

**School of Public Health**

**Health Impact Assessment of Climate Change in Rural Western  
Australia: The Blackwood Stirling Area 2030**

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**This thesis is presented for the Degree of  
Doctor of Philosophy  
of  
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## **Signed Statement of Original Work**

“This dissertation contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief this dissertation contains no material previously published by another person except where due acknowledgement has been made”.

*Signed:*

**Date: 16 August 2016**

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## **Abstract**

This study examined the vulnerability of rural and remote communities in Western Australia to climate change impacts in 2030. Climate change scenarios to 2030 identified likely changes to rainfall, temperature, extreme weather events and other direct and indirect impacts. The Blackwood Stirling is part of a geographic region within the lower South West of Australia that has high biodiversity values and is a food producing region of importance. Reduced annual rainfall and an increase in global mean surface temperature are considered likely and will impact all aspects of society. Early adaptation could protect human health and the economic basis of these communities. Adaptation strategies were identified to enhance safety and improve health in these communities.

The assessment described in this thesis is a research Health Impact Assessment (rHIA), using procedures, processes and methods as understood in the international literature. The rHIA investigates the potential impacts, likely risks, sensitivities, vulnerabilities and adaptation options relating to climate change hazards. Multiple data collection methods were used to ensure triangulation of data and consistency of data. Focus group meetings were conducted in 11 rural communities (n 48) utilising climate change scenarios to 2030 to provide perspectives of future sensitivity, vulnerability and likely impacts. Stakeholder interviews were conducted to determine existing adaptation policies, practices and barriers to adaptation in government and non-government agencies (n 19). An expert panel assessed the likelihood and consequences of potential health hazards through a qualitative health risk assessment method (n 9) and gained consensus that the likely health impacts to the study population would be a result of exposure to extreme weather events and air quality factors. Community participants (n 51) completed a survey that provided insights into annual adaptation priorities and expenditure for households and businesses. While this sample cannot be considered representative of the general population, the survey participants placed a high priority on future energy and water security.

Adaptation strategies for government and non-government agencies, industry, business and individuals were examined. The cost effectiveness of adaptation strategies determined priorities for expenditure. Soft adaptation methods have higher

cost effectiveness for communities and households and may be more likely to be adopted. There was agreement between community and expert participants and the scientific literature that infrastructure adaptation to 2030 should focus on potable water security. Community participants placed a high priority on preserving biodiversity, economic security, local public health and social services.

## Contents

Signed Statement of Original Work.....	ii
Acknowledgements .....	iii
Abstract .....	iv
Prologue .....	xix
Chapter One - Introduction .....	1
1.1    Introduction .....	1
1.2    Climate Change Definitions .....	1
1.3    Statement of the Problem - Overview .....	4
1.4    Project Background .....	7
1.5    Adaptation to Climate Change .....	10
1.6    Vulnerability to Climate Change and Adaptation .....	13
1.7    Rationale for this Study .....	15
1.8    Research Aims and Objectives .....	16
1.9    Overview of the Thesis.....	17
Chapter Two - Literature Review .....	19
2.0    Introduction to the Chapter.....	19
2.1    Climate Change and Human Health .....	19
2.2    Climate Change and Rural Health.....	20
2.2.1    Demographic and Lifestyle Factors .....	20
2.2.2    Geographic and Economic Factors .....	21
2.3    Vulnerability in a Rural Setting.....	23
2.4    Adaptation in a Rural Setting .....	24
2.5    Health Impact Assessment .....	25
2.6    Conclusion of the Chapter .....	31
Chapter 3 - Research Design and Methods .....	32
3.0    Introduction to the Chapter.....	32
3.1    rHIA Methodology .....	32
3.1.1    Data Collection Procedure .....	34
3.2    Focus Groups – Community Participants.....	36
3.2.1    Rationale .....	36
3.2.1    Method .....	37

3.3	Semi-Structured Interviews with Stakeholders .....	40
3.3.1	Rationale .....	40
3.3.1	Method .....	42
3.4	Expert Panel – Expert Participants .....	43
3.4.1	Rationale .....	43
3.4.1	Method .....	44
3.5	Adaptation Survey – Community Participants .....	47
3.5.1	Rationale .....	47
3.5.1	Method .....	49
3.6	Role of Researcher .....	52
3.7	Data Collection and Secondary Sources of Data.....	52
3.8	Data Analysis.....	53
3.9	Ethical Consent and Validity.....	54
3.10	Limitations to Research in Rural Communities .....	55
3.11	Summary of Chapter Three .....	57
Chapter 4 – Community and Climate Profiling .....		58
4.0	Introduction .....	58
4.1	Profiling Data – Demographic and Climate Factors.....	58
4.1.1	Population Changes to 2030 .....	58
4.1.2	Discussion of Changes to Population to 2030 .....	60
4.1.3	Socio Economic Index and Deprivation .....	60
4.1.4	Population Density .....	61
4.1.5	Hospital Admissions .....	62
4.2	Population Profile by Local Government Area.....	63
4.2.1	Shire of Augusta-Margaret River.....	64
4.2.2	Shire of Denmark .....	64
4.2.3	Shire of Boyup Brook .....	65
4.2.4	Shire of Bridgetown-Greenbushes .....	66
4.2.5	Shire of Cranbrook.....	67
4.2.6	Shire of Manjimup .....	68
4.2.7	Shire of Nannup .....	69
4.2.8	Shire of Plantagenet .....	70
4.3	Indigenous Population.....	71
4.4	Summary of Local Government Areas.....	72
4.5	Climate Profile.....	74

4.5.1	Rainfall.....	74
4.5.2	Temperature .....	77
4.5.3	Sea Surface Temperature and Sea Level Rise.....	81
4.5.4	Pan Evaporation .....	82
4.5.5	Extreme Weather.....	83
4.5.6	Flood .....	83
4.5.7	Drought .....	84
4.5.8	Fire .....	84
4.5.8.1	Summary of Climatic Conditions .....	85
4.6	Future Climate for the Study Area .....	86
4.6.1	Stabilisation of Atmospheric Carbon.....	86
4.6.1.1	OzClim Scenario Generator .....	87
4.6.2	Rainfall 2030.....	88
4.6.3	Heavy Rain Days & Drought.....	91
4.6.4	Temperature 2030 .....	91
4.6.5	Mean Temperature .....	92
4.6.6	Minimum Temperature .....	93
4.6.7	Maximum Temperatures and Heat Waves.....	93
4.6.8	Humidity .....	96
4.6.9	Hot Nights .....	97
4.6.10	Sea Surface Temperature .....	98
4.6.11	Sea Level Rise.....	99
4.6.12	Pan Evaporation .....	100
4.6.13	Extreme Weather Events.....	100
4.7	Summary of Future Climate Change.....	100
4.8	Summary of Chapter Four .....	101
Chapter Five - Data Analysis .....		102
5.0	Introduction .....	102
5.1	Focus Group Meeting Data .....	102
5.1.1	Question One – Observed Climate Change .....	102
5.1.2	Question Two – Climate Change and Lifestyle .....	103
5.1.3	Question Three – Benefits and Opportunities.....	104
5.1.4	Question Four – Observed Impacts from Climate Change .....	105
5.1.5	Question Five – Climate Change and Mental Health.....	106
5.1.6	Question Six – Methods to Increase Benefits/Reduce Negative Impacts .....	106

5.1.7	Question Seven – Potential Risks to Community .....	108
5.1.8	Question Eight – Greatest Source of Harm.....	110
5.1.9	Question Nine – Risks that can’t be Readily Managed .....	110
5.1.10	Question Ten – Vulnerable Community Members .....	111
5.1.11	Summary of Focus Group Data .....	111
5.2	Data Analysis for Stakeholder Interviews.....	118
5.2.1	Question One.....	118
5.2.2	Monitoring .....	119
5.2.3	Building Resilience .....	121
5.2.4	Forecasting .....	123
5.2.5	Drought Resistant Crops – Genetically Modified Organisms (GMOs)... .....	124
5.2.6	Product Design.....	125
5.2.7	Developing Policies and Steering Committees .....	125
5.2.8	Energy .....	126
5.3	Question Two .....	129
5.3.1	Extent of Adaptation in Practice .....	129
5.3.2	Barriers and Obstacles for Adaptation.....	132
5.3.3	Incentives for Adaptation.....	137
5.4	Question Three .....	137
5.5	Question Four .....	139
5.6	Summary of Results from Stakeholder Interviews.....	141
5.7	Expert Panel Delphi Method .....	142
5.7.1	Expert Panel List of Health Impacts .....	142
5.7.2	Expert Panel Risk Rating .....	143
5.7.3	Consensus of Risk Rating .....	144
5.8	Community Surveys .....	146
5.8.1	Online and Mail-out Survey Results .....	146
5.8.2	Geographic Spread.....	146
5.8.3	Income and Housing Type .....	147
5.8.4	Willingness to Pay – Personal Adaptation.....	148
5.8.5	Relocation Due to Risk of Fire or Flood.....	149
5.8.6	Household – Water Supply Adaptation .....	149
5.8.7	Household – Fire Protection System.....	150
5.8.8	Household – Emergency Preparation.....	151
5.8.9	Household - Retrofit Existing Homes .....	151

5.8.10	Household – Retrofit Existing Gardens .....	152
5.8.11	Farm or Smallholding Adaptations .....	153
5.8.12	Business Adaptations .....	153
5.8.13	Other Options for Adaptations in the Household and Private Businesses .....	153
5.8.14	Limitations to Adaptation .....	154
5.8.15	Ranking Adaptation Priorities.....	154
5.8.16	Allocation of Expenditure .....	155
5.8.17	Flood Protection .....	156
5.8.18	Insurance .....	156
5.8.19	Protection of Water Supplies .....	156
5.8.20	Emergency Infrastructure.....	156
5.8.21	Emergency Services .....	157
5.8.22	Recreation Facilities.....	157
5.8.23	Resilience to Energy Network .....	157
5.8.24	Natural Resource Protection .....	157
5.8.25	Assistance to Households and Business on Low Incomes.....	158
5.8.26	Other Adaptation Initiatives – Government.....	158
5.8.27	Other Adaptation Initiatives - Community .....	158
5.8.28	Voluntary Contributions – Once off Payment .....	159
5.8.29	Vulnerability .....	159
5.8.30	General Comments about the Survey.....	160
5.8.31	Summary of the Community Survey .....	160
5.9	Community Survey for Cranbrook and Greenbushes .....	160
5.9.1	Income and Housing Type .....	161
5.9.2	Willingness to Pay – Annual Adaptation.....	161
5.9.3	Relocation Due to Risk of Fire or Flood.....	162
5.9.4	Household - Water Supply Adaptation .....	163
5.9.5	Household – Fire Protection .....	163
5.9.6	Household – Emergency Preparation.....	163
5.9.7	Household – Retrofit Home .....	164
5.9.8	Household – Retrofit Garden .....	164
5.9.9	Adaptation – Farm or Smallholding.....	164
5.9.10	Adaptation – Business.....	164
5.9.11	Reasons for Lack of Adaptation.....	165
5.9.12	Expenditure Rankings (Priority) .....	165
5.9.13	Expenditure - Flood Protection .....	165

5.9.14	Expenditure - Insurance .....	165
5.9.15	Expenditure – Water Supply .....	166
5.9.16	Expenditure – Evacuation Centres .....	166
5.9.17	Expenditure – Emergency Services .....	166
5.9.18	Expenditure – Recreation Facilities .....	166
5.9.19	Expenditure – Energy Supplies.....	166
5.9.20	Expenditure - Health Staffing .....	167
5.9.21	Expenditure – Protection of Natural Resources.....	167
5.9.22	Expenditure – Household Assistance.....	167
5.9.23	Expenditure – Other Comments.....	167
5.9.24	Summary of Greenbushes and Cranbrook Surveys .....	167
5.10	Data Analysis Summary .....	168
5.11	Conclusion.....	170
Chapter Six - Risk Analysis & Mitigation .....		172
6.0	Introduction .....	172
6.1	Uncertainty and Action.....	173
6.2	Risk Assessment Process.....	173
6.3	Temperature and Air Quality Factors.....	175
6.3.1	Increasing Global Mean Temperature.....	176
6.3.2	UV Exposure and Air Toxics.....	178
6.3.3	Heat Disruption .....	180
6.3.4	Ocean Temperature .....	181
6.3.5	Summary of Temperature Related Impacts.....	182
6.3.6	Individual Adaptation.....	183
6.3.7	Community Adaptation.....	184
6.3.8	Local Government Adaptation.....	184
6.3.9	State Government Adaptation.....	184
6.3.10	Federal Government Adaptation.....	185
6.4	Water Risks and Adaptation.....	186
6.4.1	Variable Rainfall .....	188
6.4.2	Water Demand .....	189
6.4.3	Preserving Water Sources .....	190
6.4.4	Drought and Agriculture .....	190
6.4.5	Flooding .....	191
6.4.6	Increasing Resilience to Rainfall Variability .....	192
6.4.7	Individual Adaptation.....	194

6.4.8	Community Adaptation.....	194
6.4.9	Local Government Adaptation.....	195
6.4.10	State Government Adaptation.....	195
6.4.11	Federal Government Adaptation.....	195
6.5	Extreme Weather Events Risk and Adaptation.....	196
6.5.1	Extreme Weather Events.....	197
6.5.2	Avoidance of Extreme Weather.....	198
6.5.3	Extreme Weather Event Preparation.....	199
6.5.4	Recovery from Extreme Weather Events.....	201
6.5.5	Runaway Climate Change.....	204
6.5.6	Extreme Weather Events Adaptation.....	205
6.5.7	Individual Adaptation.....	206
6.5.8	Community Adaptation.....	206
6.5.9	Local Government Adaptation.....	206
6.5.10	State Government Adaptation.....	207
6.5.11	Federal Government Adaptation.....	207
6.6	Vector Borne Disease Adaptation.....	208
6.6.1	Potential for Increases in Vector Borne Disease.....	209
6.6.2	Managing Vector Breeding Sites.....	210
6.6.3	Emerging Risks.....	211
6.6.4	Adaptation Strategies for Vector Borne Illness.....	211
6.6.5	Individual Adaptation.....	212
6.6.6	Community Adaptation.....	212
6.6.7	Local Government Adaptation.....	212
6.6.8	State Government Adaptation.....	212
6.6.9	Federal Government Adaptation.....	212
6.7	Air Quality Adaptation.....	213
6.7.1	Ozone and Particulate Matter.....	214
6.7.2	Volatile Organic Compounds.....	215
6.7.3	Legionnaire’s Disease.....	216
6.7.4	Adaptation by Individuals.....	217
6.7.5	Adaptation in the Community.....	217
6.7.6	Adaptation by Local Government.....	217
6.7.7	Adaptation by State Government.....	218
6.7.8	Adaptation by Federal Government.....	218
6.8	Species Migration Adaptation.....	218

6.8.1	Marine Species Migration .....	219
6.8.2	Terrestrial Migration .....	220
6.8.3	Human Migration .....	221
6.8.4	Adaptation by Individuals .....	222
6.8.5	Adaptation in the Community .....	222
6.8.6	Adaptation by Local Government .....	223
6.8.7	Adaptation by State Government .....	223
6.8.8	Adaptation by Federal Government .....	223
6.9	Food Adaptation .....	223
6.9.1	Food Borne Illness .....	226
6.9.2	Food Security .....	226
6.9.3	Irrigated Agriculture .....	229
6.9.4	Adaptation by Individuals .....	230
6.9.5	Adaptation in the Community .....	230
6.9.6	Local Government Adaptation .....	230
6.9.7	State Government Adaptation .....	230
6.9.8	Federal Government Adaptation .....	231
6.10	Summary of the Risks from Climate Change in the Blackwood Stirling..	231
6.10.1	Public Health .....	232
6.10.2	Rural and Urban Impacts .....	232
6.11	Adaptation by Local Government Area .....	233
6.11.1	Shire of Augusta Margaret River .....	233
6.11.2	Shire of Nannup .....	235
6.11.3	Shire of Bridgetown-Greenbushes .....	237
6.11.4	Shire of Boyup Brook .....	239
6.11.5	Shire of Cranbrook .....	240
6.11.6	Shire of Manjimup .....	241
6.11.7	Shire of Denmark .....	244
6.11.8	Shire of Plantagenet .....	245
6.12	Summary of Chapter Six .....	247
Chapter Seven - Discussion and Conclusion .....		248
7.0	Introduction to the Chapter .....	248
7.1	Focus of the Research .....	248
7.1.1	Research Focus .....	248
	Specific Objectives .....	248
7.2	Key Findings From the Study .....	249

7.2.1	Objective One .....	250
7.2.1.1	Identifying Risks and Vulnerability Through Primary Sources .....	251
7.2.2	Objective Two .....	255
7.2.2.1	Focus Group Evaluation – Community Participants .....	256
7.2.2.2	Expert Evaluation of Impacts .....	258
7.2.2.3	Stakeholder Participant’s Evaluation of Risks.....	259
7.2.2.4	Community Survey - Evaluation of Impacts .....	261
7.2.2.5	Risk Assessment Summary.....	261
7.2.3	Objective Three.....	262
7.2.4	Objective Four.....	263
7.2.4.1	Extreme Weather Adaptation.....	266
7.2.4.2	Adaptation to Diminished Air Quality.....	267
7.2.4.3	Embedding Climate Change in Future Planning .....	268
7.2.4.4	Building Community Resilience.....	268
7.2.5	Objective Five .....	268
7.2.5.1	Adaptation to Thermal Changes .....	269
7.2.5.2	Adaptation to Variable Precipitation and Water Scarcity.....	269
7.2.5.3	Extreme Weather Adaptation.....	270
7.2.5.4	Vector Borne Disease Adaptation.....	270
7.2.5.5	Air Quality Adaptation .....	271
7.2.5.6	Species Migration Adaptation .....	271
7.2.5.7	Food and Nutrition Adaptation .....	271
7.2.5.8	Limitations to Adaptation .....	272
7.2.6	Future Directions and Research .....	272
7.3	Conclusion.....	273
	Glossary of Terms .....	275
	Chapter Seven - Bibliography .....	278
	Chapter Eight - Appendices .....	356
	Appendix 1.0 Focus Group Questions.....	356
	Appendix 2.0 Semi Structured Interview Questions .....	356
	Appendix 3.0 Sample Size Calculation .....	357
	Appendix 4.0 Community Survey .....	359
	Appendix 5.0 Community Survey Greenbushes and Cranbrook.....	364
	Appendix 6.0 SEIFA by Suburb.....	369

Appendix 7.0 Highest and Lowest Rainfall on Record by Community .....	370
Appendix 8.0 Variation Between Daily Minimum and Maximums.....	372
Appendix 9.0 Expert Panel Review Delphi Method Round One .....	373
Appendix 10.0 Expert Panel Review Delphi Method Round Two.....	374
List of Figures	
Figure 1 Vulnerability to Climate Change .....	4
Figure 2 Global Mean Temperature .....	6
Figure 3 Map of the Blackwood Stirling Region .....	8
Figure 4 UNDP Adaptation Policy Framework .....	11
Figure 5 Determinants of Health and Wellbeing .....	33
Figure 6 Timeline of the Research. ....	35
Figure 7 Focus Group Pre-test Feedback. ....	37
Figure 8 Focus Group Participants.....	38
Figure 9 Sectors Identified as Stakeholders in Adaptation Research in Western Australia. ....	41
Figure 10 Characteristics of Stakeholders Interviewed. ....	43
Figure 11 Expert Participants.....	47
Figure 12 Phone Response to Invitation to Complete Survey. ....	50
Figure 13 Population Density South West Australia .....	61
Figure 14 Trend in Total Rainfall 1900-2015 .....	74
Figure 15 Trend in Number of Heavy Rain Days 1970-2008.....	75
Figure 16 Trend in Number of Very Heavy Rain Days 1970-2008.....	76
Figure 17 Trend in Mean Temperature 1970-2015.....	77
Figure 18 Trend in Number of Very Hot Days 1970-2008.....	79
Figure 19 Trend in Number of Hot Nights.....	80
Figure 20 Sea Surface Temperature 1970-2015 ( <sup>0</sup> C/10yr) .....	82
Figure 21 Trend in Pan Evaporation 1970 – 2015 (mm/yr).....	83
Figure 22 Rainfall Deciles 2016 .....	84
Figure 23 Global Carbon Emissions for Scenario Family, to 2100 .....	87
Figure 24 Change in Rainfall 2030 (A1FI) .....	89
Figure 25 Change in Rainfall 2030 (B1).....	90
Figure 26 Percentage Change in Total Rainfall 2030 A1B .....	91
Figure 27 Percentage Change to Mean Temperature from 1990-2030 A1FI .....	92

Figure 28 Percentage Change to Mean Temperature B1 Scenario 1990-2030.....	92
Figure 29 Mean Temperature Increase, A1B Moderate Global Warming 1990-2030 .....	93
Figure 30 Mean Maximum Temperature 2030, A1F1 .....	94
Figure 31 Humidity 2030 under Low, Medium and High Scenarios.....	96
Figure 32 Sea Level Rise 2030 .....	99
Figure 33 Expert Consensus of Health Risks.....	145
Figure 34 Risk Assessment of Direct and Indirect Impacts.....	174
Figure 35 Vulnerability Model of Temperature Increase and Heat Waves .....	178
Figure 36 Vulnerability Model - Air Toxics .....	180
Figure 37 Vulnerability Model - Heat Disruption .....	181
Figure 38 Vulnerability Model - Sea Level Rise .....	182
Figure 39 Vulnerability Model - Reduction in Rainfall.....	189
Figure 40 Vulnerability Model - Reduced Water Supply .....	191
Figure 41 Vulnerability Model – Flooding .....	192
Figure 42 Emergency Management Process .....	198
Figure 43 Vulnerability Model - Extreme Weather Evacuation Delays.....	199
Figure 44 Vulnerability Model - Lack of Emergency Preparation .....	201
Figure 45 Vulnerability Model -Emergency Events and Recovery .....	203
Figure 46 Vulnerability Model - Runaway Climate Change .....	204
Figure 47 Vulnerability Model - Vector Borne Disease .....	210
Figure 48 Vulnerability Model - Epidemic and Pandemic Conditions.....	211
Figure 49 Vulnerability Model - Air Quality factors .....	216
Figure 50 Vulnerability Model – Marine Recreational Water and Marine Food Products.....	220
Figure 51 Vulnerability Model – Terrestrial Species Loss and Migration .....	221
Figure 52 Vulnerability Model - Climate Change Migration .....	222
Figure 53 Vulnerability Model - Food Borne Illness.....	226
Figure 54 Vulnerability Model - Food Production .....	227
Figure 55 Vulnerability Model - Increasing Food Costs .....	229
Figure 56 Research Process. ....	249

**List of Tables**

Table 1 Health Impact Scoping Matrix.....	30
-------------------------------------------	----

Table 2 Categories for Health Consequences .....	46
Table 3 Likelihood Categories .....	46
Table 4 Qualitative Health Risk Assessment Matrix .....	47
Table 5 Remoteness by Suburb.....	62
Table 6 Population of Shire of Augusta-Margaret River 2011 .....	64
Table 7 Population of Shire of Denmark 2011 .....	65
Table 8 Population of Shire of Boyup Brook 2011.....	66
Table 9 Population of Shire of Bridgetown-Greenbushes 2011 .....	67
Table 10 Population of Shire of Cranbrook 2011 .....	68
Table 11 Population of Shire of Manjimup 2011.....	69
Table 12 Population of Shire of Nannup 2011.....	70
Table 13 Population of Shire of Plantagenet 2011.....	71
Table 14 Number of Persons with Aboriginal and Torres Strait Islander Heritage...	72
Table 15 Daily Maximum Temperature Records.....	78
Table 16 Heat Wave Historical Records.....	79
Table 17 Lowest Temperatures Recorded.....	81
Table 18 Annual Rainfall 2030 using Low, Moderate and High Rates of Global Warming.....	89
Table 19 Humidity and Temperature Heat Stroke Guide .....	94
Table 20 Humidity 2030 by Community under Low, Moderate and High Rates of Global Warming.....	97
Table 21 Temperature Change of Sea Surface Temperature for Coastline .....	98
Table 22 Observed Climate Change. ....	103
Table 23 Lifestyle Impacts from Climate Change. ....	104
Table 24 Benefits and Opportunities from Climate Change.....	105
Table 25 Observed Impacts from Climate Change.....	106
Table 26 Mental Health Impacts of Climate Change.....	106
Table 27 Methods to Increase Benefits/Reduce Negative Impacts.....	108
Table 28 Potential Risks to Community. ....	109
Table 29 Greatest Source of Harm.....	110
Table 30 Risks that can't be Readily Managed.....	110
Table 31 Vulnerable Community Members.....	111
Table 32 Themes from Question One of Reference Group Interview.....	119

Table 33 Expert Participant Identification of Health Impacts. ....	143
Table 34 Participant Households by Postcode. ....	146
Table 35 Participants' Household Income .....	147
Table 36 Potential Impacts - Temperature .....	176
Table 37 Health Factors Assessed.....	185
Table 38 Potential Impacts – Rainfall and Water .....	188
Table 39 Health Factors Assessed.....	196
Table 40 Potential Impacts - Extreme Weather Events .....	197
Table 41 Health Factors Assessed.....	208
Table 42 Potential Impacts - Vector Borne Disease .....	209
Table 43 Health Factors Assessed.....	212
Table 44 Potential Impacts - Air Quality Factors .....	214
Table 45 Health Factors Assessed.....	218
Table 46 Potential Impacts - Species Migration .....	219
Table 47 Health Factors Assessed.....	223
Table 48 Potential Impacts - Food Production and Consumption .....	225
Table 49 Health Factors Assessed.....	231
Table 50 SEIFA by Suburb .....	369
Table 51 Highest and Lowest Rainfall on Record (Monthly and Daily) .....	371
Table 52 Variation Between Daily Minimum and Maximum .....	372
Table 53 Expert Panel Review Delphi Method Round One .....	373
Table 54 Expert Panel Review Delphi Method Round Two.....	375

## Prologue

Through the course of this study I was able to connect with local pioneers in the field of sustainability; people with the knowledge, interest and compassion to prepare for climate change. As a family we attempted to be as carbon neutral as possible. It became clear that adaptation was possible and made easier through supportive networks. Contemporary climate change activists provided inspiration:

- Shani and Tim from Ecoburbia, Perth Western Australia
- Colin Beavan, “No Impact Man”, USA
- Janaia Donaldson “Peak Moment” USA, and
- Derrick Jensen of “Deep Green Resistance” USA.

It is likely that the work of generations is needed to remedy our unsustainable living practices.

# Chapter One - Introduction

*“Global warming is altering ecosystems and human settlements in several ways that threaten human health and well-being” (p. 1 World Health Organization, 2016a).*

## 1.1 Introduction

This Chapter provides a brief summary of the issue under investigation, key terms, and the aims of the research Health Impact Assessment (rHIA). The rHIA uses procedures, processes and methods as described in the international literature on HIA, to research and investigate the potential impacts, likely risks, sensitivities, vulnerabilities and adaptation options relating to climate change hazards. The Chapter finishes by providing an overview of the thesis to follow.

## 1.2 Climate Change Definitions

The following terms are used throughout the thesis and will be defined here. The intent of the rHIA is to determine the potential positive and negative impacts arising from climate change to the year 2030 and to develop appropriate adaptation strategies.

### Adaptation

“Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, autonomous and planned” (Intergovernmental Panel on Climate Change (IPCC), 2007, p. 76). Hard and soft adaptation strategies differ. Hard adaptation methods refer to higher cost, inflexible and longer term strategies; soft adaptation refers to less expensive, flexible and natural strategies (Sovacool, 2011).

### Adaptive Capacity

“The whole of capabilities, resources and institutions of a country or region to implement effective adaptation measures” (IPCC, 2007, p. 76).

### Climate Change

“Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its

properties, and that persists for an extended period, typically decades or longer... The United Nations Framework Convention on Climate Change (UNFCCC)...defines climate change as...a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods” (IPCC, 2007, p. 78). This rHIA refers to anthropogenic climate change.

#### **Climate Scenario**

“A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change” (IPCC, 2007, p. 78).

#### **Exposure**

Exposure refers to being unable to avoid something harmful. This could include the human population and their livelihoods, environmental services, resources and infrastructure. Economic, social and cultural assets may also be exposed to climate change hazards (IPCC, 2012).

#### **Hazard**

The IPCC defines a hazard as “the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources” (IPCC, 2012, p. 560).

#### **Health**

Health is referred to using the World Health Organization definition “a state of complete mental, physical and social well-being, not merely the absence of infirmity or disease” (World Health Organization, 1946).

#### **Potential Impact**

Impact refers to potential “effects on natural and human systems...of physical events, of disasters and of climate change” (IPCC, 2012, p. 561). Direct impacts may include exposure to higher summer temperatures (such as extended heat waves) that result in heat stress. Indirect impacts may include reduced agricultural output of cereals in

southern latitudes that may contribute to reduced food supplies and nutrition (Garnaut, 2008).

#### **Resilience**

“The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions” (IPCC, 2012, p. 563).

#### **Risk**

Risk refers to the potential for harm to occur following exposure to a hazard (IPCC, 2007). “Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur...for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and infrastructure” (IPCC, 2014a, p. 1772). For the purposes of this rHIA, risk refers to potential harm to human health as a result of climate change.

#### **Sensitivity**

“Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or climate change. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea level rise)” (IPCC, 2007, p. 86).

#### **Susceptibility**

Susceptibility refers to the degree to which a system is openly sensitive to climate hazards and may result in damage if exposed to a hazard. Susceptibility may relate to natural or manmade systems and its inhabitants (IPCC, 2001a, p. 894).

#### **Vulnerability**

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity

(IPCC, 2007, p. 89). The following figure outlines the relationship between exposure to a climate hazard and vulnerability.

**The Vulnerability and Its Components image (Allen Consulting Group, 2011, p. ix) is unable to be reproduced here due to copyright restrictions.**

**The Vulnerability and Its Components image can instead be accessed via**

**<http://www.sfrpc.com/Climate%20Change/4.pdf>**

Figure 1 Vulnerability to Climate Change  
(Allen Consulting Group, 2005, p. ix).

### **1.3 Statement of the Problem - Overview**

Anthropogenic climate change is considered ‘unequivocal’ and is 95% probable that it is caused through atmospheric emissions of carbon dioxide and other gases (IPCC (2014b)). Climate change impacts cannot be avoided, adapting to climate variability must be undertaken to reduce vulnerability (Heal, 2009). Lower income countries have historically contributed less to GHG emissions, yet may experience greater vulnerability to the effects of climate change. Higher income countries have contributed to the majority of GHG emissions and have greater adaptive capacity. Middle income countries such as India and China are increasing annual emissions of GHGs, however may not realise the same social and economic benefits of developed countries (Satterthwaite, 2009). Low income and vulnerable groups within high income countries (the fourth world) are judged to have limited adaptive capacity and are more likely to have higher exposure to climate change effects (Altman & Jordan, 2008). Poverty is associated with sensitivity to climate hazards and increases vulnerability to all negative health impacts caused by climate change (Adger, Paavola, Huz & Mace, 2006; Lorenzoni, Nicholson-Cole & Whitmarsh, 2007). Higher income countries are judged to have higher costs associated with climate change adaptation, as existing infrastructure is expensive to protect, retrofit and rebuild (Dulal, Shah & Ahmad, 2009; United Nations Framework Convention on Climate Change (UNFCCC), 2007).

Mitigation of carbon emissions requires an 80% reduction of current emissions by the year 2050 (United Nations Development Programme (UNDP), 2008). Countries ratifying the Kyoto Protocol have shown a reduction in carbon emissions, however this falls short of the global goal of limiting global warming beyond two degrees Celsius ( $^{\circ}\text{C}$ ) (Grunewald & Martinez-Zarzoso, 2016). The Paris Agreement in 2015 outlined a commitment between 195 countries to prevent dangerous climate change through reducing GHG emissions, coming into effect in 2020 (UNFCCC, 2016). Limiting the global average temperature increase to  $2^{\circ}\text{C}$  would still have significantly negative environmental and health impacts in future, with an atmospheric carbon concentration of between 350 and 400 parts per million (IPCC, 2007).

Australia contributes to approximately 1.5 per cent of global carbon emissions (Australian Bureau of Statistics, 2010), however has one of the highest per capita emissions due to a reliance on coal. Agriculture systems in Australia have a higher emission profile compared to other nations due to an extensive livestock industry. Given its status as a high income country, Australia has the opportunity to develop adaptation policies and strategies to reduce the vulnerability of its economic basis, social and environmental wellbeing and exposed infrastructure (Department of Agriculture, Fisheries & Forestry, 2013a; Garnaut, 2008).

There has been an inconsistent approach in national politics to meet carbon reduction targets outlined in the Kyoto protocol, which over time have proved to be relatively ineffective (through cap and trade programmes) (Parliament of Australia, 2013). The Australian Government target is to reduce overall emissions by 26-28% by 2030 from levels in 2005 (Australian Government, 2015). Close proximity to the Asia Pacific region as trading partners for agriculture and mineral resources (particularly energy resources) will put additional pressure on meeting trade targets. Carbon reduction targets also need to be pursued from all sectors to limit the increase of global mean temperatures to no more than  $2^{\circ}\text{C}$  to avoid catastrophic health impacts (Bosnjakovic, 2012).

Low income countries will be disproportionately affected by climate change and will still need to commit to mitigation targets (Huq, Rahman, Konate, Sakona & Reid, 2003).

Figure 2 outlines climate change impacts by sector, for an increase in the global mean temperature relative to the reference period 1980-1999. It can be noted that water availability, species extinction, decrease in cereal production in southern latitudes, damage from weather events and mortality and morbidity impacts are likely with a 2<sup>0</sup>C temperature rise. Since 2004, global GHG emissions have surpassed the IPCCs worst case scenario (with the exception of 2009), consequently a broad range of adaptive strategies are essential (Jennings, 2013).

**The Key impacts as a function of increasing global average temperature change image (IPCC, 2007) is unable to be reproduced here due to copyright restrictions.**

**The Key impacts as a function of increasing global average temperature change image can instead be accessed via  
[https://www.ipcc.ch/publications\\_and\\_data/ar4/wg2/en/spmssp-c-15-magnitudes-of.html](https://www.ipcc.ch/publications_and_data/ar4/wg2/en/spmssp-c-15-magnitudes-of.html)**

Figure 2 Global Mean Temperature  
(IPCC, 2007, p. 10).

In the absence of global action toward mitigation or sequestration of carbon emissions it is likely that the carbon already locked in the atmosphere and ocean will result in long term impacts for at least 30 years but may persist for hundreds if not thousands of years (Mackey et al., 2013; Shaw, Colley & Connell, 2007). Reducing carbon emissions (mitigation) and investing in adaptation will be very costly measures, but as Stern (2007) illustrates, failing to reduce current emission levels or initiate appropriate adaptation will not only be significantly more costly financially, but also result in losses to critical ecosystem services and infrastructure. Declining oil production (peak oil) is estimated to occur around 2030, with the global population reaching a peak in 2050 of between 8 and 10 billion citizens (United Nations (U.N.), 2004). Adaptation is essential and needs to be carefully managed to ensure that it does not contribute to the continued emissions of carbon dioxide and other gases or exacerbate existing equity issues (Stern, 2007; Stearns & Stearns, 2010).

#### **1.4 Project Background**

Climate change scenarios to 2030 for the lower South West of Western Australia indicate a continuing stepwise decline in annual rainfall and streamflow which has been observed since the 1920's, with the annual mean temperature observed to be increasing each decade by  $0.15^{\circ}\text{C}$  since 1970 (Vaghefi & Yu, 2016). Impacts of climate change and climate variability can be addressed through appropriate adaptation (Hallegatte, 2009). Global Climate Models (GCM) forecast to 2030 were used to inform decision making for the study area (Spickett, Brown & Katscherian, 2008). These climate change scenarios indicate (with high confidence) that the annual mean temperature will increase by  $0.5^{\circ}$  to  $1.1^{\circ}\text{C}$  by 2030 from the 1985-2005 recorded temperature and show a decrease in the frequency of frost days, decrease in winter and spring rainfall (with an overall reduction in annual rainfall) and an increase in meteorological drought time compared to present day. Other changes (with high confidence) are for decreased mean winter wind speed, little change for solar radiation or humidity, harsher fire weather conditions, increased ocean acidification and ocean temperature, and continued sea level rise. A very high confidence has been reported for an increase in mean, maximum and minimum temperatures, with a rise in observed daily maximums on the hottest days, and increased frequency of hot days and warm spells (Hope et al., 2015).

The study area is known as the Blackwood Stirling region, made up of coastal areas from the Augusta-Margaret River Shire to the Denmark Shire and inland areas to Mount Barker, Cranbrook and Boyup Brook. This region has a Mediterranean type climate with niche ecology areas and freshwater rivers of the South West including the Blackwood, Meerup, Frankland, Denmark and Margaret River systems (Sander & Wardell-Johnson, 2011). This geographical land mass covers an area of 24,934 km<sup>2</sup> (Western Australian Electoral Commission, 2011) and is considered to be one of the most bio-diverse regions under threat from climate change (Gole, 2006). Mediterranean type climates face the largest proportion of biodiversity loss under climate change scenarios and may require establishment of new protection areas and restoration of habitat (Klausmeyer & Shaw, 2009).

**The Electoral District of Blackwood Stirling image (Western Australian Electoral Commission, 2011) is unable to be reproduced here due to copyright restrictions.**

**The Electoral District of Blackwood Stirling image can instead be accessed via**  
**<http://www.boundaries.wa.gov.au/sites/default/files/distribution/2007/BLS.pdf>**

Figure 3 Map of the Blackwood Stirling Region  
(Western Australian Electoral Commission, 2009).

The Blackwood Stirling is an electoral region of Western Australia. In 2011 this was expanded to include the towns of Donnybrook and Balingup and was renamed the Warren-Blackwood (Western Australian Land Information Authority, 2011). These new towns are not included in the study as the original Blackwood Stirling map and boundaries are used. The region has a population of 39,268 residents in eight local government areas (Australian Bureau of Statistics (ABS), 2013a). These are Augusta-Margaret River Shire, Shire of Nannup, Shire of Manjimup, Shire of Bridgetown-Greenbushes, Shire of Boyup Brook, Shire of Cranbrook, Shire of Denmark and Shire of Plantagenet. Regional centres along with remote and sparse

populations feature in the area. Recent population growth has been observed in the south west region, with increases to the population of 2.8 per cent (2014-2015) in Margaret River and Augusta (ABS, 2016). Future population growth is predicted to occur in coastal towns (Margaret River, Augusta and Denmark), with other areas retaining a relatively stable population, the Shire of Manjimup has been identified as a 'super town' and may experience population growth of up to 3.4 per cent in the next three decades, but has recently observed population decline (Western Australian Planning Commission (WAPC), 2015a; WAPC, 2015b). A profile of each local government area will be discussed fully in Chapter Four. The study area is characterised by rural and remote communities and regional centres. Rural Western Australians face specific barriers to healthy lifestyles, including reduced physical activity and mental health risk factors (Bourke, Humphreys, Wakerman & Taylor, 2012).

Annual rainfall in the region varies from 500 to 1200 mm (for the period 1976-2005); southern coastal communities have the highest recorded annual rainfall, for example Augusta, Northcliffe, Denmark and Walpole (BOM, 2011a). From the 1970's a sudden decrease in annual rainfall of about 20% across the South West area has affected stream inflow and groundwater recharge (by up to 40%) (Ummerhofer, SenGupta, Pook & England, 2008). Following notable declines in rainfall and streamflow for a number of decades, the Indian Ocean Climate Initiative was developed to examine past and future trends of climate in Western Australia and provide knowledge for decision making in various sectors across the South West. Climate scenarios indicate greater stress on water supplies for domestic, agricultural and industrial users, combined with an increase in the global mean temperature. This may have implications for food production, thermal comfort, increased risks from heat wave activity and more intense extreme weather events (Indian Ocean Climate Initiative, 2012).

The Blackwood Stirling serves as one of the five food bowls in Australia - providing food and other services to Australia and international markets. The region has important agricultural values that can help to ensure future food security in the Asia-Pacific region (Preston, Suppiah, Macadam & Bathols, 2006). The number of farms

in Australia is declining, with the median age of farmers increasing (currently 53 years of age). Diminishing financial viability may result in further reductions in agricultural output in Australia (Australian Bureau of Statistics, 2013b). Demographic changes in the region are expected in future following the 'baby boom', with notable increases in the elderly and very elderly population groups that may have a higher reliance on medical and social services, (with further distances required to access these services). These factors contribute to the study area having high sensitivity to climate change and a need to develop a broad range of adaptive responses (Davis, Crothers, Grant, Young & Smith, 2012; Garnaut, 2008; Stokes & Howden, 2008).

Environmental degradation is associated with mental health disorders, vulnerability to mental disorders (such as affective disorders and anxiety disorders) in rural Western Australia and is also associated with socio-economic disadvantage (Speldewinde, Cook, Davies & Weinstein, 2009). Migration of young adults from rural areas to urban centres decreases the viability and range of local community health and public services that the population left behind may be relying on, thus increasing the socio-economic disadvantage of these communities (National Rural Health Alliance Inc., 2005). Indigenous Australians face an increased risk for depression, suicide and hospitalisation for mental disorders (National Rural Health Alliance Inc., 2009a). It is reported that rural Australians have an increased risk for suicide (1.4 to 1.8 times more likely to commit suicide) than urban Australians (National Rural Health Alliance Inc., 2009a). Male youth suicide in rural areas is twice the rate of male suicides in an urban setting. Suicide amongst farmers is more likely for persons aged above 55 and is associated with environmental, social and economic factors (National Rural Health Alliance Inc., 2009a; Speldewinde, Cook, Davies & Weinstein, 2009).

### **1.5 Adaptation to Climate Change**

This research aims to identify adaptation strategies for the study area (Blackwood Stirling) in order to reduce the vulnerability to actual or predicted impacts from climate change. The focus is to the near term (2030) as climate projections with longer time spans have greater modelling uncertainty associated with economics,

technology and demographic changes. Adaptation strategies should be re-evaluated as scientific research, climate conditions, mitigation and technological advances change (Hallegatte, 2009). The UNDP Adaptation Policy Framework Process (UNDP APFP) has informed the rHIA methodology used in this study. The UNDP APFP is comprised of the components and sub-components shown in Figure 4. Engaging with stakeholders throughout the rHIA process informs adaptation and is based on current and future vulnerability and climate risks.

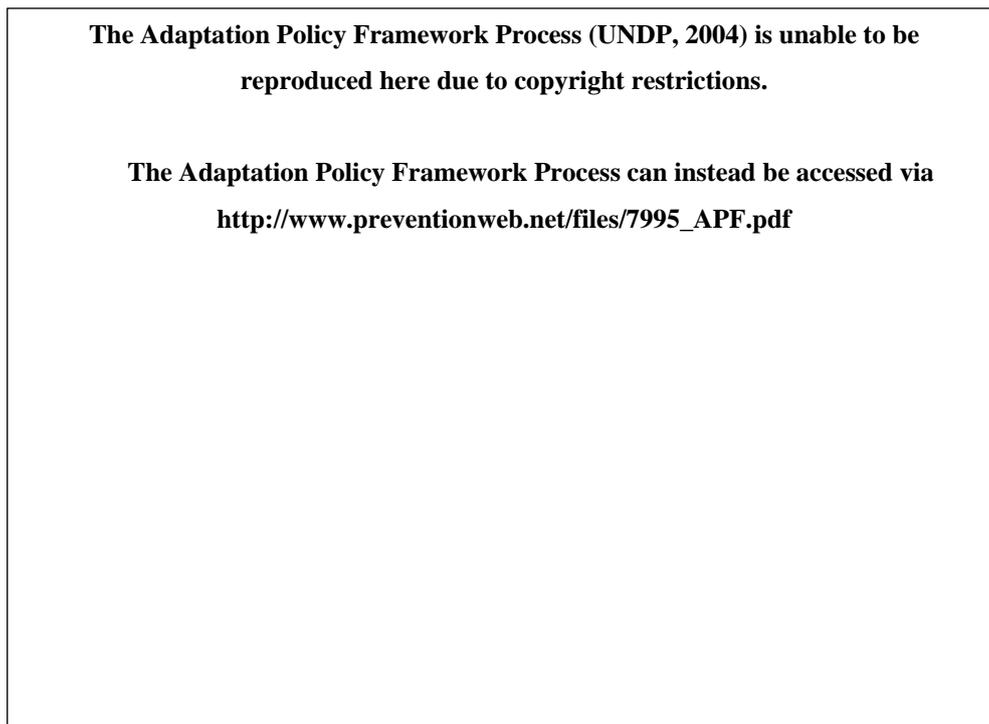


Figure 4 UNDP Adaptation Policy Framework  
(UNDP, 2004).

Humanity has adapted to a range of climatic conditions across the globe over time, (Adger et al., 2009), the costs of adaptation and the population size exposed to climatic risks are a new phenomenon. While mitigation attempts may reduce the most severe impacts of climate change (even radical mitigation will not prevent some climate change due to carbon stored in the atmosphere and ocean), adaptation is judged to be a crucial aspect of sustainable development, risk prevention and harm minimisation (Pielke, 1998) and should be mainstreamed into decision making processes for communities and government (Wilbanks & Kates, 2010). Adaptation

refers physical infrastructure and technological changes along with behavioural and social changes.

Barriers and limitations to adaptive capacity include resource constraints, presentation of scientific data that is not culturally appropriate, political influences and institutional factors (Eisenack et al., 2014; Jennings, 2013). Enhancing adaptive capacity has the potential to reduce exposure to climate hazards and decrease vulnerability, as well as exploiting any potential benefits in order to protect public health (Ebi, Smith, Burton & Scheraga, 2006). While there may be some positive impacts of climate change, for example reduced exposure to cold weather extremes and reduced winter mortality, overwhelmingly the impacts are potentially negative (IPCC, 2001b). Anticipating the adverse impacts of climate change and taking advantage of potential benefits prior to the changes occurring will save resources and protect health (Smit, Burton, Klein and Wandel, 2000). Early adaptation that acknowledges the mathematical uncertainty, complexity and severity of potential outcomes and is informed by the values of the communities and expert participants provides quality assurance for decision making (Funtowicz & Ravetz, 2003; Tamburrini, Gilhully & Roxas-Harris, 2011). Early adaptation will not prevent residual impacts from climate change hazards, yet it may provide positive social and economic impacts regardless of the magnitude of climate change (Fussler, 2007).

Linear and non-linear (runaway) climate change scenarios will have likely impacts to the global population, with low income countries and low income groups having higher sensitivity. Exposure to climate hazards may have direct and indirect impacts. Direct health impacts include those caused by extreme weather events, air quality factors, and thermal stress. Indirect health impacts include energy, food and water security and economic considerations (Shea, 2007). Adaptation activities that reduce exposure to climate hazards, increase the resilience of communities and reduce sensitivity to exposure will overall reduce vulnerability to climate change. Adaptation methods can include 'hard' and 'soft' options of engineering, retrofitting, planning and behavioural factors (Ruth & Ibarraran, 2009).

## **1.6 Vulnerability to Climate Change and Adaptation**

Vulnerability to climate change is determined by the degree to which a system is susceptible to, or unable to cope with the adverse effects of climate change. It is also dependant on the character, magnitude and rate of climate change to which a system is exposed, its sensitivity and adaptive capacity (IPCC, 2012). The study area has several emerging climate change related vulnerabilities that include climate dependant industries, sensitivity to sea level rise, high public service delivery costs (especially health and social care), heavy reliance on volunteers, potential exposure to extreme weather events (bushfires) and transport costs (Nelson et al., 2010; Williams, et al., 2009). Susceptible communities are open and exposed to climate hazards and in the absence of adaptation are likely to experience impacts. Susceptibility to climate change may relate to socio-economic or geographic factors such as poverty or exposure to sea level rise. Adaptation strategies reduce susceptibility, focus on avoiding exposure and mitigate negative impacts. Preparedness for climate hazards, having adequate resources to respond and recover and improving health outcomes can decrease susceptibility (Keim, 2008).

Diminished adaptive capacity is associated with resource and technology constraints, low human, civic and social capital, lack of universal health care, income inequality, and inability to access information (IPCC, 2007). Communities with low adaptive capacity may be less able, or unable to cope with the adverse effects of climate change. The resilience of a community is determined by how much the system or community can absorb and recover from climate hazards without permanent adverse effects. For example, in the case of a bushfire, resilience factors would include anticipation of the event, e.g. early warning systems and early notification of the potential threat to householders. Containing the event would include fire preparation amongst landowners (preparedness to stay and defend, or early evacuation) with sufficient resources to fight or contain the fire and resources for recovery. Recovery strategies may include adequate insurance and appropriate restoration. Bushfire recovery could include restoring infrastructure, agriculture and ecosystems, along with replanting, restocking and rebuilding. Access to social and medical services are components of the coping and recovery cycle following a disaster (Eriksen & Prior, 2013; Mackinnon & Derickson, 2013).

High susceptibility and low resilience increase vulnerability. The following groups have been identified as being more vulnerable to climate change:

- Indigenous populations
- Nomadic populations
- Elderly people
- Children
- Chronically ill people
- People with a low income
- Homeless people (WHO, 2003a).

Rural Australians are judged to have higher vulnerability to increased global mean temperatures and air quality factors due to the trend for persons living outside of major cities to experience poor health outcomes. Increasing remoteness is associated with worsening health outcomes. For example, mortality due to cardiovascular disease (CVD) for rural Australians is 16.5% higher than for urban Australians. Mortality rates for chronic obstructive pulmonary disease (COPD), is also higher in rural areas compared to urban areas in Australia by 26% (Australian Institute of Health and Welfare, 2014; National Rural Health Alliance, 2015). Indigenous Australians have poorer health outcomes independent of remoteness (Australian Institute of Health and Welfare, 2005). Low educational attainment and lack of employment opportunities increases vulnerability due to relative poverty, along with an increased risk of substance abuse and other social factors (National Rural Health Alliance, 2009a). Financial and environmental stress will disproportionately affect rural residents (Vines, 2011; ABS, 2013b).

Reducing vulnerability is achieved by preventing exposure to, or mitigating the potential risks from climatic hazards. Increased resilience is achieved by being prepared, having the resources to adequately respond and recover and is better dealt with by healthy people living in healthy communities with adequate financial resources (Keim, 2008). Adaptation should ideally be developed as a participatory process for local communities to address climate change risks utilising local knowledge and resources (van Aalst, Cannon & Burton, 2008). Enhancing adaptive

capacity in rural communities could be achieved through improving their socio-economic status and collective action of agreed adaptation priorities (UNDP, 2004).

Adaptation activities may reduce vulnerability of communities to potential impacts from climate change. The type of exposure and the sensitivity of the community will determine the extent of residual impacts. Lack of, or inappropriate adaptation is referred to as maladaptation (Smit, Burton, Klein & Wandell, 2000). Implementing adaptation does not imply that there are likely to be no risks, but that the risk of adverse impacts and the severity of impacts are likely to be minimised under linear climate change scenarios (Brooks, 2003).

### **1.7 Rationale for this Study**

The National Adaptation Research Plan (Human Health) outlines current gaps in knowledge and these will be explored including heat exposure, extreme weather events, vector borne disease, mental health issues, community and Indigenous health factors, health services and infrastructure (Hanna et al., 2012). The WHO has called for health impact assessments (HIAs) in order to identify vulnerable groups affected by climate change and to review the “mitigation and adaptation options available to reduce the potential adverse impact of climate change and stratospheric ozone depletion on human health” (WHO, 2003a, p. 14). HIA is a “combination of procedures, methods and tools which a policy, program or project may be judged as to its potential effects on the health of the population and the distribution of those effects within the population” (WHO European Centre for Health Policy, 1999, p. 4).

Building on existing climatic hazard knowledge from a local community perspective is the preferred option in developing adaptation strategies. Ensuring that adaptation addresses multiple hazards and has low sensitivity to climate hazards is likely to increase benefits (Wilbanks & Kates, 2010). Local knowledge is also likely to develop comprehensive adaptation plans that are more acceptable and meets a number of development goals in communities (McNamara & Westoby, 2011).

Research that includes the costs and acceptability of climate change adaptation in a community context is required (Howden, Crimp & Stokes, 2008) however costs of

adaptation are difficult to calculate separately as they have other functions and benefits other than protection from climate change (UNFCCC, 2007).

### **1.8 Research Aims and Objectives**

A rHIA of climate change and adaptation in a primarily rural area in Western Australia will be one the first of its type. The research will provide an approach and range of outcomes that can be used by other communities in Australia and internationally to help minimise negative health impacts in communities.

The objectives of the rHIA were to:

1. Identify the potential sensitivities and vulnerabilities of and impacts and risks to local communities; taking into account a range of climatic hazards, local socio-economic and local environment (urban, rural, natural, agricultural) characteristics.
2. Assess the potential positive and negative impacts on health of climate change in the region.
3. Use qualitative health risk assessment methods to analyse the likelihood and magnitude of the identified human health impacts to determine priorities.
4. Develop, through discussions with stakeholders, the research participants and a review of the literature, potential adaptation measures/interventions and strategies to minimise the potential risks of the identified human health impacts and the severity of those impacts.
5. Review and assess the possible adaptation strategies in terms of who is or would be best placed to action them at local/district, state and national levels.

This future oriented study has examined the impacts of near term climate scenarios to 2030 in the Blackwood Stirling region using rHIA procedures, processes and methods as understood/described in the international literature on HIA, to research and investigate the potential impacts, likely risks, sensitivities, vulnerabilities and adaptation options relating to climate change hazards. Climate change models have been used to determine the potential changes to the climate in the region (Spickett, Brown & Katscherian, 2008). Near term scenarios generated by climate models are likely to have higher accuracy than longer range scenarios. The relationship between

climate factors and health will be analysed to determine future health risks to the population (Turner, Alderman, Connell & Tong, 2013). Risks refer to the potential for harm to occur following exposure to a hazard (Spickett, Brown, Matison & Katscherian, 2006). Determining risks through a qualitative health risk assessment process is part of this rHIA to develop priority adaptation strategies and methods to protect human health (UNDP, 2004). The study will evaluate adaptation options and will propose recommendations for action to improve health outcomes for these rural and remote communities. The rHIA process has several steps that include screening, scoping, profiling, risk assessment and management which will be discussed in further detail in Chapter Two (EnHealth, 2001).

### **1.9 Overview of the Thesis**

Chapter One of the thesis described an overview of the rHIA, the study area and the timeframe.

Chapter Two introduces the literature review and discusses the rHIA in more detail. The relationship between health and climate is considered, along with vulnerability and adaptation in rural areas. A brief summary of future health risks for the study are described.

Chapter Three examines the research design and methods for the rHIA. Data collection methods and procedures are detailed. This includes the number of participants, types of research instruments and the criteria for the selection of the participants. Data analysis methods and limitations to the research are detailed.

Chapter Four examines the demographic and socioeconomic profile of the study area, along with recorded climate data and climate scenarios.

Chapter Five presents the data analysis for data collected using qualitative methods. Data from community participants was analysed using determinants of health and wellbeing factors to frame responses. The stakeholder participants were interviewed and responded to questions about adaptation barriers and practices. Themes that emerged from the interviews are discussed. Expert participants conducted a qualitative health risk assessment of the impacts of climate change. This expert panel

utilised qualitative risk assessment methods and a two-round Delphi to develop a consensus of climate change risks. A paper survey administered to a random sample of community participants examined the priority for expenditure on adaptation projects and the willingness to pay towards these projects.

Chapter Six details the potential vulnerability to climate change in the study area and presents adaptation methods and strategies to reduce or mitigate risks.

Chapter Seven concludes the study with a discussion of rHIA and the key findings from the study.

Chapter Eight lists the complete Bibliography and Chapter Nine includes the Appendices.

## Chapter Two - Literature Review

*“To progress towards a durable ‘bio-economy’ will require a collaborative mission that dwarfs the Apollo program” (Crutzen & Schwagerl, 2011, p. 12).*

### 2.0 Introduction to the Chapter

Chapter Two presents the literature review examining the relationship between climate change and health. The significance of climate change as a global health issue will be explored, along with the additional research required. The rHIA processes will be discussed. Chapter Three will then detail the research design and methods.

### 2.1 Climate Change and Human Health

The relationship between environment and health is well known, with 23% of the global burden of disease linked with modifiable environmental factors. Climate is an environmental factor with potentially catastrophic impacts to human health on a global scale (Pruss-Ustun, Wolf, Corvalan, Bos, & Neira, 2014). Climate change has been reported as “the biggest global health threat of the 21<sup>st</sup> century” (Costello et al., 2009, p.1693). Observed impacts to human health as a result of climate change include the reduction of cold related deaths in some regions, shifting to heat related in others and changes to the distribution of vectors causing human infections. By 2030 it is estimated that climate change will result in substantial additional deaths; 38,000 persons (heat exposure of elderly persons), 48,000 persons (diarrhoea), 60,000 persons (malaria), and 95,000 persons (childhood under nutrition) worldwide (WHO, 2014).

In order to determine future climate scenarios, computer modelling is used to determine various climate factors with the associated likelihood of occurrence. The IPCC provides scientific reports that indicate the likelihood of climate impacts and related influences on health. It is considered very likely that there will be an increase in hot extremes, heat waves and heavy precipitation and likely to be an increase in cyclone intensity. Water security and agricultural decline are also projected for southern Australia (IPCC, 2007). Climatic parameters that will be assessed for the

rural communities in the Blackwood Stirling use the Commonwealth Scientific and Industrial Research Organisation (CSIRO) OzClim tool (2007a) and are:

- evaporation
- humidity
- maximum temperature
- mean temperature
- minimum temperature
- rainfall.

Geographic regions are identified in literature as having higher likelihood of health conditions dependent upon environmental and socio-economic factors, for example malaria transmission in third world nations (World Health Organization, 2014). Climate change will influence both of these factors through direct and indirect mechanisms (Craig, Snow & Le Sueur, 1999). Key elements relating to climate related health impacts to 2030 across Western Australia are: extreme weather events, temperature increase (and related changes), water-borne diseases, water quality, vector-borne disease, air quality (and related impacts), food borne diseases, food production and social impacts including community and lifestyle impacts and mental health influences (Spickett, Brown & Katscherian, 2008). Health impacts range from mild conditions (allergy, hay fever, insect bites) to chronic health impacts (asthma, Ross River Virus) to risks of mortality (e.g. cardiac arrest following thermal stress) (Spickett, Brown & Katscherian, 2008; WHO, 2014). Many studies suggest overwhelmingly that climate change will have negative health impacts (IPCC, 2007).

## **2.2 Climate Change and Rural Health**

The potential health impacts of climate change are significant, from chronic persistent health impacts to acute exposure of harmful agents in emergency situations. The factors influencing rural health status will now be discussed.

### **2.2.1 Demographic and Lifestyle Factors**

Rural areas typically have a lower percentage of overseas migrants than urban areas and a higher proportion of Indigenous Australians. Education and employment opportunities particularly in higher income brackets are limited. Out-migration of

young people (in the age bracket 18-35 years of age) leaves a population with lower educational attainment and reduced health status, with increased likelihood of drug and alcohol abuse and risky behaviour (including sexual behaviour) (Commonwealth of Australia, 2008). Illegal drug use in the South West of Western Australia is higher than metropolitan areas. Most of the offenders are youths and young adults between 15 and 34 years of age (Drug and Alcohol Office & Western Australia Police, 2006).

Unemployment appears to be the most significant indicator contributing to drug offences (Crime Research Centre University of Western Australia, 1999). Persons identified at risk of illicit drug use are; Indigenous Australians, people with mental health disorders, alcohol and other drug problems, and people in rural and remote areas (Government of Western Australia Drug and Alcohol Office, 2012, p. 3). Injury and traffic accidents are also more likely when linked with young rural men abusing drugs and alcohol (or poly-drug use) (National Rural Health Alliance, 1998). Climate change factors such as drought may exacerbate unemployment and mental health factors, influencing drug use and risk taking behaviour (Centre for Rural and Remote Mental Health, 2008).

Remote populations are less physically active than urban populations and have reduced access to healthy and nutritious fruit and vegetables due to cost. Persons outside of major cities were more likely to consume recommended servings of vegetables, however not the recommended serving of fruit. Indigenous families in rural and remote communities were reported as less likely to consume recommended servings of fruit or vegetables and were more likely to experience food insecurity (Australian Institute of Health and Welfare, 2008). As a result, lifestyle diseases may be more likely. In rural areas injury remains a leading cause of mortality in children and adults (ABS, 2008a; Australian Institute of Health and Welfare, 2008; Department of Health Western Australia, 2012; Peng et al., 2011).

### **2.2.2 Geographic and Economic Factors**

Following any injury or accident, the distance to major hospitals and time taken to access emergency health care increases the risk of mortality. Persons in rural and remote areas are increasingly vulnerable with distance to hospital facilities (Fatovich,

Phillips, Langford, & Jacobs, 2011). Rural communities have higher living costs compared to urban areas, particularly with regards to personal transportation. Despite having reduced services, many rural communities report having higher community cohesion and support networks with reduced crime. Conversely social stigma and lack of help seeking behaviour (linked with increased self-reliance) are factors that contribute to poor health in rural areas. Overall life expectancy is lower, with higher suicide rates in rural areas, particularly amongst Indigenous Australians (ABS, 1998; Australian Institute of Health and Welfare, 2013).

Despite considerable distances, rural communities engage with their community in a number of important ways that improve health and wellbeing, particularly through sport and other social gatherings (Maybery, Hodgins, Pope & Hitchener, 2010). Children are more likely to spend time outdoors in more remote communities, however are less able to access extra-curricular activities (Australian Institute of Family Studies, 2011).

The environmental quality of rural areas will directly influence incomes and in turn health status (National Rural Health Alliance, 2011a). Air quality is generally superior in rural areas, however periods of burning (including firewood burning) and storms will reduce air quality through exposure to particulate matter, pollens and air toxics (D'Amato, Liccardi, D'Amato & Cazzola, 2002; Reisen et al., 2011; Shea, Truckner, Weber & Peden, 2008). Indoor air quality impacts health as Australians spend significant amounts of time indoors. Overall, rural areas will be less affected by the urban heat island effect however will still face health risks associated with early summer heat wave activity, particularly in resource poor households (Luber & McGeehin, 2008; Nazaroff, 2013). Low income households in rural communities are likely to have lower capacity to deal with extreme weather events and may be disproportionately affected compared to urban areas (Australia Council of Social Services, 2013). A reduction in annual rainfall and declining water quality will have greater impacts to rural areas that rely on rainfall and runoff for potable use and irrigation (National Rural Health Alliance Inc. 2009b). Solastalgia is more likely in rural areas where place attachment values are higher, particularly for Indigenous Australians (Albrecht, 2005).

Migration of retirees to the study area, along with existing elderly and very elderly persons will increase the demand for health services. Persons with fixed incomes (e.g. pensions) will have limited opportunities for expensive adaptation options (Tillett, 2013).

### **2.3 Vulnerability in a Rural Setting**

Sensitivity to climate change refers to the degree to which a system is affected by climate hazards. In rural areas this may include beneficial climate impacts to agricultural output due an extension of the growing season and increases in crop yield. Sensitivity could include reduced winter rainfall and a decrease in water captured for irrigation. The severity of the impact is potentially mediated by the adaptive capacity of the exposed system, for example, increasing water storage infrastructure in order to prepare for variable rainfall conditions. Vulnerability then relates to sensitivity to impacts and the adaptive capacity of that system (Nelson et al., 2010). Rural populations that are considered vulnerable have high or moderate exposure to climate variability with moderate to low adaptive capacity (Nelson et al., 2010, p. 20).

The South West area of Western Australia has been identified as having moderate adaptive capacity with sensitivity to climate change for certain types of agricultural production. Secondary impacts of climate change (for example an increase in the cost of living) are more likely to impact rural communities with low socio economic status. Marginalised groups within communities are particularly at risk as they are less likely to access help before, during and after crises; these marginalised groups include Indigenous Australians, women and individuals with a mental illness (Doherty & Clayton, 2011; O'Halloran, 2004, p. 267). Research on social capital in rural communities reveals that higher levels of community involvement and volunteering commonly occurs, decreasing some of the effects of low financial capital. Marginalised individuals or groups may be unable to access benefits from existing social capital and will be particularly at risk from direct and indirect health impacts (Baum, 1999).

Risk from bushfire is associated with areas in rural and peri-urban locations with sufficient biomass and exposed populations. People migrating to rural or semi-rural

areas that have little experience in preparing or responding to bushfires are at increased risk. Large tracts of national park and state forest are a feature of the study area along with communication black spots (Balcombe, 2007; Bushfire Cooperative Research Centre (CRC), 2013a; Fire and Emergency Services Authority, 2011a).

Other areas of vulnerability include future and existing federal and state government policies that benefit only urban areas and increase difficulties in rural communities; for example discontinuing health services in remote communities that are crucial to the continuation of ageing in place in rural communities (Collits, 2011).

#### **2.4 Adaptation in a Rural Setting**

Adaptation to climate change refers to actions or adjustments taken in a human or natural system in order to avoid, manage or reduce effects of climate change (Victorian Centre for Climate Change Adaptation Research, 2014). As climate change modelling improves, adaptation options should be reviewed and revised (Fisher-Vanden, Wing, Lanzi & Popp, 2011).

Adaptive capacity is dependent on the cumulative resources at the individual and community level, these involve human, social, natural, physical and financial capital (CSIRO, 2011a). Enhancing adaptive capacity is one strategy to decrease vulnerability in rural communities. Community, economic development and ecological repair programs will assist in these goals (Kinrade, Arold, Marsden Jacob Associates & Public Policy Consultants, 2010).

Engineered and technological adaptation (hard adaptation methods) have been the most common form of adaptation and are associated with higher costs, with increasing value given to ecosystem, institutional and social adaptation responses (soft adaptation methods) that reduce sensitivity to direct and indirect climate impacts (Noble et al., 2014). 'No cost' and 'low cost' actions or adjustments relate to behaviour changes and efficiency measures. 'Win-win' adaptation provides a benefit despite the severity of climate change using soft (flexible and natural) and hard (technological and infrastructure) engineering options. Examples are improving the thermal efficiency of households which will improve comfort and save on heating and cooling costs. Behavioural and efficiency mechanisms are particularly beneficial

for water and energy systems. Where there is significant uncertainty relating to future impacts with a high level of risk, early action (anticipatory adaptation) involving hard adaptation may be inadequate or inappropriate (maladaptation) (Kemmer, 2008; Kriebel & Tickner, 2001; Mendelson, 2012; Wilby & Dessai, 2010).

