Appendix 8.2

Description of AERMOD Model

APPENDIX 8.2

8.2.1 Description of the AERMOD Model

The AERMOD (version 24124) dispersion model has been developed, in part, by the U.S. Environmental Protection Agency (USEPA)[3]. The model is a steady-state Gaussian model used to assess pollutant concentrations associated with industrial sources. The model is an enhancement on the Industrial Source Complex-Short Term 3 (ISCST3) model which has been widely used for emissions from industrial sources. The Guidelines on Air Quality Models has promulgated AERMOD as the preferred model for a refined analysis from industrial sources, in all terrains[1].

Improvements over the ISCST3 model include the treatment of the vertical distribution of concentration within the plume. ISCST3 assumes a Gaussian distribution in both the horizontal and vertical direction under all weather conditions. AERMOD, however, treats the vertical distribution as non-Gaussian under convective (unstable) conditions while maintaining a Gaussian distribution in both the horizontal and vertical direction during stable conditions. This treatment reflects the fact that the plume is skewed upwards under convective conditions due to the greater intensity of turbulence above the plume than below. The result is a more accurate portrayal of actual conditions using the AERMOD model. AERMOD also enhances the turbulence of night-time urban boundary layers thus simulating the influence of the urban heat island.

In contrast to ISCST3, AERMOD is widely applicable in all types of terrain. Differentiation of the simple versus complex terrain is unnecessary with AERMOD. In complex terrain, AERMOD employs the dividing-streamline concept in a simplified simulation of the effects of plume-terrain interactions. In the dividing-streamline concept, flow below this height remains horizontal, and flow above this height tends to rise up and over terrain. Extensive validation studies have found that AERMOD performs better than ISCST3 for many applications and as well or better than CTDMPLUS for several complex terrain data sets[3]

AERMOD has made substantial improvements in the area of plume growth rates in comparison to ISCST3[3]. ISCST3 approximates turbulence using six Pasquill-Gifford-Turner Stability Classes and bases the resulting dispersion curves upon surface release experiments. This treatment, however, cannot explicitly account for turbulence in the formulation. AERMOD is based on the more realistic modern planetary boundary layer (PBL) theory which allows turbulence to vary with height. This use of turbulence-based plume growth with height leads to a substantial advancement over the ISCST3 treatment.

Improvements have also been made in relation to mixing height[3]. The treatment of mixing height by ISCST3 is based on a single morning upper air sounding each day. AERMOD, however, calculates mixing height on an hourly basis based on the morning upper air sounding and the surface energy balance, accounting for the solar radiation, cloud cover, reflectivity of the ground and the latent heat due to evaporation from the ground cover. This more advanced formulation provides a more realistic sequence of the diurnal mixing height changes.

AERMOD also contains improved algorithms for dealing with low wind speed (near calm) conditions. As a result, AERMOD can produce model estimates for conditions when the wind speed may be less than 1 m/s, but still greater than the instrument threshold.

8.2.2 AERMET

AERMOD incorporates a meteorological pre-processor AERMET[36]. AERMET allows AERMOD to account for changes in the plume behaviour with height. AERMET calculates hourly boundary layer parameters for use by AERMOD, including friction velocity, Monin-Obukhov length, convective velocity scale, convective (CBL) and stable boundary layer (SBL) height and surface heat flux.

AERMOD uses this information to calculate concentrations in a manner that accounts for changes in dispersion rate with height, allows for a non-Gaussian plume in convective conditions, and accounts for a dispersion rate that is a continuous function of meteorology.

The AERMET meteorological preprocessor requires the input of surface characteristics, including surface roughness (z_0), Bowen Ratio and albedo by sector and season, as well as hourly observations of wind speed, wind direction, cloud cover, and temperature. A morning sounding from a representative upper air station, latitude, longitude, time zone, and wind speed threshold are also required.

Two files are produced by AERMET for input to the AERMOD dispersion model. The surface file contains observed and calculated surface variables, one record per hour. The profile file contains the observations made at each level of a meteorological tower, if available, or the one-level observations taken from other representative data, one record level per hour.

