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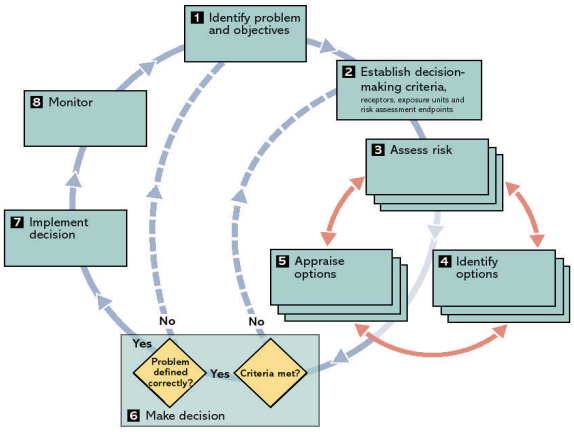
The Isle of Man Climate Change Scoping Study

Technical Paper 1

Technical summary



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A digital copy of the summary and technical papers can be downloaded from the following sites:

http://www.gov.im/dlge/enviro/climatechange.xml

www.acclimatise.uk.com

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Introduction

The Isle of Man government commissioned this report to identify the potential impacts of climate change for the Isle of Man. The study was managed by the Department of Local Government and the Environment (DLGE). A steering group whose membership was drawn from a cross-section of Island stakeholder organisations provided guidance.

This paper provides a technical summary of each of the elements of the study, represented by a series of technical papers. The technical papers published from this study are:

1. Technical summary
2. Methodology
3. Climate indicators
4. Future climate change scenarios
5. Costing the impacts of climate change: estimated costs of three historic events
6. Socio-economic scenarios
7. Historic costings under future climate change scenarios
8. Sector impacts
9. The Isle of Man's economy in a global context
10. Climate change and water resources on the Isle of Man
11. Workshop reports
12. Adaptation policy framework

The following sections set out the key issues and conclusions taken from each of the technical papers.

There is a further Executive Summary document which provides a non-technical overview of the scoping study. This document also identifies key themes and issues for the Isle of Man.

Technical paper 2: Methodology

This technical report sets out the methodology used during the study. Extensive use has been made of the following tools and techniques developed by the UK Climate Impacts Programme (UKCIP):

- UKCIP02 climate scenarios[1]
- Socio-economic scenarios[2]
- Costing[3]
- Risk [4]

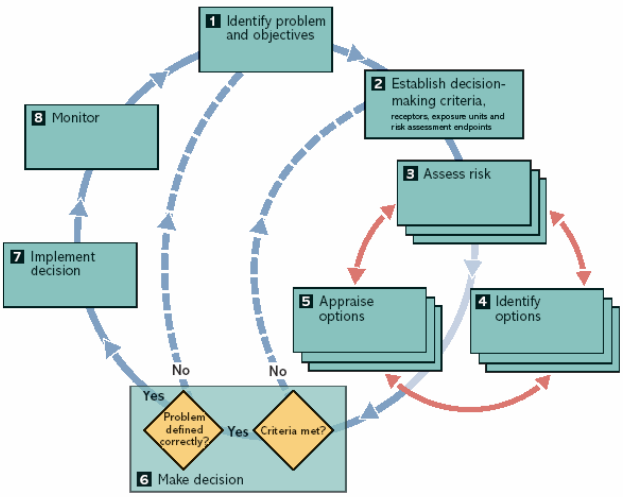
In addition to the work undertaken by UKCIP the study has also used the climate scenarios published by the:

- British Irish Council – BIC Climate Scenarios
- ICARUS - report to the Republic of Ireland Environmental Protection Agency

A key feature of the study has been the identification of potential impacts for the Isle of Man within a risk management framework. The methodology used has adopted the tools developed by the UK Climate Impacts Programme (UKCIP) and published in their report: Risk Uncertainty and Decision-Making Framework (2004) (RUD)[4].

The UKCIP framework (RUD) sets out a risk assessment process, which is iterative, transferable and allows climate change risks to be integrated within existing decisions and procedures. An outline of the RUD framework is provided in Figure 1.

Figure 1: UKCIP Risk, Uncertainty and Decision-Making Framework[4]



[1] Hulme,M., Jenkins,G.J., Lu,X., Turnpenny,J.R.,Mitchell,T.D., Jones,R.G., Lowe,J., Murphy,J.M.,Hassell,D., Boorman,P., McDonald,R. and Hill,S.(2002) Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report, Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK.

[2] UK Climate Impacts Programme, (2001), *Socio-economic scenarios for climate change impact assessment: a guide to their use in the UK Climate Impacts Programme.* UKCIP, Oxford.

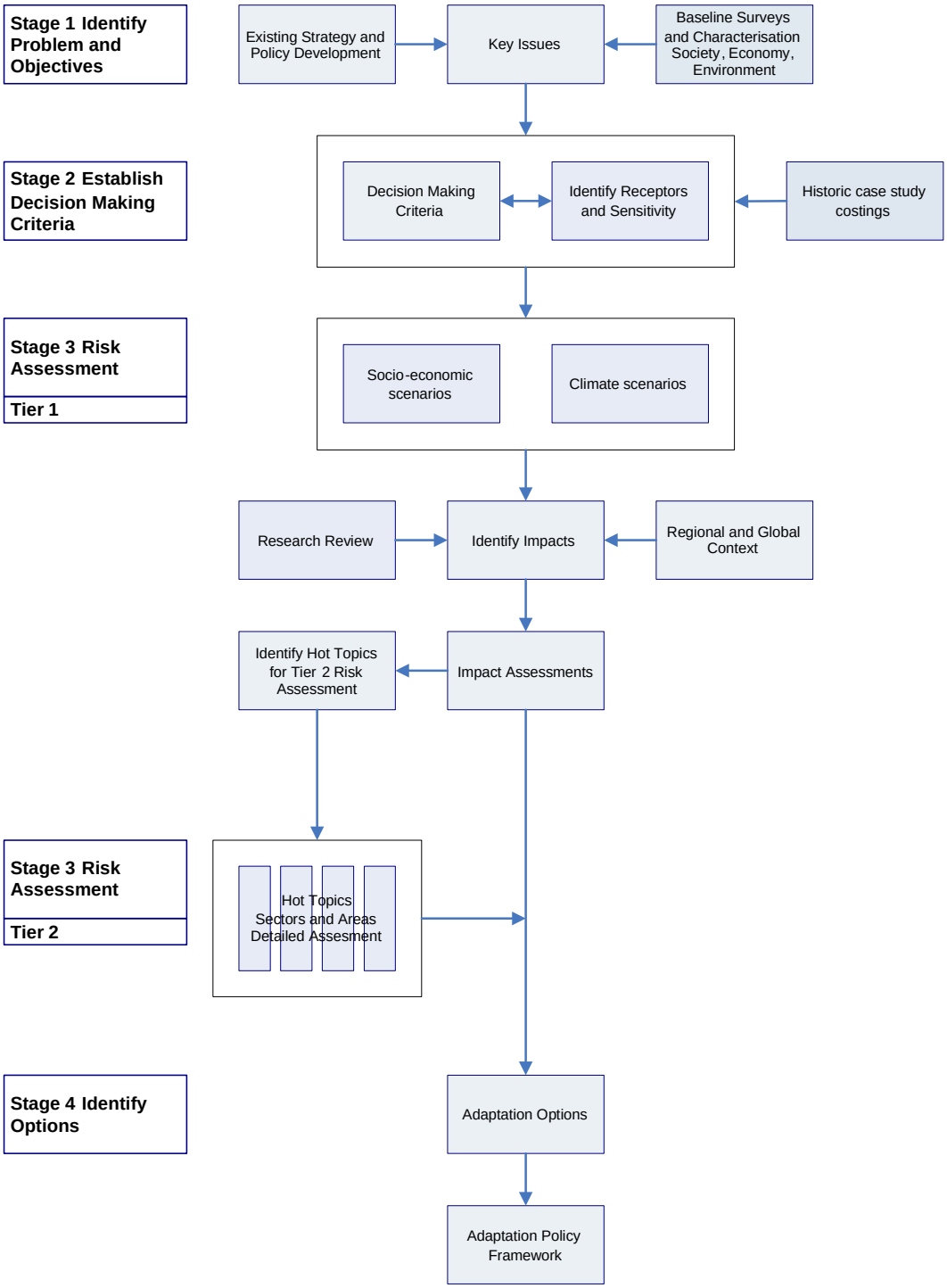
[3] Metroeconomica (2004). Costing the impacts of climate change in the UK: overview of guidelines. UKCIP Technical Report. UKCIP, Oxford.

[4] Willows, R.I. and Connell, R.K. (Eds.). (2003). Climate adaptation: Risk, uncertainty and decision-making.UKCIP Technical Report. UKCIP, Oxford.

The RUD framework has eight key stages. The Isle of Man study has focussed on stages 1 to 4.

An overview of the methodology is provided in Figure 2.

Figure 2: Methodology overview



Technical paper 3: climate indicators

The current scientific consensus attributes most of the increase in global temperature experienced since the middle of the 20th century, to human activities (IPCC, 2001). This warming is associated with increasing concentrations of greenhouse gases in the atmosphere since the beginning of the Industrial Revolution. The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2001) is the most authoritative assessment of global climate change to date. In terms of past global climate the principal observations of this report include the following:

- Global average temperature has increased by $0.6 \pm 0.2^{o}C$ since 1860 with accelerated warming apparent in the latter decades of the last century.
- The last century was the warmest of the last millennium in the Northern Hemisphere, with the 1990s being the warmest decade and 1998 the warmest year. Indeed eight of the ten warmest years on record have occurred in the last decade (1996-2005) with 2005 being the second warmest year recorded by the UK Met Office.
- Global sea level has risen by 0.1- 0.2 metres over the past century, an order of magnitude larger than the average rate over the past three thousand years.
- Precipitation has increased over the landmasses of temperate regions by 0.5-1.0% per decade, while the frequency of intense rainfall events appears to be increasing in the Northern Hemisphere.

As a consequence of the continued increase in concentrations of greenhouse gases it is likely that global temperatures will increase significantly during the course of the present century. Projections of global climate, derived from Global Climate Models (GCMs) suggest that:

- Globally averaged surface temperature is likely to increase by between 1.4 and $5.8^{o}C$, over the period 1990 to 2100, with the extent of warming depending on future greenhouse gas emissions.
- Precipitation increases are likely by the middle of the present century in the mid to high latitudes in winter, with large year-to-year variations.
- An increase in maximum temperatures and in the frequency of hot days is very likely.
- More intense precipitation events are very likely over mid to high latitude areas of the Northern Hemisphere
- The present day retreat of mountain glaciers is likely to continue during the course of the 21st century. While Antarctica is likely to gain mass due to enhanced precipitation, Greenland is likely to lose mass due to a greater increase in runoff over precipitation increases.
- The best estimate for global mean sea-level rise over the present century is 0.48 metres. Sea levels are likely to continue to rise after 2100.

Indicators of climate change for the Isle of Man

With the aim of assessing whether the global trends described above are occurring at the regional scale of the Isle of Man, the available meteorological data for Douglas and Ronaldsway are analysed for long-term trends over the period of record. The focus of this examination is on temperature and precipitation but additional climate parameters such as wind and storminess are also discussed. The key findings are as follows:

- Annual temperatures relative to the mean for the 1961-1990 period display

changes that are largely consistent with the global record. However, the Isle of Man displays a faster rate of warming from the 1980s onwards than is apparent at the global level. This characteristic is consistent with changes in the Central England temperature series and Irish temperature records.

- 6 of the 10 warmest years on record in the Isle of Man have occurred since 1988, making the 1990s the warmest decade on record.
- Minimum temperatures were found to be warming at a greater rate than maximum temperatures while seasonal increases in minimum and maximum temperatures are consistent with global trends.
- The 1990s have seen the number of frost days reduced by half in comparison to previous decades.
- Annual precipitation, which varies largely from year to year, displays no significant trend. However, a significant increasing trend was found in the spring receipts at Douglas, while a decreasing trend at Ronaldsway during the summer months was also found to be significant.

The trends in temperature identified for the Isle of Man are largely consistent with findings from other studies and in line with global trends. While some seasonal trends in precipitation were found to be consistent with other studies in the region, recent research suggests that some changes in observed winter rainfall are inconsistent with those found in England.

