Appendix 14.2 Details of AERMOD Dispersion Model

AERMOD Air Dispersion Model

A.1.1 There are several dispersion models available to predict concentrations arising from emission sources, though the most commonly used in the UK are ADMS 5 produced by Cambridge Environmental Research Consultants, and AERMOD which is one of the US EPA's air quality models. Both have been widely used for predictive dispersion modelling of emissions from energy from waste plants and other emission sources, and for this assessment AERMOD and ADMS have both been used.

A.1.2 From 9th December 2005 AERMOD was recommended by the US EPA for adoption in its "Guideline on Air Quality Models", and since 9th December 2006 has been fully promulgated as its regulatory default dispersion model and replacement to its Industrial Source Complex (ISC3) model. AERMOD incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, and includes treatment of both surface and elevated sources, and both simple and complex terrain. It is freely available via the US EPA website including the model code, documentation, supporting documents and evaluation databases. The model code and supporting documents are not static but evolve to accommodate the best available science, with the version utilised 120600 released on 29/02/12.

A.1.3 AERMOD is a steady-state plume model, using Gaussian distributions in the vertical and horizontal for stable conditions, and in the horizontal for convective conditions. The vertical concentration distribution for convective conditions results from an assumed bi-Gaussian probability density function of the vertical velocity. It uses hourly meteorological data and thereby predicts hourly concentrations at each receptor point defined around the sources for the duration of the meteorological records. The data can then be summarised and presented on an hourly, daily, annual basis or other specific duration, and with more years of hourly data utilised, the greater the confidence in the predictions. The US EPA suggests that generally a model user should acquire enough meteorological data to ensure that worst-case meteorological conditions are adequately represented in the model results, and recommends that five years of representative meteorological data should be used with consecutive years from the most recent, readily available 5-year period preferred.

A.1.4 The generally accepted accuracy of Gaussian dispersion models including the model used for this odour assessment is plus or minus approximately 50%, and typically the greatest accuracy is at distances greater than 100 metres from the source. Below that distance where the dispersion parameter curves within the model have been extrapolated, the predicted concentration may be less certain. Uncertainty in the output of a dispersion model is generally assessed by checking the sensitivity of the output to the various input parameters, e.g. in order to ensure the output being used is likely to be conservative. Therefore it is not necessary or warranted to replicate modelling using alternative software, as there are also published comparisons.

A.1.5 For example ADMS is the most commonly used alternative dispersion model to AERMOD, and over flat terrain those generally show quite similar performance, though they can produce markedly different predictions in specific circumstances, such as complex terrain where AERMOD will invariably predict higher concentrations. An example of that is the Dunbar Energy Recovery Facility PPC Application Air Quality Technical Appendix, which found that in all years for both short-term and long-term averaging periods, the AERMOD model predicted greater concentrations than ADMS. Thus it is believed using AERMOD and ADMS for this study and an appraisal of the dispersion model sensitivity, provides a comprehensive assessment approach.

AERMOD Requirements

A.1.6 The main inputs to the air dispersion model include the emission rates from the main sources at the sewage treatment works, the physical dimensions of the plant and buildings, the terrain topography and the meteorological data.

A.1.7 The input file for the AERMOD model makes use of a keyword (parameter) approach to specifying the options and input data for running the model. The descriptive keywords and parameters that make up this input instructions file may be thought of as a command language through which the user communicates with the model what the user wishes to accomplish for a particular model run. The keywords specify the type of option or input data being entered on each line of the input file, and the parameters following the keyword define the specific options selected or the actual input data. Some of the parameters are also input as descriptive secondary keywords.

A.1.8 The input instructions file is divided into five functional "pathways." These pathways are identified by a character pathway ID placed at the beginning of each pathway. The pathways and the order in which they are input to the model are as follows:

- **CO** for specifying overall job **CO**ntrol options.
- **SO** for specifying **SO**urce information.
- **RE** for specifying **RE**ceptor information.
- **ME** for specifying **ME**teorology information.
- **OU** for specifying **OU**tput options.

A.1.9 The following sections detail the information in each of those pathways with an input file used for the AERMOD dispersion modelling provided at the end of this Appendix. For expediency Atkins utilises the Lakes Environmental's windows software ISC-AERMOD View which enables easier dispersion model set up, processing and interaction with the model set up and output, and can utilise an unlimited number of processors via the Lakes Environmental's Aermod Parallel feature.

A.1.10 It also features a Multi-Chemical Utility which is designed to allow each source in a given project to emit multiple chemicals with each at a specified emission rate, thereby allowing the modelling of the contributions from each pollutant quickly and concisely. These chemicals, and emission rates, can be different for each source, and the utility can be used as an alternative to running separate projects for each different emitted chemical. The Multi-Chemical Utility works by creating individual batch/input files for each source, running them through the specified model (e.g. AERMOD), and combining them into a single result to be viewed. The output is the contribution from each individual pollutant for all the sources, and output files are created for each source, with unitized emission rates, but chemical specific output files are not created.

