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NSW DEPARTMENT of ENVIRONMENT, CLIMATE CHANGE and WATER (DECCW)

ATMOSPHERIC THERMAL INVERSIONS MEASURED IN THE COLLIE BASIN
COLLIE WA

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FOR

NSW DEPARTMENT of ENVIRONMENT, CLIMATE CHANGE and WATER (DECCW)

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APPENDICIES

Attached; Data Disc

1. INTRODUCTION

The NSW Department of Environment, Climate Change and Water (DECCW) commissioned Herring Storer Acoustics to carry out an assessment of atmospheric conditions, particularly thermal inversions in the Collie Basin, approximately 220km south of Perth, Western Australia.

Data utilised for this thermal inversion study was recorded during an acoustic "sound propagation" study conducted in the Collie Basin in 2007. Although the aim of the Collie Basin study in 2007 was to assess sound propagation, atmospheric conditions were recorded at the time.

Atmospheric inversion strengths are a key factor when analysing noise and air quality. Predictive modelling utilises algorithms based on (amongst other values) inversion strengths as "degrees Celsius per 100m". As the true measurement of these atmospheric conditions for different geographical areas is difficult, allowance is generally made based on the extrapolated value from either ground level to 10m or, where available, 10m and 30m temperature values.

The purpose of this assessment is to analyse the atmospheric data recorded as a part of the 2007 study and provide the following information;

- Calculated atmospheric lapse rates based on static (met station) data at 10m and 30m.
- Actual atmospheric lapse rates based on measured temperature up to 100m.
- Actual degrees per 100m compared to extrapolated values from static data (met station).

2. BACKGROUND

2.1 COLLIE BASIN STUDY 2007

This report presents results from a study of sound propagation in the Collie Basin in Southern WA, conducted for the Department of Industry and Resources. The specific area of interest for this study is the area to the west of the Collie A Power Station, bounded by the Collie-Williams Road (or just beyond), the eastern edge of the Collie town-site and the Collie-Darkan Road.

The aims of the study were as follows.

- Investigate the effectiveness of standard sound propagation models in predicting noise levels from industrial sources in this area. The models specifically to be investigated are the ENM environmental noise model, produced by RTA Software, and SoundPlan, produced by Braunstein & Berndt. In all results for this study, SoundPlan calculations used the CONCAWE prediction algorithms.

- Using results from the above investigations, develop a definitive model of sound propagation in this area which can be used for prediction of the impact of both existing and future noise sources.

The sound propagation study involved two separate types of noise measurement:

- Controlled measurements of noise from a loudspeaker source, conducted over four nights in July and August 2007; and

- Measurements of uncontrolled noise from existing industrial sources in the area, conducted on the same nights at times when the controlled source was not in operation.

During the measurements, detailed records were gathered of meteorological conditions, including wind speed, wind direction and temperature at a purposely installed weather station on a Griffin tower at the Ewington II Mine Site at heights of 10 and 30 metres. Meteorological data was also collected in the area of actual sound measurements through a series of balloon flights during each night. The Ewington data provided the basis for meteorological parameters specified in the standard predictive models. The data gathered from the balloon flights is more comprehensive than is required for these models; however, it was used to confirm the sound gradient conditions relative to the model inputs. Although not used directly in this study, this additional data, together with the measured noise levels, is available for future study.

The measured noise levels for both controlled and uncontrolled measurements were compared with predicted levels produced by the standard models. As expected, measured noise levels were found to exhibit large variations over time scales from seconds to hours. Much of this variability clearly cannot be described without analysing short-range and short-term meteorological data (and it is unclear whether even with such data the actual noise level at any instant could be accurately predicted). Hence, comparisons between measured and predicted noise levels were directed at the models' ability to predict relevant features of the acoustic environment, notably the higher percentiles of the distribution of actual noise levels under the specified meteorological conditions.

This process led to the production of a final "definitive" model, which predicts the probability distribution of noise levels at a given location, under the range of meteorological conditions applying in the area. The model allows for the introduction of new sources, and provides a direct method of evaluating the impact of such new sources on existing or new noise-sensitive receivers.

3. METHODOLOGY

3.1 STATIC MONITORING STATION – EWINGTON MINE SITE COMMUNICATIONS TOWER

The Ewington Mine site is an open cut coal mine operated by The Griffin Coal Company. Permission was granted to install two directional anemometers and temperature / humidity probes to their 40m communications tower along with logging and communications systems.

The Griffin communications tower is located atop a residue hill at the Ewington II mine site and is one of the highest positions in the Collie Basin area. For reference purposes the estimated elevation[1] based on Australian Height Datum (AHD) and UTM coordinates are:

- 429827.60E 6308367.50N
- Elevation (Ground Level) 265m

1 Elevation is based on GPS values plus allowance for the height of the waste dump (30m).

Instrumentation used was a Unidata system consisting of a RM Young, wind monitor, model 6533A and temperature / humidity sensor, model 6501-EU.

The tower station consisted of two data collection units, one located at a height of 10m and the other at a height of 30m. The height differential gives an indication of temperature and wind gradient and will be consistent with data that will be readily available for assessment of historical data.

Data was collect via a Unidata Star Logger at one or two second intervals. Downloading of the data occurred remotely via a modem fitted to the main unit.

Photographs of the installation process and the data collection units are shown below.

