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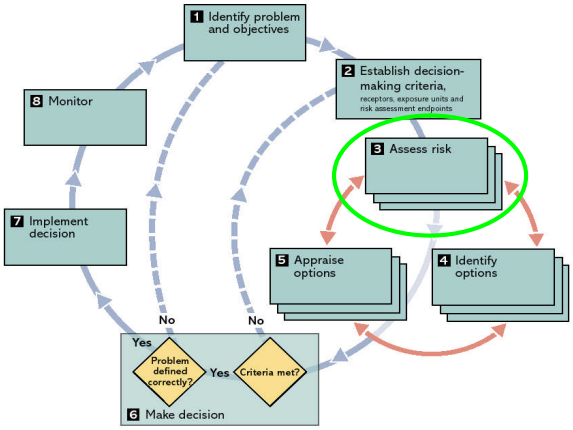
The Isle of Man Climate Change Scoping Study

Technical Paper 5

Costing the impacts of climate change: estimated costs of three historic weather events



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COSTING THE IMPACTS OF CLIMATE CHANGE IN THE ISLE OF MAN:

- Estimated Cost of Historic Weather Events -

- Final Report -

Prepared for:

The Government of the Isle of Man

Prepared by:

Metroeconomica Limited with assistance from acclimatise

February 2006

EXECUTIVE SUMMARY

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.

In technical report 7: Costings under future climate scenarios, these costs for the three extreme events are assessed under future climate scenarios and different emissions scenarios. Where possible, results from this study are used to present a picture of the future evolution of the costs of these impacts.

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

Table 1: estimated costs of three weather events

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

Sulby Flooding 8th December 2000

A starting-point for the integration of results of the physical modelling and costing the predicted change in the realisation of future flooding events was the costing of the flood in Sulby. 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, including on October 24th 1998. A summary of the estimated costs of the Sulby flood is presented in Table 2.

Table 2 : Summary of Estimated Damages for December 2000 Floods at Sulby, by Duration of Flood (£2004)

	Flood Duration < 12 Hours		Flood Duration > 12 Hours	
	Low	High	Low	High
Direct property damage:				
Residential property	1,574,220	1,741,960	1,915,460	2,109,890
Garages	28,410	48,590	88,110	76,560
Conservatories	101,890	101,890	101,890	101,890
Non-residential property	319,000	319,000	319,000	319,000
Other Effects:				
Temporary accommodation	13,760	13,760	13,760	13,760
Residential clean-up	556,740	556,740	556,740	556,740
Additional power	74,220	90,270	74,220	90,270
Health	334,430	334,430	334,430	334,430
Emergency services [a]	202,570	220,520	239,090	214,400
Secondary effects [b]	3,790	4,120	4,470	4,860
Total (sensitivity test) [c]	3,209,030	3,431,280	3,647,170	3,821,800
Total ('best guess') [d]	3,078,730	3,280,800	3,457,170	3,643,350
Total (£ per affected property)	55,980	59,650	62,860	66,240

Notes:
[a] Based on residential and non-residential property damage totals, without garages and conservatories.
[b] Based on residential and non-residential property damage totals, without garages and conservatories.
[c] Assumes that all affected residential properties have a garage and a conservatory.
[d] Excludes damages to residential garages and conservatories.

As can be seen from table 2, 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.

Most of the cost estimates are derived from market price data, and therefore do not necessarily capture the full welfare cost of the impact of the flood on specific categories. In general, market prices will undervalue the welfare costs of specific impacts. Where possible, the true welfare costs have been approximated from the market price data. There also remain a number of impacts, including a number of health effects that have not been costed in the current exercise through lack of data. Our cost estimates should therefore be regarded as under-estimates of the total welfare cost that can be attributed to the Sulby flood.

Windstorm event 7th-8th January 2005

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. Gusts reached 85 mph at Peel breakwater, 92 mph at Ronaldsway Airport, 96 mph at Douglas and 98 mph at the Point of Ayre. At one point the winds were Storm Force 11. The storm peaked at around 5-6 am on Saturday though given that the storm lasted for 24 hours this peak time is not thought to be very significant. This windstorm had significant impacts on property and other impact categories as shown in Table 3 below. As can be seen from the table significant impacts were experience on private property and transport.

Table 3: Damage Cost Estimates for January 2005 windstorm

Cost Item	Estimated damages (£mn)
Property damage	**10.3**
of which	
Private property	10.0
Government property	0.26
Forestry losses	**2.89**
of which	
Broadleaf damage	2.84
Conifer Damages	0.04
Non timber forest products	NQ
Non government owned forests	NQ
Utility losses	**0.05 to 0.1**
of which	
Power sector - lost revenue	0.004
Power sector - disruption to consumers (low)	0.045
Power sector - disruption to consumers (high)	0.120
Power sector - direct costs to MEA	NQ
Water sector	NQ
Transport sector	**2.6**
of which	
Flight cancellations	0.036
Flight delays	NQ
Ferry cancellations	.024
Ferry delays	.004
Bus service disruption	NQ
General traffic disruption	2.5
Emergency costs	**1.1**
Other Impacts	**NQ**
of which	
Exam disruption	NQ
Disruption to business	NQ

NQ: Not Quantified

Storm surge 1st February 2002

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). 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. A summary of the estimated costs of this event is presented in Table 4 below.

It can be seen from the table that 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. This is an area that needs further investigation.

Table 4: Damage Cost Estimates of Storm Surge of February 2002

Cost item	Estimated damages (£mn)
Property damage	**7.5**
of which	
Private property	7.5
Government property	NQ
Health impacts	**0.321**
Transport disruption	**0.013**
of which	
Flight disruptions	NQ
Ferry cancellations	0.007
Ferry delays	0.007
Road disruptions	0
Utility disruption	**NQ**
of which	
Electricity sector	NQ
Water sector	NQ
Emergency costs	**0.8**

Data on the frequency of flood events, windstorms and storm surges for the Isle of Man under climate change scenarios are not available at the time of writing this report. It is likely that these events may increase in frequency and, potentially, intensity. The costs presented above show that climate change may have a significant impact on the Manx economy in terms of property damage and transport disruption in particular. Future work will investigate the future costs of these events, drawing on socioeconomic scenarios for future developments in the Isle of Man, which is reported in technical paper 7.

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SECTION 1: INTRODUCTION

Justification for study

The justification for undertaking an exercise to assess the economic costs of climate change impacts in the Isle of Man is that these costs may be important to the people of the island and have not been collated previously to understand the full costs of such events. Such welfare cost changes should therefore be assessed in order to inform present policy making related to greenhouse gas mitigation and adaptation to potential impacts. For example, the costs of adaptation responses such as higher flood defences may be justified by demonstrating that the benefits of the impacts avoided are greater.

It is recognised that the nature of climate change impacts may - in a number of instances - not have welfare effects that are readily translated into monetary costs. Examples include impacts on peoples' mental state that may be associated with having their home flooded, and the effects on ecosystem from inundation of salt-water marshes as a consequence of sea level rise. However, where there is evidence that people do make monetary trade-offs that reflect such welfare changes, then costing these impacts using a money metric may provide information that will be useful in making decisions about resource use.

This study represents a first attempt at expressing in monetary terms a number of impacts in a historical context that are associated with future weather events in the Isle of Man, which in turn may be associated with climate change. The events considered are flooding, windstorms and storm surges. These events were chosen because of their relative importance in the potential range of climate change impacts so far identified to directly affect the Isle of Man in the future– a perception borne out of recent experience. Furthermore, these events clearly have potential significant resource implications for the Manx Government in relation to investment in flood and sea defences, as well as other preventative measures.

Approach to study

An effective way of deriving estimates of future climate change costs is to use a historical analogue of an expected climate change event as a starting point. This study takes as its starting point recent events of significance – the Sulby flood of 8th December 2000, the windstorm of 7th and 8th January 2005, and the storm surge and tidal flooding of 1st February 2002. These events were selected to give a broad range of impact types and because it was felt that data were likely to be available on these events.

Where necessary, we extrapolate from the results of previous studies on the costs of climatic events in the UK to attempt to fill gaps in the knowledge on the impacts of these events on the Isle of Man. In this way, impacts on transport disruption (estimated using UK data) and emergency service costs can be included in the analysis. For transport disruption, levels of transport flow in regions in the UK similar to the Isle of Man were used to provide a reasonable estimate. Ideally data on the Isle of Man specific case would be used, but this was not possible as this data does not exist in the Manx case.

The study has the following elements:

- An overview of the UKCIP costing guidelines
- A detailed case study of the costs of the Sulby flood
- A detailed case study of the costs of the windstorms of January 2005
- A detailed case study of the costs of the storm surge of February 2002
- Conclusions and areas for further research

SECTION 2: THE UKCIP COSTING METHODOLOGY – AN OVERVIEW

In broad terms, the UKCIP Climate Change Impact and Adaptation Costing Methodology comprises two elements, or stages. Before the impacts of historic or predicted future weather-related events can be valued they must first be identified and measured. Only once they have been quantified is it possible to determine their relative economic importance by expressing them in monetary terms. The identification and measurement (i.e. quantification) of impacts is therefore a prerequisite to their valuation. This requirement is common to all valuation exercises in environmental economics, whether in the context of climate change, air quality, waste management, transport, etc.

The two-stage nature of the Costing Methodology, as applied to a historic weather-related event and a predicted future event, is illustrated in Box 1 and Box 2, respectively. This two-stage process underpins the approach to valuation prescribed in the UKCIP Costing Guidelines[1], as well as the approach adopted in this study.

Of course, successful application of the Methodology depends not only on the identification of weather-related or climate change impacts, but also on sufficient quantitative data being available, and in an appropriate format. It is likely that there will be many types of identified impacts for which appropriate quantitative data is simply not available, and thus valuation cannot take place. For example, changes in the hydrological regime and resulting impacts on natural habitat might be considered a likely consequence of climate change-inducted coastal erosion in an area, but there may as yet be no evidence as to the extent or implications of the impacts. It is also likely, given the state-of-the-art of economic valuation, that it will not be possible to value certain impacts, even if appropriate quantitative data is available (e.g. impacts on species and ecosystems). However, these impacts are real, and relevant to the appraisal of alternative adaptation strategies, regardless of the fact that they cannot be valued. In order to place the impacts actually costed in each case study within the context of the full range of potential impacts, we have developed impact matrices for each event – illustrations of which are given in the forthcoming sections.

[1] Metroeconomica (2004) Costing the Impacts of Climate Change. Report prepared for Defra and UK Climate Impacts Programme. http://www.ukcip.org.uk/.

Box 1: The General Approach to Valuation Used in the UKCIP Costing Guidelines (historic event)

The cost (or benefit) of a historic weather-related event on a specific vulnerable receptor (£ per event in year *t*)
is equal to
The observed 'physical' impact on the vulnerable receptor (the number of units affected by the event in year *t*)
times
The appropriate economic unit value or 'price' (£ per affected unit in year *t*)

Box 2: The General Approach to Valuation Used in the UKCIP Costing Guidelines (predicted event)

The cost (or benefit) of a predicted future weather-related event on a specific vulnerable receptor, under selected climate and socio-economic scenarios (£ per event in year *t*)
is equal to
The predicted 'physical' impact on the vulnerable receptor, under selected climate and socio-economic scenarios (the number of units affected by the event in year *t*)
times
The appropriate forecast economic unit value or future 'price' (£ per affected unit in year *t*)

In the next three sections we develop cost estimates for three historic weather-related events of significance to residents of the Isle of Man. The three events considered are:

- 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.

