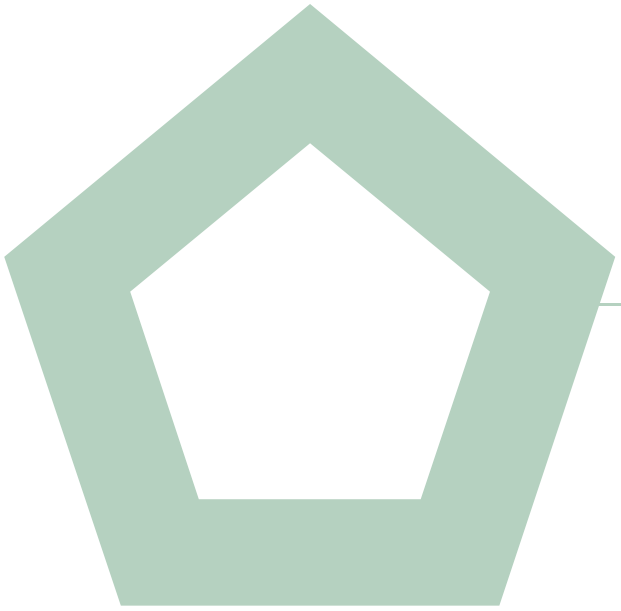
HOARE LEA

Christie Hospital Labs. Manchester.
Vinci – IHP.

BUILDING PHYSICS
STAGE 3 REPORT – POLLUTANT DISPERSION STUDY
REPORT SUBTITLE
REVISION P01 – S3



STAGE 3

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Audit sheet.

Rev.	Status	Date	Description of change / purpose of issue	Prepared	Reviewed	Authorised
P01	S3	20/04/2025	Stage 3 Issue	EL	EC	EC

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Executive summary.

Hoare Lea has been appointed by Vinci – Integrated Health Projects (IHP) to carry out a Computational Fluid Dynamics (CFD) dispersion assessment to evaluate rooftop fume/dissection extract performance, where stack outlets are close to neighbouring roof-level AHU intakes and natural ventilation openings, for the lab redevelopment of Christie Hospital (the 'Development') located on Wilmslow Road, Manchester (the 'Site'). To quantify the suitability of the exhaust system two scenarios were assessed for different wind speeds:

- Scenario 1: Low wind speed (2.13 m/s).
- Scenario 2: High wind speed (6.21 m/s).

The four flues modelled have different flow rates, however, have been fitted with a nozzle to ensure the exhaust velocity is 12 m/s for all the flues.

The assessment considers a spill scenario within a single nominal fume cabinet, accounting for a 'basket' of 362 different chemicals (including volatile organic compounds). The assessment investigated threshold limits for the safe dispersion of the chemicals likely to be used in the labs of the Development.

The list of chemicals in use on site is limited to Methylated Spirits (10% Methyl alcohol), Xylene and Formalin (Formaldehyde solution (37%). Of these substances, Formalin requires the highest dilution of approximately 67:1 according to the RWDI methodology. Accordingly, a conservative dilution ratio of 200:1 was used for the assessment. This dilution ratio is also consistent with 72% of the 362 chemicals often used in laboratories which required a dilution ratio of 200:1. The list of chemicals is in Appendix A.

The dilution target of 200:1 is based on a reference volumetric of 1000 cfm (0.47 m^3/s) for a single stack. The volumetric flow rate is adjusted to reflect the individual flow rates of each flue.

The calculated dilution target also assumes a typical 8.8 ft^2 (0.82 m^2) laboratory fume cupboard, which limits the surface area of any chemical spill to these dimensions. Or, alternatively, this also corresponds to a maximum chemical volume of 406 ml (assuming a spill depth of 0.5 mm).

For both low and high wind speeds, none of the wind directions tested resulted in plumes intersecting either the development or any surrounding buildings. Therefore, for chemicals with a required dilution ratio of 200:1 there would be no risks associated with dispersion and mitigation measures would not be required for these wind scenarios.

1. Introduction.

Laboratories, vital for scientific research, pose inherent risks, especially within an urban environment in the event of a chemical spill from a fume cupboard. The subsequent dispersion of these chemicals (including volatile organic compounds) into the atmosphere interacts with the wind dynamics influenced by rural and urban context creating complex flow structures that can only be understood through a detailed assessment.

This assessment employs Computational Fluid Dynamics (CFD) to analyse the relationship between wind behaviour and the transport of gaseous concentrations from a chemical spill, specifically considering the role of fume extract flues. The primary objective is to model the discharge from these fans, assessing potential risks to the surrounding environment, including neighbouring buildings and pedestrian areas, as well as any entrainment into intakes of the building. On-site and off-site receptors will be analysed.

The report encapsulates key assumptions and scenarios, aiming to detect the impact of the proposed design on chemical dispersion in the event of an accidental spill in laboratory settings. The focus is on practical insights that can enhance safety measures within and around these critical scientific spaces. Two scenarios were assessed for two different dilution ratios:

- Scenario 1: Low wind speed (2.13 m/s).
- Scenario 2: High wind speed (6.21 m/s).

2. Site Description.

The site is located on Wilmslow Road, Manchester (see Figure 1) where the lab location is outlined in red and the wider hospital site is outlined in yellow. The Site is surrounded predominantly by residential properties on all sides. The exact location of the site is provided here.



Figure 1 - Location of the site outlined in red and surrounding context in top view.

2.1 The Development.

The Site is surrounded by residential properties on all sides with the Development (lab) being surrounded by other hospital buildings, that would impact the wind flow approaching from all directions. The terrain is considered in the model along with the surrounding buildings within a 500 m radius from the Site (Figure 2).

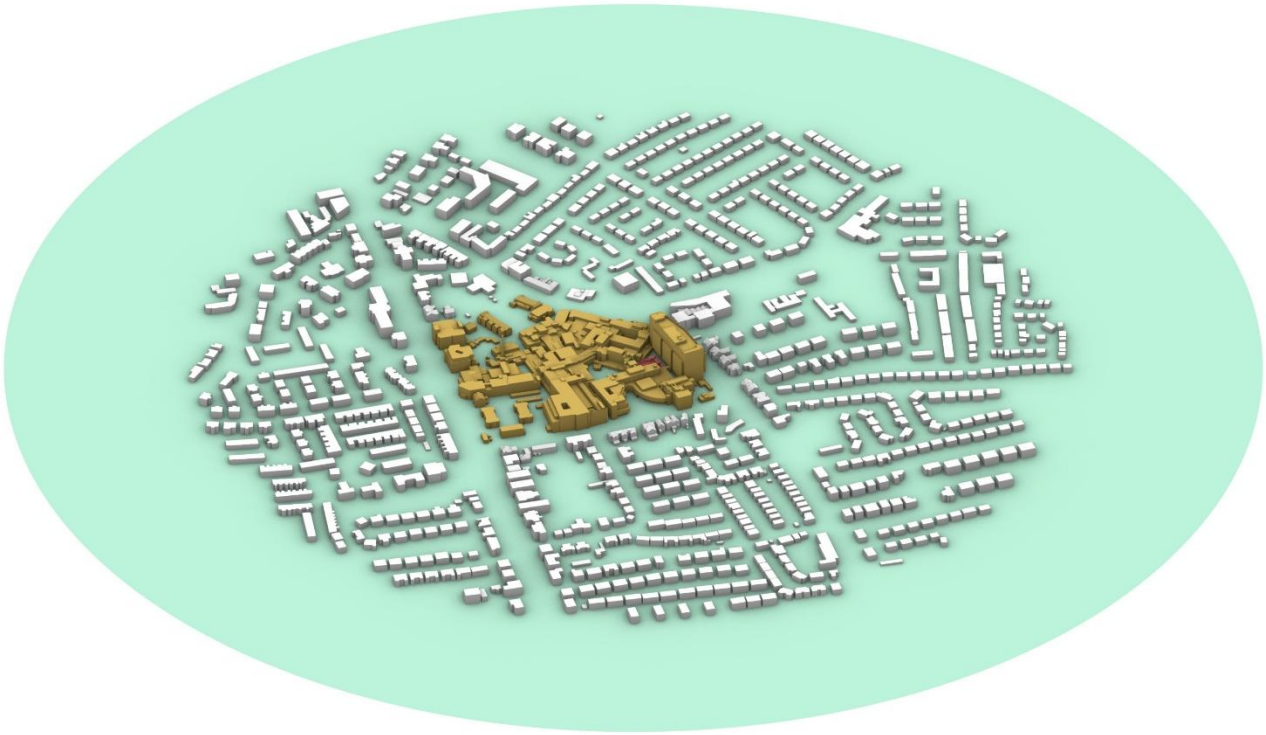


Figure 2 - Rendering of the Development in the context of existing surrounds with landscaping.

The Development is proposed to include a new exhaust system with associated flues. Figure 3 details the plant on the roof of the Development in which four flues and mechanical plant equipment have been modelled. Four flues are modelled and are designated as follows: FEF1 (PBMC Lab Fume), FEF2 (Histology Lab), FEF3 (Dissection & Tissue Processing) and FEF4 (Flammables Store).

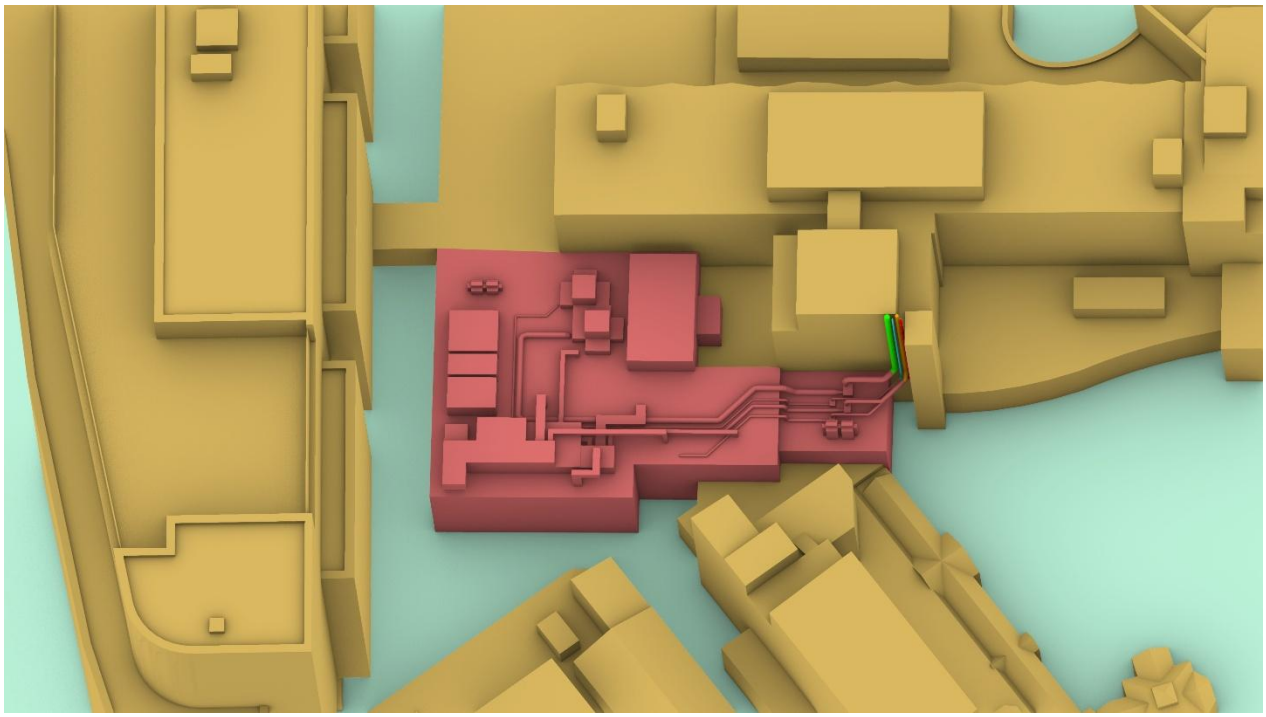


Figure 3 - Rendering of the Development with details of the plant on the roof showing flues and photovoltaic panels.

2.2 Flues.

The flues exhaust at approximately 5 m above the roof height as shown in Figure 4. Flow rates are different for each flue, but nozzles are fitted to ensure the exhaust velocity of all flues is 12 m/s. The flow rates and exhaust diameters for each flue is summarised in Table 1

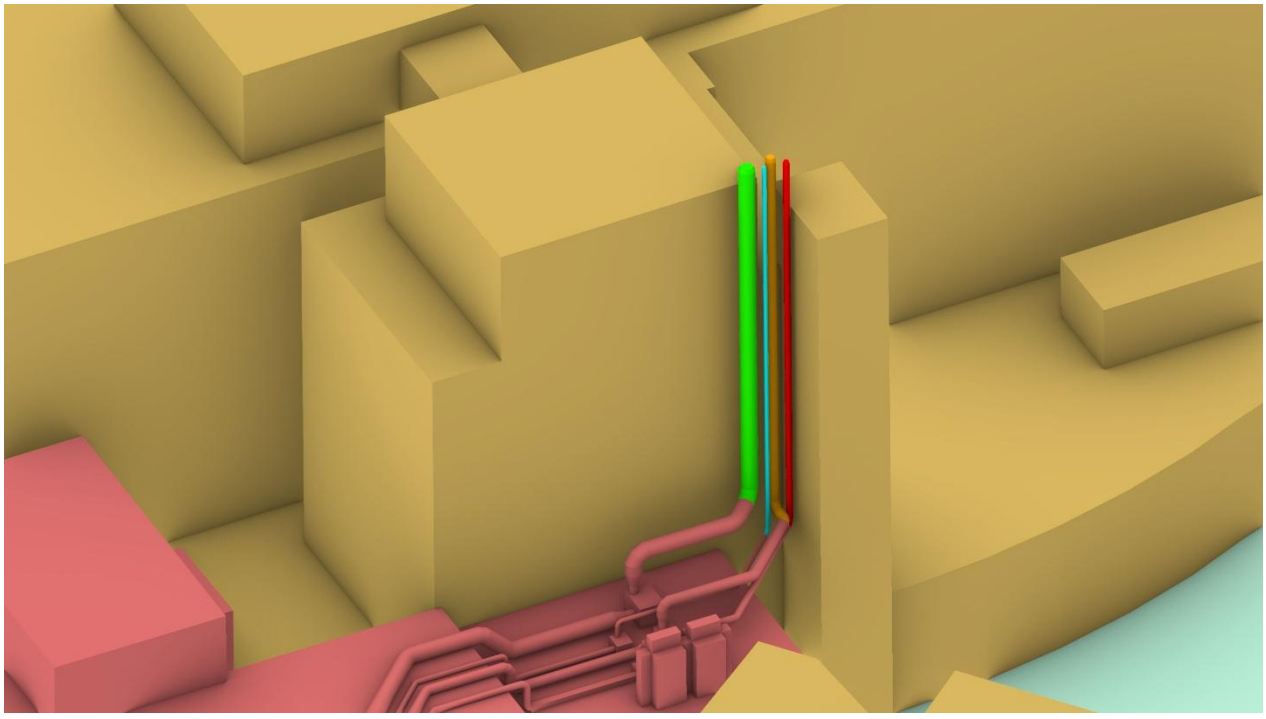


Figure 4 - Model representation of flues. FEF1 (Red), FEF2 (Orange), FEF3 (Green), FEF4 (Blue)

Table 1 – Summary of Flues

Flue	Source	Volume Flow (m^3/s)	Exhaust Diameter (m)
FEF1	PBMC Lab Fume Hood	0.24	0.160
FEF2	Histology Lab	0.63	0.259
FEF3	Dissection & Tissue Processing	1.545	0.405
FEF4	Flammables Store	0.12	0.113

3. Methodology.

3.1 Modelling Overview.

The assessment investigated whether the proposed fume extract flues arrangement could help adequately discharge at a high level to ensure dilution to non-hazardous levels, on buildings and sensitive receptors, caused by accidental emission of chemicals above the threshold limits into the atmosphere. The analysis combines the vertical momentum of the exhausted flow, produced by the fume extract flues, with the effect of the wind, that will force the emitted plume towards the ground. The source is defined as having a pollutant-specific concentration modelled as a passive scalar.