It is likely that businesses and householders will adapt spontaneously following exposure to experiences such as climate change variability, particularly following an extreme weather event (e.g. drought). Anticipatory adaptation measures are more likely to be carried out by government agencies, for example upgrading road and drainage systems to cope with heavy rainfall. Hard adaptation compared to soft adaptation methods refer to technological and infrastructure retrofitting with associated expenses as opposed to natural, diverse and flexible arrangements with lower costs (Kinrade, Arold & Marsden Jacob Associates Economic and Public Policy Consultants, 2010; Sovacool, 2011). Taking advantage of adaptation opportunities in future housing, renewable energy and coastal defences will reduce vulnerability to climate change (IPCC, 1997).

### **2.5 Health Impact Assessment**

HIA has a number of stages; these are screening, scoping, profiling, risk assessment and risk management. The screening stage examines the potential health impacts of climate change, and if these impacts can readily be controlled under current management strategies and policies (EnHealth, 2001). The WHO recommends using HIA methods to assess the impacts of climate change, with the initial scoping stage identifying the concerns of vulnerable groups, the current health burdens and risks and issues (profiling) for assessment. The assessment stage identifies likely future impacts and adaptive capacity and evaluates adaptation plans, policies and programs. Risk management proposes actions to minimise impacts on health (WHO, 2003b).

Prevention of exposure to risks is the primary goal of low cost health interventions, followed by early treatment of populations that have been exposed. Tertiary health care includes long term treatment of vulnerable and exposed individuals in their community and can be the most costly (Blashki, McMichael & Karoly, 2007; Institute for Work and Health, 2006).

Climate hazards have the potential to impact health outcomes directly and indirectly in the Blackwood Stirling, these are outlined in Health Impact Scoping Matrix (Table 1).

Health Impact Scoping Matrix		
Climate Hazards	Potential Health Impact	Vulnerable Groups or Individuals
<p><b>Extreme weather events</b></p> <p>Damage to infrastructure, transport and communication systems, access to health care, food and water</p>	<p>Fatalities, injuries, heat stress, exacerbation to existing medical conditions, exposure to pathogens and pollutants</p>	<p>Elderly</p> <p>Young</p> <p>Immuno-compromised</p> <p>People with no access to air-conditioning</p> <p>People that have not adequately prepared for extreme weather events (lack of communication, or ability to cope, lack of insurance) (California Natural Resource Agency, 2009; Spickett, Brown &amp; Katscherian, 2008)</p>
<p>Housing</p>	<p>Increases in the costs of housing and maintenance with higher building costs to tolerate extreme weather events, and increased costs of insurance</p>	<p>Low income groups (The Climate Institute, 2011)</p>
<p>High demand on volunteers for emergency services due to intensified weather conditions</p>	<p>Stress</p>	<p>Volunteers, remote communities (Garnaut, 2008; McLennan, 2008)</p>
<p><b>Temperature and Rainfall</b></p> <p>Vector borne diseases:</p> <ul style="list-style-type: none"> <li>• Ross River Virus disease</li> <li>• Barmah Forest Virus</li> </ul>	<p>Morbidity and mortality</p>	<p>Persons exposed to mosquitoes (near breeding sites) (Spickett, Brown &amp; Katscherian, 2008)</p>

Health Impact Scoping Matrix		
Climate Hazards	Potential Health Impact	Vulnerable Groups or Individuals
<ul style="list-style-type: none"> <li>• Dengue</li> <li>• Murray Valley Encephalitis</li> <li>• Other exotic disease</li> </ul>		
Vermin	Spread of disease	Primarily children (Spickett, Brown & Katscherian, 2008)
<p><b>Temperature Related</b></p> <p>Food borne illness</p> <p>Salmonella, Campylobacter, Listeria spp. (high temperatures), Cryptosporidiosis (heavy rainfall events), mycotoxins and aflatoxins (temperature increase)</p>	Food poisoning	Young, Elderly, Pregnant women, immuno-compromised (California Natural Resource Agency, 2009)
<p>Food production</p> <p>Costs and availability of foods may change due to extreme weather events and changes to rainfall</p>	<p>Obesity, micronutrient deficiency</p> <p>Increased costs of food</p>	Low income groups and remote and regional communities (Garnaut, 2008)
<p><b>Air Quality</b></p> <p>(Bushfire, dust, smog, O3, VOC and particulate matter, Legionnaires disease)</p>	Respiratory effects, asthma, allergic reactions	Young, Elderly, immuno-compromised, outdoor workers, people with pre-existing respiratory illnesses or heart conditions (Spickett, Brown & Katscherian, 2008)

Health Impact Scoping Matrix		
Climate Hazards	Potential Health Impact	Vulnerable Groups or Individuals
<p><b>Temperature and Rainfall</b></p> <p>Biodiversity Loss (drought, bushfire, precipitation and streamflow changes, changes to seasonal timing, saltwater intrusion and eutrophication, increase in invasive species, land degradation)</p>	<p>Costs and availability of goods and services, sense of place, mental health impacts</p>	<p>The communities in the study area, and in particular Indigenous residents and farmers (Gole, 2006)</p>
<p><b>Mean Global Temperature Increase</b></p>	<p>Reduction in winter colds, increase in summer heat stress</p>	<p>Young, elderly, immuno-compromised, athletes, pregnant women. People with no access to cool environments (e.g. no air-conditioning)</p>
<p>Marine Environment</p>	<p>Increases in marine algal blooms, increase in Ciguatoxin, southward migration of <i>Vibrio</i> spp.</p>	<p>Community, fishing industry, tourists</p>
<p>UV Exposure</p>	<p>Increases in UV exposure due to more outside recreation (cancer, eye disease)</p>	<p>Outdoor workers, recreation outdoors (California Natural Resource Agency, 2009)</p>
<p><b>Reduction in Annual Rainfall</b></p>	<p>Less water for industry, agriculture and domestic use. Degradation of recreational areas, increase in food production costs, changes to food types</p>	<p>Farmers, low income groups (Spickett, Brown &amp; Katscherian, 2008)</p>

<b>Health Impact Scoping Matrix</b>		
Climate Hazards	Potential Health Impact	Vulnerable Groups or Individuals
<b>Sea Level Rise</b> (damage or loss of infrastructure and places of recreation and economic activities)	Psychological stress, forced migration, loss of income (anxiety, depression), loss of essential services	Communities that experience sea level rise (California Natural Resource Agency, 2009)

Table 1 Health Impact Scoping Matrix.

More research is required in Australia regarding the economic, social, psychological and cultural components of vulnerability and adaptive capacity. Limitations for institutions and government to support adaptive responses require investigation (IPCC, 2014b). The National Climate Change Adaptation Research Facility (NCCARF) outlines research priorities for human health in the areas of heat exposure, extreme weather events, vector-borne disease, food, air and water quality, community and Indigenous health and health services and infrastructure (McMichael, et al., 2009). Using the HIA methods, these research priorities will be examined.

## **2.6 Conclusion of the Chapter**

Chapter Two explained the significance of climate change, adaptation and vulnerability in a rural setting. An introduction to the health impacts of climate change and limitations to future decision making due to uncertainty was also considered. Chapter Three examines the research designs and methods utilised in the study. Chapter Four details the profile of the research area and climate conditions. Chapter Five details the data analysis and Chapters Six and Seven examine the risks and appropriate adaptation strategies and presents a discussion and conclusion.

## Chapter 3 - Research Design and Methods

*“It is important that all the ways of life  
be taken account of in the policy  
process...all the ‘voices’ heard, and  
responded to by the others”  
(Verwiej et al., 2006, p. 6).*

### 3.0 Introduction to the Chapter

This Chapter describes the methodology used to conduct this rHIA. rHIA methodology includes several steps such as screening, scoping, profiling, identifying potential health impacts, assessing the impacts, decision making and evaluating the process. This Chapter describes the difficulties faced and the various adaptations the researcher had to make to secure credible data. The role of the researcher along with ethical considerations concludes the Chapter.

### 3.1 rHIA Methodology

The WHO recommends using HIA methods to assess the impacts of climate change and to formulate appropriate adaptation. Examining the concerns of vulnerable groups in a regional context (in this case the Blackwood Stirling) and the adaptive capacity of these groups will inform the adaptation to reduce or minimise risks (WHO, 2003b). The role of the person or team undertaking a rHIA is to facilitate the various stages of the assessment and to collect the evidence and ensure sustainable recommendations (EnHealth, 2001). The HIA practitioner or researcher should also be able to “gain insight into the complex systemic interactions between natural process, management policies and local people depending on the resource” (Hjortso, Christensen & Tarp, 2005, p. 1).

Screening is the process that identifies any significant health impacts of climate change that need to be managed (Spickett, Katscherian & Brown, 2015). The National Climate Change Adaptation Research Facility (NCCARF) has identified the South West of Western Australia as a vulnerable region to climate change that would benefit from an impact assessment to provide information about the implications of climate change, and possible adaptations (NCCARF, 2007). The scoping process

identifies potential health impacts prior to data collection and sets the objectives of the assessment (Spickett, Katscherian & Brown, 2015).

Profiling of the study area identifies baseline data for the population; demographic data, health status, observed climate and future projections (Spickett, Katscherian & Brown, 2015). Health determinants considered in the thesis are illustrated in the figure below; factors considered include biological and lifestyle factors, personal circumstances, social influences, availability and access, environment and economic conditions. Determinants of health and wellbeing influence the health status of communities and individuals. Climate change is likely to influence health and wellbeing determinants and may alter the sensitivity of communities to impacts (Costello et al., 2009). Community consultation will identify health and wellbeing determinants (EnHealth, 2001). A variety of communication methods and techniques were developed to gain a full picture of the views of the community.

**The Wider Social and Environmental Determinants of Health and Wellbeing image (International Council on Mining & Metals 2010) is unable to be reproduced here due to copyright restrictions.**

**The Wider Social and Environmental Determinants of Health and Wellbeing image can instead be accessed via <https://www.icmm.com/website/publications/pdfs/792.pdf>**

Figure 5 Determinants of Health and Wellbeing  
(International Council on Mining & Metals 2010, p. 14).

The assessment of the risks is achieved through qualitative or quantitative analysis. Qualitative assessments of climate change impacts utilise qualitative health risk assessment matrices to determine the likelihood and consequences of the risk occurring (Brown, Spickett & Katscherian, 2014). In order to gain consensus of the risk rating of future risks, expert judgments using the qualitative health risk assessment process can generate a single forecast using the Delphi Method. The Delphi method collects knowledge from experts through a series of questionnaires with controlled feedback to gain consensus of risk ratings. The qualitative assessments made by the expert participants in the Delphi method remain anonymous in order to prevent bias (Lange, Sala, Vighi & Faber, 2010).

The identification and development of adaptation strategies was informed by the data collected and the literature review and focuses on priority risks and vulnerable sectors in the communities (Brown, Spickett & Katscherian, 2014).

### **3.1.1 Data Collection Procedure**

Prior to any data collection, ethics approval for “Research with Minimal Risk” was applied for and endorsed by the Curtin University of Technology Human Research Ethics Committee – Approval Number SPH 32 2009. All participants were provided with information and consent forms that displayed the ethics approval number, along with contact details for further information. Participants signed a letter of consent that confirmed they had read the participant information sheet and understood the terms of their engagement. The online participants were not required to provide a signature of consent. All participants were given the opportunity to withdraw from the study at any time and informed that participation would remain confidential. The four sources of data collection were focus group meetings, stakeholder interviews, expert panel qualitative health risk assessment and a community survey. Community participants refer to persons residing within the study area that participated in focus group meetings and surveys. Stakeholder participants were interviewed about the current state of adaptation in the study area and expert participants refer to local and state government health experts.

The focus group meetings (n 48) conducted in eleven locations considered community expectations of the impacts, risks, vulnerabilities to and opportunities arising from climate changes. The semi structured interviews (19) of government and non-government stakeholders identified the policy and vision of various organisations in their preparation for climate change to 2030.

The Delphi Method was used to assess the health risks to the region through an iterative process between environmental health, public health and environmental science professionals in local and state government. The final aspect to the data collection was a survey distributed to individuals in the study area to identify priorities of expenditure for climate change adaptation.

The research process is illustrated in the following figure:

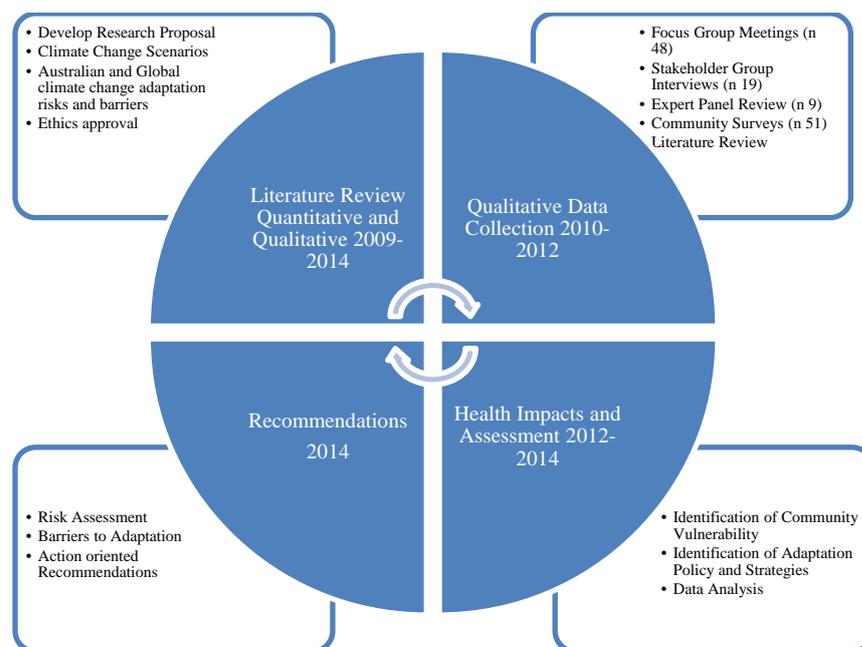


Figure 6 Timeline of the Research.

Each data collection process will be discussed separately, with data analysis methods discussed in Chapter Five.

## **3.2 Focus Groups – Community Participants**

### **3.2.1 Rationale**

Sheppard et al. (2011) argue that there is an urgent need to engage with local communities for a holistic approach to climate change and adaptation issues. Focus groups are a means to gather data from multiple participants discussing concepts concentrating on climate change adaptation (Millward, 1995). This gives the opportunity for participants to make “connections between individual and collective experiences” (Pini, 2002, p. 1). Themes identified during the focus group meetings form the basis for data analysis and were analysed using the NVivo 8 software package (QSR International, 2011).

Focus group meetings were held with the aim of linking the climate change information with local people who are able to conceptualise, visualise and localise future storylines (Shaw et al., 2009) and global emission scenarios and to make recommendations on how adaptation may evolve. Focus group meetings have been successfully used in Western Australia regarding adaptation strategies for the state as a whole (Spickett, Brown & Katscherian, 2008).

Local people are well versed in the nature of their communities from a physical and socio-economic context and are able to identify vulnerability from existing climatic hazards and current coping capacity and then identify the impacts from new and emerging hazards (van Aalst, Cannon & Burton, 2008). Having focus group meetings in different communities allows a range of social, physical and economic concerns to emerge from the research. The boundaries between the communities were defined by postal codes for ease of analysis with Australian Bureau of Statistics (ABS) data. In this way a group of unique communities with some similar geographic features can be analysed and compared. Shared geography and facilities such as rivers, national parks, road and communication networks, employment and hospitals, along with other informal links join these communities together.

The focus group questions were designed following the literature review of research gaps and opportunities of health impacts of climate change in Australia. The aim of the focus groups was to establish a variety of opinions (and themes) and to determine

current risks and vulnerabilities, future risk and vulnerabilities and opportunities for adaptation. Discrepant cases and outlier values were also sought (Ritchie, 2001). Some participants requested feedback at the end of the process in ‘layman’s terms’ which the researcher intends to oblige with a results summary being distributed by email. Diversity of the participants is desirable to increase the richness of data; however this is outside the limits of control where the participants are self-selected. Comparing the data between communities and with other forms of data collected is one method to triangulate the research data (Berry et al., 2009).

### 3.2.1 Method

A pilot focus group meeting was conducted prior to the community meetings in the researchers’ home. Two sessions were conducted involving (3) and (4) participants of approximately 2 hours each. These participants had a range of qualifications and employment that included agriculture, horticulture, forestry, business management, volunteer ambulance officers and education. A balance of male and females were included. The participants ranged between the ages of 35-65. Following the presentation the participants were invited to suggest improvements to the presentation. Pilot Group one had the following suggestions for improvement:

#### Pre-test Feedback

Rainfall: Provide rainfall data – past, present and future (5, 10, 20 years)

Rural community: Reiterate focus on rural community (not urban or regional context inappropriate to small rural communities)

Uncertainty: Appreciated factoring in uncertainty and explanation of uncertainty

Figure 7 Focus Group Pre-test Feedback.

Pilot Group two did not have any suggestions for improvement, however provided the following feedback:

“That was fine, all saturated with information”

“Did well, you did great”

“Very appropriate for this week”

The initial aim was to involve between four and twelve participants per meeting, or a minimum of 44 participants. Three different newspapers across the geographic area were used to advertise the dates of the eleven meetings, with three participants in total phoning in to express interest. Identifying and attracting active community members was more successful in recruiting participants than newspaper advertising and more cost effective. Participants were self-selected following community newspaper advertising, emailing networked individuals from within local Telecentres, along with phoning and emailing community centres.

The characteristics of the focus group meetings are displayed in the following table:

<u>Focus Group Participants</u>			
	Number of Participants	Gender	Age
Pilot 1	3	1 male 2 female	35-60
Pilot 2	4	2 male 2 female	40-65
Walpole	2 *drop out	1 male 1 female	50-60
Bridgetown	7	3 male 4 female	40-75
Pemberton	2 *drop out	1 male 1 female	35-50
Northcliffe	4	1 male 3 female	50-60
Nannup	4	3 male 1 female	50-65
Manjimup	1 *drop out	1 female	45
Greenbushes	6	5 male 1 female	40-65
Denmark	2	1 male 1 female	65-75
Augusta	5	5 male	50-65
Mt Barker	3	2 male 1 female	20-60
Boyup Brook	2 * drop out	2 female	40-65
Total	48	25 male 20 female	20-75

Figure 8 Focus Group Participants.

Drop out was an issue which affected the minimum number of participants, with a number of participants indicating they would participate and then not attending. One meeting per community only was offered due to the extensive travel involved (approximately 2,300 km). Refreshments were offered as an incentive and to make the participants comfortable. Meetings were held in Telecentres which were available

in each community (except Manjimup and Mt Barker where a Community Volunteer and Resource Centre and TAFE were used respectively). All focus group meetings were held during the January School holiday period in 2010 to encourage parents of school children to attend. The questions framing the focus group meetings are found in Appendix 1.0. Questions about what the participants have observed or read about the changing climate and how future changes might impact their lifestyles was the initial focus in the meetings. Opportunities arising from a changing climate and impacts to local amenities and places of importance were then discussed, followed by methods to increase benefits or reduce risks. Harm to the community in terms of costs, health impacts and damages were then discussed from direct and indirect climatic influence. Risks that cannot be prepared for (residual impacts) and the vulnerable sectors within the community were then identified.

Each participant was given the opportunity to speak and to discuss their findings with other participants within a set time. All the questions in Appendix 1.0 were covered in each community meeting with divergent views examined using peer reviewed data. All participants were kept in a safe and comfortable environment and were able to speak freely. Focus group meetings were recorded with a T10 iRiver recorder (iRiver, n.d.) and notes taken during the meeting. The focus group minutes were then transcribed verbatim (Kitzinger, 1995).

Text based information, group discussion and visual images (maps, graphs and photos) were used to demonstrate, define and elaborate on each topic during the PowerPoint presentation (Shaw et al., 2009). Visual representations of Global emission scenarios (maps of potential changes to rainfall and the global mean temperature) were shown and discussed, along with the likely indirect impacts identified in the literature review. Real life stories of observations to rainfall patterns and extreme weather events were discussed in the context of future climate change. Engaging with community participants to understand the links between risk and adaptation has been adopted for decision making in large and smaller communities; including London, New York, Boston, Nova Scotia, Vancouver and Seattle (Clean Air Strategy, 2007) and more locally in Australia, City of Melbourne Climate Adaptation Strategy 2009, (Maunsell Australia Pty. Ltd., 2008), and Eastern

Metropolitan Regional Council (EMRC) Climate Change Adaptation Project 2009-2013 (EMRC, n.d.).

### **3.3 Semi-Structured Interviews with Stakeholders**

#### **3.3.1 Rationale**

In order to examine regional climate change impacts, risks and adaptation actions, it was necessary to consult with a diverse range of stakeholders from local government, state government, NGOs, business and other sectors. Stakeholder interviews inform the research through qualitative methods and offer additional knowledge that may not be available elsewhere in a regional context (Bell, Turner, Meinke & Holbrook, 2014; Jones, Nix & Snyder, 2014). Stakeholder participants have a rich source of data and are employed in local government and community organisations. These stakeholders are responsible for and have interest in climate change and adaptation and can visualise and contextualise impacts and the action that needs to be taken. Stakeholder participants can identify locally observed impacts and potential risks that could be incorporated into government and NGO decision making (Holm, Stauning & Sondergard, 2011).

Research that examines the multi-level approaches to link up adaptation activities and policy is required for regional areas to effectively overcome and understand barriers to policy integration for adaptation. Those non-government organisations engaged with increasing equity in the community are also an essential part of this process. Engaging with busy professionals has challenges in terms of time and confidence in the process, particularly if the researcher is unknown, or has little stake in the outcome. Sectors that have influence over policy within the region include the following; health, transport, agricultural, infrastructure, land use, water, environmental, economic, food, social, energy and education policy (Daniell et al., 2011).

Adaptation research in Western Australia by Spickett, Brown and Katscherian (2008) has identified government and non-government stakeholders statewide. These are listed in the following figure.

**Sectors identified as stakeholders in adaptation research for Western Australia**

Treasury and all agencies	Indigenous
Welfare	Tourism
Recreation	OHS
Education	Quarantine
Community	Conservation
Forestry	Fisheries
Immigration	Insurance
Planning	Consumer Affairs
Emergency Services	Allied Industries
Communication	Health
Local Government	Environment
Water	Energy
Transport	Building / Housing

Figure 9 Sectors Identified as Stakeholders in Adaptation Research in Western Australia.

Inclusion for recruitment for the stakeholder group included senior government employees in local, state and national fields, with a minimum of five years' experience, along with stakeholders listed in Figure 9. It was estimated between fifteen and thirty six interviews would be required (Guest, Bunce & Johnson, 2006) using an adapted climate change policy questionnaire (Burton, Huq, Lim, Pilisova & Schipper, 2002).

Four questions were developed to investigate the current state of adaptation practices and policies in the region (Appendix 2.0). The semi structured interview questions focused on existing adaptation action in the region, adaptation action under development and barriers and limitations to adaptation. The benefits and costs of adaptation action were discussed, along with the inclusion of concerns from local communities in formulating the development of adaptation policies. The data collected was analysed and coded, with themes emerging for each question.

This provides an opportunity to identify gaps where adaptation may be required and opportunities to link up adaptation processes. This information can be used to make recommendations for local, state and national governance with the aim being to prevent negative health impacts and enhance positive health impacts where possible. Achieving saturation of interview data is the intended goal, however as climate change policy is being rapidly developed and is also dependent on several external

factors, this may not be possible (e.g. global and national policies pertaining to energy). Further, saturation can only be achieved following analysis of the qualitative data and the determination and examination of themes. Returning the data to the participants goes some way to verify and ensure the quality of data, along with comparing themes generated to similar studies (Cutcliffe & McKenna, 2002).

### **3.3.1 Method**

A pilot interview was conducted on the 29<sup>th</sup> January 2010 with a senior government officer known to the researcher to determine the length and appropriateness of questions, which took approximately 20 minutes. A total of fifty seven (57) government and non-government agencies were invited to participate in the research. Each agency was initially contacted by telephone; willing participants were forwarded four interview questions prior to an interview taking place. All interviews were conducted between January and May 2010 (questions found in Appendix 2.0). The interviews were conducted by telephone due to distance of the participants from the researcher (in Western Australia). The questions were provided to participants prior to the interview by email. For the reasons listed previously many working professionals declined an interview, this included political figures, state and local government, business and non-government organisations.

Any gaps in data on adaptation activities by government and non-government will be addressed through secondary data in the literature review. The interviews were recorded with an mp3 device (iRiver), some participants requested to complete the questions by email only. The interviews took between 15 minutes to 45 minutes. Each interview was transcribed verbatim and the participants were given the opportunity to verify and reconsider any pertinent details.

In total, 19 interviews were conducted (or a 33% return rate from initial contact), these included the following industries and interest groups:

### **Characteristics of Stakeholder Interviews**

Environment and Conservation (government and non-government)

Transition Network

Fire and Emergency

Water

Environmental Engineering and Waste

Resilience Approaches to Governance and Management

Local Government

Non-Government Organisation – Energy Equity

Insurance

Indigenous and Health Issues

Local Fire Brigade

Agriculture and Technology

Figure 10 Characteristics of Stakeholders Interviewed.

## **3.4 Expert Panel – Expert Participants**

### **3.4.1 Rationale**

Complex problems, such as defining health risk for climatic change (with uncertainty for future outcomes) lend themselves to decision making tools such as the Delphi method, or expert panel method. Iterative approaches to gaining consensus for a complex problem begin with an initial question to a number of experts. Experts should be respected by their peers as having considerable knowledge about the subject (in this case public health) (Mertens et al., 2004). The responses, or answers are then communicated to each expert participant in a series of anonymous rounds, with the group being advised of the outcomes in a confidential way until some consensus is achieved (e.g. an opportunity to review one's answers until agreement is achieved about the level of risk for each health impact). In this case the consensus would be to conduct a qualitative health risk assessment of the potential health risks and to rate them according to the potential consequences and likelihood of the risk occurring. A risk rating for each health impact (either very low, low, medium, high or extreme) can then be determined (Spickett, Goh, Katscherian & Ellies, 2010).

A limited number of rounds between expert participants to achieve consensus regarding risks was utilised to reduce the likelihood for drop out. As drop out had posed a problem in the initial data collection processes it was determined that two consensus rounds would be offered, one to take place at the initial brainstorming meeting and one electronically by email. A modified Delphi deviates from the traditional method as there are less than three rounds and panelists may use a variety of feedback mechanisms including post, email, or online (Hasson & Keeney, 2011). Anonymity of results allows participants the option of changing their minds and to avoid bias due to group dynamics (Doria, Boyd, Tompkins & Adger, 2009). Limitations can include poor question design, poor execution and limited expert involvement, or fatigue from a long or lengthy consensus program and drop out (Geist, 2010).

### **3.4.1 Method**

Expert participants that contributed to the qualitative health risk assessment and Delphi Method were located in Perth (Department of Health) (n 7) and the lower South West (local government) (n 2). Permission was gained from Department of Health (DOH) Management prior to inviting senior public health participants in Perth (persons with at least 5 years' experience in a public health or environmental health role) to undertake the expert panel review. The lower South West participants were contacted by telephone. These participants were employed in senior roles managing Environment and Environmental Health Departments in local government.

The expert participants in Perth were invited by email to attend the expert panel review at Grace Vaughan House (Perth) on the 26<sup>th</sup> July 2010 (n 6). Lower South West participants (n 2) conducted their review in Bunbury on the 24<sup>th</sup> January 2011. Information was provided to the participants prior to the meetings that included consent to participate, a summary of the research and a description of the study region. Details of the procedure for the Delphi Method and the qualitative health risk assessment were also provided. The expert panel review had three processes; identifying the potential health impacts, conducting a qualitative health risk assessment to determine the likelihood and consequences of each impact and to develop a risk rating. In the final process, experts were able to review the risk ratings

developed by the other participants prior to conducting a second qualitative health risk assessment of all the listed impacts. Each expert's judgment of risk was kept confidential between the participants.

A PowerPoint presentation was delivered to the expert participants that detailed the rHIA, a description of the study area, climate change scenarios (including uncertainty), community participant concerns of vulnerability and the method of undertaking a qualitative health risk assessment. The expert participants were invited to ask questions and clarify any points of interest throughout the presentation. The expert participants were asked to identify and discuss likely health impacts and list these using stationary provided. For the impacts each participant had listed, they were instructed to apply the risk rating criteria. This involved making a judgment of the health consequence of being unable to avoid that impact (for example experiencing an injury during a bushfire). A judgment of the likelihood of the impact occurring, along with the consequences are used to form a risk rating for that risk.

The tables used to make risk judgments are listed below.

**The Categories for Health Consequences image (Spickett, Goh, Katscherian & Ellies, 2010, p. 11) is unable to be reproduced here due to copyright restrictions.**

**The Categories for Health Consequences image can be accessed via  
<http://ww2.health.wa.gov.au/~media/Files/Corporate/general%20documents/Environmental%20health/Health%20risk%20assessment/HRA-Scoping.pdf>**

Table 2 Categories for Health Consequences  
(Spickett, Goh, Katscherian & Ellies, 2010, p. 11).

**The Likelihood Categories for HIA image (Spickett, Goh, Katscherian & Ellies, 2010, p. 13) is unable to be reproduced here due to copyright restrictions.**

**The Likelihood Categories for HIA image can be accessed via  
<http://ww2.health.wa.gov.au/~media/Files/Corporate/general%20documents/Environmental%20health/Health%20risk%20assessment/HRA-Scoping.pdf>**

Table 3 Likelihood Categories  
(Spickett, Goh, Katscherian & Ellies, 2010, p.13).

**The Risk Matrix for HIA (Qualitative) image (Spickett, Goh, Katscherian & Ellies, 2010, p. 13) is unable to be reproduced here due to copyright restrictions.**

**The Risk Matrix for HIA (Qualitative) image can instead be accessed via <http://ww2.health.wa.gov.au/~media/Files/Corporate/general%20documents/Environmental%20health/Health%20risk%20assessment/HRA-Scoping.pdf>**

Table 4 Qualitative Health Risk Assessment Matrix  
(Spickett, Goh, Katscherian & Ellies, 2010, p. 13).

By using a risk matrix the expert participants judged the risks to be either very low, low, medium, high, or extreme. The information was then collected, with the expert participants being informed that they would conduct a second health qualitative health risk assessment and would be contacted by email with the data collection instrument. The meetings took approximately one hour each. Following the expert panel review in Perth an additional DOH expert (n 1) was invited to participate in the second round of the qualitative health risk assessment

The total number of expert participants involved with the expert panel was nine (9) which meets the criteria outlined in the literature review (Sobal, 2001).

<b>Expert Participants</b>	
Department of Health Perth	7
Local Government in South West	2
Total	9

Figure 11 Expert Participants.

### **3.5 Adaptation Survey – Community Participants**

#### **3.5.1 Rationale**

The National Climate Change Adaptation Research Plan (Human Health) outlines significant gaps in knowledge relating to differential vulnerability within communities and the assessment of adaptive strategies. Assessments should include cost benefit analysis (PMSEIC Independent Working Group, 2007), an indication of the urgency of implementing adaptations and the need to change any current

interventions. Benefits should be assessed with regards to equity and continued vulnerability of sub-groups within the population (with regards to geographic or socio-economic factors) (McMichael et al., 2009). Willingness to pay is another method to estimate the amount individuals will sacrifice from their household budget in order to avoid damages or obtain benefits (e.g. from the environment) (Witzke & Urfei, 2001) (these could include soft and hard adaptation activities) and no regret options (AECOM, 2010a).

A mixed mode approach of web and mail was utilised for the survey to reach a large population and to save time and costs associated with telephone, or face to face interviews. Advantages of online questionnaires include reduced data entry tasks and potential for error. Methods to increase response rates included contacting the participant prior to the release of the survey instrument and having a low number of questions that are reasonably easy to understand and follow (Guise, Chambres, Valimaki & Makkonen, 2010). One limitation of this is that complex problems are difficult to address when simple, linear questions are asked (Verweij et al., 2006). Question design should therefore give options to for open ended questions, as well as standard Likert or scaling choices (Sawyer, 1990). Low response rates are critical factors with regards to mail out surveys, in fact web surveys may have higher non-response rates and are inclined to favour the 'youth' demographic (Borkan, 2010).

A community survey was developed to gather quantitative and qualitative data relating to views on adaptation from local participants in the Blackwood Stirling region in order to capture information and 'outlier' views that may not have been recorded in other methods. Using the method described by Lo (2009) it was determined that approximately 400 responses would be a sufficient sample size for a random sample, (for a population between 10,000 and 100,000). The sample size calculation is appended (Appendix 3.0).

In order to manage time and expenses associated with data collection and analysis the survey was distributed to random participants across 600 households. The survey had 32 questions and took approximately 10-15 minutes to complete. A pre-test of the survey to three participants resulted in some minor changes that were

incorporated in the final survey (question style and adaptation options). A complete list of the questions can be found in Appendix 4.0.

The survey began with easy questions that defined the financial underpinning for further adaptation cost questions (Questions 1-6). Questions 7-16 were related to the individual's home and work life that may need changing to adapt to a different climate by 2030. A list of options was provided about what types of changes could be undertaken and how much money would be set aside each year to complete these changes. Question 17 asked individuals to rank the order of importance for expenditure towards critical infrastructure and ecological sites within their community. Questions 18-27 asked individuals to allocate funds (in monetary terms) to the areas of infrastructure that might be required for adaptation. Question 28 asked individuals about further action the government could take to prepare for climate change. Question 29 asked the participants about other initiatives that were required in their community. Question 30 asked if they would be willing to pay for any of these investments from their own income. Question 31 asked participants if any households would remain vulnerable despite adaptation, with question 32 giving the opportunity to provide feedback about the survey itself (Lee & Cameron, 2008).

### **3.5.1 Method**

Invitations to participate in the survey were sent to 600 households in the study area in July 2011. Using the local telephone directory (South Western W.A.), systematic sampling was used by counting every 12 names starting from A (to obtain 300 names), then L (to obtain 300 names) (ABS, 1996). The invitations listed the consent and information details and information for an online survey that was available through a free server to students, "Survey Gizmo" (Survey Gizmo, 2011). A limit of one month was given to try to achieve a reasonably fast turnaround, but also to fit in with persons that had a busy schedule.

Five surveys were completed online. Following this low feedback, each 600 phone numbers was contacted once, a message was left if a message device was available, or the householder was spoken to regarding the nature of the study and the survey. Of the twenty eight persons that agreed to complete an email survey, only one

returned a completed form. Reasons given for not completing the online survey were feelings of insecurity putting personal details on the ‘internet’ and lack of access to a computer. Bearing this in mind, participants were told they did not have to answer every question and a paper survey could be posted.

Of the telephone refusals received, ‘lack of time’, ‘not interested’, ‘disability/illness’ and ‘old age’ were the main reasons. Of the nearly two hundred messages left, only one person telephoned to say they would be interested in completing the survey. A further 152 surveys were posted to the willing participants contacted by telephone; each person was supplied with an addressed stamped envelope. Motivation for participating may be related to interest in climate change, supporting local research or having available time (retirees in particular). In total fifty one persons completed the survey, or an 8.5% response rate.

<b><u>Phone response to invitation to complete survey</u></b>	
Declined	49
Left message	196
Could not be contacted	175
Emailed survey information	28
Posted survey	152
Completed Surveys	51

Figure 12 Phone Response to Invitation to Complete Survey.

The low response rate to the survey results in the data being unable to be applied to the population as a whole has similar results to a self-selected convenience (purposive) sample where persons who are interested in the research are more likely to return the survey than those who are not (Yoon & Horne, 2004). Many persons were unable to answer more complex questions relating to allocating funds for expenditure in their local community and did not answer the questions correctly, or did not answer them at all. Some individuals gave feedback regarding the questions.

In order to increase the response rate for the survey, an additional paper survey was released to two communities with low socio-economic status that were identified as having limited services with a small population. Greenbushes and Cranbrook have Socio-economic indexes for area (SEIFA) of 862 and 919, based on 2006 Census results. Using the same procedure for the primary survey, a minimum sample size of 158 participants for Cranbrook and 189 participants for Greenbushes was calculated (Appendix 3.0). In total 175 surveys were mailed out per community (350 in total) would yield an adequate sample size (Lo, 2009). Each community has a minimum of 70% couple households, or couple with children households (e.g. two or more persons per household) (ABS, 2007). Greenbushes has approximately 300 post office boxes and Cranbrook approximately 280. The survey was posted to the even numbered post box numbers in January 2012, (e.g. PO Box 2, 4 etc.) to 176. The participant information sheet was also shortened and simplified. Only two sheets per envelope ensured less reading and a simpler process for participants. In order to adapt to community concerns relating climate change within a broader focus of sustainability, the survey was amended to examine these issues, existing vulnerability, as well as to look at climate change issues. In this way it was hoped that the survey would appeal to a wider audience and decrease drop out (Baker, Homan, Schonoff & Kreuter, 1999). Having a higher number of open ended questions allowed participants to illustrate several areas of interest, instead of likert or tick-a-box options.

The secondary survey found in Appendix 5.0 was two pages long with eighteen questions. Questions one to five ask participants about positive and negative aspects of their community and how these will change by 2030. Questions 6 and 7 focus on vulnerabilities to the communities and how these might change. Questions 8 to 11 focus on personal income and assets and how much people are prepared to spend on adaptation. Questions 12 to 14 ask what government priorities ought to be when considering risks to communities. Questions 15 and 16 ask about reducing vulnerability and factors that prevent people from adapting (or being more sustainable). Question 17 asks specifically what aspects of climate change are most concerning and question 18 leaves room for open comment. The survey concludes with thanks and an area for a participant signature.

### **3.6 Role of Researcher**

The role of the researcher is to objectively collect data, determine the potential risks and impacts and to be open to alternative beliefs and priorities of differing groups (Harris-Roxas, Simpson & Harris, 2004, p. 7). Feedback from community participants was generally positive; some participants stated that the wide number of topics under consideration did not allow for detailed answers, more open ended questions may be required to gain understanding of community participant views. Two participants from different communities suggested in order to effectively address climate change a holistic approach would be required, one that incorporated all sectors of the community and their concerns and interests.

The aim of a rHIA is to assess the impacts of climate change by following the methods outlined in this Chapter. It is likely that there is some bias for data collected from self-selected participants as they may have an interest in climate change that is not representative of the whole population. These biases are reported with any associated findings (Leung, 2009). All data collected was recorded and transcribed verbatim to reduce or eliminate reporting bias. Pretesting data collection instruments was also employed to improve focus group, stakeholder interview and survey questions. Using software to analyse qualitative data reduces the possibility of reporting bias (Kanuha, 2000).

### **3.7 Data Collection and Secondary Sources of Data**

The literature review involved database searching of peer reviewed journals, a grey literature search and a search for recent material. The most commonly used databases were Proquest, PubMed and ScienceDirect. Fields in health, social science, environment, climate and ocean research were searched. Search terms included (health, impact, climate, sea level rise, risk, Western Australia and climate change and were used in alternate combinations). The Google search engine was used to look for recent publications and websites regarding climate change and health, as developments and research in these areas were being rapidly developed during this research period (Harris-Roxas, Simpson & Harris, 2004). Data collection involved the literature review of peer reviewed journal articles, government publications (including ABS statistics and reports) and international and local guidelines and research regarding health and climatic change.

The focus groups and semi structured interviews were recorded and transcribed verbatim, with data being uploaded into NVivo8 as word documents. The audio material was recorded onto a USB Drive and uploaded to a secure external hard drive until 2016, at which time it will be destroyed. The Delphi Method collected paper material from the meetings along with information by email for the second round of decision making.

### **3.8 Data Analysis**

The literature review was used to inform the research during each stage of the rHIA process; screening, scoping, profiling, risk assessment, risk management and project evaluation. All qualitative data was analysed using content analysis methods (Hsieh & Shannon, 2005). During the focus group meetings member checking was achieved as each participant had the opportunity to discuss and clarify views with the presenter and other participants (Harper & Cole, 2012). Discussion of issues beyond the questions outlined in Appendix 1.0 occurred freely within the time limits of the meetings to ensure for saturation of data and to determine other factors that would influence health. Focus group meeting data was analysed and collated using NVivo8 as a tool in order to develop themes and connections between communities using coding stripes. Case nodes were assigned to each community and all material was explored using the themes of the ten questions identified in Appendix 1.0 as codes (QSR International, 2011). As other themes emerged from the data, (e.g. water and energy) these were also coded to examine connections between places and topics. Word frequency searches were run to interpret the frequency of themes or codes as being important to participants in the context of research (Wathen & Harris, 2006). Outlying values are identified during the meetings as well as following the examination of the data.

The semi structured interviews were analysed by identifying themes that emerged from the responses to the four questions in Appendix 2.0 by counting and comparing similar responses (or themes) to each question. Each theme was interpreted in the context of the respondent from government and non-government agencies. Locally observed impacts that had a negative impact were a priority for government and non-government agencies and the resources or policy changes that would be required to address these; an example being the reduction in recharge of dams and inlets that

provide water for domestic and industrial uses. The stepwise decline in annual rainfall and reduced water quality increases the costs of treatment. For the stakeholders that had not observed local impacts, priorities related to the costs and benefits of adaptation and the vulnerability of various groups to climate effects. For example, thermal stress experienced by people that are renting and are unable to change the insulation standard of their dwelling will have greater reliance on air-conditioning and the associated costs, or may have health effects.

Expert participants identified future health impacts following a Power Point presentation and group discussion. The participants then used the qualitative health risk assessment matrix (Table 4) to determine the likelihood and consequences for the identified health impacts and made judgments of the risks to be from; very low, low, medium, high and extreme. During the expert panel review, minutes were taken that were later transcribed verbatim. During the third and final phase of the expert panel review the expert participants conducted another qualitative health risk assessment using the same methods for all the potential health impacts that were identified, including some additional impacts recognised in the literature review.

Data collected from the paper survey were analysed to examine the similarities or differences between household hold type, income, location, type of home ownership and adaptation and potential expenditure; themes relating to adaptation priorities were developed (Hseih & Shannon, 2005).

### **3.9 Ethical Consent and Validity**

Ethical consent was obtained from every participant prior to conducting the data collection. As this is qualitative research using climate change scenarios of future events and populations with significant levels of uncertainty, the qualitative risk assessment has limitations. The views and concepts of importance held by the community participants are however “sound, credible and trustworthy” (Ritchie, 2001, p. 154) and the study can be replicated in future in other communities by researchers at various intervals in time as climate forecasting changes. Multiple methods of data collection were used to increase understanding of the phenomena being researched. Where agreement was found between the scientific literature and

the various types of data collected, this ensures the validity of the results (triangulation).

Qualitative research requires sampling extensiveness in order to provide answers, or data that is useful, is credible and is achievable within a time period with appropriate resources (Lorenzoni, Nicholson-Cole & Whitmarsh, 2007). Extensiveness refers to number and diversity of the participants and the breadth of inquiry (Safman & Sobal, 2004). Saturation refers to the collection of data in a study until repetition begins to occur and no new data is found (Walker, 2012). Where saturation cannot be obtained, purposive sampling is a plausible alternative (Sobal, 2001). Participants are selected in purposive sampling on the basis that rich and unique information will be obtained that is of value to the study (Suen, Huang & Lee, 2014).

The use of qualitative research methods to understand human behavior enhances the research process and leads to fuller development of knowledge, rather than examining numerical values in quantitative data alone (Ritchie, 2001). The data collected may differ between the study group and another region due to difference in education and life experiences of participants and their ability to communicate views, climatic experience of that region (including extreme weather events and bushfire), and health knowledge (Last, 1983).

Self-selected participants and snowballing techniques to engage interested individuals may not present all the views held within the community and a lack of health knowledge in the participants would also decrease brainstorming ideas relating to public health. The expert panel is made up a diverse group of individuals that over time may change their opinions on risk as their knowledge and experience increases and risk from climate change become more or less apparent, so the risk assessment carried will likely change. The stakeholder group can only comment on the gaps in adaptation policy as they occur during the research, which may also change for the reasons listed.

### **3.10 Limitations to Research in Rural Communities**

As rural community populations are typically smaller than urban communities, a limitation for quantitative or qualitative research is to have access to a large enough

sample size to produce statistically significant results and to prevent participant fatigue or dropout through contacting willing participants a number of times (Brehman et al., 2009; King & McCarthy, 2009). In order to attract participants to focus groups or surveys, advertising or direct contact of known networks can be employed; these techniques are known as opportunistic sampling or snowballing. Self-selected participants may have selection bias that has limitations for generalising any results across the study group (Palinkas et al., 2013). Drop out and fatigue may also contribute to low numbers, lack of understanding of the question or responses that are unusable. In order to ensure heterogeneity, multiple methods are useful – a diversity of residents of local communities to ensure that all key themes are picked up e.g. using paper and online surveys as well as focus group approaches. Triangulation can help to enhance the credibility and robustness of the findings e.g. comparing responses of local communities and professional stakeholders can help to identify consensus/differences within and between these two groups of participants.

Adapting the research tools to facilitate greater feedback through shortening the number of questions or question design may increase the sample size. If initial results do not yield useful information due to question type, changing the types of questions to be more open ended or with more limited choices (such as a likert scale) may yield more useful data. Questions that may influence participation such as personal income could be avoided if there are concerns relating to privacy, particularly for online surveys (O’Neil, Penrod & Bornstein, 2003; Wray, Markovic & Manderson, 2007). The physical distances in Australia between rural communities are also a time limitation for urban or remote researchers to make contact with rural populations which may encourage more paper surveys compared with meetings or interviews. This may also limit multiple points of contact between the researcher and the participants for review of responses or project evaluation. Ensuring adequate time in the field to increase participation in meetings and interviews and offering a number of times and locations will attract various demographics within communities and will be dependent on the research budget (Gifford, 1996).

### **3.11 Summary of Chapter Three**

Chapter Three examined the rHIA methodology used in the research and presents the methods and rationale for the data collection and analysis. The Chapter outlines the multiple qualitative research methods and multiple data sources used to ensure validity, convergence of data and triangulation of results. Issues of consent and ethics, limitations and research timeline are discussed. Chapter Four outlines the profile of the study area for the population and future climate using ABS data, Bureau of Meteorology observations and climate scenario data, with Chapter Five analysing the data collected. Chapter Six provides a risk assessment for the future health impacts and Chapter Seven is an overview of the research and future recommendations.

## **Chapter 4 – Community and Climate Profiling**

### **4.0 Introduction**

Chapter Four will discuss the current and future population in the study area of the Blackwood Stirling region, along with current demographic trends relating to health and socio-economic factors. Local government areas are examined, along with climate and extreme weather history. Likely future changes to climatic ranges are discussed, using climate models. Stabilisation of the climate and potential worst case scenarios are examined. Future climate scenarios for the region include humidity, temperature, evaporation and rainfall.

### **4.1 Profiling Data – Demographic and Climate Factors**

#### **4.1.1 Population Changes to 2030**

The community profile considers the future population of the Blackwood Stirling to 2030 using projected trends from the ABS and some existing data on the current population. These trends rely on assumptions about migration, fertility and life expectancy that are linked with social, economic and environmental conditions and are therefore subject to considerable uncertainty (ABS, 2009). Factors to be considered include population changes and demographic changes, particularly with regards to changes to the profile of the elderly to very elderly. Socio-Economic Index for Areas (SEIFA) will be used to identify areas of vulnerability to future climatic and socio-economic changes. Historical climate data and future climate, along with associated health risks will also be considered looking at different suburbs within local government areas.

The future population of the Blackwood Stirling is forecast to be 47,429 by 2027 (ABS, 2008b). Growth is expected to continue along the coast in the urban areas of Margaret River, Augusta and Denmark and has been linked with overseas migration to W.A., migration of elderly retirees to the region and lifestyle/employment and services opportunities. As a result the demand for goods and services relating to health and aged care are expected to increase in the region (Western Australian Planning Commission (WAPC), 2009). Supertown initiatives may influence future population growth to Margaret River and Manjimup, with potential doubling of the population over the next three decades, Manjimup has recently observed a reduction

population by 0.5 per cent per annum over the last five years (WAPC, 2015a). Another feature of the ageing population is the change to the dependency ratio. In 2007 for each older person there were five working aged people; in 2056 for each older person there will be three working aged people which could also have social implications (ABS, 2009a). The old age dependency ratio is higher in rural areas compared to urban areas as these regions are popular for retirees. Taxation for working age persons may need to be adjusted to accommodate the higher costs associated with non-working persons (e.g. medical costs). Social isolation may add to the vulnerability of older persons, especially those persons in a single income household reliant on a pension (ABS, 2009; Australian Government 2008a).

Potential population change per local government area to 2027 are summarised below:

- The population of the Shire of Augusta-Margaret River is expected to rise from 11,570 persons in 2007 to 17, 315 persons in 2027.
- The Shire of Boyup Brook is expected to decrease from 1,576 persons in 2007 to 1,564 persons in 2027.
- The Shire of Bridgetown Greenbushes is expected to increase from 4,244 in 2007 to 4,442 in 2027.
- The Shire of Cranbrook is expected to increase from 1,129 people in 2007 to 1,239 people in 2027.
- The Shire of Denmark is expected to rise from 5,011 people in 2007 to 6,529 people in 2027.
- The population of the Shire of Manjimup is expected to decrease from 9,843 in 2007 to 9,023 people in 2027. The population of Manjimup may increase due to the Supertown initiative.
- The Shire of Nannup is expected to increase from 1,293 people in 2007 to 1,545 people in 2027.
- The Shire of Plantagenet is expected to increase from 4,804 people in 2007 to 5, 772 people in 2027 (ABS, 2008b; WAPC, 2015a).

### **4.1.2 Discussion of Changes to Population to 2030**

Population decline may be observed in the Shire of Boyup Brook and the Shire of Manjimup by 2030, however due to the Supertown initiative, the Shire of Manjimup may observe an increase in population over the next three decades (WAPC, 2015a). Local government amalgamations may increase efficiency and service provision (Dollery, Goode & Grant, 2010).

Strong growth in the very elderly group on average of 200% (or doubling aged over 85) is a demographic transition for this region, which may also increase lone householders of women (ABS, 2008b). Low income elderly groups are recognised as being socially disadvantaged and will form a significant new demographic Australia wide (United Nations, 2002).

### **4.1.3 Socio Economic Index and Deprivation**

The Socio Economic Index For Area (SEIFA) uses a summary of variables to describe socioeconomic advantage or disadvantage for an area (by state suburb) relative to other areas, the information used to define the indexes relates to access to “material and social resources; and ability to participate in society”. The average score is 1,000. There were a diverse range of socio-economic ratings within these geographic boundaries (ABS, 2008a). When comparing National Health Data with SEIFA deciles the ABS has concluded that self-reported health status (compared to Index of Economic Resources Decile) declines with lower values, that smoking increases in this scenario (Index of Relative Disadvantage) and body mass index increases (obesity) with lower Index of Education and Occupation deciles. Mental health status is measured to have higher levels of distress in areas with an index of relative disadvantage when compared to areas of relative advantage (Pink, 2006). Community development, employment and education opportunities are critical to preserving, enhancing and maintaining health (McCabe & Davis, 2012). Communities with lower SEIFA may be considered to have lower adaptive capacity to deal with climate change impacts; Table 50 lists the SEIFA for each community from the lower range to the higher range in the study area (Appendix 6.0).

Population decline and low socioeconomic status in some areas of the Shires of Manjimup and Boyup Brook may impact adaptive capacity due to financial constraints, when compared to adjacent local government areas (ABS, 2007). Pockets of affluence exist within local government areas, for instance comparing Walpole town with Manjimup town, or Denmark town with Shadforth. Satellites suburbs out from the town centre appear to have higher SEIFA ratings, with the exception of Greenbushes. A higher proportion of elderly residents on fixed incomes will also affect the SEIFA rating. The Shire of Cranbrook may also be considered vulnerable based on the SEIFA data.

Local government areas with the primary industries and employment of sheep, beef and cattle farming (and school education) appear to have lower SEIFA indexes than regions that have more industries based around beverage manufacturing and accommodation (ABS, 2007). Communities that aren't able to capitalise on value adding of farm grown produce may be more vulnerable to shocks from climate change, particularly small Wheatbelt operations along with pasture fed beef in the south coast region (Nelson et al., 2010).

#### 4.1.4 Population Density

The following figure reveals population density in the region:

**The Geographic Distribution of the Population image (ABS, 2008c) is unable to be reproduced here due to copyright restrictions.**

**The Geographic Distribution of the Population image can instead be accessed via [http://www.abs.gov.au/websitedbs/CaSHome.nsf/4a256353001af3ed4b2562bb00121564/2b4f4a25b3b0b7f2ca257305002bce30/\\$FILE/ATTD0Z68.jpg/Figure%201.jpg](http://www.abs.gov.au/websitedbs/CaSHome.nsf/4a256353001af3ed4b2562bb00121564/2b4f4a25b3b0b7f2ca257305002bce30/$FILE/ATTD0Z68.jpg/Figure%201.jpg)**

Figure 13 Population Density South West Australia  
(ABS, 2008c).

The Shire of Augusta-Margaret River has the highest population density in the region, due to development of coastal areas and close location to the capital City Perth and Cities of Busselton and Bunbury.

The table below demonstrates remoteness by community:

Suburb	Remoteness Type
Augusta Boyup Brook Bridgetown Cowaramup Cranbrook Denmark Gracetown Greenbushes Karridale Manjimup Margaret River Mount Shadforth Nannup Narrikup Pemberton Prevelly Rocky Gully Tenterden Tone River	Outer Regional
Northcliffe Quinninup Walpole Windy Harbour Cranbrook (some areas)	Remote
Mount Barker	Inner Regional

Table 5 Remoteness by Suburb  
(ABS, 2013e; ABS, 2013f Doctor Connect, 2013).

The locations that are considered remote are in the Shire of Manjimup and Cranbrook, with increased distances to services.

#### 4.1.5 Hospital Admissions

Hospital admissions in regional towns such as Manjimup, Margaret River, Augusta and Denmark may be utilised more per person than urban hospitals due to the lower socio-economic status and a higher proportion of chronic conditions in rural

communities (Government of Western Australia, 2013a). Some health issues will likely involve transfers to larger regional hospitals, or to Perth. The Royal Flying Doctor Service is critical to access specialised treatment, with outcomes for patients in rural areas declining with distance to hospital care (Fatovich, Philips, Langford & Jacob, 2011).

Private hospitals may also be utilised by locals (such as Bunbury St John of God), accessing Perth facilities may involve lengthy transfers and private costs if not covered under the patient assisted travel scheme (PATS) (Langford, 2009). The PATS provides a subsidy towards the cost of travel and accommodation for those patients that need to travel long distances for specialist medical services (Department of Health, 2011a). Preventing unplanned hospital admissions by strengthening primary health care (e.g. addressing the causes of multimorbidity, mental health factors and socio-economic deprivation) is of relevance now and in future. Low levels of physical activity, obesity and smoking also have strong links to socio-economic factors. Access and consumption of fresh fruit and vegetables was considered to be below the recommended guidelines across all areas of socio-economic advantage and disadvantage in Australia (Australian Government, 2010; Australian National Preventive Health Agency, 2013; Payne, Abel, Guthrie & Mercer, 2013).

Multimorbidity risk factors were higher in the elderly age groups, however also relate to those persons under sixty with regards to health status and health literacy, obesity, education attainment, polypharmacy, marital status and country of birth (Taylor et al., 2010).

#### **4.2 Population Profile by Local Government Area**

The population profile of the region will describe the age, gender, birth rate, ethnicity, employment, remoteness and SEIFA data. Climate and weather data will follow with identification of the at-risk regions, based on both exposure to climate and vulnerability factors. The determinants of health and wellbeing as depicted in Figure 5 will be more fully explored in the data analysis Chapter, using the community participant data collected to shape the perceived risks, with additional literature to examine any trends.

#### 4.2.1 Shire of Augusta-Margaret River

This Shire has a land area of 2,242.4 km<sup>2</sup>, with a total population of 11,761 persons, or, 5.2 persons/km<sup>2</sup>. All of the residents were classified as “outer regional”, which refers to distance to service centres (Doctor Connect, 2013). In the 2011 census 5,898 persons were male and 5,863 were female, or 50.1% male and 49.9% female. Age distribution by percentage is described in the following table:

Persons 0-14 years	21
Persons 15-24 years	9.1
Persons 25-34 years	12.8
Persons 35-44 years	17.5
Persons 45-54 years	15.0
Persons 55-64 years	13.0
Persons 65-74 years	6.9
Persons 75-84 years	3.9
Persons 85 years and over	1.6

Table 6 Population of Shire of Augusta-Margaret River 2011  
Age by Percentage (ABS, 2013a).

The total fertility rate for 2012 was 2.18 (ABS, 2013c), with 18.9% of the population born overseas. Overseas countries of birth were England, New Zealand, Scotland, Germany and South Africa with other languages spoken at home being German, Italian, French, Portuguese and Dutch (ABS, 2013a). The Socio-Economic Index for Area (SEIFA) for the Shire in the 2011 Census was recorded as 1013 (ABS, 2013d). The Indigenous population was recorded at 113 persons. When examining the labour force in 2011, 51.2% work fulltime, 4.2% were unemployed, with 36.4% working part time or in other employment arrangements (ABS, 2013a).

#### 4.2.2 Shire of Denmark

The Shire of Denmark has a land area of 1860.1 km<sup>2</sup> with a total population of 5,194 persons, or 2.79 persons per km<sup>2</sup>. All of the residents were classified as outer regional. In the 2011 census there were 2,554 males and 2,640 females, or 49.2%

male and 50.8% female of the population (ABS, 2013a). Age distribution by percentage is described in the following table:

Persons 0-14 years	19.2
Persons 15-24 years	8.5
Persons 25-34 years	7.4
Persons 35-44 years	12.3
Persons 45-54 years	16.6
Persons 55-64 years	16.0
Persons 65-74 years	12.2
Persons 75-84 years	5.8
Persons 85 years and over	2.0

Table 7 Population of Shire of Denmark 2011  
Age by Percentage (ABS, 2013a).

The fertility rate in 2012 was 2.3 (ABS 2013c), with 29.1% of the population born overseas. Countries of origin include England, New Zealand, Scotland, South Africa and Germany with other languages spoken including German, Dutch, Italian, French and Afrikaans (Australian Bureau of Statistics, 2013a). The SEIFA was 987 (ABS, 2013d). There were 55 Indigenous persons recorded as residing in the Shire in the 2011 Census. When examining the labour force in 2011 there were 45.4% of the total labour force working full time, with 41.1% working part time or with other arrangements and 4.8% unemployed (Australian Bureau of Statistics, 2013a).

#### **4.2.3 Shire of Boyup Brook**

The Shire of Boyup Brook has a land area of 2,827.4km<sup>2</sup> with a population of 1,588 estimated for 2011. This gives a density of persons per 0.56 km<sup>2</sup> (ABS, 2013a). The entire population is classified as outer regional. The ABS estimates that in 2011 there were 788 males and 800 females in the Shire, or 49.6% male and 50.4% female (ABS, 2013a). Age distribution by percentage is described by the following table:

Persons 0-14 years	21.7
Persons 15-24 years	6.1
Persons 25-34 years	9.5
Persons 35-44 years	13.5
Persons 45-54 years	15.5
Persons 55-64 years	15.6
Persons 65-74 years	11.4
Persons 75-84 years	4.9
Persons 85 years and over	2.1

Table 8 Population of Shire of Boyup Brook 2011  
Age by Percentage (ABS, 2013a).

The fertility rate for the Shire was 2.54 in 2012 (ABS, 2013c) with 19.2% of the population born overseas (England, New Zealand, Scotland, Germany and the Netherlands). Languages spoken other than English included Italian, Dutch, Afrikaans, Portuguese and French (ABS, 2013a). The SEIFA was 985 (ABS, 2013d). Persons in the labour force in 2011 were made up of full time employees, at 54.4%, and part time or other employment of 30.1% with an unemployment rate of 4.3% (ABS, 2013a).

#### **4.2.4 Shire of Bridgetown-Greenbushes**

The Shire of Bridgetown-Greenbushes has a land area of 1,339.8 km<sup>2</sup> with a population of 4,319 in 2011, giving a population density of 3.22 persons per km<sup>2</sup>. The entire population is classified as outer regional. The ABS states that in 2006 there were 2,118 males and 2,201 females, or 49.0% males and 51.0% females (ABS, 2013a). Age distribution by percentage is described by the following table:

Persons 0-14 years	20.7
Persons 15-24 years	7.6
Persons 25-34 years	7.9
Persons 35-44 years	12.1
Persons 45-54 years	15.6
Persons 55-64 years	17.9
Persons 65-74 years	12.5
Persons 75-84 years	4.4
Persons 85 years and over	1.4

Table 9 Population of Shire of Bridgetown-Greenbushes 2011  
Age by Percentage (ABS, 2013a).

The fertility rate for the Shire was 2.62 in 2012 (ABS, 2013c), with 25.4% of the population born overseas. Those countries of origin were England, New Zealand, Netherlands, Scotland and USA, with the other languages spoken being Italian, Dutch, Filipino, German and French. The SEIFA was 968, based on the 2011 census (ABS, 2012d). Of the labour force in 2011, 52.3 % worked full time, with 36.5% working in part time or other arrangements and 4.3% being unemployed (ABS, 2013a).

#### **4.2.5 Shire of Cranbrook**

The Shire of Cranbrook has a land area of 3,278.7 km<sup>2</sup> with a population of 1,079 persons based on the 2011 census (ABS, 2013a). This gives a density of 0.3 persons per km<sup>2</sup> (ABS, 2007). There were 86% of persons classified as outer regional and 14% classified as remote. The ABS estimated that in 2009 there were 578 males and 501 females in the Shire, or 53.6% male and 46.4% female. Age distribution by percentage is described by the following table:

Persons 0-14 years	21.9
Persons 15-24 years	8.5
Persons 25-34 years	10.6
Persons 35-44 years	14.1
Persons 45-54 years	15.1
Persons 55-64 years	14.2
Persons 65-74 years	9.8
Persons 75-84 years	4.9
Persons 85 years and over	0.9

Table 10 Population of Shire of Cranbrook 2011  
Age by Percentage (ABS, 2013a).

The fertility rate for the Shire was 2.56 in 2012 (ABS, 2013c), with 21.2% of the population born overseas; England, New Zealand, Zimbabwe, Afghanistan and the Philippines. Languages spoken other than English included Italian, Mandarin, Auslan, Afrikaans and Dutch (ABS, 2013a). The SEIFA was 966 (ABS, 2013d). Persons that were in the labour force in 2011 were made up of full time employees at 63.8% and part time or other employment of 23.3% with an unemployment rate of 5.3%.

#### **4.2.6 Shire of Manjimup**

The Shire of Manjimup has a land area of 7,026.8 km<sup>2</sup> with a population estimated at 9,183 persons in 2011, giving a density of 1.3 persons per km<sup>2</sup>. Of the population, 85.4% were considered outer regional, and 14.6 % were considered remote. Age distribution by percentage is described by the following table:

Persons 0-14 years	21.6
Persons 15-24 years	10.4
Persons 25-34 years	8.8
Persons 35-44 years	13.1
Persons 45-54 years	16.0
Persons 55-64 years	14.2
Persons 65-74 years	9.1
Persons 75-84 years	5.0
Persons 85 years and over	1.7

Table 11 Population of Shire of Manjimup 2011  
Age by Percentage (ABS, 2013a).

The fertility rate in 2012 was 2.3 (ABS, 2013c), with 20.2% of the population born overseas. Countries of origin were England, New Zealand, Italy, Scotland and Germany. Other languages spoken at home, not including English were Italian, Macedonian, Dutch, Filipino and German. The SEIFA was 946 (ABS, 2013d). Of the labour force in 2011, 54.0% were employed full time, with 33.5% being employed part time or with other arrangements. There was 4.4% of the labour force unemployed (ABS, 2013a).

#### 4.2.7 Shire of Nannup

The Shire of Nannup has a land area of 2,934.9 km<sup>2</sup> with a population of 1,325 persons (estimated for 2008), giving a population density of 0.45 persons per km<sup>2</sup>. The entire population is considered outer regional, there were 675 males and 587 females, or 53.5% male and 46.5% female (ABS, 2013a). Age distribution by percentage is described by the following table:

Persons 0-14 years	16.0
Persons 15-24 years	7.7
Persons 25-34 years	7.6
Persons 35-44 years	12.0
Persons 45-54 years	15.8
Persons 55-64 years	22.3
Persons 65-74 years	13.5
Persons 75-84 years	4.1
Persons 58 years and over	1.0

Table 12 Population of Shire of Nannup 2011  
Age by Percentage (ABS, 2013a).

The fertility rate in 2012 was 1.93, and 26.2% of the population was born overseas (ABS, 2013c). Countries of origin were England, New Zealand, Switzerland, Scotland and Wales, with languages other than English spoken at home being German, Italian, Albanian, Indonesian and Estonian. The SEIFA for the Shire was 968 (ABS, 2013d). Of the workforce in 2011, 48.5% were employed full time, with 35.6% employed in part time work, or in other arrangements. Of the total, 4.7% of the population were unemployed (ABS, 2013a).

#### 4.2.8 Shire of Plantagenet

The Shire of Plantagenet has a land area of 4,875.3 km<sup>2</sup> with an estimated population of 4,882 in 2011, giving a density of 1.01 persons per km<sup>2</sup>. All of the population is considered outer regional with the exception of the Mount Barker town site being considered inner regional. There were 2,497 males and 2,385 females, or 51.1% males and 48.9% females (ABS, 2013a). Age distribution by percentage is described in the following table:

Persons 0-14 years	19.5
Persons 15-24 years	10.5
Persons 25-34 years	9.3
Persons 35-44 years	12.8
Persons 45-54 years	15.9
Persons 55-64 years	15.5
Persons 65-74 years	10.1
Persons 75-84 years	4.6
Persons 85 years and over	1.8

Table 13 Population of Shire of Plantagenet 2011  
Age by Percentage (ABS, 2013a).

The total fertility rate for the Shire was 2.24 in 2012 (ABS, 2013c) with 26.1% of the population born overseas, with countries of origin being England, New Zealand, Scotland, Afghanistan and South Africa. Languages other than English spoken were German, Dari, Italian, Afrikaans, Hazaragi and Italian. The SEIFA for the Shire was 953 (ABS, 2013d). Of the labour force in 2011, 54.4% worked full time, with 32.2% working part time or in some other arrangement and 5.6% were unemployed (ABS, 2013a).

### **4.3 Indigenous Population**

In Western Australia (2011) of the 88,277 people that identified as Indigenous, around 15% lived in the South West region, with 37% living in the Perth metropolitan area (Australian Indigenous Health Infonet, 2013a). Indigenous Australians are considered to be vulnerable to the effects of climate change as they are more likely to experience poverty and have higher rates of communicable and non-communicable diseases than the rest of the population, this may also reduce resilience to new health risks (Hennessy, et al., 2007).

