POWERFUEL

Portland energy recovery facility

Environmental statement
Second addendum
Appendices

3.2

3.2

Modelling uncertainty

FICHTNER

Consulting Engineers Limited

Portland Energy Recovery Facility

Powerfuel Portland Ltd

Annex A to Schedule 5 request – Modelling Uncertainty

ENGINEERING CONSULTING

Document approval

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Contents

1 Introduction....4
1.1 Background....4
1.2 Objectives....4
2 Clarifications....5
2.1 Stack emissions data....5
2.2 Ecological receptors....6
2.3 Metals analysis....7
2.4 Updated AQALs....8
3 Validation of ADMS Model....9
3.1 Introduction....9
3.2 Model description....9
3.3 Model validation....9
4 Sensitivity analysis....17
4.1 Minimum Monin-Obukov length....17
4.2 Surface roughness....19
4.2.1 Meteorological site....19
4.2.2 Dispersion site....20
4.3 Terrain....22
4.4 Meteorological data....23
4.4.1 Sources of data....23
4.4.2 Sensitivity....25
4.5 Dispersion model....26
5 Modelling Uncertainty....28
5.1 Uncertainty....28
5.2 Conservative assumptions....28
5.2.1 Interannual variability....28
5.2.2 Plant availability....29
5.2.3 Emission limits....29
5.2.3.1 VOCs....29
5.2.3.2 Cadmium....30
5.2.3.3 Acid gases....30
5.2.3.4 Nitrogen oxides and ammonia....30
5.2.4 Short term impacts....31
5.3 Overall effect on results....31
6 Summary and conclusions....32
Appendices....33
A Figures....34
B CERC Technical Note....39

1 Introduction

1.1 Background

Powerfuel Portland Ltd (the Client) submitted an application for an Environmental Permit (EP) to the Environment Agency (EA) (reference: EPR/AP3304SZ/A001). The detailed dispersion modelling methodology was set out in Technical Appendix D.2 Process Emissions Modelling (Fichtner document reference: S2953-0030-0005RSF rev 2 dated 25/08/2020), referred to within this report as the Dispersion Modelling Assessment (DMA).

As part of the determination, the EA has issued a request for more information under Schedule 5 of the Environmental Permitting (England and Wales) Regulations 2016. This report has been produced to provide the technical information needed to answer these questions.

1.2 Objectives

This report has the following objectives:

1. To provide clarification to the EA on the approach used.
2. To conduct a sensitivity analysis and to comment on the modelling uncertainty to answer question 2 of the Schedule 5 request for information.

2 Clarifications

2.1 Stack emissions data

Table 7 of the DMA includes 2 typographical errors with the stack diameter and flue gas velocity. The modelling was based on a stack diameter of 1.85 m and a resultant flue gas velocity of 20 m/s and all of the results presented in the DMA were based on this modelling.

Table 8 of the DMA also includes 2 typographical errors with the emission rate for ammonia and hydrogen fluoride incorrect. However, these were not carried through into the analysis.

The corrected Tables 7 and 8 are provided below. The changes are provided in red text.

Table 7 Corrected : Stack source data

Item	Unit	Value
Stack Data		
Height	m	80
Internal diameter	m	1.85
Location	m, m	369607, 74248
Flue Gas Conditions		
Temperature	°C	140
Exit moisture content	% v/v	14.90%
	kg/kg	0.105
Exit oxygen content	% v/v dry	8.11%
Reference oxygen content	% v/v dry	11.0%
Volume at reference conditions (dry, ref O_2)	Nm^3/s	39.07
Volume at actual conditions	Am^3/s	53.81
Flue gas exit velocity	m/s	20.0

Table 8 Corrected : Stack emissions data

Pollutant	Conc. (mg/Nm^3)		Release rate (g/s)	
	Daily or periodic	Half-hourly	Daily or periodic	Half-hourly
Oxides of nitrogen (as NO_2)	120	400	4.689	15.630
Sulphur dioxide	30	200	1.172	7.815
Carbon monoxide	50	150(1)	1.954	5.861
Fine particulate matter (PM)(2)	5	30	0.195	1.172
Hydrogen chloride	6	60	0.234	2.344
Volatile organic compounds (as TOC)	10	20	0.391	0.781
Hydrogen fluoride	1	4	0.039	0.156
Ammonia (3)	8	-	0.313	-

Pollutant	Conc. (mg/Nm³)		Release rate (g/s)	
	Daily or periodic	Half-hourly	Daily or periodic	Half-hourly
Cadmium and thallium	0.02	-	0.781 mg/s	-
Mercury	0.02	0.035	0.781 mg/s	1.368 mg/s
Other metals(4)	0.3	-	11.722 mg/s	-
Benzo(a)pyrene (PaHs)(5)	0.105 µg/Nm³	-	4.103 µg/s	-
Dioxins and furans	0.06 ng/Nm³	-	2.344 ng/s	-
PCBs(6)	5.0 µg/Nm³	-	4.103 µg/s	-

Notes:

All emissions are expressed at reference conditions of dry gas, 11% oxygen, 273.15K.

(1) Averaging period for carbon monoxide is 95% of all 10-minute averages in any 24-hour period.

(2) As a worst-case it has been assumed that the entire PM emissions consist of either PM_{10} or $PM_{2.5}$ for comparison with the relevant AQALs.

(3) A more stringent limit for ammonia is being applied for 8 mg/Nm^3

(4) Other metals consist of antimony (Sb), arsenic (As), lead (Pb), chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni) and vanadium (V).

(5) The highest recorded emission concentration of B[a]P from the Environment Agency's public register was 0.105 ug/m³, or 0.000105 mg/m³ (dry, 11% oxygen, 273K). In lieu of any specific limit, this has been assumed to be the emission concentration for the Facility.

(6) The Waste Incineration BREF provides a range of values for PCB emissions to air from European municipal waste incineration plants. This states that the annual average total PCBs is less than 0.005 mg/Nm³ (dry, 11% oxygen, 273K). In lieu of any specific limit, this has been assumed to be the emission concentration for the Facility.

2.2 Ecological receptors

The impact at ecological receptors was calculated by post processing the gridded output to determine the maximum impact at any grid point contained within the ecological site. Figure 3 contained in Appendix A shows the points used for each UK and European designated ecological sites. Figure 4 contained in Appendix A shows the points used for the local wildlife sites.

A separate excel file has been provided which includes the co-ordinates for each of the grid points used for the ecological sites, in order to facilitate the AQMUA audit.

2.3 Metals analysis

As part of the EP Application and as set out in the DMA, the impact of metals was carried out using the methodology set out in the EA document "Guidance on assessing group 3 metal stack emissions from incinerators"[1].

1. The first stage was to take the worst-case screening approach assuming each metal is released at 100% of the group ELV. In this case, this was the proposed emission limit value (ELV) of 0.3 mg/Nm^3.
2. The second stage was to assume that the Portland ERF would have emissions no greater than the maximum monitored concentration as set out in Table A1 of the EA guidance.

Table 18 and Table 19 of the DMA presented the emissions concentration of each metal as a percentage of the ELV. This was the maximum measured concentration set out in the EA guidance, expressed as a percentage of the proposed ELV of 0.3 mg/Nm^3 rather than as a percentage of the Industrial Emissions Directive (IED) ELV presented in the EA guidance.

The following table provides a summary of the maximum measured concentration, and then shows this as a percentage of the IED group 3 ELV (as presented in the EA guidance) and as a percentage of the proposed ELV of 0.3 mg/Nm^3 (as presented in the DMA).

Table 1: Metals Assumptions

Pollutant	Maximum Measured Concentration (mg/Nm^3)	Percentage of the IED Group 3 ELV	Percentage of the Proposed ELV
Antimony	0.0115	2.3%	3.8%
Arsenic	0.0250	5.0%	8.3%
Total chromium	0.0920	18.4%	30.7%
Chromium VI	1.3×10^{-4}	0.026%	0.043%
Cobalt	0.0056	1.1%	1.9%
Copper	0.0290	5.8%	9.7%
Lead	0.0503	10.1%	16.8%
Manganese	0.0600	12.0%	20.0%
Nickel	0.2200	44.0%	73.3%
Vanadium	0.0060	1.2%	2.0%
Notes: IED Group 3 ELV is 0.5 mg/Nm^3 Proposed ELV as set out in the EP application is 0.3 mg/Nm^3			

As shown, the maximum as a percentage of the proposed ELV matches the data set out in Table 18 and Table 19 of the DMA. This demonstrates that the DMA was based on the assumption that emissions from the Portland ERF would be no greater than the maximum monitored concentration as set out in Table A1 of the EA guidance.

[1] EA, Guidance on assessing group 3 metal stack emissions from incinerators, version 4

2.4 Updated AQALs

Since the DMA was submitted to the EA there have been some updates to the Environmental Assessment Levels (EALs) (referred to as Air Quality Assessment Levels (AQALs) in the DMA). The following AQALs are different to those used in the DMA:

- Annual mean AQAL for $PM_{2.5}$ reducing from 25 µg/m^3 as used in the DMA to 20 µg/m^3
- AQAL for benzene changing from 195 µg/m^3 as an hourly mean to 30 µg/m^3 as a daily mean.
- Annual mean AQAL for arsenic increasing from 3 ng/m^3 as used in the DMA to 6 ng/m^3
- Annual mean AQAL for chromium VI increasing from 0.2 ng/m^3 as used in the DMA to 0.25 ng/m^3.

As shown, the arsenic and chromium VI AQALs are larger than that used in the DMA. Therefore, the impact as a percentage of the AQAL for these pollutants will be lower and so we have not reconsidered these. However, the AQAL for $PM_{2.5}$ is lower and the AQAL for benzene has changed the averaging period used. The following table sets out the impact of the Portland ERF with reference to these two updated AQALs. These results have been factored from the data presented in Table 12 of the DMA and therefore represent the point of maximum impact based on operation at the daily ELVs. The analysis has used the maximum predicted impact using 5-years of weather data and conservatively assumes that:

- The ERF continually operates at the daily ELVs;
- The entire dust emissions consist of only the $PM_{2.5}$ fraction; and
- The entire TOC emissions consist of only benzene.

Table 2: Updated AQALs Analysis

Pollutant	Averaging period	Units	AQAL	Max PC	Max PC as % of AQAL
$PM_{2.5}$	Annual mean	µg/m^3	20	0.05	0.23%
VOCs (as benzene)	Maximum daily mean	µg/m^3	30	1.29	4.29%

As shown, the change to the AQALs does not alter the conclusions of the DMA with relation to these pollutants that the impact can be screened out as “insignificant” as the process contribution is less than 1% of the long term or less than 10% of the short term AQAL.

3 Validation of ADMS Model

3.1 Introduction

Dispersion modelling of process emission from the Portland ERF was carried out using ADMS (version 5.2) produced by Cambridge Environmental Research Consultants (CERC). The detailed methodology was set out in the DMA which was submitted with the EP application.

In this section, we have described the model and explained why we consider that it is appropriate for modelling impacts of the proposed ERF.

3.2 Model description

ADMS is a new generation dispersion model which characterises the atmospheric boundary layer in terms of the atmospheric stability and the boundary layer height. In addition, the model uses a skewed Gaussian distribution for dispersion under convective conditions, to take into account the skewed nature of turbulence. The model also includes modules to take account of the effect of buildings and complex terrain.

Within ADMS, the FLOWSTAR module is used to generate a new flow and turbulence field based on the terrain. This simulates the changes to the movement of air in the horizontal and vertical direction as a result of the terrain features in that the air flow is simulated flowing above and around raised ground. This modified flow field is then used by the model to adjust the plume height and plume spread parameters calculated by the flat terrain model. The ADMS model can also handle cases of strongly stable flow using a separate plume impingement model.

The technical specification document for the complex terrain module[2] explains that *"terrain should have no more than moderate slopes (up to 1:3) although the model is useful even when this criterion is not met (say up to 1:2)"*.

Figure 5 contained in Appendix A shows the Ordinance Survey Terrain 50 data and identifies the areas where terrain slopes are greater than 1:3 in orange, and greater than 1:2 in red. As shown the majority of the area the terrain slopes are less than 1:3. The hill to the west of the Portland ERF the slope is just over 1:3 but within the 1:2. This shows that there are only small areas where the terrain slopes are outside of the range of 1:2.

CERC note that during very low wind stable conditions in hilly terrain, horizontal gradients in density can cause katabatic (downslope) winds, which may influence the background flow in deep valleys[3]. These effects are not specifically accounted for in ADMS. However, the local area does not include valleys and as such this limitation of the model is not relevant to this project.

The technical note produced by CERC specifically sets out why CERC consider that the use of ADMS is entirely appropriate as the model has been designed for these types of locations[4].

3.3 Model validation

CERC validates its models against available measured data obtained from real world situations, field campaigns and wind tunnel experiments. The validation studies are published on the CERC

[2] CERC, P14/01S/17 Complex Terrain Module, March 2020

[3] CERC, Note 110 Temperature Inversions in ADMS, 20 April 2017

[4] CERC, Technical Note: Portland Energy Recovery Facility, attached as Appendix B.

website[5]. Table 3 provides a summary of each of the validation studies presented on the CERC website and Fichtner's interpretation as to whether they are representative of the conditions across the Portland ERF study area.

Table 3: Model Validation Studies

Study	Description	Similar to Portland ERF study area?
Baldwin Power Plant	Plant in a rural area on a flat river plain, with terrain rising to the east up to a height of 115 m above the river plain. Buoyant source. Stack height ~180 m. Building height ~44% of height of stack. SO_2 monitored at 10 points. Characterised as "complex terrain below the stack height".	No. Terrain below stack height unlike the Portland ERF study area.
Martins Creek	Rural area along a river with terrain to the south-east and north-west rising above the height of the stacks. Buoyant source, 8 stacks of varying heights from ~65 m to ~183 m. Building height ~50% of height of stack. SO_2 monitored at 7 points. Characterised as "complex terrain rising above the stack height".	No. Terrain above the stack height like the Portland ERF study area but terrain rising to the south-east and north-west. The closest stacks to the terrain MC12, MC3 and MC4 are ~183m with the terrain only rising to ~200m. So not much difference between the terrain height and stack for the main emission sources.
Clifty Creek Power Plant	Plant located within the creek with cliffs rising about 115 m above the river immediately to the north of the plant. Buoyant source, 3 stacks each with a height of ~210 m. No buildings included in model. SO_2 monitored at 6 points. Characterised as "complex terrain below the stack height".	No. Terrain below stack height unlike the Portland ERF study area.
Hogback Ridge Tracer Experiments	Small hill, with a maximum elevation of 104 m above the minimum elevation in the area. Tracer gases released from a tower at two heights (50 m and 70 m) and another point at 20 m under stable conditions. No buildings included in model. Tracer gas released and 74 monitoring sites located on the terrain adjacent to the release.	No. Limited amount of data for model validation purposes and only considers stable conditions.

1[5] https://www.cerc.co.uk/environmental-software/model-validation.html

Study	Description	Similar to Portland ERF study area?
	Characterised as “complex terrain rising above the stack height”.	
Lovett Power Plant	Plant located on a river with terrain increasing from river level to 270 m. Plant has a single 145 m stack, buoyant source. No buildings included in model. SO_2 monitored at 12 sites. Characterised as “complex terrain rising above the stack height”.	Considered to be representative (see further discussion below)
Tracy Power Plant	Plant located in a valley surrounded by complex terrain with peaks rising to around 950 m above the power plant. Plant with a single 90 m stack, buoyant source. No buildings included in model. SF6 monitored at 110 receptors around the site. Height of receptors were 0.5 m above ground, but also 3 elevated receptors were positioned at heights of 43, 105 and 145m on a tower.	No. Significantly more complex terrain.
Westvaco Corporation	Plant located close to very complex terrain within a meandering part of a river valley. Buoyant source released at a height of 190 m. No buildings included in model. SO_2 monitored at 11 sites. Characterised as “complex terrain rising above the stack height”.	No. Plant located in meandering river valley, unlike ERF.

Of the studies listed above, the Lovett Power Plant study is considered to be similar to the conditions at Portland ERF study area for the following reasons:

- Both plants have a buoyant release.
- The terrain in both instances rises above the stack height by at least 50 m (unlike Martins Creek where the stack is close to the peak elevation).
- The terrain is flat for a wide area of water before approaching the terrain – i.e. established laminar flow with low surface roughness.

However, the Lovett Power Plant study does not include the effect of building downwash and the validation is carried out against sulphur dioxide (SO_2) concentrations. In the validation document[6] CERC explain that there are issues with using SO_2 as a tracer which include:

- The limitations of detection are usually of the order of 16 µg/m^3, and concentrations below these are set to one-half of the limit. This leads to considerable inaccuracy when modelled concentrations are low.
- SO_2 is released from other sources. If estimates of these background concentrations are not available, then the model will underestimate concentrations, particularly long-term averages.

[6] CERC, ADMS 5 Complex Terrain Validation Lovett Power Plant, November 2016

The Baldwin Power Plant and Martins Creek validation documents are based on complex terrain and buildings. However, the complex terrain in both instances is unlike that at Portland. As complex terrain is the main driver for the Portland ERF, it is considered appropriate to consider the Lovett Power Plant study.

The validation studies include scatter plots, quantile-quantile plots, and a comparison between the observed and modelled maximum and robust highest concentration.

- The scatter plots compare predicted and measured concentrations at a particular location at a particular time.
- The quantile-quantile plots compare the distribution of predicted and measured concentrations during the period having abandoned the (x,t) pairing – i.e. comparing the first highest concentration from the monitored with the first highest concentration predicted.
- The highest concentration is subject to extreme variations. Therefore, the robust highest concentration (RHC) is used due to its stability which is based on a tail exponential fit to the upper end of the distribution. The RHC is strongly related to the average and standard deviation.

Figure 1: Frequency Scatter and Quantile-quantile Plots - Lovett Power Plant Validation Study

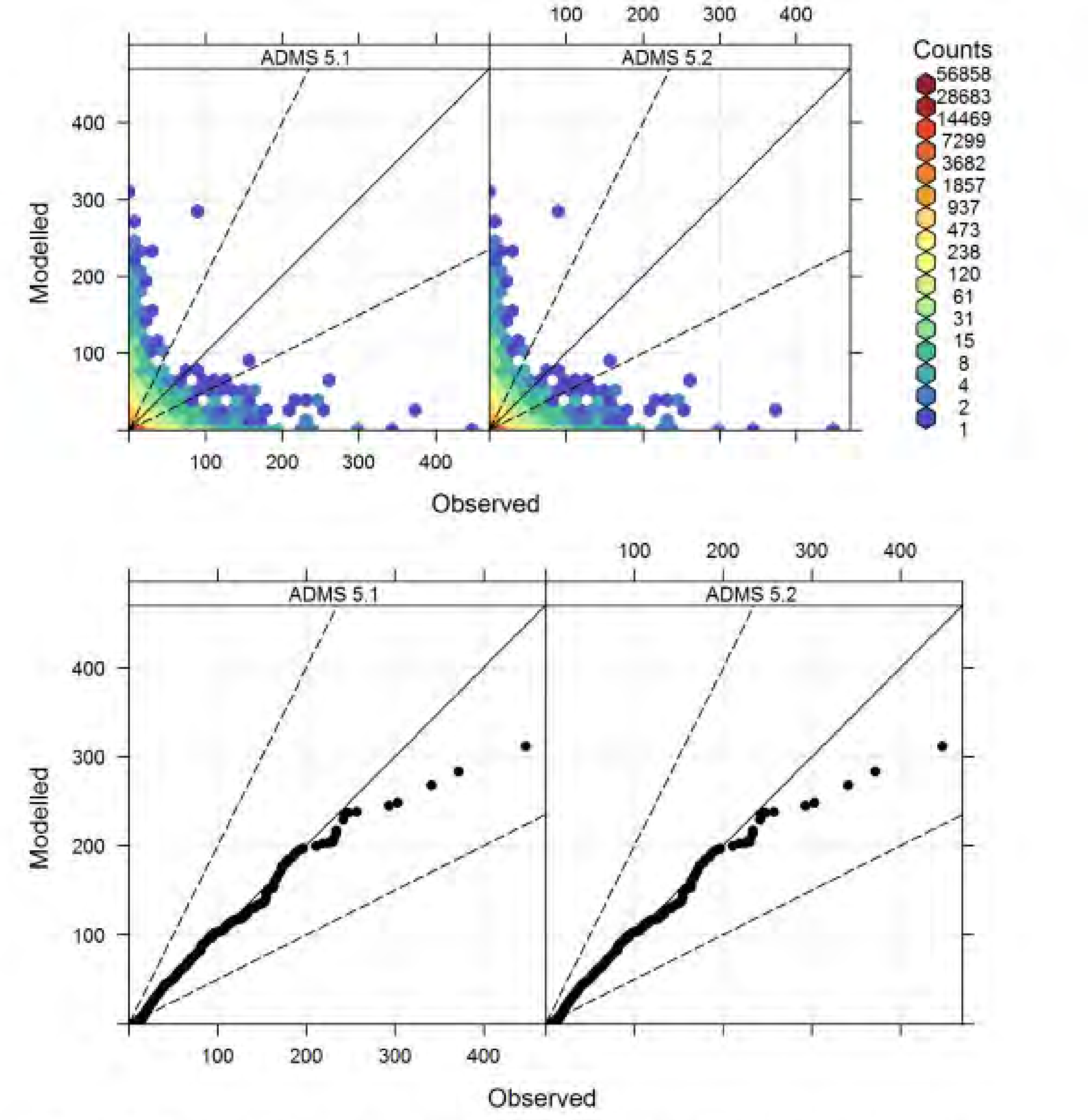


Figure 6 – Frequency scatter plots and quantile-quantile plots of ADMS results against observed concentrations (μg/m^3).

Source: CERC Lovett Power Plan Validation Study Nov 2016

The scatter plot and quantile-quantile plots (Figure 1) show a relatively good agreement between the modelled and observed concentrations for ADMS 5.2 with only a few of the higher concentrations being under predicted in ADMS.

The statistics, extracted from this validation study, extracted from the CERC Lovett Power Plan Validation Study Nov 2016, presented below, demonstrate this with the mean monitored to observed ratio being within 5% for the RHC.

Statistics	Data	Maximum Concentrations (µg/m³)									Mean M/O ratio
		P3	P4	P5	P6	P7	P8	P9	P10	P11	
1-hour maximum	Observed	231	257	151	448	372	157	230	193	155	-
	ADMS 5.1	115	101	131	237	312	174	238	229	181	0.85
	ADMS 5.2	115	101	131	237	312	174	238	229	181	0.85
3-hour maximum	Observed	146	137	66	184	136	109	102	103	83	-
	ADMS 5.1	61	67	67	179	168	141	185	164	98	1.11
	ADMS 5.2	61	67	67	179	168	141	185	164	98	1.11
24-hour maximum	Observed	76	22	21	40	47	21	22	29	19	-
	ADMS 5.1	25	17	43	90	107	59	63	34	24	1.76
	ADMS 5.2	25	17	43	90	107	59	63	34	24	1.76

Table 5 – Observed (O) and modelled (M) maximum concentrations (ug/m³) per receptor point, and the mean ratio of modelled/observed values for each statistic.

Statistics	Data	Robust Highest Concentrations (µg/m³)									Mean M/O ratio
		P3	P4	P5	P6	P7	P8	P9	P10	P11	
1-hour RHC	Observed	287	235	119	408	255	171	237	181	108	-
	ADMS 5.1	116	108	158	293	374	204	242	208	177	1.04
	ADMS 5.2	116	108	158	293	374	204	242	208	177	1.04
3-hour RHC	Observed	174	138	74	217	141	107	105	112	58	-
	ADMS 5.1	65	68	75	162	188	99	149	123	106	1.03
	ADMS 5.2	65	68	75	162	188	99	149	123	106	1.03
24-hour RHC	Observed	51	27	23	42	47	23	23	28	23	-
	ADMS 5.1	18	17	23	41	46	34	40	33	16	1.01
	ADMS 5.2	18	17	23	41	46	34	40	33	16	1.01

Table 6 – Observed (O) and modelled (M) robust highest concentrations (RHC) per receptor point, and the mean ratio of modelled/observed RHC for each statistic (number of points = 26).

Source: CERC Lovett Power Plan Validation Study Nov 2016

A ratio above 1 indicates that the model is over predicting the monitored concentration and a ratio below 1 indicated that it is under predicting the monitored concentration.

There is variation between sites. However, the highest RHC is predicted well:

- 1-hr RHC – highest observed value is 408, compared to highest modelled value of 374 (ratio 1.09).
- 3-hr RHC – highest observed value is 217, compared to highest modelled value of 188 (ratio 1.15).
- 24-hr RHC – highest observed value is 51, compared to highest modelled value of 46 (ratio 1.10).

Hence, we consider that the validation study confirms that the ADMS modelling results are, on average and as a maximum, within 10% of the hourly and daily concentrations. We would expect the accuracy over a longer time frame, such as a year, to be at least as high as this. This study does not indicate that the level of uncertainty would affect the conclusions of the DMA.

The Tracy Power Plant validation study is not considered to be representative of the conditions around the Portland ERF due to the significantly more complex terrain. However, the Tracy Power Plant validation study[7] still shows that for ground-level receptors (i.e. those following the level of the terrain and actually at a height of 0.5 m) the quantile-quantile graph shows good representation of observed data with higher observed concentrations being slightly over predicted using ADMS (figure 5 of the CERC validation study, reproduced below as our Figure 2).

Figure 2: Frequency Scatter and Quantile-quantile Plots - Lovett Power Plant Validation Study

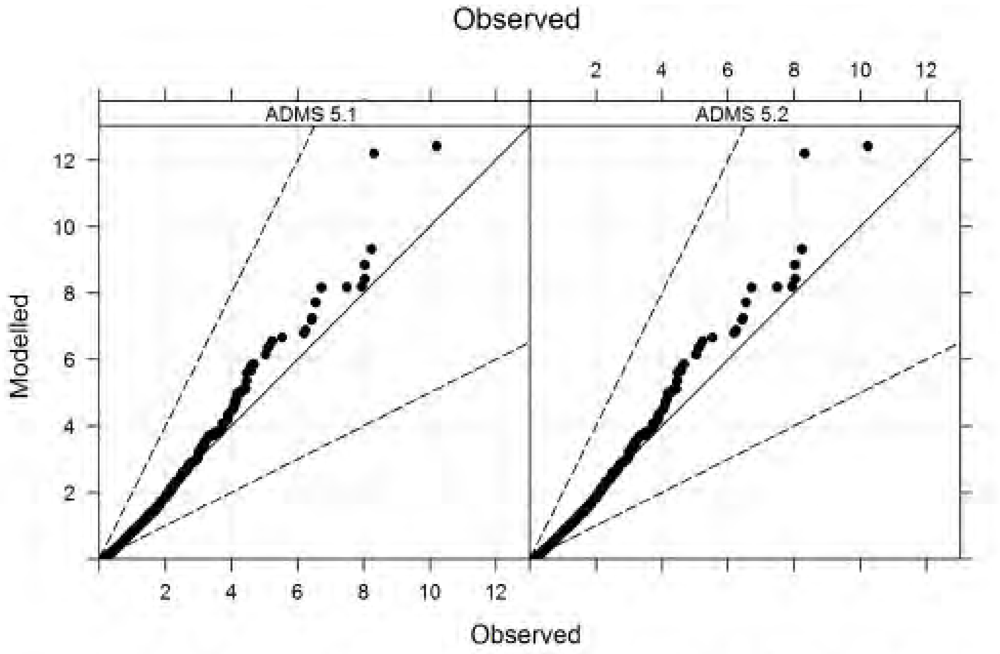


Figure 5 – Scatter plots and quantile-quantile plots of ADMS results against for the ground-level receptors (us/m³).

Source: CERC Lovett Power Plan Validation Study Nov 2016

The Tracey Power Plant study also includes two elevated points which are located on a tower at a height of 43 m and 104 m above the terrain. While the results at those specific elevated points are underestimated, this does not indicate that results at ground level are underestimated. As set out in the CERC validation document the analysis at height is for a single location and the expected accuracy of the model is lower. The validation study provides an additional explanation for the reduced accuracy in predictions for the 43 m height receptor, explaining that the AERMOD meteorological profile indicates that for a number of hours in the experiment there was reverse flow region in the valley and this is not fully represented in the ADMS model. This is not an issue which would be experienced at Portland as there are no valleys present.

The Tracy Power Plant validation study does not show that the ADMS model underestimates observed predictions at elevated receptors associated with gradients, merely that the model does not perform well at a single point in the atmosphere well above ground level. At ground level, the model performs well.

[7] CERC, ADMS 5 Complex Terrain Validation Tracy Power Plant, November 2016

In conclusion it is acknowledged that the ADMS model may not be suitable in extremely complex terrain. However, as shown there is only a very small area of the calculated flow field (the study area) where the terrain slopes are greater than the recommended levels. The CERC model validation study has shown that in a similar setting the model performs well. Whilst there are other studies which show less favourable validation in complex terrain these are not considered to be representative of the Portland area. The validation studies do not indicate that the level of uncertainty would affect the conclusions of the DMA. The additional technical note produced by CERC sets out why CERC considers that the use of ADMS is entirely appropriate as the model has been designed for these types of locations.

4 Sensitivity analysis

The DMA includes full details of the input parameters used. As set out in in section 6 of the DMA, a sensitivity analysis of the choice of surface roughness length for the dispersion site and terrain data was not included as it was deemed that it would be appropriate to model taking into account both the variable terrain and surface roughness lengths across the area of interest, rather than using a single value. This section details the sensitivity of the predicted impacts to the choice of inputs, specifically the choice of:

- Minimum Monin-Obukov length;
- Surface roughness length;
- Terrain data;
- Meteorological data; and
- Dispersion model.

4.1 Minimum Monin-Obukov length

The Monin-Obukov length provides measure of the stability of the atmosphere. In urban areas there is a significant amount of heat generated from buildings and traffic which warms the air this is known as the urban heat island effect. This has the effect of preventing the atmosphere from ever becoming very stable. In general, the larger the area, the more heat is generated and the stronger this effect becomes. This means that in stable conditions the Monin-Obukov length will never fall below a minimum value, the larger the city, the larger the minimum value.

ADMS has a function to be able to set the minimum Monin-Obukov length which allows the model to account for the urban heat island effect which is not reflected in the meteorological data.

The value for the Portland meteorological site used in the dispersion model is considered to be representative of the local area given that the site is located away from any built-up area and there is not likely to be any significant warming effect from the built environment. Therefore, the sensitivity of the model results to the choice of minimum Monin-Obukov length for the meteorological site has not been carried out.

The value for the dispersion site was selected as 10 m in the DMA. This is the value recommended in the ADMS model interface for areas described as “small towns”, such as Portland. The other values recommended in the ADMS interface are:

- Default value for rural areas = 1 m
- Mixed urban / industrial areas = 30 m
- Cities and large towns = 30 m
- Large conurbations > 1 million = 100 m

Clearly the area is not a large conurbation of more than 1 million and so a Monin-Obukov length of 100 m would be entirely inappropriate. Therefore, the dispersion model has been re-run with a minimum Monin-Obukov length for the dispersion site set to the default value or 1m and 30 m to determine the sensitivity of the predicted results to the choice of this parameter.

The following table presents the annual mean, maximum 1-hour, 99.79%ile of 1-hour and maximum 24-hour concentration for the point of maximum impact, all as a percentage of the predicted concentration using the assumption in the original dispersion modelling.

Table 4: Minimum Monin-Obukov Length

Minimum Monin-Obukov length	Percentage of value calculated using assumptions in DMA			
	Annual mean	Maximum 1-hour mean	99.79%ile of 1-hour mean	Maximum 24-hour mean
Point of maximum impact				
Default – rural	99%	89%	100%	100%
10 m	100%	100%	100%	100%
30 m	101%	106%	100%	100%
Maximum on land				
Default – rural	99%	89%	100%	100%
10 m	100%	100%	100%	100%
30 m	101%	106%	100%	100%
Maximum at Portland eco site				
Default – rural	99%	81%	100%	100%
10 m	100%	100%	100%	100%
30 m	104%	106%	100%	100%
Maximum at Chesil eco site				
Default – rural	99%	100%	100%	100%
10 m	100%	100%	100%	100%
30 m	110%	111%	100%	100%
Note: Original DMA assumed a minimum Monin-Obukov length for the dispersion site of 10m.				

As shown the choice of minimum Monin-Obukov length has very little effect on the maximum 24-hour mean or 99.79%ile of 1-hour mean. The maximum 1-hour and annual mean impact varies slightly with a slightly greater impact with the higher minimum Monin-Obukov length.

The contour plots presented in Figure 6 to Figure 8 contained in Appendix A show that there is very little difference in the distribution of emissions on an annual mean or 24-hour basis. There is some difference in the distribution of peak 1-hour concentrations with the peak concentration predicted to occur closer to the stack with the higher minimum Monin-Obukov length.

The value of 10 m is considered appropriate for the modelling domain given the nature of the local area. However, if a higher value was to be used, which would indicate a larger urban heat island effect, the peak 1-hour concentration would be predicted to be slightly higher than that presented in the DMA. When considering the impact in relation to the AQAL the peak 1-hour nitrogen dioxide concentration increases from 6.1% to 6.4% of the AQAL if operating at the daily ELV, but the 99.79 percentile impact does not change.

Therefore, the choice of minimum Monin-Obukov length is not considered to have a significant effect on the predicted impacts.

4.2 Surface roughness

Surface roughness length is proportional to the average height of the roughness elements of the surface. This is the height at which the mean horizontal wind speed is zero and is used to define the wind-speed profile with height.

The ADMS user interface includes the following recommended values for specific land coverings:

- Sea = 0.0001
- Short grass = 0.005 m
- Open grassland = 0.02 m
- Root crops = 0.1 m
- Agricultural (min) = 0.2 m
- Agricultural (max) = 0.3 m
- Parkland, open suburbia = 0.5 m
- Cities, woodlands = 1 m
- Large urban areas = 1.5 m

4.2.1 Meteorological site

In the DMA, the surface roughness length for the meteorological site was set to 0.0001 m which is appropriate for areas of sea. This is considered to be representative of the 1 km square around the observation site, given that the prevailing wind direction would mean that the winds would come from the sea which is located only just over 200 m from the observation site (as shown in Figure 20 in Appendix A). However, closer to the observation site a higher roughness value could be deemed more appropriate. The model has been re-run changing the surface roughness value for the observation site to 0.005 m which is appropriate for short grass. Given the nature of the headland, this is considered to be the most representative surface roughness value for the immediate surroundings of the observation site and is the highest value which could be reasonably justified.

The following table presents the annual mean, maximum 1-hour, 99.79%ile of 1-hour and maximum 24-hour concentration based on the modelled NOx release rate for the point of maximum impact as a percentage of the predicted concentration using the assumption in the original dispersion modelling. Figure 9 to Figure 11 set out in Appendix A show the distribution of emissions.

Table 5: Surface Roughness Length - Met Site

Surface roughness length	Percentage of value calculated using assumptions in DMA			
	Annual mean	Maximum 1-hour mean	99.79%ile of 1-hour mean	Maximum 24-hour mean
Point of maximum impact				
0.0001 m	100%	100%	100%	100%
0.005 m	114%	87%	102%	108%
Maximum on land				
0.0001 m	100%	100%	100%	100%
0.005 m	114%	87%	102%	108%
Maximum at Portland eco site				
0.0001 m	100%	100%	100%	100%

Surface roughness length	Percentage of value calculated using assumptions in DMA			
	Annual mean	Maximum 1-hour mean	99.79%ile of 1-hour mean	Maximum 24-hour mean
0.005 m	140%	88%	103%	140%
Maximum at Chesil eco site				
0.0001 m	100%	100%	100%	100%
0.005 m	105%	116%	96%	106%
Note: Original DMA assumed a surface roughness length for the meteorological site of 0.001 m.				

As shown the choice of surface roughness length for the meteorological site has a slight effect on the predicted impact. The predicted maximum impact is generally greater with the higher surface roughness value for the meteorological site with the exception of the peak 1-hour concentration which is lower closer to the stack. Whilst the change as a percentage of the value used in the DMA is in some instances up to 40% greater (maximum 24-hour mean), the distribution of impacts is similar as shown in Figure 9 to Figure 11 contained in Appendix A.

The peak annual mean nitrogen dioxide impact would increase from 1.4% of the AQAL to 1.6%, but this is not considered to be a significant difference. The annual mean impact at Portland ecological site would increase from 1.3% to 1.8% and the daily mean impact from 12.6% to 17.6%. Contour plots of the annual mean and daily mean oxides of nitrogen impact as a percentage of the Critical Level are provided in Figure 12 and Figure 13 of Appendix A. This demonstrates that, whilst there is a difference in the peak impact, the change in distribution of impacts is marginal.

Therefore, whilst the choice of surface roughness length for the meteorological site has some effect, it is not considered to be significant, and this does not change the conclusions of the assessment.

4.2.2 Dispersion site

The modelling domain has significant differences in the surface roughness with the sea areas having a very low value compared to the higher values in the built-up environment. A variable surface roughness file was generated using the recommended values from the ADMS interface and analysis of the aerial mapping of the area. A visualisation of the surface roughness values used in the original modelling was set out in Figure 2 of the DMA and has been reproduced in Figure 14 contained in Appendix A.

Due to the significant differences in surface roughness, across the modelling domain the use of a constant surface roughness value was not deemed to be appropriate. However, it is acknowledged that the model could be sensitive to the choice of surface roughness length used.

As an alternative source of surface roughness length, the land-use class for each point in the file has been extracted from the CORINE Land Cover database[8] and cross-referenced with the most likely surface roughness length value[9]. The following tables sets out the land use classifications within the CORINE Land Cover database identified within the extents needed for modelling

8 https://land.copernicus.eu/pan-european/corine-land-cover

9 Taken from “Roughness length classification of Corine Land Cover classes”, Megajoule Consultants, 2007.

purposes and the associated surface roughness length. A visual representation is also provided in Figure 14 contained in Appendix A.

Table 6: Surface Roughness Lengths Used for Different Land Use Classes Identified in Domain

Land Use Classification	CORINE 2018 Land Use Codes	Surface Roughness Length (m)
Coastal lagoons	521	0.0001
Sea and ocean	523	0.0001
Beaches, dunes, sands	331	0.0003
Mineral extraction sites	131	0.005
Sparsely vegetated areas	333	0.005
Natural grasslands	321	0.1
Pastures	231	0.3
Discontinuous urban fabric	112	0.5
Industrial or commercial units	121	0.5
Port areas	123	0.5
Broad-leaved forest	311	0.75

The CORINE Land Cover database has allocated the hillside to the west of the Portland ERF to be code 311 (“broadleaved forest”) and the recommended surface roughness value is 0.75 m. However, this area is actually scrub habitat and it is considered that a surface roughness value of 0.5 is more appropriate, albeit still on the high side. As such, a modified variable surface roughness file, reducing the surface roughness of the land to the west of the Portland ERF to 0.5 m, has also been generated. A visualisation of this modified surface roughness file is provided in Figure 14 contained in Appendix A.

The dispersion model has been re-run with a surface roughness file based on the CORINE Land Cover database (and the modified version) to determine the sensitivity of the choice of surface roughness length to the predicted results.

The following table presents the annual mean, maximum 1-hour, 99.79%ile of 1-hour and maximum 24-hour concentration for the point of maximum impact as a percentage of the predicted concentration using the assumption in the original dispersion modelling. Figure 15 to Figure 17 of Appendix A show the distribution of emissions.

Table 7: Surface Roughness - Modelling Domain

Surface roughness length	Percentage of value calculated using assumptions in DMA			
	Annual mean	Maximum 1-hour mean	99.79%ile of 1-hour mean	Maximum 24-hour mean
Point of maximum impact				
Original	100%	100%	100%	100%
Corine	102%	103%	100%	92%

Surface roughness length	Percentage of value calculated using assumptions in DMA			
	Annual mean	Maximum 1-hour mean	99.79%ile of 1-hour mean	Maximum 24-hour mean
Modified Corine	105%	106%	101%	101%
Maximum on land				
Original	100%	100%	100%	100%
Corine	102%	103%	100%	92%
Modified Corine	105%	106%	101%	101%
Maximum at Portland eco site				
Original	100%	100%	100%	100%
Corine	94%	103%	98%	103%
Modified Corine	102%	99%	101%	103%
Maximum at Chesil eco site				
Original	100%	100%	100%	100%
Corine	95%	104%	101%	102%
Modified Corine	94%	102%	101%	103%

As shown the choice of surface roughness length has a minor effect on the predicted impacts, with some increasing and some decreasing, and the distribution of impacts is similar.

When considering the impact in relation to the AQAL, Critical Levels and Critical Loads the change in impact is minimal and would not significantly change the impacts presented in the DMA.

Therefore, whilst the choice of surface roughness length for the dispersion site has some effect this is not considered to be significant.

4.3 Terrain

The terrain data used for the model was taken from the Ordnance Survey (OS) Terrain 50 dataset. This is clearly the most appropriate data available for the UK and so no other data has been used. However, the terrain data is processed by ADMS and the sensitivity of the model to this processing has been considered.

A discussion of how ADMS treats terrain is provided in Section 3.2. The CERC technical specification explains that for each wind direction a wind-aligned rectangle is described around the terrain points. An internal calculation grid is set up over the rectangle. The resolution of this grid can be specified by the user. A finer grid can lead to a more accurate representation of the terrain, but will also significantly increase the run time of the model. Therefore, in the DMA, a grid resolution of 128 x 128 was used as this was considered to be a reasonable balance between accuracy and runtimes.

The dispersion model has been re-run with a various flow field resolutions to determine the sensitivity of the choice of resolution to the predicted results. The following table presents the annual mean, maximum 1-hour, 99.79%ile of 1-hour and maximum 24-hour concentration as a percentage of the predicted concentration using the assumption in the original dispersion modelling. Figure 18 to Figure 20 contained in Appendix A show the distribution of emissions.

Table 8: Terrain Resolution

Terrain grid resolution	Percentage of value calculated using assumptions in DMA			
	Annual mean	Maximum 1-hour mean	99.79%ile of 1-hour mean	Maximum 24-hour mean
Point of maximum impact				
32 x 32	77%	82%	81%	71%
64 x 64	95%	88%	91%	97%
128 x 128	100%	100%	100%	100%
256 x 256	100%	105%	103%	100%
Maximum on land				
32 x 32	77%	82%	81%	71%
64 x 64	95%	88%	91%	97%
128 x 128	100%	100%	100%	100%
256 x 256	100%	105%	103%	100%
Maximum at Portland eco site				
32 x 32	83%	82%	88%	82%
64 x 64	96%	89%	93%	87%
128 x 128	100%	100%	100%	100%
256 x 256	101%	104%	101%	100%
Maximum at Chesil eco site				
32 x 32	96%	93%	95%	94%
64 x 64	99%	98%	97%	98%
128 x 128	100%	100%	100%	100%
256 x 256	100%	101%	98%	101%

As shown the choice of terrain resolution for the flow field has a significant effect on the predicted impacts. The maximum predicted impacts using a coarser grid (32 x 32 and 64 x 64) are lower. The maximum predicted impacts using the 128 and 256 grid resolutions are similar as is the distribution of emissions. However, the 256 resolution model took significantly longer to run.

Therefore, there is limited benefit of running all the models with the 256 x 256 resolution flow field resolution. The use of the 128 x 128 resolution flow field grid as used in the DMA is considered appropriate and the use of the more detailed resolution would not significantly change the predicted impacts.

4.4 Meteorological data

4.4.1 Sources of data

The dispersion modelling was carried out using 5 years of weather data from the Isle of Portland observation station. This was considered appropriate for use given that the observation station is located in a similar setting to the dispersion site, monitors all of the data needed for a dispersion model, and has a high level of data capture. The location of the meteorological observation site is presented on Figure 21 contained in Appendix A.

Wind roses of the data from the Isle of Portland observation station are presented in Figure 22 contained in Appendix A. This shows that at the Isle of Portland observation station generally the winds are from the south-west but with a large westerly component. This is expected given the location to the south of the UK on a headland protruding into the English Chanel. Using this data, the prevailing wind direction would mean that generally emissions from the Portland ERF would travel in a north-westerly direction across the sea and away from any sensitive receptors. However, there is also a small contribution of winds from the east and north-east. During these periods emissions from the Portland ERF would be blown towards the land and towards sensitive receptors.

An additional breakdown of the wind data has been carried out for this sensitivity study to determine the seasonal variability in the wind direction and speed. This shows that generally the more easterly winds (i.e. those which would mean emissions from the Portland ERF would travel towards sensitive receptors) occur in the spring and summer months.

In the DMA (section 4.3.2), it was explained that an alternative source of meteorological data from the harbour was available. The location of this site is shown on Figure 21 of Appendix A. This data is available covering the period from March 2016 but only includes wind speed and direction. As such, this was not sufficient to carry out the dispersion modelling as parameters such as temperature, relative humidity and cloud cover were not available. However, a high-level comparison of the wind roses was carried out which demonstrated that the wind data was similar between the datasets (i.e. the wind speed and direction was comparable) and it was concluded that using the complete dataset with all the parameters needed for modelling purposes and over a 5-year period was appropriate.

Further analysis of the meteorological data has been carried out for this sensitivity study analysing the seasonal variability in the wind data. This has focussed on 2017 and 2018 so a direct comparison can be made of the full year of data from each site. Annual and seasonal wind roses of the wind data recorded at Portland Harbour can be found in Figure 23 of Appendix A. As shown, on an annual basis these are similar to that from the Isle of Portland observation station. However, there is a slightly larger contribution of winds from the east during the spring and summer than for the Isle of Portland dataset.

The OpenAir package[10] has been used to analyse if there is any bias in the wind speed and direction in the Portland Harbour data compared to the Isle of Portland data as used in the DMA. The results are presented as a wind rose, with an angle of 0° (shown as pointing north) meaning no bias and an angle of 30° meaning that the Portland Harbour data for that hour is 30° greater than the Isle of Portland dataset. This is shown in Figure 24 contained in Appendix A. This confirms that the datasets are broadly similar.

- In 2017, around 80% of the wind measurements were within 20° of each other, with an overall bias of 7° clockwise.
- In 2018, around 75% of the wind measurements were within 20° of each other, with an overall bias of 4° clockwise.
- The difference in wind speeds is about 0.5 m/s on an annual basis.