Conclusions

In this chapter, meteorological data from the Isle of Man were assessed for any changes that may have occurred over the course of the 20th century. Temperature and precipitation, two key climatic parameters, from Douglas and Ronaldsway were examined for trends to determine if, and how, climate on the island is responding to global warming.

Annual temperature anomalies, which displayed a large degree of interannual variability, were found to be largely consistent with global temperature anomalies. However, they display a faster rate of warming from the 1980s onwards than is apparent in the global anomalies. The warming rates evident in the 10 year moving averages of annual anomalies from the Isle of Man were found to be highly consistent with more regional indices, such as the Central England Temperature series and the annual anomalies from the Irish temperature records.

An index of mean annual air temperature demonstrates warming occurring after 1980, with 6 of the 10 warmest years on record occurring after 1988, making the 1990s the warmest decade on record. This warming trend was found to be significant.

Consistent with global trends, minimum temperatures were found to be warming at a greater rate than maximum temperatures, with the greatest warming occurring in minimum temperatures during autumn at Douglas. Winter minimum temperatures displayed the greatest increases at Ronaldsway. Increases in the seasonal minimum temperatures from both stations were found to be significant; maximum temperatures from Ronaldsway were also significant. Seasonal increases in minimum and maximum temperatures per decade are consistent with global trends. Significant increases in the lowest daily temperatures were also found.

While no significant trends were found in the annual frequency of frost days, the decadal average for the 1990s represents a reduction of approximately half in the number of frost days when compared to previous decades. These findings are consistent with the increases found in minimum temperatures.

While no significant trend was found in annual precipitation data, large interannual variability is evident in the series, with a decreasing tendency from the 1980s onwards. However, a significant and increasing trend was found in the spring receipts at Douglas, while a decreasing trend at Ronaldsway during the summer months was also found to be significant. No apparent changes in the annual count of rain days or wet days were found to be occurring.

A significant and increasing trend was found in the number of sun hours during the winter months after 1990, which up to this point had been decreasing. This may reflect changes in cloud cover and extent, and may partially explain the reductions in precipitation after the 1980s.

The trends identified in this chapter are largely consistent with findings from other studies and in line with global trends. Precipitation series require further analysis. Despite the oceanic influence of the Atlantic, seasonal precipitation series were found to be unrelated to the large-scale circulation represented by the North Atlantic Oscillation, results which are inconsistent with findings from both the UK and Ireland and which may explain the decreasing trends found in the 90th percentile of rainfall and 5-day maximum rainfall amounts on the Isle of Man.

Technical paper 4: Future climate change scenarios

In order to obtain future projections of climate change for the Isle of Man data from a Global Climate Model was obtained, which utilised a range of future greenhouse gas emissions scenarios. Emissions scenarios are based on predicted global development pathways and range from a fossil fuel intensive future with high levels of greenhouse gas emissions to a less greenhouse gas intensive future where the emphasis is placed on environmental sustainability. The results of this analysis for the 2080s (see figure 1) using a medium high emissions scenario suggest that:

- On an annual basis mean temperature is projected to increase by 2.4°C, while a slight reduction of 1% in annual rainfall is likely.
- Increases in mean temperature are projected for all seasons, with greatest increases in summer and autumn of 2.7°C and 2.8°C respectively. Increases of 1.7°C and 2.2°C are suggested for winter and spring.
- Increases in winter and spring precipitation with decreases in precipitation for summer and autumn are likely. The greatest increases in precipitation are suggested for the winter months, with a likely increase of 20%, while the greatest decreases are suggested for summer with a reduction of 36% likely by the end of the current century.
- Large seasonal changes in precipitation reflect a more marked seasonal contrast in rainfall amounts with wetter winters and drier summers likely. These changes in rainfall may have a significant impact on water supply and storage during the summer and winter months.
- The variability of both temperature and precipitation between individual years is also projected to change, with a reduction in variability in mean winter temperatures and an increase in the variability of summer temperatures. Year to year variation in summer precipitation is likely to decrease for the summer months, while an increase in the variability of winter precipitation is suggested.
- The suggested changes in seasonal temperature and precipitation are broadly in line with previous work conducted for Britain and Ireland.
- Differences between the emissions scenarios employed are not that apparent in the 2020s, but by the 2080s the difference in winter precipitation ranges from 13% in the Low Emissions scenario to 25% in the High Emissions scenario.

	DJF	MAM	JJA	SON	ANN
Mean temperature (°C)	+1.7	+2.2	+2.7	+2.8	+2.4
Max. temperature (°C)	+1.8		+3.0		
Min. temperature (°C)	+1.8		+2.4		
Precipitation (%)	20	12	-36	-8	-1
Snow (%)	-75				
Cloud cover (%)	-3	-4	-9	-8	-6
Relative humidity (%)	-0.8	-1.8	-4.4	-1.6	-2.1
Soil moisture (%)	2	2	-12	-7	-4

Figure 1: Changes in seasonal and annual values for a selection of variables for the Isle of Man by the 2080s for the Medium-High emissions scenario.

Precipitation changes have been modelled and a summary of the results for 2020s, 2050s and 2080s are within Figure 2.

Precipitation changes	Summer ppt	Winter ppt
2020s	-10.4 to -8.6	+4.8 to +5.8
2050s	-24.4 to -15.5	+8.6 to +13.6
2080s	-42.4 to -22	+12.2 to +23.6

Figure 2: Precipitation Changes 2020s, 2050s, 2080s

Temperature changes were also modelled and a summary of the results for temperatures changes in 2020s, 2050s and 2080s are within Figure 3.

Temperature changes	Summer degrees ^{o}C	Winter degrees ^{o}C
2020s	+0.6 to +0.8 ^{o}C	+0.4 to +0.5 ^{o}C
2050s	+1.1 to +1.8 ^{o}C	+0.7 to +1.2 ^{o}C
2080s	+1.6 to +3.1 ^{o}C	+1.1 to +2.0^{o}C

Figure 3: Temperature changes for 2020s, 2050s and 2080s

Sea level is set to change under climate change. Global projections for a rise in mean sea level, from a range of global climate models (GCMs), indicate an increase of between 0.09 and 0.88 metres over the period 1990 to 2100 (IPCC, 2001). As the geographical distribution of sea-level changes will be dependant on regional factors, such as thermal expansion, sediment loadings and isostatic changes, some regions are likely to experience above average sea level rise, while other areas may experience a fall in relative sea level (IPCC, 2001). To assess future sea level rise for the Isle of Man, the global estimates were employed. Future sea level rise, accounting for isostatic rebound, for the Isle of Man for a medium-high emissions scenario results in a rise of 2.4-12.4cm for the 2020s, 5.1-29.1cm for the 2050s and 8-54cm by the 2080s (see figure 4).

Emissions Scenario	2020s	2050s	2080s
Medium-High emissions (accounting for isostatic rebound)	2.4-12.4cm	5.1–29.1 cm	8 - 54cm

Figure 4: Potential change in sea level for the Isle of Man for 2020s, 2050s, 2080s

It is difficult to predict how the climate of the Isle of Man will change in the future as there are many uncertainties surrounding the emission rate of greenhouse gases and how the climate will respond to these. However, it is inevitable that anthropogenic driven climate change will occur. Climate change scenarios for the Isle of Man, based on a high resolution regional climate model, show warming in all seasons and all periods in the future, coupled with an increasing tendency towards wetter winters and drier summers than currently experienced. Changes in wind speeds are projected to decrease marginally, except in the winter season. By the 2080s, under the medium-high emissions scenario, precipitation is expected to increase in winter and spring, and decrease in summer and autumn. Snow cover, relative humidity and cloud cover are also expected to decrease in all seasons and annually.

Over the course of the present century significant climate change can be anticipated in the Isle of Man. Changes in temperature and precipitation are likely to have

considerable knock on effects for hydrology and water resources management, while sea level rise and increased storm surges coupled with increasing winter runoff are likely to heighten flood risk and erosion in many areas. Considerable uncertainty remains with respect to future climate conditions and more research is required in several key areas. However, forward planning is needed now so as to maximise the potential for adaptation.

Conclusions

Regional climate models projections suggest that climate change on the Isle of Man is likely to follow projected regional scale trends for Europe over the course of the present century. Warming in all seasons and for all periods is anticipated, coupled with an increasing tendency towards wetter winters and drier summers than is presently experienced. Changes in wind speeds are projected to decrease marginally in all seasons, except winter, these projections have a high degree of uncertainty associated with them. While changes in the climatological mean of a particular climate variable may be small, changes in extremes are likely to be greater in the future, such as an increase in the frequency of extreme hot days, extreme wind speeds or more intense precipitation events. Resultant changes in secondary meteorological variables, such as, potential evapotranspiration, frost frequency and growing season length and sea level rise, with consequent changes in surge return periods, is likely to impact the Isle of Man both positively and negatively.

While some sectors may be 'isolated' from changes in climate, global scale climate events may play a more significant role than those occurring at the local scale. However, each sector needs to assess the potential impact of climate change, both globally and locally, in order to minimise the potential negative impacts and be better positioned to capitalise on the potential positive impacts. There is a requirement that policy needs to be 'climate proofed' in order to achieve this end.

Recommendations

In order to more fully investigate the trends in the observed meteorological data, an analysis of daily data, as oppose to monthly or annual values, should be undertaken. Daily data would also facilitate an examination of extremes, which was not possible in the current research. In addition, an analysis of precipitation receipts in conjunction with circulation types may also be beneficial in explaining the lack of correlation between the North Atlantic Oscillation and precipitation. Analysis of changes in precipitation intensity would also be possible with higher temporal resolution data.

In order to address issues of uncertainty with regards to future projections of climate on the Isle of Man, output from a range of GCMs should be employed, either by RCMs or statistical downscaling.

Technical paper 5: Costing the impacts of climate change: estimated costs of three historic events

This study represents a first attempt at expressing in economic terms a number of physical impacts that are associated with historic weather events in the Isle of Man as a step towards costing the impacts of climate change on the Manx people. The events chosen were:

- The flood at Sulby on the 8th of December 2000.
- The storm surge and tidal flooding that affected coastal areas of the island on the 1st of February 2002.
- The windstorm that hit the island on the 7th and 8th of January 2005.

These events were selected to represent potential historic analogues for future climate change related events. Flooding, storm surges and wind storms are all likely to increase as a result of climate change though the uncertainty surrounding possible changes in frequency and intensity of these types of extreme weather events remains significant.

Estimated damage costs for the selected weather events in Isle of Man are presented in the following table.

Weather event	**Estimated costs (2005 prices)**
Sulby floods, December 2000	>£3.2 - £3.7 million
Tidal Surge, February 2002	>£8 million
Windstorm, January 2005	>£15 million

Table 1: estimated costs of three weather events

Sulby flooding

On the 8th of December 2000 the Sulby River overflowed, leading to serious flooding of about 30 residential and commercial properties in Sulby at Carrick Park Estate and along the Mill Race. Over the last 30 years, the Sulby area has in fact been flooded on at least 6 occasions.

The largest cost category was damage to residential property, with between £1.6 and £2.1 million of damages. Residential clean up, health costs and costs to the emergency services represent a significant cost as well. There remain a number of impacts, including a number of health effects that have not been costed in the exercise through lack of data. The cost estimates should therefore be regarded as under-estimates of the total costs that can be attributed to the Sulby flood.

Windstorm event

Windstorms are anticipated to increase in frequency and intensity, though the dynamics of such storm patterns are not as well understood as the processes for precipitation. To give a first estimate of the possible impacts of climate change related storms, the windstorm of 7-8 January 2005 was selected as an historical analogue. This storm saw wind gusts of 112 mph recorded on the Mountain Road– a 1 in 100 year occurrence and gusts reach 92 mph at Ronaldsway Airport. At one point the winds were Storm Force 11. The windstorm had significant impacts on property, both private and government, and transport.

Storm surge

Storm surges may increase in frequency and intensity as a result of climate change. The historical analogue of the storm surge, which occurred on The 1st of February 2002, was selected to provide estimates of the costs of such events in the Manx case. Astronomical high tides were predicted, but a deep depression over the northeastern Atlantic produced gale force southwesterly winds (with gusts to around 70 mph), which generated a storm surge, that added more than a metre to the predicted tide level (reaching a level of around 8.4 metres on the Douglas tide gauge, compared with an average of 2 metres). The result was that sea levels exceeded many of the promenades and quaysides around the island. Coasts exposed to the southwesterly winds also had high seas to deal with.