The Indigenous population in the region is listed in the following table, by local government area:

Shire of Augusta-Margaret River	115 persons
Shire of Denmark	57 persons
Shire of Boyup Brook	20 persons
Shire of Bridgetown-Greenbushes	64 persons
Shire of Cranbrook	19 persons
Shire of Nannup	15 persons
Shire of Manjimup	246 persons
Shire of Plantagenet	150 persons

Table 14 Number of Persons with Aboriginal and Torres Strait Islander Heritage  
(ABS, 2013a).

Indigenous persons face specific risks under climate change due to having poorer overall health outcomes compared to non-Indigenous persons in Australia. The Shires of Manjimup, Plantagenet and Augusta-Margaret River have higher numbers of Indigenous persons than other local government areas and while this group is a relatively small proportion of the population, is identified as potentially vulnerable.

#### **4.4 Summary of Local Government Areas**

The Shire of Manjimup has the largest geographical area, followed by Plantagenet, Cranbrook, Nannup, Boyup Brook, Margaret River, Boyup Brook, Augusta-Margaret River, with Denmark and Bridgetown Greenbushes having the least area. As population is centred on the coast and Bridgetown-Greenbushes, these areas have the higher population densities. Shires of Manjimup and Cranbrook were the only local governments with areas considered to be remote (ABS, 2013e; ABS, 2013f), these areas also have low SEIFA in suburbs (towns).

The Shire of Manjimup has a number of Indigenous persons that may be vulnerable to climate change. The male to female ratio was similar across the local government areas, however there were large variations in population numbers between the ages of 15-65 years. The age bracket 15-35 years shows a decline in population, which is common in rural areas as young adults leave for education and employment opportunities. The elderly and very elderly groups make up approximately 15% of the population across the area, with children under the supervision of adults being approximately 20% of the population of the region between each local government

area. Children and the elderly are vulnerable sub groups that made up approximately 35% of the population. The greater region of Perth had slightly less of this group, at approximately 31% (ABS, 2013g).

Persons born overseas were approximately 20% or more for all areas, with Denmark having the most persons born overseas for the population (over 29%). This was substantially lower than the capital city Perth, which has approximately 40% of persons born overseas (ABS, 2013g). Being a recent migrant has a positive health effect compared to being Australian born, however the effect diminishes over time to match that of the Australia born population (Australian Institute of Health and Welfare, 2013; Biddle, Kennedy & McDonald, 2007). Bridgetown Greenbushes, Boyup Brook, Manjimup and Cranbrook have the highest fertility rates, with Augusta-Margaret River having the least. The average fertility rate for the study area was 2.35. This was a higher fertility rate than the Australian total fertility rate, which was 1.93 babies per woman in 2012 (ABS, 2013c). Of those persons working, the Shire of Cranbrook has the highest full time work rate, followed by Plantagenet and Boyup Brook. The lowest full time work rate was in the Shire of Nannup. The highest unemployment rate was also in Plantagenet followed by Cranbrook. The greatest wage discrepancies between local governments were Plantagenet and Cranbrook. Risk factors relating to remoteness were more likely to impact the Shires of Manjimup and Cranbrook.

The cost of living in rural areas is marginally higher than urban areas, however housing stress is more likely due to lowered employment opportunities and services, even though the cost of housing may be lower. Access to employment and services further increases the risks of household poverty in rural (outer regional and remote) areas, in contrast to urban and regional areas (National Rural Health Alliance Inc. & ACOSS, 2013). The Census data indicates that rural areas are at risk of the health impacts of climate change due to an ageing population, proportionally more vulnerable groups (children and elderly), along with the added challenges of remoteness, lack of full time employment opportunities, lack of services and higher costs of living.

#### **4.5 Climate Profile**

Observed climate change in the South West of Western Australia includes a stepwise reduction in annual rainfall of about 15% from the 1970's and in particular a reduction in winter rainfall. Very high rainfall years were a common feature in the region, which are now reportedly absent. Streamflow has declined by about 50% in the South West region since the 1970's (CSIRO & BOM, 2014). Agriculture in the region includes beef and sheep farming, dairy, horticulture, nut growing, cereal crops and wine making. Tree plantations (agro-forestry), state and national forest make up a significant land area that may be vulnerable to climate change due to rainfall and temperature changes. Tourism that relies on the natural and pristine parks is also at risk (Jones et al., 2010). Climate factors will now be discussed.

##### **4.5.1 Rainfall**

The following figure depicts the changes to total rainfall from 1900-2015. This map shows the trend for rainfall reduction by 10-15mm/10 year period.

**The Trend in Total Rainfall 1900-2015 (mm/10yr) image (BOM, 2016a) is unable to be reproduced here due to copyright restrictions.**

**The Trend in Total Rainfall 1900-2015 (mm/10yr) image can instead be accessed via <http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=trend-maps>**

Figure 14 Trend in Total Rainfall 1900-2015  
(BOM, 2016a).

The South West corner of Western Australia shows the most significant levels of rainfall reduction in Australia.

Heavy rain days (Figure 15) have decreased in summer and spring in most parts of Australia from 1910-2005 (Nicholls, 2009). The following figure indicates the trend of decreasing heavy rain days in Australia (count of days in a year with rainfall exceeding 10mm). There is a decrease in approximately 16 days of heavy rain for Margaret River and Denmark, with Nannup heavy rain days decreasing by 8 days per year. There is a 24 day increase in heavy rain days adjacent to the Mount Barker region.

**The Trend in no. of heavy rain days 1970-2008 (days/100yrs) image (BOM, 2009a) is unable to be reproduced here due to copyright restrictions.**

**The Trend in no. of heavy rain days 1970-2008 (days/100yrs) image can instead be accessed via [http://www.bom.gov.au/cgi-bin/climate/change/extremes/trendmaps.cgi?map=R\\_10&period=1970](http://www.bom.gov.au/cgi-bin/climate/change/extremes/trendmaps.cgi?map=R_10&period=1970)**

Figure 15 Trend in Number of Heavy Rain Days 1970-2008  
(BOM, 2009a).

Very heavy precipitation days are also demonstrated in this figure, with trends of decreasing heavy precipitation across Australia (this refers to number of days per year with rainfall exceeding 30mm per day). A small increase of very heavy rain days is recorded in an area south of Nannup and west of Manjimup in the map below.

**The Trend in no. of very heavy rain days 1970-2008 (days/100yrs) image (BOM, 2009a) is unable to be reproduced here due to copyright restrictions.**

**The Trend in no. of very heavy rain days 1970-2008 (days/100yrs) image can instead be accessed via [http://www.bom.gov.au/cgi-bin/climate/change/extremes/trendmaps.cgi?map=R\\_30&period=1970](http://www.bom.gov.au/cgi-bin/climate/change/extremes/trendmaps.cgi?map=R_30&period=1970)**

Figure 16 Trend in Number of Very Heavy Rain Days 1970-2008 (BOM, 2009b).

Highest and lowest rainfall observations (Monthly and Daily) for each community are listed in Table 52, Appendix 7.0. The data range is from when each of the weather stations began operation to the year 2010. The variability of rainfall conditions are anticipated to increase in future (Williams, Kniveton & Layberry, 2010). In the region, the area with highest (monthly) rainfall recorded was Pemberton, followed by Cape Leeuwin (Augusta), Manjimup, Bridgetown, Mount Barker, Jarrahwood (Nannup), Windy Harbour, Shannon (Northcliffe) and Frankland Vineyards. Weather stations began operating at different times for each location.

The lowest monthly rainfall recorded (drought years) (lowest to highest mm) are listed: Bridgetown, Mount Barker, Frankland Vineyards, Manjimup, Jarrahwood, Cape Leeuwin, Pemberton, Shannon and Windy Harbour. The highest daily rainfall events were recorded in Mount Barker 139.2 mm, Cape Leeuwin (Augusta) 123.2mm, Jarrahwood (Nannup) 106.4mm and Bridgetown 100.8 mm.

Bridgetown, Mount Barker and Jarrahwood have a history of variability with both droughts and heavy precipitation occurring at these locations. Adequate water storage and engineering mechanisms would be essential to maximise capture of water at these locations and minimise damage from heavy rainfall (extreme) events (Spickett, Brown & Katscherian, 2008).

### 4.5.2 Temperature

Annual mean temperatures in this region have increased by 0.15°C per decade since 1970 in all seasons except summer (IOCI, 2009). The following figure indicates the trend in mean temperature from 1970-2015 (°C/10 year period) in Australia. Temperature increases are observed across the region.

**The Trend in mean temperature Annual 1970-2015 (C<sup>0</sup>/10yr) image (BOM, 2016a) is unable to be reproduced here due to copyright restrictions.**

**The Trend in mean temperature Annual 1970-2015 (C<sup>0</sup>/10yr) image can instead be accessed via**

**<http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=trend-maps>**

Figure 17 Trend in Mean Temperature 1970-2015  
(BOM, 2016a).

Using the BOM's historical data, daily maximum events (degrees Celsius) for weather stations are listed in the following table. Weather stations began operating at different times for each town (from the late 1880's to the 1920's) and some weather stations may be outside of the town site. The data is from the date the weather station began its observations to 2010.

Weather Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Windy Harbour	39.5	39.8	40.3	34.5	30.2	24.7	22.7	22.7	26.3	29.6	37.2	36.2
Pemberton	43.2	41.7	40	33.8	28.5	23.2	22	24.9	28.3	33.6	38	40.4
Manjimup	42.7	41.6	41.2	33.6	29.2	22.9	21.6	24.4	28.2	33.3	38.7	41.1
Bridgetown	40.1	40.5	41.3	34	28.7	22	21.3	24	27.1	30.2	38.3	41.2
Boyup Brook	41.9	43	38.8	36.1	31.3	24.7	21.2	22.2	25.5	34.4	36.4	41
Jarraewood (adjacent to Nannup)	41.5	41.9	41.2	34.6	29.5	23.6	23.9	24	28	34.3	37.5	40.5
Margaret River	38.8	39.2	37	32.2	26.9	23.3	20.1	20.5	24	31.6	36.8	39
Witchcliffe	39.3	38	39	31.1	27.7	22.5	21.2	22.1	25	30.4	36.2	39.3
Cape Leeuwin (Augusta)	41	42.8	39.9	35	29.3	24.5	22.5	24	27.8	31.8	36.1	38.4
Shannon	41	39	41	33	29	22	21	24	28	30.3	38	41
North Walpole	38.4	38.1	40.7	30	26.8	22.7	20.9	24.2	25.8	29	36.9	34.5
Rocky Gully	43.1	40.3	40.7	33.8	29	22.4	21.5	23.4	27.4	30.6	38.1	41.8
Mount Barker	43.9	43.6	40.6	37.2	32.2	24.3	22.2	25	29.3	35.6	39.4	42.9

Table 15 Daily Maximum Temperature Records  
(BOM, 2010a).

According to these records of daily maximums, heat waves and very hot days have the potential to occur between October to March (and/or April) for many communities (BOM, 2010). The hottest days observed for each town are listed in order from the highest summer maximum observed to the lowest summer maximum; Mount Barker, Pemberton, Rocky Gully, Manjimup, Cape Leeuwin, Shannon, Jarraewood, Bridgetown, Boyup Brook, Windy Harbour, North Walpole, Witchcliffe and Margaret River. The last four towns are likely to have coastal influences that reduce summer maximum temperatures observed compared to inland regions (Batt, 2011). Heatwaves are defined as high daily maximum and minimum temperatures for three to four days that are outside of the normal range for that particular location (BOM, 2016b).

The trend in ‘very hot days’ (days over 40<sup>0</sup>C) recorded by BOM, indicate no trends for the Blackwood Stirling, as shown in Figure 18.

**The Trend in Number of Very Hot Days 1970-2008 (days/10yrs) image (BOM, 2009c) is unable to be reproduced here due to copyright restrictions.**

**The Trend in Number of Very Hot Days 1970-2008 (days/10yrs) image can instead be accessed via <http://www.bom.gov.au/cgi-bin/climate/change/extremes/trendmaps.cgi?map=HD40&period=1970>**

Figure 18 Trend in Number of Very Hot Days 1970-2008  
(BOM 2009c).

Deaths and injuries associated with heatwave events in Australia are listed in the table below.

Area	Date	Deaths/Injuries
Southern Region Australia	1/12/1895-1/1/1896	437 deaths, 5,000 injured
Southern States, Australia	7/12/1907-8/1/1908	246 deaths
Australia wide	9/12/1909-10/2/1910	109 deaths
Australia wide	1/12/1911 – 1/2/1912	143 deaths
Australia wide	1/12/1913-1/2/1914	122 deaths
Australia wide	1/12/1920-1/2/1921	147 deaths
Southern States, Australia	26/12/1926-27/1/1927	130 deaths
Australia wide	1/12/1958-1/2/1959	98 deaths, 1,000 injured
Southern Australia	1/12/1972-1/2/1973	99 deaths, 1,000 injured
South West W.A.	20/1/1996-20/2/1996	Not recorded

Table 16 Heat Wave Historical Records  
(Australian Government Attorney-General's Department, 2011).

Heatwaves are associated with more deaths in Australia than any other natural hazard (Coates, 1996). Hot nights (nights exceeding 20<sup>0</sup>C) are linked with thermal discomfort, and are increasing by a small margin in the Augusta region according to the following trend map.

**The Trend in number of hot nights 1970-2008 (days/10yrs) image (BOM, 2009d) is unable to be reproduced here due to copyright restrictions.**

**The Trend in number of hot nights 1970-2008 (days/10yrs) image can instead be accessed via <http://www.bom.gov.au/cgi-bin/climate/change/extremes/trendmaps.cgi?map=HN20&period=19>**

**70**

Figure 19 Trend in Number of Hot Nights  
(BOM, 2009d).

Similar maps indicate warm days and nights are also a trend for Augusta compared to all other areas (BOM, 2009e; BOM, 2009f). Heat wave activity in the South West has been associated with tropical cyclones off the West or North West coast line which also contribute to risks from fire weather activity (BOM, 2011b). Warm days and nights refer to the percentage of days with the maximum temperature exceeding the 90<sup>th</sup> percentile (BOM, 2009g). A reduction of the diurnal range (difference between temperatures of day and night) are a feature of climate change (Roderick & Farquhar, 2004).

Daily minimum temperatures are forecast to increase; resulting in less cold days and nights, including less frosts and cold spells (Whetton & Power, 2007). Lowest temperatures (lowest daily minimums) are listed in the following table. As previously mentioned, each weather station began operation at different times (between the period 1880-1920); this data includes that time period to 2010.

Temperature (Celsius)	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Jarrahwood (Nannup)	1.5	3.4	1	-1.2	-2.5	-4.4	-2.2	-2.5	-2.0	-2.0	-.05	1
Cape Leeuwin (Augusta)	9.4	10	8	7.2	5.3	3.3	4.4	5	4.2	4.3	5.8	9.4
Frankland Vineyards (west of Cranbrook)	5.7	4	4.5	2	.5	-1	-0.5	-0.5	-0.8	0	1.5	3.5
Mount Barker	1.7	4	3.6	2.2	0.6	-1.1	-2.2	-1.3	-0.6	0.1	1.1	1.1
Pemberton	4	5.6	3.9	-0.8	2	-0.4	0	0	0.4	0.6	2.5	4.4
Bridgetown	0.9	0.5	-0.9	-2.2	-2.5	-5.1	-4.4	-3.9	-2.8	-2.2	-0.9	-5.1
Shannon (Northcliffe)	4	6	3	2	0	-2	-1	0	1	1	1	3
Windy Harbour	6.5	5	3.5	4.4	1.7	1	0.7	2.3	1.5	3.8	5	4.5
Manjimup	6	5.6	3.3	1.6	-0.6	0.2	-0.6	0	0.6	0.1	2.3	4.4

Table 17 Lowest Temperatures Recorded  
(BOM, 2010).

Towns with the coldest daily minimums were Bridgetown and Jarrahwood, followed by Pemberton, Manjimup, Mount Barker, Frankland Vineyards and Shannon (Northcliffe). Cape Leeuwin and Windy Harbour have no records of days below 0 degrees Celsius (BOM, 2010a).

#### 4.5.3 Sea Surface Temperature and Sea Level Rise

Sea surface temperature changes are apparent offshore in the Blackwood Stirling, as depicted in the following figure, showing a 0.16<sup>0</sup>C increase. The Leeuwin current (which circulates warmer water from the tropics), increases the water temperature by 3<sup>0</sup>C compared to offshore temperature along the Augusta-Margaret River shoreline (IOCI, 2005).

**The Trend in SST for the Australian Region ( $^{\circ}\text{C}/10\text{yr}$ ) annual 1970-2015 image (BOM, 2016a) is unable to be reproduced here due to copyright restrictions.**

**The Trend in SST for the Australian Region ( $^{\circ}\text{C}/10\text{yr}$ ) annual 1970-2015 image can instead be accessed via  
<http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=trend-maps&tQ=map%3Dsst%26area%3Daus%26season%3D0112%26period%3D1970>**

Figure 20 Sea Surface Temperature 1970-2015 ( $^{\circ}\text{C}/10\text{yr}$ )  
(BOM, 2016a).

Sea level rise has accelerated in the early 20<sup>th</sup> century, following thousands of years of stabilisation. Sea level rise does not occur uniformly and is impacted by additions of water from the land and icesheets, along with thermal expansion and contraction. Sea level is also impacted by tides, storm surges and wave processes. El Nino/La Nina also impacts sea level rise in different regions (IPCC, 2007). Global sea levels have risen by 17cm from 1900-2000 (Whetton & Power, 2007).

#### **4.5.4 Pan Evaporation**

The following figure depicts changes to Annual Pan Evaporation in Australia from 1970-2015 (mm/year) with the Blackwood Stirling region showing an increase in evaporation between 0-2.5mm/year. Increases in evaporation would correspond with an increase in air temperature near the land surface (Roderick & Farquhar, 2004). Mediterranean type climates are at risk of drying due to climate change, such as those in the South West corner of Australia (Silberstein et al., 2012).

**The Trend in Annual Total Pan Evaporation 1970-2015 (mm/yr) image (BOM, 2016a) is unable to be reproduced here due to copyright restrictions.**

**The Trend in Annual Total Pan Evaporation 1970-2015 (mm/yr) image can instead be accessed via**  
**<http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=trend-maps&tQ=map%3Devap%26area%3Daus%26season%3D0112%26period%3D1970>**

Figure 21 Trend in Pan Evaporation 1970 – 2015 (mm/yr)  
(BOM, 2016a).

#### **4.5.5 Extreme Weather**

The Blackwood Stirling region has been affected by cyclonic and storm activity; cyclone Alby caused catastrophic damage in the area in 1978, resulting in 5 deaths, storm surge and fires flaring up in the region, burning 114,000 hectares of state forest and private farmland (BOM, 2011a; BOM, 2011c). The BOM website indicates the following cyclones have passed over, or near the study area from 1969 to 2006; Alby, Vincent, Idylle, Vida, Kristy and Marcelle (BOM, 2011a; BOM, 2011c). The region is subject to severe seasonal thunderstorms, which cause more damage than any other natural hazard in Australia (BOM, 2011c). In 2010 a thunderstorm impacting Perth on March 22<sup>nd</sup> resulted in damages costing over \$100 million, storm damage costs were associated with the higher density of urban areas and high costs of assets, in contrast to rural areas (Western Australian Regional Office Bureau of Meteorology, 2010).

#### **4.5.6 Flood**

The literature review revealed flood history for the major River systems in the Blackwood Stirling and included the Blackwood River floods of 1955, 1963, 1964 and 1982, affecting the towns of Nannup, Bridgetown and Boyup Brook (Geoscience Australia, 2010a). Using the Department of Water (2016) Geographic Data Atlas, the

100 year floodplain maps show potential flooding (1 per cent chance that flooding of that scale will occur any given year) in the town sites of Augusta, Margaret River, Boyup Brook, Nannup, Denmark, Bow River and Bridgetown. Local governments manage approvals for development in floodplain areas with some of the risks potentially being mitigated through building conditions (Government of Western Australia, 2016).

#### **4.5.7 Drought**

The South West of W.A. has a history of drought conditions, in particular since the 1960's, with the period from the year 2000 to the present being the driest on record (BOM, 2016c). The following map illustrates the dry conditions in the Blackwood Stirling (using all available data), for the period 1<sup>st</sup> January 2000 to 30<sup>th</sup> June 2016, with the rainfall deciles being the lowest on record.

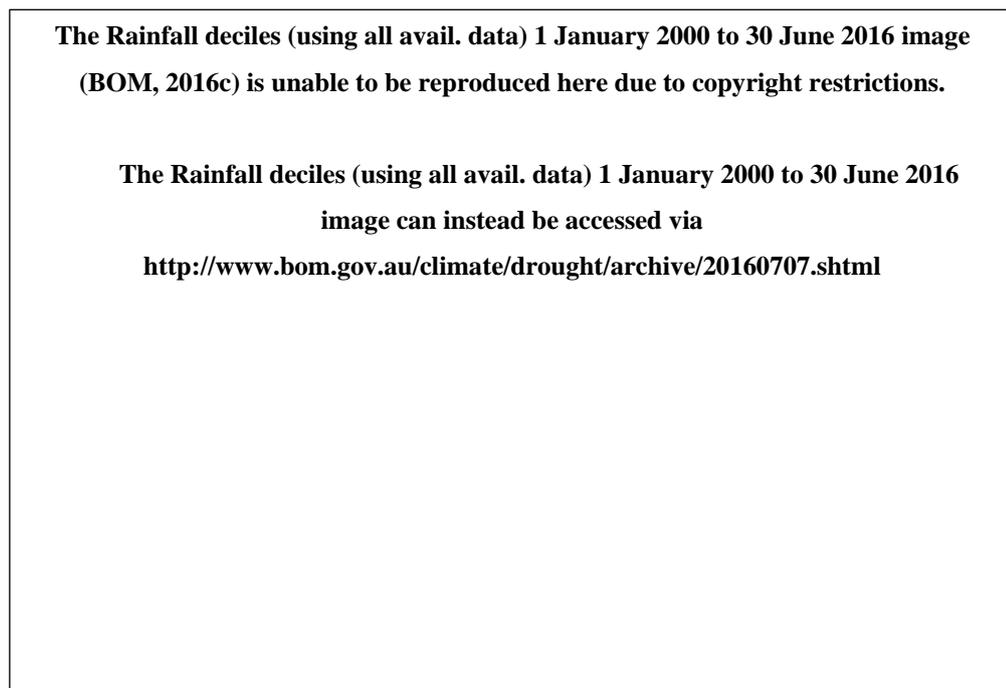


Figure 22 Rainfall Deciles 2016  
(BOM, 2016c).

#### **4.5.8 Fire**

Having large areas of biomass and hot dry summers, the region is also of the most fire prone in the world (Bushfire CRC, 2010). Recent devastating fires occurred in:

- 2015, with the O’Sullivan Fire burning 98,000 hectares between Northcliffe and Windy Harbour (caused by lightning)
- 2012, with the Babbington fire (close to Northcliffe and Windy Harbour) burning over 30,000 hectares (caused by lightning)
- 2011, the prescribed Margaret River burn that escaped and burnt or damaged 65 dwellings and burnt over 3,500 hectares
- 2009, burning several homes in Bridgetown and over 5,000 hectares of land, cause unknown
- 1960, that burnt over 500,000 hectares from Shannon River to Dwellingup, and
- 1951, that burnt 23,000 hectares from Dwellingup to the Manjimup area (Australian Institute of Criminology, n.d.; Department of Environment and Conservation, 2012a; Government of Western Australia, 2011; Department of Environment and Conservation, 2009; Department of Fire and Emergency Services, 2015).

#### **4.5.8.1 Summary of Climatic Conditions**

Historically costs associated with climate conditions are largely related to storm activity (damage and recovery). Potential bushfire impacts to housing and population groups may be minimised through effective firebreaks, early warning systems, evacuation and effective management of the fire front.

High daily rainfall events can cause temporary flooding but currently pose minimal risks to the region; low rainfall years and protracted drought, such as the winter rainfall reduction observed across Western Australia pose risks to ecosystems, agricultural output and the quality and quantity of water available to potable water users.

High summer temperatures pose health risks (single days of extreme heat and heat waves). Records show risks for exposure to high temperatures could occur from October to April. Humidity will impact the likelihood of developing heat stress and heat stroke which will be discussed further in the Chapter Five. Inland areas such as

Mount Barker, Nannup and Bridgetown have a history of high summer temperatures above 40<sup>0</sup>C, along with low daily minimums in winter-spring.

Most communities have a history of variability with regards to rainfall and temperature and most have been exposed to risks from bushfires, storms, flooding, heat waves, low rainfall years and cyclonic activity. If you consider sensitivity from remoteness, the Shire of Manjimup and Cranbrook have areas considered to be remote.

#### **4.6 Future Climate for the Study Area**

Climate change scenario models have been developed by agencies such as the IPCC, CSIRO (Nicholls, 2009) and IOCCI based on low, mid and high carbon emissive futures along with sociological factors, or socio-economic data and scenarios (SRES) (Morgan, 2008).

Scenarios built to the year 2030 produce less uncertainty than models forcing simulations to the year 2100 and will be time frame referred to in the research (Whetton & Power, 2007). Scenarios were used (van Vuuren et al., 2010) to develop possible outcomes for rain, temperature, extreme weather events, sea surface temperature, sea level rise and pan evaporation. The use of future scenarios enables future planning for adaptation to climatic changes and risk avoidance.

##### **4.6.1 Stabilisation of Atmospheric Carbon**

The global mean temperature has increased by 0.78<sup>0</sup>C between the period of 1850 to 2012, with the global sea level rising by 19 cm (IPCC, 2013a). Future stabilisation rates of atmospheric carbon dioxide will influence the increase to global mean temperature increases and is dependent on economic and political activity (growth and mitigation), however this does not factor in catastrophic future scenarios, such as volcanic activity. Carbon dioxide and other gas emissions released into the atmosphere enhance the warming process of the natural greenhouse effect, currently at levels above the worst case scenario outlined by the IPCC (IPCC, 2007). An increasing global mean temperature may result in an intensified hydrological cycle,

with ice sheets melting, more intense storm conditions and higher sea levels predicted (Ramanathan & Feng, 2009).

IPCC SRES scenarios outline potential future developments and growth and the subsequent effects of climate change, based on economic and demographic changes. The A1 storyline represents market based solutions and a focus on education with high rates of investment and innovation. The A1B scenario suggests diversity in technology and supply, it is the mid-range scenario used by Australia Climate Change Science Programme (Whetton & Power, 2007) with A1F1 describing a fossil fuel intensive future. The B1 future scenario suggests a global transition to environmental and social sustainability, with an egalitarian governance of resources. The B1 scenario is linked with lower fertility and mortality rates, higher food costs and greater environmental protection (IPCC, 2000). Total global carbon dioxide emissions (GtC) by each SRES scenario are presented in the following graph of GtC/year to 2100. The B1 scenario shows the greatest reduction in future emissions.

**The Global CO<sub>2</sub> emissions (GtC/yr, standardised) from all sources for the four scenario families from 1990 to 2100 image (IPCC, 2001c) is unable to be reproduced here due to copyright restrictions.**

**The Global CO<sub>2</sub> emissions (GtC/yr, standardised) from all sources for the four scenario families from 1990 to 2100 image can instead be accessed via**

**<https://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=17>**

Figure 23 Global Carbon Emissions for Scenario Family, to 2100 (IPCC, 2001c).

#### **4.6.1.1 OzClim Scenario Generator**

The ‘Ozclim’ scenario generator produced three future scenarios for Australia based on a low impact/low rate of global warming (corresponding with B1 emission scenario), a moderate impact/moderate rate of global warming (corresponding with

A1B emission scenario), and a high impact/rate of global warming (corresponding with A1FI emission scenario future) (CSIRO, 2007a).

The climate model used in the thesis is CSIRO-Mk 3.5, which shows similar trends to other local and international models (Hobday, Poloczanska & Matear, 2008) and will be used throughout to maintain internal consistency with results (CSIRO, 2008). It does not however show the “hotter or wetter” future scenarios, and while these are extremes they will be noted as plausible. All models available will not be used as the median, wetter and drier scenarios show the full range of potential scenarios. Future scenarios should be presented with their subsequent level of uncertainty (DeCarolis, 2011) which is represented by the difference between low, mid and high warming scenarios, bearing in mind that A1FI is as plausible as B1 (Betts et al., 2010).

Many risk assessment guidelines for governance give future scenarios for regions, which show percentile reductions in rainfall, not future annual rainfall, or specific temperature parameters. This is not useful at a community level where greater spatial resolution would be more useful for agriculture and ecological purposes to determine total rainfall, winter rainfall, and associated runoff (Valdivia et al., 2010). For this reason a reliance on OzClim, because of the downscaling properties has been used.

The impacts to rural areas from losses of rainfall and runoff and temperature ranges are required and complex and complete data is more beneficial when conducting an impact assessment (Moss et al., 2010). As climate modelling science improves, greater detail in downscaling will be available for communities (Maurer, 2006). Each future scenario will be discussed below.

#### **4.6.2 Rainfall 2030**

The following figure shows a percentage change in annual rainfall from 1990-2030 using the CSIRO-Mk 3.5 Model, A1FI scenario and high emission future. All OzClim scenarios may have “inherent defects or deficiencies” and the change from 1990-2030 actually refers to the period from 1980-1999 (Whetton & Power, 2007). The Blackwood Stirling shows a percentage decrease between 0-5 and 5-10% in annual rainfall.

**The Percentage Change in Total Rainfall (%), in Australia for the year 2030, Annual (A1FI) image (CSIRO, 2011b) is unable to be reproduced here due to copyright restrictions.**

**The Percentage Change in Total Rainfall (%), in Australia for the year 2030, Annual (A1FI) image cannot be accessed as the OzClim data portal is no longer available.**

Figure 24 Change in Rainfall 2030 (A1FI)  
(CSIRO, 2011b).

Annual rainfall for 2030 using the CSIRO Mk3.5 model for low, moderate and high warming futures are listed in the table below (where available). This does not show the uncertainty of each figure, as low, moderate and high scenarios would need to be used for each storyline, with difference in values showing the uncertainty.

<b>Town</b>	<b>A1F1 High Annual Rainfall (mm)</b>	<b>A1B Moderate Annual Rainfall (mm)</b>	<b>B1 Low Annual Rainfall (mm)</b>
Manjimup	954.9	800.5	812.8
Quinninup	977.3	986.1	999.9
Pemberton	1059.6	1070	1086.4
Northcliffe	1072.1	1111	1129.7
Windy Harbour	1099.1	1012.2	1067.8
Walpole	1111.8	1125.3	1146.3
Denmark	1049.3	892.3	1083.1
Mount Barker	651.1	459.4	504.3
Cranbrook	440.5	445.8	454.3
Rocky Gully	647.8	599.8	665
Tonebridge	593.3	599.6	609.4
Nannup	827.5	836.8	851.3
Augusta	922.3	933.8	951.6
Witchcliffe	990.7	1003.7	1024
Margaret River	971.17	920.5	917.7
Greenbushes	790.3	725.9	811.9
Bridgetown	664.7	671.4	815.4
Boyup Brook	683.1	505.5	700.6

Table 18 Annual Rainfall 2030 using Low, Moderate and High Rates of Global Warming  
CSIROMK3.5 (CSIRO, 2011b).

For a look at possible extremes for rainfall for the District, the GFDL:GFDL2.1 Model will be used which represents a stronger warming pattern compared to other models and the MIUB/KMA: ECHO-G for a wetter future scenario. Several possible scenarios using models have been produced that indicate change in rainfall including increases, (Whetton & Power, 2007), however this information is not as site specific compared with OzClim (downscaling is not available). There is an agreement between models that it is most likely that the South West of the state will be hotter and drier in future (Silberstein et al., 2012).

All scenarios indicate that the regions with the highest rainfall in future are Pemberton, Northcliffe, Windy Harbour and Walpole, with Quinninup and Witchcliffe yielding slightly less. The driest communities under climate change scenarios are Cranbrook and Tonebridge.

The following figure shows a lower global warming future, using the B1 future scenario, using the CSIRO-Mk 3.5 Model.

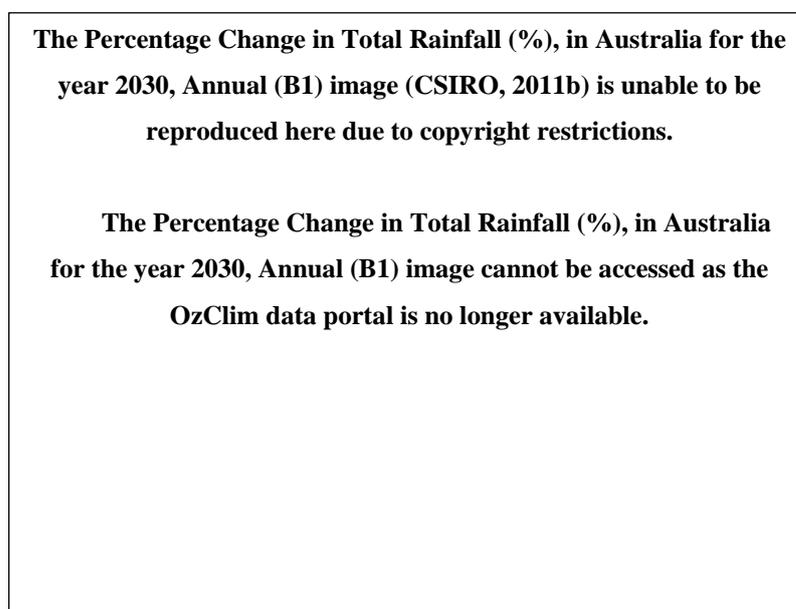


Figure 25 Change in Rainfall 2030 (B1)  
(CSIRO, 2011b).

This figure reveals a lower percentage in rainfall declines, of 0-5 per cent less per annum compared to 1990 levels. The final figure shows a moderate rate of global warming, using the A1B scenario and CSIRO-Mk3.5 Model; this reveals a

percentage reduction in rainfall of 0-5%. The figures also show that the Blackwood Stirling region will have rainfall impacted less than most other regions in the state. Specialist ecological niches rely on specific ranges of rainfall; even the slightest disruption will have impacts (Isaac, Valentine & Wilson, 2009).

**The Percentage Change in Total Rainfall (%), in Australia for the year 2030, Annual (A1B) image (CSIRO, 2011b) is unable to be reproduced here due to copyright restrictions.**

**The Percentage Change in Total Rainfall (%), in Australia for the year 2030, Annual (A1B) image cannot be accessed as the OzClim data portal is no longer available.**

Figure 26 Percentage Change in Total Rainfall 2030 A1B (CSIRO, 2011b).

### **4.6.3 Heavy Rain Days & Drought**

Natural variability and decadal variation for rainfall will still remain however; there is a likelihood that heavy rain fall events will increase, along with protracted dry spells (Garnaut, 2008).

### **4.6.4 Temperature 2030**

Available data for temperature forecasting to 2030 includes mean changes to surface temperature, minimum temperatures, maximum temperatures, heat spells (waves), humidity and hot nights. Health impacts from these temperature parameters are briefly discussed, Chapter Five will examine this information further.

#### 4.6.5 Mean Temperature

Percentage change to the mean land surface temperature from the period 1990 – 2030 shows an increase by 10%, using the A1FI scenario with a high rate in global warming. The following map shows a fairly even increase in heat across the country.

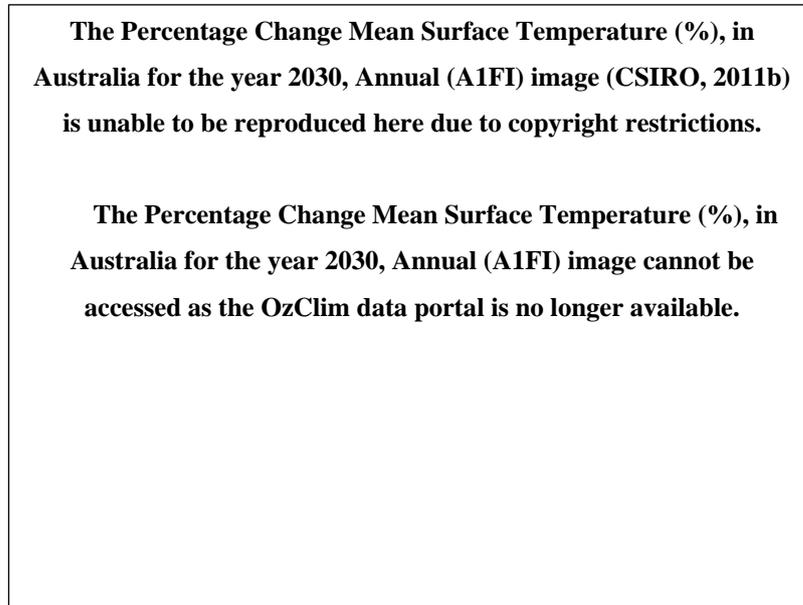


Figure 27 Percentage Change to Mean Temperature from 1990-2030 A1FI (CSIRO, 2011b).

The B1 scenario and low global warming future shows the same result, with a 10% increase in mean temperature across Western Australia.

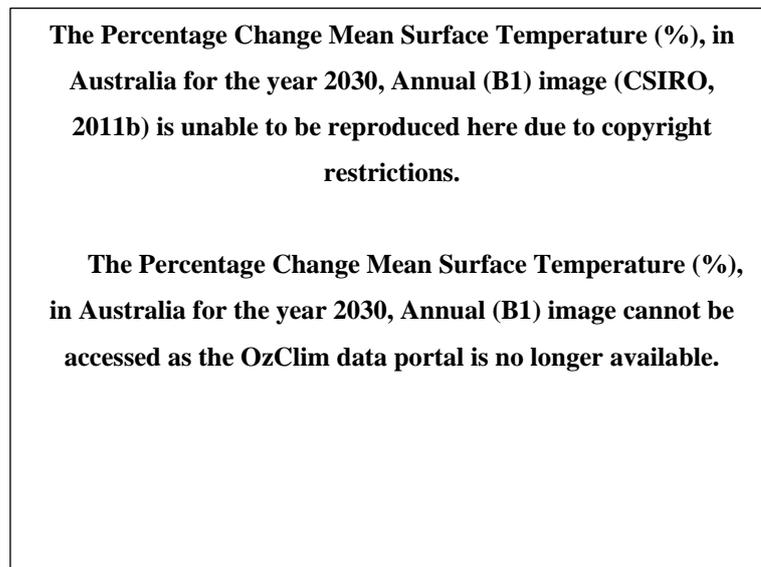


Figure 28 Percentage Change to Mean Temperature B1 Scenario 1990-2030 (CSIRO, 2011b).

The A1B and moderate global warming shows the same future of around 10% increase in mean temperature.

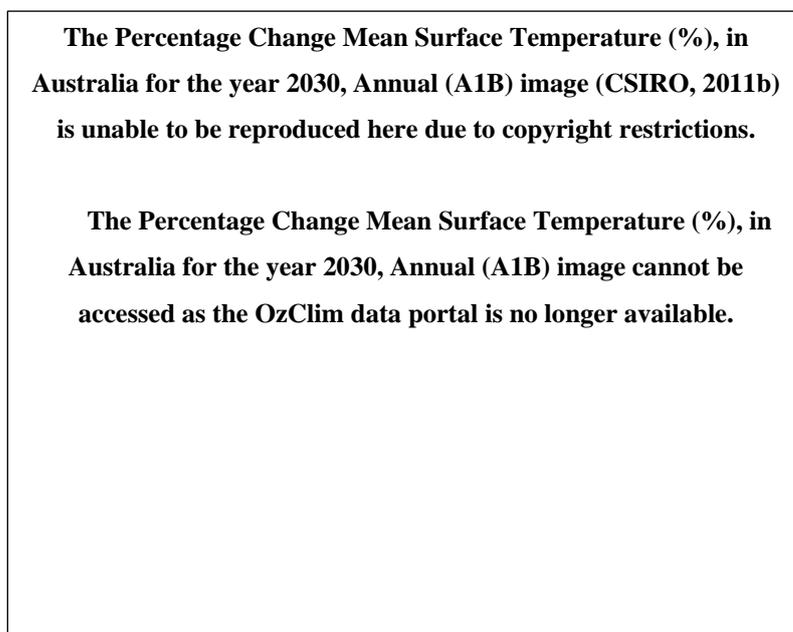


Figure 29 Mean Temperature Increase, A1B Moderate Global Warming 1990-2030 (CSIRO, 2011b).

#### **4.6.6 Minimum Temperature**

Minimum winter temperatures for a high warming scenario are at 10-14<sup>0</sup>C on the Margaret River to Augusta coastline and 6-10<sup>0</sup>C for the rest of the district. Low global warming, B1 scenarios; show the same, with a lower winter temperature range for Boyup Brook of less than 6<sup>0</sup>C. Minimum summer temperatures above 24<sup>0</sup>C are related to health impacts (Nicholls, Skinner, Loughnan & Tapper, 2008), the minimum summer temperature for all are discussed below and do not exceed 16.9<sup>0</sup>C. Cold related illness may be reduced should winter minimums increase, for example illness relating to asthma and rhinitis (Kalkstein, Koppe, Orlandini, Sheridan & Smoyer-Thomic, 2009).

#### **4.6.7 Maximum Temperatures and Heat Waves**

Maximum temperatures for 2030 using high global warming future coupled with A1F1 scenario, show future temperatures at a maximum of between 18-22<sup>0</sup>C for Pemberton to Denmark, with a 22-26<sup>0</sup>C maximum for other regions. Maximum

temperatures are the lowest in the state in the study region. Temperatures less than 32°C are better dealt with physiologically through thermoregulation (depending on humidity and pre-existing health issues). Days exceeding 35°C for three days or longer, or minimum daily temperatures (overnight temperature) exceeding 23°C or more form part of the criteria for health alerts for Western Australia (Government of Western Australia Department of Health, 2010). Heat thresholds can vary within a particular place depending on the time in the season (e.g. early and late summer hot days) and can be impacted by socio-economic factors, for instance access to air conditioning with actual health impacts being used to guide alerts and warnings (Kalkstein et al., 2009). Humidity factors also influence the ability to cope with heat exposure, as detailed in Table 17.

Humidity	40%	50%	60%	70%	80%	90%	100%
Temperature	42°C	40°C	38°C	36°C	36°C	34°C	32°C
	44°C	42°C	40°C	38°C			

Table 19 Humidity and Temperature Heat Stroke Guide

(GeoScience Australia, n.d).

The following figure projects maximum surface temperature (annual) to 2030 using the A1FI scenario.

**The Projected Maximum Surface Temperature, (°C) in Australia for the year 2030, Annual (A1FI) image (CSIRO, 2011b) is unable to be reproduced here due to copyright restrictions.**

**The Projected Maximum Surface Temperature, (°C) in Australia for the year 2030, Annual (A1FI) image cannot be accessed as the OzClim data portal is no longer available.**

Figure 30 Mean Maximum Temperature 2030, A1FI

(CSIRO, 2011b).

Summer maximum temperatures range between 26<sup>0</sup>C on the coast (from Cowaramup to Denmark) and 30<sup>0</sup>C inland (Boyup Brook, Cranbrook, Tone River, Mount Barker) (CSIRO, 2011b). This does not include impacts from heat wave activity, which have historically risen well over 40<sup>0</sup>C as previously listed in Table 14.

Daily minimum and maximum summer temperatures for each community are expressed in Table 52 (found in Appendix 8.0) using the AIFI scenarios. This might represent one of the ‘worst case scenarios’ in terms of maximum summer heat, however does not include heat wave activity (high daily maximum and minimums for a period of three days or more). The difference between the daily minimum and maximum creates risk factors for heat related mortality, as high night time temperatures are associated with heat stress (Chestnut, Breffle, Smith & Kalkstein, 1998).

Variations between maximum and daily minimums are subject to considerable uncertainty as previously discussed however Table 24 demonstrates that the highest variation between minimum and maximum temperatures occurs more commonly in December and that coastal communities show the least amount of variation. These areas offer some protection from heat wave and temperature variation during summer months. Towns with lowest daily maximums (mild summer) temperatures are listed in order from lowest to highest (these towns may have milder summers);

- Augusta
- Margaret River
- Walpole
- Denmark
- Northcliffe
- Pemberton
- Mt Barker
- Nannup
- Cranbrook
- Manjimup
- Bridgetown
- Boyup Brook.

Increasing mean temperatures are associated with hotter days and heat wave activity. Heat-related deaths are preventable, vulnerability to heat stress is associated with living in inner city areas due to the heat island effect, being elderly, having a disability, and ethnicity (non-English speaking). As persons in regional and rural areas generally have a higher burden of disease they are also vulnerable to heat stress (Casa & Csillan, 2009; Loughnan, Tapper, Phan, Lynch & McInnes, 2013).

#### 4.6.8 Humidity

Humidity will reduce the body's ability to sweat and cool down (Maloney & Forbes, 2011). Sweating, type of clothing (and direct skin exposure to sun) and impacts of the nervous system all influence summer acclimatisation (Taniguchi et al., 2011). The following figure shows Relative Humidity for summer in W.A. by 2030, revealing a possible 0.5% increase in humidity.

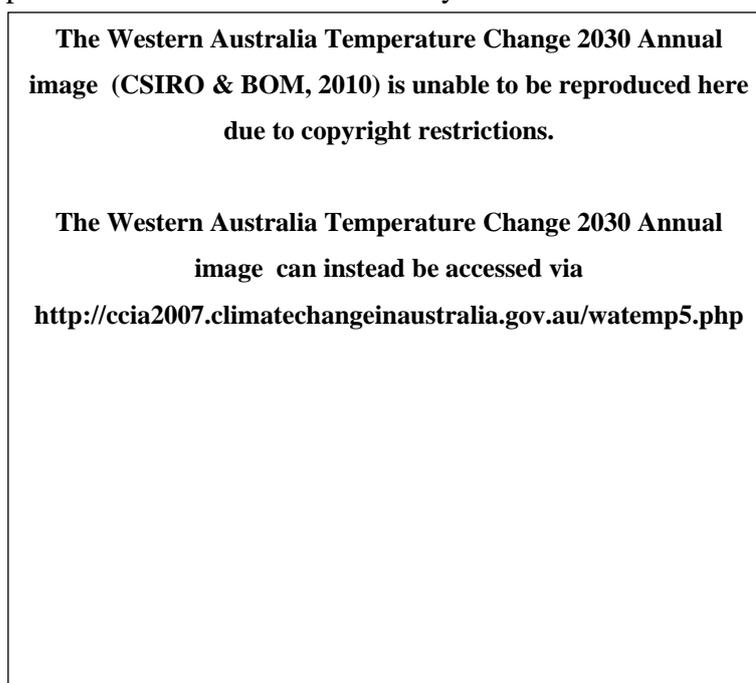


Figure 31 Humidity 2030 under Low, Medium and High Scenarios (CSIRO & BOM, 2010).

Summer humidity for each town (where available) is listed in the following table. Uncertainty is not expressed for each storyline; this represents a range of possible scenarios.

Town	A1F1 (high warming)	A1B (moderate warming)	B1 (low warming)
Denmark	71.8%	72.2%	72.3%
Walpole	73.1%	73.2%	73.2%
Northcliffe	72.4%	70.3%	70.3%
Pemberton	70.2%	70.3%	70.3%
Manjimup	67.2%	67.2%	67.3%
Bridgetown	65.8%	65.9%	65%
Nannup	66.8%	66.9%	66.9%
Augusta	70.6%	70.6%	70.6%
Witchcliffe	69.7%	69.8%	69.8%
Margaret River	69.7%	69.8%	69.8%
Cowaramup	68%	68.1%	68.1%
Boyup Brook	61.5%	62.6%	61.7%
Quinninup	69.5%	69.5%	69.6%
Cranbrook	63.1%	63.1%	63.2%
Mt Barker	69%	66.1%	66.2%
Windy Harbour	72.4%	72.4%	72.4%

Table 20 Humidity 2030 by Community under Low, Moderate and High Rates of Global Warming (CSIRO, 2007b).

Humidity levels above 70% are associated with discomfort, particularly above 80% (Work Safe ACT, 2011). Communities with summer humidity below 70% for all future scenarios are; Manjimup, Bridgetown, Nannup, Witchcliffe, Margaret River, Cowaramup, Boyup Brook, Quinninup, Cranbrook and Mount Barker. Communities with humidity above 70% (and potential increased levels of thermal discomfort) are Windy Harbour, Denmark, Walpole, Northcliffe and Pemberton. Socio economic and demographic factors influencing adaptive and coping behaviour with regards to thermal comfort will be discussed later in the thesis. Rapid temperature change within one day increases mortality risk for some groups within the population (Lim, Park & Kim, 2011).

#### 4.6.9 Hot Nights

Hot evenings are defined by temperatures above 23<sup>0</sup>C; the difference between daily maximums and minimums is called the diurnal range (Sawka, Castellani, Pandolf & Young, 2001). High night time temperatures reduce “physiological recovery from day time heat”, (English et al., 2009, p. 1674). Evenings (or minimum daily temperatures) exceeding 23<sup>0</sup>C form part of the criteria for health alerts in Western

Australia (Government of Western Australia Department of Health, 2010). Hot evenings above 23<sup>0</sup>C have not been identified using OzClim.

#### 4.6.10 Sea Surface Temperature

The complexity of the changes to both sea and land mean extrapolation of results from models for sea surface temperature changes are difficult with regards to impacts to the ecosystems and health impacts (Fleming et al., 2006). The changes for annual sea surface temperature from 1990 to 2030 are listed in the following table (all show an increase between 0.4<sup>0</sup>C and 0.9<sup>0</sup>C). Potential increases to temperatures in 2030 are listed below; the coast line from Margaret River to Windy Harbour is consistently warmer than the sea surface at Denmark (CSIRO, 2011c).

A1B (low)	B1 (medium)	A1FI (high)	A1FI Summer
0.5 <sup>0</sup> C Margaret River to Windy Harbour	Margaret River 0.6 <sup>0</sup> C	Margaret River 0.8 <sup>0</sup> C	Margaret River 0.9 <sup>0</sup> C
0.4 <sup>0</sup> C Windy Harbour to Denmark	Denmark 0.5 <sup>0</sup> C	Denmark 0.7 <sup>0</sup> C	Windy Harbour 0.7 <sup>0</sup> C
Margaret River 20-22 <sup>0</sup> C Windy Harbour to Denmark 18-20 <sup>0</sup> C	Margaret River 20-22 <sup>0</sup> C Windy Harbour to Denmark 18-20 <sup>0</sup> C	Margaret River to Windy Harbour 20-22 <sup>0</sup> C Walpole to Denmark 18-20 <sup>0</sup> C	Margaret River to Windy Harbour 20-22 <sup>0</sup> C Denmark 18-20 <sup>0</sup> C

Table 21 Temperature Change of Sea Surface Temperature for Coastline (1990-2030) Under Annual Low, Medium and High Emission Scenarios, and High Emission Summer Scenarios (CSIRO, 2011b).

#### 4.6.11 Sea Level Rise

By 2030 a moderate scenario for sea level rise off the coasts of Margaret River to Denmark is between an increase of 50mm, and a decrease (off shore), of 50mm.

**The SRES A1B projected departures from the global mean for 2030 (mm) – CSIRO Mk 3.5 image (White, 2010) is unable to be reproduced here due to copyright restrictions.**

**The SRES A1B projected departures from the global mean for 2030 (mm) – CSIRO Mk 3.5 image can instead be accessed via [http://www.cmar.csiro.au/sealevel/sl\\_proj\\_regional.html](http://www.cmar.csiro.au/sealevel/sl_proj_regional.html)**

Figure 32 Sea Level Rise 2030  
(White, 2010).

Using the A1B scenario; departure from global mean at 2030 shows a decrease of approximately 25mm, with a standard deviation showing a possible increase of less than 5 mm, or a decrease of 50mm. Possible scenarios (individual runs) show an increase of up to approximately 30mm or decreases of up to 75mm. Using Bruun's rule (which has several limitations) (White, 2008), this would result in a loss of beach of 3 metres as a worst case scenario, or an increase in shoreline retreat of up to 5 metres, with the mean scenario showing a shoreline retreat of up to 2.5 metres (UNFCCC, 2011a).

A long range scenario risk assessment (with low confidence) to the year 2100 shows some properties to be at risk from sea level rise in Augusta-Margaret River Shire that are 55 metres from the coast (80 buildings) and 110 metres from the coastline (170 buildings). There is little consensus regarding the worst case scenario for sea level rise due to uncertainty about impacts from melting ice sheets and glaciers, along with non-linear impacts which could account for several metres of sea level rise in the coming centuries (Department of Climate Change, 2009).

#### **4.6.12 Pan Evaporation**

Pan evaporation is the amount of water that evaporates from an open pan; the amount of evaporation depends on wind speed, temperature and cloudiness. No clear trend for changes to evaporation have been found using climate data from the 1970s, it is expected that pan evaporation will increase by 2030 and lead to a reduction in soil moisture in southern Australia (BOM, 2016b; Whetton et al., 2015).

#### **4.6.13 Extreme Weather Events**

Extreme weather refers to cyclones, extreme precipitation, flooding, bushfires (Mills, 2009), sudden frosts and hail storms (CSIRO, 2011d). Bushfires are likely to have a longer season with more intense fires, with very high fire weather to increase by 10-30 days and extreme fire weather to increase by 15-65 days by 2030 (Garnaut, 2008). Drought months will increase by up to 20% by 2030 over most of Australia, with fire danger ratings to increase by 4-25% by 2020. The total number of tropical and cool season tornadoes is thought to be decreasing; however the intensity of these events will increase (Whetton & Power, 2007).

### **4.7 Summary of Future Climate Change**

It is likely that rainfall (annual rainfall) will decrease in future, from 0-5 per cent, up to 10% in the study area. Rainfall variability (heavy rain and drought) may present more challenges to health than reductions in rainfall due to the impacts on the potable water supply and irrigation demand. Pan evaporation (which is more likely in Wheatbelt areas) will also influence overall water demand as more water is required for irrigation in intensive agriculture. Temperature impacts are more likely in those areas that experience early summer heatwave activity and in particular those areas that experience high humidity. Southern coastal areas may be more vulnerable to humidity impacts relating to hot weather, however all areas have historically experienced heat wave activity. Sea level rise data is uncertain and is difficult to make any future decisions regarding the impacts to 2030. It is likely that extreme weather (in particular storms) will increase in intensity and have high associated costs.

#### **4.8 Summary of Chapter Four**

Chapter Four examined the profile of the current and future population demographic in the Blackwood Stirling region and explored the historical and future climate and extreme weather events. Uncertainty is discussed as a limiting factor to risk assessments for future risks. The profiling of the future demographic indicates potential population growth in coastal areas with population decline in the Shire of Manjimup. Future climate and some potential health risks were discussed. The Chapter concludes with a summary of the local government areas and potential climate impacts. Chapter Five presents the data collected, Chapter Six assesses the risks and Chapter Seven concludes the thesis with an overview of the research.

## **Chapter Five - Data Analysis**

### **5.0 Introduction**

Chapter Five will describe the data analysis results following the four stages of data collection. These were focus group meeting data, stakeholder group interview data, expert panel review data and community survey data. Likely climatic changes leading to social, environmental and economic impacts all influence health and these are considered and examined in the data analysis. The Chapter will conclude with a summary of the likely future health impacts. Chapter Six outlines the risk assessment process of the rHIA and risk management strategies. Chapter Seven discusses the research findings and concludes the thesis.

### **5.1 Focus Group Meeting Data**

The focus group meetings were held in eleven different communities. The meetings were facilitated using a typical teaching-learning (constructivist) approach, the aim was to give the participants the opportunity to reorganise some of their preconceptions about climate change issues (Higgins & Toness 2010, p. 13). A future oriented discussion (to 2030) concerning the impacts of climate change relied on comprehensive and up to date literature review data, future scenarios of each community was communicated through maps, tables and models (temperature, rainfall, humidity etc.) and other visual information. Ten basic themes framed the discussions in local communities (Appendix 1.0) and will be discussed below with themes outlined in a table for each question. Uncertainty was explained at length, which included human responses to climate change and mitigation, along with mathematical uncertainty (Ebi & Semenza, 2008).

Word frequency searches were useful for developing themes however as the communities had diverse participants and risks (e.g. communities at risk of drought compared to communities at risk from flooding events) the codes developed from the ten questions along with emerging themes were used to interpret the data.

#### **5.1.1 Question One – Observed Climate Change**

Most of the community participants stated they had observed declining rainfall and impacts to flora and fauna; (including shifting seasons). Not all participants believed

this was solely attributed to climate change (a few dismissed the theory of climate change and believed we were in a climate cycle) and implicated land use practices (clearing) to deteriorating ecosystems and reduced precipitation. Some participants did not observe any climate changes. Themes association with observed climate change were;

<p><b>Rainfall:</b> Reduced rainfall, shifting seasons, reduced winter storms, reduced groundwater, reduced water quality, reduced riverine flushing, changes to grasses sown for pasture due to reduced summer rain, less winter flooding, land clearing (deforestation) linked to rainfall reduction, cutting hay later, inland communities receiving less rain and rainfall tracking in a southerly direction, reduced streamflow.</p> <p><b>Temperature:</b> Colder spring weather, cutting hay later, less temperature and humidity (less mist), less winter frosts, increased summer temperatures, increased stress to local flora, glaciers melting</p> <p><b>Marine Environment:</b> Changes to sea surface temperature, sea level rise, glaciers melting, coastal erosion and sea level rise due to land mass change.</p> <p><b>Extreme Weather:</b> Higher exposure to UV, increased bushfire risk and less winter flooding.</p>
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Table 22 Observed Climate Change.

### 5.1.2 Question Two – Climate Change and Lifestyle

All community participants believed climate change would in some way affect their lifestyles; many comments related to increased cost of living, diminished government services and changes to the types of agriculture (cropping, livestock and horticulture) along with types of seafood available. Further damage to ecosystem services was a concern for participants, particularly fauna that was already under pressure through loss of habitat. Recreation was given high value by the participants, particularly nature based activities such as the coast, fishing, and involving children with outdoor pursuits.

<p><b>Recreation:</b> Getting sunburnt more easily (age related), more time at the beach, negative impact to National Park use, more opportunity for swimming, more flies with warmer temperatures, costs of maintaining irrigated pitches and playing fields (sport).</p> <p><b>Impacts to Housing:</b> Impacts to elderly populations in coastal communities.</p> <p><b>Economy:</b> Increase in tourism, tree plantation yields, changed timing of tree planting (silviculture), loss of valued community members following local employment disruption.</p> <p><b>Stakeholder collaboration:</b> To maximise benefits of climate change between agencies.</p> <p><b>Lifestyle:</b> More likely to stay indoors in hot weather.</p>
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Table 23 Lifestyle Impacts from Climate Change.

### 5.1.3 Question Three – Benefits and Opportunities

Some participants stated there would be more opportunities for recreation due to less rain and warmer temperatures. This might also facilitate new crops and food grown in the region and more opportunities for tourism. Some participants stated that the opportunity was to introduce sustainable farming practises that relied on organic methods and would eliminate the need for herbicides and pesticides (Biodynamic farming). Some landholders stated they had already planted local native trees and shrubs in order to protect natural biodiversity and weren't concerned about capitalising from a carbon market economy. Another participant stated that the early warnings of climate change presented an opportunity to protective vulnerable niche ecologies by taking steps now to create safe havens. In recognising the possible risks to agriculture and the global food chain from climate change effects, one participant stated that growing food locally would prevent vulnerability to these impacts, "an opportunity to grow your own [local food] again as it is going to be more expensive to import it".

<p><b>Economy:</b> Increase in yields for some agricultural industries, costs to industry associated with reduced water supply, little impact to aquaculture businesses due to location in high rainfall area, diversification of incomes on farming properties and changing of work and school hours to avoid heat exposure.</p> <p><b>Emissions Trading Scheme:</b> Influence energy use.</p> <p><b>Technology:</b> Water treatment and desalination.</p> <p><b>Self Sufficiency:</b> To save money.</p> <p><b>Renewable energy:</b> Water treatment using solar, bio-diesel, wind power (argument over aesthetics).</p> <p><b>Retrofitting:</b> Insulation.</p> <p><b>Housing demand/development:</b> Choosing to live in the South West for the mild climate, solar passive and 6 star energy rating.</p> <p><b>Education:</b> Reduce water and energy use (associated with increasingly affluence), promote sustainability in schools and decrease meat consumption.</p> <p><b>Mitigation:</b> Delayed reward for mitigation activities, mitigation is crucial to prevent damage.</p> <p><b>Reduced spending:</b> To reduce environmental damage from consumerism.</p> <p><b>Recycling:</b> Improve cost benefits.</p> <p><b>Technology and Patents:</b> Ensuring products are released to the market for benefits for society.</p> <p><b>Community resilience:</b> Work together to adapt.</p> <p><b>Reduced Car dependency:</b> More delivery and freight services, shopping bus.</p> <p><b>Intergenerational Justice:</b> Younger generations caring for older members of the community and today's generation ensuring that future generations have the same opportunities.</p> <p><b>Fire Safety:</b> Housing materials and greenbelts (fire breaks).</p> <p><b>Agriculture:</b> Organic farming (soil microbes), mulch, sell potable water, biodynamic farming, timing of pasture seeding and fencing off riverine areas to protect water quality.</p> <p><b>Baseline knowledge:</b> More weather stations to collect data, and flora and fauna studies.</p>
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Table 24 Benefits and Opportunities from Climate Change.

#### 5.1.4 Question Four – Observed Impacts from Climate Change

The community participants had observed impacts from climate change (since the 1970's) to water quality in various catchments in the study area and the impacts this had on species types (fish and riverine plants). Temperature changes were said to impact breeding cycles of frogs, cause stress to trees and shrubs (heat stress) and changes to bird migration patterns across the region. Some participants believed sea surface temperature was influencing whale migration and behaviour. This is summarised in the table below.

**Rainfall:** Bird migrations southerly due to less rain inland, rivers becoming saline, river fish species changing, pests in the river systems due to decreasing water quality (total dissolved solids), increased runoff and loss of topsoil (reduced pasture). Deterioration of rainfall and water quality observed in: Dumbleyung catchment, Warren River, Blackwood River and Wilson Inlet.

**Temperature:** Increased stress to local flora, changes to frog breeding due to colder winters.

**Marine Environment:** Disruption to whale migration and beaching of whales, more weeds in the river systems.

Table 25 Observed Impacts from Climate Change.

### 5.1.5 Question Five – Climate Change and Mental Health

The community participants identified determinants of health and wellbeing (e.g. economy, services ecosystem health), however few made the links to health outcomes (infectious disease, chronic disease, nutritional disorders, injury and mental health). Health outcomes were seen as a result of community exposure to environmental, social, and economic conditions, (e.g. loss of industry, leading to declining sources of income, services and the associated impacts to the community) but were not viewed as being directly related to exposure to climatic changes in the future (e.g. indoor air quality factors). The range of health determinants and outcomes were discussed more succinctly by the expert participants that undertook a health risk analysis/component of the rHIA. One participant stated, “you would see our forests disappear; that’s pretty traumatic because it creates its own mini/micro climate...all the species that relate to that...it would be a tragedy”.

**Temperature:** High temperatures increase irritability.

**Extreme Weather:** Crime.

**Loss to ecosystems:** Less enjoyment from natural surrounds, sadness from loss of niche flora and fauna.

**Stakeholder collaboration:** Frustration at lack of action, leadership and vision.

**Species Extinction:** Depression.

Table 26 Mental Health Impacts of Climate Change.

### 5.1.6 Question Six – Methods to Increase Benefits/Reduce Negative Impacts

In order to take advantage of potential increases to tourism in the region, having access to sustainable transport options (e.g. bus or train services to replace private car

use) would be required in order to prevent an increase in carbon emissions. High costs of maintaining a vehicle was said to reduce disposable incomes. Most of the participants recognised that growing a percentage of household fruit and vegetables was a benefit physically, mentally and financially. In order to maximise benefits from changing climates, some farmers stated that long term assistance through the provision of technical support from the Department of Agriculture was required. It was stated that in their personal experience as a farmer in a farming community, initiatives from government departments were not always followed through with technical advice and other forms of support. In terms of the goal of adapting farms and farmlands to climate change, one participant employed in the agro-forestry industry stated it was better to, “have a better conceptual plan of how you work with communities to go towards that goal, rather than ... political hyperbole that actually achieves nothing”. In other words a longer term commitment to provide technical assistance to farming communities to take advantage of any beneficial impact under climate change scenarios. Another participant stated in order to provide services in rural communities and to increase social capital that more volunteering may be required. They stated, “we seem to be suffering from an enormous shortage of time despite the fact we live so automated”.

<p><b>Future planning:</b> Stakeholder collaboration, social transformation, low interest loans, support family planning abroad, create bush corridors (Gondwana Link) and social/community development (local government).</p> <p><b>Health Benefits:</b> Less asthma.</p> <p><b>Education and volunteering:</b> Land care and supporting volunteers enhance awareness of environmental issues, energy audits, Transition Network, provide skills training to children to be more resilient and catastrophic impacts of climate change.</p> <p><b>Engineering works:</b> Coastal engineering may lead to unintended negative impacts.</p> <p><b>Increase rainfall:</b> Tree planting and other revegetation action.</p> <p><b>Urban High Density Type Development:</b> Impacts to environment.</p> <p><b>Agriculture:</b> Plant stress, increased pests and diseases, increase locally grown food, need to increase water storage (dams), increase in irrigation, eat low carbon emitting livestock (e.g. kangaroo meat), selecting stock to cope with increased UV and consume native plants.</p> <p><b>Industry:</b> Costs due to higher energy costs and reduced water supply.</p> <p><b>Port upgrades:</b> Cope with rising sea levels and continue shipping.</p> <p><b>Insurance:</b> Ensuring adequate insurance coverage.</p> <p><b>Housing:</b> Retrofitting to maximise water capture and reduce use of air-conditioning (increase resilience).</p> <p><b>Town Planning:</b> Prevent overdevelopment as a result of higher demand for South West properties.</p> <p><b>Renewable Energy:</b> Electric cars, solar power (avoid summer blackouts), tidal power and efficient use energy.</p> <p><b>Reafforestation of depleted areas:</b> South America and Indonesia.</p> <p><b>Ethical Trade:</b> Within Australia and abroad, increase education of these issues.</p> <p><b>Health Service:</b> Increase in locum Doctors.</p> <p><b>Carbon sequestration:</b> Paid and unpaid programs, tree plantations absorb carbon, protect vegetation of primary dunes in national parks.</p> <p><b>Reduce Waste:</b> Clean the oceans to improve resilience.</p> <p><b>Adaptive governance:</b> Support agriculture with less bureaucracy, support democracy in third world nations, water restrictions and ban lawns.</p> <p><b>Stakeholder collaboration:</b> Eradicate pests, weeds and feral animals.</p>
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Table 27 Methods to Increase Benefits/Reduce Negative Impacts.

