STATIC VS DYNAMIC ODOUR CONTROL: A BETTER AND MORE COST EFFECTIVE SOLUTION

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ABSTRACT

In this case study, the Hampton Roads Sanitation District in Virginia Beach, Virginia, USA operates a conventional activated sludge biological reactor with secondary clarifiers. This process is not preceded by a primary clarifier. The air emissions from the process have been associated with odour complaints downwind of the facility. Conventional treatment options would be to cover and treat the activated sludge tank and treat the exhaust in an odour control system or to add chemicals to the influent flow to react with the target odorant to reduce the odour emissions.

Static Odour Control

The classical approach to evaluating odour control alternative is where the odour source is sampled during a single campaign and the olfactometric results are used to define a single steady state characterisation of the source. Odour dispersion modelling is done using historical meteorological data. The result is a probabilistic odour impact assessment based on the pairing of "worst case" emissions with "worst case" dispersion. Compliance is based on some "acceptable" level of exceedance expressed as a percentile of number of hours. Static modelling may be the only option for new or proposed odour emission sources, as the odour source does not exist and cannot be monitored.

In such an approach, chemical addition might appear to be too costly as the continued use of chemicals on an annual basis would begin to offset the low capital investment. This might lead to a conclusion that a cover, capture and treat system might be more cost effective and better achieve the odour reduction goals defined by the static odour assessment approach.

Dynamic Odour Control

An alternative approach is to look at the emissions and impacts dynamically. Dynamic odour control assessment is a pairing in real time of monitored odour emissions and measured on-site meteorology. The pairing of emissions and dispersion are not independent parameters, as in the case above. The critical aspect is that odour control measures can be applied dynamically, based on predicted exposures and not limited to controlling the worst case condition. Dynamic modelling is the preferred option where the odour emission source is large and not easily contained using conventional odour control technology. In this case, chemical use is highly cost effective since applied dosages can now be applied to the actual level of control required, reducing long term chemical usage.

This case study will examine the operational data for 2013 to assess whether dynamic odour assessment methods resulted in more cost effective odour control strategies when compared to classical odour assessment methodologies.

Key Words

odour modelling, dynamic odour control, odour impact assessment, olfactory assessment

1. INTRODUCTION

The Chesapeake-Elizabeth wastewater treatment plant (CETP) in Virginia Beach, Virginia, USA is one of several plants operated by the Hampton Road Sanitation District (HRSD). The CETP treats 24 millions of gallons per day (MGD) or 91 million litres per day (MLD) of wastewater using a physical-chemical- biological secondary treatment process. The Phase I improvements to the CETP included adding odour control to the preliminary treatment facility which included a portion of the aeration basins. However, the uncovered portion of the activated sludge biological reactor continued to be a source of on-site and off-site odours. Further treatment of the emissions from the aeration basins would be required. Figure 1 shows the CETP site with the open activated sludge biological reactors highlighted in red.

Figure 1 – Aerial View of the CETP with the Activated Sludge Biological Reactors in Red

2. DISPERSION MODELLING

Dispersion modelling defines the relationship between the emission source and the receptor. While control measures may be applied to the emission source, compliance with odour nuisance standards depend on whether the odour concentrations at the receptor have been adequately reduced with respect to their Frequency, Intensity, Duration, Offensiveness and Receptor or location, (FIDOR or FIDOL). The dispersion model AERMOD Version 14134 was used for both the static and dynamic modelling analyses.

2.1 Static Modelling

Static modelling is where the odour source is sampled during a single campaign and the olfactometric results are used to define a single steady state characterisation of the source. Modelling is done using historical data (1 to 5 years). The result is a probabilistic odour impact assessment based on the pairing of "worst case" emissions with "worst case" dispersion. Compliance is based on some "acceptable" level of exceedance expressed as a percentile of number of hours. Static modelling is the only option for new or proposed odour emission sources, as the odour source does not exist and cannot be monitored. Static modelling is also called odour dispersion modelling assessment, or odour impact study.

2.2 Dynamic Modelling

Dynamic modelling is a pairing in real time of monitored odour emissions and measured meteorology. The pairing of emissions and dispersion are not independent parameters as in the case above. The critical aspect of this is that odour control measures can be applied dynamically, based on predicted exposures and not limited to controlling the worst case condition. Dynamic modelling is the preferred option where the odour emission source is large and not easily contained using conventional odour control technology.

