Hunter, Central and Lower North Coast

Regional Climate Change Project

2010

CASE STUDY 2: Potential Impacts of Climate Change on Extreme Heat Events Affecting Public Health in the Hunter, Lower North Coast and Central Coast Region

An Initiative of the Hunter & Central Coast Regional Environmental Management Strategy

(Hunter & Central Coast Regional Environmental Management Strategy – a program of the Environment Division of Hunter Councils)

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TABLE OF CONTENTS

Executive Summary **1**

Introduction **2**

Overview of Key Climate Change Concerns **3**

Discussion of key climate parameters 3

Case Study Methodology **5**

Historical Climate Variability and Trends **7**

Extreme Heat Events >= 37^{0} Threshold 7

Extreme Heat Events Using Relative Thresholds 8

Yearly Worst 3-day Extreme Heat Event 10

Average Temperature 11

Projected Changes in Climate **16**

Maximum Temperature Projections 16

Extreme Heat Day Projections 16

Average Temperature Projections 17

Risk Assessment Process and Outcomes **18**

Conclusion **21**

References **22**

Appendix 1 – Risk Assessment Matrix **24**

Appendix 2 – Guidelines for Assessing Liklihood and Consequence Scales **27**

List of Figures

Figure 1 – Study Region 2

Figure 2 - Heat stress temperature thresholds by region 5

Figure 3 - Study region comprising coastal, central and western climate zones. 6

Figure 4 - Annual trend in extreme heat days at Taree and Newcastle 7

Figure 5 - Annual trend in extreme heat days at Lostock Dam and Paterson 7

Figure 6 - Annual trend in extreme heat days at Murrurundi and Jerry's Plains 8

Figure 7 – Extrapolated heat stress temperature thresholds for Taree, Newcastle, Jerrys Plains and Murrurundi 9

Figure 8 - Frequency of EHEs (1970-2007) 10

Figure 9 - Trend in yearly worst 3-day extreme heat events (1970-2007) 11

Figure 10 – Trend in annual average temperature for the 1970-2007 epoch in the coastal zone 12

Figure 11 - Seasonal average temperature trends 1970-2007 in the coastal zone 12

Figure 12 - Trend in annual average temperature for the 1970-2007 epoch in the central zone 13

Figure 13 - Seasonal average temperature trends 1970-2007 in the central zone 14

Figure 14 - Trend in annual average temperature for the 1970-2007 epoch in the western zone 14

Figure 15 - Seasonal average temperature trends 1970-2007 in the western zone 15

Figure 16 - Difference in frequency of summer and spring STs relative to 1968-1996 16

Figure 17 - Frequency of 1day and 3day extreme heat events by ST for Murrurundi, Newcastle, Jerrys Plains and Taree 17

Figure 18 - Risk Assessment Matrix (source: Commonwealth of Australia 2006. Climate Change Impacts and Risk Management: A Guide for Business & Government). 18

List of Tables

Table 1 - 1 day and 3 day maximum temperature thresholds by region...4

Table 2 –Difference between 1 day and 3 day maximum temperature thresholds and the summer/spring average (SSA) maximum temperature by region...4

Table 3 - 1 day and 3 day maximum temperature thresholds for Taree, Murrurundi, Newcastle, Jerrys Plains, Paterson and Lostock Dam...8

Table 4 - Summary of risks and potential adaptation strategies..19

GLOSSARY

BOM	**BUREAU OF METEOROLOGY**
CSIRO	**COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION**
GCM	**GLOBAL CLIMATE MODEL**
EHE	**EXTREME HEAT EVENT**
HCLNC	**HUNTER, CENTRAL AND LOWER NORTH COAST**
IPCC	**INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE**
ISC	**INPATIENT STATISTICS COLLECTION**
LGA	**LOCAL GOVERNMENT AREA**
SLP	**SEA LEVEL PRESSURE**
ST	**SYNOPTIC TYPE**

EXECUTIVE SUMMARY

This case study provides an analysis of historic and projected changes in key temperature variables and extreme heat related indices to improve understanding of the potential impacts of climate change on community health (heat impacts) in the Hunter, Central and Lower North Coast region of NSW.

The analysis has identified that:

- With the exception of Newcastle, the frequency of extreme heat days ≥ 37°C over the period 1970-2007 has been increasing at each of the climate stations analysed across the region's three climate zones. These increases have been statistically significant at Taree and Murrurundi; and
- Statistically significant increasing trends in yearly worst 3-day heat events have been identified at Jerrys Plains (2.2°C) and at Murrurundi (1.75°C) over the 1970-2007 period (ie extreme events in the region are also becoming hotter).

Projected changes in extreme events that pose a potentially increased risk to community health include:

- An overall increase in the frequency of extreme heat events at the current threshold levels are expected during the period from 2020-2080 across the region.
- Projected decreases in average maximum temperature during summer and spring are likely to lower extreme heat event threshold levels. Based on the calculations used to extrapolate the threshold values in this case study, a 0.2°C decrease is projected for Taree, a 0.5°C decrease in Murrurundi and Newcastle, and a 0.4°C decrease in Jerrys Plains.
- The lowering of threshold levels combined with projected increases in extreme heat events at current threshold levels is likely to increase the *frequency of occurrence* of extreme heat events beyond known variability.
- Projected decreases in average maximum temperature during summer and spring are likely to have minimal impact on reducing the intensity of yearly worst 3-day heat events. Combined with an historic increasing trend, projections suggest that increases in the intensity of these events is likely to continue.

This analysis has also underpinned a broad scale risk assessment process completed with the assistance of NSW Department of Health representatives. This has identified and ranked the potential risks to human health arising from projected changes in extreme heat events across the region. Of particular note is the fact that all risks identified were rated as either extreme or high. This clearly indicates the significance that an increase in extreme heat events represents as a community health issue to the region. These risks include:

- Heat related morbidity and mortality (heat related injuries, dehydration & other disorders of fluid, electrolyte and acid base balance. Examples include heat fatigue, heat cramps, heat syncope, heat exhaustion & heat stroke)
- Increase in production of photochemical smog and particulate pollution from bushfires
- Reduced access to emergency services and facilities
- Injury, trauma and related effects as a result of violence & trauma
- Disruptions to essential services (eg electricity & water supplies)
- Reduced access to transport services

A full description of all of the risks identified and potential adaptation strategies for dealing with these are included in Table 4 and Appendix 1 of this report.

INTRODUCTION

International and Australian experience demonstrate that heat waves increase the incidence of illness and death particularly for people most at risk. While the effects of natural disasters such as floods, bushfires and cyclones are obvious and dramatic, the impacts of heat on human health are more likely to be cumulative and subtle, yet potentially more dangerous in their ultimate impact (Mella & Madill, 2007). High risk groups include:

- Older people, including those over 65 and particularly those over 75;
- Those with a chronic medical condition or disability, particularly obesity, reduced cardiovascular capacity & asthma;
- Those on certain types of medication, especially cardiac and psychiatric related;
- People living alone or socially isolated (eg elderly, mentally ill, disabled and homeless);
- Children, due to their immature thermoregulatory responses; and
- Outdoor workers with high exposure to extreme heat events (State of Victoria, 2009 & Lloyd, G., 2010 pers. comm.).

Therefore in the context of climate change, historic and projected changes in average maximum temperatures and extreme heat conditions have the potential to impact on the severity of heat related illness in the community. Heat waves and heat related illness have been identified as posing the greatest health risk in NSW for both urban and rural communities arising from climate change (Mella & Madill, 2007). However, given that heat related illness is largely preventable and can be largely addressed through strategies to ensure adequate hydration and reducing exposure to extreme conditions (Mella & Madill, 2007), there is significant potential to reduce negative impacts on the community through the implementation of appropriate adaptation strategies.

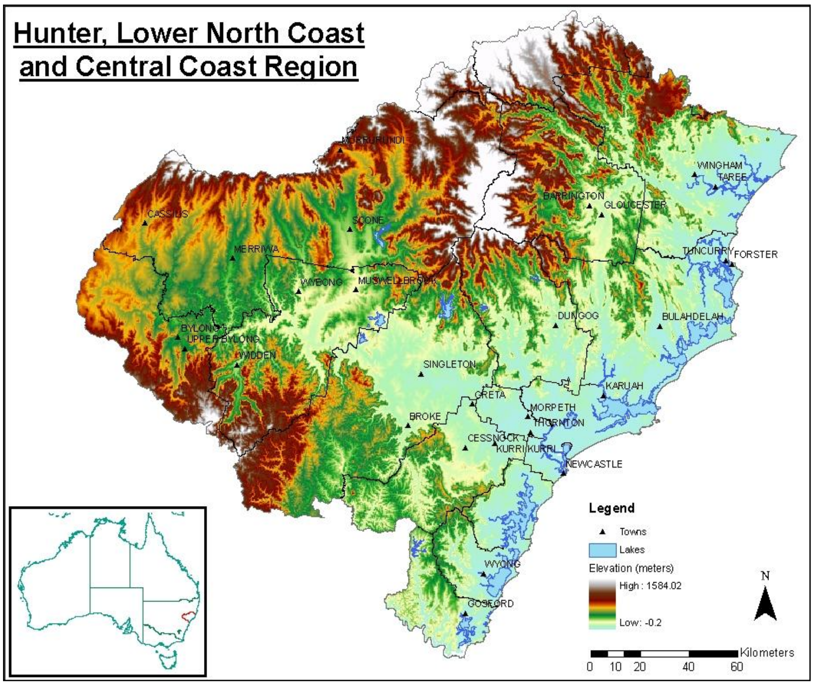

Figure 1 – Study Region

To better understand and prepare for the potential impacts of climate change on heat related illness in the Hunter, Central and Lower North Coast region of NSW, this case study provides a sub regional analysis of both historic and projected climate change through analysis of key temperature variables and extreme heat related indices. The study region it encompasses extends from above Taree in the north (31°16'54."S) to below Gosford in the south (33°34'48.97"S), and from a most easterly point on the coast (152°48'13.5"E) to inland of Cassilis in the west (149°40'8.49"E). In total, an area of 39,021.58 sq/km is considered in this study (Figure 1).

The region encompasses 14 local government areas (LGAs) that include Greater Taree, Great Lakes, Gloucester, Upper Hunter, Dungog, Port Stephens, Maitland, Newcastle, Singleton, Muswellbrook, Cessnock, Lake Macquarie, Wyong and Gosford.

This case study has been completed as part of a broader research program to identify the regional and sub regional scale impacts of climate change in the region. In addition to an overall analysis of historic and projected climate change for the region (Blackmore & Goodwin 2008; Blackmore & Goodwin 2009) generated by this research, 4 case studies (of which this is one) have been developed to more specifically analyse and understand the potential impacts of climate change in key sectors at a regional scale.