Figure 1 - Ewington Meteorological Station

3.2 LOCALISED METEOROLOGICAL DATA

Localised atmospheric conditions were measured in the vicinity of the test area (near to the sound source) similar to the Ewington tower setup except as spot measurements at varying heights. The method used to gather the data was similar to the Ewington station in the equipment employed. For reference purposes the elevation (AHD) and UTM coordinates are:

- 428092.20E 6311380.10N
- Elevation (Ground Level) 255m

An anemometer, thermistor and altimeter were attached to a helium filled blimp. This system was generally raised and lowered in 10m increments over the course of the noise measurement period. Typically the blimp was raised to around 200m however the effective height was limited to the wind strength and the ability to control the blimp. Data was recorded for height, wind speed, wind direction and temperature for each 10m interval via a wireless recording system.

The blimp meteorological recordings were used as comparison data to ensure the Ewington data was typical of the prevailing conditions at the test site and additionally to provide higher level data relative to temperature and wind gradients.

Details of equipment types and pictures of the weather system are shown below:

Table 1 - MET Data Collection Equipment

Description	Make / Model	Parameter
Altimeter	ZLOG	Height in meters, logged at pre-set intervals
Temp/ Humidity Logger	Logtag	Temp (degrees C) Humidity (%RM) - Logged at pre-set intervals
Anemometer	RM Young 653B	Wind Speed (m/sec) Logged at selected intervals.
Temp Probe	Unidata Thermistor	Temp (Degrees C) Logged at selected intervals
Wind Direction		Directional bearing logged by observation.

Figure 2 - Local Site Weather Collection Equipment

3.3 BUREAU OF METEOROLOGY - EAST COLLIE WEATHER STATION

The East Collie location is a calibrated, Bureau of Meteorology (BoM) station, which records hourly meteorological data. Information from the station was provided post study and has been included for reference purposes. Location information for the East Collie station is as follows:

- 428092.20E 6311380.10N
- Elevation (Ground Level) 255m

4. RESULTS AND ANALYSIS

4.1 RESULTS

For the overall study period, three night's data were used to conduct the analysis. Due to the large amount of data collected, summary values have been used for only the relevant parameters to this study and are as follows:

1. Temperature 10m Ewington Met Station
2. Temperature 30m Ewington Met Station
3. Temperature Localised Site (Blimp)
4. Altimeter, Height for Localised Site (Blimp)
5. Temperature 10m BoM site

The summary of each nights meteorological data is shown below in Tables 2,3 and 4.

In the example instance, data was collected at the static weather station at two-second intervals and around three minute intervals at the local site (blimp). Graphical plots for each of the periods are shown in Appendix B.

Table 2 – Summarised Results – 15th July 2007

Time	Ewington 10m	Ewington 30m	BoM 10m	Localised Blimp Data	
	Temperature degC	Temperature degC	Temperature degC	Temperature degC	Height metres
16:55	15.4	14.8	16.8	15.1	10
16:57	15.3	14.8	16.8	15.2	20
16:59	15.3	14.7	16.8	15.0	30
17:03	15.2	14.5	14.9	14.9	50
17:07	15.0	14.4	14.9	14.5	60
17:08	15.0	14.4	14.9	14.4	70
17:12	14.8	14.2	14.9	14.0	80
17:21	14.4	13.9	14.9	13.4	90
17:26	14.3	13.9	14.9	13.1	110
17:29	14.2	13.8	14.9	13.1	120
17:30	14.1	13.6	14.9	13.0	140
20:48	11.5	11.3	8.4	10.5	160
21:02	11.0	11.0	7.3	10.3	140
21:05	11.0	11.0	7.3	10.4	120
21:07	11.0	10.9	7.3	10.5	100
21:23	11.0	10.7	7.3	10.5	20
03:40	9.3	9.4	4.7	10.0	130
03:44	9.2	9.4	4.7	10.0	120
03:49	9.2	9.4	4.7	9.7	96
03:59	8.8	9.4	4.7	9.6	70
04:07	9.1	9.8	5.4	9.1	40
05:38	8.9	8.9	5.7	9.5	30

Table 3 - Summarised Results – 10th August 2007

Time	Ewington 10m	Ewington 30m	BOM 10m	Localised Blimp Data	
	Temperature degC	Temperature degC	Temperature degC	Temperature degC	Height metres
20:58	9.2	9.4	7.2	6.8	n/a
21:01	9.3	9.4	6.0	7.3	13
21:02	9.3	9.5	6.0	7.9	24
21:04	9.3	9.6	6.0	8.2	36
21:06	9.4	9.6	6.0	8.4	46
21:08	9.4	9.6	6.0	8.9	55
21:10	9.4	9.6	6.0	9.3	64
21:11	9.4	9.6	6.0	9.3	65
21:12	9.4	9.6	6.0	9.4	75
21:15	9.4	9.4	6.0	9.5	85
21:17	9.4	9.4	6.0	9.5	95
21:18	9.4	9.4	6.0	9.6	95
21:20	9.4	9.4	6.0	9.5	102
21:21	9.4	9.3	6.0	9.5	111
21:23	9.4	9.3	6.0	9.6	110
21:25	9.3	9.4	6.0	9.5	114

