Appendix H

Updated Damage Assessment

DAMAGE ASSESSMENT METHODOLOGY AND OUTPUTS

BALLATER ADDITIONAL FLOOD STUDY

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Damage Assessment
Methodology and Outputs
D01
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1 DAMAGE ASSESSMENT METHODOLOGY

1.1 Guidelines

The RPS methodology to damage assessments follows the guidance in “Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal" (Penning-Rowsell, *et al*., 2013). This book is a successor to and replacement of the highly respected manual and handbook “The Benefits of Flood and Coastal Defence: A Manual of Assessment Techniques" (Flood Hazard Research Centre, Middlesex University, UK, 2005). This document was often referred to as the ‘Multi-Coloured Manual’ (MCM).

The new manual draws on collaboration between the Flood Hazard Research Centre, the Environment Agency, Defra and other stakeholders. Its use, accompanied by the MCM-Online, has been recommended for benefit assessment as part of a flood and coastal erosion risk management appraisal.

The MCM is a result of research carried out by Middlesex University Flood Hazard Research Centre and provides data and techniques for assessing the benefits of flood risk management in the form of flood alleviation. The MCM has focused on the benefits that arise from protecting residential property, commercial property, and road disruption amongst other areas as experience has shown that these sectors constitute the vast majority of the potential benefits of capital investment.

Based on this research the MCM provides depth damage data for both residential and commercial properties. For certain depths of flood water, a monetary damage has been assigned to a property. This damage is a combination of the likely items within the building and the building structure itself. The damage to each property is dependent on the property type; as such the MCM has categorised both the residential and commercial properties. An example of depth damage data for residential properties is shown in Figure 1.1. Property damages are available for a number of different flood sources, including fluvial, coastal surge and wave overtopping. The appropriate datasets are sourced for the applicable flood mechanism/s which is assessed for the subject area.

Long Duration Major Flood Storm No Warning (2022-2023 Price base)