OVERVIEW OF KEY CLIMATE CHANGE CONCERNS

Global, national and regional historical records show a statistically significant increasing trend in temperature. Regionally, temperature increases in the order of 1 degree Celsius have occurred during the past century (Blackmore & Goodwin, 2008). These figures are in line with those published nationally (CSIRO 2007). Output from global climate change models (GCMs) show increases in temperature are likely to continue to occur through to 2100AD (IPCC 2007) and beyond.

Of interest in this case study are the potential regional impacts of increased temperature, specifically extreme heat events (EHEs), on human health. Although a number of different definitions of EHEs exist, they are considered in this case study to include single days equal or above 37^{o}C, a single day with maximum temperature recorded above a given heat stress threshold, or consecutive days with a three day moving average temperature above a given threshold.

The level of threshold values can vary across regions. In this case study, the relative nature of EHEs has been taken into consideration when analysing historic trends and when considering future changes in synoptic patterns associated with these events. That is, various extreme heat thresholds have been used for the region that are relative to the average temperatures experienced within each sub regional climate zone. To facilitate this case study, liaison with relevant organisations, including the NSW Department of Health, has been undertaken.

DISCUSSION OF KEY CLIMATE PARAMETERS

The key climate parameter considered in this case study is daily maximum temperature. This parameter is used to analyse historic trends in EHEs and yearly worst 3-day extreme heat events. Threshold values for considering historic and projected trends in EHEs and yearly worst 3-day extreme heat events are discussed in this section.

A general threshold value of maximum temperature greater than or equal to 37 degrees Celsius for single day EHEs is used in this analysis. In addition, relative single day and three day moving average maximum temperature threshold values are derived based on findings from recent research. Historic changes in EHEs for 6 selected BOM stations within the region are considered (see Figure 3).

A recent Department of Health report (Khalaj, et al., in press) produced single day and three day moving average thresholds for five NSW regions. This report presented results of a project examining the admission details of patients admitted to hospital during EHEs. Data analysis was based on the Inpatient Statistics Collection (ISC) for the spring and summer seasons from 1998 to 2006. A key finding from the project was that temperature thresholds for hospital admissions varied by region. These varying temperature thresholds are shown in Table 1.

Region	1day Threshold	3day Threshold
Illawarra	34	32.5
Sydney East	36.2	33.5
Gosford Wyong	37.2	35.1
Newcastle	38.4	36.4
Sydney West	38.7	36.3

Table 1 - 1 day and 3 day maximum temperature thresholds by region

In addition to the published thresholds, the summer average and spring average maximum temperatures, the average maximum temperature for these two seasons (SSA) and the deviation from the combined season average maximum for both the one day (1Day-SSA) and three day (3Day-SSA) thresholds for each of the regions have also been calculated (Table 2). On average, the difference between the regional one day threshold and the spring/summer average maximum temperature is 11.91°C. For three day moving average temperatures, this threshold is slightly lower. Impacts to human health occur when the average temperature recorded over a three day period exceeds the regions average temperature by 9.77°C. The relationship between average temperature (for spring and summer) and the threshold values is evident in Figure 2[1].

Region	Summer Average	Spring Average	Summer/Spring Average (SSA)	1Day Threshold-SSA	3Day Threshold-SSA
Illawarra	25.39	21.80	23.60	10.40	8.90
Sydney East	26.54	22.56	24.55	11.65	8.95
Gosford Wyong	27.43	23.41	25.42	11.78	9.68
Newcastle	27.99	23.66	25.83	12.57	10.57
Sydney West	27.72	23.43	25.58	13.12	10.72
				11.91	9.77

Table 2 –Difference between 1 day and 3 day maximum temperature thresholds and the summer/spring average (SSA) maximum temperature by region

[1] It should be noted that these figures are obtained from data available for only five (5) NSW regions. The small number of regions (i.e. five) means that statistical analysis of the relationship between threshold values and average regional temperatures is not possible. Additionally, the difference between threshold values and regional values is not uniform and appears to increase in regions with higher average temperatures (i.e. Newcastle and Sydney West). Thus, care should be taken in the broad application of these figures, particularly to regions outside of NSW and further inland.

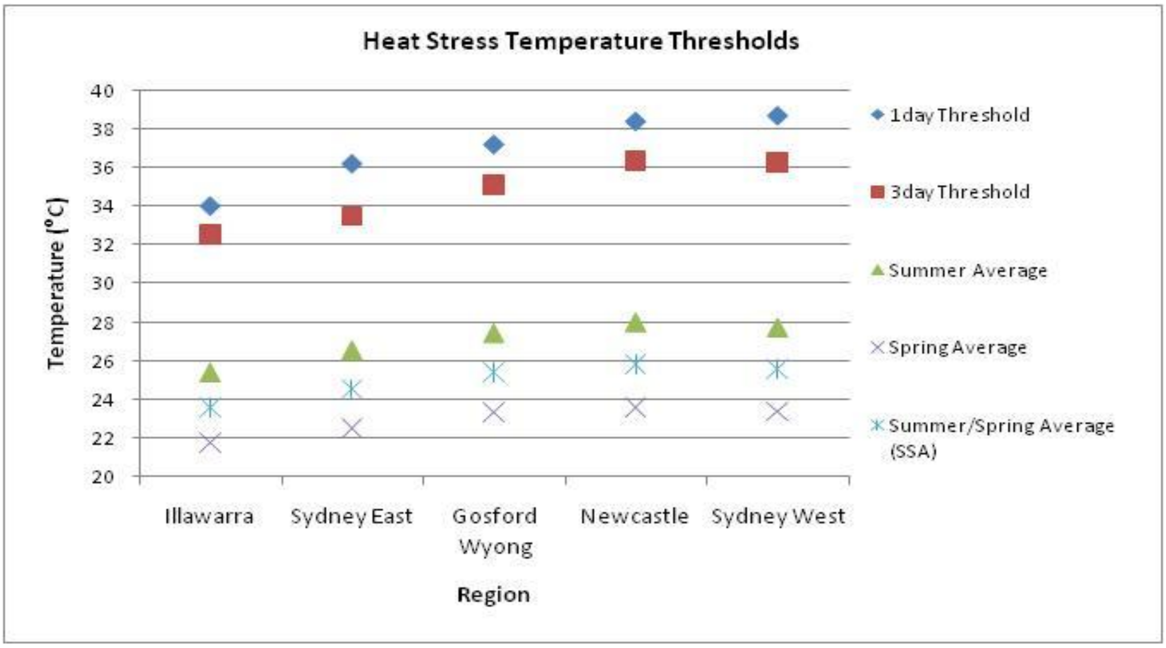

Figure 2 - Heat stress temperature thresholds by region

Unfortunately only two of these regions (Gosford-Wyong and Newcastle) lie within the study region. However, the identified relationship between average temperature and the threshold values can be used to extrapolate the results to other areas within the study region. The basic assumption made is that the heat stress threshold of a region or centre is related to the average temperature of that region or centre. As a result of this assumption, historic and projected changes in average temperature in the region are also included.

In addition to one day and three day EHEs, the yearly worst 3-day extreme heat event is also analysed. The yearly worst 3-day extreme heat event is used as a measure of the intensity of heat events (Deo, et al., 2007). This index is obtained by calculating 3-day moving averages from daily maximum temperature data from January 1970 to December 2007. The maximum 3-day moving average value for each year in the time series is then plotted. A linear trend line is then fitted to the data to ascertain whether an increase, decrease or no change in yearly worst 3-day extreme heat event is evident. Whereas the use of threshold values allows analysis of the frequency of EHEs, this measure provides an indication as to whether the intensity of extreme temperatures experienced are increasing or decreasing over time.

CASE STUDY METHODOLOGY

A two step methodological process has been adopted for the analysis of climate parameters completed for this case study. Firstly, key climate indices relevant to extreme heat events have been identified and changes in these indices are assessed using historic records obtained from the Bureau of Meteorology (BOM). Secondly, climate projections for the region obtained from the Global Climate Model (GCM) output for the A2 (high) emissions scenario, and a process called Statistical Downscaling (SD), have been utilised to assess likely impacts on the relevant key climate indices for the period from 2020-2080 A.D.

GCMs generate future climate scenarios and provide output for a range of key climate variables. The CSIRO Mk3.5 GCM and the A2 scenario have been determined as the most appropriate to identify projected changes in climate for the Hunter, Central and Lower North Coast region. Because of the coarse scale outputs generated by GCM's however, the additional process of SD has also been used to generate climate projections more relevant and applicable for regional scale analysis and management purposes. SD is a term given to techniques used to derive values for climate variables at a regional or sub-regional level from the coarse scale output of GCMs. Specifically, a weather typing approach to SD has been adopted for the research presented in this case study. In summary, this process has included:

1. Identifying the key synoptic types that drive climate variability in the region.

2. Identifying the relationships between these STs and BOM historic records for key climate variables.

3. Using the GCM to identify projected changes in the frequency of occurrence of these key STs based on sea level pressure (SLP) output data generated by the GCM.

4. Combining our understanding of how the region's weather is impacted by these key STs with projected changes in their frequency to project likely changes in key climate variables across the region.

A more detailed description of the methodology is included in the report *Climatic Change Impact for the Hunter, Lower North Coast and Central Coast Region of NSW* (Blackmore & Goodwin 2009). The key benefit of this approach is that it provides a richer understanding of the "drivers" of weather patterns within the region and how these drivers are likely to change in the future.

The climate change projections are reported in terms of three climate zones derived for the (HCLNC) region (Blackmore & Goodwin 2008) (Figure 3).

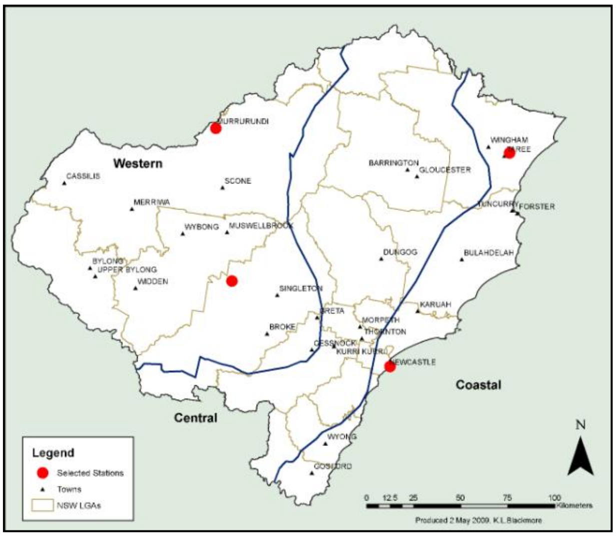

Figure 3 - Study region comprising coastal, central and western climate zones.

