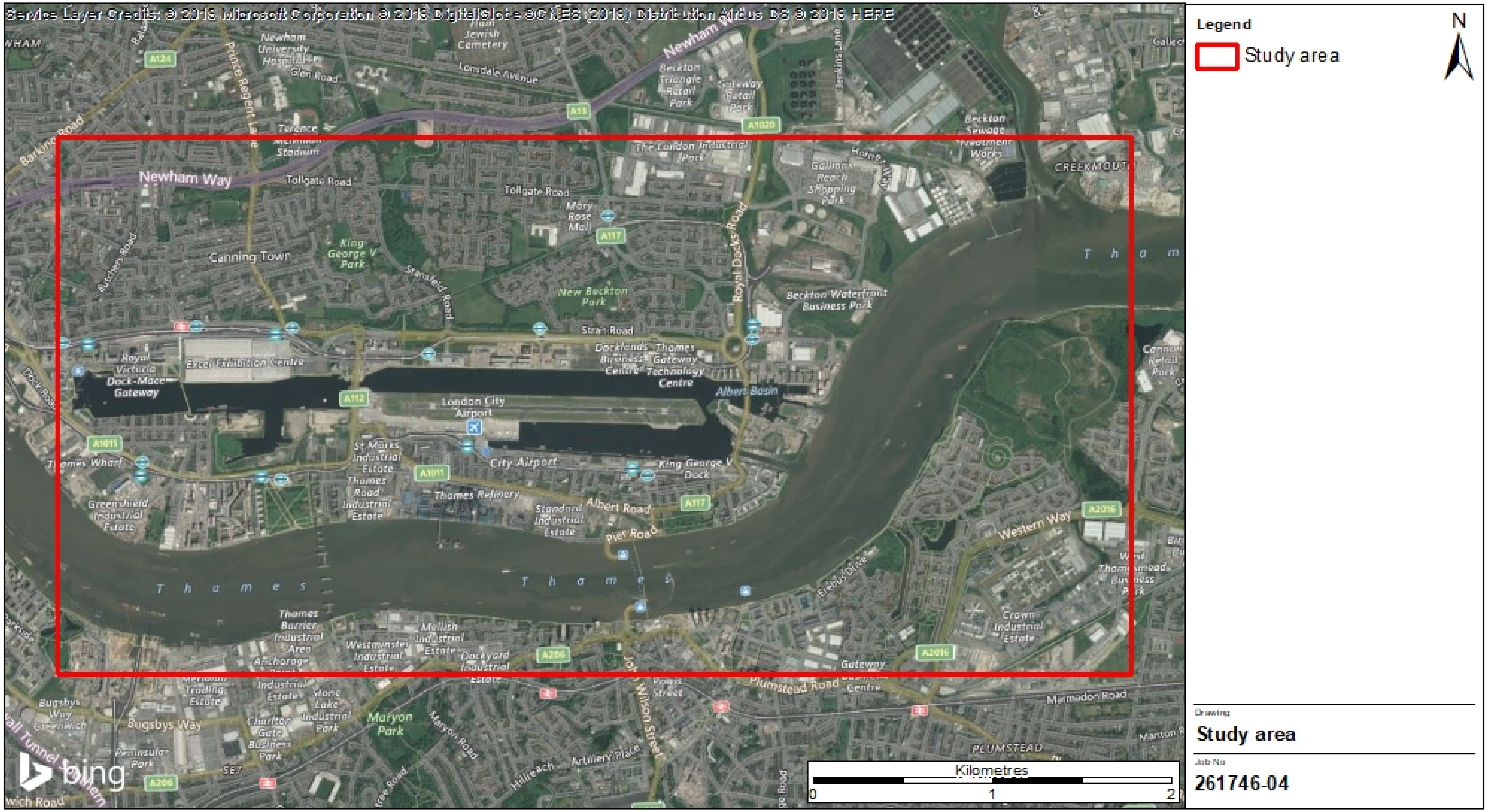
Study area and sensitive receptors

Contents

A1 Study area

The study area for the assessment has been defined as a 6km x 3km domain centred on the airport to account for both airport sources and the road network. Figure 1 presents the study area.

Figure 1: Study area



A2 Human receptors

Table 1 presents the details of the human receptors included in the air quality assessment, which are classified as ‘Education’, ‘Healthcare’ or ‘Residential’. Figure 2 presents the location of these receptors in the study area.

Table 1: List of human receptors

ID	Description	Type of receptor	OS coordinates (m)		Height(s) (m)
			X	Y	
R1	Camel Road/Hartmann Road	Residential	541982	180307	1.5
R2	Camel Road/Parker Street	Residential	542133	180304	1.5
R3	Parker Street (Portway Primary School)	Education	542177	180229	1.5
R4	Newland Street (opposite entrance to LCY car park)	Residential	542549	180153	1.5
R5	Newland Street/Kennard Street	Residential	542687	180145	1.5
R6	Brixham Street/Dockland Street	Residential	543127	180121	1.5
R7	Platterns Court/Billingway Dock Head	Residential	543676	180077	1.5
R8	Albert Road/Woolwich Manor Way	Residential	543709	180015	1.5
R9	Robert Street adj Albert Road (north side)	Residential	543523	179954	1.5
R10	Collier Close adj Gallions Way Roundabout (eastern side)	Residential	543715	180875	1.5
R11	Yeoman Close adj Royal Albert Way	Residential	543612	180883	1.5
R12	Straight Road/Campton Close	Residential	542826	180920	1.5
R13	Mill Rd adj North Woolwich Road (west)	Residential	540854	180110	1.5
R14	Connaught Road/Leonard Street	Residential	542321	180086	1.5
R15	Gallions Primary School adjacent to Royal Docks Road	Education	543749	181324	1.5
R16	Drew Road/Leonard Street	Residential	542306	180219	1.5
R17	Woolwich Manor Way (UEL)	Education	543800	180701	1.5
R18	Woolwich Manor Way (UEL)	Education	543650	180655	1.5, 20.0
R19	West Silvertown 1	Residential	540846	180439	1.5, 20.0
R20	West Silvertown 2	Residential	540681	180448	1.5, 20.0
R21	Flats on Drew Road	Residential	542050	180261	1.5

R22	Flats on Docklands Street	Residential	543133	180047	20.0, 40.0
R23	Gallions Quarter	Residential	543868	180637	1.5, 20.0
R24	Gallions Quarter	Residential	543919	180684	1.5, 20.0
R25	University of East London Student Accommodation	Education	543478	180695	1.5, 10.5
R26	Felixstowe Court	Residential	543810	180174	1.5, 10.5
R27	Silvertown Quays 1	Residential	541614	180468	1.5, 20.0
R28	Silvertown Quays 2	Residential	541460	180476	1.5, 20.0
R29	Silvertown Quays, 30m from Connaught Bridge	Residential	541587	180372	1.5, 20.0
R30	Royal Albert Basin	Residential	544067	180548	1.5, 20.0
R31	Royal Albert Basin	Residential	544088	180710	1.5, 20.0
R32	North Side of Royal Albert Dock	Residential	542418	180704	1.5, 20.0
R33	North Side of Royal Albert Dock	Residential	542979	180691	1.5, 20.0
R34	North side of Royal Albert Dock (10m from Royal Albert Way)	Residential	542884	180843	1.5
R35	North Side of Royal Albert Dock	Residential	541917	180713	1.5, 20.0
R36	Barrier Park East	Residential	541583	180149	1.5, 20.0
R37	UNEX	Residential	541862	180129	1.5
R38	Royal Wharf	Residential	540890	180071	1.5
R39	Royals Business Park Hotel Site 2.3	Residential	541882	180859	1.5, 10.5
R40	Royals Business Park Hotel Site 2.2	Residential	541716	180852	1.5, 20.0
R41	Fox & Connaught Hotel, Lynx Way	Residential	541627	180863	1.5, 13.5
R42	Garvary Road/ Prince Regent Lane	Residential	541082	181287	1.5
R43	Prince Regent Lane	Residential	541209	181042	4.5, 16.5
R44	The Royal Docks Academy	Education	541248	181037	1.5
R45	Tree Road/ Prince Regent Lane	Residential	541118	181254	1.5
R46	Richard House Children's Hospice	Healthcare	541833	180974	1.5

R47	Calverton Primary School	Education	541740	181069	1.5
R48	Children Garden Nursery	Education	543375	180697	1.5
R49	Founder Close	Residential	543649	181118	1.5, 7.5
R50	Trader Road	Residential	543702	181006	1.5
R51	Tynemouth Close	Residential	543643	181216	1.5
R52	Vulcan Close	Residential	543441	181231	1.5
R53	Claremont Close	Residential	543409	180110	1.5, 10.5
R54	Pier Road	Residential	543329	179924	4.5
R55	Albert Road/ Winifred Street	Residential	542773	180015	1.5
R56	Albert Road (West)	Residential	542157	180109	1.5

Figure 2: Human receptors

Appendix B

Emissions methodology

Contents

B1 Airfield map

Figure 1 presents a map of the airfield with labels at key locations that are referred to in the emissions inventory.

Figure 1: Airfield map

B2 Aircraft

From the 80,299 ATMs recorded at the airport in 2017, six modelling categories (MCATs) were defined for inclusion in the dispersion modelling. For the 2035 future year scenario in which 151,500 ATMs are estimated, two additional MCATs were defined. Table 1 presents all eight MCATs alongside the representative aircraft type, the selected engines used for the emissions calculations and the ATMs in each MCAT for both assessment scenarios. Figure 2 and Figure 3 present the aircraft fleet composition for 2017 and 2035 respectively.

For turbofan engines, the pollutant emissions indices and fuel flows were obtained from the ICAO databank. The indices for the turboprop and piston engines were taken from the FOI database and the FOCA database, respectively. Table 2 presents the fuel flow (in kg/s) and NOx emission indices (in g/kg) for each engine used in the assessment at different percentage thrusts.

Emissions of pNO_2 were derived using the fractions described in the PSDH methodology. These were 4.5% pNO_2 at 100% thrust, 5.3% pNO_2 at 85% thrust, 15% pNO_2 at 30% thrust and 37.5% pNO_2 at 7% thrust. For intermediate thrust settings, the pNO_2 fractions were derived linearly.

Emissions of PM_{10} were derived from the smoke number, fuel flow and hydrocarbon emission indices following the methodology described in the ICAO airport air quality manual. Table 3 and Table 4 present the smoke number, hydrocarbon and PM_{10} emission indices respectively. For turboprop engines, smoke number indices were not available in the FOI database. Therefore, as a conservative case, it was assumed that PM_{10} emissions from the turboprop engines were the same as those for the piston engine of Piper PA-31 Navajo, given in the FOCA database.

The Embraer E190-E2 is equipped with two Pratt & Whitney PW1900G engines and pollutant emission indices were not available from the ICAO databank. Therefore, this was derived using the product specification produced by MTU Aero Engines, which compares the performance of the PW1900G engines against current engines, assumed to be the General Electric CF34-10E5 engine used for Embraer E190.

Emissions (E) for each MCAT and each LTO mode were calculated using the following equation:

$$E\,[g] = EI * FF * TIM * \text{number of engines} * ATMs$$

where EI is the emission factor in g/kg, FF is the fuel flow in kg/s and TIM is the time-in-mode in seconds.

Table 1: Representative aircraft types and ATMs

MCAT	Description	Representative aircraft type	Aircraft type ICAO	Engine	ATMs	
					2017	2035
1	Turboprop engine aircraft*	DHC Dash 8	DH8D	PW150A	15,359	20,000
		ATR 42-500	AT45	PW127	3,541	-
		Dornier 328JET	J328	PW306B	1,001	-
		Fokker F50	F50	PW125B	296	-
2	Turboprop engine aircraft	SAAB 2000	SB20	RR AE2100-A	2,625	-
		ATR 42-300	AT43	PW120	398	-
		Dornier 328	D328	PW119B	351	-
3	Narrow body, short to medium range aircraft	Airbus A318	A318	CFMI CFM56-5B9	585	500
4	Regional jets, short to medium range aircraft	Embraer 190	E190	GE CF34-10E5	34,204	32,000
		Embraer 175	E170	GE CF34-8E5	11,363	-
5	Regional jets, short to medium range aircraft	Airbus A220	BCS1	PW1524G	504	16,000
6	Regional jets, short to medium range aircraft with four engines	British Aerospace Avro RJ85	RJ85	Lycoming ALF507-1F	10,051	-
		British Aerospace 146-200	B462	Lycoming ALF502R-5	22	-
7	Narrow body, short to medium range aircraft	Airbus A320NEO	A20N	CFM LEAP-1A	-	3,000
8	Regional jets, short to medium range aircraft	Embraer 190-E2	E290	PW1900G	-	80,000
				Total ATMs	**80,299**	**151,500**
Note: *includes jet centre ATMs						

Figure 2: Aircraft fleet composition (ATMs) for 2017

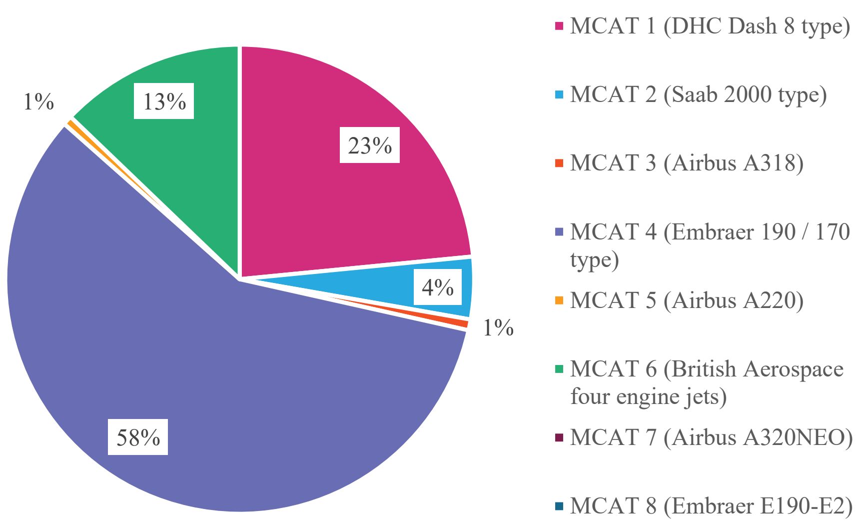


Figure 3: Aircraft fleet composition (ATMs) for 2035

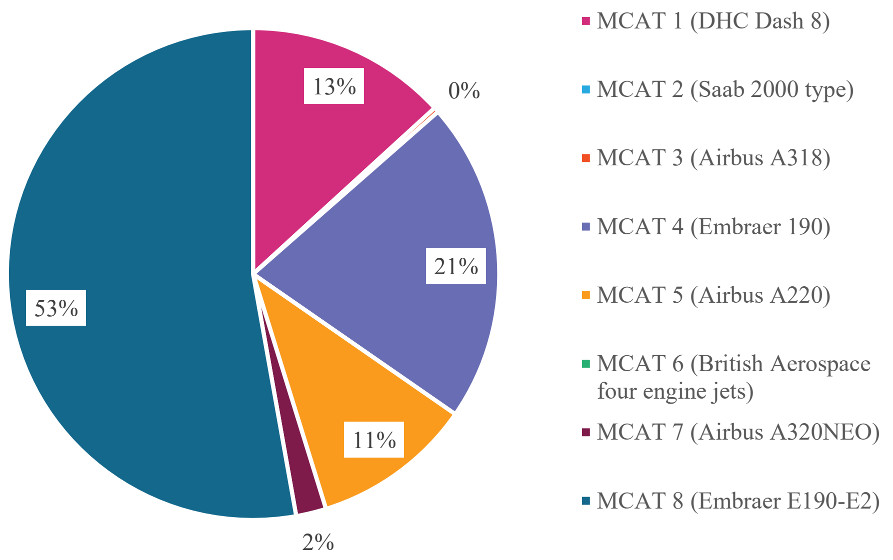


Table 2: Fuel flow and NOx emission indices for aircraft at different percentage thrusts

MCAT	Aircraft type ICAO	Database	Fuel flow (kg/s)					NOx (g/kg)				
			85%	78%	30%	15%	7%	85%	78%	30%	15%	7%
1	DH8D	FOI	0.25	0.24	0.14	0.08	0.05	18.81	17.76	10.58	5.60	2.94
1	AT45	FOI	0.15	0.14	0.08	0.05	0.03	16.90	16.07	10.40	6.82	4.91
1	J328	ICAO	0.26	0.24	0.10	0.06	0.04	19.26	18.32	11.87	6.91	4.26
1	F50	FOI	0.14	0.13	0.08	0.05	0.03	16.30	15.52	10.20	6.62	4.71
2	SB20	FOI	0.20	0.19	0.11	0.06	0.04	11.86	11.36	7.91	4.46	2.63
2	AT43	FOI	0.11	0.11	0.07	0.04	0.03	12.40	11.92	8.60	5.68	4.12
2	D328	FOI	0.13	0.12	0.08	0.05	0.04	15.20	14.54	10.00	6.68	4.91
3	A318	ICAO	0.79	0.73	0.28	0.16	0.10	14.76	13.93	8.26	5.43	3.92
4	E190	ICAO	0.65	0.60	0.22	0.13	0.09	14.97	14.03	7.59	4.96	3.55
4	E170	ICAO	0.53	0.49	0.18	0.10	0.06	12.65	12.41	10.77	6.75	4.61
5	BCS1	ICAO	0.65	0.60	0.23	0.13	0.08	21.20	19.91	11.10	7.84	6.10
6	RJ85	ICAO	0.30	0.27	0.11	0.07	0.05	12.02	11.30	6.39	4.36	3.28
6	B462	ICAO	0.30	0.27	0.10	0.06	0.04	10.56	10.06	6.60	4.76	3.78
7	A20N	ICAO	0.86	0.71	0.24	0.14	0.11	18.77	11.16	8.67	6.04	5.16
8	E290	n/a#	0.73	0.60	0.20	0.12	0.09	13.88	11.44	5.60	3.64	2.99
Note: # emission factors derived from engine product specification												

Table 3: Bypass ratio, smoke number and hydrocarbon emission indices for aircraft at different percentage thrusts

MCAT	Aircraft type ICAO	By-pass ratio	Smoke number			Hydrocarbons (g/kg)		
			85%	30%	7%	85%	30%	7%
1	J328	4.5	0.80	0.00	0.20	0.00	0.00	4.36
3	A318	5.9	8.40	2.10	2.10	0.03	0.07	3.01
4	E190	5.1	5.10	0.11	0.60	0.10	0.13	4.94
4	E170	5.1	2.24	0.00	0.00	0.02	0.06	0.13
5	BCS1	11.1	2.80	2.40	2.50	0.10	0.10	0.10
6	RJ85	5.1	10.20	6.90	6.80	0.01	0.12	4.72
6	B462	5.6	12.70	5.70	2.30	0.05	0.22	5.39
7	A20N	11.0	1.17	1.31	1.25	0.02	0.04	0.28
8	E290	12.0	6.91	0.10	0.50	0.09	0.10	4.02

Table 4: PM_{10} emission indices for aircraft at different percentage thrusts

MCAT	Aircraft type ICAO	Database	PM_{10} (g/kg)				
			85%	78%	30%	15%	7%
1*	DH8D	FOI	0.07	0.05	0.04	0.05	0.05
1*	AT45	FOI	0.07	0.05	0.04	0.05	0.05
1	J328	ICAO	0.06	0.06	0.05	0.07	0.08
1*	F50	FOI	0.07	0.05	0.04	0.05	0.05
2*	SB20	FOI	0.07	0.05	0.04	0.05	0.05
2*	AT43	FOI	0.07	0.05	0.04	0.05	0.05
2*	D328	FOI	0.07	0.05	0.04	0.05	0.05
3	A318	ICAO	0.09	0.09	0.06	0.08	0.08
4	E190	ICAO	0.08	0.07	0.06	0.07	0.08
4	E170	ICAO	0.06	0.06	0.05	0.05	0.05
5	BCS1	ICAO	0.07	0.07	0.07	0.07	0.07
6	RJ85	ICAO	0.10	0.10	0.10	0.13	0.14
6	B462	ICAO	0.12	0.12	0.10	0.10	0.10
7	A20N	ICAO	0.05	0.05	0.06	0.06	0.06
8	E290	n/a[#]	0.09	0.08	0.05	0.07	0.07

Note: * assumed same emission factors as PA31
[#] emission factors derived from engine product specification

To derive the horizontal distance and time-in-mode for the phases of approach, landing, take-off and climb in the LTO cycle, details of travelling speeds and climb angles have been used. This information has been provided for representative aircraft within each modelling category by Bickerdike Allen Partners using the AEDT software.

For MCATs 1, 5, 7 and 8, this information was not available. For MCAT 2, it was assumed that the travelling speeds and climb angles are the same as MCAT 1 as both modelling categories represent turboprop engine aircraft. For MCAT 5 and MCAT 7, the travelling speeds and climb angles were assumed to be the same as MCAT 3 due to their similar maximum take-off weight. The Embraer E190-E2 in MCAT 8 was assumed to have the same travelling speeds and climb angles as the successive aircraft model of the Embraer E190 in MCAT 4.

In the dispersion model, only emissions below 1,500ft were included since emissions above 1,500ft would have negligible impact on ground level concentrations. This means that emissions from the modes of upper approach and climb out were calculated but not included in the dispersion model.

For the **approach** of the arriving aircraft, emissions were calculated in two segments: upper approach from 3,000ft to 1,500ft (914.4m to 457.2m) and final approach from 1,500ft (457.2m) to the ground. Emissions were calculated using a 15% thrust for upper approach and 30% thrust for final approach. An approach angle of 5.5° was used for all aircraft. Table 5 presents the final approach parameters included in the model for the lead aircraft in each MCAT which were used for both 2017 and 2035.

Table 5: Final approach model parameters for 2017 and 2035

MCAT	Aircraft	Speed	Horizontal distance (m)	Time (s)
1*	DH8D	from 68m/s to 56m/s	4,748	76
2	SB20	from 68m/s to 56m/s	4,748	76
3	A318	from 106m/s to 65m/s	4,748	56
4	E190	from 103m/s to 66m/s	4,748	56
5#	BCS1	from 106m/s to 65m/s	4,748	56
6	RJ85	from 103m/s to 63m/s	4,748	57
7#	A20N	from 106m/s to 65m/s	4,748	56
8+	E290	from 103m/s to 66m/s	4,748	56
Note: * assumes same parameters as MCAT 2 # assumes same parameters as MCAT 3 + assumes same parameters as MCAT 4				

For the **landing** phase, emissions were calculated using a 7% thrust which is the ICAO default. No reverse thrust was applied during landing as its use is discouraged by London City Airport to manage noise levels.