Control Pathway

A.1.11 The AERMOD model has been run in its regulatory (US EPA) default mode (i.e. non regulatory default options have not been selected) with the output type as "concentration" for one hour, eight hour, 24 hour and annual averaging periods as required for comparison of the output to assessment criterion.

Source Parameters

Source Locations

A.1.12 The dispersion model was run using the physical plant and source data as detailed in the following tables. Due to there being emissions from the EfW stack, those emissions may be subject to building wake effects and downwash and therefore the following building details were input to enable the model predictions to incorporate those possible effects.

Table 0.1 – Structure Locations and Dimensions

Structure	Model ID	Easting, Northing of SE Corner	Ground Elevation m	Height m	X Length m	Y Length m	Rotation
EfW Tipping Hall	UEA	Polygon 329011.90, 380103.68 329023.51, 380116.58 329017.41, 380122.06 329019.09, 380123.92 329011.80, 380130.48 328996.84, 380113.87 329004.13, 380107.31 329005.80, 380109.17	245.0	14.51	N/A	N/A	N/A
EfW Residue Silos	UEP	329083.89, 380134.54	245.0	34.17	14.61	14.78	48°
EfW Fuel Bunker	UEB	329044.16, 380064.34	245.0	36.00	31.70	50.30	48°
EfW Flue Gas Treatment	UVC	329093.66, 380145.40	245.0	27.50	17.89	14.78	48°
EfW Boiler House	UHA	329056.28, 380096.08	245.0	44.0	47.05	25.12	48°
EfW Bottom Ash Bunker	UET	Polygon 329071.21, 380082.17, 329075.02, 380086.41, 329070.56, 380090.42, 329082.43, 380103.60, 329071.76, 380113.27, 329056.28, 380096.08, 329065.37, 380087.90, 329065.14, 380087.64	245.0	11.0	N/A	N/A	N/A
EfW Staircase 10	UHD-10	329037.64, 380112.92	245.0	47.3	5.90	8.7	48°

Structure	Model ID	Easting, Northing of SE Corner	Ground Elevation m	Height m	X Length m	Y Length m	Rotation
EfW Reagent Storage	UVE Tier 1	329082.68, 380155.29	245.0	9.5	15.71	6.42	48°
EfW Reagent Storage	UVE Tier 2	329088.28, 380166.68	245.0	15.5	Diameter 2.80	N/A	N/A
EfW Reagent Storage	UVE Tier 3	329085.66, 380163.60	245.0	22.98	Diameter 2.80	N/A	N/A
EfW Reagent Storage	UVE Tier 4	329081.31, 380159.89	245.0	31.4	Diameter 2.80	N/A	N/A
EfW Turbine Building	UMA	329090.23, 380096.64	245.0	21.0	18.47	24.84	48°
EfW Air Cooled Condenser	URC	329118.39, 380120.12	245.0	24.0	29.13	29.03	48°
EfW Stack	UHN	329113.235, 380178.144	245.0	80.0	Diameter 2.70		
IBA	IBA	329321.71, 380206.03	237.04	12.0	70.0	110.0	-5.5°
Biofilter Tier 1	BIOFILTER	329287.30, 380142.11	260.0	4	15.0	77.1	52.9°
Biofilter Tier 2	BIOFILTER	329262.39, 380160.98	260.0	8.35	15.00	14.50	52.9°
MBT Tunnel Building	MBT1	329257.76, 380083.46	260.0	11.89	50.47	93.0	52.9°
MBT Trailer loading and bale storage	MBT2	Polygon 329211.80, 380084.46 329228.07, 380105.95 329201.36 , 380126.17 329193.95 , 380116.80 329183.14 , 380124.94 329174.13 , 380112.99	260.0	12.07	N/A	N/A	N/A
MBT Mechanical process plant	MBT3	329190.37, 380056.16	260.0	18.03	35.5	53.55	52.9°
MBT Reception	MBT4	329163.09, 379995.29	260.0	18.03	65.0	68.5	52.9°
MBT Tipping hall	MBT5	329151.01, 379979.34	263.5	13.88	20.0	68.5	52.9°
MBT Workshop	MBT6	329177.85, 37998414	260.0	8.26	12.47	18.50	52.9°
MBT Bale Storage	MBT7	329070.31, 379887.92	263.0	77.4	70.60	12.0	52.2°

Structure	Model ID	Easting, Northing of SE Corner	Ground Elevation m	Height m	X Length m	Y Length m	Rotation
Notes: 1. The locations, ground elevations and dimensions have been taken from the design drawings.							

A.1.13 The proposed buildings have been modelled with a high flat roofs to give large structure profiles and hence a conservative estimate of the possible downwash effects. Note AERMOD takes account of the possible affect of structures on point sources only.

