NIWA
Taihoro Nukurangi

Definition of Activity Classes for Industrial Boilers

Part 3: Applicability to other Regions

Prepared for Marlborough District Council

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Contents

Tables

Figures

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Executive summary

Marlborough District Council is in the process of reviewing its rules relating to air discharges. The review includes evaluating and streamlining rules relating to industry to improve consistency in rules across different zones where this is appropriate. A similar review is being carried out in Southland and two technical reports were commissioned to assist with the evaluation. These were:

Definition of Activity Classes for Industrial Boilers Stage 1: Assessment of Effects
Definition of Activity Classes for Industrial Boilers Stage 2: Setting Limits

Stage one involved atmospheric dispersion modelling for a range of fuels, emission rates and chimney heights using selected model input parameters assessment and a meteorological data set for Invercargill. Stage two used the results of the dispersion modelling to develop a schedule of chimney heights for diesel, liquid petroleum gas (LPG), coal, light fuel oil (LFO), heavy fuel oil (HFO), wood, pellets (custom) and pellet conversions for a range of emission rates. The chimney height schedule provides an indication of the heights required to disperse emissions to achieve ground level concentrations of 2.5 µg m^{-3} for PM_{10}, 70 µg m^{-3} for SO_2 and 40 µg m^{-3} for NO_2 and were used to recommend limits and conditions for the classification of permitted activities.

The objectives of this report were:

1. To evaluate the likely applicability of the Invercargill modelling to other urban areas of New Zealand.

2. To further investigate building downwash impacts in particular to evaluate whether permitted activity conditions could be revised to allow a building height of 6 metres within a 25 metre radius.

The applicability of the evaluation for Southland to other urban areas depends primarily on the likely differences in the modelled ground level concentrations for different meteorological data sets. This report evaluates the differences in modelled GLCs for 1MW, 3MW and 5MW diesel boilers and 100kW, 300kW and 500 kW coal boilers for five different meteorological data sets. The data sets included in the study were for the areas of Invercargill, Blenheim, Te Kuiti, Masterton, Christchurch and Hastings.

Modelling was also carried out based on a revised building height of six metres to determine the extent of influence of building downwash on GLCs, the chimney height schedule and the recommended limits.

Results showed that modelled GLCs for Invercargill were typically higher than for the other meteorological data sets. There were a few exceptions and all but two values were within 20% of the Invercargill value. The largest discrepancy was a value for Masterton for a 5MW diesel boiler at 8 metres which resulted in a 38% increase in PM_{10} concentrations. An adjustment of the chimney height schedule to 9 metres for a 3 MW boiler (Blenheim only) and a 5 MW diesel boiler (Blenheim, Masterton, Te Kuiti and Hastings) was recommended. In addition the chimney height schedule was revised for wood, pellets, heavy fuel oil (HO), light fuel oil (LFO) and LPG in these areas to allow a 20% buffer in modelled GLCs because these fuels were not modelled specifically with the area specific meteorological data sets.

This resulted in the following revisions to the permitted activity status to be recommended for Invercargill:

- Heavy fuel oil – no permitted activity status (requires a resource consent at any heat output)
- Pellet fuel (conversion) – permitted up to 400 kW (subject to compliance with chimney height schedule and other conditions)
- Pellet fuel (custom) – permitted up to 1 MW (subject to compliance with chimney height schedule and other conditions)

An evaluation of the impact of building wakes on dispersion indicated that in Blenheim a building height of six metres was unlikely to result in maximum GLCs of more than 2.5 µg m^{-3} for a 100 kW coal boiler with a chimney height of 11 metres. It is recommended that the permitted activity condition for building heights be reviewed to six metres for Blenheim. Adjusting this condition was not recommended for Invercargill owing to higher modelled GLCs.

1 Introduction

Concentrations of PM_{10} exceed National Environmental Standards (NES) in Blenheim during the winter months. To address this issue Marlborough District Council is in the process of reviewing its rules relating to air discharges. The review also includes evaluating and streamlining rules relating to industry to improve consistency in rules across different zones where this is appropriate.

One of the technical limitations to preparing rules for industrial combustion activities is that previously a chimney height specification has been used by many Councils as a condition for permitted or controlled activities which uses unknown and outdated input parameters. It is likely that continued reliance on this specification would result in unacceptable ground level concentrations of contaminants. To address this issue two technical reports were carried out for Environment Southland. These form the basis for the work being undertaken for Marlborough District Council in this report and are as follows:

- Definition of Activity Classes for Industrial Boilers Stage 1: Assessment of Effects (Somervell & Wilton, 2012)
- Definition of Activity Classes for Industrial Boilers Stage 2: Setting Limits (Wilton & Somervell, 2012)

The first of these reports involved atmospheric dispersion modelling for a range of fuels, emission rates and chimney heights using selected model input parameters assessment and a meteorological data set for Invercargill. The second report used the results of the dispersion modelling to develop a schedule of chimney heights for diesel, liquid petroleum gas (LPG), coal, light fuel oil (LFO), heavy fuel oil (HFO), wood, pellets (custom) and pellet conversions for a range of emission rates. The chimney height schedule provides an indication of the heights required to disperse emissions to achieve ground level concentrations of 2.5 µg m^{-3} for PM_{10}, 70 µg m^{-3} for SO_2 and 40 µg m^{-3} for NO_2 and were used to recommend limits and conditions for the classification of permitted activities.

The method used the maximum modelled PM_{10} concentration and the second highest PM_{10} concentration for SO_2 and NO_2 as the basis for determining the chimney height schedule and consequently the recommended limits. The PM_{10} concentration is based on a 24-hour average and therefore use of the maximum concentration is appropriate. Use of the second highest concentration is appropriate because it is recommended in the Good Practice Guide for Atmospheric Dispersion Modelling (Ministry for Environment, 2004) for hourly average concentrations.

The conditions for “permitted activities included a requirement that the chimney height comply with the schedule developed and the requirement that there are no buildings within a 25 metre radius that are higher than five metres. The reason for the latter condition was the modelling input parameters for the original modelling which included building downwash impacts from a five metre high building. On review of those reports it was considered useful to conduct a further evaluation of the impact of raising this height to six metres to potentially enable more industries with low heat output boilers to be permitted activities.