The differences are explained by the location of each site in relation to the land mass. The Portland Harbour site is located off the breakwater and as such is not influenced by any land when the wind

[10] Carslaw, D. C. and K. Ropkins, (2012) openair --- an R package for air quality data analysis. Environmental Modelling & Software. Volume 27-28, 52-61

direction is from the east, but is likely to see slightly fewer and slower winds from the south-west. The Isle of Portland observation station is located on the west of the headland and based on the topography it is likely that winds from the east would be slowed down by the land mass.

4.4.2 Sensitivity

Neither weather station will be perfectly representative of the winds at the Portland ERF site, which is also influenced by the land mass. It is likely that the true position will lie between the two. Therefore, the sensitivity of the choice of meteorological data has also been carried out. To do so, meteorological datasets in ADMS format has been created for 2017 and 2018 by substituting the wind speed and direction in the Isle of Portland dataset with that from Portland Harbour, but using the other parameters (temperature, relative humidity and cloud cover) from the Isle of Portland dataset as these would not be expected to vary significantly across the Isle.

The following table presents the annual mean, maximum 1-hour, 99.79%ile of 1-hour and maximum 24-hour concentration as a percentage of the predicted concentration using the Isle of Portland data. Figure 25 to Figure 27 contained in Appendix A show the distribution of emissions.

Table 9: Met Data Source

Scenario	Percentage of value calculated using assumptions the Isle of Portland data			
	Annual mean	Maximum 1-hour mean	99.79%ile of 1-hour mean	Maximum 24-hour mean
Point of maximum impact				
Harbour 2017	119%	134%	114%	141%
Harbour 2018	130%	117%	107%	104%
Maximum on land				
Harbour 2017	119%	134%	114%	141%
Harbour 2018	130%	117%	107%	104%
Maximum at Portland eco site				
Harbour 2017	115%	130%	121%	108%
Harbour 2018	178%	117%	107%	158%
Maximum at Chesil eco site				
Harbour 2017	57%	96%	89%	64%
Harbour 2018	86%	112%	96%	195%

As shown the choice of meteorological data has an effect on the distribution of emissions, which would be expected due to the slight differences in the wind speed and direction between the two datasets. Generally, the maximum predicted impacts are higher using the Harbour data. Although the percentage change in the peak predicted impacts is a useful statistic, consideration of the extent of impacts and impact in relation to the assessment level is also important.

The following table provides a break-down of the annual mean and daily mean oxides of nitrogen impact as a percentage of the Critical Level at the Portland and Chesil ecological sites using each of the five years of data from the Isle of Portland (as used in the DMA) and the two years of data from Portland Harbour.

Table 10: Met Data Sensitivity - Effect on on Ecological Impacts

Met data	Annual mean impact (as % of CL)		Daily mean impact (as % of CL)	
	Portland	Chesil	Portland	Chesil
2014 Isle of Portland	0.9%	0.5%	9.6%	3.8%
2015 Isle of Portland	0.8%	0.5%	14.3%	3.4%
2016 Isle of Portland	1.0%	0.5%	15.3%	3.8%
2017 Isle of Portland	0.9%	0.5%	11.3%	5.4%
2018 Isle of Portland	1.3%	0.5%	12.6%	3.8%
2017 Portland Harbour	1.0%	0.3%	12.2%	3.4%
2018 Portland Harbour	2.2%	0.5%	19.8%	7.4%
Average using all data	1.2%	0.5%	13.6%	4.4%
Average using Isle of Portland only	1.0%	0.5%	12.6%	4.0%

Figure 28, shows the areas where the annual mean NOx impact is greater than 1% of the Critical Level, and Figure 29 where the maximum daily mean NOx impact is greater than 10%, using the 5 years of data from the Isle of Portland (as used in the DMA) and the two years of data from Portland Harbour. As shown, using the 2018 data from Portland Harbour results in a larger area of the land where impacts cannot be screened out as insignificant. However, this is away from the port area and the hillside. Using the 2017 data from Portland Harbour, the 1% contour is within the 1% contour using the 2018 data from the Isle of Portland. Therefore, whilst there are some differences between the predicted impacts the change is considered to be within the variability of using different years of meteorological data and the results are considered to be broadly similar.

Therefore, whilst the impacts are different using the wind data from the Portland Harbour, the wind data is not significantly different, the model results are broadly similar and the conclusions of the DMA would be the same.

4.5 Dispersion model

An alternative gaussian plume model is AERMOD. This was developed by AERMIC a collaborative group formed of the American Meteorological Society and the US Environmental Protection Agency (USEPA).

A significant difference between ADMS and AERMOD is the treatment of terrain. Within AERMOD, the effect of terrain is modelled by scaling the sum of two possible extreme plume states. As detailed in the technical response from CERC[11]:

> *"AERMOD …. uses a weighted average of terrain following and sea-level following plumes, effectively ensuring a smooth transition between the two extreme cases (so no splitting into*

[11] CERC, Technical Note: Portland Energy Recovery Facility.

two layers). In both cases, the plume trajectories follow a straight line in the wind direction, meaning that the sea-level following plume can end up going 'through' the hill and out the other side. This means it includes some effects of plume impaction even for only moderately stable flows, resulting in totally unrealistic elevations in concentration on hillsides in such conditions. Such increases in concentration are unphysical and should be ignored except possibly for hills of many hundreds of metres in height, when ADMS would also model plume impaction"

Therefore, Fichtner does not consider that AERMOD is a suitable model in this instance where variations in meteorological effects are significant due to the presence of terrain (and variable surface roughness). The dispersion model has been re-run with AERMOD to substantiate this.

The following table presents the annual mean, maximum 1-hour, 99.79%ile of 1-hour and maximum 24-hour concentration as a percentage of the predicted concentration using ADMS. Figure 30 to Figure 32 contained in Appendix A show the distribution of emissions. Contours have been presented both with and without the effects of terrain included in the model.

Table 11: ADMS vs AERMOD

Scenario	Percentage of value calculated using ADMS			
	Annual mean	Maximum 1-hour mean	99.79%ile of 1-hour mean	Maximum 24-hour mean
AERMOD				
Point of maximum Impact	153%	631%	347%	325%
Maximum on land	153%	631%	347%	325%
Maximum at Portland eco site	281%	660%	365%	365%
Maximum at Chesil eco site	61%	68%	95%	73%

The maximum hourly average predicted using AERMOD is over 6 times higher than for ADMS at the point of maximum impact, which for AERMOD is on the rising terrain close to the stack. These short term differences lead to a significantly higher annual mean impact. The contour plots clearly show this but also show that without the effect of terrain the results are comparable between ADMS and AERMOD, confirming that the differences are primarily due to the different approaches to terrain modelling.

In contrast, AERMOD predicts lower impacts around the headland at Chesil and The Fleet SAC. This is because ADMS stimulates the flow of the airflow (and emissions) around the terrain, unlike AERMOD which assumes straight line transport.

Therefore, the choice of model (ADMS or AERMOD) has a significant effect on the predicted impact with the impact using AERMOD significantly higher than ADMS. However, Fichtner considers that AERMOD is not a suitable model in this situation as it is unable to account for the terrain, as explained by CERC. Therefore, Fichtner considers that the results from AERMOD should be ignored.

5 Modelling Uncertainty

The Environment Agency has requested that the level of uncertainty in the predictions is estimated. To do so, the results of the model validation documentation and the sensitivities have been considered, and the conservatism in the modelling has been reviewed.

5.1 Uncertainty

The validation documentation shows that the levels of uncertainty in the ADMS model with respect to the peak predicted concentrations are typically within 10% of the hourly and daily concentrations, with accuracy over long time frames expected to be at least as high as this.

The sensitivity analysis shows that varying the Monin-Obhukov length and changing the approach to surface roughness leads to changes in the peak results of around 5-15%, which is a similar order to the modelling uncertainty.

Variations in weather data are more complex and feed into the inter-annual variability discussed below.

5.2 Conservative assumptions

In order to allow for modelling uncertainty, the DMA includes a number of conservative assumptions. These are explained and quantified in this section.

5.2.1 Interannual variability

The detailed results tables presented in the DMA included the breakdown of the peak concentration using each year of meteorological data. The maximum predicted impact over the 5-years of data was then used as the basis of the assessment.

Although the interannual variability in the data was presented (in Table 12 and Table 13 in the DMA), the variability of the results was not discussed. This section expands upon the detailed results tables presented in the DMA. The following table provides a breakdown of the range of the predicted impacts for each averaging period. Within this analysis “Portland eco site” refers to the grid points contained within the Isle of Portland to Studland Cliffs SAC and Isle of Portland SSSI, and “Chesil eco site” refers to the grid points contained within Chesil and The Fleet SAC and SSSI.

Table 12: Interannual Variability

Averaging time	Impact as percentage of maximum	
	Minimum	Average
Point of maximum impact		
Annual mean	71%	88%
Max 1-hour	80%	95%
99.79%ile 1-hour	86%	94%
99.73%ile 1-hour	83%	92%
99.9%ile 15-min	88%	93%
Max 24-hour	57%	81%

Averaging time	Impact as percentage of maximum	
	Minimum	Average
Maximum at Portland eco site		
Annual mean	67%	78%
Max 24-hour	63%	82%
Max weekly mean	56%	81%
Maximum at Chesil eco site		
Annual mean	87%	94%
Max 24-hour	64%	75%
Max weekly mean	76%	85%

For the point of maximum impact, the annual average over all five years of weather data is 88% of the highest year, with a range from 71% to 100%. This suggests that using the peak year introduces a conservatism of around 10%. There is less inter-annual variability for shorter-term impacts but still a 5% conservatism is introduced.

At the Portland ecological site, the annual average over all five years of weather data is 78% of the highest year, with a range from 67% to 100%. For ecological impacts the long-term deposition rate of pollutants is important, allowing for interannual variability assuming the impact is the maximum is extremely conservative and on average concentrations would be lower.

5.2.2 Plant availability

The DMA was based on the assumption that the Portland ERF would operate for 100% of the time. This is a very conservative assumption. The plant would be off for periods of maintenance with the expected annual availability of approximately 8,000 hours per year (91%).

5.2.3 Emission limits

The DMA was based on the assumption that the Portland ERF would operate at the long term emission limits for 100% of the time. The ERF will be designed to achieve the limits so would need to operate below these with a safety margin, which means that the actual emissions would be at least 10% below the emission limits. For some pollutants, operating data from other ERFs shows that emissions would be even lower than this.

5.2.3.1 VOCs

The analysis assumed that the entire TOC emissions consist of only benzene or 1,3-butadiene. This is an extremely conservative assumption as the emissions would consist of a range of VOCs and typically emissions are well below the daily ELV of 10 mg/Nm^3. Fichtner has analysed annual performance reports submitted to the EA from all of the energy from waste plants across England in 2019. This has shown that, in 2019, the maximum monitored daily VOC concentration across the entire fleet was 4.3 mg/Nm^3 (or 43% of the ELV) and the average was 0.53 mg/Nm^3 (or 5.3% of the ELV).

5.2.3.2 Cadmium

As set out in Section 7.4 of the DMA, the Waste Incineration BREF shows that the average concentration recorded from UK plants equipped with bag filters was 1.6 µg/Nm^3 (or 8% of the ELV of 0.02 mg/Nm^3), the highest recorded concentration of cadmium and thallium was 14 µg/Nm^3 (or 70% of the ELV of 0.02 mg/Nm^3) and only three lines recorded concentrations higher than 10 µg/Nm^3 (or 50% of the ELV of 0.02 mg/Nm^3).

Assuming that the Portland ERF would operate at the level of the average UK plant the impact would be 0.29% of the AQAL at the point of maximum impact using the maximum predicted impact over 5 years of weather data. Taking into account the average concentration using the 5-years of weather data the impact would be reduced to 0.26 % of the AQAL. This still conservatively assumes that the Portland ERF would operate 100% of the year.

5.2.3.3 Acid gases

A lime (or sodium bicarbonate) dosing system is used for the control of acid gases on other energy from waste plants in England. The level of dosing is linked to achieve the emission limit. Hydrogen chloride is usually used as the marker and the dosing linked to achieving the limit within about 10%. The level of dosing typically ensures that sulphur dioxide levels are also reduced. The Waste Incineration BREF introduces a lower ELV for hydrogen chloride and sulphur which none of the existing energy from waste plants needs to currently achieve. However, the review of the annual performance reports submitted to the EA from all of the energy from waste plants across England has shown that in 2019 the maximum monitored daily mean sulphur dioxide concentration was 43 mg/Nm^3 (compared to the current ELV of 50 mg/Nm^3) and the average was 14.7 mg/Nm^3. The average monitored concentration was well within the proposed ELV of 30 mg/Nm^3.

In addition to this, it is expected that the dosing rate of lime will be increased at existing UK plants (and at Portland) to achieve the lower hydrogen chloride ELV. This will also result in lower sulphur dioxide levels.

5.2.3.4 Nitrogen oxides and ammonia

Typically, an energy from waste plant uses an SNCR system to control emissions of oxides of nitrogen. An ammonia / urea solution is used and can result in emissions of ammonia (known as ammonia slip). Fichtner has analysed annual performance reports submitted to the EA from all of the energy from waste plants across England. This shows that the lower the level of oxides of nitrogen emissions, the higher the levels of ammonia slip.

The system is designed to inject sufficient ammonia to achieve the emission limit and typically will operate within 10% of the limit for oxides of nitrogen. The levels of ammonia slip vary considerably but all are well within the emission limit. The limit for oxides of nitrogen at Portland ERF is significantly lower than any of the existing plants and so it cannot be confirmed what the likely levels of ammonia would be. However, the plant will be designed to achieve the limits for oxides of nitrogen and ammonia simultaneously with a margin of error, which means that actual emissions will be around 10% less than emission limit.

5.2.4 Short term impacts

For short term impacts (as set out in Section 7.5 of the DMA) it was assumed that the period when the plant would need to operate at the half-hourly ELV would occur for an entire hour, during the worst-case weather conditions for dispersion. Even with this assumption, all short term impacts could be screened out as insignificant with the exception of nitrogen oxides and sulphur dioxide.

This is a highly conservative assumption. In order to achieve the daily ELV, ERFs are operated to achieve the daily ELV for each hour, with only occasional emissions above this.

Furthermore, the half-hourly ELV is that from the IED. The WI BAT Conclusions introduce a lower daily limit for oxides of nitrogen and sulphur dioxide, which mean that the Portland ERF will generally be operating at lower emission levels and so short term excursions above the daily ELV are likely to be lower. The IED half-hourly limit for oxides of nitrogen is 2 times the IED daily limit, whilst the half-hourly limit for sulphur dioxide is 4 times the daily limit. With the reduced ELVs, the half-hourly limit will be 3.3 times the daily ELV for oxides of nitrogen, and 6.7 times the daily ELV for sulphur dioxide. Therefore, it is unlikely that peaks in short term emissions would be this high given that a lower daily ELV needs to be achieved.

A breakdown of the effect of this upon the short-term nitrogen dioxide and sulphur dioxide impacts was presented in Table 17 of the DMA. This showed that if this same ratio is applied to the emissions from the Portland ERF and it is assumed that the plant operates at this level during the worst-case meteorological conditions for dispersion, then the maximum 1-hour impact of nitrogen dioxide and sulphur dioxide is less than 10% of the AQAL. The maximum impact of 15-minute sulphur dioxide emissions remains slightly above 10% of the AQAL but this would be over a very small area. This is not considered to be a significant impact.

5.3 Overall effect on results

The conservative assumptions explained above mean that the overall impacts presented in the DMA will be overestimates.

1. Annual mean impacts are overstated by around 10% due to plant availability, by around 10% when inter-annual variability is considered and by at least 10% when allowing for operation below the emission limits. This means that, overall, the annual mean impacts in the DMA have inbuilt conservatism of at least 30%.
2. For short term impacts, selecting the worst case weather conditions across all five years of weather data introduces conservatism of at least 5%, and assuming operation at the short term ELVs introduces conservatism of as much as 50-70%.
3. The validation documentation shows that the level of uncertainty in the model are on average within 10% of the hourly and daily concentrations, with accuracy over long time frames expected to be at least as high as this.
4. The sensitivity analysis shows that variations in modelling assumptions leads to changes in the peak concentrations of 5-15%.

Therefore, it is considered that the results presented in the DMA are robust as the inbuilt conservatism is of a similar order to the uncertainty in the modelling.

6 Summary and conclusions

This report has been produced to provide clarifications on the approach used in the DMA and to conduct a sensitivity analysis on the effect of the choice of model inputs on the predicted impacts.

A review of the technical and validation documents for the ADMS model has been undertaken and used to explain why it is considered that the ADMS model is appropriate for modelling impacts from the proposed ERF in Portland. This has demonstrated that the location conditions are well within the modelling capabilities. CERC has provided a technical note which explains that the use of the model is entirely appropriate as the model has been designed for these types of locations.

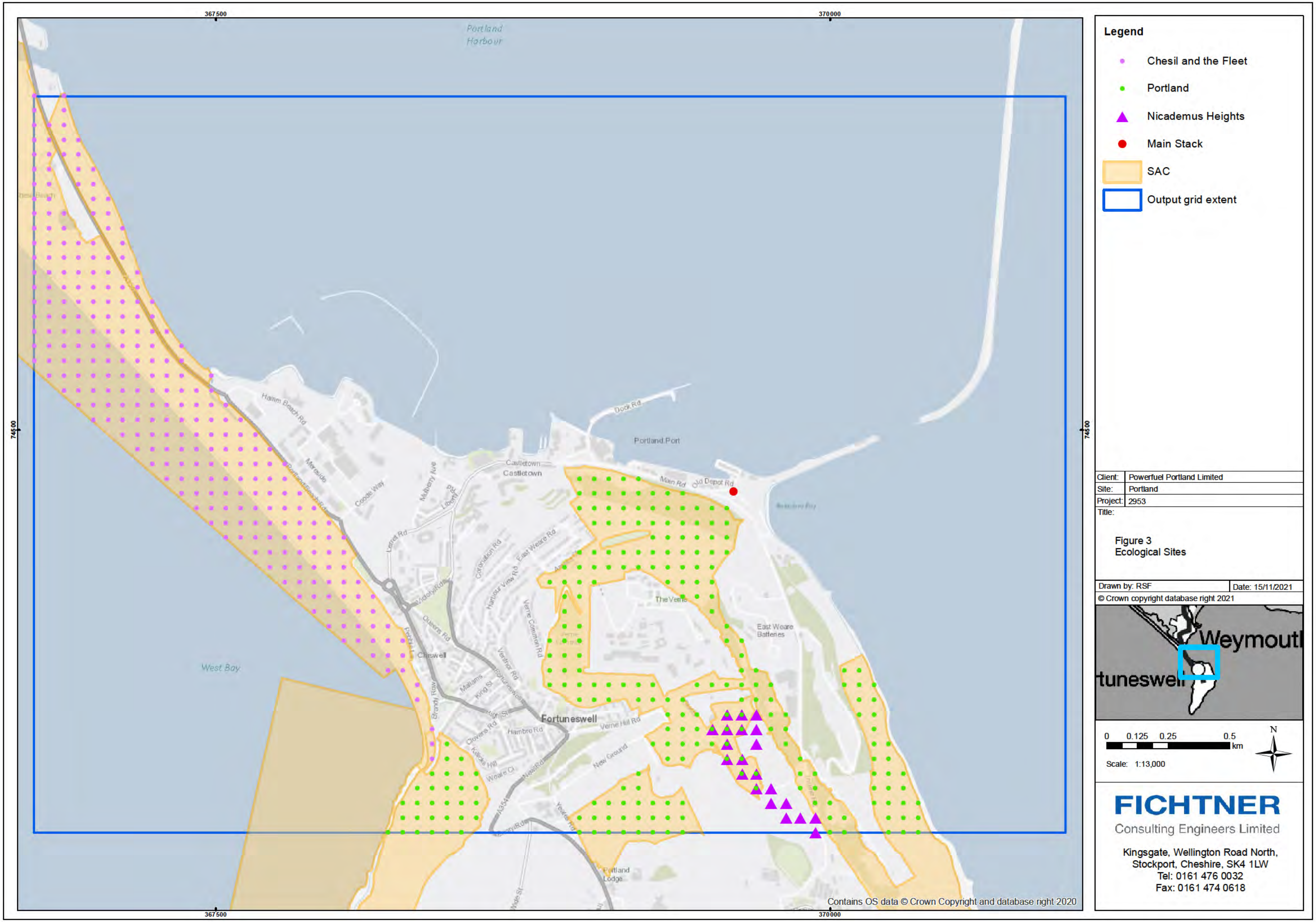
The sensitivity analysis has shown that, whilst the dispersion model is sensitive to the choice of input parameters for the ADMS model, these do not have a significant effect on the predicted results with the distribution of emissions broadly similar. In each case, the conclusions of the DMA would be the same if different input parameters were used.

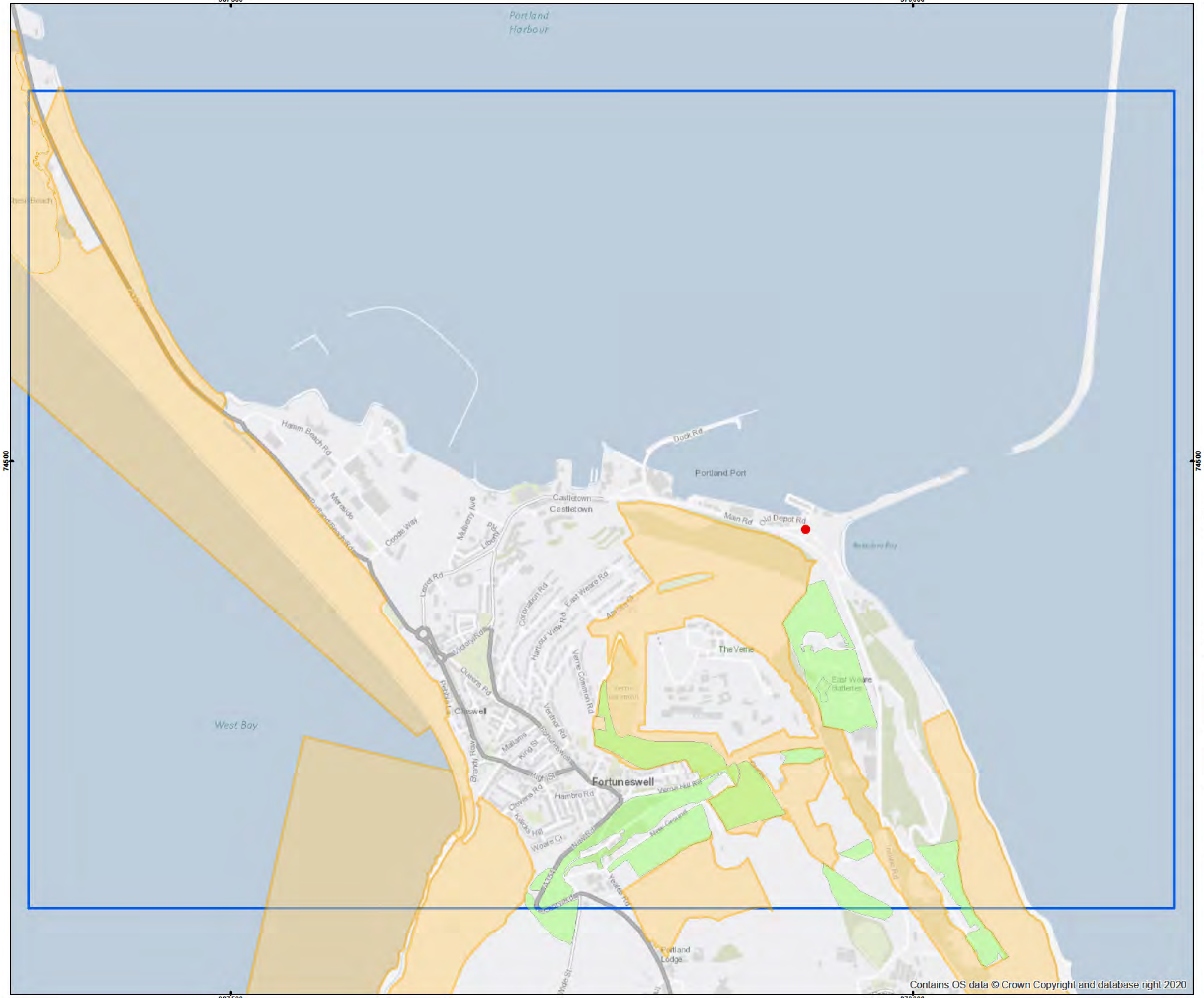
The choice of model has a significant effect with significantly higher impacts predicted using AERMOD on the area of elevated terrain close to the plant. However, Fichtner considers that AERMOD is not a suitable model for the terrain around the Portland ERF and therefore considers that the results from AERMOD should be disregarded.

An estimation of the uncertainty in the modelling has been carried out to determine whether the uncertainty would affect the conclusions set out in the DMA. This has shown that the overall impacts presented in the DMA are robust as the inbuilt conservatism is of a similar order of uncertainty in the modelling.

Appendices

A Figures


Legend
Chesil and the Fleet
Portland
Nicademus Heights
Main Stack
SAC
Output grid extent
Portland Harbour
Portland Port
Dock Rd
Main Rd
Old Depot Rd
Castletown
Hamm Beach Rd
The Verne
East Weare Batteries
Chiswell
Fortuneswell
West Bay
Verne Hill Rd
New Ground
Portland Lodge
367500
370000
74500
Contains OS data © Crown Copyright and database right 2020
Client: Powerfuel Portland Limited
Site: Portland
Project: 2953
Title:
Figure 3
Ecological Sites
Drawn by: RSF
Date: 15/11/2021
© Crown copyright database right 2021
Weymouth
Fortuneswell
0 0.125 0.25 0.5
km
Scale: 1:13,000
N
FICHTNER
Consulting Engineers Limited
Kingsgate, Wellington Road North,
Stockport, Cheshire, SK4 1LW
Tel: 0161 476 0032
Fax: 0161 474 0618



Legend

- Main Stack
- Local ecological sites
- SPA
- SAC
- Output grid extent

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 4 Local Ecological Sites

Drawn by: RSF | Date: 15/11/2021

0 0.125 0.25 0.5 km

Scale: 1:13,000

N

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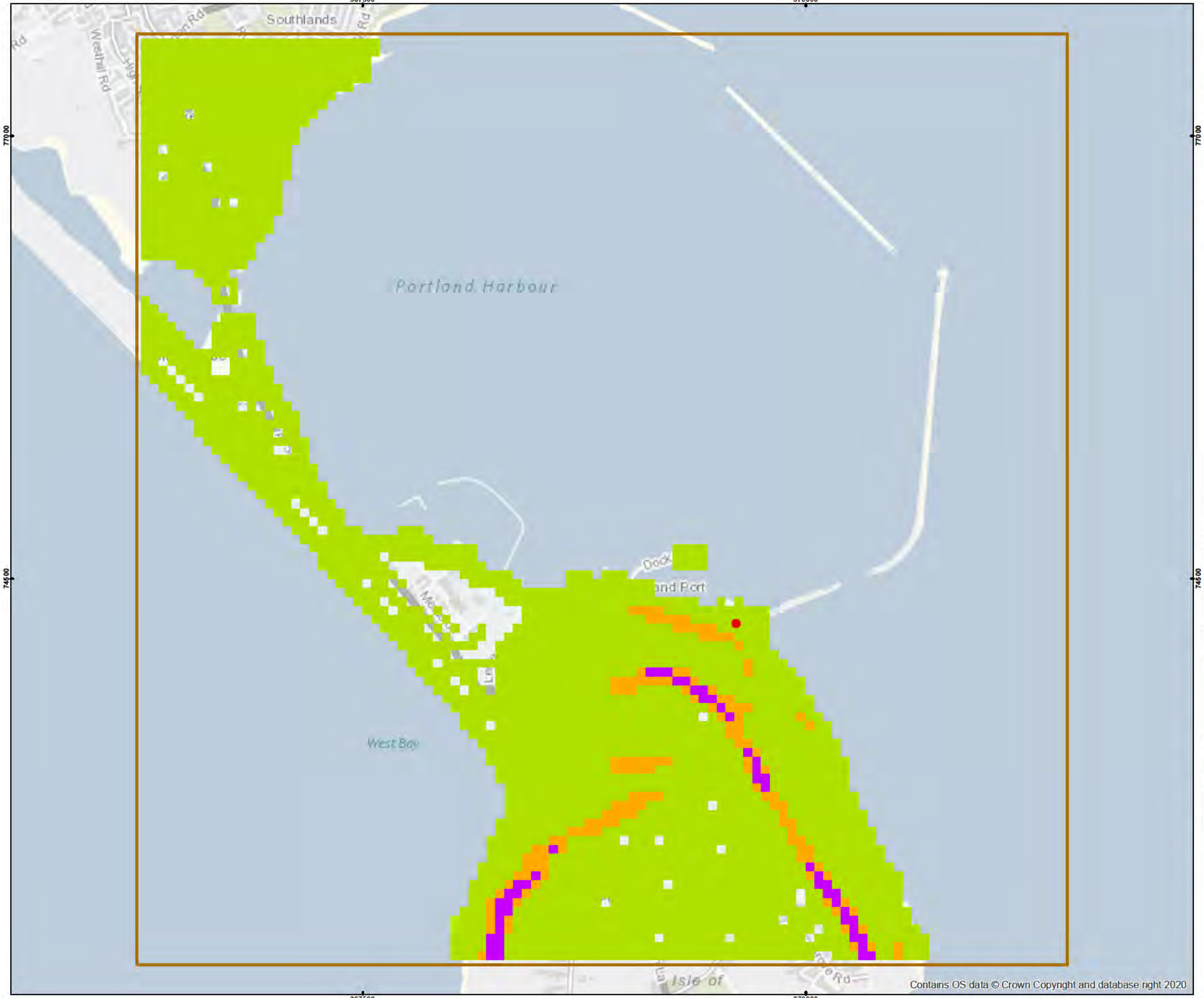

Legend

- Main Stack
- Terrain Extents

Angle of Slope

- 0 - 1
- 1 - 33%
- 33 - 50% i.e. > 1:3
- >50% i.e. > 1:2

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 5 Slope Analysis
Drawn by: RSF	Date: 15/11/2021

0 0.2 0.4 0.8 km

Scale: 1:20,000

N

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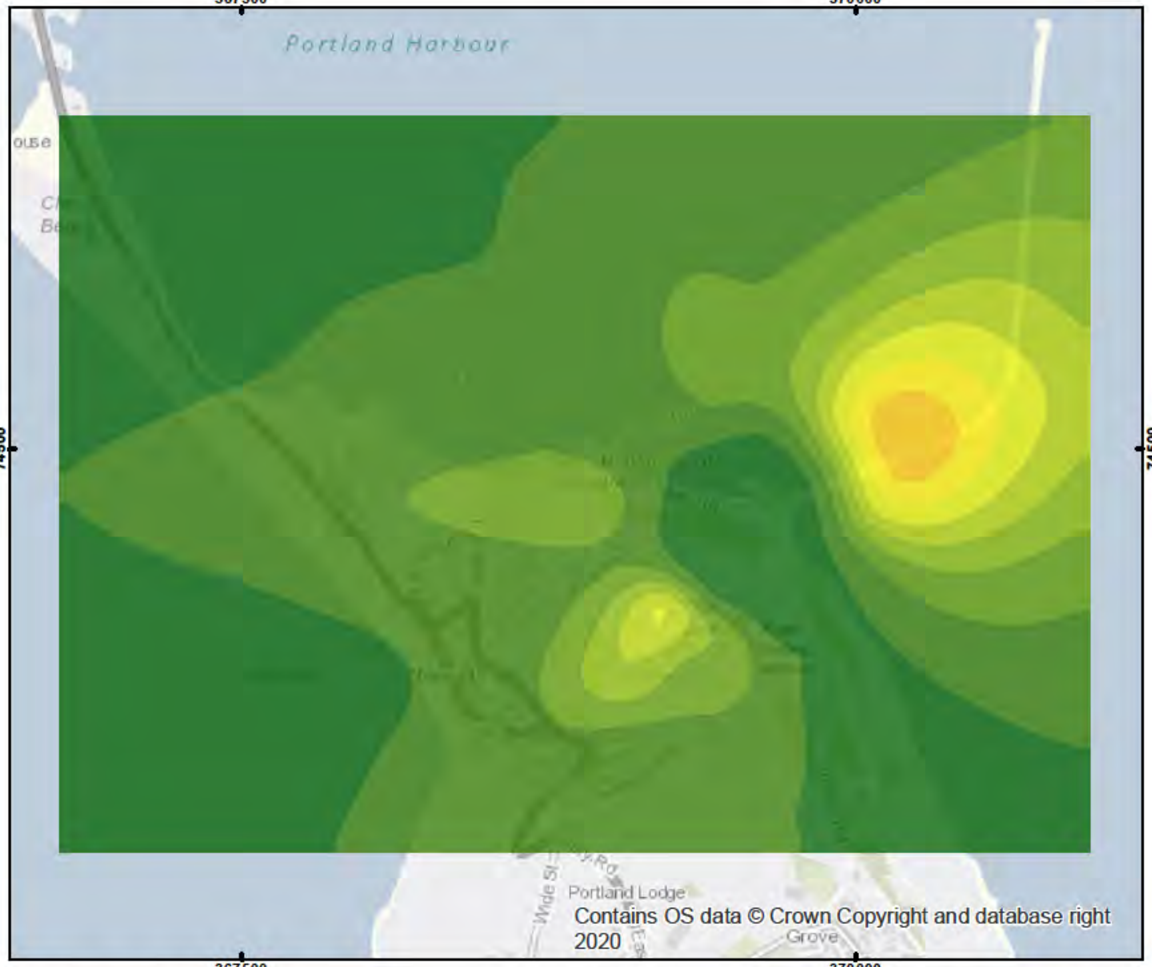
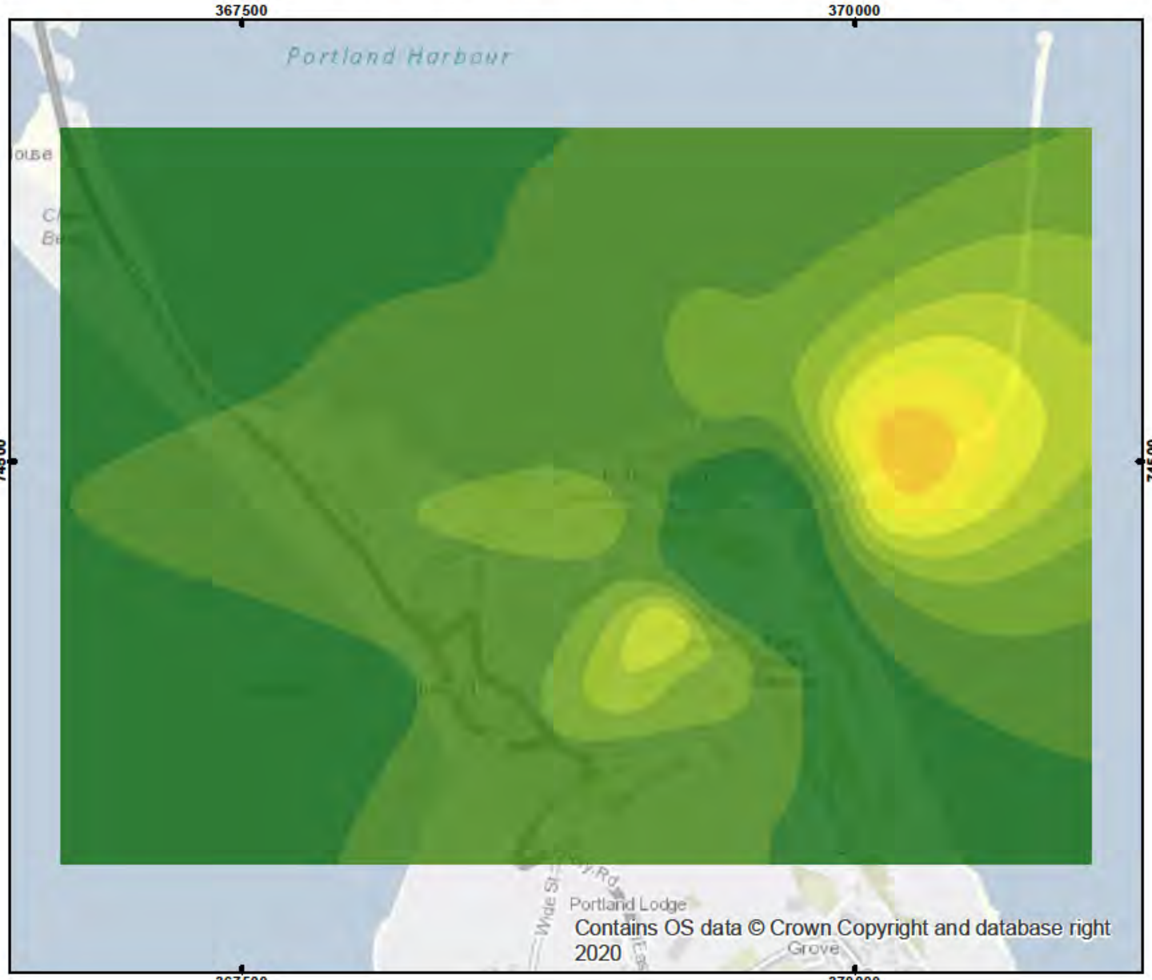
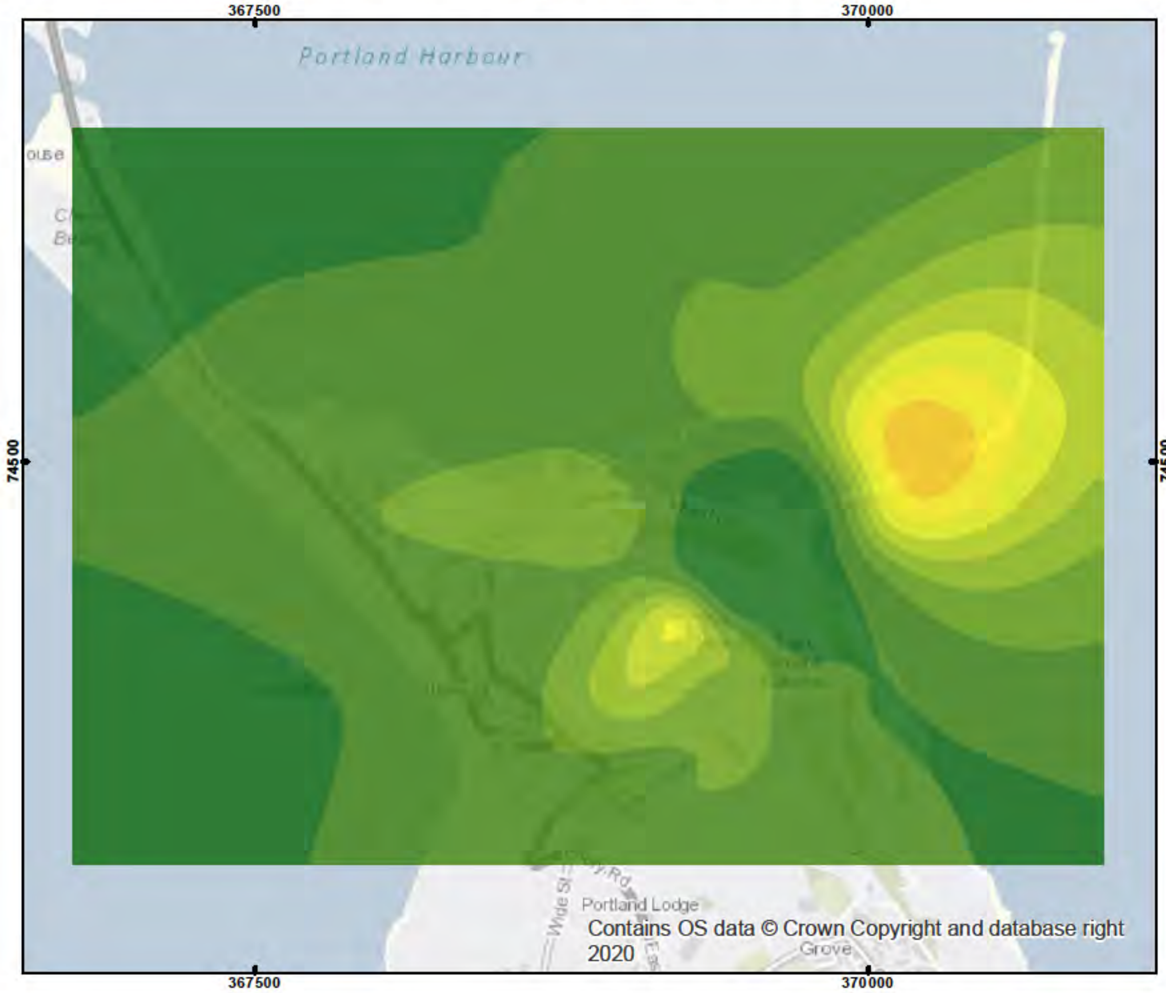
Base



Minimum Monin Obukov Length = 1 m - default



Minimum Monin Obukov Length = 30 m



Legend

Annual mean NOx

ug/m3

- <0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1
- 1 - 1.1
- 1.1 - 1.2

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 6: Minimum Monin Obukov Length Sensitivity Analysis
Drawn by: RSF	Date: 09/11/2021