3.2 CFD Model.

Figure 2 illustrates the computational model used for CFD simulations of the Development in the context of existing surrounds. The surrounding buildings are within 500 m radius of the site centre. The simulations were conducted using ANSYS CFX 2025 R1 for 12 wind angles at two different wind speed percentiles (discussed in Section 3.4), spaced equally around the compass at 30° intervals. The wind directions were selected to evaluate the possibility of risk, due to their frequency and magnitude and their orientation relative to the building massing and surroundings.

This assessment uses the Reynolds-Averaged Navier-Stokes (RANS) approach with a k-ω SST turbulence model to simulate the wind environment within and around the site. A limitation in the turbulence model is that it cannot fully resolve the wind dynamics associated with gusting, although it has been proven in the literature to adequately predict steady-state characteristics of the flow. Note that buoyancy effects of the flue discharges have been neglected as they are considered small in relation to the jet momentum of the discharge and the wind transport effects.

The computational model was discretised into approximately 20 million hexahedral/tetrahedral cells, with refinements around the Development and fume extract flues up to sufficient height to accurately capture the plume.

The dispersion assessment is generally carried out in four stages:

- Stage 1. Analysis of most appropriate weather station wind data to determine wind speeds.
- Stage 2. Adjustment of weather station data to local site conditions to determine wind profile.
- Stage 3. Conduct CFD simulations to predict the wind velocities of different wind directions and chosen wind speeds.
- Stage 4. Determine gas concentration by estimating dilution ratio of calculated chemicals to plot plume size.

3.3 Dilution and Discharge Characteristics of Nominal Fume Cabinets.

The methodology considers a spill scenario within a single nominal fume cabinet, accounting for a 'basket' of 362 different chemical substances used in laboratories (RWDI).

The list of chemicals in use on site is limited to Methylated Spirits (10% Methyl alcohol), Xylene and Formalin (Formaldehyde solution (37%). Of these, Formalin requires the highest dilation of approximately 67:1 according to the RWDI methodology, which provides a conservative method and reference dilution values.

A conservative dilution threshold of 200:1 has been chosen for the CFD analysis to ensure the flues are dispensing the chemicals at a safe dilution.

Initially, potential chemical concentrations at the cabinet exhaust were calculated and compared to safety & nuisance limits to establish a limiting external concentration which satisfies the requirements of the majority (~72%) of the considered chemicals (see Figure 5).

The resulting progressive dilution of the emitted discharge can then be tracked and compared to the limiting concentrations established. This can be plotted as a discharge plume at the limiting concentration, which can be evaluated for contact with potential receptors such as air intakes, openings, or occupied areas on or around the source including adjacent buildings.

This initial modelling is based on nominal fume cabinet properties and discharge flows to provide an initial assessment of discharge characteristics and risks.

The list of additional chemicals considered by this method can be found in Appendix A. The dilution target provided (200:1) is based on a 1000 cfm (0.47 m^3/s) base volumetric flowrate for a single stack. The calculated dilution target also assumes a typical 8.8 ft^2 (0.82 m^2) laboratory fume cupboard, which limits the surface area of any chemical spill to these dimensions. Or, alternatively, this also corresponds to a maximum chemical volume of 406 ml (assuming a spill depth of 0.5 mm).

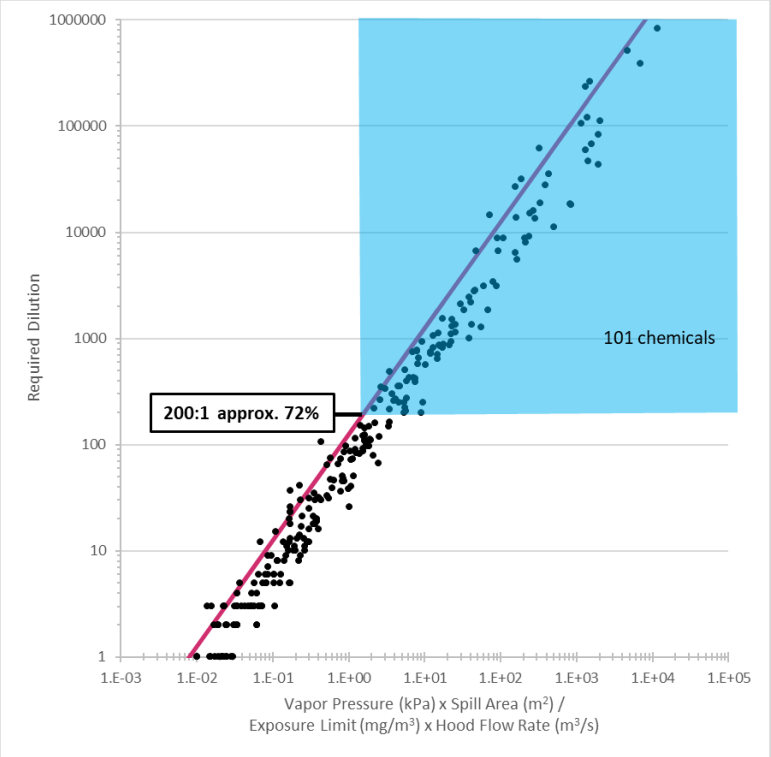


Figure 5 - Required dilution for fume hood spills for a basket of 362 chemicals. The dilution ration of 200:1 was selected accounting for 72% of the chemicals within the list provided by RWDI methodology (RWDI).

The enclosed value within Figure 5 denotes the percentage of chemicals that would conform to odour and health standards at the specified dilution, assuming a fume hood flow rate of 1,000 cfm, an 8.8 ft^2 spill area, health limits set by ACGIH, OSHA and NIOSH, and published odour thresholds.

In the event of a dilution ratio of 200:1, the remaining 28% of chemicals may necessitate specialised handling procedures to mitigate the risk of significant spills and releases.

Note that the trend line in Figure 5 was designed to offer a cautious estimate of a dilution target for a chemical not included within the 72% of chemicals (dilution ratio of 200:1), listed in Appendix A, of frequently used laboratory chemicals. It is important to note that these values should not be relied on to determine precise dilution targets for a particular chemical.

3.4 Weather Data.

The most appropriate weather station to the Site, with sufficient available data, is Ringway Lat 53.356 Lon -2.279, about 8 km to the southwest of the Site.

The wind data recorded at Ringway for the past 50 years was used to develop the wind rose shown in Figure 6. Each outer edge of the coloured sections represents the probability of the wind velocities in meters per second. The areas in the wind rose indicate, for most of the time, wind speeds are in the range of 4-8 m/s with a predominant wind direction from the south.

Wind probability data from the weather station are adjusted to the Site conditions by taking into consideration differences in terrain roughness and topology. Deaves and Harris methodology is employed to make this adjustment to the wind speed profiles for all assessed wind directions.

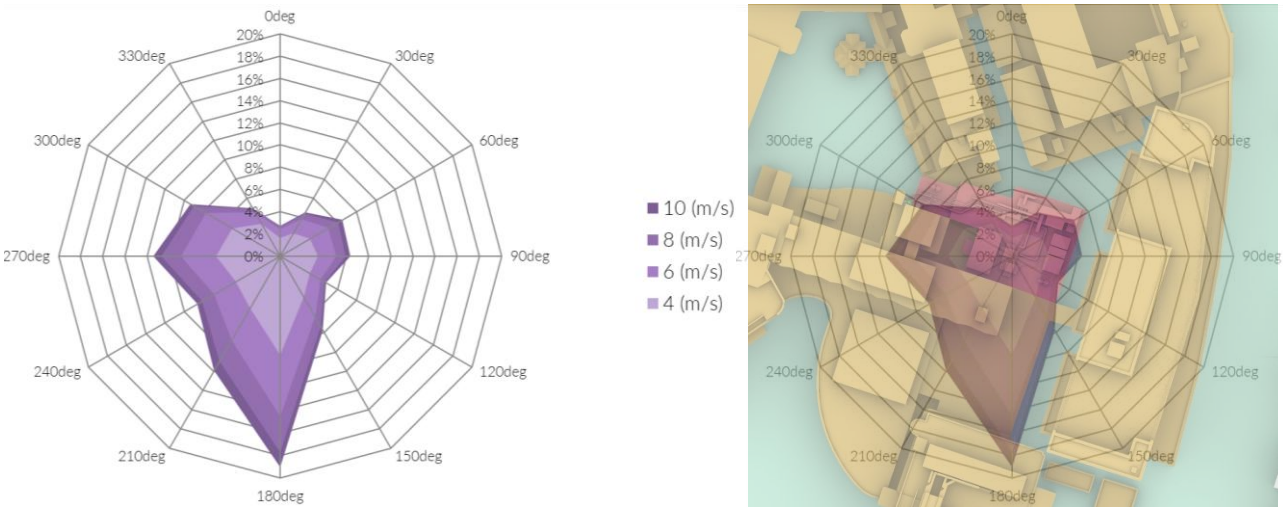


Figure 6 - Annual wind rose for the past 50 years' worth of hourly mean wind speed data from Ringway.

The scenarios considered in this assessment are a combination of wind direction and indicative low and high wind speeds. Twelve wind directions have been chosen, according to the possibility of the exhaust plumes to travel towards the areas of interest and the critical surroundings and have an impact on the surrounding buildings and at ground level. The strongest and most frequent wind directions that are indicated by the annual wind rose in Figure 6 are considered to have a potential greater and more frequent impact.

The simulated velocity of the wind is equivalent to 2.13 m/s for low wind speed and 6.21 m/s for high wind speed. These wind speeds are the 20th and 80th percentile for most frequent wind speeds during the year at the site respectively.

4. Results.

This section summarises the results from the assessment. The full set of results of the plumes are located in Appendix B.

The steady state analysis was conducted on twelve wind directions at two wind speeds (2.13 m/s and 6.21 m/s), for a dilution ratio of 200:1, resulting in a total of 24 wind scenarios. A representative sample of images is reported within this section to explain the finding from the analysis, highlighting sensitive areas and potential risks.

The following results show the plumes of possible pollutants above the threshold concentrations, simulated utilising a 200:1 dilution ratio which satisfies 72% of the chemicals tested in this report (full set of results are provided in Appendix B).

For both low and high wind speeds, none of the wind directions tested resulted in plumes intersecting the either the development or any surrounding buildings. Therefore, for chemicals with a dilution ratio of 200:1 there would be no risks associated with dispersion and mitigation measures would not be required for these wind scenarios.

It is important to note that the results presented in this study are based on a model methodology which considers a worst-case scenario of spillage within a fume hood which does not represent day-to-day operations of laboratory spaces.

4.1 Dilution ratio 200:1.

The results of the dilution ratio 200:1 show that there are no wind directions tested where the plumes intersect the Development or surrounding buildings.

4.1.1 High wind speed 6.13 m/s

High wind speeds are typically characterised by small plumes due to increased dilution but greater deflection of the exhaust. None of the wind directions indicate the plumes intersecting with the surrounding buildings.

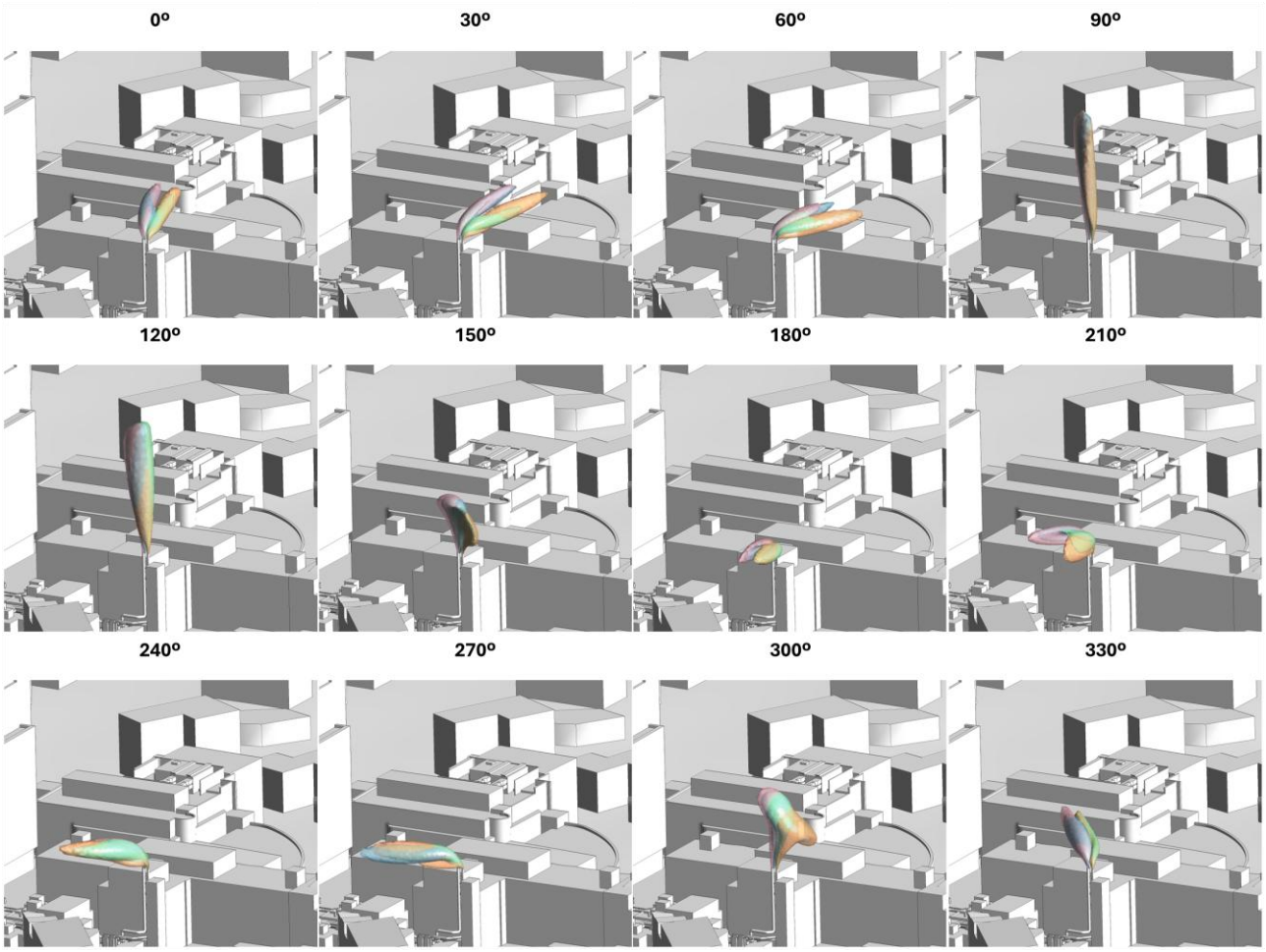


Figure 7 - Plot of plumes from flues with a dilution threshold of 200:1 for all wind directions at high wind speed

4.1.2 Low wind speed 2.1 m/s

The low wind speed scenario results in no areas of exceedance at the wind directions tested.