Time	Ewington 10m	Ewington 30m	BOM 10m	Localised Blimp Data	
	Temperature degC	Temperature degC	Temperature degC	Temperature degC	Height metres
21:26	9.4	9.4	6.0	9.5	104
21:59	9.4	9.4	6.0	8.9	100
22:01	9.3	9.4	5.7	9.2	100
22:02	9.4	9.4	5.7	9.2	100
22:03	9.4	9.4	5.7	9.3	100
22:04	9.4	9.4	5.7	9.4	100

Table 4 - Summarised Results – 17th August 2007

Time	Ewington 10m	Ewington 30m	BOM 10m	Localised Blimp Data	
	Temperature degC	Temperature degC	Temperature degC	Temperature degC	Height metres
21:27	11.9	12.6	5.9	10.9	10
21:27	11.9	12.6	5.9	10.9	10
21:40	11.4	12.6	5.9	13.2	83
21:42	11.4	12.4	5.9	13.3	83
21:44	11.4	12.5	5.9	13.3	100
21:45	11.4	12.5	5.9	13.3	100
21:47	11.4	12.6	5.9	13.3	113
21:50	11.4	12.6	5.9	13.5	132
21:50	11.4	12.6	5.9	13.5	133
21:52	11.3	12.6	5.9	13.5	143
21:57	11.3	12.6	5.9	13.4	164
21:58	11.3	12.6	5.9	13.3	164
22:01	11.6	12.7	4.6	13.3	171
22:01	11.6	12.7	4.6	13.3	171
22:03	11.6	12.6	4.6	13.3	186
22:04	11.7	12.7	4.6	13.3	186
22:06	11.7	12.6	4.6	13.3	198
22:08	11.7	12.6	4.6	13.2	210
22:09	11.7	12.6	4.6	13.1	216
22:10	11.8	12.6	4.6	13.2	215

4.2 ANALYSIS

Calculations to enable the above results to be converted to an atmospheric lapse rate (temperature) to degrees per 100m are based on the extrapolated values dependant on the measurement height. For example at 21:44 on 17th Aug 07 the temperature between the 10m and 30m recordings for the static station at Ewington was:

$Temp^1$ at 10m 11.4°C
$Temp^2$ at 30m 12.5°C

Extrapolating these two values out to provide an atmospheric lapse rate per 100m would be:

$$^{o}C \text{ per } 100m = (temp^2 - temp^1) \times [100/(30-10)]$$

therefore, the atmospheric lapse rate for the static recording station is **5.5°C** per 100m.

The actual measured temperature at the same time period for a height of 100m was 13.3^{o}C.

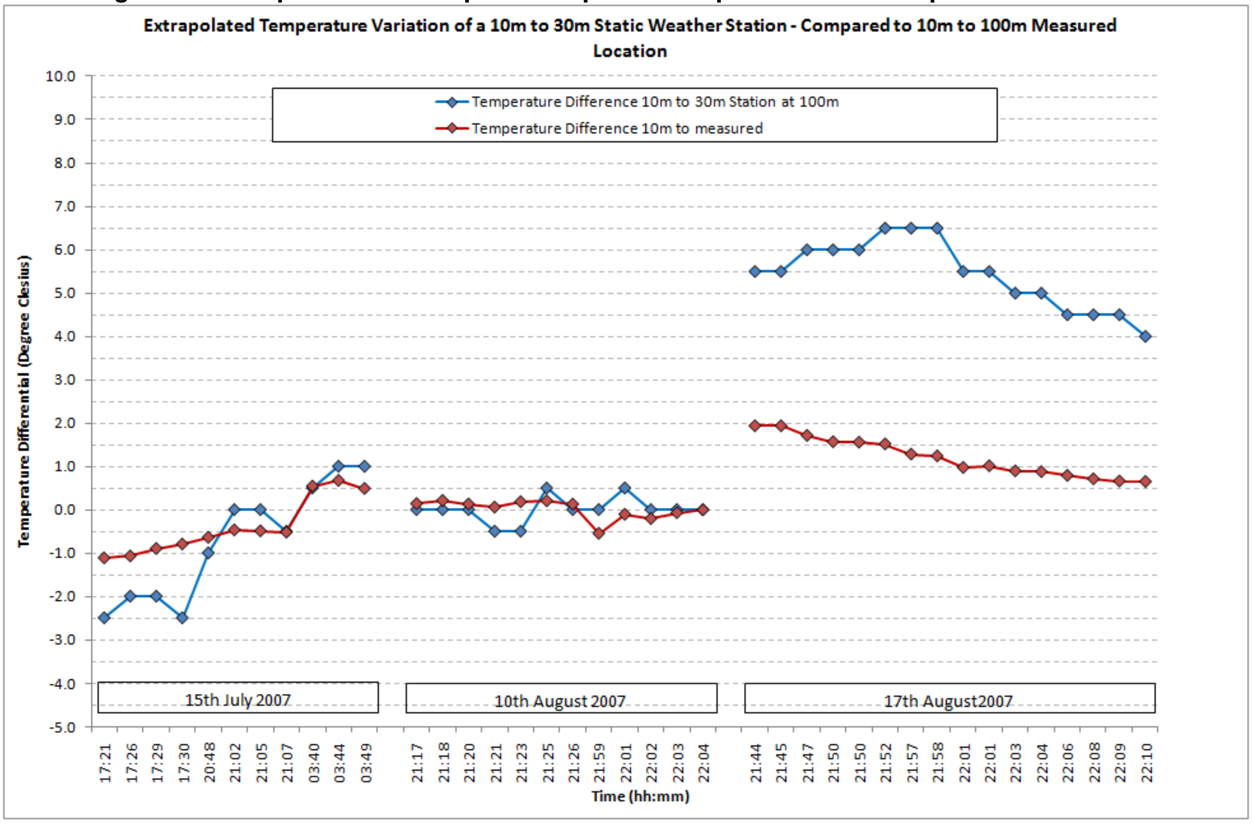
Given the 10m temperature was 11.4^{o}C this would calculate to an atmospheric lapse rate of **1.9^{o}C** per 100m