The objectives of this report were:

1. To evaluate the likely applicability of the Invercargill modelling to other urban areas of New Zealand.

2. To further investigate building downwash impacts in particular to evaluate whether permitted activity conditions could be revised to allow a building height of 6 metres within a 25 metre radius.

2 Summary of Stage I: Assessment of Effects

Stage one of this project involved atmospheric dispersion modelling of a range of emission rates to determine the chimney heights required to mitigate the impacts of discharges to air from external combustion sources. Effective mitigation was assessed against ground level concentrations of 2.5 µg m^{-3} (24-hour average) for PM_{10}, 70 µg m^{-3} (hourly average) for SO_2 and 40 µg m^{-3} (hourly average) for NO_2, as determined in Section 2.2 of the stage I report (Somervell & Wilton, 2012). The fuels included in the assessment were coal, wood, diesel and pellets for PM_{10}, light fuel oil (LFO) and heavy fuel oil (HFO) for SO_2 and LPG for NO_2. For coal PM_{10} was identified as the main contaminant for coal sulphur contents of less than 2%. Emission rates and fuel consumption were calculated based on Table 1.

Table 1: Summary data for fuel consumption and emission rate calculations.

Fuel	Efficiency	Calorific Value mJ/kg	PM_{10} Emission Factor g/kg
LPG *	80%	45.65	3.07
LFO	78%	41.2	40
HFO	78%	40.5	60
Diesel	78%	42.86	0.28
Wood	72%	15.8	1.6
Pellets	75%	19.2	0.8
Coal	72%	28.03	2

The emission rate for PM_{10} was assumed to be constant over the 24-hour period. This is likely to result in an overestimate of PM_{10} concentrations and therefore increases the conservatism around the PM_{10} ground level concentration estimates.
The model used was Ausplume version 5.4. Model input parameters used were:

- Meteorological data from the Invercargill Airport for 2004 and 2007
- Chimney diameters of 20 cm (heat outputs < 1MW), 30 cm (1-5 MW) and 40 cm (>5MW)
- Exit velocities based on Winflue calculations (Brady, 2004)
- An exit temperature of 200 degrees C
- One building of 30m width and 5m high.

Depending upon pollutant, results were reported for the highest modelled 24 hour averaged concentration or second highest hourly concentration for a range of emission rates and chimney heights.

3 Summary of Stage 2: Schedule of Chimney Heights and Setting Limits

A schedule of chimney heights was derived in stage two using the GLC outputs from the stage one report. The chimney heights were selected based on the modelled GLCs being less than 2.5 µg m^{-3} for PM_{10}, 70 µg m^{-3} for SO_2 and 40 µg m^{-3} for NO_2. In the case of PM_{10} a number of GLCs came out at 2.5 µg m^{-3}. In these cases an additional half a metre was added to the chimney height in the schedule.

The chimney height tables were derived for boilers less than 10 MW for diesel and LPG, 500 kW for wood, coal, LFO and HFO, 1MW for pellets (conversions) and 1.3 MW for custom built pellet boilers. Details of how the tables can be used to determine an appropriate chimney height that will disperse contaminants from boilers so that "acceptable" GLCs are obtained are also given in the Stage two report. The tables only apply to external combustion for the fuels specified.

Because of the potential for variability from the conditions modelled (e.g., different chimney diameters) a limit needs to be established above which site specific modelling of discharges is required. This limit was set at a chimney height of 12 metres. Beyond this height the effects are considered significant enough for the discharge to require individual assessment via a resource consent. For the more polluting fuels (wood, coal, LFO and HFO) chimney heights in excess of 12 metres are required to disperse emissions at significantly lower heat outputs (e.g., 200 kW or less). These fuels typically require a chimney height increase of at least one metre per 100 kW increase in heat output. Greater care is required when setting limits for these fuels as a small increase in heat output can have a big impact on GLCs. The emission limits recommended in the Stage two report are shown in Table 2. The conditions associated with the limits are shown in Appendix A. Any industrial discharge not meeting those conditions would be classified as a discretionary activity and required to obtain a resource consent for the air discharge.

Table 2: Recommended activity classifications for external combustion of fuels.

	Diesel	LPG	LFO	HFO	Wood	Coal	Pellet - conversion	Pellet - custom
Permitted	10MW	10MW	40 kW	40kW	40kW	100kW	500kW	1.3 MW
Controlled								
Discretionary	>10MW	>10MW	>40 kW	>40 kW	>40W	>100kW	>500kW	1.3 MW
Prohibited	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

The chimney height schedules from the stage 2 report are shown in Table 7 and 8. Table 8 shows the chimney height schedule for LFO, HFO and LPG reported in the stage two report for Invercargill which has not been revised.

Table 3: Chimney height schedules for diesel, coal, wood and pellet boilers for Invercargill .

DIESEL			COAL			PELLET (conversions)		
PM_{10} Emission Rate g/hr	Indicative Heat output	Chimney Height Metres	PM_{10} Emission Rate g/hr	Indicative Heat output	Chimney Height Metres	PM_{10} Emission Rate g/hr	Indicative Heat output	Chimney Height Metres
1	40 kW	6.0	14	40 kW	8.0	8	40kW	7.0
3	100 kW	7.0	36	100 kW	10.5	20	100 kW	8.5
6	200 KW	7.0	72	200 kW	13.0	40	200 kW	10.0
9	300 kW	7.0	107	300 kW	14.5	60	300 kW	10.5
12	400 kW	7.0	175	1 MW	20.0	80	400 kW	12.0
15	500 kW	7.0				100	500 kW	12.0
30	1MW	8.0				152	700 kW	13.0
45	2MW	8.0				253	1MW	15.0
90	3 MW	8.0	Wood			PELLET (custom)		
121	4 MW	8.0	PM_{10} Emission Rate g/hr	Indicative Heat output	Chimney Height Metres	PM_{10} Emission Rate g/hr	Indicative Heat output	Chimney Height Metres
151	5 MW	8.0	20	40kW	9.0	8	100 kW	7.0
181	6 MW	9.5	51	100 kW	12.5	15	200 kW	8.5
211	7 MW	9.5	100	200 kW	15.0	23	300 kW	8.5
241	8 MW	10.0	152	300 kW	17.0	30	400 kW	10.0
271	9 MW	10.0	203	400 kW	>18	38	500 kW	10.0
302	10 MW	10.0	253	500 kW	>18	63	700 kW	10.5
						75	1 MW	12.0
						98	1.3 MW	12.0

Note – columns shaded indicate areas where chimney heights have been estimated because no modelling has been carried out.