From the surface characteristics (i.e. surface roughness, albedo and amount of moisture available (Bowen Ratio)) AERMET calculates several boundary layer parameters that are important in the evolution of the boundary layer, which, in turn, influences the dispersion of pollutants. These parameters include the surface friction velocity, which is a measure of the vertical transport of horizontal momentum; the sensible heat flux, which is the vertical transport of heat to/from the surface; the Monin-Obukhov length which is a stability parameter relating the surface friction velocity to the sensible heat flux; the daytime mixed layer height; the nocturnal surface layer height and the convective velocity scale which combines the daytime mixed layer height and the sensible heat flux. These parameters all depend on the underlying surface.

The values of albedo, Bowen Ratio and surface roughness depend on land-use type (e.g., urban, cultivated land etc) and vary with seasons and wind direction. The assessment of appropriate land-use type was carried out to a distance of 10km from the location of the meteorological station in line with USEPA recommendations[4-6] for albedo and Bowen ratio with a 1km geometric determination undertaken for the surface roughness. In relation to wind direction, a minimum sector arc of 30 degrees is recommended. In the current model, the surface characteristics of Cork Airport were assessed and two sectors identified with distinctly varying land use characteristics.

8.2.2.1 Surface roughness

Surface roughness length is the height above the ground at which the wind speed goes to zero. Surface roughness length is defined by the individual elements on the landscape such as trees and buildings. In order to determine surface roughness length, the USEPA recommends that a representative length be defined for each sector, based on an upwind area-weighted average of the land use within the sector, by using the eight land use categories outlined by the USEPA. The inverse-distance weighted surface roughness length derived from the land use classification within a radius of 1km from Cork Airport Meteorological Station is shown in Table A8.1

Table A8.1 Surface Roughness based on an inverse distance weighted average of the land use within a 1km radius of Cork Airport Meteorological Station.

Sector	Area Weighted Land Use Classification	Spring	Summer	Autumn	Winter[Note 1]
350-50	60% Urban, 40% Grassland	0.213	0.305	0.093	0.093
50-350	100% Grassland	0.050	0.100	0.010	0.010

(1) Winter defined as periods when surfaces covered permanently by snow whereas autumn is defined as periods when freezing conditions are common, deciduous trees are leafless and no snow is present (Iqbal (1983))[4]. Thus for the current location autumn more accurately defines "winter" conditions in Ireland.

8.2.2.2 Albedo

Noon-time albedo is the fraction of the incoming solar radiation that is reflected from the ground when the sun is directly overhead. Albedo is used in calculating the hourly net heat balance at the surface for calculating hourly values of Monin-Obuklov length. A 10km x 10km square area is drawn around the meteorological station to determine the albedo based on a simple average for the land use types within the area independent of both distance from the station and the near-field sector. The classification within 10km from Cork Airport Meteorological Station is shown in Table A8.2.

Table A8.2 Albedo based on a simple average of the land use within a 10km × 10km grid centred on Cork Airport Meteorological Station.

Area Weighted Land Use Classification	Spring	Summer	Autumn	Winter[Note 1]
19% Urban, 81% Grassland	0.17	0.18	0.20	0.20

(1) For the current location autumn more accurately defines "winter" conditions in Ireland.

8.2.2.3 Bowen Ratio

The Bowen ratio is a measure of the amount of moisture at the surface of the earth. The presence of moisture affects the heat balance resulting from evaporative cooling which, in turn, affects the Monin-Obukhov length which is used in the formulation of the boundary layer. A 10km x 10km square area is drawn around the meteorological station to determine the Bowen Ratio based on geometric mean of the land use types within the area independent of both distance from the station and the near-field sector. The classification within 10km from Cork Airport Meteorological Station is shown in Table A8.3.

Table A8.3 Bowen Ratio based on a geometric mean of the land use within a 10km × 10km grid centered on Cork Airport Meteorological Station.

Area Weighted Land Use Classification	Spring	Summer	Autumn	Winter[Note 1]
19% Urban, 81% Grassland	0.47	0.95	1.14	1.14

(1) For the current location autumn more accurately defines "winter" conditions in Ireland.