Based on this calculation, a comparison of the atmospheric lapse rates for each of the measurement periods has been carried out. These values are tabulated blow with a graphical representation in Figure shown in table 5 below.

Table 5 – Comparison Atmospheric Lapse Rates per 100m – Extrapolated vs Actual

Time Period		Extrapolated Atmospheric Lapse Rate Based on 10m and 30m Values	Actual Atmospheric Lapse Rate Based on 100m Measurements
15th July 2007	17:21	-2.5	-1.1
	17:26	-2.0	-1.1
	17:29	-2.0	-0.9
	17:30	-2.5	-0.8
	20:48	-1.0	-0.6
	21:02	0.0	-0.5
	21:05	0.0	-0.5
	21:07	-0.5	-0.5
	21:23	-1.5	-2.6
	03:40	0.5	0.5
	03:44	1.0	0.7
	03:49	1.0	0.5
10th August 2007	21:17	0.0	0.1
	21:18	0.0	0.2
	21:20	0.0	0.1
	21:21	-0.5	0.1
	21:23	-0.5	0.2
	21:25	0.5	0.2
	21:26	0.0	0.1
	21:59	0.0	-0.5
	22:01	0.5	-0.1
	22:02	0.0	-0.2
	22:03	0.0	-0.1
	22:04	0.0	0.0
17th August 2007	21:44	5.5	1.9
	21:45	5.5	1.9
	21:47	6.0	1.7
	21:50	6.0	1.6
	21:50	6.0	1.6
	21:52	6.5	1.5
	21:57	6.5	1.3
	21:58	6.5	1.2
	22:01	5.5	1.0
	22:01	5.5	1.0
	22:03	5.0	0.9
	22:04	5.0	0.9
	22:06	4.5	0.8
	22:08	4.5	0.7
	22:09	4.5	0.7
	22:10	4.0	0.7

Figure 3 - Comparison Atmospheric Lapse Rates per 100m – Extrapolated Vs Actual



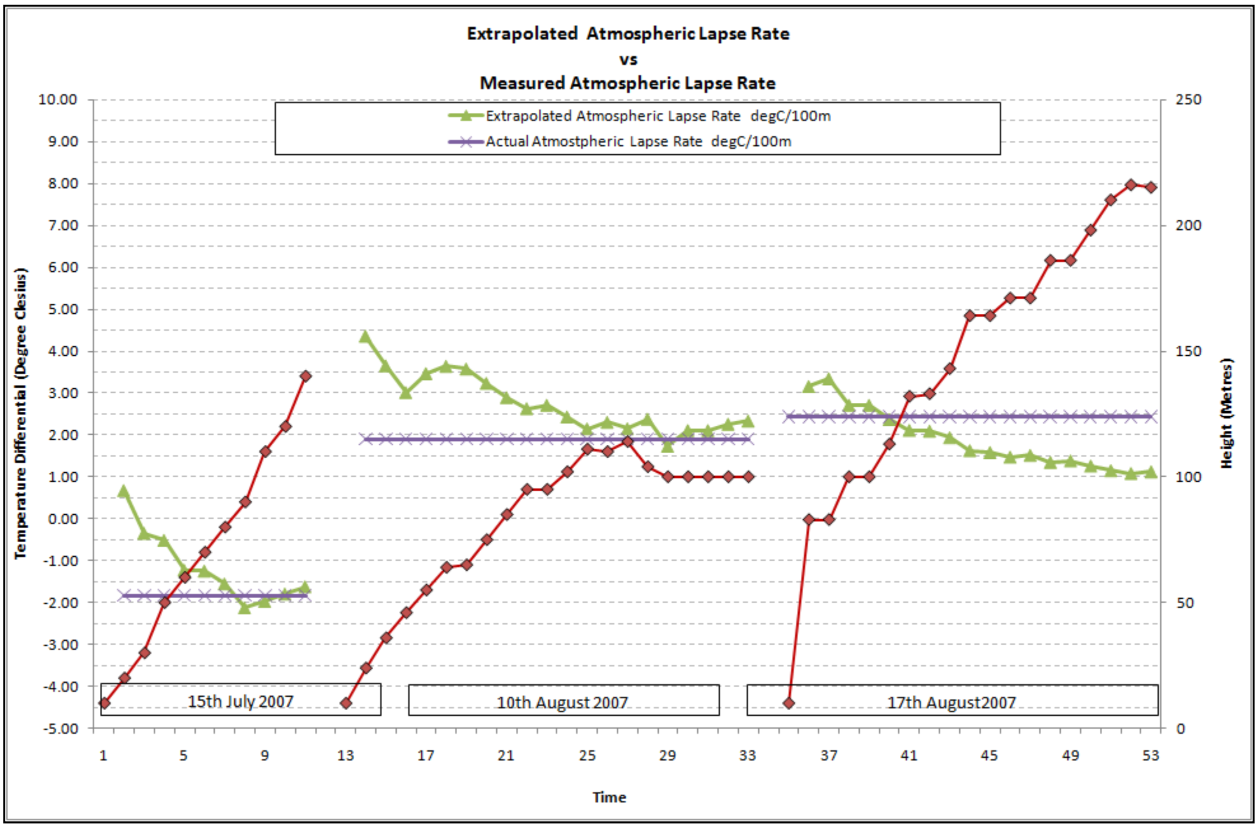
Further analyse of only the actual measured temperatures (blimp data) at heights from 10m to 215m has been conducted. The purpose of this analysis is to further identify variance between extrapolated calculation and actual measurement data due to height.