The estimated cost of these events will subsequently feed into analysis of the future costs of similar weather-related events, under various climate and socio-economic scenarios.

In each of the case studies we describe how the various impacts are costed, but we do not outline the detail of each calculation (e.g. indexing prices, calculating present values, etc.), as such detail is already provided in the UKCIP Costing Guidelines[1]. The interested reader should consult these Guidelines.

SECTION 3: CASE STUDY OF THE SULBY RIVER FLOODING

Introduction

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.

Impact assessment

The first step in applying the Costing Guidelines to historic events is to identify all the weather-related impacts that have occurred and distinguish who have been affected by the impacts. For future events it is also necessary to determine the frequency with which the impacts of such events may occur.

Figure 1 presents a matrix of broad (first-order and key second-order) impacts from a river-flooding event, those sectors most likely to be affected by these broad impacts, potential economic consequences and the main stakeholder groups. Of course, any specific river flood will not necessarily give rise to all these impacts (e.g. in some cases affected areas will not contain objects of cultural or heritage value, include agricultural land, etc.). Moreover, as noted above, not all these potential impacts will have been reported, of which only sub-set will have been measured. Quantification of impacts is a pre-requisite to valuation.

Against a background of regular serious flooding of property in Sulby, Bullen Consultants were appointed by the Department of Transport to investigate options to provide acceptable levels of flood defence for local residents and property in the face of future risks, as well as enhance the natural river environment. For the purpose of this case study, the consultant's final report of November 2002 is used to define the physical impacts of the December 2000 flood at Sulby, given that detailed impact data was not available for the event itself.

Figure 1: Impact Matrix for Flooding from Increased Winter Precipitation – Potentially Relevant Economic Impacts

First-order Impact	Sector Affected	Potential Economic Impacts	Relevant Stakeholders
River Flooding → Direct Physical Damage	Habitat	Mortality in 'valued' species (foregone use and non-use value)	General public, tourists, national interest groups, government departments
		Destruction of 'valued' ecosystems (foregone use and non-use value)	
	Forestry	Destruction of trees (loss of timber products and producer surplus)	Timber producers, consumers, national interest groups, government departments, general public
		Destruction of trees (loss of recreation and amenity)	
	Agriculture land	Loss of crops (lost producer surplus)	Local farmers, consumers of farm products, government departments
		Loss of livestock (lost producer surplus)	
	Transport infrastructure	Loss of infrastructure/equipment (replacement necessary)	Transport operators, contractors, local public (users and employees in this sector), business and wholesale distributors
		Damage to infrastructure/equipment (repairs necessary)	
	Buildings (residential, commercial, industrial, agriculture, government)	Loss of private and public property (replacement necessary)	Households, property owners, insurers, contractors, business
		Damage to private and public property (repairs necessary)	
	Historical and cultural heritage	Loss of cultural objects (foregone amenity and non-use value)	Local public, tourists, national interest groups, government departments, insurers, business
		Damage to cultural objects (repairs necessary)	
	Human health	Increased risk of mortality (fatal injuries)	Local public, employers, insurers, NHS, government, regulators
		Increased risk of morbidity (non-fatal injuries and anxiety)	
	Utilities	Damage to transmission network	Power generators and suppliers, electricity customers - both households and business (prices), regulator, insurers, other utilities, government departments
		Damage to power generation infrastructure	
		Damage to water treatment facilities and pumping stations	Water authority, customers - both households and business (prices), regulator, insurers, government departments
		Damage to distribution and sewer system	
	Flood protection infrastructure	Decreased strength (damage), increased maintenance and repair requirements	Local authorities, government departments, contractors, general public, property owners, insurers
		Destruction (replacement required)	

Continued: Impact Matrix for Flooding from Increased Winter Precipitation – Potentially Relevant Economic Impacts

First-order Impact	Sector Affected	Potential Economic Impacts	Relevant Stakeholders
Flooding → Short-term Disruption	Road transport	Increase in travel cost (individual, work time)	Local population, users and operators of public transport (buses), businesses, highways authorities
		Increase in travel cost (individual, non-work time)	
		Disruption to inputs / sales (business losses)	
		Change in demand for unaffected, alternative transport routes or modes	
		Increase in highway agency's costs	
Flooding → Evacuation	Households / government	Increase in costs of 'emergency service' and related activities	Local public, emergency services, government departments
		Temporary accommodation costs	
		Disutility costs to individual (e.g. from stress and anxiety)	

Second-order Impact	Sector Affected	Potential Economic Impacts	Relevant Stakeholders
Damage to Utilities → Outages / Disconnections	Electricity	Disutility (individual)	Power generators and suppliers, electricity customers - both households and business (lost services), regulator
		Lost output / increased costs (business customers)	
		Additional costs / foregone producer surplus (supplier)	
	Water	Disutility (individual)	Water authority, customers - both households and business (lost services), regulator
		Lost output / increased costs (business customers)	
		Additional costs / foregone producer surplus (supplier)	
Damage to property → Short-term disruption	Commerce and industry	Lost business during repairs / replacement (lost producer surplus)	Local manufacturing and service sector, insurers

The work undertaken by Bullen Consultants included hydrological modelling of flow regimes, of various return periods, at different intervals along the Sulby River, including at Sulby itself. Based on the predicted river flows at Sulby, flood depths were computed for those properties (residential and non-residential) deemed to be at risk, for each of the modelled return periods. In total, 54 residential properties and 1 non-residential property, the distillery at Kella Mill, were identified as susceptible to flooding. We assume that the same properties were also at risk to the flood on the 8th of December 2000.

The modelled flood level at each property under a range of return periods, for the consultant's "no project" scenario, is shown in Table 4. We assume that the "no project" scenario (i.e. before any additional flood defences are introduced, or the ones that existed in 2000 are "serviced") is most representative of conditions and risks that prevailed during the flood on the 8th of December 2000.

The modelled river flow at Sulby Bridge, for different return periods, is shown in Table 5. Bullen Consultants also estimated the peak flow at Sulby Bridge on the 8th of December 2000 at 73.5 m^3 per second. Flow levels that gave rise to the December 2000 floods at Sulby therefore roughly equate to a 1-in-250 event – that is, with an annual probability of occurrence of 0.4%. However, for the "no project" scenario, the consultant's report did not provide flood levels for a return period of 250 years. We have estimated these flood levels by, first, fitting a logarithmic function to the data for each property and, second, using these functions to predict the flood level corresponding to a 250-year return period at each property. The results are shown in the shaded column in Table 4. The estimated depth of flooding at each property (our measure of "impact") is then computed as the difference between the 250-year flood level and the modelled floor level, both in metres, as shown in the final column in Table 4. We assume that this is roughly equivalent to the depth of flooding experienced by the listed properties on the 8th of December 2000.

Table 4: Estimate Flood Levels and Depths at Sulby for Various Return Periods

Property Name and Street		Type	Number of Properties	Floor Level	Return Period Flood Level						Predicted Depth of Flooding
					10	20	30	50	100	250	250
				(m AOD)	(m AOD)	(m AOD)	(m AOD)	(m AOD)	(m AOD)	(m AOD)	(m)
12	Mill Race	Residential	1	17.01	15.70	16.62	16.77	16.93	17.03	17.74	0.727
11	Mill Race	Residential	1	17.11	15.70	16.61	16.76	16.92	17.01	17.71	0.600
9 & 10	Mill Race	Residential	2	16.82	15.70	16.61	16.76	16.92	17.01	17.71	0.890
7 & 8	Mill Race	Residential	2	16.66	15.70	16.61	16.76	16.90	16.99	17.68	1.021
6	Mill Race	Residential	1	16.55	15.70	16.60	16.74	16.87	16.96	17.63	1.083
4 & 5	Mill Race	Residential	2	16.36	16.12	16.33	16.43	16.46	16.68	16.88	0.519
3	Mill Race	Residential	1	16.22	16.12	16.33	16.43	16.46	16.68	16.88	0.659
2	Mill Race	Residential	1	16.01	15.95	16.16	16.29	16.44	16.67	16.95	0.940
1	Mill Race	Residential	1	16.10	15.95	16.16	16.29	16.44	16.67	16.95	0.850
Burnbrae	Sulby Road	Residential	1	16.91	15.70	16.60	16.73	16.86	16.94	17.61	0.696
Sabrew	Sulby Road	Residential	1	16.30	15.58	15.80	15.93	16.08	16.30	16.59	0.285
Strooam-y-Wyllin	Sulby Road	Residential	1	16.59	15.58	15.80	15.93	16.08	16.30	16.59	- 0.005
Glenlea & Mosdale	Sulby Road	Residential	2	15.92	15.58	15.80	15.93	16.08	16.30	16.59	0.665
Ballahowin & Fy Yerrey	Sulby Road	Residential	2	16.27	15.58	15.80	15.93	16.08	16.30	16.59	0.315
Riverside	Ramsey Road	Residential	1	15.86	15.36	16.62	16.74	16.90	16.95	17.83	1.970
2	Carrick Park	Residential	1	15.38	15.47	15.67	15.78	15.92	16.12	16.38	0.996
3	Carrick Park	Residential	1	15.43	15.47	15.67	15.78	15.92	16.12	16.38	0.946
4	Carrick Park	Residential	1	16.26	15.47	15.67	15.78	15.92	16.12	16.38	0.116
5	Carrick Park	Residential	1	16.69	15.47	15.67	15.78	15.92	16.12	16.38	- 0.314
12	Carrick Park	Residential	1	16.11	15.47	15.67	15.78	15.92	16.12	16.38	0.266
13, 21 & 24	Carrick Park	Residential	3	16.00	15.71	15.93	16.05	16.20	16.43	16.71	0.709
14 & 27	Carrick Park	Residential	2	15.70	15.71	15.93	16.05	16.20	16.43	16.71	1.009
15 & 16	Carrick Park	Residential	2	16.15	15.83	16.04	16.16	16.30	16.52	16.73	0.583
17	Carrick Park	Residential	1	15.93	15.83	16.04	16.16	16.30	16.52	16.73	0.803
18 & 36	Carrick Park	Residential	2	16.29	15.95	16.16	16.29	16.44	16.67	16.95	0.660
19	Carrick Park	Residential	1	17.01	15.95	16.16	16.29	16.44	16.67	16.95	- 0.060
20	Carrick Park	Residential	1	16.40	15.83	16.04	16.16	16.30	16.52	16.73	0.333
22	Carrick Park	Residential	1	16.71	15.71	15.93	16.05	16.20	16.43	16.71	- 0.001
23	Carrick Park	Residential	1	16.55	15.71	15.93	16.05	16.20	16.43	16.71	0.159
25	Carrick Park	Residential	1	15.49	15.71	15.93	16.05	16.20	16.43	16.71	1.219
26	Carrick Park	Residential	1	15.69	15.71	15.93	16.05	16.20	16.43	16.71	1.019
28 & 29	Carrick Park	Residential	2	15.96	15.71	15.93	16.05	16.20	16.43	16.71	0.749
30	Carrick Park	Residential	1	16.80	15.71	15.93	16.05	16.20	16.43	16.71	- 0.091
31	Carrick Park	Residential	1	16.86	15.95	16.16	16.29	16.44	16.67	16.95	0.090
32	Carrick Park	Residential	1	16.11	15.95	16.16	16.29	16.44	16.67	16.95	0.840
34 & 37	Carrick Park	Residential	2	16.05	15.95	16.16	16.29	16.44	16.67	16.95	0.900
35	Carrick Park	Residential	1	15.80	15.95	16.16	16.29	16.44	16.67	16.95	1.150
38	Carrick Park	Residential	1	15.85	15.83	16.04	16.16	16.30	16.52	16.73	0.883
39	Carrick Park	Residential	1	15.60	15.83	16.04	16.16	16.30	16.52	16.73	1.133
40	Carrick Park	Residential	1	15.18	15.71	15.93	16.05	16.20	16.43	16.71	1.529
41	Carrick Park	Residential	1	15.22	15.71	15.93	16.05	16.20	16.43	16.71	1.489
42	Carrick Park	Residential	1	15.31	15.71	15.93	16.05	16.20	16.43	16.71	1.399
Kella Mill	Sulby Road	Distillery	1	16.81	17.11	17.42	17.58	17.80	17.73	18.13	1.316

Source: Bullen Consultants (2002, Annex E) plus author's calculations

Table 5: Results of Hydrological Modelling: Modelled Peak Flow at Sulby Bridge

Flow Return Period	Peak Flow
5 years	29.2 m^3 / sec
10 years	35.1 m^3 / sec
30 years	46.8 m^3 / sec
50 years	53.0 m^3 / sec
100 years	64.1 m^3 / sec
250 years	74.2 m^3 / sec

Source: Bullen Consultants (2002, Table 3.2, p. 18)

The next step is to calculate the monetary damage associated with the predicted depth of flooding at each property.