MCM Direct damage data (£). Depth in metres (m) - Initial Appraisal

Property-Type	mcm_code	property_type_age	-0.3	0	0.05	0.1	0.2	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3
Detached	111	pre-1919 Detached	5,215	10,571	40,679	58,808	78,706	93,703	104,076	108,354	115,111	126,048	135,687	148,843	156,683	167,064	179,255
	112	1919-1944 Detached	3,447	5,367	16,215	24,403	33,164	38,366	40,985	43,672	46,988	51,581	56,545	65,229	69,337	74,700	81,258
	113	1945-1964 Detached	3,263	5,685	18,757	28,250	37,364	42,329	44,964	47,578	50,749	55,084	59,444	68,746	73,239	78,980	86,346
	114	1965-1974 Detached	2,491	4,446	13,823	21,471	29,931	34,847	37,303	39,655	42,190	47,238	50,946	58,859	62,731	67,332	73,165
	115	1975-1985 Detached	2,435	4,394	15,185	23,597	33,802	40,480	44,423	47,278	49,384	54,631	58,902	67,252	70,074	73,345	77,817
	118	post-1985 Detached	2,372	4,365	15,524	24,541	34,863	42,842	47,160	50,308	52,318	58,176	63,139	72,126	74,603	77,635	81,684
Semi-detached	121	pre-1919 Semi-detached	3,954	4,970	13,056	19,233	25,825	30,301	32,643	34,203	36,145	40,584	43,942	50,223	52,935	56,814	61,757
	122	1919-1944 Semi-detached	4,153	5,783	14,914	21,751	28,062	31,856	33,719	35,472	37,849	41,816	44,753	52,341	55,487	59,524	64,264
	123	1945-1964 Semi-detached	4,153	5,783	15,054	21,717	28,106	31,948	33,615	35,445	37,534	41,860	44,800	51,746	54,893	58,930	63,669
	124	1965-1974 Semi-detached	2,073	3,387	10,882	16,566	22,679	27,106	29,517	31,840	34,515	39,166	42,656	49,623	53,674	59,448	65,435
	125	1975-1985 Semi-detached	2,124	3,171	10,824	17,462	24,373	28,933	31,398	33,255	34,690	38,576	40,907	46,300	48,294	50,652	53,368
	128	post-1985 Semi-detached	2,064	2,984	10,878	18,261	25,146	30,775	33,524	35,399	36,817	40,647	43,211	49,071	50,751	52,933	55,318
Terrace	131	pre-1919 Terrace	3,946	5,076	13,280	19,815	26,529	31,625	34,328	35,938	38,332	41,738	44,708	52,137	54,666	58,480	62,398
	132	1919-1944 Terrace	4,191	5,927	16,180	23,868	30,723	34,272	35,776	37,508	39,714	43,588	46,170	53,071	55,459	57,950	61,496
	133	1945-1964 Terrace	2,974	3,824	8,345	11,041	13,929	15,817	16,839	18,200	19,225	20,855	22,210	26,562	27,513	28,360	29,672
	134	1965-1974 Terrace	2,471	3,898	11,800	18,768	25,050	28,669	30,360	32,195	34,186	37,465	40,113	49,153	51,558	54,118	57,518
	135	1975-1985 Terrace	1,902	2,834	9,369	14,651	20,169	23,698	25,523	26,975	28,499	31,058	32,941	38,931	40,589	42,745	45,056
	138	post-1985 Terrace	1,833	2,587	9,559	15,569	21,135	25,995	27,941	29,419	30,667	33,351	35,414	41,301	42,617	44,602	46,571
Bungalow	141	pre-1919 Bungalow	4,125	5,551	16,033	23,681	31,695	37,348	40,458	42,302	44,002	47,724	50,270	57,366	59,706	62,367	65,644
	142	1919-1944 Bungalow	3,828	6,587	21,558	31,631	40,300	45,603	48,605	51,659	55,449	61,159	65,987	77,040	81,822	87,510	94,671
	143	1945-1964 Bungalow	3,956	6,023	19,097	28,978	37,354	41,864	44,318	47,083	50,026	56,129	61,935	72,811	78,073	84,310	93,631
	144	1965-1974 Bungalow	2,993	6,171	22,465	34,656	44,485	50,134	53,192	56,809	60,996	68,180	74,343	85,935	91,286	96,987	105,222
	145	1975-1985 Bungalow	2,780	4,875	18,476	29,445	39,770	46,295	50,679	54,058	56,979	63,593	68,441	78,451	81,536	84,344	88,468
	148	post-1985 Bungalow	2,656	4,388	19,012	31,664	42,094	51,582	56,338	59,836	62,176	69,116	74,434	84,282	86,627	89,068	92,425
Flat	151	pre-1919 Flat	3,771	4,829	10,720	16,252	21,137	24,194	25,197	26,356	27,564	28,937	30,527	35,245	36,609	38,123	40,423
	152	1919-1944 Flat	3,333	5,650	19,995	29,755	37,276	41,250	43,043	45,242	47,745	50,409	53,378	60,810	63,230	65,696	69,469
	153	1945-1964 Flat	2,818	3,854	10,110	15,325	20,248	23,181	24,341	25,450	26,647	28,345	30,093	34,941	36,418	37,954	40,080
	154	1965-1974 Flat	1,893	3,937	14,091	21,611	27,890	31,617	33,361	35,415	37,592	40,096	43,037	50,611	53,106	56,083	60,278
	155	1975-1985 Flat	1,766	2,832	10,445	17,309	24,148	28,543	30,883	32,482	33,791	35,894	37,800	44,219	45,479	46,953	48,915
	158	post-1985 Flat	1,687	2,506	10,523	18,226	25,094	31,019	33,479	35,086	36,068	38,273	40,347	46,615	47,477	48,754	50,319