Table 6 contains results of the calculated temperature lapse rates per 100m, compared to the actual temperature lapse rate based on the temperature measured at 100m for that series of data. Graphical plots have been included in Figure 4.

Table 6 – Calculated Temperature Variation Compared to Actual Variation

Date	Time	Temperature (Degree Celsius)	Measurement Height (Metres)	Extrapolated Temperature Lapse Rate per 100m	Actual Temperature Lapse Rate per 100m
15th July 2007	16:55	15.1	10	0.0	1.8
	16:57	15.2	20	0.7	
	16:59	15.0	30	-0.3	
	17:03	14.9	50	-0.5	
	17:07	14.5	60	-1.2	
	17:08	14.4	70	-1.2	
	17:12	14.0	80	-1.6	
	17:21	13.4	90	-2.1	
	17:26	13.1	110	-2.0	
	17:29	13.1	120	-1.8	
	17:30	13.0	140	-1.6	
10th August 2007	21:01	7.3	10	0.0	2.0
	21:02	7.9	24	4.4	
	21:04	8.2	36	3.7	
	21:06	8.4	46	3.0	
	21:08	8.9	55	3.5	
	21:10	9.3	64	3.6	
	21:11	9.3	65	3.6	
	21:12	9.4	75	3.2	
	21:15	9.5	85	2.9	
	21:17	9.5	95	2.6	
	21:18	9.6	95	2.7	
	21:20	9.5	102	2.4	
	21:21	9.5	111	2.1	
	21:23	9.6	110	2.3	
	21:25	9.5	114	2.2	
	21:26	9.5	104	2.4	
	21:59	8.9	100	1.7	
	22:01	9.2	100	2.1	
	22:02	9.2	100	2.1	
	22:03	9.3	100	2.3	
	22:04	9.4	100	2.3	
17th August 2007	21:27	10.9	10	0.0	2.4
	21:40	13.2	83	3.2	
	21:42	13.3	83	3.3	
	21:44	13.3	100	2.7	
	21:45	13.3	100	2.7	
	21:47	13.3	113	2.4	
	21:50	13.5	132	2.1	
	21:50	13.5	133	2.1	
	21:52	13.5	143	1.9	
	21:57	13.4	164	1.6	
	21:58	13.3	164	1.6	
	22:01	13.3	171	1.5	
	22:01	13.3	171	1.5	
	22:03	13.3	186	1.3	
	22:04	13.3	186	1.4	
	22:06	13.3	198	1.3	
	22:08	13.2	210	1.2	
	22:09	13.1	216	1.1	
	22:10	13.2	215	1.1	

Figure 4 - Calculated Temperature Variation Compared to Actual Variation



5. DISCUSSIONS

Comparison of the atmospheric lapse rate for the first two nights of data (15th and 10th) show little difference between the static met station and actual measured levels based on blimp data. The highest differential was generally around 1°C per 100m.

Comparative levels for the third night's data (17th) showed a larger differential between calculated and actual measured atmospheric lapse rates. Generally, there was a 4 to 5°C difference in the temperature per 100m with the extrapolated level from the static weather station over predicting.

Thermal inversions in the atmosphere likely only occurred on the final night of measurements.

Variations in temperature between extrapolated and actual measured levels fluctuated from heights of 10m up to 80m for the blimp data. For heights generally between 80 and 130m the there was little to no variance between measured and extrapolated atmospheric lapse rate levels. Generally, for measured levels above 130m the differential increased. This is shown clearly in figure 4 where the differential between calculated and actual coincides from 80 to approximately 110m in height for all three measurement periods.

6. CONCLUSION

Based on the assessed data, the use of 10m and 30m temperature measurements from weather stations, for general predictions of atmospheric lapse rates, requires careful evaluation.

From the small sample of data (three nights), as per this assessment, values for the atmospheric lapse rates can vary 1 to 5°C per 100m from actual to extrapolated levels.

Generally, extrapolating the measured values (as per this assessment) for the 10m and 30m recorded levels showed an over prediction in the thermal inversion by up to 5°C at 100m when a thermal inversion is present.

Variations between calculated and actual measured levels indicate the appropriate height for measurement of atmospheric lapse rates for comparison to 10m temperatures is no less than 80m. Results from the final measurement period, where an inversion was present, showed measured levels beyond 80m remained static with little variation.