The most significant damages were in terms of property damage. However, it was not possible to quantify a number of impacts due to a lack of data on this event. In particular, road disruptions were not given value as the statistics provided did not indicate any road closures, though the anecdotal evidence suggests that inundation of coastal roads did occur.

Technical paper 6: Socio-economic scenarios

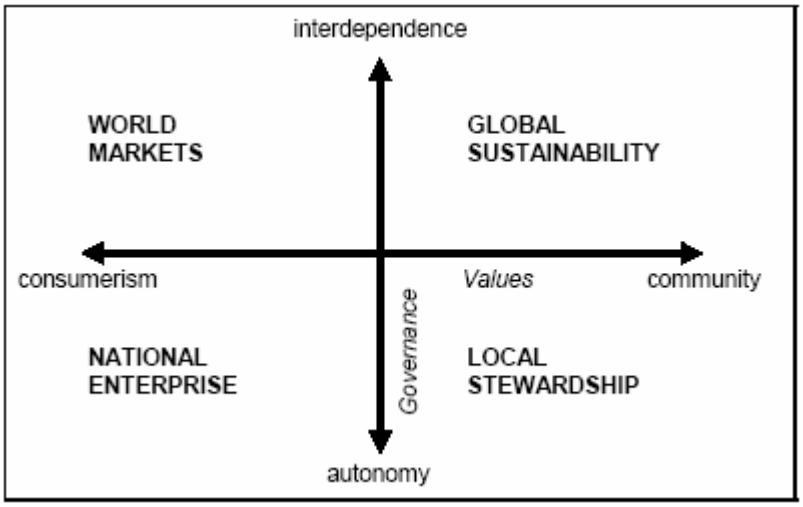
The identification of climate impacts and a risk assessment should not be undertaken in isolation from a consideration of potential changes in our society and economy. Published scenarios prepared for UKCIP were used to provide a briefing that assisted with the identification of climate impacts. This helps provide an understanding of how the receptors, their thresholds and sensitivities may change over time, providing the context for assessing climate impacts. Whilst the focus of the project was the Isle of Man, it is important to recognise that the climate change impacts must be assessed within a regional and an international context. The Isle of Man's social, economic and environmental systems do not exist in isolation from the rest of the world and climate change impacts elsewhere may have significant implications.

This technical paper provides background information on the characterisation of socio-economic change on the Isle of Man, in order to help understanding of how climate change impacts might change over time. This information is needed since consideration of possible future socio-economic contexts allows a more realistic assessment of future vulnerability to climate change than one based on current socio-economic conditions. It also enables us to examine the relative significance of climate change next to socio-economic change in determining overall changes in impacts. The forward-looking nature of such a characterisation necessarily introduces significant uncertainties since no-one knows what the future will look like. To accommodate this uncertainty it is good practice to construct alternative scenarios of possible socio-economic futures. We therefore outline how socio-economic scenarios have been constructed for the climate change context in the UK and how they may be interpreted for the Isle of Man.

We have used as a corner stone of our analysis the socio-economic scenarios prepared for UKCIP (UKCIP, 2001), together with material developed to supplement these scenarios by the BKCC BESEECH project and the interpretive work on the UKCIP scenarios already undertaken for the North West and East England of England by the REGIS projects. Clearly in the first time period centred on the 2020s there are specific relevant socio-economic projections made for planning purposes by the Isle of Man Government and these help to inform our interpretation of the UKCIP socio-economic scenarios.

The UKCIP socio-economic scenarios have attempted to describe possible future states of the world in such a way as to retain plausibility and consistency. They build upon the existing global futures literature in identifying key dimensions of socio-economic change. These dimensions include: "Governance and the capacity of institutions at different levels to manage change" and "the orientation of social and political values" and these are combined to generate four distinct socio-economic scenarios, as presented in Figure 1.

Figure 1: Diagrammatic representation of UKCIP Socio-Economic scenarios



In the report, we indicate in qualitative terms, how the changes foreseen under the World Markets, National Enterprise, Local Stewardship and Global Responsibility (also known as Global Sustainability) scenarios might affect the factors relevant to climate vulnerability in sectors including: Social/political values & households; Welfare and health; Economic development; Planning; Regional trends; Transport; Construction and Agriculture:

Table 1 below summarises some key quantitative indicators that help describe the socio-economic scenarios in the context of the Isle of Man. Clearly, whilst the North West of England is the closest UK region to the Isle of Man its current socio-economic profile is not the same. As a consequence, it is safest to regard the scenarios based on the UK as a whole as the most robust when interpreting from the Isle of Man's perspective. Indeed, the high relative importance of financial services to the economy of the Isle of Man makes it impossible to approximate closely to another UK region. However, in order to give some idea of the sensitivity of the socioeconomic scenarios to the background assumptions driving socioeconomic scenarios, we additionally present both changes based on the analysis of UK socioeconomic scenarios and the scenarios for the North West where these have been identified in the BESEECH study.

In a separate report (see technical paper 7), we apply these socio-economic scenarios to specific climate change impacts, where historical weather events are used as the baseline data. However, the principle of how these scenarios may be applied can be easily shown. The case study of the Sulby flood has shown that, (without the new flood defence system), property damage would be likely to be a significant part of future climate related costs from increased flood frequency or intensity. Property damage is driven by a number of factors, including the number of properties. It can be seen from Table 1 that the number of properties in the Isle of Man is likely to change since the number of households may change from the current level of 31,521 to between 27,000 or 45,000 depending on the scenario. This will therefore impact the stock at risk. Overall vulnerability will also be dependent on building design and flood management practices, which will vary under alternative socio-economic scenarios.

It is clear that scenarios such as these are not entirely exogenous to the decision-making process: it is possible that the Isle of Man may use these scenarios as a basis for guiding decisions relating to the minimisation of climate change impacts. The planning process is a good example of a policy that is determined primarily by the Isle of Man Government and that could be used to mitigate e.g. transport infrastructure and building flooding and subsidence from climate change-induced weather events

Table 1: Key Summary Statistics for Isle of Man under different socioeconomic scenarios

		Socioeconomic scenario								Assumptions
		2020s				2050s				
	Current	NE	LS	WM	GR	NE	LS	WM	GR	
Population										
Based on UK SES	76,315	82,521	80,923	85,560	83,938	81,445	78,844	90,575	87,924	Based on BESEECH scenarios
Based on NW SES	76,315	77,211	76,893	78,582	78,072	73,436	73,900	79,716	78,219	Based on BESEECH scenarios
Households										
UK SES	31,521	36,820	33,779	39,170	37,831	36,937	28,940	45,334	40,810	Based on BESEECH scenarios
NWSES	31,521	33,796	31,488	35,283	34,518	32,626	26,588	39,079	35,568	Based on BESEECH scenarios
Household size										
UKSES	2.42	2.24	2.40	2.18	2.22	2.20	2.72	2.00	2.15	Based on above estimates
NW SES	2.42	2.28	2.44	2.23	2.26	2.25	2.78	2.04	2.20	Based on above estimates
GDP/capita (£)										
UK SES	14,902	27,815	23,307	34,642	32,206	51,887	36,431	91,752	69,559	Based on BESEECH scenarios
Sectoral Contribution to National Income (£k)										
Manufacturing	98,883	206,104	177,594	205,363	180,882	385,006	286,313	408,250	275,903	Based on GVA increase of manufacturing growth (averaged)
Finance	539,996	1,114,168	855,614	1,654,110	1,389,027	2,060,899	1,220,192	5,215,575	3,294,580	Based on GVA increase of Banking, insurance and business services
Tourist Industry	74,168	172,595	130,871	226,534	217,586	354,718	207,735	712,675	571,946	Based on GVA increase of Hotels, catering and recreational services
Construction	134,631	240,260	205,234	375,297	323,394	376,391	279,907	1,092,320	719,281	Based on GVA increase of Construction and quarrying
Agriculture and fisheries	17,808	31,661	58,785	35,661	53,172	49,354	132,129	66,104	141,472	Based on GVA increase of Agriculture, Forestry and Fishery
Public admin	63,202	126,048	112,818	149,296	155,736	225,258	180,918	362,058	355,135	Based on GVA increase of Public Administration
Professional and scientific services	227,101	469,075	412,263	627,642	606,317	868,565	670,760	1,812,175	1,484,256	Based on GVA increase of Education and health
Other services	271,444	364,706	321,184	478,680	463,987	320,440	285,951	643,803	612,343	Based on GVA increase of other services

Technical paper 7: Historic costings under future climate change scenarios

The costings work that was outlined in technical paper 5 together with the socio-economic scenarios work (technical paper 6) and the climate scenarios (technical paper 4) have been used to provide some initial estimates of the type of costs that might result from extreme events under future climate change scenarios. The estimated damage costs for the three historical events are presented in Table 1.

Table 1. Estimated damage costs for selected weather events in Isle of Man

Weather event	Estimated costs (2005 prices)
Sulby floods, December 2000	>£3.2 - £3.7 million
Tidal Surge, February 2002	>£8 million
Windstorm, January 2005	>£15 million

A summary of the impact categories included in quantitative terms in the costing of the weather event historical analogues is given in table 2.

Table 2: Summary of impact categories covered in analysis of historical analogues

Weather Event	Impact Categories					
	Property	Utilities	Emergency Services	Forestry	Transport	Health
Sulby flood	√		√			√
Storm Surge	√		√		√	√
Windstorm	√	√	√	√	√	

To estimate the future vulnerability of these impact categories the quantitative data available from the report on the interpretation of the socio-economic scenarios was used to calculate how the number of impact receptor units may change, for the three 30-year time-slices centred on the 2020s, the 2050s and the 2080s.

Sulby flood

The results for a Sulby flood-type event are in table 3 and are presented on the basis of aggregating flood costs per household-equivalents of £55,980 and £66,240. These per household costs incorporate all property damages, emergency services costs and health costs associated with households. Table 4 shows that the aggregate costs differ little between the low and high scenarios used here. This is partly because these quantitative results are driven by population and household size data given by the socio-economic scenarios. There are a large number of other socio-economic factors that are likely to be important in determining the overall costs. We judge that the net impact of these other

factors is likely to be to reduce the cost estimates under the low scenario and increase the cost estimates under the high scenario, thus exacerbating the existing difference in cost estimates under the two scenarios.

Table 3. Aggregate costs of Sulby 2000-type floods under alternative UKCIP socio-economic scenarios (£m)

	£ per affected property	2020s		2050s		2080s	
		Low	High	Low	High	Low	High
No of properties		65	67	70	78	75	91
	55,980	3.63	3.76	3.91	4.35	4.20	5.09
	66,240	4.29	4.45	4.63	5.14	4.97	6.03

The total costs of a windstorm event such as the one that impacted on the island in January 2005 are summarised in Table 4 4.

Table 4. Total costs of a January 2005 windstorm event under alternative socio-economic scenarios – high estimates (£m)

Impact category	2020s		2050s		2080s	
	Low	High	Low	High	Low	High
property residential	9.1	9.4	9.8	10.9	10.6	12.6
property business	2.9	3.1	6.3	8.2	13.5	21.8
property vehicles	0.1	0.1	0.1	0.1	0.1	0.1
emergency services	1.0	1.0	1.1	1.2	1.1	1.4
utilities	0.1	0.2	0.2	0.2	0.2	0.2
forestry	2.9	2.9	2.9	2.9	2.9	2.9
transport	3.8	5.1	5.7	10.2	8.6	27.2
Total	**20.0**	**21.8**	**26.1**	**33.7**	**37.1**	**66.3**

The total costs of a tidal surge event such as the one that impacted on the island in February 2002 are summarised in table 5.