Emissions were modelled at ground level and times-in-mode were derived using travelling speeds from Bickerdike Allen Partners, and distances on the runway from information provided by London City Airport. Table 6 and Table 7 Table 1present the landing parameters included in the model for the lead aircraft in each MCAT for 2017 and 2035 respectively.

Table 6: Landing model parameters for 2017

MCAT	Aircraft	Speed	Runway 09		Runway 27	
			Horizontal distance (m)	Time (s)	Horizontal distance (m)	Time (s)
1*	DH8D	from 56m/s to 8m/s	505	16	1,045	33
2	SB20	from 56m/s to 8m/s	505	16	1,045	33
3	A318	from 65m/s to 8m/s	505	23	970	27
4	E190	from 66m/s to 8m/s	505	25	1,045	28
5#	BCS1	from 65m/s to 8m/s	505	23	970	27
6	RJ85	from 63m/s to 8m/s	505	26	1,045	29
7	A20N	-	-	-	-	-
8	E290	-	-	-	-	-

Note: * assumes same parameters as MCAT 2
assumes same speed as MCAT 3

Table 7: Landing model parameters for 2035

MCAT	Aircraft	Speed	Horizontal distance (m)	Time (s)
1*	DH8D	from 56m/s to 8m/s	1,280	40
2	SB20	-	-	-
3	A318	from 65m/s to 8m/s	1,280	35
4	E190	from 66m/s to 8m/s	1,280	35
5#	BCS1	from 65m/s to 8m/s	1,280	35
6	RJ85	-	-	-
7#	A20N	from 65m/s to 8m/s	1,280	35
8+	E290	from 66m/s to 8m/s	1,280	35

Note: * assumes same parameters as MCAT 2
assumes same parameters as MCAT 3
+ assumes same parameters as MCAT 4

For the **take-off** phase, emissions were calculated using an 85% thrust for the engines. The 85% thrust for take-off is different from the ICAO default of 100% but follows the recommendations by the PSDH methodology. Table 8 and Table 9 present the take-off parameters included in the model for the lead aircraft in each MCAT for the two runways for 2017 and 2035 respectively.

Table 8: Take-off model parameters for 2017

MCAT	Aircraft	Speed	Runway 09		Runway 27	
			Horizontal distance (m)	Time (s)	Horizontal distance (m)	Time (s)
1*	DH8D	from 0 to 62m/s	1,280	41	560	18
2	SB20	From 0 to 62m/s	1,280	41	560	18
3	A318	from 0 to 69m/s	1,027	37	1,280	16
4	E190	from 0 to 74m/s	1,280	35	560	15
5#	BCS1	from 0 to 69m/s	1,027	37	1,280	16
6	RJ85	from 0 to 70m/s	1,280	37	560	16
7	A20N	-	-	-	-	-
8	E290	-	-	-	-	-
Note: * assumes same speed as MCAT 2 # assumes same speed as MCAT 3						

Table 9: Take-off model parameters for 2035

MCAT	Aircraft	Speed	Horizontal distance (m)	Time (s)
1*	DH8D	from 0 to 62m/s	1,280	41
2	SB20	-	-	-
3	A318	from 0 to 69m/s	1,280	37
4	E190	from 0 to 74m/s	1,280	35
5#	BCS1	from 0 to 69m/s	1,280	37
6	RJ85	-	-	-
7#	A20N	from 0 to 69m/s	1,280	37
8+	E290	from 0 to 74m/s	1,280	35
Note: * assumes same parameters as MCAT 2 # assumes same parameters as MCAT 3 + assumes same parameters as MCAT 4				

For the **climb** phase of the arriving aircraft, emissions were calculated in two segments: initial climb from the ground up to 1,500ft and climb out from 1,500ft to 3,000ft. Emissions were calculated using an 85% thrust for initial climb, consistent with the take-off thrust, and 78% thrust for climb out, as recommended by the PSDH methodology.

Table 10 presents the initial climb parameters included in the model for the lead aircraft in each MCAT for 2017 and 2035.

Table 10: Initial climb model parameters for 2017 and 2035

MCAT	Aircraft	Angle	Speed	Horizontal distance (m)	Time (s)
1*	DH8D	11°	from 62m/s to 68m/s	2,288	35
2	SB20	11°	from 62m/s to 68m/s	2,288	35
3	A318	7°	from 69m/s to 106m/s	3,569	41
4	E190	10°	from 74m/s to 103m/s	2,703	31
5#	BCS1	7°	from 69m/s to 106m/s	3,569	41
6	RJ85	6°	from 70m/s to 103m/s	4,581	53
7#	A20N	7°	from 69m/s to 106m/s	3,569	41
8+	E290	10°	from 74m/s to 103m/s	2,703	31
Note: * assumes same speed as MCAT 2 # assumes same speed as MCAT 3 + assumes same speed as MCAT 4					

Brake and tyre wear were represented in the model as volume sources (Figure 16 and Figure 17). PM_{10} emission rates were calculated following the PSDH methodology as amended in the 2005/6 emissions inventory for Gatwick Airport. Brake and tyre wear were calculated using the following equations:

*Brake wear = 2.5 * 10^{-7} * MRW [kg PM_{10} per LTO]*

*Tyre wear = 10% * (2.23 * 10^{-6} * MRW – 0.0879) [kg PM_{10} per LTO]*

where MRW is the maximum ramp weight. However, Maximum Take-Off Weight (MTOW) has been assumed to be equal to MRW for this assessment. It was assumed that $PM_{2.5}$ emissions were 40% for brake wear and 70% for tyre wear of PM_{10} emissions.

For **taxiing** in and out of the arriving and departing aircraft, emissions were calculated using a 7% thrust for the engines, which is the ICAO default. Emissions were distributed spatially on the taxiways based on the stand location and the 2017 flight schedule provided by LCY. Times-in-mode were derived from the detailed 2017 movements; the average values were 3.5 minutes for taxi-in and 7.5 minutes for taxi-out.

Hold emissions for departing aircraft were calculated using a 7% thrust for the engines which is the ICAO default. The average time-in-mode of 1.5 minutes was calculated using the difference between the Eurocontrol taxi-out time for the airport and the observed taxi-out time from the detailed fleet data at the airport. Emissions were distributed spatially at the holding positions on the airfield.

In the dispersion model, MCAT 1 and MCAT 2 were combined and represented as volume sources in accordance with the ADMS-Airport User Guide for the LTO modes of final approach, landing, take-off and initial climb. This is presented in Figure 4 and Figure 5 for operations using 09 and 27 runway directions respectively.

The other MCATs were modelled as aircraft sources for all phases of the LTO cycle. Figure 6 and Figure 7 present the modelled aircraft sources for arrival operations using the 09 and 27 runway directions in 2017. Figure 8 and Figure 9 present the modelled aircraft sources for departure operations using the 09 and 27 runway directions. Since the lengths of final approach, landing, take-off and initial climb varies by MCAT, the figures present a typical length for these modes.

Figure 10 and Figure 11 present the modelled LTO volume sources in 2035 for 09 and 27 runway directions respectively, whereas Figure 12 to Figure 15 present the modelled aircraft sources for arrival and departure operations using the 09 and 27 runway directions.