Table 4: Chimney height schedules for LFO, HFO and LPG

LFO			LPG		
SO_2 Emission Rate g/hr	Indicative Heat output	Chimney Height Metres	NO_2 Emission Rate g/hr	Indicative Heat output	Chimney Height Metres
179	40 kW	10.0	30	100KW	6.0
448	100 kW	13.0	75	250 kW	6.5
896	200 kW	14.0	151	500 KW	7.0
2240	500 kW	18.0	225	750 kW	8.0
HFO			302	1MW	9.0
SO_2 Emission Rate g/hr	Indicative Heat output	Chimney Height Metres	605	2MW	11.0
			907	3MW	12.0
			1209	4MW	11.0
			1512	5MW	11.0
			2116	7.5MW	11.0
			3023	10MW	12.0
259	40 kW	12.0			
649	100 kW	14.0			
1297	200 kW	18.0			
3243	500 kW	0.0			

4 Impact of meteorological data sets

Details of the different meteorological datasets compiled for this analysis can be found in Appendix B.

The variations in ground levels concentrations for different meteorological data sets are shown in Table 5. Situations where modelled GLCs for other areas are higher than those modelled for Invercargill are highlighted in grey in Table 5. Yellow highlights indicate where the difference would result in a revised chimney height requirement. These suggest that the chimney height specifications for 3MW diesel boilers should be increased to nine metres for Blenheim and to nine metres for 5MW boilers in Blenheim, Masterton, Te Kuiti and Hastings.

These data show that the highest estimated ground level concentrations for coal boilers typically occur for the Invercargill meteorological data set but that this meteorological data set also results in the lowest concentrations for diesel boilers.

Table 5: Ground level concentrations of PM_{10} using different meteorological datasets

	Chimney Height	Highest modelled ground level PM_{10} (24-hour average)					
		Invercargill	Blenheim	Christchurch	Masterton	Te Kuiti	Hastings
	metres	µg m-3	µg m-3	µg m-3	µg m-3	µg m-3	µg m-3
Diesel 1MW		4.27	5.08	3.76	3.37	3.49	3.43
	6	2.65	2.84	2.73	2.30	2.60	2.35
	7	1.70	1.87	1.91		1.91	
Diesel 3 MW	7	2.82		2.97	2.69	2.79	3.33

	8	2.00	2.57	2.20	2.28	2.17	2.30
	9		1.90				
Diesel 5 MW	7	3.58		2.98		3.11	
	8	2.42	2.93	2.35	3.35	2.59	2.67
	9		2.31		2.22	2.11	2.04
Coal 100 kW	8		3.34	2.80	2.53		3.45
	9	3.65	2.24	2.24		3.57	2.42
	10	2.88				2.76	
	11	2.22				2.33	
Coal 300 kW	11	4.30	2.81	2.96	2.83	4.06	
	12	3.48	2.33	2.33	1.97	3.18	2.85
	13	2.78	1.78			2.13	2.26
	14	2.43	1.57				
Coal 1 MW	14		2.54	2.70	2.76	2.69	
	15		2.29	2.43	2.46	2.44	
	16	2.92			2.18		2.96
	17	2.69			1.93		2.52
	18	2.48					2.31

Adjusting the required chimney height shown in Table 3 to be 9 metres (rather than 8 metres) for 3MW and 5MW diesel boiler would address differences in meteorological datasets to provide a chimney height schedule suitable for the areas modelled. Applying the schedule outside of these areas would require the assumption that meteorology will not be worse than in the areas considered in this report. This assumption should be evaluated for each application of the schedule. If it is not considered reasonable additional locations specific modelling should be undertaken.

It is noted that the sensitivity assessment around meteorological data sets was limited to diesel and coal boilers, being more common fuels. Based on the variability observed for these fuels some variability to the chimney height requirements for other fuels may be warranted. Tables 6 and 7 show a revised chimney height schedule based on maximum concentrations for wood, coal and pellets and second highest concentrations for LFO, HFO and LPG with wood, pellet, LFO, HFO and LPG chimney heights based on allowing a 20% buffer in GLCs. That is, a criterion of 2 µg m^{-3}, 56 µg m^{-3} and 32 µg m^{-3} for PM_{10}, SO_2 and NO_2 in other areas. Further modelling is recommended for these fuels in other areas if a higher degree of certainty is required. For example, if wood was a common fuel for small scale boilers then greater certainty around this fuel might be required.

Table 6: Chimney height schedules for diesel, coal, wood and pellet boilers (other areas).