Table 5. Total costs of a 2002-type Tidal Surge event under alternative socio-economic scenarios – high estimates (£m)

Impact category	2020s		2050s		2080s	
	Low	High	Low	High	Low	High
property	9.1	9.4	9.8	10.8	10.5	12.6
health	0.4	0.4	0.4	0.5	0.4	0.5
emergency services	1.0	1.0	1.0	1.2	1.1	1.3
transport	0.02	0.03	0.03	0.05	0.05	0.1
Total	10.4	10.8	11.3	12.5	12.2	14.5

In the second stage of the impact assessment we estimate how the frequency (or probability) of a given climate event changes under alternative climate scenarios. This

allows us to calculate expected monetary values of these impacts. The non-climate change annual probability of occurrence of the Sulby flood event was 0.004, whilst those for the January 2005 windstorm event and the February 2002 storm surge event were approximately 0.02. Thus, the annual expected average costs of the three events under non-climate change scenarios can be estimated by multiplying the total event costs for each socio-economic scenario by these probabilities, for the Sulby flood event, the January 2005 windstorm event and the February 2002 storm surge event respectively. The climate change probabilities for the Sulby flood event and the storm surge event were derived from the UKCIP02 climate scenarios and transferred to the Isle of Man context. The results for non-climate change and climate change scenarios – both incorporating the socio-economic change – for the Sulby flood-type event are presented in terms of Annual Average Damage costs in table 6. We can see that the "with climate change" AADs for the high socio-economic scenario in 2020s are over two times greater than the "no climate change AADs (0.19m compared to £0.08m), whilst they rise to almost six times greater in the 2080s.

Table 6. Estimated AADs for climate change and non-climate change scenarios – Sulby flooding type event (£)

	2020s		2050s		2080s	
	Low	High	Low	High	Low	High
Non CC (prob)	0.004	0.004	0.004	0.004	0.004	0.004
AAD (Low cost est.)	10000	20000	20000	20000	20000	20000
AAD (High cost est.)	20000	20000	20000	20000	20000	20000
With CC (prob)	0.006	0.01	0.008	0.016	0.0112	0.0228
AAD (Low cost est.)	20000	40000	30000	70000	50000	120000
AAD (High cost est.)	30000	40000	40000	80000	60000	140000
Net CC Impact						
AAD (Low cost est.)	10000	20000	10000	50000	30000	100000
AAD (High cost est.)	10000	20000	20000	60000	40000	120000

The same type of comparison of the "with climate change" and "no climate change" results can be made for the storm surge event. Here the differences are even greater than for the Sulby flooding-type event. For the same scenarios, in 2020s the "with climate" result is over three times greater than the "no climate change" result whilst by the 2080s it is almost 20 times greater. Note that by this time, under the "high" scenario, the climate change induced costs are projected to be over £1 million per year. Note that in both cases, the climate change element dominates the socio-economic change element. The costs of climate change therefore dramatically increase the costs of weather events, annualised over the time periods considered.

Table 7. Estimated AADs for climate change and non-climate change scenarios – 2002 Storm Surge event (£m)

	2020s		2050s		2080s	
	Low	High	Low	High	Low	High
Non CC (prob)	0.02	0.02	0.02	0.02	0.02	0.02
AAD (Low cost est.)	0.19	0.19	0.20	0.22	0.20	0.24
AAD (High cost est.)	0.21	0.22	0.23	0.25	0.24	0.29
With CC (prob)	0.02	0.06	0.02	0.1	0.04	0.4
AAD (Low cost est.)	0.19	0.58	0.20	1.08	0.40	4.77
AAD (High cost est.)	0.21	0.65	0.23	1.25	0.49	5.82
Net CC Impact						
AAD (Low cost est.)	0	0.39	0	0.86	0.20	4.53
AAD (High cost est.)	0	0.43	0	1.00	0.24	5.53

Note that these estimates are calculated as gross impacts with no consideration of possible adaptation responses that might mitigate these impact costs. Note also that as this method is applied it only gives climate change costs for specific-intensity events. To estimate climate change costs for all extreme weather events, the costs for the full range of probability-events would have to be estimated.

There are no available estimates of the changes in frequency of extreme windstorms for the Isle of Man or the UK. As a consequence, we are not able to estimate the annual average damage costs associated with climate change. Instead, in table 8 below, we present the AADs for the non-climate change costs for the three future time periods incorporating socio-economic change. Threshold analysis could be used to explore the value of AAD that would justify a proposed adaptation decision.

Table 8. Estimated AADs for non-climate change scenarios – 2005 Windstorm event (£m)

	2020s		**2050s**		**2080s**	
	Low	High	Low	High	Low	High
Total - Low	19.0	20.7	22.6	26.8	30.2	41.6
Total - High	20.0	21.8	26.1	33.7	37.1	66.3
Non CC (prob)	0.02	0.02	0.02	0.02	0.02	0.02
AAD (Low cost est.)	0.38	0.41	0.45	0.54	0.60	0.83
AAD (High cost est.)	0.40	0.44	0.52	0.67	0.74	1.33

The cost estimates presented above are only indicative and are dependent on the robustness of the many assumptions that have had to be made. However, it is clear that socio-economic change matters and has to be considered in making climate cost estimates. The cost of the weather events may be up to 4 times as much or 50% less than the historical cost estimates, depending on the time-slice and particular socio-economic scenario being considered.

When climate change and the related increases in frequencies of the events considered are accounted for, the Annual Average Damage Costs increase significantly over the time

horizon to 2100. In the two cases – riverine flooding and storm surge damages – where the AADs can be calculated it is clear that they are two and three times higher than at present, even in the first time period. This seems to provide additional justification for the decision already made to invest in improved flood defence systems in Sulby. It is therefore hoped that the AAD cost evidence presented above may be used to inform other decisions regarding public investment in climate change adaptation measures.

The previous sections have taken the estimation of climate change costs for the Isle of Man for three extreme weather events as far as the science will currently allow. Socio-economic change has been imposed on the costs of these weather events identified through study of historical analogues. Clearly, the resulting cost estimates are only indicative and are dependent on the robustness of the many assumptions that have had to be made. However, it is clear that socio-economic change matters and has to be considered in making climate cost estimates. The cost of the weather events may be up to 4 times as much or 50% less than the historical cost estimates, depending on the time-slice and particular socio-economic scenario being considered. When climate change, and the related increases in frequencies of the events considered are accounted for, the Annual Average Damage Costs increase significantly over the time horizon to 2100. In the two cases – riverine flooding and storm surge damages – where the AADs can be calculated it is clear that they are two and three times higher than at present, even in the first time period. This seems to provide additional justification for the decision already made to invest in improved flood defence systems in Sulby. As the procedure outlined in the preceding sub-section suggests, it is hoped that the AAD cost evidence presented above may be used to inform other decisions regarding public investment in climate change adaptation measures.

Technical paper 8: Sector impacts

This technical paper looks at the potential impacts and adaptation options for a number of key sectors reflecting the diversity of the Isle of Man's society, economy and environment.

The process follows the stages set out in the UKCIP Risk, uncertainty and decision making framework (see figure 1 below). Each sector has been laid out following the risk framework, allowing stakeholders to review, repeat or update the information presented at a later date.

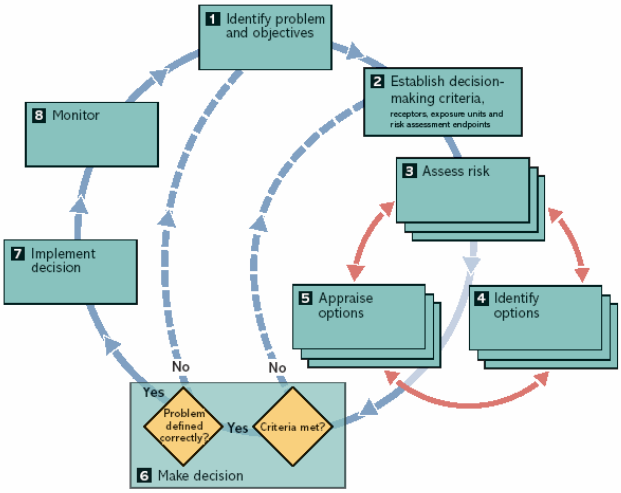


Figure 1: UKCIP Risk, uncertainty and decision making framework

The key social. economic and environmental sectors for the Isle of Man have been categorised as:

- Transport
- Business and the economy
- Tourism
- Society and culture
- Historic environment
- Health
- Leisure and recreation
- Communications and energy infrastructure
- Water management
- Waste management
- Built environment
- Natural resources and environmental quality
- Marine environment
- Agriculture, fisheries and forestry

Stage 1 and 2: Baseline characterisation and decision making criteria

A baseline characterisation has been completed for each sector, reviewing the existing sector challenges, current and proposed strategies, programmes and action plans from published sources. This looks at all challenges, not just those which are driven by climate change or climate variability. Any current issues and problems are identified together with any receptors, exposure units and sensitivities (where information is available). The outputs presented here take into account the two workshops and discussions with stakeholders on the Island.

In these stages the following questions were asked:

- What are the important decisions for the Isle of Man both now and in the future?
- Is climate already an issue? Is it being taken into account now?
- Will climate change become a factor or more of a factor?
- Who are the key stakeholders?
- Are there any timescales involved?
- What are the criteria for recognising a successful outcome?
- What are the legislative requirements or constraints?

The responses are contained within a characterisation statement and a stages 1 and 2 issues matrix for each sector.

Stage 3: Impact assessment

A review of existing published sources and stakeholder engagement has allowed possible impacts to be identified. The active involvement of stakeholders has been particularly important during the process. The impacts have been provided in a series of impact matrices for each sector for ease of reference. Each impact has been classified according to information source

This analysis is contained in a stage 3 impact matrix for each sector.

Stage 4: Identify Options

A number of potential adaptation options were identified ranging from the need to do something now or to monitor future change. The inputs from the workshops and the steering group played a major role in this stage, which were combined with existing published impact assessments in order to provide a wide range of potential responses.

Stage 4 adaptation option matrixes have been included for each sector and have been arranged following the process developed for UKCIP as part of the UK Adaptation Policy

Framework. This identifies adaptation actions under two broad headings: building adaptive capacity (BAC) and delivering adaptive action (DAA). A review of the actions for BAC and DAA can be found in technical paper 12. Examples of actions for BAC and DAA are:

Building Adaptive Capacity

Examples include:

- Research / data collection and monitoring e.g. use research to better understand the climate risk
- Changing standards, regulation, policy e.g. strengthen planning guidance on developments in flood risk areas;
- Awareness raising /working in partnership e.g. increase public awareness about coping with flooding at home.

Delivering Adaptation Action

Examples include:

- Prevent the effects: structural and technological e.g. strengthen building foundations to cope with climate change
- Accept impacts and bear loss e.g. accept that some land will flood in winter
- Spread/share impacts e.g. insure business against weather losses
- Avoid negative impact / exploit opportunities e.g. grow new agricultural crops better suited to new climate

Where possible 'Low Regret', 'No Regret' and 'Win-Win' options were identified. These are classified as follows:

- *No regret* options are those that will deliver benefits whatever the extent of climate change (and even under the absence of manmade climate change.) A no regret option is determined to be worthwhile now (in that it would yield immediate economic and environmental benefits which exceed the cost), and continue to be worthwhile irrespective of the future climate.

- *Low regret* options are where the implementation costs are low (bearing in mind the uncertainties with future climate change projections) whilst the benefits under future climate change may potentially be large. For example, raising awareness of flood risks and the need to use water wisely are all low regret options.

- *Win- Win* options are where the options deliver a benefit for adapting to climate change and also a benefit for another purpose. For example, improving food hygiene and preparation standards meets the challenge of increased risks arising from higher temperatures but also improves overall hotel and catering standards for the benefit of tourism on the Island.

At the end of each sector a commentary has been provided by acclimatise which summarises the key risks and opportunities. A discussion as to other important aspects is also included, together with any significant adaptation options that should be investigated.

In this technical summary the commentary sections for each of the key social, economic and environmental sectors for the Isle of Man have been reproduced.

Transport

Transportation links to the island are already at risk from extreme events, climate change will increase the risk of disruption. Design, maintenance and operational standards will need to take climate change into account if the Island is to meet its objectives for a safe, reliable and quality transport system.

Transportation on the Island is also at risk of disruption from major storms and river, coastal and storm surge flooding. The management of, and response to these types of events should be given further consideration.

A number of major transport infrastructure projects planned for the Island i.e. marina improvements, harbours, Douglas promenade, the airport and the rail infrastructure renewal programme where the design life of these will extend into the middle / latter part of this century must take into account potential impacts on the design, operation and management of these facilities. Using historic climate data as a basis for design will reduce the resilience of assets to cope with future climate change, leading to a risk of infrastructure and service failure. Climate proofing new projects during the design stage through an integrated risk assessment process may lead to significant cost savings, when compared with the costs of extreme events and future remedial works. The work undertaken in technical papers 5 and 7 exploring the costs of extreme events illustrates the impact of climate change on transport infrastructure and services.