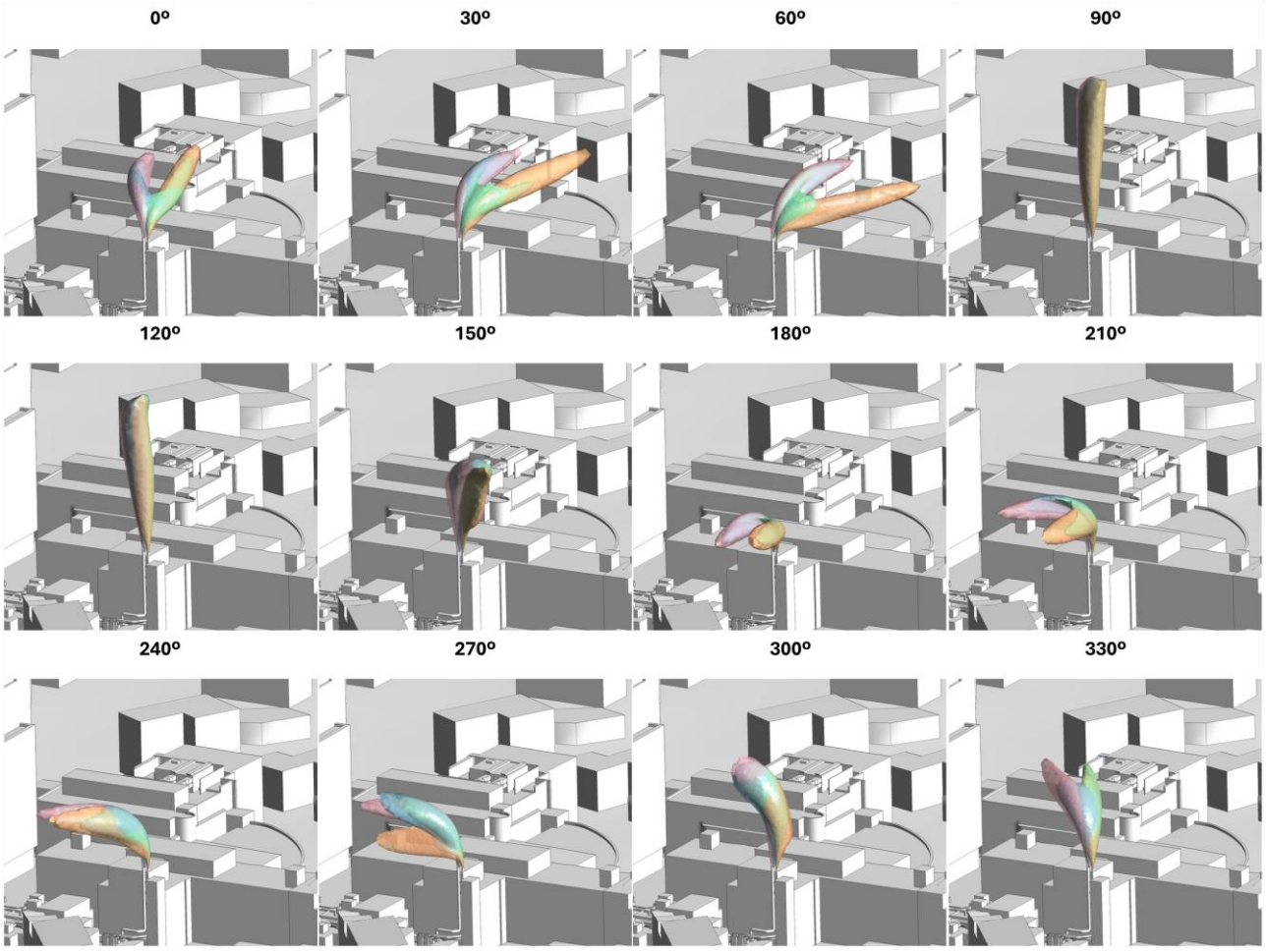


Figure 8 - Plot of plumes from flues with a dilution threshold of 200:1 for all wind directions at high wind speed

5. Summary and Conclusions.

The following summarises the findings of this report:

1. The study consisted of 12 wind directions and two wind speeds (2.13 m/s and 6.21 m/s).
2. All results presented in this report assume a dilution of 200:1 at point of exhaust. This conservative assumption has been applied to all chemicals used in the laboratory and is supported by RWDI guidance, which indicates that 72% of the chemicals considered fall within this dilution criterion. The dilution target is based on a 1,000 cfm (0.47 m^3/s) base volumetric flowrate for a single stack and the volumetric flow rate is adjusted for the individual flow rates of each flue.
3. The calculated dilution target also assumes a typical 8.8 ft^2 (0.82 m^2) laboratory fume cupboard, which limits the surface area of any chemical spill to these dimensions. Or, alternatively, this also corresponds to a maximum chemical volume of 406 ml (assuming a spill depth of 0.5 mm).
4. For both low and high wind speeds, none of the wind directions tested resulted in plumes intersecting the either the development or any surrounding buildings.
5. Therefore, for chemicals with a dilution ratio of 200:1 there would be no risks associated with dispersion and mitigation measures would not be required for these wind scenarios.
6. In summary, for a dilution ratio of 200:1, the existing design is sufficient to adequately dilute the emitted chemicals examined in this study, across all wind scenarios, in the quantity assumed in an accidental chemical spill.

Appendix A – List of Chemicals for 200:1.

Table 2 – The list of chemicals at a 200:1 dilution ratio that will be handled by the stack design.

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health / Odor
Acetic anhydride	108-24-7	102.10	0.47	1.97E-02	0.07	1.40E-03	22.45	47.58	0.58	20.00	20.00	0.58	81
Acetone	67-64-1	58.08	24.40	5.82E-01	0.11	1.83E-03	865.85	1834.64	147.28	1782.00	590.00	147.28	12
Acetone cyanohydrin	75-86-5	85.10	0.11	3.74E-03	0.10	1.73E-03	5.25	11.13	10.44	4.00	NV	4.00	3
Acetonitrile	75-05-8	41.05	9.70	1.63E-01	0.11	1.88E-03	250.06	529.86	1947.57	101.00	34.00	101.00	5
Acetophenone	98-86-2	120.15	0.13	6.41E-03	0.06	1.21E-03	6.29	13.32	1.57	NV	49.00	1.57	8
Acrylamide	79-06-1	71.00	0.001	2.9E-05	0.10	1.73E-03	0.04	0.09	NV	NV	0.03	0.03	3
Acrylic acid	79-10-7	72.06	0.40	1.18E-02	0.09	1.58E-03	15.16	32.13	0.27	NV	5.90	0.27	118
Allyl alcohol	107-18-6	58.08	2.30	5.48E-02	0.09	1.62E-03	72.29	153.18	4.04	10.00	1.19	4.04	38
Ammonium hydroxide sol'n (10%), as NH4	1336-21-6	35.00	15.00	2.16E-01	0.19	2.61E-03	457.20	968.74	24.34	24.00	17.00	24.00	40
Ammonium hydroxide sol'n (20%), as NH4	1336-21-6	35.00	29.50	4.24E-01	0.19	2.61E-03	897.60	1901.90	24.34	24.00	17.00	24.00	79
Ammonium hydroxide sol'n (30%), as NH4	1336-21-6	35.00	74.20	1.07E+00	0.19	2.61E-03	2257.68	4783.76	24.34	24.00	17.00	24.00	199
n-Amyl alcohol	71-41-0	88.15	0.22	7.89E-03	0.06	1.23E-03	7.89	16.71	5.59	NV	NV	5.59	3
t-Amyl alcohol	75-85-4	88.15	1.60	5.79E-02	0.06	1.23E-03	57.88	122.64	0.83	NV	NV	0.83	148
2-Anisidine	90-04-0	123.15	0.01	6.57E-04	0.10	1.73E-03	0.92	1.96	NV	NV	0.50	0.50	4
Benzyl chloride	100-44-7	126.58	0.13	6.75E-03	0.07	1.31E-03	7.20	15.25	0.21	5.00	5.00	0.21	72
Biphenyl	92-52-4	154.00	0.001	8.22E-05	0.10	1.73E-03	0.12	0.24	0.00	NV	1.00	0.003	74
Boron tribromide	10294-33-4	251.00	5.33	5.49E-01	0.05	1.03E-03	459.89	974.45	NV	10.00	NV	10.00	97
Bromoform	75-25-2	252.77	0.67	6.95E-02	0.06	1.25E-03	70.74	149.90	17.45	NV	5.00	5.00	30
n-Butyl acetate	123-86-4	116.16	1.33	6.34E-02	0.06	1.24E-03	64.10	135.82	1.47	950.00	710.00	1.47	92
sec-Butyl acetate	105-46-4	116.16	1.30	6.20E-02	0.06	1.24E-03	62.66	132.76	21.76	NV	950.00	21.76	6
Isobutyl alcohol	78-83-1	74.00	1.20	3.65E-02	0.10	1.73E-03	51.23	108.54	10.90	NV	150.00	10.90	10
n-Butyl alcohol	71-36-3	74.00	0.60	1.82E-02	0.07	1.40E-03	20.77	44.00	3.63	150.00	61.00	3.63	12
sec-Butyl alcohol	78-92-2	74.00	1.60	4.86E-02	0.07	1.36E-03	53.85	114.10	9.69	455.00	300.00	9.69	12
Butyl Cellosolve (2-butoxyethanol)	111-76-2	118.17	0.10	4.85E-03	0.10	1.73E-03	6.82	14.44	0.48	NV	24.00	0.48	30
n-Butyl ether	142-96-1	130.23	0.64	3.42E-02	0.06	1.20E-03	33.32	70.61	0.97	NV	NV	0.97	73
n-Butyl glycidyl ether (BGE)	2426-08-6	130.00	0.43	2.29E-02	0.06	1.20E-03	22.35	47.36	NV	30.00	133.00	30.00	2
n-Butyric acid	107-92-6	88.11	0.06	2.06E-03	0.07	1.32E-03	2.22	4.70	0.09	NV	NV	0.09	50
n-Butyronitrile	109-74-0	69.10	2.55	7.23E-02	0.10	1.73E-03	101.65	215.38	NV	NV	22.00	22.00	10
Carbon tetrachloride	56-23-5	154.00	12.00	7.59E-01	0.07	1.37E-03	842.18	1784.49	1587.24	12.60	31.00	12.60	142
Chloroacetone	78-95-5	92.50	2.80	1.06E-01	0.10	1.73E-03	149.41	316.58	NV	3.80	NV	3.80	83
Chlorobenzene	108-90-7	112.60	1.20	5.55E-02	0.07	1.34E-03	60.41	128.01	5.99	NV	46.00	5.99	21
Chlorobromomethane	74-97-5	129.00	15.00	7.94E-01	0.08	1.48E-03	954.04	2021.50	2100.00	NV	1050.00	1050.00	2

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health / Odor
Chlorodiphenyl (42% free chlorine)	53469-21-9	258.00	1.30 E-04	1.38E-05	0.10	1.73E-03	0.02	0.04	NV	NV	0.001	0.001	41
Chlorodiphenyl (54% free chlorine)	11097-69-1	326.00	8.00 E-06	1.07E-06	0.10	1.73E-03	0.002	0.003	NV	NV	0.001	0.001	3
1-Chloro-1-nitropropane	600-25-9	123.60	0.80	4.06E-02	0.10	1.73E-03	57.04	120.86	NV	NV	10.00	10.00	12
Ortho-Chlorotoluene	95-49-8	126.58	0.48	2.49E-02	0.10	1.73E-03	35.05	74.27	1.13	375.00	250.00	1.13	66
Chromic acid	1333-82-0	100.00	0.13	5.34E-03	0.10	1.73E-03	7.50	15.89	NV	0.10	0.001	0.10	159
Cyclohexane	110-82-7	84.00	10.27	3.54E-01	0.09	1.56E-03	450.05	953.60	2679.75	NV	344.00	344.00	3
Cyclohexanol	108-93-0	100.00	0.13	5.34E-03	0.06	1.29E-03	5.58	11.83	0.65	NV	200.00	0.65	18
Cyclohexanone	108-94-1	98.00	0.53	2.13E-02	0.07	1.30E-03	22.55	47.77	14.03	NV	100.00	14.03	3
Cyclohexylamine	108-91-8	99.00	1.43	5.81E-02	0.10	1.73E-03	81.67	173.04	217.92	NV	40.00	40.00	4
Cyclopentane	287-92-3	70.10	53.33	1.53E+00	0.10	1.73E-03	2156.58	4569.54	NV	NV	1720.00	1720.00	3
Decaborane	17702-41-9	122.00	0.03	1.35E-03	0.10	1.73E-03	1.90	4.03	0.30	0.75	0.25	0.30	13
Diacetone alcohol	123-42-2	116.00	0.11	5.24E-03	0.06	1.26E-03	5.36	11.35	1.28	NV	238.00	1.28	9
Dibutyl phosphate	107-66-4	210.20	0.13	1.12E-02	0.10	1.73E-03	15.76	33.40	NV	10.00	5.00	10.00	3
o-Dichlorobenzene	95-50-1	147.00	0.13	7.84E-03	0.06	1.26E-03	8.05	17.06	4.21	300.00	150.00	4.21	4
p-Dichlorobenzene	106-46-7	147.00	0.17	1.03E-02	0.06	1.26E-03	10.53	22.31	0.72	NV	60.00	0.72	31
1,2-Dichloroethylene (sym)	540-59-0	96.94	24.00	9.55E-01	0.10	1.73E-03	1342.12	2843.79	25.75	NV	790.00	25.75	110
trans-1,2-Dichloroethylene	156-60-5	97.00	71.00	2.83E+00	0.10	1.73E-03	3972.89	8418.08	NV	NV	790.00	790.00	11
1,2-Dichloroethane	107-06-2	99.00	8.80	3.58E-01	0.08	1.47E-03	427.64	906.12	105.28	8.00	4.00	8.00	113
1,1-Dichloro-1-nitroethane	594-72-9	144.00	2.00	1.18E-01	0.07	1.37E-03	131.69	279.04	NV	60.00	10.00	60.00	5
1,1-Dichloroethane	75-34-3	99.00	24.00	9.75E-01	0.08	1.47E-03	1166.30	2471.24	1044.87	NV	400.00	400.00	6
1,3-Dichloropropene	542-75-6	111.00	4.00	1.82E-01	0.10	1.73E-03	256.13	542.71	NV	NV	4.50	4.50	121
1,2-Dichloropropane	78-87-5	113.00	5.73	2.66E-01	0.10	1.73E-03	373.52	791.44	NV	508.00	347.00	508.00	2
Diethyl ketone	96-22-0	86.10	4.70	1.66E-01	0.10	1.73E-03	233.44	494.63	9.86	1057.00	705.00	9.86	50
Diisobutyl ketone	108-83-8	142.00	0.23	1.32E-02	0.06	1.20E-03	12.85	27.23	9.30	NV	145.00	9.30	3
N,N-Dimethylaniline	121-69-7	121.20	0.07	3.43E-03	0.06	1.19E-03	3.33	7.05	0.07	50.00	25.00	0.07	101
Dimethylformamide	68-12-2	73.00	0.36	1.08E-02	0.08	1.54E-03	13.49	28.59	20.47	NV	30.00	20.47	1
Dimethylsulfate	77-78-1	126.00	0.07	3.47E-03	0.08	1.43E-03	4.02	8.52	NV	NV	0.50	0.50	17
1,4-Dioxane	123-91-1	88.00	3.90	1.41E-01	0.07	1.42E-03	163.19	345.79	43.19	3.60	72.00	3.60	96
1,3-Dioxolane	646-06-0	74.00	10.53	3.20E-01	0.10	1.73E-03	449.51	952.45	122.22	NV	61.00	61.00	16
Epichlorohydrin	106-89-8	93.00	1.70	6.49E-02	0.08	1.46E-03	76.83	162.80	3.73	NV	1.90	1.90	86
2-Ethoxyethanol (EGEE)	110-80-5	90.12	0.54	2.00E-02	0.10	1.73E-03	28.07	59.48	9.95	NV	1.80	1.80	33
2-Ethoxyethylacetate	111-15-9	132.00	0.30	1.63E-02	0.06	1.23E-03	16.30	34.54	0.32	NV	2.70	0.32	107