3. SOURCE CHARACTERISTICS

The current approach of Olfactometry-Dispersion Modelling uses the odour concentrations (dilution ratios) to define the odour emission rate. The physical characteristics of the source are defined as point, area or volume sources, depending on the nature of the release. Only the open surfaces of the aeration basin are modelled in this case study.

3.1 Odour Emission Rates

Odour concentration as defined by Olfactometry is a volume ratio and therefore dimensionless. It is given the pseudo units of "odour units per cubic meter" or OU/m^3. Odour concentrations may also be described as a "dilution to threshold" ratio and be given the pseudo units of D/T. To calculate the odour emission rate for dispersion modelling analyses, the odour concentration is multiplied by the exhaust air flow rate, expressed in cubic meters per second, m^3/s. The result is an odour emission rate expressed as "odour units per second" or OU/s that is compatible with dispersion modelling.

The aeration basins are defined as an area source with a rectangular surface. Air flux through the surface is determined by the aeration rate through the fine bubble diffusers in the basin. The odour emission flux rate is defined as the odour concentrations times the aeration divided by the surface area of the open basin. This gives units of odour units per square meter per second (OU/m2/s).

In Static Modelling analyses, the odour emission rate would be limited to the odour concentration obtained during the sampling campaign and Olfactometry analysis. The sampling procedure would be designed to characterise worst case conditions. For this case study, the 98 percentile emission rate as determined from the continuous odour emission rates measured by the electronic nose (eNose). In Dynamic Modelling analyses, the odour emission rate is directly measured continuously with electronic noses and source odour emission rate is updated live for each model iteration to account for fluctuation caused by unsteady state processes or variations caused by external factors such as weather conditions. For this case study, the hourly average emission rates were calculated from the continuous odour emission rates measured by the electronic nose.

3.2 Source Parameters

While the odour emission rate is directly proportional to the odour impact, the source characteristics at the point of release can greatly influence how effectively the odours will disperse. The aeration basin is defined as an area source. It is characterised as an open area where emissions are released actively as a result of the aeration air flow rate. It is describe by the horizontal length and width of the surface area, and effective release height.

For Static Modelling analyses, the source parameters are fixed to the values that represent the worst case release scenario observed during the sampling analysis, In a Dynamic Modelling analysis, the exhaust gas temperature and exit velocity can be adjusted for each model iteration. There are fewer variables to adjust for area or volume source releases.

3.3 Building Cavity and Wake Effects

The airflow around nearby buildings and structures can greatly influence the dispersion from point sources. Depending on the wind speed, zones of recirculating air or areas of downward moving air can increase impacts from point source, compared to point sources not affected by a nearby structure. To account for this effect, the dimensions (length width and height) of nearby structures are entered into a modelling pre-processor algorithm along with the relative distance of the building to the point source. The output of this pre-processor is an effective building profile which potentially affects plume dispersion in each of the 36 radial directions. This building profile array is entered into the dispersion model along with the other source parameters.

While this algorithm does not apply directly to area or volume sources, the modeller may adjust the effective release height or initial dispersion dimensions of the source to account for the influence of a nearby building or structure. Buildings remain stationary and are not affected by static or dynamic modelling approaches.

4. LAND USE AND METEOROLOGICAL DATA

The structure of the surface boundary layer and turbulence intensity are directly related to the land use characteristics surrounding the plant site. The land use characteristics can be directly related to three parameters critical in defining turbulence intensity, surface roughness, albedo and Bowen ratio. Once the land use characteristics have been defined for a project site, they usually do not change for either the static or dynamic modelling analysis. Although, dynamic modelling could account of some changes in albedo or Bowen ratio depending on the quantity and type of precipitation.

Meteorological data used in a dispersion modelling analysis must be representative of weather conditions at the plant site. It defines the direction of the plume's travel, ambient turbulence intensities and depth of the surface mixing layer. It is critical to defining the environment between the source where odours are released and receptor where compliance with odour nuisance standards is determined

4.1 Land Use Parameters

Surface roughness is directly proportional to the physical size of structures and vegetation. It defines the friction velocity in the surface boundary layer and the shape of the vertical wind speed profile. The surface roughness can change with the seasons if the surrounding land use is vegetated (i.e., farm land or forested). Surface roughness may also change with wind sector if an urban or suburban land use exists on one side of the plant site and field or forest exists on the other side.

Albedo is the fraction of incoming solar radiation that is reflected back to the atmosphere. The albedo is small for dark surfaces such as roads and buildings and large for bright surfaces like snow or sand. It is used to define the vertical temperature profile and the depth of the convective boundary layer.