Table 0.2 – Point Source Locations and Dimensions

Source	Model ID	Easting, Northing	Ground Elevation	Release Height	Diameter (or equivalent)
EfW stack	EFWsuffix	329113.060, 380177.95	245m	95m	2.0m
MBT biofilter	BFsuffix	329268.45, 380180.997	260m	20m	2.0m
Notes: 1. A ground elevation has been estimated based on the design drawings. 2. For model ID 'EFWsuffix', a suffix no. as the IED emission rate (in mg/m3) was generally used, except for an unit emission rate of 1g/s where a model ID 'EFW1GS' was used. Other model source IDs were used for sensitivity analysis. 3. For model ID 'BFsuffix', a suffix as the substance was used, the emission rate being as for that specific substance.					

Source Emission Rate Parameters and Uncertainty

A.1.14 The source emission rate values utilised are indicated in the report text. The following table indicates other relevant inputs to the model.

Table 0.3 – Source Emission Data

Model ID	Temp (K)	Velocity (m/s)
Point Sources		
EFWsuffix	403	16.185
BFsuffix	Ambient	11.9366

A.1.15 In reality each source emission rate may vary differently in terms of magnitude and duration, as for example on average emissions from the EfW will need to be below the IED ELVs to ensure compliance, and the fact that variable emission rates occur is one of the main sources of uncertainty to the output of a dispersion model.

A.1.16 A summary of the anticipated parameters for normal operating conditions for the proposed EfW at design load point LPB, and for the normal operating conditions for the MBT are provided in the following tables.

Table 0.4 – Anticipated Parameters for Normal Operating Conditions for the Proposed EfW at design load point LPB

Parameter	Value	Comment
Internal stack diameter	2m	Design value.

Parameter	Value	Comment
Stack height	95m	Design value.
Volumetric flow rate in accordance with waste flow model	183,048Am^3/hr	Design value for moisture 21.5% and oxygen 6.61% dry
Exit temperature	130°C	Design value.
Exit velocity	16.185m/s	Design value.
Normalised volumetric flow rate (273K, 101.3kPa, 11% oxygen, dry)	140,000Nm^3/hr (38.89m^3/s)	Calculated.
Notes: 1. The design load point LPB is shown on the Capacity Diagram for the EfW provided at the end of this appendix.		

Table 0.5 – Anticipated Parameters for Normal Operating Conditions for the Proposed MBT

Parameter	Value	Comment
Maximum actual volumetric flow rate	135,000m^3/hr	Maximum design value. May vary down to 75,000m3/hr depending on operational requirements.
Internal stack diameter	2m	Design value.
Emission exit velocity	11.9366m/s	Calculated based on maximum actual volumetric flow rate and stack internal diameter.
Emission release height	20m	Design value.
Emission exit temperature	Ambient	Assumed – air temperature maybe slightly higher in the building but is controlled to less than 38°C and the extracted air is moisture conditioned to pass through the biofilter. The Met. data indicates maximum local temperatures of 28°C and the model predictions at an exit temperature of 'ambient' were found to be effectively the same as at 'ambient +10°C'.

Building Effects

A.1.17 Building downwash occurs when the aerodynamic turbulence induced by nearby buildings cause a pollutant emitted from an elevated source to be mixed rapidly toward the ground (downwash), resulting in higher ground-level concentrations. Each structure produces an area of wake effect influence downwind from the trailing edge of the structure that extends out to a distance of five times the lesser of the structure height or structure width. Hence building downwash information (direction specific building heights and widths) for point sources within that zone should be included.

A.1.18 Due to the new incinerator stack being located near to buildings, nearby building location and height details have been utilised within the US EPA BPIP-PRIME (Building Profile Input Program - Plume Rise Enhancement) model to derive the building downwash parameters within the AERMOD input files. Note that in AERMOD it is only point sources that take account of building downwash parameters.

Receptors

A.1.19 To ensure the air dispersion model output reflected the local terrain, Land & Property Services Ordnance Survey Northern Ireland digital terrain data (airborne Radar derived elevation data on a 10m grid with 95% providing a vertical accuracy of ±1m) has been utilised to provide base elevations for the receptors and surrounding terrain. Also available was topographical survey data for the quarry and its immediate surrounds. Those two ground level data sets were combined and processed to derive a terrain data file with elevations on a 5m grid within and to 25m outside the quarry edge to provide good resolution of the steep quarry faces, then at a 25m grid to 2km from the EFW stack location within the quarry, a 50m grid to 4km, a 100m grid to 6k and a 250m grid to 10km. For use in AERMOD that terrain file was processed by AERMAP with re-sampling on a 10m grid to provide receptor elevations.