HISTORICAL CLIMATE VARIABILITY AND TRENDS

EXTREME HEAT EVENTS >= 37^{o} THRESHOLD

In the coastal zone, a slight decreasing trend (non significant) in days per year with maximum temperature greater than or equal to 37^{o}C over the period from 1970-2007 is evident at Newcastle (Figure 4). An increasing linear trend is evident at Taree. This increase is statistically significant. On average, Taree records between 3 and 4 days per annum with temperatures greater than or equal to 37^{o}C. Over the period from 1970 to 2007, an increase of approximately 3.3 days in total is evident.

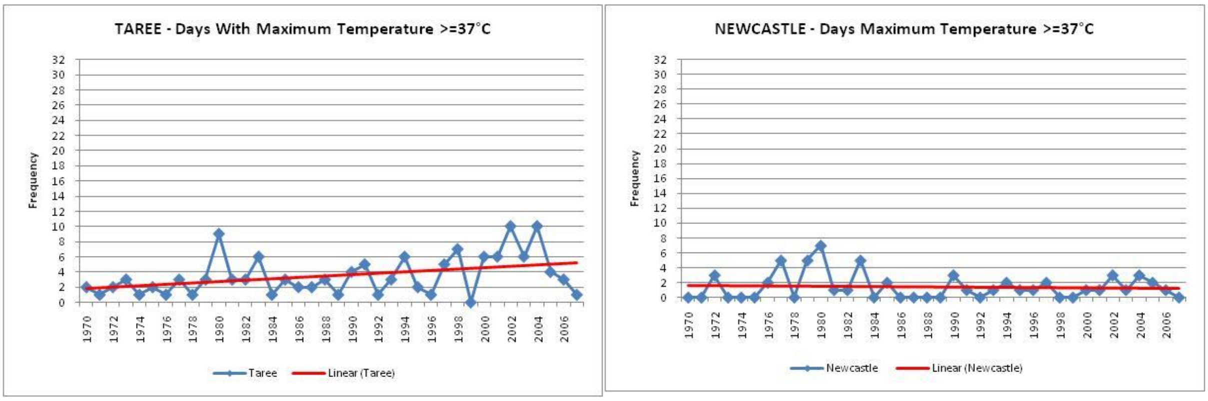

Figure 4 - Annual trend in extreme heat days at Taree and Newcastle

In the central zone, an increasing linear trend in days per year with maximum temperature greater than or equal to 37^{o}C over the period from 1970-2007 is evident at Lostock Dam and Paterson (Figure 5). On average, Lostock Dam and Paterson record 7 to 8 and 5 to 6 days per annum with temperatures greater than or equal to 37^{o}C respectively.

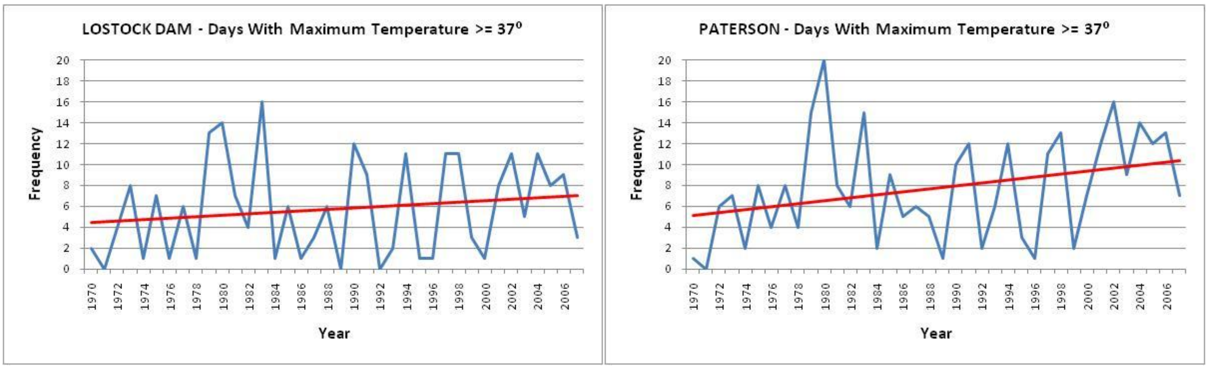

Figure 5 - Annual trend in extreme heat days at Lostock Dam and Paterson

In the western zone, an increasing linear trend in days per year with maximum temperature greater than or equal to 37^{o}C is evident at both Murrurundi and Jerry's Plains (Figure 6 over page). The increase recorded at Murrurundi is statistically significant. On average, Murrurundi records between 2 and 3 days per annum with temperatures greater than or equal to 37^{o}C. Over the period from 1970 to 2007, an increase of approximately 2.5 days in total is evident.

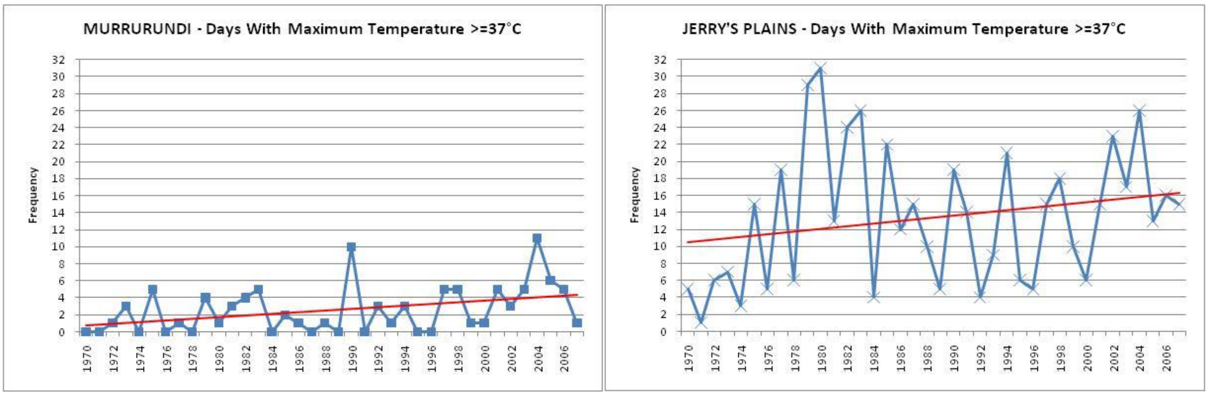

Figure 6 - Annual trend in extreme heat days at Murrurundi and Jerry's Plains

EXTREME HEAT EVENTS USING RELATIVE THRESHOLDS

The threshold values and relationships between extrapolated heat stress temperature thresholds for Taree, Murrurundi, Newcastle[2] , Jerrys Plains, Paterson and Lostock Dam and the average maximum summer and spring temperatures are shown in Table 3 below and Figure 7 over page. These calculated threshold values for each station are used to analyse trends in the frequency of occurrence of EHEs at each station location.

BOM Station	1Day Threshold	3Day Threshold	Summer Average	Spring Average	Spring/Summer Average
Taree	38.72	36.58	29.02	25.02	27.02
Murrurundi	38.03	35.89	29.37	23.19	26.28
Newcastle	35.27	33.13	24.92	21.70	23.31
Jerrys Plains	39.80	37.66	30.86	25.53	28.19
Paterson	38.44	36.30	29.17	24.50	26.83
Lostock Dam	37.97	35.83	28.81	24.01	26.41

Table 3 - 1 day and 3 day maximum temperature thresholds for Taree, Murrurundi, Newcastle, Jerrys Plains, Paterson and Lostock Dam

[2] Historical analysis at Newcastle is conducted using data from the Nobby's Head BOM station as this station has a significantly longer length of record than the Newcastle station located at the University of Newcastle. Due to temperature differences between these locations, an extrapolated value is used for Newcastle.

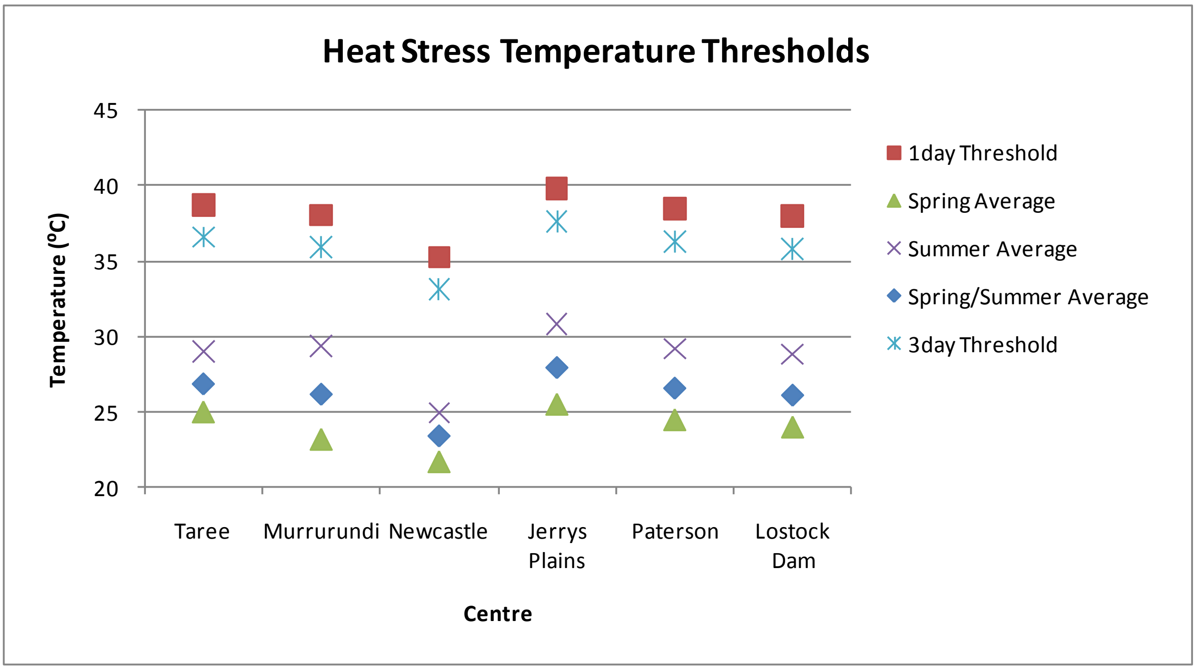

Figure 7 – Extrapolated heat stress temperature thresholds for Taree, Newcastle, Jerrys Plains and Murrurundi

Analysis of trends in the frequency of occurrence of days per annum greater or equal to the defined 1 day and 3 day threshold values for each of the stations reveals some interesting patterns (Figure 8 over page). EHEs occur more frequently in Murrurundi, Jerrys Plains, Paterson and Lostock Dam relative to the interpolated heat stress thresholds for these locations (i.e. the number of days exceeding the threshold temperature is relatively greater in these locations). Referring back to Figure 7, these four stations exhibit the largest range between spring and summer average maximum temperatures.