### 5.1.7 Question Seven – Potential Risks to Community

Risks to the communities were considered as economic, social and environmental. If job opportunities and economic growth (or a stable economy) was threatened by climate change, this was given high levels of concern, as the flow on effects from job losses and impacts to business and government services would impact the whole

community. Social risks included marginalisation of vulnerable groups based on race or ethnicity, remoteness and age. This was also due to older members of the community being unable to drive and remain independent, meaning a greater reliance on health and social services. Environmental risks included salinisation of water supplies and losses/extinction of vulnerable species.

<p><b>Extreme weather events:</b> Bushfire, summer lightning, service disruption and migration, towns may be uninhabitable due to fire risk and protracted drought.</p> <p><b>Water Supply:</b> Reduced rainwater for houses that use rainwater tanks, increase in costs to provide water supply, reduced water supply for agriculture and carting water.</p> <p><b>Economy:</b> Disruption to industry will impact employment and may lead to out migration, tree plantations (tree plantations replacing agriculture) destroying local communities (loss of population) and scarcity leading to crime.</p> <p><b>Agriculture:</b> Losses to wheat production (increased food cost), reduced yields for avocados and potatoes (less water availability), loss of valued farmland to tree plantations and carbon sinks, increased cost of food and more imports.</p> <p><b>Climate change:</b> Peak oil, cost of non-renewable energy is limiting renewable technology, methane, and melting permafrosts.</p> <p><b>Temperature:</b> Heat Island effect, housing not appropriate for higher temperatures, greater exposure for children and other at risk groups (government and privately owned) and summer blackouts (no air-conditioning during heat waves).</p> <p><b>Political influence:</b> Delaying early adaptation and mitigation, budget cuts to health services and grants for environmental monitoring and management.</p> <p><b>Future population:</b> Will have to deal with risks, unexpected human behaviour during food shortages, technology is reducing contact with nature, global overpopulation, and mass human displacement in Asia.</p> <p><b>Biodiversity loss:</b> Changing to breeding of amphibians, loss of water recharge, and impacts to fauna and stress to flora.</p>
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Table 28 Potential Risks to Community.

One participant stated that the low cost of oil was preventing renewable technology adoption, “cost of oil would be one, you will never have good battery cars til the oil runs out”.

Another participant stated,

“That’s the tragedy of the commons, as individuals we can’t affect climate change in this sparse community, we can’t affect climate, all we’ve got is adaptation”

### 5.1.8 Question Eight – Greatest Source of Harm

The greatest source of potential physical harm was reported to be from bushfire. In the experience of many of the participants (who had actively fought fires) they believed much of the risk could be minimised through preparation and avoidance. Many community participants reported that loss to the local economies would contribute to more long term harm than direct climate change impacts.

<p><b>Extreme weather events:</b> Bushfire, pressure on volunteers and conflict about prescribed burning.</p> <p><b>Economic decline:</b> Loss of volunteer base and lack of resources to adapt.</p> <p><b>Temperature:</b> Impact to outdoor workers.</p> <p><b>Ecosystem impacts:</b> Extinction.</p>
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Table 29 Greatest Source of Harm.

### 5.1.9 Question Nine – Risks that can't be Readily Managed

Risks that couldn't be readily managed related to global and political forces that could create harm to individuals, businesses and communities. These included an increase in environmental refugees, food scarcity due to extreme weather events destroying staple food crops and increases in the human global population.

<p><b>Extreme weather:</b> Bushfire in areas with dense vegetation (Quinninup, Dean Mill, Nornalup, Northcliffe and Walpole) and drought will limit population growth in areas.</p> <p><b>Temperature:</b> Housing quality.</p> <p><b>Cost/Benefits:</b> Hard to determine where to spend money in future with uncertain impacts.</p> <p><b>Economy:</b> Any local decline will negatively influence adaptation; out migration will negatively influence volunteer structure of community, misinformation about meat consumption (health benefits of meat and low water use in pasture fed cattle).</p> <p><b>Pests/Weeds:</b> Increased use of herbicides and insecticides.</p> <p><b>Ecosystem damage:</b> Loss of adequate water recharge (impact to native fauna), loss of Tingle Forest and niche species.</p> <p><b>Vector borne:</b> Mosquito borne illness.</p> <p><b>Government Policies:</b> Water taxes and access.</p>
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Table 30 Risks that can't be Readily Managed.

### 5.1.10 Question Ten – Vulnerable Community Members

Community members that had no preparation to climate change due to cognitive dissonance were identified as being vulnerable and potentially would rely on other community members when they experienced the impacts of climate change. Elderly and disabled people were identified as being vulnerable in an emergency situation as requiring assistance for evacuation. An over-reliance on technology and disconnection with nature were other reasons given for increased vulnerability, particularly for young people. Any changes to the costs of fresh produce would impact low income families as described by one participant. “Definitely those of us on low incomes too you know, I’m struggling ... we eat ... the basics, the shop is too expensive here”. The effect of a lack of medical services was suggested by another participant. “The main problem is keeping older people in the area by providing enough medical services, instead of forcing people in older person homes”.

**Housing:** Location near biomass (bushfire risk).

**Building Quality:** Children and elderly exposed to high temperatures.

**Low income households:** Cost of food and lack of emergency provisions.

**People with allergies:** Increased pollen production.

**Lack of Health Services:** Rural communities have low access to GP’s, burnout for volunteer Paramedics and elderly residents forced to leave due to low access to medical services.

**Pre-existing health condition:** Heart, lungs and asthma.

**Emergency Evacuation:** Poorly designed evacuation.

**Farm properties:** Theft in an extreme weather event.

**Fishing Industry:** Impacts to marine species.

Table 31 Vulnerable Community Members.

### 5.1.11 Summary of Focus Group Data

Participants addressed many of the health and wellbeing factors associated with health impacts from climate change. Vulnerable groups were identified, with methods to adapt, ranging from changing government policy to increasing water storage or retrofitting dwellings. The theme of sustainability was embedded into most discussions; with climate change being a result of overconsumption and environmental degradation. Overpopulation and inefficient use of resources were also repeated by participants in each community meeting.

Participants mentioned several factors influencing agriculture and food production in their communities, despite the fact many of them were not employed in agriculture. Agricultural pursuits form part of the 'rural identity'. Impacts related to policies and research, pressure from overseas markets influencing local growers and consumption habits, food miles, storage conditions (power failure), rainfall, temperature, pressure on aquatic resources and increasing costs from various factors. Community participants identified positive benefits including increasing temperatures that allow longer growing periods for farmers and the opportunity to grow different plants (adjust growing seasons for products to enter the market at alternate times in the year). Participants did not mention carbon fertilisation as a factor that may influence crop quantity or quality. Carbon fertilisation refers to increasing photosynthesis from rising carbon dioxide levels (MacBean & Peylin, 2014). Some participants mentioned that transforming arable farmland or pasture to tree farms (as carbon sinks) may result in decreased food availability and therefore increase costs to consumers, with the responsibility of reducing mitigation at the household or industrial level merely being shifted 'elsewhere'.

Policies that would benefit farmers were suggested; decreasing overseas imports; this would reduce food miles, increase food quality, and improve access to markets by local producers that have more equitable employee arrangements. Research to assist farmers to operate competitively with reduced water supplies (or quality) and changing climatic conditions was suggested as being critical to a successful transition for local agricultural enterprises. A small number of participants claimed that consistent and ongoing support from the Department of Agriculture was said to be lacking in the past. The role of supermarkets' influence on both prices to consumers and farming viability was discussed, with farmers accepting low prices for products (meat, fruit and vegetables) and facing competition from other areas in Australia or overseas. It was suggested that this could be addressed through direct purchasing by consumers (similar to Community Supported Agriculture). A suggestion of supermarket collusion in relation to abattoirs was suggested by two different communities, in that the two major supermarket chains in Western Australia were controlling meat prices, with a mark-up of 1000% in some cases (from price at the farm gate to packaged price in the supermarket) (Australian Competition and

Consumer Commission, 2008). Beef cattle farmers were concerned that the nutritional profile of beef was being overlooked by researchers and that greenhouse gas emissions did not take into account the health benefits of meat, this claim is supported by research conducted by Vieux, Darmon, Touazi & Soler (2012). Other land owners were voluntarily restoring bushland and revegetating (planting trees) in existing paddocks and received no financial benefit for doing so.

Fishing for recreation and professional fishing operations were said to be under threat due to changes to fish stocks (species shifting), overfishing and pollution to riverine environments (along with reduced flushing due to declining streamflow). Aquaculture projects, such as Abalone farms were suggested as a local source of income and employment. Lack of secondary processing facilities in the local area created additional food miles for local products. Farmers had assessed the cost and stated that it wasn't worth trucking cattle and meat produced back to their communities. Local, small abattoirs were one way suggested of reducing these food miles.

Creating agricultural based tourism enterprises was said to be hampered by "bureaucracy" that created financial disincentives (e.g. number of wheelchair access toilets and road specifications in remote areas). Other state policies relating to "regulating" and de-regulating industries, (e.g. dairy) meant that many farming businesses have changed or ceased, and dairy products were now facing competition from other areas due to cost factors. Having other sources of income to farmers, other than the wholesale market was one suggestion in keeping rural areas viable. Cost of farmland and debt of farmers was said to restrict and diminish investment into environmentally friendly agriculture, and also prevent young growers from entering the industry (or moving to rural areas). Suggestions for long term sustainable agriculture included biodynamic and organic methods. Pressure from the state government to maintain working agricultural land also reduces ability to expand the population through urban style sprawl, some farmers have suggested they get paid very little to produce food, and have less access to facilities to their urban counterparts, creating a feeling of inequity.

In terms of management of personal food supplies, many participants suggested growing some, if not all of their required food needs (particularly vegetables and poultry). Some participants believed this would also provide some sort of insurance if food prices fluctuated in future due to crop damage or drought conditions elsewhere. This approach is promoted in order to benefit from active, outdoor living (Department of Climate Change and Energy Efficiency, 2012a). Some participants stated that climate change would expose their community to fluctuating fuel, utility and food prices that would inevitably increase. Health impacts were considered likely by participants due to low affordability of healthy food. This could also have consequences for groups that are currently marginalised; these statements are supported by research (Bellotti, 2010; Food and Agriculture Organization of the United Nations, 2011).

Comments relating to reduced access to water (through drought or reduced streamflow) would limit the ability of farmers to produce certain types of food. Smallholders felt that producing vegetables through summer was becoming increasingly difficult due to higher temperatures, water restrictions and ageing. Another way of insuring personal food supplies was to have adequate food storage and backups (e.g. freezers and generators). In many respects the region is in a superior position with regard to food security due to the agricultural basis of the economy and coastal location.

Leisure was mentioned several times by community participants. Leisure was seen as a contributor to health and wellbeing, social cohesion and for the physical benefits for activity and relaxation. Some of the discussion veered away from climate change impacts to the social components of leisure in a strong, resilient community; however community participants found the topic important for future resilience of their towns.

Increases in the population within some communities (coastal regions) with the migration of retirees to these areas, were viewed by some participants as segmenting the town (through social isolation and lack of participation). Reduced community 'mindedness', or lack of shared purpose through sport and recreation was a result of an influx of newcomers to town, although other participants also stated that with

many options for various community groups it was easy to find likeminded companions. Preventing volunteer burnout and whole of community support was considered vital for retaining sports in local communities (there was increased pressure for minimum training and coaching qualifications, and increased insurance expenses).

Out of season sunny days were seen as encouraging people outside during months when it was usually too cold, but would increase exposure to harmful UV rays (particularly for older people with more sensitive skin). Exposure to mosquitoes was considered an increased risk to leisure by some participants. Elderly people without transportation were also mentioned as people with reduced opportunity for group leisure and at risk from social isolation.

Loss of biodiversity rich habitats was a risk factor mentioned in three communities for a loss of nature based leisure and included higher impacts from leisure on to the remaining existing landscapes. Habitat and species loss was mentioned in all fishing communities, with particular regard to bird life, riverine health, fishing opportunities and associated loss of tourism investment. Also community participants that resided in areas with large tracts of forests were concerned with the loss of biodiversity and the impact on mental health and wellbeing. One participant stated the most responsible form of tourism would be for local holidaying.

Currently the main source of economic production is based on mining, property and manufacturing, with other industries including agriculture, horticulture, viticulture, timber and forest products, retail, tourism, construction, services, fishing and aquaculture. The region has a low level of unemployment, with tourism accounting for approximately 7 per cent of employment in the wider region (Garnaut, 2008). Unemployment was not discussed as being a critical factor for the region by the participants; however in several different discussions, global economic factors, peak oil and government policy were said to strongly influence income levels, with subsequent effects on small businesses and services within the community.

The cost of transport is described by one participant as the key feature that may make rural living too expensive, and lead to rural population decline. Farmers have stated this already impacts the price they receive for their produce and this is likely to continue. With limited public transport by bus (usually one service a day for smaller towns), this does not support commuting to work and demands that private car use is kept high (Sloan, Sipe & Dodson, 2008). Two of the larger growing coastal areas (Margaret River and Denmark) have limited public transport infrastructure servicing their towns (Regional Development Australia Great Southern W.A., 2010; Shire of Augusta-Margaret River, 2012). Increasing costs of transportation are likely to impact access to retail and health services in other regions, both for consumers, and providers (e.g. government providers of primary and tertiary health care).

Poor housing stock (lack of insulation) was described by some participants as increasing discomfort if temperatures increase, particularly in summer. Some participants stated that much of the heat wave risk could be ameliorated with behavioural changes (e.g. drawing curtains and growing shade bearing plants). Some participants demonstrated a lack of knowledge relating to thermal stress being associated with age. Persons that were renting were described by participants as unable to upgrade their dwelling (some participants stated that retirees and elderly people on a low income were unlikely to invest in their house any further). Limited investment in housing in rural towns due to expense can make it difficult for these regions to revitalise their communities (Hillier, Fisher & Tonts, 2002).

Lack of involvement by young adults (18-30) was seen as an issue by the more elderly participants, but not by the younger participants. One participant stated in an extreme event rural properties were vulnerable to theft, as by their nature they are rich in food and water supplies. Distance to hospitals, and perceived lack of privacy with regards to treatment, along with an ethic of self-reliance in rural areas could prevent uptake of health and services (particularly for men) (Gorman et al., 2007). Lack of access to GPs was raised for the communities of Manjimup, Pemberton and Northcliffe, with lack of home care services stated as being an issue in Walpole.

Many participants in the Shire of Manjimup stated there was insufficient GP's available, along with low numbers of volunteer Paramedics (this was also mentioned for Greenbushes) which resulted in an increased demand on existing local volunteers. Some participants stated there were a small number of beds available (e.g. Nannup hospital) or that facilities were underutilised due to lack of staff (Pemberton hospital). One community stated its Silver Chain program was being reduced (by reducing staff numbers) even though demand was likely to increase, given the ageing population. The Silver Chain services promotes ageing in place by providing nursing and allied health care in peoples' homes (thus reducing the need to travel to health services and reducing social isolation) (Silver Chain, 2016).

Waste management represents an opportunity to reduce carbon emissions through altering purchasing habits to prevent excessive waste from entering the waste stream (Lou & Nair, 2009). Community participants stated that purchasing low quality materials that were more likely to be discarded than repaired was one of the factors that has led to a 'throw-away society', along with lack of appreciation for food which meant higher food waste. Some participants stated that the sense of disconnect with nature and lack of appreciation in younger generations perpetuated these habits. Participants saw the creation of waste as a problem of indulgence in society (made possible by high wages, dual incomes, marketing and cheap imported products).

When considering existing sensitivity to climate change, community participants in Pemberton and Manjimup (2010) stated that there were a high number of children that had respiratory illnesses (asthma). One suggestion was that this related to high pollen counts outdoors. Water quality was considered an issue with regards to reduced rainfall and quality of potable water. Advanced water treatment systems for bores and dams were a possible solution suggested by participants for declining quantity and quality, however the waste products generated were considered a disincentive (e.g. salts and metals). Ground water extraction for the Perth water supply was said by community participants in Nannup to have significant downstream impacts to the ecosystem of the Blackwood River that was already suffering from a lack of flushing events. The participants stated that adaptation to

climate change would require multisectoral collaboration and holistic management of the environment, and support for communities.

## **5.2 Data Analysis for Stakeholder Interviews**

In total, 19 government and non-government organisations or private individuals (academics) were interviewed as part of the reference group appraisal of existing or emerging policy dealing with climate change and adaptation in Western Australia to 2030. The interviews took place during January 2010. Non-response bias may occur where departments and organisations did not respond to an interview request. Due to confidentiality no personal details are provided with the quotes. The results may therefore be incomplete as to the current state of adaptation.

The four guiding questions asked were:

1. What is your organisation doing to prepare for the future climate and demographic up to 2030?
2. What is the extent of adaptation in practice and what are the barriers, obstacles or incentives to adaptation?
3. To what extent have stakeholders (including those at risk) been involved in the policy development process?
4. What are the costs of adaptation and what benefits can be anticipated?

The perspectives gained from the interviews will be discussed separately using each question (above). The method outlined in Chapter Three, describes the data collection process. The themes for each question will be discussed, along with any pertinent statements from the participants.

### **5.2.1 Question One**

#### **What is your organisation doing to prepare for the future climate and demographic up to 2030?**

After analysing and coding the data, the themes answering the first question relate to; monitoring, forecasting, resilience, plant technology, product design, plans and policies, steering groups, energy and transport. The following box explains each component and each item is explained in the following section:

<p>Monitoring (environmental soil, flora, fauna and streamflows).</p> <p>Building resilience (community, landscape and emotional resilience).</p> <p>Forecasting (rain, streamflow, storm surge and sea level rise) and research.</p> <p>Drought tolerant plants (genetic modification).</p> <p>Product design (improvement, re-use and reintegration of products back to supply chain and minimising waste).</p> <p>Developing steering committees and plans/policies at local government level (sustainability advisory committee, climate change advisory committee, energy working group, waste water, building design and orientation, ICLEI (International Council for Local Environment Initiatives) involvement).</p> <p>Energy (greenhouse gas emissions and inventory, power minimisation, solar blankets, PV panels for small communities, exploring other renewable sources (wind) and Green Power).</p> <p>Transport (public transport and Green Fleet Policy).</p>
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Table 32 Themes from Question One of Reference Group Interview.

### 5.2.2 Monitoring

Monitoring included direct observation of changes to plants and animals, species monitoring, water monitoring (streamflow, groundwater levels) and crop monitoring.

Direct observation and interaction with nature is a key part of Indigenous communities' way of life and hence they have noted changes in food availability and flowering times (seasonal changes). One stakeholder was quoted as saying;

“Obviously our heritage is where we were hunter gatherers so the land to us that’s our Mother, that’s the basis for everything...we used to enjoy out there bush food and so forth...it is a lot hotter now...but there is a great change to our bush scenery ... I think in future if things aren’t done...a lot will rely on us Aboriginal people”.

To deal with this changing scenery, land management is critical, with family and community being directly involved. The stakeholder went on to say;

“most work that seems to appear the most urgent need...land care work, hunting, water conservation, ensuring that water courses are clean and not clogged up by introduced plants”.

Declining water recharge has led to drying of marginal areas and increased risks for peat and swamp fires (and smoke creation). This is also being monitored by government departments in order to preserve niche and biodiverse rich ecological systems in a Mediterranean type climate. Runoff to recharge groundwater and riverine systems needs to be carefully managed for all stakeholders relying on rainfall and streamflow. As one participant outlines;

“We need to maintain the ecology – this is how much is available for users to pump out. What we haven’t embedded is in the adaptive management feedback so when you haven’t got a high rainfall year everything drops. The water level in the environment drops – that’s what happened naturally. The user share drops and you have this feedback loop. That’s the sort of sophisticated water management stuff that needs to happen. As a state we are not well placed mainly because a lot of farmers attitudes to private property rights. Farmers in W.A. believe the government shouldn’t be meddling or interfering...they still believe that they own water”.

Marginal areas in the Blackwood Stirling include towns that fringe on the forested areas and the Wheatbelt. These include Boyup Brook, Cranbrook and Mt Barker. Changes to the ecology (from both land change and climate change) have been monitored, including impacts from drought and salinity. In many respects Wheatbelt farmers will have more experience with land degradation and are better prepared to deal with climate change than the Southern Forests region;

“the south coast and lower South West corner hasn’t been on anyone’s radar and all of a sudden people are realising climate change is happening down here...we haven’t done anything about it”.

### 5.2.3 Building Resilience

Building resilience is approached in various ways. Environmental resilience was being tackled by revegetation programs to reduce the amount of fragmented bush land in W.A., improving salinity and enhancing biodiversity values. Other features of this program include;

“protecting remaining bushland but increasingly revegetation not just as simple systems of shelter belts but more useful habitats...conscious inclusion of things like food sources for fauna species and linking up wherever possible the native remnant areas by replanting between them”.

One concept of building emotional resilience within organisations is based on self-reflective thinking tools to develop adaptive responses towards climate change. This does not promote goal setting, rather to assess any risks through self-inquiry;

“to bring inner and outer worlds together...it doesn't matter what framework you have it will still be applied by people...if the people are adaptive in their thinking, then they are better equipped if a scenario pops up we don't have a policy for”.

This kind of emotional resilience building is available through the local government Climate Change Adaption Toolkit (ICLEI, 2008) that at least two of the local governments have been involved with. Major environmental, economic or social threats are likely to have a whole of government approach to rescue and recovery. A Public Health “adaptation response to climate change has the potential to improve public health infrastructure in ways that will better position us to handle routine needs as they intensify and to move public health, law and policy toward an approach that emphasises “resilience”...rather than “preparedness”...” (Wiley, 2010, p. 519). Resilience strategies increase the ability of a system to absorb and recover from climate impacts (thereby reducing vulnerability), this differs from preparedness which is designed to cope and recover from extreme events (Keim, 2008).

Adaptive capacity can be enhanced through emergency preparation and also preparation for a changing economic and renewable energy future (as well as climate change). The focus of fire preparation in state and local government policies and legislation is based on reducing fuel loads around the property (to up to 50 metres) to protect dwellings. This is monitored by local government. Participants have noted that not enough is done domestically, and people quickly forget the danger once it's over;

“locals are threatened because of their attitudes, lack of understanding of fire behaviour...they have an unrealistic expectation...to be...saved in any situation...in a really bad situation...most people with fire understanding won't be around...for some reason we don't prepare for it til it's too late, and that's the majority of the population, me included.”

One participant stated that

“fire is seen as less of a concern when compared to sea level rise. This is due to global insurers that do not insure sea level issues (coastal inundation). There is likely to be a bigger increase in storms and cyclones as more common events when compared to fire events”.

The Transition Network is an organisation that aims to increase the resilience of communities to climate change effects and to reduce carbon dioxide emissions (Transition Network, 2013). The Transition Network is operating in some of the communities in the study area (including Manjimup, Denmark, Bridgetown, and Pemberton). One of the participants stated that the Transition Network helped to;

“become self-reliant, re-localised, sustainable, and resilient to peak-oil, climate change and economic downturns (credit crunch). These global challenges are all intrinsically related”.

#### 5.2.4 Forecasting

Forecasting was used by several organisations, for use of water allocation, community planning (demographic forecasting), emergency management and infrastructure protection. From a planning perspective, insurance does not cover sea level rise;

“local government mapping may be used to determine areas subject to sea level rise issues and events for future planning and development.”

Water planning for the next few decades is being achieved by;

“using some of the climate change scenarios and our hydrological models. Putting those into our hydrological models and working out what water availability is going to look like”.

When examining current water use and shortage patterns, and relating these to future water availability, there is evidence that the current allocation may be lacking;

“I think towns are going to get caught out...places like Denmark, Walpole. It hasn't been on anyone's radar. The Water Corporation has been busy worrying about Perth, building the desalination plant there”.

Two of the smaller communities are looking at taking their water supply, 'off the grid'; this refers to having an independent water supply, and not utilising scheme water.

“Witchcliffe and Gracetown are working on this at the moment.”

Ecosystems relying on water bodies that are currently stressed will experience worsening conditions under climate change scenarios; this will also increase the costs of treatment as lower quality water supplies are used.

### 5.2.5 Drought Resistant Crops – Genetically Modified Organisms (GMOs)

Plant technologies form part of a rapid response by the Agriculture sector to climate change and can include genetically modified crops that deal with a lower rainfall future. There are mixed public perceptions regarding growing and consuming GMOs. Some studies indicate that farming GM crops have associated high use of pesticides and herbicides, yet the need to produce sufficient food for an increasing global population and increased risks of drought conditions may make the use of GMOs more viable and influence consumer perception (Cardoso & James Jr., 2012; Twardowski & Malyska, 2015), As one participant stated;

“genuine community engagement is needed to get over barriers, those obstacles what are preventing investment into other crops particularly food crops such as wheat and rice to produce food we need, for the population which could get to 9 billion in our lifetime”. Whether you like them or not they are looking at them...they are getting prepared...I think the broader [sic] acre farming areas ... is probably not going to be as badly hit and then they’re getting prepared”.

Broadacre farms have paddocks larger than 4000m<sup>2</sup> (Parliament of Australia, 2014). Plant technologies also aim to;

“double yields in core crops globally....and we want to do that by reducing key inputs, particularly fertiliser and water use by 30%, that’s a global goal”.

In terms of cost;

“cost of any technology is going to be more expensive than what farmers are doing already...we are protecting investment...as well allowing companies to invest in sustainable technology”.

Some local governments (e.g. Denmark Shire) have moved to make the entire area GMO free. Other local governments opposing GMOs are: Boyup Brook, Plantagenet,

and Manjimup (Farm Weekly, 2009). The challenge of producing food in variable climatic conditions, including drought may increase the demand and acceptance of GM crops. The potential environmental impacts from GM farming practices need to be carefully managed to ensure that weeds, toxins and biodiversity issues are prevented (Dale, Clarke & Fontes, 2002). Concerns about potential health impacts from consuming GMOs (including potential novel food allergies) may mean these foods will not be purchased by some consumers (Landrigan & Benbrook, 2015).

### **5.2.6 Product Design**

Product design is seen as a critical factor to improve, re-use and reduce obsolete objects entering the waste stream;

“people who are creating those products...they should design or engineer that way so that it’s safe for the planet and it stops climate change...re-look at all the products now available...re-engineer them for a better product.”

Improving all products before they reach the consumer (including building/construction materials) will reduce a considerable amount of GHG emissions and through increased recycling, reduce the energy and water needs for the life of the product. Waste contributes approximately 3 per cent of the total global emissions as a sector (WHO, 2008).

### **5.2.7 Developing Policies and Steering Committees**

Developing policies and steering committees was most reported at the local government and community level and involved collaboration with some existing groups (or energy providers) to work towards sustainability in many forms (e.g. energy use, transport use). Bridgetown and Augusta-Margaret River Shires have Sustainability Advisory Committees and Denmark Shire has a Climate Change Advisory Committee, with the goal to advise and educate the community about key issues. Other plans, policies and strategies include a Local Energy Action Plan to “reduce community and corporate emissions by 20% by 2017”.

Other plans and policies included:

- Completed a water recycling project
- Renewable Energy Policy
- Solar Orientation Policy
- Conservation Incentive Strategy
- Coastal Management Plan
- Climate Change Action Plan
- Energy Emissions Information Management Action Plan
- Climate Change Energy Policy for Council
- Rainwater, Grey-water, and Renewable Energy Policy
- Energy Efficiency Building Design Town Policy
- Green Vehicle Fleet Policy
- South Coast Power Working group.

Plans and policies described by stakeholder participants were developed for a number of reasons, including through public demand, institutional requirements and legislative requirements. Each local government may have different policies and plans to address adaptation based on access to resources and strong leadership in this area (Mukheibir, Kuruppu, Gero & Herriman, 2013).

### **5.2.8 Energy**

In many cases the participants mentioned energy; this included GHGs, energy auditing, minimising energy requirements and providing additional energy to the power grid.

In one example, reduction of power use as a behavioural adaptation is driven by cost minimisation, rather than a focus on GHG emissions. One local government viewed purchasing decisions using whole of life cycle costs rather than simply focusing on carbon emissions only. Another example showed that the position of local government is to act as a leader in the community on important issues, taking steps towards implementing policies and plans;

“Long term benefits are that we are a passionate green community and are seen to be a leader to the community in mitigation and adaptation measures towards Climate Change impacts”

Involvement with ICLEI in two local government areas has led to a higher number of policies and plans dealing with energy, water and transport compared than other local government areas (these local governments also have a higher SEIFA). Innovation is driven therefore by funding and public demand. However, in response to this, one participant acknowledged;

“I’ve got a real concern about creating documents, policies and statements that don’t mean a lot; it seems to be that real measures are not being followed through by local and state government and people in the community in general. We take a very realistic approach to these types of matters ... if you can’t afford to do it then why go down the policy path. I don’t see a lot of things on the ground yet in W.A. and the barrier to doing all of this is the financial resource. If you don’t have a Council, board of directors, or group of politicians demanding and leading the change/action then it’s unlikely to be funded and it will not get done”.

There are statutory processes with regards to local government management of waste; this is based on a license system; however GHG emissions reporting and inventory is a voluntary system. Other methods to tackle mitigation of greenhouse gases include a Green Vehicle fleet, installing alternate energy, opting for ‘green power’ by the energy provider and simply minimising energy use through behaviour change. As stated by stakeholder participants; small scale examples of action include installing solar blankets on local swimming pools and installing PV panels on Shire buildings.

Through appropriate planning laws and policies, power minimisation is achieved through correct building design and orientation, including;

“proper orientation of the Lot, proper orientation of the house/windows...generation of some of the homes energy needs through renewable sources...eaves/awnings/windows coverings...appropriate insulation...appropriate planting of vegetation outside the home...deciduous trees to the northern aspect...to achieve maximum solar benefit”.

Denmark and Walpole residents, in collaboration with the energy provider have encouraged householders to invest in energy efficient appliances and reduce power use during peak times in summer (between 5:30 and 7:30pm) as they are more susceptible to blackouts due to peak demand (Western Power, 2012).

Other state organisations have a GHG inventory as part of their management processes. Transition towns plan to reduce local energy consumption, transport and food miles, by becoming reliant on local sources of food. Retraining unemployed people as energy auditors is one way a non-government organisation plans to reduce GHGs and create employment. Transport as a theme included both organisational transport, along with community transport needs. Reducing transport use in daily life is one of the goals of the transition town movement;

“we are hoping to address the current high food miles of much of our imported food by encouraging more local food initiatives such as community gardening, public fruit trees, community supported agriculture and anything else the community thinks of”.

Lack of public transport infrastructure in rural areas is a challenge;

“we are pushing public transport as a significant issue in the Shire...we are getting pressure from the community and for that we are looking at measures to introduce public transport to the Shire. As an example we have funding for a community bus to pick up elderly from Northcliffe to travel to Manjimup for fitness/wellbeing programs. We have a long way to go...”

Residents of rural and remote communities are heavily reliant on private vehicle use for daily transportation as are residents of larger regional centres who do not have access to public transport services (e.g. Margaret River, Manjimup and Denmark).

### **5.3 Question Two**

What is the extent of adaptation in practice and what are the barriers, obstacles or incentives to adaptation?

#### **5.3.1 Extent of Adaptation in Practice**

The extent of adaptation was based on immediate need, funding, available information, public and political will. The main areas of adaptation are currently energy, water, agriculture, ecology and self-reliance. Already constrained water and energy sectors have developed strategies (e.g. effective power consumption campaigns, looking for new water sources, and looking at expanding treatment facilities in water supplies of declining quality). For smaller populations desalination facilities have not been considered (e.g. Margaret River compared to Perth), these solutions use intensive amounts of energy and may not be viable for smaller populations unless local sources are severely degraded or required for ecological purposes over and above existing needs. Long term plans for water provision in the lower South West is based on groundwater extraction from the Yarragadee aquifer (Strategen, 2005).

With adequate roof area, most households in the study area could provide their own potable water needs with the use of rainwater tanks and greywater recycling. Water and energy sectors are likely to develop long term plans with regards to provision (e.g. 20 year planning). Water is currently being carted by truck to Walpole and Northcliffe on a daily basis (they are not pipe connected to other urban centres, nor do they have reservoirs or local treatment plants). There are some 'off the grid' plans catered for small communities (Witchcliffe and Gracetown). Some of the participants identified installing water tanks as a standard feature on each dwelling as being an appropriate adaptation. Amending the Australian building code is a rapid way to alter new dwellings (it is updated annually) with appropriate building designs and orientation to be addressed in the local government town planning scheme for

emerging climate conditions. Existing dwellings are not covered by these types of legislation. Rebate schemes may be less effective in areas where drinking rain water is not permitted (e.g. urban centres), even though in the space of a few kilometers, rural dwellings use rainwater as their potable water supply. While the need to improve local water supplies was indicated by community participants, action towards this is limited by funds and planning rules.

Water recycling is being tackled by one local government that has;

“...recently completed a waste water recycling project. The majority of residential waste water is now being used to irrigate reserves, school grounds and sporting ovals, rather than having to rely upon potable sources of water”

Adaptation in the agricultural sector was considered to be greater in the Wheatbelt areas, with indications that plant technology for drought resistant grains was a method to improve yields in declining conditions;

“the institute of agriculture...and they’ve got a really broad research program looking at things like grains and crops and how to respond to less water and stuff like that. So I think the broader acre farming area is probably not going to be as badly hit and then they’re getting prepared. They are doing the research”

Benefits of any new technology would need to have rapid returns to remain a sustainable practice on any farm. Farmers regularly adapt to changing conditions through stock and crop selection and breeding programs. Climate change may be seen as an extension of existing programs. This statement suggests that beef cattle, dairy, horticulture and silviculture are less prepared as a sector.

Indigenous perspectives on the food supply have indicated that some types of food are no longer available; adaptation is therefore a change (and/or reduction) in the types of species consumed. The danger of lack of preparation for climate change is illustrated by the following statement;

“Noongars and Aboriginal people will notice it...living just for today let tomorrow worry about itself, which is probably an inheritance from living off the land. We didn't have to worry if you picked just enough fruit or took just enough animals from the bush there was always going to be enough, replenish itself...once colonisation came that changed”

Further, there are concerns that the quality of food is deteriorating;

“... the two things human beings need is food and water, and you know the environment is something we need we have to protect ourselves from the cold, wet, heat, all manner of things...food is something we put into our bodies which can and will affect us”

From an environmental perspective, adaptation is occurring by converting privately owned farmland to ecological niches, either by the landholder or by an organisation purchasing farms through private donations, to enhance and;

“restore some of the capacity for adaptive change, genetic continuity and ability to adapt to changing conditions”.

At the community level, groups similar to and including Transition Towns are actively increasing self-reliance, and withdrawal from demands on public utilities (such as reducing water demand through recycling, and improving rainwater capture).

Adaptation to changing fire behaviour through good management and preparation is currently being pursued. Future bushfires will be non-characteristic of historical patterns, particularly with delayed autumn rains and an increase in storm and lightning activity in this period. Ongoing fuel reduction strategies play an important part of this management;

“prescribed burning is an important part of land management and needs to be tailored to land management objectives...houses should be built in the safe

areas...ensure proper planning access to egress should not be limited by one way roads...making sure all tracks are maintained, and that the fuel loads is managed...set backs of trees to assets of at least 50 metres”.

### **5.3.2 Barriers and Obstacles for Adaptation**

Barriers to adaptation for local governments include a lack of sufficient resources to provide additional services or infrastructure and that adaptation was considered a low priority. Other barriers include inappropriate policy design, maladaptation, delayed adaptation and lack of information or misinformation. There is some reluctance from the housing development industry towards taking steps towards more sustainable practises, one participant stated;

“In my view, the extent of adaptation is not fast enough given the knowledge base which we have regarding likely future climate and other events.

In my area of work the barrier is for the most part, the fact that the government is very tuned into the desires and expectations of the development industry who resist rapid change”.

One of the participants questioned leadership from the government over climate change issues;

“We do have an office of climate change meant to be leading government policies but they’ve got buried in the department of DEC - that is my personal perspective and I don’t think they are really doing what they should be doing. I don’t think we’ve got clear government policy leading this stuff”.

One of the barriers to effective governance was lack of collaboration between government and community;

“I think we need to get better collective planning at a community level. I mean we plan for water but we don’t plan urban subdivisions around water availability, and we don’t plan industry development around water availability. In the region I think there is a bit of a disconnect across

government as to how we are planning to take account the full suite of climate issues. I mean I don't think we are well equipped in the way institutions are set up and I don't think we are well equipped in the relationships between the various departments to deal with things like climate change”.

Lack of suitable alternatives is also a limiting factor to adaptation. In terms of diversity of water supply, alternate water sources such as bores may have limiting factors in some communities due to issues such as Acid Sulphate Soils (ASS), which are listed as a potential problem in the Bridgetown and Boyup Brook areas.

Energy efficiency of housing influences the additional heating and cooling required to achieve thermal comfort. Energy poverty is an issue for persons on a low income, unemployed people or people that are at home during peak energy use. Older housing or low quality housing stock contributes to energy demand, or may mean residents will be exposed to temperatures that contribute to negative health outcomes. As one participant explained;

“In Australia there must be huge improvements to housing stock and the building quality of housing, including retrofitting. This includes insulation; the policy was good, but the roll out became an issue. We need to give people access, including education to reduce energy use; people with lower levels of education can also be affected, so when roll outs occur, education and behavioral change programs should run side by side”.

Where energy efficient appliances and PV panels have been installed in private dwellings, it is reported that net energy consumption has in some cases actually increased;

“conversely people have been installing solar panels in their homes and buying energy efficient products and have actually increased their energy use because they have become less conscious of the amount of energy they are

using. Six star energy rated homes are not being run to their full capacity and this is from behavioural factors”.

The more vulnerable groups in the community are less able to adapt to climate change;

“those who need it most are those that can’t afford to do it, from lack of resources, finances and knowledge”.

Ensuring the sustainability of regional and rural communities is also important in protecting the urban environment;

“loss of community in these regional areas would be too great and would increase pressure on the metro area...it would also lead to additional costs for transport, and production with associated greenhouse gases”.

Barriers to being adaptive can also occur from a mindset to developing rigid policies, which may need to be rapidly reviewed from sudden climatic change (reverting to emergency management);

“to know exactly how it’s going to play out and what it’s going to look like even the best science in the world so much is speculative it’s not possible to know for sure”.

Housing developments and developers may resist changes to the requirements for energy efficiency due to higher costs for buyers that may make these investments or home ownership choices less viable (Taylor, Wallington, Heyenga & Harman, 2014). A participant stated;

“...in my view, the extent of adaptation is not fast enough given the knowledge base which we have regarding likely future climate and other events. In my area of work the barrier is for the most part, the fact that the

government is very tuned into the desires and expectations of the development industry who resist rapid change”.

Other reasons given relating to resistance/barriers to adaptation are lack of financial incentives for farmers to change their practices. Farming practices that have negative environmental consequences may be related to high farmer debts. One participant stated;

“...for the most part have a fairly high debt load farmers are carrying. Sometimes you know very fluctuating cash flows with the global commodities driving the farming activity in W.A., the trend has been to increase larger operations, larger machinery, Ag [sic] machinery in order to lift their Ag [sic] product and that has some quite severe consequences for natural landscapes...seeing a lot of remaining paddock trees small patches they have an ecological role to play they are only small remnants and a lot of that has disappeared in a drive for larger farms, a cost difficulty we come up against, for the W.A. environment particularly wheat belt areas there are very few alternative land uses for commercial returns for farmers”.

In order to reduce adaptation costs to government or private providers (for example water and water quality), early and proactive management for sensitive systems may provide savings longer term. Monitoring and risk management are required;

“we’ve missed some opportunities to get it right that would have cost far less if we had got our act together a decade ago down here...example is Denmark – if we’d protected the Denmark River and put in some stream buffers down the side of the river to protect the water quality....we would have saved ourselves lots of grief now”.

Legislation and education for this issue is seen to be lacking;

“the government has a big role in making people aware...they should do more with the media”,

“previously there was a Cities for Climate Change Program in place. In June 2009, the Federal Government ceased funding this program. Local governments, MP’s and community groups need to start lobbying government to re-introduce these programs and incentives if we are going to have any real impact on reducing climate change”.

Resource constraints were seen as the biggest challenge;

“barriers...obstacles is primarily funding and time and resource constraints”,

“cost of any technology is going to be more expensive than what farmers are doing already”.

“I would say there is very little preparation and this is due to the resources or the resource constrained environment within local government down here. When you look at things like the coastal areas, the large population areas, where those councils are looking at sea level increase, there isn’t really that kind of awareness down here...we do look seriously at drainage issues but then again a lot of the problems with drainage are extremely hard to rectify because they are old systems put in many years ago...the town has increased after that; so they are totally inadequate now...we are well aware of the new technologies that the Shires on the coastal strip are using and where we can use them. But a lot of the time it is resource constrained”, and,

“...not many people are acting early and I’m of the opinion we have more than enough on our plates at the moment, our financial resource is being pulled in all directions our communities are not growing. It is different for a metro local authority that has a 1 per cent rate increase [which] might be \$8-900,000 increase in revenue...that [1 per cent increase] would add up to \$59,000 [for us]...”.

### 5.3.3 Incentives for Adaptation

Incentives for local government were based on cost savings, and innovation. Other incentives were based on legislative requirements for GHG emissions inventories.

Incentives for local communities to reduce their vulnerability to climate extremes and variability included enhancing local food security through increased local agricultural production, increasing water storage potential for residents and on farm land and supporting volunteers to provide services.

The main incentive for adaptation across the board was based on ‘cost saving’, with benefits to begin immediately. Reducing energy and water usage results in immediate benefits.

### 5.4 Question Three

To what extent have stakeholders (including those at risk) been involved in the policy development process?

Community consultation is an important part of climate change programs and policies. Using a wider lens, sustainability work usually involves collaboration with the community and existing organisations. Methods of consultation may involve directly identifying and approaching groups, or individuals for collaboration, or, advertising plans and policies for comment;

“when the...develop policy, it is typically in an inclusive manner and is put out for a period of public review, with input being invited at this time”.

Identifying key vulnerable groups was not mentioned specifically by local government (this does not imply its omission), but forms part of the work by non-government groups and state government agencies;

“we have...a lot of stuff about our ... planning work and what people’s perceptions are of the future. Also a lot of Indigenous work down here as well, that is, what Indigenous communities think”.

“As these community services also deal with some of the more vulnerable groups of the population it can also have a flow on effect to pass down learning (or training) regarding energy use to the most vulnerable segments of the population and increase the capacity of the those persons most effected by rising energy tariffs”.

A crisis may also increase the interest and collaboration between the public and stakeholders of certain agencies;

“there has been a mini crisis in the last few years and all of a sudden people are interested and want to know, want to learn and government institutions are responding by doing better work and providing info. But it almost needs that kick in the pants to get people to do something you know”.

For land rehabilitation work, the lack of existing collaboration between environmental groups is a challenge, with new links to be forged;

“how to build partnerships to work across different sectors and um... particularly in W.A. there is not a long history of private conservation organisations working across such large landscapes and um you know I guess we are sort of it feels as though we are having to develop approaches on the run because we don't have templates or models we are following from elsewhere, so a lot of what we are doing is trying to I guess based on the premise that a lot of the things that have been tried in the past haven't been working as well as they need to for the rate of change being seen now and in the future, creating new partnerships”.

Local government has undertaken considerable collaboration with stakeholders with regards to sustainability matters, climate change advice (leadership for mitigation and adaptation), peak oil and work with non-government groups;

“Transition Towns are community owned processes that welcome local government collaboration. All existing planning by community and local

government groups is incorporated and integrated into the overall community Transition plan”.

### **5.5 Question Four**

What are the costs of adaptation and what benefits can be anticipated?

Costs per project were not discussed; however the implications of expenditure were discussed by some participants. Areas of response included local government, planning, land rehabilitation and community groups. Expenditure on adaptation was less of a priority than meeting existing needs and dealing with existing resource constraints. This point is illustrated in the comments below;

“when you start to cost out the financial implications of these sorts of projects, which we do agree that they are good initiatives, they need to be compared in terms of priority of other things we need to be doing. For example if we are going backward by 3 million a year for our road network, how can we look 20 years in advance at climate change issues? We can’t look after our roads now, so in terms of priorities that is the conundrum we’ve got, this other stuff yes it’s nice but to put real things on the ground is going to cost money and we can’t afford to do that in our current financial circumstances”,

“we don’t have the money to throw at it and that’s what I call the flowery money, it’s doing good climate change things but in our case comes at the expense of infrastructure and other programs”,

“...it is primarily driven by how can we do things cheaper or better and get results, if there is an environment benefit that is a bonus but it is not the driver”,

“other cost-related initiatives require a business case to be drafted up. Any business case relating to climate change should be environmentally, socially and economically sustainable”,

“Shire is a relatively small regional Council with limited funding and resources and so financial costs upfront are substantial in comparison to incoming funds”.

Behavioural change is seen as a cost effective way to adapt to changing climate and save money (a win-win scenario);

“some initiatives can be achieved simply by educating the community and organisations on ways to reduce climate change impacts, whether at home, in the workplace or during everyday life”,

“as they relate to residential property development, the costs are debatable - for instance, research undertaken by this Department has concluded that an equivalent number of lots can be achieved within a given site, if all lots are orientated so as to achieve the maximum solar benefit, as opposed to a subdivision which is designed to achieve different objectives. Obviously this would vary from site to site”.

In terms of residential housing and development, strategy and design could result in long term savings in energy, and improvements in thermal comfort by;

“simple and cost effective ways of slowing climate change by making residential dwellings more energy efficient would be the proper orientation of the lot, the proper orientation of the house/windows on the lot, generation of some of the home’s energy needs through renewable sources. Eaves/awnings/windows coverings, appropriate insulation, appropriate planting of vegetation outside the home - e.g. deciduous trees to northern aspect”.

In terms of agriculture, if ecological niches are not valued financially, particularly for larger farming operations they are removed;

“that has some quite severe consequences for natural landscapes seeing a lot of remaining paddock trees...small patches...they have an ecological role to play they are only small remnants and a lot of that has disappeared in a drive for larger farmers, a cost difficulty we come up against, for the W.A. environment particularly wheat belt areas there are very few alternative land uses for commercial returns for farmers...have less impact ecologically”.

Planting GM crops is a potential strategy to adapt to climate change and may provide stable income returns to farmers when compared to conventional farming, as one participant explained;

“the cost in adaptation are that growers will spend more on technology than in the past...insuring the product by spending that extra money they get better weed control, tighter range of costs for weed control, not blow outs from year to year for conventional weed control through the use of regular chemicals [herbicide], they grow better yields, better flexibility in their system”.

As discussed previously, GM technology may have potential negative impacts to the environment and health.

### **5.6 Summary of Results from Stakeholder Interviews**

Climate change adaptation in the Blackwood Stirling is being implemented through plans and policies at the government level, however, according to some of the participants the action is weak and not led or driven in a consistent way, with many of the local government’s resource constrained due to small populations (reduced rates revenue in comparison to urban local governments). While the impacts to the weather, flora and fauna are being observed, direct action is not occurring (with regards to mitigation and adaptation). Lack of financial benefits or incentives with regard to preserving sites of ecological value is a barrier to conservation on private property. Technological approaches to agriculture that can cope with drought and increased weed prevalence may face increasing costs, and have been prohibited from many local government areas following concerns over health and safety.

### 5.7 Expert Panel Delphi Method

On the 26<sup>th</sup> of July 2010 an Expert Panel was assembled in the Department of Health's (Environmental Health Directorate) in Western Australia. Permission was granted by the Department prior to the review and the six participants were specialists in their fields.

The panel review began with an overview of the research aims, objectives, and methodology; the social, economic and geographic factors of the study community and the potential future climate change scenarios to 2030. Each participant had the opportunity to present issues to the group they surmised to be most important based on their area of expertise.

#### 5.7.1 Expert Panel List of Health Impacts

The health impacts discussed by the group can be categorized into the following themes: water, heat, food, mental health, population pressure, behavioural risk factors, air quality, vector-borne disease, extreme events and access. The potential hazards are listed in the table below.

Climate Hazards	Potential Impacts
<b>Direct Impacts</b>	
<b>Rainfall</b>	<ul style="list-style-type: none"> <li>Reduced access to water</li> <li>Reduced potable water</li> <li>Grey water use in agriculture</li> <li>Loss of water supply</li> </ul>
<b>Temperature</b>	<ul style="list-style-type: none"> <li>Heat exposure</li> <li>Heat wave response</li> </ul>
<b>Extreme Events</b>	<ul style="list-style-type: none"> <li>Bushfire response</li> </ul>
<b>Air Quality</b>	<ul style="list-style-type: none"> <li>More exceedence days of ozone</li> <li>More exceedence days of particulate matter</li> <li>Increase in air pollution related health impacts with elderly population growth in area</li> </ul>
<b>Vector-borne disease</b>	<ul style="list-style-type: none"> <li>Change to the range of vector borne diseases</li> </ul>
<b>Indirect Impacts</b>	
<b>Food</b>	<ul style="list-style-type: none"> <li>Food labeling absent</li> <li>Food Supply loss</li> </ul>

	Less availability of fresh fruit and vegetables Higher prices of fruit and vegetables More food safety risks at individual household level (water availability) Diets of people with lower incomes likely to reduce in quality Food Poisoning Food Production
<b>Mental Health</b>	Stress for water shortage and failure of farms Stress; concern about water supply, cost of carting
<b>Demographic Factors</b>	Population migration to towns with limited capacity
<b>Socio-economic Factors</b>	No adaptation to climate change Access to food Access to drinking water Transport to hospitals and services

Table 33 Expert Participant Identification of Health Impacts.

As discussed in Chapter Two, non-communicable (lifestyles) diseases are the main cause of morbidity and mortality in Australia.

### 5.7.2 Expert Panel Risk Rating

Following the identification of potential health impacts, the participants were asked to carry out a qualitative health risk assessment following the Health Risk Assessment (Scoping) Guidelines (Spickett, Goh, Katscherian & Ellies, 2010). An explanation of the Guidelines was provided. The expert participants were asked to decide how likely the risk was to occur in the study area within the given time period, and the potential for illness, death and injury. This resulted in a risk assessment rating from very low, low, medium, high, and extreme for each potential health impact. In some cases the participants listed the consequences of the health impact instead of using the qualitative health assessment risk matrix.

The level of agreement for the first round of the qualitative health risk assessment was based on the number of participants agreeing with the level of risk divided by the total number of participants. The risk selection and rating was consistent with the results from the publications “Health impacts of climate change: adaptation strategies for Western Australia” (Spickett, Brown & Katscherian, 2008) and “Identifying key

health adaptation opportunities in greater western Sydney” (Bambrick & Burton, 2010). Consensus for the group for Round 1 are listed in Table 53 (Appendix 9.0).

Following the initial assessment, some additional factors that could have been included in the second round of assessment and were not mentioned during the first meeting were incorporated. This was based on the literature review of climate change health impacts and includes: Extreme weather events (extreme), energy poverty and thermal comfort in homes (extreme), UV exposure (extreme), reduced physical activity (extreme), changes to biodiversity in a manner that influence mental health outcomes and local economies (for example farmers) (extreme).

The second round of the qualitative health risk assessment process was emailed to the six participants for review and returned by email. A further DOH expert participant in Perth was contacted and invited to join the second round of assessments. Expert participants were also sought out from several state and local government areas in the South West, with the City of Bunbury providing expert opinion during a meeting held on the 24<sup>th</sup> January 2011. The total number of expert participants for the second assessment was nine. Not all expert participants followed the instructions outlined in the Power Point presentation for the qualitative health risk assessment. For the participants that came to the same conclusion (e.g. bushfire rating was extreme), in order to determine the level of agreement between all the participants, the percentage of experts that agreed was calculated. For each of the impacts considered, the expert participants’ qualitative health risk assessment rating is in Table 54 in Appendix 10.0.

### **5.7.3 Consensus of Risk Rating**

Kalay et al. (2010) indicate that agreement is reached when 75% of the participants select the same outcome. The complexity of the risk rating for some participants resulted in a non-response bias for the group, this created difficulties in comparing the first round to the second round. Accordingly for the above risks, agreement has only been made for Bushfire (extreme risk), extreme weather events (extreme risk) and exposure to ozone (medium risk), for the participants who answered those questions. A weak consensus for the following was also been reached (between 50%

and 75% agreement); increase in vector borne disease (medium risk), UV exposure (extreme risk), ‘particulate matter’ ‘exceedance of days of high exposure’ (extreme risk), reduced physical activity (medium risk), loss or reduction in biodiversity (medium risk), population migration (extreme risk) and reduced food supply (high risk).

Other risk factors ranged from low to extreme with little consensus, e.g. the expert participant’s opinions varied on likelihood of fatalities and injury occurring as a result of climate change in the region to 2030. Expert participants employed by a local government generally scored higher risks for each factor and related the risks to individual incidents or specific events that could result in health impacts.

In order of importance, the risks identified by the expert participants are outlined in Figure 33.

<b>Expert Participant Consensus of Health Risks following Delphi Method</b>
Consensus;
Extreme weather events – extreme risk
Bushfire – extreme risk
Exposure to ozone – medium risk
Weak consensus;
Population migration - extreme risk
UV exposure – extreme risk
Particulate matter (exceedance of days of exposure) - extreme risk
Reduced food supply - high risk
Increase in vector-borne disease – medium risk
Reduced physical activity - medium risk
Loss or reduction in biodiversity - medium risk

Figure 33 Expert Consensus of Health Risks.

Priorities for adaptation, based on the qualitative health risk assessment, are therefore related to extreme weather events and bushfire, air quality issues (ozone, UV and particulate matter), population migration, food supply, vector-borne illness, reduced physical activity and loss or reduction in biodiversity.

## 5.8 Community Surveys

### 5.8.1 Online and Mail-out Survey Results

The surveys were designed to evaluate attitudes towards expenditure at the household level and the community level and to prioritise the importance of various types of adaptation activities. Current income and the value of the participants' homes were used to compare to the willingness to pay figures, along with household type (Kotchen, Boyle & Leiserowitz, 2012). Perceptions of costs for projects may not accurately reflect the true costs of infrastructure and staffing. Further, acceleration of climate change impacts including nonlinear climatic changes would undoubtedly increase exposure to climate risks, and increase expenditure on protective projects (Parry et al., 2009).

### 5.8.2 Geographic Spread

In total, 51 households (double or single income) completed all or part of the survey which represented 71 adults with their children or dependents. The number of children or dependents were not counted as the survey did not ask for this. The following table indicates the number of responses per community listed.

Postcode of Participants	
Boyup Brook	2
Augusta	3
Nannup	2
Narrikup	2
Margaret River	8
Denmark	4
Northcliffe	1
Walpole	3
Pemberton	4
Bridgetown	6
Manjimup	6
Greenbushes	2
Mt Barker	2
Witchcliffe	1
Kendenup	2
Metricup	1
Unknown	2
Total	51

Table 34 Participant Households by Postcode.

### 5.8.3 Income and Housing Type

Survey participants were asked to identify their household income as a range of possibilities, from less than \$25,000 to above \$150,000. Currently the old aged pension is \$17,914 for a single pensioner or \$27,008.80 for a couple per year (Australia Government Department of Human Resources, 2012). A quarter of the participants reported an annual household income of less than \$25,000. Single income households with no children may not necessarily indicate old aged pensioners living alone, but this is the most likely response, given the large elderly population in the region. Single income households represent 39% of the total participants. The income spread is identified in Table 35.

<b>Income</b>	
<\$25,000	12
\$25,000 - \$34,999	6
\$35,000-\$49,999	8
\$50-74,999	9
\$75,000-99,999	4
\$100-124,999	6
\$125,00-\$149,999	2
\$150K +	1

Table 35 Participants' Household Income

The mean Australian annual income is \$53,731.60 (ABS, 2012a). The income spread allows for an indication of adaptation priorities between lower and higher income groups in the communities. Single income with no children is the predominant household type in the sample (39%), followed by double income households with no children or dependents are the second most common household type, or, 37%, Double income with children or dependents, at 13% and single income with children or dependents at 11%.

#### 5.8.4 Willingness to Pay – Personal Adaptation

To analyse the participant's willingness to pay for adaptation on an annual basis, annual household income from the survey was compared to the annual figure they were willing to spend on adaptation. The midpoint for the range of values for adaptation expenditure was compared with the average of their annual income. For example, if the participants chose to spend between \$0 and \$50 per year, the midpoint of \$25 was used to determine expenditure. Taking the mean of the range of the annual incomes was used for calculations; for example if the participant selected the option that they earned between \$100,000 to \$124,999, the mean of these two figures was used (\$112,499.50). Of the 43 participants that answered this question, the mean annual expenditure on adaptation was 3.3 per cent of their annual household income. The maximum expenditure of three of the participants was significantly higher than the other participants, with these results removed; the mean annual household expenditure for participants was 2 per cent of annual income.

When looking at the value of the homes of the participants, the range of options that the participants could select included living in a rental property to having a home of any value. High value properties may include farmland that is run as a business with associated debts and doesn't necessarily equate with higher spending capacity. Comparing housing values to willingness to pay for adaptation did not reveal any patterns in expenditure, households that had a home with a value of over 1 million dollars might only spend \$25 a year on adaptation, in the same way a person who is renting might pay \$25 a year.

When comparing household types with annual expenditure on adaptation, having children or dependents impacted the amount of money spent per year. For single income households, five had children or dependents and sixteen had no children or dependents. Those with no children would spend a higher amount of income per year on adaptation, with one household stating they would be willing to spend between \$2,000 and \$10,000 a year. For the double income households, those with no children would be willing to spend more on adaptation than those with children or dependents. Of the self-selected participants, having children or dependents was the biggest determinate of stated willingness to pay on adaptation on an annual basis.

Geographically, the participants in the following communities indicated they would spend the most on adaptation; Walpole, Kendenup, Bridgetown, Mt Barker, Margaret River and Nannup. This seemed to be related to personal values or income. The least amount of expenditure was indicated in the following communities; Boyup Brook, Pemberton, Walpole, Greenbushes and Denmark. The middle range of values were selected for in; Nannup, Kendenup, Witchcliffe, Greenbushes, Walpole, Pemberton and Northcliffe. As the participants selected a range of willingness to pay amounts for each community, it is unlikely that location impacts expenditure, as much as income and household type.

#### **5.8.5 Relocation Due to Risk of Fire or Flood**

Relocation referred to permanently relocating due to flooding or fire safety issues. Of the 49 households that answered this question, 28% indicated they would relocate. These households were in the communities of Manjimup, Margaret River, Augusta, Narrikup, Mt Barker, Metricup, Bridgetown and Pemberton. The remaining participants would not relocate, (approximately 72%).

#### **5.8.6 Household – Water Supply Adaptation**

Of the four options provided, installing rainwater tanks was selected as being the most preferable water adaptation, with 86% of participants selecting this option, followed by greywater at 75%, dams (this would depend on block and housing type) at 24% and groundwater extraction at 4 per cent.

Rainwater tanks are not cost effective when compared to scheme water, however 19% of Australian households harvest rainwater and the strong interest indicates other factors restrict the use of tanks. This may include cost, space on the property, or planning limitations (Marsden Jacob Associates, 2009). Greywater systems vary in price and complexity and may not provide ready benefits for the cost; they are particularly useful during periods of water restriction in areas with scheme water (Choice online, 2012). Bucket disposal of bath water for instance is free, however unsuitable for those persons with limited mobility. Reducing overall water use may

also be more cost effective than installing a greywater system (Environment Agency, 2011).

Dam systems require a suitable land area and usually a sloped site, with the cost effectiveness being related to 'storage to excavation ratio' (Government of Western Australia Department of Agriculture, 2005, p. 11). Cost benefits of bores are dependent on several factors including; water table, soil type and location (potential for salt water intrusion and contamination) (Government of Western Australia Water and Rivers Commission, 1998). Any additional water storage device or savings will have to take into account variable future rainfall, potential for flooding, and potential for salt water intrusion or contamination for groundwater extraction. They also all have ongoing maintenance costs (e.g. desludging and pump costs).

#### **5.8.7 Household – Fire Protection System**

Of the six options the two most popular are already in force by local government, these are clearing vegetation and flammable materials (selected by 74% of the participants), followed by preparing an evacuation plan (70%). Installing or enhancing a reticulation or pumping system was selected by 34% of participants, and planting a fire resistant vegetation corridor was selected by 21% of the participants answering the question. Increasing involvement with the local fire brigade was selected by 19% of participants, and installing a fire bunker was selected by 11%. Additional comments included were; "to keep firebreaks clear", this is clearing vegetation, to "build to Australian Standard in bushfire areas", "remain the same", and "always be fire conscious, winter and summer especially". The cost of a bunker would be associated with the size and features, there is no existing Australian Standard to date and all require an adequate supply of oxygen. Bunker costs are typically between \$1,000-\$9,000 but can be (considerably) more than that. Adequate warning systems would be required for the household to safely enter the fire bunker prior to radiant heat preventing access; safety may not be guaranteed (Victorian Bushfires Royal Commission, 2009).

### **5.8.8 Household – Emergency Preparation**

Of the five options listed with emergency preparation, the most popular was first aid equipment and or training (73% selected), followed by alternate power supply (69%) and having 14 days of food and water (65%). A two way radio was selected by 20% of participants and water treatment chemicals were selected by 14%. Answers for ‘other’ were “having a battery backup power supply”, “knowledge of refuge sites and evacuation”, “fire fighting units”, “adhering to the status quo”, “already doing all of the suggestions listed in the survey (for over 40 years)”, “having a UHF radio, light, mobile, small battery operated radio for local news” and “maintaining a 400 litre firefighting unit, trailer mounted”. Costs associated with these factors may be beyond the reach of low income earners. First aid training for one day for example is \$199.00 (Saint John Ambulance, 2012), a generator, approximately \$200, two way radio, \$50. Low income and disadvantaged groups are more likely to experience food insecurity at the household level (and subsequently be less able to prepare for an emergency event) (Australian Government Department of Health and Ageing, 2012). These groups are Indigenous, unemployed, single parent households, low-income earners, rental households and young people. Other barriers to emergency preparation for extreme weather events and bushfires may be a result of language barriers, lack of transport options, having a disability or chronic illness and addiction issues (Australian Institute of Family Studies, 2012).

### **5.8.9 Household - Retrofit Existing Homes**

Of the six options that the participants would prefer, installing alternate energy was the most popular (66%) followed by changing to water efficient appliances (62%) and changing to energy efficient appliances (62%). Installing insulation was preferred by 55% of participants and 25% selected installing an air conditioner. Installing double glazed windows was selected by 19% of participants. Other responses were “building a sustainable house”, “already having completed most of the suggestions given”, “already having a climate friendly house with most of the suggested retrofitting ideas”, “installation of nine solar panels”, “having the top four suggestions already in place” and “having solar hot water and power”.

Solar (PV) systems are priced between \$4,500 and \$10,500 and could take from 6 – 20 years to payback on initial investment (Choice online, 2011). Energy and water efficient appliances and fixtures may save overall costs (Living Greener, 2012). Three quarters of the water used in a home is from toilets, washing machines and showers (Department of Water, 2012). Heating and cooling and water heating use over half of the energy demand from the home, followed by other appliances, refrigeration (seven per cent), lighting (seven per cent), cooking (four per cent) and standby (three per cent) (Milne & Reidy, 2010). Air conditioning units may offer health benefits and have a range of costs associated with size, number of rooms and ongoing maintenance, the costs of running an air conditioner may be cost prohibitive for low income or fixed income households. Air conditioners can provide optimal temperatures for vulnerable households; particularly the elderly, young children, infants, and those persons with ongoing medical conditions (Mudarri, 2010). Remodeling a home to increase the energy efficiency is difficult to estimate, as it depends on scale of works, and location.

#### **5.8.10 Household – Retrofit Existing Gardens**

Of the three options, 32% of participants said they would change their garden to be more water efficient and self-sustaining, 30% said they would grow their own food, and 18% said they would grow plants to increase shade cover outdoors. For the ‘other’ option the responses were to “do all of these”, “have no garden”, “recycle by composting all green waste”, “use the community garden” and “adhere to the status quo”.

Approximately 39%-45% of water used in an urban household is used on the garden, applying water wise gardening techniques and drought tolerant natives and exotics will further reduce the need for garden water (Department of Water, 2009). Costs will depend on scale of garden and ability of the home owner to make the changes (e.g. disability). Growing fruit and vegetables from home can be cost effective and reduces energy used in transportation and refrigeration. Limitations to home gardening may result from disabilities or illness or lack of time (Department of Agriculture and Food, 2007).

### **5.8.11 Farm or Smallholding Adaptations**

Thirteen of the participants responded to this question (25% of the total participants). Of the three questions asked, 85% of participants stated they would switch to stock or crops in the future that required less water and 38% said they would switch to stock or crops that are more disease and pest resistant. Fifteen per cent said they would switch to stock or crops that could withstand higher temperatures.

These factors are difficult to estimate as they are based on many complex factors, including climate uncertainty and size and location of agricultural operations (Crimp, Gaydon, DeVoil & Howden, 2007).

### **5.8.12 Business Adaptations**

Of the total participants, 24 answered these questions. Of the seven questions asked; 70.8% of participants selected reducing water use through behavioural change and greater water efficiency, 58% selected reducing energy use, 45% selected reducing transport use and 41% selected providing “my own water and energy needs”. Adaptation to higher temperatures may involve using personal protective equipment, this could include appropriate clothing, e.g. Ultraviolet Protection Factor (UPF) 50 clothing. Training and facilities was selected by 29% of participants and 25% claimed they would diversify their existing business. Four per cent of participants claimed they would relocate their business. Other options were, “we are already doing this as we sell renewable energy”.

### **5.8.13 Other Options for Adaptations in the Household and Private Businesses**

Sixteen participants answered this question, with most popular response being installation of solar power (31%), with ‘no’ being the second most popular at 18%. The following responses were made by one participant each; “less polluting vehicle”, “north facing windows and doors”, “we won’t change much because we are already doing most of this”, “increase tank water capacity”, “cut down town commutes, share shopping trips, reduce fuel and energy consumption”, “existing home does not have greywater recycling or efficient heating”, “throw out air-conditioner”, “no, home is

energy efficient” and “have done renovations”. The common theme here is related to energy use, both within the home, and transport.