Figure 4: Modelled LTO volume sources in 2017 – Runway 09

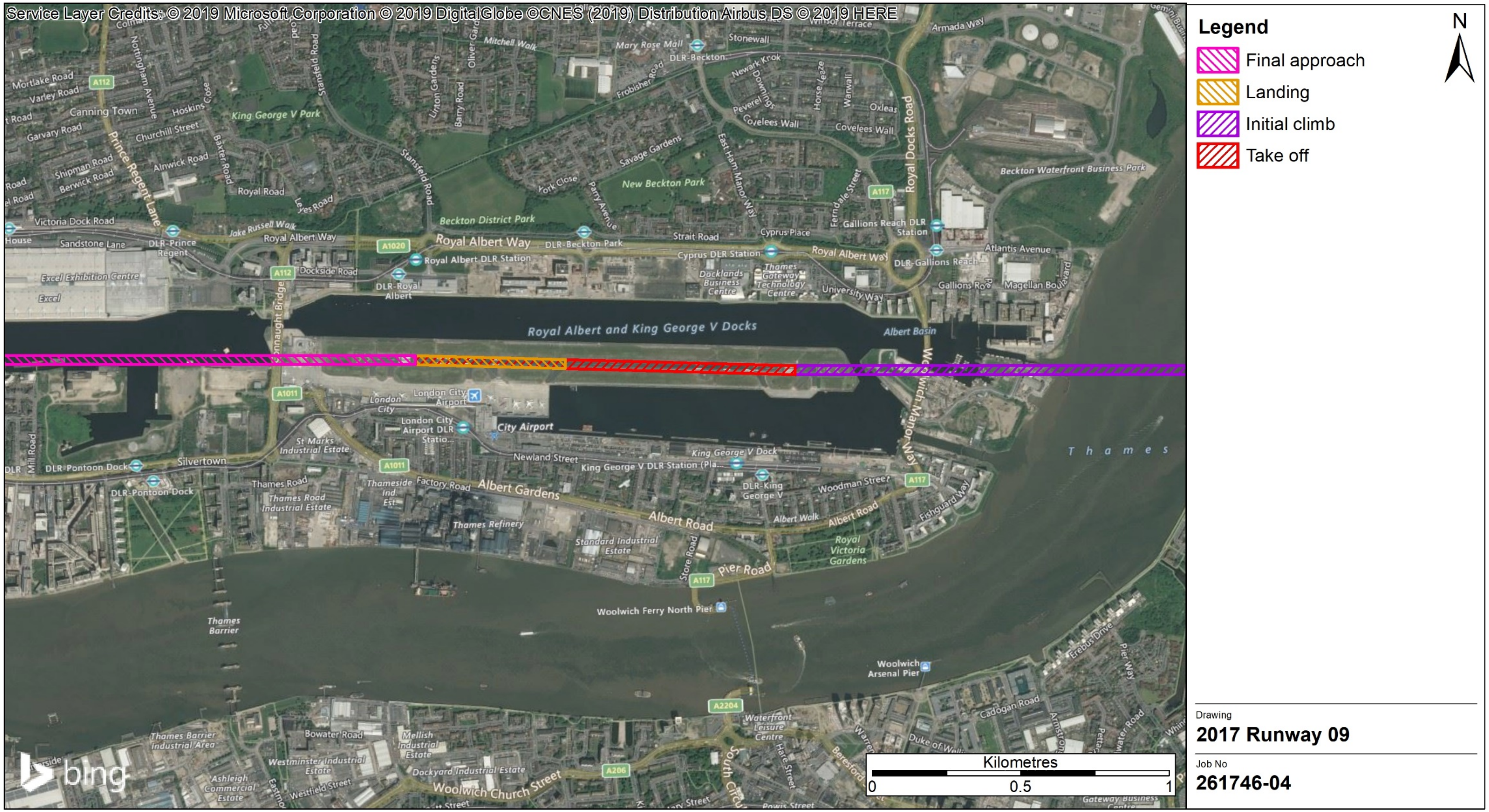


Figure 5: Modelled LTO volume sources in 2017 – Runway 27

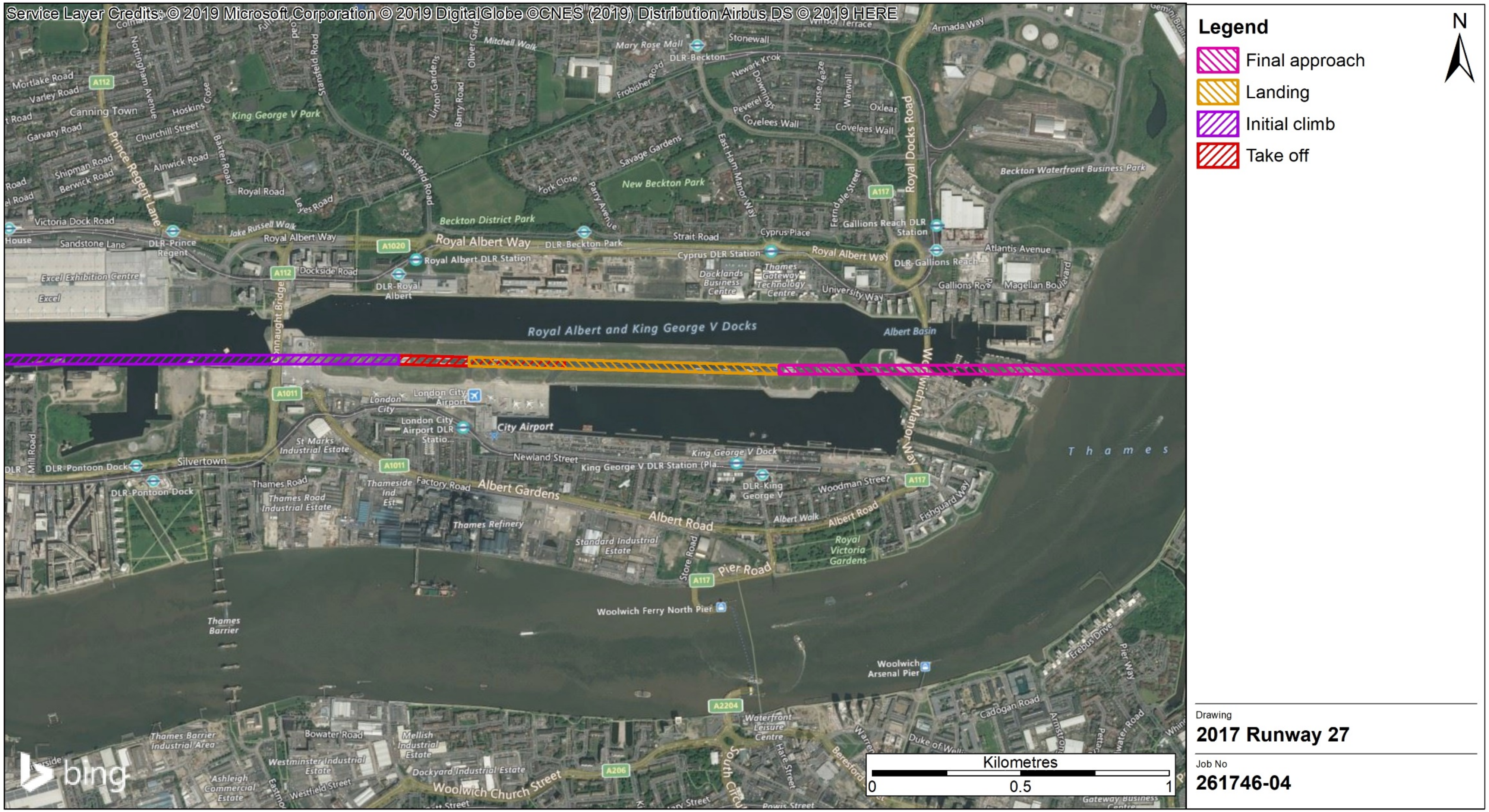


Figure 6: Modelled LTO aircraft sources in 2017– Arrivals 09

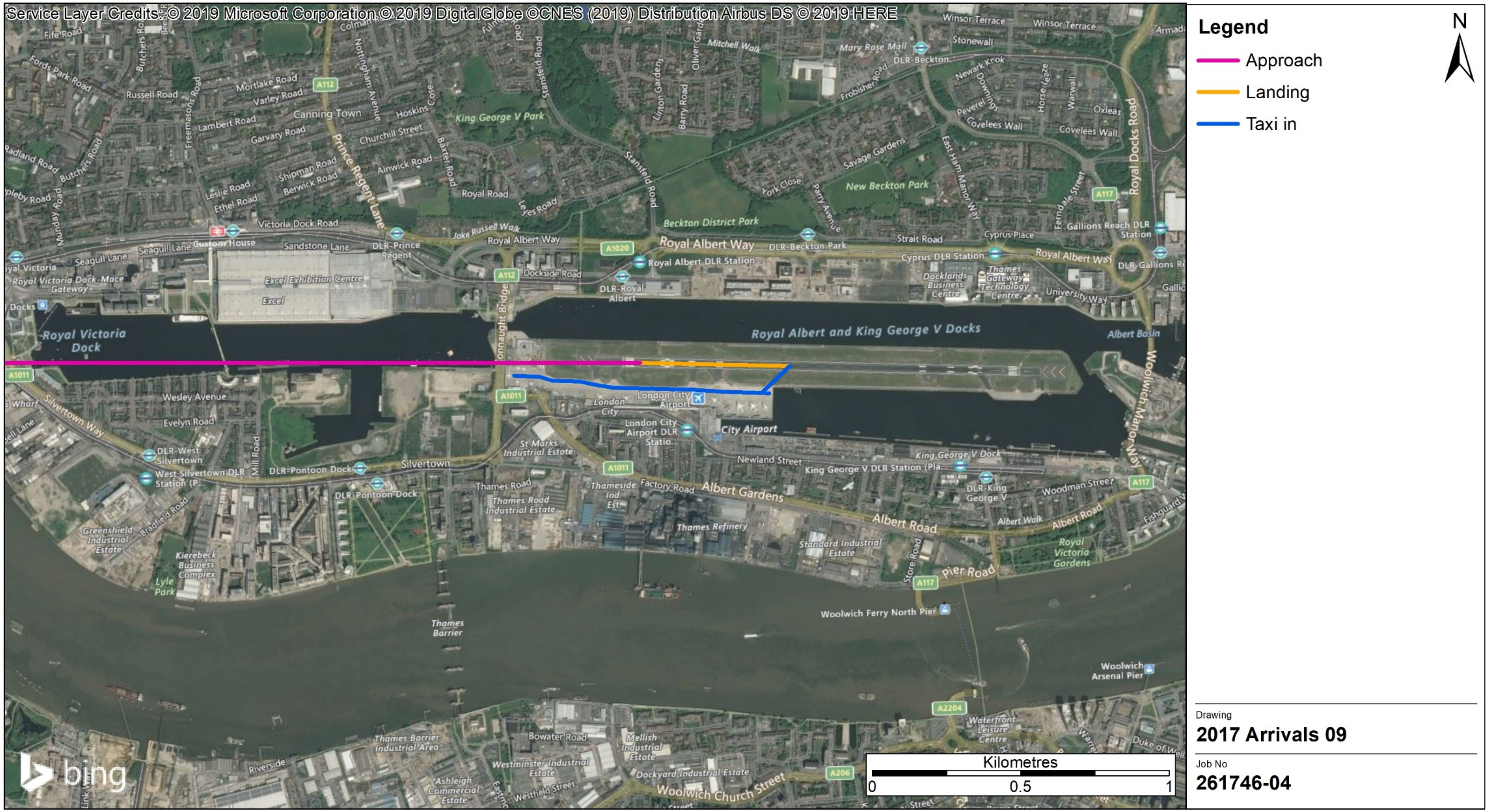


Figure 7: Modelled LTO aircraft sources in 2017 – Arrivals 27

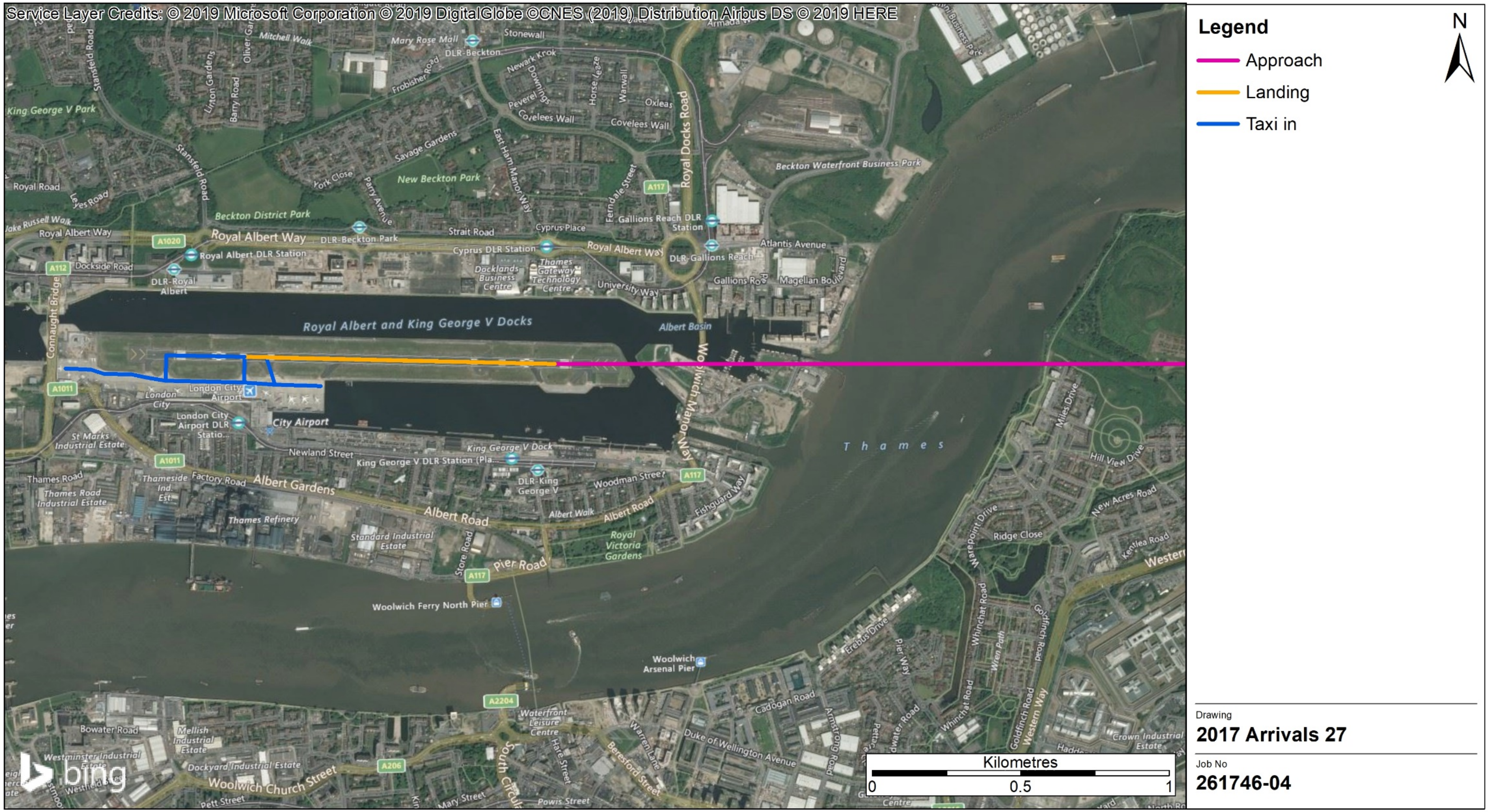


Figure 8: Modelled LTO aircraft sources in 2017 – Departures 09

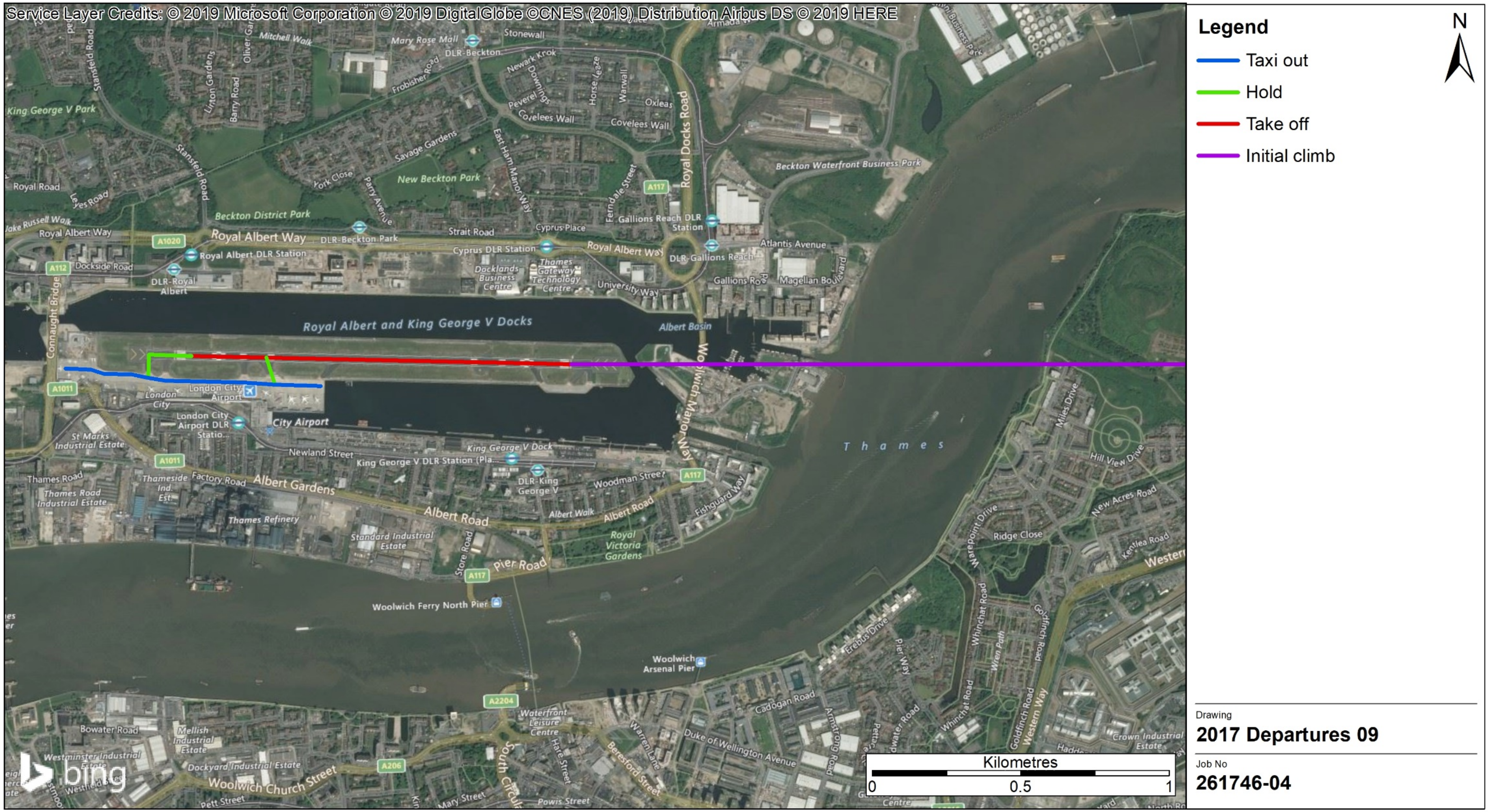


Figure 9: Modelled LTO aircraft sources in 2017 – Departures 27

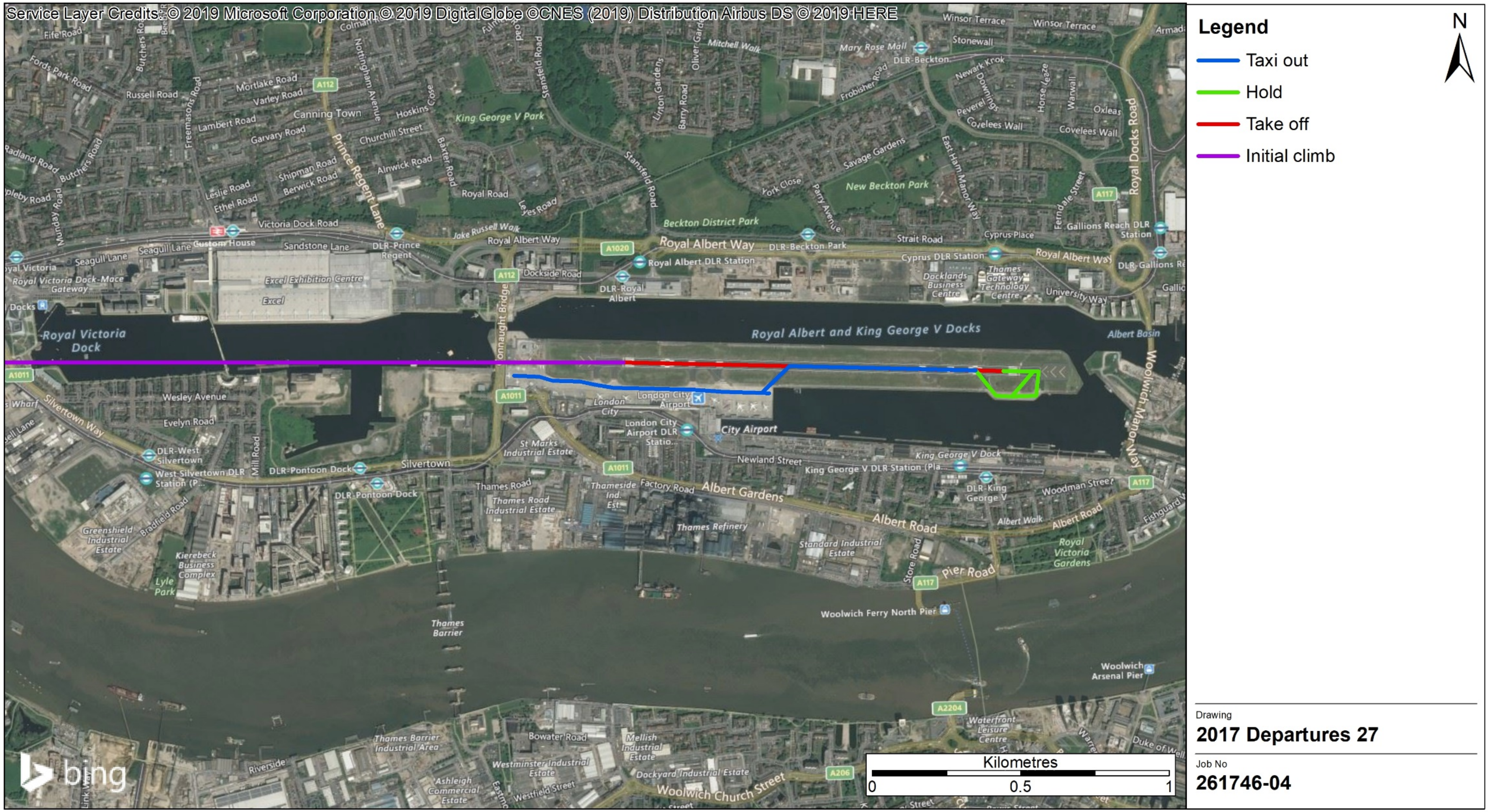


Figure 10: Modelled LTO volume sources in 2035 – Runway 09

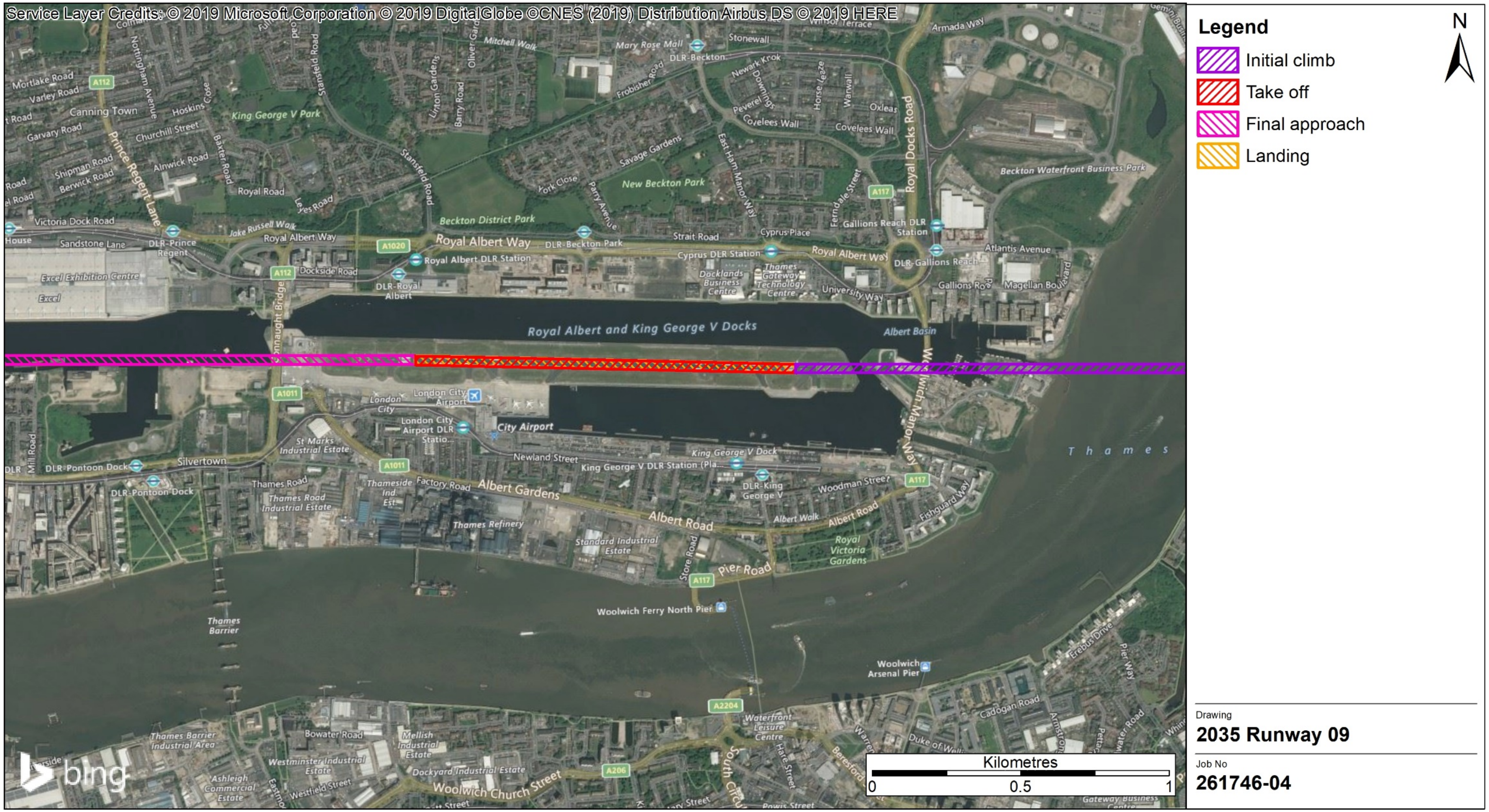


Figure 11: Modelled LTO volume sources in 2035 – Runway 27

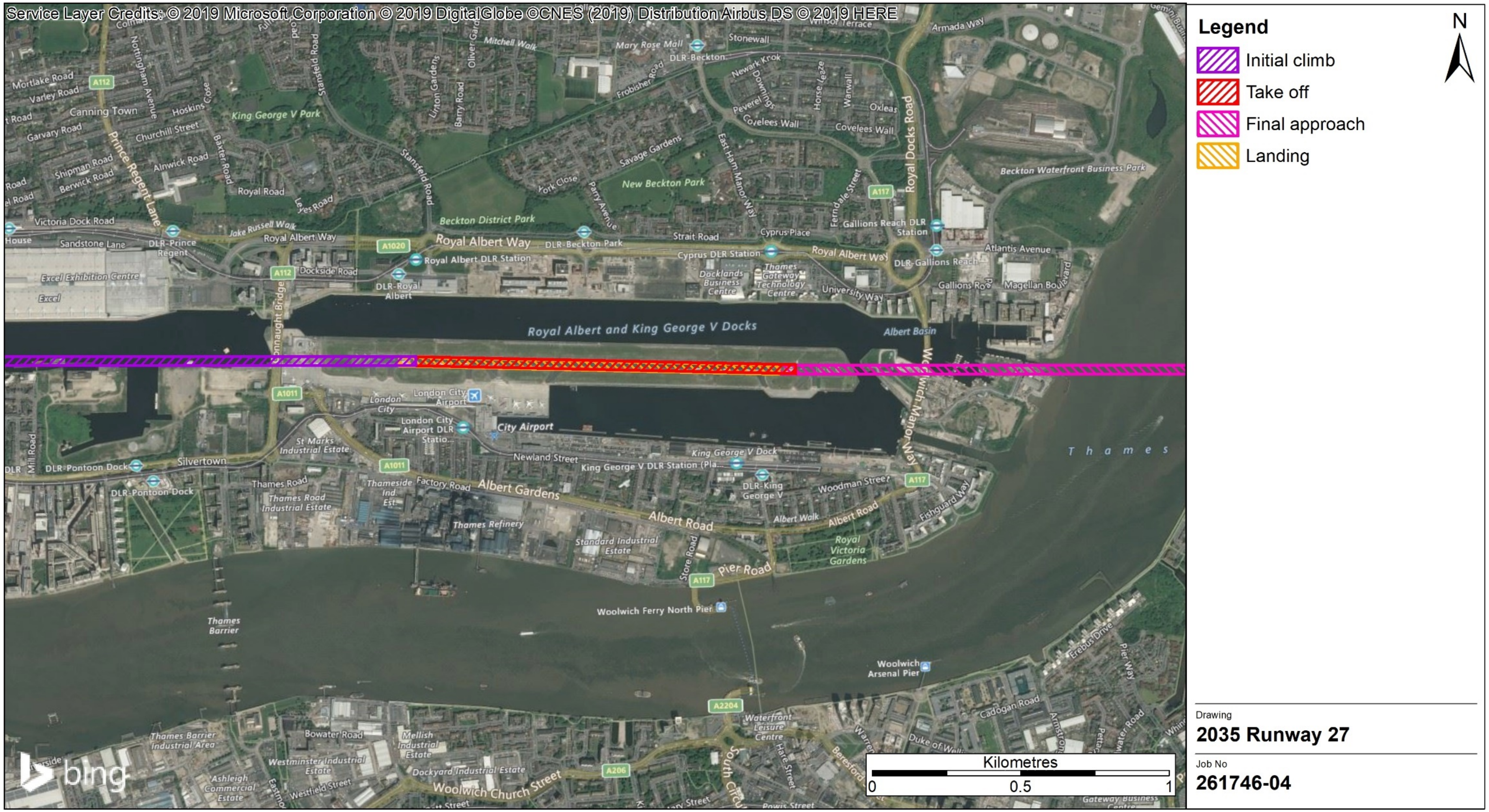


Figure 12: Modelled LTO aircraft sources in 2035– Arrivals 09

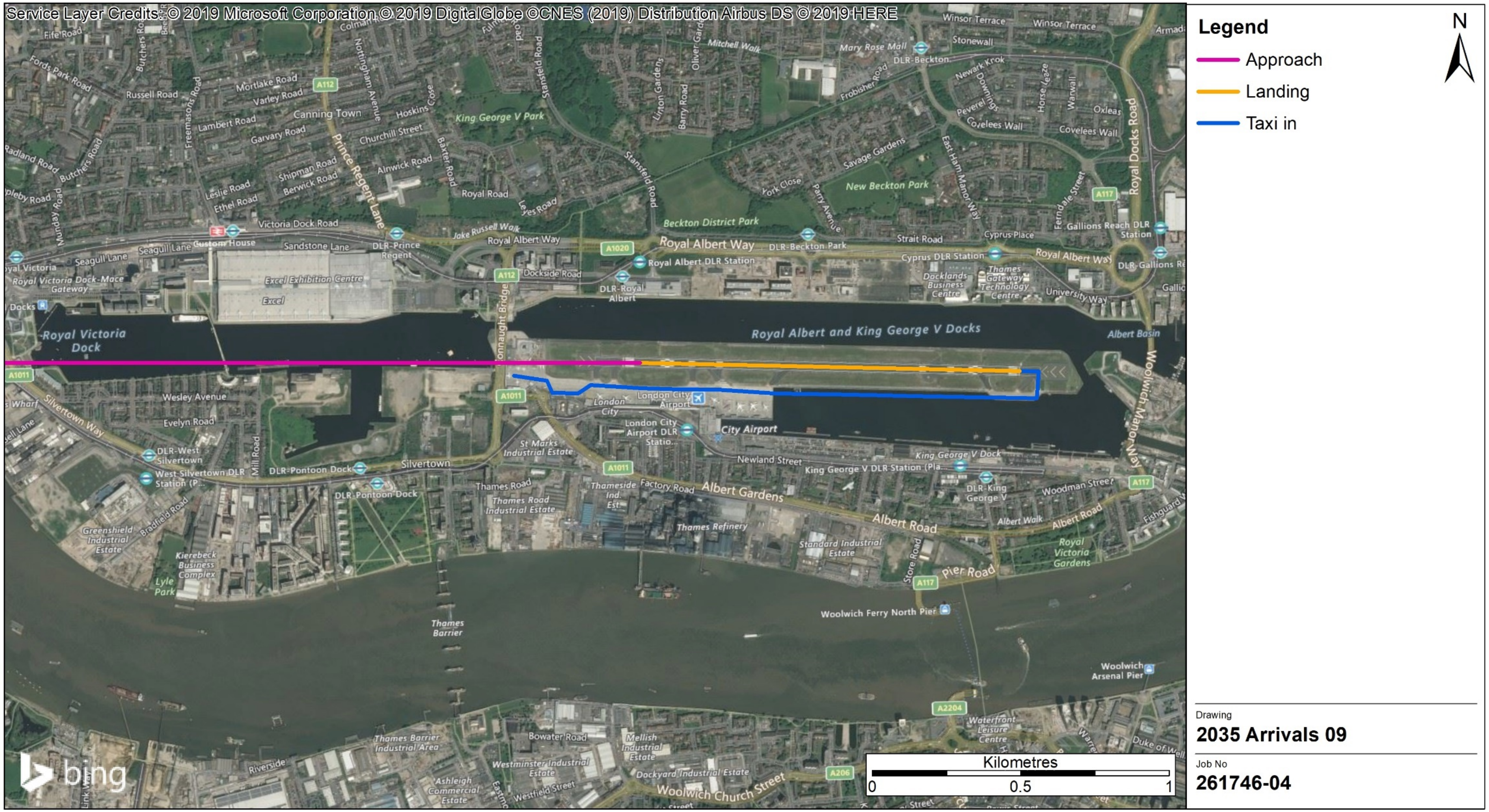


Figure 13: Modelled LTO aircraft sources in 2017 – Arrivals 27

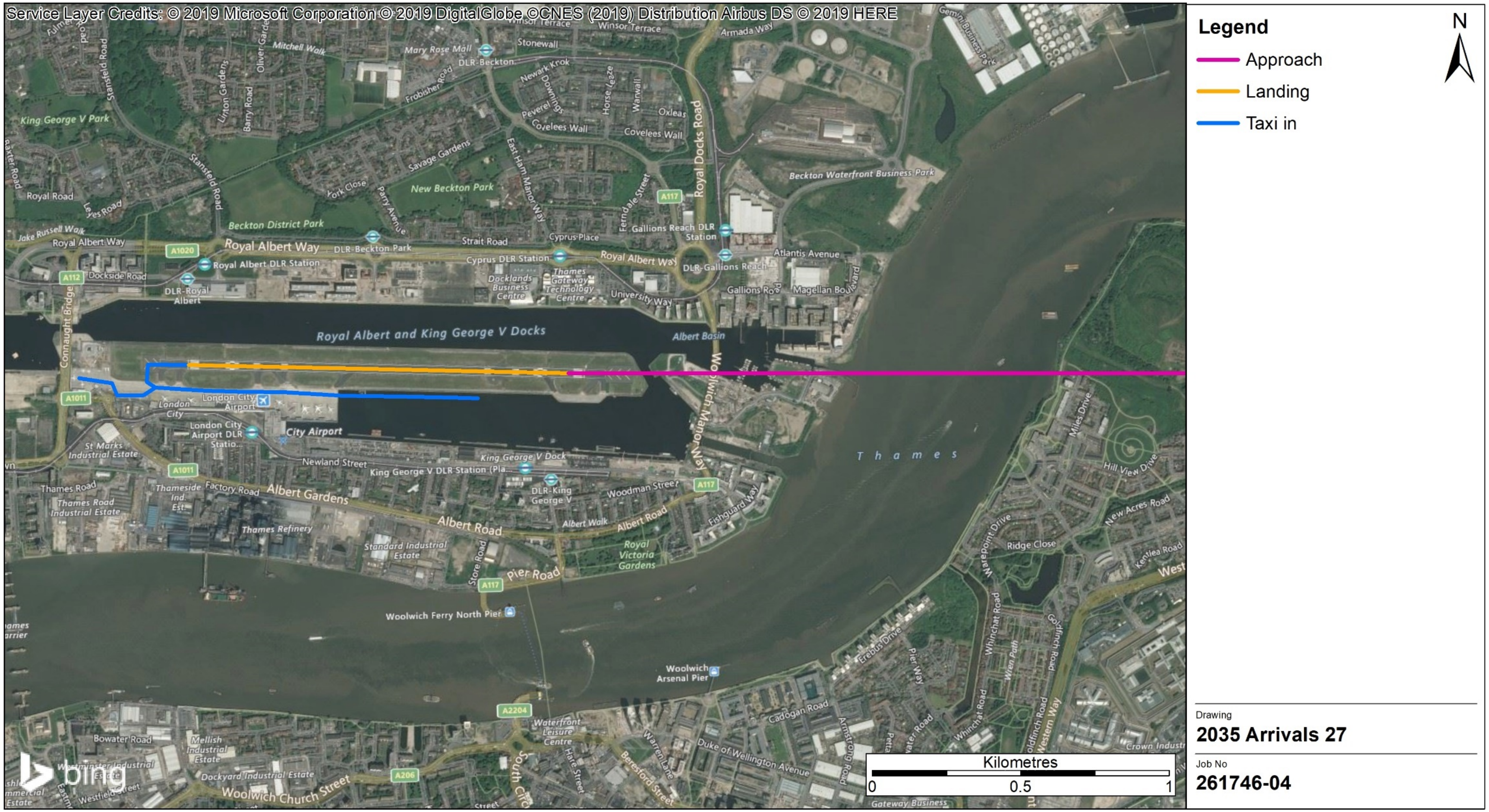


Figure 14: Modelled LTO aircraft sources in 2017 – Departures 09

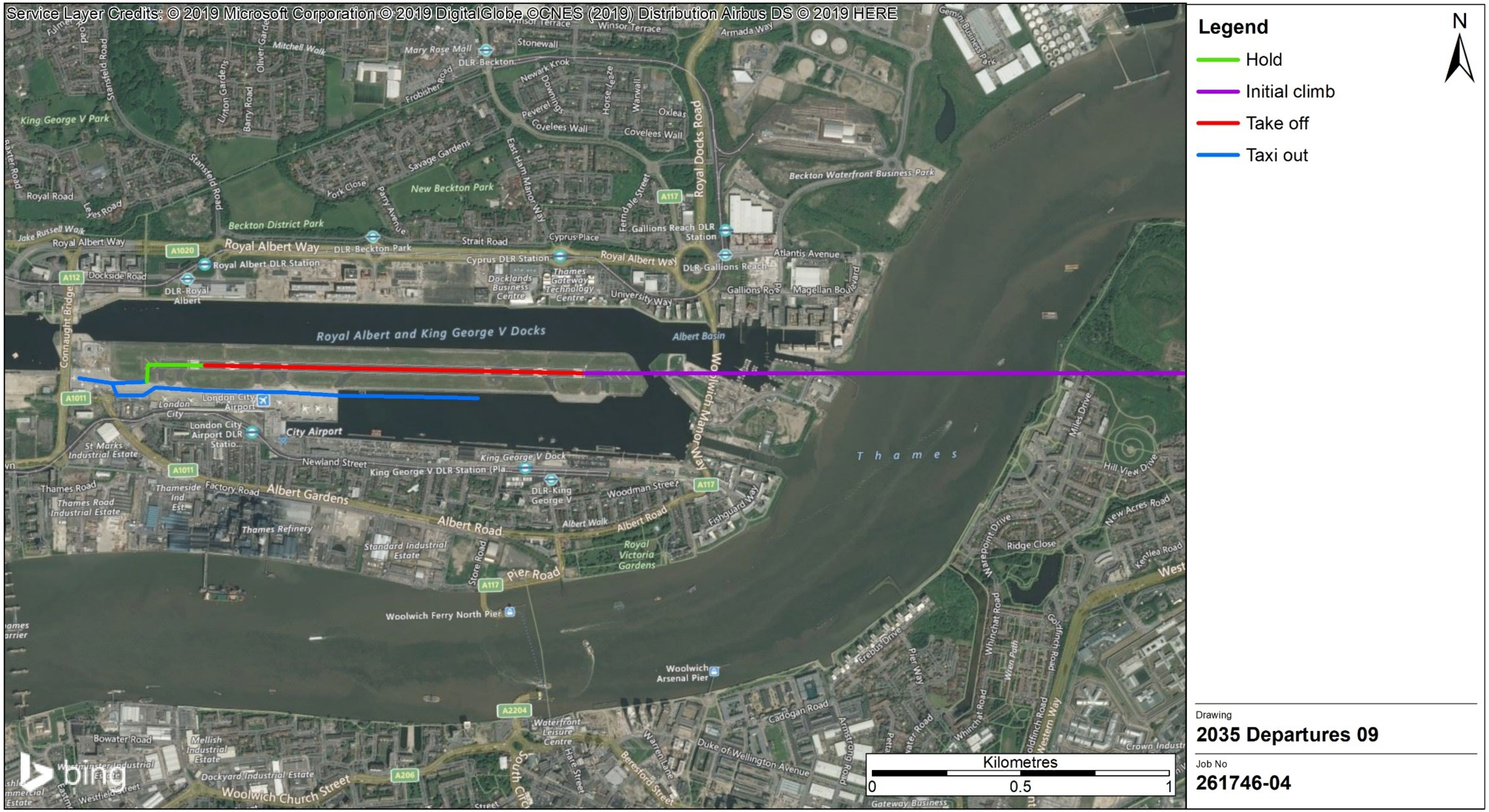


Figure 15: Modelled LTO aircraft sources in 2017 – Departures 27

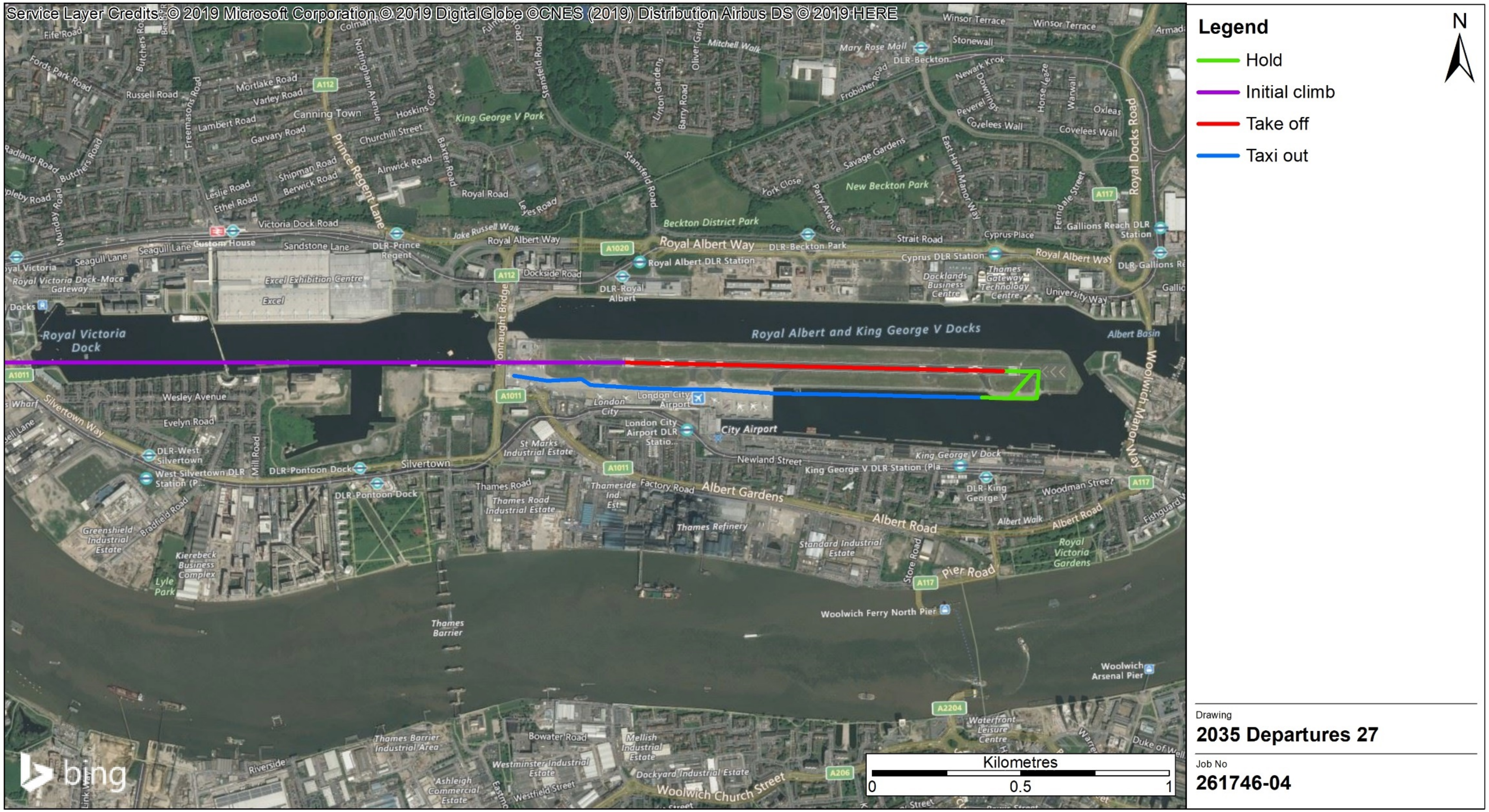


Figure 16: Modelled LTO sources – Brake and tyre wear in 2017

Figure 17: Modelled LTO sources – Brake and tyre wear in 2035

B3 Aircraft engine testing

Detailed data on aircraft engine testing was provided by London City Airport for 2017. There were 201 tests during the year, 163 ground idle runs and 38 high-power runs at the stands. Ground idle runs occur at all stands, whereas high-power runs only occur at stands 10 and 24. The aircraft types for these tests were classified according to their respective MCATs (Table 11) and emissions were calculated using the same approach as the aircraft in the LTO cycle. A thrust setting of 15% was assumed for ground idle runs and 85% for high-power runs. The run times for each aircraft type were calculated using the data provided by London City Airport. A diurnal profile was also applied, as shown in Figure 18. Figure 19 presents the location of the engine testing on the aprons near the stands on the airport in 2017.

For the 2035 future year scenario the engine testing emissions were scaled by the increase in ATMs. The calculated emissions were then spatially distributed at the airport on the aprons near the stands (Figure 20).

Table 11: Engine testing at stands

MCAT	Aircraft type ICAO	Ground idle runs		High-power runs	
		Number of runs	Time (s)	Number of runs	Time (s)
1	DH8D	22	332.7	-	
	J328	16[a]	374.3[c]	2[a]	690.0[c]
2	D328	4	585.0	-	
3	A318	5	528.0	-	
4	E170	23[b]	349.6	6	1380.0
	E190	55[b]	364.4	28	1326.9
6	RJ85	29	337.2	4	375.0
	RJ1H	9	286.7	-	

Note: [a] There were 16 ground idle runs and two high-power runs for jet types not included in MCATs. These runs were added to MCAT 1 and their emissions were assumed to be the same as a J328.

[b] There were two ground idle runs for E170 and E190 aircraft type with unknown stand locations; these were attributed to stands 1-10 and stands 21-24, as these were the most commonly used stands.

[C] This was an average run time for the jet types assumed to be a J328 aircraft type

Figure 18: Diurnal profile for engine testing

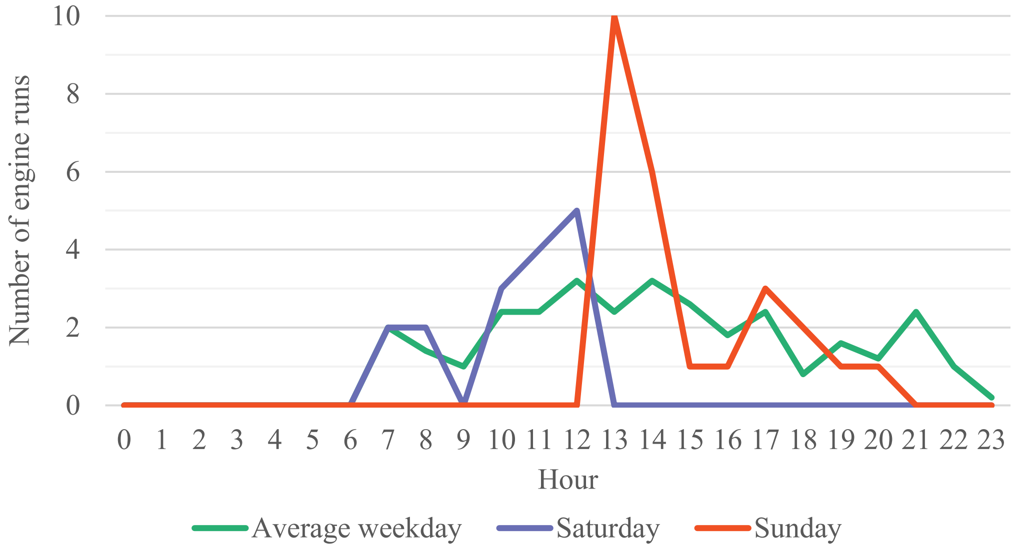


Figure 19: Location of engine testing modelled at stands in 2017

Figure 20: Location of engine testing modelled at stands in 2035

B4 Auxiliary Power Units (APUs)

Emissions from APUs were calculated using representative engines for each MCAT. If information was not available on the type of APU for an aircraft type, emissions were taken from a similar aircraft. Table 12 presents the APU types and emission factors, taken from the EDMS software and IATA's long-term traffic and emission forecast. It was assumed that pNO_2 emissions were 10% of NOx, taken from the EMIT software. Figure 21 presents the modelled sources for the APUs at the stands in 2017.

For the 2035 future year scenario the APU emissions have been calculated from the projected 2035 aircraft fleet and the increase in ATMs. The calculated emissions were then spatially distributed at the airport on the aprons near the stands, based on the stand use. Figure 22 presents the modelled sources for the APUs at the stands in 2035.

Table 12: APU emission factors

MCAT	Aircraft type	APU	NOx (kg/hr)	PM_{10} (kg/hr)
1	DH8D	APS 1000/T-62T-46C12	0.459	0.074
	AT45	GTCP 36 (80HP)	1.012	0.062
	J328	36-150DD	0.310	0.062
	F50	GTCP 36 (80HP)	1.012	0.062
2	SB20	T-62T-46C7	0.459	0.074
	AT43	GTCP 36-150[]	0.310	0.062
	D328	36-150DD	0.310	0.062
3	A318	APU GTCP 36-300 (80HP)	1.012	0.062
4	E190	Sundstrand APS 2300	0.510	0.155
	E170	Sundstrand APS 2300	0.510	0.155
5	BCS1	Honeywell 131-9C	0.770	0.093
6	RJ85	APU GTCP 36-100	0.353	0.062
	B462	GTCP 36-100	0.353	0.062
7	A20N	APU GTCP 36-300 (80HP)	1.012	0.062
8	E290	Sundstrand APS 2300	0.510	0.155

Figure 21: Location of modelled APUs in 2017

Figure 22: Location of modelled APUs in 2035

B5 Fire training ground