0 0.3 0.6 1.2 km

N

Scale: 1:30,800

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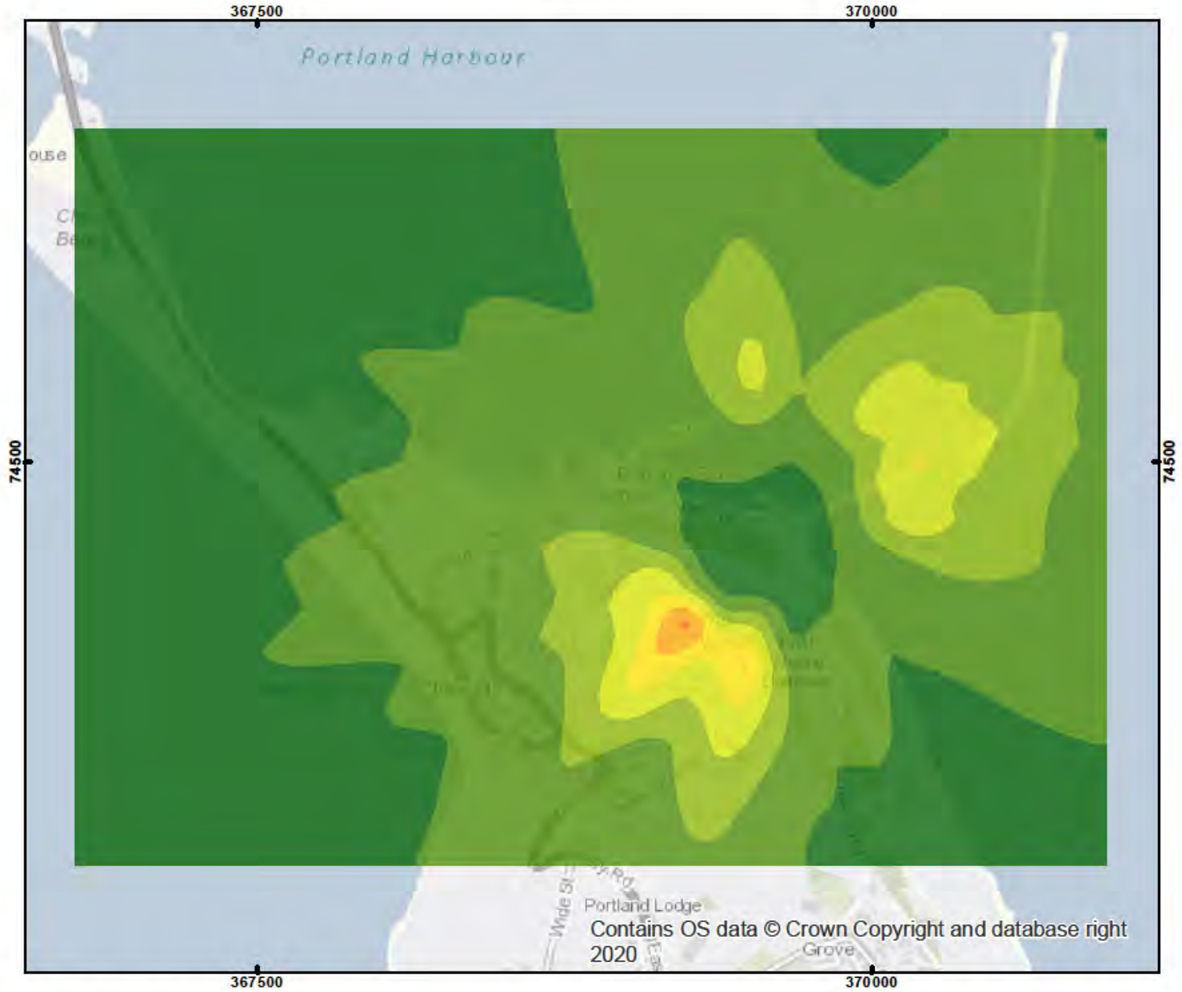
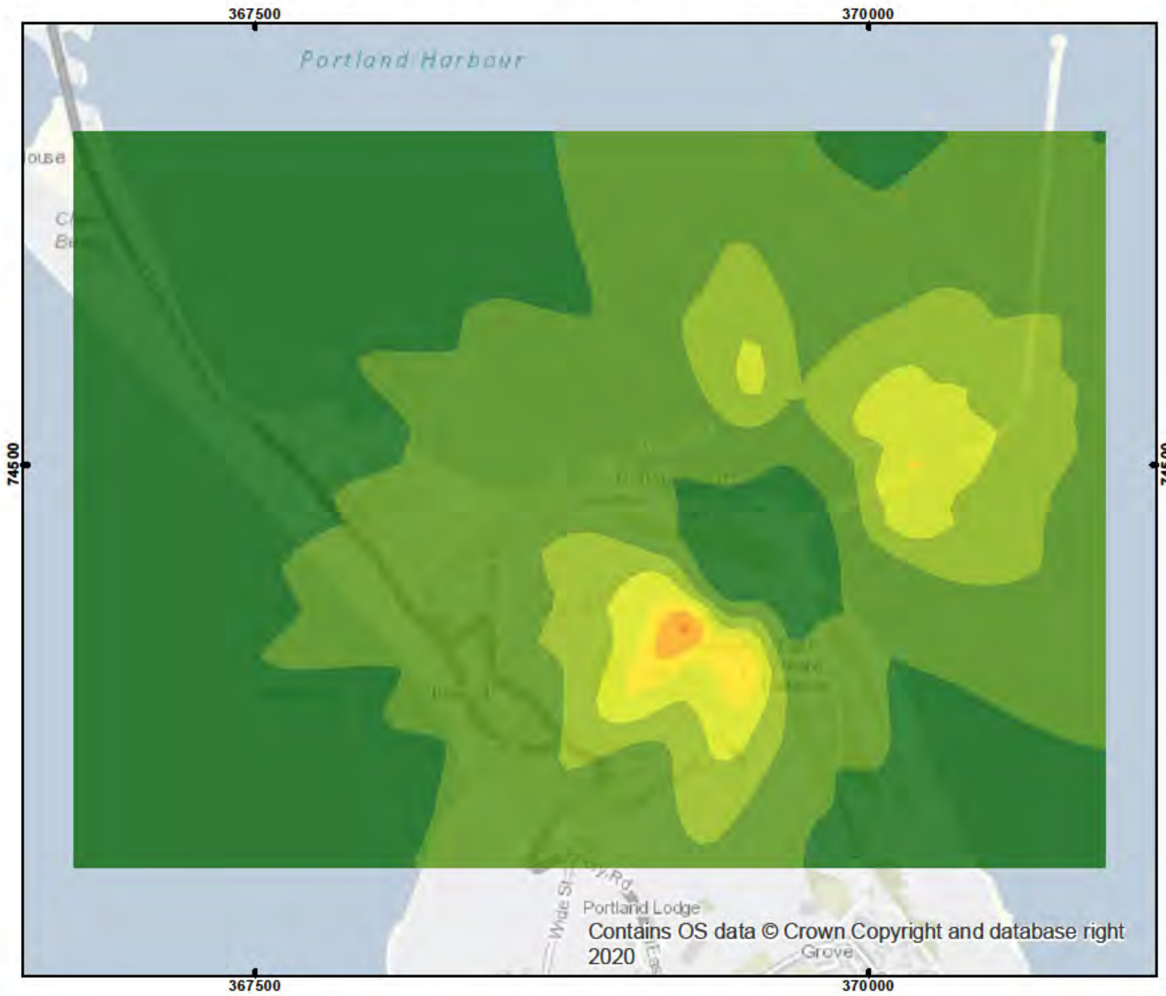
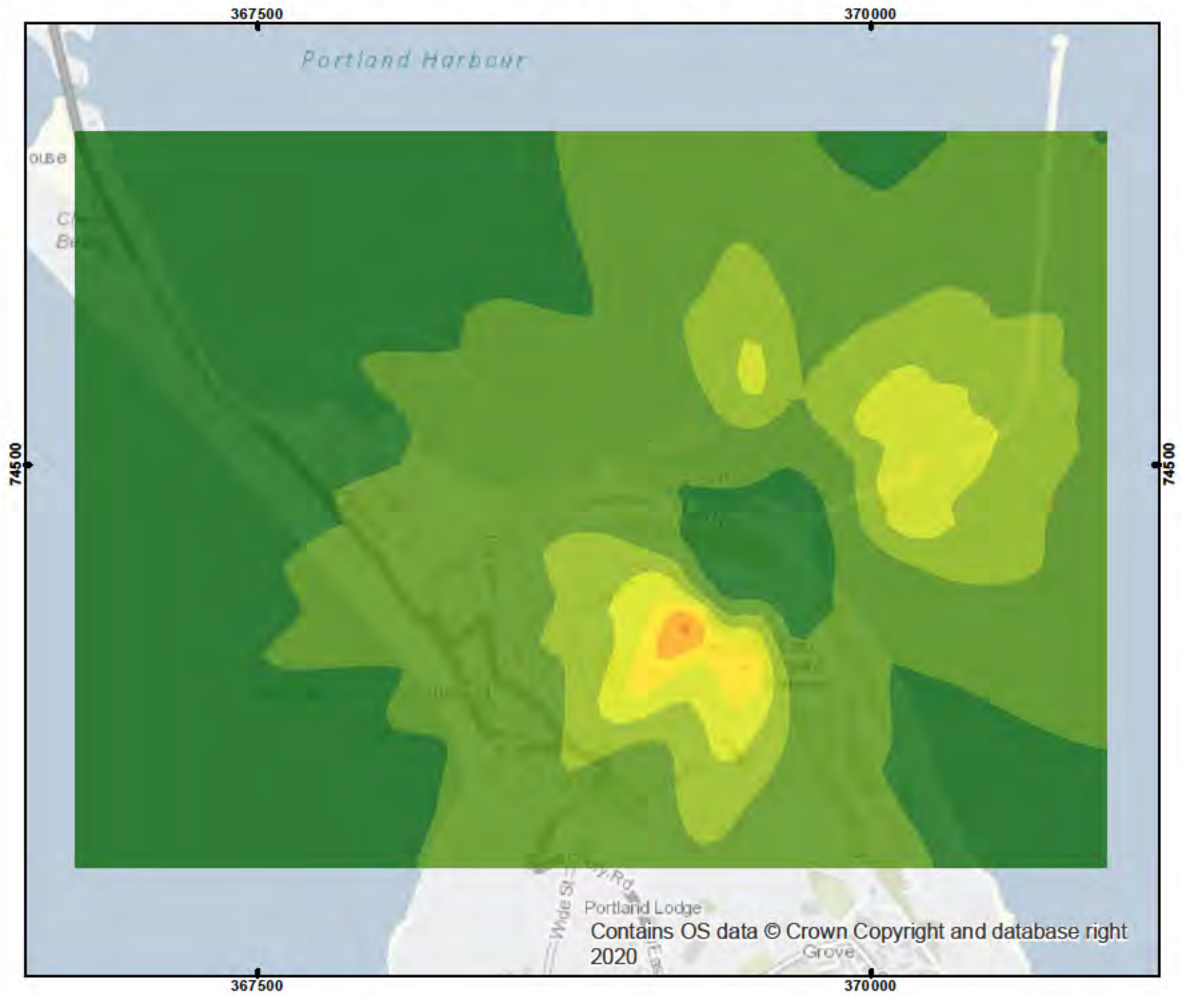
Base



Minimum Monin Obukov Length = 1 m - default



Minimum Monin Obukov Length = 30 m



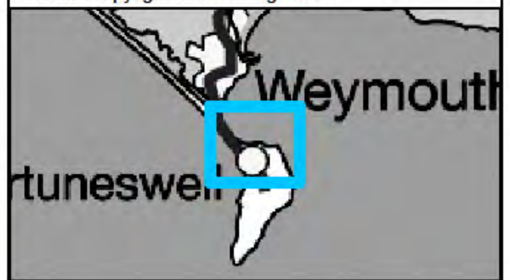
Legend

Maximum 24-hour mean NOx

ug/m3

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 7: Minimum Monin Obukov Length Sensitivity Analysis
Drawn by: RSF	Date: 09/11/2021



0 0.3 0.6 1.2 km

N

Scale: 1:30,800

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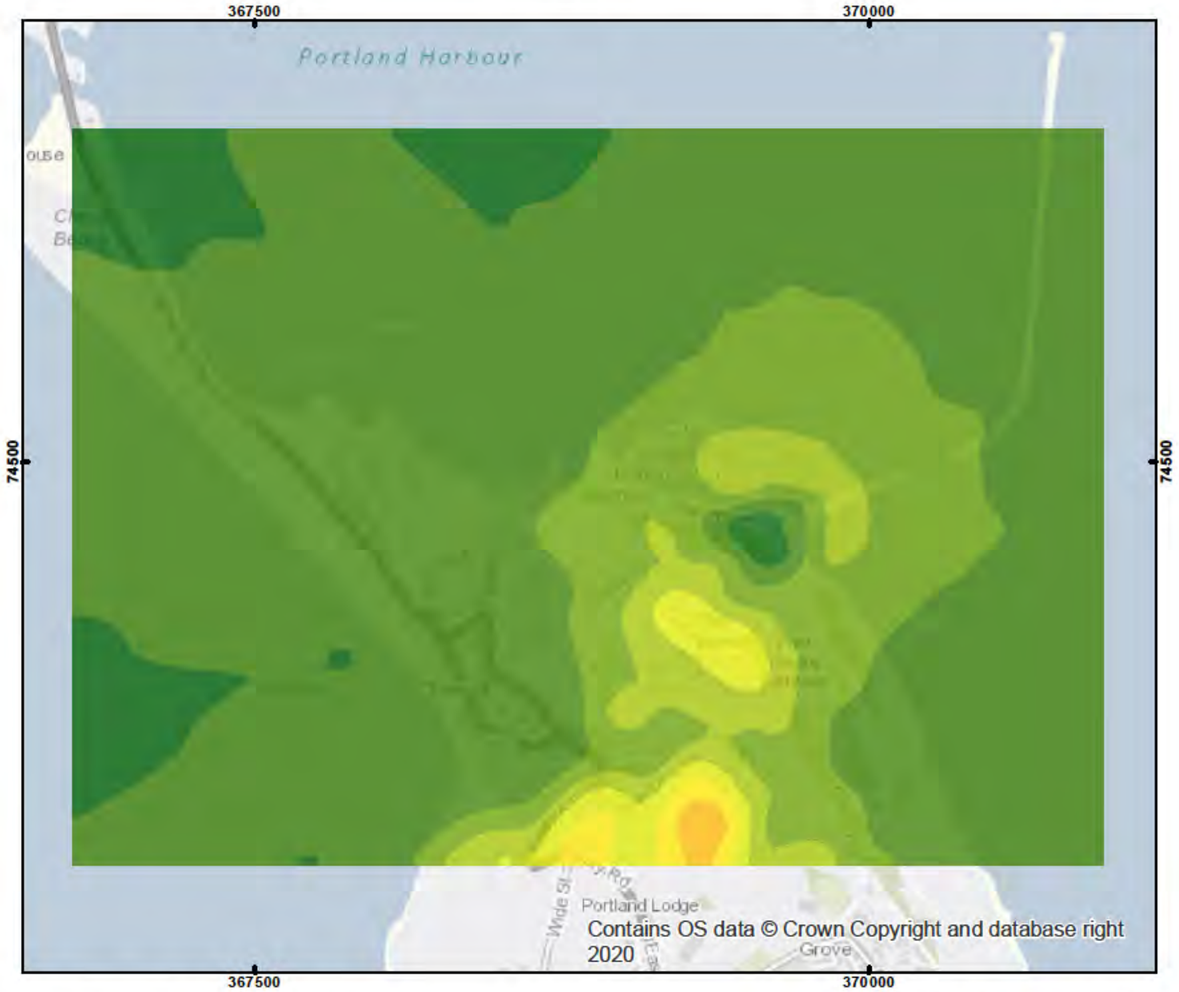
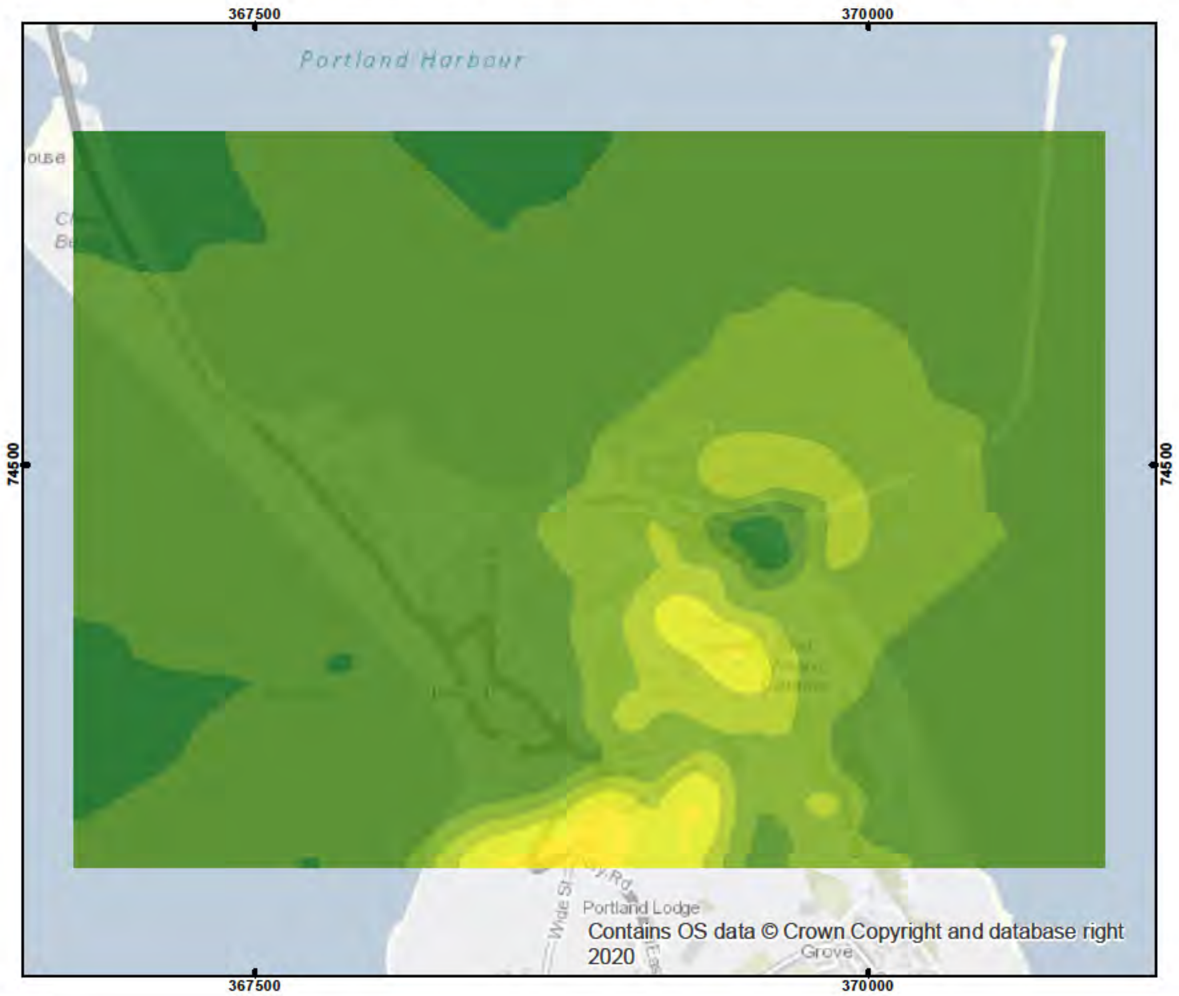
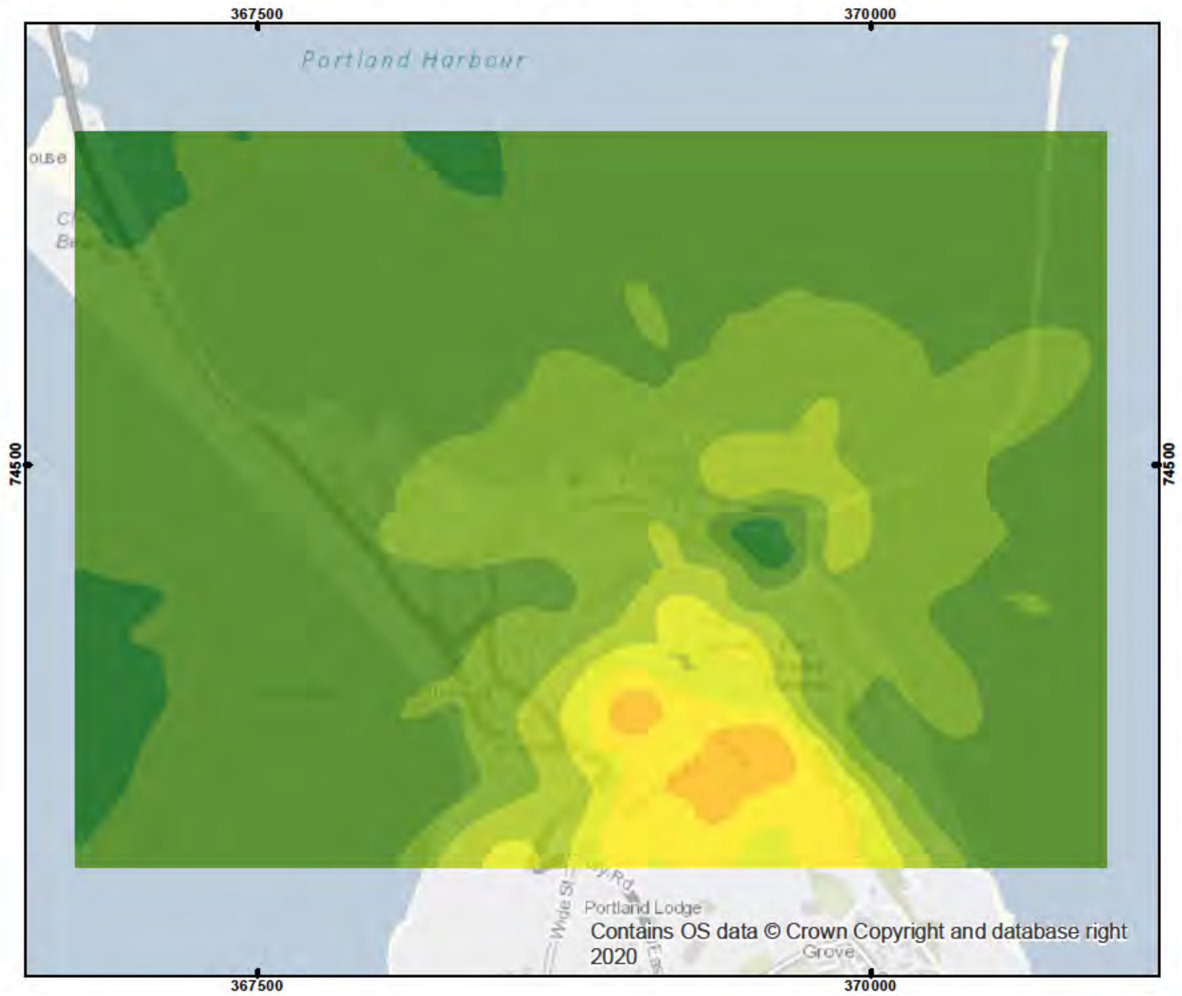
Base



Minimum Monin Obukov Length = 1 m - default



Minimum Monin Obukov Length = 30 m



Legend

Maximum 1-hour mean NOx

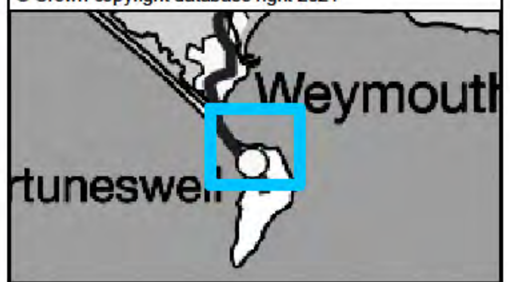
ug/m3

- <5
- 5 - 10
- 10 -15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	

Figure 8:
Minimum Monin Obukov Length
Sensitivity Analysis

Drawn by: RSF	Date: 09/11/2021



0 0.3 0.6 1.2 km

N

Scale: 1:30,800

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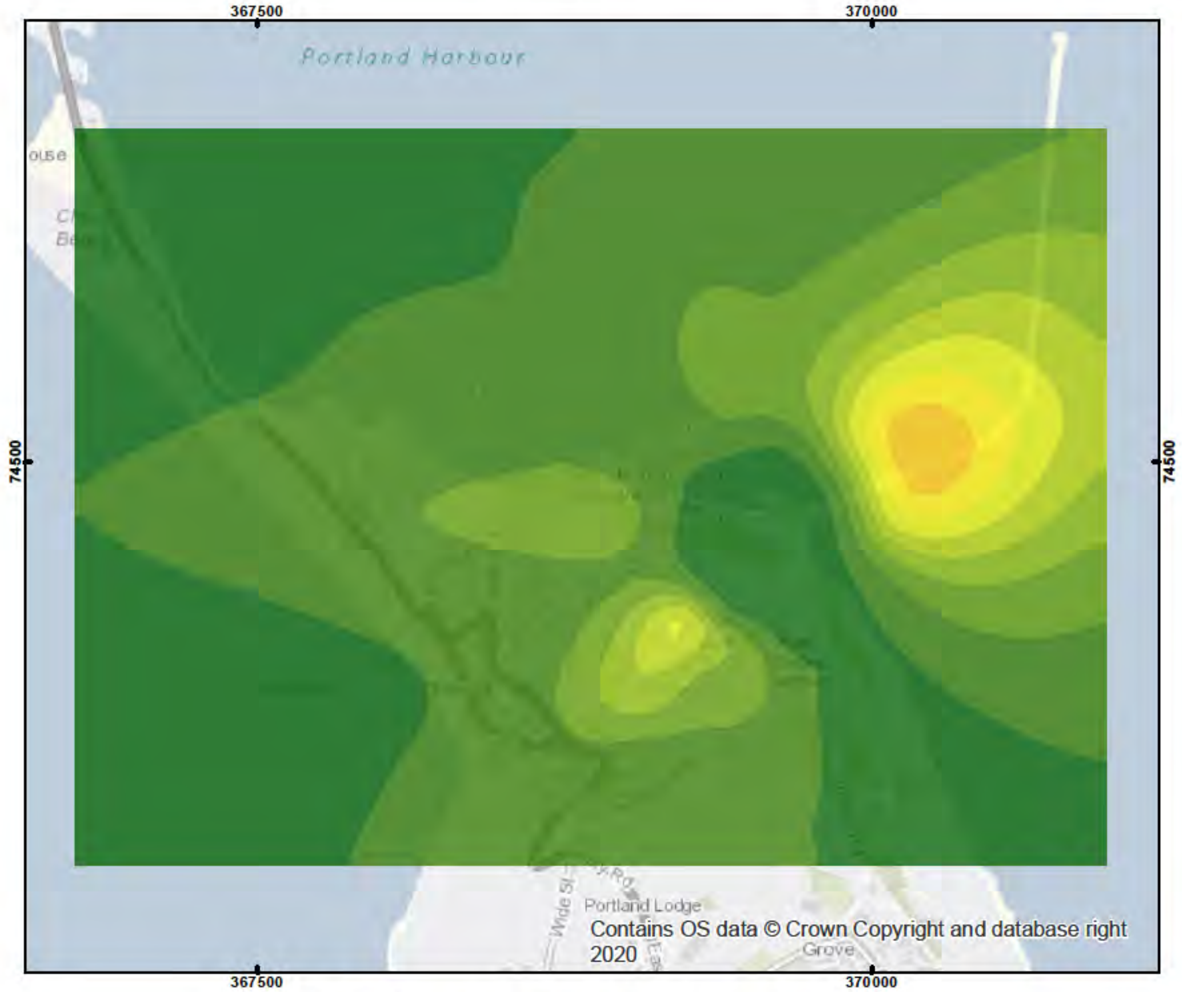
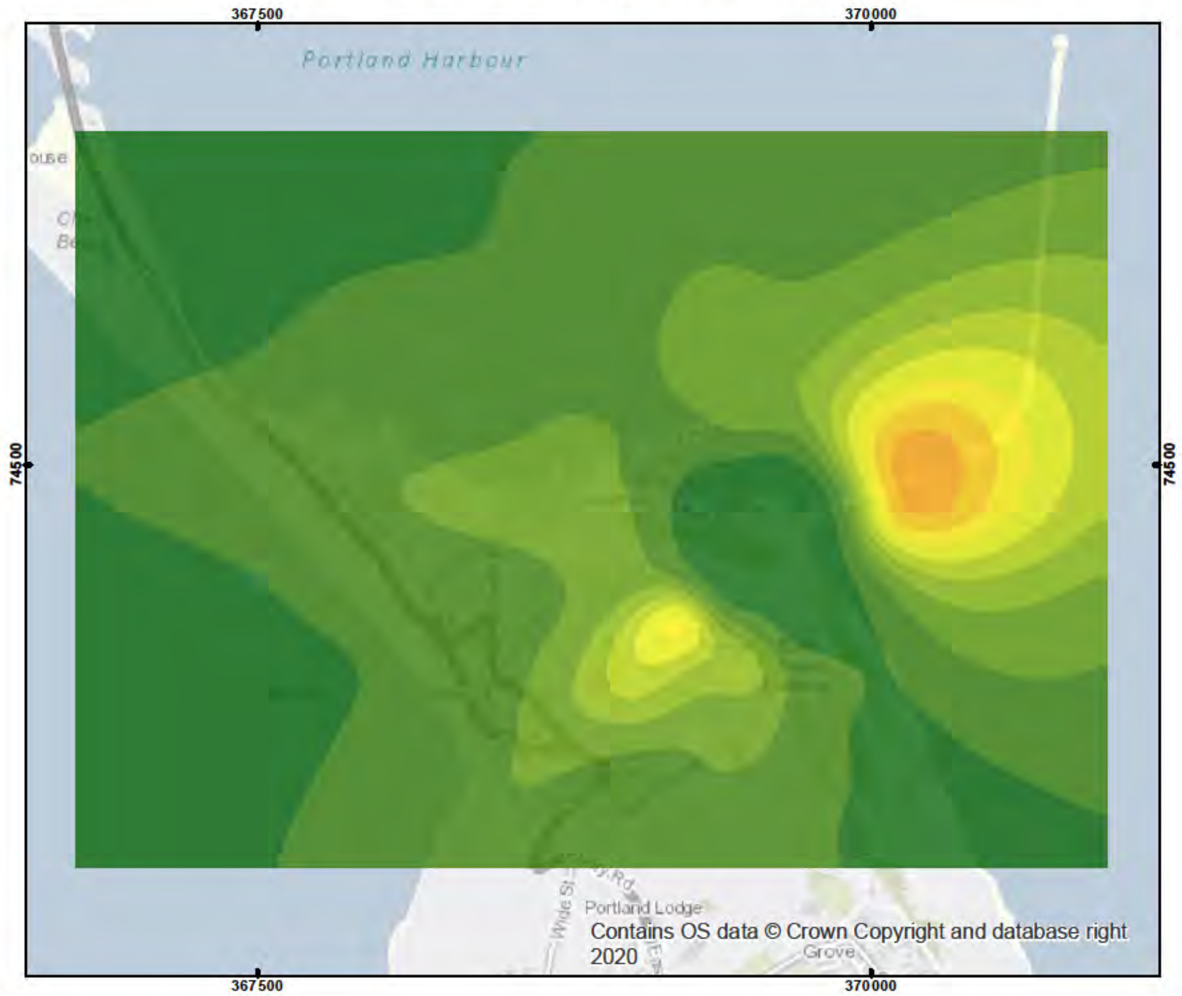
Base



Met Site Surface Roughness = 0.005 m

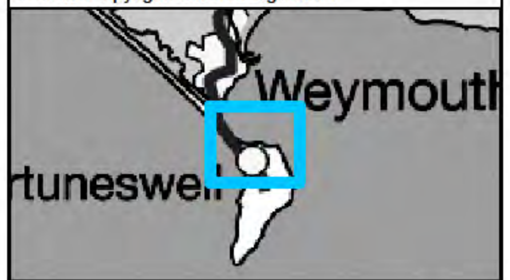


Legend

Annual mean NOx ug/m3

- <0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1
- 1 - 1.1
- 1.1 - 1.2

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 9 Met Site Surface Roughness Length Sensitivity Analysis
Drawn by: RSF	Date: 09/11/2021



Scale: 1:30,800

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Tel: 0161 476 0032
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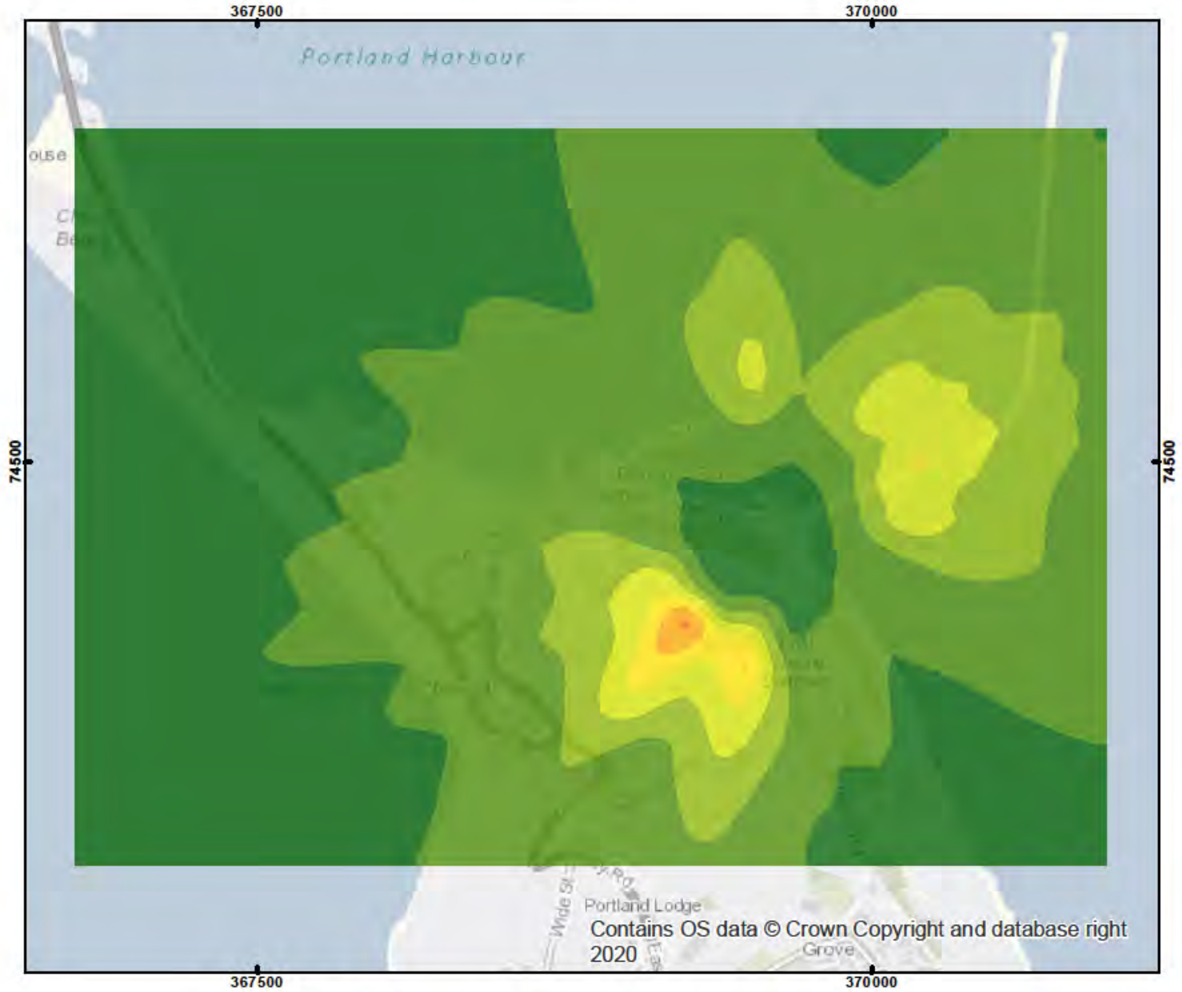
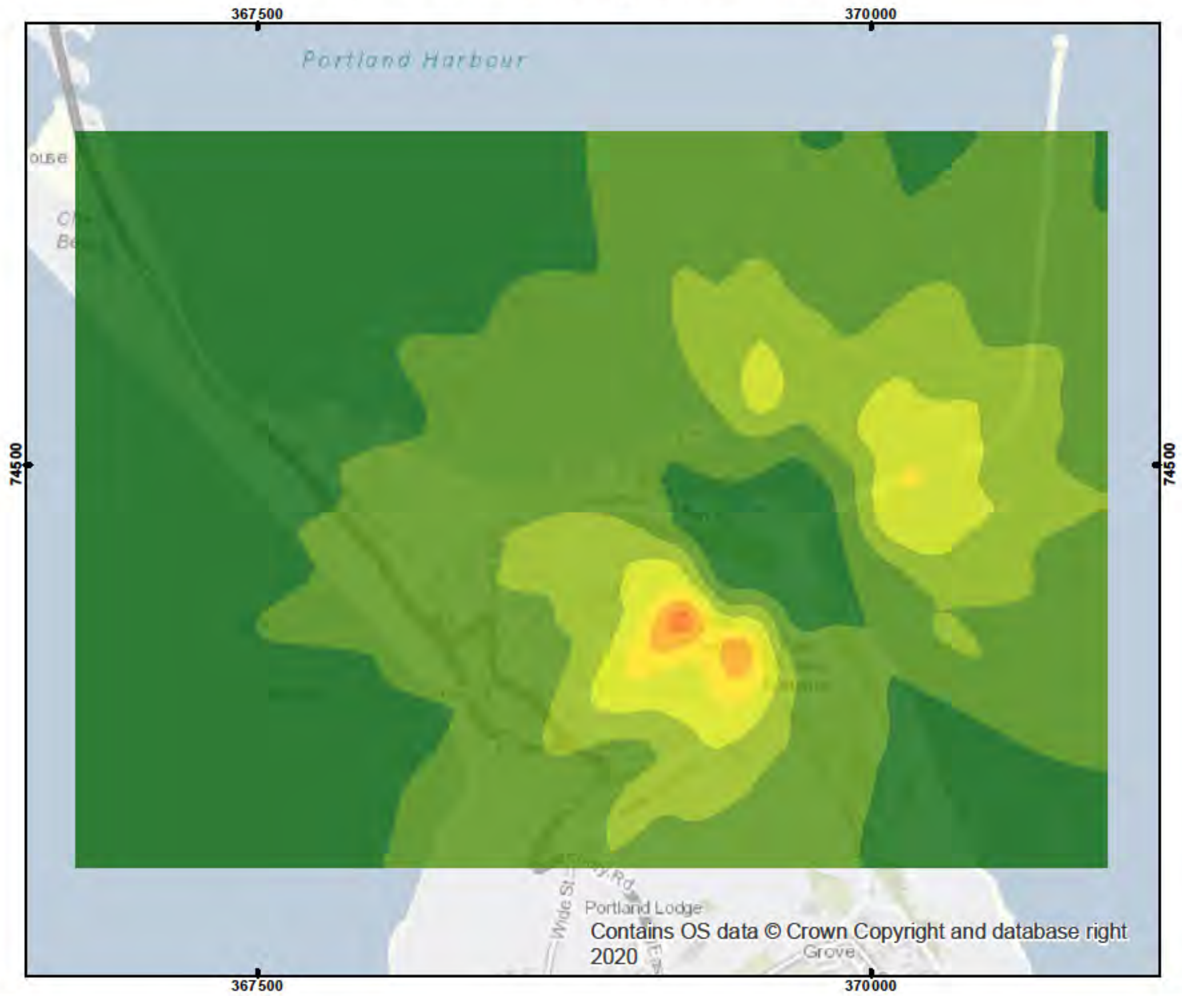
Base



Met Site Surface Roughness = 0.005 m



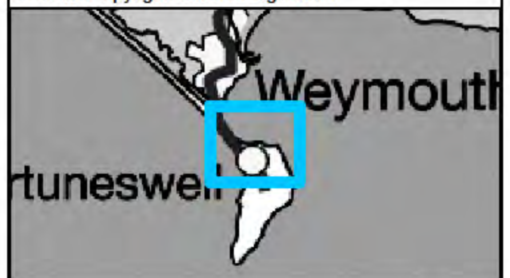
Legend

Maximum 24-hour mean NOx

ug/m3

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 10 Met Site Surface Roughness Length Sensitivity Analysis
Drawn by: RSF	Date: 09/11/2021



0 0.3 0.6 1.2 km

Scale: 1:30,800

N

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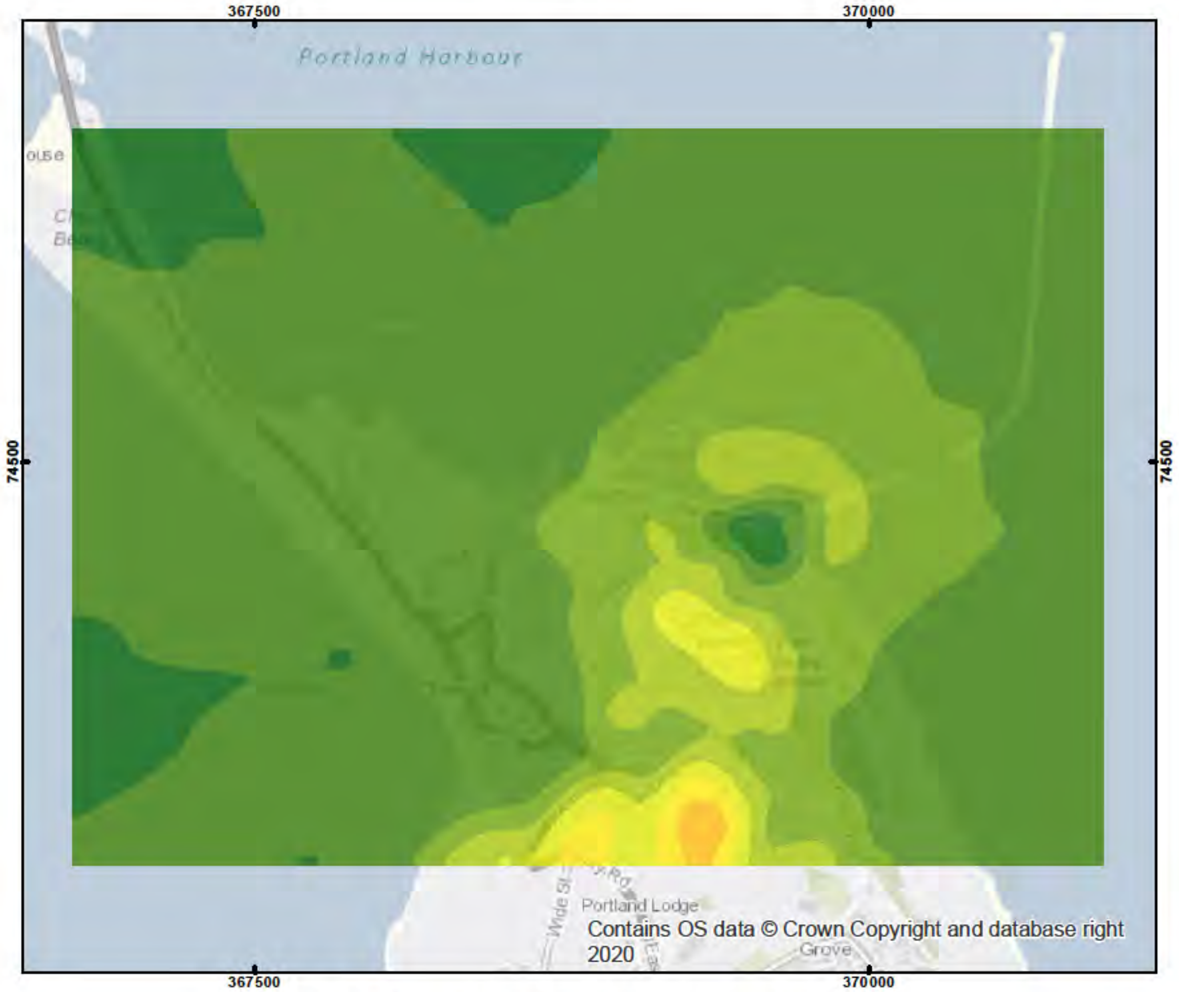
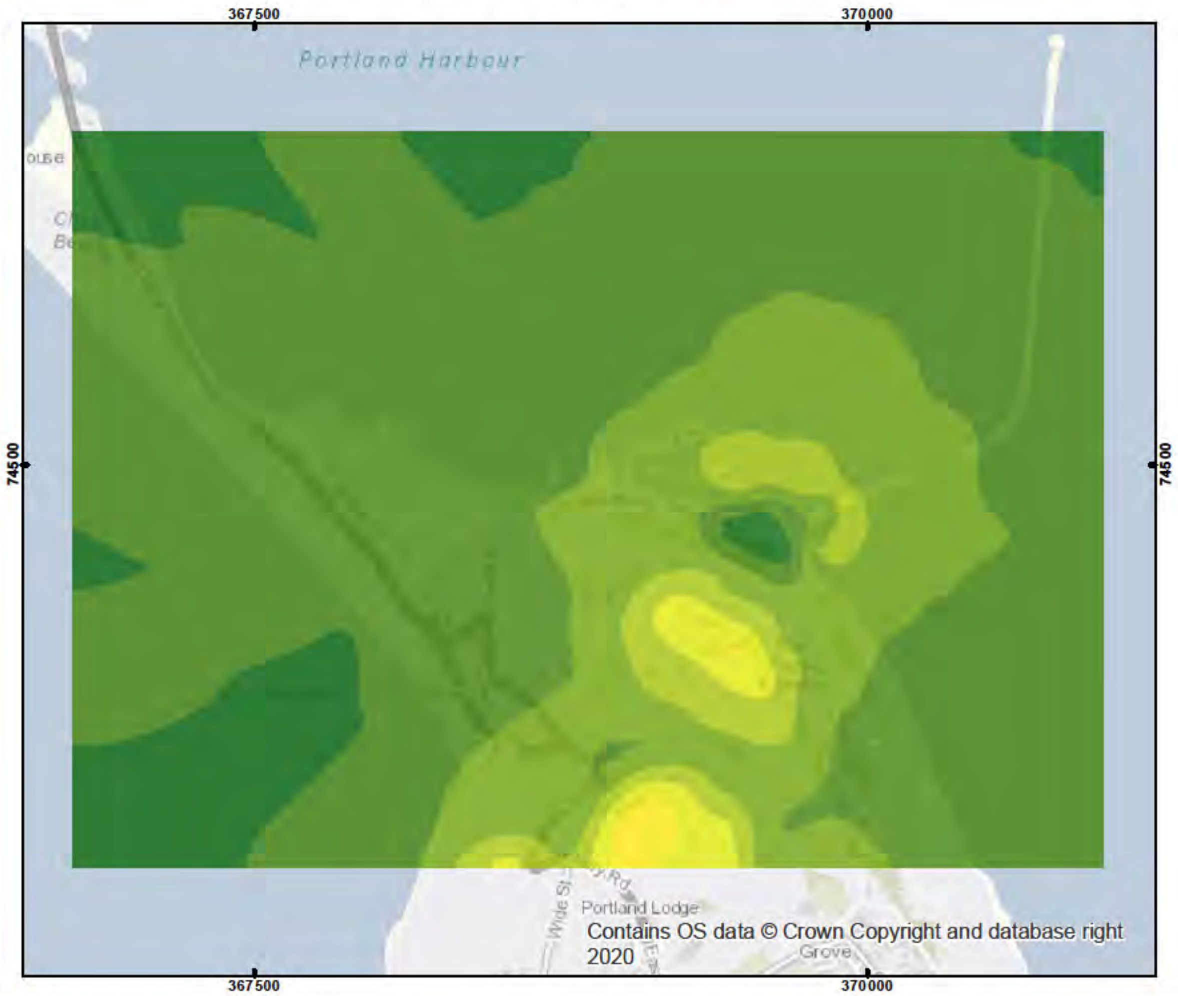
Base



Met Site Surface Roughness = 0.005 m



Legend

Maximum 1-hour mean NOx

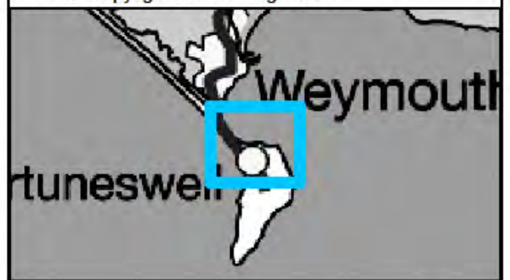
ug/m3

- <5
- 5 - 10
- 10 -15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	

Figure 11
Met Site Surface Roughness Length Sensitivity Analysis

Drawn by: RSF	Date: 09/11/2021



0 0.3 0.6 1.2 km

N

Scale: 1:30,800

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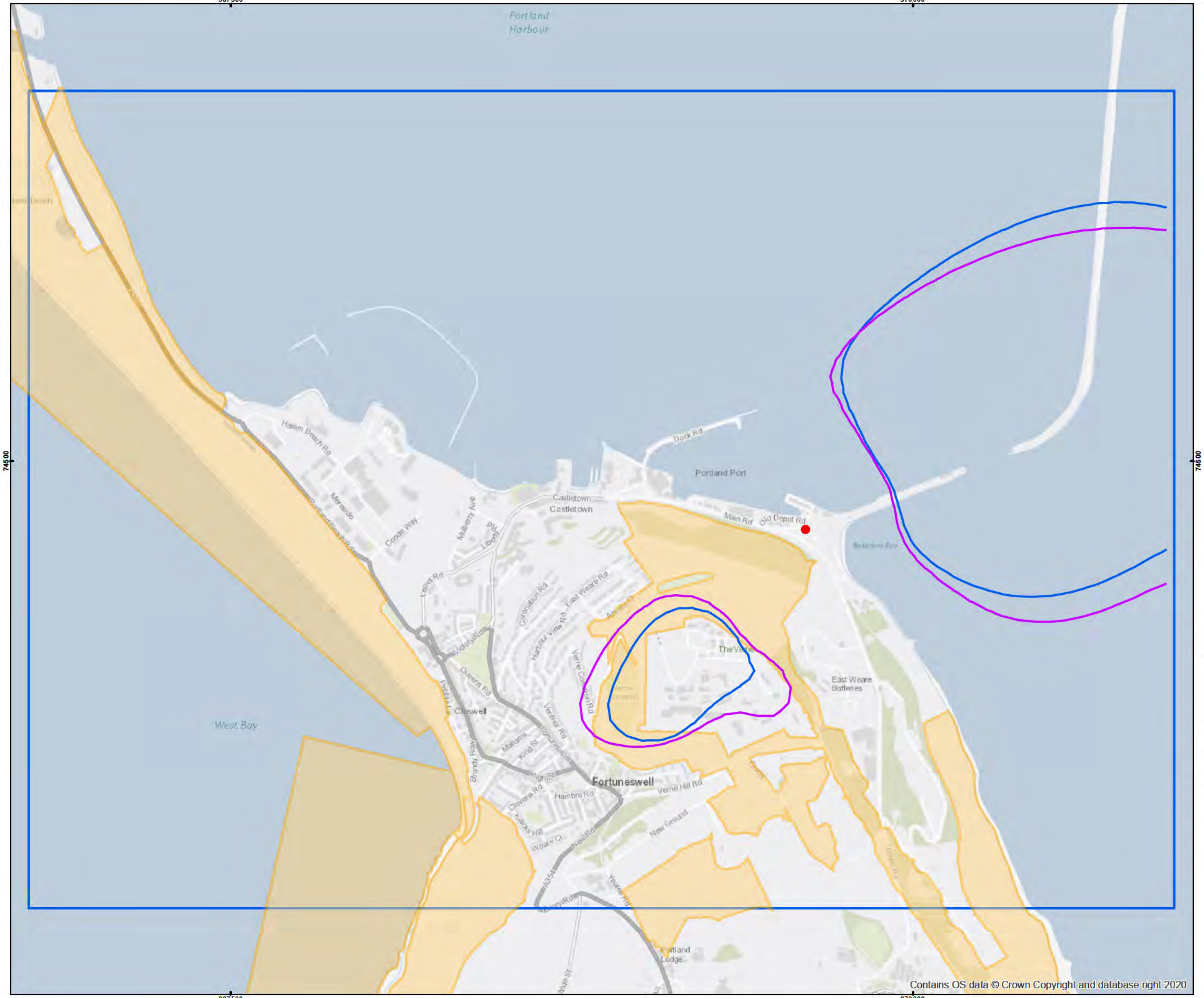