A.1.20 The main receptor grid was set as a uniform polar grid centred between the proposed EfW and MBT development (grid reference 329150.00, 380110.00), at 50m intervals from 200m to 1000m, then 75m intervals to 2.5km, 100m intervals to 5km, 500m to 10km, along 36 radials (i.e. one every 10°), with the receptor height set as 0m to provide ground level concentrations. The majority of the proposed development and its buildings are within that initial 200m radius, and the receptor spacing provides some predictions within the site boundary including over the visitor and staff parking area, and at least 50m from the biofilter stack. To provide increased definition when modelling emissions from the MBT biofilter stack a uniform polar grid centred on the MBT biofilter stack was used, with 25m intervals from 50m to 300m, 40m intervals to 500m, 50m intervals to 1000m, 75m intervals to 1300m, 100m intervals to 2km, along 36 radials (i.e. one every 10°), with the receptor height set as 0m to provide ground level concentrations.

A.1.21 Individual discrete receptor locations were also included, for particular sensitive receptors such as nearby dwellings or habitat locations, and details of those receptors locations are provided in the report text.

Meteorological Information

A.1.22 This pathway includes details of the meteorological data to be used, i.e. the location of a surface met data file and a profile met data file output by AERMET and the period of met data to be used.

A.1.23 Hourly sequential meteorological data for 2004 to 2012 acquired for Belfast (Aldergrove) International Airport, (elevation 89.61m, anemometer height 10m) have been used for the air dispersion model, that meteorological station having data with the necessary parameters for the dispersion model.

A.1.24 The air dispersion model has been run for each of the individual years of data to appraise the sensitivity of the output to the different years of data. For emissions from the EfW the wind data for 2004 was found to produce the highest annual mean, whereas wind data for 2012 produced the highest one hour mean, and wind data from 2011 produced the highest 8hr and 24hr means. AERMOD uses a full profile of wind speeds above the anemometer threshold which is typically 1 knot (0.5144m/s). However AERMOD calculates period and annual averages by summing the total number of hourly concentrations in the period and dividing by the number of hours minus calm hours. That is referred to as calms processing but for which a calm hour is defined as an hour of meteorological data during which the average wind speed is less than 1m/s. During these conditions the measurement precision of wind speed and wind direction is deemed unacceptable (by the US EPA), therefore, the calms processing routine sets concentrations to zero for calm hours and short term averages are calculated according as per the calms processing. For example, if five hours of data are run for a pollutant concentration, in which hour 2 is a calm hour, a simple average would result in a lower concentration due to the inclusion of the calm hour's zero value. However, calms processing, excludes zero concentrations from the calm hour yielding a more reasonable result. For multi-year runs annual averages are calculated using the calms processing, are then summed and divided by the number of years in the run.

A.1.25 Prior to use by the AERMOD air dispersion model, the raw meteorological data has to be pre-processed, typically using AERMET (version 06341), a program which organizes and processes the available meteorological data into a format suitable for use by AERMOD. There are three stages to processing the data. The first stage extracts meteorological data and assesses the data quality through a series of quality assessment checks. The second stage merges all data available for 24-hour periods and writes these data together in a single intermediate file. The third and final stage reads the merged meteorological data and, estimates the necessary boundary layer parameters for dispersion calculations by AERMOD. For Stage 3 AERMET can process using upper air meteorological data, or using a modified Stage 3 process which estimates the upper air data from the hourly surface data. For this study the latter option was utilised and considered adequate because for odour dispersion it is predictions of near ground level dispersion and concentrations that are of primary interest.

A.1.26 In addition to the raw meteorological data, key inputs to AERMET are the meteorological station and a site's latitude and longitude, their elevations and height of anemometer, and surface parameters (average midday Albedo, average midday Bowen Ratio, and surface roughness) specific to characteristics of the land around the site. Those parameters have to be specified for sectors around the site and typical values are available in AERMET related to land use but which can be varied annually, seasonally or monthly, though the Albedo (fraction of solar radiation reflection so a bright surface has a higher Albedo and more reflection results in less convective turbulence) and Bowen Ratio (ratio of sensible heat flux to latent evaporative heat flux, a high ratio being a dry surface, the ratio being used in calculations related to daytime convective conditions) are not used for night time hours. The surface roughness length is related to the height of obstacles to wind flow, and is in principle the height at which the mean horizontal wind speed is zero, with values ranging from 0.001m over calm water to 1m over a forest or urban area. The surface characteristics within a dispersion model area are invariably not homogeneous so exact values for the surface parameters cannot be easily determined and are therefore normally based on relationships with general vegetation coverage. The recommendations for determining surface characteristics are presented in Section 3.12 of the AERMOD Implementation Guide (EPA, 2009) as follows, though generally for small studies the derivation of land use parameters can be kept simple:

- "The determination of the Surface Roughness Length should be based on an inverse distance weighted geometric mean for a default upwind distance of 1 kilometre relative to the measurement site. Surface roughness length may be varied by sector to account for variations in land cover near the measurement site; however, the sector widths should be no smaller than 30 degrees.
- The determination of the Bowen ratio should be based on a simple un-weighted geometric mean (i.e., no direction or distance dependency) for a representative

domain, with a default domain defined by a 10km by 10km region centred on the measurement site.