#### **5.8.14 Limitations to Adaptation**

Of the 25 people that answered this question 52% claimed that cost was the main factor, followed by ‘no’ at 20%. Eight per cent listed age as a factor and 4 per cent indicated they would make the changes. Other individual answers were; “not convinced of the political climate argument”, “I am willing to accept bushfire risk to live in a place of beauty”, “most measures are already in place” and “lack of government funding”.

#### **5.8.15 Ranking Adaptation Priorities**

This question was not answered by all participants and not always answered according to the directions given. The participants were instructed to prioritise a list of adaptation options from one to nine in order of preference (one being the most important and nine being the least important). The adaptation option most often cited as the number one priority was for water supply protection (chosen by 51% of the 47 people that answered this question), followed by the number two priority being upgrading the electricity supply (26%). The third priority most often cited was to increase staffing to emergency and health services for communities (29.8%). The fourth priority most often cited was to “upgrade electrical supply to meet future demand” (15%). The fifth priority most often cited was to “increase staffing to emergency and health services for communities (20.9%). The sixth priority most often cited was for public services (recreation facilities) at 23.8%. The seventh priority most often cited was also public services (recreation facilities), the eight priority most often cited was upgrading electrical supply (30%) and nine priority most often cited was for flooding (42.9%).

Emergency bunkers and services, along with insurance, and protection of natural resources were selected as options, but not in large numbers. The ranking question confirmed the main interest of the participants was in water and energy as being major concerns for the future.

When examining adaptation priorities and comparing these to income of the participants, water was the main concern for all income groups. Lower income participants more than often chose emergency staffing, followed by insurance. Middle income participants more than often selected bunkers, electrical supply and protection of natural resources. Higher income participants more often selected protection of natural resources as priorities.

When examining adaptation priorities by community, the following towns listed emergency and health staffing as a priority: Manjimup, Margaret River and Pemberton. Denmark and Pemberton participants listed flood protection as being a priority. Assistance to low income households and business was selected by Narrikup and Margaret River, despite the participants having high incomes. Protection of natural resources was selected by Augusta, Nannup and Northcliffe. Insurance was selected for the communities of Metricup and Bridgetown. Emergency bunkers and services were selected by persons from Narrikup, Denmark, Manjimup and Bridgetown.

When comparing priority of expenditure to the value of the participants' home, participants that were renting selected water supply as their main priority, then natural resources. Participants that stated their home had a value between \$250,000-\$500,000 selected water supplies as their main priority, then increases in staffing to emergency and health services, following by upgrade of the electrical supply. Participants that stated they had a home with a value between \$500,000 and \$1,000,000 selected water supplies as their main priority, followed by upgrading of the electrical supply. Participants that stated they had a home with a value above \$1,000,000 selected flood protection as their main priority, then protection of natural resources.

#### **5.8.16 Allocation of Expenditure**

Participants were asked to estimate annual expenses for adaptation projects in their community. This question can be compared with the priorities for adaptation in their communities. Higher figures may correspond with the participant's needs assessment

of their community's services or higher costs. The figures listed by participants may not correspond with the value of these potential projects. These projects would need to be funded from government, NGO's or other funding sources. This question had the most non-responses, and some people commented that they didn't have enough information or that lay-people did not have the knowledge relating to the costs of infrastructure to estimate these costs.

#### **5.8.17 Flood Protection**

No money was allocated towards flood protection. Even those people that selected flood protection as a priority did not allocate any funds towards it.

#### **5.8.18 Insurance**

The lowest value for this adaptation was \$100,000, the highest \$10 million. The mean expenditure was \$3.2 Million. Higher income earners predicted higher values for insurance costs. Other comments were; "householders should have own insurance", "my house wont' melt", "yes", and, "the whole insurance system needs to be addressed".

#### **5.8.19 Protection of Water Supplies**

The lowest value for this was \$100,000, the highest \$20 million. The mean value was \$5.3 million. Other comments were; "it is not possible to mitigate flood from rising sea levels", "no!" and "protect our underground water supply this is our future". The participants who allocated expenditure of over \$10 million on protecting water supplies were from the following towns: Margaret River, Denmark, Manjimup and Bridgetown (higher population centres).

#### **5.8.20 Emergency Infrastructure**

The lowest value as \$100,000, the highest \$8 million. The mean value was \$2.6 million. Other comments were; "government will inevitably have to develop strategies to protect life and infrastructure", "yes", "must be kept up to date", "most communities have plans implemented for this" and "\$5 million towards airstrip, fire

fighting helicopter and firefighting equipment” (this comment was from a community participant in Walpole). Also “\$8 million; update of fire fighting and radio equipment” (this comment was from a community participant in Margaret River).

#### **5.8.21 Emergency Services**

The lowest value allocated was \$300,000, the highest value allocated was \$10 million. Additional comments were “more local health professionals”, “more hospital and aged care beds” (Margaret River), “increase doctors to service this area” (Manjimup), “increase in paid staff rather than volunteers plus specialised training in emergency services”.

#### **5.8.22 Recreation Facilities**

The lowest value was \$20,000, the highest \$5 million. The mean value was \$1.8 million.

#### **5.8.23 Resilience to Energy Network**

The lowest value was \$100,000, the highest \$20 million. Additional comments were “people have control over their own power switch”, “more solar” and “yes within reason”. The participant who allocated expenditure of over \$20 million on making energy networks more resilient was from Denmark, and the participants that that allocated \$10 million were from Bridgetown and Margaret River.

#### **5.8.24 Natural Resource Protection**

The minimum allocation for this adaptation was \$50,000, the maximum \$40 million. The mean value was \$8.35 million. Additional comments were “provide strategic resources with adequate finances”, “reduce logging of native forest”, “W.A. has quite a good structure in place”, “yes” and “that has to be addressed”.

### **5.8.25 Assistance to Households and Business on Low Incomes**

The minimum allocation for this adaptation was \$500,000; which is the highest minimum allocation in the survey. The maximum allocation was \$10 million, with no clear median. The mean was \$3.9 million. Additional comments are, “we have adapted to changes in the past without assistance, over time humans adapt to natural changes so why do we need to provide assistance”, “tell them to get a job”, “bus services for the elderly in the community”, “yes” (this was listed three times), “rebates for water tanks”, “none” and “refuse, reuse, recycle”.

### **5.8.26 Other Adaptation Initiatives – Government**

Sixteen responses to this question relate to water, energy, reforestation, fire, communication, education and transport. Money was not allocated to each answer, apart from the following, reforestation \$10 million, better building standards \$50 million, rainwater tanks every household \$1 million (this was relating to Margaret River), alternate energy supplies, (e.g. solar) \$5 million, reduce energy use, water use \$1 million and build bunkers in remote vulnerable properties \$2,000 per household (Augusta).

Comments without money allocated were; “low cost housing”, “do not believe the government should be funding projects that are politically motivated by the parliament of the day”, “warning systems”, “plant more native trees on degraded government land”, “education re self-sufficiency, efficient use of resources, energy efficient building codes”, “phone coverage upgrade”, “ don’t know”, “not qualified to answer”, “public transport” (Margaret River) and, “solar and rainwater tank subsidies for households”.

### **5.8.27 Other Adaptation Initiatives - Community**

The answers to this question are related to the following themes; transport, wildlife, education, waste water issues, building, employment, localisation and communication.

The individual comments area included; “reduce vehicle use, mobile retail vans”, “wildlife corridors”, “climate change is not the issue, but world population”, “alarm system”, “education”, “greywater”, “stop corruption of the forest products commission”, “locally owned alternate energy and water, community gardens”, “local employment”, “sewerage”, “deep sewerage”, “not sure”, “building appropriate dwellings for bush environments”, “protection of existing vineyards and farming land against developers”, “build solar passive” and “mobile shopping/home deliveries”.

#### **5.8.28 Voluntary Contributions – Once off Payment**

The participants were asked to identify the amount they would be willing to donate to a community project (adaptation) as a once off contribution/payment. For example if the community decided to invest in a community solar bank to improve energy resilience, each household could voluntarily contribute to the project. For the participants that answered this question in the survey, the individual amounts listed by different participants were \$0, \$100, \$200, \$500, \$1000 or \$5,000. Other comments were, “patronise them”, “nothing”, “very little”, “not much”, “more information required”, “no” and “a contribution to fire fighting”.

#### **5.8.29 Vulnerability**

The themes for answers in this section were related to income, buildings, forest, flooding and planning. Individual comments relating to income are, “lower income people may need support to maintain adaptations”, “people on a limited income”, “low income would assistance be enough”.

Building related comments were; “timber homes, flammability”, “bushfires”, “yes, especially older homes that have been built, earlier” and “isolated farms and dwellings”. Comments related to forests are “bushfires”, and

“all of us, no one will be spared, global warming is already upon us, our native forests are already showing warning signs of insect infestation as well as the effects of drought dieback and the like”.

Comments related to flooding were, “yes, low lying houses on the Blackwood River”.

Comments related to planning were; “people not planning ahead and not anticipating danger and other such events”, “need for a new access road to Prevelly, in case of fire”, “attitude change is more important and more difficult than infrastructure change”.

Additional comments are “all are vulnerable, this is an uncertain time”, “not sure”, “households lacking adequate forms of communication e.g. no mobile phone coverage”.

#### **5.8.30 General Comments about the Survey**

Themes from the participant responses were related to taxation, world cooperation, pollution, population, energy (solar, efficiency and water), building codes, lack of understanding, more information needed, environmental water quality, forestry, government assistance, smaller communities needing help and climate.

#### **5.8.31 Summary of the Community Survey**

The self-selected sample revealed some interesting findings; water and energy are the main concern of the group. Participants with household types with children or dependents were likely to spend less on adaptation activities than other household types (this was the same for low and high income households). There was a strong demand for PV panels and rain water tanks, regardless of the low benefits or delayed payoffs for cost.

### **5.9 Community Survey for Cranbrook and Greenbushes**

In order to examine smaller, potentially more vulnerable communities an additional paper survey was sent to Cranbrook and Greenbushes post office boxes. The survey was sent to post boxes in those communities as outlined in Chapter Three. Both towns have approximately 300 post boxes each (600 post boxes in total). 350 surveys were mailed with return envelopes. The return rate was approximately 5 per cent. The results of the survey are discussed below.

### 5.9.1 Income and Housing Type

#### **Cranbrook**

Of the 11 participants, 5 responded that they had an annual household income less than the Australian mean of \$53,731.60 (ABS, 2012a). The mean income for the Cranbrook participants was \$79,999. Five households were single income with no children, three households were single income with children, and two households were double income with children. Nine of the ten participants stated they were home owners; the participant's properties had a mean value of approximately \$220,000.

#### **Greenbushes**

Of the twelve participants, 10 reported that their household income was less than the Australian mean of \$53,731.60 (ABS, 2012a). The mean annual income for the participants' households was \$59,000. Six of the participant households were single income households with no children, five households were double income households with no children and one participant's household was single income with children or dependents. One participant stated that three adults were living together on adult pensions in one household. The mean value of the participants' homes was approximately \$430,000.

### 5.9.2 Willingness to Pay – Annual Adaptation

#### **Cranbrook**

As described in section 5.8.4 of this Chapter, the midpoint of the range of values for willingness to pay for annual adaptation expenses was compared with the mean annual household income of the participants. Of the 11 participants that answered this question, two selected \$25, four selected \$275, three chose \$1250 and two participants selected \$6,000. Of the 11 participants that answered this question, the mean annual willingness to pay on adaptation activities was four per cent of their annual household income. This group had two outlier values of 24% and 13% of willingness to pay towards adaptation activities. When the outlier values are removed from the data and the mean re-analysed, the group mean for willingness to pay annually for adaptation activities was 1.3 per cent.

The value of the homes ranged between \$150,000 to 500,000 with one participant renting or boarding. The mean value of housing was \$245,000.

There appear to be no patterns with regards to household willingness to pay on adaptation and housing type, as participants living in a household with a single income with children spent as much as participants living in a double income household with children.

### **Greenbushes**

Of the 12 participants that responded to this question, three stated that annual household willingness to pay towards adaptation was likely to be \$25, two participants selected \$275 and four participants selected \$1250. One participant selected \$6,000 and another \$35,000. Other responses included “already doing what I can, pensions do that to a budget” and “very limited as we only have our pension to live on”; these were regarded as \$0.

Of the 12 participants that answered this question, the mean annual willingness to pay towards adaptation activities was 3.2 per cent of their annual household income. This group had one outlier value of 23% of annual income being willing to be paid towards adaptation activities. When the outlier value was removed from the data and the mean was re-analysed, the group mean for annual expenditure is 1.4 per cent. The value of the homes ranged between \$150,000 to above \$1 million, with one participant renting or boarding.

When comparing the participant’s household type, the single income household participants stated they would be willing to pay as much as participants in a double income household type.

### **5.9.3 Relocation Due to Risk of Fire or Flood**

The majority of the participants that answered this question indicated they would not relocate due to risk of flood or fire (permanent relocation), with 25% (Cranbrook) and 17% (Greenbushes) stating they would leave.

#### **5.9.4 Household - Water Supply Adaptation**

Of the participants that answered this question, the most popular adaptation options that the participants would prefer to have were rainwater and grey water (9 each). Some participants claimed to have dams (3) and one participant claimed to have a bore. Three participants claimed that they had achieved a level of self-sufficiency in terms of their water supply; these participants may not have had the option to be connected to the mains water supply. For the participants connected to mains water, having both rainwater and greywater were expensive options, however for those participants with their own water supply, rainwater and re-use of greywater may be more cost effective.

#### **5.9.5 Household – Fire Protection**

Of the participants that responded to this question the most popular answer was preparing an evacuation plan and clearing vegetation (11 each). While these types of preparations are mandated, using vegetation to move the fire away from assets, (fire retardant planting) was selected by six (6) participants. Installing fire fighting reticulation or pumping was selected by 8 participants, with two people suggesting they would use a fire bunker and two joining the local fire brigade. Additional comments included that building design and materials should be able to withstand some fire risks, that people are currently volunteer firefighters, that clearing already takes place, and that some government assistance may be required to install a fire bunker, or enhance reticulation protection.

#### **5.9.6 Household – Emergency Preparation**

Of the participants that answered these answers, about 50% of participants claimed to have 14 days supply of food and water. This fits with many studies that indicate that less than 50% of householders are prepared for an emergency event. Approximately 40% of the participants claimed to have first aid equipment or training, and a 30% claimed to have access to alternate power in case of blackouts. Sixteen per cent of participants claimed to have alternative communication devices (two way radio), and three participants (12%) claimed to have water treatment chemicals. Some individuals stated that they would only buy a two way radio if government assistance

were available and another said they had everything “bar water treatments”. This data indicates that for a short term emergency, 50% of participants have limited preparation.

### **5.9.7 Household – Retrofit Home**

Adaptation activities that would be preferred by participants in the survey were to change to water efficient appliances (30%), install insulation (30%), purchase energy efficient appliances (25%) and install air conditioning (30%). Some participants claimed they have upgraded their dwellings, however that the more expensive options (PV solar panels, and double glazing) would only be affordable with government assistance.

### **5.9.8 Household – Retrofit Garden**

The most popular change that the participants would prefer to have for their household was growing more food at home, which 37% of the participants selected. A quarter of the participants would prefer to grow plants to provide shade and increase the water efficiency of the plants through design and planting.

### **5.9.9 Adaptation – Farm or Smallholding**

It is difficult to determine the number of farmers completing the survey as questions about occupation were not part of the survey design. Those participants that explicitly stated they were farmers selected all of the possible adaptation options that they would prefer, or claimed to have done to adapt to variable rainfall, temperature, pest and disease risks.

### **5.9.10 Adaptation – Business**

Of the participants that found this question relevant, the participants stated they would prefer to provide the business with its own water and energy needs, followed by reducing water use and energy use. Many participants also would prefer to diversify the income streams of the business. Some participants suggested that government assistance would be required to reduce energy usage and the least

popular responses were reducing transport use and adaptation to higher temperatures. Promoting ‘green businesses or materials’ and retrofitting infrastructure to make it more fire resistant were also suggested.

#### **5.9.11 Reasons for Lack of Adaptation**

Several reasons were listed for lack of adaptation, these included resource constraints, particularly for those participants that had retired or were living on the pension, or living in a government rental property. Physical ability for elderly people to make any changes was also a limiting factor along with health problems. Participants that owned a property for farming suggested that the scale of works recommended for adaptation would be too costly for the financial return.

#### **5.9.12 Expenditure Rankings (Priority)**

In summary, the priority for adaptation options most often selected was water supply, followed by staffing at hospitals and emergency centres and assistance to household and business to adapt. The third priority that was most frequently selected was emergency bunkers and evacuation services followed by protection of natural resources, and flood protection. Protecting natural resources, energy security and recreation facilities were selected as areas of lower priority.

#### **5.9.13 Expenditure - Flood Protection**

Two participants answered this question, with amounts for expenditure within their town being \$600,000 and \$1 million, however two participants stated flooding had not been observed. One participant claimed that flooding had occurred following heavy rainfall.

#### **5.9.14 Expenditure - Insurance**

Participants that answered this question listed insurance expenditure of \$1 million, \$2.5 million and \$10 million, with community buildings being adequately insured, as well as farmer’s goods and properties. Another participant stated that insurance was the responsibility of the individual.

### **5.9.15 Expenditure – Water Supply**

Some participants had specific concerns over the quality of the infrastructure in the Greenbushes and Hester areas, as they had rubberised piping vulnerable to fire, with amounts for upgraded listed as; \$500,000, \$1 million and \$3 million.

### **5.9.16 Expenditure – Evacuation Centres**

Six participants responded to this question with amounts varying from \$500,000, \$1 million, \$1.5 million and \$5 million. One participant suggested that people weren't aware of where the evacuation centres were located, and another that upgrades are required for existing evacuation areas. This indicates that in an emergency event, without clear communication individuals may not access existing facilities, or those facilities may not provide adequate protection.

### **5.9.17 Expenditure – Emergency Services**

Two participants made comments regarding emergency services in their area; “no cost can be too high for safety” and “especially more staff and water bombing aircraft/helicopters”. Expenditure amounts listed included \$500,000, \$1 million, and \$2 million.

### **5.9.18 Expenditure – Recreation Facilities**

Figures suggested for recreation facilities included \$500,000, \$900,000, \$1 million and \$10 million, however what these facilities might have been was not listed.

### **5.9.19 Expenditure – Energy Supplies**

One respondent suggested that the energy supply was vulnerable to fire, and a significant amount of \$1 million per year should be spent upgrading the current system. Another participant suggested \$2 million, “it must be done” and another “nil”. One respondent suggested no money should be spent.

### **5.9.20 Expenditure - Health Staffing**

Expenditure ranged from \$1 million, \$1.5 million, \$2 million and \$10 million. The comments related to increasing local hospital staff (nurses and paid ambulance officers). Mental health care was listed as a priority, as was providing adequate services for obese patients, aged care and flying doctor services.

### **5.9.21 Expenditure – Protection of Natural Resources**

One participant commented on this question, “not enough is being done” but what was required wasn’t listed. Amounts listed for expenditure were \$0, \$1million and \$3 million per annum.

### **5.9.22 Expenditure – Household Assistance**

Participants stated that subsidies for solar/photovoltaic cells, rainwater, greywater and insulation were needed for action to be taken as the costs of these were prohibitive. Participants suggested that to enhance adaptation at the household level, monetary assistance would be required, and stated \$1 million, \$2 million and \$5 million would be required.

### **5.9.23 Expenditure – Other Comments**

These projects were listed as being important for adaptation;

1. The mining industry should provide \$50 million of tax revenues to the “Shire”.
2. Wind farms.
3. Training and education relating to sustainability and agriculture.
4. Water efficiency.
5. Rainwater tanks for each household.
6. Government transparency on expenditure of climate change issues.

### **5.9.24 Summary of Greenbushes and Cranbrook Surveys**

The main concerns stated by the participants for these communities related to energy and water, followed by the ability of local services to meet future demands for water, energy, emergency response and health care. The expenditure listed didn’t match

with the priorities listed, however this is difficult for lay persons to evaluate, assess and determine costs for service provision.

### **5.10 Data Analysis Summary**

The community participants in the focus group meetings compared climate change scenarios with observed climate impacts and many of the participants concluded that adaptation would depend on economic and lifestyle factors (recreation, quality of life for children, access to affordable fresh fruit and vegetables and other consumer goods) and environmental protection. The majority of the community participants expressed acceptance that climate was changing (in particular the stepwise reduction in rainfall) with some objections about how climate change science could be used politically and how this might influence land use policy (possibility of land used for carbon sinks), without consideration of the impacts to local communities, agriculture and food affordability.

There was little awareness that many of the health influences of climate change may exacerbate co-morbidities such cardiovascular, diabetic, or mobility factors (apart from evacuation). In contrast, the expert participants viewed climate hazards with the potential for mortality as being more important than everyday (indirect) concerns. These hazards included exposure to extreme weather or bushfire events, and exposure to air quality factors (ozone). Effective, timely evacuation may reduce many of the risks of these events. A weaker consensus for other factors relating to air quality (particulate matter and pollution), human migration, food supply and recreation were listed and expert risk rating was between extreme to medium. These factors (with the exception of air quality) were also more important to local communities.

Stakeholder participants had observed and monitored environmental degradation (water quality, soil quality, biodiversity). Leadership and resources to take action to repair, restore and provide additional services were stated to be insufficient. Many local governments and community members were taking action to increase resource efficiency by reducing consumption and highlighting climate change issues. It is unknown if these initiatives were making any great impact, apart from the Denmark community that improved energy efficiency following summer blackout periods.

Both Denmark and Manjimup communities had been observing water use restrictions, however the water supply issue has not been resolved. Strong demand for household water tanks and solar energy exists within the community, however many listed the cost for these products as being too great, particularly for elderly persons and those on fixed incomes. Many government agencies suggested that there was concern for the future of the water supply on the south coast area, and that protective action for existing water resources was occurring too slowly, or too late. Stakeholder participants stated that additional costs to provide extra services for adaptation may be unaffordable. For government departments; to focus on efficiency and reduction in the use of resources may create many gains financially and environmentally.

In order to maintain the current standards of quality of living for community members, ensuring that sufficient water and energy is available and affordable under future climate change scenarios is required. In order to reduce peak energy demand during summer the thermal (energy rating) of buildings could be enhanced with adequate insulation, and deciduous trees to shade dwellings can significantly reduce summer heating with minimal costs (Dave, Varshney & Graham, 2012). Energy and water efficient appliances would reduce consumption, however may not be affordable for many of the residents; many elderly community participants in the surveys and focus group meetings suggested such measures were not possible or a priority compared to daily living expenses. The community participants that completed the surveys stated that annual adaptation expenses were likely to be less than 2 per cent of their current household income. Zero percent interest loans may assist greater uptake of expensive items such as water tanks, greywater, insulation and PV panels.

Retrofitting infrastructure, changing energy and water use and efficiency have a part to play, health promotion activities should focus on reducing the health burden associated with non-communicable diseases in rural areas through behavioural changes. The demand for hospital services and ambulatory care is very unlikely to be reduced considering likely demographic changes of population growth and ageing. Reducing the impact of health costs of non-communicable diseases is essential, as

these will influence tolerance to temperature and air quality factors. Community participants placed a high priority on recreation facilities and community cohesion; future planning in local government could identify opportunities for increased participation being inclusive of demographic changes (Nyqvist, Forsman, Giutoli & Cattan, 2013).

### **5.11 Conclusion**

Community, stakeholder and expert participants identified future sensitivities and vulnerability to climate change in the study area. Community participants identified social, environmental and economic factors that may have a likely influence on health outcomes and adaptive capacity. The qualitative health risk assessment and Delphi Method conducted by the expert participants identified extreme weather events and air quality factors as potential future health risks. Stakeholder participants identified opportunities, barriers and limitations to adopting adaptation practices and policies. Resource constraints and competing priorities were stated to be prohibitive to adopting adaptation practices and policies. Having a 'sustainability' focus and longer term planning strategies were considered opportunities to embed climate change adaptation into local government and regional management.

There was consensus amongst all participants that climate change would impact health outcomes and that vulnerable groups within these communities are more likely to be impacted. Vulnerable groups identified by the participants included persons living in poor quality housing, persons residing in areas susceptible to bushfires (forested regions, areas with poor access and egress and areas with communication black spots), the elderly, and persons with existing health conditions. There was consensus amongst all the participants that climate change would have negative health consequences, some opportunities for increased tourism and diversification of horticulture production was identified by community participants in relation to future temperature and rainfall changes.

Effective adaptation involves reducing exposure to direct and indirect climate change impacts. Community resilience to climate change impacts was stated to be associated with social capital (active volunteering and a highly networked community), having sufficient local services (medical, community, transport and recreation) and

providing infrastructure to meet future water and energy demands. Household adaptation preferences were for increased water storage (water tanks) and PV solar panels. Households with fixed incomes were identified by participants in focus groups and community surveys as having reduced adaptive capacity. Adaptation activities that focus on cost savings (by enhancing efficiency) may be more likely to be adopted due to the stated limitations and barriers. Community and stakeholder perspectives regarding risks, vulnerabilities and preferences for adaptation activities and practices can assist government decision making processes (Stordalen, Rocklov, Nilsson & Byass, 2013). Chapter Six discusses in detail the risk assessment for the region.

## Chapter Six - Risk Analysis & Mitigation

*“We also need to recognise that unsustainability is not merely a quality and consequence of a modern economy. It became an inherent feature of our collective being which became amplified and made visible by modern modes of resource extraction, production, exchange, industrial and domestic utilisation. Intrinsically, as soon as we denaturalised ourselves and started intervening in the natural, the die of unsustainability was cast” (Fry, 2011, para. 9).*

### **6.0 Introduction**

This Chapter will use the qualitative health risk assessment process to analyse the risks for each of the health determinants discussed in the previous Chapters and determine priorities for action. The likelihood of the health impacts of the risks associated with climate change were determined by the expert participants, as described in Chapters Three and Five; Research Design and Methods and Data Analysis. The health risks to be discussed are related to temperature, water (rainfall, flooding and water quality), extreme events, vector borne illness, air quality factors, species migration, and food impacts. A health risk matrix is used to introduce the health and wellbeing factors associated with climate change hazards, with a discussion to follow of the potential health effects and the adaptations that can be utilised to prevent exposure, minimise harm or exploit positive benefits. The health risk matrix will determine the vulnerable sub groups, with a risk rating from low to extreme and the adaptation methods required to reduce the effect of the impact or to mitigate the risk. Vulnerability diagrams are adapted from Spickett, Brown and Katscherian (2008) and demonstrate exposure, sensitivity, impacts, adaptive capacity and vulnerability for likely climate risks.

Residual impacts could occur where adaptation is not able to prevent exposure to risks such as infrastructure damage following an extreme weather event. Many of the potential health impacts can be mitigated or managed dependant on behaviour, resources, cognition and existing health concerns. Maintaining a healthy body and

good mental health will increase resilience to physical, environmental and social threats associated with climatic changes (Berry et al., 2010; Walker et al., 2011). Maintaining a healthy community and bio-region through partnerships, rehabilitation (recovery), and cooperation will enhance rural resilience (Severi, Rota & Zanasi, 2010). Rehabilitation of the ecology in rural economies includes re-forestation and restoring degraded soil (Adger et al., 2005; Harris, Hobbs, Higgs & Aronson, 2006).

A discussion of the health risks influenced by climate change is covered in the literature review in Chapter Two. The data analysis in Chapter Five will inform the vulnerability assessment of this Chapter to determine sensitivity of the communities and determine the adaptive capacity for various regions. The adaptation strategies developed will maximise positive health gains and minimise or mitigate where possible the negative health impacts from climate change. A priority of actions for private citizens, non-government organisations, communities and the various tiers of government will seek to avoid health risks, and improve health outcomes (Safi, Smith Jr. & Liu, 2012). This Chapter will conclude with a summary of the risks and discussion of each local government area and the key concepts relating to future climate change and risk reduction (Mercer, 2010). The following Chapter (Chapter Seven) will discuss the key findings of the research, the significance of the research, and the application of this research model for other rural regions in Australia.

### **6.1 Uncertainty and Action**

Uncertainty of future climate change will impact adaptation responses and may delay or impede decisions regarding priorities for action (United States Environmental Protection Agency, 2009). This study has analysed the uncertainty and influences affecting health in the Blackwood Stirling region to provide action oriented, win-win recommendations to all sectors of the community (van Beek, 2009). Decisions about adaptation should be used based on the precautionary principle (Veraart & Bakker, 2009).

### **6.2 Risk Assessment Process**

The process for the risk assessment has been discussed in the literature review in Chapter Three (3.1). Climate change risks are detailed below; the risks under examination include the data collected from expert panel qualitative health risk

assessment and stakeholder and community participants. Risks that have been identified in regional assessments by the IPCC (2012) are also incorporated. Climate change risks are evaluated using a qualitative health risk assessment process, with risks being rated according to their likelihood and consequences from very low, low, medium, high or extreme. The qualitative health risk assessment process follows the protocols outlined in the documents ‘Health Risk Assessment in Western Australia’ (Spickett, Brown, Matison & Katscherian, 2006) and ‘Health Risk Assessment (Scoping) Guidelines’ (Spickett, Goh, Katscherian & Ellies, 2010). In summary, the risk assessment process includes identifying the risks, evaluation of the risks (risk rating), and responding to the risks through appropriate adaptation.

The direct and indirect climate hazards are outlined in the following table:

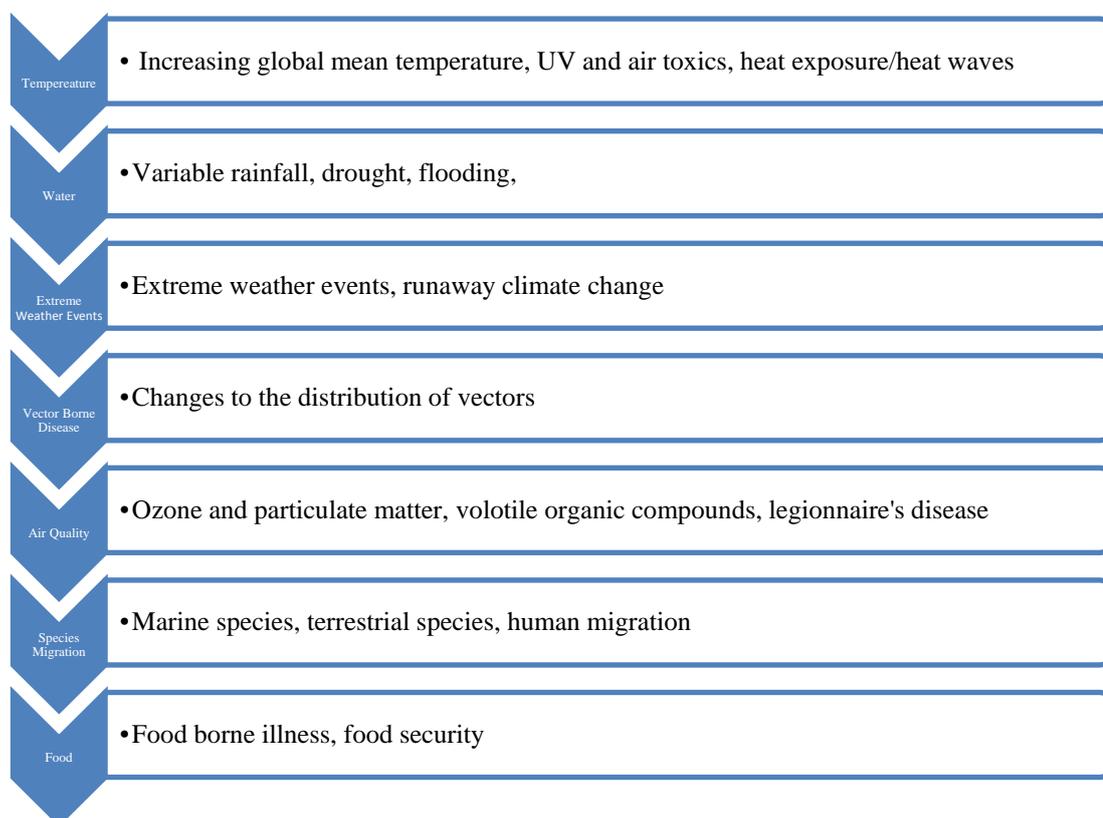


Figure 34 Risk Assessment of Direct and Indirect Impacts.

Each adaptation listed at the conclusion of each health factor indicates if the method is soft (behavioural/flexible) or hard (engineering, rigid) along with low or no regret adaptation options.

### 6.3 Temperature and Air Quality Factors

The following table outlines the health impacts, risks and adaptation required for temperature and air quality factors. Temperature relates to daily means, extremes in temperature, air quality factors relating to natural phenomena and air pollution.

Impact Type	Health and Wellbeing Factor	Vulnerable subgroups	Risk Assessment Risk Rating	Adaptation required
Temperature				
Reduction in cold weather extremes	Reduction in cold-related deaths	Elderly/Immunocompromised	Low	Increased thermal efficiency of dwellings
	Reduction in food production for those types that require winter chilling, e.g. nuts and fruit	Farmers, consumers	Low	Change to variety of trees grown (agricultural adaptation)  Change in diet
Increased global mean temperature	Heat stress – humans	Direct exposure – outdoor workers homeless persons persons working or living in buildings with insufficient insulation or cooling devices (especially, elderly, infants, children and immunocompromised) pre-existing mental health factors	High	Increase thermal efficiency of buildings Public education Access to cooling centres Behaviour modification (hours worked)
Disruption to power supply – peak energy demand	Pharmacokinetic impacts of heat stress/exposure	Persons on medication	High	Managed by GP's
Increase in exposure to UV (increased outdoor recreation)	Heat stress – reduced food production	Farmers, consumers	Low	Stock and crop adaptation Change in diet
Increased exposure to air toxics (ozone, particulate matter, gaseous matter)	More time spent outdoors increasing exposure to UV radiation	All persons exposed to UV, especially children	Extreme	Precautions for UV exposure (UPF clothing, head protection, sunscreen)
Increase in ocean temperatures - Sea Level Rise - Distribution changes to marine species (pole ward	Indoor and outdoor air quality	Young, old, pregnant, immunocompromised, existing cardiopulmonary illnesses	Medium	Behaviour, thermal efficiency of buildings, adequate ventilation

Impact Type	Health and Wellbeing Factor	Vulnerable subgroups	Risk Assessment Risk Rating	Adaptation required
shift) - Ocean Acidification - Coral Bleaching	Sea Level Rise Changes to types and distribution of edible fish and ocean plant species	Coastal communities, commercial and recreational fishing, consumers (reduction in fish species and types available)	Medium	Human migration, coastal infrastructure adaptation (engineering works), diet change, sustainable fishing practices, increase in land based aquaculture

Table 36 Potential Impacts - Temperature

(Californian Natural Resource Agency, 2009; Health Canada, 2005; Spickett, Brown & Katscherian, 2008).

### 6.3.1 Increasing Global Mean Temperature

Global mean temperatures have increased by approximately 0.85<sup>0</sup>C from the period 1880-2012. It is likely (with medium confidence) that the global mean temperature will increase by a further 0.3 to 0.7<sup>0</sup>C from 2016 to 2035 (IPCC, 2013b). Human exposure to heat extremes (increasing number of hot days, and heat wave activity) can result in early mortality. Improving thermal efficiency of dwellings and moving to a cooler environment as required may prevent health impacts occurring (Loughnan, Nicholls & Tapper, 2012). Heat waves in rural areas have different effects than heat waves in urban areas, some rural areas have much higher vegetation coverage to increase shading and cooling of dwellings and do not have the heat island affect delaying afternoon cooling. Other more sparsely vegetated areas more common in Wheatbelt communities (some areas of Cranbrook, Plantagenet and Boyup Brook) will have more impacts from heat waves to people and livestock, due to the ground radiating heat, lack of cooling sea breezes and hot easterly winds (Li & Bou-Zeid, 2013; Sudmeyer, Bicknell & Coles, 2007; Walsberg, 2000). Exposure to high temperatures will occur depending on location of dwelling (coastal versus inland), quality of housing and building materials (Department of Health, 2010a; Victorian Council of Social Service, 2013).

PV systems will reduce the pressure on the grid during peak summer energy demand with the exception of widespread blackouts during the times that air conditioning is required the most (Environment Agency, 2007). Higher energy rated dwellings with

their protective benefits and eco-design housing developments may be more likely to be constructed in regional/urban areas or by absentee landowners with holiday homes in the region (Kelly & Haslam McKenzie, 2005).

Participants in the focus group meetings stated that exposure to increasing mean global temperatures would have likely environmental impacts, many stated that humans would adapt to these temperature increases. Some participants stated that using air conditioning decreased acclimatisation to summer temperatures and some mistakenly believed that reducing water intake improved acclimatisation. Health promotion that focuses on how to acclimatise and to prevent heat stress may be required. Community participants stated that as outdoor workers they have found it harder to tolerate working during the day in summer. The increase of temperature beyond what individuals have acclimatised to over a period of days, even if they have previously lived in warmer locations, does not mean that they are able to cope with sudden changes in heat, such as early summer heatwave activity (Yardley, Sigal & Kenny, 2011). Local government, in consultation with communities could allocate appropriate buildings to be available as cooling centres, and determine any additional transportation assistance that might be required. Examples are community centres or local libraries with air conditioning and backup power to be used in the case of power blackouts following peak summer electricity demand. Persons living remotely to these centres that do not have access to transport and persons that fail to recognize the potential risks from heat exposure may have increased vulnerability during these times (Huang, et al., 2013).

Pre-existing illnesses that impact the body's ability to regulate temperature include diseases of the circulatory, respiratory and endocrine systems which are more commonly associated with lifestyle disease (New South Wales Government, 2013). This may be associated with increased demand for health care (Loughnan, Nicholls & Tapper, 2010). As the smaller communities are reliant on volunteer paramedics, preventing morbidity from heat related and other climate related illness will prevent overuse of ambulance services (Kawakami, Ohshige, Kubota & Tochikubo, 2007). Adaptive capacity may be limited for those persons who are renting or who have limitations to expenditure for adaptation activities to improve the thermal efficiency

(or alternative power) of their home or business. There is scope to introduce mandatory thermal control to ensure that buildings/dwellings have at least one cool room to prevent heat stress (ideally in the range of 24<sup>0</sup>C) (Kravchenko, Abernethy, Fawzy & Lyerly, 2012; Ormandy & Ezratty, 2012; The National Archives, 2016; Zhang, Nitschke & Peng, 2013).

Some Indigenous persons in Western Australia may have genetic protective factors to extreme heat that allow the body to cope with temperatures up to 45 degrees Celsius (Qi, Chan, Read Zhou & Carrell, 2013).

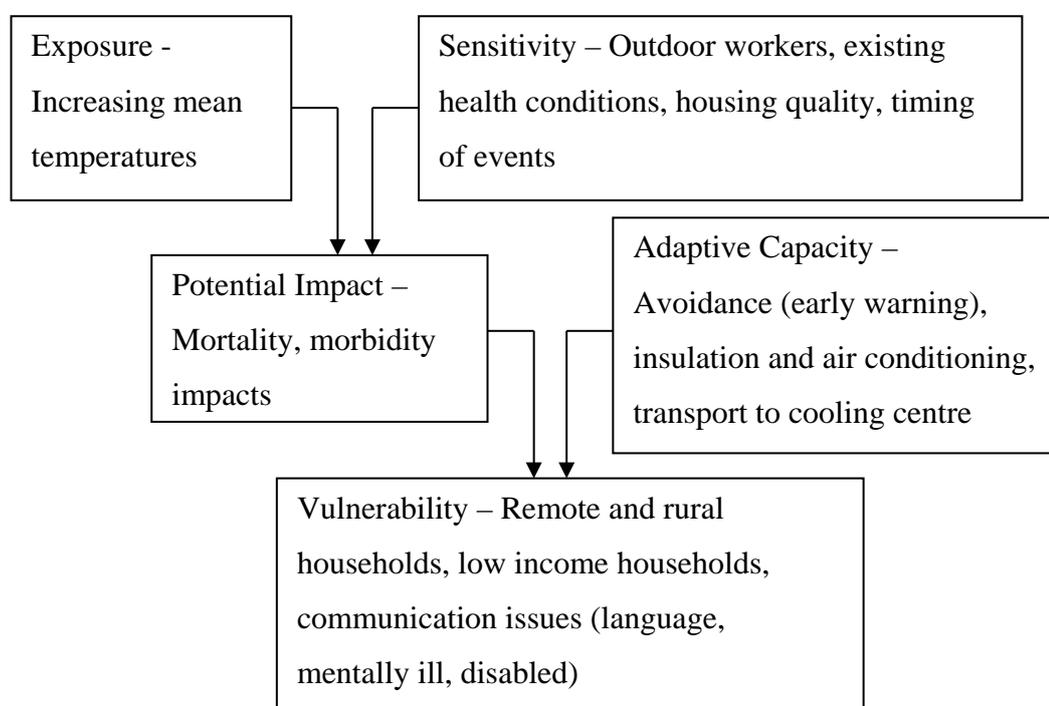


Figure 35 Vulnerability Model of Temperature Increase and Heat Waves

(Adapted from Spickett, Brown & Katscherian, 2008) (Kravchenko, Abernethy, Fawzy & Lyerly, 2012; Kwasinki, 2010; Ormandy & Ezratty, 2012; Zhang, Nitschke & Peng, 2013).

### 6.3.2 UV Exposure and Air Toxics

Exposure to UV (ultraviolet radiation) and air toxics will be discussed together. Air toxics include ozone, particulate matter (including allergens) and gaseous matter that lead to health impacts (American Academy of Paediatrics, 2004). UV radiation is at its greatest between 10 am and 4 pm and should be avoided or limited during this period, with health effects including cancer, eye and skin damage and reduced

immunity (Smith, Harrison, Nowak, Buettner & MacLennan, 2013; World Health Organization, 2003c). Appropriate UV protection for persons working or recreating outdoors requires more investment and attention, some studies indicate that rural children spend more time outdoors and may be more vulnerable to UV exposure (Bulliard, Reeder & McAllister, 2000; Erbas, Ebeling, Cough & Wark, 2008; National Rural Health Alliance Inc., 2011a; Rai, Chanmuga & Srinivas, 2012; Sandercock, Angus & Barton, 2010).

Indoor air quality can be more harmful than outdoor air quality, particularly during hot periods in the day (or through processes of combustion and cooking) (Weisel, 2002). Ventilation is required to dilute the off gassing of indoor air contaminants (Shaw, Salares, Magee & Kanabus-Kaminska, 1999). Opening windows can also expose occupants to outdoor air pollutants, such as smoke and allergens (Field, 2010; Reisen et al., 2011).

Exposure to air toxics is more likely in built up and urban areas where the population has greater exposure to road vehicle emissions, industrial emissions and higher heat levels (heat island effect). In the study area, regional centres such as Manjimup and Margaret River have higher density housing. Newer dwellings also have a higher loading of indoor air contaminants, with more recent growth in the coastal regions of Margaret River and Denmark with satellite suburb development (D'Amato, Checchi, D'Amato & Liccardi, 2010; Wilby, 2008). Exposure to air quality factors in the study area may be higher in areas adjacent to mining activities and other activities that create dust, spray drift or smoke emissions. Spring time controlled burning, wildfires, increased pollen loads, and home biomass burning for heating and combustion are all sources of potential air pollution (United Nations Environment Programme, 2005).

Using wood heaters in rural areas is common, with associated air toxics from wood smoke being a potential health impact. The sustainability of wood as a heat source when burnt correctly in a quality wood stove is much higher with less carbon emissions than electricity or gas (Wilton & Cavanagh, 2012). Tight houses encourage backflow of smoke into the house and increase the level of air toxics,

particulate matter, carbon monoxide, nitrogen oxide and volatile organic compounds (VOCs), adequate ventilation is required to prevent health problems. Ensuring adequate housing insulation may reduce the need for additional heating sources (Almeida et al., 2011; Cutis & Oven, 2012; Galbally et al., 2009; Sheffield & Landrigan, 2011). To improve indoor air quality factors, particularly for persons with chronic obstructive pulmonary disease (COPD), an adequate filtration system such as HEPA (high efficiency particulate arrestance) or HVAC (heating, ventilating and air conditioning) have proven health benefits (Sublett et al., 2010).

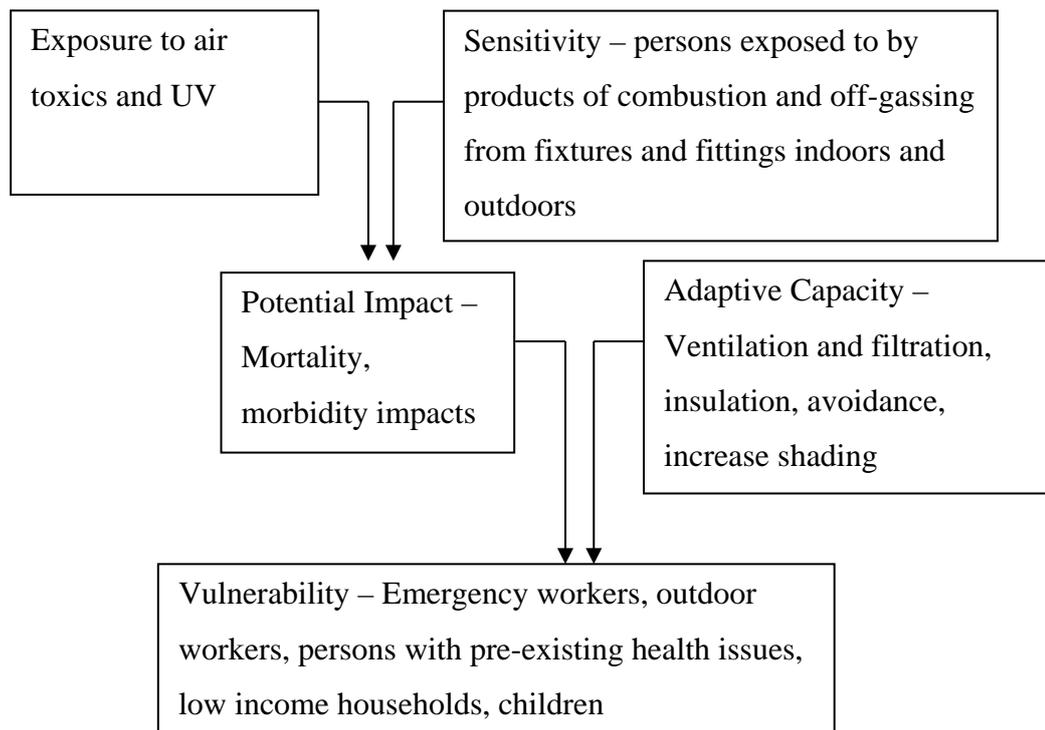


Figure 36 Vulnerability Model - Air Toxics

(Adapted from Spickett, Brown & Katscherian, 2008) (Bulliard, Reeder & McAllister, 2000; Erbas, Ebeling, Cough & Wark, 2008; National Rural Health Alliance Inc., 2011a; Rai, Chanmuga & Srinivas, 2012; Sandercock, Angus & Barton, 2010).

### 6.3.3 Heat Disruption

Heat disruption can impact transportation, livestock and food crops in rural areas. Heat disruption to transport and energy networks could influence supply chains for various industries in the region including agriculture and mining (Shorpe & Fennell, 2012; The Royal Academy of Engineering, 2011). The likely outcome may be an increase in the cost of basic necessities and the possibility of delays to goods and services, particularly for remote communities (Garnaut, 2008; Hacker et al., 2007;

Shonkoff, Morello-Frosch, Pastor & Sadd, 2011). Adequate disaster preparation such as The Red Cross (RedIPlan) for householders is required (Australian Red Cross, 2009). Remote communities are Pemberton, Northcliffe, Windy Harbour, Walpole, Quinninup and surrounding settlements (Australian Government Department of Health & Ageing, 2012).

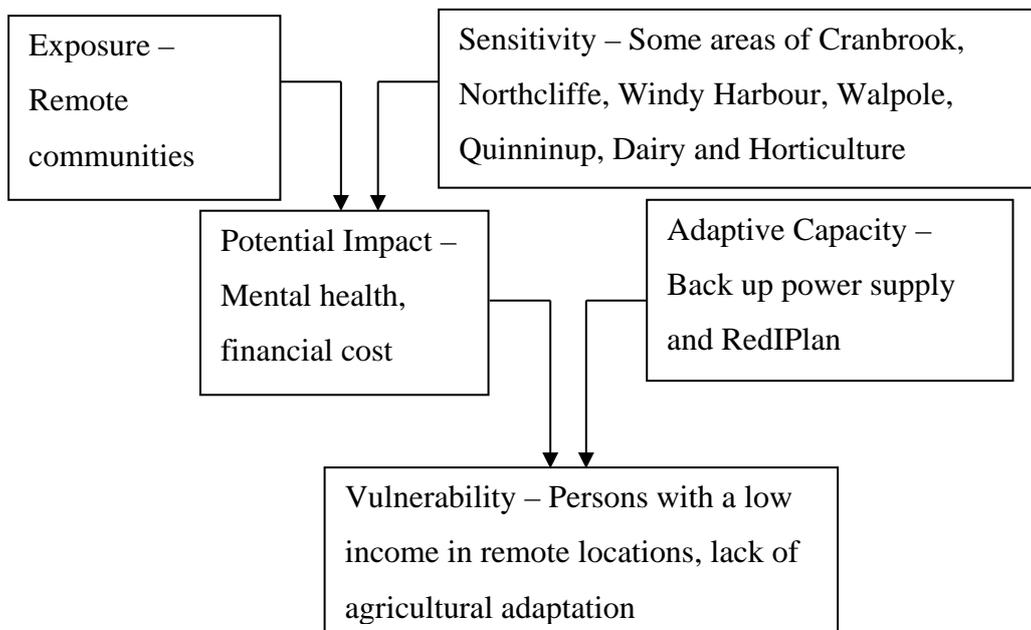


Figure 37 Vulnerability Model - Heat Disruption

(Adapted from Spickett, Brown & Katscherian, 2008) (Australian Red Cross, 2009; Garnaut, 2008; Hacker et al., 2007; Shonkoff, Morello-Frosch, Pastor & Sadd, 2011).

### 6.3.4 Ocean Temperature

Increased warming of the ocean could potentially increase wave height and tidal storm surge, leading to localised flooding in coastal areas. Assessments to date projected to the year 2100 for gradual sea level rise indicate a small number of dwellings in the Augusta-Margaret River area adjacent to soft erodible shorelines may be at risk, however the uncertainty in the modelling was stated to be too high to make risk management decisions (Eliot & Pattiaratchi, 2010; Malone et al., 2010). Infrastructure and dwellings in Western Australia's coastal cities are vulnerable to sea level rise. State government planning policies have taken shoreline erosion into account for new developments, existing properties may be exposed to sea level rise

(Bicknell, 2010; Kuhn, Tuladhar & Corner, 2011; Maslowski, Kinney, Ruckelshaus et al., 2013).

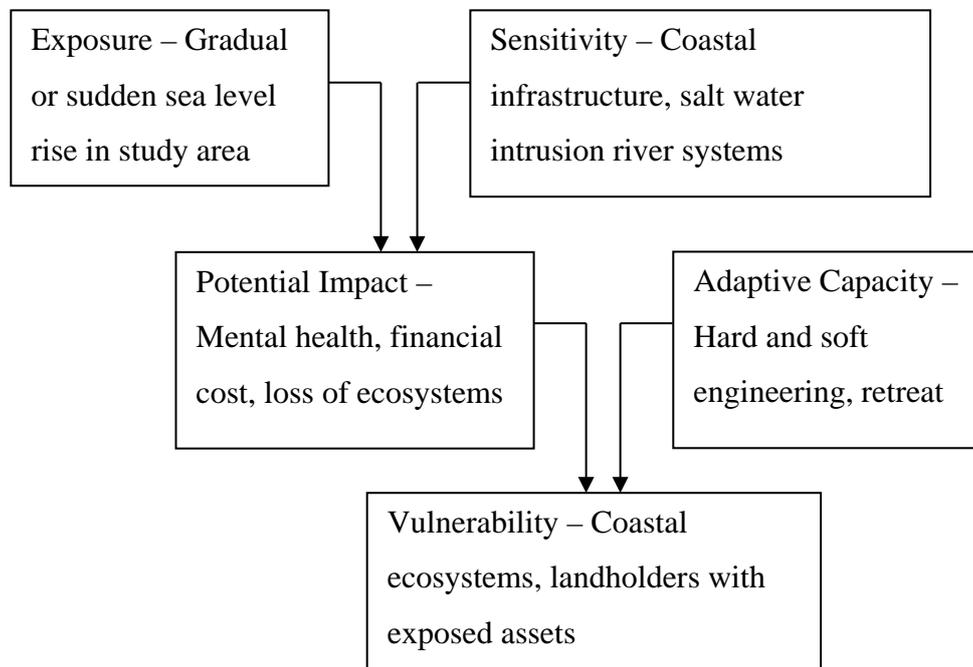


Figure 38 Vulnerability Model - Sea Level Rise

(Adapted from Spickett, Brown & Katscherian, 2008) (Kuhn, Tualhar & Corner, 2011; Stern, 2007).

### 6.3.5 Summary of Temperature Related Impacts

In summary, temperature related vulnerability is dependent on location, existing health concerns and socio-economic status. Estimating future morbidity using health forecasting would indicate that the mental health and lifestyle disease burden will continue to increase vulnerability to temperature extremes (Kjellstrom, Butler, Lucas & Bonita, 2010). Private dwellings, schools, hospitals, workplaces and aged care facilities should provide safe air environments, along with reducing reliance on heating and cooling devices (Diesendorf, 2010; Zecca & Crhiari, 2012). As older people and low income householders tend to spend a high proportion of time at home indoors, the energy costs and potential for heat related impacts are greater than other sectors of the community (Urmee, Thoo & Killick, 2012).

Communities and industries vulnerable to heat stress are those that are remote to services and economic centres (including ports) and industries reliant on refrigeration

and high water use to provide goods to the market place (e.g. dairy, horticulture, livestock production) (McMichael, Powles, Butler & Uauy, 2007; Stokes & Howden, 2008). Lack of private car ownership, coupled with lack of public transport further increases vulnerability to heat extremes. Reliance on air conditioning throughout summer, particularly for elderly citizens is likely in the absence of dwelling retrofitting (based on the proliferation of air conditioning in Western Australia). Enhancing insulation and appropriate air filtration/ventilation would use significantly less energy than overreliance on air conditioning (Banwell, Dixon, Bambrick, Edwards & Kjellstrom, 2012; Energy Efficient Strategies, 2005; Growth Management Queensland, 2011). The following lists of adaptations to temperature related health impacts are focused on each tier of the community and are based on the literature review and existing government policy. Soft adaptation and hard adaptation are listed for each recommendation along with low or no regret options (Hallegatte, 2009).

### **6.3.6 Individual Adaptation**

1. Thermal efficiency of dwellings to be maximised to reduce energy use (low regret)<sup>1</sup>.
2. Maintain healthy body mass and cardiovascular health (no-regret)<sup>2</sup>.
3. The use of shade bearing deciduous trees to the north, east and west side of dwellings to increase efficiency of air conditioning and insulation factors (soft, no-regret)<sup>1</sup>.
4. Behavioural adaptations to avoid exposure to UV, other air toxics and excessive heat (soft, no-regret)<sup>3</sup>.
5. Back-up power supply to maintain refrigeration and air conditioning (hard, low regret)<sup>4</sup>.
6. Use of appropriate air filters and cooling devices (hard, low regret)<sup>3</sup>.
7. Knowledge of first aid, access to local community cooling centres and services (soft)<sup>4</sup>.
8. Access to transportation (soft)<sup>4</sup>.
9. Checking on vulnerable community members during heat waves (rapid reporting and treatment) (soft)<sup>4</sup>.

### **6.3.7 Community Adaptation**

1. Provision of cooling centres using existing facilities and providing adequate transportation (low-regret)<sup>3,4</sup>.
2. Community notification of heat wave event, or air quality event (soft)<sup>5</sup>.
3. Identification and checking of vulnerable individuals (e.g. elderly, persons living in substandard housing, children, persons with pre-existing illness) (soft)<sup>4</sup>.
4. Provide first aid assistance and training (soft, low-regret)<sup>4</sup>.
5. Businesses to prepare for power blackouts and disruption to transport networks at appropriate times (hard, low-regret)<sup>7</sup>.

### **6.3.8 Local Government Adaptation**

1. Support property owners to increase thermal efficiency of dwellings through education, and planning policies (soft, no-regret)<sup>1</sup>.
2. Support recreation in local communities through policies (soft)<sup>8</sup>.
3. Provide advice during a heat wave (soft)<sup>5</sup>.
4. Provide advice during air pollution events (e.g. bushfires) (soft)<sup>5</sup>.
5. Provide advice regarding transportation options during emergency events (heat wave events) when required (soft)<sup>6,8</sup>.
6. Allocate existing buildings to be used as cooling centres in each community (soft, no-regret)<sup>4</sup>.

### **6.3.9 State Government Adaptation**

1. Future planning should allocate sufficient medical staff at health services to cope with unplanned use of hospital services following heat exposure and exposure to air toxics (soft)<sup>6</sup>.
2. Implement health promotion that targets lifestyle diseases such as smoking, recreational drug use, occupational health and safety to prevent injuries, binge drinking, preventing lifestyle disease and supporting breast feeding (soft)<sup>10</sup>.
3. Provide heat wave notifications (soft)<sup>6</sup>.
4. Provide smoke and smog notifications (soft)<sup>5</sup>.
5. Enhance public awareness of heat waves, UV radiation and air toxics (soft)<sup>6</sup>.

6. Encourage installation of Photovoltaic panels for business, community and individuals, along with an overall reduction in energy use (soft) <sup>11</sup>.
7. Coordinate a rapid response to transport disruption (railways etc.) and ensure that emergency transport systems are available (soft)<sup>12</sup>.
8. Ensure integrity of emergency communication in an emergency event (low-regret)<sup>13</sup>.

### 6.3.10 Federal Government Adaptation

1. Initiate carbon mitigation programs (soft, low-regret)<sup>15</sup>.
2. Update the Australian Building Code to incorporate thermal comfort responsive to future climate change (soft, low-regret) <sup>15</sup>.
3. Include perennial farming systems or land management in carbon sequestration programs (soft, no-regret) <sup>16</sup>.
4. Research health impacts and mitigation of air quality factors (soft) <sup>12</sup>.

*1 (Dave, Varshney & Graham, 2012) 2 (Lowe, 2014), 3 (Remoundou & Koundouri, 2009; Bateman et al., 2005; Saman et al., 2012; Lowe, Ebi & Forsberg, 2011) 4 (Australian Red Cross, 2009; Bambrick et al., 2011; Australian Emergency Management, 2006; Fire and Emergency Services Australia, 2007; Maunsell Australia Pty Ltd., 2008; American Red Cross, 2009) 5 (Blashki et al., 2010; Department of Parks and Wildlife, 2013) 6 (Disaster Management Unit of the Western Australian Department of Health, 2012; Saliba, 2008) 7 (Crawford & Seidel, 2013) 8 (Friel & The Department of Epidemiology and Public Health, University College London, 2009) 9 (Tirado, Clarke, Jaykus, McQuatters-Gollop & Frank, 2010) 10 (Moodie et al., 2009) (National Rural Health Alliance Inc., 2011b) 11 (Geoscience Australia, 2010b; Macintosh & Wilkinson, 2011) 12 (Australian Government Department of Environment, 2013) 13 (Howes et al., 2013)14 (Weaver, Blashki, Capon & McMichael, 2010) 15 (Commonwealth of Australia, 2013) 16 (Mng'omba & Beedy, 2013).*

#### Health Factors Assessed

Temperature and air quality	✓
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Table 37 Health Factors Assessed

#### 6.4 Water Risks and Adaptation

The following table explains the health impacts, risks and adaptation for water; this includes potable water using existing infrastructure, along with private sources of water from dams, rainwater and bores. Water quality and quantity may be challenged by shifting seasons, increased demand due to higher mean temperatures, heat wave events and reduced water quality due to contamination. Reduced annual rainfall and flooding area also discussed. The agricultural, forestry and industrial industries are sensitive to increases in costs and availability of water. Following the table is a discussion of the health impacts relating to rainfall, flooding, drought, and water contamination.

Impact Type	Health and Wellbeing Factor	Vulnerable subgroups	Risk Assessment Risk Rating	Adaptation required
Rainfall and water				
Reduction in rainfall	Decreased access to potable and irrigation water	All of the community	High	Increased water efficiency for domestic and industrial uses  Increased water recycling  Water rationing  Increasing the price of water
	Decrease in irrigation intensive agriculture	Farmers, food availability and freshness	High	Changes to diet and seasonal availability
	Loss of green space and rainfall recharge (riverine, and land based)	Recreation, mental health	Medium	Increase efficiency of water use to preserve existing water resources carbon mitigation, afforestation
Increase in flooding	Damage to housing and infrastructure	Floodplains and riverine areas	Medium	Building design, emergency communication and response
	Loss of farming land, stock, crops	Agricultural Sector (increased cost of food)	Very Low	Insurance, government assistance depending on the nature and scale of the incidence

Impact Type	Health and Wellbeing Factor	Vulnerable subgroups	Risk Assessment Risk Rating	Adaptation required
	Localised flooding (street and drainage networks)	Local residents	Very Low	Maintenance of infrastructure by local government
	Contamination of drinking water supplies	Private land owners with own water supply, town water supplies. Human and stock water at risk	High	Monitoring of water quality. Appropriate action if supplies are contaminated.
	Increased expenses for water	Businesses, individuals and communities.	Low	Risk diversification, multiple sources of water, water use reduction, water efficiency, increased reliance on recovery of water from other sites, and desalination
		Mental health impacts	Low	
	Disruption to Transport Systems	Individuals and business	Low	Emergency preparation, surplus storage, alternative transport systems
	Disruption to Power Supply – Impacts to food handling safety	Businesses	Low	Safe food handling practises, backup power supplies, , appropriate behaviour
	Exposure to recreational pathogens in water after flooding	Vulnerable individuals; young (0-4), elderly, pregnant, immune-compromised individuals	High	Behaviour, hygiene practises, local government ensuring signage at potentially unsafe sites
Recreational water users, recovery emergency staff				
Exposure to contaminated greywater	Agricultural workers, Individuals and communities (sporting grounds)	Directly as an aspirant, contaminated food, or dermal contact	Medium	Ensure approved systems are installed, monitoring of large scale agricultural applications (water quality testing), behavioural practises, washing produce before consumption

Impact Type	Health and Wellbeing Factor	Vulnerable subgroups	Risk Assessment Risk Rating	Adaptation required
Drought	Financial hardship for farmers and their communities	Rural communities, consumers, local income households	High/Medium	Drought assistance, insurance
	Economic impact including increased cost of food		Low	Ensure fresh affordable produce is available, public education/health promotion

Table 38 Potential Impacts – Rainfall and Water

(California Natural Resource Agency, 2009; Health Canada, 2005; Spickett, Brown & Katscherian, 2008).

### 6.4.1 Variable Rainfall

Variability in rainfall, including heavy rainfall events, or reduced annual precipitation, (including drought) can influence health in several ways. Declining supplies of water (scarcity), contamination of water through chemical, or biological materials, or flooding are some of the potential concerns associated with climate change. Rural properties that provide their own potable, stock and irrigation water are potentially vulnerable to declining water quality (Arnell & Delaney, 2006).

Avoiding risks from reduced annual rainfall would include increasing the diversity of water sources for householders and communities e.g. rainwater and stormwater harvesting and water treatment technology (for instance treating hard or saline water). Increasing water use efficiency through appropriate technology and practises, greywater recycling and increasing rainfall capture through water tanks or dams are viable alternatives. Groundwater extraction has limitations due to the likely decline in groundwater recharge by 2030 across the study area and in particular inland regions (CSIRO, 2009; Hanak & Lund, 2012; McCaffree, 2008). Inland, low rainfall areas such as Cranbrook and Boyup Brook may be more vulnerable to variable precipitation along with increased heat in summer (Garnaut, 2008). One of the stakeholders interviewed suggested the south coast region (Walpole and Denmark) were less prepared for drought events than the Wheatbelt region and that costs for supplying potable water would increase as a result of diminishing supply. Water use in Western Australia’s South West area is primarily irrigated agriculture,

followed by mining and industry (making up 84% of total use) (Department of Water, 2007a). Reducing water demand through behaviour, retrofitting appliances and fixtures (technology), and enhancing water efficiency is required, especially by these sectors to ensure sustainable economies (Mankad & Tapsuwan, 2011).

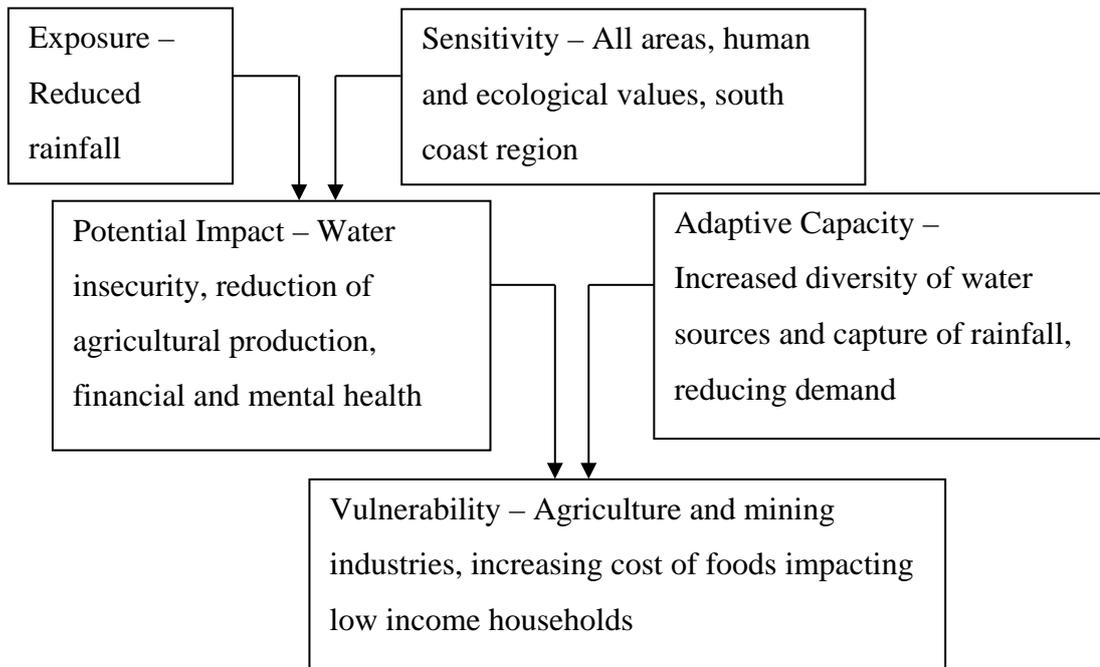


Figure 39 Vulnerability Model - Reduction in Rainfall

(Adapted from Spickett, Brown & Katscherian, 2008) (Department of Water, 2007; Hanak & Lund, 2012; McCaffree, 2008).