The Bowen ratio is related to the amount of moisture in the surface soils. Surface moisture can contribute to the release of latent heat and enhance mixing in the convective boundary layer.

4.2 Surface Observations

In a Static Modelling analysis, historical meteorological data are taken from the nearest airport. Surface data includes, ambient temperature, wind speed, wind direction, and cloud cover. Barometric pressure, relative humidity and precipitation may also be collected, but are not used directly in modelling analysis.

Figure 2 shows a wind rose from the Norfolk International Airport for 2013 with the wind rose showing the direction from which the wind is blowing. The critical issue here is that the meteorological data becomes an independent variable from the odour emissions.

Figure 3 shows a wind rose from the on-site station at the CETP for 2013. At first glance these wind roses look similar, as the Norfolk International Airport is not far from the treatment plant site. However there are some very important differences. The wind speeds at the CETP are lower than those at the Norfolk International Airport. The average wind speeds are 2.68 m/s and 4.23 m/s, respectively. The frequency of calm wind conditions is also greater at the CETP. Thus, odours released near the surface are less likely to disperse using the on-site meteorological data than the airport data.

There are differences in wind direction also. The winds from the north, south and south-southwest are less frequent in the on-site data than the Norfolk airport data. Winds from the southeast are more frequent in the on-site data than the Norfolk airport data.

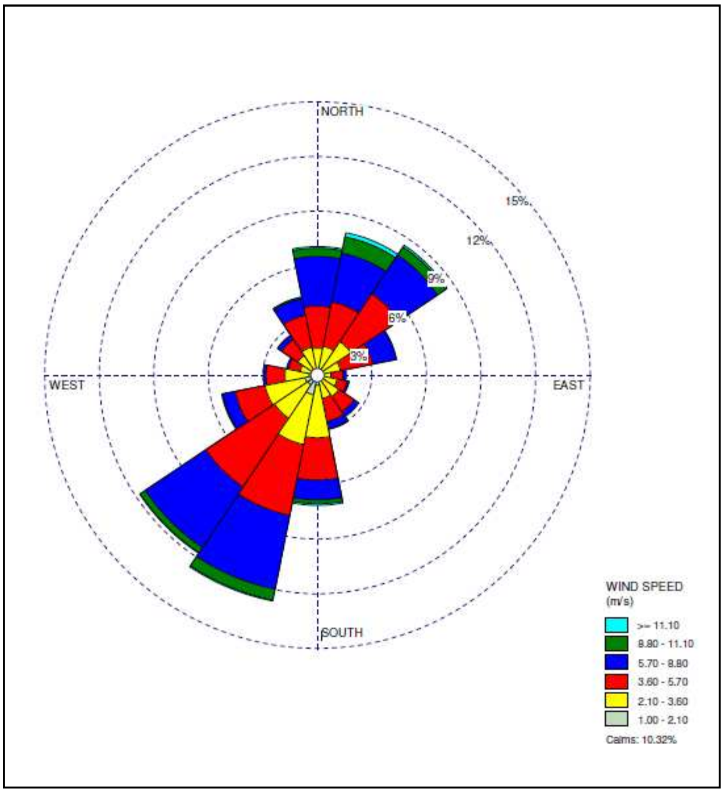

Figure 2 – Wind Rose for Norfolk International Airport for 2013(blowing from)