Figure 1.1: Example of MCM's Depth Damage Data for Residential Properties

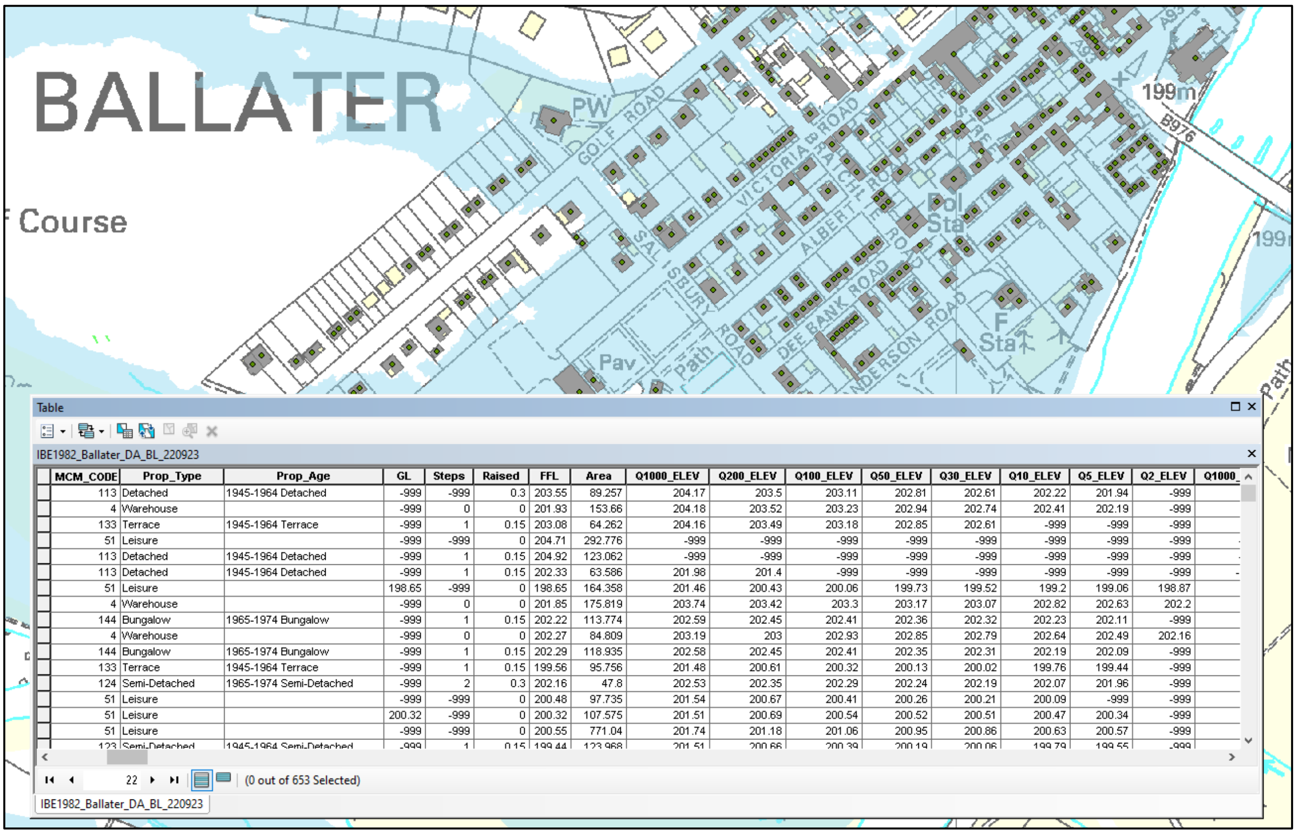
1.2 Recording Damage Assessment Data

Damage assessments are carried out in order to quantify the economic risk to the study area. This requires many details to be recorded such as background data, interim calculations and final damage results. RPS creates geo-referenced shapefiles with relevant data recorded in their attribute tables, an example of which is shown in Figure 1.2. Each flood mechanism to be assessed requires a building polygon shapefile and a damage assessment point file.

Building polygon shapefiles are created to contain background data for building polygons including building use and area. These commonly originate from datasets provided by the relevant local authority.

Damage assessment point files are created to contain all information needed to complete the damage assessment. Information such as building area, finished floor level (FFL) and water elevations extracted from the modelled flood events are combined into this shapefile to give flood depths referenced to finished floor level for each simulated event. For buildings with multiple water elevation entries, the maximum level of water above FFL is taken. These shapefiles are used to display economic risk of properties relating to a range of flood events.

The following sections detail how damage assessments are carried out and the data that is recorded during various processes.