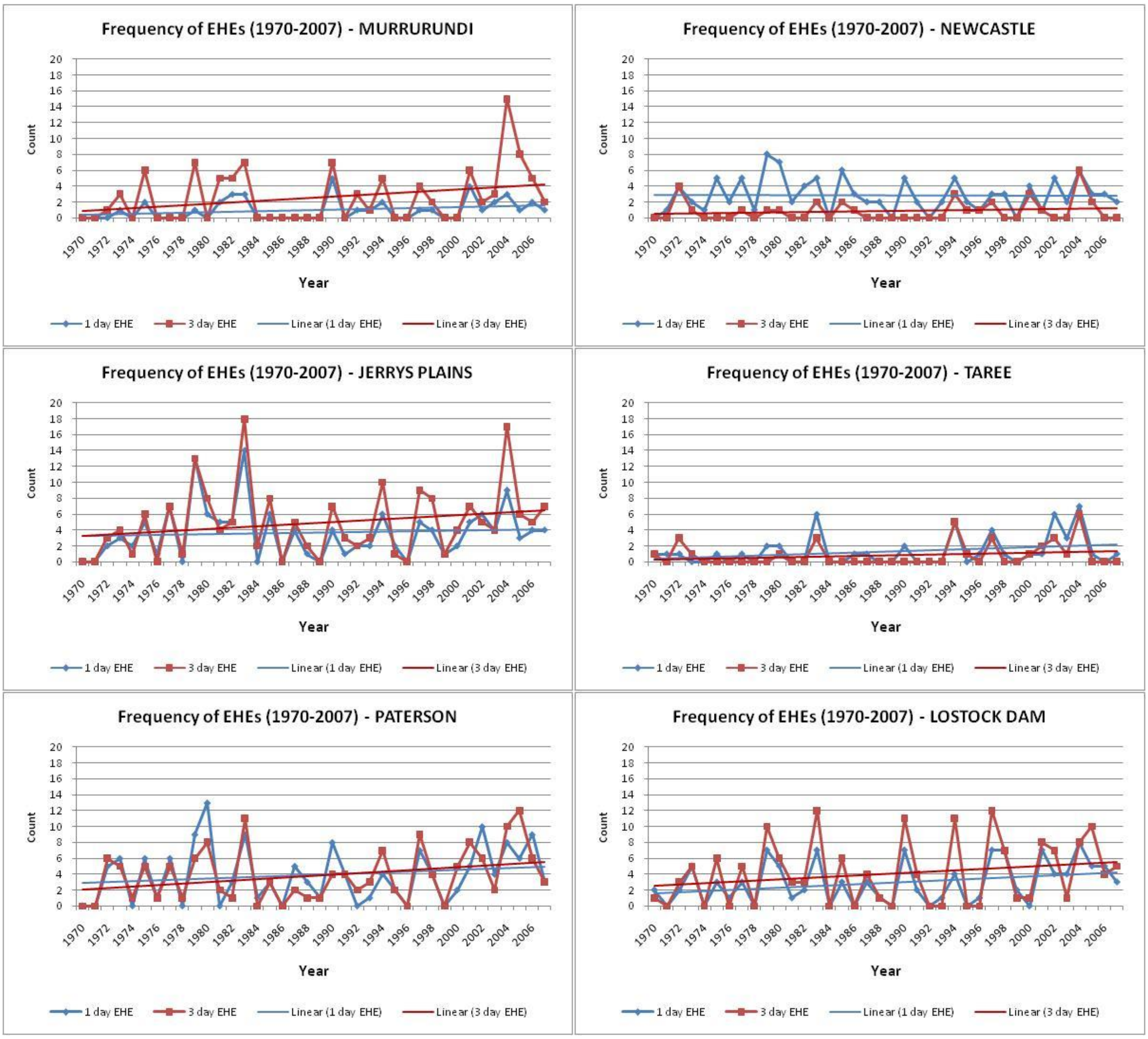

Figure 8 - Frequency of EHEs (1970-2007)

All stations analysed show a slight increasing trend in the frequency of occurrence of 1day EHEs. These increases are only in the order of approximately 1-3 additional days in total over the period from 1970-2007 and no trends are statistically significant at the 5% level (i.e. $P>0.05$). Similarly, slight increases in the frequency of occurrence of 3day EHEs are also evident at all stations other than Newcastle. As with 1day events, none of these trends are statistically significant.

YEARLY WORST 3-DAY EXTREME HEAT EVENT

The yearly worst 3-day EHE is used as a measure of the intensity of heat events (Deo et al, 2007). The recorded temperature of each year's worst 3-day EHE for each station for the period from 1970 to 2007 is shown in Figure 9. All stations show positive linear trends; stations in the west and central climate zones of the region show the strongest increases; 2.2^{o}C at Jerrys Plains and 1.75^{o}C at Murrurundi in the western zone;

1.8^{o}C at Lostock Dam and 1.1^{o}C at Paterson in the central zone; and an increase of 1^{o}C at Taree and 0.7^{o}C at Newcastle in the coastal zone. The trends in yearly worst 3-Day EHEs in both Jerrys Plains and Murrurundi are statistically significant at the 5% level (i.e. $P<0.05$).

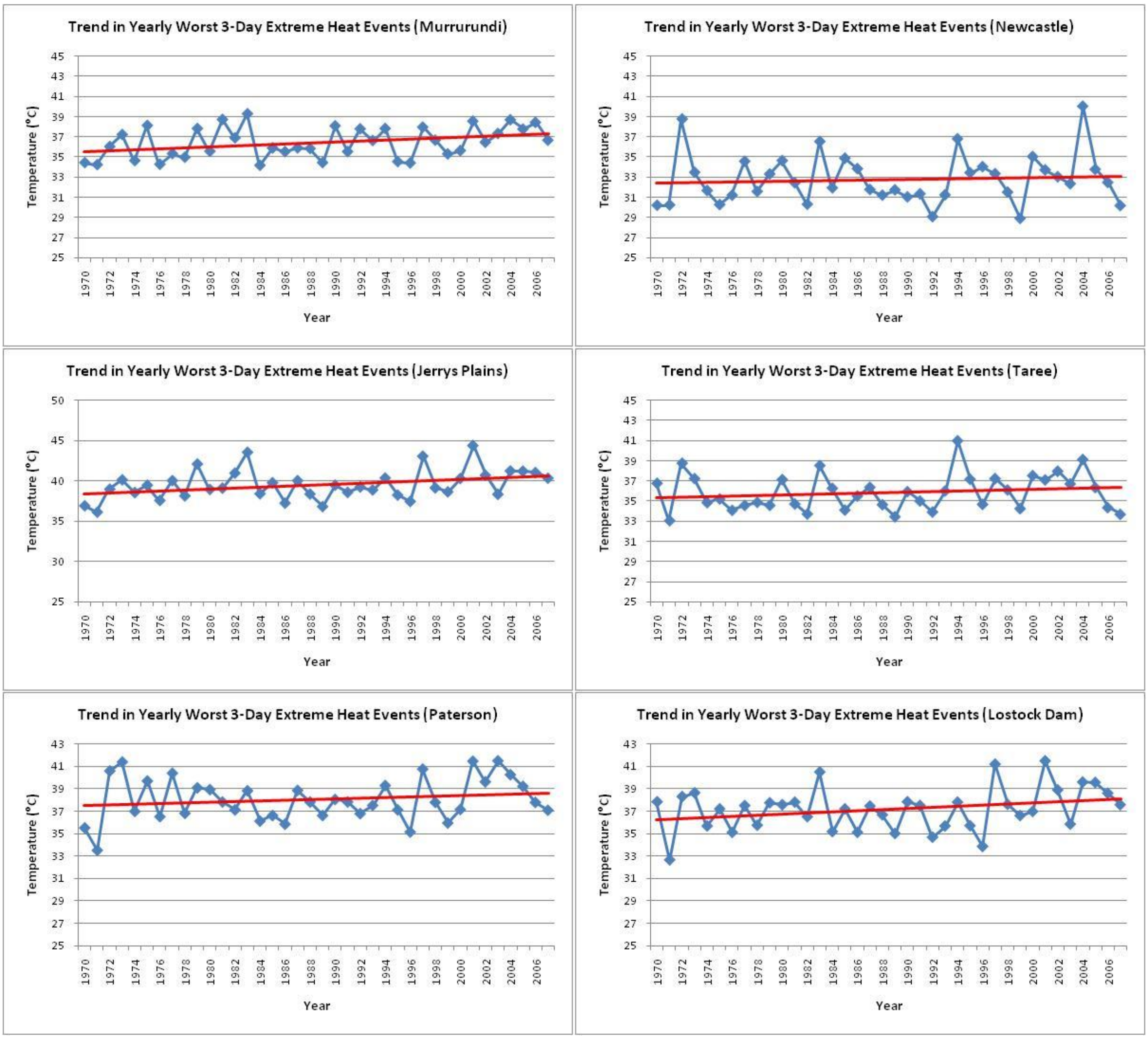

Figure 9 - Trend in yearly worst 3-day extreme heat events (1970-2007)

AVERAGE TEMPERATURE

The annual average temperature is calculated by adding the recorded average monthly maximum and minimum temperatures and dividing by two (i.e. (average monthly maximum temperature + average monthly minimum temperature) / 2). The recorded annual average temperature for the coastal zone from 1970 to 2007 is 18.2^{o}C. Over the period from 1970 to 2007, an increasing linear trend in annual average temperature in the coastal zone is evident (Figure 10). This trend is statistically significant and equivalent to an increase of approximately 0.9^{o}C over this entire period.

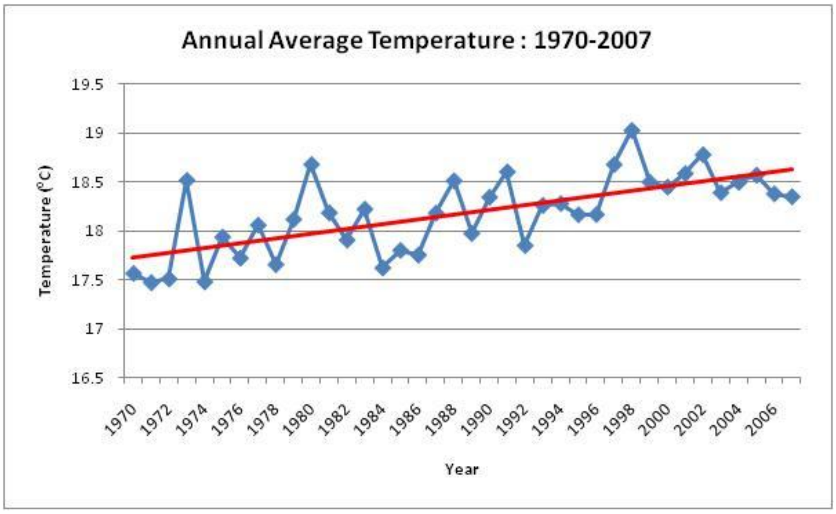

Figure 10 – Trend in annual average temperature for the 1970-2007 epoch in the coastal zone

During summer, temperatures average 22.8^{o}C in the coastal zone, decreasing to 19.2^{o}C during autumn and 13.2^{o}C during winter. Spring temperatures average 18.6^{o}C. Average temperatures show increases in all seasons over the period from 1970-2007 in line with the annual trend (Figure 11). The seasonal increases occurring in autumn (~0.7^{o}C), winter (~1.0^{o}C) and spring (~1.2^{o}C) are statistically significant.