Maintenance procedures of existing infrastructure will need to be regular reviewed to ensure that disruption is minimised, service maintained and the effective use of resources, including finance, is assessed. For example, an increase in the incidence of fretting of road surfaces will in turn increase maintenance expenditure.[5] Furthermore, hotter drier weather will increase the risks to break-up of asphalt surfacing. Both of these raise important issues of safety and maintenance, particularly for motorcyclists, especially as the TT races play a vital role in the tourism of the Island.

The current transport demand forecasts may be less robust due to the effect of climate change. Indirect impacts and adaptation responses taken by other sectors need to be taken into account e.g. tourism and the built environment.

Examples of potential impacts

- Disruption to transport modes from flooding and other extreme weather events
- Maintenance and repair of existing assets need to take into account climate risks

[5] Prioritising future construction research and adapting to climate change infrastructure (transport and utilities) By M I Wilson and M H Burtwell PR/IS/13/02 CRISP Commission 01/13 Feb 2002 TRL that refers to unpublished project report by UK's Transport Research Limited (TRL) on climate change and the Highways Agency. 2001

- Asset failures under increasing temperatures e.g. road surfaces, expansion joints, railway track and equipment
- Impact of storm surge and tidal flooding on coastal roads
- Increase in cycling and motorcycling accidents in summer

Examples of opportunities

- Climate proofing new projects at the design stage may lead to significant longer term cost savings
- Reduction in de-icing of runways and aeroplanes, with consequential cost savings and improvements in surface water discharge quality.

Potential adaptation options

- Improve land / storm drainage to prevent flooding / damage to roads
- Strategy to retrofit assets to cope with climate change
- Asset vulnerability inspections and mapping
- New road schemes with improved drainage systems
- Maintenance procedures and standards regularly reviewed to take the changing climate into account

Business and the economy

One of the reasons why the Isle of Man has been so successful in attracting inward investment and foreign / offshore business is through its reputation of having a high quality of life associated with its landscape, socio-environmental and economic systems. The effects of climate change on the Island will impact on many of the contributing factors to the quality of life and character of the Island, which will indirectly affect the economy and business as a whole.

Existing building premises including shops, offices and factories are designed to historic climate standards. In existing warm spells people already experience uncomfortable conditions in their place of work. The impact of climate change will exacerbate this impact particularly in hotter, warmer conditions. Internal temperatures above 25°C will become more frequent, the temperatures above which performance and business productivity drops and employees complain about their working conditions.[6]

Companies with staff working outside will need to consider the health and safety implications of increasing temperatures and exposure to UV radiation. Food preparation, public health and hygiene issues will become an increasing issue under higher temperatures during both winter and summer.

[6] Hacker, JN, Belcher, SE & Connell, RK (2005). Beating the Heat: keeping UK buildings cool in a warming climate. UKCIP Briefing Report. UKCIP, Oxford.

All business should be aware of the increasing risk of disruption to support services, including transportation. Even if not affected directly – business may suffer through indirect effects to their supply chains (both on and off the Island).

Businesses will face increasing insurance premiums resulting from disruptions to their business and damage to their property and assets. Businesses need to adopt a risk management approach to ensure their processes and operations are resilient to climate threats and to make the most of opportunities arising.

An interesting feature of the Isle of Man's economy is its openness – in that the bulk of income used to fund domestic consumption is generated from exporting goods and services (primarily financial services). The performance of the island's economy is therefore strongly linked with global events and economic conditions in trading partners (particularly in the UK). Further consideration of the effects of climate change on global economic issues and the consequential impacts on the Isle of Man is provided in technical paper 9.

The Isle of Man, in comparison with some other offshore financial service centres around the world, is likely to be at a lower risk from the effects of climate change e.g. the Cayman Islands and the Bahamas. This may provide the Island with a growing competitive advantage and increasing attractiveness to international financial services companies. It can be expected that that such companies when carrying out their due diligence before locating to the Isle of Man, will assess government strategies and climate risk management measures before relocating or continuing business on the Island.

Businesses face different risks as a result of climate change, depending on the markets in which they operate and their geographic location. There are essentially five broad categories of climate-related risk to which businesses (and investors) are exposed:

- **Regulatory Risk**: Policy measures adopted at the international, national and local level will have direct (financial) implications for businesses and sectors.
- **Physical Risk**: The physical impacts of climate change (including storms, floods, droughts and sea level rise) will directly affect some sectors and businesses – especially those that are heavily dependent on the physical environment, water and weather. Sectors at particular physical risk include: agriculture, insurance, real estate, tourism, water, health care, and transport.
- **Litigation Risk:** Just as the tobacco and asbestos industries faced lawsuits for the impacts they caused, it is always possible that businesses responsible for significant amounts of greenhouse gas emissions could be held liable for damages arising from climate change. Failure to take into account a changing climate will place Companies, directors and their professional advisors at risk of future legal action.
- **Competitiveness Risk:** Businesses that fail to proactively take measures to adapt and mitigate climate-related risks may place themselves at competitive disadvantage relative to competitors that do so.
- **Reputational Risk:** Businesses that are viewed negatively may find themselves damaged in markets where the general public is concerned about climate change.

These potential risk exposures need to be recognised both at Government and at corporate levels and included within risk assessment procedures.

Examples of potential risks

- Increasing insurance and regulatory costs for business
- Impacts of climate change on regional and worldwide markets for financial services
- Business continuity
- Health and safety implications for workforce
- Disruption to business and supply chains and transportation systems by extreme events

Examples of potential opportunities

- Indirect impacts from outside /external climate change impacts on the Island – Isle of Man may have a competitive advantage
- Opportunity for the Isle of Man to provide business continuity support facilities for major financial companies affected by extreme events around the world.
- Changing markets and demands for good and services

Potential adaptation options

- Due diligence and corporate governance procedures to include climate risk assessments
- Stress-testing decisions against alternative climate scenarios
- Planning and design requirements for buildings
- Assess potential costs over a longer time horizon
- Awareness raising within the business community

Tourism

The risk of flooding in Douglas and its potential impact on tourism is already an issue for the Isle of Man. The risk of flooding and the financial costs will increase under the climate change scenarios. (In technical paper 7 an analysis of the potential costs of an extreme event has been undertaken which will provide further guidance on this issue). Increasing summer temperatures and more extreme high temperatures will have implications for the cooling of buildings (accommodation, leisure and tourist attractions, restaurants etc.) Designing in climate resilience now will ensure that the infrastructure is robust for the future.

The tourist sector is reliant upon supporting services and infrastructure on the Island, which also need to be resilient to climate change. If climate impacts are not considered then the levels of services to tourists and visitors may decline. Increasing temperatures for example will have impacts for food hygiene, food preparation and storage; maintaining high standards in these areas is vital if the Island is to meet its strategy of developing a tourism industry based on high-income visitors.

Baseline data indicates that the tourist sector is currently less reliant on good weather as most visits to the Island are event or activity driven. Increases in temperatures throughout the year together with a warmer and prolonged summer season may provide additional opportunities to develop tourist related events and activities. However there may be disadvantages associated with increased visitor numbers, e.g. impact on transport infrastructure and other supporting services.

Tourism is intrinsically linked with the natural resources and landscape character of the Island. Changes in these areas will have impacts upon the industry. Increases in tourism will also in increase the stress upon these areas. A recent study undertaken in the north-west of England[7] highlighted the consequential risks for the environment, e.g. footpath erosion, heath and moorland fires, associated with a changing climate and increasing visitor numbers.

The study also noted:

> "Until recently, the common belief that the warmer, drier summers brought about by climate change would stimulate a boom in visitor numbers, has not been questioned. However, the relationship between climate and visitor demand is complicated, and the economic opportunities may not be this straightforward. Although based on limited data, the research findings suggest that recreational behaviour in the Northwest appears to be fairly resilient to the weather – this resonates with other recent research findings internationally. Climate influence on visitor behaviour is more likely to be overshadowed by socio-economic trends, particularly how we choose to spend our leisure time in the future."

Examples of risk

- Visitor facilities and accommodation may need to be upgraded to provide expected levels of service under higher temperatures.
- Increased risk of upland fires
- Increase in the risk of food poisoning arising from the impact of higher ambient air temperatures on food hygiene, preparation and storage.
- Impact of storm surge on main accommodation areas in Douglas.

Examples of opportunities

- Expansion of café culture and outdoor dining
- A longer, more reliable summer and warmer winter extending the tourist season
- New markets in specialist activity/event holidays based on water sports/leisure and eco-tourism

[7] McEvoy, D., Handley, J. F., Cavan, G., Aylen, J., Lindley, S., McMorrow, J. and Glynn, S. (2006). Climate Change and the VisitorEconomy: the challenges and opportunities for England's Northwest,Sustainability Northwest (Manchester) and UKCIP (Oxford).

Potential adaptation options

- Fiscal incentives to encourage improvements to buildings to cope with excessive heat in summer and / or wet weather in winter
- Monitor and review food hygiene, preparation and storage procedures – introduce new standards
- Landscape assessment to identify at risk areas and tourist 'carrying capacity'
- Review land-use planning policies to encourage farm diversification and development of holiday accommodation

Society and culture

There is a strong national identity on the Island and this should be considered an important aspect when considering climate impacts. The determination and pride in the Manx national identity has created a natural resilience, which may prove to be of wider benefit in meeting the challenges of climate change. Small island states are often acknowledged as being particularly exposed to the potential impacts of climate change, a point noted by the Intergovernmental Panel on Climate Change (IPPC):

'small island states clearly are a vulnerable group of countries and hence are significantly at risk from climate change'[8]

The Isle of Man's unique political, social and economic position with regard to the UK and the EU has led to the development of a culture of 'adaptive capacity' and self-reliance. This culture, supported by a strong national identity and natural resilience, will help the Island adapt and manage the climate risks and opportunities.

Social changes play a significant role in how much impact climate change will have on the Isle of Man, as already demonstrated in technical report 6 which looks at the impact of future socio-economic scenarios.

Education plays a vital role in securing the future of the Island. Raising awareness within children is a major adaptive action. The Isle of Man should carefully examine opportunities for building adaptive capacity through education.

Further research on the affect of a changing climate on social services and support organisations (particularly the voluntary sector), social structures, and on the culture of the Isle of Man is desirable.

Examples of risk

- Impacts on vulnerable sections of society: the elderly, young children, and those with respiratory illnesses

[8] IPPC Intergovernmental Panel on Climate Change reports http://www.ipcc.ch/

- Impact on reputation of Isle of Man – extensive (potentially adverse) media coverage of extreme events
- Voluntary social service and support organisations ability to cope in extreme events

Examples of opportunities

- Lifestyles and health may benefit from a move to a more outdoors culture throughout the year, providing that the potential adverse health impacts from increased exposure to sunlight and air pollution are managed
- The Island's response to the challenge of climate change may reinforce 'national identity'

Potential adaptation options

- Identification of vulnerable groups in society and action plans developed for extreme events
- Engaging children through the education curricula. Climate change can be an interesting and informative topic for covering a range of topics and can be approached quantitatively and qualitatively.
- Examine potential correlation between 'climate change' and 'quality of life' indicators

Historic environment

Recent extreme events have highlighted the existing vulnerability of the Island's historic assets to the weather. Under climate change this vulnerability may be increased and further exacerbated by seasonal changes.

The impacts of climate change may question the 'save all' approach to the historic environment to be reviewed, as it may not be realistic to conserve all features for posterity, particularly those on coastal sites. Value and significance must also be assessed when reviewing the impacts of climate change to ensure that resources are used effectively.

Existing baseline data for each site should be reviewed to identify potential climate sensitivities and impact thresholds. A programme of historic site routine monitoring would allow deterioration rates to be tracked and provide further information on climate impacts.

There is a great deal of information regarding the impacts of climate change on the historic environment, although there is little supporting information on adaptation options. Further research and assessment of suitable options for individual sites or buildings is required. Although generic 'options' guidance will be beneficial, it is important that risk assessments are undertaken at a site specific level to identify the most appropriate adaptation action.