MCM_CODE	Prop_Type	Prop_Age	GL	Steps	Raised	FFL	Area	Q1000_ELEV	Q200_ELEV	Q100_ELEV	Q50_ELEV	Q30_ELEV	Q10_ELEV	Q5_ELEV	Q2_ELEV
113	Detached	1945-1964 Detached	-999	-999	0.3	203.55	89.257	204.17	203.5	203.11	202.81	202.61	202.22	201.94	-999
4	Warehouse		-999	0	0	201.93	153.66	204.18	203.52	203.23	202.94	202.74	202.41	202.19	-999
133	Terrace	1945-1964 Terrace	-999	1	0.15	203.08	64.262	204.16	203.49	203.18	202.85	202.61	-999	-999	-999
51	Leisure		-999	-999	0	204.71	292.776	-999	-999	-999	-999	-999	-999	-999	-999
113	Detached	1945-1964 Detached	-999	1	0.15	204.92	123.062	-999	-999	-999	-999	-999	-999	-999	-999
113	Detached	1945-1964 Detached	-999	1	0.15	202.33	63.586	201.98	201.4	-999	-999	-999	-999	-999	-999
51	Leisure		198.65	-999	0	198.65	164.358	201.46	200.43	200.06	199.73	199.52	199.2	199.06	198.87
4	Warehouse		-999	0	0	201.85	175.819	203.74	203.42	203.3	203.17	203.07	202.82	202.63	202.2
144	Bungalow	1965-1974 Bungalow	-999	1	0.15	202.22	113.774	202.59	202.45	202.41	202.36	202.32	202.23	202.11	-999
4	Warehouse		-999	0	0	202.27	84.809	203.19	203	202.93	202.85	202.79	202.64	202.49	202.16
144	Bungalow	1965-1974 Bungalow	-999	1	0.15	202.29	118.935	202.58	202.45	202.41	202.35	202.31	202.19	202.09	-999
133	Terrace	1945-1964 Terrace	-999	1	0.15	199.56	95.756	201.48	200.61	200.32	200.13	200.02	199.76	199.44	-999
124	Semi-Detached	1965-1974 Semi-Detached	-999	2	0.3	202.16	47.8	202.53	202.35	202.29	202.24	202.19	202.07	201.96	-999
51	Leisure		-999	-999	0	200.48	97.735	201.54	200.67	200.41	200.26	200.21	200.09	-999	-999
51	Leisure		200.32	-999	0	200.32	107.575	201.51	200.69	200.54	200.52	200.51	200.47	200.34	-999
51	Leisure		-999	-999	0	200.55	771.04	201.74	201.18	201.06	200.95	200.86	200.63	200.57	-999
123	Semi-Detached	1945-1964 Semi-Detached	-999	1	0.15	199.44	123.968	201.51	200.66	200.39	200.19	200.06	199.79	199.55	-999

Figure 1.2: Example Damage Assessment Property Shapefile with Attributes Showing Damage Assessment Data

1.3 Categorisation of Properties

All properties within the largest modelled floodplain/s are surveyed and classified according to MCM guidelines. Based on the level of assessment, the following attributes may be recorded for residential properties; property type, age and social class. Social class data is provided in the MCM based on social classes AB, C1, C2 and DE based on England and Wales. As social class data is not collated under the same categories and methodology in Scotland as in England and Wales, these cannot be made comparable. As such, social class is not considered in economic damage assessments in Scotland.

The MCM assigns a code to each property type to aid the damage calculations. Table 1.1 and Table 1.2 detail the various residential and non-residential property types.