Legend

- Short Grass Surface Roughness
- DMA Assumption
- Main Stack
- SAC
- Output grid extent

Contour of 1% of Critical Level, assuming 100% operation at the ELV

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	

Figure 12
Annual Mean NOx Impact - Met Station Surface Roughness Sensitivity

Drawn by: RSF	Date: 15/11/2021

0 0.125 0.25 0.5 km

Scale: 1:13,000

N

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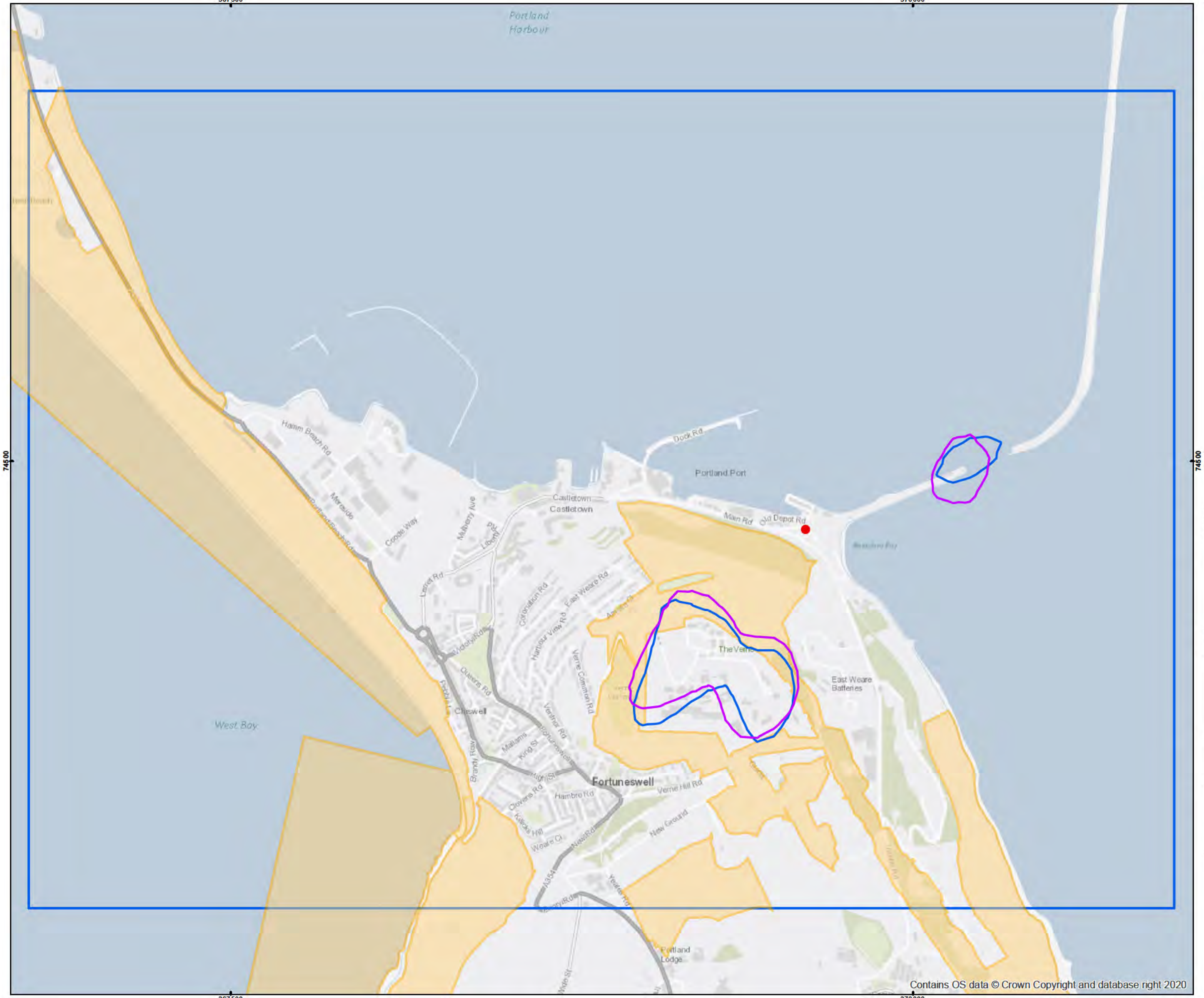


Legend

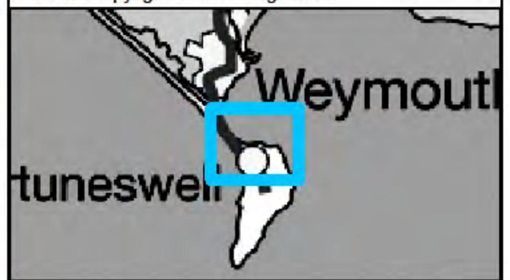
- Short Grass Surface Roughness
- DMA Assumption
- Main Stack
- SAC
- Output grid extent

Contour of 10% of Critical Level, assuming 100% operation at the ELV

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	

Figure 13
Daily Mean NOx Impact - Met Station Surface Roughness Sensitivity

Drawn by: RSF	Date: 15/11/2021



0 0.125 0.25 0.5 km

Scale: 1:13,000

N

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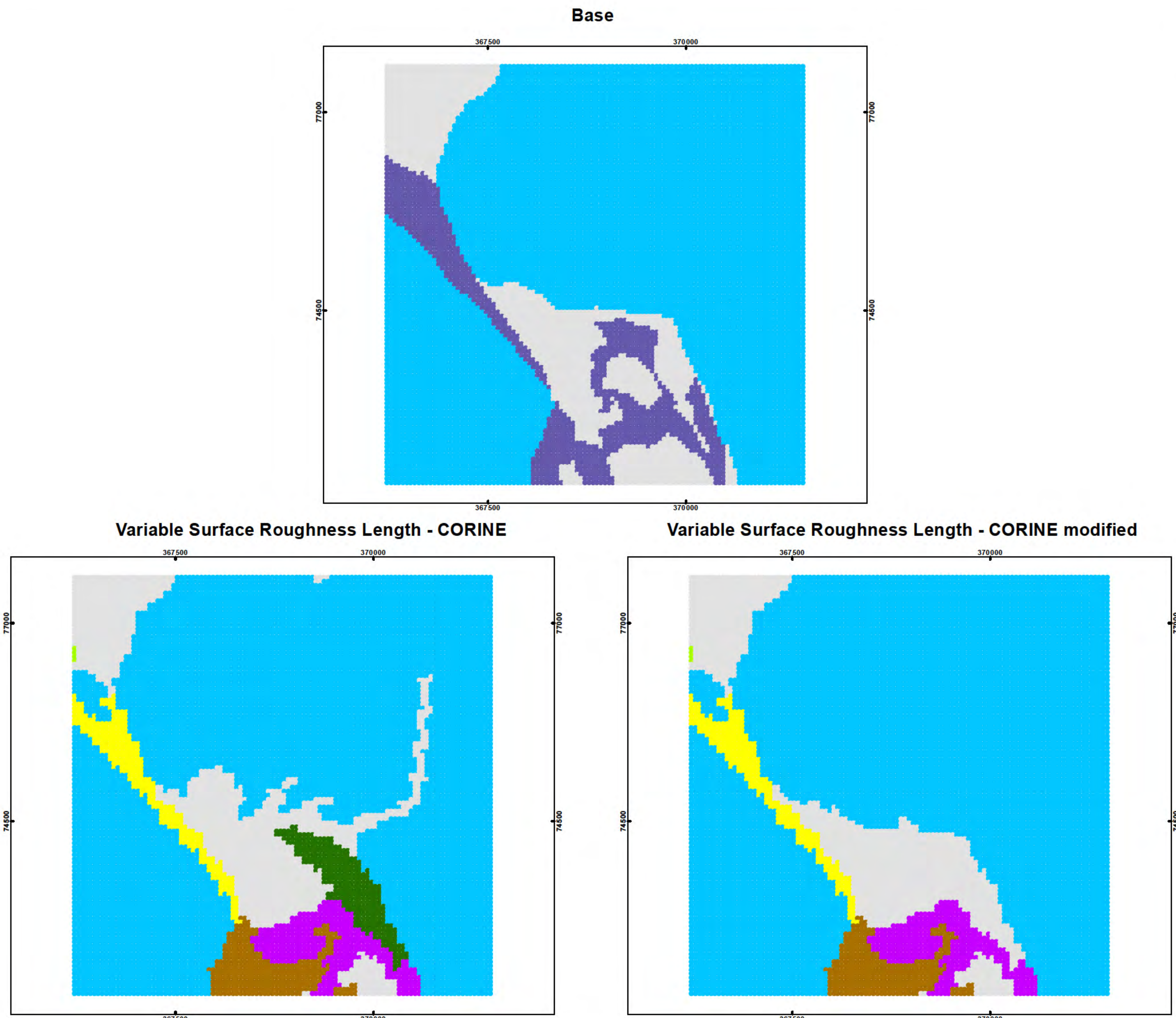


Legend

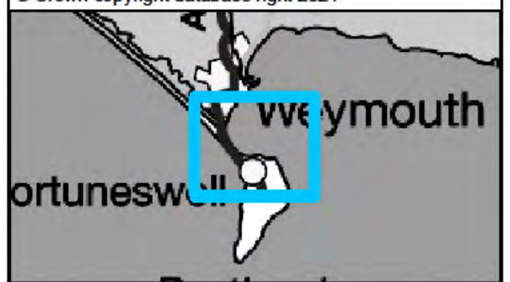
Roughness Length (m)

- 0.0001
- 0.0003
- 0.005
- 0.02
- 0.1
- 0.3
- 0.5
- 0.75

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	

Figure 14
Domain Surface Roughness Length

Drawn by: RSF | Date: 15/11/2021



0 0.475 0.95 1.9 km

N

Scale: 1:45,759

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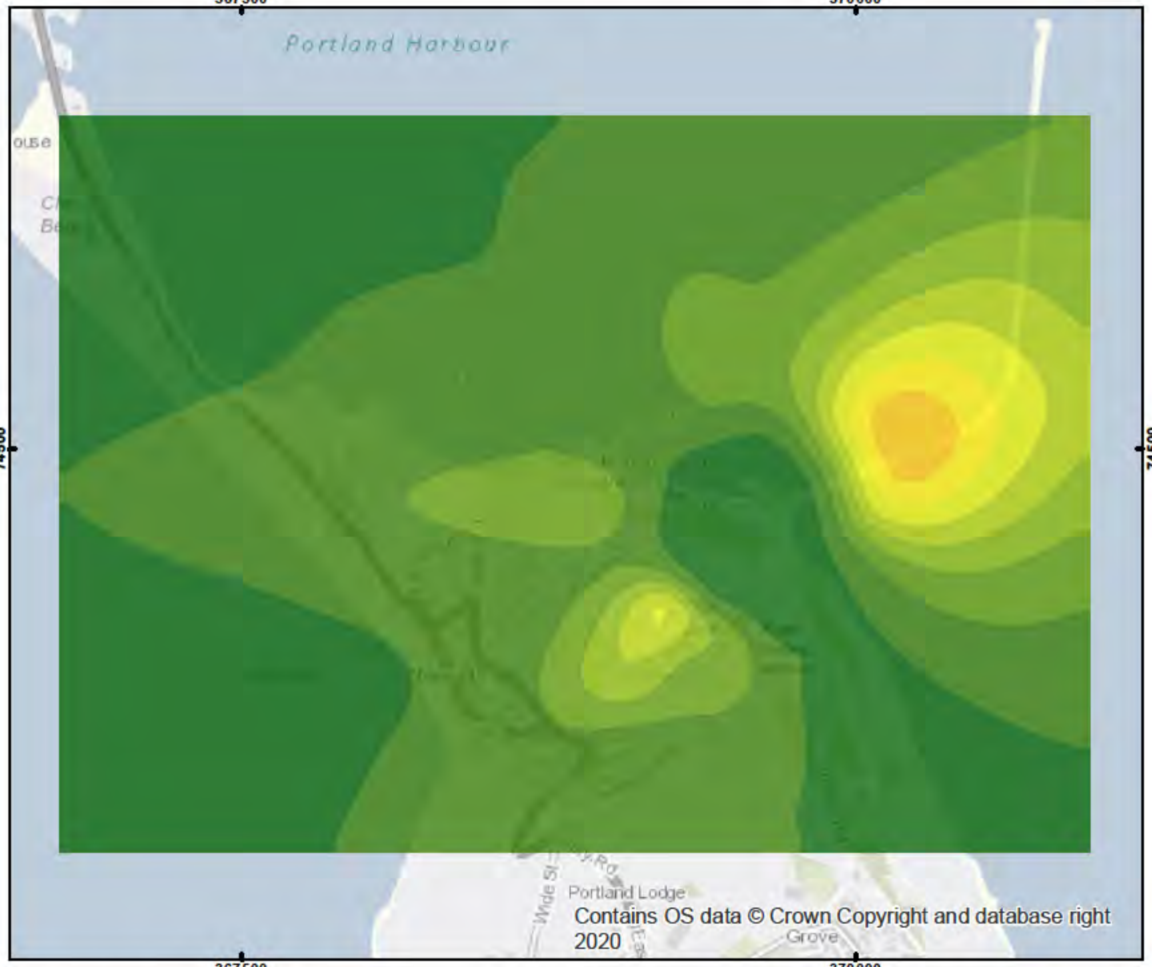
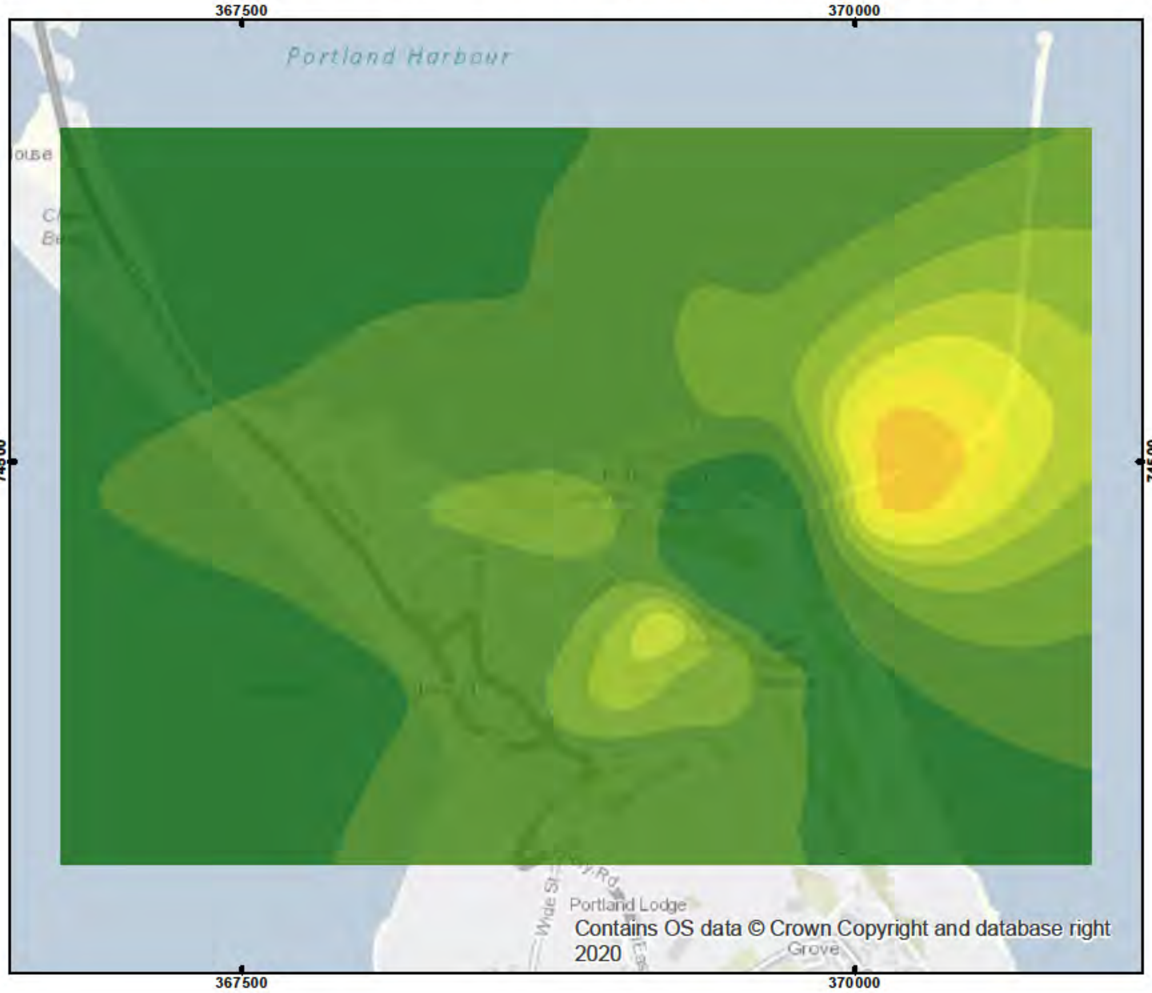
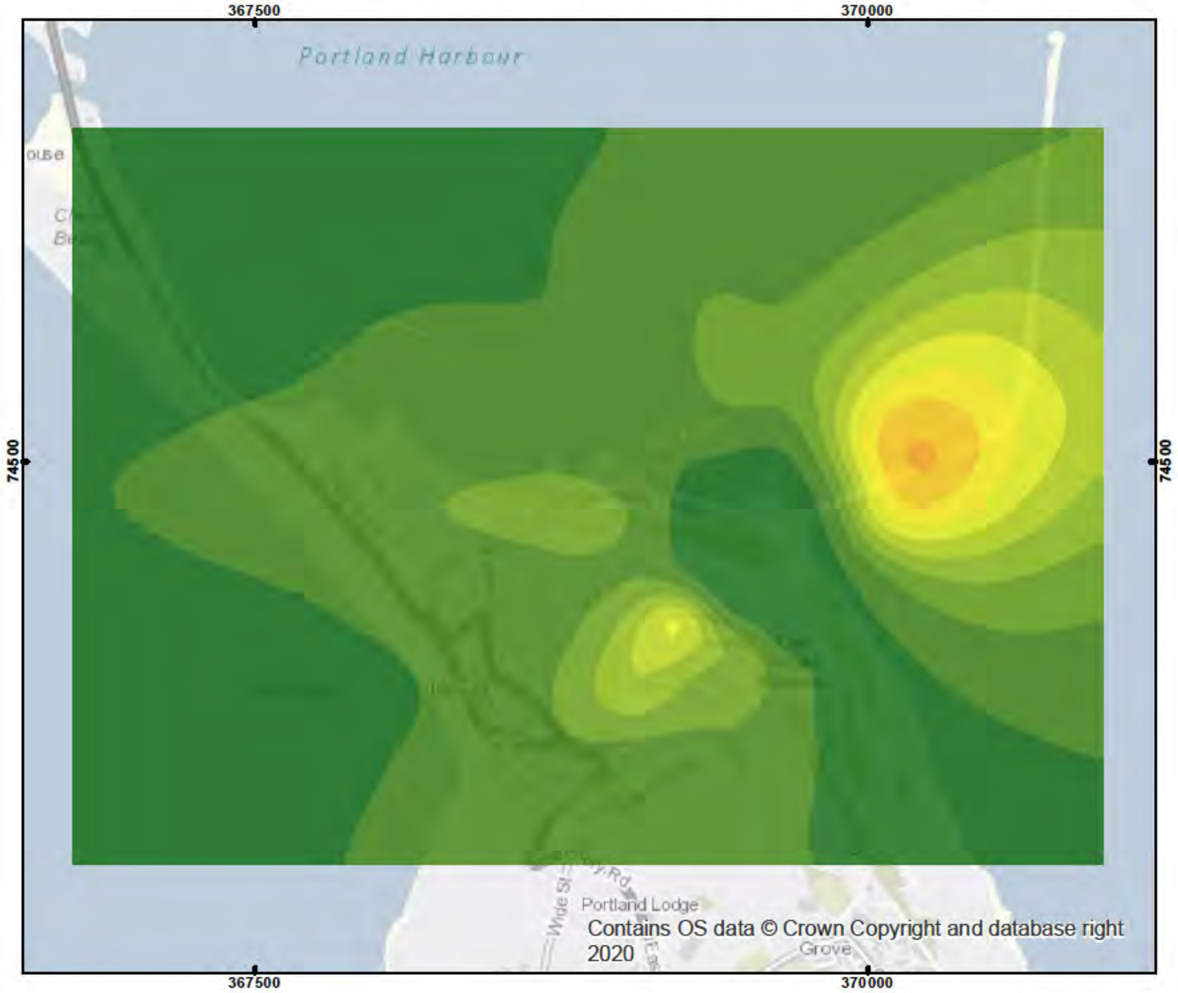
Base



Variable Surface Roughness Length - CORINE



Variable Surface Roughness Length - CORINE modified



Legend

Annual mean NOx ug/m3

- <0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1
- 1 - 1.1
- 1.1 - 1.2

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 15 Domain Surface Length Sensitivity Analysis
Drawn by: RSF	Date: 15/11/2021

0 0.3 0.6 1.2 km

Scale: 1:30,800

N

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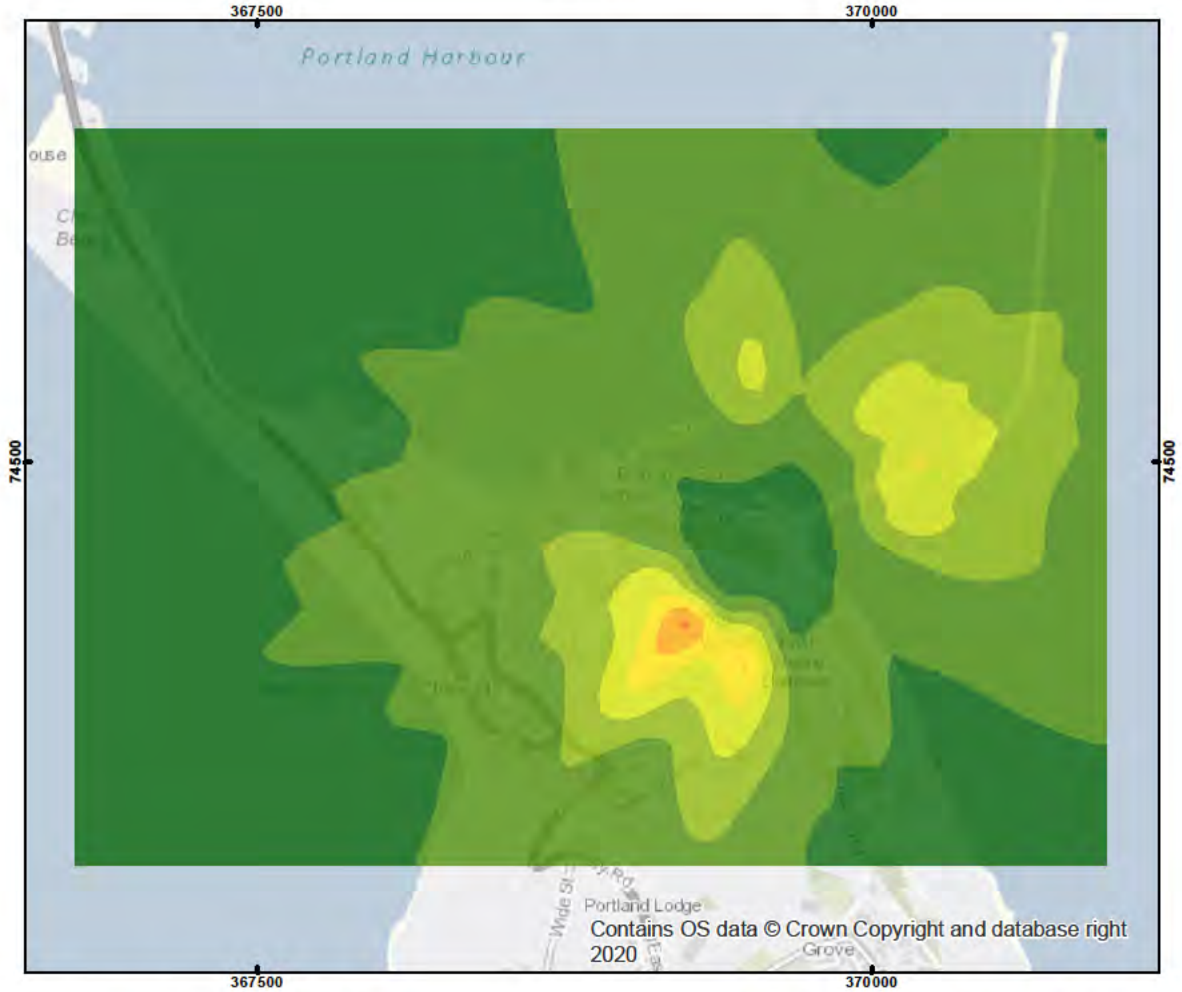
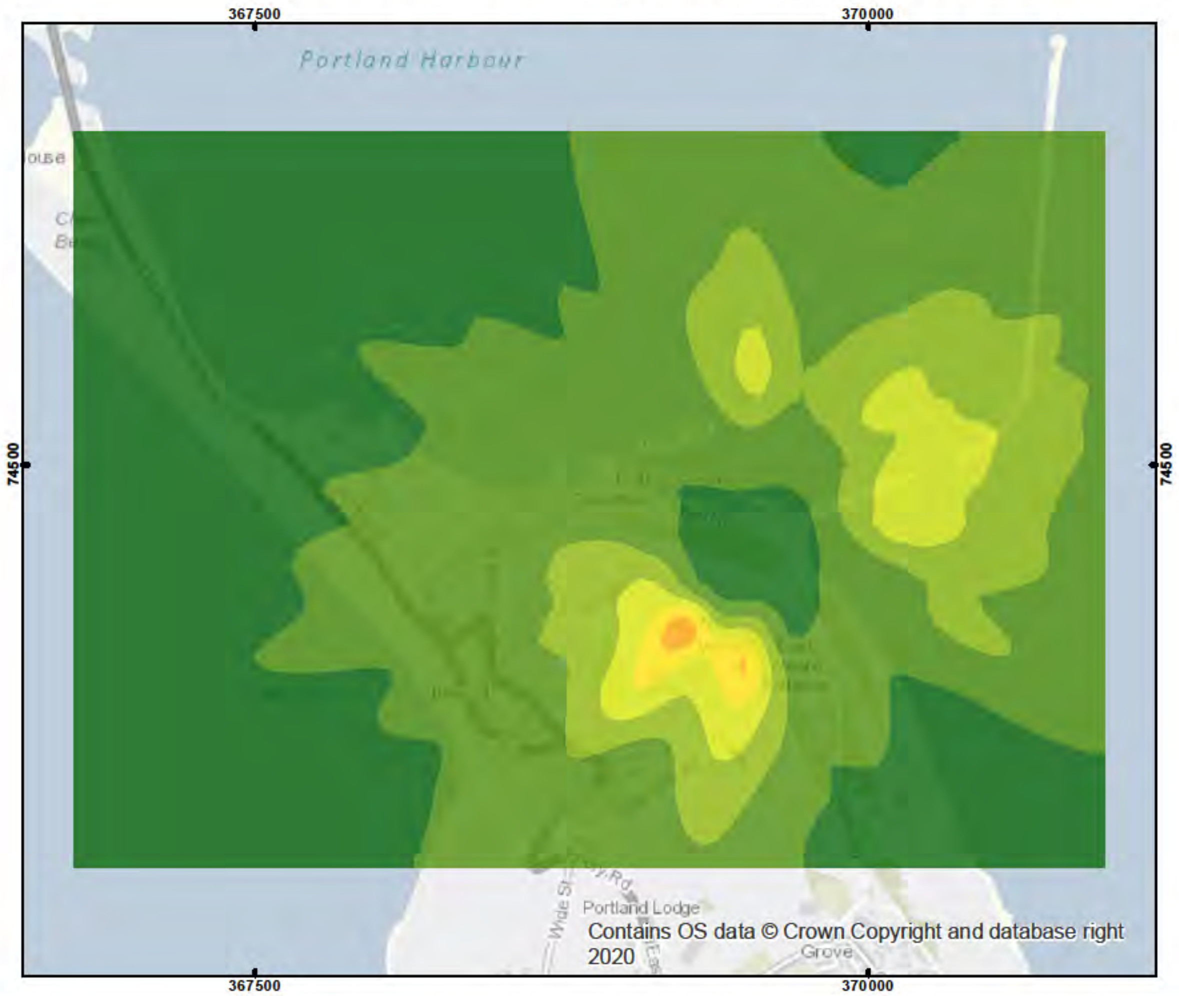
Stockport, Cheshire, SK4 1LW
Tel: 0161 476 0032
Fax: 0161 474 0618

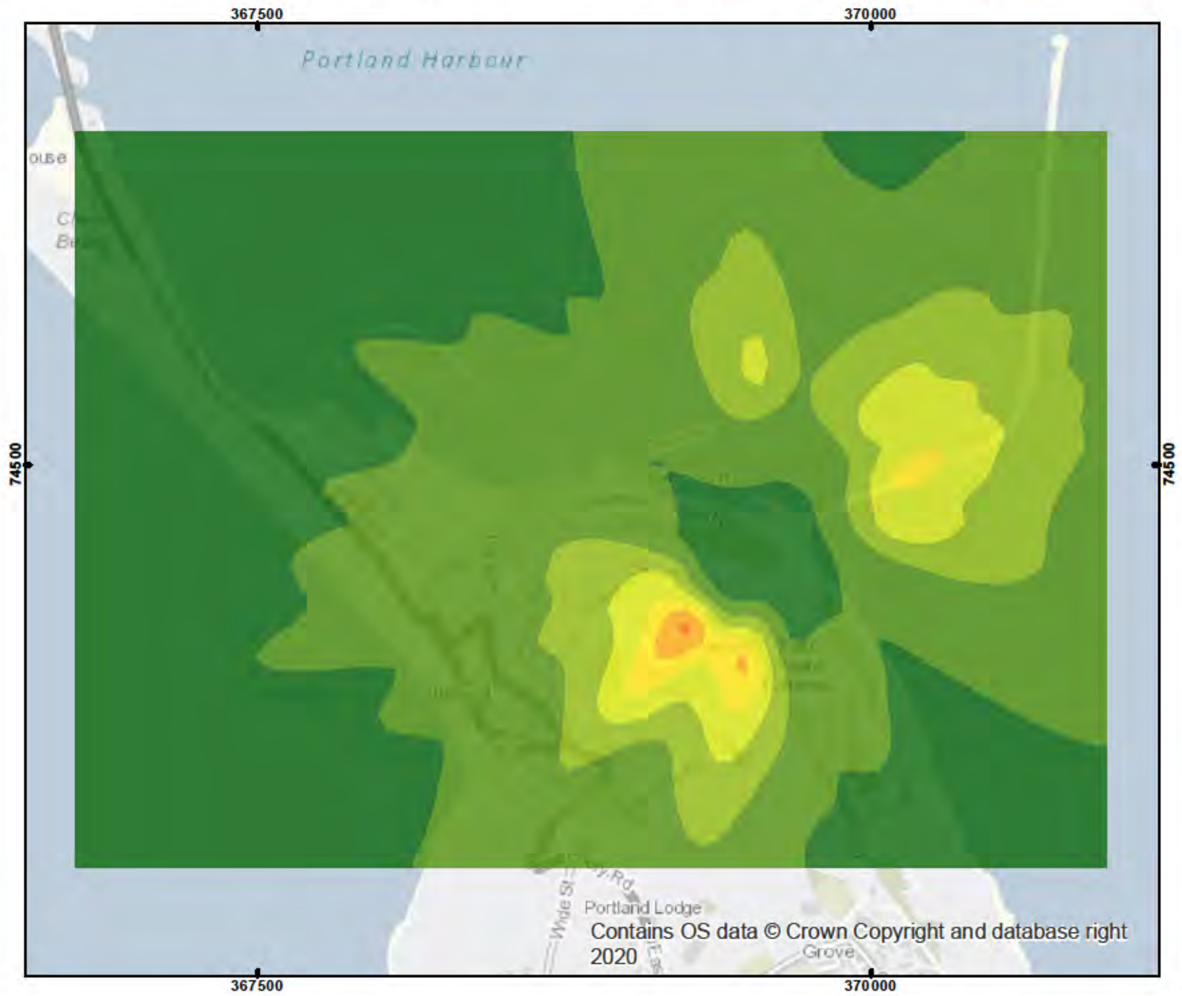
Base



Variable Surface Roughness Length - CORINE



Variable Surface Roughness Length - CORINE modified



Legend

Maximum 24-hour mean NOx

ug/m3

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	

Figure 16
Domain Surface Length
Sensitivity Analysis

Drawn by: RSF	Date: 09/11/2021

0 0.3 0.6 1.2 km

Scale: 1:30,800

N

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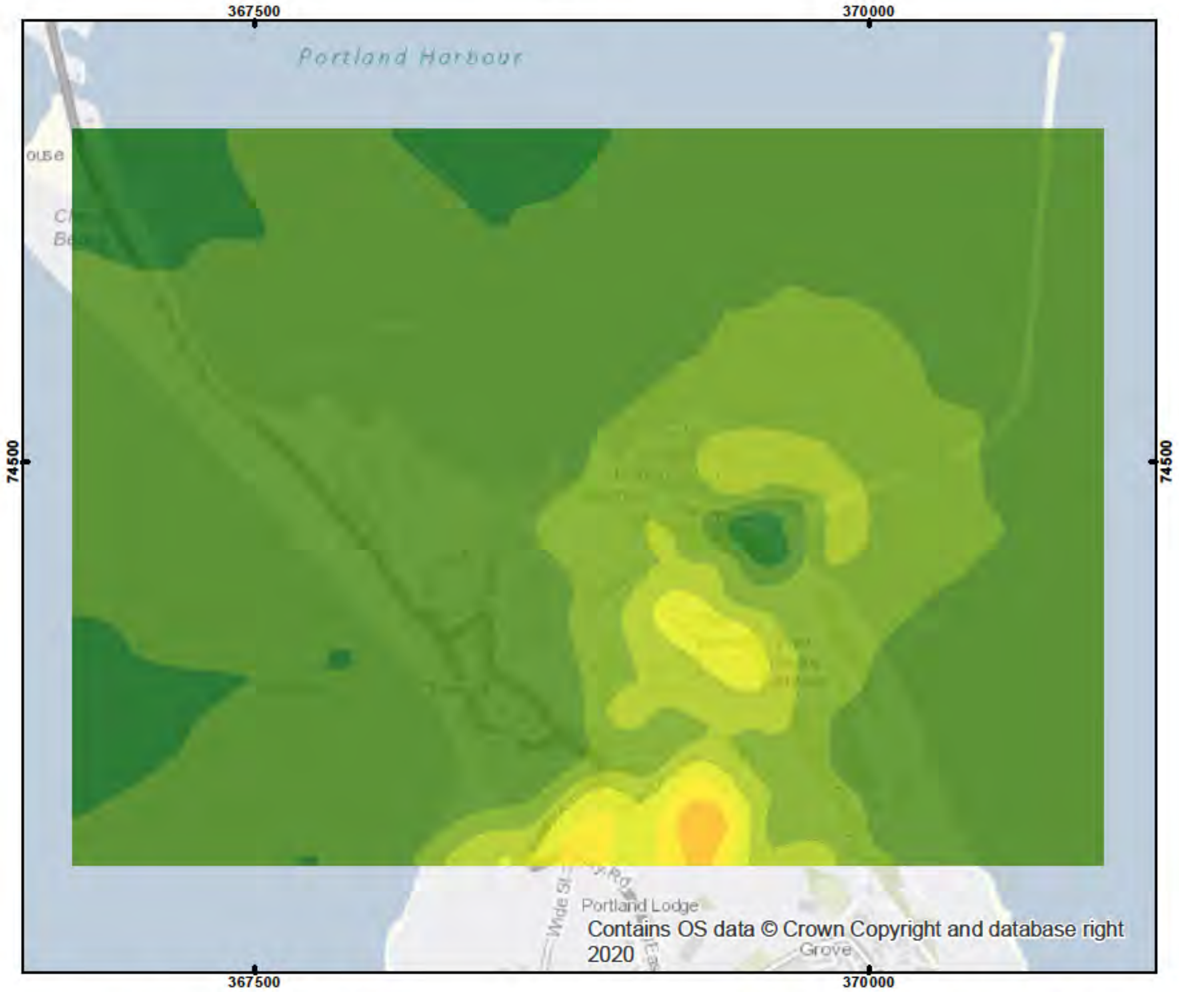
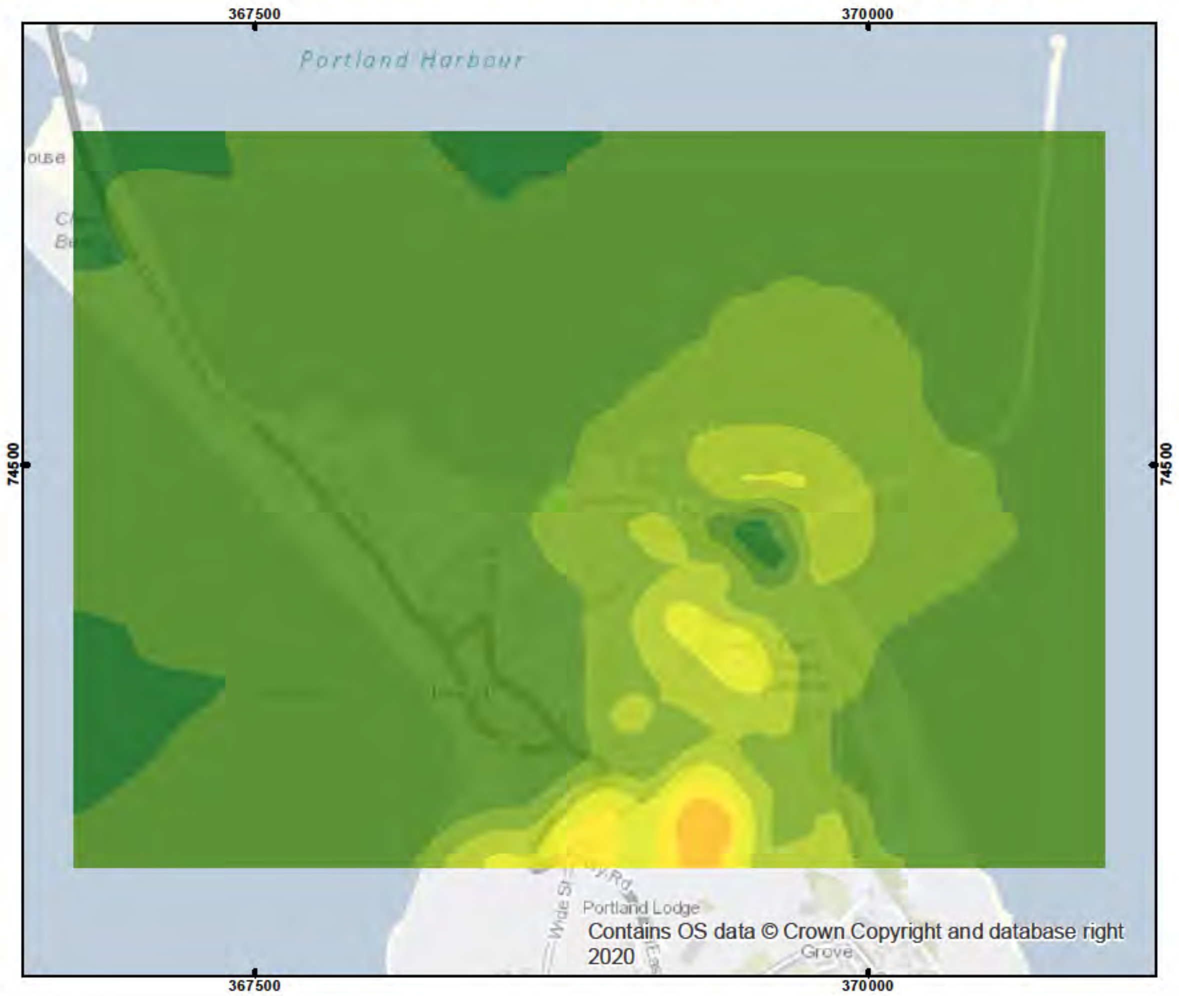
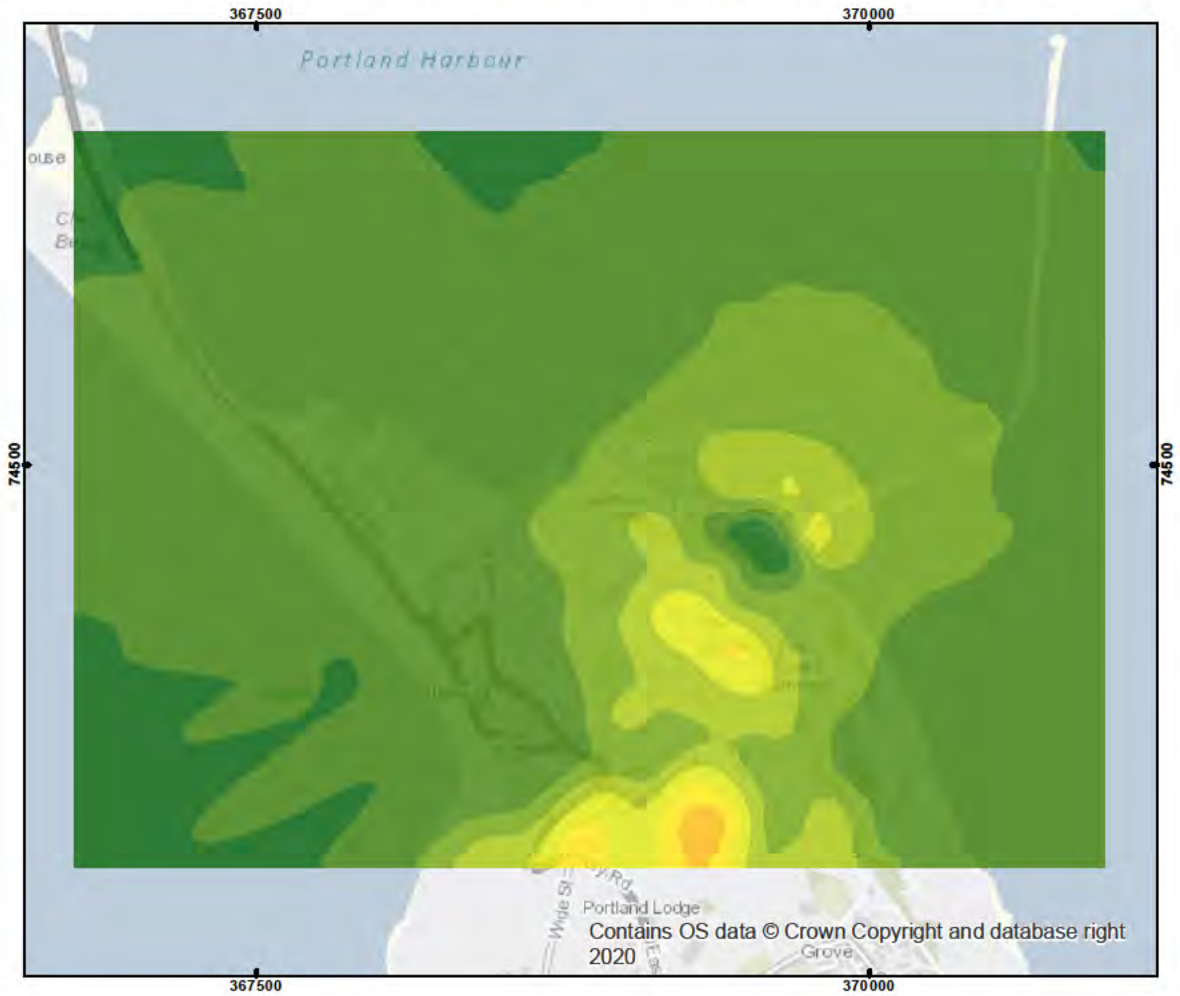
Base



Variable Surface Roughness Length - CORINE



Variable Surface Roughness Length - CORINE modified



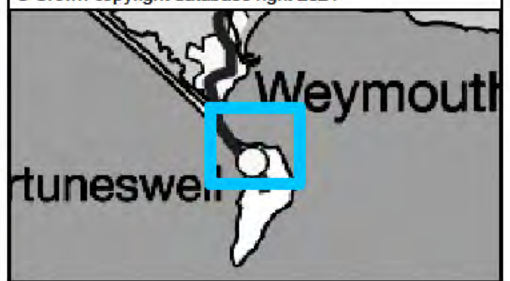
Legend

Maximum 1-hour mean NOx

ug/m3

- <5
- 5 - 10
- 10 -15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 17 Domain Surface Length Sensitivity Analysis
Drawn by: RSF	Date: 09/11/2021