Coastal Zone

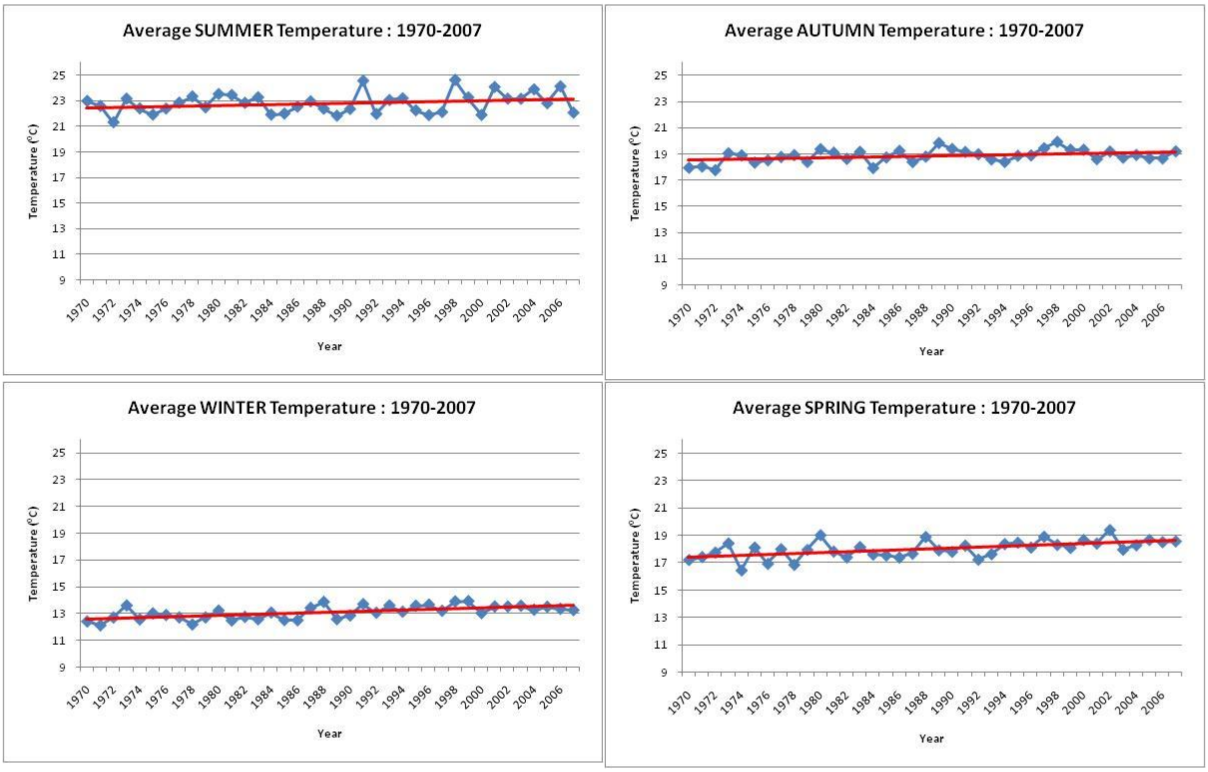

Figure 11 - Seasonal average temperature trends 1970-2007 in the coastal zone

The recorded annual average temperature for the central zone from 1970 to 2007 is 17.8°C. Over the period from 1970 to 2007, an increasing linear trend in annual average temperature in the central zone is evident (Figure 12). This trend is statistically significant and equivalent to an increase of approximately 0.9°C over this entire period.

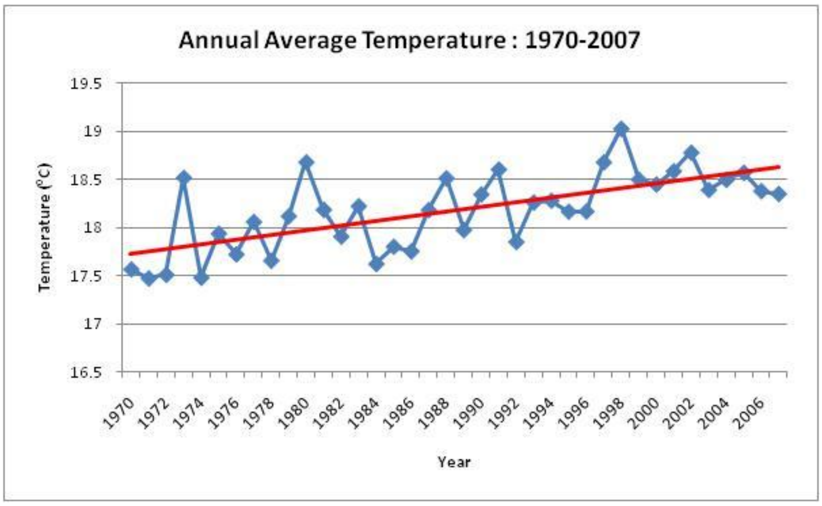

Figure 12 - Trend in annual average temperature for the 1970-2007 epoch in the central zone

During summer, temperatures average 23.0°C in the central zone, decreasing to 18.1°C during autumn and 12.3°C during winter. Spring temperatures average 17.9°C. Average temperatures show increases in all seasons over the period from 1970-2007 in line with the annual trend (Figure 13 over page). The seasonal increases occurring in winter (~0.8°C) and spring (~1.3°C) are statistically significant.

Central Zone

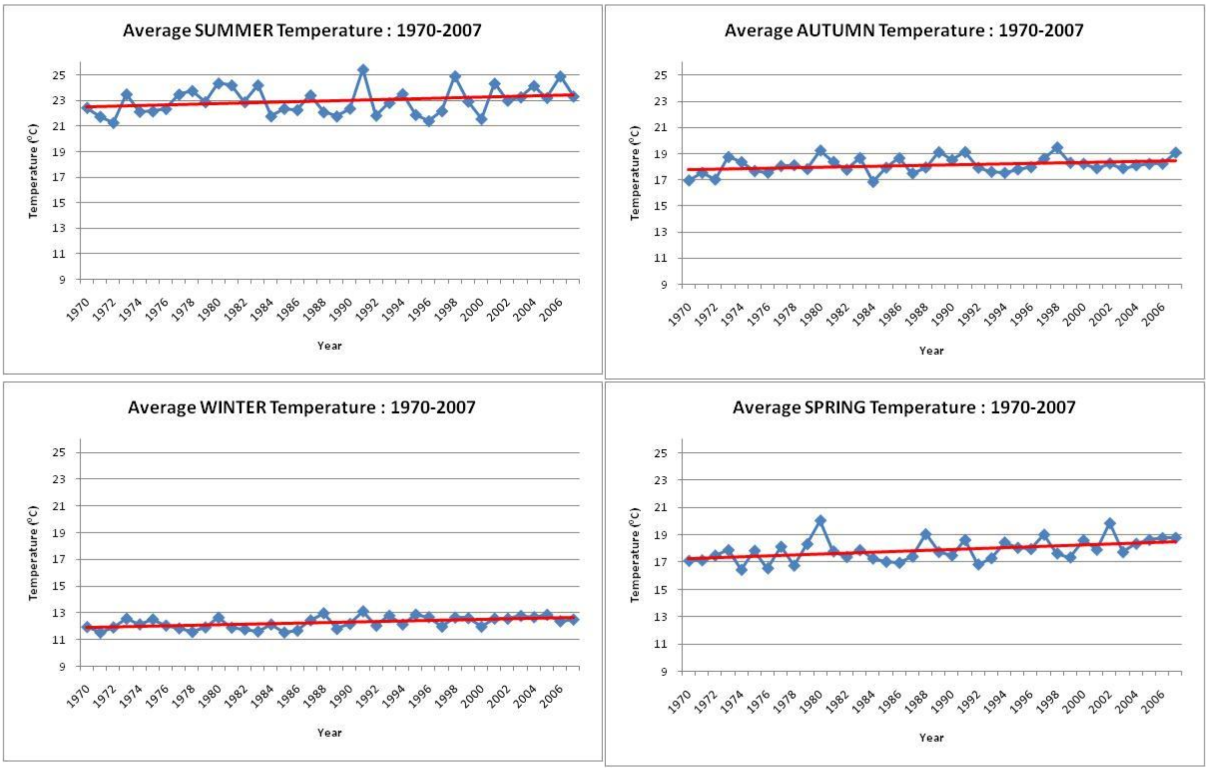

Figure 13 - Seasonal average temperature trends 1970-2007 in the central zone

The recorded annual average temperature for the western zone from 1970 to 2007 is 17.0°C. Over the period from 1970 to 2007, an increasing linear trend in annual average temperature in the western zone is evident (Figure 14). This trend is statistically significant and equivalent to an increase of approximately 0.6°C over this entire period.

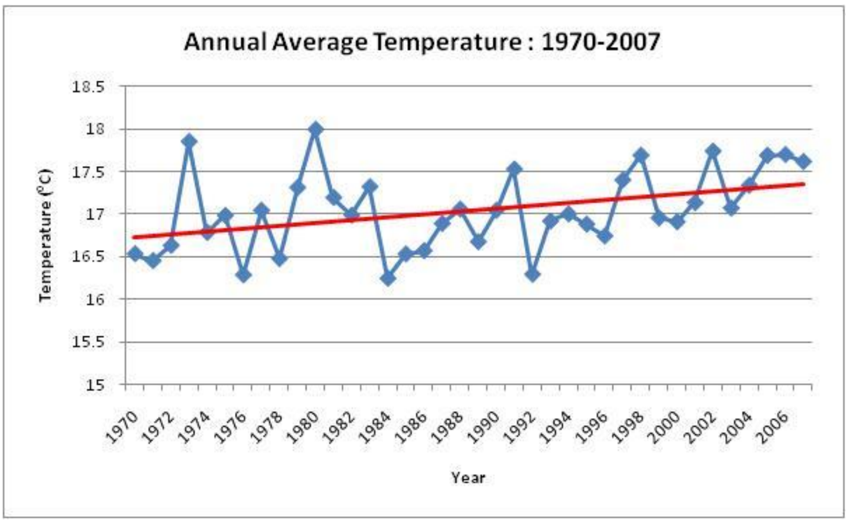

Figure 14 - Trend in annual average temperature for the 1970-2007 epoch in the western zone

During summer, temperatures average 23.1^{o}C in the western zone, decreasing to 17.3^{o}C during autumn and 10.7^{o}C during winter. Spring temperatures average 17.1^{o}C. Average temperatures show increases in all seasons over the period from 1970-2007 in line with the annual trend (Figure 15) however none of these seasonal trends are statistically significant.