Table 1.1: Residential Properties MCM Codes

Property Type	MCM code	Property Type - Age
Detached	111	Pre-1919 Detached
	112	1919-1944 Detached
	113	1945-1964 Detached
	114	1965-1974 Detached
	115	1975-1985 Detached
	117	Utility Detached
	118	Post-1985 Detached
Semi-Detached	121	Pre-1919 Semi-Detached
	122	1919-1944 Semi-Detached
	123	1945-1964 Semi-Detached
	124	1965-1974 Semi-Detached
	125	1975-1985 Semi-Detached
	127	Utility Semi-Detached
	128	Post-1985 Semi-Detached
Terrace	131	Pre-1919 Terrace
	132	1919-1944 Terrace
	133	1945-1964 Terrace
	134	1965-1974 Terrace
	135	1975-1985 Terrace
	137	Utility Terrace
	138	Post-1985 Terrace
Bungalow	141	Pre-1919 Bungalow
	142	1919-1944 Bungalow
	143	1945-1964 Bungalow
	144	1965-1974 Bungalow
	145	1975-1985 Bungalow
	148	Post 1985 Bungalow
Flat	151	Pre-1919 Flat
	152	1919-1944 Flat
	153	1945-1964 Flat
	154	1965-1974 Flat

Property Type	MCM code	Property Type - Age
	155	1975-1985 Flat
	157	Utility Flat
	158	Post 1985 Flat

Table 1.2: Non-Residential Property MCM Codes

MCM CODE	PROPERTY TYPE
2	Retail
3	Offices
4	Warehouses
5	Leisure and Sport
51	Leisure
52	Sport
521	Playing Field
523	Sports Centre
526	Marina
525	Sports Stadium
6	Public Buildings
8	Industry
9	Miscellaneous
910	Car park
960	Sub-Station

Depth damage data is not provided for garages and sheds in the MCM. Properties classified as garages, sheds, or other buildings which will not incur damage are classified with the MCM code -999 and are screened out prior to the next stage in the assessment.

The following categorisation details are recorded for each building within the largest modelled flood extent:

Table 1.3: Categorisation of Properties Data

Data Type	Attribute Name	Data Details
Property Use	Use	"R" for residential and "C" for commercial
MCM Code	MCM_CODE	As per MCM guidelines
Property Type	Prop_Type	As per MCM guidelines
Floor Area	Area	Floor area of the property

1.4 Property Threshold Level

The damage assigned to a property relates to the depth of water above floor level. As such the threshold level of all properties is required as part of the damage assessment. As a general rule most properties are constructed with the floor level raised 300mm above the adjacent ground level. This would be particularly characteristic of fluvial or coastal floodplains which are generally low lying and flat in nature. Steep topography also has an influence on finished floor levels whereby some properties have split level front doors and back doors and some properties enter at ground level but have basements below.

Where a finished flood level (FFL) survey has been carried out, as was the case for the Ballater Flood Protection Study, FFLs are directly transposed into the damage assessment shapefile/s. These are considered the most accurate method of providing FFLs. RPS ensure that any FFL surveys which are carried out specify the surveyor to use a total station, to avoid errors induced by differential GPS stations being used close to buildings which reduced the accuracy due to disturbing clear lines of site to GPS satellites. In the occurrence of multiple entrances to a property being surveyed, a conservative threshold is chosen based on the lowest level surveyed for the FFL.

In absence of FFL surveys, for example where properties could not be accessed for survey, RPS calculate the average level from LiDAR across the building footprint to provide a ground level. A survey of steps into the property allows the height the FFL is raised to be estimated. Each step is counted as +150mm above LiDAR defined ground level. For example, if there are two steps the raised height above ground level would be 300mm. Table 1.4 shows the details recorded in the damage assessment shapefile. A number of QA checks are carried out to ensure damages are not over / underestimated.

Table 1.4: Property Threshold Data

Data type	Attribute name	Data details
Ground Level	GL	LiDAR data extracted at each property, measured in mOD Newlyn. Where an FFL survey is available, a null value of -999 is recorded.
How many steps into property	Steps	Number of steps into property entrance. Where details of property entry are unknown "-999" value recorded.
Is ground floor raised	Raised	Calculated from "Steps" column. Each step to be 0.15m, on basis of 0.3 standard entry to residential properties. Where "-999" value recorded the 0.3m standard entry is assumed for residential properties and 0m for non-residential properties.
Finished Floor Level	FFL	GL + Raised = FFL. For properties with basements FFL is calculated to be ground level minus 2.5m.