Data on the fuel consumption for the fire training ground was provided by London City Airport. The fire training ground used red diesel, propane and wood in 2017. The emission factors were taken from the NAEI and then converted to kg/litre or kg/kg for use in the assessment (Table 13). The fire training ground was used for approximately two hours every day, so a diurnal profile was applied accordingly. Figure 23 presents the location of the fire training ground on the airport.

For the 2035 future year scenario the fire training ground emissions have been assumed to remain unchanged.

Table 13: Fuel consumption at the fire training ground

Fuel type	**Fuel consumption (litres)**	**Emission factor**	
		NOx (kg/litre)	**PM_{10} (kg/litre)**
Red diesel	8,760	1.82×10^{-2}	7.08×10^{-4}
Fuel type	**Fuel consumption (kg)**	**NOx (kg/kg)**	**PM_{10} (kg/kg)**
Propane	5,450	2.92×10^{-3}	3.08×10^{-5}
Wood	1,860	1.67×10^{-3}	2.63×10^{-3}

Figure 23: Location of modelled fire training ground

B6 Ground Support Equipment (GSE)

Data for the airside vehicles at the airport was provided by London City Airport, including a record of all permitted vehicles for airside access, total number of airside vehicles operating at the airport and total litres of diesel used in 2017. For the emissions calculations, GSE were split into road vehicles and non-road mobile machinery (NRMM) and spatially distributed at the airport on the aprons near to the stands (Figure 24). The NRMMs were assumed to be compliant to Stage IIIA emission standards and the road vehicles were assumed to be compliant to Euro4/IV emission standards. There was a total of 28 NRMMs and 113 airside vehicles, excluding those that are electric-powered. The 113 airside road vehicles consisted of cars (12%), LGVs (43%) and buses and HGVs (44%). The emission factors used for each vehicle type are presented in Table 14.

A total of 209,095 litres of diesel was consumed by GSE in 2017 and it was assumed that all vehicles had diesel engines. The diesel at the airport was assumed to supply all of the GSE vehicles. However, if the road vehicle GSEs also filled up with fuel off-site (outside of the airport and on the local network), the impact of these vehicles entering the airport (airside) would be offset by the road vehicles filling up with diesel from the airport and travelling off-site.

For the 2035 future year scenario the diesel consumption has been factored up by the increase in ATMs. The same proportions of road vehicles and NRMMs were assumed. All the NRMMS were assumed to be Stage IIIB in 2035 to comply with the Mayor of London's control of dust and emissions during construction and demolition supplementary planning guidance. All road vehicles were assumed to be Euro 6/VI (diesel) in 2035 which would also make them compliant with the expanded Ultra Low Emission Zone (ULEZ) from October 2021. The calculated emissions were then spatially distributed at the airport on the aprons near the stands (Figure 25).

Table 14: Emission factors for GSE

Vehicle type	NOx	PM_{10}
NRMM (g/tonnes)		
Stage IIIA	15,653	950
Stage IIIB	11,933	98
Road vehicles (g/km)		
Car (Euro 4)	0.8219	0.0372
Car (Euro 6d)	0.2720	0.0008
LGV (Euro 4)	1.0710	0.0442
LGV (Euro 6d)	0.7093	0.0008
Bus and HGV (Euro IV)	4.6003	0.0383
Bus and HGV (Euro VI)	0.0828	0.0018

Figure 24: Location of modelled GSE in 2017

Figure 25: Location of modelled GSE in 2035

B7 Ground Power Units (GPUs)

The red diesel fuel consumption for nine Ground Power Units (GPUs) in 2017 was provided by London City Airport. In total, 16,064 litres was drawn over the year. The GPUs at London City Airport are EU Stage IIIA emission compliant and the emission factors are presented in Table 15. The data provided also included the date of withdrawals, so a monthly profile was applied as shown in Figure 26. The GPU emissions were spatially distributed at the airport on the aprons near to the stands in 2017 (Figure 27).

For the 2035 future year scenario the GPU emissions were scaled up by the increase in ATMs and then divided by the percentage of jet centre ATMs, as it was assumed that GPUs will only be used for aircraft at the jet centre. The calculated emissions were then spatially distributed across the jet centre apron (Figure 28).

Table 15: Emission factors for GPUs

Emission standard	NOx (g/tonnes)	PM_{10} (g/tonnes)
Stage IIIA	15,653	950

Figure 26: Fuel consumption for GPUs in 2017

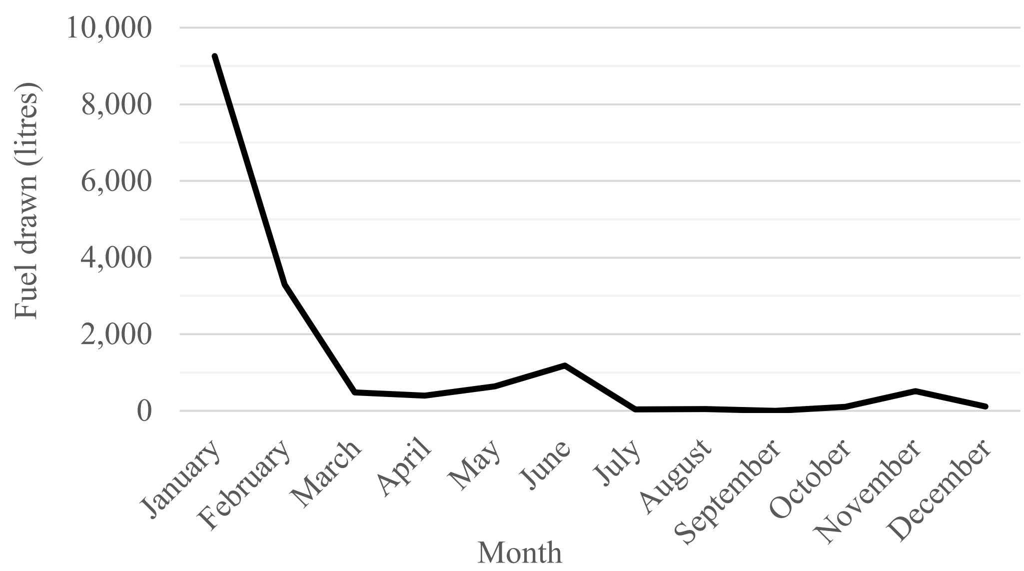


Figure 27: Location of modelled GPUs in 2017

Figure 28: Location of modelled GPUs in 2035

B8 Energy centres

In 2017 there was one energy centre at London City Airport at the terminal with two boilers exhausting via one stack. By 2035 the Eastern Energy Centre (EEC) described in the City Airport Development Programme (CADP1) report[1] will be operational. It will include two CHPs which would exhaust via one stack and six operational boilers which would exhaust via two stacks.

Data for the energy centres was taken from data sheets provided and the CADP report. The location and heights have been estimated from drawings attached to the same updated Environmental Statement. Table 16 presents the model parameters used. The energy centres were represented in the model as point sources; their locations are shown in Figure 30.

For the 2035 future year scenario the energy centre emissions at the terminal have been assumed to remain unchanged.