Western Zone

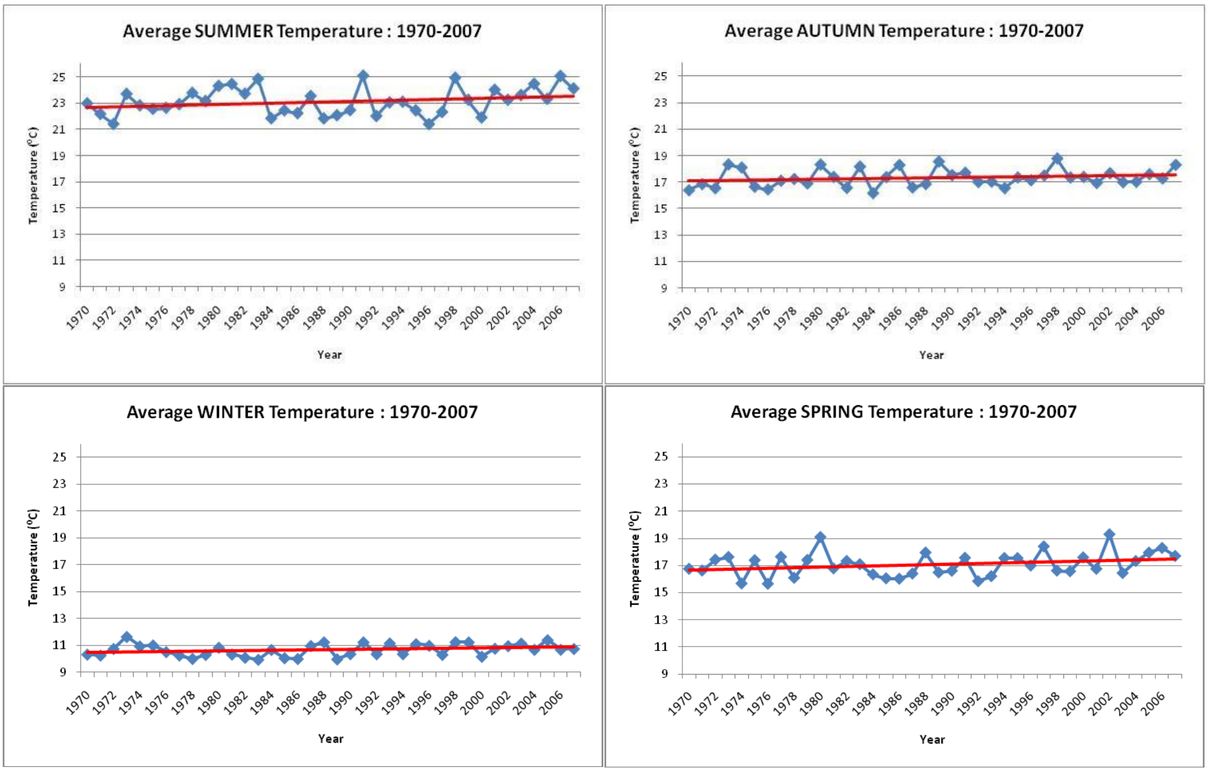

Figure 15 - Seasonal average temperature trends 1970-2007 in the western zone

PROJECTED CHANGES IN CLIMATE

MAXIMUM TEMPERATURE PROJECTIONS

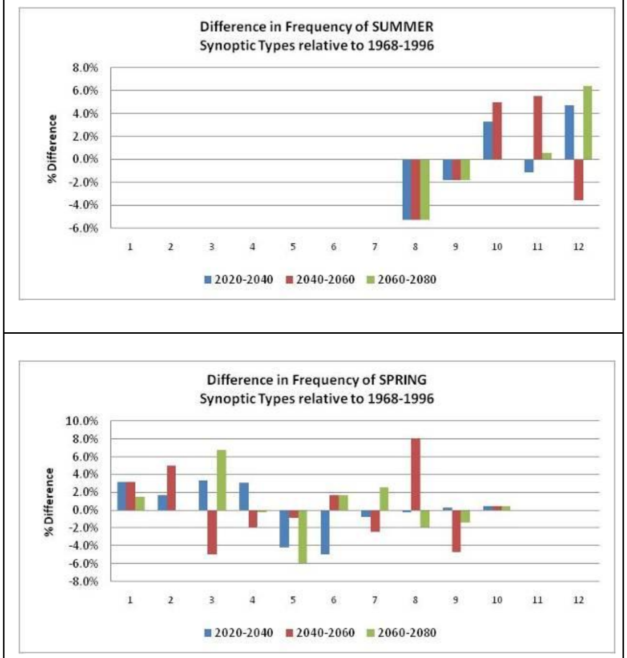

Figure 16 - Difference in frequency of summer and spring STs relative to 1968-1996

Projected changes in maximum temperature are derived by analysing the difference in frequency of STs for the projected period (2020-2080) relative to their frequency of occurrence during the period from 1968 to 1996 (Figure 16). The STs are each associated with a relative average maximum temperature while changes in ST frequency impact on the maximum temperatures experienced.

The most significant changes in average maximum temperatures are projected to occur during autumn and winter in the region. Projections (2020-2080) in the coastal and western zones for summer are for decreases in average maximum temperature of ~0.2^{o}C relative to the 1970-2007 period. No change for summer is projected in the central zone.

The study region is likely to experience lower spring average maximum temperatures with a decrease of ~0.7^{o}C projected for the coastal zone, and ~1.3^{o}C in the central and western zones.

EXTREME HEAT DAY PROJECTIONS

Following a similar methodology, a clear relationship between ST12 and EHEs exists in all zones (Figure 17 over page). This relationship is strongest in the west of the region (Murrurundi) where ~78% of all one day EHEs and ~77% of three day EHEs (average temperature for three consecutive days) occur when ST12 is the dominant monthly type.

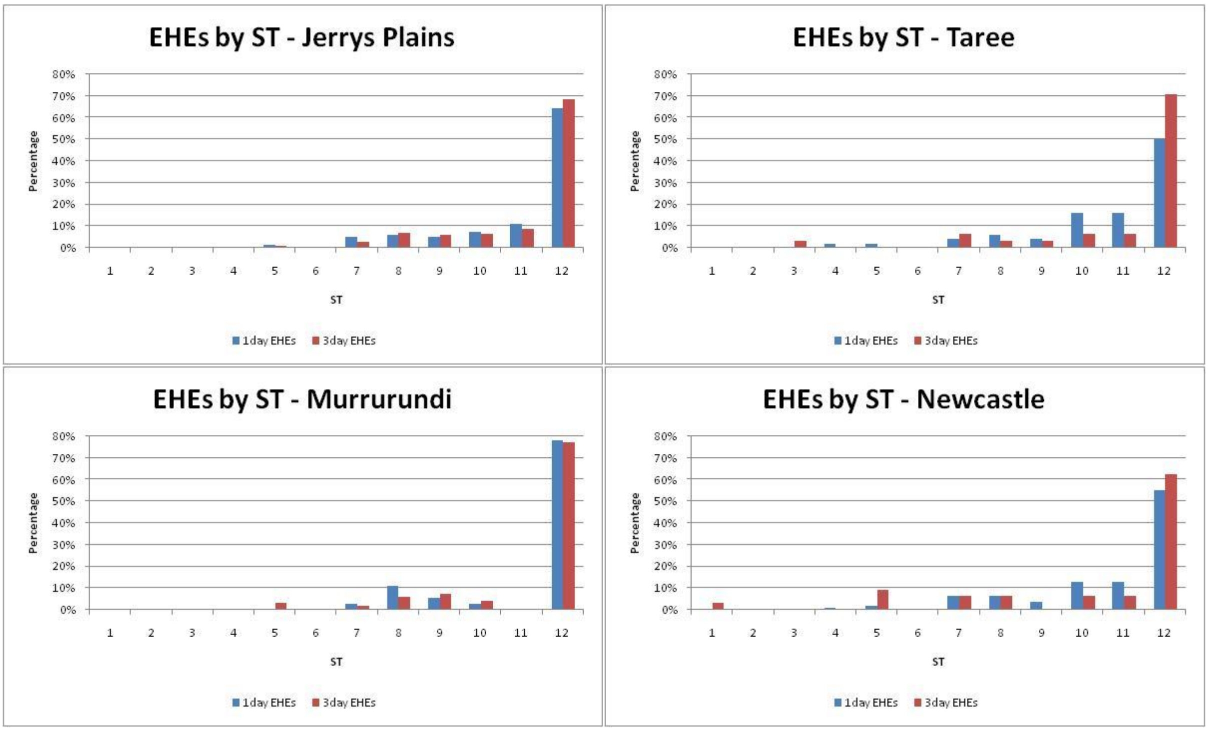

Figure 17 - Frequency of 1day and 3day extreme heat events by ST for Murrurundi, Newcastle, Jerrys Plains and Taree

Projected increases in the frequency of occurrence of ST12 during summer are likely to result in an increased frequency of EHEs in the region during the period from 2020-2080. Specifically, an approximate 5% increase is xpected during the period from 2020-2040, followed by a decrease of approximately 4% during 2040-2060 and an approximate 6% increase from 2060-2080. Overall, an increase of approximately 7% is projected however it should be noted that fewer EHEs are likely for the period from 2040-2060. ST12 does not occur during spring and thus no change to the frequency of EHEs during this season is obvious from the shifting synoptic patterns.

AVERAGE TEMPERATURE PROJECTIONS

Given that in this case study extreme heat thresholds have been related to average temperatures, changes in this parameter during summer and spring are also considered. Generally, a decrease in average temperature during these seasons is projected for the region. Projections (2020-2080) in the coastal, central and western zones for summer are for decreases in average temperature of ~0.5°C relative to the 1970-2007 period. The study region is likely to experience lower spring average temperatures with a decrease of ~0.4°C projected for the coastal zone, and ~0.8-0.9°C in the central and western zones. These decreases arise from a projected decrease in average minimum temperatures in these seasons greater than projected increases in average maximum temperatures.

RISK ASSESSMENT PROCESS AND OUTCOMES

In addition to providing an analysis of historic and projected climate change as it relates to extreme heat events in the Hunter, Central and Lower North Coast region of NSW, this Case Study also aims to demonstrate the applicability of this climate data to risk assessment and adaptation planning processes. For this purpose, a broad scale risk assessment process has been completed collaboratively by HCCREMS and representatives from the NSW Department of Health.