Economic valuation

Residential and non-residential property damage

Here we estimate the direct damages of flood waters on residential and non-residential building fabric and inventory items.

Direct: residential

In assessing the direct flood damage to residential property we utilise depth-duration-damage curves published by the Flood Hazard Research Centre (FHRC) in their "Multi-coloured Manual"[2]. Depth-duration-damage curves are available for:

- 5 different house types;
- 5 different building periods (years of construction); and
- 4 different social classes.

The data used to develop these curves are based on economic[3] and not financial[4] values.

In developing the depth-duration-damage curves, the FHRC collected details of the effect of flood waters of varying depths and durations on every component of a property's inventory (content) and building fabric (structure). In total, fifteen depths and two durations have been analysed (see Box 3).

[2] Penning-Rowsell et al (2006) *The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques*. Flood Hazard Research Centre, Middlesex University Press.

[3] Economic: (a) Valued from the standpoint of the nation as a whole. (b) Corrects the actual money transfer in order to calculate the real opportunity cost. (c) VAT is excluded as are other indirect taxes because they are money transfers rather than real losses or gains.

[4] Financial: (a) Valued from the standpoint of the individual household or organisation involved. (b) Uses the actual money transfer involved to evaluate the loss. (c) VAT is included as are other indirect taxes as they affect the individual household or organisation involved.

Box 3: Depth and Duration of Damage Information

Two durations

Short: Above ground floor level for less than 12 hours

Long: Above ground floor level for more than 12 hours

Fifteen depths above and below ground floor level

-0.3m: To include damage to sub-floor level

0.0m: Ground floor level to include damage to floors

0.05m: To include damage to carpets and floor coverings

0.1m: To include superficial damage to both internal fabric and inventory items

0.2 to 0.3m: To include superficial damage to both internal building fabric and inventory items

0.6m to 3.0m: In incremental steps of 0.3m to include progressively more items of damage

Source: Flood Hazard Research Centre, Multi-coloured Manual, 2003.

In the absence of data on property type, construction period and social class (we return to this below) we have used the "sector average" depth-duration-damage curve for the UK. To the extent that the mix of these three factors in the affected properties in Sulby differs from the UK average, we will under/overestimate the true damages. Also, we have used depth-duration-damage curve for both short and long duration floods, given that we do not know the duration of flooding at each property on the 8th December 2000. These curves are shown in Figure 2 and in Figure 3.

The data underlying the depth-duration-damage curves relates to 2002. We have up-rated the data to 2004 prices using a combination of the Isle of Man's RPI index (applied to the inventory component of the cost data) and a house price index (applied to the building fabric component of the cost data), which we derived from time series data on average house prices on the island.

Table 6 presents our estimates of the total direct flood damage to the 54 residential properties assumed to be affected by the Sulby River Flood on the 8th of December 2000. If the flood duration was less than 12 hours, the average cost per property was about £30,700. The average cost per property rises to about £37,300 if the flood duration was more than 12 hours.

Figure 2: Sector Average Depth-duration-damage Curve for Floods with Durations of Less than 12 Hours (2004 prices)

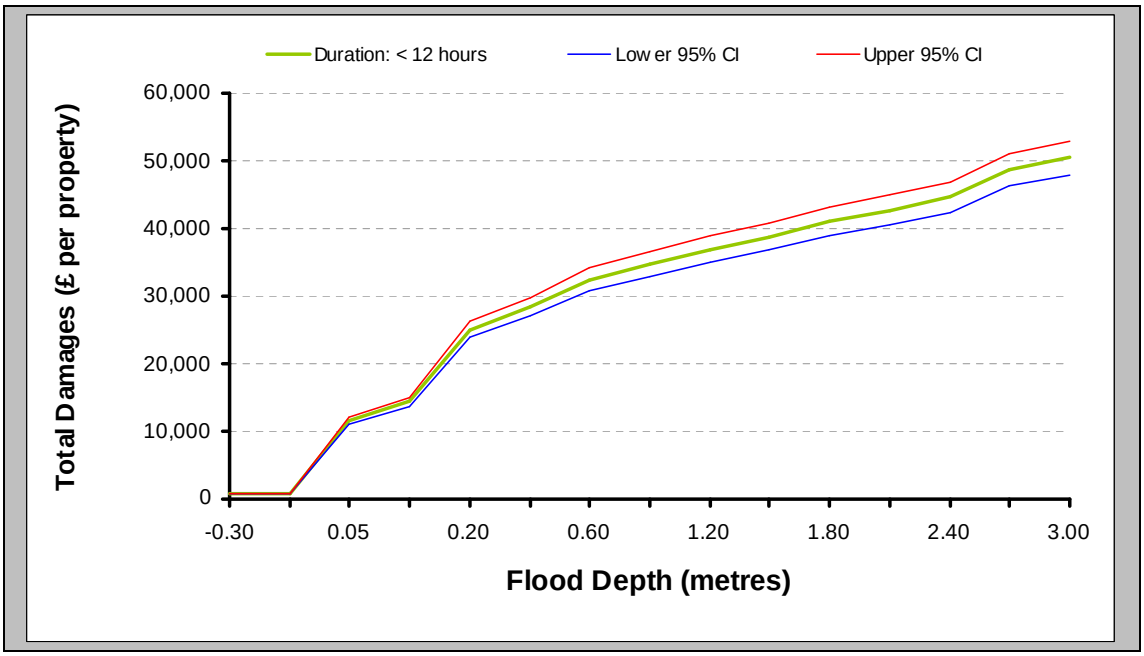


Figure 3: Sector Average Depth-duration-damage Curve for Floods with Durations of More than 12 Hours (2004 prices)

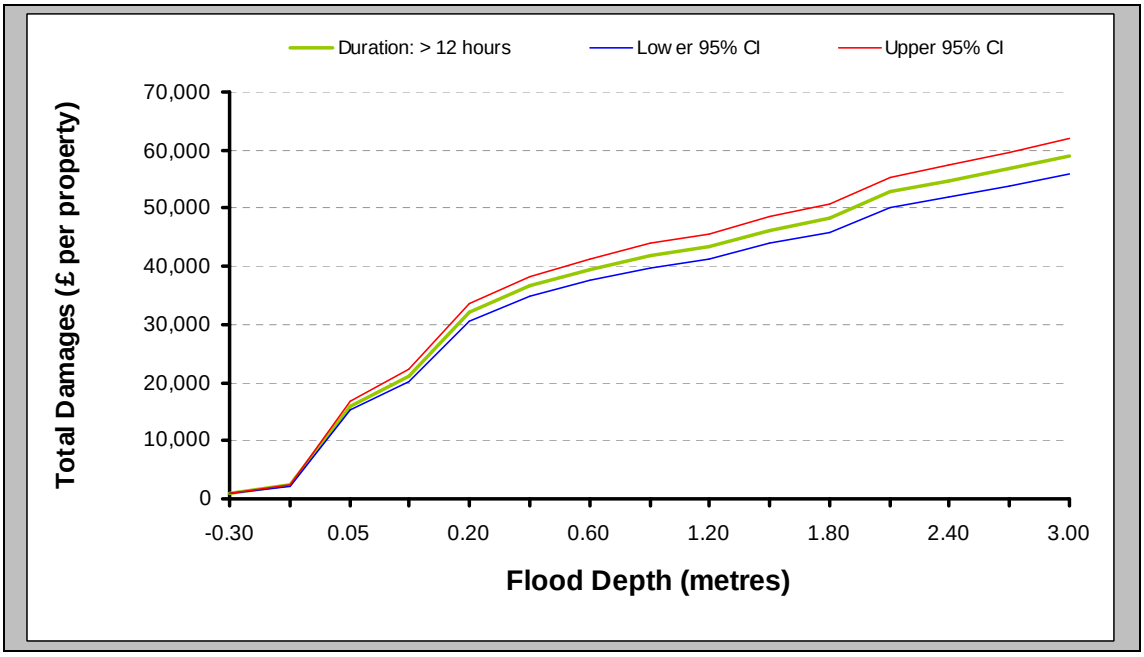


Table 6: Estimated Total Direct Flood Damage to At-risk Residential Property in Sulby (2004 prices)

Total Direct Property Damage (Fabric and Inventory)					
Duration of Flood < 12 Hours			Duration of Flood > 12 Hours		
Lower 95% CI	Mean	Upper 95% CI	Lower 95% CI	Mean	Upper 95% CI
(£)	(£)	(£)	(£)	(£)	(£)
31,684	33,370	35,084	38,402	40,341	42,304
30,828	32,442	34,082	37,485	39,355	41,249
65,795	69,369	73,006	79,403	83,474	87,595
67,591	71,257	74,973	80,832	84,993	89,189
34,209	36,062	37,936	40,735	42,835	44,949
59,385	62,467	65,600	73,435	77,061	80,732
31,185	32,828	34,500	37,867	39,766	41,688
33,244	35,051	36,886	39,991	42,045	44,122
32,612	34,375	36,169	39,396	41,408	43,446
31,470	33,138	34,833	38,173	40,094	42,040
26,433	27,750	29,090	34,066	35,692	37,341
668	707	746	2,103	2,251	2,414
62,512	65,811	69,166	75,886	79,696	83,553
54,339	57,098	59,903	70,027	73,394	76,806
39,836	41,962	44,110	48,319	50,874	53,457
33,589	35,412	37,261	40,256	42,327	44,417
33,244	35,051	36,886	39,991	42,045	44,122
21,951	22,955	23,983	28,514	29,855	31,222
-	-	-	-	-	-
25,823	27,086	28,371	33,204	34,779	36,378
94,625	99,645	104,751	114,747	120,530	126,383
67,315	70,968	74,673	80,619	84,767	88,953
61,152	64,346	67,594	74,628	78,344	82,106
32,255	33,988	35,752	39,013	40,998	43,007
62,512	65,811	69,166	75,886	79,696	83,553
668	707	746	1,893	2,024	2,167
27,422	28,818	30,236	35,184	36,880	38,599
668	707	746	2,103	2,251	2,414
54,614	57,145	59,707	62,166	64,808	67,462
35,092	36,989	38,899	41,457	43,602	45,754
33,727	35,556	37,411	40,363	42,440	44,535
63,654	67,048	70,502	77,110	81,010	84,959
668	707	746	1,726	1,843	1,969
13,265	13,848	14,453	19,116	20,079	21,071
32,541	34,298	36,086	39,319	41,326	43,358
65,937	69,523	73,173	79,556	83,638	87,771
34,691	36,568	38,461	41,107	43,230	45,363
32,826	34,607	36,419	39,625	41,655	43,710
34,553	36,423	38,311	41,001	43,117	45,245
36,886	38,871	40,891	44,044	46,348	48,682
36,628	38,602	40,608	43,736	46,021	48,335
36,116	38,064	40,038	42,976	45,215	47,474
1,574,215	**1,657,428**	**1,741,957**	**1,915,458**	**2,012,106**	**2,109,892**

The depth-duration-damage curves do not cover potential flood damage to garages and conservatories, where present. Using average unit costs for a typical garage and conservatory (up-rated to 2004 prices) and observed relationships between flood depth and structural susceptibility, we have estimated the potential flood damages to these structures for each property. The results are shown in Table 7. However, we do not know whether the affected properties actually have a garage and / or conservatory. Consequently, simply adding the damage estimates in Table 6 to those in Table 7 will overstate the true costs of the event. The total from Table 6 therefore constitutes a minimum property cost estimate whilst the totals of Tables 6 and 7 aggregated constitute a maximum.