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Ethyl acetate	141-78-6	88.00	9.60	3.47E-01	0.07	1.38E-03	389.67	825.67	64.79	NV	1400.00	64.79	13
Ethyl benzene	100-41-4	106.00	0.93	4.05E-02	0.07	1.31E-03	43.02	91.16	1.90	543.00	434.00	1.90	48
Ethyl butyl ketone	106-35-4	114.00	0.53	2.48E-02	0.06	1.22E-03	24.63	52.18	4.66	350.00	230.00	4.66	11
Ethyl-3-ethoxy propionate	763-69-9	146.00	0.09	5.57E-03	0.10	1.73E-03	7.83	16.60	0.11	NV	NV	0.11	151
Ethyl formate	109-94-4	74.00	26.00	7.90E-01	0.08	1.54E-03	988.10	2093.67	57.43	NV	300.00	57.43	36
2-Ethyl hexanol	104-76-7	130.00	0.01	3.74E-04	0.10	1.73E-03	0.52	1.11	0.80	NV	NV	0.80	1
Ethylene chlorohydrin	107-07-3	80.50	0.67	2.21E-02	0.09	1.56E-03	28.12	59.59	1.32	3.00	16.00	1.32	45
Ethylene glycol dinitrate	628-96-6	152.10	0.01	5.99E-04	0.10	1.73E-03	0.84	1.78	NV	0.10	0.31	0.10	18
Ethylenediamine	107-15-3	60.00	1.30	3.20E-02	0.09	1.66E-03	43.23	91.61	8.37	NV	25.00	8.37	11
Formaldehyde solution (37 %)	50-00-0	30.03	0.173	2.1E-03	0.15	2.25E-03	3.89	8.25	2.20	0.12	0.02	0.12	67
Formic acid	64-18-6	46.00	4.47	8.44E-02	0.13	2.07E-03	141.87	300.60	43.88	19.00	9.00	19.00	16
Furfural	98-01-1	96.08	0.13	5.25E-03	0.10	1.73E-03	7.37	15.62	2.80	NV	7.90	2.80	6
Glutaraldehyde (50 %)	111-30-8	100.00	0.002	8.21E-05	0.07	1.36E-03	0.09	0.19	0.16	0.20	NV	0.16	1
Glycidol	556-52-5	74.00	0.12	3.65E-03	0.10	1.73E-03	5.12	10.85	NV	NV	6.10	6.10	2
Hexachlorocyclopentadiene	77-47-4	273.00	0.01	1.23E-03	0.10	1.73E-03	1.73	3.67	2.22	NV	0.10	0.10	37
Hexamethylene diisocyanate	822-06-0	168.00	0.01	4.83E-04	0.10	1.73E-03	0.68	1.44	0.07	0.14	0.03	0.07	21
1,6-Hexane diamine	124-09-4	116.00	0.40	1.90E-02	0.10	1.73E-03	26.77	56.72	NV	NV	2.30	2.30	25
n-Hexane	110-54-3	86.00	16.53	5.84E-01	0.10	1.73E-03	820.06	1737.62	446.58	NV	176.00	176.00	10
sec-Hexyl acetate	108-84-9	144.00	0.40	2.36E-02	0.10	1.73E-03	33.23	70.41	2.30	NV	295.00	2.30	31
Hydrobromic acid	10035-10-6	80.91	2.10	6.97E-02	0.10	1.73E-03	98.02	207.69	6.66	9.90	10.00	6.66	31
Hydrochloric acid (30 %)	7647-01-0	36.47	1.41	2.12E-02	0.10	1.73E-03	29.73	63.00	2.39	7.00	NV	2.39	26
Hydrogen peroxide (35 %)	7722-84-1	34.00	0.05	6.98E-04	0.19	2.63E-03	1.49	3.17	NV	NV	1.40	1.40	2
Hydrogen peroxide (50 %)	7722-84-1	34.00	0.05	6.98E-04	0.19	2.63E-03	1.49	3.17	NV	NV	1.40	1.40	2
Hydrogen peroxide (70 %)	7722-84-1	34.00	0.10	1.40E-03	0.19	2.63E-03	2.99	6.33	NV	NV	1.40	1.40	5
Hydrogen peroxide (90 %)	7722-84-1	34.00	0.18	2.51E-03	0.19	2.63E-03	5.38	11.39	NV	NV	1.40	1.40	8
Isoamyl acetate	123-92-2	130.20	0.54	2.89E-02	0.10	1.73E-03	40.56	85.94	1.17	532.00	266.00	1.17	73
Isobutyl acetate	110-19-0	116.20	1.74	8.30E-02	0.10	1.73E-03	116.64	247.14	5.23	NV	700.00	5.23	47
Isophorone	78-59-1	138.00	0.04	2.27E-03	0.10	1.73E-03	3.18	6.75	1.07	28.00	23.00	1.07	6
Isopropyl acetate	108-21-4	102.20	6.33	2.66E-01	0.10	1.73E-03	373.19	790.75	17.14	836.00	418.00	17.14	46
Isopropyl alcohol	67-63-0	60.00	4.41	1.09E-01	0.10	1.73E-03	152.64	323.42	105.52	984.00	491.00	105.52	3
Iodine	7553-56-2	253.80	0.04	4.17E-03	0.10	1.73E-03	5.86	12.41	9.00	1.00	NV	1.00	12
Kerosene	8008-20-6	175.00	1.40	1.01E-01	0.10	1.73E-03	141.33	299.47	4.70	NV	100.00	4.70	64
Methacrylic acid	79-41-4	86.00	0.09	3.07E-03	0.10	1.73E-03	4.32	9.15	1.90	NV	70.00	1.90	5
Methyl acetate	79-20-9	74.00	23.00	6.99E-01	0.08	1.54E-03	874.09	1852.09	544.79	757.00	606.00	544.79	3
Methyl alcohol	67-56-1	32.00	13.00	1.71E-01	0.13	2.08E-03	288.77	611.87	209.41	325.00	260.00	209.41	3
Methyl n-amyl ketone	110-43-0	114.00	0.20	9.36E-03	0.10	1.73E-03	13.15	27.87	0.86	NV	233.00	0.86	32

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Methyl cellosolve acetate	110-49-6	118.13	0.30	1.45E-02	0.10	1.73E-03	20.44	43.32	1.59	NV	0.50	0.50	87
Methyl ethyl ketone	78-93-3	72.00	10.40	3.07E-01	0.10	1.73E-03	431.96	915.27	47.12	885.00	590.00	47.12	19
N-Methyl aniline	100-61-8	107.15	0.04	1.76E-03	0.10	1.73E-03	2.47	5.24	7.84	NV	2.00	2.00	3
Methyl formate	107-31-3	60.00	64.00	1.58E+00	0.09	1.58E-03	2021.86	4284.09	4907.98	368.00	246.00	368.00	12
5-Methyl-2-hexanone (methy isoamyl ketone)	110-12-3	114.00	0.67	3.14E-02	0.10	1.73E-03	44.06	93.36	0.63	NV	234.00	0.63	148
Methyl isobutyl carbinol	108-11-2	102.18	0.37	1.55E-02	0.10	1.73E-03	21.81	46.21	20.40	165.00	100.00	20.40	2
Methyl isobutyl ketone (MIBK)	108-10-1	100.00	0.80	3.28E-02	0.06	1.29E-03	34.37	72.82	3.60	300.00	205.00	3.60	20
Methyl propyl ketone	107-87-9	86.17	3.60	1.27E-01	0.10	1.73E-03	178.95	379.18	27.14	881.00	530.00	27.14	14
Methyl salicylate	119-36-8	152.00	0.01	8.11E-04	0.10	1.73E-03	1.14	2.42	0.74	NV	NV	0.74	3
Methylcyclopentadienyl manganese tricarbonyl	12108-13-3	218.00	0.01	6.00E-04	0.10	1.73E-03	0.84	1.79	NV	NV	0.20	0.20	9
Methylal	109-87-5	76.10	44.10	1.38E+00	0.10	1.73E-03	1935.97	4102.10	NV	NV	3100.00	3100.00	1
Methylene chloride	75-09-2	85.00	53.00	1.85E+00	0.10	1.73E-03	2598.79	5506.53	556.24	435.00	87.00	435.00	13
Methylene iodide	75-11-6	268.00	0.09	9.98E-03	0.10	1.73E-03	14.02	29.71	NV	NV	10.00	10.00	3
alpha-Methyl styrene	98-83-9	118.20	0.31	1.49E-02	0.10	1.73E-03	20.93	44.35	15.48	480.00	240.00	15.48	3
Methylamine (40 %)	74-89-5	31.00	31.50	4.01E-01	0.10	1.73E-03	563.31	1193.59	5.96	19.00	6.40	5.96	200
Naphtha (coal tar)	8030-30-6	110.00	3.47	1.57E-01	0.10	1.73E-03	219.94	466.02	420.00	NV	400.00	400.00	1
Naphthalene	91-20-3	128.00	0.01	3.78E-04	0.10	1.73E-03	0.53	1.13	0.20	75.00	50.00	0.20	6
Nicotine	54-11-5	162.00	0.01	3.79E-04	0.10	1.73E-03	0.53	1.13	NV	NV	0.50	0.50	2
Nitric acid (70 %)	7697-37-2	63.02	0.73	1.89E-02	0.13	2.07E-03	31.77	67.31	0.70	10.00	5.00	0.70	97
Nitrobenzene	98-95-3	123.11	0.02	1.01E-03	0.10	1.73E-03	1.42	3.01	1.86	NV	5.00	1.86	2
Nitromethane	75-52-5	61.00	3.70	9.26E-02	0.10	1.73E-03	130.20	275.88	124.00	NV	50.00	50.00	6
1-Nitropropane	108-03-2	89.09	1.01	3.69E-02	0.10	1.73E-03	51.91	109.98	510.13	NV	90.00	90.00	1
2-Nitropropane	79-46-9	89.09	1.74	6.36E-02	0.10	1.73E-03	89.42	189.48	556.53	NV	36.00	36.00	5
Nitrotoluene (m isomers)	99-08-01	137.10	0.01	7.32E-04	0.10	1.73E-03	1.03	2.18	0.10	NV	11.00	0.10	23
Nitrotoluene (o isomers)	88-72-2	137.00	0.01	8.27E-04	0.10	1.73E-03	1.16	2.46	0.10	NV	11.00	0.10	26
Nitrotoluene (p isomers)	99-99-0	137.00	0.01	7.31E-04	0.10	1.73E-03	1.03	2.18	0.10	NV	11.00	0.10	23
1-Octanol	111-87-5	130.20	0.01	4.65E-04	0.05	1.16E-03	0.44	0.93	0.69	NV	NV	0.69	1
Oxo-hexyl acetate	88230-35-7	144.00	0.19	1.10E-02	0.10	1.73E-03	15.51	32.86	0.93	NV	NV	0.93	35
Pentane	109-66-0	72.00	65.00	1.92E+00	0.10	1.73E-03	2699.74	5720.43	1087.95	1800.00	350.00	1087.95	5
Phenol	108-95-2	94.00	0.05	1.93E-03	0.07	1.40E-03	2.20	4.66	0.23	60.00	19.00	0.23	20
Phenyl ether	101-84-8	170.20	0.003	1.89E-04	0.05	1.09E-03	0.17	0.35	0.07	14.00	7.00	0.07	5
Phenylhydrazine	100-63-0	108.00	0.01	2.22E-04	0.10	1.73E-03	0.31	0.66	NV	0.60	0.44	0.60	1
Phosphoric acid (75 %)	7664-38-2	98.00	0.75	3.02E-02	0.10	1.72E-03	42.12	89.24	NV	3.00	1.00	3.00	30

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Phosphoric acid (85 %)	7664-38-2	98.00	0.29	1.17E-02	0.10	1.72E-03	16.32	34.59	NV	3.00	1.00	3.00	12
Potassium Hydroxide	1310-58-3	56.00	0.27	6.21E-03	0.10	1.73E-03	8.72	18.48	NV	2.00	2.00	2.00	9
beta-Propiolacetone	57-57-8	72.10	0.31	9.09E-03	0.10	1.73E-03	12.77	27.06	NV	NV	1.50	1.50	18
Propionic acid	79-09-4	74.10	0.40	1.22E-02	0.08	1.55E-03	15.32	32.46	0.20	45.00	30.00	0.20	162
n-Propyl alcohol	71-23-8	60.09	2.00	4.93E-02	0.09	1.55E-03	62.21	131.81	13.03	614.00	492.00	13.03	10
n-Propyl nitrate	627-13-4	105.00	2.40	1.03E-01	0.10	1.73E-03	145.37	308.02	210.00	170.00	105.00	170.00	2
Propylene glycol 1-methyl ether	107-98-2	90.00	1.60	5.91E-02	0.10	1.73E-03	83.07	176.01	121.00	540.00	360.00	121.00	1
Propylene glycol-1-methyl ether-2-acetate	108-65-6	132.00	0.50	2.71E-02	0.10	1.73E-03	38.07	80.67	0.70	NV	NV	0.70	115
Pyridine	110-86-1	79.10	2.40	7.79E-02	0.10	1.73E-03	109.51	232.04	2.14	NV	15.00	2.14	109
Quinone	106-51-4	108.00	0.02	9.75E-04	0.10	1.73E-03	1.37	2.90	0.40	NV	0.40	0.40	7
Sodium Hydroxide (50%)	1310-73-2	40.01	0.20	3.28E-03	0.10	1.73E-03	4.62	9.78	NV	NV	2.00	2.00	5
Stoddard solvent (Mineral spirits)	8052-41-3	144.00	0.53	3.13E-02	0.10	1.73E-03	44.03	93.29	28.76	1800.00	350.00	28.76	3
Styrene, monomer	100-42-5	104.00	0.57	2.43E-02	0.10	1.73E-03	34.20	72.46	0.60	170.00	85.00	0.60	122
Sulfuric acid (100 %)	7664-93-9	98.00	0.04	1.61E-03	0.10	1.73E-03	2.26	4.79	0.60	3.00	1.00	0.60	8
Sulfuric acid (98 %)	7664-93-9	98.00	0.04	1.61E-03	0.10	1.73E-03	2.26	4.79	0.60	3.00	1.00	0.60	8
Sulfuric acid (93 %)	7664-93-9	98.00	0.04	1.61E-03	0.10	1.73E-03	2.26	4.79	0.60	3.00	1.00	0.60	8
Sulfuric acid (78 %)	7664-93-9	98.00	0.04	1.61E-03	0.10	1.73E-03	2.26	4.79	0.60	3.00	1.00	0.60	8
1,1,2,2-Tetrachloroethane	79-34-5	167.90	0.67	4.62E-02	0.10	1.73E-03	64.89	137.50	50.13	NV	6.90	6.90	20
Tetrachloroethylene	127-18-4	166.00	1.87	1.27E-01	0.10	1.73E-03	179.07	379.43	319.10	685.00	170.00	319.10	1
Tetraethyl lead	78-00-2	323.00	0.02	2.65E-03	0.10	1.73E-03	3.73	7.90	NV	NV	0.08	0.08	105
Tetrahydrofuran	109-99-9	72.10	19.00	5.62E-01	0.10	1.73E-03	790.25	1674.45	91.42	735.00	590.00	91.42	18
Thioglycolic acid	68-11-1	92.10	1.33	5.03E-02	0.10	1.73E-03	70.66	149.72	NV	NV	3.80	3.80	39
Toluene	108-88-3	92.00	2.90	1.10E-01	0.08	1.44E-03	128.18	271.59	6.02	560.00	188.00	6.02	45
Toluene-2,4-diisocyanate	584-84-9	174.00	0.003	2.36E-04	0.10	1.73E-03	0.33	0.70	7.40	0.14	0.04	0.14	5
m-Toluidine	108-44-1	107.20	0.13	5.85E-03	0.10	1.73E-03	8.22	17.43	7.22	NV	8.80	7.22	2
o-Toluidine	95-53-4	107.20	0.04	1.76E-03	0.10	1.73E-03	2.47	5.24	1.78	NV	8.80	1.78	3
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	187.40	37.80	2.91E+00	0.10	1.73E-03	4086.37	8658.53	592.36	9500.00	7600.00	592.36	15
1,2,4-Trichlorobenzene	120-82-1	181.46	0.13	9.91E-03	0.10	1.73E-03	13.92	29.50	21.97	37.00	NV	21.97	1
1,1,1-Trichloroethane	71-55-6	133.42	17.00	9.31E-01	0.10	1.73E-03	1308.42	2772.38	2128.17	1910.00	1900.00	1910.00	1
1,1,2-Trichloroethane	79-00-5	133.00	2.53	1.38E-01	0.10	1.73E-03	194.11	411.30	NV	NV	45.00	45.00	9
Trichloroethylene	79-01-6	131.40	7.70	4.15E-01	0.07	1.38E-03	466.65	988.78	440.69	11.00	134.00	11.00	90
Trichlorofluoromethane	75-69-4	137.00	92.00	5.17E+00	0.10	1.73E-03	7270.84	15406.05	181.03	5600.00	5600.00	181.03	85
1,2,3-Trichloropropane	96-18-4	147.40	0.40	2.42E-02	0.10	1.73E-03	34.01	72.07	40.31	NV	60.00	40.31	2
1,2,4-Trimethylbenze	95-63-6	120.00	0.13	6.55E-03	0.10	1.73E-03	9.21	19.51	11.78	NV	123.00	11.78	2

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health / Odor
ne (as mixed isomers)													
Xylene (o,m, p-isomers)	1330-20-7	106.16	0.87	3.79E-02	0.10	1.73E-03	53.28	112.89	86.84	651.00	434.00	86.84	1

Notes:
All chemical properties can be referenced to Canadian Centre for Occupational Health and Safety www.ccohs.ca
NV indicates no value for air quality or odour standards N/A indicates required dilution is not applicable.
"none" indicates criterion met at the source (i.e., no dilution required).