Table 16: Model input parameters for current and future energy centres

Parameter	Terminal boilers (combined efflux)	EEC CHP (combined efflux)	EEC boilers (combined efflux for one stack)
Operating year	2017 and 2035	2035	2035
OS co-ordinates[a]	542363, 180328	542949, 180208	542947, 180208
			542948, 180208
Height (m)[a]	20.00	11.91	11.91
Diameter (m) [a]	0.28	0.15	0.50
Exhaust velocity (m/s)	3.49	29.74	4.85
Exhaust temperature (°C)	80	120	80
NOx emission rate (g/s)	0.01	0.03	0.03
Note: [a] estimated from drawings			

Time varying files were applied to both the existing and future energy centre emissions for modelling the boilers and CHPs. Profiles were taken from the CADP[1] report to apply diurnal and seasonal variation to the energy centres. It was assumed from the report that the energy centre operational hours were 05:00-23:00 every day. The CHPs would run at 50% during that period across the year and the boilers across the same period at a maximum of 10% with a seasonal variation as shown in Figure 29.

[1] Atkins (March 2018) City Airport Development Programme (CADP1), Condition 61: Energy Assessment

Figure 29: Seasonal variation applied to the modelling of the existing and future boilers

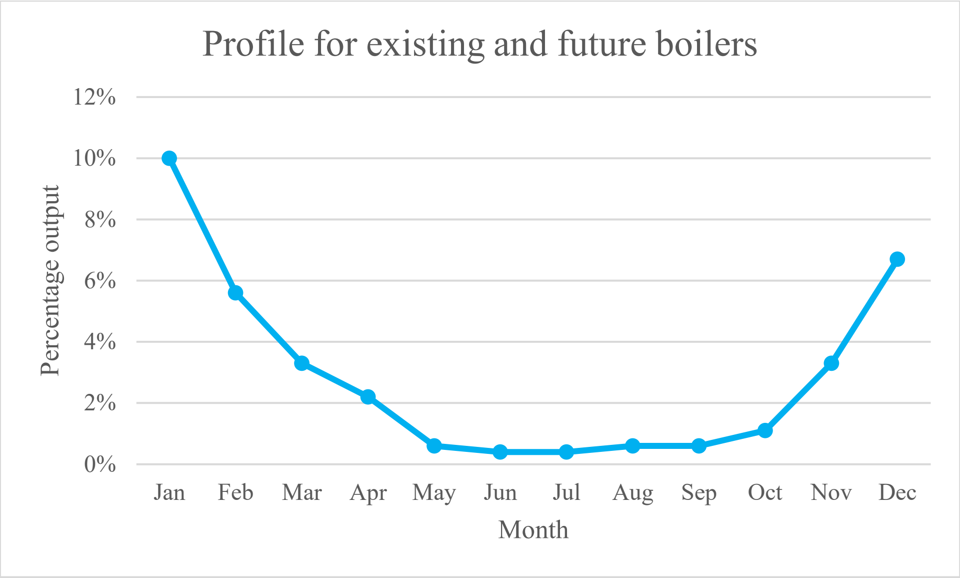
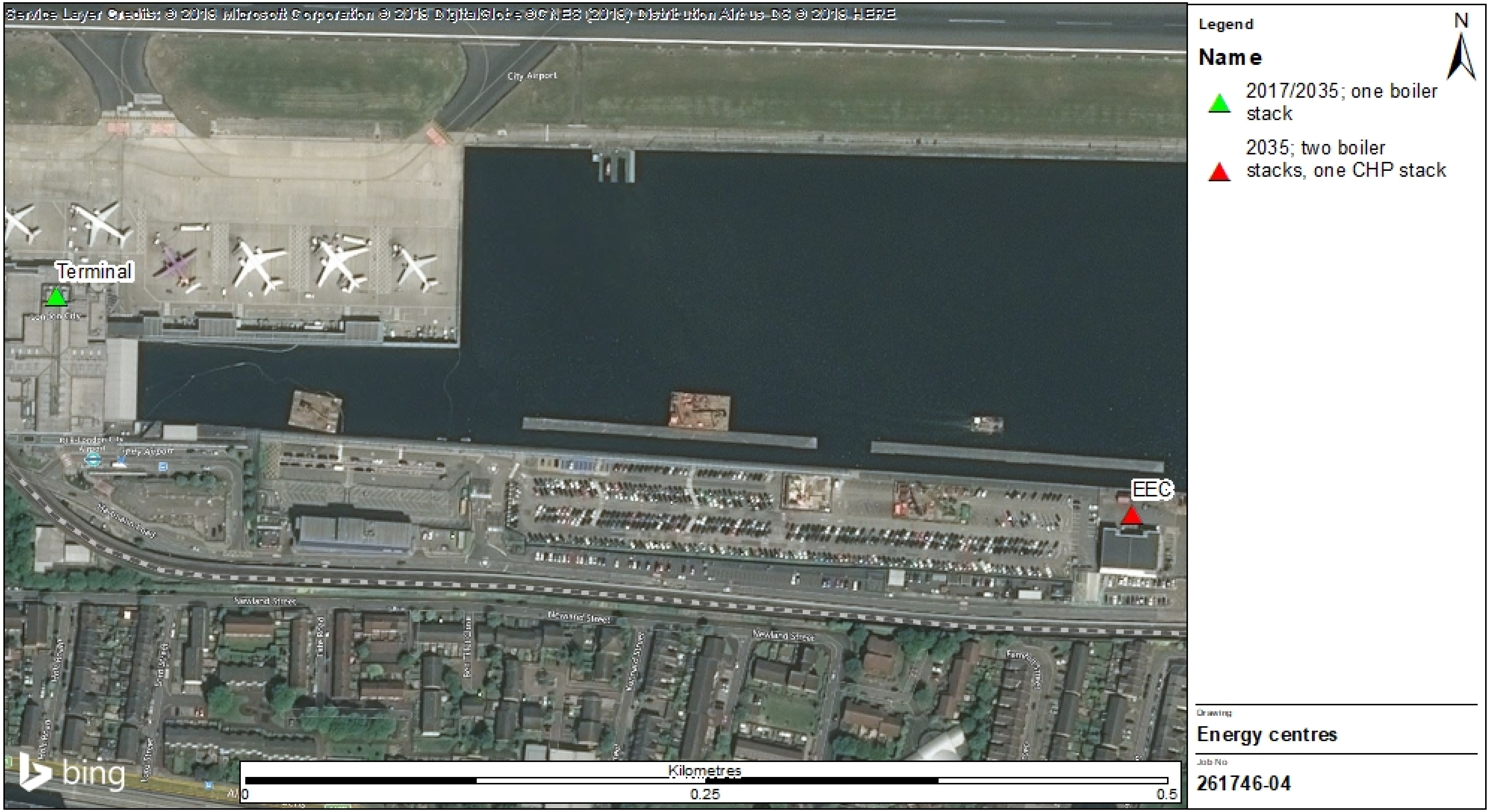


Figure 30: Locations of modelled energy centres in 2017 and 2035



Appendix C

Traffic data

Contents

C1 Road network

Figure 1 shows the extent of the modelled roads and the location of junctions. The annual average daily traffic (AADT) for the modelled roads in 2017 and 2035 is presented in Table 1. The traffic data was obtained from DfT traffic counts and Arup transport counts. Figure 2 and Figure 3 show the roads colour-coded based on the AADT flows in 2017 and 2035.

Figure 1: Modelled road network in 2017 and 2035

Table 1: Traffic data for modelled road network in 2017 and 2035

Road	Mean speed (kph)	2017		2035		Source of data
		AADT	% HGV	AADT	% HGV	
Victoria Dock Road	50	9,068	2.9	9,068	2.9	DfT
Royal Albert Way East Bound	65	10,130	7.0	10,130	7.0	DfT
Royal Albert Way East Bound (West of roundabout)	65	5,065	7.0	5,065	7.0	DfT
Royal Albert Way East Bound on-slip	65	5,065	7.0	5,065	7.0	DfT
Royal Albert Way West Bound	65	10,130	7.0	10,130	7.0	DfT
Royal Albert Way West Bound (West of roundabout)	65	5,065	7.0	5,065	7.0	DfT
Royal Albert Way West Bound off-slip	20	5,065	7.0	5,065	7.0	DfT
Woolwich Manor Way	50	10,517	1.8	10,517	1.8	DfT
Albert Road	50	5,880	10.6	5,880	10.6	DfT
Sir Steve Redgrave Bridge	50	11,229	7.3	17,900	5.0	Arup
Fishguard Way (East of crossroads)	20	2,371	0.9	2,400	1.0	Arup
Fishguard Way (West of crossroads)	50	45	40.0	4,700	1.0	Arup
Albert Road	50	10,494	7.6	11,300	4.0	Arup
Pier Road	50	5,252	12.5	5,252	12.5	DfT
A1011 Connaught Road (South-east of roundabout)	50	18,506	3.7	19,600	1.0	Arup
A1011 Connaught Road (West of roundabout)	20	19,100	3.7	20,100	1.0	Arup
Hartmann Road	50	14,240	6.0	12,400	1.0	Arup
A112 Connaught Bridge (North of roundabout)	50	23,446	7.1	26,700	4.0	Arup
A112 Connaught Bridge (South of roundabout)	50	30,293	6.0	37,500	4.0	Arup
Prince Regent Lane	50	11,991	2.3	11,991	2.3	DfT
Connaught roundabout	20	14,215	5.7	15,299	4.7	Arup / DfT
Airport roundabout	20	24,280	5.6	28,100	3.0	Arup
A1011 Connaught Road roundabout	20	18,803	3.7	19,850	1.0	Arup
Woolwich Manor Way roundabout	20	14,002	7.7	16,226	7.0	Arup / DfT

Figure 2: 2017 AADT

Figure 3: 2035 AADT

C2 Car parks

Table 2 presents the traffic data flows for the car parks around the airport. The data is presented as AADT flows (in flows plus out flows) for cars and were provided by London City Airport. Figure 4 and Figure 5 present the locations of the modelled car parks in 2017 and 2035.

Table 2: Traffic flows for modelled car parks in 2017 and 2035

Description	Car AADT	
	2017	2035
Terminal	1,504	-
Long stay	83	-
Staff	1,684	-
Multi-storey car park (MSCP)	-	7,995

Figure 4: Location of modelled car parks in 2017

Figure 5: Location of modelled car parks in 2035

Appendix D

Emissions inventory

Contents

D1 Emissions inventory

Table 1 presents a summary of the estimated annual NOx, PM_{10} and $PM_{2.5}$ emissions for both 2017 and 2035. Total emissions of each pollutant are predicted to be higher in 2035 than in the baseline year of 2017. Total NOx emissions are predicted to increase from 110.1t/yr in 2017 to 168.7t/yr in 2035; PM_{10} emissions are predicted to increase slightly from 4.63t/yr to 5.02/yr; and $PM_{2.5}$ emissions would increase from 3.45t/yr to 3.62t/yr.

Emissions from road traffic are predicted to reduce from 27.6t/yr of NOx in 2017 to 8.2t/yr of NOx in 2035 with a decrease in PM_{10} and $PM_{2.5}$ emissions as well. Beyond the immediate vicinity of the airport it is road traffic emissions that are likely to give rise to high ambient concentrations and therefore this predicted decrease in road traffic emissions will tend to reduce concentrations at those receptors.

Emissions of NOx from APUs and GSEs are predicted to decrease by approximately 50% due to the mitigations planned by London City Airport:

- provision of Fixed Electrical Ground Power on all future stands;
- ensuring all vehicles owned by the airport will be ULEZ compliant by December 2020; and
- ensuring all airside vehicles with a permanent vehicle pass will be electric (or zero emissions) or use renewable fuels by 2030.

Emissions due to aircraft on the ground and in the air are predicted to increase due to the increase in ATMs.

Table 1: Summary of annual pollutant emissions (t/yr)

Source	NOx emissions (t/yr)		PM_{10} emissions (t/yr)		$PM_{2.5}$ emissions (t/yr)	
	2017	2035	2017	2035	2017	2035
Aircraft in the air						
Upper approach (3000 to 1,500 ft)	2.4	4.0	0.03	0.06	0.03	0.06
Final approach (below 1,500 ft)	7.8	13.1	0.05	0.10	0.05	0.10
Initial climb (below 1,500ft)	20.3	40.0	0.11	0.22	0.11	0.22
Climb out (1,500 to 3,000ft)	12.6	23.0	0.07	0.13	0.07	0.13
Aircraft on the ground						
Landing	0.5	1.3	0.01	0.03	0.01	0.03
Taxi in	4.4	7.9	0.10	0.18	0.10	0.18
Hold	1.4	2.6	0.03	0.05	0.03	0.05
Taxi out	9.8	17.5	0.22	0.39	0.22	0.39
Take-off	12.5	43.2	0.07	0.25	0.07	0.25
Brake wear			0.42	0.80	0.17	0.32
Tyre wear			0.09	0.19	0.06	0.19
APUs	4.5	2.1	1.05	0.51	1.05	0.51
Engine testing	0.8	0.8	<0.01	<0.01	<0.01	<0.01
Ground equipment						
GSE	2.7	1.5	0.07	0.01	0.07	0.01
GPUs	0.2	<0.1	0.02	<0.01	0.01	<0.01
Fixed plant						
Fire training ground	0.2	0.2	0.01	0.01	0.01	0.01
Energy centre	<0.1	0.4				
Car parks	0.3	0.5	0.03	0.08	0.03	0.07
Roads	27.6	8.2	2.24	1.96	1.35	1.06
Total	**110.1**	**168.7**	**4.63**	**5.02**	**3.45**	**3.62**

Figure 1 to Figure 6 show the apportionment of airport-related NOx, PM_{10} and $PM_{2.5}$ emissions in 2017 and 2035. For 2017, the largest emission source for NOx is aircraft in the air which contributes 39.1% of total emissions. The second largest source for NOx is aircraft on the ground at 30.7%. For PM_{10}, the largest emission source is roads which accounts for 48.3% of the total and is followed by aircraft on the ground, contributing 43.0% of PM_{10}. For $PM_{2.5}$, aircraft on the ground is the largest emission source at 49.6% and roads is the second largest source at 39.0%.

In comparison, for 2035, the source apportionment of PM_{10} and $PM_{2.5}$ generally remains the same but with a greater proportion attributed to aircraft in the air and aircraft on the ground and a lower contribution from roads. For NOx, the source apportionment changes considerably. Roads are predicted to contribute just 4.9% of total emissions while aircraft in the air and aircraft on the ground contribute 47.6% and 44.8% of NOx emissions respectively.

The increases in all estimated pollutant emissions are due to the greater number of ATMs in 2035 which increases pollutant emissions from aircraft in the air and aircraft on the ground. Although the fleet composition is predicted change to include a higher percentage of engines with lower emissions (cleaner aircraft), including the Embraer E190-E2 and A320neo, the increase in aircraft numbers and the predicted increase in time-in-mode for take-off and landing result in an overall increase in pollutant emissions attributed to the aircraft sources.

Emissions arising from road traffic are predicted to decreases between 2017 and 2035. This is due to predicted improvements in vehicle technology. The decrease in pollutant emissions associated with roads for PM_{10} and $PM_{2.5}$ is smaller than that for NOx as improved emissions from vehicle hot exhausts are just one component of particulate emissions, there are also the emissions due to brake, tyre and road wear.