The presence (or absence) of household contents, clearly, has an effect on flood damage potential. Furthermore, the ownership of household goods, as well as their quality, varies between socio-economic groupings. As mentioned above, the inventory damage data was compiled using social class as a measure of inventory quality and thus value. 'Good quality' has been ascribed to the contents of AB[5] social class dwellings, 'medium quality' to C1[6] and C2[7] social class dwellings and 'poor quality' to DE[8] social class dwellings.

The HM Treasury Green Book recommends that distributional impacts are considered in economic analysis where it is necessary and practical to do so. Taking distributional impacts into account basically involves weighting, in this case, the damage costs incurred by each household, in accordance with their social class. The weighting is undertaken prior to aggregating costs across households. The weights to be applied are as follows: AB = 0.74, C1 = 1.12, C2 = 1.22 and DE = 1.64 (DEFRA, 2004[9]) . However, at present it is not possible to weight the costs per property in Table 6 and Table 7 when deriving a total damage cost, since we do not have the information to categorise each household into one of the four social classes.

[5] Upper middle and middle class: higher and intermediate managerial, administrative or professional.
[6] Lower middle class: supervisory or clerical and junior managerial, administrative or professional.
[7] Skilled working class: skilled manual workers.
[8] Working class and those at the lowest level of subsistence: semi-skilled and unskilled manual workers. Unemployed and those with no other earnings (e.g. state pensioners).
[9] Defra (2004) Supplementary Note to Operating Authorities, July 2004.

Table 7: Estimated Damage to Garages and Conservatories if Present at Flooded Residential Property in Sulby (2004 prices)

Total Direct Property Damage (Garages and Conservatories)					
Duration of Flood < 12 Hours			Duration of Flood > 12 Hours		
Timber Garage	Conc. Garage	Conservatory	Timber Garage	Conc. Garage	Conservatory
(£)	(£)	(£)	(£)	(£)	(£)
496	937	1,838	1,654	1,489	2,451
460	827	1,838	1,532	1,379	2,451
1,097	2,187	3,676	3,656	3,290	4,902
1,152	2,426	4,657	4,167	3,529	5,882
588	1,268	2,574	2,206	1,820	3,186
827	1,489	3,309	2,880	2,592	4,534
475	873	1,838	1,583	1,425	2,451
560	1,140	2,002	1,920	1,691	2,614
536	1,057	1,838	1,787	1,608	2,451
487	910	1,838	1,624	1,461	2,451
276	496	1,225	1,164	1,048	1,838
-	-	-	-	-	-
956	1,765	3,676	3,186	2,868	4,902
623	1,121	2,492	2,471	2,224	3,717
2,711	2,086	5,596	3,064	3,070	6,556
570	1,186	2,206	2,022	1,737	2,819
560	1,140	2,002	1,920	1,691	2,614
135	276	1,103	858	772	1,716
-	-	-	-	-	-
245	441	1,225	1,103	993	1,838
1,471	2,757	5,515	4,902	4,412	7,353
1,144	2,390	4,493	4,085	3,493	5,719
899	1,618	3,595	3,023	2,721	4,820
521	1,011	1,838	1,736	1,562	2,451
956	1,765	3,676	3,186	2,868	4,902
-	-	-	-	-	-
322	579	1,287	1,256	1,131	1,900
-	-	-	-	-	-
429	276	3,064	1,838	1,654	3,676
643	1,388	3,084	2,471	1,939	3,697
574	1,204	2,288	2,063	1,756	2,900
1,005	1,912	3,676	3,350	3,015	4,902
-	-	-	-	-	-
49	221	613	551	496	1,103
533	1,048	1,838	1,777	1,599	2,451
1,103	2,206	3,676	3,676	3,309	4,902
603	1,333	2,859	2,349	1,884	3,472
545	1,085	1,838	1,818	1,636	2,451
598	1,314	2,778	2,308	1,866	3,391
1,593	1,673	3,758	3,064	2,243	4,371
1,471	1,636	3,636	3,023	2,187	4,248
1,195	1,553	3,452	2,839	2,105	4,065
28,406	**48,594**	**101,899**	**88,112**	**76,562**	**132,148**

Direct non-residential

Four main damage components have been identified as most relevant to flood impacts on non-residential properties, namely:

- Building structure, fabric and services;
- Fixtures and fittings;
- Moveable equipment; and
- Inventory or stock (either inputs or outputs).

Obviously, these components will vary depending upon the type and size of the properties concerned. The size of premises will affect levels of total flood damage, and average floor size per property varies considerably, depending upon the nature of the business that takes place within. Moreover, each of the components will vary in their susceptibility to flood damage.

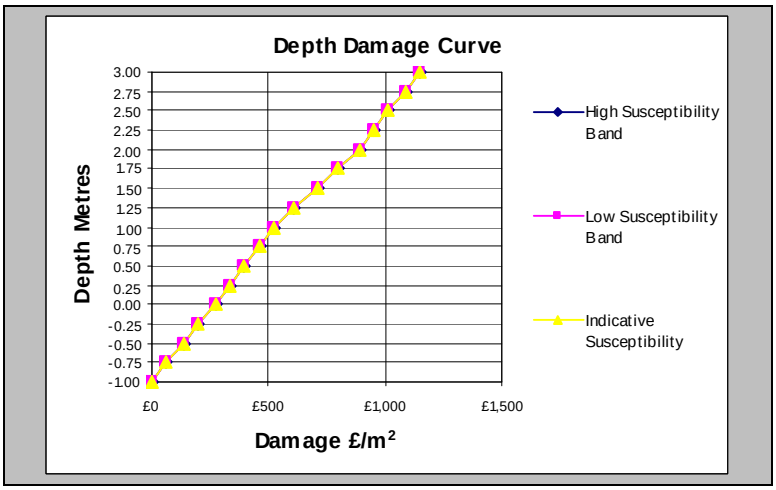
The Multi-coloured Manual[10] contains a database of susceptibility-values for each of the four damage components. From this information high (maximum) and low (minimum) depth-damage curves, as well as indicative (arithmetic mean) depth-damage curves have been developed for categories of non-residential property, for a range of flood scenarios.

It is difficult to find a non-residential land-use category that corresponds exactly to the distillery at Kella Mill. The closest match from the dataset is an industrial "laboratory". The depth-damage curve for one flood scenario is shown in Figure 4. As with the residential depth-duration-damage curves, we have up-rated the depth-damage curve to 2004 prices.

To calculate the direct property damage to the distillery from the December 2000 flood we applied the depth-damage curve in Figure 4 to the estimated flood depth, as shown in Table 4, assuming that the ground floor area of the distillery is 500 m^2 (from the Bullen Consultants report). A flood depth of 1.32m will result in total damages across all four components of £638 per m^2; aggregating over 500 m^2 yields a total direct flood damage cost of £319,000.

[10] Penning-Rowsell et al (2006) op. cit.

Figure 4: Depth-damage Curve: Laboratory: River flood of more than 12 hours duration with no flood warning being issued (2004 prices)



Source: Flood Hazard Research Centre, Multi-coloured Manual, 2003.

Indirect effects

According to Defra (2000[11]) approximately 50% of all households can be expected to leave their home, for an average of 30 days, when flood levels in their property exceeds 0.3m. In looking at the flood depths in Table 4, this implies that 22 (44 x 0.5) households would require temporary accommodation for 30 days. Consultations on the Isle of Man suggest that this is a reasonable approximation to what actually happened. Obviously, the average cost of house rentals per week is dependent on the location, size and type of property. The mean weekly rents, average over all tenancy types in England in 2000 was about £95 (or £145 in 2004 prices, assuming rental values increase in line with average house prices) for assured short hold tenancies (SEH, 2000). In the absence of a figure for the Isle of Man, we have used this weekly rental value in our calculations. The total cost of temporary accommodation is thus close to £13,670.

In addition to building fabric and household inventory items, clean-up costs are also an important variable in determining the potential damages to residential properties. Average clean-up costs have been derived by the FHRC for flooding below and above depths of 0.1m depths, based on actual observed damage costs[12]:

- Average clean-up costs for flood depths below 0.1m are estimated to be £6,205 per property (2004 prices).

- Average clean-up costs for flood depths above 0.1m are estimated to be £10,825 per property (2004 prices).

The estimated total clean-up cost for all 54 flooded residential properties is thus £556,735; found by applying the appropriate average unit cost to the data in Table 4.

While these clean-up cost estimates include the rental and labour costs of dehumidifiers, they do no include electricity costs. On average, a dehumidifier utilises

[11] Defra (2000) FCDPAG3, Project Appraisal Guidance 3 - Economic Appraisal. Available online at http://www.defra.gov.uk/environ/fcd/pubs/pagn/fcdpag3/default.htm

[12] Penning-Rowsell et al (2006) op. cit.

3kw per hour of electricity, which at 2004 prices costs roughly between 9 and 11 pence per kWh. The electricity cost for one dehumidifier for a 24-hour period is thus between £6.50 and £7.90. For flood depths below 0.1m (which requires four units for 28 days) the total average electricity cost would then be £730 to £885 per property. And for a flood depth above 0.1m (which requires four units for 56 days) the total average electricity cost would then be £1,455 to £1,770 per property. The estimated cost of powering dehumidifiers for all 54 flooded residential properties is thus £74,220 to £90,270.

Floods not only impact upon the property directly affected, but that the impact can spread further into neighbouring economic units, in turn causing general disruption to the regional or sub-regional economy. Such impacts are typically termed secondary effects, and are notoriously difficult to measure. Nonetheless, FHRC (2003) reports the findings of a case study of flooding in the Thames Valley in which secondary effects were calculated. They found that secondary effects in the locality of the flood (i.e. within 15-20 kilometres of the flood plain) were 0.2 per cent of total direct losses, which would amount to under £5,000 in the case of the Sulby flood on the 8th of December 2005.

Health effects

The health (or 'intangible') effects of flooding are now recognised as being quite significant. The effects on human health as a consequence of flooding range from risks to life, hypothermia and injuries during, or immediately after, the flood, to more long term physical and psychological health effects during the weeks or months following a flood (e.g. anxiety during heavy rainfall, increased stress levels, mild, moderate, and severe depression, flashbacks to flood, etc.). We have only informal reports of the health consequences of the Sulby flood. Our estimates are therefore based on values transferred from wider UK studies.