Appendix B – Full Sets of Results.

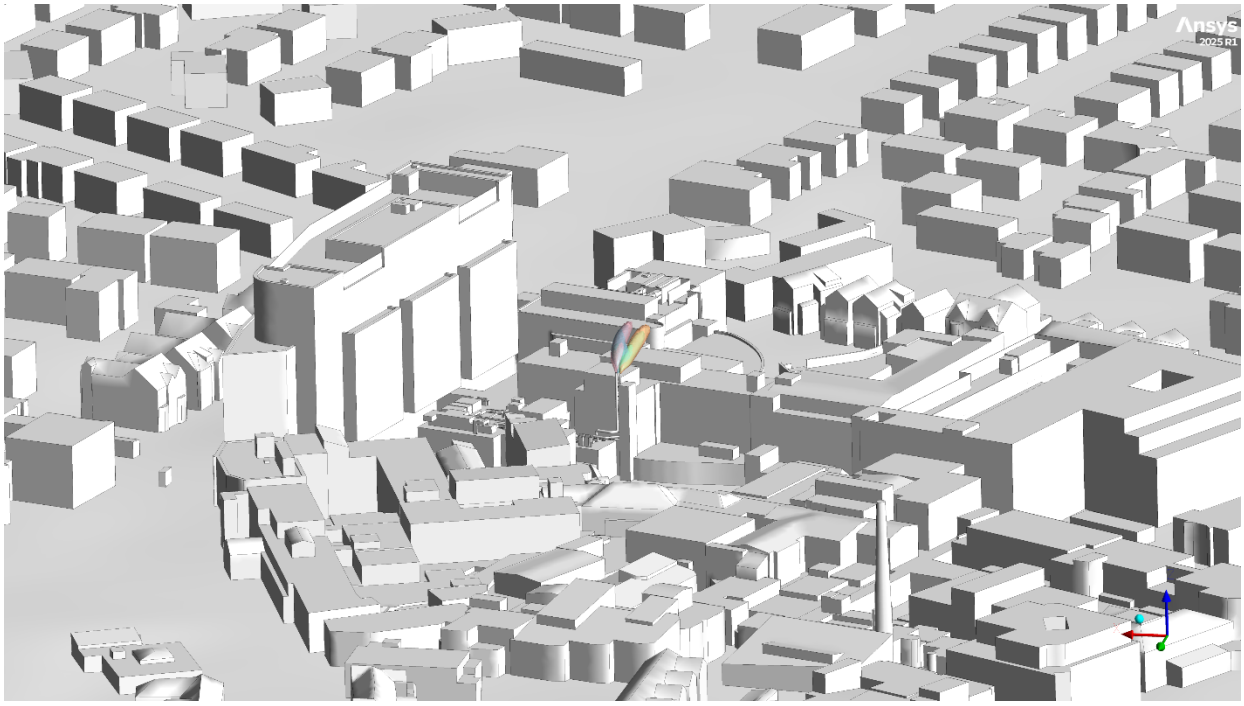


Figure 9 - The plume for high-speed winds approaching from 0°.

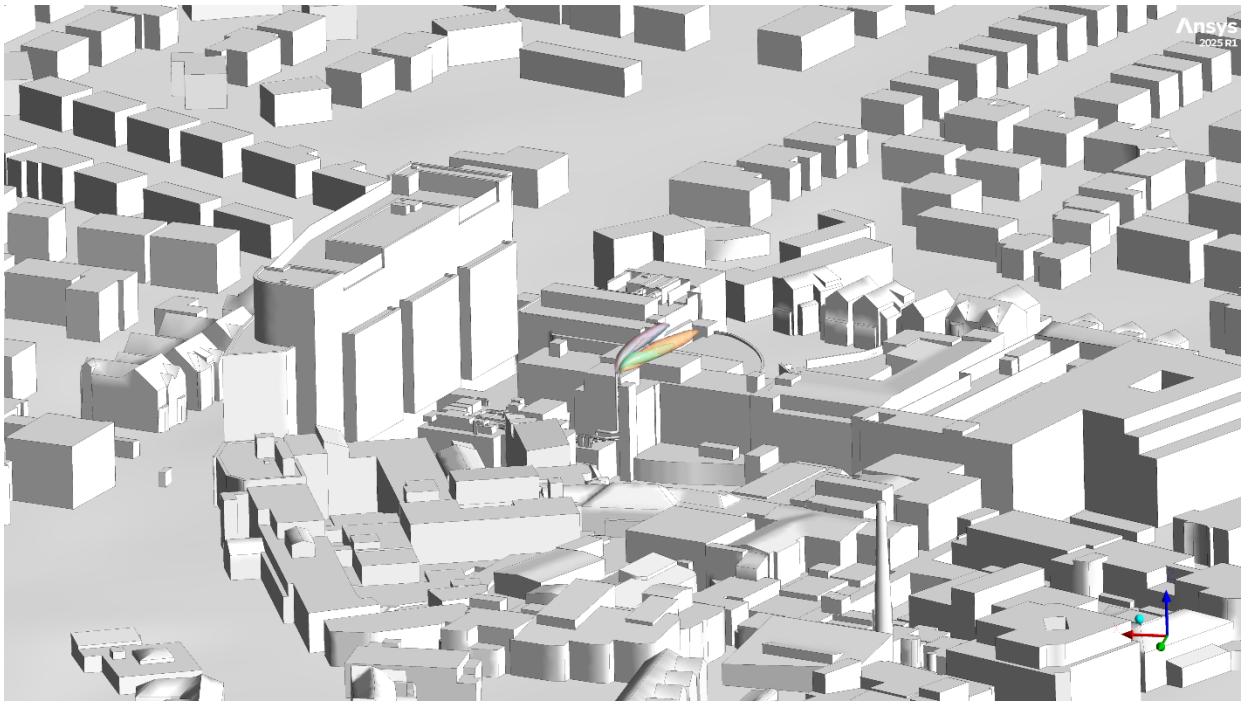


Figure 10 - The plume for high-speed winds approaching from 30°.

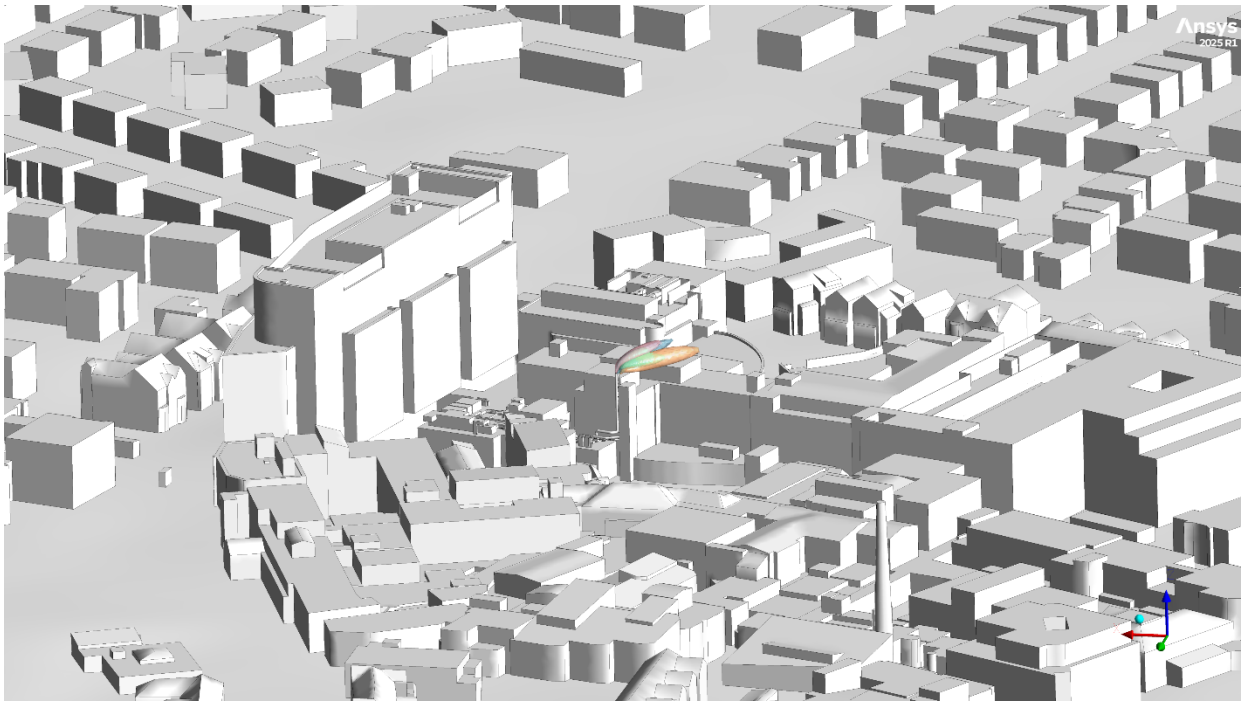


Figure 11 - The plume for high-speed winds approaching from 60°.



Figure 12 - The plume for high-speed winds approaching from 90°.

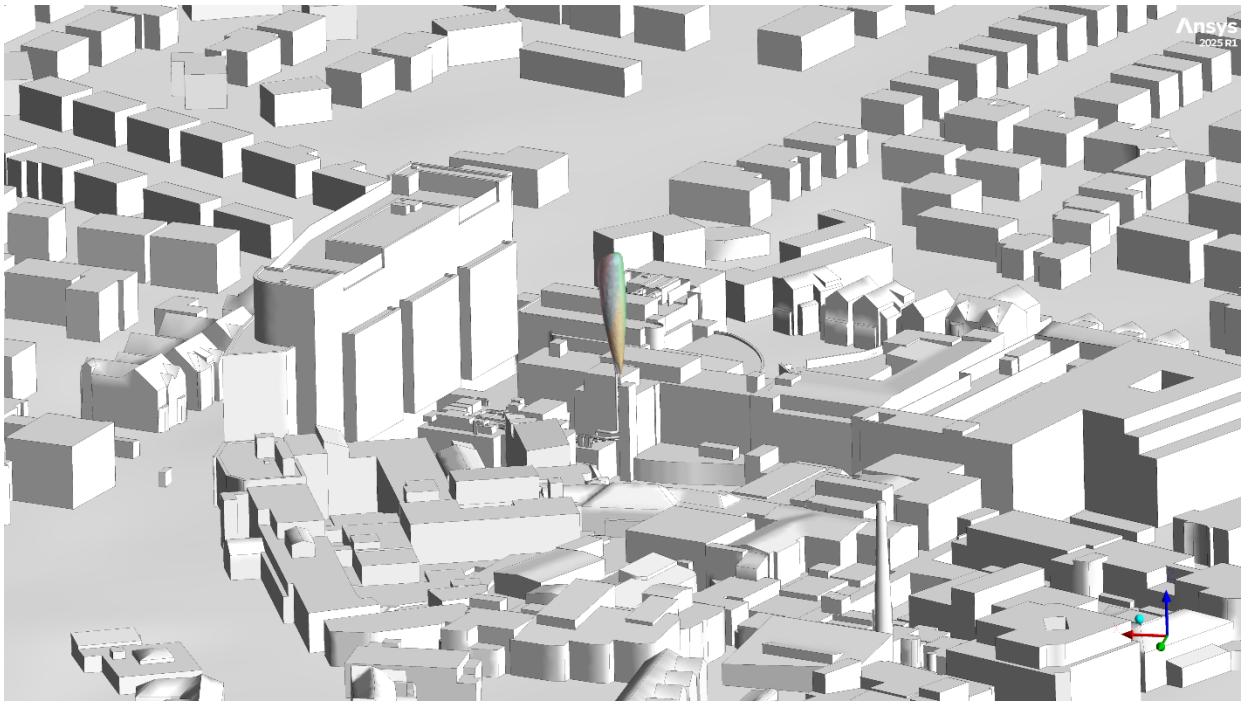


Figure 13 - The plume for high-speed winds approaching from 120°.

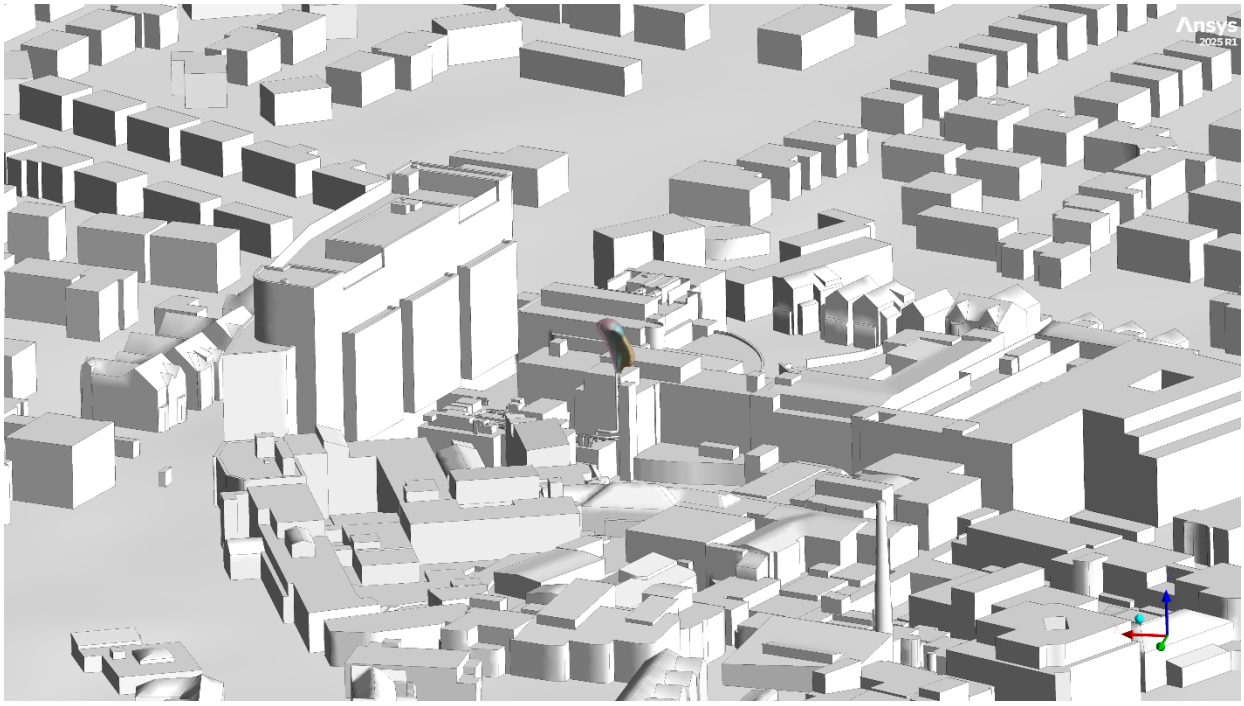


Figure 14 - The plume for high-speed winds approaching from 150°.