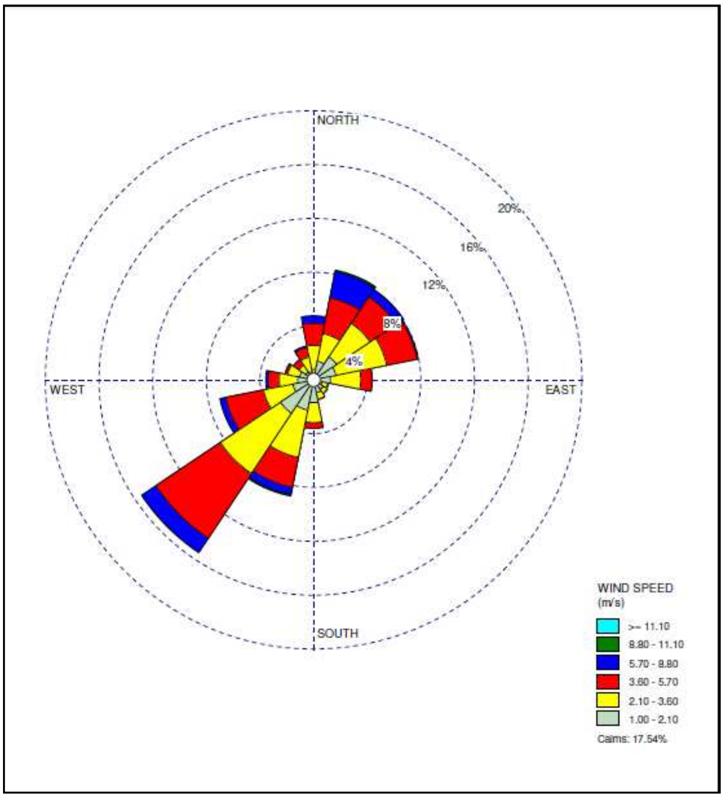

Figure 3 – Wind Rose of the On-site Station at CETP for 2013 (blowing from)

4.3 Upper Air Data

In a Static Modelling analysis, the depth of the mixing layer is determined by radiosonde data collected by balloons that are sent upward through the depth of the atmosphere. The number of stations that perform these upper air soundings is limited and in many parts of the world the timing of the releases are not helpful in determining the depth of the mid-day convective boundary layer or the early morning stable boundary layer.

In Dynamic Modelling, measures to determine the depth of the surface mixing layer are not taken. The modelling analysis assumes an unlimited surface mixing layer. Since odour emission sources are non-buoyant, often released close to the ground and maximum predicted impacts are typically on or near the plant property boundary, this assumption does not adversely affect the results. If a hot exhaust was released from a tall stack, the lack of a cap on the surface mixing layer would be a more significant concern.

5. CONTROL ALTERNATIVES

The conventional approach for controlling odours from the aeration basin would be to cover the basins and duct the air to an odour control system. In the summer of 2009, HRSD considered this approach but had some funding constraints and sought an alternative solution. By October of 2009, HRSD decided to apply a combination of chemicals, iron salts and peroxide, in a process defined as the Peroxide Regenerated Iron Sulphide Control (PRI-SC©). Initially, the OdoWatch odour monitoring system was installed only to document the potential reduction in emissions. Later, the results of the OdoWatch system were used to optimise the chemical dosing system resulting in a 10 percent reduction in the peroxide chemical use whilst still achieving maximum downwind odour plume control.

In this case study, there are three potential odour control strategies:

- Cover, capture and treat the exhaust air from the aeration basin.
- Chemically treat the influent wastewater with PRI-SC© system to mitigate the worst-case impact as defined by static modelling.
- Chemically treat the influent wastewater with the PRI-SC© system using the dynamic modelling capabilities of the OdoWatch system to modulate chemical dosing requirements.

6. CONCLUSIONS

The differences in static verses dynamic modelling are summarised in Table 1.

Table 1 – Summary of Parameters Used in Static and Dynamic Modelling Analyses

	Static Modelling	Dynamic Modelling
Weather data		
Period	Historical 1 to 5 years	Real-time and historical data
Frequency	1 hour average	As low as 4 minute intervals
Representatively	Regional scale	Local scale next to the source
Location	Nearest airport, far from the site (20+km)	Onsite
Upper air	2 x per day usually remote location far from the site (50+km)	Assumes unlimited surface mixing layer

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Table 1 continude – Summary of Parameters Used in Static and Dynamic Modelling Analyses

	Static Modelling	Dynamic Modelling
Source Characteristics		
Odour Emission Rates	Constant values as obtained during sampling campaign	Integration with real-time odour measurement
Source parameters	Fixed to the values that represent the worst case release scenario or observed during sampling analysis	Measured on site and adjusted for each model iteration according to process fluctuations
Source location	Constant or as planned over the course of the project	Taken into account as operations evolve on a daily or weekly basis
Process fluctuations	Mostly consider steady state operating conditions	Account for process evolution and unsteady state fluctuations
Building Cavity & Wake Effects	Taken into account. Hard to consider volume source with non-constant openings	Taken into account. Consider door opening/closing in real-time
Land Use Parameters	Once characteristics have been defined for a project site, they usually do not change	Account of changes in albedo or Bowen ratio based on the quantity & type of precipitation
Topography & Receptor Array	Taken in consideration	Taken in consideration
Models		
Regulatory Approved Models	AERMOD or CALPUFF	AERMOD or CALPUFF
Results	Historical (average / max / percentiles)	Real-time + historical (average / max / percentiles)
Utilisations		
Alert upon threshold exceedance	Not possible	Visual, sound or email
Forecast	Not possible	Predicted exceedances can trigger measures to mitigate odour emissions
Compliance determination	For new sources and existing sources	For existing sources
Review of specific odour event	No	History of all archived plumes. Animation (movies) of odour events in the last 24 hours
Current compliance assessment	No	Yes
Complaint validation	Yes but limited to average exposure	Yes on a case by case event
Automated report	No	Yes on demand
Process optimisation	Limited to average results	Process optimisation with control loop adjusted every model iteration