- The determination of the Albedo should be based on a simple un-weighted arithmetic mean (i.e., no direction or distance dependency) for the same representative domain as defined for Bowen ratio, with a default domain defined by a 10km by 10km region centred on the measurement site."

A.1.27 The land around Hightown Quarry is mainly grassland or cultivated with some localised heathland, for example adjacent the quarry. The following annual parameter values listed in the following table were used, derived from the sector land uses tabulated at the end of this appendix.

Table 0.6 – Surface Parameters used in AERMET

Radial Sector	Albedo	Bowen Ratio	Surface Roughness
0-30°	0.24	1.05	0.12453
30°-60°			0.14534
60°-90°			0.11255
90°-120°			0.09644
120°-150°			0.09644
150°-180°			0.013064
180°-210°			0.20655
210°-240°			0.19583
240°-270°			0.15995
270°-300°			0.06676
300°-330°			0.07387
330°-360°			0.07791

A.1.28 AERMOD also requires a user specified elevation for the base of the temperature profile (z_{base}), which has been set to 89.61m for the Belfast (Aldergrove) International Airport meteorological station. For use in plume rise calculations, AERMOD uses that value to develop a vertical profile of potential temperature from its estimate of the temperature gradient profile.

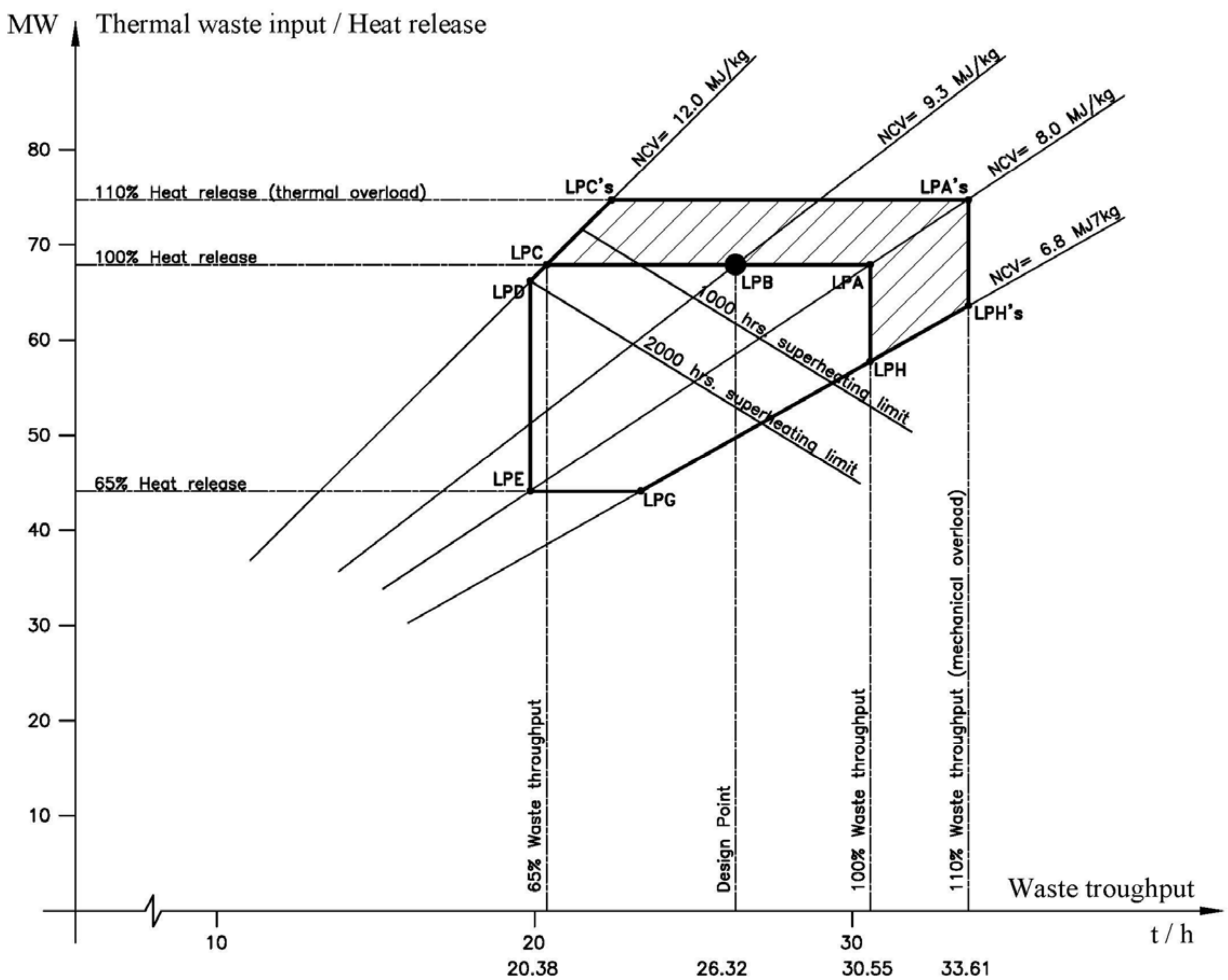
A.1.29 The concept of potential temperature is used by the AERMOD model to simplify calculations, as potential temperature allows air temperatures at different altitudes to be compared accurately. Potential temperature is the temperature that a parcel of air would have if it was adiabatically (without adding or removing heat) brought to one atmosphere (1000 mbar) of pressure. AERMOD calculates a vertical profile of potential temperatures from a reference temperature, which is typically measured at the meteorological station. In order to use this reference temperature to calculate the profile, it must first be converted to a potential temperature. In order to convert the reference temperature into a potential temperature, it is necessary to know at what pressure the temperature was measured, which in turn is dependent on the elevation above mean sea level, which is why the base elevation of the meteorological tower above mean sea level is required by AERMOD.