Figure 1: Source apportionment of airport NOx emissions in 2017

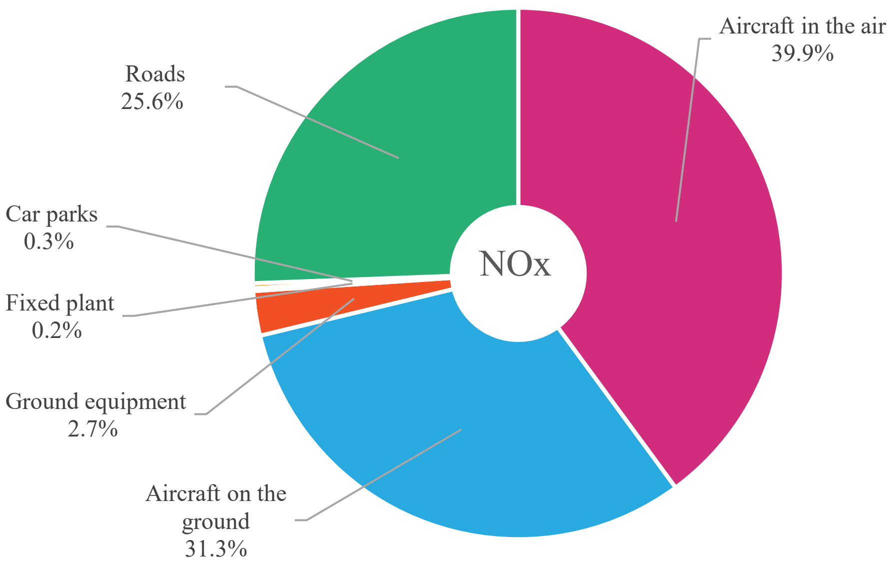


Figure 2: Source apportionment of airport NOx emissions in 2035

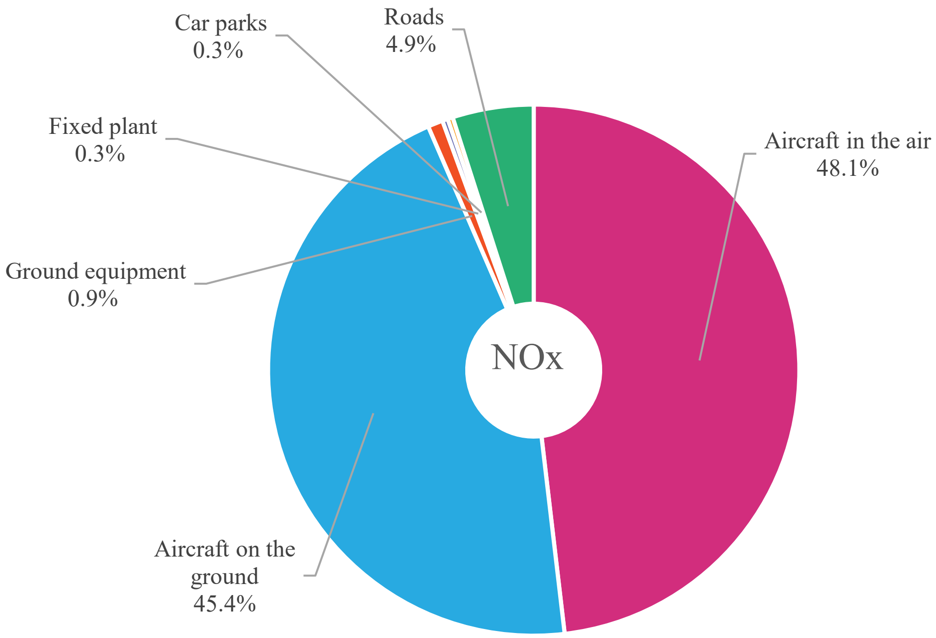


Figure 3: Source apportionment of airport PM_{10} emissions in 2017

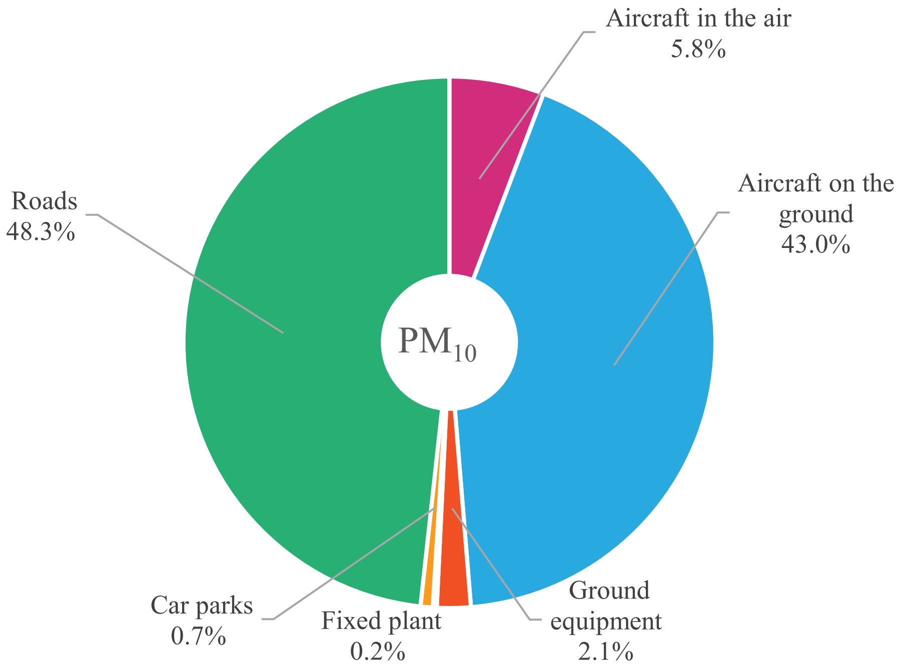


Figure 4: Source apportionment of airport PM_{10} emissions in 2035

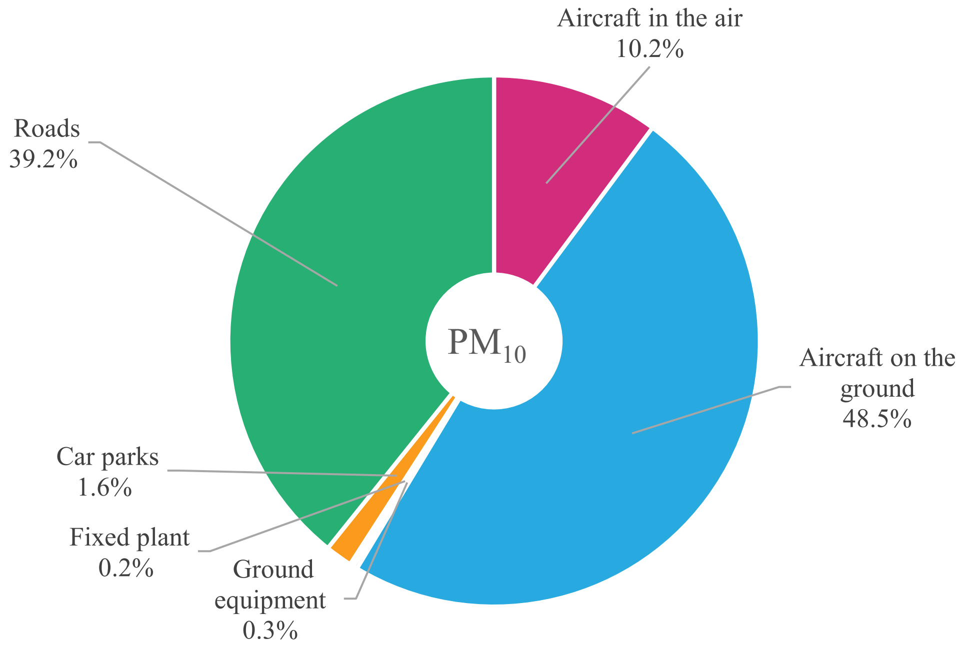


Figure 5: Source apportionment of airport $PM_{2.5}$ emissions in 2017

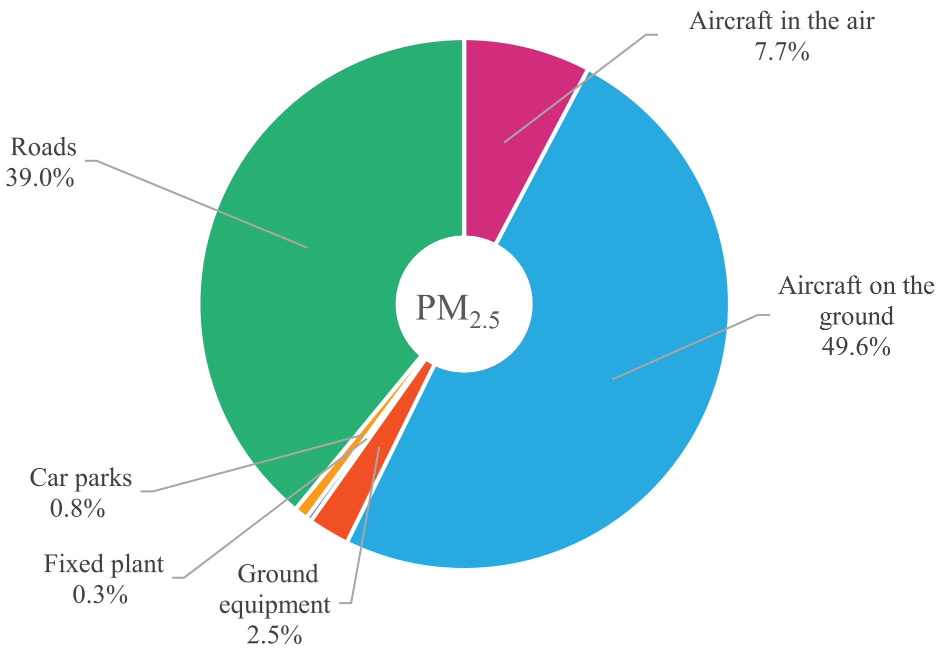
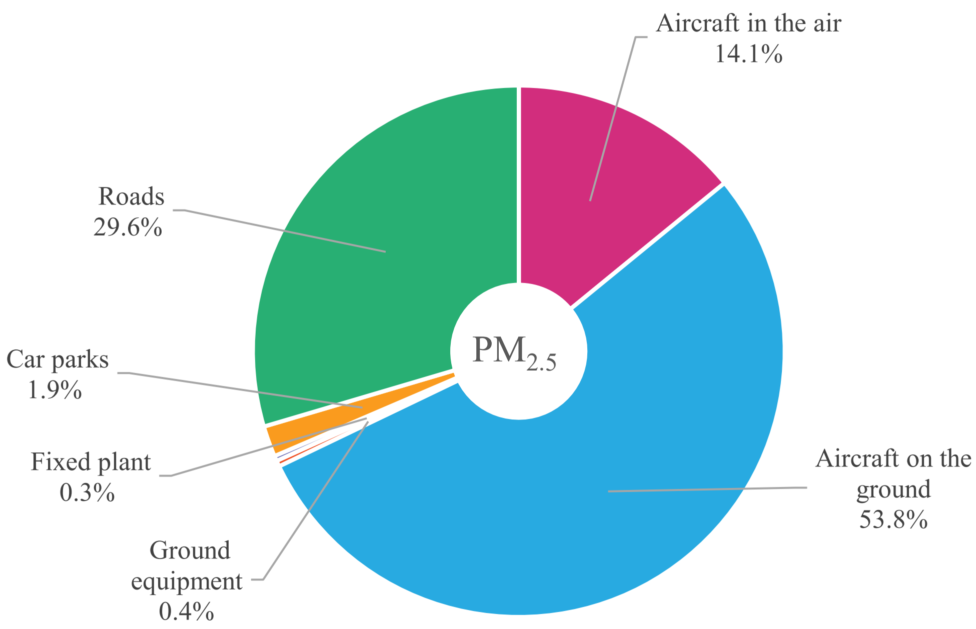


Figure 6: Source apportionment of airport $PM_{2.5}$ emissions in 2035



Appendix E

Model setup and verification

Contents

E1 Model setup

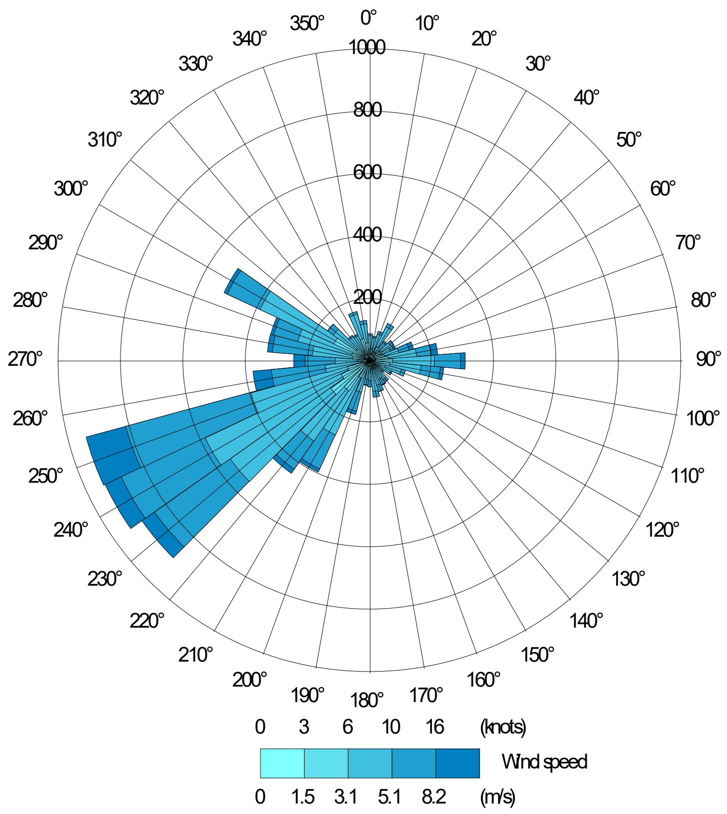
E1.1 Meteorology

The model requires hourly sequential meteorological data as an input. Data from London City Airport, collected over the period 1st January 2017 to 31st December 2017 (inclusive), was obtained for the air quality assessment.

The ADMS-Airport software treats calm conditions by setting the minimum wind speed to 0.75m/s. Defra's TG16 guidance recommends that the meteorological data file is tested by running the meteorological pre-processor of the dispersion model and checking the relevant output log file to determine the number of missing and calm hours that cannot be used by the model. This is important when considering predictions of high percentiles and the number of exceedances. The guidance recommends that meteorological data should only be used if the percentage of usable hours is greater than 75% and preferably 90%.

In the 2017 data from London City Airport there were 8,718 usable hours of data, i.e. 99.5% of the data. Figure 1 presents the windrose for 2017; it can be observed that the prevailing wind direction in the study area is from the south-west.

Figure 1: Windrose for London City Airport 2017



E1.2 Other model parameters

The extent of mechanical turbulence (and hence mixing) in the atmosphere is affected by the surface / ground over which the air is passing. Typical surface roughness values range from 0.0001m (for water or sandy deserts) to 1.5m (for cities, forests and industrial areas). In this assessment, the general land use in the study area can be described as between “Cities, woodlands” and “Parkland and Open Suburbia” with a corresponding surface roughness of 0.75m. The same surface roughness value was used for the meteorological station site.

Another model parameter is the minimum Monin-Obukhov length, which describes the minimum level of turbulence in the atmosphere, which is limited due to the urban heat island effect. Typical values range from 1m to 10m for rural and sparsely populated areas. In urban area, where traffic and buildings cause the generation and/or retention of more heat, these values are higher. In this assessment, a Monin-Obukhov length of 30m has been used in this assessment. It is suggested in ADMS-Roads that this length is suitable for “Cities and large towns”. The same Monin-Obukhov length was used for the meteorological station site.

E1.3 Diurnal profile

From the detailed aircraft fleet data for 2017, the runway use was calculated as 26% for 09 operations (i.e. easterly) and 74% for 27 operations (i.e. westerly). This was compared against the meteorological data and a wind profile was applied to aircraft emissions in the model. When the wind in the meteorological data was between 10^o and 170^o, then the 09 operations were assumed, and when the wind was between 180^o and 360^o then the 27 operations were assumed. This resulted in a similar split of 25% and 75% of emissions in the model for the 09 and 27 runways respectively.

Diurnal profiles were applied to the aircraft models, derived from the detailed flight schedule for 2017 and a separate profile applied for weekday, Saturday and Sunday for each of 09 and 27 arrivals, and 09 and 27 departures. Figure 2 to Figure 5 present the diurnal profiles for 2017.

Weekday diurnal profiles in 2035 were assumed to be the same as 2017 as airfield operating hours remain the same. The proposed airfield operating hours on Saturdays in 2035 will be between 06:30 and 22:30 which is the same as the airfield operating hours on a weekday. Therefore, it has been assumed that Saturday will share the same diurnal profile as weekdays. The Sunday diurnal profile has been assumed to follow that of weekdays but only for the hours of operation on Sunday which is between 10:30 and 22:30 in 2035. Figure 6 to Figure 9 present the diurnal profiles for 2035.

No monthly profile was applied to the aircraft models as it was assumed there is no seasonal variation.

Figure 2: Diurnal profile for aircraft emissions in 2017 (09 arrivals)

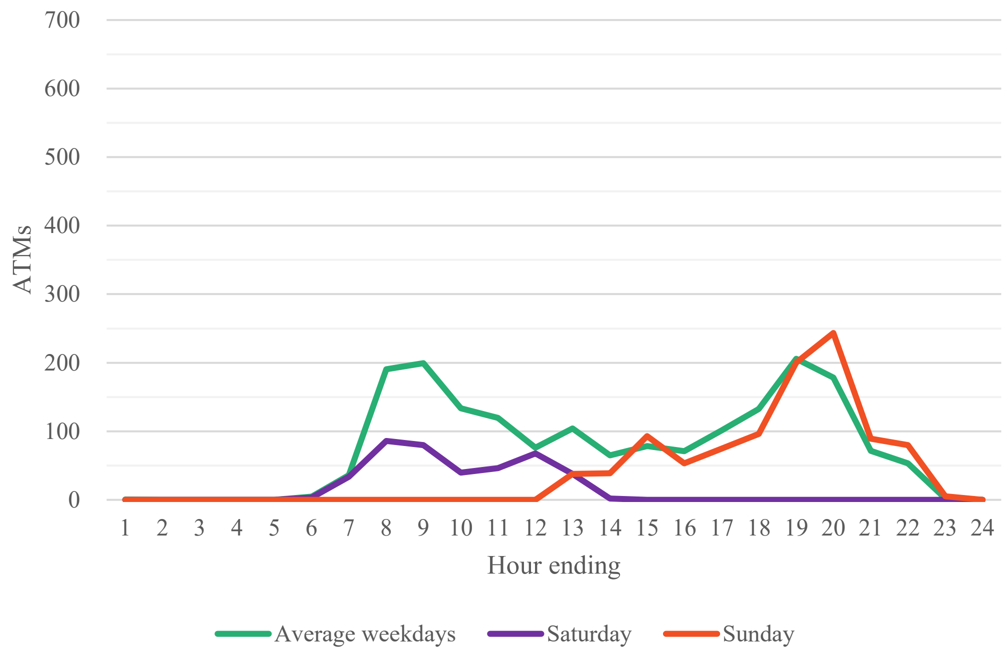


Figure 3: Diurnal profile for aircraft emissions in 2017 (27 arrivals)

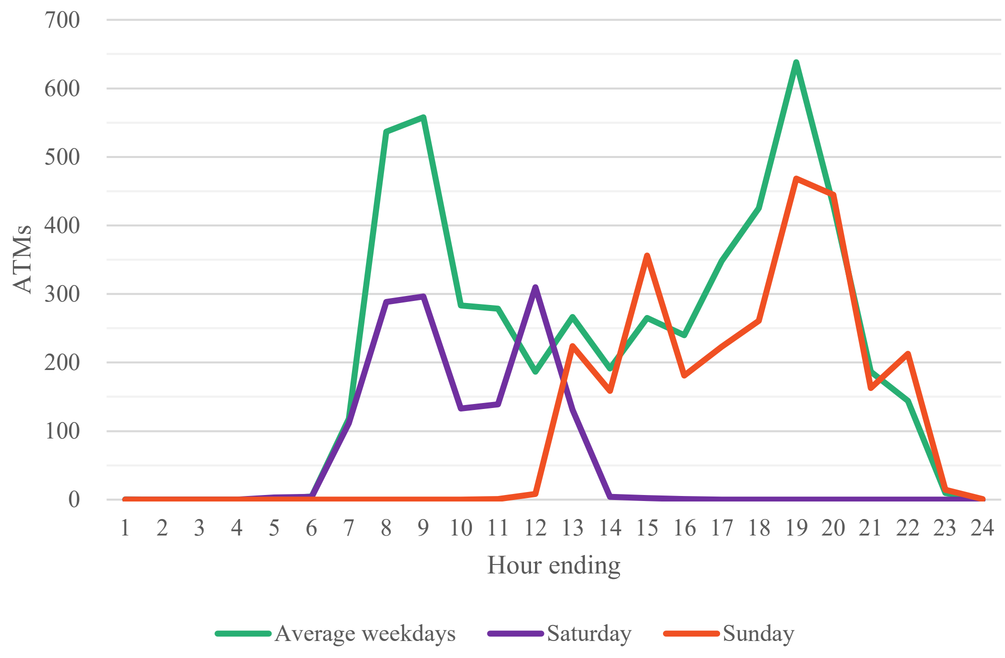


Figure 4: Diurnal profile for aircraft emissions in 2017 (09 departures)

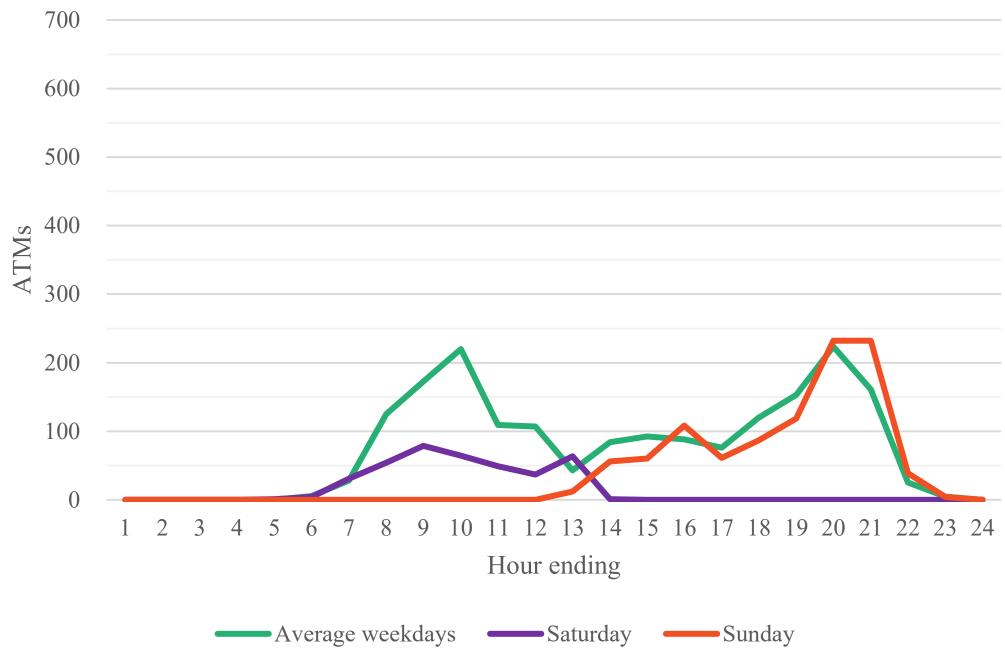


Figure 5: Diurnal profile for aircraft emissions in 2017 (27 departures)

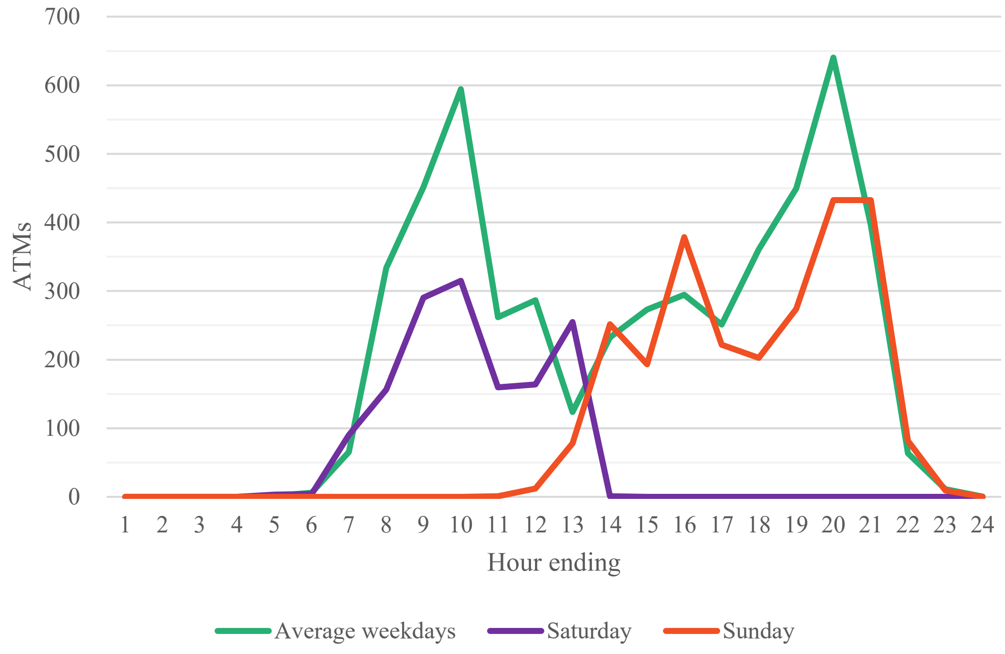


Figure 6: Diurnal profile for aircraft emissions in 2035 (09 arrivals)

Figure 7: Diurnal profile for aircraft emissions in 2035 (27 arrivals)

Figure 8: Diurnal profile for aircraft emissions in 2035 (09 departures)

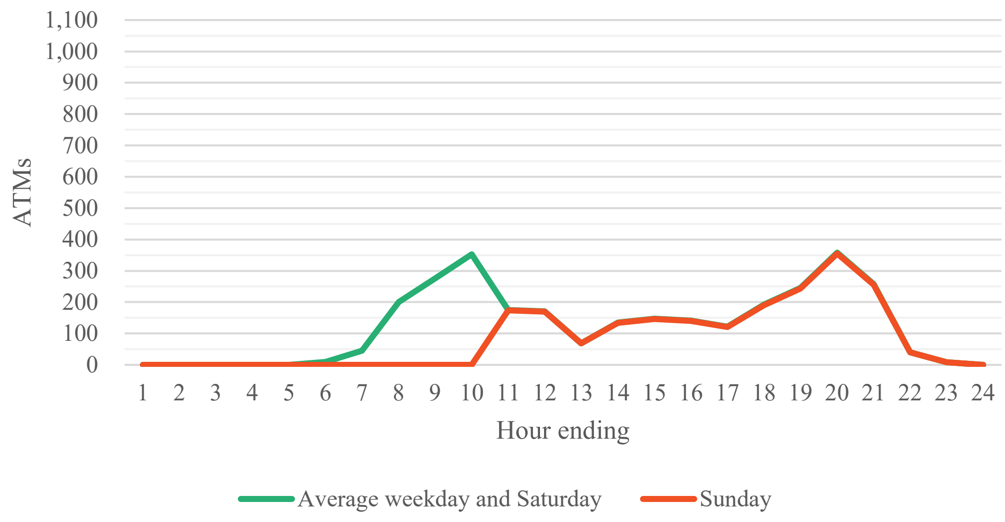


Figure 9: Diurnal profile for aircraft emissions in 2035 (27 departures)

E2 Model verification

The model verification exercise included the comparison of the modelled and the measured concentrations at the monitoring sites in the study area.

From the monitoring data in the study area, 12 sites were selected for inclusion in the model verification exercise. Urban background locations, sites with low data capture (< 75%) or those far from the modelled sources were excluded. The justification for the selection or not of each monitoring site is presented in Table 1.

.

Table 1: Justification for the selection of monitoring sites for model verification

ID	Monitoring site	Justification for inclusion or exclusion
LCY CAH	City Aviation House	No confidence in height of modelled diffusion tube - excluded
LCY ND	Newham Dockside	Included in model verification
LCY 1	Parker Street	Included in model verification
LCY 2	Camel Road, adjacent to nearest property on Hartmann Street	Included in model verification
LCY 3	Silvertown Quay	Road next to the monitoring site is not included in the model, and low monitored data capture – excluded
LCY 4	To east end of Newham Dockside	Included in model verification
LCY 5	Straight Road	Large hedge creates a barrier between the road source and the diffusion tube – excluded
LCY 6	Gallions Way	Missing road sources on roundabout – excluded
LCY 7	Gallions Way	Included in model verification
LCY 8	Brixham Street	Railway line creates a barrier between the road source and the diffusion tube – excluded
LCY 9 (CAH)	City Aviation House	No confidence in height of modelled diffusion tube - excluded
LCY 10	Jet Centre	Included in model verification
LCY 11	Eastern end of the University of East London	Included in model verification
LCY 12	South of Royal Albert Dock	Included in model verification
LCY 13	North west corner of Newham Dockside	Included in model verification
LCY 14	Western end of Newham Dockside	Included in model verification
LCY 15	Royal Albert Way	Included in model verification
LCY 18 (ND)	Newham Dockside	Included in model verification
GW 49	Plumstead Rd	Not close to modelled sources – excluded
GW 52	Wricklemarsh Rd	Not close to modelled sources – excluded
GW 61	Millennium Village	Background monitoring site, not close to modelled sources – excluded
GN 2	Millennium Village	Background monitoring site, not close to modelled sources – excluded
NM 3	Wren Close	Background monitoring site, not close to modelled sources – excluded
NM 11	Hartmann Road, City Airport	Car park next to the monitoring site is not included in the model – excluded
NM 12	Galleons Roundabout	Missing road sources on roundabout – excluded

Table 2 and Figure 10 present the comparison of modelled with monitored NO_2 concentrations prior to any adjustment, for all monitoring sites selected for inclusion in verification.