1.5 Flood Depth of Properties

To estimate the damage to a property, estimations of predicted flood depths are required for a wide range of flood events. The depths to which properties in the assessment are flooded are calculated for modelled events prescribed in the brief; for Scottish assessments the events prescribed are commonly 1 in 2, 1 in 5, 1 in 10, 1 in 30, 1 in 50, 1 in 100, 1 in 200 and 1 in 1000.

The depth of flooding is calculated by finding the difference between the flood water elevation and the estimated threshold level. The flood elevations are extracted from the hydraulic model outputs to find the maximum depth of water touching each building polygon for each event. This process is achieved by carrying out a statistical analysis in ArcGIS. Table 1.5 below shows details which are recorded within the attribute tables of the damage assessment shapefile:

Table 1.5: Flood Depth of Properties Data

Data type	Attribute name	Data details
Flood level for all flood events	Q1000_ELEV, Q200_ELEV, Q100_ELEV, Q50_ELEV, Q30_ELEV, Q10_ELEV, Q5_ELEV, Q2_ELEV.	The maximum flood level adjacent to the building (mOD).
Flood depth for all flood events	Q1000_Dp, Q200_Dp, Q100_Dp, Q50_Dp, Q30_Dp, Q10_Dp, Q5_Dp, Q2_Dp.	Difference between the flood level and FFL.

1.6 Flood Damage to Properties

Once the depths of flooding are known the damage can be calculated using the MCM depth damage data. This is known as direct damage in that the flooding directly damages assets; it does not account for indirect damages such as heating costs to dry out the house. For each property type, a typical damage based on historical data has been assigned to a depth of flooding. The latest version of the MCM data is sourced, where the damage per square metre of the floor area of a building is used. This assessment adopted the fluvial depth damage data.

The direct damage in each flood event for each building in pounds sterling prices per square metre is calculated by interpolating between the depth damage figures provided in the MCM guidance. This damage figure is then multiplied by the floor area of the property to give the total damage. This information is recorded in the attributes listed in Table 1.6.

Table 1.6: Flood Damage to Properties Data

Data type	Attribute name	Data details
Direct damage per meter square	Q1000_M2Dm, Q200_M2Dm, Q100_M2Dm, Q50_M2Dm, Q30_M2Dm, Q10_M2Dm, Q5_M2Dm, Q2_M2Dm.	Damage per meter square to each property according to the depth of flooding from each flood event as per MCM data.
Principal Direct Damage (PDD) - Damage to property over full floor area	Q1000_PDD, Q200_PDD, Q100_PDD, Q50_PDD, Q30_PDD, Q10_PDD, Q5_PDD, Q2_PDD.	Damage per meter square multiplied by floor area of building.

1.7 Indirect Costs

Indirect costs account for tangible costs incurred that are not included in the direct damages. The MCM provides damage data for a range of indirect costs, which are considered at different economic levels of analysis. The South Kinross Flood Protection Scheme considered the following indirect costs; emergency, utility and evacuation costs.

1.7.1 Evacuation Costs

Where a damage to a property has occurred due to flooding, evacuation from the property may be necessary to allow any damage to be repaired. Research into previous flood events found the evacuation costs comprised a significant proportion of the costs relating to flooding; therefore, a methodology was developed to allow this to be considered in economic assessments.

The MCM provides indicative costs, based on the depth of flooding inside the property and the property type. Based on the depth inside the property the MCM has attributed indicative durations, which were also considered in the evacuation costs provided.

The MCM provides data for three different damage levels: high, mid / indicative, and low. RPS adopted the evacuation costs provided from the mid / indicative category, as to avoid over or under estimation of damages and subsequent benefits derived from flood alleviation measures. The evacuation costs in the MCM are presented in Figure 1.3