### 6.4.2 Water Demand

To meet future food demands of a growing global population and energy through biofuels, the demand for irrigation water for agriculture will increase (Jaggard, Qi & Ober, 2010; Mooney & Tan, 2012). The Blackwood Stirling is an important agricultural region that produces fruit and vegetables, wheat and livestock, olive oils, meat and dairy, and beverages from grapes and other fruit. Uncertainty relating to climate change along with declining commodity prices in some industries may discourage technological adaptation methods on farms (Rogers, Curtis & Mazur, 2012).

### **6.4.3 Preserving Water Sources**

Protecting existing water sources from contamination through the management of flora, fauna and human activities, along with investment in upgrading water facilities (pipe work and treatment facilities) is undertaken by the W.A. State Government (Rygaard, Arvin, Bath & Binning, 2011).

A commitment to protecting fresh water sources and associated biodiversity values will have positive outcomes for future generations; this includes all riverine resources in the Blackwood Stirling (such as the Blackwood River) which is currently threatened by salinity and eutrophication (Vorosmarty et al., 2010; Western Australian Planning Commission, 2004).

Greywater is an additional source for irrigation particularly for areas with low or variable annual rainfall or areas under water restriction, in recent years this has included Manjimup and Denmark despite having adequate annual rainfall for rainwater harvesting (tanks). Boyup Brook and Cranbrook are communities that may benefit from increasing the use of grey water recycling due to having hot dry summers and relatively lower annual rainfall than other regions. Greywater devices must be approved for use by the Department of Health, with potential risks from recycled water carefully monitored, such as odours, pests and skin irritants (Gross et al., 2005). Delays in adaptation to household and industrial water supplies may increase future costs to water providers, government, business and individuals (Connor, Schwabe, King & Knapp, 2012). Reduced water availability, quality and poor sanitation has the potential to cause significant health issues (Fink, Gunther & Hill, 2011; Pruss-Ustun, Bos, Gore & Bartram, 2008; Whittington, Jeuland, Barker & Yuen, 2012).

### **6.4.4 Drought and Agriculture**

Alternate water sources during drought years or years with variable rainfall could include ground water extraction and treatment, or carting water from other communities. Businesses and communities in remote locations may face higher water supply costs; these include Cranbrook and Manjimup Shires (Rijsberman, 2004). Larger farming operations using precision farming methods may have more

resilience to climate change, leaving smaller farms and low income groups with the least adaptive capacity (Abler & Shortle, 2000; Vorosmarty et al., 2010).

Drought years could have several impacts to communities including financial difficulties, with flow on affects to small local businesses and community groups. Protracted drought could potentially lead to migration from these areas (Garnaut, 2008). Following protracted drought, stress and mental health issues could result from financial and environmental stress and losses (McDonald, Coldrick & Christensen, 2008; Taylor, 2012).

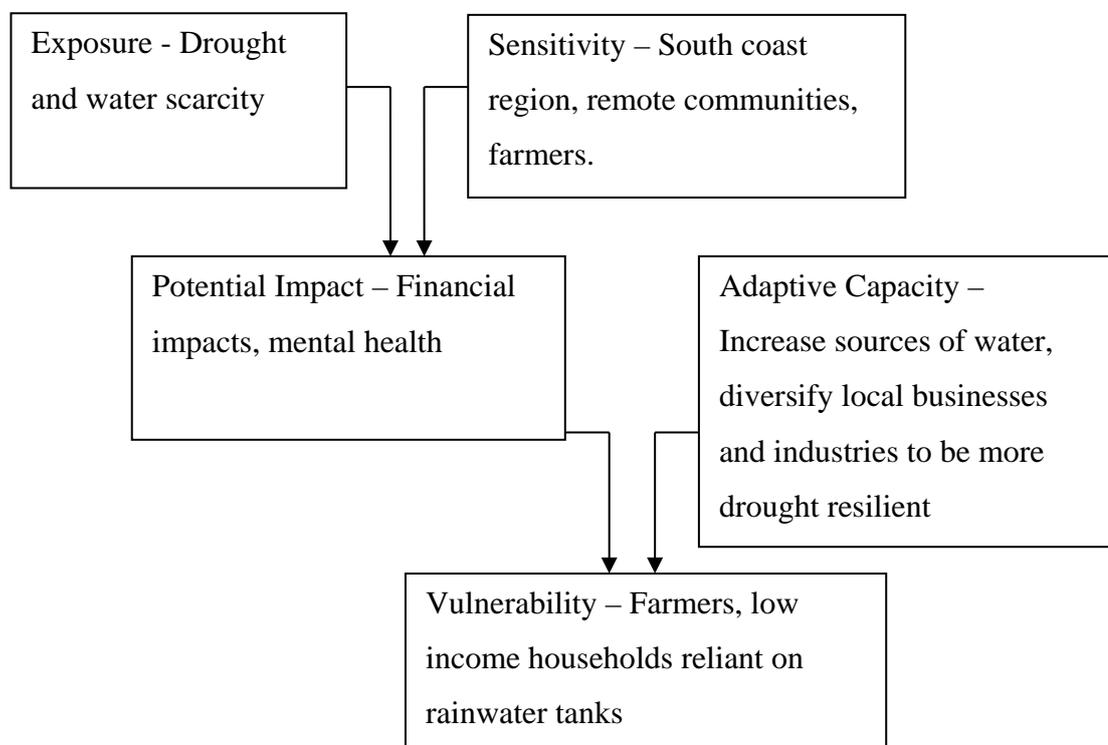


Figure 40 Vulnerability Model - Reduced Water Supply

(Adapted from Spickett, Brown & Katscherian, 2008) (Abler & Shortle, 2000; Rijsberman, 2004; Vorosmarty et al., 2010).

### 6.4.5 Flooding

Small localised flooding is possible in the study area following a heavy rainfall event historically these have not been to the nature or scale that would result in injury, or death. Expert participants have not identified flooding as a future risk factor. Local governments may upgrade roads and drainage as required to manage more frequent heavy rainfall events and prevent damage to roads or other infrastructure (Roy et al.,

2008). Losses of food and farm products may occur when floods affect the growing seasons of fruit, vegetables and pasture/hay, and in turn influence food availability and cost (Edwards et al., 2011). It is possible power and transport could be disrupted for a small period of time during a flooding event, but householders could be prepared using the Red Cross REDiPlan and other tools (e.g. Pantry List) that outline how to prepare for emergencies and to follow appropriate evacuation notices (Jones, Davies & Macdonald, 2012; Thevanaz & Resodihardjo, 2010).

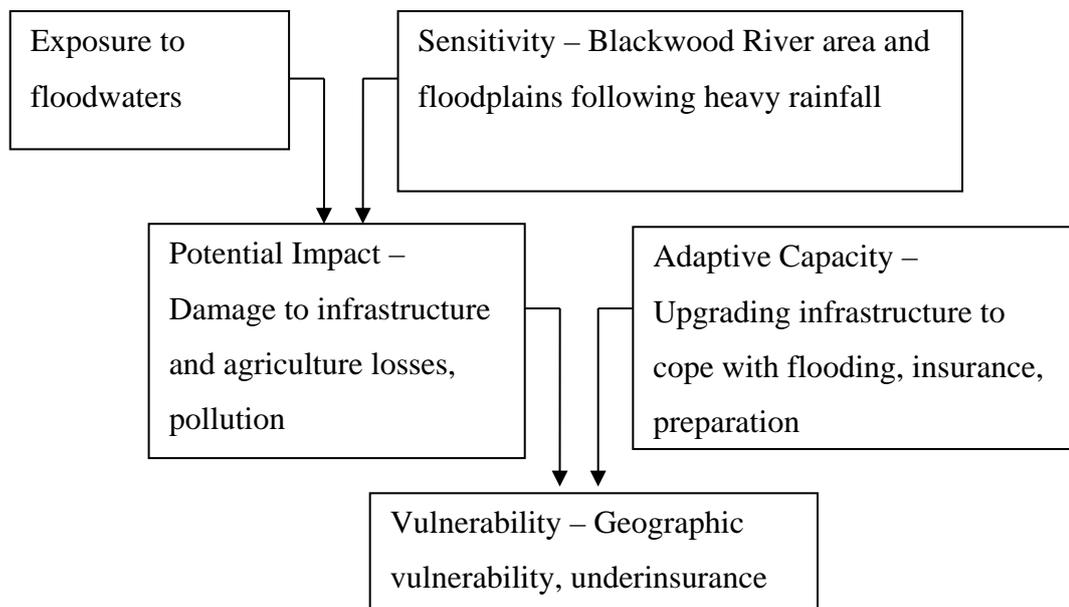


Figure 41 Vulnerability Model – Flooding

(Adapted From Spickett, Brown & Katscherian, 2008) (Roy et al., 2008; Snow & Prasad, 2011; Stern, 2007).

#### 6.4.6 Increasing Resilience to Rainfall Variability

Businesses or households that are not connected to mains water supply may be more vulnerable in future to the costs for supply and carting water, and may mean lower water quality is used. Rural areas have 30% of all the rainwater tanks in Western Australia. Adequately maintaining a water tank is required to prevent exposure to biological or chemical contamination (Australia Government, 2004; Australian Government Productivity Commission, 2011). Ensuring rural and remote householders have access to safe potable water could be an emerging issue as a result

of increasing mean temperatures and summer rainfall events (Ahmed, Vieritz, Goonetilleke & Gardner, 2010; The World Economic Forum Water Initiative, 2011).

Desalinated water is not climate dependent; yet the costs are significant (over ten times higher than water supplied from surface reservoirs). In order to benefit rural areas that are not connected to mains water supply, desalinated water would need to be carted to these communities or be piped in (NCCARF, 2013). Desalination is an energy intensive process and waste by-products may have environmental and health impacts (Kelley, 2011). Salt water intrusion may impact areas with a high water table (coastal flood plains) and groundwater quality which could add to water scarcity (Werner, 2010).

New building and housing developments in the South West and Perth region can incorporate water sensitive design through appropriate planning policies and building design. Currently, installing a water tank and greywater is not considered cost effective due to the current charges for water, if these prices change, it is likely that adapting early will prove to be a cost saving (Horne, 2012). All new housing developments can encourage water efficiency and re-use options at the beginning of the design phase of the project (Sullivan, 2008). Continued expansion of Perth suburbs (urban sprawl) and population may place increased pressure on water resources of the South West (McFarlane et al., 2012). Ensuring metro water demand does not threaten ecological systems in the South West needs careful management (Ali et al., 2012). Given the majority of water extracted is used for agriculture, mining and industry, investments in water efficiency, reuse and storage could be initiated by these groups (Ananda, 2012). Reducing water used for landscape irrigation can be achieved through 'green' landscape practises that include mulching and permeable street scaping to prevent drainage issues and retain moisture (Faucette et al., 2007; Attarian, 2010).

Carbon sequestration and the agro-forestry industry could potentially impact streamflow to ecological systems and riverine areas. Tree farms have had a significant effect on streamflow and groundwater recharge and ensuring carbon sinks allow for sufficient groundwater recharge will need to be an important design feature

(Onaindia, de Manuel, Madariaga & Rodriguez-Loinaz, 2013; Vertessy, Zhang & Dawes, 2003).

The following adaptation measures illustrate how each sector of society can contribute to water adaptation in the study area, with hard, soft, low and no-regrets listed with each adaptation.

#### **6.4.7 Individual Adaptation**

1. Increase water efficiency in the home by replacing appliances, fixtures and fittings, and reducing water used for gardens (hard, no-regrets)<sup>1</sup>.
2. Ensuring emergency water supplies are available (hard, low-regrets)<sup>2,4</sup>.
3. Having sufficient funds and storage capacity to cope with low rainfall years (hard, low-regrets)<sup>3</sup>.
4. Having adequate insurance or diversity of income (or savings) to cope with the financial impact from droughts or damage to water infrastructure (soft)<sup>3</sup>.
5. Having water testing and treatment materials (hard, low-regrets)<sup>4</sup>.
6. Ensure gutters and drainage can cope with heavy rain, or flooding events (soft)<sup>4</sup>.
7. Ensure septic systems are functioning after a flood event (soft)<sup>4</sup>.
8. Check on community members that may be affected from low rainfall or drought (soft)<sup>5</sup>.

#### **6.4.8 Community Adaptation**

1. Increase rainfall capture and storage for community buildings and sporting facilities (hard, low regrets)<sup>6</sup>.
2. Promote water recycling and efficiency (soft)<sup>7</sup>.
3. Provide education for farming communities to build resilience in to their business model and management practises (soft)<sup>5</sup>.
4. Provide and promote mental health services (soft)<sup>5</sup>.
5. Provide emergency supplies of food and water and other essential materials (food bank) (soft, no-regrets)<sup>4</sup>.

6. Prevent access of livestock and feral animals to riverine and wetland environments that could pollute or damage these eco-systems (adequate fencing and animal control) (hard, no-regrets)<sup>8</sup>.

#### **6.4.9 Local Government Adaptation**

1. Promote water efficiency and cost effective grey water recycling (soft)<sup>9,10</sup>.
2. Carry out a climate change risk assessment using the WALGA Climate Change Management Toolkit (soft, no-regrets)<sup>11</sup>.
3. Identify areas that are susceptible to sea level rise in the future and liaise with appropriate stakeholders to prepare a plan of action (soft)<sup>12</sup>.
4. As drainage and road systems are upgraded as part of the usual maintenance cycle, rebuild to a standard to withstand higher rainfall and flooding conditions (wait and see)<sup>13</sup>.
5. Utilise and promote the use of ‘green infrastructure’ such as sheet mulching and permeable pedestrian infrastructure in street design to retain water in the landscape (hard, low-regrets)<sup>14</sup>.

#### **6.4.10 State Government Adaptation**

1. Promote water efficiency and water recycling (soft)<sup>15</sup>.
2. Protect rural and regional water sources (catchment and groundwater) by limiting extraction to sustainable levels (soft)<sup>16</sup>.
3. Develop emergency planning policies to address non-linear climate change (soft)<sup>17</sup>.
4. Promote water sensitive urban design with integrated use and reuse of potable, stormwater, sewerage and rainwater catchment (soft)<sup>16</sup>.

#### **6.4.11 Federal Government Adaptation**

1. Ensure building codes capture water efficiency for domestic, community and commercial dwellings (soft)<sup>18</sup>.
2. Enhance the resilience of farmers through education and training for variable climate scenarios (soft)<sup>20</sup>.
3. Promote and enhance carbon sequestration across Australia (soft)<sup>21</sup>.
4. Provide financial assistance to local governments that do not have the resources or capacity to carry out climate change risk assessments (hard, no-regrets)<sup>22</sup>.

1 (Department of Industry, 2014) 2 (Department of Water, 2007b; Australian Red Cross, 2009) 3 (PMSEIC Independent Working Group, 2007) (de Loe, Kretzviser & Moraru, 2001) 4 (State Government of Victoria, 2013) (Fire and Emergency Services Australia, 2011b) 5 (National Rural Health Alliance Inc., 2004) 6 (Science Network Western Australia, 2012) 7 (Cook, Hall & Gregory, 2012) (Willis et al., 2011) 8 (Jansen & Healey, 2003) 9 (Department of Health, 2002) 10 (City of Subiaco, 2008) 11 (Western Australian Local Government Association, 2014) 12 (Rodgers, 2013) 13 (Atkinson, Brait, Murphy & Rogers, 2007) 14 (West Coast Environmental Law, 2012) 15 (Western Australian Government, 2012) 16 National Climate Change Adaptation Research Facility, 2013) (McFarlane et al., 2012) 17 (Bicknell, 2010) 18 (Maddocks, 2012) 19 (Glover et al., 2008) (Zerbe, 2004) 20 (Department of Agriculture, 2012) (Marangos & Williams, 2005) 21 (Department of Agriculture, 2014) 22 (Lake Macquarie City Council, n.d.) 23 (Onaindia, de Manuel, Madariaga & Rodriguez-Loinaz, 2013).

Health Factors Assessed

Temperature and Air Quality	✓
Water	✓

Table 39 Health Factors Assessed

**6.5 Extreme Weather Events Risk and Adaptation**

The following table describes the health impacts from extreme weather events such as cyclones, storms and bushfires in the study area, showing the vulnerable subgroups, risk rating and adaptation to be adopted to mitigate the risks. Extreme weather events have the highest risk rating in the study due to the widespread nature of damage from bushfires or cyclone and storm activity, along with the unpredictability of the severity of these events. For vulnerable populations extreme weather events can result in mental health impacts immediately after the disaster and longer term mental health effects, particularly for children (Sheffield & Landrigan, 2011). Following the table is a discussion of each of the risks with a vulnerability assessment, with a list of adaptations to ameliorate those risks.

Impact Type	Health and Wellbeing Factor	Vulnerable subgroups	Risk Assessment Risk Rating	Adaptation required
Direct Impacts from Extreme Events				
Cyclones and storms and fires	Mortality and morbidity impacts	Persons exposed to extreme conditions due to location, lack of evacuation or building design not fit for purpose (e.g. not to cyclone standard)	Extreme	Ensure early evacuation during cyclone and fire events where required (effective communication)
	Damage to critical	Location dependant	Low	Improve building

Impact Type	Health and Wellbeing Factor	Vulnerable subgroups	Risk Assessment Risk Rating	Adaptation required
	infrastructure (water, energy supplies)			standards in areas where storm and cyclone intensity will increase, Emergency preparation, off grid energy and personal water supplies
	Hospital and emergency responders are overstretched	Location dependant, early evacuation of the vulnerable population will reduce demand on health services	High	Emergency communication and evacuation
	Damage to community and business infrastructure	Mental health impacts, particularly children	Low	Improve building standards to cope with increased intensity of storms Ensure fire control measures are followed
	Damage to food crops, or stock losses	Farmers, food availability and freshness	High	Emergency assistance, insurance
	Damage to transport systems (road and rail)	Financial, mental health, and resource impacts	Low	Emergency response, volunteer network, communication
	Damage to eco-system	Mental health impacts	Low	Revegetation, animal rescue, monitoring of species
	Lack of insurance, underinsurance	Financial and mental health impacts	Medium	Government assistance, emergency housing, charity and private donations

Table 40 Potential Impacts - Extreme Weather Events

(Alexandra & Riddington, 2007; Garnaut, 2008; Linnenluecke & Griffiths, 2012; O’Sullivan, Kuziemy, Toal-Sullivan & Corneil, 2013; Sheffield & Landrigan, 2011).

### 6.5.1 Extreme Weather Events

Extreme weather events are a seasonal risk in Western Australia, with storm activity during the winter months and fire danger days during spring, summer and autumn.

To adequately prepare for extreme weather the emergency management model shows the methods to prevent exposure to these events through preparation, avoidance of the hazard, rapid response to any incidences and recovery following exposure, see below.

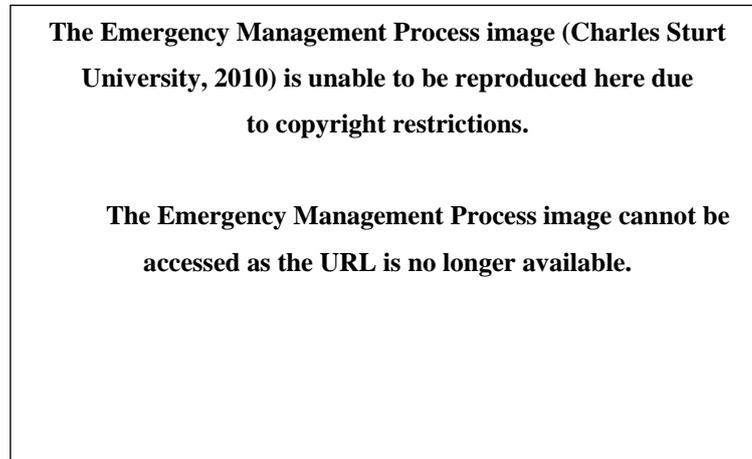


Figure 42 Emergency Management Process  
(Source Charles Sturt University, 2010).

Preventing exposure to extreme weather can be limited by the structural integrity of infrastructure to cope with extremes of wind, flood and fire damage. Unless a future of energy descent to low or zero carbon emissions is enacted, then preparedness, response and recovery must be strengthened to cope with highly variable climatic extremes. Climate extremes will become increasingly expensive to recover from and insure, this increases the importance of social capital in each community (Alexandra & Riddington, 2007; Linnenluecke & Griffiths, 2012; O’Sullivan, Kuziemy, Toal-Sullivan & Corneil, 2013).

### **6.5.2 Avoidance of Extreme Weather**

Direct weather impacts could result in death or injury from exposure to cyclonic winds, flying debris, radiant heat, flames (burning) and smoke inhalation. Early warning, effective and reliable communication and evacuation will ensure mortality and morbidity is limited. Older people have been identified as being particularly vulnerable to evacuation during disasters for a number of reasons; fear of loss of dwelling or possessions, lack of alternate accommodation, responsibilities in the home and lack of adequate time to leave. Assistance and provision of alternate

accommodation is required for vulnerable populations, particularly those people with limited finances and mobility (Langan & Palmer, 2012).

There are instances when extreme weather events develop so rapidly that no evacuation or access to safe areas can be organised, for instance in the case of bushfires. Having well designed and constructed dwellings with adequate emergency provisions (e.g. underground bunkers) will reduce exposure to a hazard particularly for remote communities however are not yet well tested in the Western Australian context (Garcia & Fearnley, 2012; Government of Western Australia, 2013b; Paveglio, Boyd & Carroll, 2012).

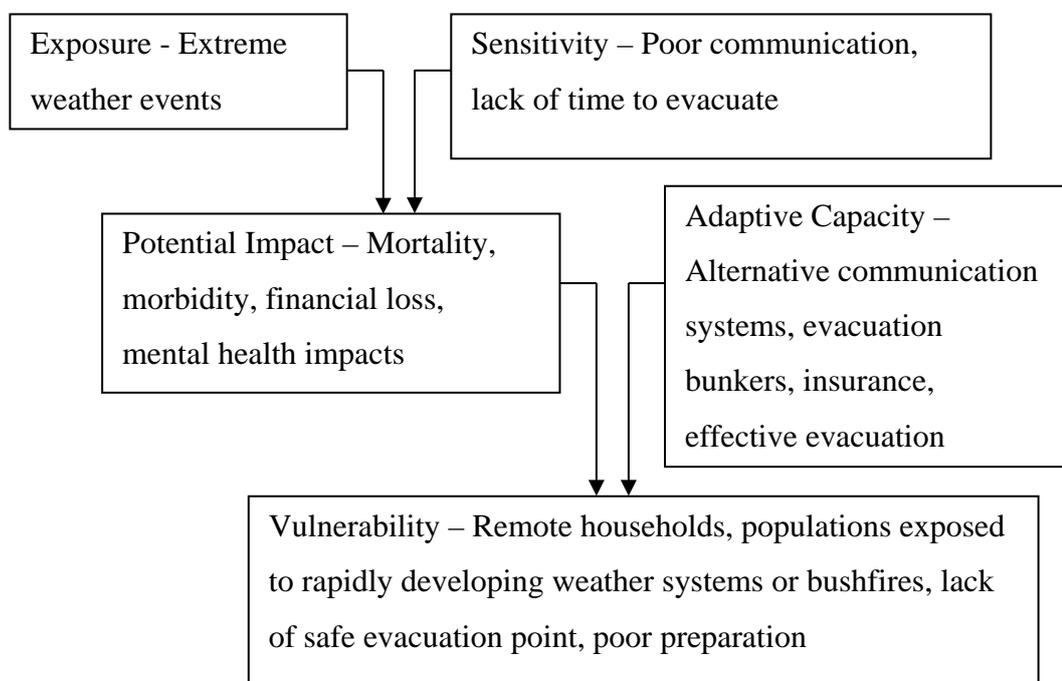


Figure 43 Vulnerability Model - Extreme Weather Evacuation Delays

(Adapted from Spickett, Brown & Katscherian, 2008) (Department of Environment and Conservation, 2009; Langan & Palmer, 2012).

### 6.5.3 Extreme Weather Event Preparation

Appropriate cyclone and fire season preparation in local communities will assist any recovery process, and prevent excessive delays from returning to ‘business as usual’, these include the measures outlined in the Red Cross RedIPlan and by following local government legislation and guidelines (Australian Red Cross, 2009; Levac,

Toal-Sullivan & O'Sullivan, 2012; Queensland Government, 2012). Active volunteering in these communities will improve communication, readiness, and recovery. Rural residents (particularly men) are more likely to be engaged in volunteering in emergency services and this may enhance social capital and emergency skills. Appropriate and accurate information by the media will assist safe behaviour (e.g. radio reports), yet despite emergency preparation and the decision to 'stay and defend', some residents may still be unprepared for bushfire conditions (Brudney & Gazley, 2009; Clarke & Chess, 2008; Eriksen, Gill & Head, 2010; Victorian Bushfires Royal Commission, 2009).

The potential to re-evaluate building standards and to renovate or construct buildings in a way that will better cope with storms, cyclones and fires is a field for further research and community and local government planning. Innovative, rapidly built housing (especially housing with higher energy standards) during the recovery period may be a future priority (Federal Emergency Management Agency, 2011; Zari, 2010). Building construction using local materials and low carbon building methods will be necessary under a B1 future (Urban, Mitchell & Silva Villanueva, 2010). Assisting the communities to improve the engineering integrity of existing dwellings is a possible option, however during some extreme events they may be forced to evacuate (Morton, Betschneider, Coley & Kershaw, 2011; Gupta & Gregg, 2012). 'Tree changers' (persons that have relocated to areas rich in forests and national parks) may have higher sensitivity to extreme weather events as they have not had the experience of maintaining and defending a rural property from bushfires or extreme weather (Eriksen, Gill & Head, 2010).

Communication is the most critical factor during an emergency event; any losses to the telephone and mobile communication network will prevent advice from reaching the vulnerable population, or individuals being able to request assistance to evacuate. Having an alternate communication system to the landline, internet and mobile telephone network (that do not work if a mobile phone tower fails) could be critical to avoiding deaths (Oloruntoba, 2010). Rural areas that have limited options for communication (no mobile or limited mobile phone coverage) are particularly vulnerable before and during emergency events. Communication 'black spots' are

prevalent throughout the study region in remote areas. Having hand held radio systems with the appropriate training is a reliable form of communication in the event of power outage and loss to telephone networks (Emergency Management Australia, 1998).

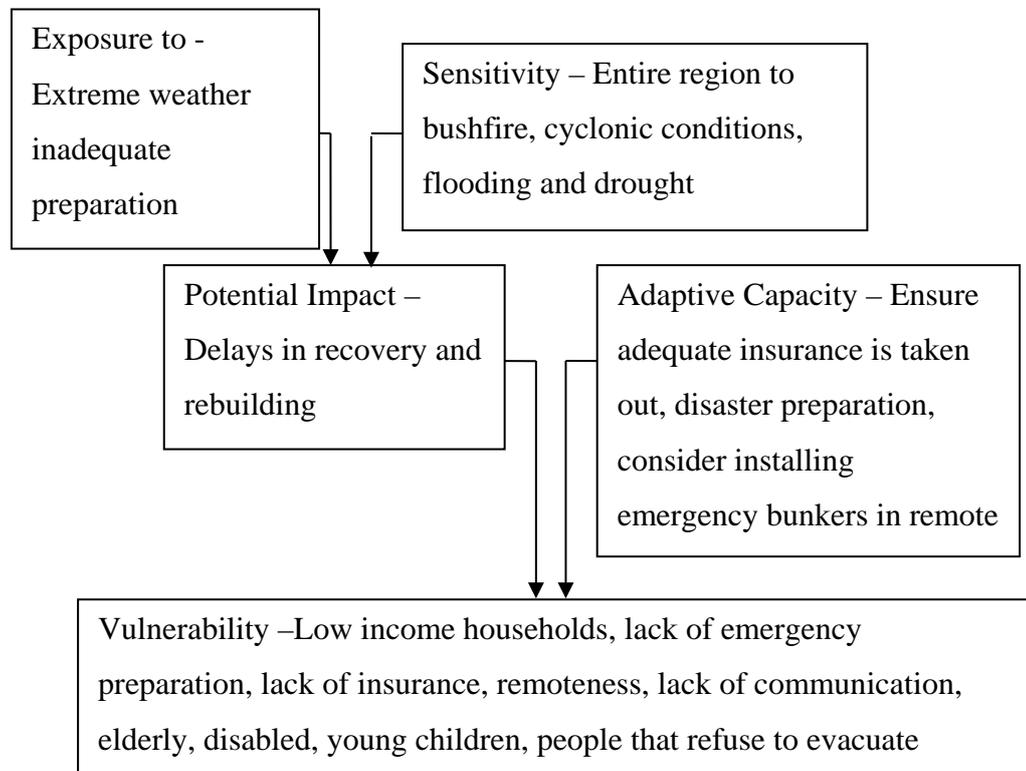


Figure 44 Vulnerability Model - Lack of Emergency Preparation

(Adapted from Spickett, Brown & Katscherian, 2008) (Garnaut, 2008; Gupta & Gregg, 2012; Morton, Betschneider, Coley & Kershaw, 2011).

#### 6.5.4 Recovery from Extreme Weather Events

If the fire season becomes increasingly risky by the year, it is possible the expense and availability of adequate insurance cover could change (Oh & Reuveny, 2010). The effect of this will influence infrastructure decisions and may influence migration to a less fire prone area, approximately 25% of survey participants stated they would move away from a fire prone area (Poudyal, Johnson-Gaither, Goodrick, Bowker & Gan, 2012). The mental health impacts of moving to a new location after being exposed to a disaster are significant and these people will need to be supported by the relevant agencies (Bailey, 2011; Barrett, 2012).

As half of the bushfires in Western Australia are deliberately lit, focusing on preventing arson and management of prescribed burning are increasingly relevant. Unsupervised adolescent males with co-existing mental health issues are stated to be the most likely candidates for arson activity (Langton, Mackay, Fedlberg, Ward & Marton, 2012; Stanley & Kestin, 2010). Preparation, well managed evacuation, education and fire safety training are therefore the major adaptations to coping with an increase in fire activity and have reasonably low costs (Handley, 2011). Planning decisions that include comprehensive fire management plans are paramount to preventing suburb designs that expose dwellings to a high fuel load (e.g. as one community participant stated this was the case for Prevelly in Margaret River) (Paveglio, Jakes, Carroll & Williams, 2009; Williams et al., 2009).

Rebuilding after cyclone or fire damage as rapidly as possible will benefit the whole community, particularly children, who are vulnerable to mental health impacts following extreme weather events (Madrid & Grant, 2008). Rural areas have greater obstacles in rebuilding due to limited access to skilled labourers and high transport cost of materials (Australian Housing and Urban Research Institute, 2014). Designing buildings that can withstand greater destructive wind forces and fire events could be investigated and implemented, however it is impossible to prevent damage to all infrastructure (Costello et al., 2009).

Damage to farmer's goods, storage, stock and crops from these extreme events could also be localised, or widely distributed. Farm insurance could ensure that businesses remain viable after some extreme events, unless forms of insurance are no longer viable. A disaster would most likely see increased involvement of federal and state governments to rebuild (disaster assistance). Any major damage to a food growing area would have flow on affects to consumers and increase costs of food products, whether the disaster is local or abroad (Miles & Purnell, 2005).

Damage to built infrastructure, such as roads, energy and drainage networks could be localised or widespread (e.g. Cyclone Alby compared with a one in five year storm). Adaptation would involve having sufficient resources to rebuild, particularly if

insurance coverage is inadequate, along with volunteers and contractors to carry out the work in a timely fashion (Taylor & Philp, 2010; Vu, 2012).

Fire events, other than potentially leading to fatalities and injuries, can cause mental health impacts due to losses of community members and damage to infrastructure and environment. Mental health impacts can occur in up to 42% of survivors in some cases. The 2011 prescribed burns that led to bushfires in the Ellensbrook/Prevelly forests in Margaret River resulted in ‘significant’ emotional impact with 139 people displaced a month before Christmas (Bell & Adams, 2008; Government of Western Australia, 2011, p. 3; Johnston, 2009; Nicol, 2004; Valianatos, Tolhurst, Siems & Tapper, 2003). The following diagram illustrates potential vulnerability to residents in geographic areas exposed to recovery events following extreme weather.

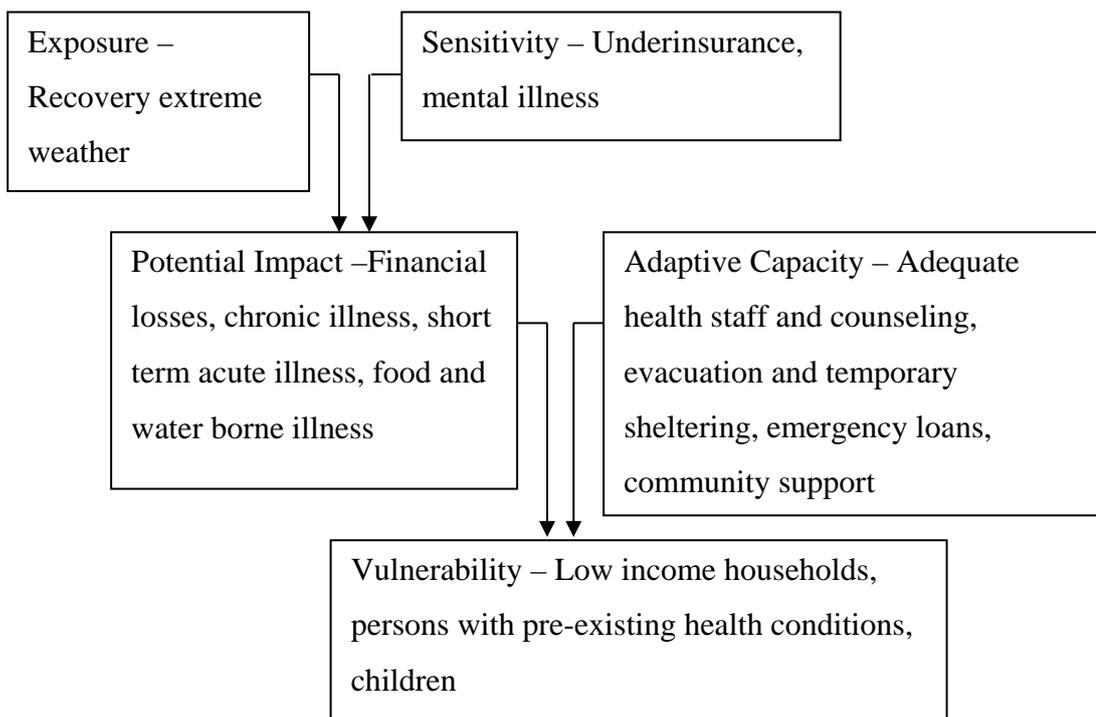


Figure 45 Vulnerability Model -Emergency Events and Recovery

(Adapted from Spickett, Brown & Katscherian, 2008) (Bell & Adams, 2008; Johnston, 2009; Nicol, 2004; Valianatos, Tolhurst, Siems & Tapper, 2003).

### 6.5.5 Runaway Climate Change

Abrupt (or runaway climate change) is associated with the magnitude of the global mean temperature rise this century and is dependent on emissions. Impacts could include sea level rise of up to 7 metres and temperature increases of up to 4<sup>0</sup>C (from the global mean average). Responding to abrupt climate change must take into account the impacts to marine, freshwater and terrestrial systems, that will be significant (IPCC, 2014b; Schneider, 2004; Lowe et al., 2006; Rust & Totton, 2011; Sustainable Energy Association of Australia, 2013; Stern, 2007). The following model indicates the potential vulnerability for regions exposed to runaway climate change and sea level rise impacts (Li, 2011; Schuur & Abbot, 2011).

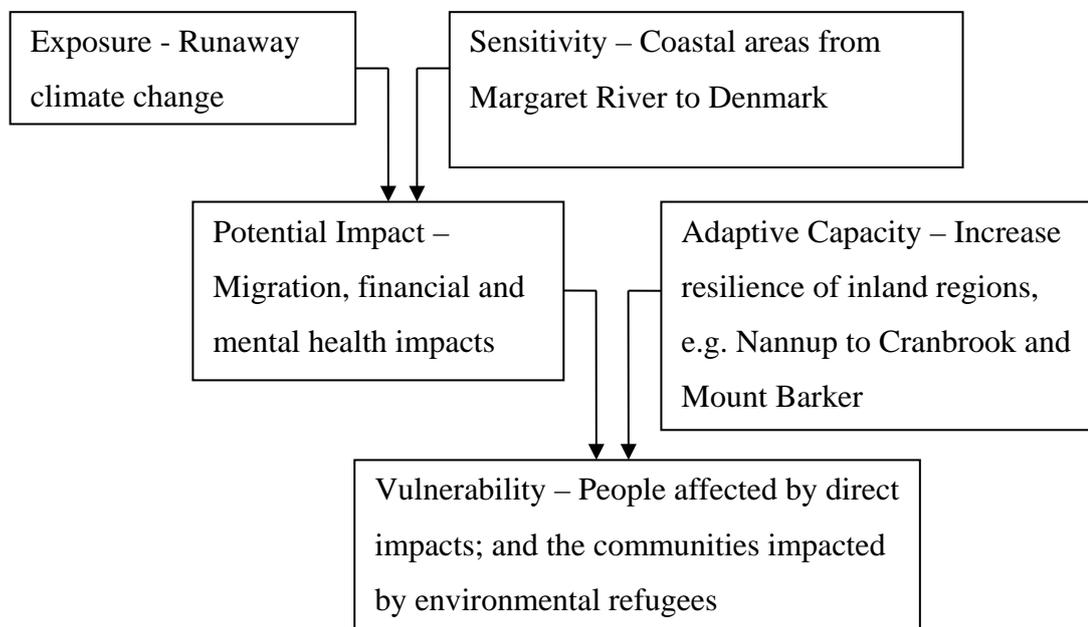


Figure 46 Vulnerability Model - Runaway Climate Change

(Adapted from Spickett, Brown & Katscherian, 2008) (McDonald et al., 2010).

The following adaptation plan is responds to likely extreme weather events, based on historical occurrences and risk factors for new climatic conditions. Runaway climate change is beyond the capacity of any single agency, individual or community organisation, apart from existing emergency management. Radical mitigation and low carbon, or carbon negative responses (radical afforestation) are the main defence against the risks for runaway climate change. Having a strong ‘sense of community’ and high levels of self-efficacy are reported enhance coping skills in the face of

climate surprises. Local communities with a high proportion of volunteering often report a higher sense of community with rich social capital.

Demographic change (increases or decreases to population size) in small communities following extreme weather events, or runaway climate would need to be managed to protect community cohesion. Social media is an effective tool to communicate with community members in densely populated regions during emergency events, both to minimise harm and to coordinate emergency volunteers (Barratt, Pearman & Waller, 2009; Davoudi, Brooks & Mehmood, 2013; Hunt et al., 2011; Macintosh, 2010; Merchant, Elmer & Lurie, 2011; Smith, Moran & Seemann, 2008; Tompkins & Adger, 2004).

#### **6.5.6 Extreme Weather Events Adaptation**

The following adaptation options are designed to prevent exposure to extreme weather events through retrofitting dwellings and structures and by removing individuals from harm through timely evacuation. Extreme weather events should form the focus of adaptation in the study region as it is the most likely cause of mortality and morbidity. It is likely rural residents will require a higher degree of personal resilience to emergency events than their urban counterparts due to distance to facilities and reliance on volunteers in emergency situations.

Preparation for emergency weather events includes psychological preparation, in the case of an emergency some individuals may not be able to cope with the intensity of the situation and may be better to evacuate early. Other forms of preparation include having sufficient equipment and sources of water to actively defend a fire, or having enough food and water to cope with extensive power outages or damage to road networks affecting supply chains. Having fire and emergency and first aid training are useful life skills that also assist during emergency events.

Early warning systems and timely communication to advise of extreme weather events will also give people time to prepare their property (including livestock) and make decisions about staying and defending, or evacuation. Recovery from an

extreme weather event takes all sectors of the community, government and non-government agencies to restore infrastructure, schools, homes and other workplaces.

### **6.5.7 Individual Adaptation**

1. Sound knowledge of emergency preparation, including first aid equipment and training, medication, fire safety training, as outlined in the Red Cross RedIPlan or similar (soft)<sup>1</sup>.
2. Preparation at home for storms, fires, and cyclones (soft and hard, no-regrets)<sup>2,3</sup>.
3. Adequate insurance (soft)<sup>4</sup>.
4. Active volunteering in community to assist in the case of an emergency (soft)<sup>5</sup>.
5. Alternate communication devices (hand held radios), backup generators in the case of protracted power outages (hard, no-regrets)<sup>1</sup>.
6. Check on neighbours to assess damage, and administer help where required (soft)<sup>2</sup>.

### **6.5.8 Community Adaptation**

1. Having stocks of emergency supplies following a disaster event (food, bedding, water, temporary accommodation etc.) (hard, no-regrets)<sup>5</sup>.
2. Training facilities, and training courses for first aid, fire safety (soft)<sup>5</sup>.
3. Preparing a sufficient volunteer network to rapidly respond to an emergency situation (soft)<sup>5</sup>.
4. Coordinate alternative transport for evacuation of vulnerable groups using existing resources (soft)<sup>5</sup>.
5. Promote counselling and mental health services available locally (soft)<sup>6</sup>.
6. Develop a phone tree network or utilise social media to rapidly assess damage and potential threats, and health impacts (soft)<sup>7</sup>.
7. Promote economic resilience through diversity of land use (soft)<sup>8</sup>.

### **6.5.9 Local Government Adaptation**

1. Respond to increasing fire danger through appropriate policies and action (soft)<sup>9</sup>.

2. Respond to changing intensity of storms, rainfall and cyclones through policies and procedures, including waiting and see adaptation of infrastructure (soft)<sup>10</sup>.
3. Promote water sensitive landscaping to cope with variable rainfall and flooding (soft)<sup>11</sup>.
4. Coordinate transport of vulnerable groups as required (soft)<sup>12</sup>.

#### **6.5.10 State Government Adaptation**

1. Promote higher density building developments to prevent loss of natural habitat (clearing) (soft)<sup>15</sup>.
2. To use technology to monitor areas during and after extreme weather events (e.g. satellites, and unmanned aircrafts) (hard, low-regrets)<sup>16,17</sup>.
3. To plan for increases in risky fire weather days through appropriate staffing and infrastructure (soft and hard, low-regrets)<sup>18</sup>.
4. To increase resilience of energy networks to extreme weather (hard, no-regrets)<sup>20</sup>.
5. To ensure communication during extreme weather events is factual, rapid, and reaches all vulnerable individuals (soft)<sup>3,24</sup>.

#### **6.5.11 Federal Government Adaptation**

1. Amend the Building Code to enhance the durability of new dwellings to cope with changing weather conditions to the year 2070 (soft)<sup>26</sup>.
2. Provide information to encourage land owners to upgrade all, or part of their dwellings to increase safety from fire, wind shear and flooding (soft)<sup>26</sup>.
3. Promote leadership of carbon mitigation and adaptation (soft)<sup>27</sup>.
4. Ensure telecommunications remain effective in an emergency event (hard, no-regrets)<sup>25,28</sup>.

*1 (Australian Red Cross, 2009) 2 (Bureau of Meteorology, n.d.; Fire and Emergency Services Authority, 2007; Fire and Emergency Services Authority, 2011b) 3 (Calfire, 2012; Emergency Management Australia, 2006) 4 (Australia Government Productivity Commission, 2013) 5 (Council of Australian Governments, 2009; Queensland Reconstruction Authority, 2011; Farmsafe Australia Inc., 2014) 6 (Stain et al., 2011) 7 (CSIRO, 2013; Department of Education, 2013) 8 (Alston, 2012) 9 (Western Australian Planning Commission & Fire and Emergency Services Authority, 2010; Department of Fire and Emergency Services, 2014) 10 (Zeppel, 2011) 11 (Snow & Prasad, 2011) 12 (Department of the Environment, 2013) 13 (Department of Health, 2014a) 14 (The World Bank & GFDRR, 2012) 15 (McDonnell, Monroe, Boles & Mashour, 2008) 16 (New South Wales Government, 2014) 17 (International Federation of Red Cross and Red Crescent Societies, 2013) 18 (McLennan, 2008) 19 (Department of Fire & Emergency Services, 2014) 20 (Australian Government, n.d.; O'Brien & Hope,*

2010) 21 (Garnaut, 2008) 22 (Queensland Reconstruction Authority, 2012) 23 (Hurricane Sandy Rebuilding Taskforce, 2013) 24 (Victorian Bushfires Royal Commission, 2009) 25 (Emergency Management Australia, 2013) 26 (Dave, Varshney & Graham, 2012) 27 (Jones, 2013) 28 (Burke & Gridley, 2013) 29 (Productivity Commission, 2011a) 30 (Nogrady, 2013).

#### Health Factors Assessed

Temperature and Air Quality	✓
Water	✓
Extreme Weather Events	✓

Table 41 Health Factors Assessed

### 6.6 Vector Borne Disease Adaptation

Vectors are living organisms such as mosquitoes that can transmit infectious diseases between humans or from animals to humans (WHO, 2016b). Rainfall, temperature, urbanisation and poverty influence the rates of vector borne infection. In Australia Ross River Virus and Murray River Encephalitis are vector borne diseases that are associated with flooding events (WHO, 2000). The geographic range of vector borne infections may increase; the study area has previously reported cases of dengue virus (Russell et al., 2009). Table 41 identifies the potential impacts caused by vector borne pathogens; appropriate adaptations are listed. Controlling vector borne illness is largely as a success of monitoring (surveillance), quarantine, treatment (including behavioural factors) and vaccination. A discussion of the interaction between climate change and vectors follows the table below.

Impact Type	Health and Wellbeing Factor	Vulnerable subgroups	Risk Assessment Risk Rating	Adaptation required
Direct Impacts from Vector Borne disease				
Mosquito borne <ul style="list-style-type: none"> <li>Ross River Virus</li> <li>Barmah Forest Virus</li> <li>Dengue</li> <li>Murray Valley Encephalitis</li> <li>Malaria</li> <li>Japanese Encephalitis</li> <li>West Nile Virus</li> </ul>	Mortality and morbidity impacts	Location specific, several kilometres from breeding sources  Vulnerable groups include pregnant women, infants, pre-existing illness	High	Monitoring, water treatment, enforcement, and disease notification (behavioural) avoiding times of exposure, use insect repellent and appropriate clothing, affective communication following an outbreak  Building standards, adequate screening of doors and windows

Impact Type	Health and Wellbeing Factor	Vulnerable subgroups	Risk Assessment Risk Rating	Adaptation required
Tick-borne <ul style="list-style-type: none"> <li>• Tick borne encephalitis</li> <li>• Lyme Disease</li> </ul>	Morbidity and mortality (rare)	Grasslands and bushed areas	High	Keep grass mown and leaf litter controlled, trim overhanging branches. Wear appropriate clothing (preferably light). Use insect repellent.
Rodent Borne and other zoonoses	Damage to food crops, economic impacts, morbidity impacts	Farmers, areas recovering from a disaster event (flooding and drought), exposure to infection through faeces	High	Monitoring of potential breeding areas, baiting programs, maintenance and waste disposal, hygiene and water source protection

Table 42 Potential Impacts - Vector Borne Disease

(Garnaut, 2008; Mills, Gage & Khan, 2010; Smith, Speers & Mackenzie, 2011; Taylor, Playford, McBride, McMahon & Warrilow, 2012).

### 6.6.1 Potential for Increases in Vector Borne Disease

Climate change, socio-economic and behavioural factors can influence the spread of vector borne-disease, which have the potential to become a significant public health problem. In the past there have been recorded cases of Dengue fever, currently the two most common mosquito borne viruses in the study area are Barmah Forest and Ross River Virus. Risks from mosquito borne viruses are currently being managed through seasonal alerts and appropriate management by state and local governments. Vectors can be influenced by changes to temperature and rainfall, leading to species migration (latitude and altitude) or adaptation, including an extended breeding season (Mills, Gage & Khan, 2010). As these rural areas are rich in recreation and tourism opportunities, along with many areas for potential breeding sites, exposure to mosquitoes and other vectors may be a risk during certain months of the year. Outdoor workers, including farmers may also be vulnerable to exposure to vector borne diseases, such as Q fever, along with persons living in substandard accommodations, or homeless persons (Smith, Speers & Mackenzie, 2011; Taylor, Playford, McBride, McMahon & Warrilow, 2012).

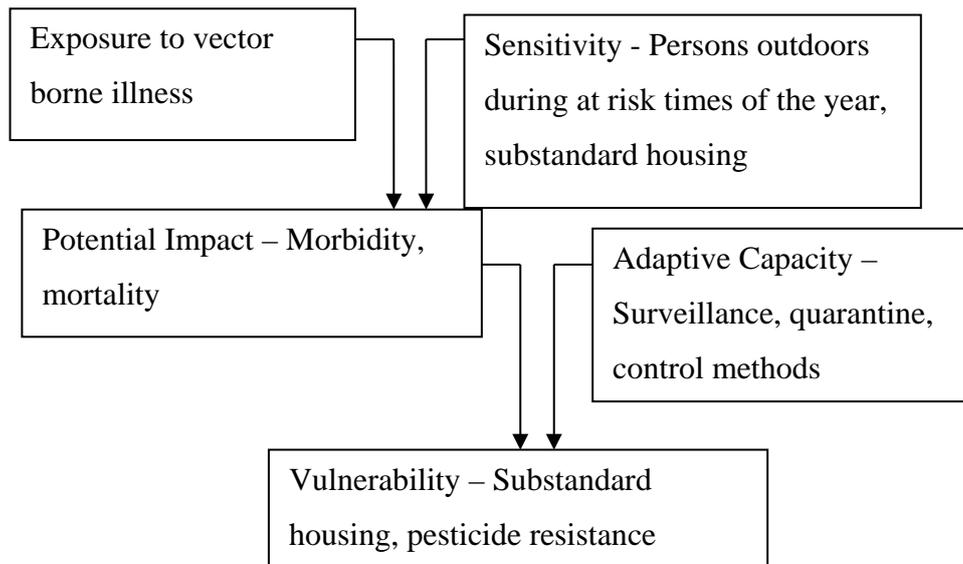


Figure 47 Vulnerability Model - Vector Borne Disease

(Adapted from Spickett, Brown & Katscherian, 2008) (Smith, Speers & Mackenzie, 2011; Taylor, Playford, McBride, McMahon & Warrilow, 2012).

### 6.6.2 Managing Vector Breeding Sites

The Western Australian Department of Health in company with local governments manage vector borne disease through integrated vector management. Methods of vector control include education, environmental management, sanitation, biological controls and chemical controls (Garnaut, 2008). Some of the community participants reported a concern for mosquito borne illness.

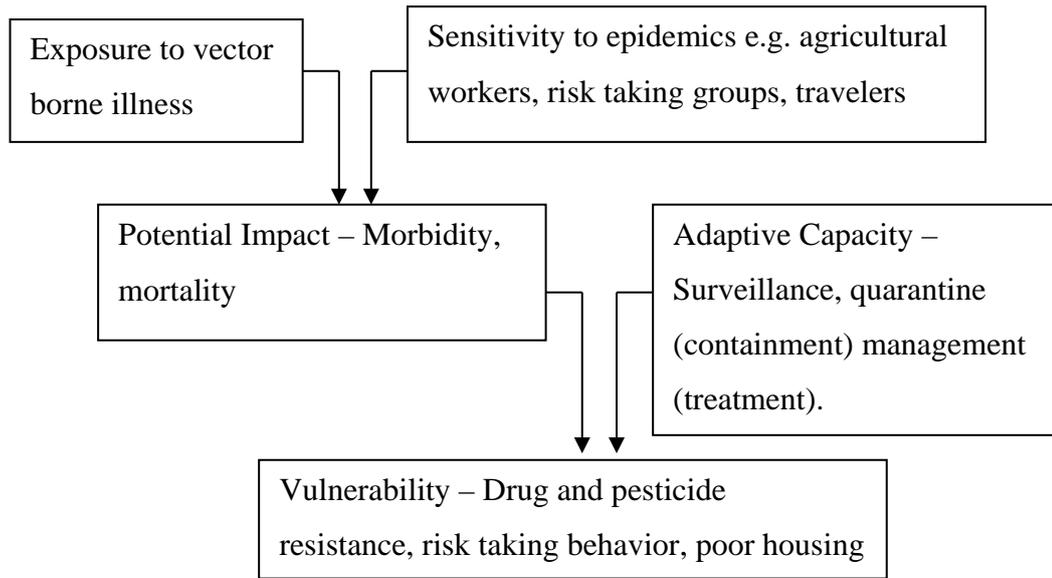


Figure 48 Vulnerability Model - Epidemic and Pandemic Conditions  
 (Adapted from Spickett, Brown and Katscherian, 2008) (Garnaut, 2008).

### 6.6.3 Emerging Risks

Future challenges from vector borne illnesses may occur from losses to biodiversity, changes in rainfall, drug resistance, and irrigation projects (Isaacs, 2010; Molyneux, 2003). It is difficult to pin point climate change as the primary driver influencing vector borne illness. Computer modelling has significant uncertainties; however several emerging factors such as higher density populations, globalisation, extreme weather events, drug and pesticide resistance could promote the proliferation of vector borne disease. These are not currently linked with the study area (Godfray et al., 2010; Hongoh et al., 2011; Lake et al., 2012; Sutherst, 2004).

The following adaptation methods are based on avoiding risks and managing and mitigating the risks from Vector borne disease.

### 6.6.4 Adaptation Strategies for Vector Borne Illness

Climate change may influence the geographic range of vectors. Health authorities are currently monitoring vector borne diseases in Western Australia and have surveillance programs. One stakeholder participant stated that future risks may result from refugees bringing in mosquito larvae on fishing vessels, as well as planning

approvals for dam projects that will later act as reservoirs for vector breeding (e.g. damming the Ord River in the Kimberley) .

### 6.6.5 Individual Adaptation

1. Monitor property for mosquitoes and other insects and take appropriate remediation (soft)<sup>1,2,3</sup>.

### 6.6.6 Community Adaptation

1. Identify vector breeding sites and work with local government to treat and manage any issues (soft)<sup>4</sup>.

### 6.6.7 Local Government Adaptation

1. Ensure land clearing and development does not create vector breeding sites through appropriate planning controls (soft)<sup>7</sup>.

### 6.6.8 State Government Adaptation

1. Ensure watershed development prevents the development of sites that encourage vector breeding (soft)<sup>10</sup>.

### 6.6.9 Federal Government Adaptation

1. Maintain border controls and security to ensure diseases (or vector breeding species / vessels) are contained (soft)<sup>12</sup>.

*1 (Department of Health, 2014b) 2 (Department of Health and Ageing, 2010) 3 (Speare & Breinl, 2011) 4 (Department of Agriculture, Fisheries and Forestry, 2014) 5 (Singleton, Hinds, Krebs & Spratt, 2003) 6 (Tomerini, Dale & Sipe, 2011) 7 (McFarlane, Sleigh & McMichael, 2013) 8 (Public Health Advocacy Institute of Western Australia, n.d.; Kelly et al., 2013; City of Vincent, 2001) 9 (Department of Health, 2014c) 10 (Greenway, Dale & Chapman, 2003) 11 (Productivity Commission, 2011b) 12 (Beilharz, 2009; Parliament of Australia, 2010b; Viennet, Darmon, Touazi, & Soler., 2013) 13 (AusAID, 2011; Cannon, 2000) 14 (Commonwealth Secretariat, 2009).*

#### Health Factors Assessed

Temperature and Air Quality	✓
Water	✓
Extreme Weather Events	✓
Vector Borne Disease	✓

Table 43 Health Factors Assessed

## 6.7 Air Quality Adaptation

The following table outlines the health risks resulting from poor air quality and the potential adaptations. A discussion of the health risks and vulnerability follows. A comprehensive list of adaptations concludes this section. The following health risk assessment table outlines the health risks, wellbeing and health factors, vulnerable groups, risk assessment risk rating for air quality and adaptation required.

Impact Type	Health and Wellbeing Factor	Vulnerable subgroups	Risk Assessment Risk Rating	Adaptation required
Direct Impacts from Air Quality Factors (outdoor and indoor)				
Ozone	Respiratory impacts  Medication impacts	Older adults, during a hot-weather period, during physical exertion, children, asthmatics and sensitive individuals	High-Extreme	Remain indoors with air conditioning  Avoid exertion during high ozone periods
Particulate matter <ul style="list-style-type: none"> <li>• combustion</li> <li>• dust</li> <li>• spray drift (chemical, faecal)</li> </ul>	Cardio-pulmonary impacts  Mortality, morbidity	Persons with pre-existing health concerns, infants and children, the elderly, pre-existing heart or lung disease, asthmatics, persons working with dusty or fibrous materials, persons exposed to local sources to spray drift	High-Extreme	Stay indoors, seal home, evacuate to clean air area (designated by local government when appropriate)  PPE, ventilation and containment  Use vegetation as dust suppressant
Aeroallergens (including pollen)	Asthmatics Sensitive individuals, existing cardio pulmonary diseases	Persons exposed to mould, or damp homes, elderly, infants/children aged 0-4, persons in poor quality housing, persons exposed to pollen load from grasses, shrubs and trees (location)	High	Stay Indoors Pollen forecasting (early warning)  Treat home for mould and dampness through adequate ventilation, humidity control and appropriate furnishings/fittings or repairs
VOCs	Nausea, allergies, wheezing	Increased activity during thunderstorms and bushfires	High-Extreme	Ventilation

Impact Type	Health and Wellbeing Factor	Vulnerable subgroups	Risk Assessment Risk Rating	Adaptation required
Legionnaires Disease	Lung infection (morbidity, mortality)	Cleaning products and pregnancy, chronic illnesses, chemical sensitivity, building contractors, cleaners  Seasonal; humidity, rain, flooding, air conditioning and water supply risks, people with an immune deficiency	Extreme	Product choice; furniture, cleaning products, construction materials, or retrofitting products  Maintenance of air conditioning units (including portable air conditioning), hygiene practises and PPE Ventilation

Table 44 Potential Impacts - Air Quality Factors

(Bushfire CRC, 2013b; Kravchenko, Abernethy, Fawzy & Lyerly, 2012; Reisen et al., 2011; Schulte & Chun, 2009).

### 6.7.1 Ozone and Particulate Matter

Ozone at ground level has the potential to increase breathing difficulties for vulnerable individuals, with ozone levels higher outdoors. Increased reliance on asthma medication (as an example) maybe required during peak ozone exposure which is usually in the warmer months, and during the afternoon. Physical exertion should be avoided at this time for vulnerable individuals (Jacob & Winner, 2009; Pascal et al., 2012). Rural areas typically have lower levels of ozone at ground level when compared to urban areas, with the exception of bushfire events (Reisen et al., 2011). As the region is located in one of the most fire-prone regions in the world, exposure to particulate matter (PM) and Ozone may be an increasing risk if bushfires are more frequent (Bushfire CRC, 2013b).

Exposure to PM from natural or anthropogenic sources can include fine or course particles, or secondary particles produced when chemicals react in the atmosphere. PM is associated with dust, combustion, and atmospheric reactions of sulphur and nitrogen oxides along with VOCs and other gases. Avoiding harmful PM (less than 10 micrometres) can be achieved through dilution (ventilation of buildings) and appropriate personal protective equipment when working in areas with high PM loads (mining, agriculture, fire control) (Kravchenko, Abernethy, Fawzy & Lyerly,

2012; Schulte & Chun, 2009). Vegetation barriers to suppress dust, and spray drifts can be factored into areas where drift could enter domestic or other sensitive dwellings (e.g. schools) (Grantz et al., 1998).

Smoking, including exposure to environmental tobacco smoke, increases the risk factors for exposure to all types of air pollution. Climate change may lead to increased exposure to aeroallergens (e.g. pollen and spores) due to early warm spring temperatures increased allergenicity and increased stormy and windy weather. Avoiding exposure to aeroallergens has only one approach, by staying indoors and ensuring the dwelling is free from potentially harmful mould spores (Beggs & Bennett, 2011; Giles et al., 2011). Avoiding exposure to sources of combustion indoors and outdoors (e.g. through extraction, filtration and ventilation) and using appropriate personal protective equipment (PPE) will reduce exposure to PM and other gases (Xu et al., 2012; Yu, 2011). Ozone and particulate matter exposure were considered an important risk by the expert participants, however were given little consideration by community participants.

### **6.7.2 Volatile Organic Compounds**

An Australian study has indicated that VOC concentrations indoors are 8-10 times higher than outdoors. Selecting low VOC fixtures and fittings and cleaning products could reduce exposure. VOCs combine with nitric dioxide to form ozone at ground level (through the action of sunlight). This peaks in the hottest part of the afternoon; particularly on days with low wind. Increasing mean global temperatures could influence the concentrations of VOCs in dwellings. Areas inland in the study region such as Nannup, Bridgetown, Cranbrook and Boyup Brook will have hotter days with lower prevailing winds compared to coastal towns. Staying indoors in a cool environment during these hot periods will reduce exposure to Ozone at ground level (which is also produced through natural materials such as trees as well as man-made sources) (Amann, Derwent & Forsberg, 2008).

### 6.7.3 Legionnaire's Disease

Legionnaire's disease is a bacterial infection transmitted by contaminated water or soil. *Legionella* spp. are found naturally in the environment in damp conditions such as evaporative air conditioning units or potting mix. Reliance on air conditioning for longer periods of the year, along with more humid, hotter summer temperatures may increase risk of exposure (Bartram, Chartier, Lee, Pond & Surman-Lee., 2007; Greer, Ng & Fisman, 2008).

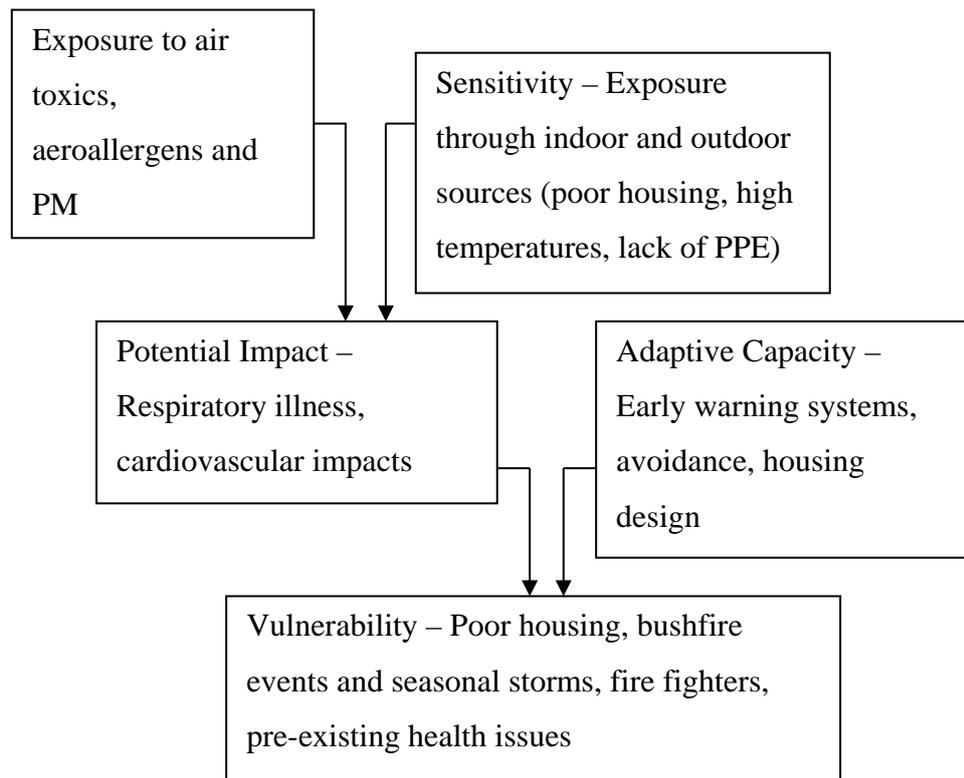


Figure 49 Vulnerability Model - Air Quality factors

(Adapted from Spickett, Brown & Katscherian, 2008) (Cooley, Moore, Herberger & Allen, 2012; World Health Organization, 2009a).

Particulate matter (coarse and fine) is formed through combustion, or by the formation of secondary particles associated with higher mean temperatures. Morbidity factors relating to lifestyle disease and aeroallergens can make some individuals more sensitive to exposure to particulates. Avoiding exposure to bushfire smoke and wood stove smoke is relevant to rural areas. Avoiding exposure to occupational hazards associated with dust and spray drifts from agriculture and mining can be achieved through appropriate PPE and ventilation. Communities can

provide facilities with ‘clean air’ during bushfire events in order to monitor individuals vulnerable to smoke inhalation (Cooley, Moore, Herberger & Allen, 2012; World Health Organization, 2009a).

#### **6.7.4 Adaptation by Individuals**

1. Avoid exposure to air pollutants in bushfire, stormy/windy, or high temperature conditions (soft)<sup>1</sup>.
2. Install an effective air filtration device in the home, with particular attention to bedrooms (hard, low regrets)<sup>2</sup>.
3. Evacuate or invacuate to a clean air area if required (e.g. during a bush fire) (soft)<sup>3</sup>.
4. Ensure air conditioner is working efficiently and correctly maintained (soft)<sup>2</sup>.
5. Ensure house is adequately ventilated to dilute air pollutants found indoors (e.g. off gassing of furniture and fixtures) (hard, no-regrets)<sup>2,5</sup>.
6. Ensure house has high thermal efficiency to prevent the indoor temperature reaching a heat range that will increase the concentration of pollutants. Thermal efficiency will also reduce or eliminate the need for combustive heating (hard, low-regrets)<sup>2,4</sup>.
7. Ensure fume hoods, vents, fans and other ventilation fixtures are working correctly (soft)<sup>2,5,6</sup>.
8. Ensure renovations limit exposure to materials that contain VOCs (soft)<sup>10</sup>.

#### **6.7.5 Adaptation in the Community**

1. Identify and maintain a ‘clean air’ building (must provide protection from smoke and particulate matter) (soft)<sup>11</sup>.
2. Ensure community buildings use low toxic materials and fixtures (soft)<sup>10</sup>.
3. Promote farming practises that reduce the risks from dust and spray drift from pesticides and herbicides (soft)<sup>14</sup>.

#### **6.7.6 Adaptation by Local Government**

1. Promote thermal efficiency for new buildings and when retrofitting existing buildings (soft)<sup>4,16</sup>.
2. Promote low toxicity building products (soft)<sup>10</sup>.