DIESEL			COAL			PELLET (conversions)		
PM_{10} Emission Rate g/hr	Indicative Heat output	Chimney Height Metres	PM_{10} Emission Rate g/hr	Indicative Heat output	Chimney Height Metres	PM_{10} Emission Rate g/hr	Indicative Heat output	Chimney Height Metres
1	40 kW	6.0	14	40 kW	8.0	8	40kW	7.0
3	100 kW	7.0	36	100 kW	10.5	20	100 kW	9.5
6	200 KW	7.0	72	200 kW	13.0	40	200 kW	10.5
9	300 kW	7.0	107	300 kW	14.5	60	300 kW	11.5
12	400 kW	7.0	175	1 MW	20.0	80	400 kW	12.0
15	500 kW	7.0				100	500 kW	13.0
30	1MW	8.0				152	700 kW	14.0
45	2MW	8.0				253	1MW	16.0
90	3 MW	9.0	**Wood**			**PELLET (custom)**		
121	4 MW	9.0	PM_{10} Emission Rate g/hr	Indicative Heat output	Chimney Height Metres	PM_{10} Emission Rate g/hr	Indicative Heat output	Chimney Height Metres
151	5 MW	9.0	20	40kW	10.0	8	100 kW	7.0
181	6 MW	10.0	51	100 kW	>12	15	200 kW	9.5
211	7 MW	10.0	100	200 kW	>12	23	300 kW	9.5
241	8 MW	10.0	152	300 kW	>12	30	400 kW	10.5
271	9 MW	10.0	203	400 kW	>12	38	500 kW	10.5
302	10 MW	10.0	253	500 kW	>12	63	700 kW	11.5
						75	1 MW	12.0
						98	1.3 MW	13.0

Table 7: Chimney height schedules for LFO, HFO and LPG (other areas).

LFO			LPG		
SO_2 Emission Rate g/hr	Indicative Heat output	Chimney Height Metres	NO_2 Emission Rate g/hr	Indicative Heat output	Chimney Height Metres
179	40 kW	12	30	100KW	6.0
448	100 kW	>12	75	250 kW	6.5
896	200 kW	>12	151	500 KW	8.0
2240	500 kW	>12	225	750 kW	9.0
HFO			302	1MW	10.0
SO_2 Emission Rate g/hr	Indicative Heat output	Chimney Height Metres	605	2MW	12.0
			907	3MW	12.0
			1209	4MW	12.0
			1512	5MW	12.0
			2116	7.5MW	12.0
			3023	10MW	12.0
259	40 kW	>12			
649	100 kW				
1297	200 kW				
3243	500 kW				

The impact of this revised schedule on recommended limits is shown in Table 8. This suggests the only changes to this table from that recommended for Southland is the removal of a permitted activity status for heavy fuel oil, a reduction in the permitted activity limit for pellet conversions (from 500 kW to 400 kW) and a reduction in the permitted activity limit for custom pellet boilers from 1.3 to 1MW.

Table 8: Recommended activity classifications for external combustion of fuels (other areas).

	Diesel	LPG	LFO	HFO	Wood	Coal	Pellet - conversion	Pellet - custom
Permitted	10MW	10MW	40 kW	n/a	40kW	100kW	400kW	1.0 MW
Controlled								
Discretionary	>10MW	>10MW	>40 kW	>0 kW	>40kW	>100kW	>400kW	>1.0 MW
Prohibited	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

5 Impact of building downwash

The dimensions of the building to which a chimney is attached and neighbouring buildings impact on plume dispersion. This impact is referred to as building downwash or building wake. The potential impacts of building downwash are considered in the chimney height schedule by the inclusion of a condition stating there are no buildings within a 25 metre radius that are higher than five metres. This would exclude any boilers attached to six metre high buildings from permitted activity status.

Further investigations are warranted to determine whether this may be unnecessarily restrictive. A small amount of additional modelling was carried out within this study for the Blenheim meteorological data set to determine if the chimney height schedule could also be applied to a six metre high building.

The scenarios modelled were:

- 1MW diesel boiler with a chimney height of 7 metres (building length of 15 and 30 m)
- 5MW diesel boiler with a chimney height of 8 metres (building length of 15 and 30 m)
- 100 kW coal boiler with a chimney height of 11 metres[1] (building length of 15 and 30 m)

Results shown in Figures 1 and 2 show that the recommended permitted activity limit for coal boilers could apply to a building height of six metres but that the 1MW diesel boiler could not tolerate a building height of six metres with chimney heights of 7 metres. The recommended revision to the condition relating to chimney height for coal boilers in Blenheim is given in Appendix A.

An addition modelling run with the Invercargill meteorological data set was carried out for the 100 kW coal boiler with a chimney height of 11 metres (building length of 15 and 30 m). The purpose of this was to determine if the permitted activity status for coal boilers could be extended to those attached to buildings up to six metres high. The maximum GLC for this additional modelling at six metres was 2.8 µg m^{-3}. This suggests that an 11 metre high chimney is unlikely to be high enough to disperse PM_{10} from a 100 kW coal boiler to achieve a maximum GLC of 2.5 µg m^{-3} or less if the building height was six metres.

It is recommended that the permitted activity condition be amended for coal boilers to reflect an allowable building height of six metres in Blenheim only.

It is recommended that an evaluation be carried out to determine if increasing the chimney height by one metre for every one metre increase in building height provides an appropriate adaptation for the chimney height schedule to allow more flexibility in the permitted activity conditions.

[1] Although the schedule specifies 10.5 metres for permitted activity status the model rounds this to a height of 11 metres.