Examples of risk

- Building decay accelerated as a rise in temperature may lead to an increased rate of chemical attack on certain structures and fabrics
- Increased winter rainfall and storminess, particularly in exposed areas, resulting in water-saturated building fabrics
- Drier compacted soils are likely to increase the risk from subsidence; vulnerable sites will require stability assessments and protective measures
- Increase in damage from increasing visitor numbers

Examples of opportunities

- Increase in visitor interest in the Isle of Man's history and culture providing additional revenue
- Drier summers and changes in crop patterns may expose previously unknown archaeological sites

Potential adaptation options

- Need to consider the susceptibility of different materials to the likely future climate
- Identify sites at risk from subsidence - vulnerable sites will require stability risk assessments and suitable protective measures
- Identify sites at risk from flooding.
- Assess potential adaptation options.
- Review baseline data for historic sites and review against climate change impacts to identify knowledge gaps.

Health

Changing patters in disease and illness will occur under climate change and need to be considered in long term planning. The impacts will not be felt uniformly across age or socio-economic groups. The more vulnerable in society are likely to be most exposed to the potential impacts. Understanding how the combination of climate change impacts on disease and health combined with the demographic and socio-economic will need to be considered in greater detail, and reviewed as our understanding of climate change improves.

The complexity of the interaction between these factors prevents means that there will be winners and losers, for example a warmer winter clearly has benefits in reducing the health risks for vulnerable groups who, for example the elderly, can face difficulties associated with the cold in winter months. By contrast during the summer, respiratory illnesses such as asthma may become an increasing problem for all age groups.

Health and social service organisations will need to monitor the impact of climate change on health and disease profiles. Adaptation responses may not necessarily take the form of

direct medical treatment. Most of the work undertaken elsewhere on health impacts has focused on changes in illness and disease, vectors and vulnerable populations. Further work is required on the impacts on health care and treatment, training, building design and facilities. Additional work is also required to understand the impacts on health support services, particularly those provided by the voluntary sector.

Food preparation, hygiene and storage together with other public health issues such as contamination of shellfish through algal blooms, vermin control, drinking water quality and waste management are important issues. A warming drier summer and a warmer winter with fewer frosts creates ideal conditions for a variety of new and increasing public health impacts. Existing standards should be regularly reviewed to ensure that standards appropriate to the changing risks are set. Continuous and improved training in all areas where public health and hygiene is at risk, with a particular emphasis on the food chain and the tourism industry will be a major adaptation action.

Examples of risk

- Increased incidence of mould growth and associated health risks (asthma, allergies etc), particularly in poorly heated / ventilated housing
- Increased risk of skin cancer, heat exhaustion and dehydration
- Exposure of vulnerable groups
- Health problems associated with food preparation, hygiene and storage in higher temperatures
- Vermin population explosions

Examples of opportunities

- Tendency towards eating healthier foods in warmer weather
- Fresh healthy and locally produced food available for a longer period
- More opportunities for outdoor activities, with associated health benefits
- Reduction in fuel poverty risks for the elderly

Potential adaptation options

- Heat warning systems for the elderly during 'heatwaves'
- Awareness raising of impacts of sun exposure and the need for preventative measures, for example, Australia's 'slip, slap, slop' campaign
- Monitoring of disease and illness against changes in climate variables,, for example, temperature, humidity, and precipitation
- Assess hospital buildings and other health care facilities (existing and proposed) – design for the future not the present.
- Stress-test existing public health regulatory standards – do they provide the protection required under a warmer climate

Leisure and recreation

Overall climate change impacts will be positive to the Island for leisure and recreation, although there are clearly risks for which appropriate adaptation options will need to be developed.

Warmer summers will increase the demand for water based leisure activities and new and improved facilities. The Island may well find an increasing demand for new and improved marinas. An increase in water leisure based activities also increases the risk of incidents with a consequential impact on the rescue and emergency services.

Freshwater fishing will be affected by changes in run-off and river flows and in water quality and temperature. The combination of these factors will have an impact on fish stocks and species. Sea fishing will be similarly affected by changes in sea temperature, pH and salinity.

Grounds maintenance and the design of outdoor sports pitches will need to take into account the climatic changes on plant growth and the increase in leisure and recreational activities.

The increasing attraction of summer outdoor sports will increase the risk of sunstroke and heat exposure, especially in children. Sports related injuries may also increase arising from the increased participation in recreational activities. There will be a need for greater education and awareness campaigns on such issues.

Any increase in walking will in turn increase the Island's footpath erosion problems. Recent research in the Lake District[7] has demonstrated that climate change in combination with visitor behaviour (i.e. increased numbers) will exacerbate the problem of erosion. Along with trampling, intense rainfall, combined with drought are critical factors in erosion rates. The research report comments 'footpaths are particularly vulnerable when trampling and rainfall alternate and, with walkers becoming better equipped and more prepared to go out in bad weather, this is more likely to occur.'

Adverse impacts arising from increasing leisure activity as a consequence of climate change can also result in an increased risk of moorland and forest fires. Research within the Peak District National Park has demonstrated that increases in, 'moorland wildfires in the Peak District National Park pose a significant and potentially costly environmental threat'. On the Isle of Man we can expect to see the warmer drier summers creating ideal conditions for moorland and forest fires. Footpath and access management plans will need to take into account these increased risks. Fires in remote areas away from roads and water supplies place severe stress on the emergency services.

Examples of risks

- Grass pitches, bowling greens, golf courses etc. may need additional drainage systems to cope with increased intensity and short duration storms
- Conversely these facilities may also have increased demand for irrigation during the warmer summer months
- Increased erosion on mountain trails for cycling and motorcycling, and on footpaths

- Increased exposure to the sun and an increase in sports-related injuries

Examples of opportunities

- Potentially greater participation in outdoor sport and leisure activities
- An extended 'season' for outdoor activities, and use of facilities with increases in revenues
- Reduction in heating requirements for indoor swimming pools and other leisure and recreational buildings
- Development of new facilities to meet increase in demand, creating wider economic benefits

Potential adaptation options

- Heat and sun exposure awareness raising campaigns
- Change to drought tolerant and harder wearing grass-seed mixes
- Sub-soil drainage systems for both natural and artificial pitches adapted to store rainwater for re-use
- Rain water harvesting and storage to irrigate sports pitches and golf courses
- Restrictions on access to vulnerable areas at risk from fire during heatwaves

Communications and energy

The energy and communications sectors both have large fixed assets that will be affected by climate change during their design life. Climate change will also have impacts upon demands (average and peak) and on security of services and supply. Asset maintenance and operating procedures will be affected by extreme events and by the changes in demand. The potential impacts and risk assessments will need to be reviewed at regular intervals as our understanding of climate change improves. All new infrastructure projects should be designed on the basis of the future climate rather than historic climate data.

Energy

Stakeholders considered that the top priority is security of supply, as the Island is reliant on off-island sources of primary energy e.g. gas, oil, coal, petrol and diesel. Energy prices are rising and consideration should be given to the possibility of fluctuations in supply from the UK. Climate change impacts have the potential to increase the potential exposure of the Isle of Man to security of supply risks. The Island may be more susceptible to changes in increased competition for available energy caused by extreme events and changing patterns in peak and average energy demands elsewhere. The Isle of Man may be left exposed by the prioritisation of energy supplies by UK and Republic of Ireland suppliers under these circumstances

Energy is likely to become more expensive in the longer term, as prices continue to rise. Prices may also rise for fossil fuel based energy sources as financial measures are taken by

governments to reduce their use. Although there is clearly a significant potential impact on the Island, it also presents an opportunity for the Isle of Man to consider alternative energy sources.

Business continuity plans should address responses to issues such as disruption to supply caused by extreme events and longer term changes in demand profile, for example peak seasonal demands shifting from winter to summer.

There is an excellent opportunity to explore the development of renewal energy sources on the Island. This could provide a 'win win' situation not only providing adaptation to climate change but also allowing the Island to be more resilient to the economic impact of energy costs and contributing to the global reduction of greenhouse gas emissions. Greater self-sustainability in renewable energy sources will also assist with the development of a robust and resilient economy. The Island has an opportunity to 'choose its path' and plan for the future making greater use of renewable energy.

Future design standards, operating rules and maintenance procedures should be reviewed and stress-tested against the climate impacts.

Increasing energy efficiency has a number of potential benefits and is an important adaptation option which also has the benefit of reducing emissions. Reducing overall demand by increasing efficiency of appliances and buildings is an important action that improves the resilience of the Island.

Telecommunications

The risk of interruptions to telecommunications and radio infrastructure from extreme events is already a significant problem. The risk is likely to increase under climate change. Climate proofing of assets, maintenance regimes and design standards needs to be undertaken. The work undertaken in this study and reported in technical paper 5 has identified the significant costs associated with extreme events and the reliance by emergency services, residents and businesses on a resilient communications network.

Future design standards, operating rules and maintenance procedures should be reviewed and stress-tested against the climate impacts.

Business continuity plans should address responses to disruptions to communications caused by extreme events.

Examples of risks

- Ground movements may affect underground cabling, pipe work, overhead and underground networks etc.
- Increasing pressure on security of supply
- Disruption of energy supplies and communications during extreme events
- Change in demand profile and related changes in plant maintenance cycles
- Flooding of installed assets

Examples of opportunities

- Development of a renewable energy generation capability on the Island reducing the exposure to external security of supply issues
- Improving energy efficiency

Potential adaptation options

- Flood proof buildings to ensure assets are not damaged and services remain uninterrupted during flooding episodes
- Business continuity requirements identified, documented and periodically reviewed
- Stress- testing design, operational and maintenance procedures

Water management

There will be a significant climate change impact on the water environment. The direct effects will be felt on water resources, the treatment and supply of drinking water, sewerage and sewage treatment and drainage. There will also be significant indirect effects on all those other sectors where the water environment is an integral element, for example, agriculture, tourism, the built environment, business, and the ecology of the Isle of Man.

Baseline data collection is extremely important. It is recognised that there are knowledge gaps (for example, accurate catchment models and watercourse flow monitoring) and steps are being taken to address some of the issues. A regular periodic review of the impacts of climate change on the water environment and on the demands for water from competing sectors is required, together with a programme of stress-testing assets. Design standards, operational procedures and maintenance regimes will have to change in response to the anticipated and actual changes in the climate.

Water resources

Climate change will affect the reliable yield and quality from reservoir and stream intake sources. The Water Authority acknowledges that the reservoir yield estimates do not presently allow for the reduction in summer and autumn runoff into the reservoirs which is predicted to result from climate change.

There will be increasing competition for the water resources, for example to maintain minimum flows in watercourses and from agriculture for irrigation.

The work undertaken in this study on the hydrological impacts of climate change (see technical paper 10) emphasises the need for routine flow monitoring in watercourses to build a better understanding of each of the catchments. Gauging stations will provide baseline data required to assess in detail the hydrological impacts of climate change from

both a resource and flood management perspective. This will allow more robust and resilient adaptation options to be assessed.

Water treatment and supply

The impact of climate change was considered during the design stage of the two new treatment works. Although the best available information was used at that time they have been designed to service a population projected to 2021, taking into account the findings of reports published in 1996 and 1998. These reports reflected the state of understanding of climate change from the early 1990s. It should be noted that there have been significant advances in our understanding of the climate change in the last 15 years. It is recommended that the designs should be stress tested against the climate scenarios presented in this report, and against the more recent guidance provided by the Environment Agency in England and Wales and the UKCIP CCDew report.

Raw water quality will be affected by climate change resulting for example from changes in water temperature, the breakdown of moorland soils leading to increased tannin levels causing discolouration and nutrient discharges from agricultural land. Water quality will also be affected in all watercourses by the impact of storm run-off during low-flow conditions. The potential increase in use of fertilisers if land at higher altitude is brought into agricultural may need to be controlled. The treatment processes at the water treatment works will need to be able to cope with a changing and perhaps more variable raw water quality over their asset life.

Hotter summers and warmer winters will create additional problems for the maintenance of water quality in supply and distribution systems. Monitoring procedures and operational practices will have to be regularly reviewed to ensure that drinking water quality at the tap does not deteriorate.

The demand for drinking water will be affected by the direct and indirect climate change impacts identified in this report. There will be increasing competition for water between agriculture, leisure, business and the environment. Extended dry and warmer periods during the summer may become an increasing problem. Demand management, water conservation, water efficient appliances, leakage control and drought contingency plans all have a role to play as adaptation measures. Additional measures such as water harvesting, use of grey water and water efficient designs for new buildings can be effective as a demand management option.