APPENDIX A

LOCATION MAPS

Figure 5 - Overall Location Map

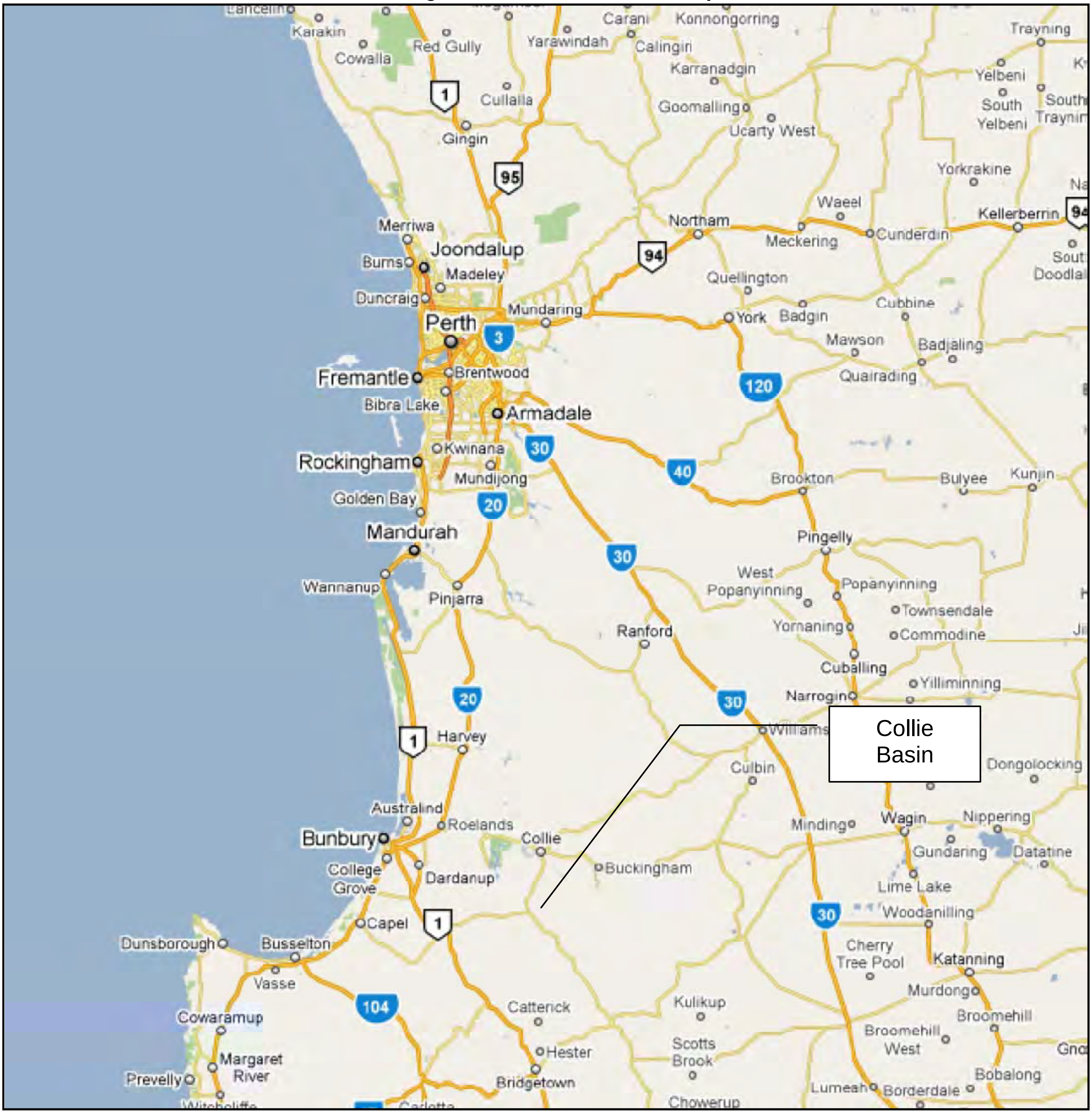
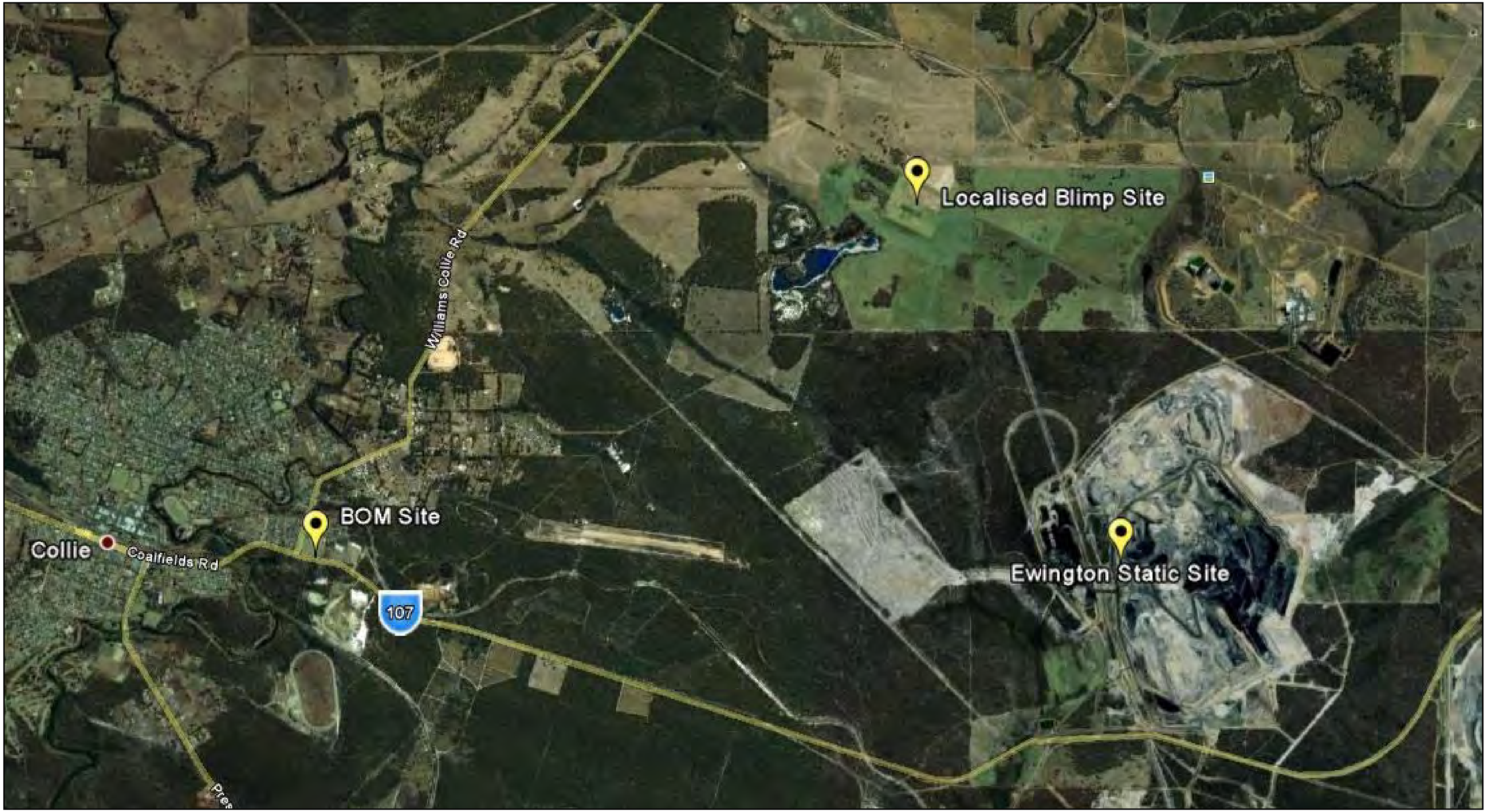