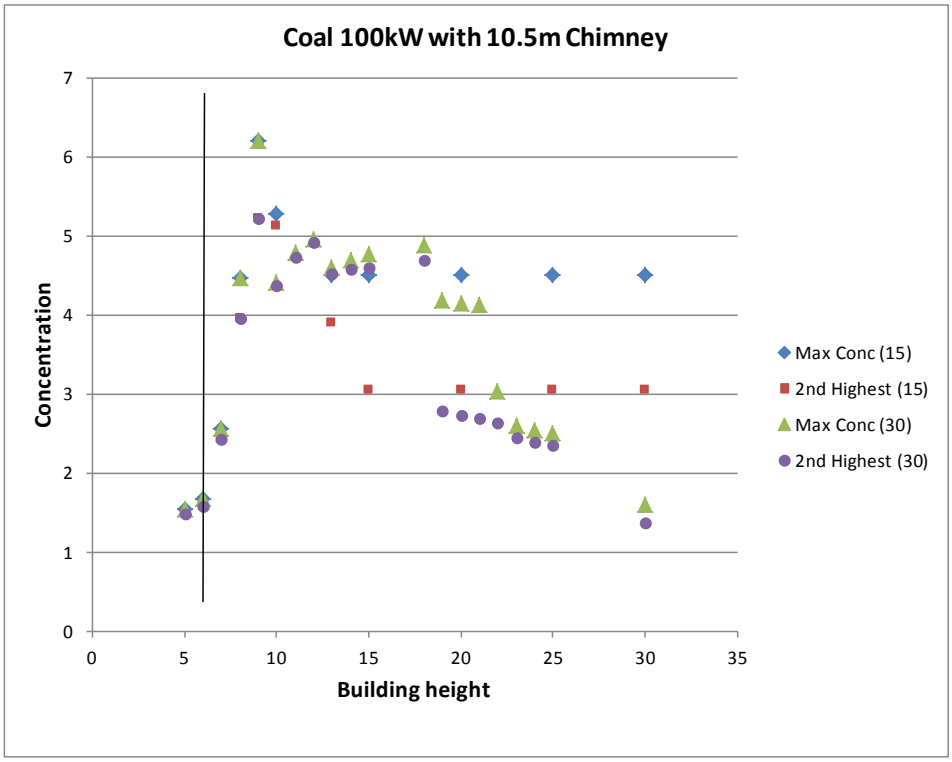

Figure 1: Impact on GLCs of increasing building height for 100 kW coal boiler with a 10.5 metre high chimney

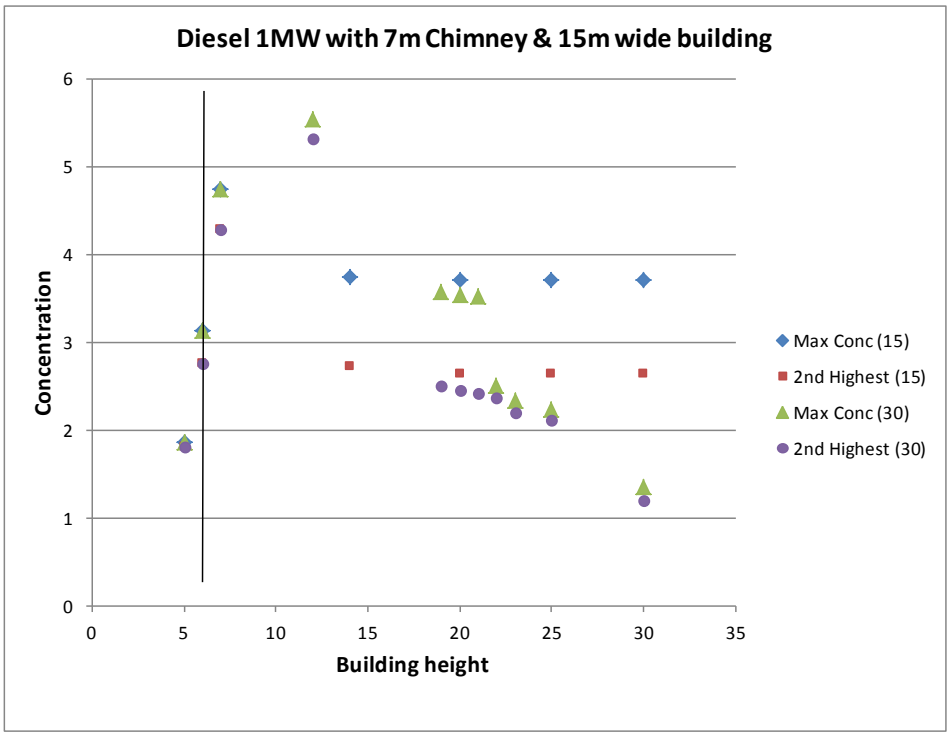

Figure 2: Impact on GLCs of increasing building height for 100 kW coal boiler with a 10.5 metre high chimney

6 Summary

The objectives of this report were:

1. To evaluate the likely applicability of the Invercargill modelling to other urban areas of New Zealand.
2. To further investigate building downwash impacts in particular to evaluate whether permitted activity conditions could be revised to allow a building height of 6 metres within a 25 metre radius.

A comparison of the Invercargill outputs for diesel and coal to outputs derived using meteorological data sets for Blenheim, Masterton, Te Kuiti, Christchurch and Hastings show that for diesel Invercargill results were lower than other areas but for coal results for Invercargill were typically higher than other areas. For these fuels the only increases to the chimney height schedule were to increase the chimney heights for 3MW diesel boilers to nine metres in Blenheim and to nine metres for 5MW diesel boilers in Blenheim, Masterton, Te Kuiti and Hastings.

A new chimney height schedule was derived for other areas that might be represented by the meteorological data sets included in the sensitivity evaluation. This was based on the Invercargill chimney height schedule modified for 5MW diesel boilers (as outlined above) and with the integration of a 20% buffer in modelled GLCs for the fuels which were not included in the sensitivity analysis. This additional conservatism resulted in the following modifications to recommended limits for MDC:

- Heavy fuel oil – no permitted activity status (requires a resource consent at any heat output)
- Pellet fuel (conversion) – permitted up to 400 kW (subject to compliance with chimney height schedule and other conditions)
- Pellet fuel (custom) – permitted up to 1 MW (subject to compliance with chimney height schedule and other conditions)

Based on additional modelling of the impact of building height it is recommended that the building height limit of five metres be increased to six metres for 100 KW coal fired boilers in Blenheim but that the five metre limited be retained in Invercargill. Additional work on the impact of building heights could result in the development of less restrictive conditions or a criteria by which increases in building heights could be offset by increases in chimney heights.

7 Acknowledgements

This report was prepared with funding from Envirolink (1221-MLDC81).

8 References

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Wilton, E., & Somervell, E. (2012). Definition of Activity Classes for Industrial Boilers Stage 2: Setting Limits. NIWA Client Report 2012-027.

Appendix A Permitted activity conditions

The following conditions were recommended in the stage two report as permitted activity conditions. Note that condition six is re-evaluated in this report for Blenheim.