8.2.2.4 Detailed Meteorological Data – Cork Airport 2020 - 2024

Table A8.4 Cork Airport 2020

Dir \ Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	27	27	99	65	15	6	239
22.5	30	29	98	94	17	0	268
45.0	20	55	84	66	15	1	241
67.5	25	48	111	66	13	3	266
90.0	41	68	159	113	23	7	411
112.5	40	55	167	77	7	0	346
135.0	31	53	94	92	29	11	310
157.5	56	52	134	109	44	25	420
180.0	52	81	184	168	81	18	584
202.5	51	70	280	285	153	93	932
225.0	34	112	567	461	162	82	1,418
247.5	29	78	320	245	116	31	819
270.0	39	64	191	138	49	7	488
292.5	50	93	292	185	50	21	691
315.0	41	105	380	229	62	42	859
337.5	19	66	221	132	36	7	481
Total	585	1,056	3,381	2,525	872	354	8,773
Calms							11
Missing							0
Total							8,784

Table A8.5 Cork Airport 2021

Dir \ Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	23	17	87	76	3	0	206
22.5	26	28	83	49	0	0	186
45.0	30	49	93	30	9	1	212
67.5	33	37	147	82	13	3	315
90.0	41	36	188	120	36	6	427
112.5	44	71	133	76	30	16	370
135.0	51	69	143	86	27	17	393
157.5	54	91	227	146	33	23	574
180.0	89	96	281	176	55	25	722
202.5	93	125	353	251	129	37	988
225.0	64	139	441	246	66	40	996
247.5	43	116	268	139	34	8	608
270.0	38	102	193	128	34	17	512
292.5	53	122	335	169	44	7	730
315.0	43	106	462	241	33	11	896
337.5	25	68	304	206	17	3	623
Total	750	1,272	3,738	2,221	563	214	8,758
Calms							2
Missing							0
Total							8,760

Table A8.6 Cork Airport 2022

Dir \ Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	18	16	94	42	8	0	178
22.5	16	36	91	43	4	0	190
45.0	18	26	76	95	7	0	222

67.5	26	44	126	53	8	3	260
90.0	25	47	163	71	23	11	340
112.5	37	52	175	100	33	6	403
135.0	40	56	124	102	58	23	403
157.5	67	82	248	179	66	25	667
180.0	80	80	237	207	97	15	716
202.5	75	114	280	303	123	20	915
225.0	64	114	495	410	90	17	1,190
247.5	46	75	250	184	56	10	621
270.0	47	95	195	153	36	14	540
292.5	58	114	291	174	29	15	681
315.0	44	140	459	204	25	3	875
337.5	38	58	300	136	24	1	557
Total	699	1,149	3,604	2,456	687	163	8,758
Calms							2
Missing							0
Total							8,760

Table A8.7 Cork Airport 2023

Dir \ Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	15	22	88	63	1	0	189
22.5	11	46	108	34	5	0	204
45.0	14	49	106	38	3	0	210
67.5	19	32	86	83	16	0	236
90.0	34	54	144	160	26	4	422
112.5	34	65	188	82	29	1	399
135.0	28	38	180	145	35	9	435
157.5	65	82	230	181	32	13	603
180.0	92	80	189	189	37	9	596
202.5	107	110	334	350	96	38	1,035
225.0	70	144	538	386	105	32	1,275
247.5	41	88	338	259	70	7	803
270.0	57	75	205	155	47	11	550
292.5	39	97	244	181	38	21	620
315.0	41	102	345	212	77	20	797
337.5	30	52	170	114	16	2	384
Total	697	1,136	3,493	2,632	633	167	8,758
Calms							1
Missing							1
Total							8,760

Table A8.8 Cork Airport 2024

Dir \ Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	14	26	129	98	11	1	279
22.5	18	24	153	63	3	0	261
45.0	25	22	78	82	8	2	217
67.5	30	28	75	55	12	2	202
90.0	41	56	107	67	27	4	302
112.5	34	60	119	65	25	10	313
135.0	29	41	157	122	50	11	410
157.5	61	78	157	155	52	14	517
180.0	66	75	217	143	51	19	571
202.5	74	90	294	280	118	57	913

225.0	63	155	545	334	78	34	1,209
247.5	42	78	331	171	25	10	657
270.0	39	85	191	138	30	10	493
292.5	41	123	281	193	48	23	709
315.0	30	110	453	291	87	12	983
337.5	30	55	344	241	22	3	695
Total	637	1,106	3,631	2,498	647	212	8,731
Calms							53
Missing							0
Total							8,784