The results of a recent national survey concluded that the benefits of avoiding the health effects of river flooding were in the order of £205 per household per year (associated with reducing the Annual Flood Probability from 0.05 to 0.007) (DEFRA, Supplementary Note to Operating Authorities, July 2004). One could also look at this figure as the welfare cost of experiencing a 1-in-150 year flood as opposed to a 1-in-20 year flood. The Annual Flood Probability at Sulby is 0.07. Thus the benefits of avoiding the health effects of the floods on the 8th of December 2005 are likely to be at least as high as £205 per households per year, i.e. we can apply £11,100 as an annual total as an expected value for all 54 affected households.

Using population, household and age data for the Parish of Lezayre from the 2001 Isle of Man census and life expectancy tables from the UK Actuarial Service, we have estimated the capitalised (present value) of the health damages for affected residents (in accordance with the declining discount rate schedule recommended by the HM Treasury Green Book) at £334,430.

Emergency costs

Floods also disrupt communications and impose extra costs on those involved in managing the flood event and in the recovery process. Depending upon the severity of the flood event, several emergency services may be involved in both emergency works and clean-up operations, during and after the flood event. Extra staff time and materials may be required, and additional administrative costs may be involved.

In the absence of precise data from the Sulby event we take an estimate of the

emergency service costs as a percentage of total property losses from a flood event of comparable severity in Yorkshire in Autumn 2000. Based on detailed research of the autumn 2000 floods in Yorkshire, FHRC (2003) found that the total cost of all emergency services as a percentage of total economic property losses was 10.7%. This historical analogue can be used as a multiplier on top of property damages that accounts for emergency costs - though in practice the size of this multiplier will vary with the intensity of event and location. We have therefore multiplied total property losses, estimated above, by a factor of 1.107 to allow for extra emergency costs. These are shown separately in table 8.

Missing impacts

The 'main river' upstream of Ramsey is about 13.8 km in length. The land-use along both banks is mixed, with areas of agricultural, commercial, residential and park land. The latter are important areas of open space for recreation (for the local community) and wildlife. Indeed, Sulby itself is considered on of the most scenic parts of the Isle of Man and it has been proposed that Sulby Glen is designated a Conservation Area.

A potentially significant omission from the case study thus relates to the impact of the floods on (a) agriculture in the Sulby area and (b) on recreation and amenity for local residents and visitors. However, the data necessary to include these categories within the study are not available.

A further significant omission relates to disruption caused to the road network as a result of the floods. Again, no data is available to estimate the cost of such disruption to the transport system.

Cost summary

Our estimates of the total damages from the floods at Sulby on the 8th of December 2005 are shown in Table 8. Total damages range from £3.1 to £3.6 million (2004 prices), depending on the duration of the flood. This is equivalent to between £56k and £66k per affected residential and non-residential property. Direct property damages comprise around two-thirds of the estimated total costs.

For the reasons set out above we have not included the damages to residential garages and conservatories in these figures. If they were included, as a sensitivity test, total damages would increase to between £3.2 and £3.8 million.

Note that given the limited data available for the Sulby event itself, we have supplemented this with unit values available elsewhere in the UK, where we have felt this was reasonable to do. A degree of uncertainty is therefore attached to the results and the full range should always be presented. It is probably more accurate to view the totals given in

Table 8 as 'sub-totals', given that not all the impacts that actually occurred as a result of the flood have been captured by the analysis. Possible significant omissions include: (a) disruption to transport, (b) impacts to agriculture and (c) loss of recreation and amenity.

Table 8: Summary of Estimated Damages for December 2000 Floods at Sulby, by Duration of Flood (2004 prices)

	Flood Duration < 12 Hours		Flood Duration > 12 Hours	
	Low	**High**	**Low**	**High**
Direct property damage:				
Residential property	1,574,220	1,741,960	1,915,460	2,109,890
Garages	28,410	48,590	88,110	76,560
Conservatories	101,890	101,890	101,890	101,890
Non-residential property	319,000	319,000	319,000	319,000
Other Effects:				
Temporary accommodation	13,760	13,760	13,760	13,760
Residential clean-up	556,740	556,740	556,740	556,740
Additional power	74,220	90,270	74,220	90,270
Health	334,430	334,430	334,430	334,430
Emergency services [a]	202,570	220,520	239,090	214,400
Secondary effects [b]	3,790	4,120	4,470	4,860
Total (sensitivity test) [c]	3,209,030	3,431,280	3,647,170	3,821,800
Total ('best guess') [d]	3,078,730	3,280,800	3,457,170	3,643,350
Total (£ per affected property)	55,980	59,650	62,860	66,240

Notes:
[a] Based on residential and non-residential property damage totals, without garages and conservatories.
[b] Based on residential and non-residential property damage totals, without garages and conservatories.
[c] Assumes that all affected residential properties have a garage and a conservatory.
[d] Excludes damages to residential garages and conservatories.

SECTION 4: CASE STUDY OF JANUARY 2005 WINDSTORM

Introduction

The windstorm of 7-8 January 2005 saw wind gusts of 112 mph recorded on the Mountain Road – a 1 in 100 year event. Gusts reached 85 mph at Peel breakwater, 92 mph at Ronaldsway Airport, 96 mph at Douglas and 98 mph at the Point of Ayre. At one point the winds were Storm Force 11. The storm peaked at around 5-6 am on Saturday.

Impact assessment

A matrix of broad (first-order and key second-order) impacts likely to arise from winter windstorms are presented in Figure 5, along with those sectors most likely to be affected by these broad impacts, potential economic consequences and the main stakeholder groups. Of course, any specific windstorm event will not necessarily give rise to all these impacts and only a sub-set of actual impacts will have been reported / measured.

Figure 5: Impact Matrix for Windstorms – Potentially Relevant Economic Impacts

Winds → Direct Physical Damage

First-order Impact	Sector Affected	Potential Economic Impacts	Relevant Stakeholders
Direct Physical Damage	Habitat	Mortality in 'valued' species (foregone use and non-use value)	General public, tourists, national interest groups, government departments
		Destruction of 'valued' ecosystems (foregone use and non-use value)	
	Forestry	Destruction of trees (loss of timber products and producer surplus)	Timber producers, consumers, national interest groups, government departments, general public
		Destruction of trees (loss of recreation and amenity)	
	Agriculture land	Loss of crops (lost producer surplus)	Local farmers, consumers of farm products, government departments
		Loss of livestock (lost producer surplus)	
	Transport infrastructure	Loss of infrastructure/equipment (replacement necessary)	Transport operators, contractors, local public (users and employees in this sector), business and wholesale distributors
		Damage to infrastructure/equipment (repairs necessary)	
	Buildings (residential, commercial, industrial, agriculture, government)	Loss of private and public property (replacement necessary)	Households, property owners, insurers, contractors, business
		Damage to private and public property (repairs necessary)	
	Historical and cultural heritage	Loss of cultural objects (foregone amenity and non-use value)	Local public, tourists, national interest groups, government departments, insurers, business
		Damage to cultural objects (repairs necessary)	
	Human health	Increased risk of mortality (fatal injuries)	Local public, employers, insurers, NHS, government, regulators
		Increased risk of morbidity (non-fatal injuries and anxiety)	
	Utilities	Damage to transmission network	Power generators and suppliers, electricity customers - both households and business (prices), regulator, insurers, other utilities, government departments
		Damage to power generation infrastructure	
		Damage to water treatment facilities and pumping stations	Water authority, customers - both households and business (prices), regulator, insurers, government departments
		Damage to distribution and sewer system	
		Damage to waste water treatment plant	
		Damage to telecommunication system / lines	Telecommunication suppliers, customers - both households and business (prices), regulator, insurers, government departments

Continued: Impact Matrix for Windstorms – Potentially Relevant Economic Impacts

First-order Impact	Sector Affected	Potential Economic Impacts	Relevant Stakeholders
Winds → Short-term Disruption	Road transport	Increase in travel cost (individual, work time)	Local population, users and operators of public transport (buses), businesses, highways authorities
		Increase in travel cost (individual, non-work time)	
		Disruption to inputs / sales (business losses)	
		Change in demand for unaffected, alternative transport routes or modes	
		Increase in highway agency's costs	
	Air transport	Increase in travel cost (individual, work time)	Users and operators of airlines, tourists, businesses, airport authorities
		Increase in travel cost (individual, non-work time)	
		Disruption to inputs / sales (business losses)	
		Change in demand for unaffected, alternative transport routes or modes	
		Increase in airport authority's costs	
	Sea transport	Increase in travel cost (individual, work time)	Users and operators of airlines, tourists, businesses, harbour authorities
		Increase in travel cost (individual, non-work time)	
		Disruption to inputs / sales (business losses)	
		Change in demand for unaffected, alternative transport routes or modes	
		Increase in harbour authority's costs	
Winds → Evacuation	Households / Government	Increase in costs of 'emergency service' and related activities	Local public, emergency services, government departments
		Temporary accommodation costs	
		Disutility costs to individual (e.g. from stress and anxiety)	

Continued: Impact Matrix for Windstorms – Potentially Relevant Economic Impacts

Second-order Impact		Sector Affected	Potential Economic Impacts	Relevant Stakeholders
Damage to Utilities →	Outages / Disconnections →	Electricity	Disutility (individual)	Power generators and suppliers, electricity customers - both households and business (lost services), regulator
			Lost output / increased costs (business customers)	
			Additional costs / foregone producer surplus (supplier)	
		Water	Disutility (individual)	Water authority, customers - both households and business (lost services), regulator
			Lost output / increased costs (business customers)	
			Additional costs / foregone producer surplus (supplier)	
		Telecommunications	Disutility (individual)	Telecommunication suppliers, customers - both households and business (lost services), regulator
			Lost output / increased costs (business customers)	
			Additional costs / foregone producer surplus (supplier)	
Damage to property →	Short-term disruption →	Commerce and industry	Lost business during repairs / replacement (lost producer surplus)	Manufacturing and service sector, insurers

Property damage

The windstorm affected most of the island, damaging both residential and non-residential property (in private and public hands), as well as private and public infrastructure.

Government property

Two government departments have provided cost data on damages the windstorm caused to their estates. The Department of Home Affairs incurred total costs amounting to £22,524 (48% labour costs and 52% materials) (2005 prices) as a result of the windstorm on 7th and 8th January 2005. The cost of storm damage reported by the Department of Local Government and Environment totalled £78,650 (2005 prices) (see Table 9). These costs relate primarily to roof and building repairs, removing fallen trees, and other associated wind damages. In addition, the Department of Education reports costs of £68,000 for damages arising from the January windstorms. The Highways Division estimate costs of £93,000 for damage to the infrastructure.

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Table 9: Storm Damage Costs Department of Local Government and Environment

Parish	Total Cost (£)
Andreas	3,170
Arbory	5,070
Ballaugh	665
Bradden	4,580
Bride	1,780
Castletown	21,915
Douglas	795
German	205
Jurby	17,135
Lezayre	1,675
Lonan	15,105
Malew	2,895
Marown	210
Maughold	10
Patrick	275
Peel	235
Port Erin	1,425
Santon	1,505
All Parishes	78,650

Private property

There were reports of significant damage to private residences and property (e.g. cars), with chimney stacks being blown over and roof slates being dislodged. Significant damages were experienced, with insurance company Tower Insurance reporting 850 claims. Of these, 120 were commercial and 50 related to vehicle damage. The total claims amounted to £1.5 million, Tower Insurance has a 25% market share on the Isle of Man, hence insurance damages can be estimated (assuming that all insurers were similarly impacted) at £6 million.