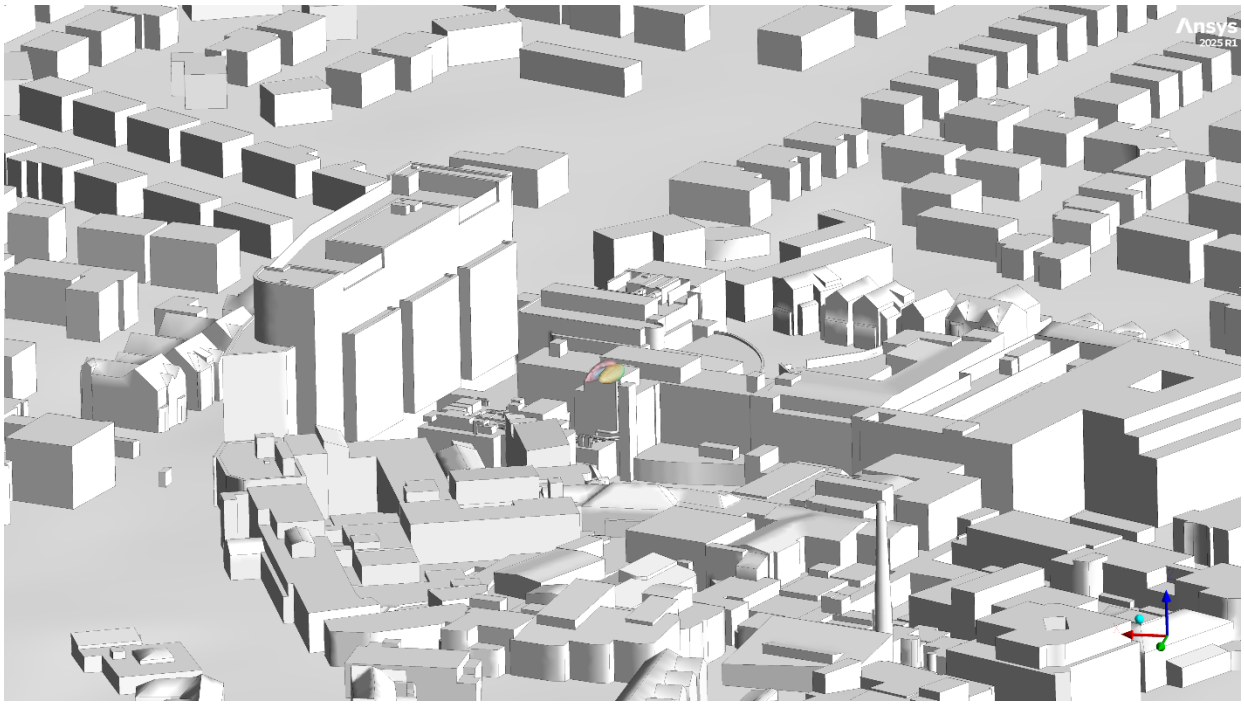


Figure 15 - The plume for high-speed winds approaching from 180°.

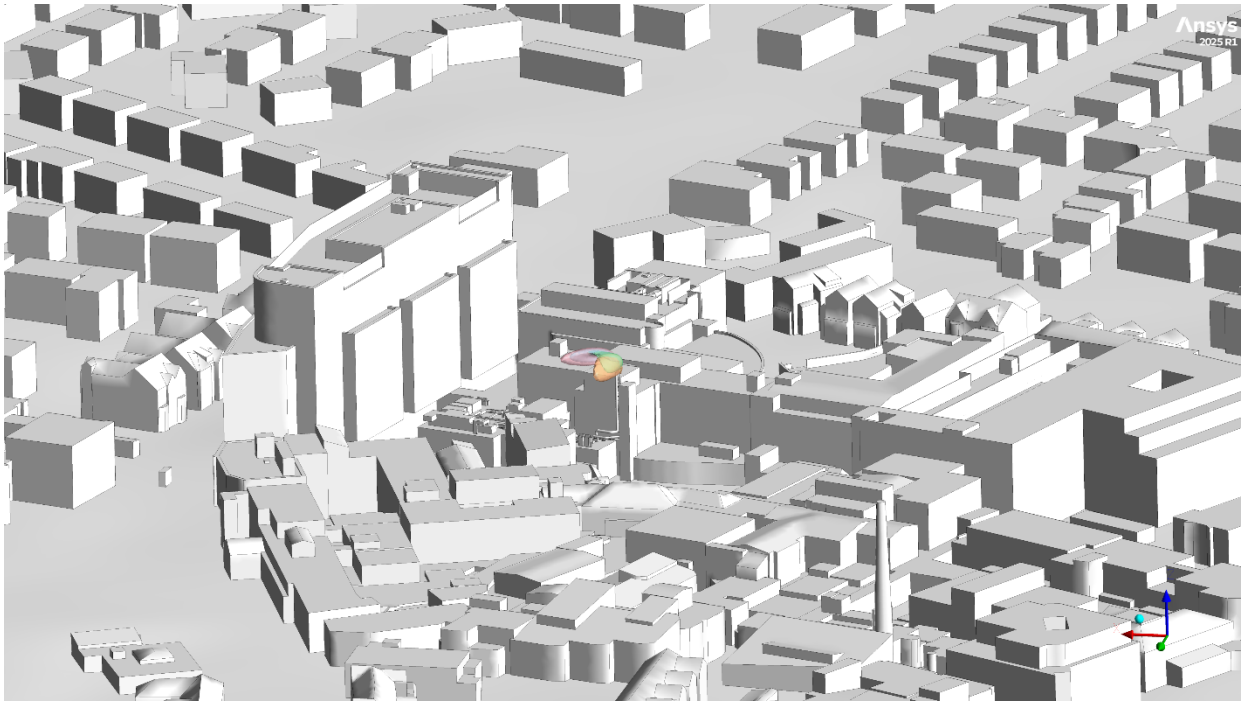


Figure 16 - The plume for high-speed winds approaching from 210°.

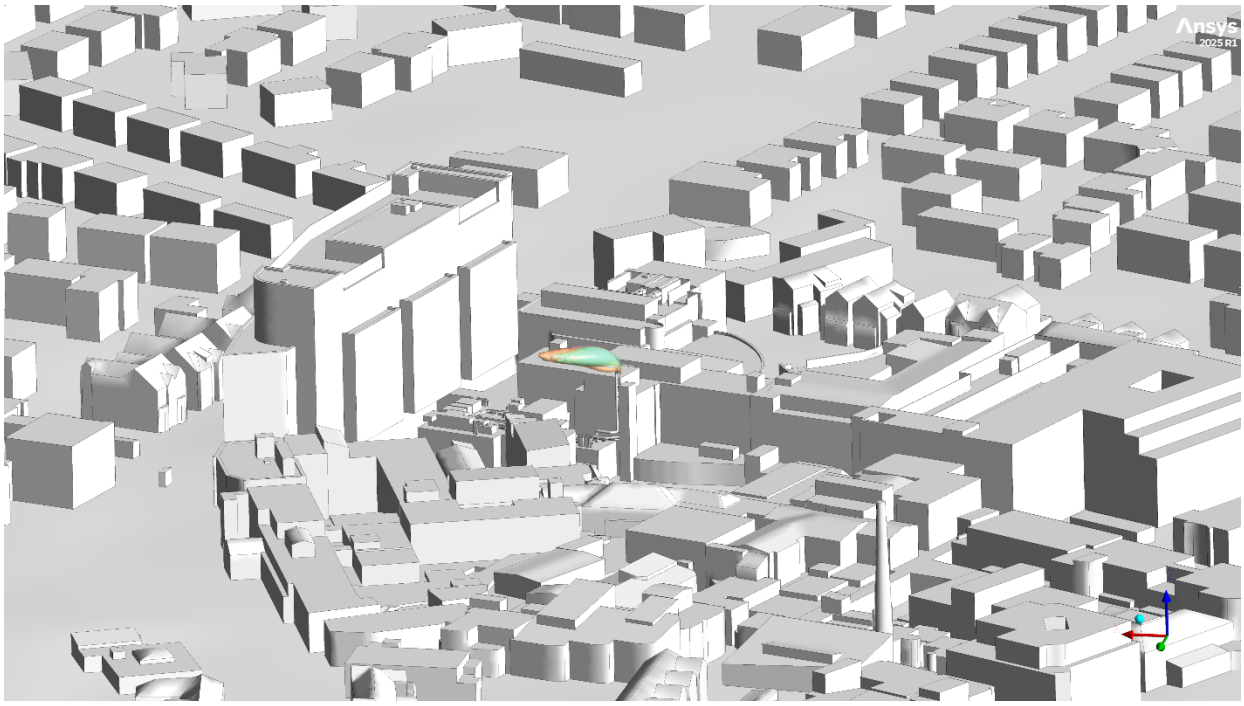


Figure 17 - The plume for high-speed winds approaching from 240°.

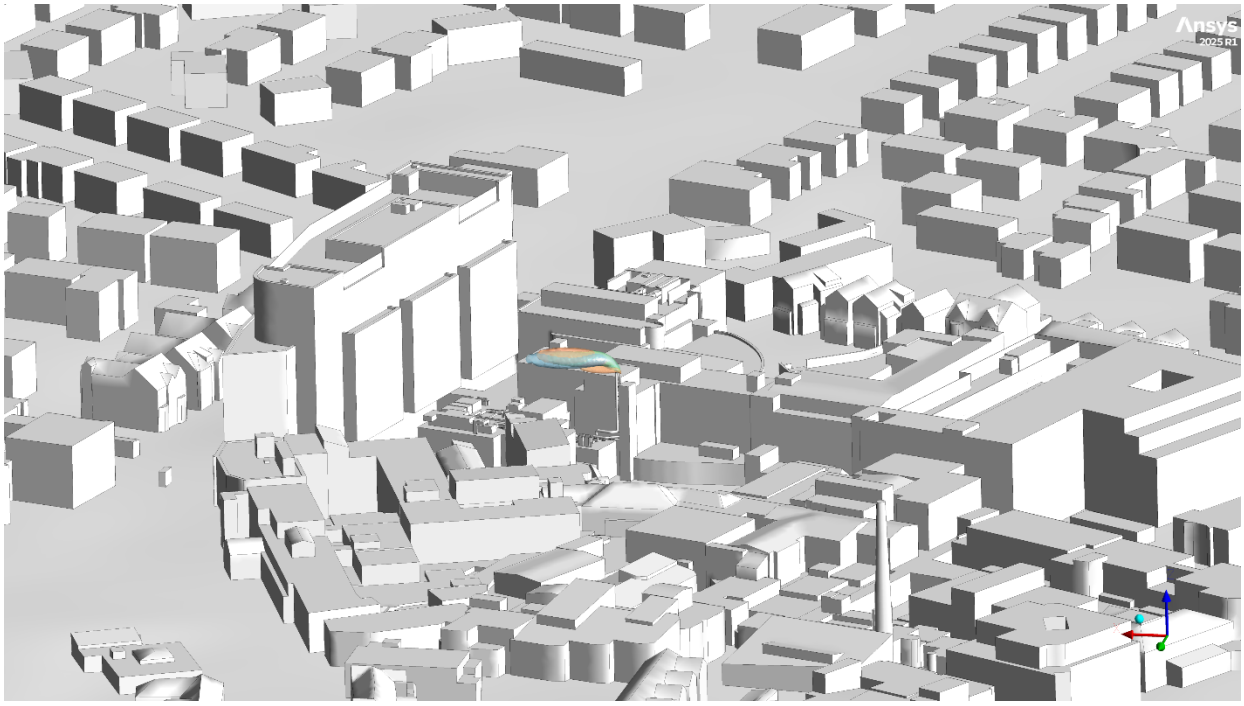


Figure 18 - The plume for high-speed winds approaching from 270°.

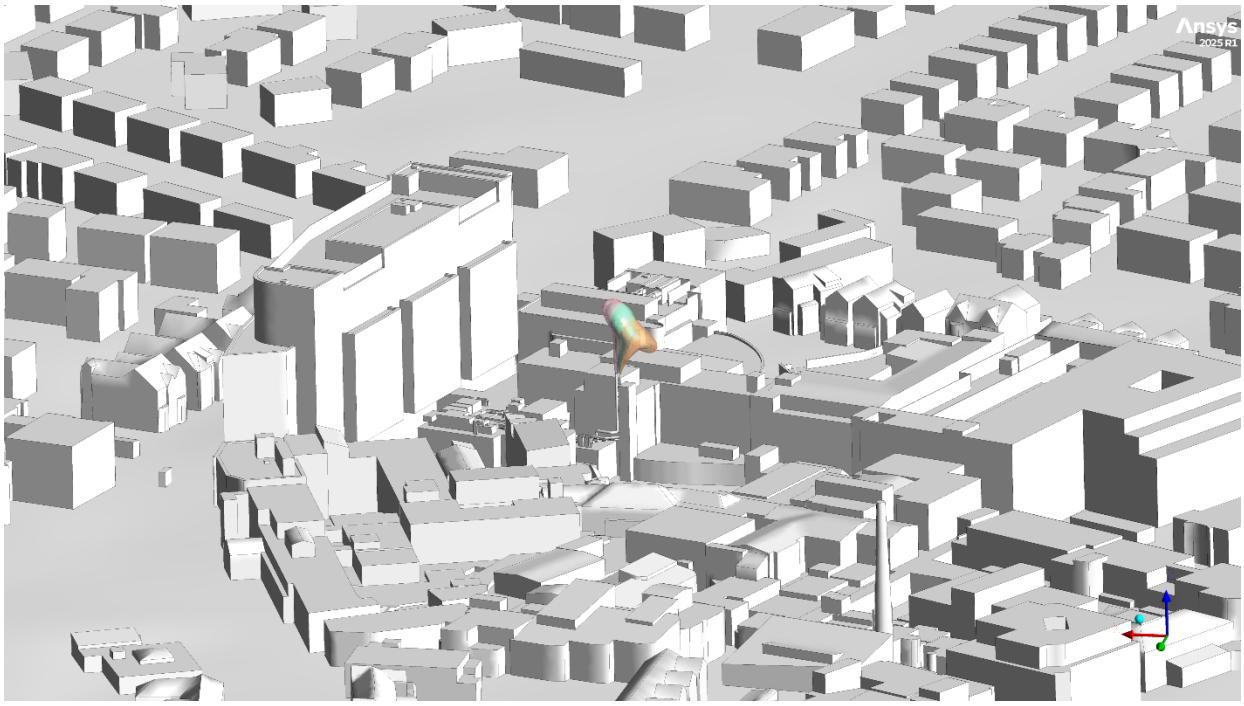


Figure 19 - The plume for high-speed winds approaching from 300°.

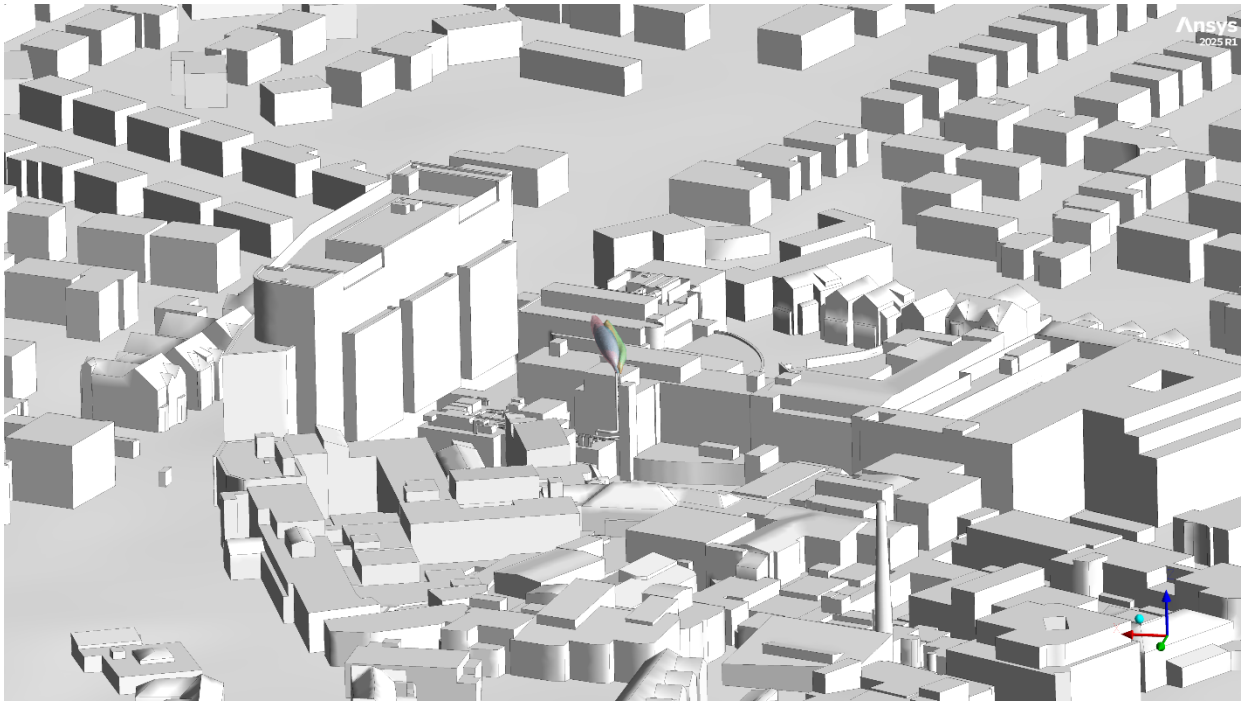


Figure 20 - The plume for high-speed winds approaching from 330°.