The four figures on the following pages show the difference in the predicted overall highest and 98th percentile odour impacts for the static and dynamic modelling approaches. Presentation of odour impact using a 98th percentile value is better representative of odour impact in that it accounts for a frequency of adverse impacts that could be considered a nuisance. In each of the following figures, the highest odour impacts are shown to be closest to the area source on the plant site. The key difference is the extent of the 1 OU/m^3 isopleth extends.

Figures 4 and 5 show the maximum off-site concentrations for the static and dynamic modelling approaches, respectively. The 1 OU/m^3 isopleth extends considerably off-site for the static modelling approach where the 1 OU/m^3 isopleth is tighter to the plant site for the dynamic modelling approach.

Figures 6 and 7 show the 98th percentile off-site concentrations for the static and dynamic modelling approaches. The 1 OU/m^3 isopleths for both of these figures is much closer to the plant site, but the static modelling approach still extends further from the plant than the dynamic modelling approach.

By using a dynamic odour modelling approach that included use of an OdoWatch eNose to measure odour emissions from the process units and on-site meteorological data, HRSD was able to manage the off-site odour impacts using a chemical dosing system rather than cover and treat the air emissions from the aeration basins. By modulating the chemical dosing rates, HRSD was able to reduce the peroxide usage by 10 percent.