Output

A.1.30 This pathway specifies the model output format, such as plot files or files for post processing to determine for example specific percentile of the predicted concentrations at each receptor. The dispersion model predictions are as a consequence of the source emissions only and exclude background concentrations.

Post Processing

A.1.31 Post processing has been used for contouring by triangulation with smoothing and to derive percentile values for specific averaging periods.



1. The boiler will be able to operate with full superheating according to the superheating lines after the specified hours of operation at 100% load.
2. Residence time can be guaranteed within the capacity diagram after 300 hrs. of operation at 100% thermal load.

● Design/Guarantee point

Peak load:
Operational fluctuation with setpoint equal or less than 100% thermal waste input.

B&W babcock & wilcox vølund		Created	LoK	21/02/20
		Checked	AKH	01/03/20
		Approved	ToH	01/03/20
ARC-21 Capacity diagram Project No: 1050822				
		To replace		
		Replaced by		
Keys: G346	General tolerances:	Scale	Drawing No.: 0437958	Revision: 0

Hightown EfW - Dispersion modelling, sectors and surface parameters for input to Aermet for the meterological data processsing

Met Station Lat: 54.660428 Long: -6.200369 Height msl 89.61 Site Lat: 54.65311 Long: -5.999544 Height msl 245

Distance	Sector Area	Fraction	Frac/Dist	Land Use (per 30degree sector)											
km	km2			0 to 30	to 60	to 90	to 120	to 150	to 180	to 210	to 240	to 270	to 300	to 330	to 360
0.1	0.003	0.0003		Quarries	Quarries	Quarries	Quarries	Quarries	Quarries	Quarries	Quarries	Quarries	Heathland	Heathland	Heathland
0.2	0.008	0.0008		Quarries	Quarries	Quarries	Quarries	Quarries	Quarries	Quarries	Quarries	Quarries	Heathland	Heathland	Heathland
0.3	0.013	0.0014		Quarries	Quarries	Quarries	Heathland	Heathland	Heathland	Quarries	Heathland	Heathland	Grassland	Heathland	Quarries
0.4	0.018	0.0019		Grassland	Quarries	Heathland	Grassland	Grassland	Heathland	Heathland	Heathland	Grassland	Grassland	Grassland	Grassland
0.5	0.024	0.0025		Grassland	Heathland	Grassland	Grassland	Grassland	Heathland	Heathland	Heathland	Grassland	Grassland	Grassland	Grassland
0.6	0.029	0.0031		Heathland	Heathland	Grassland	Grassland	Grassland	Heathland	Heathland	Heathland	Heathland	Grassland	Grassland	Grassland
0.7	0.034	0.0036		Heathland	Grassland	Grassland	Grassland	Grassland	Grassland	Heathland	Heathland	Heathland	Grassland	Grassland	Grassland
0.8	0.039	0.0042		Grassland	Grassland	Grassland	Grassland	Grassland	Grassland	Heathland	Heathland	Heathland	Grassland	Grassland	Grassland
0.9	0.045	0.0047		Grassland	Grassland	Grassland	Grassland	Grassland	Grassland	Heathland	Heathland	Heathland	Grassland	Grassland	Grassland
1	0.050	0.005		Grassland	Grassland	Grassland	Grassland	Grassland	Grassland	Heathland	Heathland	Heathland	Grassland	Grassland	Grassland
2	0.785	0.083		Semi urban	Semi urban	Heathland	Quarries	Heathland	Heathland	Grassland	Heathland	Heathland	Grassland	Grassland	Grassland
3	1.309	0.139		Urban	Urban	Heathland	Heathland	Semi urban	Semi urban	Heathland	Heathland	Grassland	Grassland	Grassland	Grassland
4	1.833	0.194		Grassland	Urban	Semi urban	Coniferous	Urban	Semi urban	Heathland	Grassland	Grassland	Grassland	Grassland	Grassland
5	2.356	0.250		Grassland	Urban	Urban	Urban	Urban	Urban	Heathland	Grassland	Grassland	Grassland	Grassland	Grassland
6	2.880	0.306		Grassland	Urban	Urban	Water	Urban	Urban	Heathland	Grassland	Grassland	Grassland	Grassland	Grassland
	9.425	1.00													