Sewerage and sewage treatment

A change in rainfall patterns (short duration, high intensity storms) will place pressure on sewerage systems, leading to increases in storm and foul flooding in urban areas, and pollution of watercourses. Sewer and pumping station design standards will need to be reviewed to take into account the change in rainfall patterns and storm return periods.

There will be an increasing risk of pollution in low flow rivers during summer months from storm overflows and surface water drainage systems. Storm overflows will operate more frequently. Drier summers will encourage the build up of silt, fats and other material, and intrusion of tree roots, leading to an increased risk of blockages and both surface and foul

flooding. Vermin control in sewerage systems during the summer and over an extended period with warmer winters will become an increasing problem. Higher temperatures combined with drier periods in the summer will increase the risk of septicity in sewerage systems leading to significant odour problems.

The operation and management of sewage treatment processes may be affected by the change in rainfall patterns and by increases in both water and ambient air temperature. Odour and fly nuisance may increase and require remedial treatment measures.

Discharge conditions for the discharge of treated effluent, surface water drainage, storm overflows, and trade effluents will need to reflect the impacts of climate change on the receiving watercourse. Tighter consent standards may require additional or new treatment measures to be introduced.

Drainage and flood management

All the climate change scenarios predict an increasing risk of flooding both from rivers and watercourses. Baseline data needs to be collected to add to the understanding of the current risks, to enable flood maps and event return curves to be created. Following on from this comprehensive modelling on flow characteristics and runoff of the watercourses across the island needs to be undertaken. This is also an important issue for strategic and emergency planning, land-use planning, the design, location and maintenance of property assets and infrastructure. The costings work (see technical papers 5 and 7) has demonstrated the significant costs associated with extreme events and the importance of climate proofing.

Coastal areas are under an increasing risk from flooding. There is a need to review defence systems to ensure they are fit to withstand the impacts of climate change on sea level rise, storm surge, wave height and tidal patterns. These impacts will also change existing erosion and deposition patterns along the coastline leading to new and increasing erosion risks and flooding. It is also important that development proposals take into account the increasing risk of coastal flooding and factor this into their design. The proposed scheme for the redevelopment of the Douglas Promenade should for example be designed to take into account a range of climate scenarios.

The changes in precipitation and storm events will also affect the extent of flood plains and the frequency of their inundation. Land-use planning has an important role to play in assessing the risks for new development, ensuring the sustainability of future development and that the risks to existing property do not increase.

A comprehensive drainage and flood management strategy is required to understand the existing risks and the impacts of climate change. Sustainable urban drainage systems have an important role to play. However whilst they can significantly reduce the risk of flooding in new developments, they are less effective (and may be entirely inappropriate) for existing urban areas.

Examples of risk

- Increased risk of algal blooms and stratification in reservoirs
- Increased river and coastal flooding risks, and flash floods in urban areas
- Increased frequency in operation of storm overflows leading to watercourse pollution
- Drinking water bacterial failures arising from increases in water temperature
- Water treatment processes unable to cope with changes in raw water quality
- Increased competition for limited raw and treated water resources

Examples of opportunities

- Increased ambient air and water temperatures may improve sewage treatment biological processes
- Potential for reuse of rainwater / rainwater harvesting
- Adopting a cross-sectoral approach to both flood management and water resources

Potential adaptation options

- Stress testing of water and sewerage assets, to assess their resilience to climate change
- Encourage water conservation and demand
- Incorporate climate change into all designs for flood defences – design for the future and not on historic data.
- Review sewerage design standards and encourage the use of SUDS for new development proposals
- Use open spaces, parks, recreational areas for temporary water storage to alleviate flooding.
- Baseline data collection on catchments, flows, flood plains and event return periods.

Waste management

There has been comparatively little research undertaken to date on the impact of climate change on waste management. The impacts and adaptation options that have been identified are mainly based on anecdotal evidence.

The Island has many challenges surrounding waste management as it examines the most appropriate sustainable strategy for the management, treatment and collection of waste. The waste management strategy for the Island is currently being reviewed and it should be stress-tested with the climate change scenarios. Climate change needs to be integrated into this decision making process as it may influence the options for the future.

The impact on climate change on other sectors, for example tourism, will have knock-on impacts for waste management. Sustainable cross sector solutions will need to be

considered. The potential public health issues arising from a warmer climate for pest and vermin control, odour management and disease with regard to waste management should be carefully assessed. Adaptation options may need to be considered involving increasing the rates of collection or different refuse storage options.

Examples of risk

- Increased rate of waste decomposition within waste reception and storage facilities leading to higher levels of odour, vermin and insect infestations.
- Impact on the combustion process if waste is of higher moisture content than anticipated. This may result in variations to chemical and reagent usage in flue gas treatment systems.
- Higher intensity rainfall would almost certainly increase rates of erosion and may also increase the spread of ground contaminants on landfill sites.

Potential adaptation options

- Increased refuse collections – to reduce health risks as temperatures increase.
- Design waste collection containers to keep waste dry.
- Education needed on waste separation and segregation.

Built environment

The built environment is one of the most susceptible sectors to the impacts of climate change. The buildings, assets and infrastructure, their design and layout, their function and form were all based on a traditionally stable climate. Adaptability in both form and function to a changing climate and to changes in the needs of society is an important issue for the Isle of Man.

Increasing temperatures will affect the maintenance, operations and usability of buildings. Temperature increases will mean that buildings may become too hot, limiting their usefulness and function. The introduction of air conditioning will increase energy usage, adding to emissions. Passive cooling mechanisms need to be investigated for both existing and new buildings.

Climate is already a factor in existing building design with dampness a major problem in older properties. Under the climate change scenarios in warmer wetter winters this problem may increase. Adaptation options will have to be considered to reduce this impact and the associated health problems.

Some parts of the Island would be particularly sensitive to a rise in sea levels, e.g. Ramsey and Douglas. This may require existing buildings to be protected or relocated. It will also influence the location of future developments.

The hydrological impacts (see technical paper 10) will affect the extent of flood plains and the frequency and intensity of flooding. Flood mapping for land use planning should be

based on return period events using the climate change scenarios, rather than events drawn from historic climate data.

Changes in precipitation will have an impact on urban drainage systems. Baseline data collection is required to understand the current situation so forward looking projections can take climate change into account.

The economic impact of floods both coastal and riverine should be considered in development and any defences that are required. As demonstrated by the future costing work of extreme events flooding can be very costly and a balance needs to be struck between the siting of development and the economic implications of flooding. Insurance coverage has already been identified as an issue and will play an increasing role in determining the economic viability of development.

Examples of risk

- Overheating in existing and new buildings
- Increased requirement for specialist expertise in technical aspects such as cooling, ventilation, passive solar design
- More robust designs required for rainwater disposal systems above and below ground
- Increasing dampness leading to mould
- Increased risk of coastal and river flooding and sewer flooding
- Increased risk of subsidence

Examples of opportunities

- Increased solar gain for passive water heating, photovoltaic etc
- Less days lost through frost on construction sites

Potential adaptation options

- Strengthening of roofs and claddings on existing buildings
- Use the ground floor space for flood compatible uses e.g. car parking or raise the ground floor above the likely flood level
- Restrict location of new development

Natural resources and environmental quality

The natural environment will be significantly affected by climate change. A great deal of research has already been undertaken on this sector. Habitats and natural resources are sensitive to climate and the Island is already beginning to experience change.

Climate change needs to be built into land management plans. There will be difficult decisions ahead not least with regard to the conservation of 'at risk' areas already under stress.

The environment is a significant asset to the Isle of Man and climate is one of the key determinants of species distribution and habitats. As the climate changes, the distribution patterns of species and the composition of habitats will change. As the Monarch report states, 'if we are to understand the likely changes and so assess the vulnerability of different species, as well as their ability to adapt, we need to understand how current patterns of distribution are related to our climate.' This is a key action within building adaptive capacity for the Isle of Man as there is a need to gather more baseline data so progress can be measured and benchmarked.

As shown in the Monarch report there will be a shift in species – some species will thrive and 'win' from the changing in climate, but others – in particular montane species – will have their 'climate space' reduced and will be threatened by climate changes.

Other pressures on the environment will increase through climate change. Increased visitor numbers may mean there is more footpath erosion, greater fire risk or even increased development as population grows. (This is discussed in the leisure and recreation section). A sustainable approach that is forward looking needs to be incorporated into biodiversity plans.

Examples of risk

- Increased temperature stress on cold water fish species
- Climate change will alter the probability of invasive and alien species establishing, which may have important effects on local biodiversity
- Drying out of wetlands in summer (A)
- Lower summer river flows providing less dilution for existing discharges – river quality problems (A)

Examples of opportunities

- Provision of more food e.g.insects and therefore enhance biodiversity
- Amphibians may benefit from warmer wetter winter conditions
- Opportunities for range expansion of habitats and species

Potential adaptation options

- Managed retreat, encourage new habitats and increase biodiversity
- Manage protected and designated areas. Integrated land use and management strategies developed
- As a small island with limited resources need to prioritise on monitoring e.g. indicator species for each habitat.

Marine environment

The Isle of Man, like the rest of Europe, has become warmer in recent decades. The 1990s have been recorded as the warmest decade of the 20th century. There is also evidence of warmer autumns, significant increases in night-time minimum temperatures, reductions in the number of frost days and increasing rainfall in the east (Douglas) in spring and decreasing rainfall in the south (Ronaldsway) in summer. There are also clear signs that the marine areas around the United Kingdom and Ireland are changing in response to the warming of the atmosphere. Higher sea temperatures (across the whole of the Northern Hemisphere), associated with increased wind strength and wave heights all contribute to changes in our coastal ecosystems.

Many of the impacts on the Isle of Man's marine environment and biodiversity will be most apparent in coastal areas. Significant changes in response to increased sea temperatures, more intense storms and wind strength and rising sea level are likely. There is evidence of a disruption in the marine food chain, from plankton to fish to sea birds and mammals. An area not previously mentioned, although possibly increasing in importance, is that of increased acidity in the sea. The effects and impacts are not yet fully understood, but research has found that carbon dioxide is also raising acidity levels in the oceans. As expected this will impact upon marine organisms, especially the shells of coral and shellfish such as crabs and oysters. This would also have major implications all through the food chain. Changes in marine species will occur, although the extent to which this occurs is difficult to predict. The expansion of new species into the coastal area will probably be at the expense of other species, either through reduction of prey, increased competition or exploitation. New fish species will be able to colonise areas where fish sensitive to temperature change are displaced. However, the detailed knowledge of how or when this may occur is still not possible.

For impacts on the marine environment, continued close cooperation with the UK and Ireland, as well as other European studies will expand our knowledge of what is happening in the coastal regions of the Isle of Man and the Irish Sea. There are large gaps in knowledge of species and habitats, so it is difficult to assess what the impacts of climate change will be upon them. Ideally long-term data sets are needed, but in the case where a few exist, they need to be maintained and added to.

There is a need to put a greater emphasis on protecting the marine environment from the changes predicted in sea level and storm surges. Monitoring of habitat change and 'coastal squeeze' are important so that adaptation and mitigation measures can be implemented.

Agriculture, forestry and fisheries

The Regis study looked at two regions, East Anglia and the Northwest in the UK to show what the future may look like under climate scenarios. The study concluded that climate change may have a noticeable impact at a regional level in the UK, but there is still uncertainty about the scale and nature of the impacts. Socio-economic developments are

likely to have a major influence on the scale of these impacts.[9] This was particularly true when looking at agriculture. There is a similar situation on the Island, as climate will have an impact on agriculture, but other external influences will have a greater role to play.

This was also demonstrated in recent research[10], which showed that the vulnerability of both farmers and species is dependent on the climate scenario under consideration. Agriculture is particularly sensitive to scenarios of socio-economic change and these lead to different patterns of intensification, extensification and abandonment. 'Natural' species are more sensitive to climate change scenarios. In both cases, adaptation options and potential were strongly influenced by different socio-economic futures and policy intervention. The analysis shows how adaptation in the agricultural sector can influence the adaptation potential of natural species, highlighting the importance of cross-sectoral assessments and policy development.

Agriculture on the Island faces significant challenges in the future and there is an excellent opportunity to incorporate climate change into policy development and to make the most of opportunities that may present themselves. Although agriculture may be able to quickly adapt by changing crops the supporting services and infrastructure may not be able to adapt as quickly. Water availability may become a problem in summer, particularly when there are competing needs between other sectors. Winter storage options may be a suitable solution to provide summer irrigation requirements.