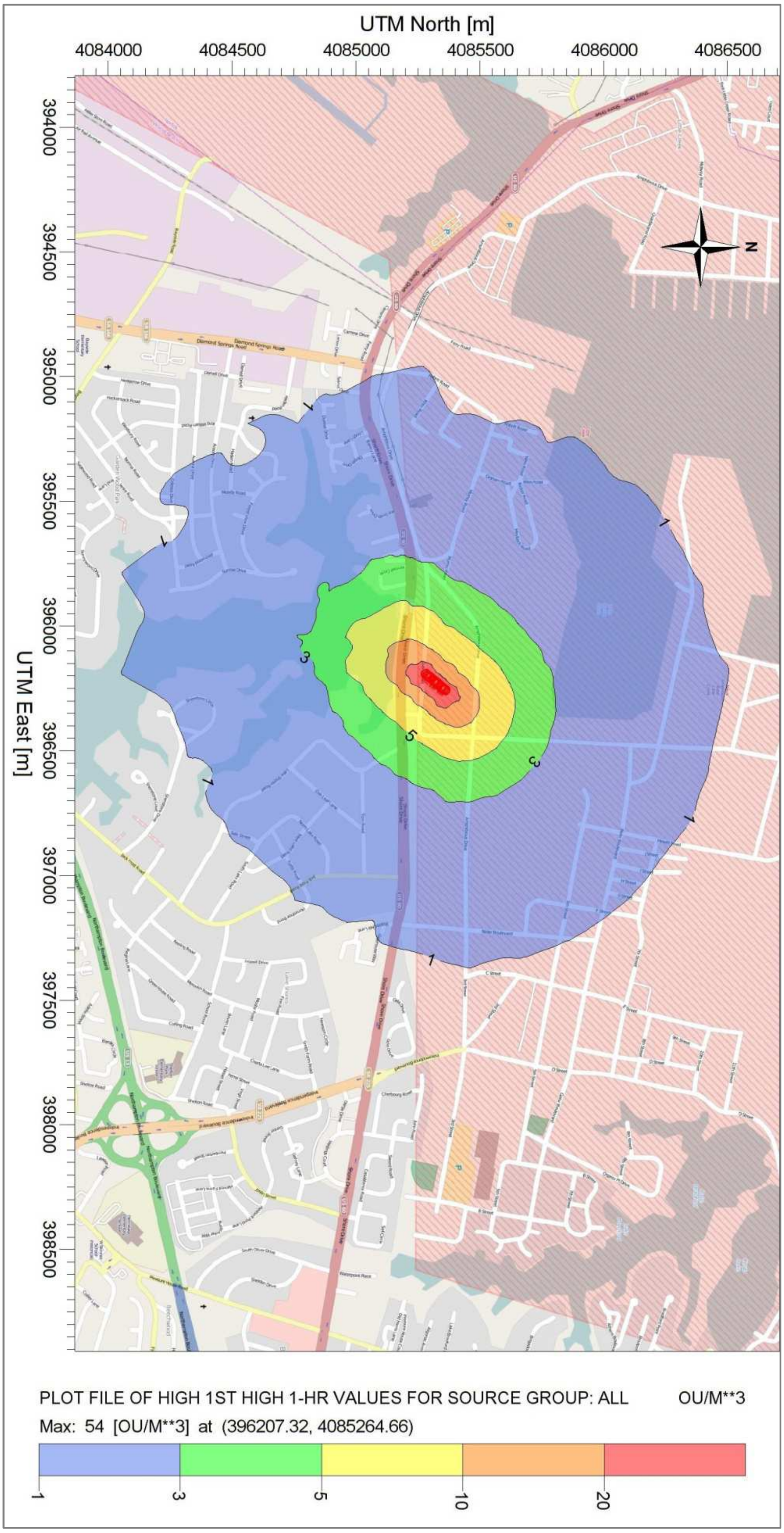

Figure 4 – Maximum Odour Concentrations for the Static Modelling Approach

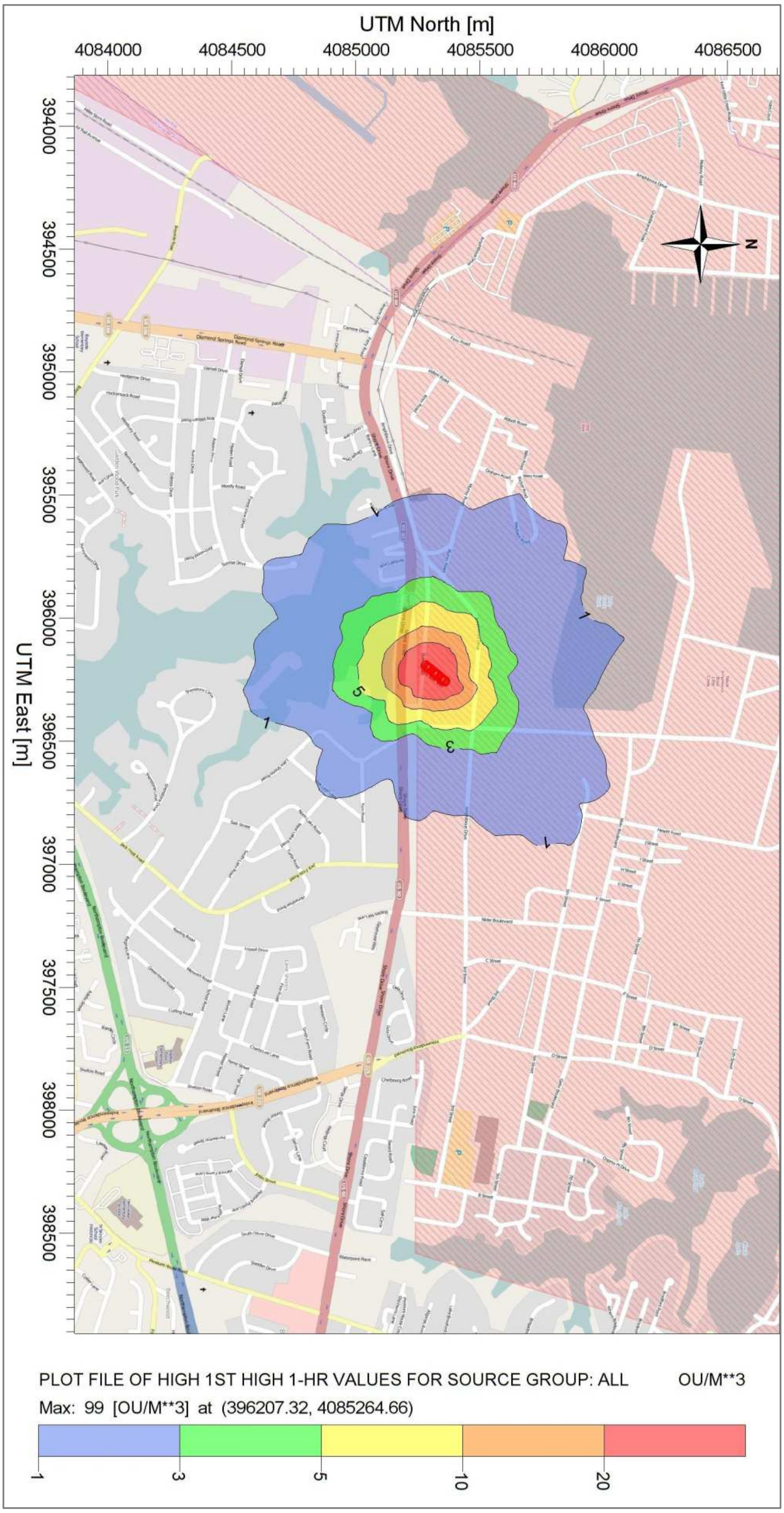