The Risk Assessment Framework used as the basis for this process is shown in the following figure. This has been sourced from `*Climate Change Impacts and Risk Management: A Guide for Business & Government, Commonwealth of Australia 2006'*. A summary of the outcomes of the risk assessment process are included in Table 4 on the following page. The complete risk analysis matrix identifying all of the climate data that informed the risk assessment process, the potential risks identified and their rating, and the potential adaptation strategies for managing these are also included in Attachment 1. Guidelines for the determination of liklihood and consequence scales are included in Appendix 2.

	Consequences				
Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Low	Medium	Medium	High	High
Unlikely	Low	Low	Medium	Medium	Medium
Rare	Low	Low	Low	Low	Medium

Figure 18 - Risk Assessment Matrix (source: Commonwealth of Australia 2006. Climate Change Impacts and Risk Management: A Guide for Business & Government).

NB. In determining the Consequence Rating, it has been assumed that no current management practices are in place.

The interpretation of the risk priority levels is usually as follows:

Extreme risks demand urgent attention at the most senior level and cannot be simply accepted as a part of routine operations without executive sanction.

High risks are the most severe that can be accepted as a part of routine operations without executive sanction but they will be the responsibility of the most senior operational management and reported upon at the executive level.

Medium risks can be expected to form part of routine operations but they will be explicitly assigned to relevant managers for action, maintained under review and reported upon at senior management level.

Low risks will be maintained under review but it is expected that existing controls will be sufficient and no further action will be required to treat them unless they become more severe.

Table 4 - Summary of risks and potential adaptation strategies

NATURE OF RISK	RISK RATING	POTENTIAL ADAPTATION RESPONSES
PRIMARY IMPACTS		

Heat related morbidity and mortality (heat related injuries, dehydration & other disorders of fluid, electrolyte and acid base balance. Examples include heat fatigue, heat cramps, heat syncope, heat exhaustion & heat stroke)
Particularly vulnerable sections of the community include:
• Older people, including those over 65 and particularly those over 75;
• Those with a chronic medical condition or disability, particularly obesity, reduced cardiovascular capacity & asthma;
• Those on certain types of medication, especially cardiac and psychiatric related;
• People living alone or socially isolated (eg elderly, mentally ill, disabled and homeless);
• Children, due to their immature thermoregulatory responses; and
• Outdoor workers with high exposure to extreme heat events.
	Extreme	• Development and implementation of Heat Management Plans. Plans of this nature are appropriate at a number of scales including state, regional, and local government levels as well as individual event (eg concerts or festivals) and personal health care levels.
		• The implementation of Heat Management Plans at Local Government Area scales and below are considered most effective for engaging communities and high risk groups. Heat Management Plans should incorporate:
		    • agreement on lead agency and participating organisations
		    • a consistent, standardised warning system
		    • public education, communication and involvement (particularly during Spring and immediately prior / during extreme heat events (Mella et al, 2008))
		    • targeting high risk assets, regions, communities and individuals
		    • evaluation and revision of program
		    • monitoring of climate & health trends and making adaptations.
		• Integration of Extreme Heat Events into organisational Disaster Management Plans. A heatwave meets the first part of the definition of an emergency by Emergency Management Australia – *an emergency is an event, actual or imminent, which endangers or threatens to endanger life, property or the environment, and which requires a significant co-ordinated response as appropriate* (Mella et al, 2008).
		• Improved interventions to increase coverage and support for socially isolated older people in the community. This could include changes to social services delivery or promoting a culture of `looking out' for your Neighbour, older friend or family member during a heatwave (Mella et al, 2008)
		• Development and implementation of heat management plans at individual events (eg concerts, festivals)
		• Building Design – external shading, insulation, natural ventilation through windows or vents (Mella et al, 2008)
		• Greening the Built Environment – trees, plants and green spaces act as natural air conditioners & provide shade (Mella et al, 2008).

SECONDARY IMPACTS		
Increase in production of photochemical smog and particulate pollution from bushfires	Extreme	• Increase emergency preparedness and resourcing during heat wave conditions (eg ambulance services & hospital emergency departments) • Targeted education strategies for asthma sufferers on strategies for

NATURE OF RISK	RISK RATING	POTENTIAL ADAPTATION RESPONSES
		reducing exposure to pollution during extreme heat conditions.
Reduced access to emergency services and facilities	Extreme	• Increase emergency preparedness and resourcing during heat wave conditions (eg ambulance services & hospital emergency departments) • Increased community education and awareness of appropriate strategies for reducing exposure to extreme heat. This in turn will reduce pressure on emergency services during extreme heat conditions.
Injury, trauma and related effects as a result of violence & trauma	Extreme	• Increase emergency preparedness and resourcing during heat wave conditions (eg police and ambulance services and hospital emergency departments) • Increased community education campaigns to reduce factors contributing to domestic violence and injury during heat wave conditions (eg excessive alcohol consumption).
Disruptions to essential services (eg electricity & water supplies)	High	• Electricity and water providers to increase emergency preparedness during heat wave conditions to ensure continuity of power supply. • Encourage independent power and water supplies in households to reduce reliance on centralized power and water supplies
Reduced access to transport services	High	• Increase emergency preparedness during heat wave conditions for public transport services, including provision of alternative transport options for commuters where disruptions occur. • Ensure public transport facilities reduce community exposure to extreme heat conditions (eg air-conditioned trains and buses, cool / shaded waiting areas).

CONCLUSION

This case study provides an analysis of historic and projected changes in key temperature variables and extreme heat related indices to improve understanding of the potential impacts of climate change on community health (heat impacts) in the Hunter, Central and Lower North Coast region of NSW.

This analysis has identified that:

- With the exception of Newcastle, the frequency of extreme heat days ≥ 37°C over the period 1970-2007 has been increasing at each of the climate stations analysed across the region's three climate zones. These increases have been statistically significant at Taree and Murrurundi; and
- Statistically significant increasing trends in yearly worst 3-day heat events have been identified at Jerrys Plains (2.2°C) and at Murrurundi (1.75°C) over the 1970-2007 period (ie extreme events in the region are also becoming hotter).

Projected changes in extreme heat events that pose a potentially increased risk to community health include:

- An overall increase in the frequency of extreme heat events at the current threshold levels are expected during the period from 2020-2080 across the region.
- Projected decreases in average maximum temperature during summer and spring are likely to lower extreme heat event threshold levels. Based on the calculations used to extrapolate the threshold values in this case study, a 0.2°C decrease is projected for Taree, a 0.5°C decrease in Murrurundi and Newcastle, and a 0.4°C decrease in Jerrys Plains.
- The lowering of threshold levels combined with projected increases in extreme heat events at current threshold levels is likely to increase the *frequency of occurrence* of extreme heat events beyond known variability.
- Projected decreases in average maximum temperature during summer and spring are likely to have minimal impact on reducing the intensity of yearly worst 3-day heat events. Combined with an historic increasing trend, projections suggest that increases in the intensity of these events is likely to continue.

The analysis has also underpinned a broad scale risk assessment process completed with the assistance of NSW Department of Health representatives. This has identified and ranked the potential risks to human health arising from projected changes in extreme heat events across the region. Of particular note is the fact that all risks identified were rated as either extreme or high. This clearly indicates the significance that an increase in extreme heat events represents as a community health issue in the region. These risks include:

- Heat related morbidity and mortality (heat related injuries, dehydration & other disorders of fluid, electrolyte and acid base balance. Examples include heat fatigue, heat cramps, heat syncope, heat exhaustion & heat stroke)
- Increase in production of photochemical smog and particulate pollution from bushfires
- Reduced access to emergency services and facilities
- Injury, trauma and related effects as a result of violence & trauma
- Disruptions to essential services (eg electricity & water supplies)
- Reduced access to transport services

A full description of all of the risks identified and potential adaptation strategies for dealing with these are included in Table 4 and Appendix 1 of this report.

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APPENDIX 1 – RISK ASSESSMENT MATRIX

TABLE 1 – CLIMATE CHANGE RISK ASSESSMENT OUTCOMES – HUMAN HEALTH (EXTREME HEAT)						
Historic and Projected Change in Climate	**Potential Impact**	**Risk Assessment**			**Nature of Consequences**	**Potential Adaptation Strategies**
		Likelihood of Increase	**Consequences**	**Risk Priority**		
1. Days with temperature greater than or equal to 37°C Historic Coastal Climate Zone (1970-2007) • slight decreasing trend (non significant) in no. days per annum • increasing (statistically significant) trend in no. days pa at Taree. On average, Taree records between 3 and 4 days per annum ≥37°C. Central Climate Zone (1970 – 2007) • increasing linear trend in days per year at Lostock Dam and Paterson On average, Lostock Dam and Paterson respectively record 7 to 8 and 5 to 6 days per annum ≥to 37°C. Western Climate Zone (1970-2007) • increasing linear trend in days per annum at Murrurundi (statistically significant) and Jerry's Plains. • on average, Murrurundi records between 2 and 3 days per annum From 1970 to 2007, an increase of approximately 2.5 days in total is evident. Projected Change • ~ 5% increase expected during summer (2020-2040), followed by a decrease of ~4% during 2040-2060 and a ~ 6% increase from 2060-2080. • overall increase of approximately 7% (2020-2080) but fewer likely during 2040-2060. • no change to the frequency of extreme heat days during spring. **2. Yearly worst 3 day heat events (EHE's)** **Historic** • statistically significant increasing trends in yearly worst 3-day heat events. Historically significant increases of 2.2°C at Jerrys Plains and 1.75°C at Murrurundi **Projected Change** • increasing trend to continue due to an increase in extreme heat days (i.e. the extremes are getting hotter as well as more frequent). • overall increase in the frequency of EHEs at the current threshold levels expected during 2020-2080. This includes an overall increase	**PRIMARY IMPACTS**					

	Heat related morbidity and mortality (heat related injuries, dehydration & other disorders of fluid, electrolyte and acid base balance). Examples include heat fatigue, heat cramps, heat syncope, heat exhaustion & heat stroke.	Almost Certain	Catastrophic (due to potential loss of life)	Extreme	Vulnerable Groups
					High risk groups include:
					• Children, due to their immature thermoregulatory responses;
					• Older people, including those over 65 and particularly those over 75;
					• Those with a chronic medical condition or disability, particularly obesity, reduced cardiovascular capacity & asthma;
					• Those on certain types of medication, especially cardiac and psychiatric related;
					• People living alone or socially isolated (eg elderly, mentally ill, disabled and homeless); &
					• pregnant women.
					