3. Use existing buildings to provide a ‘clean air’ environment in each community during high risk events (e.g. bushfire)<sup>11</sup>.

### 6.7.7 Adaptation by State Government

1. Ensure prescribed burns are undertaken during periods that will minimise urban smog formation (soft)<sup>21</sup>.
2. Implement stronger emission controls (e.g. industrial emission controls), due to the future climate penalty of a weaker global atmospheric circulation (soft)<sup>23</sup>.

### 6.7.8 Adaptation by Federal Government

1. Promote mitigation, sequestration and adaptation activities to reduce the potential impacts of increases to the global mean temperature (soft)<sup>26</sup>.

1 (Asthma Australia, 2014) 2 (Nazaroff, 2013) 3 (Environmental Protection Authority Victoria, 2013) 4 (Crump, 2011) 5 (Parrott, Emmel & Beamish, 2003) 6 (Canadian Lung Association, 2012) (Singh, 2005) 7 (Department of Health, 2010b) (Fisman et al., 2005) 8 (Australian Safety and Compensation Council, 2005) 9 (Raupach & Leys, 1999) 10 (Atlee, 2011) 11 (Department of Health, 2012) 12 (Clarke, 2006) 13 (Maibach, Steg & Anable, 2009) 14 (Lee, McLaughlin, Harnly, Gunier, & Kreutzer, 2002) 15 (Health Canada, 2011) 16 (Stone & Rodgers, 2007) 17 (Dodson et al., 2012) 18 (Green Building Council Australia, 2014) 19 (Humphreys & Wakerman, n.d.) 20 (Brown et al., 2013) (Wain, Mills, McCaw & Brown, 2008) 21 (Bushfire CRC, 2008.) 22 (The Australian Academy of Technology Sciences and Engineering, 2009) 23 (Jacob & Winner, 2009) 24 (New South Wales State of the Environment, 2012; Morris, 2011) 25 (Barkenbus, 2010) 26 (The Climate Institute, 2008; Towie, 2007).

#### Health Factors Assessed

Temperature and Air Quality	✓
Water	✓
Extreme Weather	✓
Vector Borne Disease	✓
Air Quality	✓

Table 45 Health Factors Assessed

### 6.8 Species Migration Adaptation

The following aspect of the Chapter refers to species migration, not only for terrestrial ecosystems, but marine species as well. Ecosystem damage was one of the major concerns for community participants. Human migration (displacement) from vulnerable regions could result following a disaster, or protracted climatic conditions (e.g. long term drought) (Firman, Surbakti, Idroes & Simarmata, 2011; Thaler, 2012). The following table briefly illustrates health impacts from species migration, vulnerability and risk rating with adaptations.

Impact Type	Health and Wellbeing Factor	Vulnerable subgroups	Risk Assessment Risk Rating	Adaptation required
Direct Impacts from Species Migration				
Jellyfish pole ward migration	Bites/Stings	Persons exposed, recreation use	Medium	Avoid areas with Irukandji jellyfish, adequate reporting and communication
Fish species migration	Economic losses / dietary changes	Fisher-people	Medium	Changes to diet, increase in aquaculture using sustainable feed
Biodiversity Loss / Adaptation	Economic losses, mental health	Local population, persons with attachment to landscapes “places”, impacts to pest/diseases managed on farms, disruption to food imports, increases to food costs	High-Extreme	Baseline monitoring, awareness of changes, eradication of feral animals and weeds, protection of water sources, protection of catchments and revegetation where required
Human Migration (Temporary or permanent)	Mental Health impacts, potential for loss of hygiene and other health impacts dependant on housing and support	Overwhelming local capacity to support number of migrants (due to short term extreme event, abrupt or sudden global climate change, or national security factors)	Low	Mental health support, sufficient food banks and water supply to cope with demand, whole of government response

Table 46 Potential Impacts - Species Migration

(Booth, Figueira, Jenkins & Lenanton, 2012; Cheung et al, 2010; Hallegraeff, 2010; Thaler, 2012).

### 6.8.1 Marine Species Migration

Species migration is currently occurring due to changes in water temperature and marine eco-systems (e.g. acidity of oceans) which has been reported by community participants and the literature review. It is likely that some fish species (including predatory and harmful species) will migrate in a southerly direction. Fish species could migrate laterally and vertically, with unpredictable results (Booth, Figueira, Jenkins & Lenanton, 2012). Contamination by algae (pyrodinium), red tide algae (Noctiluca scintillans) or other ocean borne disease causing organisms (such as

ciguatera) has the potential to cause food poisoning (Hallegraeff, 2010). Depleted fish stocks could lead to reduced availability of seafood, along with increased catch restrictions (Garcia & Rosenberg, 2010; Pauly et al., 2002). Pressure on global fish stocks must be carefully managed to prevent species collapse (Cheung et al., 2010; Fisheries and Oceans Canada, 2009).

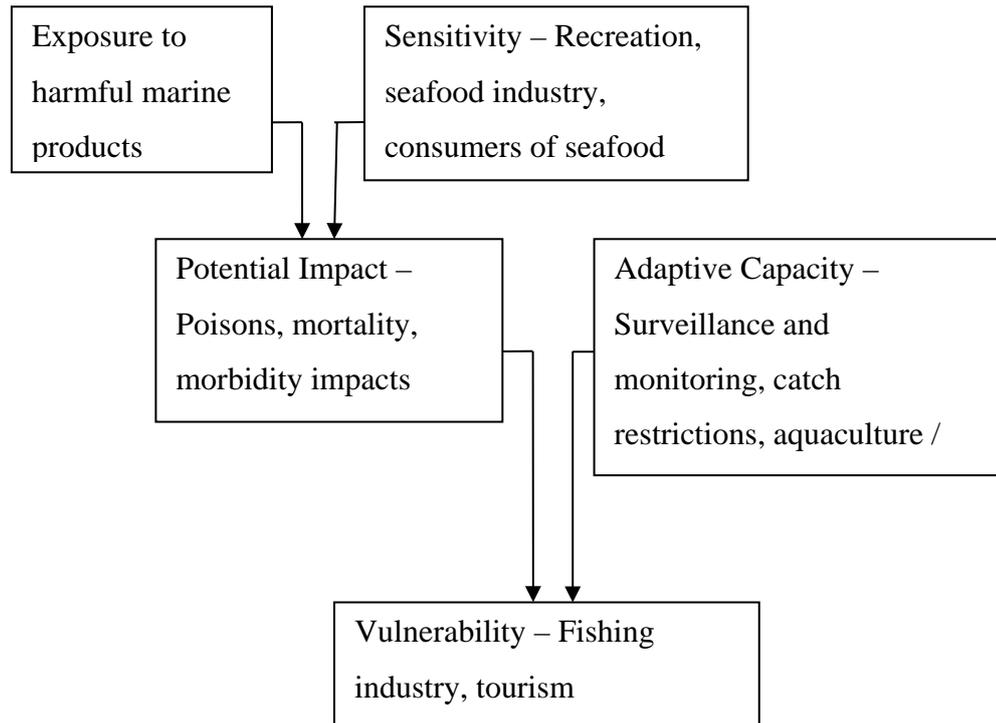


Figure 50 Vulnerability Model – Marine Recreational Water and Marine Food Products (Adapted from Spickett, Brown & Katscherian, 2008) (Garcia & Rosenberg, 2010; Hallegraeff, 2010).

### 6.8.2 Terrestrial Migration

Terrestrial migration of flora and fauna will occur within limitations arising from fragmentation of the natural landscape, loss of niche environments and potential damage from fire and drought. Aggressive generalist species (weeds and pests) may fill these niches, further eroding some of the biodiversity richness of the study area. Mountainous areas offer higher levels of species protection, in the context of the Blackwood Stirling this would include Bluff Knoll (which is over 1000 metres in height) and the Porongurups, along with areas in Denmark of 400 metres; most of the area is less than 200 metres above sea level (Google Maps, 2013). Mental health

impacts following environmental degradation are well established, with community participants identifying protection strategies, such as increasing no entry and no take park areas, along with coastal and forest rehabilitation as being important components of ensuring species diversity (Bernazani, Bradley & Opperman, 2012; Doherty & Clayton, 2011; Loarie et al., 2009; Pitelka, 1997; Thuiller, 2007).

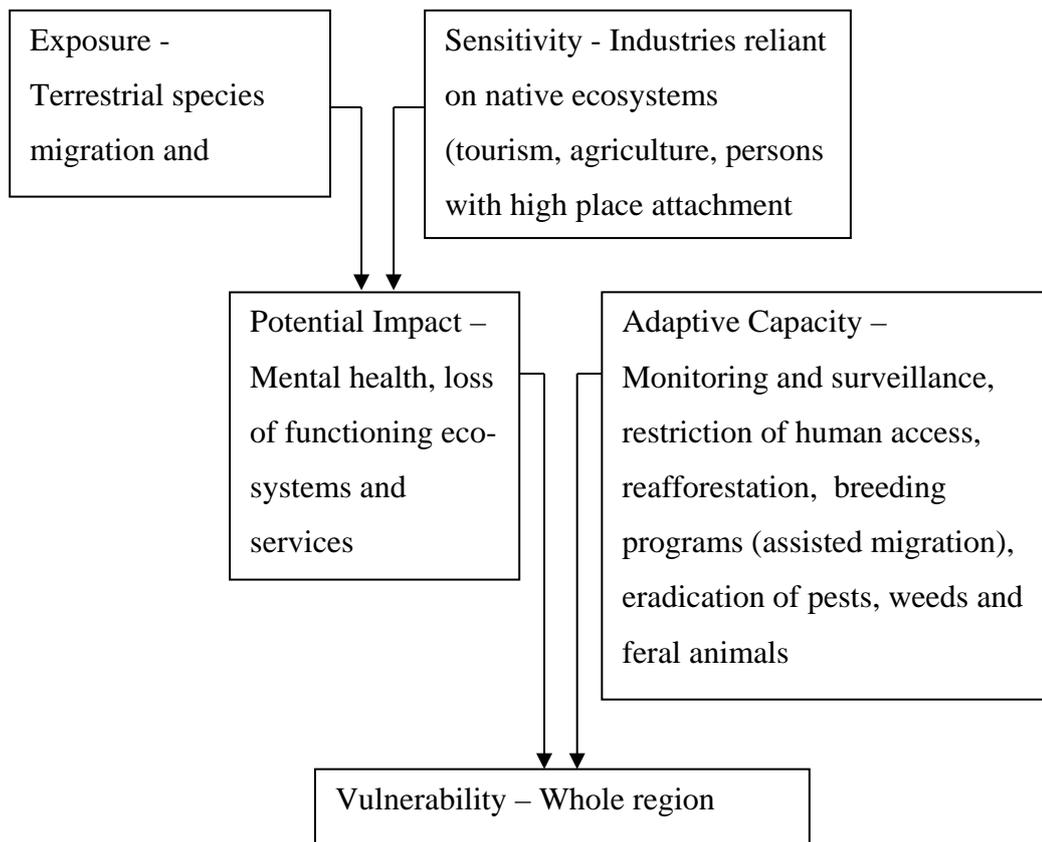


Figure 51 Vulnerability Model – Terrestrial Species Loss and Migration  
 (Adapted from Spickett, Brown & Katscherian, 2008) (Loarie et al., 2009; NCCARF, n.d.; Thuiller, 2007).

### 6.8.3 Human Migration

On the global scale human migration due to the environmental and economic consequences of climate change is likely. In the community surveys approximately 25% of participants indicated they would move if fire risk or flooding was a significant issue. The consequences of migration to safer areas due to changing climatic and economic conditions might include increased reliance on local resources, which will have positive and negative effects (Australian Government

Department of Prime Minister and Cabinet, 2013; Goodess, 2013; Smith, 2007; Stain et al., 2011; Western Australia Planning Commission, 2012; Wilby & Keenan, 2012).

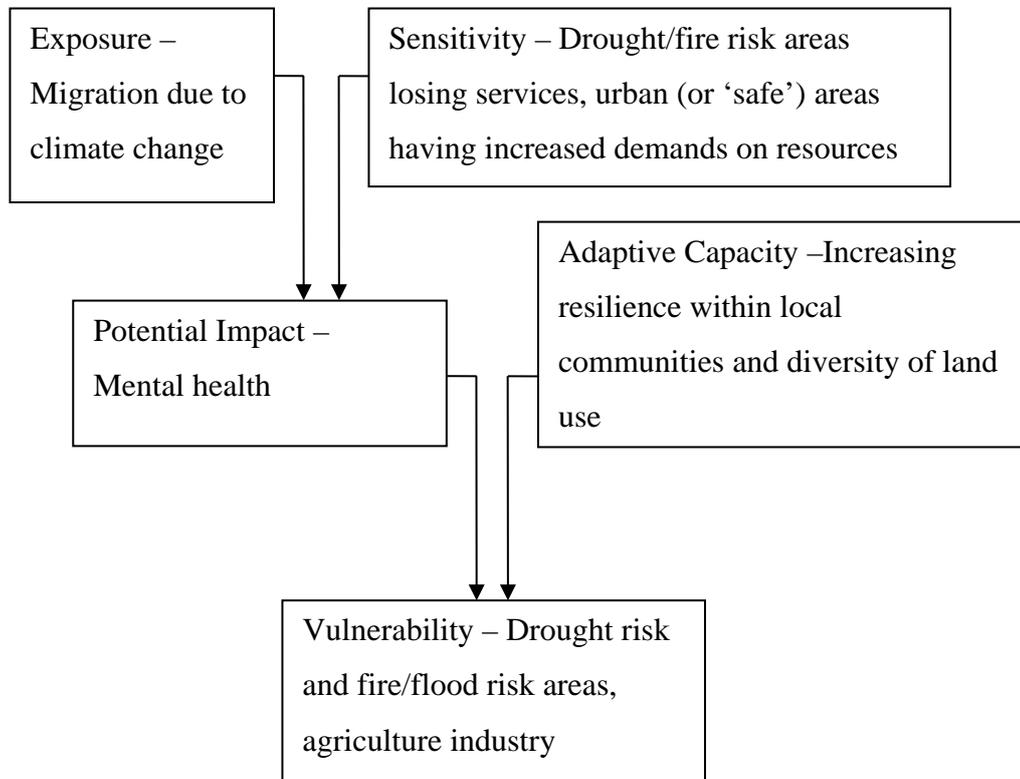


Figure 52 Vulnerability Model - Climate Change Migration

(Adapted from Spickett, Brown & Katscherian, 2008) (Goodess, 2013; Stain et al., 2011).

Appropriate adaptation strategies are listed below.

#### 6.8.4 Adaptation by Individuals

1. Restrict exploitation of marine species (soft)<sup>1</sup>.
2. Rehabilitate bushland (soft)<sup>2</sup>.
3. Increase resilience to climate change to prevent impacts to livelihood and infrastructure (soft)<sup>3</sup>.

#### 6.8.5 Adaptation in the Community

1. Identify areas of bushland to preserve, and link up fragmented bushland (soft)<sup>4</sup>.
2. Monitor species changes and migration (soft)<sup>5</sup>.

### 6.8.6 Adaptation by Local Government

1. Encourage community development projects with environmental benefits (soft)<sup>7</sup>.
2. Link up with other local government areas to develop regional strategies to preserve and enhance ecosystem functions (soft)<sup>7</sup>.

### 6.8.7 Adaptation by State Government

1. Assist migration of threatened species (hard, low-regrets)<sup>2</sup>.
2. Increase area of no take zones in marine parks and no access areas in national parks (soft)<sup>4</sup>.

### 6.8.8 Adaptation by Federal Government

1. Connect and create bush corridors including national parks to assist species migration (soft)<sup>4</sup>.
2. Manage water allocation to ensure preservation of ecosystems (soft)<sup>4</sup>.
3. Limit exploitation of marine ecosystems and prevent further deterioration of coral reefs (soft)<sup>4</sup>.

1 (Climate Action Network Australia, n.d; Hughes et al., 2003) 2 (NCCARF, n.d.) 3 (Adger, 1999) 4 (Climate Action Network Australia, n.d.) 5 (NCCARF, n.d.) 6 (Natural Resources Defence Council, 2010) 7 (Natural Resource Management Ministerial Council, 2008).

#### Health Factors Assessed

Temperature and Air Quality	✓
Water	✓
Extreme Weather Events	✓
Vector Borne Disease	✓
Air Quality	✓
Species Migration	✓

Table 47 Health Factors Assessed

## 6.9 Food Adaptation

Food consumption choices influence health outcomes and access to fresh and healthy food and may be impacted by climate change, including costs/affordability and food safety. Lifestyle diseases linked with over nutrition or micronutrient deficiency may be impacted by the direct and indirect impacts of climate change.

Biosecurity threats to current levels of food production may also increase expenditure at the farm gate. Australia produces enough food to supply the domestic market of over 20 million people, with export demands from Asian markets growing. Increases in rainfall in the period 2011-2012 showed an increase in fruit and vegetable production, decreasing prices for consumers (Department of Agriculture, Fisheries & Forestry, 2013a; Department of Agriculture, Fisheries & Forestry, 2013b). This suggests that declining rainfall may influence the price of fruit and vegetables.

Overall there has been a decrease in food production in Australia, with likely future reduction in fresh fruit and vegetables, intensive livestock, dairy and seafood (Edwards et al., 2011). This may be a challenging future scenario for South West producers to remain competitive in the international market with high labour costs. There are global concerns regarding adequate food production to feed an estimated world population of 8.2 billion by 2030, and to ensure the food is safe, affordable and accessible (United Nations Department of Economic and Social Affairs Population Division, 2006).

A reduction in availability and affordability of healthy nutritious foods will add to the risk of lifestyle disease such as diabetes and cardiovascular diseases associated with choosing energy dense food products (Neff, Palmer, McKenzie & Lawrence, 2009). Overweight and obesity rates in Australia are increasing, with over 60% of adult males and 47% of adult females reporting to be above their health body mass index (rural communities have higher levels of illness and disease risk factors) (ABS, 2013b). The importance of an appropriate calorific and nutritious diet for children will underpin their health as an adult; children in households with poor food security are at risk of lifestyle health burdens as an adult (Campbell et al., 2013; Chaperon, 2014; Lim, 2012; Quested, Cook, Gorris & Cole, 2012). The following table outlines health impacts, risks, risk rating, vulnerable groups and adaptations associated with food.

Impact Type	Health and Wellbeing Factor	Vulnerable subgroups	Risk Assessment Risk Rating	Adaptation required
Indirect Impacts via food				
Food Borne Illnesses	Allergy / Anaphylaxis  Viral/bacterial illness	Persons with food allergies  (All consumers)	Extreme  Extreme	Monitoring of imports / and labelling  HACCP Random testing (auditing of microbial counts or toxic residues) Rapid recall processes Food Handler Training Food handling education and awareness in the community
Food Production	Food scarcity; reduced grain production	All of community, low income, low education, lack of adequate access or services	Medium-High	Promote consumption and production of fresh local food
Food insecurity (local)	Under or over nutrition micronutrient deficiency ,lifestyle disease e.g. diabetes, obesity etc.	Low income, low education, unemployed, lack of access to fresh, affordable food, remote communities	Medium-high	Expand the services of food banks in communities and increase local food production e.g. community gardens, local markets etc.
Food insecurity (global)	Increase in malnutrition increasing risks for disease outbreaks and mortality (e.g. diarrhoeal and malaria), possible increases in costs of food if direct impacts affect food production and import/export market, mental health impacts for farmers	Travellers, farmers, low income groups, remote communities	Medium-high	Increase in diversity of local food production, protection of agricultural lands being developed for bio-fuels or other uses

Table 48 Potential Impacts - Food Production and Consumption

(Garnaut, 2008; Havelaar et al., 2010; Kim & Neff, 2009; Spickett, Brown & Katscherian, 2008).

### 6.9.1 Food Borne Illness

Food borne illness has a direct relationship with temperature, food handling and storage. Water scarcity, higher mean temperatures and summer heat wave activity contribute to increased risks for food borne illness to proliferate. Foods produced in the region that are identified with potential food poisoning are poultry and red meat, fish, shellfish and salad (Hall, D’Souza & Kirk, 2002; Havelaar et al., 2010).

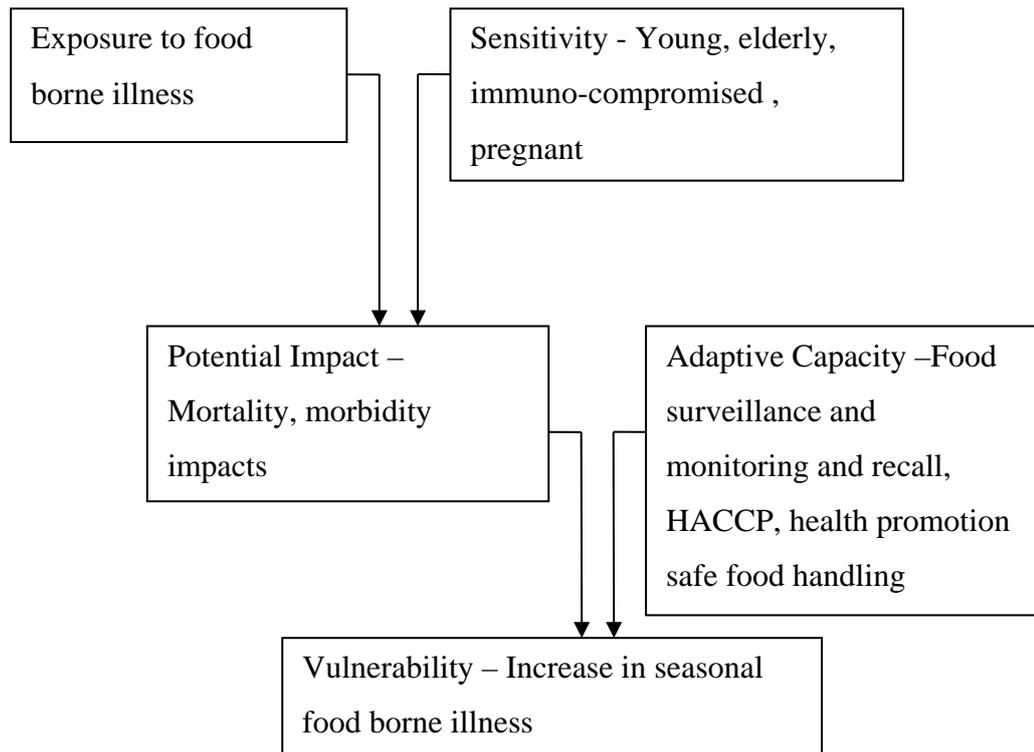


Figure 53 Vulnerability Model - Food Borne Illness

(Adapted from Spickett, Brown & Katscherian, 2008) (Hall, D’Souza & Kirk, 2002).

### 6.9.2 Food Security

Access to fresh local food means food that is available and affordable and is processed or cooked safely. Fresh local food has decreased transport and storage costs and has less preservation losses compared to tinned, irradiated or frozen food (Mundler & Rumpus, 2012). Increasing consumption of whole foods that don’t need refrigeration, such as cereals and beans, and reducing dairy and meat also reduces the carbon footprint of individuals’ diets (Kim & Neff, 2009). Over fifty percent of food produced is wasted due to a variety of reasons (e.g. harvesting methods, market/quality issues, spoilage and being unused); adding these back into the food

chain will ultimately improve food security (Lundqvist, de Fraiture & Molden, 2008).

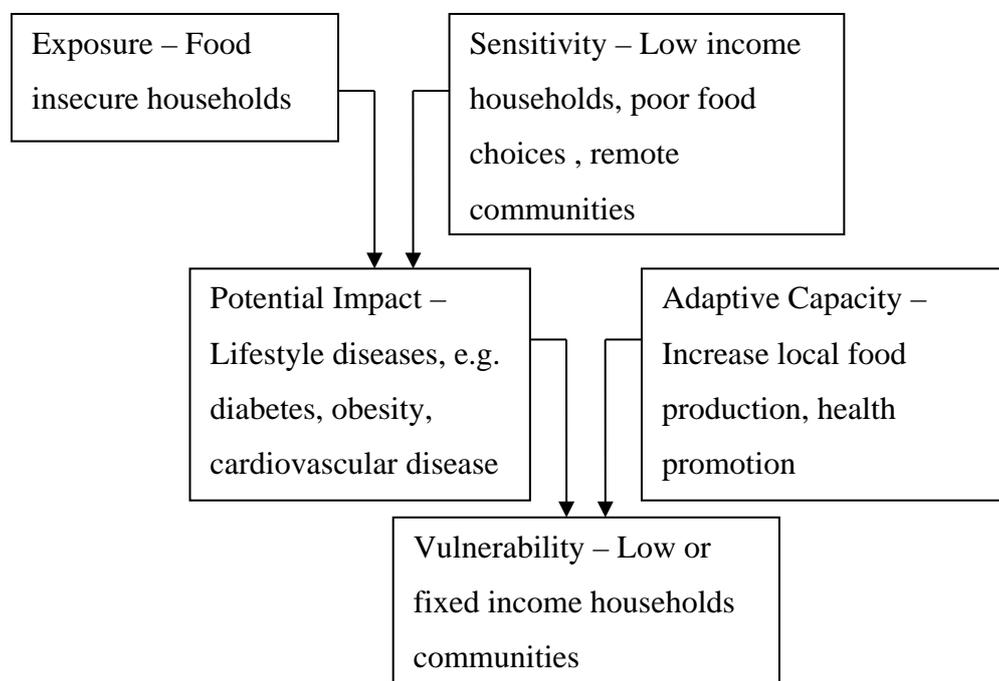


Figure 54 Vulnerability Model - Food Production

(Adapted from Spickett, Brown & Katscherian, 2008) (Lal, 2004; Muller-Lindaenlauf, 2009).

Establishing carbon markets in agriculture will likely increase consumer costs for meat and dairy foods and may encourage food choices that are rich in fruit and vegetables, however is yet untested (Lowe, 2014). Meat protein choices for livestock with lower carbon emissions include poultry, sheep, pork and kangaroo. Sustainable agricultural systems could include perennial pasture and tree food species (e.g. nuts) that could be incorporated with livestock production (Lal, 2004; Muller-Lindaenlauf, 2009). Some study participants stated that the nutritional value of grass fed cattle was superior to other forms of meat production (e.g. compared to battery hens on a formulated diet), and that land management with only carbon sequestration in mind could have damaging economic impacts to rural communities. Pasture fed cattle in the study area do not compete with cereal crops, however all agriculture takes place on former forests once rich in biodiversity (Boer & Aiking, 2011). Reducing seafood consumption to local and sustainable lower order fish, decreasing the impact of commercial net and trawl fishing is a potential adaptation to ensure future seafood sustainability (Oken et al., 2012). Increasing the production and improving the health

benefits of farmed fish is an area for future consideration and possible adaptation (Edwards et al., 2011).

Some Australian studies on future diets conclude that a higher meat production may be more likely due to market demand, less intensive inputs than cropping and horticulture, with the added benefits of carbon sequestration through perennial pasture management, and fire management (Henry, Charmely, Eckard, Gaughan & Hegarty, 2012). It is likely that the types of food available in the future will change, and will be dependant and susceptible to climatic variability, market forces, policy and financial incentives (Bonin & Lal, 2012; Kragt, Pannell, Robertson & Thamo, 2012).

Arable land in high rainfall areas may also be more sought after by overseas interests and ownership which could influence land prices and food prices; overseas investment has traditionally enhanced technological capacity and increased food production (Keough, n.d; Thomson, 2012). How this might influence local social and economic aspects of rural life is uncertain. In a free market, increased demand from Asian consumers for dairy and beef products may mean that farming properties are not utilised for lower value fruit and vegetable production (Kearney, 2010). Australian farmers currently produce enough food for an additional 40 million consumers worldwide, along with domestic requirements. Population growth in Australia to over 30 million inhabitants by 2030, along with the likely decrease in food production due to declining annual rainfall will mean food prices are likely to increase (ABS, 2012b; ABS, 2013b).

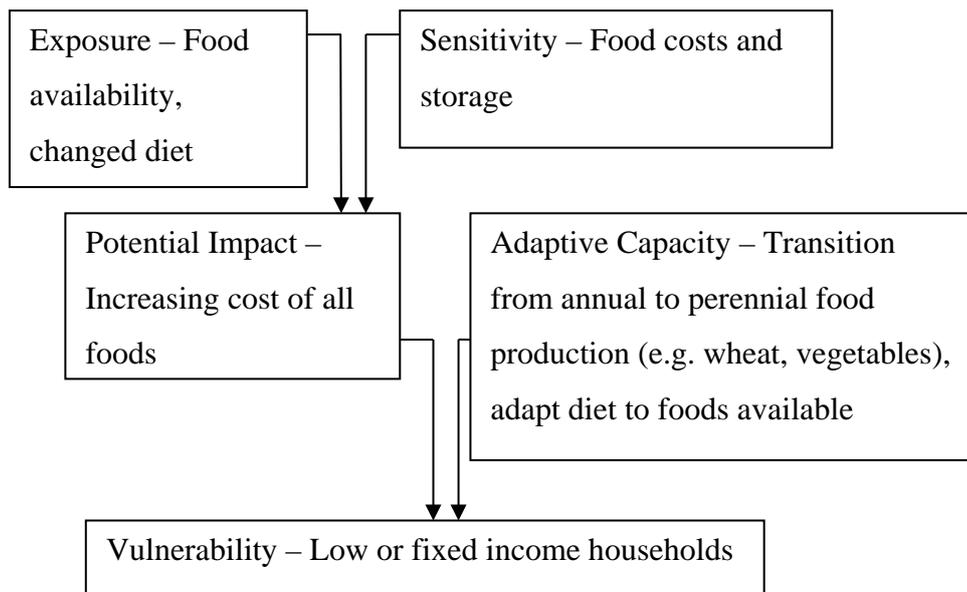


Figure 55 Vulnerability Model - Increasing Food Costs  
 (Adapted from Spickett, Brown & Katscherian, 2008; Garnaut, 2008).

### 6.9.3 Irrigated Agriculture

Water and energy costs will play a significant role in the future diets of Western Australians, irrigated agriculture is double the volume of produce compared to rain fed produce (Hanjra & Qureshi, 2010). As the Australian population increases, the current 60% excess of produce that is exported may be substantially reduced due to the effects of drought and population growth, particularly if farmers are not able to increase food production. In order to keep up with market demands, this may have significant environmental impacts if not well managed (e.g. water and soil degradation) (Lawrence, Richards & Lyons, 2012). Diversity of production, along with a sustainable and reliable water supply will be the key to sustainable agriculture (Vermuelen et al., 2012). It is unlikely food scarcity in Australia will be an issue; however food security is currently an issue for low income households, some households in rural and remote communities and Indigenous households (Cuesta-Briand, Saggars & McManus, 2011). The following lists of adaptations are suited from the individual to government and non-government institutions.

#### **6.9.4 Adaptation by Individuals**

1. Support local food production by supporting local farmers through purchasing directly from them, or via a co-op, self-grown produce, community garden or similar program (soft)<sup>1</sup>.
2. Reduce meat and dairy product consumption (soft)<sup>2</sup>.
3. Consume a diet rich in fresh seasonal fruits and vegetables, following the NHMRC's guidelines for adequate nutrition (soft)<sup>3</sup>.
4. Maintain a healthy weight according to Body Mass Index guidelines (soft)<sup>3</sup>.
5. Reduce wastage of food as far as possible, and prevent land-filling of food (soft)<sup>4</sup>.
6. Practise safe food handling including; hand washing, preventing cross contamination, and appropriate temperature control (soft)<sup>5</sup>.

#### **6.9.5 Adaptation in the Community**

1. Create and maintain a food bank for emergencies and vulnerable households (soft)<sup>6</sup>.
2. Conduct nutrition and cooking workshops to promote healthy diets and safe food handling (soft)<sup>7</sup>.
3. Link farmers and producers with consumers using tools such as Community Supported Agriculture or Co-Op Models (soft)<sup>8</sup>.
4. Encourage farmers markets (soft)<sup>8</sup>.
5. Promote community gardens through communication with stakeholders and provision of land (hard, low-regrets)<sup>8</sup>.
6. Identify vulnerable groups in the community (elderly, remote, low income) and create opportunities to increase food security, for example by providing a shopping bus (soft)<sup>9</sup>.

#### **6.9.6 Local Government Adaptation**

1. Reduce land filling of food waste through various initiatives (soft)<sup>13</sup>
2. Support local food production (soft)<sup>14</sup>.

#### **6.9.7 State Government Adaptation**

1. Support sustainable agriculture and increased water efficiency for the mining industry and irrigated agriculture (soft)<sup>16</sup>.

2. Support farmers through training and education to increase yields with reduced annual rainfall and variable climate (soft)<sup>17</sup>.
3. Support the social capital in rural communities through adequate services and amenities (soft)<sup>18</sup>.
4. Develop planning policies relating to land use for bio-fuels and timber, food production and biodiversity (soft)<sup>19</sup>.
5. Support urban farming incentives to reduce pressure on rural resources (soil, water) and reduce transportation (soft)<sup>19</sup>.
6. Provide support to farmers to restore degraded farmland(soft)<sup>22</sup>.

### 6.9.8 Federal Government Adaptation

1. Research low carbon farming methods suited to the South West of Australia (soft)<sup>24</sup>.

1 (Young, 2011; Walter, 2013) 2 (Garnett, 2007) 3 (National Health and Medical Research Council, 2013) 4 (Venkat, 2011) 5 (Spickett, Brown & Katscherian, 2008) 6 (Riches, 2002) 7 (Food Cents, 2014) 8 (Australian Food Sovereignty Alliance, 2013) 9 (Tasmanian Food Security Council, 2012) 10 (Department of Agriculture and Food, 2014) 11 (Department of Planning, 2010) 12 (Edwards & Wiseman, 2010) 13 (Giusti, 2010) 14 (Department of Agriculture, Fisheries and Forestry, n.d.) 15 (Bedsworth, 2009) 16 (Industries Development Committee Workforce, Training and Skills Working Group, 2009) 17 (Pannell, 2013) 18 (Alston, 2002) 19 (Haberl et al., 2011; Mason & Knowd, 2010) 20 (Lake et al., 2012) 21 (Hall, D'Souza & Kirk, 2002) 22 (Gretton & Salma, 1996) 23 (Department of Agriculture, 2012) 24 (George, Harper, Hobbs & Tibbett, 2012) 25 (Hawkins, 2010) 26 (de Silva-Sanigorski et al., 2010) 27 (Department of Agriculture, Fisheries & Forestry, 2013a).

Health Factors Assessed

Temperature and Air Quality	✓
Water	✓
Extreme Weather	✓
Vector Borne Disease	✓
Air Quality	✓
Species Migration	✓
Food	✓

Table 49 Health Factors Assessed

### 6.10 Summary of the Risks from Climate Change in the Blackwood Stirling

The qualitative health risk assessment carried out by the expert participants include direct and indirect risks from climate change. The highest risks are those that require the most attention for adaptation to 2030 and are primarily related to extreme weather events and air quality. Risks are more likely to be managed using soft

adaptation methods, e.g. behavioural and flexible, low cost options, based on the data collected from the community participants.

### **6.10.1 Public Health**

There is likely to be an increased health services demand in the study area in 2030; not only due to increases in the population, but changing population demographics (very elderly groups will have higher health services demands), along with chronic health issues associated with lifestyle disease and mental health factors (Blashki et al., 2010, p. 6). Many of the community participants doubted whether current emergency and hospital health services could cope with disasters (e.g. extreme weather). Travel expenses and time missed from employment are added constraints for rural residents that have to visit regional or metro health services for specialist appointments or surgery. Retaining adequate health services within rural communities are integral to rural sustainability, if health services become reduced or diminished over time, this will undermine the ability of elderly people and people with chronic illnesses to comfortably stay in rural areas (Farmer, Prior & Taylor, 2012; Robertson, Walkom & Henry, 2011; Singh, Mathiassen, Stachura & Astapova, 2010). Future health promotion strategies should focus on preventing lifestyle diseases and positive mental health (Breda, 2012; McMichael, Blashki & Karoly, 2007).

### **6.10.2 Rural and Urban Impacts**

Residents in the study area are likely to have less exposure to air contaminants and summer heat wave activity compared to urban regions with reduced night-time cooling due to the heat island effect. Many of the coastal areas will benefit from sea breezes, providing greater dilution of air contaminants and cooling. Air quality monitoring is required in rural and remote regions in order to evaluate changes attributed to climate change over time (Climate and Health Alliance, 2013; Reisein et al., 2011).

Rural people often have higher living costs compared to their urban counterparts due to the costs of transportation and lack of market competition (food, medical

expenses, other retail goods and services). Agricultural products are produced locally, but this does not always mean that local consumers are able to buy produce at a lower cost than regional or urban areas. Individuals in rural communities often develop multiple skills and greater self-reliance, sometimes this is a hardship particularly for people with impaired mobility (Iezzoni, Killeen & O'Day, 2006) and sometimes this has positive dimensions such as increased self-sufficiency and being community minded (Strasser, 2003). Whilst rural populations will have access to 'cleaner' living and working environments and may have higher levels of social capital, health outcomes for rural populations are generally poorer.

### **6.11 Adaptation by Local Government Area**

This section will discuss how each local government area may adapt to the challenges of climate change by 2030. Local government amalgamations may have economic benefits however some local government areas are reluctant to change their sense of community (Department of Local Government and Communities, 2014).

#### **6.11.1 Shire of Augusta Margaret River**

The Shire of Augusta Margaret River is ideally located on the South West coastline and is a highly regarded tourism and agriculture destination. This local government area has established a number of local policies that deal specifically with sustainability and climate change and has experienced recent population growth through suburban and semi-rural land developments (Shire of Augusta Margaret River, 2014). The vulnerabilities to the potential health impacts from climate change in the Shire of Augusta Margaret River relate to the following:

- Continued land development pressure
- Threats to biodiversity
- Risk of bushfire from natural and manmade causes
- Lack of public transport, adding to the cost of living for ageing residents
- Recreational and aesthetic water quality issues
- Economic reliance on viticulture, agriculture, beverage manufacture and tourism which are vulnerable to climatic change

- Increased health service demand due to elderly and very elderly population growth
- Impacts to the fishing industry due to marine water quality and migration of fish species.

Opportunities for effective adaptation in the region are to ensure setbacks for coastal development take into account the emerging science and emissions scenarios and that the public is made aware of the risks of coastal development (potential for storm surge on soft erodible beach areas) (Bormann, Ahlhorn & Klenke, 2012). Community engagement at a local government level will ensure community concerns and local knowledge is presented with regards to sustainable and risk averse development (Lake Macquarie City Council, 2013; Sheppard et al., 2011). Limiting suburban sprawl and focussing on higher density development may service the emerging numbers of single person and elderly households, as the most cost-effective and energy and water efficient type of housing (Australian Bureau of Statistics, 2004a; McDonell, Monroe, Boles & Mashour, 2008).

Implementing sustainable energy production in the region through solar and wind projects may reduce grid pressure during peak summer demand (Nockolds, Kuch & Ison, 2013). The region boasts perennial farming enterprise (viticulture) with other food and processing technologies and a high value tourism industry (Jones et al., 2010). Community participants were concerned that food production in the region was facing increasing constraints due to pricing competition from overseas imports and low prices for produce at the farm gate. Community participants in this region were concerned about the economic viability of farming and how this would impact the availability of affordable local produce and meat.

Protecting local biodiversity from development pressure and pollution through the management of forests, groundwater, air quality and riverine environments will preserve native flora and fauna and the economies that benefit (Reside et al., 2013). Protecting water quality by restricting ground water extraction, improving farming practises and diversification of the water supply source may enhance resilience to reduced annual rainfall in the region. Improving irrigation technology and water re-

use options will reduce water demand (Horne, 2012; Vorosmarty et al., 2010). Community participants involved in the fishing industry in the region have noticed a decline and change in the types of fish species available. This has reportedly affected tourism as well as local small businesses. Protection of marine species is managed by the Department of Fisheries, with increases to fishing restrictions a possible adaptation suggested by community participants; changes to the Leeuwin current is affecting the marine species available and this will likely continue in future (Hobday & Lough, 2011). The close proximity to Perth and Bunbury means that health services are more accessible compared to remote regions in the study area.

### **6.11.2 Shire of Nannup**

Challenges specific to the Shire of Nannup will be discussed. The Shire has a small population in the town site, farming properties of variable sizes and outer settlements such as Jalbarragup. Climate observations show greater variability in daily minimum and maximum summer and winter temperatures as the Shire is land locked by state forest and national parks and has less exposure to coastal influences. Small but sustained population growth is occurring in the Shire of Nannup and is likely to continue. The vulnerabilities to the potential health impacts from climate change in the Shire of Nannup relate to the following:

- Bushfire risks due to terrain, forest and tree farms (biomass)
- Air quality risks (indoor and ambient) due to higher temperatures
- Thermoregulation risks (insulation factors due to housing quality and energy security)
- Environmental degradation e.g. the Blackwood River water quality
- Biodiversity loss as a result of mean temperature increase and reduction in annual rainfall
- Urban demand for groundwater affecting groundwater inflow to local ecosystems
- Reduction in quantity and quality of water supply sources for agriculture and other industries
- Lack of public transport increasing the cost of living.

Nannup is located within relatively close proximity to Busselton and Bridgetown which allows access to many retail facilities, other services and employment. The main industries for employment are agriculture, manufacturing, construction and health care (ABS, 2013a). The smaller number of local facilities and lack of public transport means increased living costs associated with car ownership. Having public transport or a community bus may prove an efficient method for reducing car reliance, particularly for fixed households and the elderly, where car use declines over time (Rosier & McDonald, 2011). Future risks to Nannup may include exposure to extreme weather events such as fire and heat wave activity, and the sensitivity of the ageing population that may have limited mobility and diminished ability to thermo regulate (Cahalan & Renne, 2007; Watterson et al., 2007). There have been occasions of flooding in the town's history; increased variability of rainfall and heavy rainfall events may increase risks of flooding. Provision of a community cooling centre could be incorporated with an existing facility such as the local library, community hall or Telecentre for residents with lack of air conditioning or insulated housing. The existing health services were considered sufficient by community participants; persons more remote to town in older housing, or housing with poor insulation (especially single older males) are more vulnerable to heat wave activity and air quality factors. Having a socially cohesive community may help to encourage individuals to seek help and monitor vulnerable households in extreme conditions including heat waves and to evacuate in a timely manner (Blashki et al., 2010; Huang et al., 2013).

Implementing water and energy efficiency measures will reduce living costs and are likely to pay off in any future scenario. Urban demand for groundwater using the Leederville and Yarragadee aquifer must be balanced with the ground inflow to local ecosystems to ensure biodiversity is preserved (Australian Council of Social Service, 2013a; McFarlane et al., 2012). As maximum summer temperatures are likely to be higher inland than coastal areas, air conditioning use will also likely be higher, so improving the insulation qualities and shading of dwellings and facilities will help reduce future energy demand. Community participants reported that community resilience can be supported through active volunteering and maintaining social networks. In an emergency this will ensure preparation, prevention and social

learning relating to sustainability objectives continues. New residents could be encouraged to join the bushfire brigade to increase knowledge about fire weather and property management. Further, with good emergency preparation and property management this can reduce the risks associated with bushfires (Bushfire CRC, 2013a ; Shire of Denmark, 2014).

### **6.11.3 Shire of Bridgetown-Greenbushes**

This Shire has a history of population decline and renewal, with a likely population increase in future. Land use has included horticulture, tree plantation industries and rural subdivisions which has increased the number of serviced lots available. As the region is in close proximity to the City of Bunbury and a short drive to Perth, it is seen as a desirable rural location. Employment in the region is based on school education, agriculture, mining, food service and health care (ABS, 2013a). Within the Shire there has been a number of bushfire events, partly attributed to biomass and elevated terrain, with recent fires in 2011 resulting in property damage. Drying of native bush and farmland through diminished annual rainfall was a factor of concern amongst the community participants (Strategen, 2013). Community participants also identified land clearing as being a major factor influencing rainfall and the hilly terrain in the area increasing the risk for bushfires. Close location to the City of Bunbury's facilities increases access to retail and other services, however private vehicle reliance due to limited public transport options is also a feature of these communities.

The vulnerabilities to the potential health impacts from climate change in the Shire of Bridgetown-Greenbushes relate to the following:

- Land development in bush fire prone areas
- Lack of confidence in communication and evacuation in an emergency
- Eutrophication of the Blackwood river
- Fragmented landscape due to farming and tree plantations
- Lack of public transport for daily commuting needs
- Increasing health service demands
- Limited health services in Greenbushes

- Exposure to temperature extremes due to older housing stock
- Air quality factors.

Bridgetown has varied agricultural practises that have contributed to the eutrophication of the Blackwood River, it is uncertain how this will be affected by climate change due to variable rainfall, drought and high rainfall events (Land Assessment Pty. Ltd., 2002). The types of land use impacts the safety of the residents depending on the biomass produced, for example tree plantations and grass fires were debated by community participants as being high risk for bushfires in equal measure (Country Fire Authority, 2012). Some community participants were dismayed that fire prone planting (revegetation) was supported by local environmentalists (who supported replanting/reafforestation with Australian natives), however other community participants were concerned about damage to local flora and fauna by planting non-indigenous species. Exotic plants in gardens, along with tree plantations were said to have higher water demand and influenced inflow to groundwater. While the Bridgetown community has experienced a number of fire events, it is likely that land development will continue. Engaging with land owners around issues of ecological preservation may help to improve species migration by joining up fragmented land (Mansourian, Belourov & Stepheson, 2009). The Bridgetown-Greenbushes is in a superior location for food production, being close to the Cities of Busselton, Bunbury and Perth, along with Bunbury Port and Abattoir facilities. Having fire preparation in rural properties and effective evacuation procedures are critical to preventing future mortality and morbidity from fire events (Bushfire CRC, 2013a).

Providing adequate public transport will greatly improve quality of life in Bridgetown and surrounding settlements. Using the existing train line to Bunbury or a bus service would reduce car dependence and link this region to Perth. Utilising the existing Manjimup, Bridgetown and Bunbury rail service would reduce truck and car dependency and may improve transport opportunities of horticultural products from the region to Bunbury and Perth (Humphreys & Wakerman, n.d.; Siemens, 2011). Community participants in Greenbushes stated that increased access to local health services (General Practitioner) would benefit vulnerable residents that were unable to

drive. This may not be viewed as cost effective, however may improve community resilience (Duckett & Breadon, 2013). The Greenbushes community may be well served with a community bus providing regular services to Bridgetown, Donnybrook and Bunbury.

#### **6.11.4 Shire of Boyup Brook**

This Shire is further removed from coastal influences and has higher exposure to temperature extremes and water availability than other regions on the coast. The town has a reasonably high socio-economic index and a number of services in the community with close proximity to Bridgetown and Bunbury. Agriculture has a much higher proportion of employment at 53.1% (ABS, 2013a). If climatic changes to water availability and mean temperatures negatively affect agricultural practises without any preparatory adaptation this will have a higher impact in this local government area due to the higher proportion of employment in agriculture compared with other industries (Stokes & Howden, 2008). Country music is a special feature to Boyup Brook supporting local businesses (Liberal Party of Western Australia, 2013). The vulnerabilities to the potential health impacts from climate change in the Shire of Boyup Brook relate to the following:

- Reduction in annual rainfall
- Temperature extremes
- Distance to retail, services and health care
- Health service demands increasing with the ageing population
- Provision of adequate public transport
- Degradation of the landscape through fragmentation and climatic changes.

The closure of the rail service is something that community participants would like to see resume to link the community to the services in Bunbury (educational, retail and medical). Community buses may be more cost efficient and provide equally good service. The population is relatively stable and has less pressure for development than other regions. Larger farms and town blocks are the usual lot types. The elderly and very elderly groups are likely to increase, so providing adequate at home domestic services are required to preserve ageing in place (Productivity Commission,

2004). Availability of air conditioning or community cooling centres will be important here, as will back up power to ensure safe environments, particularly for elderly residents (O'Neill, 2003).

Relative distance to regional centres is likely to increase costs of food and fuel, which impacts fixed income households. Continued community development and building a sense of place, employment opportunities and activities that improve resilience are important components of the sustainability of rural communities (National Rural Health Alliance Inc. & ACOSS, 2013). Support for rural areas may be necessary to transition to changing climatic conditions; providing adequate training and assistance to farmers, mental health services and drought recovery programs (Pannell, 2013). Boyup Brook is in a proximate location to urban consumers in Bunbury and Perth, and provided farmers have prepared for climate change and have sustainable transport opportunities will continue to provide valuable services (Link & Ling, 2007).

#### **6.11.5 Shire of Cranbrook**

The Shire of Cranbrook is the smallest Shire in terms of population in the study area, and is comprised of wheat and sheep farming areas, viticulture, national parks and a number of small businesses and agricultural enterprises. Agriculture is the basis for the local economy employing 41% of the population (ABS, 2013a). The Shire has good proximity to the regional service centres of Mount Barker, Kojonup, and Albany (Shire of Cranbrook, 2011). The vulnerabilities to the potential health impacts from climate change in the Shire of Cranbrook relate to the following:

- Reduction in rainfall and runoff
- Shifting of seasons affecting annual cropping
- Heat extremes and increasing mean temperatures
- Distance to services increasing costs of basic necessities
- Fragmented landscape reducing quality of ecosystem services.

While the town has access to services it is still quite small in terms of infrastructure, therefore expenditure on large adaptation projects delivering energy or water security

seems unlikely (National Water Commission, 2012). If this smaller Shire were to amalgamate with a larger Shire, important positions of employment may be lost, however access to other local government services may be possible (Department of Local Government and Communities, 2014).

Community solar projects may service local needs, and community cooling centres will prevent exposure to extreme heat events and increasing summer temperatures particularly for persons in town. The large number of residents living outside the town centre means that it is more likely that adaptation for private dwellings would include improvements to insulation and temperature regulation (Dopita & Williamson, 2010; O'Neill, 2003).

Increasing storage options for water and water efficiency measures may be required, along with stock management to ensure adequate feed in years of reduced annual rainfall. Shifting of seasons may influence agricultural yield for annual cropping (Carmody, Gray & McTaggart, 2010). Community development and agricultural investment occurs by encouraging innovation and the retention of younger farmers, sustainable and consistent agricultural research and support will be critical to ensuring long term sustainability in agriculture.

It is possible that genetically modified drought resilient crops will be more likely to be grown in marginal areas with low rainfall (Rotman, 2014). Future agricultural innovation and investment may take place as a result of corporate ownership of Australian farmland with influences to smaller communities including loss or migration of locals. Provision of health services, particularly mental health services is critical for drought vulnerable areas. Provided government and private industry are supportive, carbon farming initiatives may provide valuable income through carbon sequestration and have the co-benefits of biodiversity protection (Clarke, Mauger, Bell & Hobbs, 1998; Goldman, Thompson & Daily, 2007).

#### **6.11.6 Shire of Manjimup**

The Shire of Manjimup has the largest land area for a local government in the study area, with some remote towns and communities. The township of Manjimup has a

declining population recorded over the last five years (WAPC, 2015a). Coastal communities are Windy Harbour and Walpole and much of the coast is national park that is management by the Department of Parks and Wildlife. The area is rich in fresh water bodies and has a history of boom and bust agricultural industries since group settlement in the 1920's. Employment in the region is largely school education, followed by sheep, beef, grain, fruit and tree nut growing, government administration and tourism (ABS, 2013a). The vulnerabilities to the potential health impacts from climate change in the Shire of Manjimup relate to the following:

- Declining annual rainfall the impacts to pasture fed beef production
- Longer term potable water supply sources
- Bushfire risks due to large tracts of biomass in State Forests and National Parks
- Declining water quality in significant riverine and water catchments, e.g. the Warren and Meerup Rivers
- Aged health service demands
- Fragmented landscape
- Refuge for vulnerable and migrating flora and fauna species
- Bushfire risk
- Lack of adequate public transport
- Communication black spots.

The Shire of Manjimup has attracted less development than the Shires of Denmark and Augusta-Margaret River, possibly due to limited coastal development and large areas of National Park, the Supertown initiative may influence future growth and increase the population of Manjimup by 3.4 per cent per year for the next three decades (WAPC, 2015a). Any future development should be sensitive to the value of agricultural land in future and may be better served by infill development to higher density lots in existing town sites. The issue of future water scarcity in the South West could be addressed through diversity in water supply sources and greater resilience through increased storage within communities (McFarlane et al., 2012). As many of these communities are both remote and have low socio-economic indexes, they may have higher vulnerability to climate change due to lack of adaptation, poor

emergency preparation, poorer health outcomes and risk taking behaviour (Allan, 2010).

Strengthening each community through appropriate community development, adult education and increasing local resilience in these towns will ensure that they remain viable vibrant communities (Hegney et al., 2007). Ensuring mental health services and appropriate housing (insulation and protection from mosquitoes) is critical to supporting health of vulnerable groups, particularly fixed income and single parent households. Homeless persons remain the most vulnerable to climate change emergencies in any community and are more likely to be found in rural and remote communities (Department of Social Services, 2008). Adequate domestic help and care is also required for the elderly and very elderly population that is set to increase by 2030 (Productivity Commission, 2004). Delays in ambulatory care are factors that may reduce health outcomes for people in rural and remote areas, particularly if patients need to be transported to Bunbury, or the Royal Flying Doctor to Perth (Nicholl, West, Goodacre & Turner, 2007).

In terms of bushfire management, appropriate fire preparation and evacuation may help prevent health problems associated with extreme events. According to community participants townships such as Quinninup and Nornalup are particularly vulnerable to bushfire events as they are surrounded by biomass from every direction. Vulnerability to bushfire due to reduced annual rainfall may affect Manjimup more than the other communities (based on scenarios of future rainfall) (Bushfire CRC, 2013b).

Some community participants complained about the lack of doctors and hospital services, as future demand for health services is likely to be related to non-communicable diseases; programs and policies to support healthy eating and physical activity are vital to prevention of lifestyle disease. Lack of adequate public transport could be overcome with smaller bus services between communities (Anderson, Harrison, Cooper & Jan-Llopis, 2011).

As the last area on the southern coastline (along with the Shire of Denmark) these national parks will provide the final niche for migrating flora and fauna due to changing rainfall and temperature regimes. The effects of climate change on extinction rates in the one of the most vulnerable biodiversity hotspots on the planet are unknown, however the retention and preservation of ecological niches is extremely important (Groves et al., 2012).

### **6.11.7 Shire of Denmark**

The Shire of Denmark has many organisations and policies to educate and manage climate change and sustainability issues. Despite being a five hour commute from Perth, Denmark has remained a popular travel destination and property development area and is likely to continue to grow into the future. Denmark has a strong agricultural and tourism base (along with education services) (ABS, 2013a; Shire of Denmark, 2013). The vulnerabilities to the potential health impacts from climate change in the Shire of Denmark relate to the following:

- Energy insecurity due to grid and peak summer demand
- Water security due to diminished quality of supply and reduction in rainfall
- Continued property development demand
- Biodiversity hotspot
- Water sensitive economies
- Ageing population.

Denmark is a picturesque community with coastal, pastoral and forested areas, including the elevated terrain area of Mount Shadforth. These higher elevation areas are of particular importance for flora and fauna migration in terms of species preservation and should be protected and restored as far as possible (Crimmins, Dobrowski, Greenberg, Abatzoglou & Mynsberge, 2011). The south coast is also vulnerable to declining water quality and quantity and the continued development of serviced lots was considered unsustainable by some participants. Local knowledge can be incorporated into risk management strategies when assessing development proposals and planning policies. Development in bush fire prone areas is also a

matter of concern as some of these properties were stated by participants to be difficult to defend in an emergency (Argent, 2011; McKenzie, 2004).

Western Power has undertaken many marketing activities to reduce grid use during peak hours to prevent power outages. As the pressure for energy is likely to continue, particularly during heat wave events, having sufficient and back up energy supplies is critical for people in this local government area, especially the ageing population. Denmark Shire could consider the allocation of one of their existing buildings as an allocated cooling centre during heat wave events and ensure, along with health authorities and non-government agencies, that vulnerable persons are contacted and transported if health concerns arise (Henstra, 2012). Solar energy or wind projects may supply some of energy needs of the community, particularly if these projects are implemented early (Seyfang, Park & Smith, 2013). According to some of the community participants coastal development and reliance on private car ownership for transport has socially marginalised some elderly persons in the community.

According to a stakeholder interviewed there is a lack of adaptation in the farming sector in the south coast area for reduced annual rainfall; this will need attention to improve irrigation technology, consider changing stock and cropping activities (and horticultural practises) and to reduce overall water demand. The impact of tree plantations on streamflow may also need future assessment. A comprehensive plan for both water management and repair of fragmented landscapes are necessary for effective environmental and natural resource management in future (Barron et al., 2012; Robson, Chester, Mitchell & Matthews, 2013).

#### **6.11.8 Shire of Plantagenet**

The Shire of Plantagenet is an inland local government area with moderate rainfall and has areas of national importance (e.g. the Stirling Mountain Ranges, including Bluff Knoll). Local populations show stable growth and are reliant on agricultural, manufacturing, construction, tourism, and government employment. The Shire is located close to the facilities of the City of Albany and adjacent to the existing rail service (Shire of Plantagenet, 2013). The vulnerabilities to the potential health impacts from climate change in the Shire of Plantagenet relate to the following:

- Remote communities
- Indigenous populations
- Lack of adequate public transport
- Temperature extremes
- Reduction in annual rainfall and runoff
- Vulnerable ecosystems.

The Shire of Plantagenet has the highest percentage of Indigenous persons per local government area at 3.1 per cent (followed closely by the Shire of Manjimup at 2.7 per cent) in the study area (ABS, 2013a). As Indigenous persons are listed as vulnerable to existing and future climate change health risks, extra government and non-government support including housing and primary health care may be required in future. As some of these individuals live in remote locations they face additional health burdens associated with lack of access to services and facilities. Climate dependant industries support 19% of the population in employment types that are vulnerable to climate change (ABS, 2013a; Shepherd, Li, Mitrou & Zubrick, 2012).

Access to employment, retail, government services etc. are more expensive to those persons that live in remote areas and have greater reliance on private vehicle use with the associated expenses (Shergold, Parkhurst & Musselwhite, 2012). Community development and health promotion are particularly important in these communities that have a higher predisposition to non-communicable health risks (Patrick, Capetola, Townsend & Nuttman, 2012). Due to the elevation of the landscape (mountainous terrain) this region may be able to provide for range shifts of species e.g. flora and fauna (Crimmins et al., 2011). Providing some landscape restoration and protection of important habitats may facilitate range shifts of these species following during climatic changes (e.g. increasing mean temperature or reduction in annual rainfall) (Bardsley & Sweeney, 2010).

Early adaptation with regards to heat management for livestock, and water efficiency technology will assist farmers to cope with the future of drier, hotter years (Thornton, 2010). Providing cooling centres using existing Shire infrastructure (with backup

power) will assist those individuals vulnerable to heat extremes, provided they have access to transport. Local surveillance of vulnerable persons and assistance with transport (for instance during bushfires and heat wave activity) could be managed by government health services and non-government organisations (Huang et al., 2013) (Victorian Council of Social Services, 2014).

### **6.12 Summary of Chapter Six**

This Chapter examined the potential health risks to the study area and used future scenarios to determine sensitivity, potential adaptation action and vulnerability. The action of individuals, business, community and government was considered. Cost effective adaptation should focus on disaster readiness, thermal properties of dwellings and water and energy efficiency. The adaptation recommendations are based around soft, no regret actions, or hard low regrets actions, providing win win returns under any climate scenario. Reducing lifestyle disease prevalence through consumption of fresh local produce and being physically active will provide protection against future health risks associated with extreme temperatures and air quality factors (Hale et al., 2011).

Economic resilience through diverse land use practises, community development, and environmental rehabilitation will decrease the sensitivity of local communities to climate change shocks (McCabe & Davis, 2012). Radical mitigation, re-afforestation and other sequestration activities (such as implementing perennial pasture and other perennial food crops) as part of a suite of actions towards a low carbon future, is essential to reduce the global impacts of climate change and expenditure towards adaptation (Blaustein, 2010). The following Chapter will discuss the key findings of the research, the significance of the research, and the application of this research model for other regions in Australia.

## Chapter Seven - Discussion and Conclusion

*“We can either work cooperatively to avoid catastrophe, or we will experience it”  
(MacCracken, 2008, p. 45).*

### 7.0 Introduction to the Chapter

This Chapter discusses the findings of the study, addresses the significance of the research and applicability to other regions of Australia. Recommendations for future research and limitations of future oriented climate studies are also discussed. Taking data from multiple sources, this study sought to use the rHIA methodology with climate forecasting models to identify health impacts of climate change to 2030 and to determine the most suitable adaptation strategies for rural communities in the Blackwood Stirling study area. The Chapter concludes with a summary of the research.

### 7.1 Focus of the Research

The purpose of this study was to use the rHIA methodology to identify health impacts of climate change and adaptation. Adaptation policy was then evaluated in terms of addressing these health impacts. Community and expert participants informed the research (Collins & Koplan 2009; Hall, Taplin & Goldstein, 2010).

#### 7.1.1 Research Focus

Can we enhance health through adaptation to climate change in the Blackwood Stirling District?

#### Specific Objectives

1. Identify the potential sensitivities and vulnerabilities of and impacts and risks to local communities taking into account a range of climatic hazards, local socio-economic and local environment (urban, rural, natural, agricultural) characteristics.
2. Assess the potential positive and negative impacts on health of climate change in the region.

3. Use qualitative health risk assessment methods to analyse the likelihood and magnitude of the identified human health impacts to determine priorities.
4. Develop, through discussions with stakeholders, the research participants, and a review of the literature, potential adaptation measures/interventions and strategies to minimise the potential risks of the identified human health impacts and the severity of those impacts.
5. Review and assess the possible adaptation strategies in terms of who is or would be best placed to action them at local/district, state and national levels.

### 7.2 Key Findings from the Study

The key findings of the study are linked with the specific objectives of the research and are summarised in each section below. These are to identify vulnerabilities, to evaluate the health impacts by conducting a qualitative health risk assessment and to develop adaptation strategies. Determining the role of adaptation between individuals, tiers of government and other organisations was the final key objective. A discussion of each key finding and future directions will be reviewed in this Chapter.

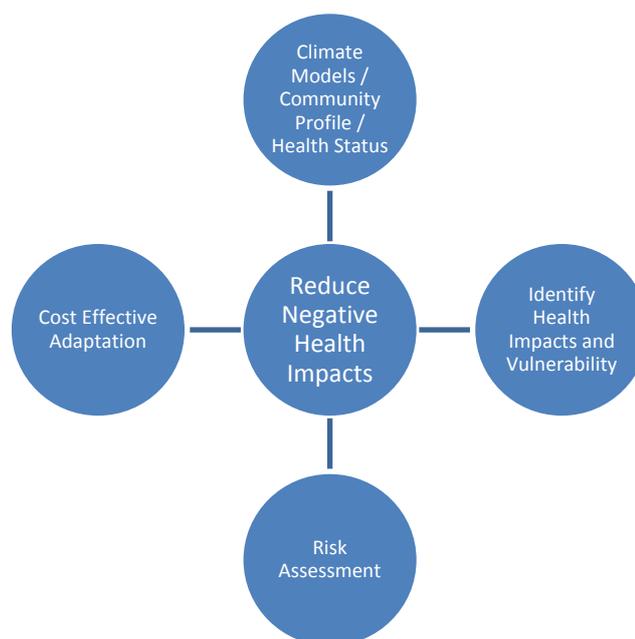


Figure 56 Research Process.

### 7.2.1 Objective One

**Identify the potential sensitivities and vulnerabilities of and impacts and risks to local communities taking into account a range of climatic hazards, local socio-economic and local environment (urban, rural, natural, agricultural) characteristics.**

Vulnerability refers to the inability to withstand shocks and risks from climate change. Risks refer to the potential for harm to occur following exposure to a hazard. Vulnerability and risks to climatic changes were identified in the study with the use of the primary and secondary data collected. Along with an extensive literature review, data was collected relating to vulnerability, adaptation and risks of the communities in the study area, with data from community, stakeholder and expert participants contributing to this knowledge (Shwartz, Bellinger & Glass, 2011).

Physical risks identified included exposure to extreme weather events such as bushfires and more intense storms, more frequent heat wave activity and higher humidity. Chemical risks included exposure to air toxics due to increasing ambient temperatures and the influences to indoor air quality factors and outdoor air e.g. smog. Biological risks include vector borne disease (leading to illnesses such as Ross River Virus), food and water contamination with biological agents, such as *Listeria spp.* and *Cryptosporidium spp.* associated with contaminated water (Spickett, Brown & Katscherian, 2008).

Socio-economic characteristics such as relative income, housing quality, access to services and education can promote or limit risks associated with chemical, physical and biological risk factors with seasonal influences (Furnee & Pfann, 2010). Little is known about willingness to pay for adaptation or costs of appropriate adaptation. This study has examined likely expenditure and barriers to action from a government, non-government and local community perspective. Climate change vulnerability is dependent on socio-economic influences, remoteness, rainfall and temperature.

### **7.2.1.1 Identifying Risks and Vulnerability Through Primary Sources**

Risks and vulnerabilities identified by community participants in the study area were in agreement with the literature review. Some risks were perceived to have higher impacts by community participants than expert participants or the literature; these related to new phenomenon with uncertain impacts. New phenomenon included environmental refugees, population migration and drought in regions previously resilient to reduced annual rainfall and impacts to ecosystems reliant on a specific (niche) range of weather conditions.

Impacts to farming conditions and economic influences on rural communities were also an area of concern based on future scenarios of reduced annual rainfall and carbon sequestration policies. If the economic basis for these communities was undermined through market or political forces it was said to be more difficult to adapt to climate change (Bormann, Ahlhorn & Klenke, 2012). Many of the community participants believed they had the skills and resources to prevent exposure to new risks through active adaptation and that vulnerability to climate change related to existing health conditions. As the community participants were self-selected they may have higher levels of self-determination compared with the general population.

Vulnerability of environmental habitats was of significant concern to community participants and related to loss of niche, rare and important ecological sites such as temperate forest areas, coastal dune and heath habitats. Prevention of ecological deterioration across bio-regions is difficult to address from an individual and community perspective without government and private land owner collaboration; lack of control over the risk will also increase to perception of the risk (Patrick, Capetola, Townsend & Nuttman, 2012).