Figure 5 – Maximum Odour Concentrations for the Dynamic Modelling Approach

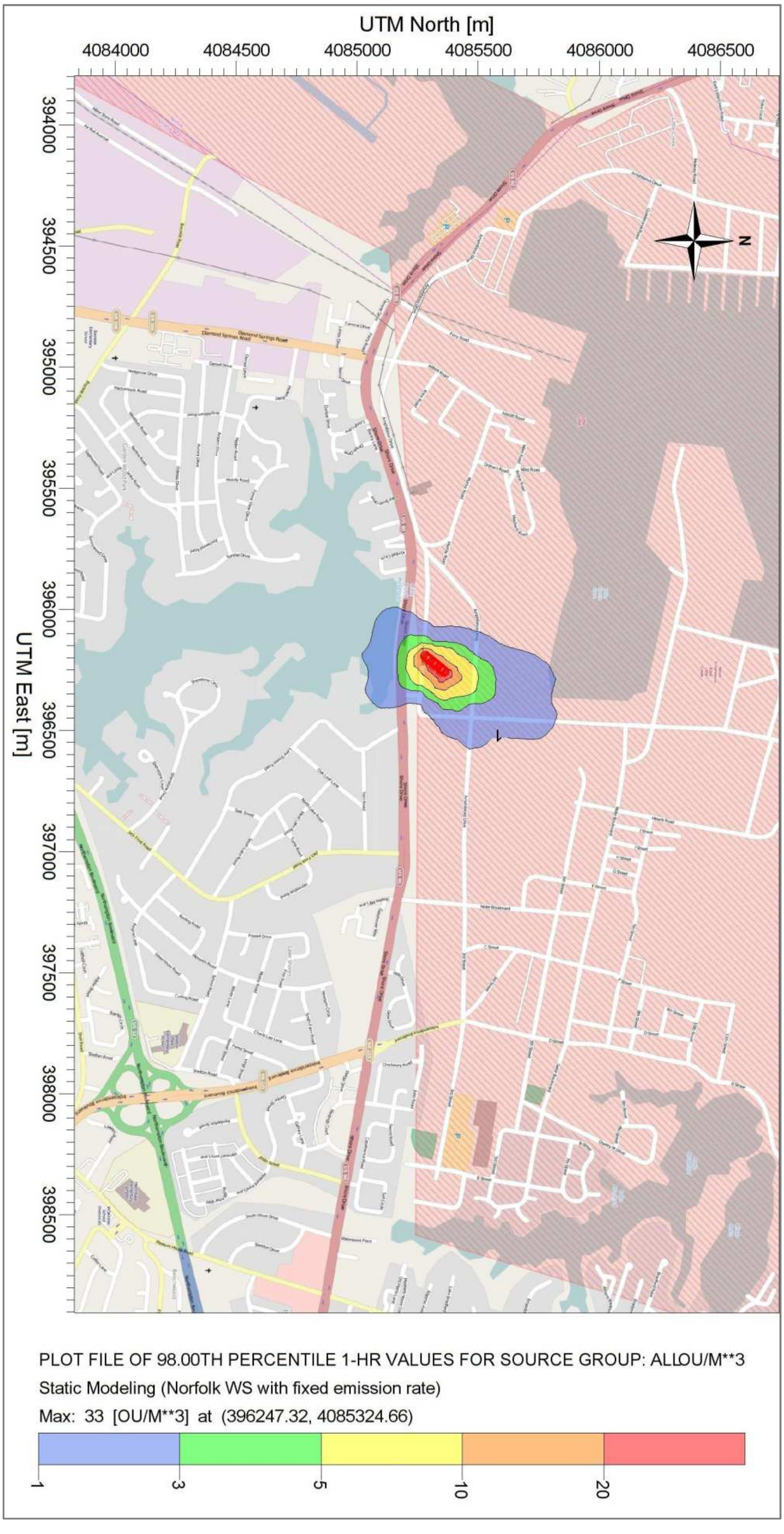

Figure 6 – 98th Percentile Concentrations for the Static Modelling Approach