1. These limits apply to the total heat output from a site. Where more than one fuel type is used on the site, the combined heat output shall not exceed the lowest MW threshold of any of the fuel types used.
2. The fuel shall be burned using fuel burning equipment, and the discharge shall be from a chimney or exhaust structure designed so that the emission is effectively dispersed upwards.
3. The opacity of the discharge when measured at the point of entry to the atmosphere shall not exceed 20%, except that a discharge in excess of this shall be allowed for a period of not more than 2 minutes continuously or for an aggregate of 4 minutes in any 60 minute period.
4. The fuel burning equipment is maintained in accordance with the manufacturer's specifications at least once every year by a person competent in the maintenance of that equipment.
5. For external combustion sources the chimney height shall comply with the requirements in Appendix xx (chimney height schedule).
6. No buildings within a 25 metre radius of the discharge are higher than 6 metres
7. The terrain on which the discharge is located and the surrounding terrain is flat. The sulphur content of any coal burnt shall be less than 2%.
8. For custom built pellet fired boilers the emission rate for PM_{10} for the boiler type must be 0.3 g/kg or less.
9. Discharges to air do not adversely affect visibility on any road or in any aircraft flight path.
10. There is no objectionable odour at or beyond the property boundary.
11. There is no objectionable deposition of particulate matter onto any land or structure at or beyond the property boundary.

A revised condition six is recommended as follows for Blenheim:

12. a) Where coal is the fuel, no buildings within a 25 metre radius of the discharge are higher than 6 metres

    b) For all other fuels, no buildings within a 25 metre radius of the discharge are higher than 5 metres

Appendix B Modelling details

The detailed method of modelling used is described in Somervell & Wilton, 2012. Briefly, the Gaussian dispersion model Ausplume was used to model boilers of various power output and fuel to establish at what chimney height the ground level concentrations from the discharge exceeded the threshold of 2.5 µg m^{-3} for PM_{10}.

The input file for Ausplume meteorology must include these factors:

- Wind speed and direction
- Temperature
- Pasquill-Gifford stability class (P-G class)
- Minimum mixing height

Temperature and winds may be taken directly from the climate station records, while the P-G class and mixing height are calculated based on wind speed, time of day, solar radiation and cloud cover, according to the method described in Golder Associates (2009), originally devised by Environmental Protection Authority of Victoria, Australia.

The emissions used are constant over the model run, thus assuming emissions 24 hours each day. For pollutants like PM_{10} that have limits set on 24-hourly average concentrations this approach most likely over-estimates the impact of the source. As emission activities and duration may vary greatly, this assumption is reasonable, but it does introduce an unknown degree of conservatism into the GLC estimates.

After reviewing documentation and applying Terry Brady's Winflue application (Brady, 2004) to the range of fuels and combustion rates, values have been chosen which are on the conservative end of the range of realistic values

Ground level concentrations are predicted for receptors arranged around the source in a grid of 25 m intervals out to 500 m in each direction. The 100 worst hourly and 24-hourly concentrations are outputted.

Preparation of meteorological input

The original modelling was based on meteorological input data drawn from the Invercargill station, situated in relatively flat terrain near the coast. Blenheim data are drawn from the ews station north-east of the town and the aero station out west at Woodbourne. Blenheim sits in a wide valley channel, fairly close to the mouth on the coast. The locations from which the other meteorological data were drawn were chosen so that a range of topographical situations would be represented:

- Hastings – open to the sea but with surrounding hills
- Christchurch – open but with regional scale drainage flows
- Masterton – surrounding hills but relatively open
- Te Kuiti – in a basin nestled in complex topography

The specific years used for each dataset were determined by previous knowledge of what years those towns had experienced the worst air quality. The one exception is Masterton, where the preferred year (2008) was not available. While one main climate station was used

for each dataset, not all required variables were always measured at this site. When a variable was missing, data from the closest station recording that variable was used instead. This occurred most frequently with cloud cover measures.

The table below shows which stations (including their climate database ID) were used for which variable.

Met. Set	Dates	Wind speed & DIrection	Temperature	Solar Radiation	Cloud Cover
Invercargill	2004 &2007	Invercargill (11104)	Invercargill (11104)	Invercargill (11104)	Invercargill (11104)
Blenheim	2011	Blenheim ews (12430)	Blenheim aero (4326)	Blenheim ews (12430)	Blenheim aero (4322)
Hastings	2008	Whakatu ews (15876)	Whakatu ews (15876)	Whakatu ews (15876)	Napier aero (2977)
Te Kuiti	2006	Te Kuiti ews (23899)	Te Kuiti ews (23899)	Te Kuiti ews (23899)	Hamilton aero (2110)
Masterton	01/03/09 to 28/02/2010	Masterton (36735)	Masterton (36735)	Masterton (36735)	Masterton (36735)
Christchurch	2006	Christchurch Kyle st (24120)	Christchurch Kyle st (24120)	Christchurch Kyle st (24120)	Christchurch aero (4843)