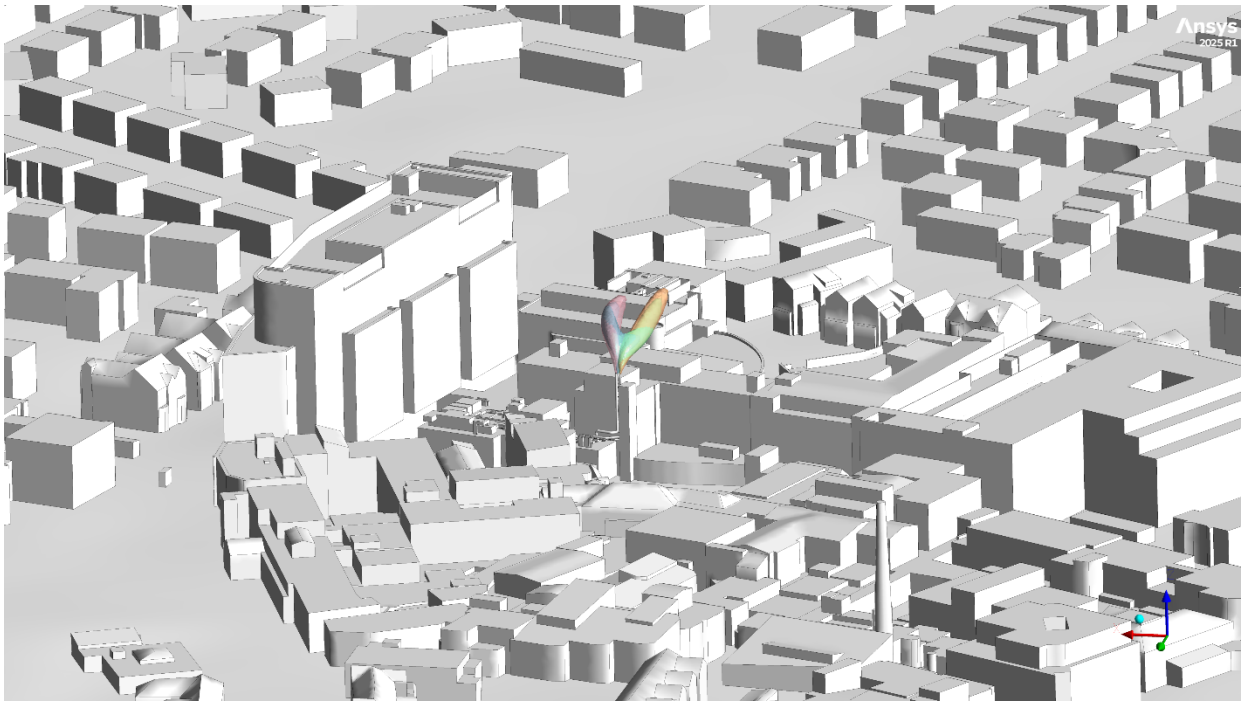


Figure 21 - The plume for low-speed winds approaching from 0°.

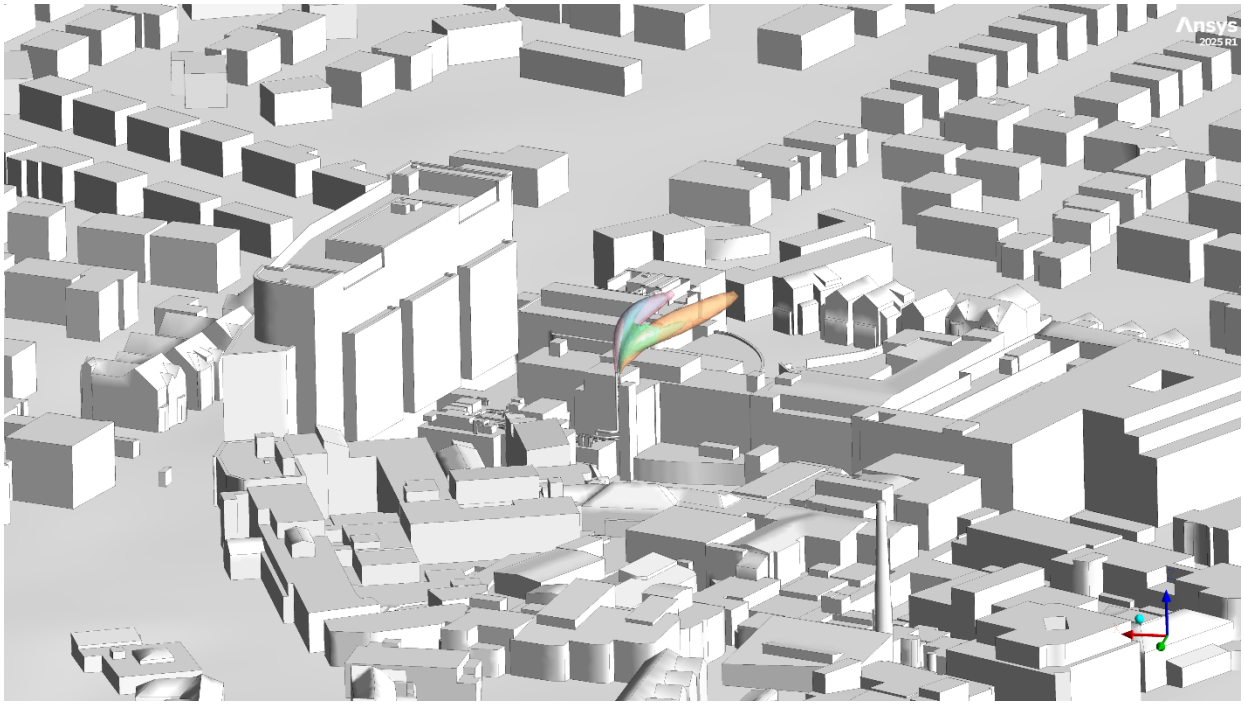


Figure 22 - The plume for low-speed winds approaching from 30°.

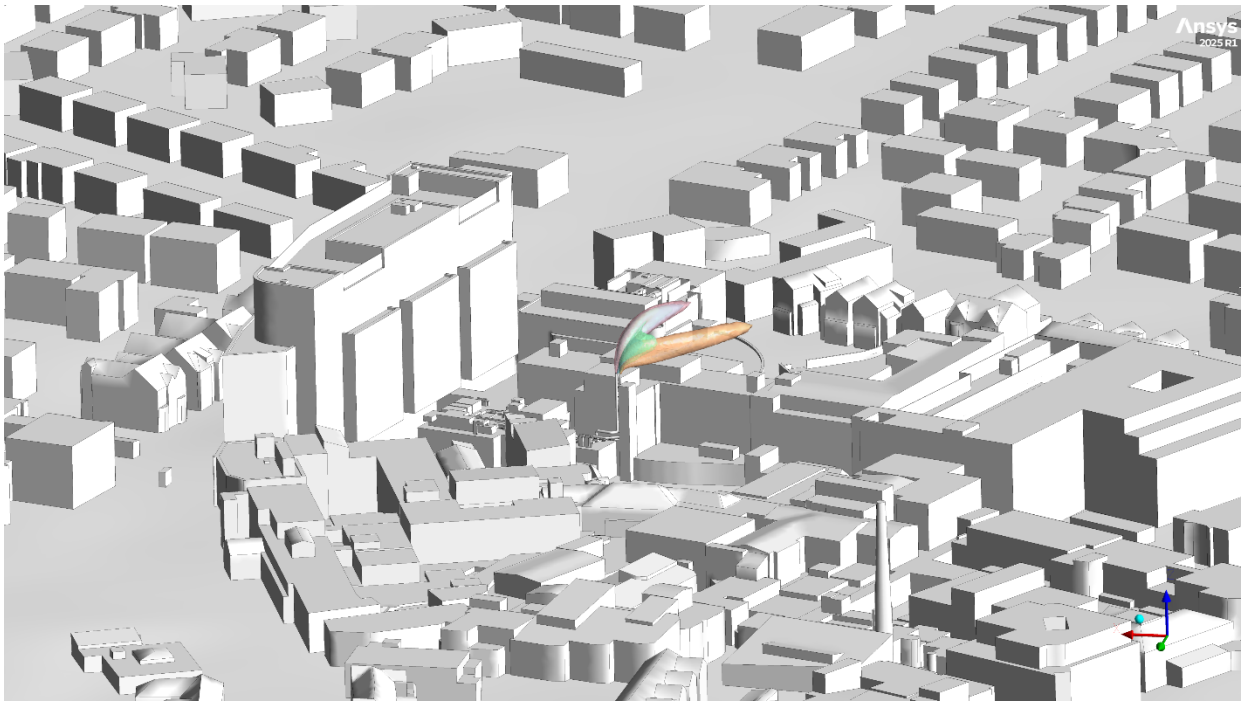


Figure 23 - The plume for low-speed winds approaching from 60°.

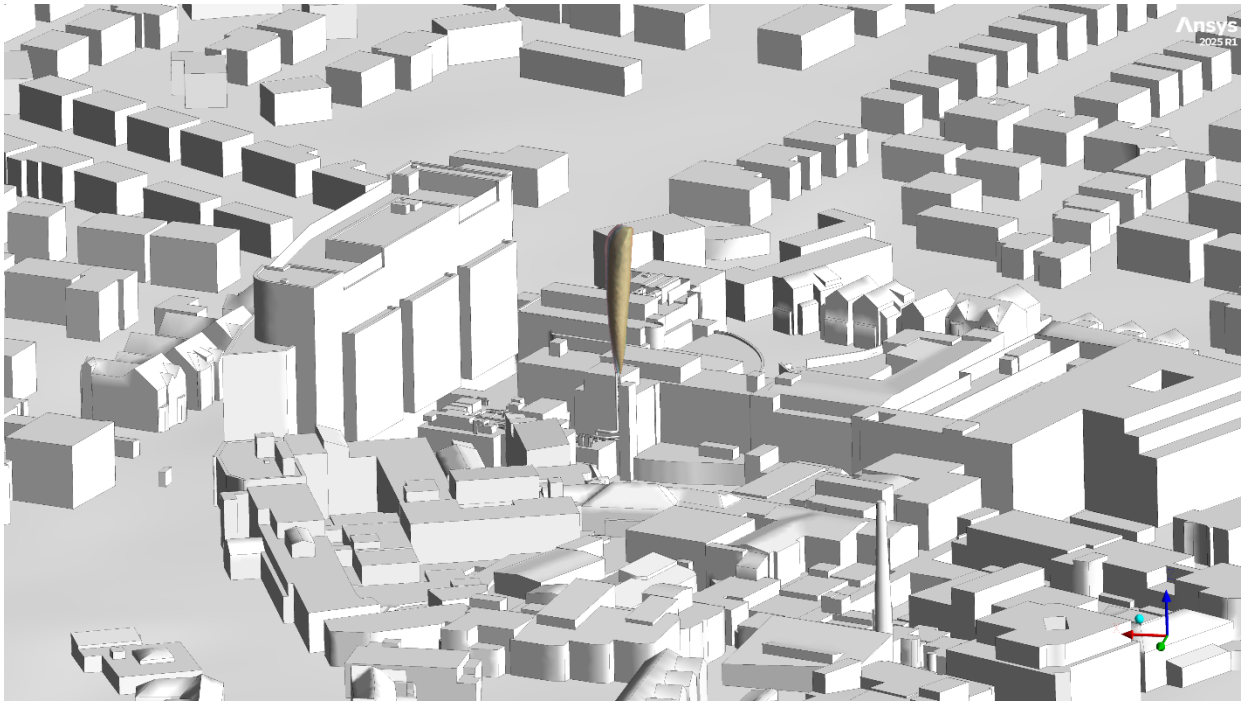


Figure 24 - The plume for low-speed winds approaching from 90°.



Figure 25 - The plume for low-speed winds approaching from 120°.

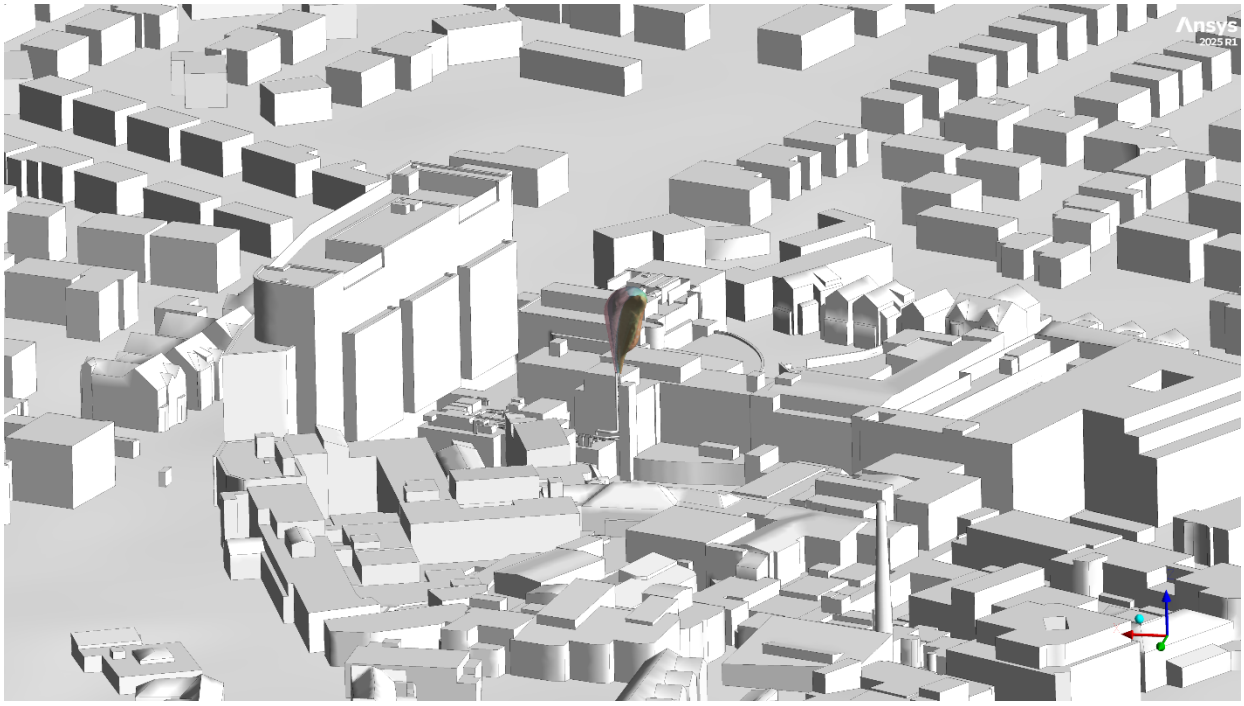


Figure 26 - The plume for low-speed winds approaching from 150°.

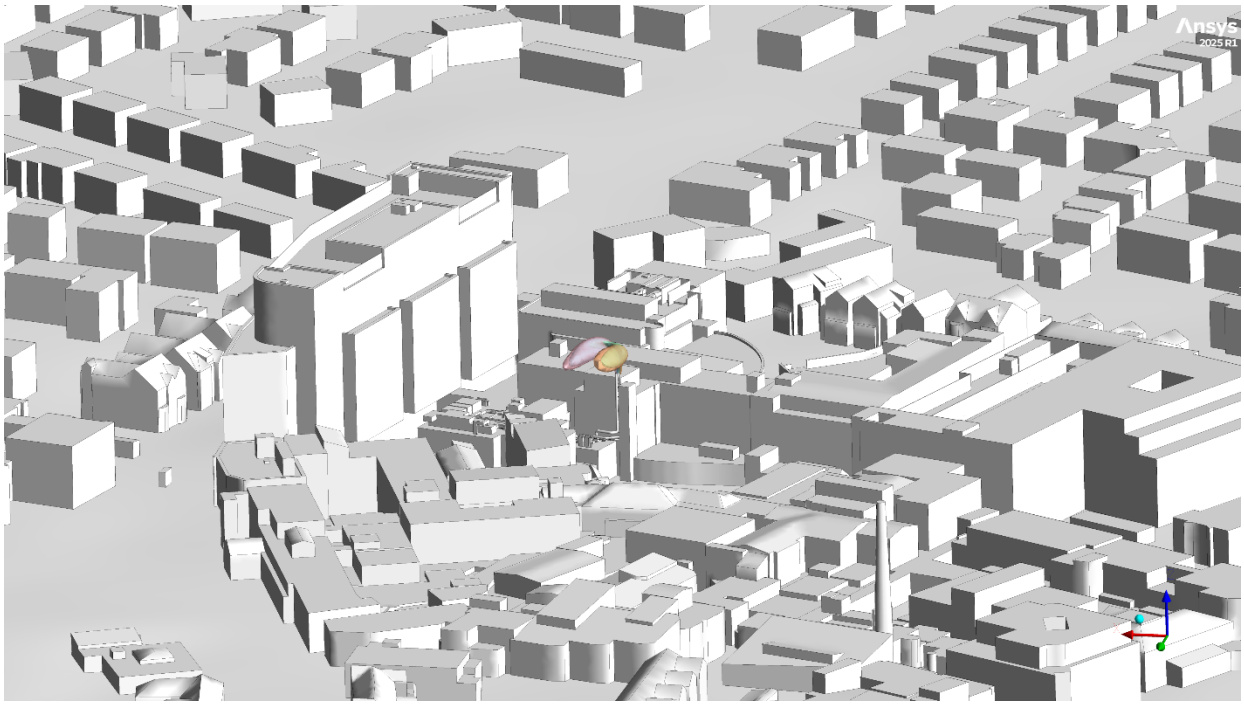


Figure 27 - The plume for low-speed winds approaching from 180°.