0 0.3 0.6 1.2 km

Scale: 1:30,800

N

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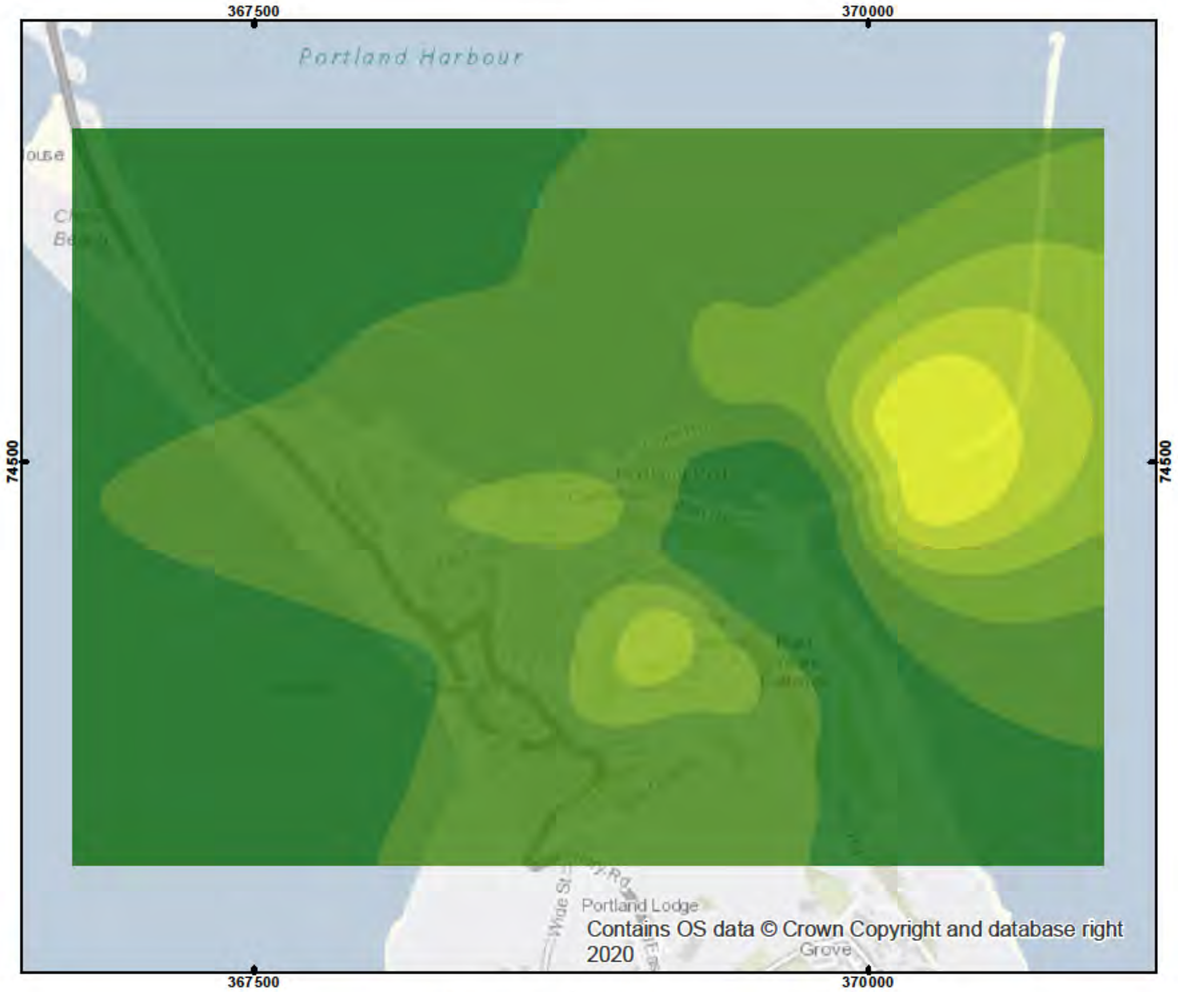
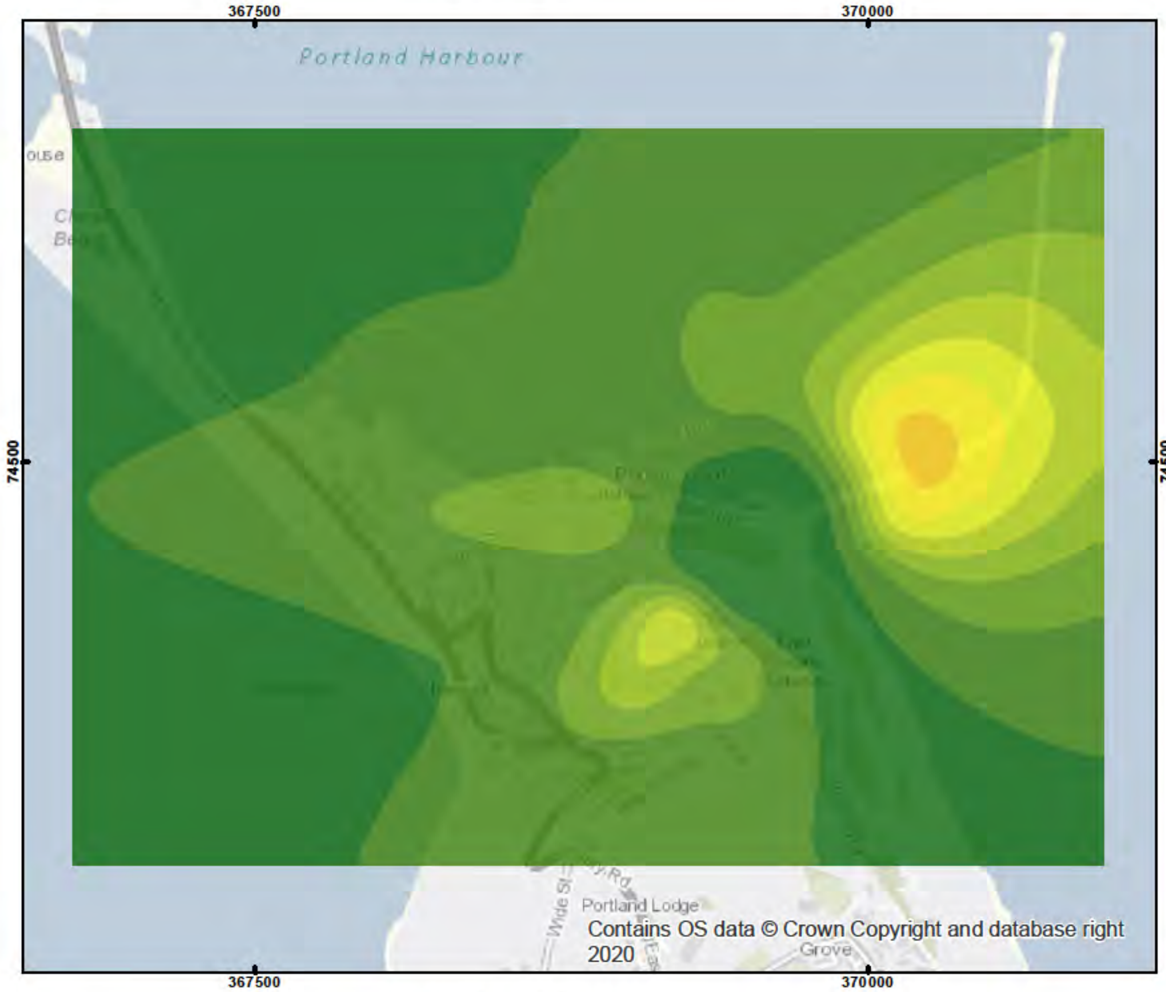
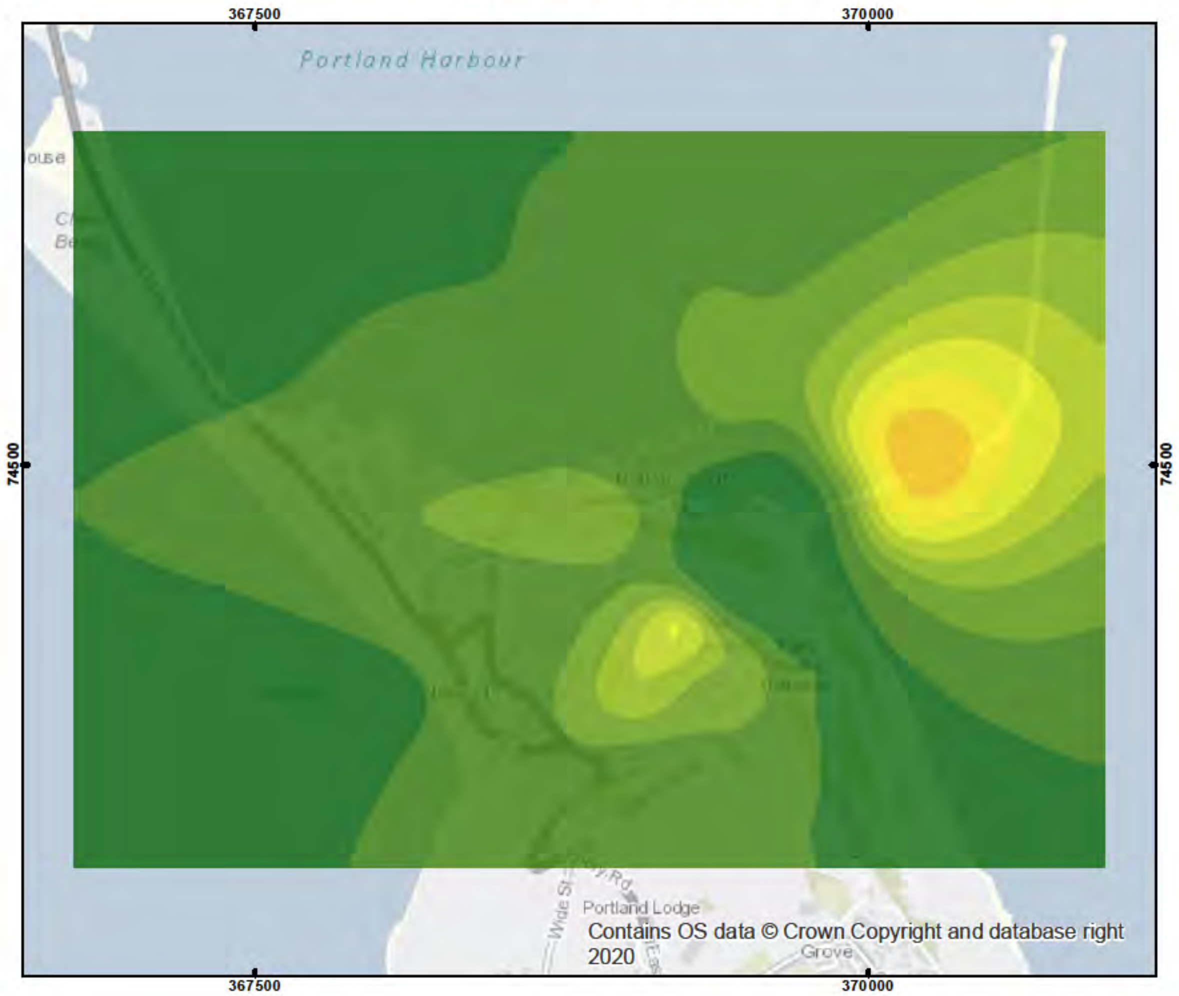
32 x 32



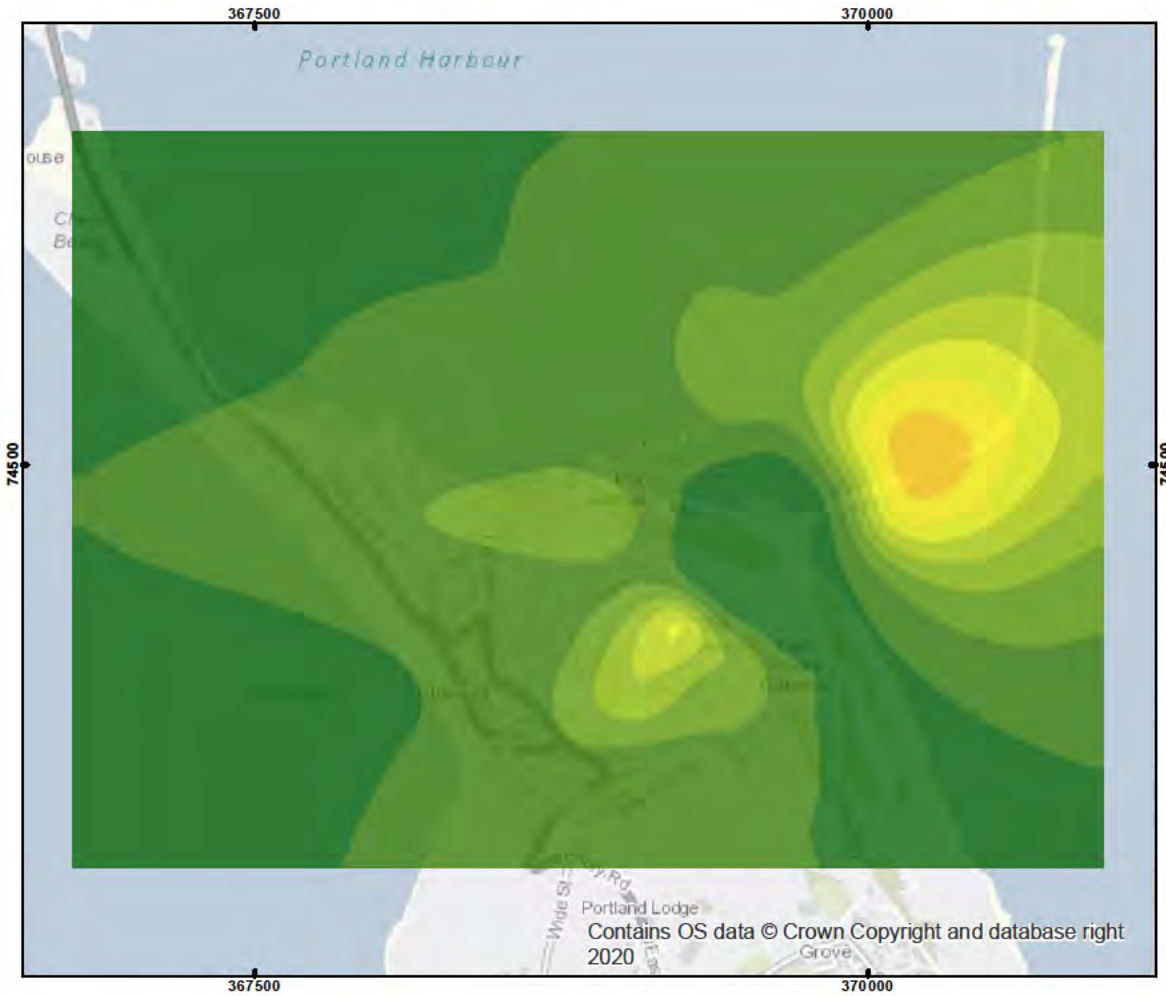
64 x 64



128 x 128 - as used in DMA



256 x 256



Legend

Maximum Annual Mean NOx

ug/m3

- <0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1
- 1 - 1.1
- 1.1 - 1.2

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 18 Flow Field Resolution Sensitivity Analysis
Drawn by: RSF	Date: 15/11/2021

0 0.325 0.65 1.3 km

N

Scale: 1:30,800

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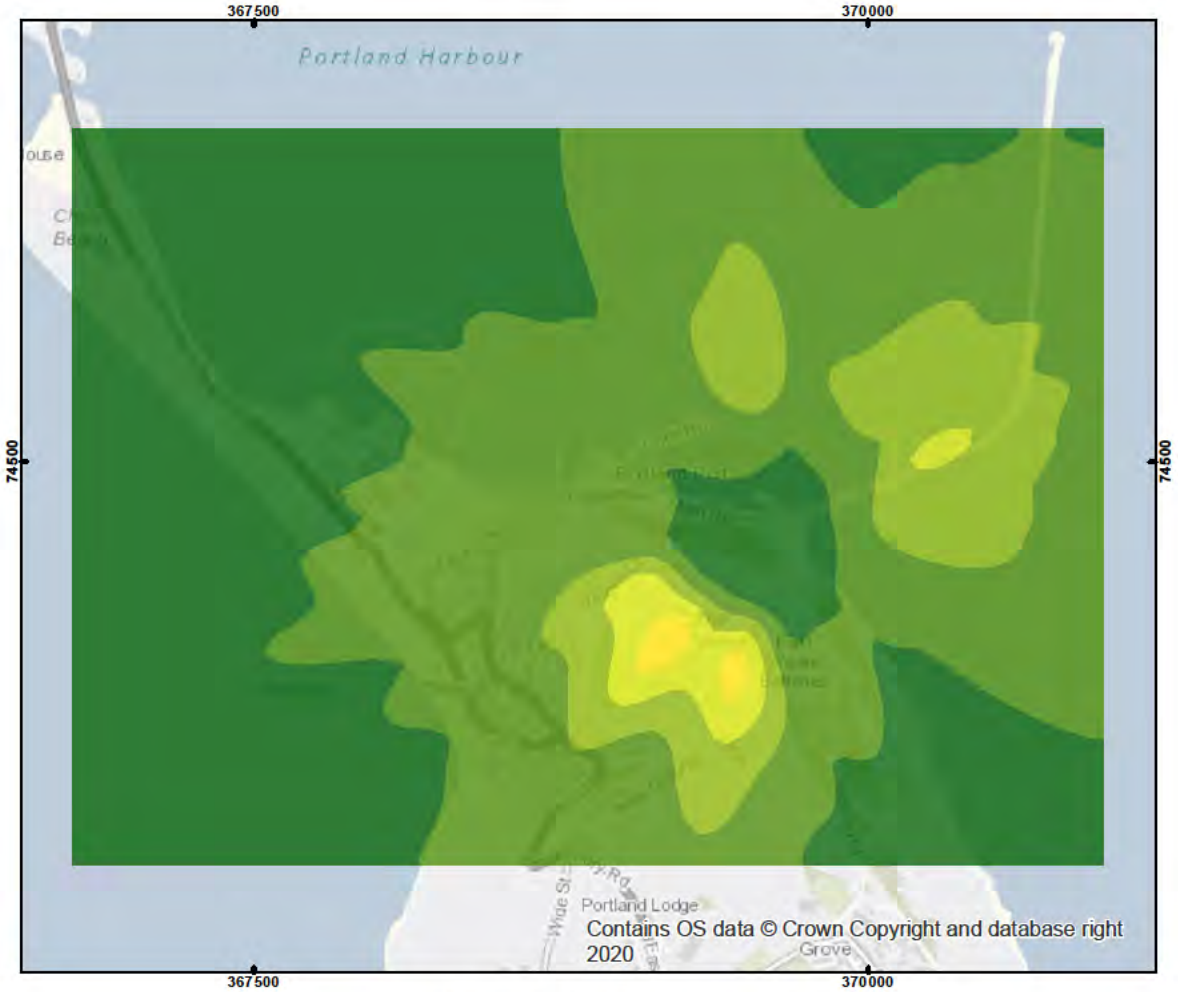
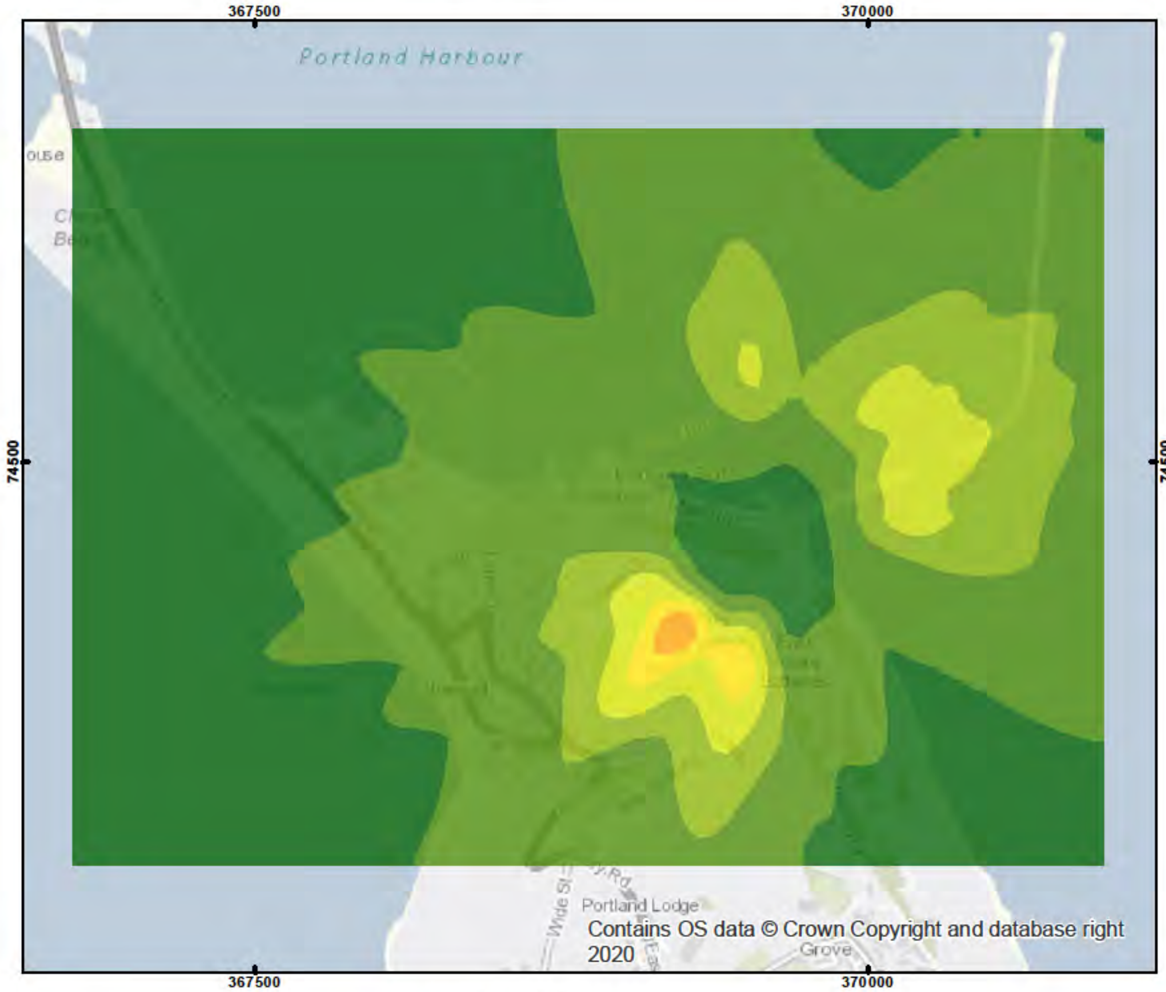
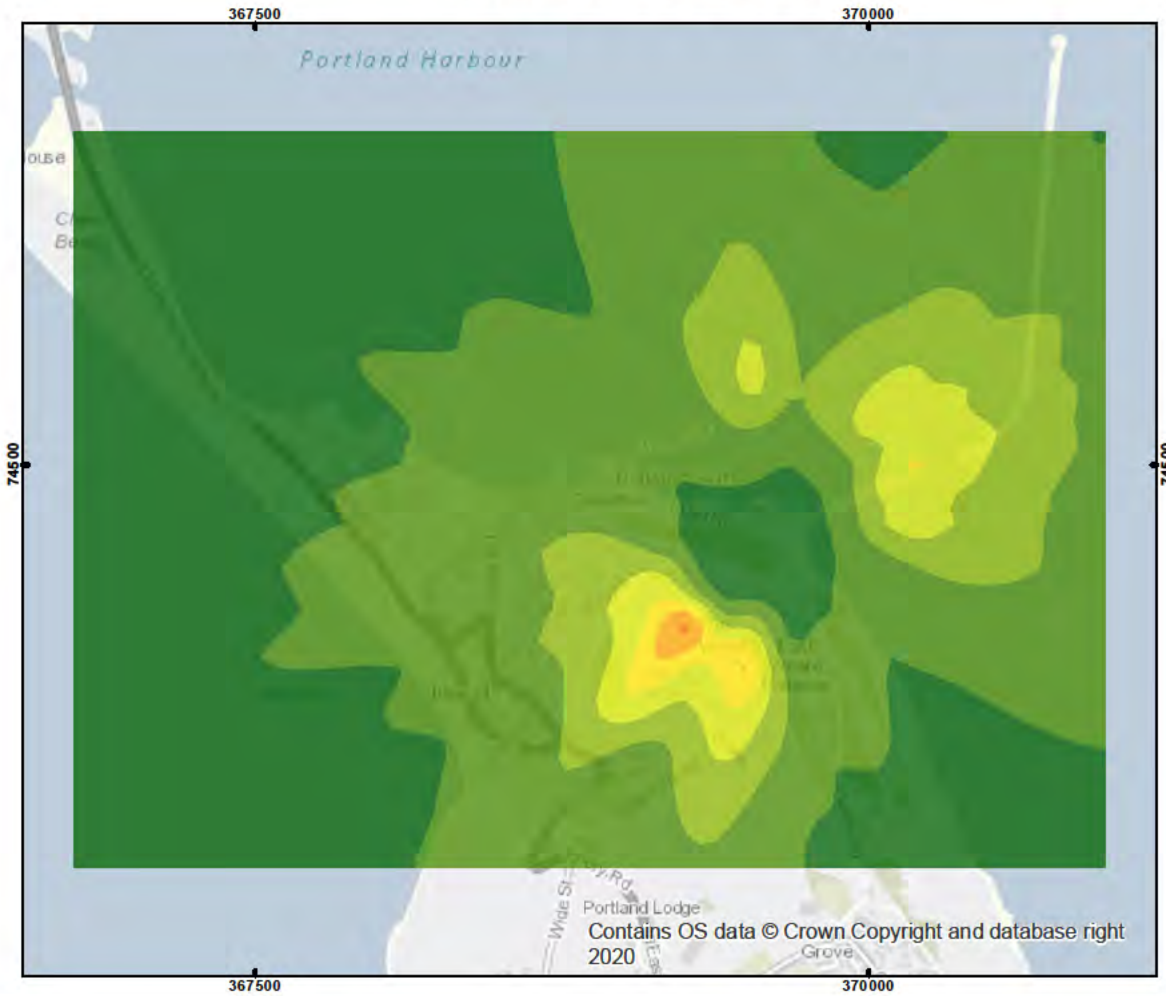
32 x 32



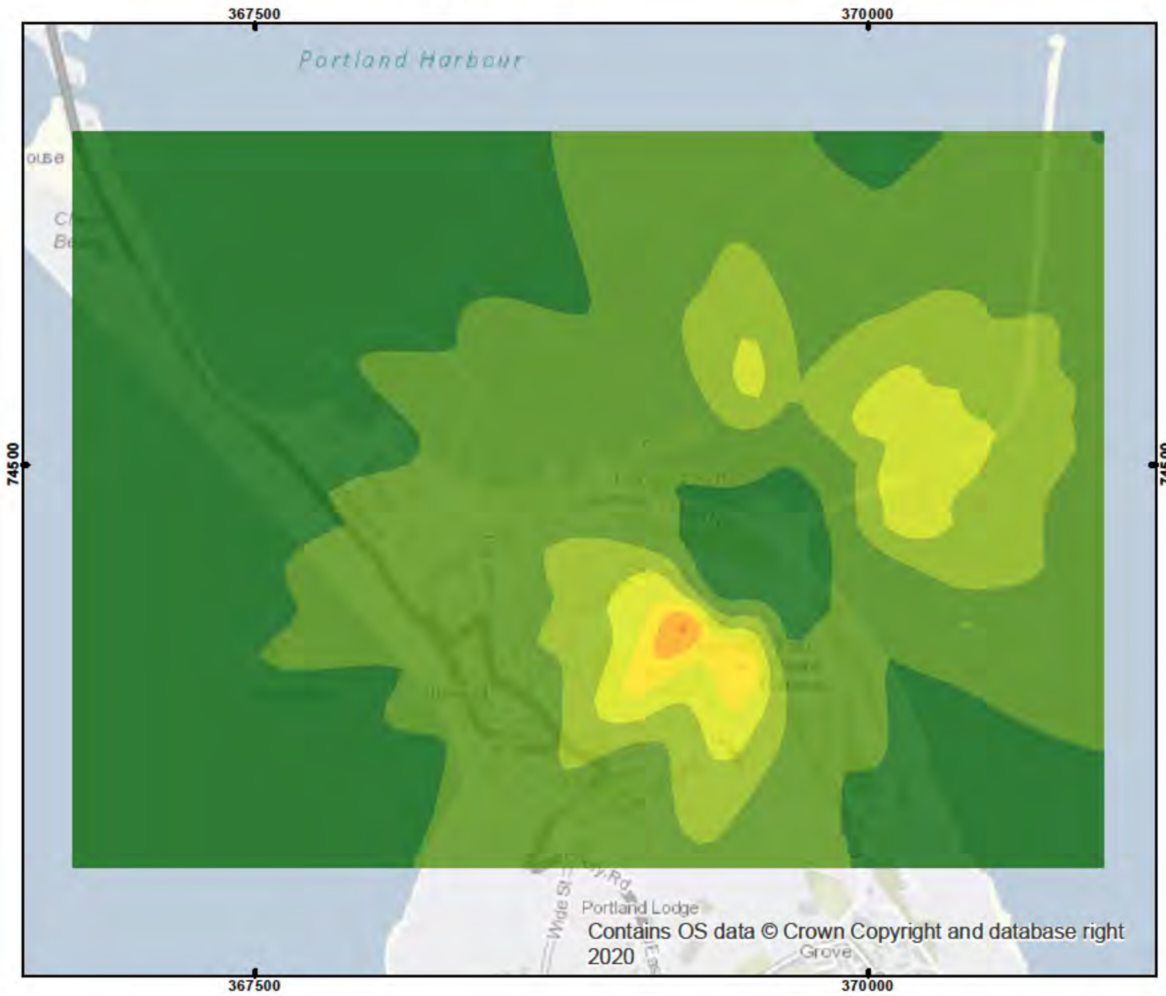
64 x 64



128 x 128 - as used in DMA



256 x 256



Legend

Maximum 24-hour NOx ug/m3

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	

Figure 19
Flow Field Resolution
Sensitivity Analysis

Drawn by: RSF	Date: 09/11/2021

0 0.325 0.65 1.3 km

N

Scale: 1:30,800

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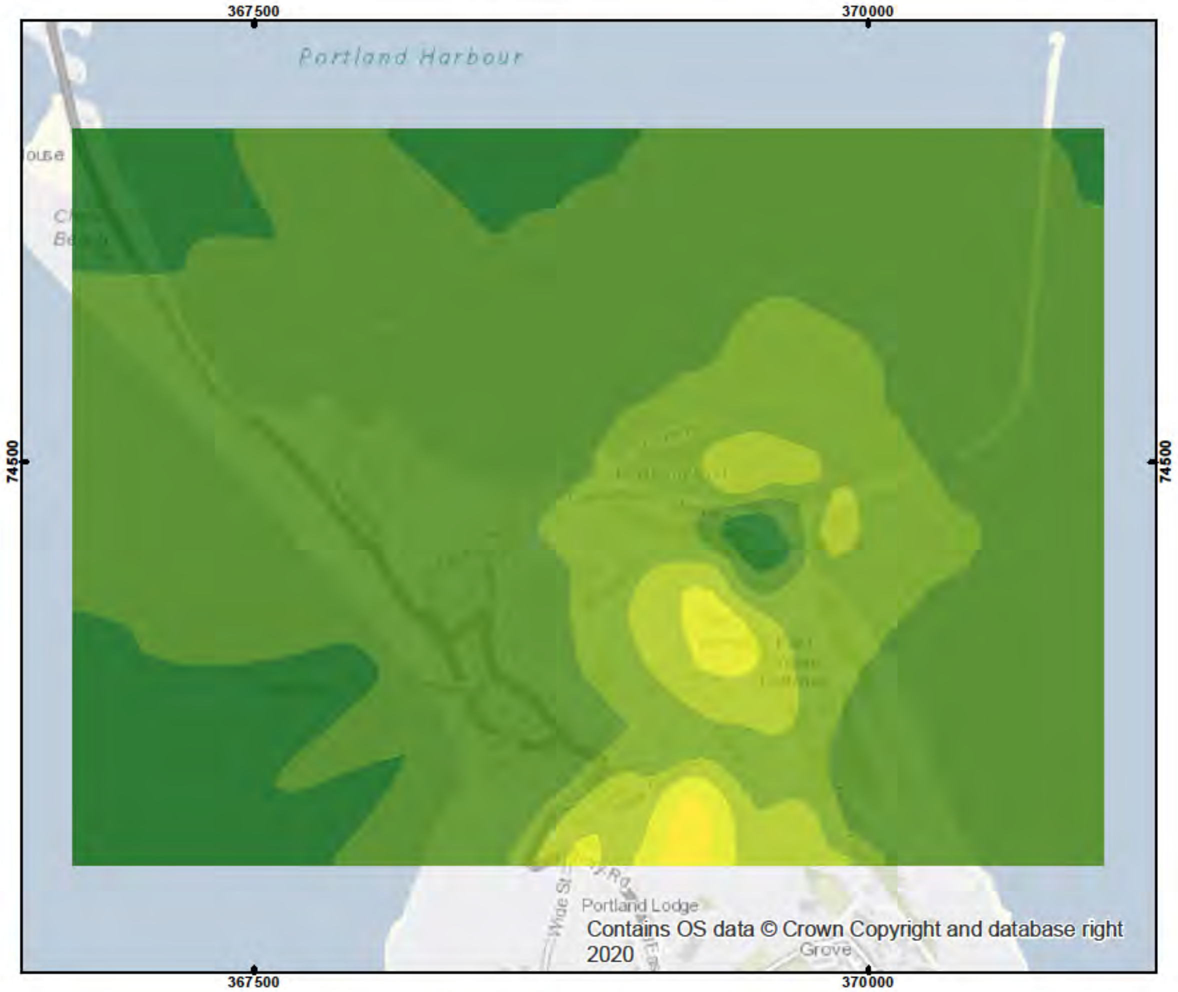
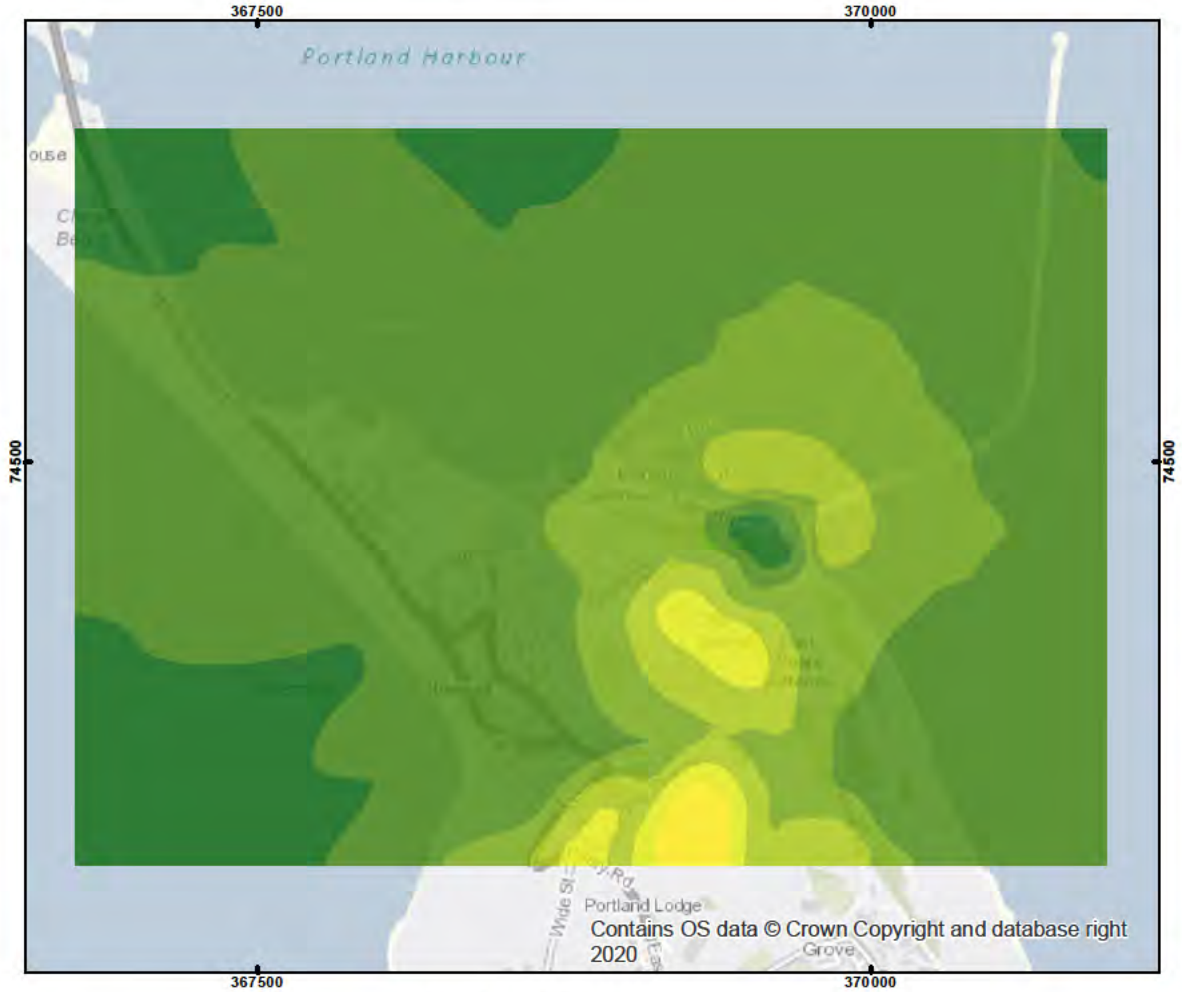
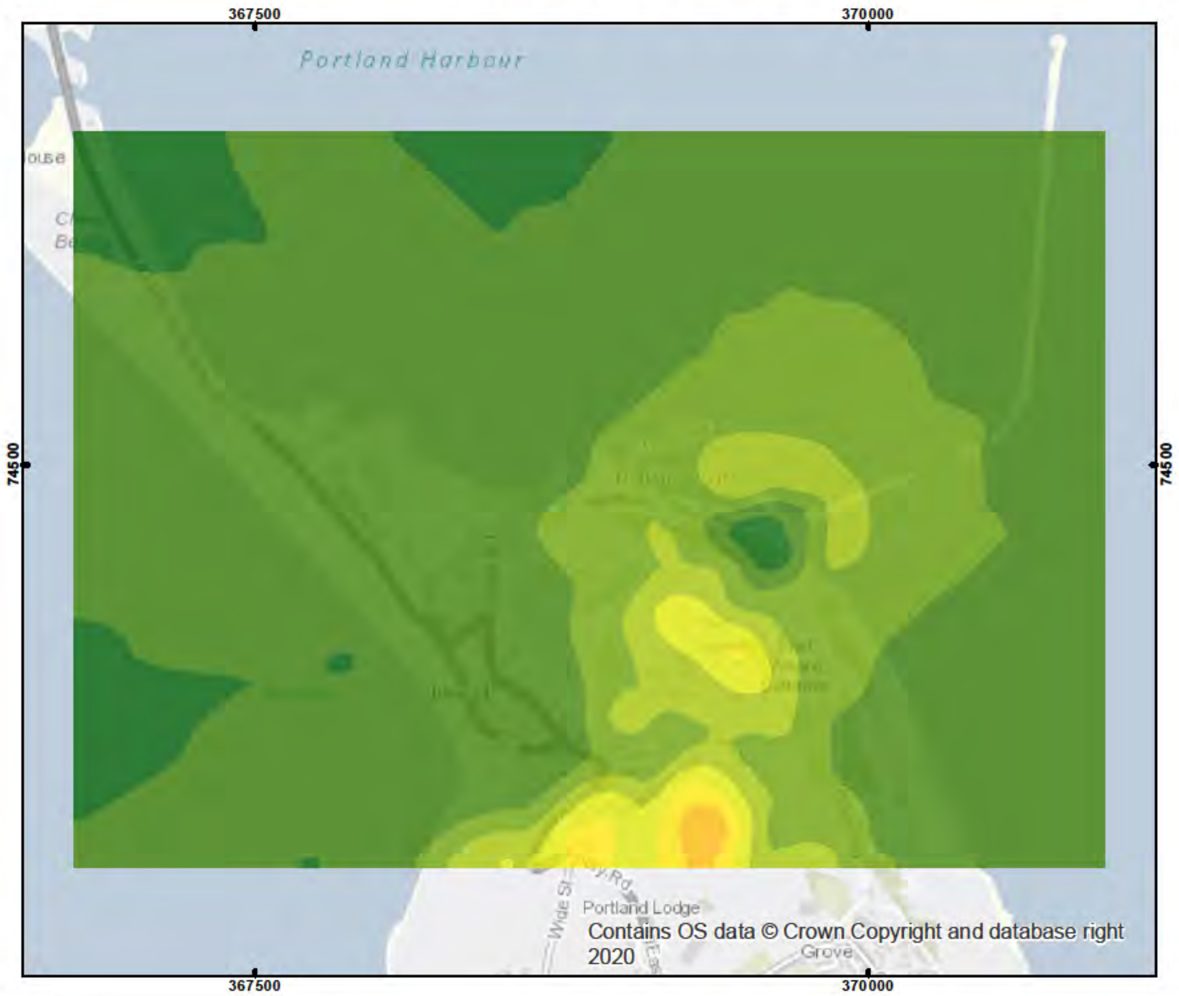
32 x 32



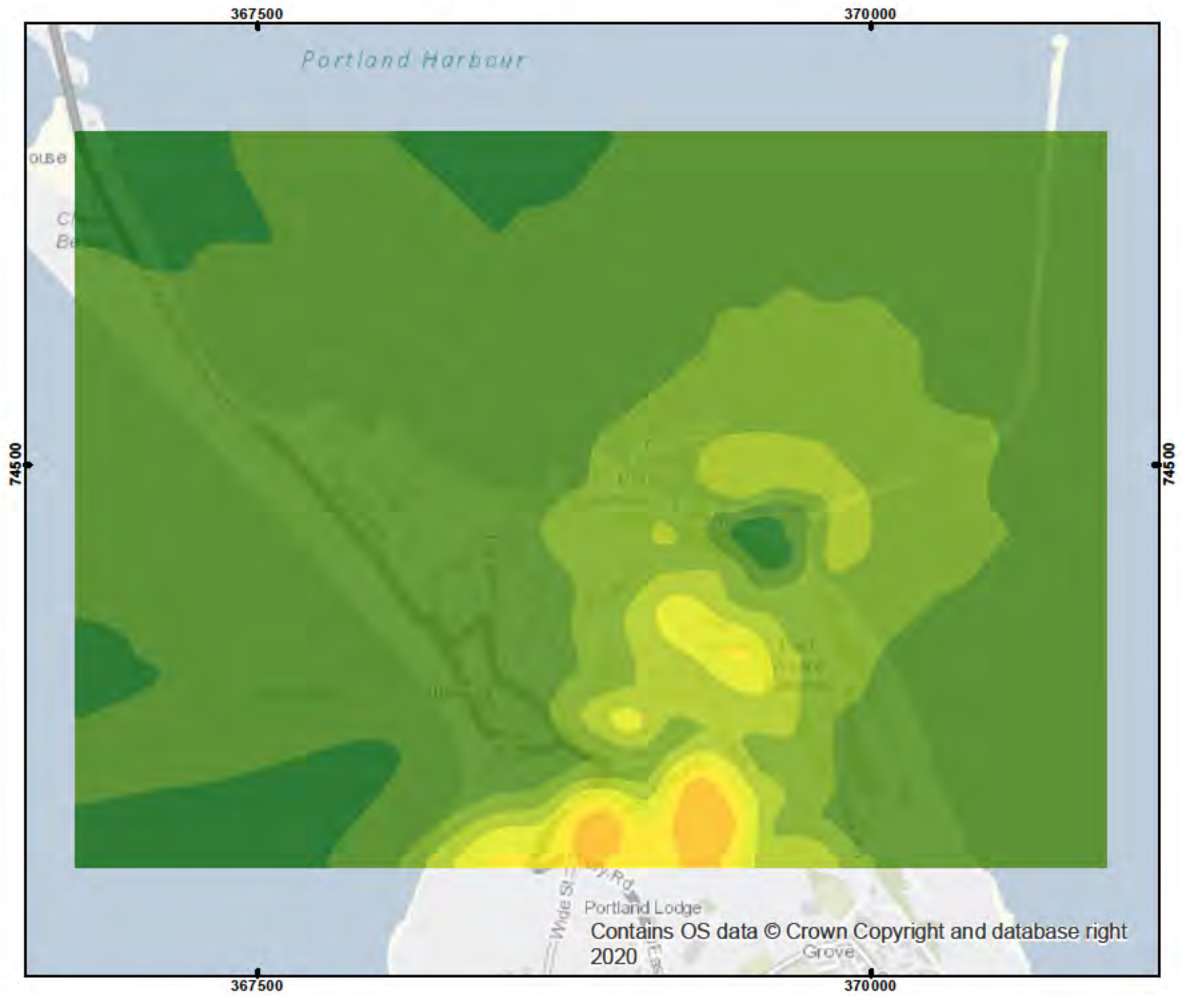
64 x 64



128 x 128 - as used in DMA



256 x 256



Legend

Maximum 1-hour NOx ug/m3

- <5
- 5 - 10
- 10 -15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 20 Flow Field Resolution Sensitivity Analysis
Drawn by: RSF	Date: 09/11/2021