MAXIMUM DEPTH INSIDE PROPERTY (CM)	EVACUATION COSTS BY PROPERTY TYPE (£)											
	DETACHED			SEMI-DETACHED			TERRACED			FLAT		
	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
0-1	755	1,116	1,808	676	959	1,573	651	929	1,538	590	867	1,474
1-10	1,450	2,138	3,466	1,296	1,833	3,009	1,249	1,774	2,940	1,129	1,653	2,816
10-20	2,784	4,060	6,602	2,474	3,446	5,684	2,379	3,329	5,544	2,138	3,084	5,295
20-30	2,987	4,356	7,082	2,654	3,697	6,097	2,552	3,571	5,947	2,294	3,308	5,680
30-60	4,020	5,842	9,507	3,565	4,943	8,163	3,426	4,771	7,959	3,074	4,412	7,595
60-100	4,814	6,983	11,371	4,266	5,899	9,750	4,098	5,692	9,504	3,673	5,259	9,064
100+	7,723	11,137	18,164	6,823	9,356	15,502	6,547	9,016	15,098	5,848	8,306	14,375

Figure 1.3: MCM Evacuation Cost Data by Property

Evacuation costs were allocated to residential properties based on the flood depth relative to the finished floor level. These figures were input into the MCM evacuation costs data and a cost per property per event was calculated.

Table 1.7: Evacuation Cost Data

Data type	Attribute name	Data details
Indirect Costs	Q1000_Evac, Q200_Evac, Q100_Evac, Q50_Evac, Q30_Evac, Q10_Evac, Q5_Evac, Q2_Evac.	Cost based on MCM evacuation cost data set as function of depth.

1.7.2 Emergency Costs

A cost will be associated with emergency services dealing with the flood events. Following the Environment Agency's Flood or Coastal Erosion Risk Management (FCERM) appraisal guidance, which the MCM guidance has been adapted to comply with, a value of 10.7% of the principal direct damages is assigned to the emergency services costs. This figure is based on data collected from previous flood events in the UK.

An economic damage will also be incurred in flood events relating to infrastructure utility assets. Examples of these may include electrical sub-stations and telecommunications assets. A utility damage of 20% of the principal direct damage is applied to account for these impacts, based on the analysis of damages from historical flooding in the UK.

The details in Table 1.8 are recorded within the economic risk shapefile attribute tables:

Table 1.8: Emergency and Utility Cost Data

Data type	Attribute name	Data details
Emergency costs	Q1000_Emerg, Q200_Emerg, Q100_Emerg, Q50_Emerg, Q30_Emerg, Q10_Emerg, Q5_Emerg, Q2_Emerg.	Equal to 10.7% of the Principal Direct Damages (PDD).
Utility costs	Q1000_Util, Q200_Util, Q100_Util, Q50_Util, Q30_Util, Q10_Util, Q5_Util, Q2_Util.	Equal to 20% of the PDD.

1.8 Event Data

The event damage is defined as the total of the direct damages in any one event, calculated to be the sum of the principal direct damage (PDD) to properties, evacuation, emergency, and utility damages. The event damage is required for later steps in the process, specifically in calculating annual average and present value damages. The event damage is recorded in the damage assessment shapefile as shown in Table 1.9.

Table 1.9: Event Damage Data

Data type	Attribute name	Data details
Event Damage	Q1000_EvDam, Q200_EvDam, Q100_EvDam, Q50_EvDam, Q30_EvDam, Q10_EvDam, Q5_EvDam, Q2_EvDam.	Summed direct damage of any one event. This is the total of the PDD, utility damage, evacuation, and emergency costs.

1.9 Annual Average Damage and Present Value Damage

To gain an appreciation of the economic risk the overall damage needs to be calculated. This is represented by assessing the likelihood of each of these flood events occurring in any given year and applying this as a percentage to the damage; this is known as the Annual Average Damage (AAD). The AAD can then be taken over the lifetime of the study that has been set at 100 years and discounted back to present day costs; this is known as the present value damage (PVD).

The AAD can best be described by considering the graph shown in Figure 1.4. The points shown represent the various design flood events where the event damage is calculated. Their position on the graph is dictated by the damage caused and the frequency of the flood event occurring in any given year. These points are joined together to create a damage curve. The area under the curve is therefore a function of the damage and the frequency and gives the AAD.