Not all property is, however, insured. It is assumed, based on previous studies[13], that 60% of damages are insured. Hence, total economic losses to private property are estimated at £10,000,000.

Damage and disruption to forests

According to the Forestry, Amenity and Lands Division of DAFF, tree losses in government owned woodlands amounted to approximately: (a) 325 broad leaves (e.g. ash, sycamore, elm, etc.) and (b) 22,000 plantation conifers with an estimated timber volume of 7,200 m^3 over an area of 17.0 hectares.

Valuing the loss of broadleaves can be done by estimating the cost of replacement. Costs vary between £5 to £50 per tree for replacing with non-semi mature trees, and up to £15,000 to £20,000 per "instant tree". Instant trees are only used in special circumstances (Peter Williamson, DAFF, *pers. comm.*). To give the full cost of replacing the trees to the state they were before the storm would involve the latter value for mature trees. However, not all trees on the Isle of Man damaged would have been mature. An estimate may be that 50% were mature. Using average values of £17,500 for replacement of a mature tree and £27.50 for replacing an immature tree gives a value of damage to broadleaves of £2.8 million.

Valuing the loss of conifer plantations depends on knowing the quality of the timber lost. The quality of the timber lost in the Isle of Man from the windstorm ranged from firewood to saw logs. Valuing the clear up costs, according to DAFF, would be "relatively easy" at the end of the harvesting operations, which are still ongoing at the time of writing this report. Data on the price of conifer wood is available from the UK Forestry Commission. The *Timber Price Indices* give the Coniferous Standing Sales Price over the period in question at between £6.13 to £6.19 per cubic metre. Using a central value of £6.16 per cubic metre, we can estimate the costs of the timber lost at £44,332.

Total impacts on government forests are hence estimated at £2.9 million.

Damages to non-government owned forests were not available, nor were the relative size of holdings of government and non-government owned forests. As such, we have not quantified the damages to non-government forests. Impacts on non-timber forest products are also not quantified. The estimate of £2.9 million is likely to underestimate the true cost to forestry.

[13] See the Foresight study on Flooding and Coastal Defense (www.foresight.gov.uk).

Damage and disruption to utilities

Electricity sector: overview

The Manx Electricity Authority (MEA) is a statutory body charged with providing the population of the Isle of Man with a safe, reliable and economic electricity supply. The MEA is responsible for all aspects of supply, including generation, transmission and distribution of electricity, as well as billing and collecting revenues for these activities.

As of the 10th of January, it was reported that about 400 properties remained without power and that it could take to the end of the week before electricity supply is restored. At the height of the storm – around 5-6 am on Saturday the 8th – about 900 customers were without power as poles were blown over, power lines ripped out of walls and trees crashed onto overland cables. It was reported that the Civil Defence volunteers were looking after people who remain without power (as of Thursday the 13th).

Five teams of electricity workers were due to arrive on Sunday night from the north of Scotland and the Midlands to assist the more than 100 MEA staff and contractors already deployed to restore power supply to affected customers.

Direct costs to MEA

The direct costs to the MEA include the costs of repairs and the lost revenues on electricity that would have been supplied if supply disruptions did not occur. Costs of repairs were not able to be provided for the study. We now try to quantify the lost revenues to the MEA.

Quantification of the energy blackouts in terms of kWh can be done, though statistics for the Isle of Man on consumption of electricity by domestic households were not available. Hence, we drew on the annual average consumption rate in the UK of 4,600kWh per household (DTI, 2005). This annual figure was distributed across the months using quarterly data on consumption and allocating quarterly consumption to the months according to number of days. This gave an estimate of the monthly consumption in January of 482.9kWh per household, or a daily estimate of 15.6kWh. The supply disruption was allocated across the days of impact based on the data provided above, with it being assumed that a total of 900 houses had impacted supplies at the peak and this initially declining at a rate of 250 per day for the first two days and a rate of 100 per day until the end of the week (see Table 10 below). This yields an **estimated impact on the supply of electricity of 39,723 kWh.**

To value the losses to the MEA, ideally one would use the gross margin for electricity. However, no such estimate exists due to commercial confidentiality. Hence, it is necessary to use the market price of electricity to value the losses to the MEA of the supply disruptions. The price of electricity in the Isle of Man is 11.04 pence per kWh. Thus, **the estimated cost of energy interruptions in terms of lost (gross) revenues to the MEA is £4,381.** The welfare loss, estimated by the gross margins approach, would of course be lower since the resource costs would be subtracted from the gross revenue total.

Costs of energy supply blackouts – welfare loss

The quantification of the amount of energy disruption to households and the estimated duration of these blackouts is given in the previous section. It was estimated that the impact on the supply of electricity of 39,723 kWh.

Blackouts cause significant annoyance to consumers and the value of this annoyance has been the subject of some investigation in the economic literature. A recent study for the EC reviewed the literature on the valuation of these supply disruptions (EXTERNEPOL, 2005). Valuation of blackouts can be based on the Value of Lost Load (VOLL). The appropriate values for the case of the Isle of Man cuts in supply are between €1.80/kWh (£1.20) for an outage of over 24 hours (Egenhofer et al, 2004) and €4.60/kWh (£3.07).

Applying these values to the case of the disruptions to supply caused by the windstorms of January 2005 in the Isle of Man gives estimates of the impacts as shown in Table 10. **The total cost in terms of the welfare loss to consumers of these cuts in supply are estimated at between £47,668 and £121,817.**

Table 10: Valuation of Energy Disruption to Consumers

Electricity losses				Valuation	
Households impacted	Day reduction	kWh lost supply per household	Total lost kWh	VOLL=£1.20	VOLL=£3.07
250	1	15.58	3,894	4,673	11,943
250	2	31.16	7,789	9,347	23,886
100	3	46.73	4,673	5,608	14,331
100	4	62.31	6,231	7,477	19,109
100	5	77.89	7,789	9,347	23,886
100	6	93.47	9,347	11,216	28,663
900			**39,723**	**47,668**	**121,817**

Power sector disruption - summary

The windstorms of January 2005 had significant impacts on the power sector. Some of these impacts have been valued, notably:

- the lost gross revenues to the MEA from energy that would otherwise have been supplied and consumed of £4,381; and

- the impact on consumers was valued at between £47,668 and £121,817.

Strictly speaking, these totals include some overlaps and therefore should not be summed. Given the size of the gross revenue loss it is therefore sensible to adjust the consumer loss downwards to give a broad range of £45,000 to £120,000.

It should be noted that we have not included values on the direct costs to the MEA of repairs, since these were confidential.

Water Sector

The Isle of Man Water Authority is a statutory body charged with providing the population of the IOM with a wholesome, reliable and economic supply of potable water. The authority is also responsible for providing the necessary treatment, distribution and sewage collection infrastructure to meet the islands needs.

The island's water treatment works and pumping stations are powered by electricity. During the peak of the storm on Saturday morning alarms indicated power failures at 10 sites, including Ballure Water Treatment Works and Ballagawne Water Treatment Works. The Isle of Man Water Authority deployed mobile generators at affected installations to ensure potable water supplies to customers. However, a number of customers remained without water on Saturday due to broken mains, which were damaged by uprooted trees. We have not been able to obtain sufficient data to value these impacts, though we note that these customers would have suffered significant adverse welfare effects.

Transport disruption

As a result of the storm all flights were delayed and ferry sailings disrupted. In addition transport networks on the island were badly affected.

Flight disruption

Anecdotal evidence suggests a number of flights were delayed or cancelled as a result of the storm. One of the major flight operators lost 4 flights out of 30 scheduled on January 7th and 8th – their Gatwick and Manchester routes. Estimates of the *potential costs* of these cancellations were provided by the airline. These do not represent actual costs to the airline, but are indicative of the maximum costs that may have been incurred as a result of the cancellations. Assumptions include:

- flights are assumed to be 2/3 full;
- all are assumed to take compensation and refunds.

Costs are estimated on the basis of compensation at £5 per passenger and revenues of average £30 and £40 for one way fares from Manchester and Gatwick respectively. Passenger rates on the flights are assumed to be 30 and 40 respectively. This leads to an estimated cost of £6,300, though sources suggest that the loss to the airline in terms of yield was approximately £700. We take the upper bound estimate for the cost as the yield loss does not include factors such as loss of reputation and also inconvenience to passengers.

This operator had 30 flights in and out of Douglas in the period in question. To estimate the total impact on flights in terms of cancellations, we calculate the impact in terms of flights cancelled on a proportionate basis. A total of 170 flights come in and out of Douglas on Fridays and Saturdays. This means, assuming all operators are equally affected, that approximately 23 flights were cancelled. Taking the average cost to BA of £1,575 per cancelled flight gives an **estimated loss in terms of cancelled flights of £36,225**.

It should be noted that this is likely an overestimate of the costs to the airlines of cancellations, as many passengers would have taken a later flight and not claimed a refund. Also we have used cost data rather than gross margins – which would further reduce these estimates and produce a reflection of the real welfare costs.

We have not had data sufficient to estimate the delay costs or the inconvenience to passengers of such delays, or the knock on effects of delays and cancellations on other scheduled flights. Clearly, these will be significant.

Ferry disruption

Ferries were badly disrupted by the storm. Tables 11 and 12 give data on the ferries delayed and cancelled during the period of the storm. The costs of cancellations are estimated using the lost yield to the ferry operator as a proxy for the welfare cost. It should be noted that we assume that delay time for outgoing ferries is the same as the delay at departure. This does not take into account the inconvenience of the cancellation. Delay costs can be estimated using work and non-work travel time values from the UK government. The value of work time delays is estimated at £30.43 per hour, with the comparative value of non-work time being £4.52 per hour. Business passengers accounted for 5% of passengers on ferries in January (Isle of Man Passenger survey).

Table 11: Ferries delayed by January 7th and 8th Windstorm

Date	Route	Dep	Arr	Delay (mins)
7th Jan	Heysham-Douglas	02.15	06.35	60
7th Jan	Douglas-Heysham	08.45		10
7th Jan	Heysham-Douglas	14.15	18.23	45
8th Jan	Douglas-Heysham	08.45		70
8th Jan	Heysham-Douglas	14.15	2020	165
8th Jan	Douglas-Heysham	19.45		110

Table 12: Ferries cancelled by January 7th and 8th Windstorm

Date	Route	Dep
7th Jan	Liverpool-Douglas	19.00
7th Jan	Douglas-Heysham	19.45
8th Jan	Heysham-Douglas	2.15
8th Jan	Douglas-Liverpool	8.00

Estimated passenger numbers and lost yield were obtained from the Steam Packet Company based on monthly data for January 2005. The average number of passengers on the Heysham service was 99.4 per sailing and the equivalent for Liverpool was 157.2 passengers. The average yield was £55.43 for Heysham and £42.20 for Liverpool. The cost of cancellations was hence estimated at £24,283 and the costs of delays was estimated at £4,431. **Total losses due to the January windstorm impacts on ferries can be estimated at £28,715.**

Bus service disruption

Bus services were also cancelled on Saturday the 8th as the emergency services battled to clear roads around the island of uprooted trees and other debris. Fallen trees blocked a number of major routes, including Peel Road at Quarterbridge. Services resumed on Sunday. Data were not available on bus passenger numbers and hence this impact is not quantified or costed.

General traffic disruption

Delays caused to general traffic on the Isle of Man by road closures due to the January windstorm are presented in Table 13. The costs of these delays can be estimated using the value of time (VOT) and vehicle operating costs (VOC). In addition, building on previous work on the cost of flooding diversions estimates for the value of stress and additional congestion on alternative routes are considered. As noted in the table, some road closures had to be excluded due to insufficient data on the duration of the closure.