0 0.325 0.65 1.3 km

N

Scale: 1:30,800

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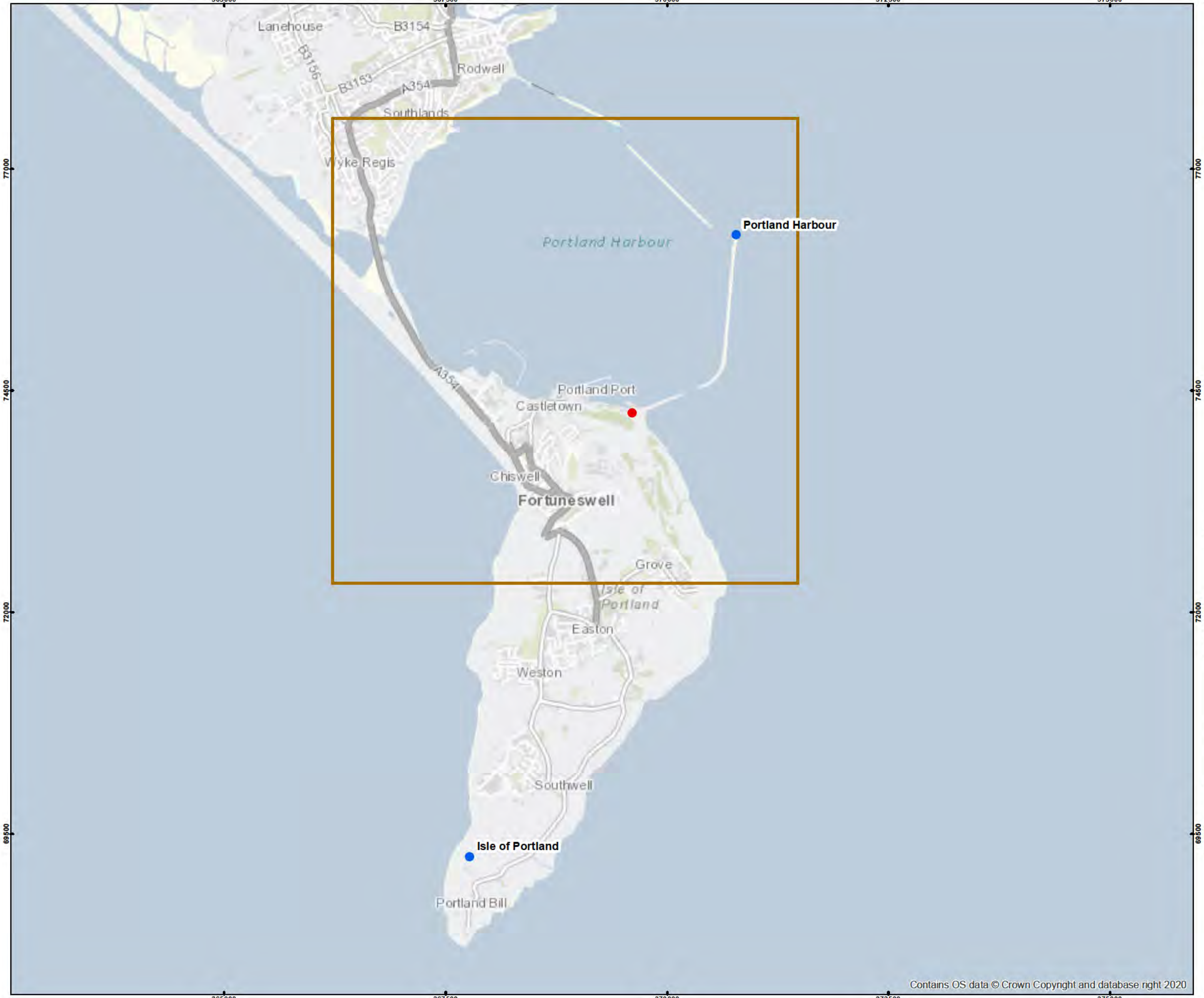
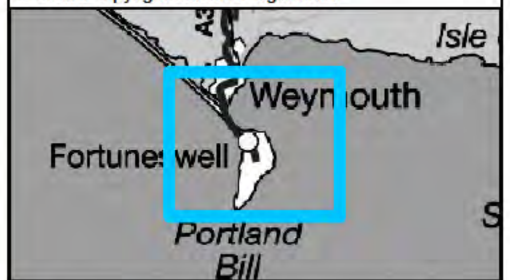
Fax: 0161 474 0618



Legend

- Main Stack
- Meteorological Observation Site
- Terrain Extents

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 21 Meteorological Observation Stations
Drawn by: RSF	Date: 09/11/2021



0 0.4 0.8 1.6 km

Scale: 1:40,000

N

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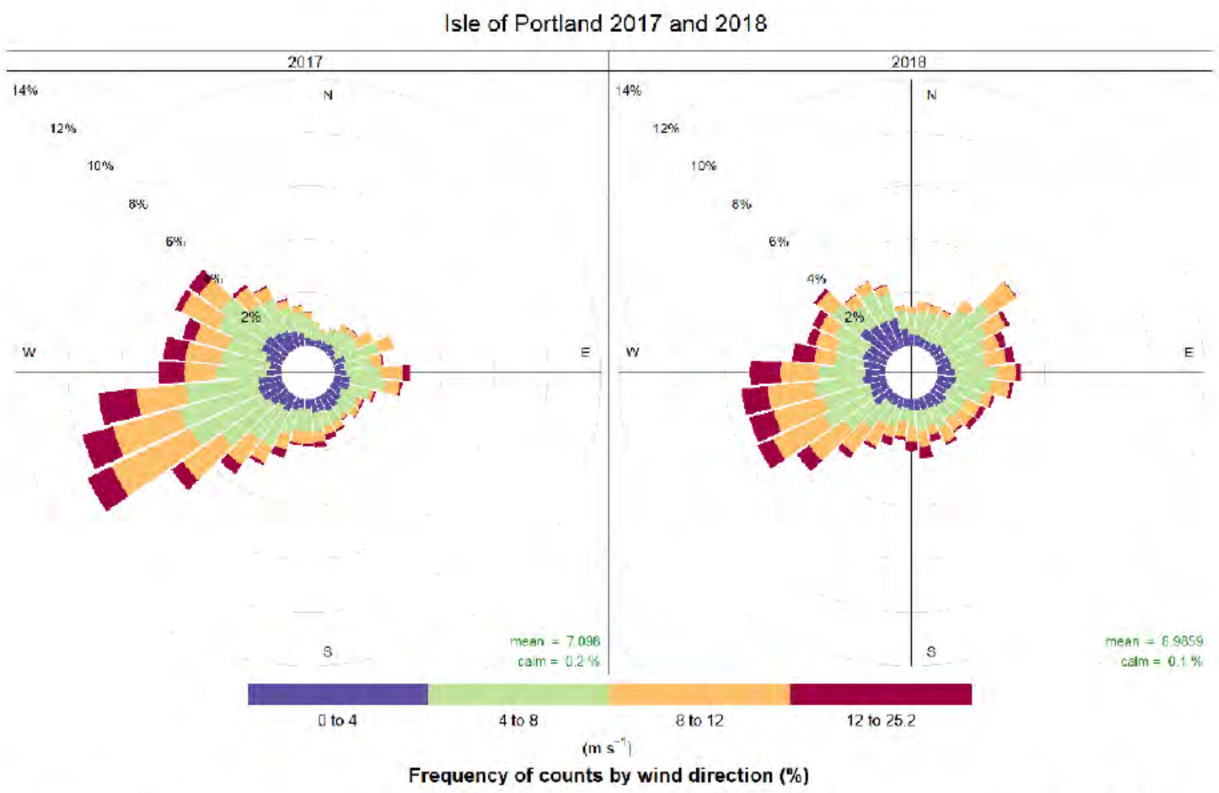
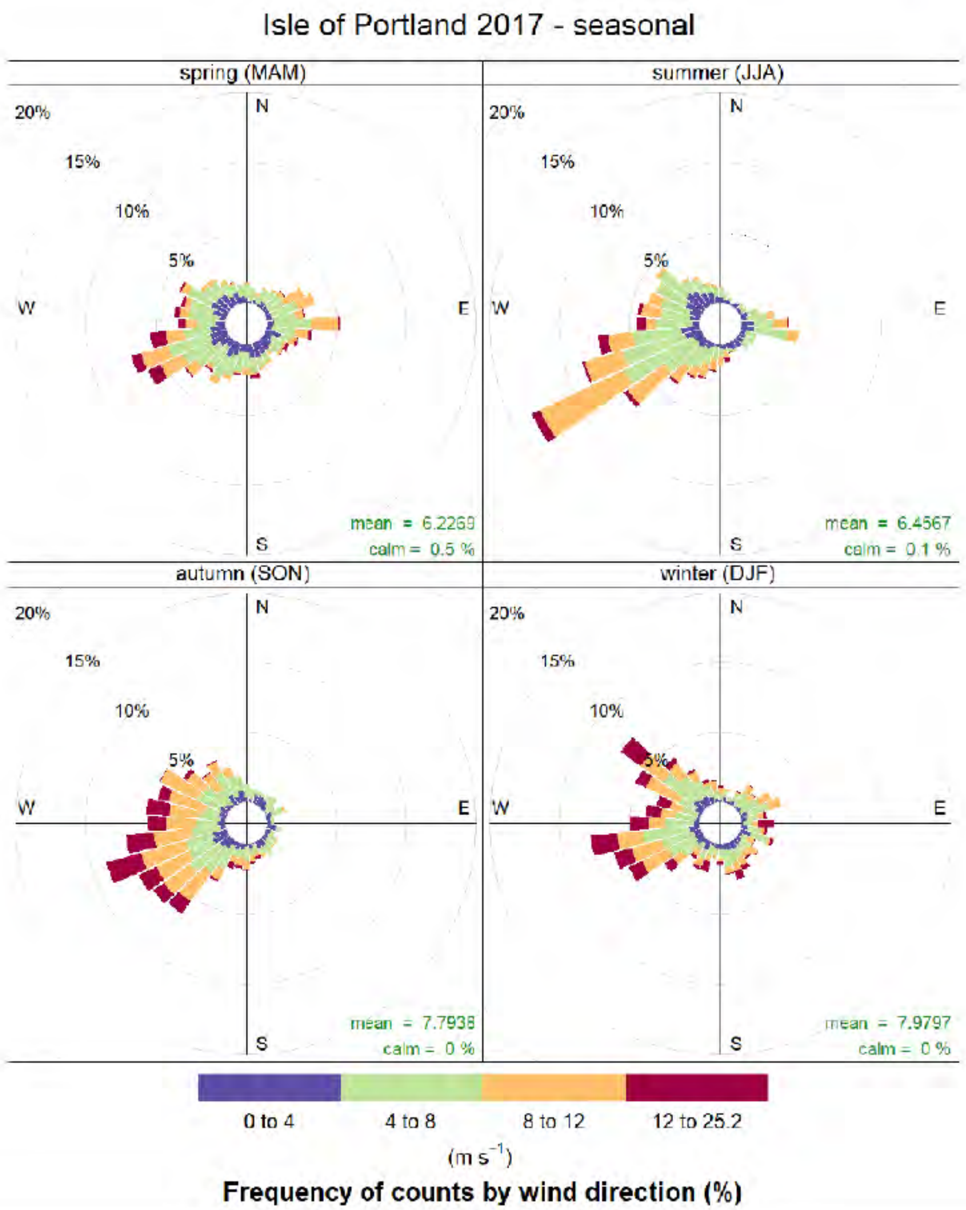
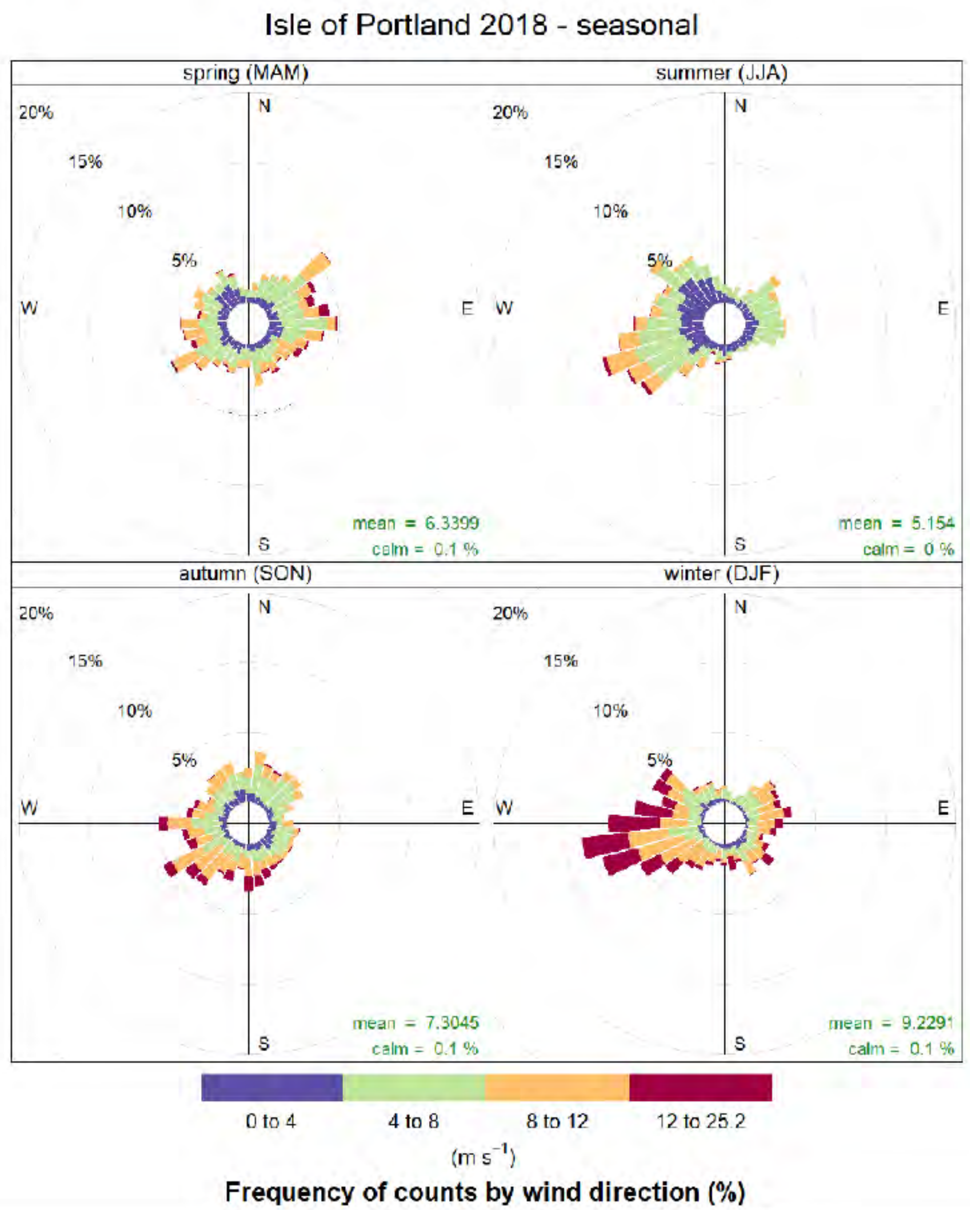




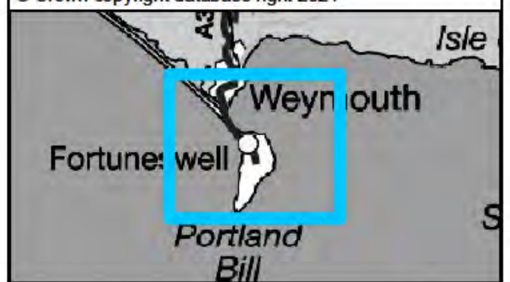


Legend

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	

Figure 22
Isle of Portland Wind Data

Drawn by: RSF | Date: 10/11/2021



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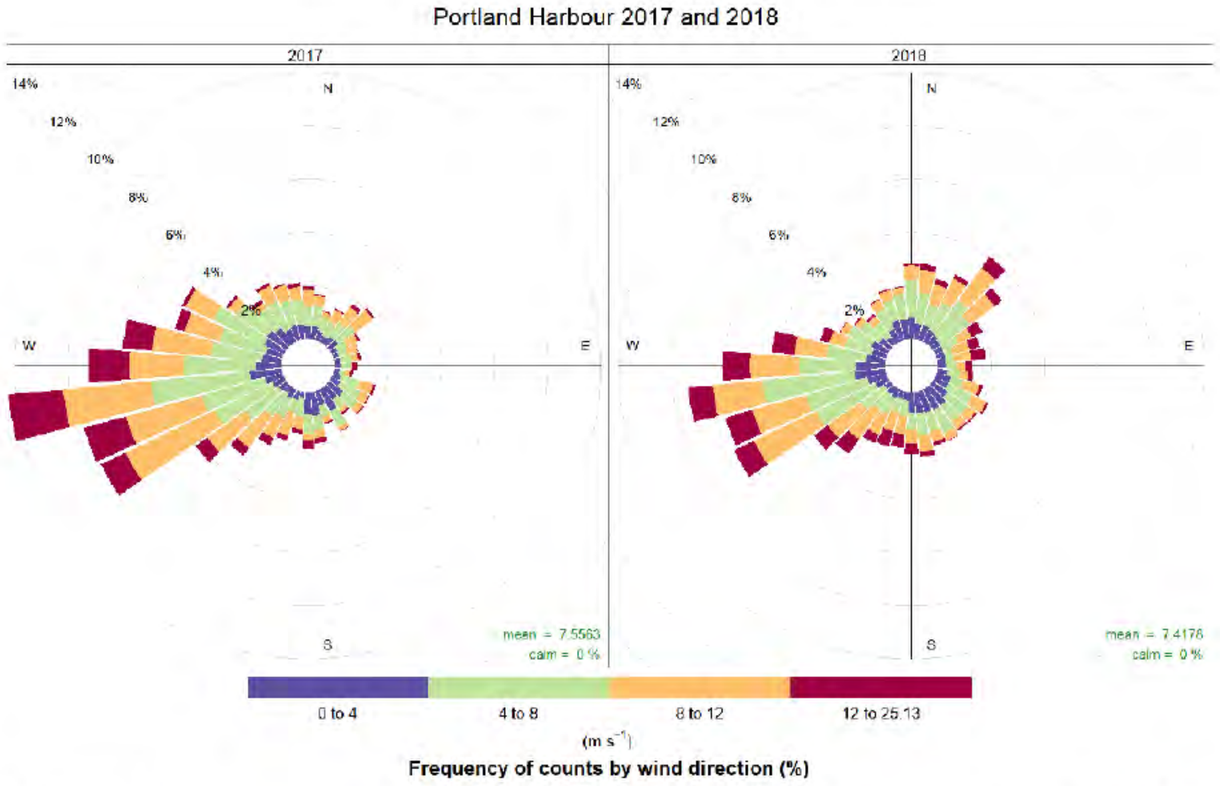
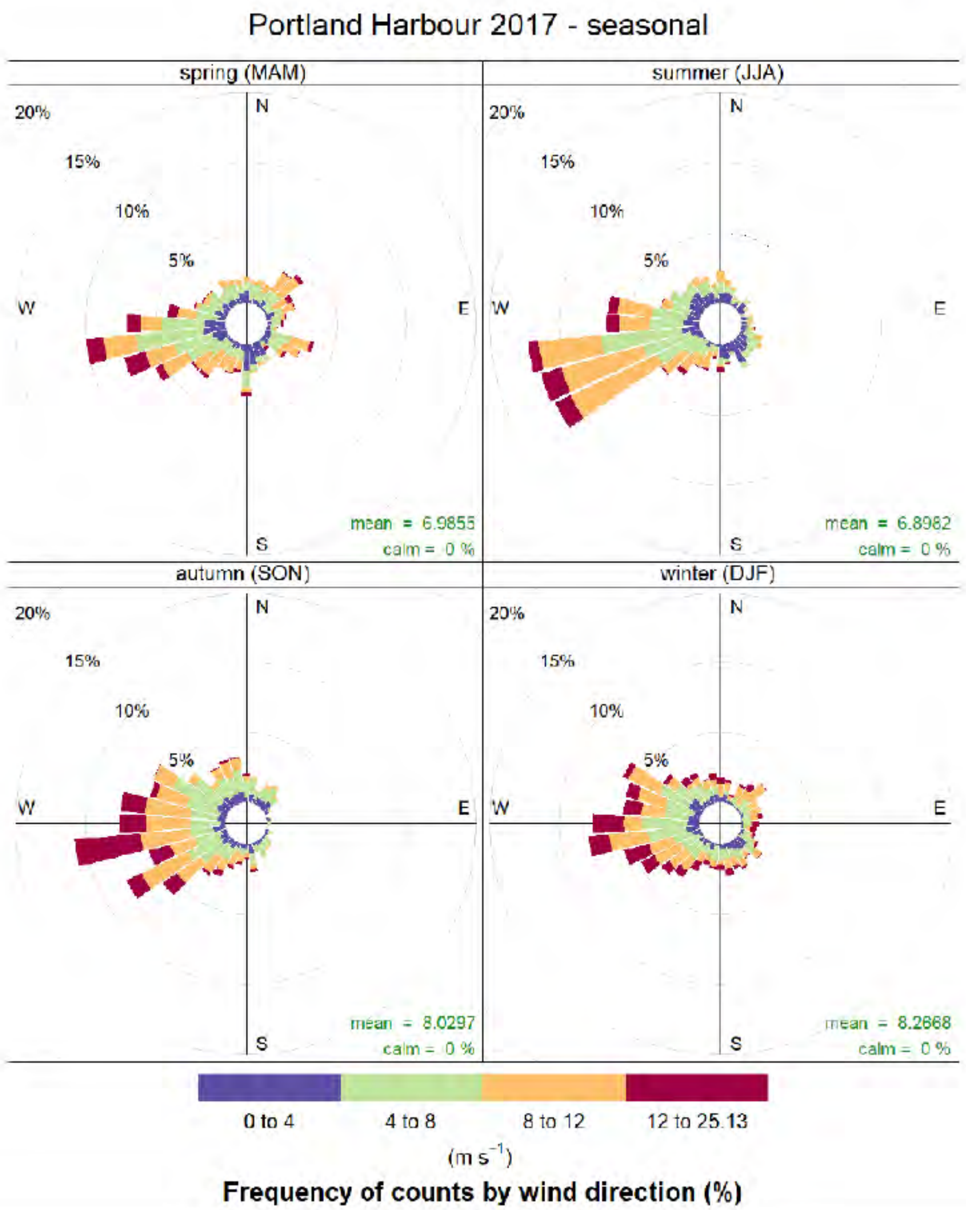
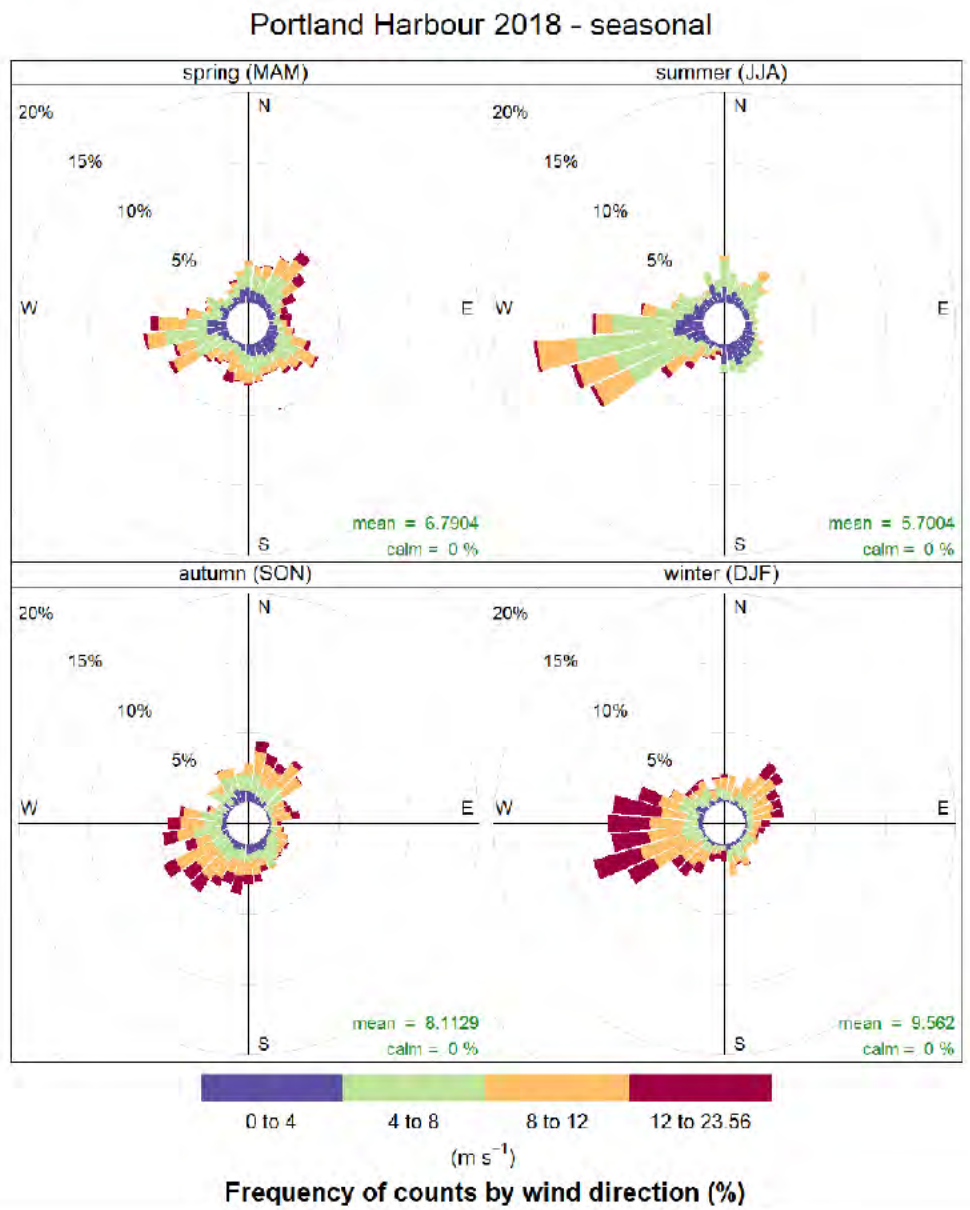
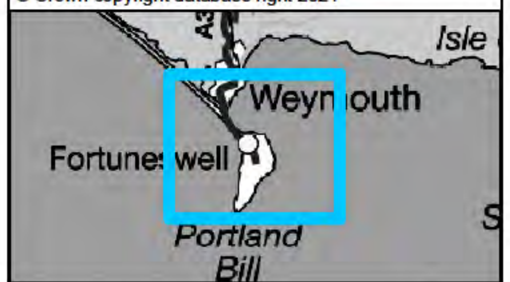






Legend

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 23 Portland Harbour Wind Data
Drawn by: RSF	Date: 15/11/2021



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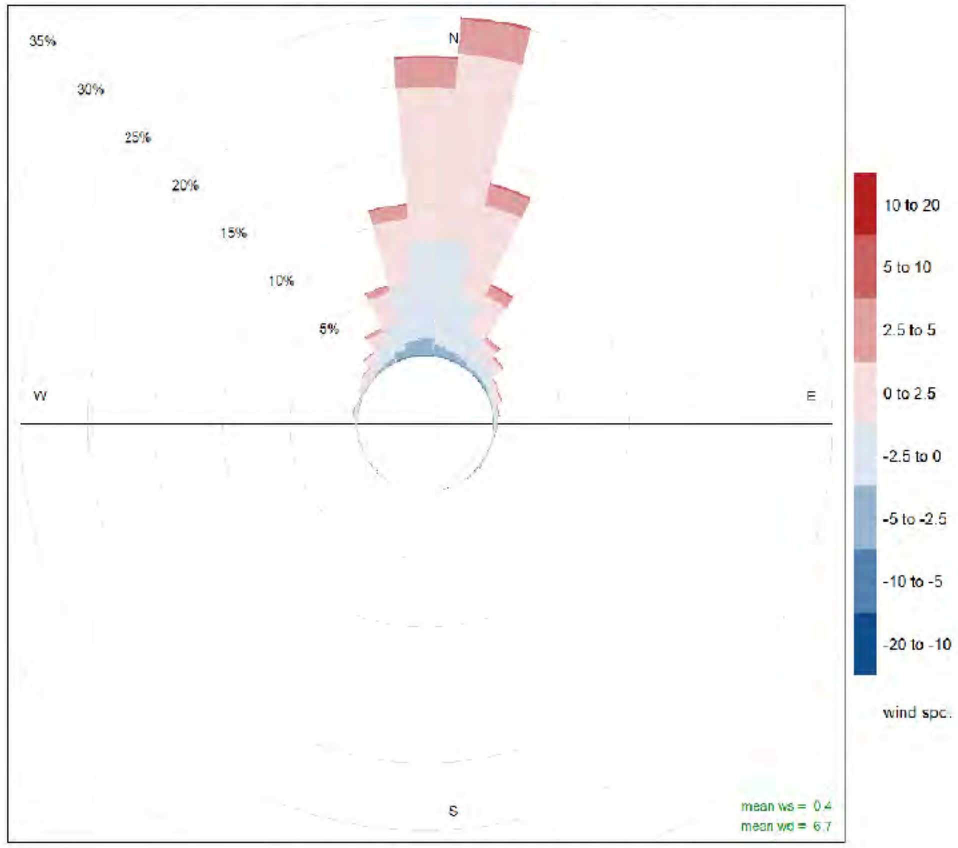
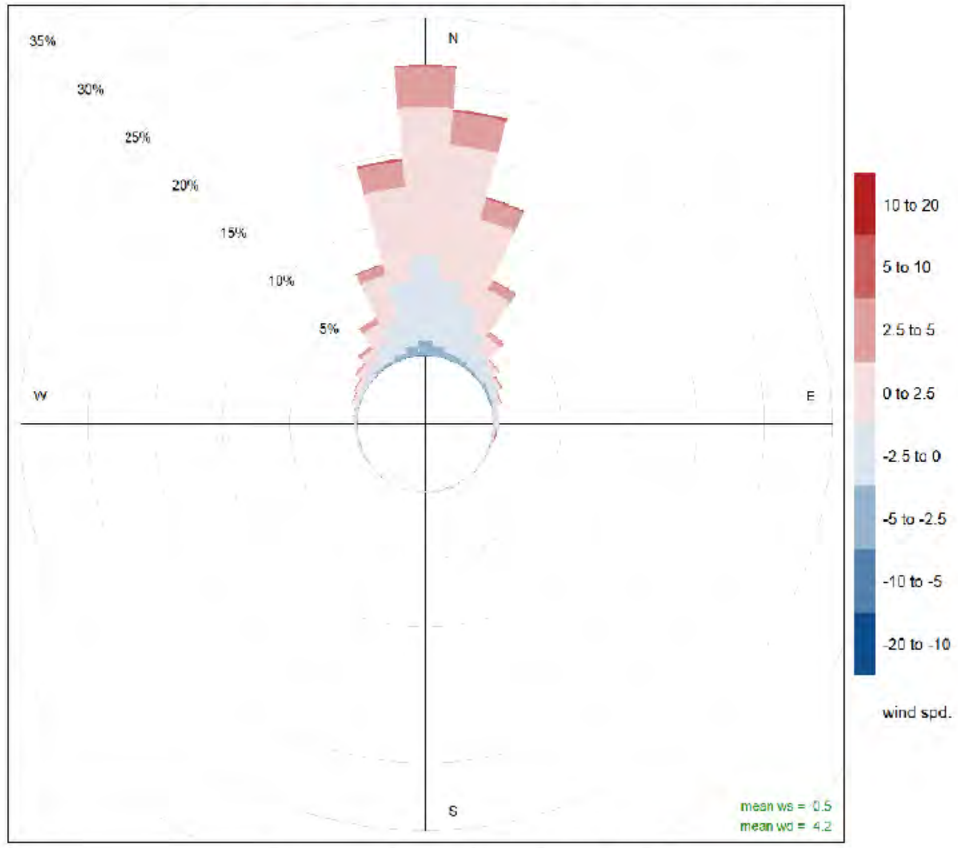
Portland Harbour 2017 compared to Isle of Portland 2017



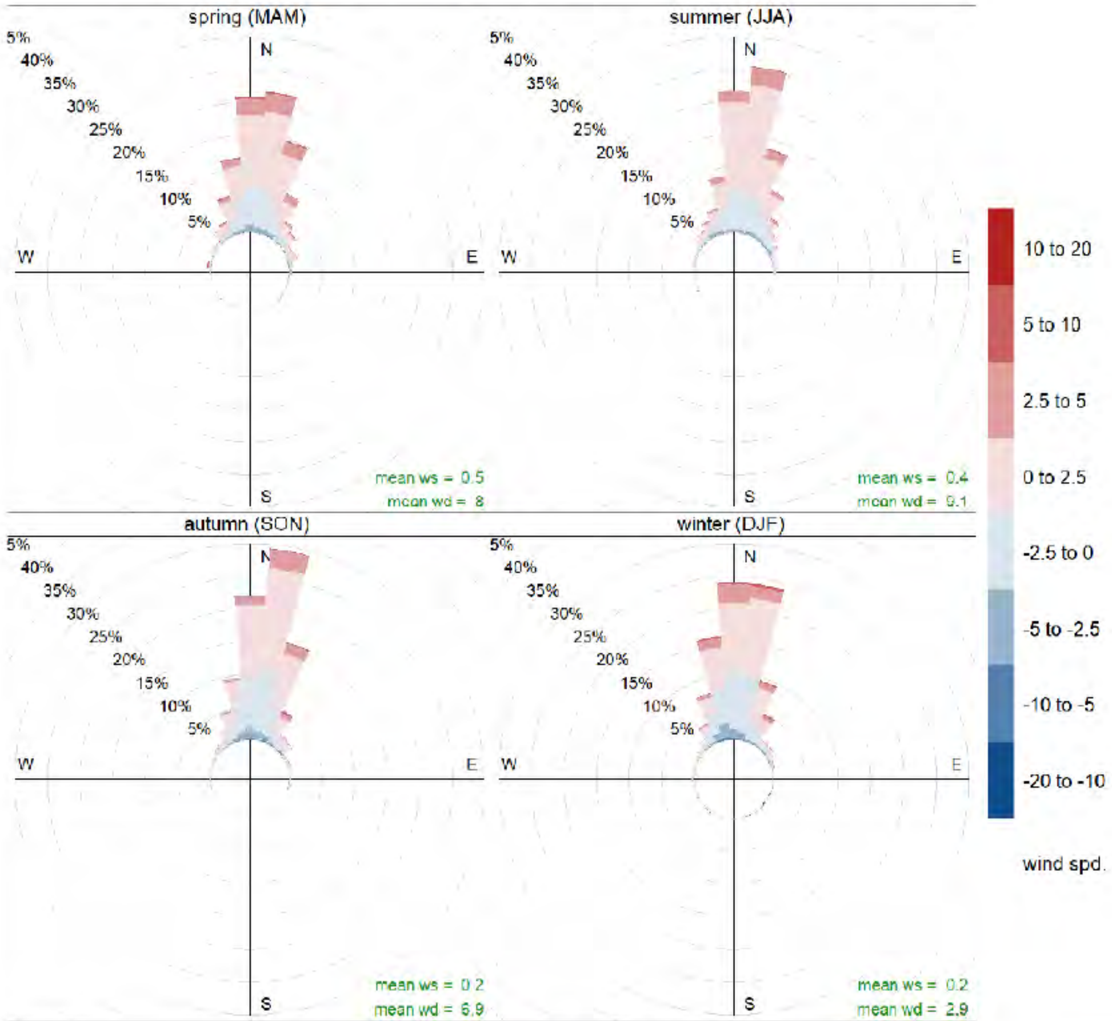
Frequency of counts by wind direction (%)

Portland Harbour 2018 compared to Isle of Portland 2018



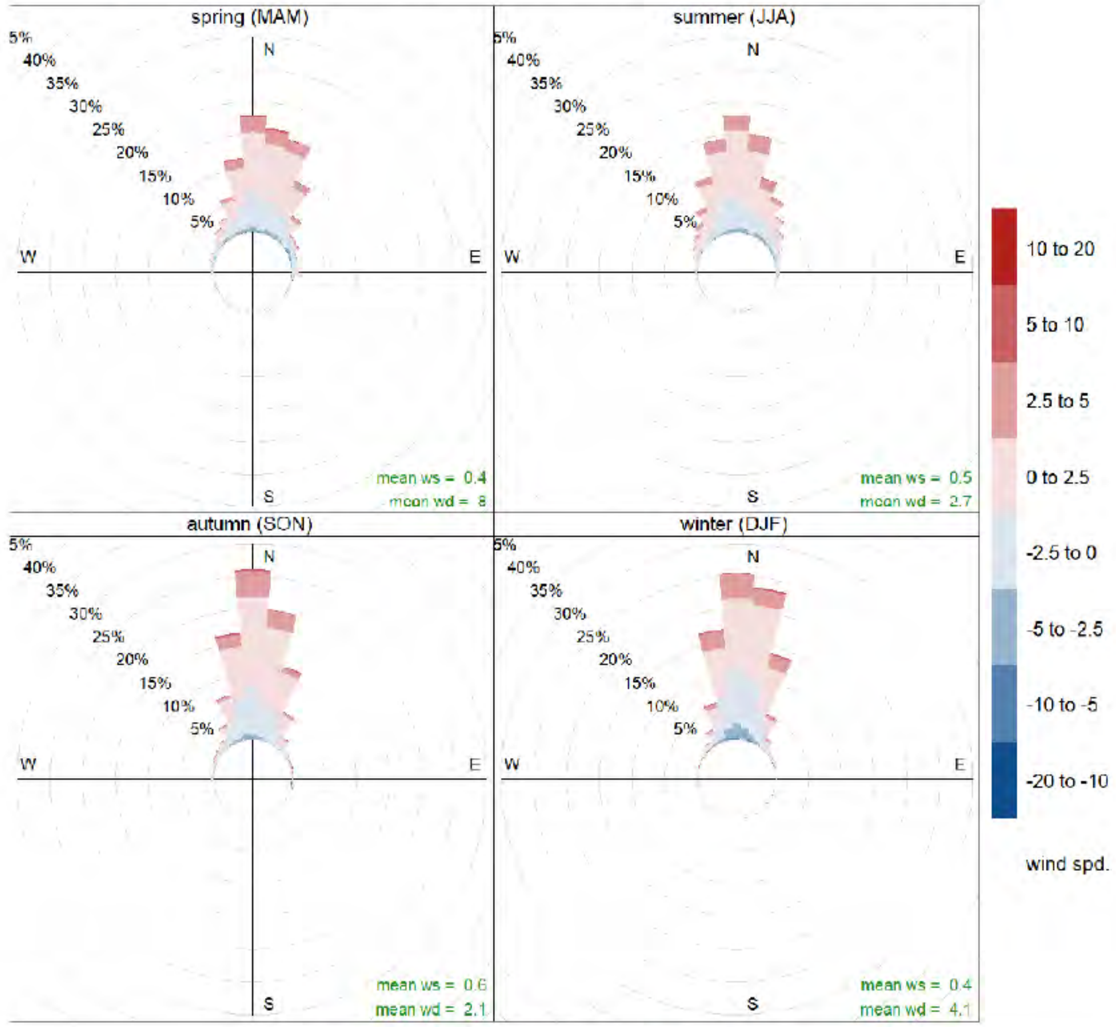
Frequency of counts by wind direction (%)

Portland Harbour 2017 compared to Isle of Portland 2017 - seasonal



Frequency of counts by wind direction (%)

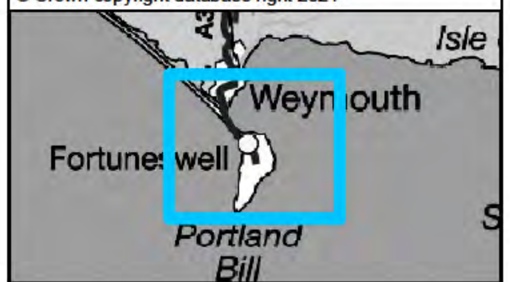
Portland Harbour 2018 compared to Isle of Portland 2018 - seasonal



Frequency of counts by wind direction (%)

Legend

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 24 Wind Data Comparison
Drawn by: RSF	Date: 15/11/2021



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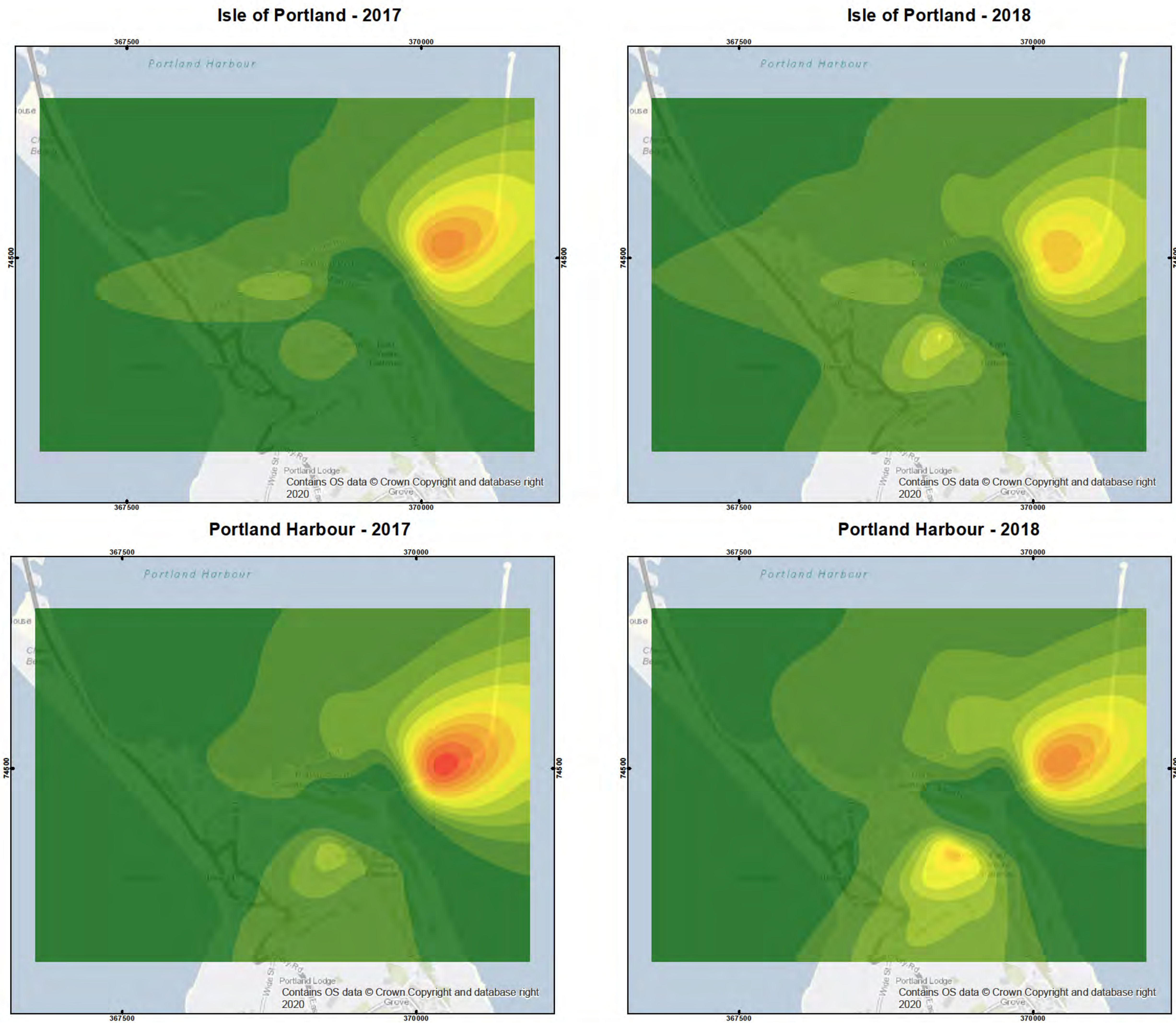


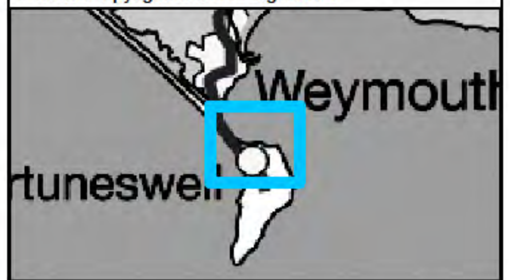
Legend

Maximum Annual Mean NOx

ug/m3

- <0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1
- 1 - 1.1
- 1.1 - 1.2

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 25 Met Data Sensitivity Analysis
Drawn by: RSF	Date: 10/11/2021