For the sites near to roads, it can be observed that the model over-estimates concentrations and the percentage difference between the monitored and modelled NO_2 concentrations is outside the recommended guideline of ±25% stated in the Defra guidance. However, as the model is over-predicting, it is considered that application of an adjustment factor to potentially reduce predicted concentrations would not be appropriate.

At the airside locations, concentrations are under- and over-predicted at different locations. This is due to different emissions sources affecting the monitoring sites. The percentage difference between the monitored and modelled NO_2 concentrations at all locations is within the recommended guideline of ±25% stated in the Defra guidance, with the percentage difference being much less than ±25%, between -6% and 13%. Therefore, no adjustment factor has been applied to the modelled NOx concentrations derived from the airside emission sources. Overall it is considered that with no the adjustment of pollutant sources, the model has performed well compared to the monitored concentrations.

Table 2: Comparison of modelled and monitored NO_2 concentrations (no adjustment)

ID	Monitoring site	Modelled NO_2 ($\mu g/m^3$)	Monitored NO_2 ($\mu g/m^3$)	Ratio[1]
Road sites				
LCY 1	Parker Street	31.0	24.7	25%
LCY 2	Camel Road	32.0	28.0	14%
LCY 15	Royal Albert Way	31.6	23.5	34%
Airside sites				
LCY ND	Newham Dockside	29.4	26.0	13%
LCY 4	To east end of Newham Dockside	29.3	30.2	-3%
LCY 7	Gallions Way	28.6	29.4	-3%
LCY 10	Jet Centre	31.8	28.6	11%
LCY 11	Eastern end of the University of East London	28.9	27.8	4%
LCY 12	South of Royal Albert Dock	30.6	31.8	-4%
LCY 13	North west corner of Newham Dockside	29.3	31.1	-6%
LCY 14	Western end of Newham Dockside	29.1	28.9	1%
LCY 18 (ND)	Newham Dockside	29.4	30.0	-2%
[1] Calculated as [(modelled – monitored) / monitored]				

Figure 10: Model performance with no adjustment

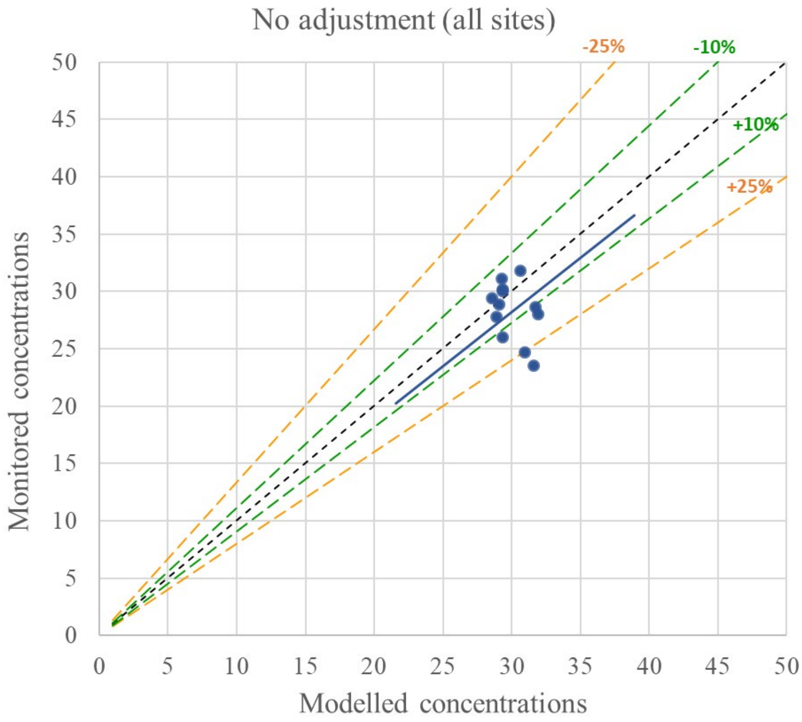


Figure 11: Model performance with no adjustment – road sites

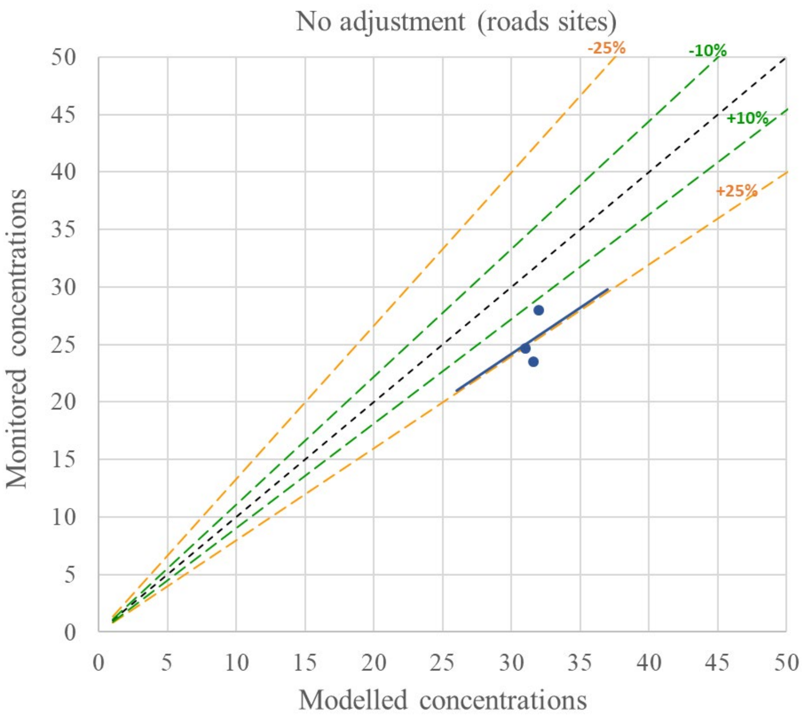
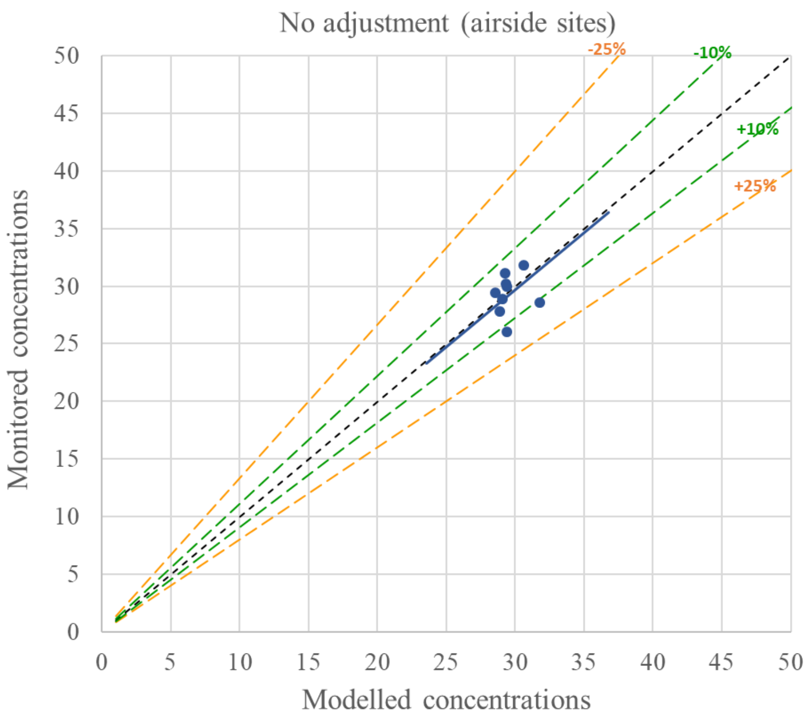


Figure 12: Model performance with no adjustment – airside sites



Appendix F

Assumptions and limitations

Contents

F1 Monitoring and backgrounds

- For the London City Airport diffusion tubes a height of 2m was assumed for verification.
- 2017 and 2035 background concentrations for this assessment were taken from Defra as an average of the three 1km^2 grid squares covering the airport.

F2 Aircraft

- Emissions of pNO_2 were derived using the fractions described in the PSDH air quality methodology and are presented in Table 1; these were 4.5% pNO_2 at 100% thrust, 5.3% at 85% thrust, 15% at 30% thrust and 37.5% at 7% thrust.

Table 1: Estimation of pNO_2 by thrust setting

Thrust setting	pNO_2
100%	4.5%
85%	5.3%
30%	15.0%
7%	37.5%

- The smoke number indices used to derive emissions of PM_{10} were not available for the turboprop engines. As a conservative case, it was assumed that PM_{10} emissions were the same as the Piper PA-31 Navajo.
- There was a difference of 1,780 ATMs between the 2017 Annual Performance Report and the detailed flight schedule provided by London City Airport. The difference was assumed to be the jet centre aircraft. These ATMs were allocated to MCAT 1 and to ensure consistency; the 5,000 jet centre ATMs for 2035 were also allocated to MCAT 1.
- The emission indices of the Pratt & Whitney PW1900G engines mounted on the Embraer E190-E2 were not available from the ICAO databank. Therefore, they were derived using the product specification produced by MTU Aero Engines. This compares the performance of the PW1900G engine against current engines, assumed to be the General Electric CF34-10E5 engine used for Embraer E190.
- The proportion of PM_{10} assumed to be $PM_{2.5}$ was:
    - Brake wear: 40%
    - Tyre wear: 70%
    - Other aircraft sources: 100%
- The assumptions for the LTO cycle are summarised in Table 2. Time-in-mode calculations were based on approach angles and runway lengths derived from the taxiing routes described by London City Airport, and climb angles

and travelling speeds provided by Bickerdike Allen Partners from the AEDT software.

- No information on aircraft travelling speeds and climb angles were provided for MCATs 1, 5, 7 and 8. It was assumed that the travelling speeds and climb angles would be the same for MCAT 1 as MCAT 2, as both modelling categories represent turboprop engine aircraft. MCAT 5 and MCAT 7 were assumed to share the same speeds and angles as MCAT 3 due to their similar maximum take-off weight. The Embraer E190-E2 in MCAT 8 was assumed to have the same travelling speeds and climb angles as the successor aircraft model of Embraer E190 in MCAT 4.
- Taxiing and hold times were assumed to be the same in 2035 as 2017 as a conservative approach.
- Information on stand usage in 2017 was provided in the detailed flight schedule by London City Airport. The average stand use (in ATMs) was applied to the new stands proposed in 2035. The stand use at every stand (existing and new stands) was then scaled up to the total ATMs in 2035.
- A diurnal profile was created from the detailed ATMs data provided by York Aviation and applied to the model.
- The diurnal profile for 2017 was based on the detailed flight schedule. For 2035, airfield operating hours will be the same for weekdays and Saturdays therefore the same diurnal profile was applied. For Sundays, the diurnal profile was assumed to be the same as weekdays for the anticipated hours of airfield operation between 10.30 and 22.30.
- For the calculation of brake and tyre wear emissions, the PSDH approach as amended in the Gatwick assessment was used. This method uses the Maximum Ramp Weight (MRW), however Maximum Take-Off Weight (MTOW) was assumed to be equal to MRW for this assessment.
- Brake and tyre wear emissions were represented in the model as volume sources. The length of the volume source varies for each runway; 500m and 1km source lengths were used for 09 runway and 27 runway respectively which aligns with the landing sources. Both volume sources were assigned a width of 30m and a height of 8m.
- For the 2035 future year scenario the brake and tyre wear emissions were scaled up from the increase in ATMs. Also, the volume sources are 1km long for both runways. The width and height are unchanged.

Table 2: Summary of assumptions for LTO cycle

LTO mode	Height (ft)	Thrust setting	Angle	Speed (m/s)	Distance (m)	TIM (seconds)
Upper approach	3,000 to 1,500	15% [a]	5.5° [b]	70 to 107 [c]	4748	44 to 68 [c,d]
Final approach	1,500 to 0	30% [a]	5.5° [b]	65 to 88 [c]	4748 [c,d]	56 to 76 [c,d]
Landing	0	7% [b]	0°	56 to 66 [c]	505 to 1045 [c,d]	14 to 33 [c,d]
Taxi in	0	7% [e]	0°	7.7	n/a	194 to 258 [d]
Taxi out	0	7% [e]	0°	7.7		435 to 502 [d]
Hold	0	7% [e]	0°	7.7		38 to 117 [f]
Take off	0	85% [a]	6° to 11° [c]	62 to 70 [c]	560 to 1280 [c,d]	15 to 41 [c,d]
Initial climb	0 to 1,500	85% [e]	6° to 11° [c]	65 to 88 [c]	2288 to 4581 [c,d]	35 to 53 [c,d]
Climb out	1,500 to 3,000	78% [a]	6° to 13° [c]	70 to 107 [c]	2062 to 4663 [c,d]	20 to 44 [c,d]

[a] Recommended by the PSDH methodology
[b] London City Airport Noise Action Plan (2013 – 2018)
[c] Individual aircraft information provided by Bickerdike Allen Partners using AEDT software
[d] Information provided in detailed flight schedule of London City Airport
[e] ICAO default
[f] Calculated as the difference between the Eurocontrol taxi-out time and observed taxi-out time

F3 Auxiliary Power Units (APUs)

- When information was not available on the type of APU for an aircraft type, emissions were taken from a similar aircraft.
- It was assumed that pNO_2 emissions were 10% of NOx, taken from the EMIT software.
- Run times for APUs in the baseline scenario were assumed to be a total of 13mins. These were based on the AOI 07, which restricts APUs to be run for 10mins prior to leaving the stands and the CADP[1] stating that APU run times range from one to five minutes on arrival.
- A schedule of APU operations recorded by the ATC in 2017 were provided. These operations were assumed to be in additional to the normal operations (assumed to be 13mins) and were mainly due weather conditions specified in the AOI 07. The emissions from these additional APU operations were included in the modelling of the 2017 baseline assessment.
- Run times for APUs in the future scenario were assumed to be a total of 3mins. These were based on the assumption that all the stands will have FEGP available in 2035, as stated in the CADP[1]. These 3mins were assumed to occur on arrival, prior to being connected to FEGP.
- In the future scenario, it was assumed that if FEGP was not available, a GPU would be used, therefore no additional APU run times were modelled.
- The APU emissions were represented in the model as volume sources with a height of 8m. This was assumed to represent the height of the exhaust of the APUs.
- A diurnal profile was applied in the model, based on the diurnal profile of ATMs.
- For the 2035 future year scenario the APU emissions are based on the projected 2035 aircraft fleet and ATMs.
- The APU emissions were spatially distributed at the airport on the aprons near the stands, based on the ATMs at each stand.

F4 Aircraft Engine Testing

- For the engine testing at the stands, detailed data on 201 aircraft engine tests were provided by London City Airport for 2017: 163 ground idle runs and 38 high power runs. The engine testing data was provided for each stand, but for modelling they were grouped: jet centre, stands 1 to 10, stands 12 to 14 and stands 21 to 24.
- Emissions were calculated using the same approach as the aircraft in the LTO cycle. A thrust setting of 15% was assumed for ground idle runs and 85% was

[1] Atkins (March 2018) City Airport Development Programme (CADP1), Condition 61: Energy Assessment

assumed for high power runs. The times for ground idle and high power runs were averaged for each aircraft type using the data provided by London City Airport.

- In the data provided there were 16 ground idle runs and two high power runs for jets. These runs were added to MCAT 1 and their emissions were assumed to be the same as a J328.
- In the data provided there were two ground idle runs for a E170 and E190 aircraft type with unknown stand locations, these were attributed to stands 1-10 and stands 21-24, as these were the most commonly used stands by these aircraft.
- Engine testing emissions were represented in the model as volume sources. The volume sources had an area equal to the apron size at stands and a height of 5m.
- A diurnal profile was created from the detailed data provided by London City Airport and applied to the model.
- For the 2035 future year scenario the engine testing emissions were factored up by the increase in ATMs. The calculated emissions were then spatially distributed at the airport on the aprons near the stands.

F5 Fire Training Ground

- Fire training ground emissions were represented in the model as volume sources. The volume sources had an area equal to the aircraft seen on satellite image of the fire training ground and a height of 10m.
- London City Airport provided estimated operating hours for the fire training ground, so a diurnal profile was applied.
- For the 2035 future year scenario the fire training ground emissions are assumed to remain unchanged.

F6 Ground Support Equipment (GSE)

- For the emissions calculations, GSEs were designated into non-road mobile machinery (NRMM) and road vehicles. This information was not provided so the designations were based on the vehicle description provided. From these assumptions, the baseline assessment included a total of 28 NRMMs (20%) and 113 airside vehicles (80%), excluding those that are electric-powered.
- It was assumed that the fuel for all GSE was diesel (total of 209,095 litres of diesel consumed in 2017).
- All of the NRMMs were assumed to be Stage IIIA and all on road vehicles were assumed to be Euro 4/IV. The emissions factors were taken from the EMEP/EEA 2016 Pollutant Emissions Inventory Guidebook.

- The fuel consumptions of the road vehicles were taken from the DfT (for HGVs) and US Department of Energy, Alternative Fuels Data Center (for cars and LGVs).
- The pNO_2 fractions of NOx emissions for the road vehicle emission were taken from the NAEI and for the NRMMs they were taken from the DfT.
- All of the road vehicles were assumed to travel at 10mph; the speed limit of apron roads, specified in the AOI 12 (Control of Vehicles Airside).
- A diurnal profile was applied in the model, based on the diurnal profile of ATMs.
- The GSE emissions were spatially distributed at the airport on the aprons near the stands, based on the ATMs at each stand in the baseline scenario.
- The 2017 diesel fuel used was factored up by the increase in ATMs from 2017 to 2035. This provided an assumed fuel consumption for 2035.
- For the 2035 future year scenario, it was assumed that all road vehicles for GSE would be Euro 6/VI, due to the airport being located in the expanded Ultra Low Emission Zone (ULEZ) from 2021.
- All the NRMMs are assumed to be Stage IIIB in 2035, following the Mayor of London's supplementary planning guidance.

F7 Ground Power Units (GPUs)

- London City Airport provided a data sheet for the GPUs. They are the C490 type, which is EU Stage IIIA compliant. NOx and PM emission factors for EU Stage IIIA compliant NRMM were taken from the EMEP/EEA 2016 Air Pollutant Emissions Inventory Guidebook. The emission calculations assumed the fuel used per square metre is equal.
- GPU emissions were represented in the model as area sources equal to the apron size at stands.
- A monthly profile was created from the fuel consumption data provided by London City Airport and applied to the model. The profile assumes the fuel drawn in any month is used in that month.
- For the 2035 future year scenario the GPU emissions were scaled up by the increase in ATMs and then divided by the percentage of jet centre ATMs, as it was assumed that GPUs will only be used for aircraft at the jet centre.
- For the 2035 future year scenario, the GPU emissions were represented in the model as area sources equal to the jet centre apron.

F8 Energy centre

- The model parameters and emissions were taken from data sheets provided for the existing terminal boilers and information on the proposed Eastern Energy Centre (EEC) in the CADP[1] report. For the 2017 baseline scenario the energy centre was modelled in its current position in the main terminal. This centre consists of two boilers exhausting via one stack.
- Both existing and future energy centres were represented in the model as point sources. The locations, heights and diameters of stacks were estimated from drawings.
- For the 2035 future year scenario the energy centre emissions were assumed to remain unchanged for the terminal boiler and new emissions were calculated for the two CHPs and six boilers in the proposed EEC. There are proposed to be eight boilers in the EEC however one is a back-up and one is for a potential hotel therefore both of these have not been modelled.
- Time varying files were applied to both the existing and proposed energy centre emissions for modelling the boilers and CHPs. Profiles were taken from the CADP[1] report to apply diurnal and seasonal variation to the energy centres. It was assumed from the report that the energy centre operational hours were 05:00-23:00 every day. The CHPs would run at 50% during that period across the year and the boilers across the same period at a maximum of 10% with a seasonal variation.

F9 Car parks

- For the terminal and long-stay car parks, transaction data was provided by London City Airport for 2017. Car park AADT was assumed to be twice the transaction data. The month of December was supplemented from 2016 data, as information was missing.
- For the staff car park, the number of permits were provided by London City Airport for 2017. Car park AADT was assumed to be double the number of permits.
- Car park emissions were calculated following the methodology in the CERC note and the car park distance was assumed to be equal to car park perimeter as a conservative assumption following TG 16 guidance.
- The cold start emission factors were taken from NAEI. The average of diesel and petrol cars in outer London was assumed from the Tfl fleet mix.
- Hot exhausts emissions were calculated using the Defra EFT calculator. Detailed option 1 was used; the type of roads was classified as “outer London” and vehicles were assumed to be travelling at a speed of 5kph.
- The pNO_2 factors were taken from NAEI for 2017 and 2035.
- The ground level car park emissions were represented in the model as area sources.

- Transaction data was used to create monthly profiles for the terminal and long-stay car park, but no profile was applied to the staff car park.
- The drop-off area, car hire parking and taxi holding area were not modelled.
- For the 2035 future year scenario the total AADT of car parks were factored up by the increase in passengers. The calculated emissions were then redistributed to the multi-storey car park.
- The multi-storey car park emissions were represented in the model as a volume source. The volume source had an area equal to the car park on the airfield plan and a height of 27m (height of 3m was assumed for each floor).