Community participants in the Bridgetown meeting had a heightened fear of bushfires compared to other communities in the study. Bridgetown topography (elevated terrain) and climate contributes to the risk of rapidly moving fire fronts (both grass fires and bushfires). Part of the fear associated with fire was a perceived lack of coordinated communication and evacuation processes following a recent fire

in 2009 that burnt several houses. More frequent and intense extreme events may increase the fear and risk assessment of these events by community participants in the study area. Health impacts from the fire front could include smoke inhalation, burns, mortality, mental health impacts and damage to housing and contents (Department of Environment and Conservation, 2009; Eriksen & Gill, 2010; Government of Victoria, 2009; Strategen, 2013).

Community participants were also concerned about the trickle down effects of climate change impacts to the cost of living, especially food and how this would influence the viability of local communities with limited services. Community participants stated that maintaining existing local health services would prevent decreases to the population of smaller towns (Dodge, 2013). Distance to hospitals was reported by community participants as a barrier to equitable health care. Most community participants acknowledged that in a serious crisis affecting many people (e.g. bushfire) local emergency health facilities would be inadequate (Leveratt, 2007).

Many of the suggested adaptation options were considered unaffordable (e.g. adding insulation to existing dwellings), due to high costs of living and living on fixed incomes in retirement. Participants were genuinely engaged and concerned with issues of sustainability (waste, transport, food production, energy production) and most believed that the core risks from climate change actually related to poor long term planning of the state's resources and that this would create unnecessary risks in the future relating to scarcity. Despite the ageing population and increasing future costs of energy there were limited public transport options in the study area due to cost inefficiency. This is a barrier to accessing existing services, impacting employment opportunities and social isolation (Rosier & McDonald, 2011). This was an issue considered important by community participants as the cost of having one or two cars per household reduced disposable incomes.

The stakeholder participants that were interviewed believed that risks from climate change were likely and that primary issues for the study region related to reduced annual rainfall, energy insecurity and slow adoption of adaptation practices and

policies. Unemployed persons and those persons spending the majority of time at home (e.g. disability, or elderly residents) would also face higher energy costs as they are at home during the peak period of energy use (Chester & Morris, 2011).

A continuation of annual rainfall decline was stated by stakeholder and community participants to affect the resources industry, agriculture, increase risks for bushfires and increase costs to supplying potable water to communities. Other concerns identified by community and stakeholder participants included maintaining the quality of ecological systems (rehabilitation of local vegetation and weed management) to preserve the protective effects of functioning ecosystems. The stakeholder participants indicated that these issues would require multi-sectoral collaboration and were difficult to manage by each individual government department and that resource constraints for current obligations meant that future initiatives were difficult to fund.

Local governments have invested in climate change and sustainability policies, however some stakeholder participants believe they did not adequately address the severity of the problem or provide any real change (for instance energy policies that did not reduce energy consumption or increase efficiency) (Mukheibir, Kuruppu, Gero & Herriman, 2013). Areas that had not experienced or adapted to a drying climate (such as pasture fed cattle regions on the south coast) were considered by stakeholder participants to be more vulnerable to climate change than grain regions that were adapting to variable climates.

The expert participants involved in the study carried out a qualitative health risk assessment, the Delphi method was then applied to reach consensus to determine the severity of future impacts. A strong consensus was achieved to determine that extreme risk (risks that would result in mortality) for the study area to 2030 relate to bushfire and extreme weather events (e.g. physical risks from storms and cyclones). In contrast some of the community participants believed that with adequate preparation (distance of infrastructure from combustible sources) and timely evacuation; that the extreme risk of bushfire may be manageable provided risky behaviour did not lead to injury or death. Sensitivity to extreme events such as bush

fires was stated by participants to be based on location (close to high risk areas) with access and egress issues, and could be managed through risk reduction methods and rapid evacuation. Community participants were concerned about the management of bush fires (lack of, or excessive prescribed burning, and emergency procedures) however this was not one of the main concerns expressed regarding the future of their communities and was stated to have been managed in the past for most areas. The Victorian Bushfires Royal Commission (2009) identified that new residents to fire prone areas with little knowledge of the risks or management of bushfires face higher risks.

A medium risk with strong consensus related to ozone exposure (exceedence of daily maximum) from indoor and outdoor sources. Community participants had little knowledge of air quality factors and how air toxics could affect their community particularly in the context of existing respiratory or cardiac conditions (that are likely to increase in future) and are associated with lifestyle disease and ageing. Stakeholder participants involved with emergency management of fires had stated health risks associated with fires (peat fires).

In order to reduce risks from ozone from outdoor and indoor sources (such as off gassing from fixtures and fittings) a clean air environment can be created with filtration and ventilation, along with lowering the indoor temperature to achieve a level of comfort (Weschler, 2006). Community surveys indicated that while improving the thermal efficiency of dwellings was a factor that was considered important, 55% would install insulation, and 25% would install an air conditioner, this would leave a large percentage of homes exposed to higher levels of indoor heat along with air toxic risks. There are currently Australian Standards (5601 and 1859) to manage some of these issues however in older dwellings, or dwellings with older gas and wood cooking and heating appliances, the risks will be higher for exposure to harmful gases and particulate matter (Department of Environment, 2001).

Physical risks associated with extreme weather include excess morbidity and mortality. Adaptation to climate change risks include behavioural or structural methods to prevent exposure, reduce or control the impacts, or rapidly recover

following exposure. Adaptation methods can be soft (policy, behaviour, reversible); or hard (infrastructure, technology, fixed). Individuals employed by government institutions that were interviewed stated that existing cost stressors prohibited investment in adaptation activities. Addressing climate change adaptation at the community level would rely on human resources, donated funds, skills and resource sharing and community development to reduce vulnerability across the region (Burton et al., 2002; Buys, Miller & van Megen, 2012).

High risk areas (e.g. peri-urban bush fire risk regions) and remote communities with limited facilities would have to increase individual, community and environmental resilience in order to decrease vulnerability. Community members with social and economic restraints (e.g. unemployment, poor housing, existing health issues and disability) would be at the highest risk (Mallon, Hamilton, Black, Beem & Abs, 2013). Risks identified by the expert participants mirrored that of the literature review, whereas the stakeholder participants made up of government and non-government stakeholders were able to apply the future risk scenarios in the context of specific risk factors for various local government areas.

Community participants contextualised risks that in some instances differed from the judgements of expert participants based on personal experience with emergency management and infrastructure/property management. Experts have a role to play in identifying gaps in risk management overlooked at the local level, in this case air quality factors. Community participant knowledge is important in identifying specific cases of vulnerability and the local resources that can manage these issues (Zaksek & Arvai, 2004).

### **7.2.2 Objective Two**

**Assess the potential positive and negative impacts on health of climate change in the region.**

In the course of the study a number of positive and negative health impacts of climate change were identified following the literature review, focus group meetings (n 48), stakeholder participant interviews (n 19), expert panel review (n 9) and

through community surveys (n 51). The focus group meetings attracted a variety of community members from farmers, professional fishermen, nurses and retirees. The risk assessment of the positive and negative health impacts took place when expert participants agreed (gained consensus) on the health risks by rating the negative health impacts using qualitative risk rating procedures. Two rounds of consensus making were used to prevent drop out from a small group. The stakeholder participant group that participated in semi structured interviews included a variety of government and non-government agencies. Random sampling methods were used to obtain participants for the community surveys.

#### **7.2.2.1 Focus Group Evaluation – Community Participants**

Some of the positive health impacts assessed by the community participants included more opportunities for recreation due to warmer weather, and more opportunities to explore different forms of cropping and horticulture with longer growing seasons. While some of the future scenarios indicated small changes to rainfall and mean temperatures in the short term that were perceived to be manageable, overwhelmingly the changes were considered negative (due to ongoing damage to the ecological basis for the communities). Participants in the community evaluation based their judgements on past experiences and knowledge of the current status of the environment, successful agriculture and existing health problems in the communities.

Some community participants reported a lack of trust in government policies being developed to address long term issues and provide continuity for rural and regional communities, as short term policy-making was said to have undermined development in the past. Policies relating to carbon trading and carbon sinks were viewed by some community participants as an added threat to future agricultural viability (Sjoberg, 1999). Some community participants stated they had experienced bushfire events in Bridgetown and in the Shire of Manjimup. These events were stated to be potentially life threatening, with communication and coordination of the emergency response possibly heightening the risks (e.g. lack of timely warning).

Community participants were more interested in the widespread economic, environmental and social factors (indirect impacts) influencing their lives as a result of climate change; and how this would affect health. This included losses or changes to agriculture, loss of water supply for human and environmental needs, damage to infrastructure, lack of medical staff or facilities, disruption and costs of energy (for heating and cooling homes) and environmental impacts from bushfires and other types of damage to pristine and rare ecosystems (UNFCCC, 2009).

These risks were judged to have higher overall impacts than one off emergency events, however were difficult to manage long term by individuals or communities. Multisectoral risks with poor collaboration were viewed as having more catastrophic health impacts by the community participants as they would ultimately deteriorate quality of life. When considering direct impacts of climate change to the health of community members, many participants indicated that there was a shortage in health services relating to the number doctors and hospital facilities. This increases disadvantage and vulnerability; for example in the occurrence of an extreme weather event with associated injuries or potential fatalities, long distance transfers to urban hospitals decreases health outcomes (Purcell & McGirr, 2014). Some participants believed some of the positive benefits of climate change, e.g. increased tourism months and longer growing periods due to warmer weather would be counterproductive to carbon mitigation goals and may leave tourism dependant economies vulnerable (Brown & Ulgiati, 2011).

Community participants that were farmers expressed concern relating to both direct impacts of weather and government policy that could increase difficulties in making a living off the farm, likely resulting in more areas being turned into carbon sinks and further reducing viability of local businesses and the population of towns. Some farmers also stated that the high cost of operating with low return meant that in the future the cost of food would rise and that the scale of operations would have to increase to remain competitive. For fishing and marine industries community participants (including professional fishermen) stated that they had witnessed a decline in cold water fish species and riverine species over the course of their careers

and had concerns about the future viability of the fishing industry and the impacts to tourism.

Participants directly involved with conservation activities reported changes to bird and amphibian populations that they believed were related to the shifting of the seasons and reduced annual rainfall across the South West region. Increased climate variability and reduced runoff groundwater inflow would further degrade these ecosystems.

#### **7.2.2.2 Expert Evaluation of Impacts**

Expert participants reached some consensus of the risks of potential health impacts in the study area using the qualitative health risk assessment process and applying the Delphi method in a series of decision making rounds. In order of high to low risks the expert participants concluded the following potential health impacts were of most concern; bushfires (and other extreme weather events) and exposure to the air pollutant ozone. Weak consensus for health risks from the expert participants were for the following; exposure to particulate matter (air quality factors), UV exposure, population migration, increase in vector borne disease, reduced physical activity and reduction in food supply. Based on the expert participants' consensus, the focus for adaptation for 2030 should be based on extreme weather events (including bushfire) and air quality factors associated with summer temperatures and pollution (ozone). Some baseline data in the Manjimup region indicates that even in a bushfire situation ozone measurements did not exceed the standard in some rural areas (outdoors). With a weaker global atmospheric circulation due to climatic change, increased heat and higher likelihood of bushfire events, this may not be the case in future (Meyer, et al., 2008; Jacob & Winner, 2009).

Air quality factors relative to indoor and outdoor air exposure are location specific (modulating influence of the ocean, dwelling type and quality). Smog alerts and other air quality alerts are usually focussed towards urban communities. Understanding of seasonal, behavioural and climatic influences on air quality is required by individuals to prevent exposure (e.g. storms distributing aeroallergens during peak flowering periods). Non-coastal communities often experience higher temperatures than coastal communities and will potentially be exposed to a greater

concentration of air toxics. Dwellings that provide little protection from heat (lack of insulation or air conditioning) will increase the occupant's exposure to environmental ozone at ground level and from fixtures and fittings that emit ozone in high temperatures (Chen, Verrall & Tong, 2006; Salisbury & Ferrari, 1997).

### **7.2.2.3 Stakeholder Participant's Evaluation of Risks**

The stakeholder participants evaluated future risks from climate change by describing current environmental and budgetary concerns in the context of increasing environmental degradation in a drier climate with more temperature extremes and variability. Stakeholders contacted worked in the fields of social services, water management, planning, insurance, emergency management, climate change and environmental restoration. Risks identified were associated with insufficient or inappropriate adaptation responses to reduced annual rainfall and increased energy demands. The south coast area (Walpole to Denmark) was described as vulnerable for a number of reasons.

Future planning to avoid risks e.g. from inappropriate development (housing or watershed) were also key areas of future vulnerability. Examples were housing developments with low standards for insulation or solar orientation to decrease energy costs, or inappropriate landscaping design with high water use. Some local government groups have developed a number of sustainability objectives and policies in order to adapt and mitigate climate change risks (relating to water and energy efficiency and re-use options).

Lack of expenditure on maintaining infrastructure (for example roads and bridges) is a current concern, particularly in sparsely populated regional and rural local government areas that will experience more intense weather patterns (Engineers Australia, 2010). Any changes to the frequency and severity of extreme weather events may challenge government resources and affordability of insurance, along with the psychological challenges of living in a more threatening environment and recovering from emergency events. Increasing resilience to climate change through psychological preparation is one area that has been given little attention but was identified by a number of stakeholder participants; readiness for both a loss of environmental habitats and unexpected climate change surprises were both

considered likely future challenges. Reliance on government action (stated by many participants to be lacking) or global action is increasing the vulnerability of local communities. At the same time lack of top down approaches to manage climate change is encouraging new groups to form such as the Transition Towns movement that deal directly with climate change issues (Levac, Toal-Sullivan & O'Sullivan, 2012; Sullivan, 2008).

Rural and regional areas have a heavy reliance on volunteers to manage emergencies; these individuals may be exposed to risky situations compared to urban residents, and be undervalued by state emergency personnel (Berry, Bowen & Kjellstrom, 2010; Birch, 2011; Booth & Williams, 2012). One stakeholder group participant stated that in risky conditions there would be many indefensible properties due to enhanced bushfire risk and access issues, local bushfire brigades may not have the capacity to protect rural infrastructure.

Having adequate supplies of water for domestic, industry and agriculture uses was a common risk factor of concern amongst all stakeholder participant members. Genetically modified organisms (GMOs) were one example of a technological adaptation to drier conditions for cropping in wheat belt communities (Australian Academy of Technological Sciences and Engineering, 2012). In contrast, community participants stated that increasing the use of perennial deep rooted plants and increasing humus and ground cover (mulch) would decrease water requirements and that GMOs had low consumer confidence with the potential for unintended environmental issues. The south coast area was viewed as being vulnerable to a future drying climate by stakeholders due to lack of adaptation experience with variable climates, when compared to more marginal areas. Pasture fed beef cattle would have higher vulnerability than sheep farmers in marginal areas. One non-government organisation used philanthropic funds to purchase farming land and revegetate these areas for environmental benefits; another described the land rehabilitation work that was needed to increase resilience in the landscape by tackling weeds, pests and feral animals.

#### **7.2.2.4 Community Survey - Evaluation of Impacts**

Participants that completed the mail out survey were mainly interested in upgrading domestic water supplies through the installation of water tanks, along with installing photovoltaic cells on their dwellings to manage future impacts of declining water availability and carbon mitigation. While this was a preference, it was also viewed as a major expense, especially for those persons on a fixed income. Government assistance was suggested as a way to overcome the financial burden. There is an opportunity for innovation in the private sector to develop more affordable products that will assist with energy use and reduction in water use. When questioned about willingness to pay money towards climate change adaptation, participants would be more likely to spend more money on community projects that would provide future payoffs to benefit their community (such as water and energy projects), than on individual projects on personal dwellings.

#### **7.2.2.5 Risk Assessment Summary**

The risk assessment component of the rHIA provides a clear and transparent methodology for qualitatively estimating the likely risks and rating them in order of likely severity of impacts. The expert participants focussed on extreme risks for this rural area by 2030; however the community participants focussed on unmanageable risks as a result of behavioural, economic and structural failures. Many of the community participants had experienced disaster events in their community and had confidence they could cope with these existing risks, even if they intensified. However new risks associated with water, energy and global security (including human migration) were seen as more threatening.

The rHIA process reveals local community concerns more succinctly than a desktop risk assessment and taking local concerns into account requires multisectoral collaboration and responses across all government and non-government sectors, along with engagement with private landholders. There is an agreement across all areas of data collection points (community and expert participants) that water availability and quality will be a fundamental challenge in the region by 2030, with the associated health effects (Clarke, 2010; McFarlane, 2009; McFarlane et al., 2012).

Expert participants reached consensus on health impacts that have potential for excess morbidity or mortality as being a priority for action. Community participants were concerned with the economic and environmental consequences of climate change, with resource constraints limiting the provision of adequate adaptation (indirect impacts to health). This includes future service gaps (scarcity) or increased expenses in service provision, including water and energy. Some rural and remote communities have lower socio-economic statuses than their urban counterparts, along with poorer health outcomes so maintaining economically viable communities is an important component of protecting health (National Rural Health Alliance, 2011a).

### 7.2.3 Objective Three

**Use qualitative health risk assessment methods to analyse the likelihood and magnitude of the identified human health impacts to determine priorities.**

Adaptation strategies that focus on the highest level of health risks from climatic factors by the year 2030 would focus on extreme weather events, bushfires and air quality factors. This is based on the expert participant's assessment, with consensus given to the most likely and most extreme impacts. In order of priority for action, preventative or anticipatory methods from both private and public groups that eliminate exposure to harm (particularly those with little or no costs) form the focus for action, followed by increasing resilience to cope with the increased scale and intensity of extreme events. Finally, allocating adequate resources to recover from an emergency event, including adequate insurance coverage, personnel and funds is important to return to business as usual following any disaster (Klein, Nicholls & Thomalla, 2003).

Extreme weather events are managed by various local governments, Department of Parks and Wildlife, Department of Environment, Department of Fire & Emergency Services, Department of Health, the Western Australia Police, individuals and community groups, and local bushfire brigades. There are currently poor levels of both insurance and emergency preparation in Western Australia which increases

risks during and after extreme weather events (Australian Government Productivity Commission, 2013; Burke & Gridley, 2013).

To improve indoor air quality, reducing exposure to high summer temperatures that are associated with air toxics is achieved by controlling or modifying indoor air quality and temperatures. This can be achieved through infrastructure retrofitting, technology or increasing tree coverage to improve shading. From a business or household perspective low returns on investment for adaptation (due to uncertainty and other current fiscal priorities) mean that adaptation is more likely amongst high income groups with higher disposable incomes. Identifying and assisting vulnerable groups during a bushfire or heat wave for example is one of the priorities for action to avoid exposure to climate change impacts (both direct and indirect) (Bateman et al., 2005; Remoundou & Koundouri, 2009).

Prioritising state government resources to identify the impacts and responses to future reduced water availability is one area described by stakeholders as having high importance for continuity and sustainable development. In order to facilitate rapid change within communities, legislation may be the most effective mechanism (e.g. mandatory installation of domestic-scale water tanks for new dwellings) (Hansen, Bi, Saniotis & Nitschke, 2013; Llosa & Zodrow, 2011; Pricewaterhouse Coopers, 2010).

#### **7.2.4 Objective Four**

**Develop, through discussions with stakeholders, the research participants, and a review of the literature, potential adaptation measures/interventions and strategies to minimise the potential risks of the identified human health impacts and the severity of those impacts.**

Adaptation methods that have no or low costs and can be implemented over time to increase resilience to climate change variability and extremes, are cited in literature as being the most efficient insurance for future outcomes (Lal, 2011). These adaptation measures would require improvement in skills and knowledge, and living conditions for community members to realise any benefits. As the survey participants typically stated they would spend only less than two per cent of their income per

annum on adaptation, small changes to improve thermal efficiency and reduce energy and water use would more likely occur very slowly on a room by room basis. Behavioural change to reduce demand for these resources is a priority prior to expenditure on upgraded fixtures and fittings (Brandt, 2013; California Department of Public Health and the Public Health Institute, 2007; McFarlane et al., 2012).

Another factor for priorities of action was to determine what adaptations should be 'wait and see' or reactionary in order to avoid high upfront costs associated with investing in infrastructure, such as gradually upgrading drainage and roads according to changing conditions may form a cost saving approach. When identifying effective strategies for climate change adaptation, a mix of adaptation methods may prove most cost effective. For example, improving extreme weather preparation (heat wave management) in communities, training and education, along with retrofitting existing buildings or ensuring vulnerable persons have access to, and are aware of cool retreat facilities (Snow & Prasad, 2011). These methods better utilise existing facilities and identify potentially vulnerable groups prior to a health hazard occurring and can in many ways build community resilience.

Where evacuation is not possible due to location or timeliness, bunkers were considered a viable alternative by some community participants; however the safety standards, cost and durability of such alternative dwellings are not completely reliable (Australian Government Productivity Commission, 2013; Holm, Stauning & Sondergard, 2011; The International Bank for Reconstruction and Development/The World Bank, 2010).

The survey participants preferred expenditure to be directed to providing water and energy security for the future, even though the pay-off may not be cost effective. One stakeholder interviewed specialised water resource management in the southern coast area and indicated that future water security is jeopardised due to over-allocation of a dwindling supply and this is also supported by evidence in the literature (McFarlane et al., 2012). Reducing water use, increasing efficiency, enhancing water storage or catchment facilities have variable costs. Solar energy, via photovoltaic cells was considered highly desirable by participants, however when factoring in the money

available for such measures, it is clear that most households would not be able to afford energy or water adaptation without rebates or other assistance. Further, much of these adaptations are not cost effective, in some cases Jevons paradox was mentioned by a stakeholder as increasing energy use overall despite increases in renewable energy sources (York, 2006).

Landscape retrofitting has the advantage of relatively low costs for high benefits; in one study by planting three extra trees per dwelling reduced energy use by up to 57% (Ferrante, 2012). This is particularly relevant for inland areas such as Nannup, Bridgetown, Boyup Brook, Cranbrook and Plantagenet that experience higher daily summer averages and have lower mediating influences from ocean breezes. Industry and transport sectors use a larger share of energy compared to households; significant progress must be made by these businesses and organisations to increase efficiency and reduce consumption (ABS, 2012c). When examining the risks with the highest risk rating (heat wave impact/extreme rating) a no regret adaptation would include increasing shading of the dwelling or building with deciduous tree coverage (Dave, Varshney & Graham, 2012; Grantz et al., 1998).

Dense tree cover reduces risks associated with UV exposure outdoors and tree cover in farming systems can reduce heat impacts to livestock. Increasing tree cover or 'green belts' helps to join up fragmented landscapes that can improve species migration. Tree selection can include less flammable deciduous trees (Chagolla, Alvarez, Sima, Tovar & Huelsz, 2012; Queensland University of Technology, 2010). In some instances indoor and outdoor air quality may be very poor and in the case of bushfires; if private dwellings are unable to provide a safe 'clean air' environment, local community centres, or voluntary evacuation may be an option (these costs are low when compared to medical intervention).

In order to reduce the health impacts of air borne particulates, ensuring the population is healthy by reducing or eliminating lifestyle diseases will reduce the health burden associated with air pollution, e.g. COPD and heart disease (Johnson, 2014). Low or no cost methods to reduce the risks of lifestyle disease can include improving diets by consuming a variety of fresh produce and supporting nutritious

and healthy cooking with adequate physical activity (such as walking or gardening). Consuming locally produced and freshly prepared whole foods will also reduce health risks associated with labelling and spoilage issues provided adequate care is taken with food handling. Training and education on these matters (safe food handling) is another low cost intervention that will benefit the whole community (Knowl, 2012). Specific methods of adaptation that may have associated costs but have the highest risk rating according to the expert participants are detailed below.

#### **7.2.4.1 Extreme Weather Adaptation**

To manage the risks of extreme weather including bushfire, storms, drought and flooding, government agencies can focus on preventative activities. These include biomass reduction (prescribed burning), monitoring private properties for risks and ensuring adequate funding and resources for training and personnel. Preparation for extreme weather events includes having a bushfire survival plan, first aid training, and an adequately prepared property and household. As up to 50% of households are unlikely to have adequately prepared for a disaster; evacuation provides more protection for vulnerable individuals. Other ‘soft’ adaptation methods include having passive water harvesting and flood mitigation, back up water supplies and adequate tree coverage to reduce wind and flood damage (Dwyer, Gunnery & Shepherd, 2009).

Evacuation responses and early warning systems will have limited effectiveness in a rapidly moving fire front or widespread devastation. Identifying local safe places for evacuation is dependent on the fire conditions and transportation options. A community education program for new residents to fire prone areas could incorporate a site visit by the local bushfire brigade or local government officers in order to improve bushfire preparation. Reassessing stay and defend mechanisms in light of the Victorian Bushfires experience may encourage unprepared residents to leave early as a preference to the potentially unexpected psychological and physical risk associated with defending a property (Australian Red Cross, 2013; Burke & Gridley, 2013; Victorian Bushfires Royal Commission, 2009). As a guide for more costly infrastructure adaptation, dwellings built between 1920 and 1940 should adapt to expected climate changes up to 2030, dwellings build after 1950 should aim to adapt to climate change expected in 2070 (Snow & Prasad, 2011). The costs are highly

variable depending on location, size and quality of building type and likely lifespan of the building.

Community preparation for extreme events could be coordinated by multiple stakeholders to increase resilience and encourage community development. An example is having a local and adequate food bank, community transportation networks (voluntary or fee for service) and emergency funds or no interest loans for restoring water supplies to dwellings. Communication during extreme events is critical to ensuring correct information and protection of vulnerable groups occurs. Adequate insurance will reduce pressure on supporting agencies following a crisis (Australia Building Codes Board, 2014; Hegney et al., 2007; Kuruppu & Liverman, 2011).

#### **7.2.4.2 Adaptation to Diminished Air Quality**

Exposure to air pollutants is more likely to occur in summer when ozone reaches greater concentrations due to pollutants and high temperatures producing toxic compounds (particularly late afternoon). Conditions such as strong winds and bushfires can increase particulate matter and pollen in outdoor air and contribute to ill health. Indoor and outdoor air quality can lead to health affects depending on wind, season, quality of housing, fixtures and fittings, thermal control, insulation and existing health issues. Adaptation to air quality can be managed through some behavioural factors (avoidance), landscaping and housing retrofitting and evacuation to clean air environments (where required).

As people spend a majority of their time inside, improving indoor air quality is a major concern in the future, with little guidance or research advising builders or householders on how to minimise health effects from air quality factors (Public Health Agency of Canada, 2013; Takaro, Knowlton & Balmes, 2013). Keeping humidity low inside dwellings through the use of effective ventilation, insulation and outdoor shading will decrease the impacts of VOC's and other air toxics (within the range of between 30% and 60% humidity) and increase thermal comfort. Ideal temperature ranges are between 23<sup>0</sup>C and 25.5<sup>0</sup>C for low humidity (30%) and 23-25.5<sup>0</sup>C for high humidity (60%) (Canadian Centre for Occupational Health and Safety, 2005). Improving the thermal performance of rooms or buildings through

insulation or shading reduces vulnerability during power outages in heat wave conditions (Garnaut, 2008; Palmer, et al., 2013).

#### **7.2.4.3 Embedding Climate Change in Future Planning**

Embedding climate change in all decision making in government and non-government groups will ensure that consideration of variable weather, diminished water supply and the increased likelihood of extreme weather events to ensure long term sustainability. Extreme weather events are not currently well prepared for at the household level and this needs to be enhanced in future through adult education, community development and health promotion principles. Early preparation will provide benefits to households despite the severity of climate change. Focussing efforts at low income households, persons with existing health conditions and marginalised groups (fixed income and homeless people) will target efforts to the most vulnerable (Smit & Wandel, 2006).

#### **7.2.4.4 Building Community Resilience**

Climate change targeted community development is a specific approach to improving the welfare of local communities in the context of climate change impacts (direct and indirect). Undertaking a needs assessment, identifying vulnerable groups, and targeting programs to improve the health and wellbeing of these groups can be achieved in partnership with other agencies. This can be run through local government or non-government organisations or by multiple stakeholders with the objective being to reduce vulnerability to extreme weather events, improve air quality and decrease the impacts of lifestyle disease. Building social capital and decreasing social stratification are soft adaptation methods to increase partnerships within communities and decrease reliance on external agencies in a crisis situation (Davoudi et al., 2012).

### **7.2.5 Objective Five**

**Review and assess the possible adaptation strategies in terms of who is or would be best placed to action them at local/district, state and national levels.**

The evaluation of the adaptation strategies in terms of potential action has been achieved through analysis of the data from community and expert participants, along

with the literature review. Costs of adaptation strategies will be reduced where global mitigation objectives can be agreed on to minimise environmental damage. Much can be achieved with a coordinated and targeted approach to preventing exposure to health impacts with a particular focus on vulnerable groups (Stern, 2007; Spickett, Brown & Katscherian 2008).

#### **7.2.5.1 Adaptation to Thermal Changes**

As most of the population spends the majority of their time indoors, sound approaches to improving thermal efficiency of dwellings, schools and workplaces are required to prevent exposure to heat extremes and poor air quality. Government agencies can assist in improving the insulation standards of dwellings through research and advice, legislation relating to energy rating and by providing local cool retreat facilities in the event of a heatwave. Identifying and protecting vulnerable groups such as homeless persons and by utilising existing infrastructure e.g. community buildings to decrease reliance on health services. New dwellings should be built to cope with higher global mean temperatures for the lifespan of that building. Parks and gardens and green spaces can be managed to ensure sufficient tree coverage and shading particularly in regional towns with densely spaced dwellings or towns with hotter climates such as the Wheatbelt areas (Bambrick et al., 2011; Dave, Varshney & Graham, 2012; Zeppel, 2011).

#### **7.2.5.2 Adaptation to Variable Precipitation and Water Scarcity**

Government led research for appropriate management of variable rainfall and drought conditions with ongoing training and support for farmers was said to be desirable by community participants. Managing increasing demand for water with a reduction in supply may be a major challenge for governance to 2030 (McFarlane, 2009; McFarlane et al., 2012). Water recycling is currently cost ineffective, in future it may be considered an affordable option if water scarcity increases. It is cost effective to upgrade appliances and fixtures to be more water efficient within dwellings and businesses; this can be promoted in new housing design through the Australian Building Code. Water sensitive design planning should be managed by state and local government and should take into account riverine health, land clearing, flood management, land use objectives, fragmented landscapes and

groundwater extraction (Arnell & Delaney, 2006; Hanak & Lund, 2012; McCaffree, 2008).

#### **7.2.5.3 Extreme Weather Adaptation**

Non-government agencies that are ancillary to the work of the government are of great importance in these communities when responding to emergencies (e.g. Australian Red Cross, Royal Flying Doctor Service and St John Ambulance). Other active NGOs following disasters include the Good Samaritans, St Vincent de Paul, and many others (Government of Western Australia, n.d.). Focussing on prevention prior to emergency should be a major focus for many of these groups; e.g. emergency preparation and community development, increasing the numbers of trained first responders, food banks and similar projects. Local government plays a role in managing bushfire safety on privately owned lots. State and local government planning decisions can prevent unnecessary fire risks through appropriate housing developments in regional areas (Australian Building Codes Board, 2014; Australian Red Cross, 2009; Balcombe, 2007; Safi, Smith Jr. & Liu, 2012).

Industry, community and individuals will need to calculate cost effectiveness for upgrading dwellings and infrastructure to cope with more intense storm conditions and other impacts. Community participants stated that hospital staff and facilities would be insufficient to cope with major disasters in small communities due to the number of hospital beds, medical personnel and distance to major hospitals, which increased the risks to patients. The Australian Federal Government has historically offered assistance to persons and businesses suffering from damage from extreme weather events (where a state of emergency is declared), these funding mechanisms may be challenged if the intensity or frequency of events increases (Barratt, Pearman & Waller, 2009; Garnaut, 2008).

#### **7.2.5.4 Vector Borne Disease Adaptation**

The Australian Federal Government is currently managing bio-security and vector borne disease threats through state and local government and will continue to adapt to changing regimes of biological threats provided adequate resources are available. Persons living in substandard housing or homeless persons may be more vulnerable to vector borne illness. Health promotion activities can focus on these groups to

prevent health impacts (Commonwealth of Australia, 2010a; Rocklov & Wilder-Smith, 2011; Smoyer-Tomic, Kuhn & Hudson, 2003).

#### **7.2.5.5 Air Quality Adaptation**

The federal and state governments may need to enhance air quality through stricter emissions standards (industrial, wood heaters, vehicle), along with increasing the availability of public transportation. Rural and remote areas have less access to public transport due to the cost-effectiveness of providing these services. Lack of public transport is an area of disadvantage for rural and regional residents. The multiple sources of air quality pollution (pollen, smoke, particulate matter, chemical sprays etc.) are location and season specific and need to be self-managed by individuals to avoid exposure. All levels of government can encourage and adopt green building methods to improve indoor air quality. Increasing tree coverage in public and private lots can be encouraged by government groups (Jacob & Winner, 2009; Xu et al., 2012; Yu, 2011).

#### **7.2.5.6 Species Migration Adaptation**

The state government can assist this process by increasing the number of no-take areas in marine parks to ensure protection to vulnerable species. Terrestrial species can be protected through creating corridors of bushland by joining up fragmented landscapes and restoring wetland or riverine environments (limiting pollution, salinity and so on). Multiple stakeholder collaboration (government and non-government) cooperation will be required to achieve these outcomes over a large scale. This will likely have high costs (loss of farming productivity) with little immediate obvious benefit, however will enhance biodiversity values in the longer term (National Climate Change Adaptation Research Facility, n.d.).

#### **7.2.5.7 Food and Nutrition Adaptation**

All tiers of government can take action to ensure that valuable farm land is not depleted, or built over through appropriate planning policies. Supporting sustainable agriculture requires appropriate consumer choices and government policies that reinforce the value of locally grown produce and livestock, and supports farmers. Appropriate action to achieve this is to target health promotion and food access to vulnerable and marginalised groups, non-government agencies can participate in this process. As over 50% of adults are overweight or obese, the importance of

consuming locally grown fruit and vegetables should be emphasised (National Rural Health Alliance, 2011a; National Rural Health Alliance, 2011b).

#### **7.2.5.8 Limitations to Adaptation**

Community participants stated that limitations to adaptation related to a lack of resources to carry out adaptation activities, and increased sensitivity to climate hazards due to location and terrain e.g. lack of escape routes in a bushfire event in densely forested areas. Literature relating to limitations to adaptation describes the physical, social and cognitive constraints that limit the ability to use future scenarios to meet the challenges of climatic changes and new risks by the year 2030 (Huang et al., 2011; Raymond & Spoehr, 2013). Government stakeholders have reported that limitations to adaptation were based on resources (monetary and future water scarcity). Persons with high vulnerability to climate change include the elderly, disabled, mentally ill, pregnant women, young children and infants. As discussed in the Literature Review in Chapter Two, rural areas will often have a higher proportion of the population with substance abuse and mental health issues compared to urban areas, particularly amongst Indigenous populations (National Rural Health Alliance Inc. 2011a). Persons living in substandard housing in remote communities have higher sensitivity to climate change impacts, particularly marginalised or socially isolated groups. Other groups in the population with greater sensitivity to climate change impacts include children, persons with low coping ability or mental illness, and those persons with a low income (Bartlett, 2008).

#### **7.2.6 Future Directions and Research**

This research used multiple data sources and collection methods to better understand the future vulnerability, sensitivity and adaptive capacity of the Blackwood Stirling region to climate change impacts to 2030. HIA is an important approach to identifying, evaluating and managing health impacts from climate change for future populations. HIA methods can be used in any nation-state and can incorporate climate change modelling scenarios for future temperature, rainfall and other factors. The scientific community is in agreement that climate change is occurring and will have greater negative consequences with associated health impacts in the absence of mitigation or adaptation. Adapting early is likely to provide future cost savings

through reducing health impacts (and associated risks). Focussing on soft adaptation methods will provide future benefits and contribute the least to carbon emissions. The uncertainty of the severity of climate change presents a novel challenge to health planning, however it is likely that future risks to health will be synergistic with lifestyle and mental health co-factors (Heyhoe, et al., 2014; Hayhoe, et al., 2004). Future research can focus on technology, engineering and social strategies to prevent exposure to extreme weather and air quality factors. Indoor and outdoor air quality should be monitored to develop a baseline for future health impacts, with strategies and technology to avoid exposure, mitigate harmful particulates and gases and improve health and wellbeing (Knowlton et al., 2004; Maryland Department of Natural Resources, 2008).

### **7.3 Conclusion**

This dissertation used HIA, its procedures, processes and methods to identify the positive and negative health impacts of climatic change to a geographical region in the South West of Western Australia to the year 2030. Adaptation methods were analysed and proposed for individuals, communities, government and non-government agencies to prevent, cope and recover from climatic events and changes. Costs and benefits of various adaptation strategies were examined through a literature review, surveys, interviews and community focus groups. Future risks identified by expert participants as being significant were extreme weather, bushfires and air quality factors. Community participants that participated in the surveys and focus groups were more concerned with the economic, social and environmental risks that they were unable to manage. There are multiple barriers to successful adaptation that relate to access to resources, more immediate priorities, high upfront costs with potentially low benefits and uncertainty of climate change scenarios. It is likely that reduced annual rainfall and temperature change will influence the health of ecosystems in future; with strong leadership and strategic collaboration required across multiple government and non-government agencies to manage and protect natural resources. Industry adaptation and leadership could have significant positive benefits to reduce water and energy demand, with individuals having collective purchasing and decision making power to mitigate carbon and restore the landscape. Adaptation methods in future need to address vulnerability, mitigate negative health risks and provide value for money; evidence in the literature states that early

adaptation provides the most benefits. Soft adaptation methods that are win/win are the most advantageous methods to adopt (Stain et al., 2011; Stern, 2007).

Adaptation in rural areas faces specific barriers of cost, low coverage, and a higher burden of chronic disease and vulnerable population groups. Adaptation in rural areas has equity considerations as these communities have significant gaps in services and economic opportunities compared to urban areas. Community development, enhancing social capital and disaster preparation will have immediate and future benefits for all communities in the study area. This study can be used for future decision making regarding adaptation for all groups with an interest in the Blackwood-Stirling region (Buys, Miller & van Megen, 2012; National Rural Health Alliance Inc., 2009b).

## **Glossary of Terms**

### **Adaptation**

“Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, autonomous and planned” (Intergovernmental Panel on Climate Change (IPCC), 2007, p. 76). Hard and soft adaptation strategies differ. Hard adaptation methods refer to higher cost, inflexible and longer term strategies; soft adaptation refers to less expensive, flexible and natural strategies (Sovacool, 2011).

### **Adaptive Capacity**

“The whole of capabilities, resources and institutions of a country or region to implement effective adaptation measures” (IPCC, 2007, p. 76).

### **Climate Change**

“Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer... The United Nations Framework Convention on Climate Change (UNFCCC)... defines climate change as...a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods” (IPCC, 2007, p. 78). This rHIA refers to anthropogenic climate change.

### **Climate Scenario**

“A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change” (IPCC, 2007, p. 78).

### **Exposure**

Exposure refers to being unable to avoid something harmful. This could include the human population and their livelihoods, environmental services, resources and

infrastructure. Economic, social and cultural assets may also be exposed to climate change hazards (IPCC, 2012).

#### **Hazard**

The IPCC defines a hazard as “the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources” (IPCC, 2012, p. 560).

#### **Health**

Health is referred to using the World Health Organization definition “a state of complete mental, physical and social well-being, not merely the absence of infirmity or disease” (World Health Organization, 1946).

#### **Potential Impact**

Impact refers to potential “effects on natural and human systems...of physical events, of disasters and of climate change” (IPCC, 2012, p. 561). Direct impacts may include exposure to higher summer temperatures (such as extended heat waves) that result in heat stress. Indirect impacts may include reduced agricultural output of cereals in southern latitudes that may contribute to reduced food supplies and nutrition (Garnaut, 2008).

#### **Resilience**

“The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions” (IPCC, 2012, p. 563).

#### **Risk**

Risk refers to the potential for harm to occur following exposure to a hazard (IPCC, 2007). “Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur... for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and

infrastructure” (IPCC, 2014, p. 127). For the purposes of this rHIA, risk refers to potential harm to human health as a result of climate change.

#### **Sensitivity**

“Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or climate change. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea level rise)” (IPCC, 2007, p. 86).

#### **Susceptibility**

Susceptibility refers to the degree to which a system is openly sensitive to climate hazards and may result in damage if exposed to a hazard. Susceptibility may relate to natural or manmade systems and its inhabitants (IPCC, 2007, p. 885).

#### **Vulnerability**

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity (IPCC, 2012, p. 564).

## Chapter Seven - Bibliography

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## **Chapter Eight - Appendices**

### **Appendix 1.0 Focus Group Questions**

1. Have you observed or heard of any changes to climate in the last three decades?
2. How might climate change influence your lifestyle?
3. What benefits and opportunities will a changing climate bring to you and your community?
4. What impacts from climate change have you identified?
5. How might the impacts of these changes affect how you feel about yourself and your environment?
6. What could be done to increase benefits, or reduce negative effects?
7. What presents the biggest risk to your community in terms of costs?
8. And potential harm?
9. Of the risks identified are there any that cannot be readily managed?
10. What sections of the community may not be able to manage emerging risks?

### **Appendix 2.0 Semi Structured Interview Questions**

1. What is your organization doing to prepare for the future climate and demographic up to 2030?
2. What is the extent of adaptation in practise and what are the barriers, obstacles or incentives to adaptation?
3. To what extent have stakeholders (including those at risk) been involved in the policy development process?
4. What are the costs of adaptation and what benefits can be anticipated?

### Appendix 3.0 Sample Size Calculation

Adapted from (Israel, 2013).

Blackwood Stirling (population 39,268)

$$SS = \frac{Z^2 \times (p) \times (1-p)}{C^2}$$

Where:

SS = Sample Size

Z = Z-value

(e.g., 1.96 for a 95 percent confidence level)

P = Percentage of population picking a choice, expressed as decimal

C = Confidence interval, expressed as decimal (e.g., .05 = +/- 5 percentage points)

$$SS = \frac{1.96^2 \times (0.05) \times (1-0.5)}{C^2}$$

$$SS = \frac{3.8416 \times 0.5 \times 0.5}{0.0025}$$

$$SS = 384$$

Sample size for a finite population less than 50,000

Where:

Pop = Population

$$\text{New SS} = \frac{SS}{\left(1 + \frac{(SS-1)}{\text{Pop}}\right)}$$

$$\text{New SS} = \frac{384}{1 + \frac{(384-1)}{\text{Pop}}}$$

$$\text{New SS} = \frac{384}{1 + \frac{(384-1)}{39,268}}$$

$$\text{New SS} = \frac{384}{1 + \frac{(383)}{39,268}}$$

$$\text{New SS} = \frac{384}{1+0.009753}$$

$$\text{New SS} = 380$$

Sample Size Calculation Greenbushes (population 375)

$$\text{New SS} = \frac{384}{1 + \frac{(\text{SS}-1)}{\text{Pop}}}$$

$$\text{New SS} = \frac{384}{1 + \frac{(384-1)}{375}}$$

$$\text{New SS} = \frac{384}{2.0213}$$

$$\text{New SS} = 189$$

Sample Size Calculation Cranbrook (population 268)

$$\text{New SS} = \frac{384}{1 + \frac{(\text{SS}-1)}{\text{Pop}}}$$

$$\text{New SS} = \frac{384}{1 + \frac{(384-1)}{268}}$$

$$\text{New SS} = \frac{384}{2.4291}$$

$$\text{New SS} = 158$$

## Appendix 4.0 Community Survey

### Health Impact Assessment of Climate Change and Adaptation in the Blackwood Stirling 2030

Please only answer questions you are comfortable with. You will not be identified in any way by this research. Please refer to the mail out for details regarding ethics approval.

2. What is your postcode?

3. Please identify your annual household income (gross).

- |                       |                       |                       |                       |                       |                        |                        |                       |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|------------------------|------------------------|-----------------------|
| Less than \$25,000    | \$25,000 to \$34,999  | \$35,000 to \$49,999  | \$50,000 to \$74,999  | \$75,000 to \$99,999  | \$100,000 to \$124,999 | \$125,000 to \$149,999 | \$150,000 or more     |
| <input type="radio"/>  | <input type="radio"/>  | <input type="radio"/> |

4. I live in a (please select appropriate response).

- Single income household with no children or dependants
- Single income household with children or dependants
- Double income household with no children or dependants
- Double income household with children or dependants

5. The Market Value of my total real estate assets are (please select response).

- |                                                |                       |                              |                              |                                 |                       |
|------------------------------------------------|-----------------------|------------------------------|------------------------------|---------------------------------|-----------------------|
| I don't own any property (renting or boarding) | Less than \$150,000   | Between \$150,000- \$250,000 | Between \$250,000- \$500,000 | Between \$500,000 - \$1 million | Above \$1 million     |
| <input type="radio"/>                          | <input type="radio"/> | <input type="radio"/>        | <input type="radio"/>        | <input type="radio"/>           | <input type="radio"/> |

6. This question will ask you what you will be willing to pay to make changes to your home to prepare for climate change on an annual basis, starting this financial year, and using today's product values to guide your choices. I am willing to pay this much per year (please select response).

- |                       |                       |                       |                       |                       |                       |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| \$0-\$50              | \$50-\$500            | \$500-\$2000          | \$2000-\$10,000       | \$10,000-\$20,000     | \$20,000-\$50,000     |
| <input type="radio"/> |

The next questions will ask you what aspects of your home and work life you would be willing to change to adapt to new climatic conditions by 2030.

7. I would relocate to a less flood or fire prone area.

- Yes
- No

8. I would improve my private water supply and onsite waste (effluent) disposal systems. (Please select one or more options).

- Rainwater
- Dams
- Groundwater (bores)
- Greywater recycling
- Other (Please specify) Please enter an 'other' value for this selection.

9. I would improve my fire protection system. (Please select one or more responses).

- Clearing vegetation and flammable materials
- Installing or enhancing my reticulation and pumping system
- Installing a fire bunker
- Planting a fire resistant vegetation corridor
- Increase my involvement as a volunteer within the local fire department (brigade)
- Preparing an evacuation plan
- Other (please specify) Please enter an 'other' value for this selection.

10. I would improve my emergency preparation for extreme events or disasters. (Please select one or more responses).

- Having 14 days supply of food and water at all times.
- Alternate power supply (e.g. generator)
- Water treatment chemicals
- Two Way Radio
- First Aid Equipment and/or Training
- Other (please specify) Please enter an 'other' value for this selection.

11. I would retrofit all or part of my house. (Please select one or more responses).

- Install insulation.
- Changing to water efficient appliances.
- Changing to energy efficient appliances.
- Installing an air conditioner.

- Installing double glazed windows.
- Installing alternate energy (e.g. solar, wind).
- Other (please specify) Please enter an 'other' value for this selection.

12. I would retrofit my garden. (Please select one or more responses).

- Grow plants to increase shade outdoors.
- Changing the garden to be more water efficient and self sustaining.
- Growing my own food.
- Other (please specify) Please enter an 'other' value for this selection.

13. Improving my farm or smallholding (where applicable).

- Switching to stock or crops that require less water, or can withstand rainfall variability.
- Switching to stock or crops that are able to withstand higher temperatures.
- Switching to stock or crops that are more disease and pest resistant under new climate conditions.
- Other (please specify) Please enter an 'other' value for this selection.

14. Improving my business.

- Reducing water use through behavioural change and greater water efficiency.
- Reducing transport use.
- Reducing energy use.
- Providing my own energy and water needs.
- Adaptation to higher temperatures with personal protective equipment, training and facilities.
- Diversifying my business to cope with a range of climatic extremes.
- Relocating the business.
- Other (please specify) Please enter an 'other' value for this selection.

15. Are there any other areas of your home or business you would change? If so please describe.

16. Are there any reasons why you would not, or could not make changes?

The next question will ask you to rank priorities for expenditure in your community by government. If you have any ideas for adaptation priorities not listed, please add this information when answering question 29.

17. Please rank the areas for expenditure by government to adapt to climate change by 2030. E.g. select from one to nine for the most important to the least important.

<b>17. Please rank the areas for expenditure by government to adapt to climate change by 2030. E.g. Select from one to nine for the most important to the least important.</b>	<b>No.</b>
<b>Flood protection</b>	
<b>Insurance (recovery for uninsured, or gaps in insurance mechanisms)</b>	
<b>Water supply protection</b>	
<b>Emergency bunkers and services</b>	
<b>Public services: recreation facilities</b>	
<b>Upgrade electrical supply to meet future demand</b>	
<b>Increase staffing to emergency and health services for communities</b>	
<b>Protection of natural resources and systems of national significance</b>	
<b>Assistance to households and businesses with low incomes to adapt</b>	

The next questions will ask you what works are required in your town, and the funds you think would be required (based on today's values). In the scenario that you had a budget of \$10 million what would spend the money on and how much per project?

*Some examples of recent projects in Western Australia include upgrading the electricity supply from Busselton to Margaret River (\$24 million), Quinninup Dam remedial works (\$200,000), Manjimup Town Water Supply upgrade (\$320,000), Boyup Brook 1000kl ground tank (\$685,000), Nannup Bore works (\$1.1 million), new Fire and Rescue Station at Australind \$6 million, Jalbarragup Bridge Construction (\$4.3 Million) and Renovation of Margaret River Recreation Centre (\$396,000).*

18. Flood Protection.

19. Insurance, this includes coverage of costs of damage to properties that do not have insurance (once off coverage, per annum). This also includes coverage of damage to farmers goods and property (crops and stock) destroyed by climatic damage.

20. Water Supply.

21. Evacuation centres for fire, flood and heat wave respite.

22. Emergency Services expenditure (facilities, equipment and employment).

23. Upgrade or build recreation centres

24. Upgrade electricity supply.
  25. Increase staff hours and positions to emergency and health services in rural communities. Please identify what changes would need to be made to cope with an increased demand for health services.
  26. Protecting natural resources and systems of national significance e.g. river systems, and rare or threatened flora and fauna.
  27. Assistance to households and businesses with low incomes to enable adaptation.
  28. What other Government funded adaptation projects should be initiated, and what should be spent?
  29. What other adaptation initiatives are required in your community?
  30. What would you be willing to contribute to any of these adaptation projects as a once off payment?
  31. Are there any households that will be vulnerable despite adaptation to climate change? Please identify the reasons why.
  32. If you have any feedback about this survey or additional comments please provide this information here.
-

## Appendix 5.0 Community Survey Greenbushes and Cranbrook

### Research Survey

#### Adapting to a Changing Climate in Cranbrook/Greenbushes

1. Please identify your annual household income (gross).

- Less than \$25,000 to \$35,000 to \$50,000 to \$75,000 to \$100,000 to \$125,000 to \$150,000  
\$25,000 \$34,999 \$49,999 \$74,999 \$99,999 \$124,999 \$149,999 or more
- 

2. I live in a (please select appropriate response).

- Single income household with no children or dependants
- Single income household with children or dependants
- Double income household with no children or dependants
- Double income household with children or dependants

3. The Market Value of my total real estate assets are (please select response).

- I don't own any property (renting or boarding)    Less than \$150,000    Between \$150,000-\$250,000    Between \$250,000-\$500,000    Between \$500,000 - \$1 million    Above \$1 million
- 

4. How much money are you prepared to spend in your household to adapt to a changing climate? If you were to start expenditure from this year, using today's product values to guide your choices. I am willing to pay this much per year (please select response).

- \$0-\$50    \$50-\$500    \$500-\$2000    \$2000-\$10,000    \$10,000-\$20,000    \$20,000-\$50,000
- 

The next questions will ask you what aspects of your home and work life you would be willing to change to adapt to new climatic conditions by 2030.

5. I would relocate to a less flood or fire prone area.

- Yes
- No

6. I would improve my private water supply and onsite waste (effluent) disposal systems. (Please select one or more options).

- Rainwater
- Dams
- Groundwater (bores)
- Greywater recycling

- Other (Please specify)

7. I would improve my fire protection system. (Please select one or more responses).

- Clearing vegetation and flammable materials
- Installing or enhancing my reticulation and pumping system
- Installing a fire bunker
- Planting a fire resistant vegetation corridor
- Increase my involvement as a volunteer within the local fire department (brigade)
- Preparing an evacuation plan
- Other (please specify)

8. I would improve my emergency preparation for extreme events or disasters. (Please select one or more responses).

- Having 14 days supply of food and water at all times.
- Alternate power supply (e.g. generator)
- Water treatment chemicals
- Two Way Radio
- First Aid Equipment and/or Training
- Other (please specify)

9. I would retrofit all or part of my house. (Please select one or more responses).

- Install insulation.
- Changing to water efficient appliances.
- Changing to energy efficient appliances.
- Installing an air conditioner.
- Installing double glazed windows.
- Installing alternate energy (e.g. solar, wind).
- Other (please specify)

10. I would retrofit my garden. (Please select one or more responses).

- Grow plants to increase shade outdoors.
- Changing the garden to be more water efficient and self sustaining.
- Growing my own food.
- Other (please specify)

11. Improving my farm or smallholding (where applicable).

- Switching to stock or crops that require less water, or can withstand rainfall variability.
- Switching to stock or crops that are able to withstand higher temperatures.
- Switching to stock or crops that are more disease and pest resistant under new climate conditions.
- Other (please specify)

12. Improving my business (PTO).

- Reducing water use through behavioural change and greater water efficiency.
- Reducing transport use.
- Reducing energy use.
- Providing my own energy and water needs.
- Adaptation to higher temperatures with personal protective equipment, training and facilities.
- Diversifying my business to cope with a range of climatic extremes.
- Relocating the business.
- Other (please specify)

13. Are there any other areas of your home or business you would change? If so please describe.

14. Are there any reasons why you would not, or could not make changes?

The next question will ask you to rank priorities for expenditure in your community by government. If you have any ideas for adaptation priorities not listed, please add this information when answering question 26.

**16. Please rank the areas for expenditure by government to adapt to climate change by 2030. E.g. Select from one to nine for the most important to the least important. No.**

<b>16. Please rank the areas for expenditure by government to adapt to climate change by 2030. E.g. Select from one to nine for the most important to the least important.</b>	<b>No.</b>
<b>Flood protection</b>	
<b>Insurance (recovery for uninsured, or gaps in insurance mechanisms)</b>	
<b>Water supply protection</b>	
<b>Emergency bunkers and services</b>	
<b>Public services: recreation facilities</b>	
<b>Upgrade electrical supply to meet future demand</b>	
<b>Increase staffing to emergency and health services for communities</b>	
<b>Protection of natural resources and systems of national significance</b>	
<b>Assistance to households and businesses with low incomes to adapt</b>	

The next questions will ask you what works are required in your town to successfully adapt to climate change, and the funds you think would be required (based on today's values). In the scenario that you had a total budget of \$10 million (per year) what would spend the money on and how much per project?

*Some examples of recent projects in Western Australia include upgrading the electricity supply from Busselton to Margaret River (\$24 million), Quinninup Dam remedial works (\$200,000), Manjimup Town Water Supply upgrade (\$320,000), Boyup Brook 1000kl ground tank (\$685,000), Nannup Bore works (\$1.1 million), new Fire and Rescue Station at Australind \$6 million, Jalbarragup Bridge Construction (\$4.3 Million) and Renovation of Margaret River Recreation Centre (\$396,000).*

15. Flood Protection (protecting or relocating infrastructure).
16. Insurance, this includes coverage of costs of damage to properties that do not have insurance (once off coverage, per annum). This also includes coverage of damage to farmers goods and property (crops and stock) destroyed by climatic damage.
17. Water Supply (protection and water treatment).
18. Evacuation centres for fire, flood and heat wave respite (constructing or upgrading facilities) NB heat waves are potentially life threatening for vulnerable people.
19. Emergency Services expenditure (facilities, equipment and employment).
20. Upgrade or build recreation centres (protection from increasing UV and other airborne contaminants).
21. Upgrade electricity supply to cope with future demand.
22. Increase staff hours and positions to emergency and health services in rural communities. Please identify what changes would need to be made to cope with an increased demand for health services.
23. Protecting natural resources and systems of national significance. E.g. River systems, or flora and fauna.
24. Assistance to households and businesses with low incomes to enable adaptation.

25. What other Government funded adaptation projects should be initiated, and what should be spent?
26. What other adaptation initiatives are required in your community?
27. What would you be willing to contribute to any of these adaptation projects as a once off payment?
28. Are there any households that will be vulnerable despite adaptation to climate change? Please identify the reasons why.
29. If you have any feedback about this survey or additional comments please provide this information here.

## Appendix 6.0 SEIFA by Suburb

Towns	SEIFA
Greenbushes	854
Cranbrook	870
Northcliffe	905
Manjimup	918
Kendenup	937
Pemberton	937
Denmark	937
Mount Barker	939
Augusta	941
Boyup Brook	942
Walpole	945
Dean Mill	953
Nannup	958
Bridgetown	967
Frankland River	987
Quinninup	996
Frankland River	987
Tenterden	1005
Narrikup	1007
Margaret River	1009
Scott River and Karridale	1012
Prevelly	1042
Shadforth	1043
Cowaramup	1048

Table 50 SEIFA by Suburb

(ABS, 2013a).

## Appendix 7.0 Highest and Lowest Rainfall on Record by Community

Rainfall (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<b>Bridgetown</b>												
Lowest (month)	0	0	0	0.8	29.3	29.7	43.5	26.2	10	3.1	0.3	0
Highest (month)	109.6	109.7	137.6	173.5	238.8	331.8	319.6	269.3	224.6	156.0	137.8	85.3
Highest (daily)	77.8	77.4	100.8	84.2	75.9	86.9	79.8	51.8	39.6	36.8	56.6	62.6
<b>Manjimup</b>												
Lowest (month)	0	0	0.5	4	26.3	45.4	42.7	46.2	23.9	8.9	2.5	0
Highest (month)	92.2	117.4	137.7	193.8	269	331.9	319.7	323.3	256.5	165.4	121.6	98
Highest (daily)	79.4	45	89.2	77	79.2	82.6	58	54.1	58.7	52.6	48.5	50.2
<b>Jarrahwood</b>												
Lowest (month)	0	0	1.2	0	43.6	44	66	23.2	27.2	11.2	0	0
Highest (month)	86.2	74.2	83	146	228.9	348.2	386.7	271.9	187.2	174.7	97.2	78.6
Highest (Daily)	66.8	27.2	31	106.4	92.6	76.6	75.2	70	37	68.2	52.6	50
<b>Pemberton</b>												
Highest (month)	95.8	86.4	131.8	212.9	336.7	365	390.5	388.2	259.8	219.6	177.4	92.3
Lowest (month)	1.1	1.1	5.1	6	36.2	76.5	66.8	49.5	45.4	13.2	6.3	2.9
Highest (daily)	60.4	36	77.2	53.1	80	61.8	67.6	50.8	48.4	53	90	56.9
<b>Shannon</b>												
Highest (month)	70	36.4	100.8	183	208.6	269	278.8	206.2	203.4	132.6	151.4	83.2
Lowest (month)	0.4	2.8	10	8.4	66.8	70.2	68.6	31.4	2.4	34	15.4	0.2
Highest (daily)	27	31	35	62	80	46	47	36	38	50	32	42.6
<b>Windy Harbour</b>												
Highest (month)	67.6	70	134.5	210.2	248.4	370.2	299.9	224.3	169.8	144.8	95	85.4
Lowest (month)	1.3	1.4	6.6	6.6	73	88.8	81.1	65.2	47.8	31.2	11.4	4.6
Highest (daily)	32.6	31.2	58.3	78	68.6	73.6	52.6	44.6	36.8	58	28.4	53.2
<b>Mount</b>												
	181.9	178.5	128.6	233.9	242.8	209.3	260.9	173.3	157	160	154.8	109.8

Barker Highest (month)												
Lowest (month)	1	0.8	2	2.8	16.3	36.6	22.4	29.8	18.4	16.3	3.3	1.3
Highest (daily)	132	72.1	57.4	139.2	70.6	68.1	72.4	48	64.6	54.4	63.8	43.9
Frankland Vineyards	121.4	55.8	83.6	176	155.8	207.2	163	133.2	145	119	84	95
Lowest (month)	0.8	0	0	3.2	29.2	23.8	41	26	23.4	20.8	5.8	0.8
Highest (daily)	87	33	49.2	92.4	38	60.8	35	34	31.2	31.6	35	38.8
Cape Leeuwin Highest (Monthly)	76.6	132.2	13.6	192.6	313.8	368.4	335.5	317.4	231.6	184.4	157.6	113.9
Lowest (monthly)	0	0	1.6	5.8	35	67.6	44.4	32	23.1	8.6	3.8	1.4
Highest (Daily)	54.9	102.4	84.4	88.4	123.2	119	104.4	174	76.2	49.5	76.2	95

Table 51 Highest and Lowest Rainfall on Record (Monthly and Daily)  
(BOM, 2010a).

## Appendix 8.0 Variation Between Daily Minimum and Maximums

December	January	February
Denmark 24.43 13.23 -11.2	25.97 14.46 -11.51	26.21 15.09 -11.12
Augusta 24.55 15.26 -9.29	26.17 16.42 -9.75	26.53 16.99 -10.2
Walpole 24.63 13.65 -10.98	26.25 14.86 -11.39	26.47 15.53 -10.94
Margaret River 24.84 14.9 -9.94	26.54 16.16 -10.38	26.99 16.34 -10.65
Mt Barker 25.13 13.26 -11.87	27.99 14.61 -13.38	28.07 15.29 -12.78
Pemberton 25.15 13.66 -11.49	27.25 14.9 -12.35	27.55 15.36 -12.19
Northcliffe 24.01C 14.1 -9.91	27.83 14.42 -13.41	27.55 15.36 -12.19
Nannup 26.08 13.48 -12.6	29.67 14.91 -14.76	29.89 15.5 -14.39
Manjimup 26.72 12.78 -13.91	29.1 14.23 -14.87	28.98 14.74 -15.24
Bridgetown 27.23 12.83 -14.4	30.7 13.91 -16.79	29.68 14.49 -15.91
Cranbrook 27.49 13.08 -14.41	29.25 14.49 -14.76	29.11 15.11 -14.0
Boyup Brook 29.35 13.0 -16.35	31.7 14.58 -17.2	31.38 15.51 -15.87

Table 52 Variation Between Daily Minimum and Maximum  
(OzClim, 2011b).

### Appendix 9.0 Expert Panel Review Delphi Method Round One

Health Risk Assessment Table Round One	
(n)	Per cent of agreement per question
Reduced Potable Water Supply (4)	
Extreme (2)	50
Major (1)	25
Medium (1)	25
Reduced Access to Water (2)	
Extreme (1)	50
Moderate (1)	50
Grey-Water Recycling (2)	
Major (1)	50
Medium (1)	50
Reduced Food Supply (3)	
Extreme (1)	33
High-Extreme (1)	33
Medium (1)	33
Reduced Food Production (2)	
Extreme (1)	50
Major (1)	50
Increased Food Safety Risks (2)	
Extreme (1)	50
Medium (1)	50
Food Labelling (2)	
Major (1)	50
High (1)	50
Heat Exposure (2)	
Extreme (1)	50
Massive (1)	50
Bushfire (1)	
Extreme (1)	100
Access / Transport to Services (1)	100
High (1)	
Population Migration (1)	100
Major (1)	
Lack of Adaptation (1)	100
Moderate-Major (1)	
Ozone (exceedence days of exposure) (1)	100
Medium (1)	
Particulate Matter (exceedence days) (1)	100
Medium (1)	
Increase of air pollution health impacts	100
Medium (1)	
Increase Vector borne disease	100
Low-Medium (1)	
Mental Health (2)	
Extreme (1)	50
Major (1)	50

Table 53 Expert Panel Review Delphi Method Round One  
(Adapted from Kalay et al., 2010).

## Appendix 10.0 Expert Panel Review Delphi Method Round Two

Health Risk Assessment			
Health Risk Factor	First Assessment	Second Assessment	Percent Agreement
Reduced Potable Water Supply	Extreme (2)	Low (2)	33
	Major (2)	Medium (1)	16
	Medium (1)	Massive (1)	16
		Extreme (2)	33
Reduced Access to Water	Extreme (1)	Moderate (1)	16
	Moderate (1)	Massive (1)	16
		High (2)	33
		Extreme (2)	33
Grey-Water Recycling	Major (1)	Low (2)	33
	Medium (1)	Medium (2)	33
		Major (1)	16
		High (1)	16
Reduced Food Supply	Extreme (1)	Major (1)	12
	High-Extreme (1)	High (5)	62
	Medium (1)	Extreme (2)	25
Reduced Food Production	Extreme (1)	Medium (1)	12
	High-Extreme (1)	Major (2)	25
	Medium (1)	High (3)	37
		Extreme (2)	25
Increased Food Safety Risks	Extreme (1)	Medium (3)	37
	Medium (1)	Moderate (1)	12
		High (1)	12
		Extreme (3)	37
Food Labelling	Major (1)	Medium (3)	42
	High (1)	Moderate (1)	14
		Major (1)	14
		High (2)	28
Heat Exposure	Extreme (1)	Extreme (5)	83
	Massive (1)	Massive (1)	16
Bushfire	Extreme (1)	Extreme (5)	83
		Catastrophic (1)	16
Extreme Weather Events (cyclones, storms, floods)	Extreme (0)	Extreme (5)	83
		Massive (1)	16
Access/Transport to Services	High (1)	Medium (1)	16
		Moderate (1)	16
		High (2)	33
		Extreme (2)	33
Population Migration	Major (1)	Medium (2)	33
		Moderate (1)	16
		Extreme (3)	50
Lack of Adaptation	Moderate-Major (1)	Medium (1)	11
		Moderate (4)	44
		Major (1)	11
		High (1)	11
		Extreme (2)	22
Lack of energy for thermal comfort in homes	Extreme (0)	Medium (2)	33
		Moderate (2)	33
		Major (1)	16
		High (1)	16
Loss or reduction in	Extreme (0)	Low (1)	16

biodiversity		Medium (3) Moderate (1) High (1)	50 16 16
Reduced physical activity	Low (0)	Low (1) Minor (1) Medium (3) High (1)	16 16 50 16
Ozone (exceedence of days of exposure)	Medium (1)	Medium (3) Moderate (1)	75 25
Particulate matter (exceedence of days of exposure)	Medium (1)	Low (1) Medium (1) Moderate (1) Extreme (3)	16 16 16 50
Increase of air pollution health impacts	Medium (1)	Medium (2) Moderate (1) High (2) Extreme (1)	33 16 33 16
UV Exposure	Extreme (0)	Major (1) High (2) Extreme (3)	16 33 50
Increase Vector-borne disease	Low-Medium (1)	Medium (4) High (1) Moderate (1) Moderate (1)	57 14 14 14
Mental Health	Extreme (1) Major (1)	Medium (1) Major (1) High (2) Extreme (2)	16 16 33 33

Table 54 Expert Panel Review Delphi Method Round Two.