0 0.3 0.6 1.2 km

Scale: 1:30,800

N

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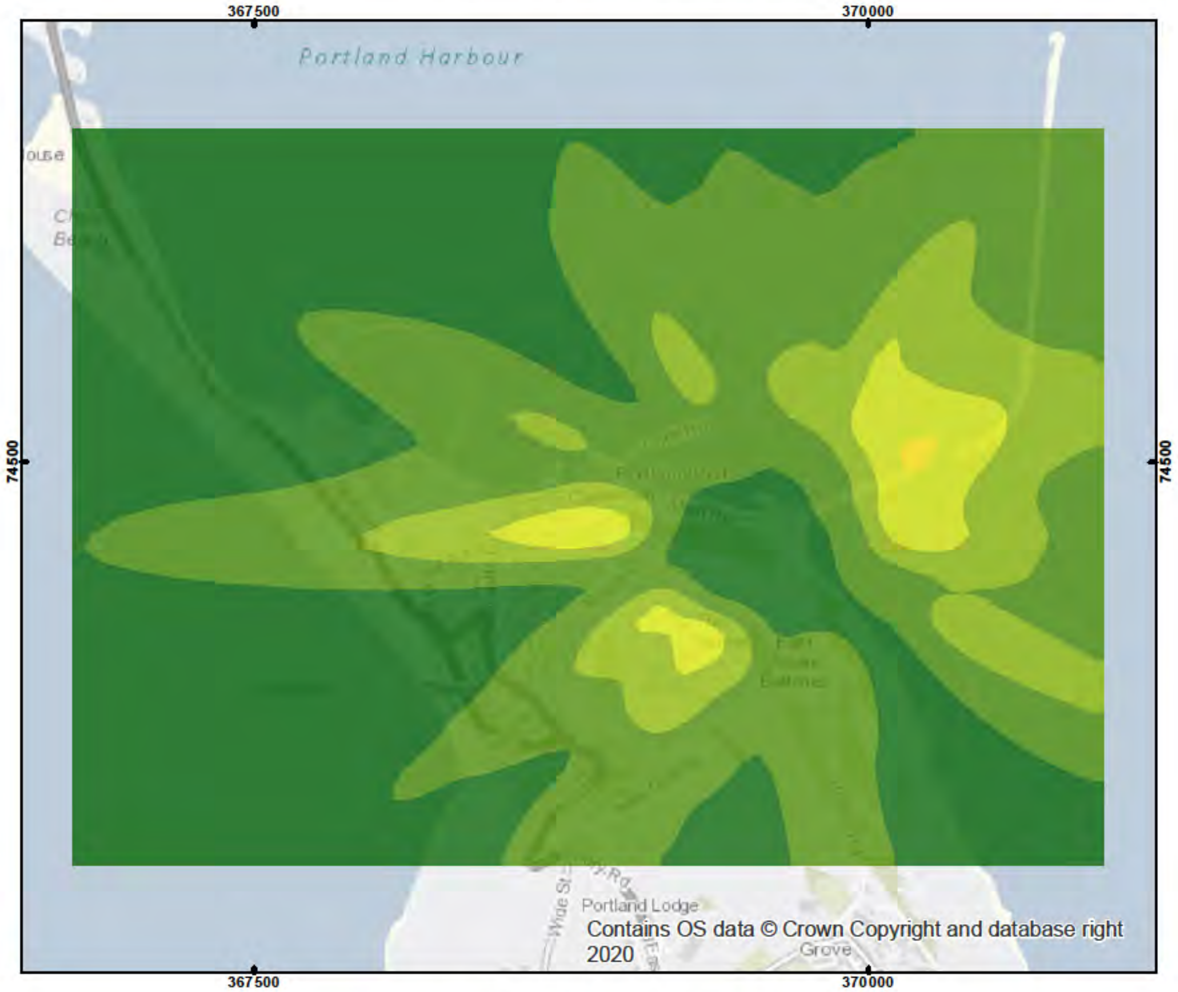
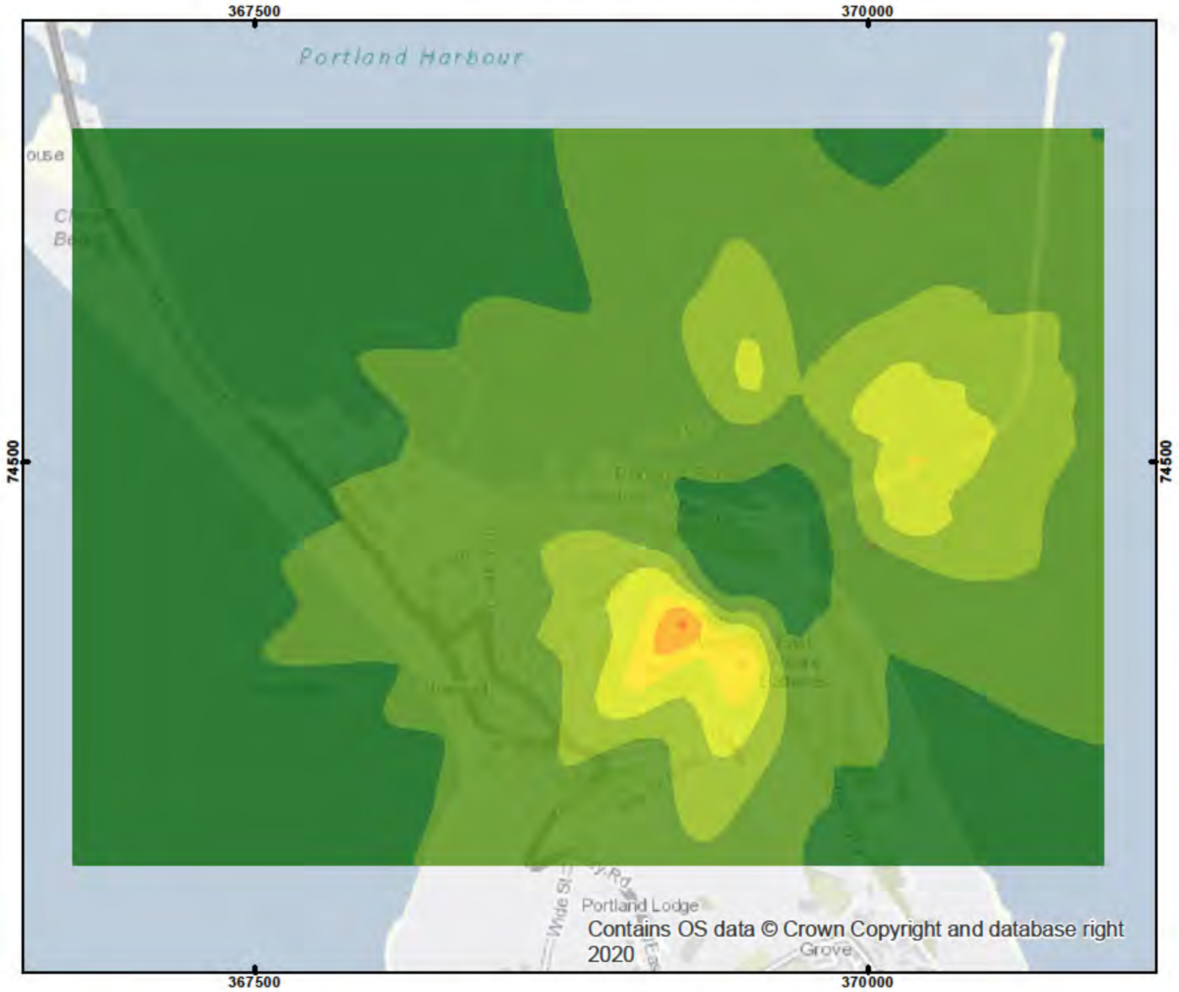
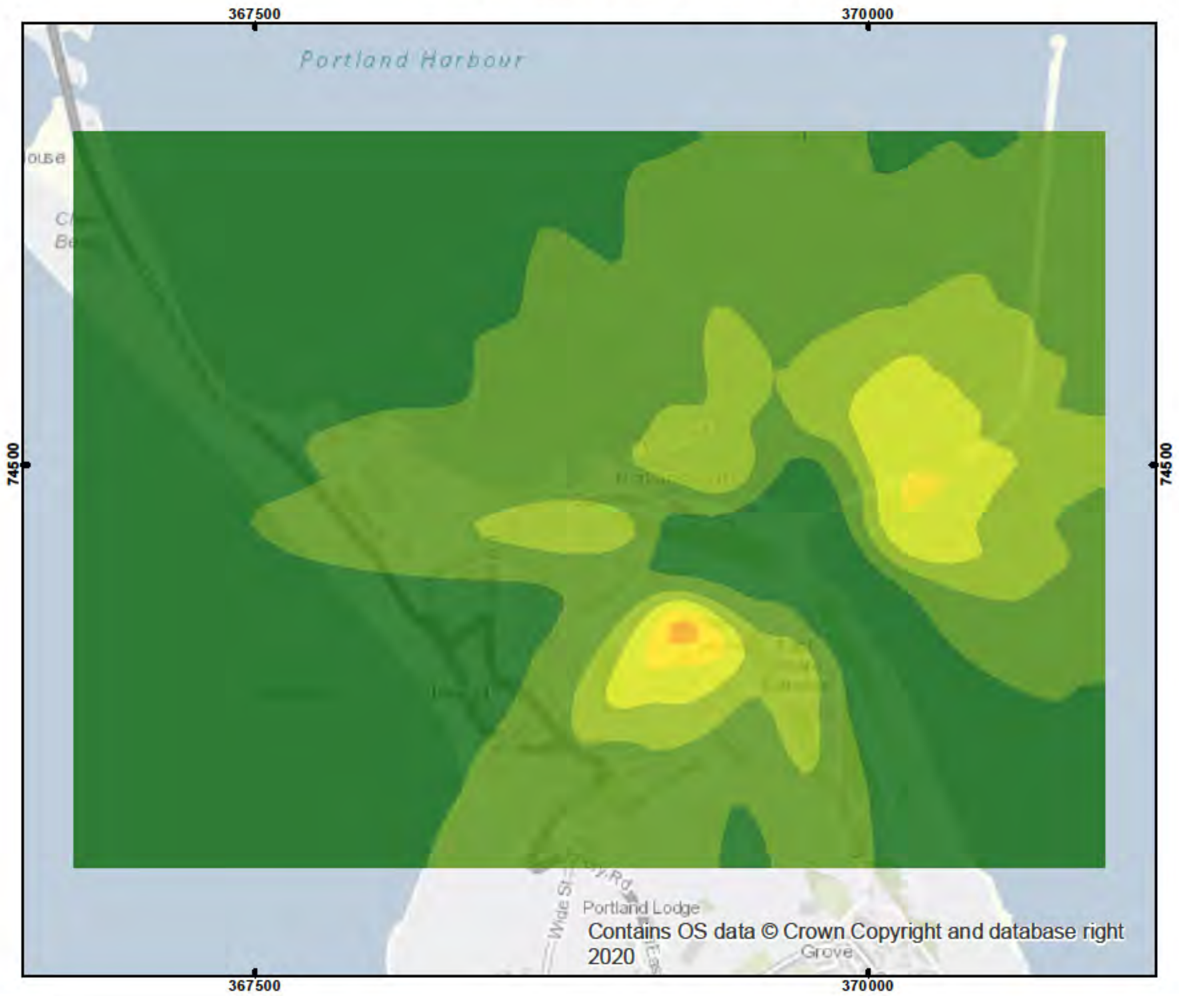
Isle of Portland - 2017



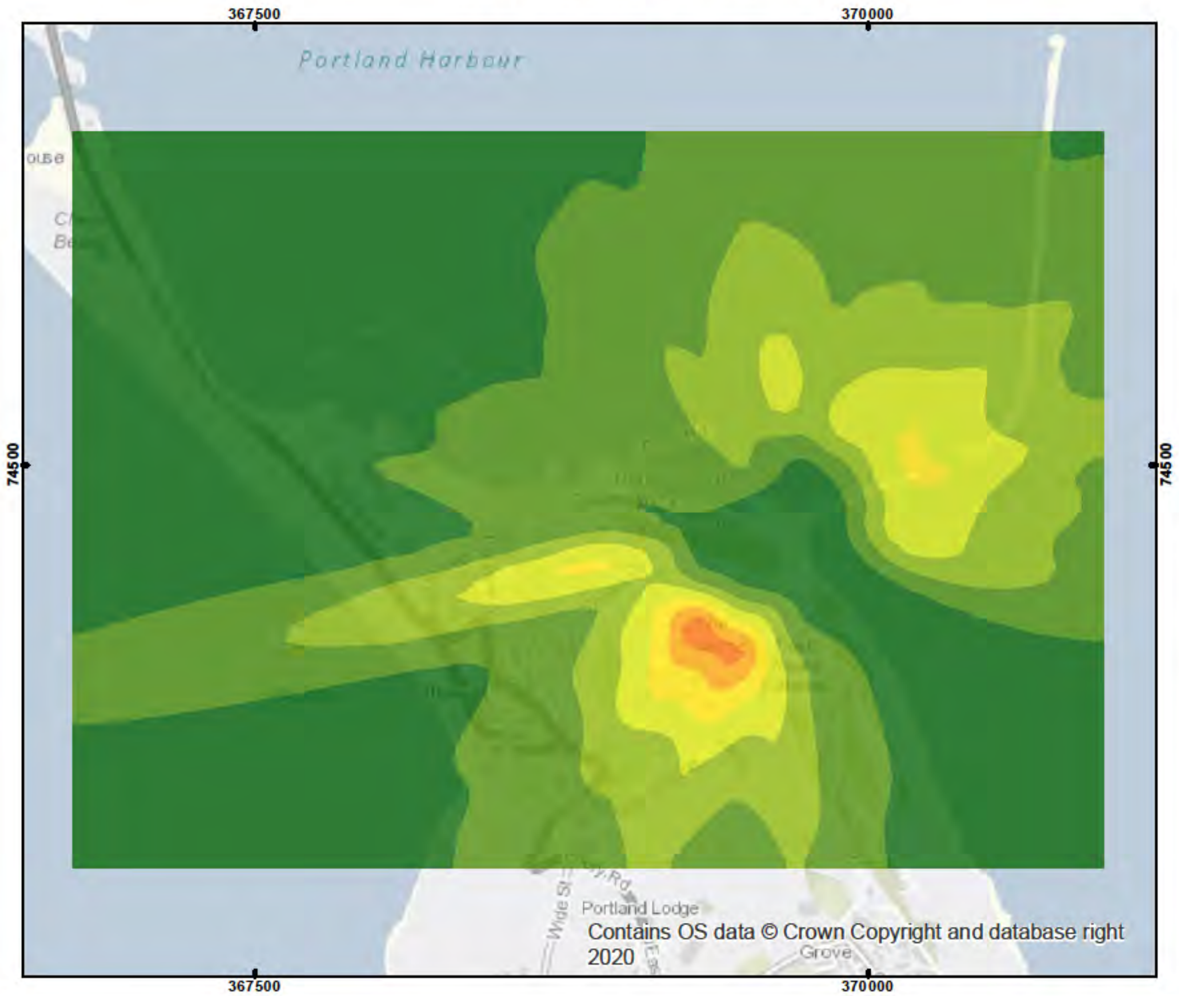
Isle of Portland - 2018



Portland Harbour - 2017



Portland Harbour - 2018



Legend

Maximum 24-hour NOx ug/m3

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 26 Met Data Sensitivity Analysis
Drawn by: RSF	Date: 10/11/2021

0 0.3 0.6 1.2 km

Scale: 1:30,800

N

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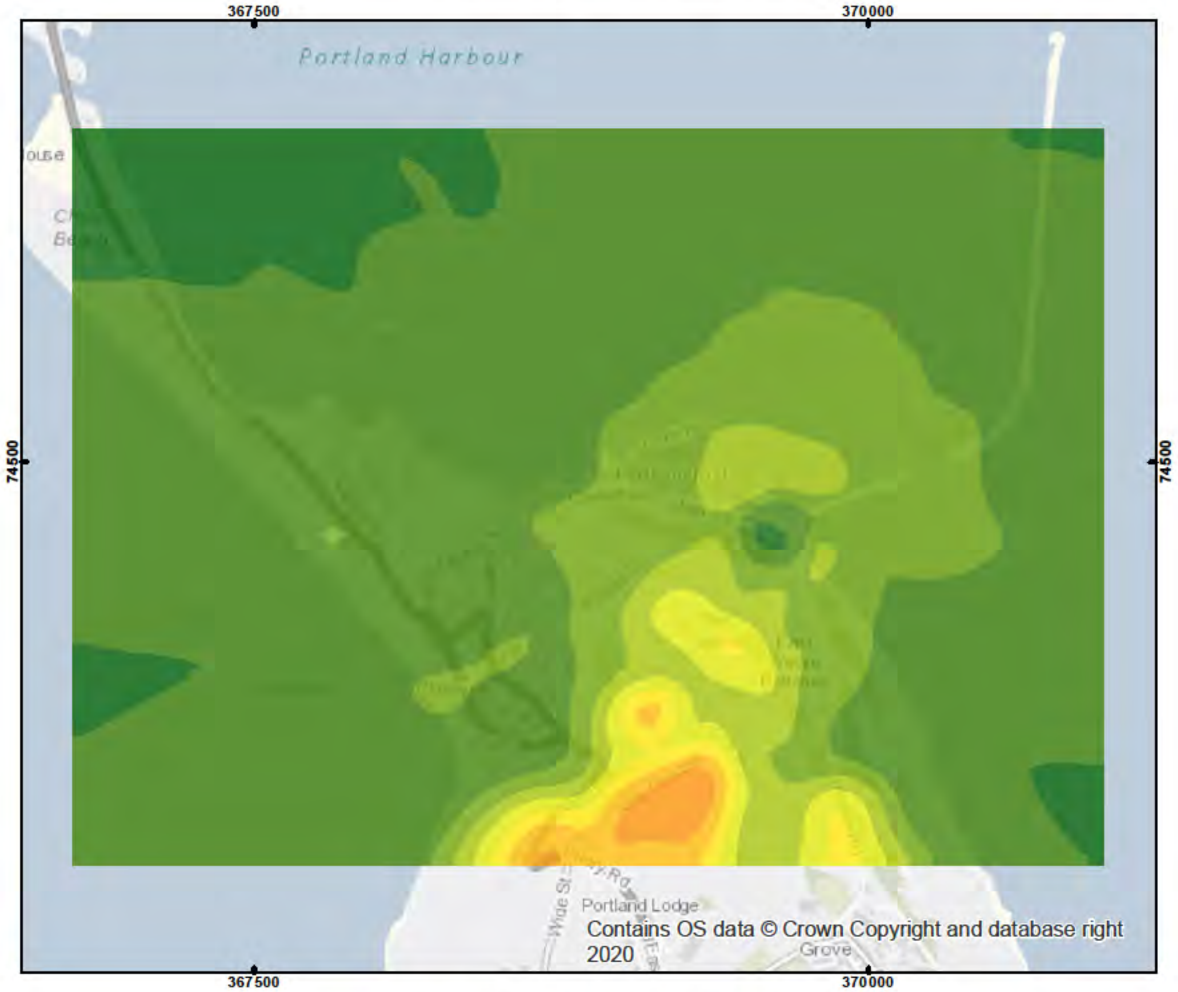
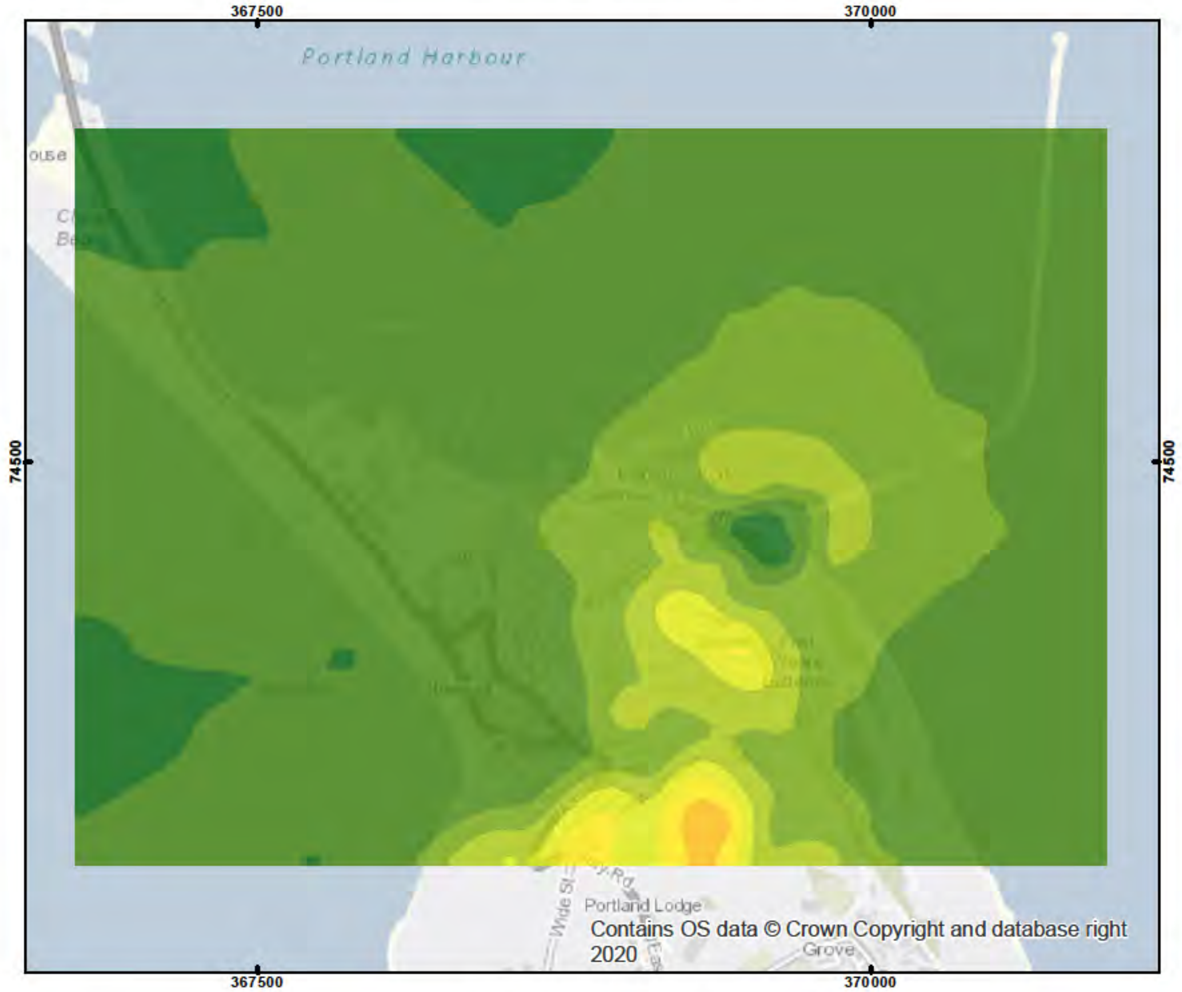
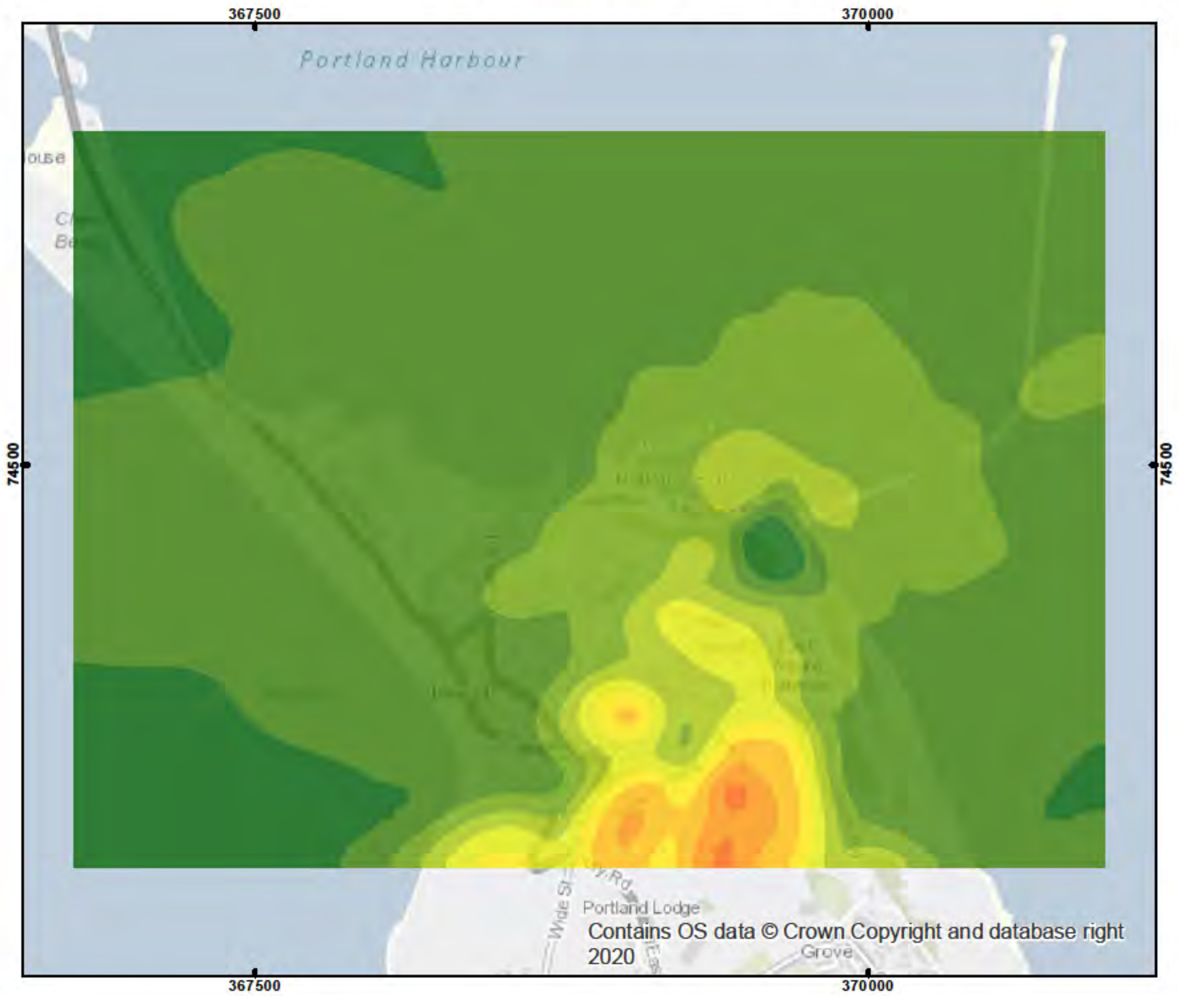
Isle of Portland - 2017



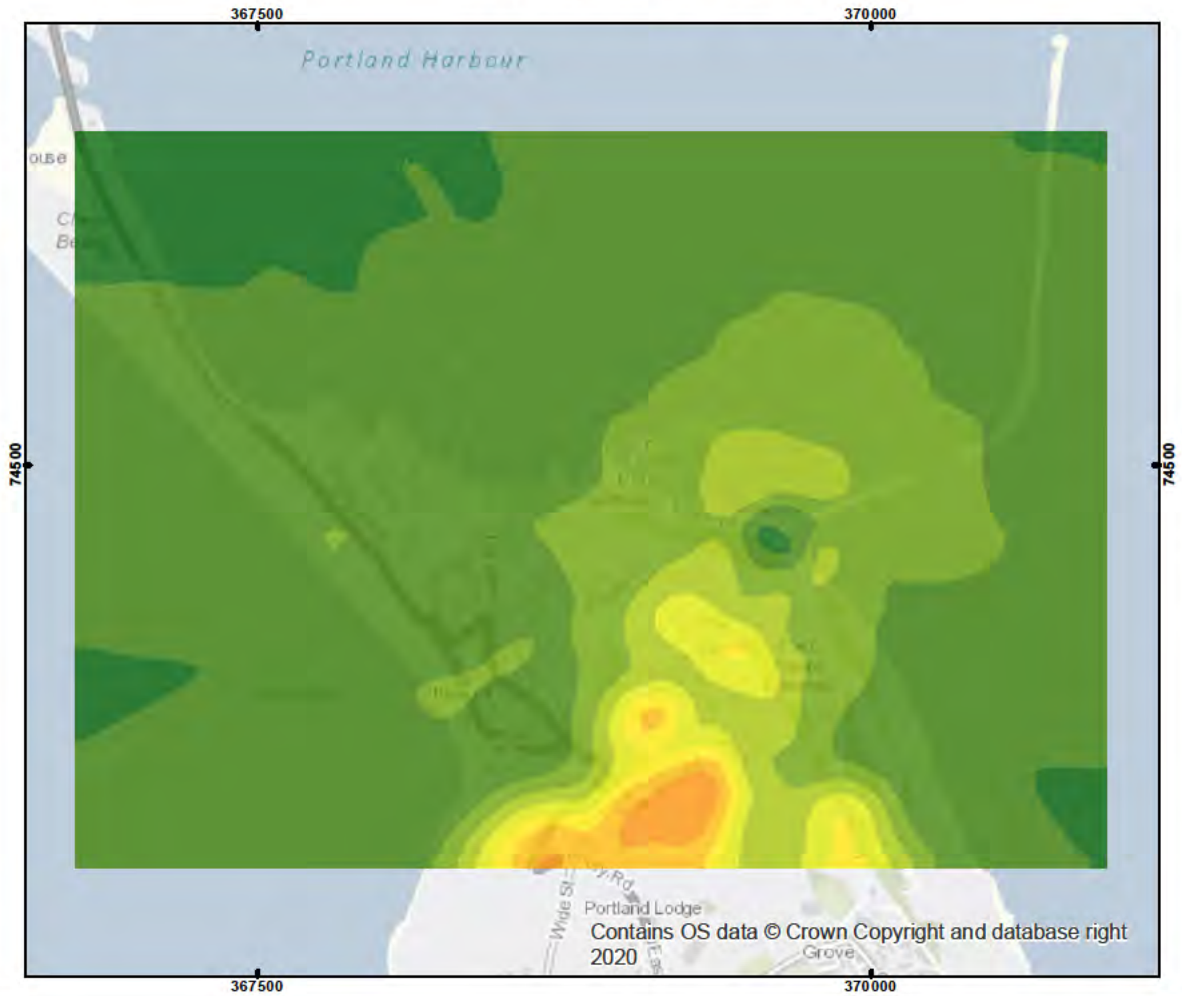
Isle of Portland - 2018



Portland Harbour - 2017



Portland Harbour - 2018



Legend

Maximum 1-hour NOx ug/m3

- <5
- 5 - 10
- 10 -15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50

Client: Powerfuel Portland Limited
Site: Portland
Project: 2953
Title:

Figure 27
Met Data
Sensitivity Analysis

Drawn by: RSF
Date: 09/11/2021

0 0.3 0.6 1.2 km

Scale: 1:30,800

N

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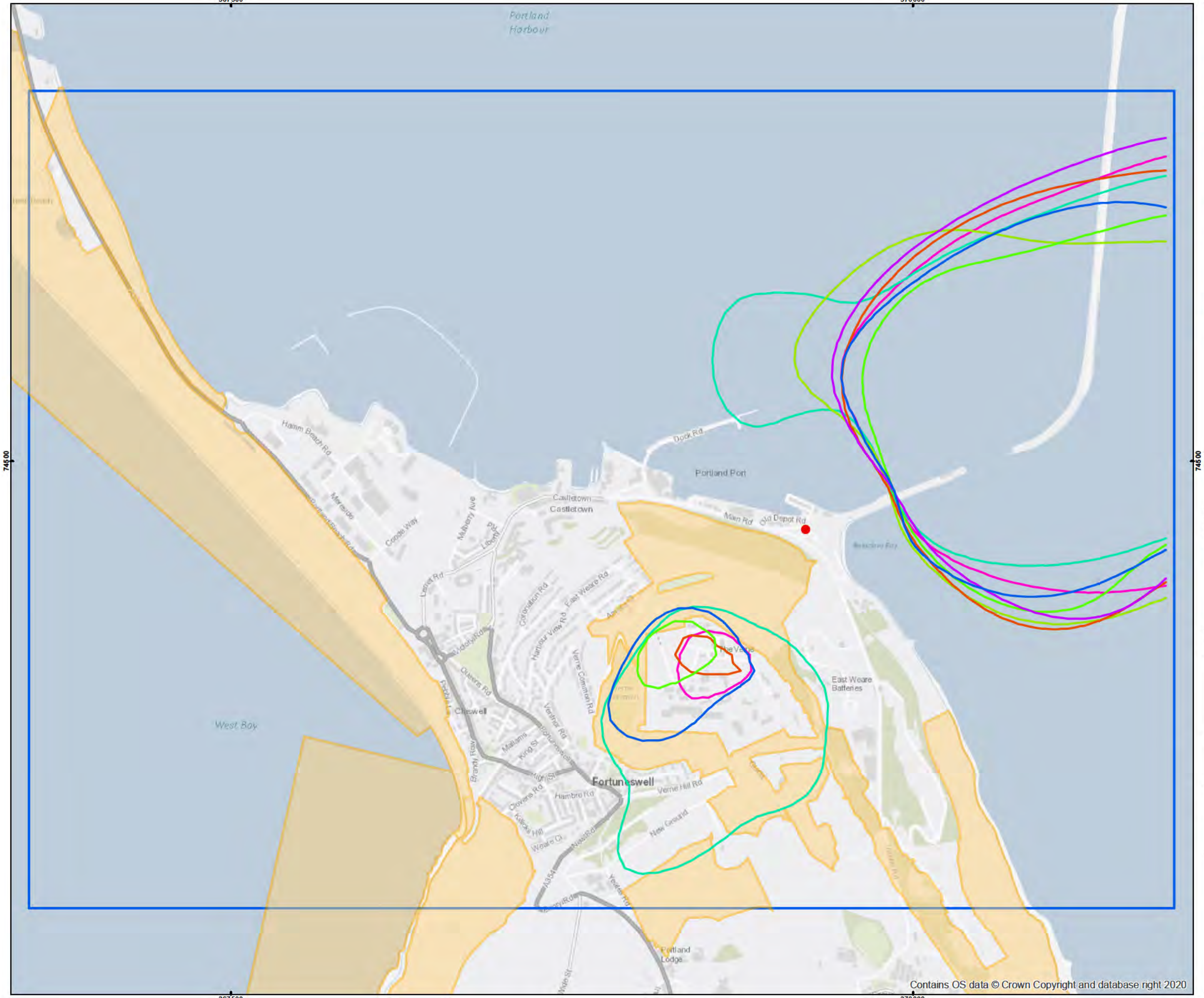

Legend

- 2018 Isle of Portland
- 2017 Isle of Portland
- 2016 Isle of Portland
- 2015 Isle of Portland
- 2014 Isle of Portland
- 2018 Portland Harbour
- 2017 Portland Harbour
- Main Stack
- SAC
- Output grid extent

Contour of 1% of Critical Level, assuming 100% operation at the ELV

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 28 Annual Mean NOx Impact Met Data Sensitivity
Drawn by: RSF	Date: 15/11/2021

0 0.125 0.25 0.5 km

Scale: 1:13,000

N

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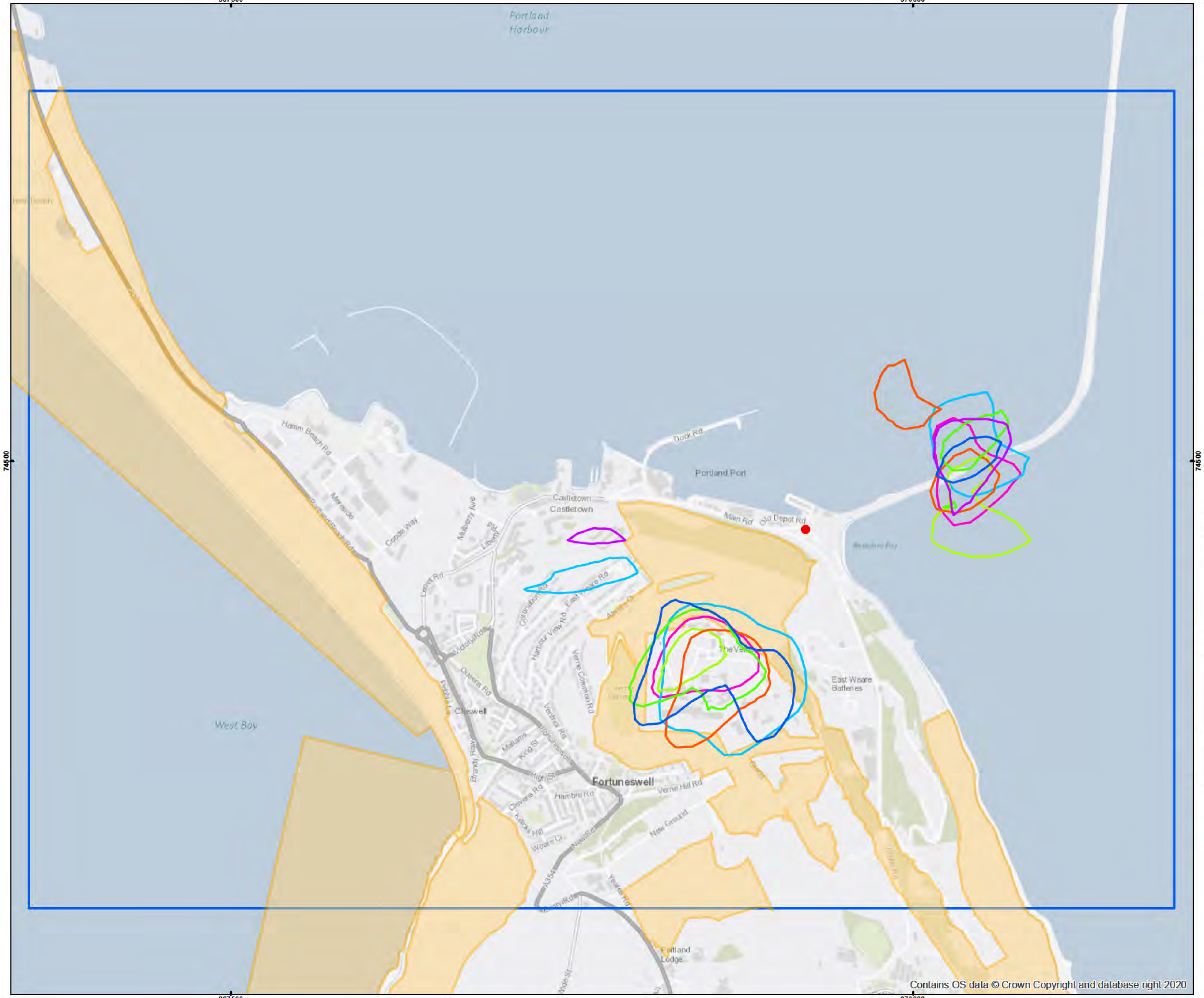
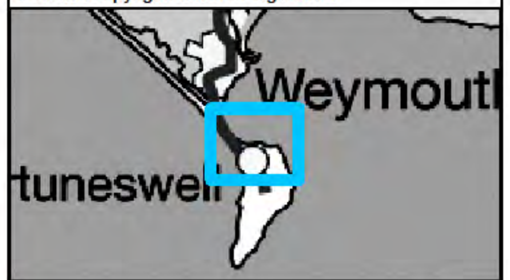


Legend

- 2018 Isle of Portland
- 2017 Isle of Portland
- 2016 Isle of Portland
- 2015 Isle of Portland
- 2014 Isle of Portland
- 2018 Portland Harbour
- 2017 Portland Harbour
- Main Stack
- SAC
- Output grid extent

Contour of 10% of Critical Level, assuming 100% operation at the ELV

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 29 Daily Mean NOx Impact Met Data Sensitivity
Drawn by: RSF	Date: 15/11/2021



0 0.125 0.25 0.5 km

Scale: 1:13,000

N

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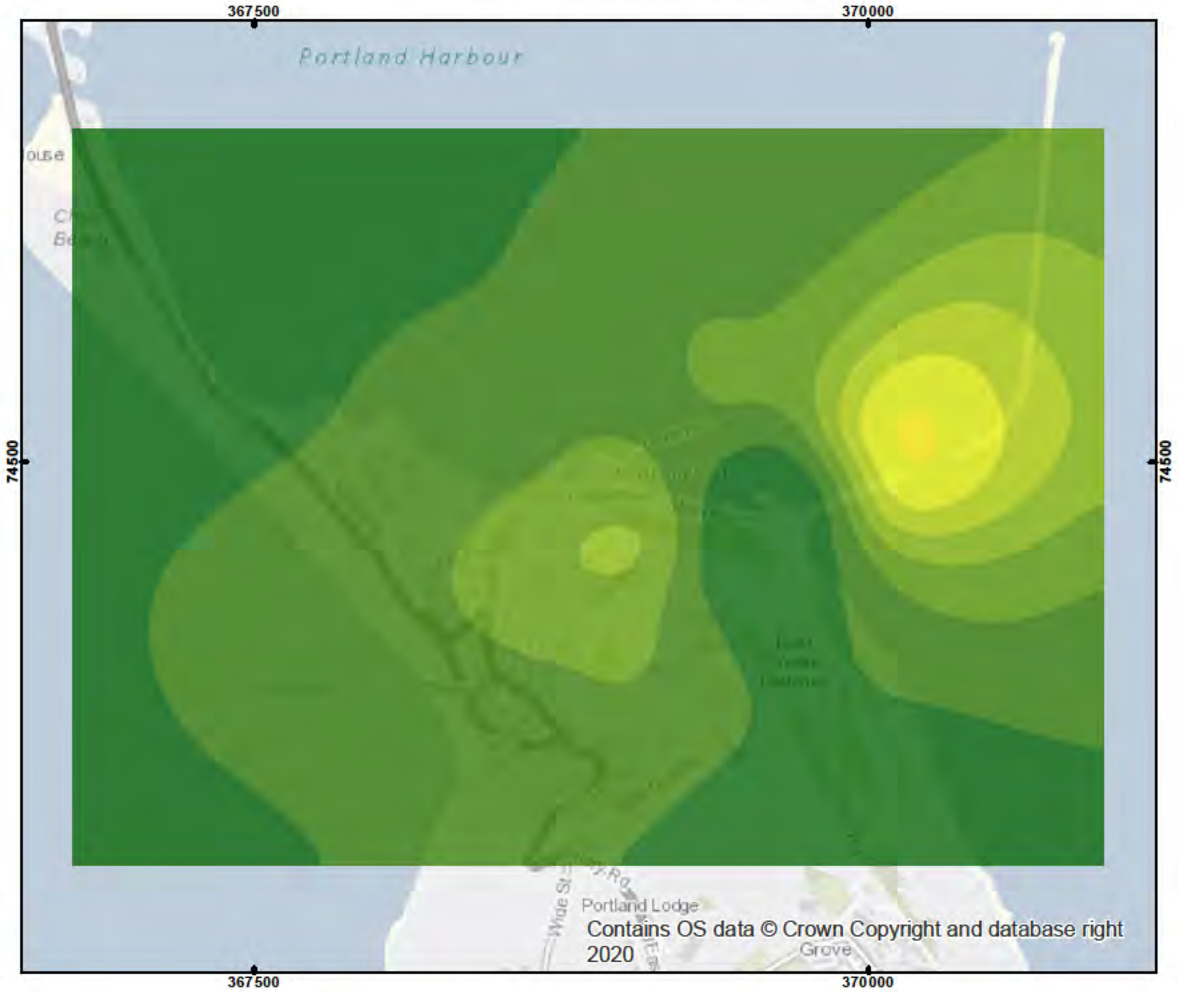
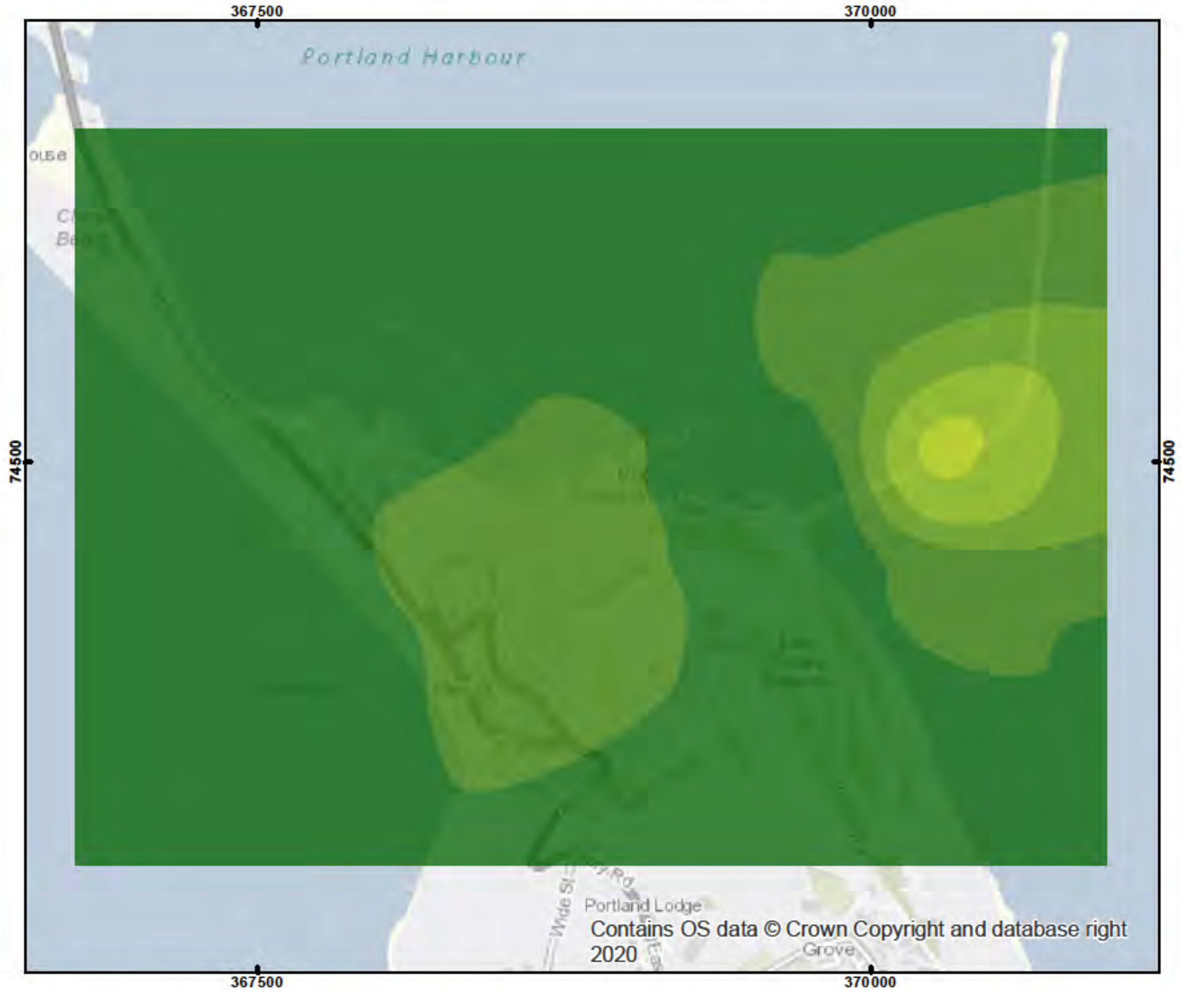
Fax: 0161 474 0618