Baseline data on traffic in the Isle of Man, in terms of vehicle kilometres per annum and average vehicle speeds, were not available. As such, we have taken values from UK regions and transferred them to approximate the case in the Isle of Man case. We have assumed that diversions are approximately 5km in length and that average daily traffic is 2,600 vehicles per day (based on data on Welsh roads[14]). The average vehicle speed assumed is that of B roads in Northern Ireland, where off peak speeds average 47.6 mph[15]. The caveats to this are:

- vehicle speeds off B roads are likely to be less (hence these estimates underestimate the true impact);
- vehicle numbers may be less as some of the roads impacted were very minor;
- diversions caused by wind may be less than those experienced by flooding.

We also assume that light goods vehicles make up 2.2% of traffic flows based on UK data.

[14] Source: http://www.dft.gov.uk/stellent/groups/dft_transstats/documents/page/dft_transstats_030361.xls
[15] Source: http://www.dhsspsni.gov.uk/publications/2003/paperspeeds.pdf

Table 13: Assumptions for Transport Impacts of Windstorms

	Minutes	Days	Average diversion (km)	Average daily traffic	Impacted vehicles	
					Passenger cars	Goods vehicles
Total Road closures	91050	63.23	3.2	2300	142228	3199

In terms of estimating the costs of these delays, Value of Time estimates were obtained from the Posford/Met Office study[16]. These show an average cost for cars of 673.6 pence per vehicle hour and 1167.7 pence per hour for light goods vehicles. Note that we have assumed that the goods vehicles travelling on roads form 2.2% of traffic, and that HGV costs are equivalent to LGV costs in the absence of data to the contrary. This is a reasonable assumption, as costs to HGV in terms of time may actually be higher than those for LGVs given the skilled nature of drivers. These assumptions lead us to estimates of Value of Time damages of £366,534 for the Isle of Man resulting from the January windstorms. To calculate the Vehicle Operating Costs, we took the proportion of VOC costs to VoT costs shown in the Posford/Met Office study for non-built up A roads in Wales. The VOC on non-built up roads in Wales was £633/day/km, compared to a VoT estimate of £4725/day/km (1994 values). This leads to an estimate of total resource costs. The total resource costs were then multiplied by a factor of 5.7 to take account of stress and anxiety (based on FHRC, 2002) to give an estimated (rounded) cost of £1.27 million. A multiplier of 2 may be applied for the knock-on effect on congestion and subsequent time losses on roads to which the disrupted traffic has been diverted, (as suggested by FHRC, 2002) **we arrive at an estimate of total damages due to road disruption of £2.55 million.**

[16] Posford/Meteorological Office/JB Chatterton Associates (2000) *Research to determine the impact of severe weather*. Unpublished.

Table 1: Emergency Orders Issued As A Result Of Weather Conditions 7-8 January 2005

Road Name	Area Closed	Dates and Times of Closure	Notes
Summerhill Road, Onchan	Blackberry Lane to The Park	15.40 08.01.05 – 15.40 09.01.05	
Slieau Whallian Back Road, Patrick	300m south of its junction with Patrick Road to Ballanass	12 Noon 10.01.05 – 6.00pm 25.01.05	
Marine Parade, Peel	From junction with Walpole Road to the	8.50am 08.01.05 – 10am 09.01.05	
Spaldrick Promenade, Port Erin	Church Road to Rowany Drive	8.45am 08.01.05 – 10am 09.01.05	
Ridgeway Street, Douglas	North Quay to Lord Street	10.30am 08.01.05 – 10am 09.01.05	
Queen Street, Castletown	The Parade to Farrants Way	10.30am 08.01.05 – 09.01.05	
Parliament Street, Ramsey	Market Hill to Court Row	11.25am 08.01.05 – 10am 09.01.05	
Ballanard Road, Douglas/Onchan	Johnny Wattersons Lane to Abbeylands	08.40am 08.01.05 – 18.40 09.01.05	
Patrick to Glen Maye Road, Patrick	Patrick Village to Glen Maye	19.30 08.01.05 – 19.30 09.01.05	
Glen Darragh Road, Marown	A1 to Ellerslie Farm Road	17.15 08.01.05 – 17.15 09.01.05	
Lhoobs Road, Patrick	A24 at the Eairy to Kionslieu Road	17.15 08.01.05 – 17.15 09.01.05	
Auckland Lane, Ramsey	Christian Street to West Street	5.00pm 10.01.05 – 6.00pm 24.01.05	
A3 Kirk Michael to Ramsey Road	Orrisdale Loop Road North to	11.15am 09.01.05 – 5.00pm 09.01.05	
Imperial Terrace, Onchan	Belgravia Road to Hague Crescent	16.00 09.01.05 – 12.00 Noon 10.01.05	
A1 Douglas to Peel Road	Ballagarey Road to Glenlough	16.35 09.01.05 – 20.00 09.01.05	
North Quay, Douglas	Quines Corner to Market Hill	10.01.05	Excluded - insufficient data
Public Right of Way No 347	Adjacent to Poyll Vaaish Quarry	4.30pm 10.01.05 – 6.00pm 18.01.05	Excluded - insufficient data
Pulrose Road, Douglas	Peel Road to Peel Road	3.00pm 11.01.05 – 6.00pm 12.01.05	
Breakwater Road, Port Erin	Raglan Pier to former Marine Biological Station	3.00pm 11.01.05 – 12.01.05	Excluded - insufficient data
Duke Street, Douglas	Wellington Street to Regent Street	12.30pm 11.01.05 – 6.00pm 12.01.05	
St Georges Walk, Douglas	St Georges Street to Peel Road	11.30am 11.01.05 – 6.00pm 12.01.05	
Parliament Street, Ramsey	Market Hill to Parliament Square	12.40pm 11.01.05 – 6.00pm 14.01.05	

Emergency Costs

Windstorms can disrupt communications and impose extra costs on those involved in managing the storm event and in the recovery process. Depending upon the severity of the event, several emergency services may be involved in both emergency works and clean-up operations, during and after the storm event. Extra staff time and materials may be required, and additional administrative costs may be involved.

Data on the additional costs to emergency services of windstorms are not available. Given that similar weather related events may have similar impacts on the emergency services, we take the costs estimated for the 2000 floods in Yorkshire and apply the FHRC (2003) finding that the total cost of all emergency services as a percentage of total economic property losses was 10.7%. This can be used as a multiplier on top of property damages that accounts for emergency costs. We have therefore multiplied total property losses, estimated above at £10.1 million, by a factor of 0.107 to allow for extra emergency costs. This leads to an **estimate of emergency costs of £1.1 million.**

Other impacts

Exam disruption

A knock-on effect of the storms on the 7th and 8th of January was that schools and the IOM College were closed on Tuesday 11th of January due to concerns over the safety of parents and students travelling in the late afternoon, when another deep depression was forecast. (As it turned out, the strongest winds did not arrive until the evening). Nonetheless, the fact that the schools were closed created problems for AS and A-level students whom were due to sit modular exams. The same exams were being sat throughout England and Wales on the same day. Since the exams sat on the Tuesday were then in the public domain, new exam scripts needed to be drafted. The exams were to be re-sat in May or June, or January 2006. This was expected to increase the pressure on those students that are due to sit their main exams at the same time (The Examiner 11/01/05).

The additional stress caused to students and their families gives rise to direct welfare losses (in an economic sense). Moreover, it may adversely affect their performance. It is also possible that re-sitting the exams would entail extra costs on the part of the examining authority. However, insufficient data exists to measure and value these effects. In any event, they are likely to be relatively small.

Disruption to businesses

At the same time that schools were closed, the adverse weather warning issued by the Department of Home Affairs (on the 10th of January) asked businesses to consider the implications that the approaching storm may have for the safety of their own staff. To the extent that businesses heeded this warning in light of events on the preceding weekend, there will have been some losses of producer surplus. Depending on pay arrangements (contracts) with employees, some workers may also have suffered a reduction in income.

Cost summary

A summary of the costs of the January 2005 windstorm is presented in Table 15. Major cost items are property damage, particularly damage to private property; transport losses, though it should be noted that general traffic disruption estimates may be overestimated due to transfers of estimates from the UK case and because no data exists on minor road use rates; and forestry losses, which are driven by broadleaf losses.

It should also be noted that a number of impacts have not been quantified. Whilst, for reasons outlined above, the costs cannot simply be summed, the total welfare effects of the January 2005 windstorm are certainly likely to be in excess of £15 million.

Table 15: Summary of costs from January 2005 windstorm (2005 prices)

Cost Item	Estimated damages (£mn)
Property damage	**10.3**
of which	
Private property	10.0
Government property	0.26
Forestry losses	**2.89**
of which	
Broadleaf damage	2.84
Conifer Damages	0.04
Non timber forest products	NQ
Non government owned forests	NQ
Utility losses	**0.05 to 0.1**
of which	
Power sector - lost revenue	0.004
Power sector - disruption to consumers (low)	0.045
Power sector - disruption to consumers (high)	0.120
Power sector - direct costs to MEA	NQ
Water sector	NQ
Transport sector	**2.6**
of which	
Flight cancellations	0.036
Flight delays	NQ
Ferry cancellations	.024
Ferry delays	.004
Bus service disruption	NQ
General traffic disruption	2.5
Emergency costs	**1.1**
Other Impacts	**NQ**
of which	
Exam disruption	NQ
Disruption to business	NQ

SECTION 5: CASE STUDY OF COSTS OF FEBRUARY 2002 TIDAL FLOODING

On Friday the 1st of February 2002 several meteorological factors combined to cause severe flooding around parts of the island's coastline. Astronomical high tides were predicted for Friday in any event, 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).

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.

Impact assessment

Figure 6 presents a matrix of broad (first-order and key second-order) impacts from storm surge in coastal areas. It also shows those sectors most likely to be affected by these broad impacts, potential economic consequences and the main stakeholder groups. As with windstorms and river flooding, any specific storm surge event will not necessarily give rise to all these impacts and only a sub-set of actual impacts will have been reported / measured.

Unlike the flooding event at Sulby, where previous detailed modelling provided us with a basis for the impact assessment, no such modelling of damage costs has been undertaken for tidal flooding similar to that experienced on the 1st of February 2002. As a result, we cannot employ the same approach adopted for the Sulby flood case study, which would be the preferred approach. Instead we have to build a picture of what happened from published sources and discussions with affected stakeholders.