Distance	Area	Fraction		Albedo Values per (30 degree sector)					*Average Value to use in Aermet:*			0.24			
km	km2			0 to 30	to 60	to 90	to 120	to 150	to 180	to 210	to 240	to 270	to 300	to 330	to 360
0.1	0.003	0.0003		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.008	0.0008		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.3	0.013	0.0014		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.29	0.2	0.2
0.4	0.018	0.0019		0.29	0.2	0.2	0.29	0.29	0.2	0.2	0.2	0.29	0.29	0.29	0.29
0.5	0.024	0.0025		0.29	0.2	0.29	0.29	0.29	0.2	0.2	0.2	0.29	0.29	0.29	0.29
0.6	0.029	0.0031		0.2	0.2	0.29	0.29	0.29	0.2	0.2	0.2	0.2	0.29	0.29	0.29
0.7	0.034	0.0036		0.2	0.29	0.29	0.29	0.29	0.29	0.2	0.2	0.2	0.29	0.29	0.29
0.8	0.039	0.0042		0.29	0.29	0.29	0.29	0.29	0.29	0.2	0.2	0.2	0.29	0.29	0.29
0.9	0.045	0.0047		0.29	0.29	0.29	0.29	0.29	0.29	0.2	0.2	0.2	0.29	0.29	0.29
1	0.050	0.0053		0.29	0.29	0.29	0.29	0.29	0.29	0.2	0.2	0.2	0.29	0.29	0.29
2	0.785	0.0833		0.16	0.16	0.2	0.2	0.2	0.2	0.29	0.2	0.2	0.29	0.29	0.29
3	1.309	0.1389		0.2075	0.2075	0.2	0.2	0.16	0.16	0.2	0.2	0.29	0.29	0.29	0.29
4	1.833	0.1944		0.29	0.2075	0.16	0.1775	0.2075	0.16	0.2	0.29	0.29	0.29	0.29	0.29
5	2.356	0.2500		0.29	0.2075	0.2075	0.2075	0.2075	0.2075	0.2	0.29	0.29	0.29	0.29	0.29
6	2.880	0.3056		0.29	0.2075	0.2075	0.14	0.2075	0.2075	0.2	0.29	0.29	0.29	0.29	0.29
	9.425	1.00	Calculated: arithmetic mean	*0.27*	*0.20*	*0.20*	*0.18*	*0.20*	*0.19*	*0.21*	*0.27*	*0.28*	*0.29*	*0.29*	*0.29*

Distance	Area	Fraction		Bowen Ratio Values (per 30 degree sector)					*Average Value to use in Aermet:*			1.05			
km	km2			0 to 30	to 60	to 90	to 120	to 150	to 180	to 210	to 240	to 270	to 300	to 330	to 360
0.1	0.003	0.0003		1	1	1	1	1	1	1	1	1	0.8	0.8	0.8
0.2	0.008	0.0008		1	1	1	1	1	1	1	1	1	0.8	0.8	0.8
0.3	0.013	0.0014		1	1	1	0.8	0.8	0.8	1	0.8	0.8	0.925	0.8	1
0.4	0.018	0.0019		0.925	1	0.8	0.925	0.925	0.8	0.8	0.8	0.925	0.925	0.925	0.925
0.5	0.024	0.0025		0.925	0.8	0.925	0.925	0.925	0.8	0.8	0.8	0.925	0.925	0.925	0.925
0.6	0.029	0.0031		0.8	0.8	0.925	0.925	0.925	0.8	0.8	0.8	0.8	0.925	0.925	0.925
0.7	0.034	0.0036		0.8	0.925	0.925	0.925	0.925	0.925	0.8	0.8	0.8	0.925	0.925	0.925
0.8	0.039	0.0042		0.925	0.925	0.925	0.925	0.925	0.925	0.8	0.8	0.8	0.925	0.925	0.925
0.9	0.045	0.0047		0.925	0.925	0.925	0.925	0.925	0.925	0.8	0.8	0.8	0.925	0.925	0.925
1	0.050	0.0053		0.925	0.925	0.925	0.925	0.925	0.925	0.8	0.8	0.8	0.925	0.925	0.925
2	0.785	0.0833		0.9	0.9	0.8	1	0.8	0.8	0.925	0.8	0.8	0.925	0.925	0.925
3	1.309	0.1389		1.625	1.625	0.8	0.8	0.9	0.9	0.8	0.8	0.925	0.925	0.925	0.925
4	1.833	0.1944		0.925	1.625	0.9	0.825	1.625	0.9	0.8	0.925	0.925	0.925	0.925	0.925
5	2.356	0.2500		0.925	1.625	1.625	1.625	1.625	1.625	0.8	0.925	0.925	0.925	0.925	0.925
6	2.880	0.3056		0.925	1.625	1.625	0.45	1.625	1.625	0.8	0.925	0.925	0.925	0.925	0.925
	9.425	1.00	Calculated: geometric mean	*1.00*	*1.52*	*1.22*	*0.82*	*1.39*	*1.24*	*0.81*	*0.89*	*0.91*	*0.92*	*0.92*	*0.92*