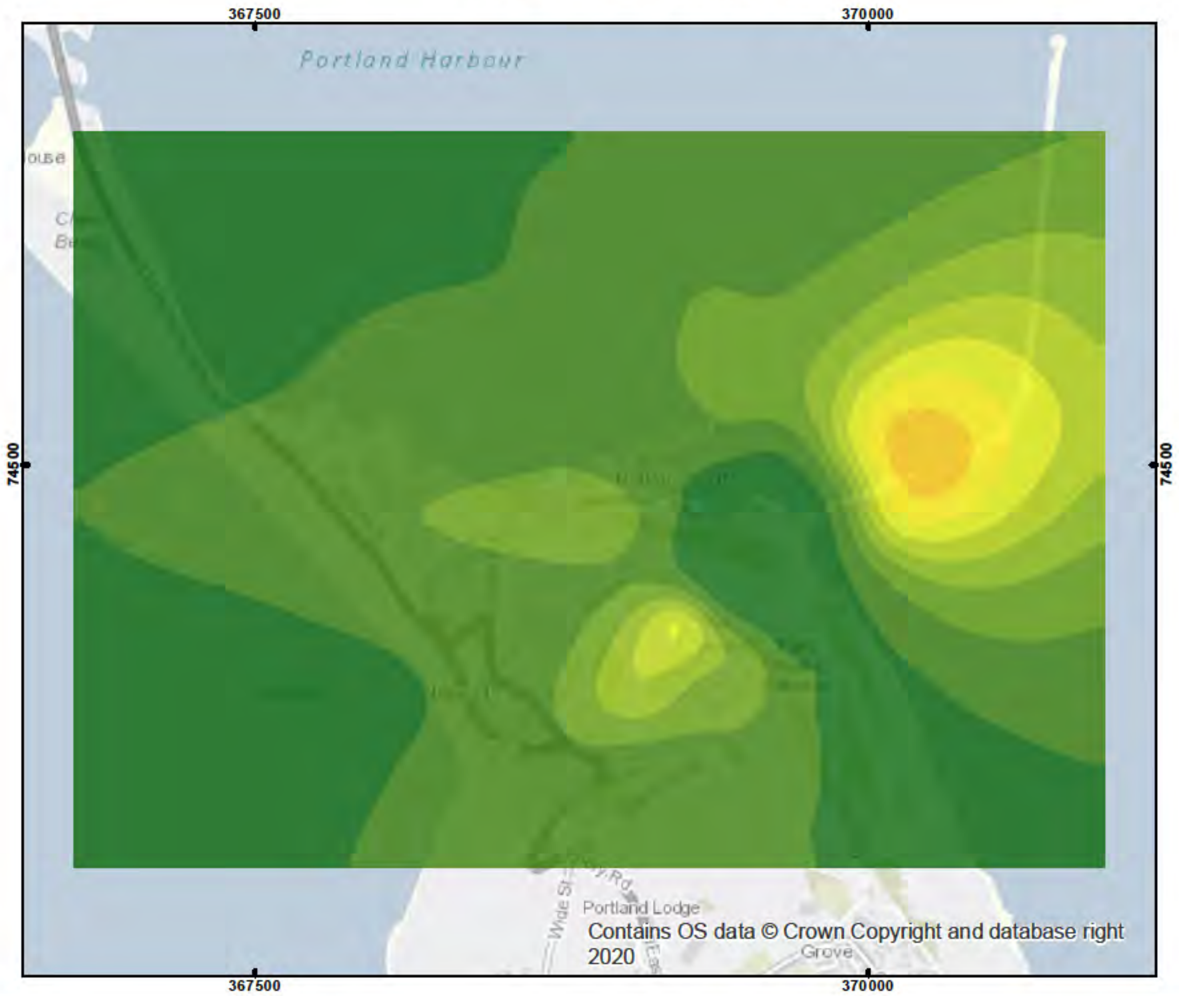
ADMS - Excluding Terrain



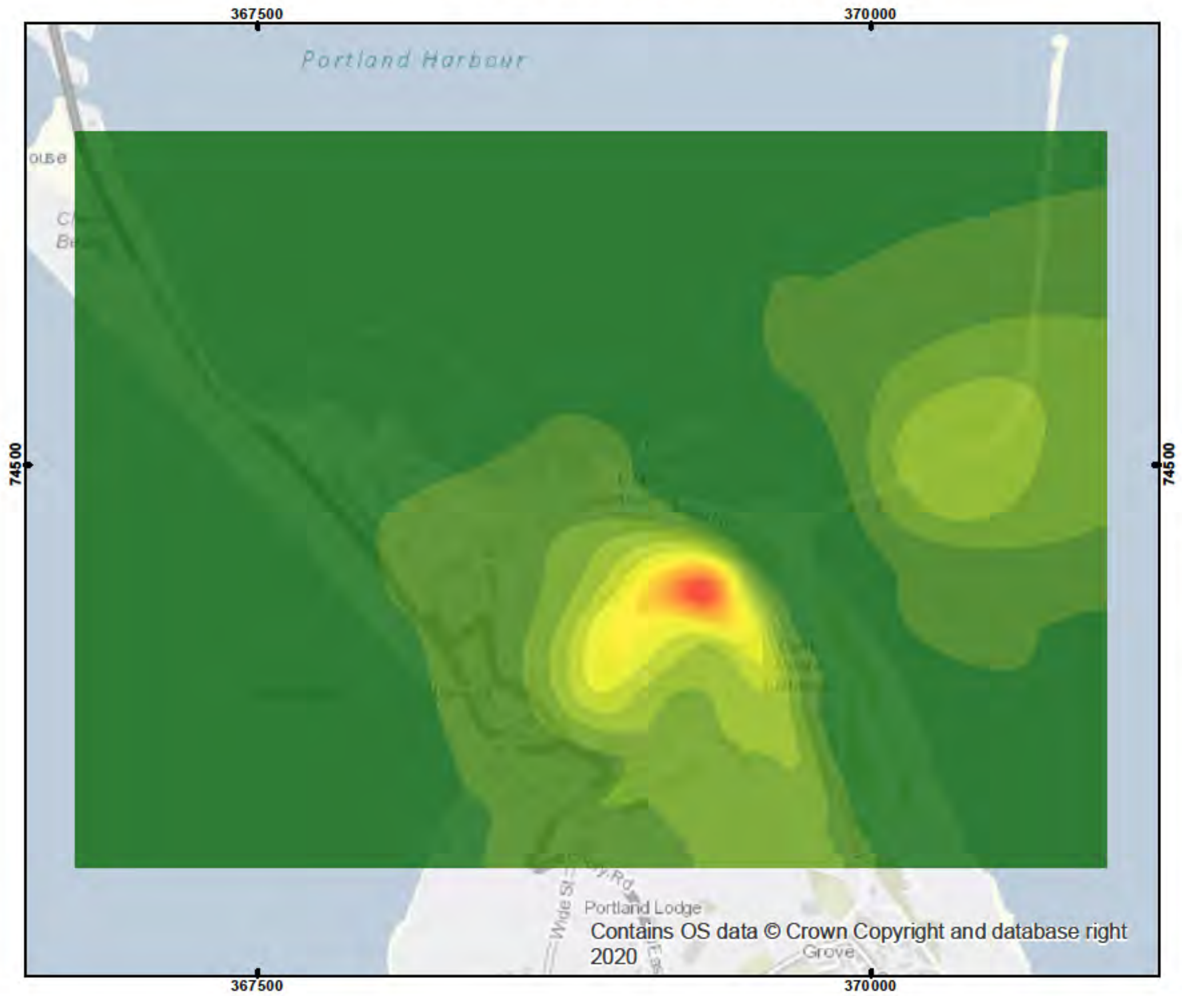
AERMOD - Excluding Terrain



ADMS - Including Terrain



AERMOD - Including Terrain



Legend

Annual Mean

ug/m3

- <0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1
- 1 - 1.1
- 1.1 - 1.2

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 30 Model Sensitivity Analysis

Drawn by: RSF | Date: 15/11/2021

0 0.325 0.65 1.3 km

N

Scale: 1:30,800

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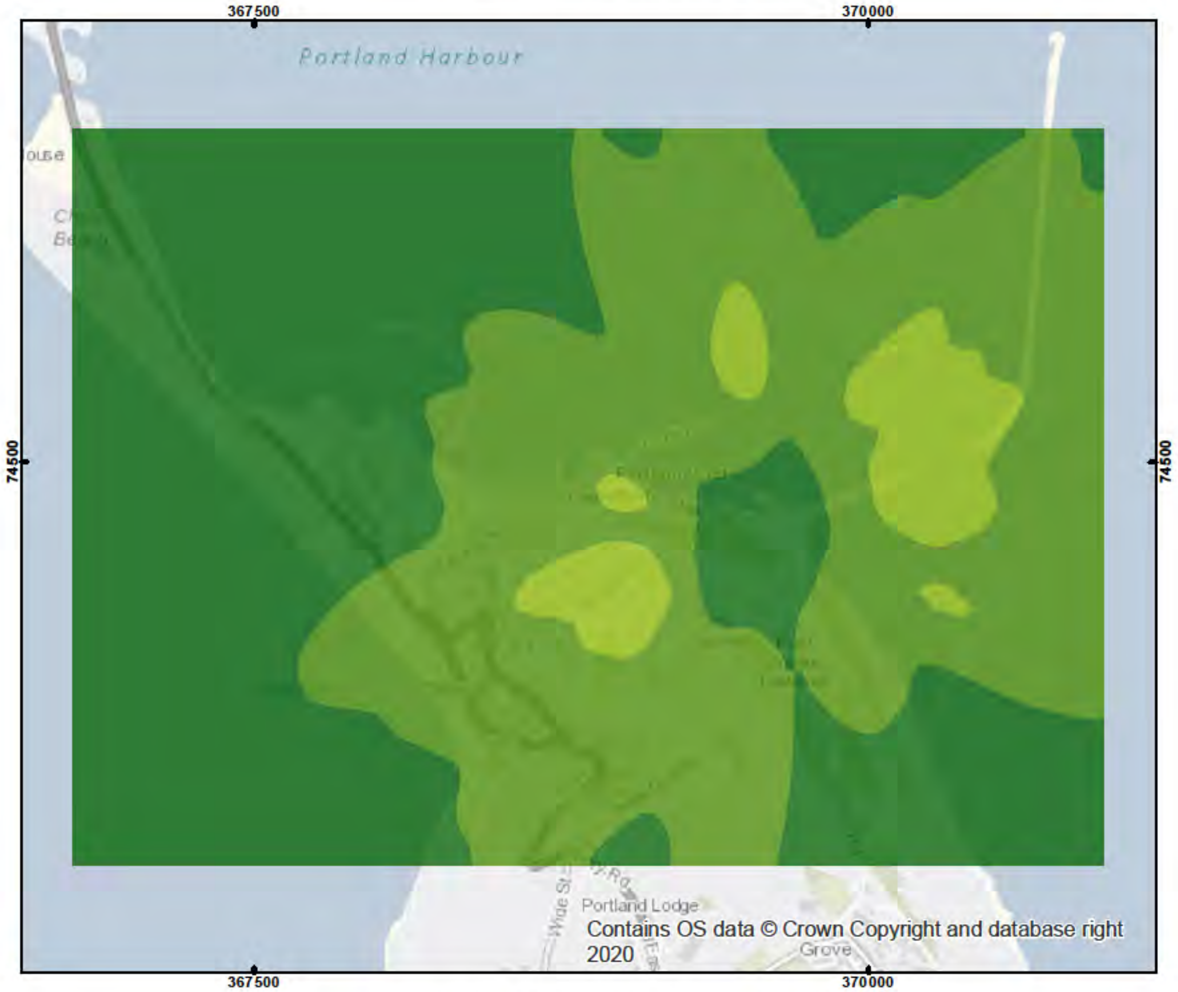
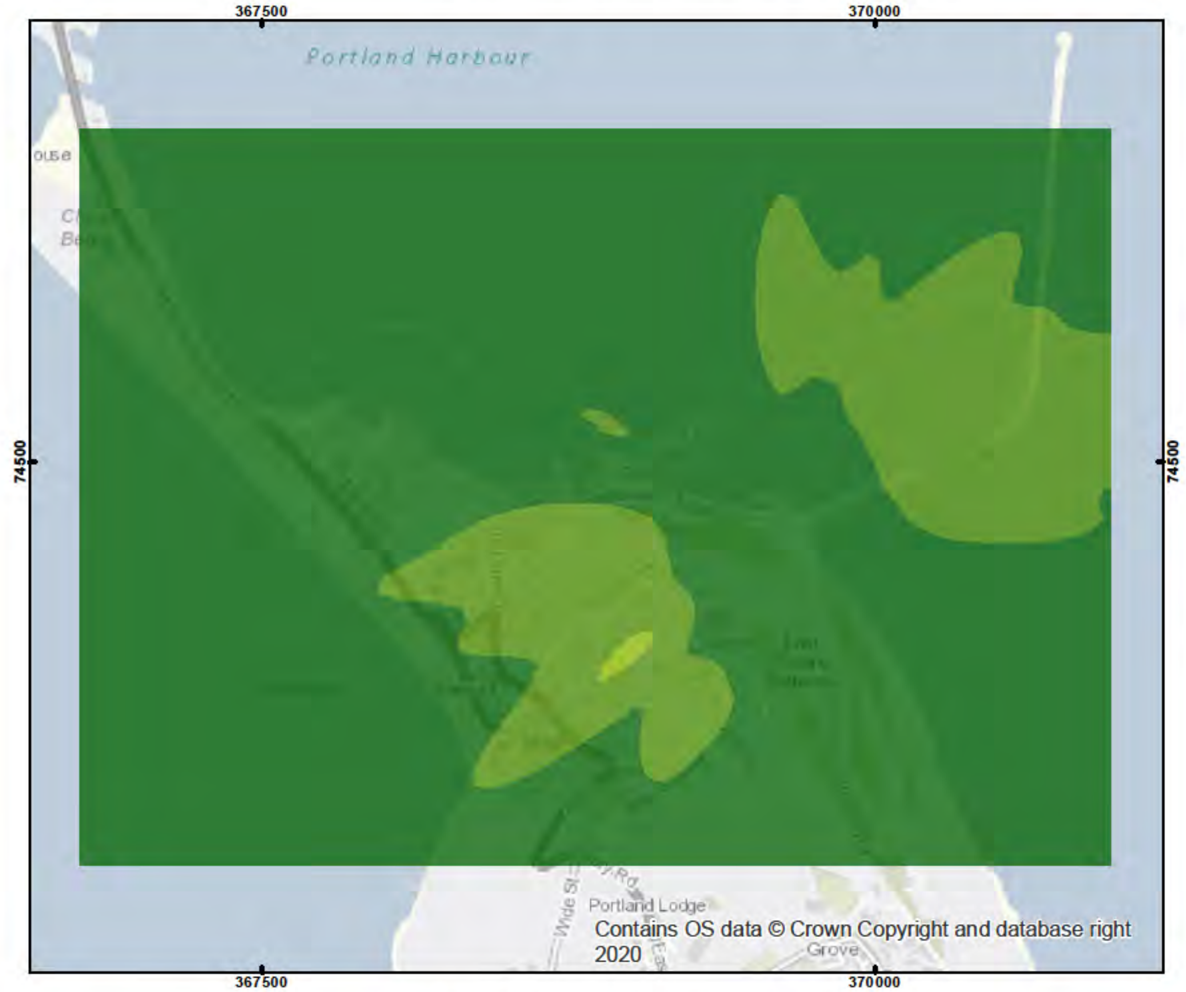
Tel: 0161 476 0032
Fax: 0161 474 0618

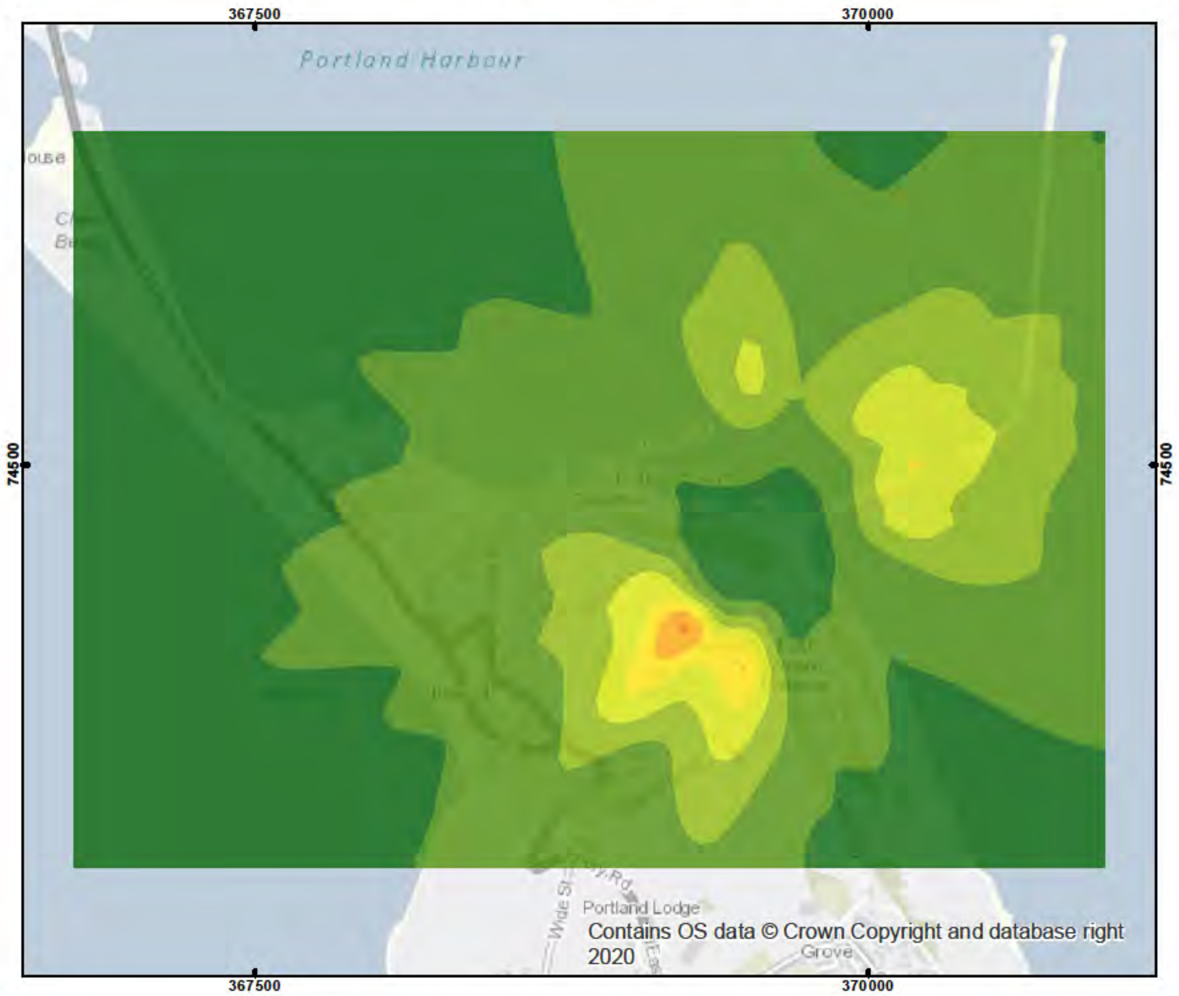
ADMS - Excluding Terrain



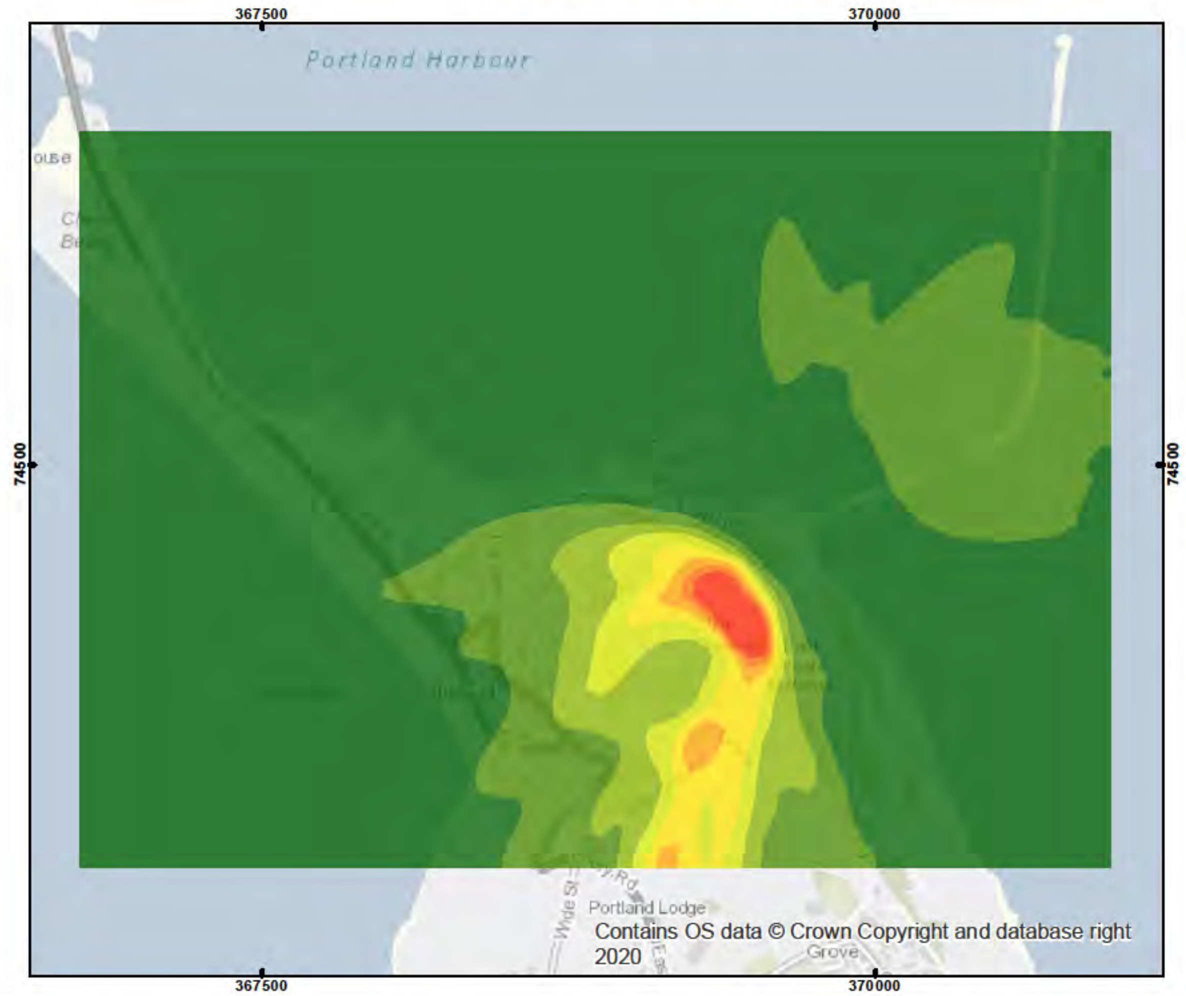
AERMOD - Excluding Terrain



ADMS - Including Terrain



AERMOD - Including Terrain

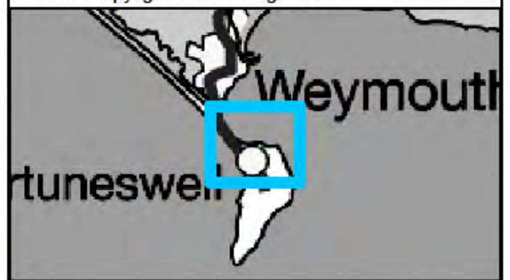


Legend

Maximum 24-hour NOx ug/m3

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- > 16

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 31 Model Sensitivity Analysis
Drawn by: RSF	Date: 15/11/2021

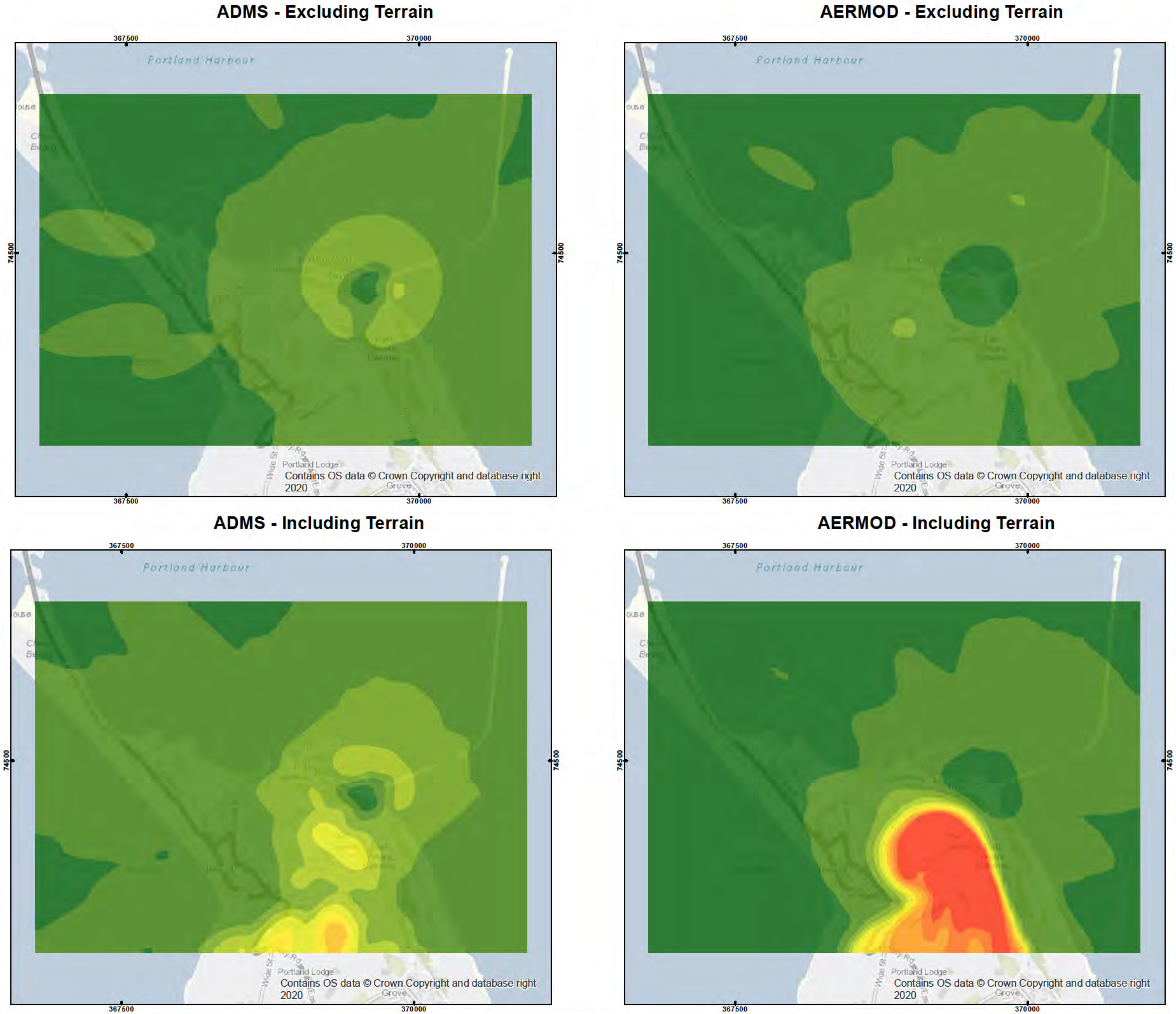


0 0.325 0.65 1.3 km

N

Scale: 1:30,800

FICHTNER
Consulting Engineers Limited
Kingsgate, Wellington Road North,
Stockport, Cheshire, SK4 1LW
Tel: 0161 476 0032
Fax: 0161 474 0618

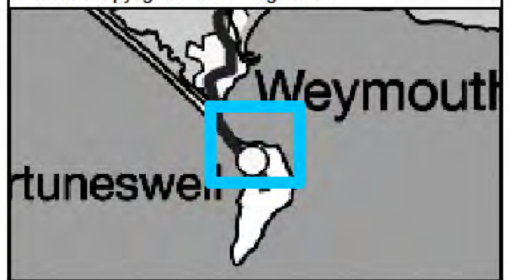


Legend

Maximum 1-hour NOx ug/m3

- <5
- 5 - 10
- 10 -15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- > 45

Client:	Powerfuel Portland Limited
Site:	Portland
Project:	2953
Title:	Figure 32 Model Sensitivity Analysis
Drawn by: RSF	Date: 15/11/2021



0 0.325 0.65 1.3 km

Scale: 1:30,800

N

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B CERC Technical Note

CERC Technical Note: Portland Energy Recovery Facility

Authors: David Carruthers and Martin Seaton
26th November 2021

This technical note is produced by CERC, the scientific and software developers of the ADMS model, in response to questions raised by Fichtner regarding dispersion modelling of emissions from the Portland Energy Recovery Facility. For reference, the terrain and stack location are shown in Figure 1.

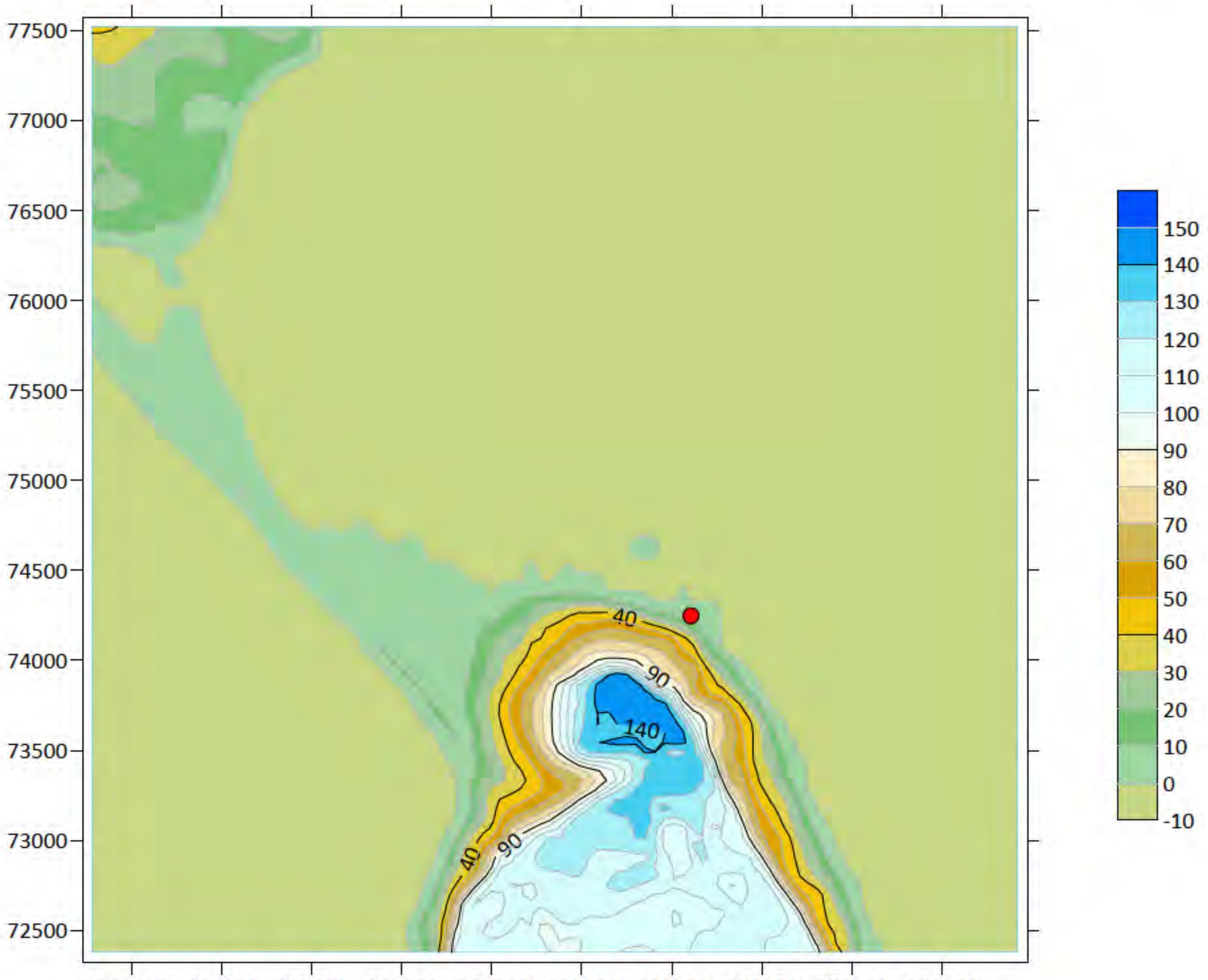

Figure 1 - Terrain and stack location (red circle)

1 Use of ADMS in complex terrain

Is ADMS appropriate where slopes are greater than 1:3? In this context, what is the relevance of US-EPA Guidance[1], especially paragraph 7.2.1.2 which states "In very rugged hilly or mountainous terrain, along coastlines, or near large land use variations, the characteristics of the winds are a balance of various forces, such that the assumptions of steady-state straight-line transport both in time and space are inappropriate."

The US-EPA guidance, especially 7.2.1.2, is discussed in our response to Question 3 below.

The ADMS documentation indicates that optimum performance of the complex terrain module is achieved for gradients of up to 1 in 3, however the model can be used beyond that limit. The ADMS 5.2 User Guide states:
"If modelled, ideally hills should have moderate slopes (say less than 1 in 3) but the model is useful even when this criterion is not met."

The Complex Terrain Technical Specification P14/01[2] on CERC's web site states:
"In line with the assumptions on which the model is based, terrain should have no more than moderate slopes (up to 1:3) although the model is useful even when this criterion is not met (say up to 1:2)."

Also of note is that Dr David Carruthers, who is one author of this note, wrote the FLOWSTAR complex flow model used in ADMS in conjunction with Professor Julian Hunt[3,4,5,6,7]. Both are experts in flow over complex topography and both have advised the US-EPA on this topic. The hill slope has most impact on the airflow immediately in the lee of hill summits where, depending on the surface roughness, local separation may take place for slopes greater than 1 in 3 (not relevant here). On the upstream slopes (of particular relevance here), impacts of higher slopes than 1 in 3 are well modelled; on these upstream slopes, of most relevance to the flow is the aspect ratio of the hill as a whole, rather than the aspect ratio of small sections of steep slopes. In this case, from stack location to hill summit the aspect ratio is 0.28, i.e. 1 in 3.6.

It is also of note that the original validation of FLOWSTAR was conducted using field data from Brent Knoll and the Isles of Askervein[8] and Blashaval[9]; these sites have similar slopes and terrain height to Portland. Modelling Portland with ADMS/FLOWSTAR seems entirely appropriate; the model is designed for these types of locations.

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[1] https://www.epa.gov/sites/default/files/2020-09/documents/appw_17.pdf
[2] https://www.cerc.co.uk/environmental-software/assets/data/doc_techspec/P14_01.pdf
[3] Hunt, J.C.R., Richards, K.J. & Brighton, P.W.M. 1988a. Stably stratified shear flow over low hills. Q.J.R. Meteorol. Soc. 114, 859-886.
[4] Belcher, S.E., Xu, D.P. & Hunt, J.C.R. 1990 The response of the turbulent boundary layer to arbitrarily distributed surface roughness changes. Q.J.R. Meteorol. Soc. 116, 611-635.
[5] Carruthers, D.J. & Choularton, T.W. 1982 Airflow over hills of moderate slope. Q.J.R. Meteorol. Soc. 108, 603-624.
[6] Carruthers, D.J. & Hunt, J.C.R. 1990 Fluid mechanics of airflow over hills: Turbulence, fluxes and waves in the boundary layer. AMS Monograph.
[7] Carruthers DJ, Hunt JCR and Weng W-S, 1988: A computational model of stratified turbulent airflow over hills—FLOWSTAR I. Proceedings of Envirosoft. In Computer Techniques in Environmental Studies (editor P. Zanetti), pp. 481-492. Springer-Verlag.
[8] https://www.cerc.co.uk/environmental-software/assets/data/doc_validation/CERC_ADMS5.2_Study_Validation_Askervein.pdf
[9] https://www.cerc.co.uk/environmental-software/assets/data/doc_validation/CERC_ADMS5.2_Study_Validation_Blashaval.pdf

2 Validation studies

What validation studies are most relevant to the Portland ERF project and what do the most relevant studies show?

The situation being modelled at Portland is of a hill (150 m) with the stack lower than the height of the hill. As noted in the response to Question 1, the case of an isolated hill was modelled in the Askervein Hill[8] and Blashaval[9] flow field validation studies. Both of these studies show good results for the wind speed, with the best performance on the upstream slope.

In terms of concentration validation studies, the Lovett Power Plant study[10] has a similar situation of a stack near to a hill. This study shows good agreement between the modelled and observed data and, as noted in the discussion section, the best agreement occurs at receptors on the upwind face of the hill rather than at the sides or downwind face.

The Westvaco corporation study[11] also has some similarities, but in this case the hill is much larger (350 m); again the modelled and observed concentrations show good agreement.

The Tracy Power Plant study[12] is more valley-like, with high (>400 m) terrain on two sides of the modelling area, this study also shows good agreement for ground level receptors between the modelled and observed concentrations.

The other studies are less relevant to Portland: either highly complex with several stacks of varying heights in various locations (e.g. Martin's Creek study[13]), or with stacks significantly higher than the surrounding terrain.

[10] https://www.cerc.co.uk/environmental-software/assets/data/doc_validation/CERC_ADMS5_Study_Validation_Lovett_5.2_vs_5.1.pdf
[11] https://www.cerc.co.uk/environmental-software/assets/data/doc_validation/CERC_ADMS5_Study_Validation_Westvaco_5.2_vs_5.1.pdf
[12] https://www.cerc.co.uk/environmental-software/assets/data/doc_validation/CERC_ADMS5_Study_Validation_Tracy_5.2_vs_5.1.pdf
[13] https://www.cerc.co.uk/environmental-software/assets/data/doc_validation/CERC_ADMS5_Study_Validation_MartinsCreek_5.2_vs_5.1.pdf

3 Differences between ADMS and Aermod treatment of complex terrain

What are the differences between the way ADMS and AERMOD treat terrain, and does this affect modelling of plume impaction with hills?

The impact of hills on airflow is well established from many studies (field experiments, wind tunnel studies and numerical simulations). For most weather conditions, the wind is deflected by terrain, and will generally flow over and or/around the hill and does not impact onto it directly (Figure 2a-c). An exception is during very stable conditions, where plume impaction onto hillsides may occur. In these very stable conditions, the flow splits into two layers, with the upper layer flowing over the hill and a lower layer impacting onto the hill and flowing around it (Figure 2d). The depth of the lower layer is determined by atmospheric stability, wind speed and the height of the hill. The height of the hill at Portland is small (150 m) so that the depth of lower layer will always be much smaller than the stack height, therefore the plume released from the stack will always flow over the hill. ADMS includes a flow model derived form FLOWSTAR for these very stable flows. The modelling, which has been undertaken, confirms no plume impaction, but the model does show the influence of the hill on concentrations in the neighbourhood of the hill top where the plume is closer to the ground due to converging streamlines; for example, see closed contour in Figure 7 in the modelling report.

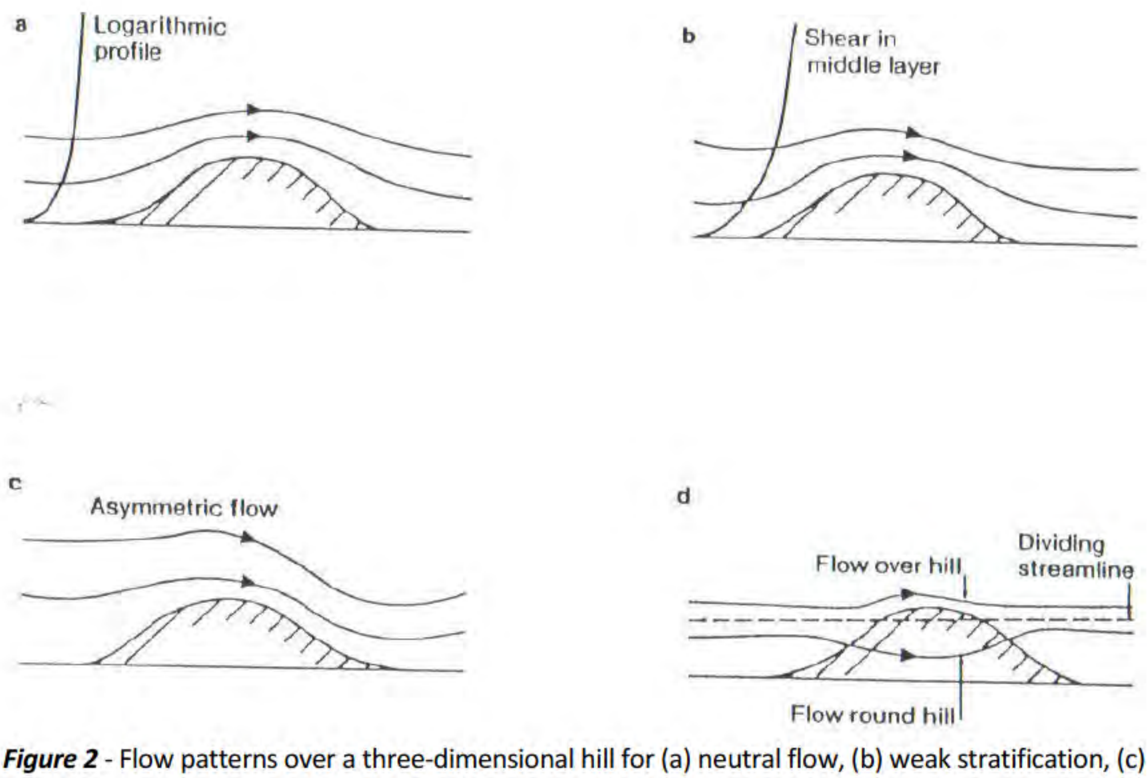

Figure 2 - Flow patterns over a three-dimensional hill for (a) neutral flow, (b) weak stratification, (c) moderate stratification and (d) strong stratification

AERMOD uses a quite different approach. It uses a weighted average of terrain following and sea-level following plumes, effectively ensuring a smooth transition between the two extreme cases (so no splitting in to two layers). In both cases, the plume trajectories follow a straight line along the wind direction, meaning that the sea-level following plume can end up going 'through' the hill and out the other side. This means it includes some effects of plume impaction even for only moderately stable flows, resulting in *totally unrealistic* elevations in concentration on hillsides in such conditions. Such increases in concentration are unphysical and should be ignored except possibly for hills of many hundreds of metres in height, when ADMS would also model plume impaction. For more details of treatment of stable flow over hills in ADMS and AERMOD, see Carruthers et al (2011).[14]

Research by ul Haq, et al., comparing outputs from AERMOD with tracer measurements in complex terrain, found that *"AERMOD overestimated the concentration at receptors which were at the point of direct impaction of plume and ridge"*.[15]

Regarding the use of models in very rugged hilly or mountainous terrain, Section 7.2.1.2 of the US-EPA document[1] states:

"In very rugged hilly or mountainous terrain, along coastlines, or near large land use variations, the characteristics of the winds are a balance of various forces, such that the assumptions of steady-state straight-line transport both in time and space are inappropriate."

The complex terrain option of ADMS is far from being a straight-line transport model. For each hour, ADMS takes the meteorological, terrain and surface roughness data and uses this to generate a fully 3D air flow and turbulence field. The plume trajectory is then calculated from this flow field and includes lateral and vertical movement of the plume; in addition, turbulent diffusion is modelled using the local turbulence field. A schematic of this is shown in Figure 3. As part of these calculations, ADMS has a special consideration for strongly stable conditions, when some airflow is likely to go around rather than over any terrain.

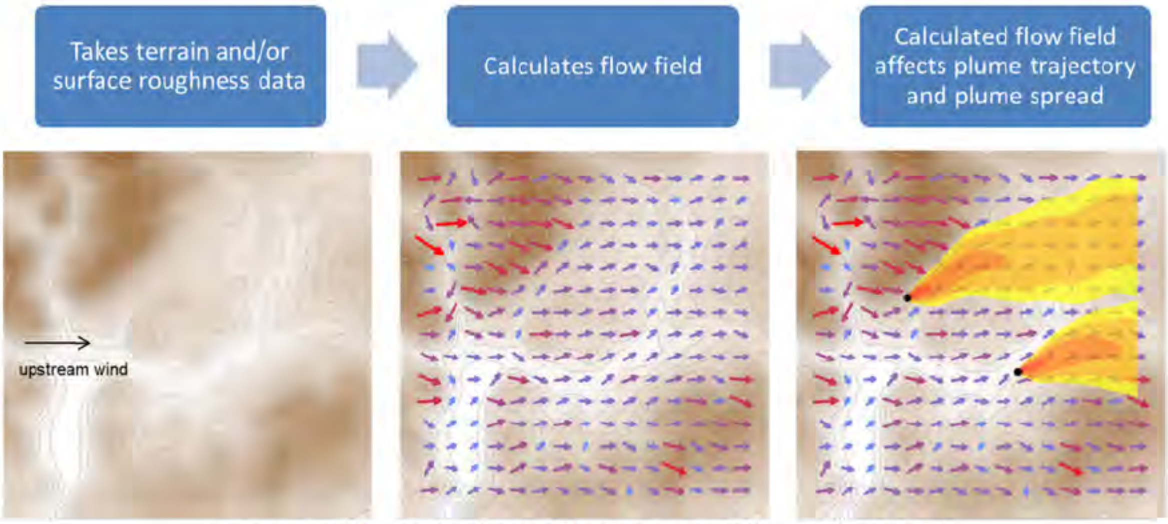

Figure 3 - Schematic of complex terrain modelling within ADMS

[14] Carruthers, D., Seaton, M., McHugh, C., Sheng, X., Solazzo, E. and Vanvyve, E. (2011) Comparison of the complex terrain algorithms incorporated into two commonly used local-scale air pollution dispersion models (ADMS and AERMOD) using a hybrid model. *Journal of the Air and Waste Management Association*, **61**, 11, 1227-1235

[15] Ul Haq, A., Nadeem, Q., Farooq, A., Irfan, N., Ahmad, M. Ali, M (2019) Assessment of AERMOD modeling system for application in complex terrain in Pakistan. *Atmospheric Pollution Research*, **10,** 1492–1497

AERMOD has no complex terrain *airflow* model. It uses a straight-line transport model with the concentration due to complex terrain calculated as a weighted average of terrain following and sea-level following plumes. It does not take account of any changes in mean flow and turbulence on turbulent diffusion.

We would caution against applying US-EPA guidance to complex terrain too literally for UK conditions. Conditions in the USA are often much more stable than in the UK, the terrain is of much larger scales and coastlines typically have large temperature contrasts with consequent buoyancy-driven flows. At Portland (essentially an island), strongly stable conditions are very rare, the terrain is of small scale and temperature contrasts between land and sea are small.

APPENDIX: Authors Qualifications and Experience

Dr David Carruthers

David's research background is in airflow, turbulence and dispersion in the atmospheric boundary layer. He has particular expertise in flow over complex terrain and within complex urban settings. At CERC, he has overall responsibility for CERC's consultancy, software and scientific research; he has been a technical director of CERC since 1994. He has directed many projects in air quality assessment both in the UK and internationally. Throughout the development of ADMS models, David has led CERC in model development and validation and has been at the forefront of technical debate in the UK and internationally. David leads CERC's participation in the US Environmental Protection Agency, UK Environment Agency and Defra co-operation on Air Quality Modelling and Exposure Science. He has participated in US-EPA Modeling Conferences and has presented the ADMS models internationally for government approval. David is a member of the UK Government's Air Quality Expert Group (AQEG) which provides independent scientific advice to Defra on air quality, and has advised national governments around the world on air quality policy. David has a PhD entitled 'Models of airflow over hills, orographic clouds and orographic rain' from the University of Manchester Institute of Science and Technology (UMIST). He is an author in over 100 scientific papers.

Dr Martin Seaton

Martin Seaton has over 15 years of experience in the field of air quality modelling. He specialises in the development and application of air dispersion models. Within CERC he oversees the scientific development of CERC's range of air dispersion models including ADMS 5 and ADMS-Roads which are regularly used for Air Quality Impact Assessments and Habitats Regulations Assessments. Martin ensures that the models are scientifically robust and developed according to strict coding standards. He is also involved with model evaluation using air pollutant concentration measurement datasets. Martin has a PhD in Mathematics from the University of Cambridge.