F10 Road network

- AADT flows were estimated from two different sources, namely local junction modelling along Hartmann Road, including Connaught Bridge Roundabout, and DfT traffic count points at various locations around the airport for 2017. The source of traffic data for each road is stated in Appendix C. Predicted traffic flows were then produced for 2035 by Arup Transport.
- Emissions were calculated using the Defra EFT calculator. Detailed option 1 was used and the type of roads was classified as "outer London".
- The speed data was retrieved from ITO, if the speed was missing then speed limit signs were used from google maps.

Appendix G

Predicted pollutant concentrations

Contents

G1 NO_2 concentrations

Table 1 presents the predicted NO_2 concentrations at human receptors in the study area. The table shows predicted NO_2 concentrations in the 2017 baseline year and the 2035 future year, as well as the change in concentrations between the scenarios.

Table 1: Predicted NO_2 concentrations at human receptors

ID	Description	Type of receptor	Height (m)	NO_2 concentrations (µg/m^3)		
				2017	2035	Decrease
R1	Camel Road/Hartmann Road	Residential	1.5	32.3	21.3	11.0
R2	Camel Road/Parker Street	Residential	1.5	31.9	21.6	10.3
R3	Parker Street (Portway Primary School)	Education	1.5	29.8	20.1	9.7
R4	Newland Street (opposite entrance to LCY car park)	Residential	1.5	30.6	20.2	10.4
R5	Newland Street/Kennard Street	Residential	1.5	30.3	20.2	10.1
R6	Brixham Street/Dockland Street	Residential	1.5	29.6	20.2	9.4
R7	Platterns Court/Billingway Dock Head	Residential	1.5	28.8	19.6	9.2
R8	Albert Road/Woolwich Manor Way	Residential	1.5	32.3	20.7	11.6
R9	Robert Street adj Albert Road (north side)	Residential	1.5	30.6	20.0	10.6
R10	Collier Close adj Gallions Way Roundabout (eastern side)	Residential	1.5	32.1	21.1	11.0
R11	Yeoman Close adj Royal Albert Way	Residential	1.5	30.3	20.5	9.8
R12	Straight Road/Campton Close	Residential	1.5	30.2	20.1	10.1
R13	Mill Rd adj North Woolwich Road (west)	Residential	1.5	28.0	18.6	9.4
R14	Connaught Road/Leonard Street	Residential	1.5	30.7	19.9	10.8
R15	Gallions Primary School adjacent to Royal Docks Road	Education	1.5	28.4	19.1	9.3
R16	Drew Road/Leonard Street	Residential	1.5	30.6	20.4	10.2
R17	Woolwich Manor Way (UEL)	Education	1.5	30.1	20.8	9.3
R18	Woolwich Manor Way (UEL)	Education	1.5	28.9	21.2	7.7
R18	Woolwich Manor Way (UEL)	Education	20.0	28.6	20.9	7.7
R19	West Silvertown 1	Residential	1.5	28.1	18.7	9.4
R19	West Silvertown 1	Residential	20.0	28.0	18.7	9.3
R20	West Silvertown 2	Residential	1.5	28.0	18.6	9.4
R20	West Silvertown 2	Residential	20.0	28.0	18.6	9.4
R21	Flats on Drew Road	Residential	1.5	30.1	20.3	9.8
R22	Flats on Docklands Street	Residential	20.0	28.6	19.5	9.1

R22	Flats on Docklands Street	Residential	40.0	28.3	19.2	9.1
R23	Gallions Quarter	Residential	1.5	30.4	20.9	9.5
R23	Gallions Quarter	Residential	20.0	28.5	19.9	8.6
R24	Gallions Quarter	Residential	1.5	29.2	20.1	9.1
R24	Gallions Quarter	Residential	20.0	28.5	19.8	8.7
R25	University of East London Student Accommodation	Education	1.5	29.0	21.2	7.8
R25	University of East London Student Accommodation	Education	10.5	28.9	21.1	7.8
R26	Felixstowe Court	Residential	1.5	31.2	20.9	10.3
R26	Felixstowe Court	Residential	10.5	28.6	19.6	9.0
R27	Silvertown Quays 1	Residential	1.5	29.7	20.0	9.7
R27	Silvertown Quays 1	Residential	20.0	28.5	19.5	9.0
R28	Silvertown Quays 2	Residential	1.5	28.6	19.2	9.4
R28	Silvertown Quays 2	Residential	20.0	28.4	19.1	9.3
R29	Silvertown Quays, 30 m from Connaught Bridge	Residential	1.5	29.9	19.9	10.0
R29	Silvertown Quays, 30 m from Connaught Bridge	Residential	20.0	28.5	19.4	9.1
R30	Royal Albert Basin	Residential	1.5	28.5	19.4	9.1
R30	Royal Albert Basin	Residential	20.0	28.4	19.3	9.1
R31	Royal Albert Basin	Residential	1.5	28.5	19.5	9.0
R31	Royal Albert Basin	Residential	20.0	28.4	19.4	9.0
R32	North Side of Royal Albert Dock	Residential	1.5	29.6	20.6	9.0
R32	North Side of Royal Albert Dock	Residential	20.0	29.2	20.3	8.9
R33	North Side of Royal Albert Dock	Residential	1.5	29.2	20.9	8.3
R33	North Side of Royal Albert Dock	Residential	20.0	29.0	20.6	8.4
R34	North side of Royal Albert Dock (10m from Royal Albert Way)	Residential	1.5	30.9	20.6	10.3
R35	North Side of Royal Albert Dock	Residential	1.5	29.1	19.7	9.4
R35	North Side of Royal Albert Dock	Residential	20.0	28.7	19.5	9.2
R36	Barrier Park East	Residential	1.5	28.6	19.1	9.5
R36	Barrier Park East	Residential	20.0	28.3	18.9	9.4
R37	UNEX	Residential	1.5	28.8	19.2	9.6
R38	Royal Wharf	Residential	1.5	28.0	18.6	9.4
R39	Royals Business Park Hotel Site 2.3	Residential	1.5	30.7	19.8	10.9
R39	Royals Business Park Hotel Site 2.3	Residential	10.5	29.2	19.3	9.9
R40	Royals Business Park Hotel Site 2.2	Residential	1.5	34.3	21.1	13.2
R40	Royals Business Park Hotel Site 2.2	Residential	20.0	28.4	19.0	9.4
R41	Fox & Connaught Hotel, Lynx Way	Residential	1.5	30.5	19.7	10.8
R41	Fox & Connaught Hotel, Lynx Way	Residential	13.5	28.8	19.1	9.7
R42	Garvary Road/ Prince Regent Lane	Residential	1.5	29.3	19.1	10.2
R43	Prince Regent Lane	Residential	4.5	28.8	18.9	9.9
R43	Prince Regent Lane	Residential	16.5	28.1	18.6	9.5
R44	The Royal Docks Academy	Education	1.5	30.1	19.4	10.7

R45	Tree Road/ Prince Regent Lane	Residential	1.5	31.0	19.8	11.2
R46	Richard House Children's Hospice	Healthcare	1.5	29.5	19.3	10.2
R47	Calverton Primary School	Education	1.5	28.6	18.9	9.7
R48	Childrens Garden Nursery	Education	1.5	29.0	21.1	7.9
R49	Founder Close	Residential	1.5	29.3	19.7	9.6
R49	Founder Close	Residential	7.5	28.8	19.5	9.3
R50	Trader Road	Residential	1.5	29.8	20.0	9.8
R51	Tynemouth Close	Residential	1.5	29.2	19.5	9.7
R52	Vulcan Close	Residential	1.5	29.3	19.5	9.8
R53	Claremont Close	Residential	1.5	29.0	19.8	9.2
R53	Claremont Close	Residential	10.5	28.7	19.7	9.0
R54	Pier Road	Residential	4.5	30.6	19.9	10.7
R55	Albert Road/ Winifred Street	Residential	1.5	29.9	19.8	10.1
R56	Albert Road (West)	Residential	1.5	31.5	20.2	11.3

G2 PM_{10} concentrations

Table 2 presents the predicted PM_{10} concentrations at human receptors in the study area. The table shows predicted PM_{10} concentrations in the 2017 baseline year and the 2035 future year, as well as the change in concentrations between the scenarios.

Table 2: Predicted PM_{10} concentrations at human receptors

ID	Description	Type of receptor	Height (m)	PM_{10} concentrations (µg/m^3)		
				2017	2035	Decrease
R1	Camel Road/Hartmann Road	Residential	1.5	17.7	16.5	1.2
R2	Camel Road/Parker Street	Residential	1.5	17.6	16.5	1.1
R3	Parker Street (Portway Primary School)	Education	1.5	17.3	16.3	1.0
R4	Newland Street (opposite entrance to LCY car park)	Residential	1.5	17.5	16.3	1.2
R5	Newland Street/Kennard Street	Residential	1.5	17.5	16.3	1.2
R6	Brixham Street/Dockland Street	Residential	1.5	17.3	16.3	1.0
R7	Platterns Court/Billingway Dock Head	Residential	1.5	17.2	16.2	1.0
R8	Albert Road/Woolwich Manor Way	Residential	1.5	17.8	16.7	1.1
R9	Robert Street adj Albert Road (north side)	Residential	1.5	17.5	16.4	1.1
R10	Collier Close adj Gallions Way Roundabout (eastern side)	Residential	1.5	17.6	16.6	1.0
R11	Yeoman Close adj Royal Albert Way	Residential	1.5	17.4	16.4	1.0
R12	Straight Road/Campton Close	Residential	1.5	17.4	16.3	1.1
R13	Mill Rd adj North Woolwich Road (west)	Residential	1.5	17.0	16.1	0.9
R14	Connaught Road/Leonard Street	Residential	1.5	17.5	16.4	1.1
R15	Gallions Primary School adjacent to Royal Docks Road	Education	1.5	17.1	16.1	1.0
R16	Drew Road/Leonard Street	Residential	1.5	17.5	16.3	1.2
R17	Woolwich Manor Way (UEL)	Education	1.5	17.3	16.4	0.9
R18	Woolwich Manor Way (UEL)	Education	1.5	17.2	16.2	1.0
R18	Woolwich Manor Way (UEL)	Education	20.0	17.1	16.2	0.9
R19	West Silvertown 1	Residential	1.5	17.1	16.1	1.0
R19	West Silvertown 1	Residential	20.0	17.0	16.1	0.9
R20	West Silvertown 2	Residential	1.5	17.0	16.1	0.9
R20	West Silvertown 2	Residential	20.0	17.0	16.1	0.9
R21	Flats on Drew Road	Residential	1.5	17.4	16.3	1.1
R22	Flats on Docklands Street	Residential	20.0	17.1	16.1	1.0
R22	Flats on Docklands Street	Residential	40.0	17.1	16.1	1.0
R23	Gallions Quarter	Residential	1.5	17.4	16.6	0.8

R23	Gallions Quarter	Residential	20.0	17.1	16.1	1.0
R24	Gallions Quarter	Residential	1.5	17.2	16.3	0.9
R24	Gallions Quarter	Residential	20.0	17.1	16.2	0.9
R25	University of East London Student Accommodation	Education	1.5	17.2	16.2	1.0
R25	University of East London Student Accommodation	Education	10.5	17.2	16.2	1.0
R26	Felixstowe Court	Residential	1.5	17.6	16.7	0.9
R26	Felixstowe Court	Residential	10.5	17.1	16.2	0.9
R27	Silvertown Quays 1	Residential	1.5	17.3	16.3	1.0
R27	Silvertown Quays 1	Residential	20.0	17.1	16.1	1.0
R28	Silvertown Quays 2	Residential	1.5	17.1	16.1	1.0
R28	Silvertown Quays 2	Residential	20.0	17.1	16.1	1.0
R29	Silvertown Quays, 30 m from Connaught Bridge	Residential	1.5	17.3	16.3	1.0
R29	Silvertown Quays, 30 m from Connaught Bridge	Residential	20.0	17.1	16.1	1.0
R30	Royal Albert Basin	Residential	1.5	17.1	16.2	0.9
R30	Royal Albert Basin	Residential	20.0	17.1	16.1	1.0
R31	Royal Albert Basin	Residential	1.5	17.1	16.2	0.9
R31	Royal Albert Basin	Residential	20.0	17.1	16.1	1.0
R32	North Side of Royal Albert Dock	Residential	1.5	17.2	16.2	1.0
R32	North Side of Royal Albert Dock	Residential	20.0	17.2	16.2	1.0
R33	North Side of Royal Albert Dock	Residential	1.5	17.2	16.2	1.0
R33	North Side of Royal Albert Dock	Residential	20.0	17.2	16.2	1.0
R34	North side of Royal Albert Dock (10m from Royal Albert Way)	Residential	1.5	17.5	16.5	1.0
R35	North Side of Royal Albert Dock	Residential	1.5	17.2	16.2	1.0
R35	North Side of Royal Albert Dock	Residential	20.0	17.1	16.2	0.9
R36	Barrier Park East	Residential	1.5	17.1	16.1	1.0
R36	Barrier Park East	Residential	20.0	17.1	16.1	1.0
R37	UNEX	Residential	1.5	17.2	16.2	1.0
R38	Royal Wharf	Residential	1.5	17.0	16.1	0.9
R39	Royals Business Park Hotel Site 2.3	Residential	1.5	17.4	16.4	1.0
R39	Royals Business Park Hotel Site 2.3	Residential	10.5	17.2	16.2	1.0
R40	Royals Business Park Hotel Site 2.2	Residential	1.5	17.9	16.8	1.1
R40	Royals Business Park Hotel Site 2.2	Residential	20.0	17.1	16.1	1.0
R41	Fox & Connaught Hotel, Lynx Way	Residential	1.5	17.4	16.4	1.0
R41	Fox & Connaught Hotel, Lynx Way	Residential	13.5	17.2	16.2	1.0
R42	Garvary Road/ Prince Regent Lane	Residential	1.5	17.3	16.3	1.0
R43	Prince Regent Lane	Residential	4.5	17.2	16.2	1.0
R43	Prince Regent Lane	Residential	16.5	17.1	16.1	1.0
R44	The Royal Docks Academy	Education	1.5	17.4	16.4	1.0
R45	Tree Road/ Prince Regent Lane	Residential	1.5	17.6	16.6	1.0
R46	Richard House Children's Hospice	Healthcare	1.5	17.3	16.3	1.0

R47	Calverton Primary School	Education	1.5	17.1	16.1	1.0
R48	Childrens Garden Nursery	Education	1.5	17.2	16.2	1.0
R49	Founder Close	Residential	1.5	17.3	16.3	1.0
R49	Founder Close	Residential	7.5	17.2	16.2	1.0
R50	Trader Road	Residential	1.5	17.3	16.3	1.0
R51	Tynemouth Close	Residential	1.5	17.2	16.2	1.0
R52	Vulcan Close	Residential	1.5	17.3	16.3	1.0
R53	Claremont Close	Residential	1.5	17.2	16.2	1.0
R53	Claremont Close	Residential	10.5	17.2	16.2	1.0
R54	Pier Road	Residential	4.5	17.4	16.4	1.0
R55	Albert Road/ Winifred Street	Residential	1.5	17.4	16.3	1.1
R56	Albert Road (West)	Residential	1.5	17.6	16.5	1.1

G3 $PM_{2.5}$ concentrations

Table 3 presents the predicted $PM_{2.5}$ concentrations at human receptors in the study area. The table shows predicted $PM_{2.5}$ concentrations in the 2017 baseline year and the 2035 future year, as well as the change in concentrations between the scenarios.

Table 3: Predicted $PM_{2.5}$ concentrations at human receptors

ID	Description	Type of receptor	Height (m)	$PM_{2.5}$ concentrations ($\mu g/m^3$)		
				2017	2035	Decrease
R1	Camel Road/Hartmann Road	Residential	1.5	11.6	10.3	1.3
R2	Camel Road/Parker Street	Residential	1.5	11.5	10.4	1.1
R3	Parker Street (Portway Primary School)	Education	1.5	11.3	10.2	1.1
R4	Newland Street (opposite entrance to LCY car park)	Residential	1.5	11.4	10.2	1.2
R5	Newland Street/Kennard Street	Residential	1.5	11.4	10.2	1.2
R6	Brixham Street/Dockland Street	Residential	1.5	11.3	10.2	1.1
R7	Platterns Court/Billingway Dock Head	Residential	1.5	11.2	10.1	1.1
R8	Albert Road/Woolwich Manor Way	Residential	1.5	11.5	10.4	1.1
R9	Robert Street adj Albert Road (north side)	Residential	1.5	11.3	10.2	1.1
R10	Collier Close adj Gallions Way Roundabout (eastern side)	Residential	1.5	11.4	10.3	1.1
R11	Yeoman Close adj Royal Albert Way	Residential	1.5	11.3	10.2	1.1
R12	Straight Road/Campton Close	Residential	1.5	11.3	10.2	1.1
R13	Mill Rd adj North Woolwich Road (west)	Residential	1.5	11.1	10.0	1.1
R14	Connaught Road/Leonard Street	Residential	1.5	11.4	10.2	1.2
R15	Gallions Primary School adjacent to Royal Docks Road	Education	1.5	11.1	10.1	1.0
R16	Drew Road/Leonard Street	Residential	1.5	11.4	10.2	1.2
R17	Woolwich Manor Way (UEL)	Education	1.5	11.2	10.2	1.0
R18	Woolwich Manor Way (UEL)	Education	1.5	11.2	10.1	1.1
R18	Woolwich Manor Way (UEL)	Education	20.0	11.1	10.1	1.0
R19	West Silvertown 1	Residential	1.5	11.1	10.0	1.1
R19	West Silvertown 1	Residential	20.0	11.1	10.0	1.1
R20	West Silvertown 2	Residential	1.5	11.1	10.0	1.1
R20	West Silvertown 2	Residential	20.0	11.1	10.0	1.1
R21	Flats on Drew Road	Residential	1.5	11.3	10.2	1.1
R22	Flats on Docklands Street	Residential	20.0	11.1	10.1	1.0
R22	Flats on Docklands Street	Residential	40.0	11.1	10.1	1.0
R23	Gallions Quarter	Residential	1.5	11.3	10.3	1.0

R23	Gallions Quarter	Residential	20.0	11.1	10.1	1.0
R24	Gallions Quarter	Residential	1.5	11.2	10.1	1.1
R24	Gallions Quarter	Residential	20.0	11.1	10.1	1.0
R25	University of East London Student Accommodation	Education	1.5	11.2	10.1	1.1
R25	University of East London Student Accommodation	Education	10.5	11.2	10.1	1.1
R26	Felixstowe Court	Residential	1.5	11.4	10.4	1.0
R26	Felixstowe Court	Residential	10.5	11.1	10.1	1.0
R27	Silvertown Quays 1	Residential	1.5	11.2	10.2	1.0
R27	Silvertown Quays 1	Residential	20.0	11.1	10.1	1.0
R28	Silvertown Quays 2	Residential	1.5	11.1	10.1	1.0
R28	Silvertown Quays 2	Residential	20.0	11.1	10.1	1.0
R29	Silvertown Quays, 30 m from Connaught Bridge	Residential	1.5	11.2	10.2	1.0
R29	Silvertown Quays, 30 m from Connaught Bridge	Residential	20.0	11.1	10.1	1.0
R30	Royal Albert Basin	Residential	1.5	11.1	10.1	1.0
R30	Royal Albert Basin	Residential	20.0	11.1	10.1	1.0
R31	Royal Albert Basin	Residential	1.5	11.1	10.1	1.0
R31	Royal Albert Basin	Residential	20.0	11.1	10.1	1.0
R32	North Side of Royal Albert Dock	Residential	1.5	11.2	10.1	1.1
R32	North Side of Royal Albert Dock	Residential	20.0	11.2	10.1	1.1
R33	North Side of Royal Albert Dock	Residential	1.5	11.2	10.1	1.1
R33	North Side of Royal Albert Dock	Residential	20.0	11.2	10.1	1.1
R34	North side of Royal Albert Dock (10m from Royal Albert Way)	Residential	1.5	11.4	10.3	1.1
R35	North Side of Royal Albert Dock	Residential	1.5	11.2	10.1	1.1
R35	North Side of Royal Albert Dock	Residential	20.0	11.1	10.1	1.0
R36	Barrier Park East	Residential	1.5	11.1	10.1	1.0
R36	Barrier Park East	Residential	20.0	11.1	10.1	1.0
R37	UNEX	Residential	1.5	11.2	10.1	1.1
R38	Royal Wharf	Residential	1.5	11.1	10.0	1.1
R39	Royals Business Park Hotel Site 2.3	Residential	1.5	11.3	10.2	1.1
R39	Royals Business Park Hotel Site 2.3	Residential	10.5	11.2	10.1	1.1
R40	Royals Business Park Hotel Site 2.2	Residential	1.5	11.6	10.4	1.2
R40	Royals Business Park Hotel Site 2.2	Residential	20.0	11.1	10.1	1.0
R41	Fox & Connaught Hotel, Lynx Way	Residential	1.5	11.3	10.2	1.1
R41	Fox & Connaught Hotel, Lynx Way	Residential	13.5	11.1	10.1	1.0
R42	Garvary Road/ Prince Regent Lane	Residential	1.5	11.2	10.1	1.1
R43	Prince Regent Lane	Residential	4.5	11.2	10.1	1.1
R43	Prince Regent Lane	Residential	16.5	11.1	10.0	1.1
R44	The Royal Docks Academy	Education	1.5	11.3	10.2	1.1
R45	Tree Road/ Prince Regent Lane	Residential	1.5	11.4	10.3	1.1
R46	Richard House Children's Hospice	Healthcare	1.5	11.2	10.1	1.1

R47	Calverton Primary School	Education	1.5	11.1	10.1	1.0
R48	Childrens Garden Nursery	Education	1.5	11.2	10.1	1.1
R49	Founder Close	Residential	1.5	11.2	10.1	1.1
R49	Founder Close	Residential	7.5	11.2	10.1	1.1
R50	Trader Road	Residential	1.5	11.3	10.2	1.1
R51	Tynemouth Close	Residential	1.5	11.2	10.1	1.1
R52	Vulcan Close	Residential	1.5	11.2	10.1	1.1
R53	Claremont Close	Residential	1.5	11.2	10.1	1.1
R53	Claremont Close	Residential	10.5	11.2	10.1	1.1
R54	Pier Road	Residential	4.5	11.3	10.2	1.1
R55	Albert Road/ Winifred Street	Residential	1.5	11.3	10.2	1.1
R56	Albert Road (West)	Residential	1.5	11.4	10.3	1.1