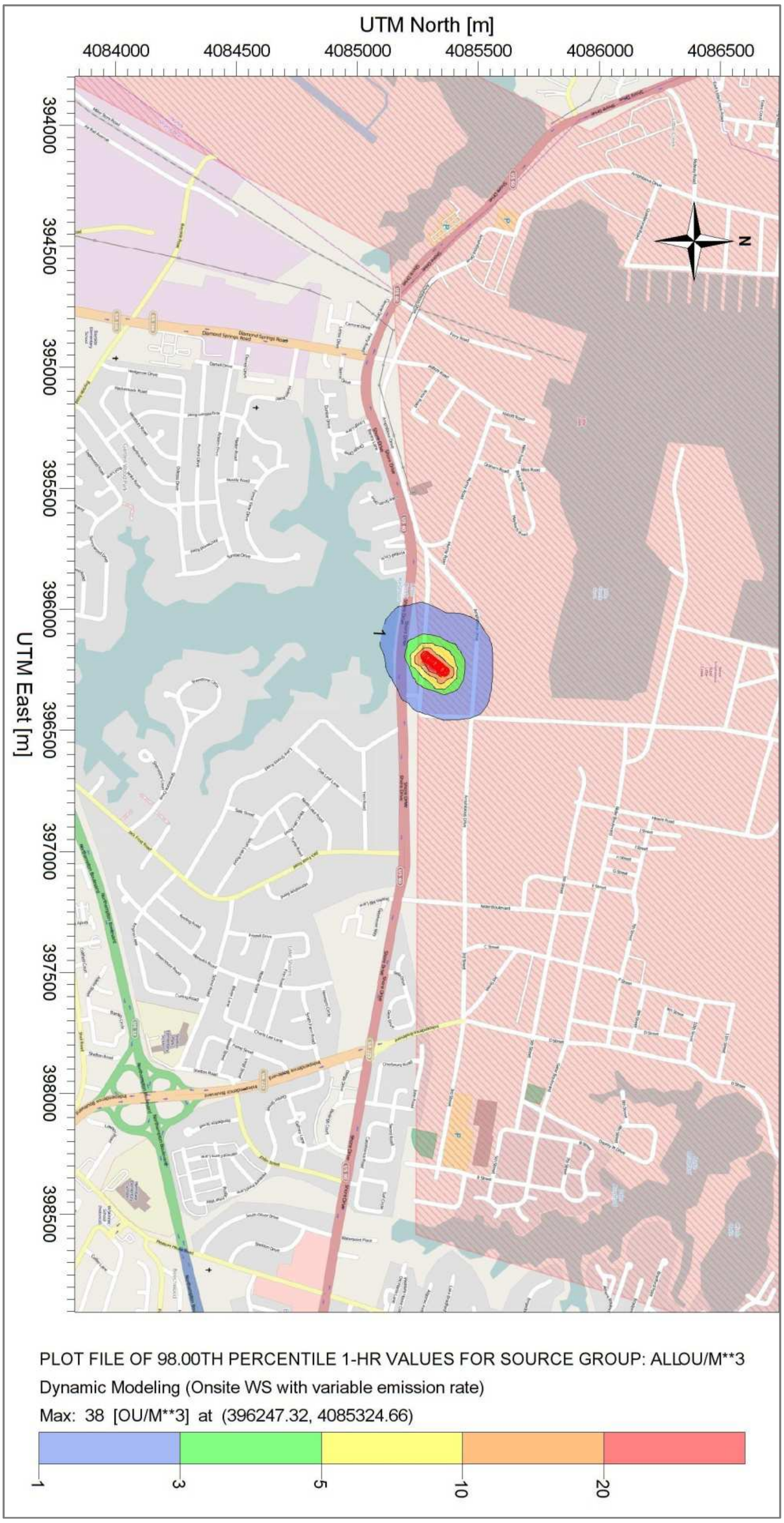

Figure 7 – 98th Percentile Concentrations for the Dynamic Modelling Approach

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