The fisheries may be affected more so as changes in climate directly link to fish habitats. Warming sea temperatures may change the species of fish in the area. Reduced water and changing water quality in rivers may become a greater issue as species change. Controls may have to be implemented to protect habitats and species.

Forestry has already been affected by climate change extreme events with potential significant costs to this sector. (See technical report 5 on costs of extreme events). These extreme events are likely to increase in the future and forest management will be required to ensure damage is limited. A changing climate may 'squeeze' the pressure on the land for forests as changing climate may suit alternative species to grow or competition may occur from other sectors such as agriculture, tourism and pressures to release land for development.

Other pressures on the environment will increase through climate change. Increased visitor numbers may mean there is more footpath erosion, greater fire risk or even increased development as population grows. (This is discussed in the leisure and recreation section). A sustainable approach that is forward looking needs to be incorporated into biodiversity plans.

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[9] Regional Climate Change Impact and Response Studies in East Anglia and North West England (RegIS) MAFF Project No. CC0337 May 2001 Soil Survey and Land Research Centre

[10] Berry, P.M., Rounsevell, M.D.A., Harrison, P.A. and Audsley, E., 2006. Assessing the vulnerability of agricultural land use and species to climate

Examples of risk

- Lack of water for crops (grass, fodder, or cash) therefore affecting farming throughout the Island
- New pests, an increase in insects leading to an increase in disease risk
- Increased temperature stress on cold water fish species
- Increased housing needed for livestock
- Climate change will alter the probability of invasive and alien species establishing

Potential adaptation options

- Agricultural related infrastructure may need to evolve to match changes in land use
- Integrated land use and management strategies developed
- Better water resources planning; and information on 'best practice' techniques for soil conservation in a shortened cultivation window
- New crops will need new infrastructure processing plants – and possibly a new market.

Technical paper 9: The Isle of Man's economy in a global context

The economy in the Isle of Man has seen unprecedented growth for nearly the last quarter of a century. Over the ten years to 2002-03 gross domestic product more than doubled in real terms. As a result of this growth, per capita GDP in the Isle of Man now surpasses that in the UK and the average for the EU as a whole. While growth has been witnessed across all sectors, the financial services sector (the largest sector in the economy) has led the way. Indeed, between 1996 and 2001 the sector grew by about 80%, and in 2000-01 'finance' accounted for 41% of national income. The main activities of the sector include: life assurance, deposit-taking, asset protection and management, packaged investments and corporate management. Banking generates around 25% of the island's GDP; the rest of the financial services sector contributing another 15 to 20%. Markets for these services are world-wide, reflecting the open nature of the island's economy. It is likely that the future of the island's economy will largely be determined by the further development in the financial services and related sectors.

In the context of this study an interesting feature of the Isle of Man's economy is its openness[11] – in that the bulk of income used to fund domestic consumption is generated from exporting goods and services (primarily financial services). The performance of the island's economy is therefore strongly linked with global events and economic conditions in trading partners (particularly in the UK). Of course, these events, which include climate change, are out of Isle of Man's control.

This section examines in a qualitative fashion the impact that climate change globally could have on the financial services sector in the Isle of Man, given the importance of this sector to the island's economy. This focus is also justified since the second biggest sector – utilities – is much less obviously likely to be influenced by international climate change impacts. The third biggest – tourism – may well be affected by climate change though patterns are hard to discern in a meaningful way.

Climate change globally presents both risks and opportunities for the financial services sector in the Isle of Man (the largest on the island) – examples of which are provided in Figure 6.

In the context of the physical risks posed by climate change, the island's economy is potentially exposed to negative impacts via the financial services sector, given that insurance companies are on the front line when it comes to those impacts of climate change that manifest through weather-related extremes. The severity of the risks will depend on many factors, but key among them are the countries in which investments are made / insurance sold, and the specific risks that are insured. Obviously, P&C insurers are exposed to weather-related risks, which are predicted to intensify with climate change. But life insurers are also at risk: first, they invest in assets at risk to extreme weather, and second, continued expansion into emerging markets has tended to focus on this business line and historically populations in these markets are significantly more prone to mortality from extreme from extreme weather events.

The financial industry (banking and asset management) is also at risk to the physical impacts of climate change, through its linkages with capital markets (and thus the

[11] No statistics are available that permit a detailed assessment of imports and exports for the Isle of Man.

insurance industry) and also directly through the vulnerability of its investments, which may under perform or in extreme cases be completely destroyed. However, banks and asset managers do not generally view climate change as a material threat to their economic viability (although this viewpoint may change as more research is conducted into the vulnerability of investments), and in fact look at the possible responses to climate change more as an opportunity – particularly in the context of managing regulatory risk via carbon market products.

To minimise the risk that global climate change impacts present the financial services sector in the Isle of Man, the sector needs to adapt its internal processes, policies and products and services, as well as raise its general awareness of such risks. Suggested responses are listed below:

- The finance sector as a whole in the Isle of Man could encourage overseas business interests to provide them (or other investors) with appropriate information on climate risks. Investment related documents (e.g. company profiles and stock market prospectuses) should address climate change risks.
- Insurers on the island covering risks in foreign countries should structure their cover agreements to encourage customers to better manage climate risks. They could also look to develop and enhance the appeal of alternative risk transfer products, such as CAT bonds and weather derivatives.
- Insurers should look to control their exposure to weather-related catastrophes that are projected to increase in intensity and / or frequency as a result of climate change.
- Insurers should seek to quantify and "price" the financial threat of climate change in markets in which they operate, and use this information to set premiums, and disseminate this knowledge to customers. To this end insurers should keep abreast of developments in the latest climate and natural hazard science, and think beyond the traditional 1-3 year risk assessment time horizon.
- Insurers should look to work closer with appropriate authorities in their markets, in order to promote and strengthen local risk management (adaptation) and remediation capabilities.
- Insurers should look to participate in adaptation workshops with countries in emerging market, and explore new products / approaches to extend insurance and reinsurance coverage in emerging markets (where the impacts of climate change will be most severe).
- Banks (lenders) should look to "price" climate risks into loan conditions, which will protect their own interest, as well as provide incentives to borrowers to adopt adequate mitigation measures.
- Asset managers (investors) should develop rigorous analytical methods to quantify the impact of climate risks (and opportunities) on equity prices, corporate performance, and relative risks in individual corporations and across their portfolios.
- Asset managers should engage with firms they invest in to better understand how climate change will impact their business and what measures they are taking to minimise risks, or take advantage of opportunities.
- Actuaries should look to develop standards that consider all aspects of climate risks, and develop risk-based pricing that recognises projected climatic events, as opposed to being grounded solely in historic events.

Figure 2: Potential Impacts of Climate Change on Segments of the Financial Services Sector

Segments of the Financial Services Industry	Potential Impacts Due to Climate Change
Providers of Capital • Individual • Corporation • Foreign investment	⇨ Disruption to global economy ⇨ Reduced confidence
Advisors • Consultant • Analyst • Credit rating	⇨ Impacts on equity value and debt quality ⇨ Implications for investor recourse
Investors • Fund manager • Investment bank • Project finance	⇨ Impaired investment performance ⇨ New markets in clean technology ⇨ Implications for fiduciary duty
Lenders • Corp. banking • Mortgages • Commercial loans	⇨ Reduced corporate creditworthiness ⇨ Damage to property and physical assets ⇨ New markets in clean technology
Insurers • Reinsurer • Underwriter • Broker	⇨ Credit and liquidity problems ⇨ Increased demand for risk transfer products ⇨ Opportunities in carbon markets
Dealers • Individual • Commodity trader • Broker	⇨ Growth of risk management requirements ⇨ Growth of carbon credit trading
Users of Capital • Individual • Corporation • Government	⇨ Increased cost of mitigation requirements ⇨ Losses due to weather extremes ⇨ Public – private partnerships
Regulators • Listing / disclosure • Accounting • Banking	⇨ Demand for greater risk disclosure ⇨ Need for accounting guidance ⇨ Loss of investor confidence

Source: Innovest (2002b, Figure 1, p. 9)

Technical paper 10: Climate change and water resources on the Isle of Man

This is the first time that GCM predictions have been employed to model effective runoff for the Isle of Man under future climate scenarios and while there are a large number of conclusions that can be taken from the above research the main characteristics of change are provided below.

- On an annual basis the reductions in effective runoff are likely for low-lying areas in the north and south of the island, while increases are suggested for the central uplands. Greatest reductions in annual effective runoff are simulated for the 2050s and 2080s.

- Winter runoff is seen to increase for all parts of the island, especially by the 2080s with national increases in the order of +15% simulated under the A2 scenario. The greatest increases are expected to occur in the central uplands.

- All parts of the island will experience substantial decreases in summer and autumn runoff. Greatest reductions are expected in the north of the island and it is likely that the frequency and duration of low flows will increase in all areas. Reductions in runoff of the extent suggested could prove problematic for a country that relies so heavily on surface water resources.

- The magnitude and frequency of individual flood events are likely to increase. Rising sea levels may also exacerbate flooding impacts. Seasonal flooding is likely to occur over larger areas and persist for longer periods of time.

- Long-term deficits in soil moisture are likely to develop due to reductions in autumn runoff. Furthermore, groundwater levels and the amount of water entering many of the islands reservoirs are likely to be significantly reduced with decreases becoming more pronounced over time. Increases in evaporation are also likely to impact on water levels in storage reservoirs.

In terms of the impacts of climate change on hydrology and water resources there are a number of areas which future research needs to address. Changes in the frequency and magnitude of flood events need to be approached on a catchment basis. Furthermore, the impacts of climate change on water quality can be specific to individual rivers and thus impacts need to be refined for 'at risk' catchments. In order to adequately meet these needs there is a requirement for reliable streamflow observations in strategically important catchments, which is presently unavailable. In terms of future water supply, the ability of individual reservoirs to deal with both increases and decreases in runoff also needs to be assessed, with impacts requiring refinement for individual catchments and water supply zones.

Technical paper 11: Workshop reports

This technical report combines the reports prepared following the two stakeholder workshops held in the Isle of Man in December 2005 and March 2006.

The results from a questionnaire exploring views on developing a formal 'climate change stakeholder partnership' are also included. The questionnaire was distributed to participants at the March 2006 workshop.

The objectives of the workshop were to:

- Raise awareness of climate change
- To give training / raise awareness of the Risk, Uncertainty and Decision Making Framework
- To understand potential climate impacts in participants' organisation / area of interest
- Identify and agree some next steps for addressing climate change.
- Identify impacts and start to look at adaptation options
- To give an overview of other partnerships within the UKCIP and to understand whether a similar partnership is wanted on the Island.

Technical paper 12: Adaptation policy framework

Adaptation is necessarily cross-cutting. It involves promoting an understanding of how the changing climate will affect all sectors, and then encouraging relevant parties to take action to reduce future risks and take advantage of future opportunities.

The study provides some guidance on the next steps, moving beyond scoping and a description of the possible impacts of climate change, to focus instead on risks and opportunities where action needs to be taken in the short, medium and longer-term. There are a number of areas where it is particularly important to respond, because decisions taken now will have long-term impacts.

To assist with this process the study takes the concept of 'building adaptive capacity/delivering adaptive action' and recommends the development of an Isle of Man 'Adaptation Policy Framework'.

It is recommended that the Isle of Man Government, major businesses and those organisations providing essential services, should consider the development of an Adaptation Policy Framework as a logical next step.

This approach has a number of advantages:

- Places the emphasis on risks and opportunities where action needs to be taken in the short, medium and longer-term
- Provides a framework for all stakeholders to develop their own responses to the risks they face.
- It is also useful when determining roles and responsibilities for key organisations.
- Draws together adaptation planning efforts, identifies actions, delivery, roles and responsibilities across government and the public and private sectors.
- Assists with the development of co-coordinated and coherent cross-departmental activities and with actions involving other stakeholders. Ensuring joint objectives are agreed.
- Provides a firm foundation for future target setting and performance measurement.
- Assists in providing a focus on quantitative analysis of the risks and exposures, to better enable effective decision making to be undertaken.
- Can be adapted to provide a checklist to assess the actions being taken by any strategy or project etc., to build adaptive capacity or deliver adaptive action
- Comparing completed BAC/DAA tables across the range of Government activities will provide an overview of the actions being taken and assist with identifying gaps.
- Completed BAC/DAA can form part of an annual progress review for the Island.

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