Comparison of the meteorological datasets

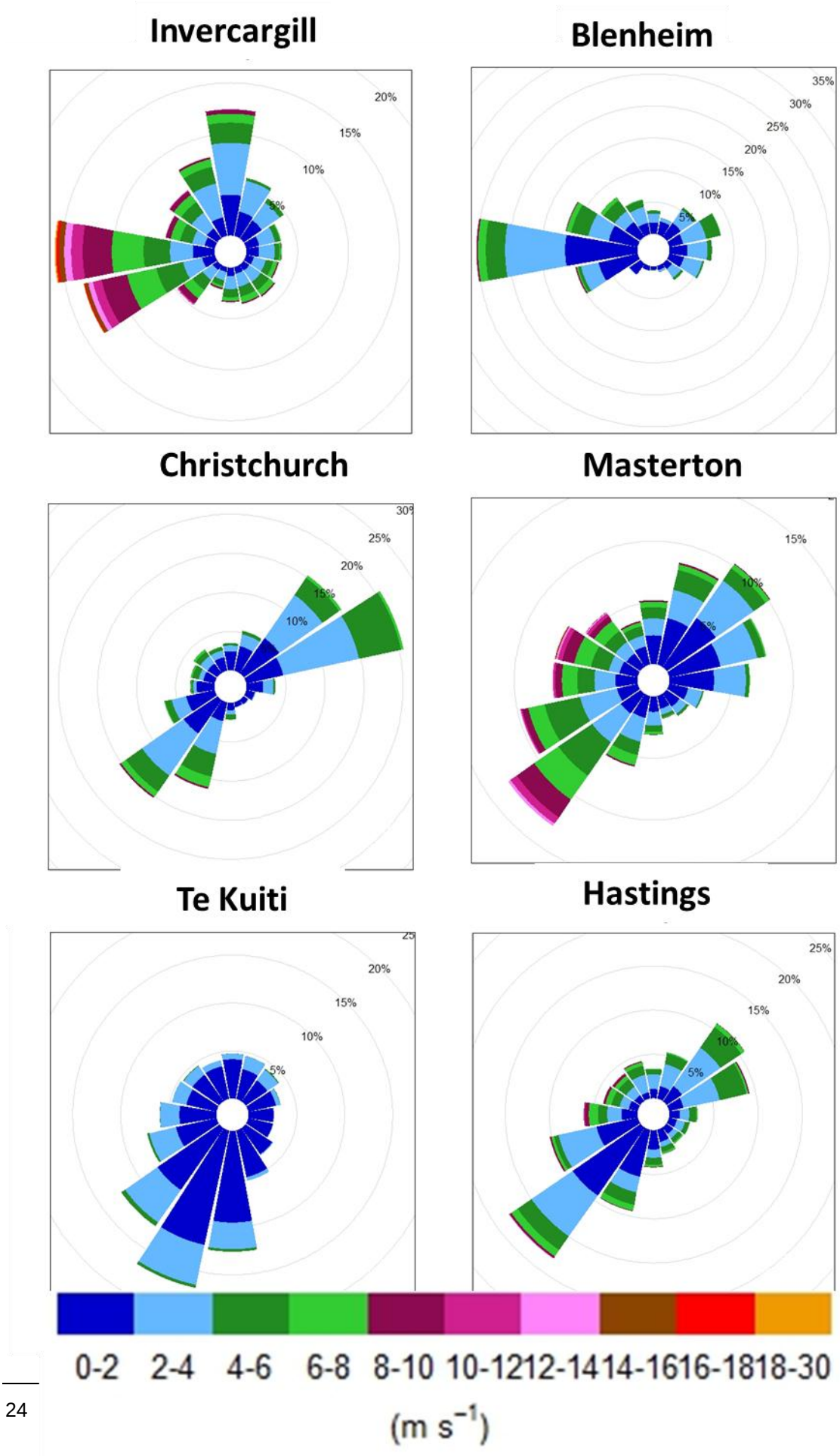
In order to see the range of meteorological conditions that each meteorological dataset includes, the following two figures show the wind speeds and directions for each location and the abundance of each P-G stability class calculated. The stability classes are as follows:

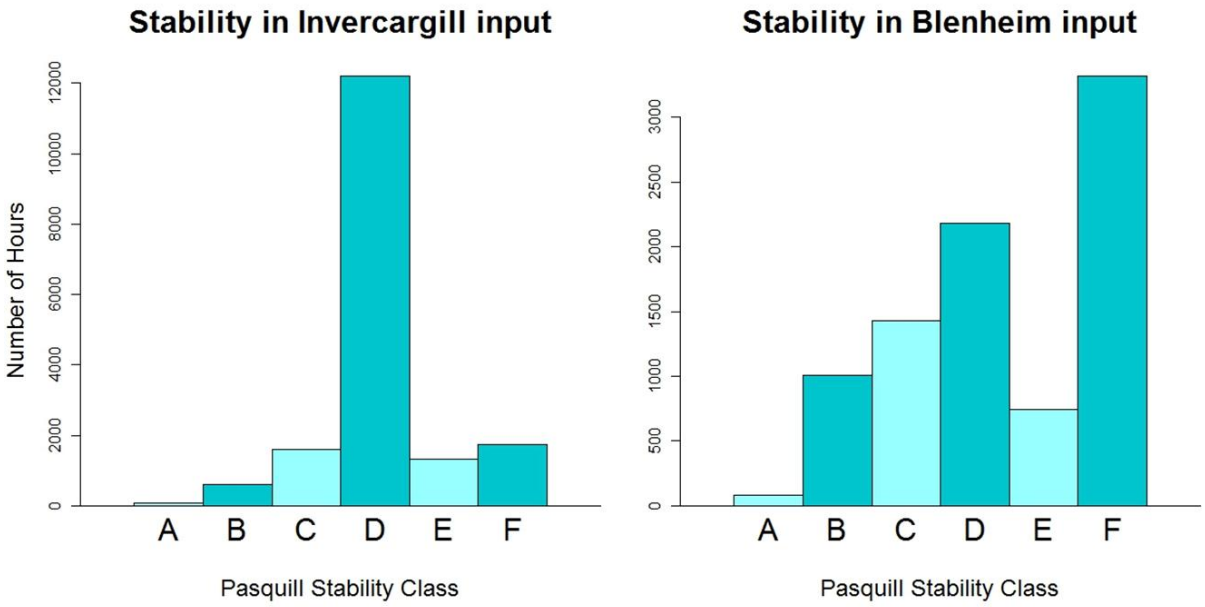
- A – very unstable
- B – unstable
- C – slightly unstable
- D – neutral
- E – slightly stable
- F – stable

Essentially, the more unstable the atmosphere, the greater the dispersion of any pollutant emitted. Conversely, the more stable the atmosphere the harder it is for adequate dispersion to take place.