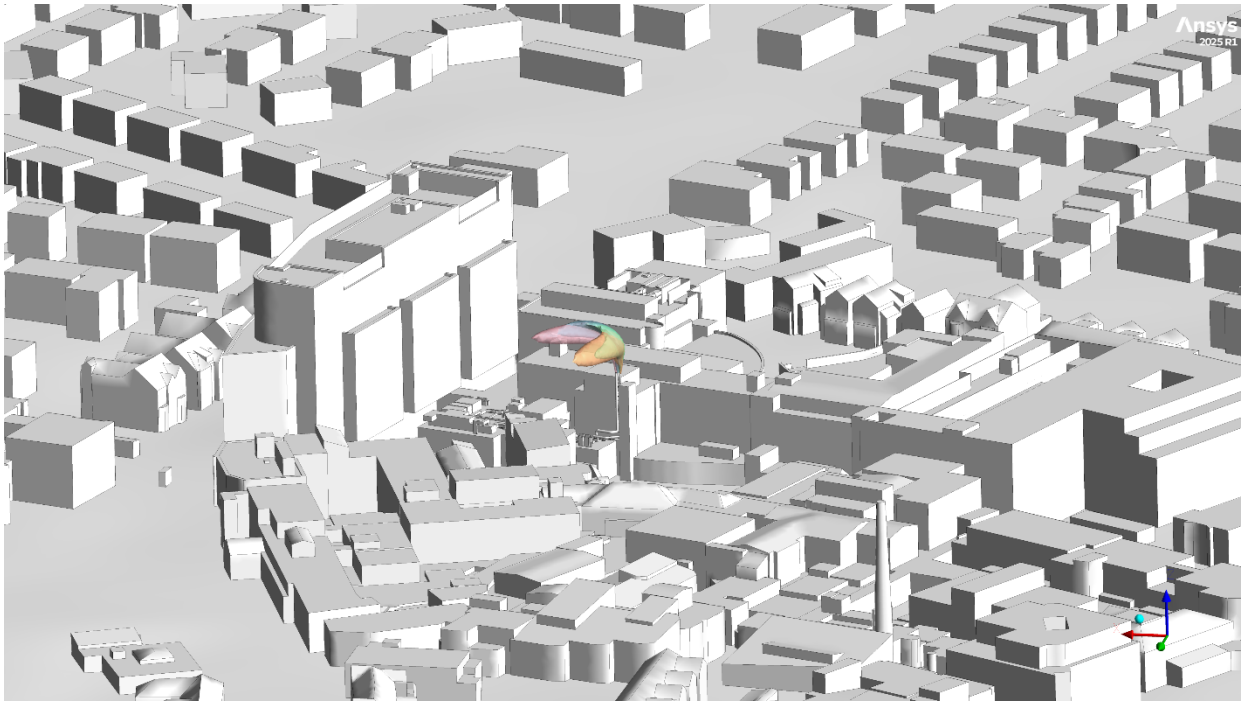


Figure 28 - The plume for low-speed winds approaching from 210°.

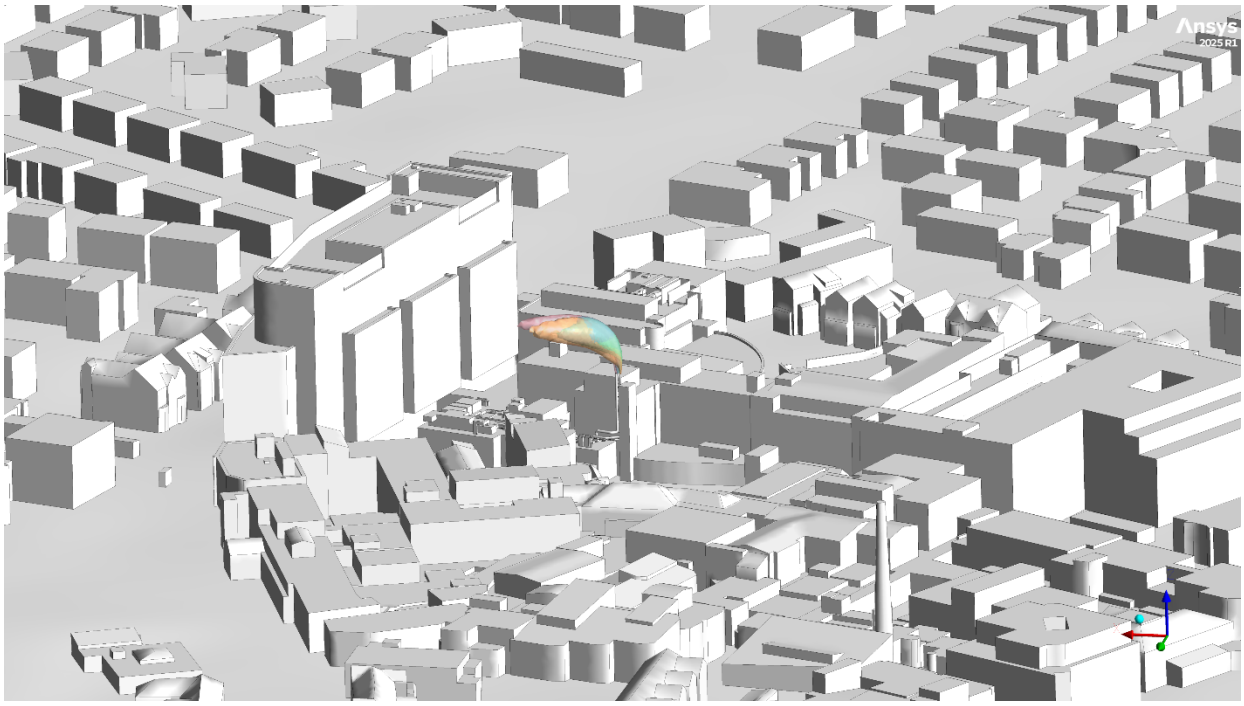


Figure 29 - The plume for low-speed winds approaching from 240º.

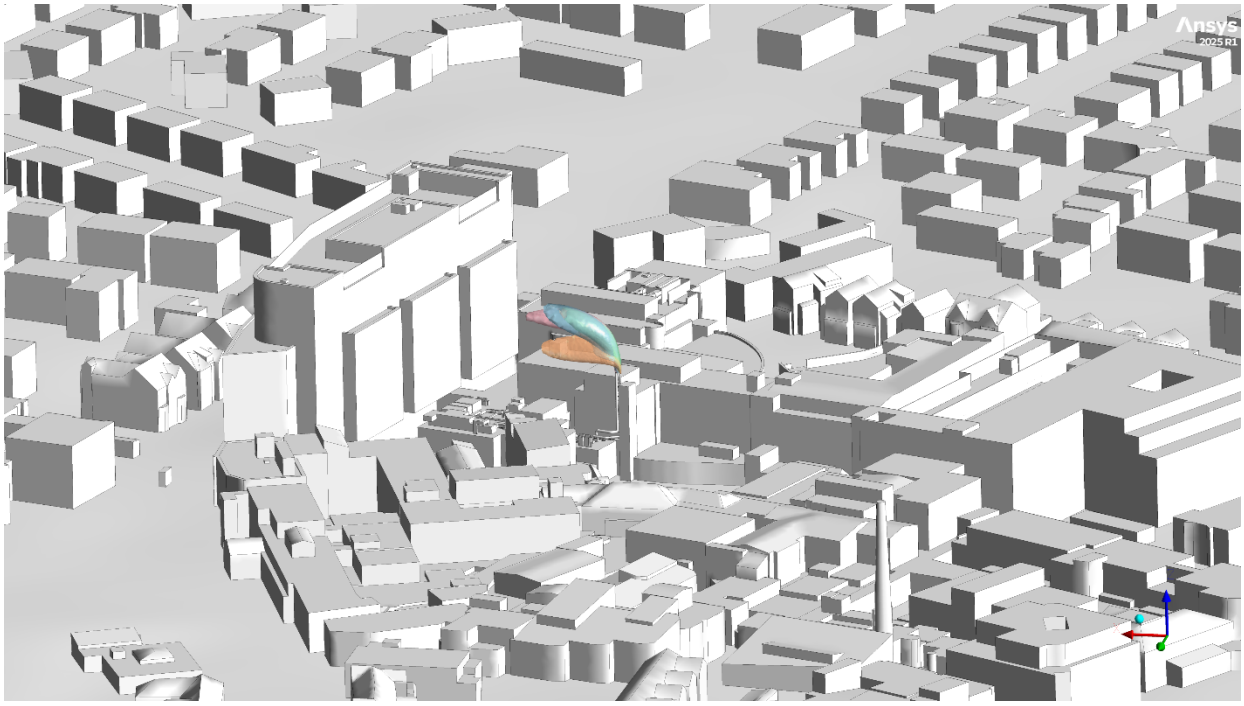


Figure 30 - The plume for low-speed winds approaching from 270º.

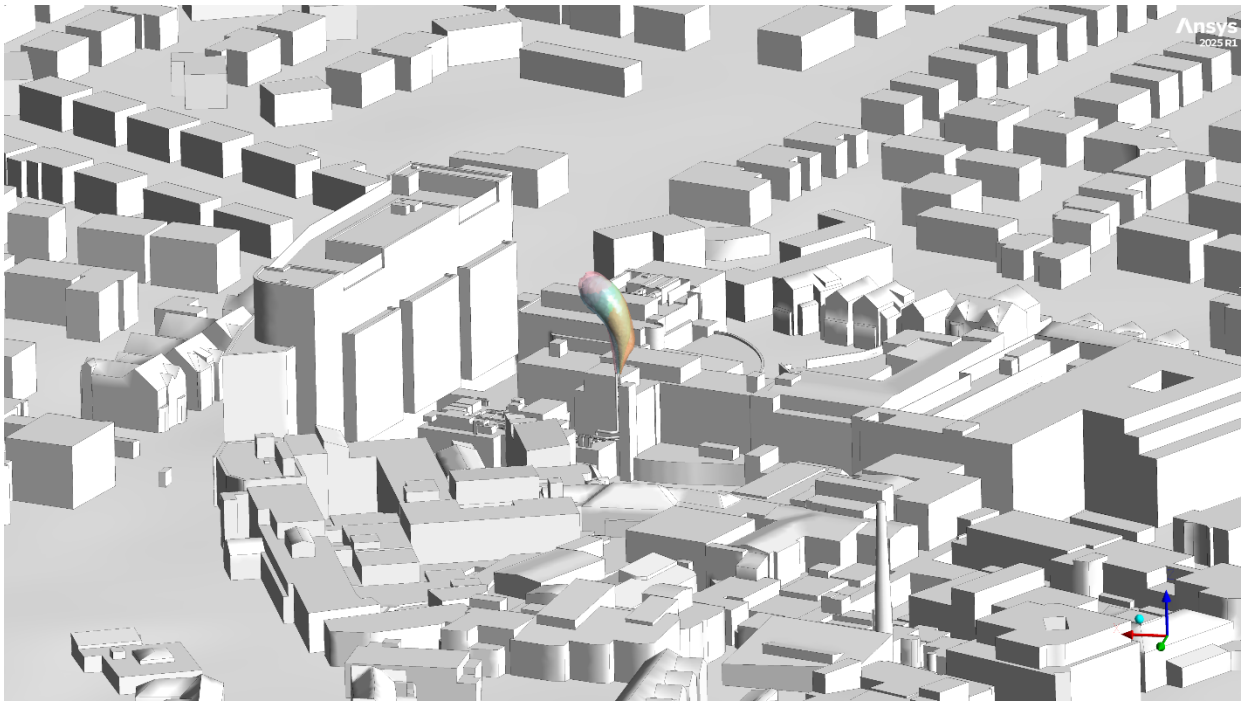


Figure 31 - The plume for low-speed winds approaching from 300°.

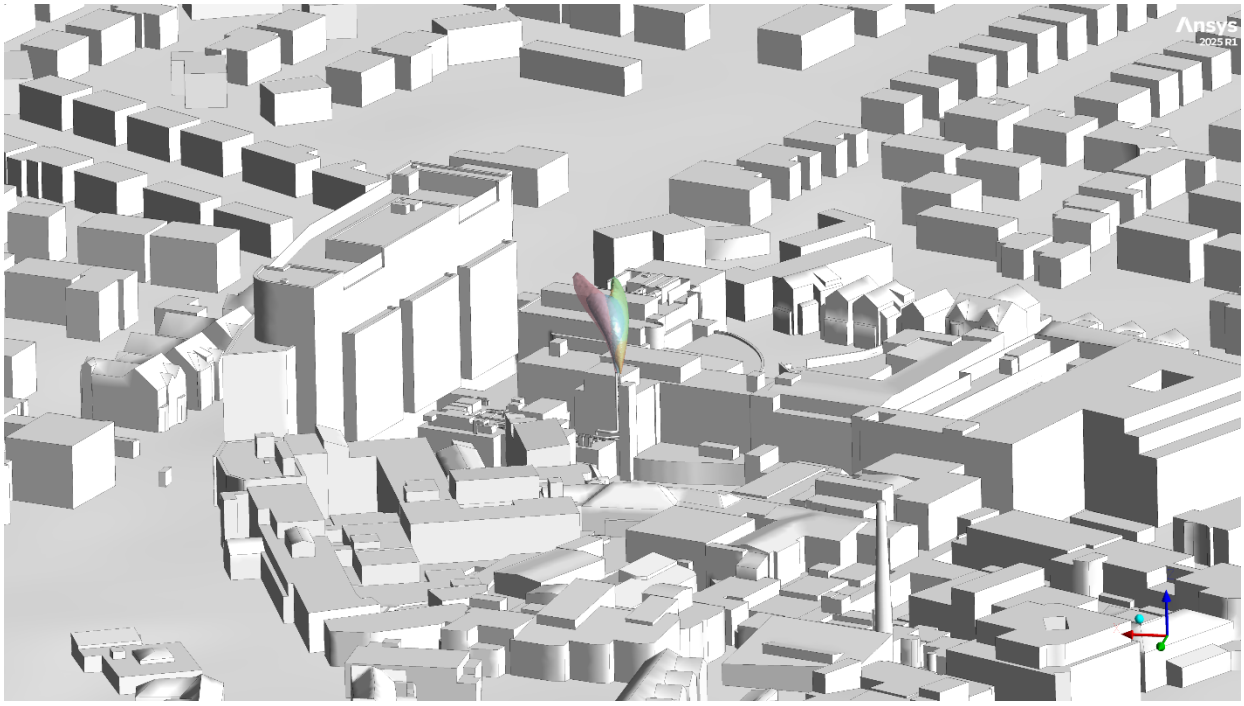


Figure 32 - The plume for low-speed winds approaching from 330°.

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RWDI. (n.d.). A Dilution Criterion for Laboratory Fume Hood Exhaust Stacks. *Tech Notes*(17).

HOARE LEA

TOM HORSFIELD
SENIOR ASSOCIATE

+44 20 8585 9525
tomhorsfield@hoarelea.com

HOARELEA.COM

Western Transit Shed
12-13 Stable Street
London
N1C 4AB
England