Figure 6: Impact Matrix for Storm Surge and Coastal Flooding – Potentially Relevant Economic Impacts

First-order Impact	Sector Affected	Potential Economic Impacts	Relevant Stakeholders
Storm Surge → Direct Physical Damage	Coastal habitat	Mortality in 'valued' species (foregone use and non-use value)	General public, tourists, national interest groups, government departments
		Destruction of 'valued' ecosystems (foregone use and non-use value)	
	Coastal agriculture	Loss of crops / productivity (lost producer surplus)	Local farmers, consumers of farm products, government departments
		Loss of livestock (lost producer surplus)	
	Coastal transport infrastructure	Loss of infrastructure/equipment (replacement necessary)	Transport operators, contractors, local public (users and employees in this sector), business and wholesale distributors
		Damage to infrastructure/equipment (repairs necessary)	
	Coastal buildings and property	Loss of private and public property (replacement necessary)	Households, property owners, insurers, contractors, business
		Damage to private and public property (repairs necessary)	
	Coastal historical and cultural heritage	Loss of cultural objects (foregone amenity and non-use value)	Local public, tourists, national interest groups, government departments, insurers, business
		Damage to cultural objects (repairs necessary)	
	Human health	Increased risk of mortality (fatal injuries)	Local public, employers, insurers, NHS, government, regulators
		Increased risk of morbidity (non-fatal injuries and anxiety)	
	Coastal / harbour infrastructure	Loss of infrastructure (replacement necessary)	Local authorities, government departments, contractors, business
		Damage to infrastructure (repairs necessary)	
	Utilities	Damage to transmission network	Power generators and suppliers, electricity customers - both households and business (prices), regulator, insurers, other utilities, government departments
		Damage to power generation infrastructure	
		Damage to water treatment facilities and pumping stations	Water authority, customers - both households and business (prices), regulator, insurers, government departments
		Damage to distribution and sewer system	
		Damage to waste water treatment plant	
		Damage to telecommunication system / lines	Telecommunication suppliers, customers - both households and business (prices), regulator, insurers, government departments

Continued: Impact Matrix for Storm Surge and Coastal Flooding – Potentially Relevant Economic Impacts

First-order Impact	Sector Affected	Potential Economic Impacts	Relevant Stakeholders
Storm Surge → Short-term Disruption	Road transport	Increase in travel cost (individual, work time)	Local population, users and operators of public transport (buses), businesses, highways authorities
		Increase in travel cost (individual, non-work time)	
		Disruption to inputs / sales (business losses)	
		Change in demand for unaffected, alternative transport routes or modes	
		Increase in highway agency's costs	
	Air transport	Increase in travel cost (individual, work time)	Users and operators of airlines, tourists, businesses, airport authorities
		Increase in travel cost (individual, non-work time)	
		Disruption to inputs / sales (business losses)	
		Change in demand for unaffected, alternative transport routes or modes	
		Increase in airport authority's costs	
	Sea transport	Increase in travel cost (individual, work time)	Users and operators of airlines, tourists, businesses, harbour authorities
		Increase in travel cost (individual, non-work time)	
		Disruption to inputs / sales (business losses)	
		Change in demand for unaffected, alternative transport routes or modes	
		Increase in harbour authority's costs	
Storm Surge → Evacuation	Households / Government	Increase in costs of 'emergency service' and related activities	Local public, emergency services, government departments
		Temporary accommodation costs	
		Disutility costs to individual (e.g. from stress and anxiety)	

Continued: Impact Matrix for Storm Surge and Coastal Flooding – Potentially Relevant Economic Impacts

Second-order Impact	Sector Affected	Potential Economic Impacts	Relevant Stakeholders
Damage to Coastal Utility Equipment → Outages / Disconnections	Electricity	Disutility (individual)	Power generators and suppliers, electricity customers - both households and business (lost services), regulator
		Lost output / increased costs (business customers)	
		Additional costs / foregone producer surplus (supplier)	
	Water	Disutility (individual)	Water authority, customers - both households and business (lost services), regulator
		Lost output / increased costs (business customers)	
		Additional costs / foregone producer surplus (supplier)	
	Telecommunications	Disutility (individual)	Telecommunication suppliers, customers - both households and business (lost services), regulator
		Lost output / increased costs (business customers)	
		Additional costs / foregone producer surplus (supplier)	
Coastal Erosion → Permanent loss / damage of beaches, dunes, cliffs/headlands	Habitat	Loss of 'valued' ecosystems	General public, tourists, national interest groups, government departments
		Loss of 'valued' species	
	Tourism (and domestic recreation)	Decrease in tourist demand (foregone producer and consumer surplus)	Travel companies, hotels and related businesses, local public, government departments
		Reduction in quality of visits (foregone consumer surplus)	
		Lost recreation amenity or reduction in quality of opportunities (individual)	
	Building and infrastructure	Loss of property and infrastructure (public and private, business and individual)	Property owners, government and insurers
	Historical and cultural heritage	Loss of objects with cultural or historic value	Local public, tourists, national interest groups, government departments, insurers, business
	Agriculture	Loss of productive land	Local farmers, government departments

Continued: Impact Matrix for Storm Surge and Coastal Flooding – Potentially Relevant Economic Impacts

Second-order Impact	Sector Affected	Potential Economic Impacts	Relevant Stakeholders
Changes in the hydrological regime → Salt water intrusion of groundwater supplies →	Water authority	Change in water treatment costs Investment in new supply sources needed	Water authority, customers - both households and business (prices), regulator, insurers, government departments
Changes in the hydrological regime → Salt water intrusion of groundwater supplies →	Autonomous abstractors	Change in productivity	Households, farmers, businesses
Changes in the hydrological regime → Changes to navigation routes →	Water transport/port authorities	Change in operational costs Change in risk of accidents	Sea transport authorities and operators, general public, government departments, emergency services
Changes in the hydrological regime → Changes in the pattern of off-shore waves →	Numerous sectors	Changes in deposition of materials (e.g. beach movements)	Local authorities, local population, tourism industry, local businesses, conservation groups
Damage to property → Short-term disruption →	Commerce and industry	Lost business during repairs / replacement (lost producer surplus)	Manufacturing and service sector, insurers

Property damage

The Tongue and North Quay in Douglas suffered extensive flooding and sea water invaded many properties along the promenade. Cars were swept away, and boats ended up on the Tongue in Douglas as the harbour flooded, with boats and vehicles damaging one another. The promenade was closed, with parts remaining closed until late Saturday.

The quayside and main streets of Ramsey were also flooded for several hours. In Laxey, the breakwater and harbour office were damaged. The area around the Creek Hotel and House of Mananan in Peel were swamped by sea water. In Port St Mary, a factory on the quayside was severely damaged. The breakwater in Castletown suffered significant damage (with about 150 feet being washed away), and as a result a large area of the town was flooded (around 50 houses). The breakwater at Gansey also failed, with sea water travelling up to 100 metres inland damaging garden walls and flooding properties.

John Riseley, claims manager at Tower Insurance, said the total insurance cost could average around £25,000 for repair work and £10,000 for contents per house damaged by the flooding. This represents 'best guesses' as of the 4th of February, and does not include commercial premises, which also suffered damage around the island. For example, 40 tonnes of sand at a timber yard in Castletown was contaminated with sea water and had to be written-off by insurers (the sand was actually given to the emergency services to fill sandbags).

In total insured losses were estimated at £4 million shortly after the event by John Riseley. More up-to-date estimates are not available. Total economic damage to private property is likely to be considerably higher however, as only about 60% of damage is able to be claimed on insurance. This means we can estimate the total economic loss to private property from the storm surge at £7.5 million (2005 prices).

Significant damage was also caused to public property, but estimates of this were not available at the time of writing this report.

Health effects

No injuries were reported, although, as with the Sulby floods, affected individuals will have suffered stress and anxiety, and associated welfare losses. If we assume that stress and anxiety were similar to the Sulby flood event case, then we can estimate the health damages of the February 2002 event at £321,000 (2005 prices).

Transport disruption

Flights and sailings to and from the island were severely disrupted. The weather also played havoc with local transport, although bus services returned to near normal around.

Ferries were slightly disrupted by the storm surge event. One ferry from Douglas to Liverpool was delayed from 8.45am to 4.07pm and the return sailing was cancelled. The costs of the cancellation are estimated using the lost yield to the ferry operator as a proxy for the welfare cost. It should be noted that we assume that delay time for

outgoing ferries is the same as the delay at departure. This does not take into account the inconvenience of the cancellation. Delay costs can be estimated using work and non-work travel time values from the UK government. The value of work time delays is estimated at £30.43 per hour, with the comparative value of non-work time being £4.52 per hour. Business passengers accounted for 5% of passengers on ferries in January (Isle of Man Passenger survey).

Estimated passenger numbers and lost yield were obtained from the Steam Packet Company based on monthly data for January 2005. The average number of passengers for Liverpool was 157.2 passengers. The average yield was £42.20 for Liverpool. The cost of cancellations was hence estimated at £6,632 and the costs of delays were estimated at £6,732. **Total losses due to the February 2002 storm surge on ferries can be estimated at £13,365 (2005 prices).**

The DOT records for 2002 indicate that a coastal footpath was closed for repair. Lack of data on the use has meant that the welfare costs associated with the closure are not estimated. Data on further road disruptions were also not available – so no costs for road disruption were found.

Damage and disruption to utilities

The water caused electricity circuits to short. An electrical sub-station in Ramsey blew apart. However, data on the costs to the utility of this are confidential and will not be included in our analysis.

Emergency costs

Storm surges can disrupt communications and impose extra costs on those involved in managing the storm event and in the recovery process. Depending upon the severity of the event, several emergency services may be involved in both emergency works and clean-up operations, during and after the storm event. Extra staff time and materials may be required, and additional administrative costs may be involved.

Data on the specific additional costs to emergency services of storm surges are not available. Given that similar weather related events are likely to have similar impacts on the emergency services, we use the multiplier between property costs and emergency costs identified in the Sulby flooding case study. This yields an **estimate of emergency costs from the February 2002 storm surge of £801,000 (2005 prices)**.

Other costs

Disruption to businesses

Whilst specific data has been unavailable, an indication of such cost components are given by anecdotal evidence from affected businesses. The manager at Tesco, Paul Gallagher, said that his store was out of stock until trucks arrived by boat on Sunday. Marks and Spencer were also reported as having stock delivered by air freight on the Saturday. In both cases additional costs will have been incurred. Tesco will have lost business (as measured by lost producer surplus), while Marks and Spencer will have had to pay the incremental cost of air freight over sea freight.

Cost Summary

The estimated damages of the storm surge of February 2002 are presented in Table 16 below. It can be seen that of the quantified damages most are due to economic losses due to flooding of private property. A number of cost elements, including impacts on government property and utilities. Clearly the total costs of the February 2002 tidal surge is likely to be more that £8 million.

Table 2:Summary of Damage Costs from Tidal Flooding February 2002 (2005 prices)

Cost item	**Estimated damages**
Property damage	**7.5**
of which	
Private property	7.5
Government property	NQ
Health impacts	**0.321**
Transport disruption	**0.013**
of which	
Flight disruptions	NQ
Ferry cancellations	0.007
Ferry delays	0.007
Road disruptions	0
Utility disruption	**NQ**
of which	
Electricity sector	NQ
Water sector	NQ
Emergency costs	**0.8**

SECTION 6: CONCLUSIONS AND AREAS FOR FURTHER RESEARCH

This study presents cost estimates for three historic weather-related events of significance to residents of the Isle of Man. The three events considered are:

- 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.

Our estimates for these three events are shown in Table 17.

Table 3: Estimated damage costs for selected weather events in Isle of Man (2005 prices)

Weather event	Estimated costs
Sulby floods, December 2005	£3.2 to £3.7 million
Tidal Surge, February 2002	>£8 million
Windstorm, January 2005	>£15 million

These events have been shown to have had significant economic costs to the Isle of Man, particularly in terms of property damage. Impacts on the forestry sector were also estimated to be significant for the windstorm of January 2005.

The estimated cost of these events will subsequently feed into analysis of the future costs of similar weather-related events, under various climate and socio-economic scenarios.

Data on the frequency of flood events, windstorms and storm surges under climate change scenarios are not available at the time of writing this report. It is however likely that these events may increase in frequency and, potentially, intensity. The costs presented above show that climate change may have a significant impact on the Manx economy in terms of property damage and transport disruption in particular. Future work will investigate the future costs of these events (see technical paper 7), drawing on socio-economic scenarios for future developments in the Isle of Man (see technical paper 6).

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