Distance	Area	Fraction	Frac/Dist	Surface Roughness Length Values (per 30 degree sector)											
km	km2			30	60	90	120	150	180	210	240	270	300	330	360
0.1	0.003	0.0100	0.20000	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.15	0.15	0.15
0.2	0.008	0.0300	0.05000	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.15	0.15	0.15
0.3	0.013	0.0500	0.05000	0.3	0.3	0.3	0.15	0.15	0.15	0.3	0.15	0.15	0.04025	0.15	0.3
0.4	0.018	0.0700	0.05000	0.04025	0.3	0.15	0.04025	0.04025	0.15	0.15	0.15	0.04025	0.04025	0.04025	0.04025
0.5	0.024	0.0900	0.05000	0.04025	0.15	0.04025	0.04025	0.04025	0.15	0.15	0.15	0.04025	0.04025	0.04025	0.04025
0.6	0.029	0.1100	0.05000	0.15	0.15	0.04025	0.04025	0.04025	0.15	0.15	0.15	0.15	0.04025	0.04025	0.04025
0.7	0.034	0.1300	0.05000	0.15	0.04025	0.04025	0.04025	0.04025	0.04025	0.15	0.15	0.15	0.04025	0.04025	0.04025
0.8	0.039	0.1500	0.05000	0.04025	0.04025	0.04025	0.04025	0.04025	0.04025	0.15	0.15	0.15	0.04025	0.04025	0.04025
0.9	0.045	0.1700	0.05000	0.04025	0.04025	0.04025	0.04025	0.04025	0.04025	0.15	0.15	0.15	0.04025	0.04025	0.04025
1	0.050	0.1900	0.05000	0.04025	0.04025	0.04025	0.04025	0.04025	0.04025	0.15	0.15	0.15	0.04025	0.04025	0.04025
	Sum	Sum	Sum	Inverse distance weighted geometric means per sector:											
	0.262	1.00	0.65	*0.12453*	*0.14534*	*0.11255*	*0.09644*	*0.09644*	*0.13064*	*0.20655*	*0.19583*	*0.15995*	*0.06676*	*0.07387*	*0.07791*

	Average annual values			Source
Land Use	Albedo	Bowen	SRL	
Coniferous	0.1775	0.825	1.3	Aermet
Cultivated	0.28	0.75	0.0725	Aermet
Deciduous	0.215	0.875	0.9	Aermet
Grassland	0.29	0.925	0.04025	Aermet
Heathland	0.2	0.8	0.15	Atkins
Quarries	0.2	1	0.3	Aersurface
Semi urban	0.16	0.9	0.525	Aersurface
Shrub - arid	0.3275	4.75	0.2625	Aermet
Shrub non arid	0.18	1.25	0.3	Aersurface
Swamp	0.18	0.45	0.1625	Aermet
Urban	0.2075	1.625	1	Aermet
Water	0.14	0.45	0.0001	Aermet

General Guidance (e.g. as a check that calculated values are reasonable for the land use)

Albedo - fraction of total incident solar radiation reflected by the surface.
Albedo - big and bright = high albedo, Aermet requires average noontime, keep it simple.

Bowen ratio - ratio of sensible heat flux to latent (evaporative) heat flux.
Bowen ratio - high value = dry surface, keep it simple.

SRL - Surface roughness length - is related to the height of obstacles to the wind flow, & is in principle height at which mean horizontal wind speed is zero. Keep it simple.
Flat areas 0.001 - 0.1 e.g. 0.05, rural / suburban areas 0.1 - 1, e.g. 0.5, urban / industrial areas 0.75 - 1.5, e.g. 1.

Calculation of albedo, bowen ratio and SRL broadling in line with the US EPA Aermod Implementation Guide 2009 Sect 3.1.2 which states:

"The determination of the SRL should be based on an inverse distance weighted geometric mean for a default upwind distance of 1 kilometre relative to the measurement site. SRL length may be varied by sector to account for variations in land cover near the measurement site; however, the sector widths should be no smaller than 30 degrees.

The determination of the Bowen ratio should be based on a simple un-weighted geometric mean (i.e., no direction or distance dependency) for a representative domain, with a default domain defined by a 10km by 10km region centred on the measurement site.

The determination of the Albedo should be based on a simple un-weighted arithmetic mean (i.e., no direction or distance dependency) for the same representative domain as defined for Bowen ratio, with a default domain defined by a 10km by 10km region centred on the measurement site."

Note for the calculations by radial sector for Albedo and Bowen ratio a 6km radius circle has been used i.e. 113.1km2, i.e. slightly greater than 10km x 10km.