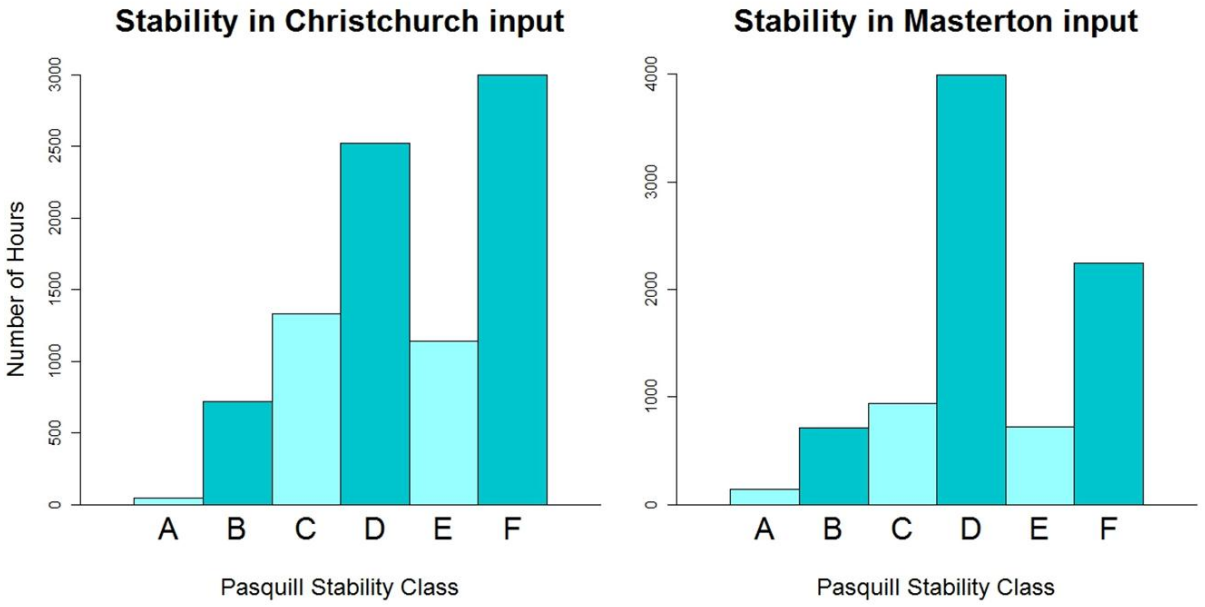
Thus, although the original meteorological data from Invercargill shows the largest range of winds, it also has preponderance of neutral stability (D)[2]. Blenheim and Christchurch show similar amounts of stable atmosphere and similar wind speeds. Blenheim's wind is more uni-directional which will lead to particular receptors west of the emission source being more exposed to pollutant than when using the Christchurch data. Te Kuiti has the lowest wind speeds and a strong proportion of neutral to stable conditions (D-E-F), in keeping with its basin-like location.

[2]This may be an artefact introduced when compensating for missing data. Where all the variables were not available for the stability calculation, the stability was set to Neutral. This may give the Invercargill data more conservative dispersion characteristics than is actually the case.

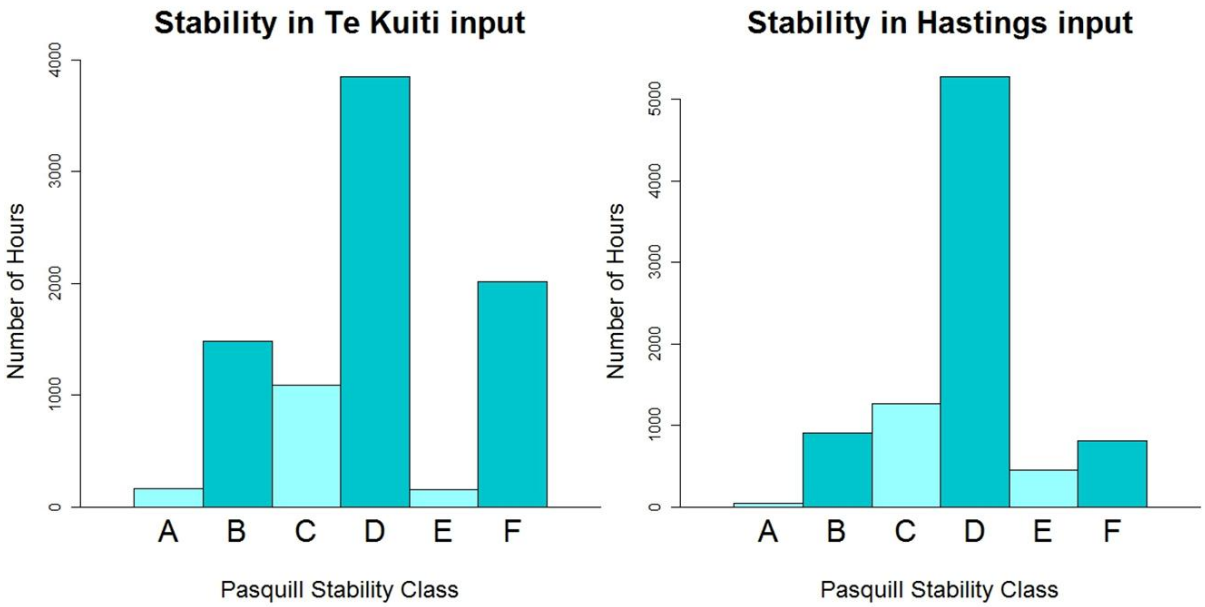

Invercargill
Blenheim
Christchurch
Masterton
Te Kuiti
Hastings
0-2 2-4 4-6 6-8 8-10 10-12 12-14 14-16 16-18 18-30
(m s^{-1})


Stability in Invercargill input
Number of Hours
0
2000
4000
6000
8000
10000
12000
A
B
C
D
E
F
Pasquill Stability Class

Stability in Blenheim input
0
500
1000
1500
2000
2500
3000
A
B
C
D
E
F
Pasquill Stability Class


Stability in Christchurch input
Number of Hours
0
500
1000
1500
2000
2500
3000
A
B
C
D
E
F
Pasquill Stability Class

Stability in Masterton input
0
1000
2000
3000
4000
A
B
C
D
E
F
Pasquill Stability Class


Stability in Te Kuiti input
Number of Hours
0
1000
2000
3000
4000
A
B
C
D
E
F
Pasquill Stability Class

Stability in Hastings input
Number of Hours
0
1000
2000
3000
4000
5000
A
B
C
D
E
F
Pasquill Stability Class