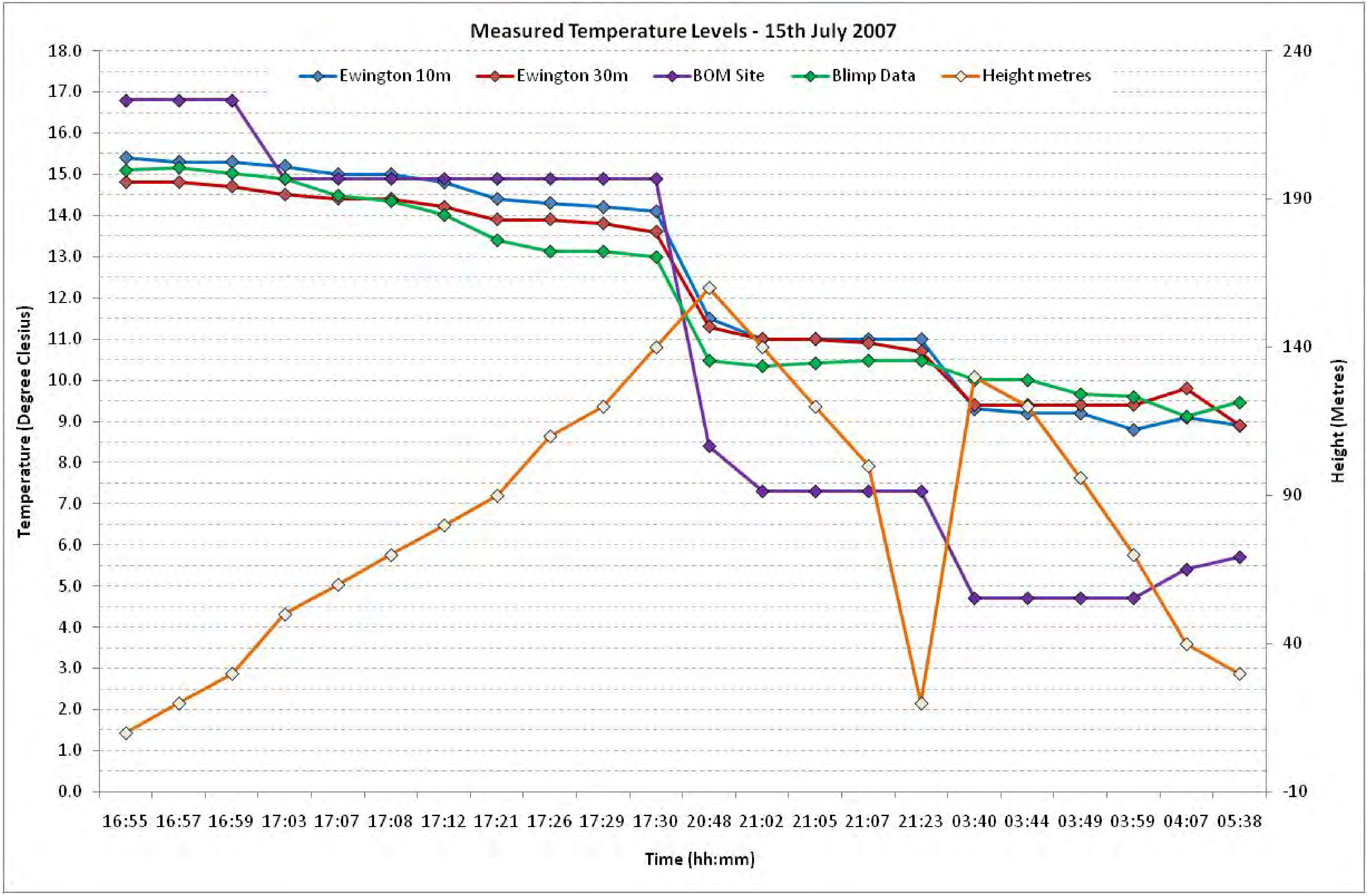
Figure 6 - Measurement Location Map



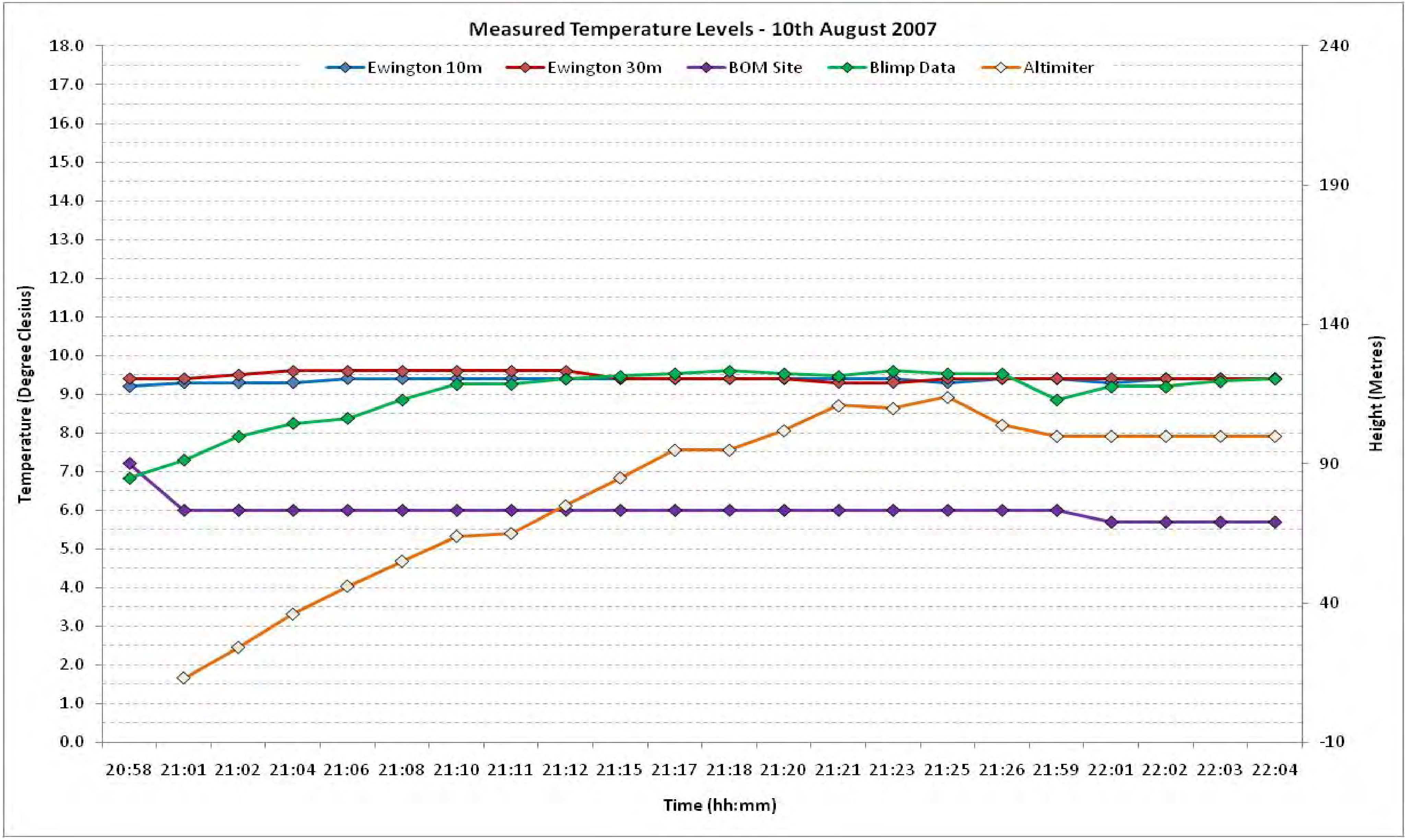
APPENDIX B

GRAPHICAL REPRESENTATION OF DATA

Graph 1 – Results for Night 1



Graph 2 - Results for Night 2



Graph 3 - Results for Night 3