					Occupational Exposure
					High risk groups include:
					• manual labourers;
					• farming and industry workers; &
					• people engaged in active sport and exercise.
						• Development and implementation of Heat Management Plans. Plans of this nature are appropriate at a number of scales including state, regional, and local government levels as well as individual event (eg concerts or festivals) and personal health care levels.
						• The implementation of Heat Management Plans at Local Government Area scales and below are considered most effective for engaging communities and high risk groups. Heat Management Plans should incorporate:
						  • agreement on lead agency and participating organisations
						  • a consistent, standardised warning system
						  • public education, communication and involvement (particularly during Spring and immediately prior / during extreme heat events (Mella et al, 2008))
						  • targeting high risk assets, regions, communities and individuals
						  • evaluation and revision of program
						  • monitoring of climate & health trends and making adaptations.
						• Integration of Extreme Heat Events into organisational Disaster Management Plans. A heatwave meets the first part of the definition of an emergency by Emergency Management Australia – *an emergency is an event, actual or imminent, which endangers or threatens to endanger life, property or teh environment, and which requires a significant co-ordinated response as appropriate* (Mella et al, 2008).
						• Improved interventions to increase coverage and support for socially isolated older people in the community. This could include changes to social services delivery or promoting a culture of `looking out for your Neighbour, older friend or family member during a heatwave (Mella et al, 2008)
						• Development and implementation of heat management plans at individual event (eg concerts, festivals) Building Design – external shading, insulation, natural ventilation through windows or vents (Mella et al, 2008)
						• Greening the Built Environment – trees, plants and green spaces act as natural air conditioners & provide shade (Mella et al, 2008).

	SECONDARY IMPACTS					
	Increase in production of photochemical smog and particulate pollution from bushfires	Likely	Catastrophic (due to potential loss of life)	Extreme	Increase in asthma and asthma related illness and death	• Increase emergency preparedness and resourcing during heat wave conditions (eg ambulance services & hospital emergency departments) • Targeted education strategies for asthma sufferers on strategies for reducing exposure to pollution during extreme heat conditions.
	Disruptions to essential services (eg electricity & water supplies)	Likely	Major	High	• Power outages impacting on people's ability to run cooling devices (eg air conditioners and	• Electricity and water providers to increase emergency preparedness during heat wave conditions to ensure continuity of power supply.

TABLE 1 – CLIMATE CHANGE RISK ASSESSMENT OUTCOMES – HUMAN HEALTH (EXTREME HEAT)						
Historic and Projected Change in Climate	Potential Impact	Risk Assessment			Nature of Consequences	Potential Adaptation Strategies
		Likelihood of Increase	Consequences	Risk Priority		

of approximately 7% during summer with no change projected for spring.
• Given projected lowering of threshold values together with projected increases in EHEs at current threshold levels, an increase in the frequency of occurrence of EHEs beyond currently experienced variability is likely
 	
3. Average Maximum Temperature
<u>Historic</u>
• Statistically significant increasing trends during Autumn and Winter.
 	
<u>Projected Change</u>
• Decreases in the coastal and western zones for summer of ~0.2ºC.
• No change for summer projected in the central zone.
• Decreases during spring of ~0.7ºC for the coastal zone, and ~1.3ºC in the central and western zones.
• A decrease in average maximum temperature during summer and spring likely to result in lower community extreme heat event threshold levels during 2020-2080. Projected changes in thresholds include:
  • 0.2^{O}C decrease in Taree
  • 0.5^{O}C decrease in Murrurundi and Newcastle
  • 0.4^{O}C decrease in Jerrys Plains
					fans)
					• Power outages causing disruptions to water supply
						• Encourage independent power and water supplies in households to reduce reliance on centralized power and water supplies

	Reduced access to transport services	Possible	Major	High	Public transport disruptions (eg loss of train services due to power outages) reduces people's ability to reach cooler locations or health facilities	• Increase emergency preparedness during heat wave conditions for public transport services, including provision of alternative transport options for commuters where disruptions occur. • Ensure public transport facilities reduce community exposure to extreme heat conditions (eg air-conditioned trains and buses, cool / shaded waiting areas).
	Reduced access to emergency services and facilities	Almost Certain	Catastrophic (due to potential loss of life)	Extreme	Competition for emergency services has potential to overload emergency services leading to increased response times (eg ambulance call outs) and emergency room waiting times.	• Increase emergency preparedness and resourcing during heat wave conditions (eg ambulance services & hospital emergency departments) • Increased community education and awareness of appropriate strategies for reducing exposure to extreme heat. This in turn will reduce pressure on emergency services during extreme heat conditions.
	Injury, trauma and related effects as a result of violence & trauma	Almost Certain	Major	Extreme	Increase in domestic violence & injury	• Increase emergency preparedness and resourcing during heat wave conditions (eg police and ambulance services and hospital emergency departments) • Increased community education campaigns to reduce factors contributing to domestic violence and injury during heat wave conditions (eg excessive alcohol consumption).

APPENDIX 2 – GUIDELINES FOR ASSESSING LIKLIHOOD AND CONSEQUENCE SCALES

(Source: Commonwealth of Australia 2006. Climate Change Impacts and Risk Management: A Guide for Business & Government)

Likelihood Scales

It is necessary to describe the likelihood of a risk arising if a particular climate change scenario comes about. This is a conditional likelihood, to be assessed as if the climate change scenario was going to happen.

A five point scale can be effectively applied for likelihood ratings. The extreme ends of this scale are those risks that are almost certain to happen and those that are almost, but not quite, certain not to happen.

There is one potential source of confusion to be addressed concerning how often the same risk might occur. Some risks are most realistically thought of as events that could happen once, such as the loss of an endangered plant or animal species at the centre of a tourism business or a permanent move of population from increasingly arid land to regional centres and major cities.

Other risks make more sense when considered as recurring events such as structural damage to domestic buildings from severe storms or episodes of heat related deaths. A scale that can be used to rate the likelihood of both single and recurrent events is shown in Table 11 below.

Table 11: Likelihood (given that the climate scenario arises)

Rating	Recurrent risks	Single events
Almost certain	Could occur several times per year	More likely than not – Probability greater than 50%.
Likely	May arise about once per year	As likely as not – 50/50 chance.
Possible	May arise once in ten years	Less likely than not but still appreciable – Probability less than 50% but still quite high.
Unlikely	May arise once in ten years to 25 years	Unlikely but not negligible – Probability low but noticeably greater than zero.
Rare	Unlikely during the next 25 years	Negligible – Probability very small, close to zero.

Source: Commonwealth of Australia 2006. Climate Change Impacts and Risk Management: A Guide for Business & Government.

Consequence Ratings

To complete the risk assessment process it is also necessary to describe the level of consequence arising from the identified risks. This is usually achieved by defining a five point scale that describes levels of consequences ranging from:

- **catastrophic**, the level that would constitute a complete failure; to
- **insignificant**, a level that would attract no attention or resources.

Scales like those in Table 8 and 9 on the following pages are proven mechanisms for describing the consequences of risks. Note that they contain no firm numbers but use simple descriptions that are understood by the participants in the process. There may be occasions where numbers are appropriate, such as in describing levels of financial loss, but even here descriptions of how the organisation would react may be adequate: for example, Catastrophic may equate to closure of operations or replacement of the senior management team, Major to having to carry a financial burden over into future years, Moderate to having to curtail planned expenditure in the short to medium term and so on.

Table 8: Example – consequence scales for a local authority

Rating	SUCCESS CRITERIA				
	Public safety	Local economy & growth	Community & lifestyle	Environment & sustainability	Public administration
Catastrophic	Large numbers of serious injuries or loss of lives	Regional decline leading to widespread business failure, loss of employment and hardship	The region would be seen as very unattractive, moribund and unable to support its community	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage	Public administration would fall into decay and cease to be effective
Major	Isolated instances of serious injuries or loss of lives	Regional stagnation such that businesses are unable to thrive and employment does not keep pace with population growth	Severe and widespread decline in services and quality of life within the community	Severe loss of environmental amenity and a danger of continuing environmental damage	Public administration would struggle to remain effective and would be seen to be in danger of failing completely
Moderate	Small numbers of injuries	Significant general reduction in economic performance relative to current forecasts	General appreciable decline in services	Isolated but significant instances of environmental damage that might be reversed with intensive efforts	Public administration would be under severe pressure on several fronts
Minor	Serious near misses or minor injuries	Individually significant but isolated areas of reduction in economic performance relative to current forecasts	Isolated but noticeable examples of decline in services	Minor instances of environmental damage that could be reversed	Isolated instances of public administration being under severe pressure
Insignificant	Appearance of a threat but no actual harm	Minor shortfall relative to current forecasts	There would be minor areas in which the region was unable to maintain its current services	No environmental damage	There would be minor instances of public administration being under more than usual stress but it could be managed

Source: Commonwealth of Australia 2006. Climate Change Impacts and Risk Management: A Guide for Business & Government.

Table 9: Example - consequence scales for a public utility

Rating	SUCCESS CRITERIA				
	Service quality	Service delivery	Interaction with other providers	Administration	Community confidence
Catastrophic	Services would fall well below acceptable standards and this would be clear to all	Services would be incorrectly targeted, delivered late or not at all in a large number of cases	The organisation would be in conflict with other providers and this would directly affect services	Administration of the organisation would be seen to have failed and in need of external intervention	There would be widespread concern about our capacity to serve the community
Major	The general public would regard the organisation's services as unsatisfactory	There would be isolated instances of services being incorrectly targeted, delivered late or not delivered at all	The effort of managing relations with other providers would drain resources and badly degrade service delivery	Administration of the organisation would be seen to be deficient and in need of external review	There would be serious expressions of concern about our capacity to serve the community
Moderate	Services would be regarded as barely satisfactory by the general public and the organisation's personnel	There would be isolated but important instances of services being poorly targeted or delivered late	Unnecessary overheads arising from relations with other providers would be a drain on resources but the public would be unaware of this	Administrative failings might not be widely seen but they would cause concern if they came to light	There would be isolated expressions of concern about our capacity to serve the community
Minor	Services would be regarded as satisfactory by the general public but personnel would be aware of deficiencies	There would be isolated instances of service delivery failing to meet acceptable standards to a limited extent	Unnecessary overheads in dealing with other providers would absorb some effort but the public would be unaware of this and would not be affected	There would be some administrative shortcomings demanding attention but they would not be regarded as serious failures	There would be some concern about our capacity to serve the community but it would not be considered serious
Insignificant	Minor deficiencies in principle that would pass without comment	Minor technical shortcomings in service delivery would attract no attention	Minor unnecessary overheads arising from relations with other providers but no material effect	There would be minor areas of concern but they would not demand special attention	There would be minor concerns but they would attract no attention

Source: Commonwealth of Australia 2006. Climate Change Impacts and Risk Management: A Guide for Business & Government.

HCCREMS Member Councils

muswellbrook shire council

MAITLAND CITY COUNCIL

WYONG SHIRE COUNCIL

Great Lakes COUNCIL

CITY OF Lake Macquarie

GOSFORD CITY COUNCIL

DUNGOG SHIRE COUNCIL 1958

Greater Taree CITY COUNCIL

Port Stephens C·O·U·N·C·I·L ... a community partnership

Singleton COUNCIL For a better future...

Gloucester Shire Council

CESSNOCK CITY COUNCIL

The City of Newcastle

Upper Hunter Shire Council