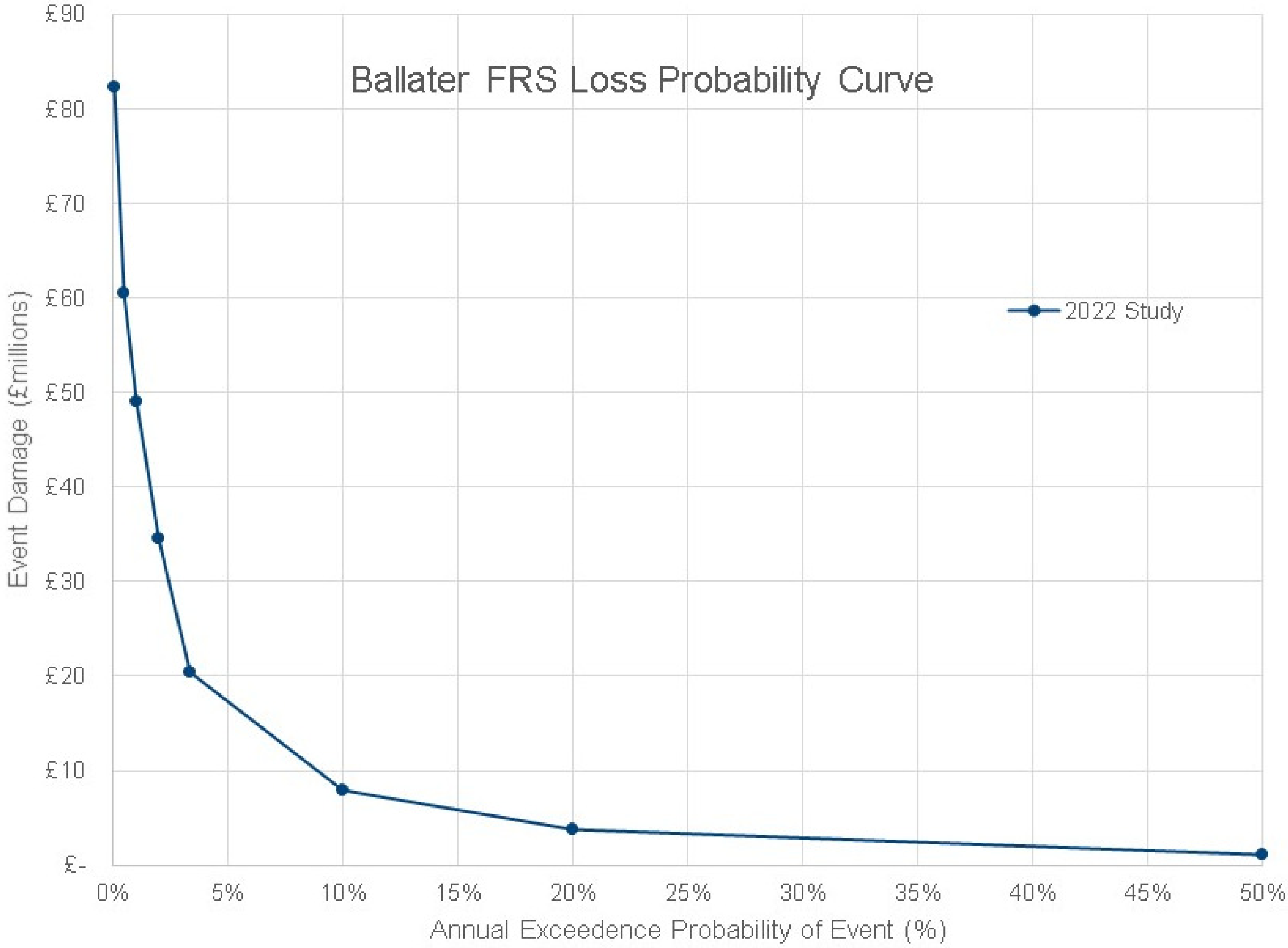


Figure 1.4: Loss Probability Curve for Ballater (2022 Study)

Once the AAD is calculated the present value damage can be determined. The present value damage calculation sums the AAD that is expected to occur for each of the 100 years considered in Scottish studies. For the damage value in each year to be comparable with each other they are discounted to represent the equivalent present damage value. Discounting damage values in the future is based on the principle that generally people prefer to receive goods or services now rather than later. This is known as time preference. The cost therefore of providing a flood management option will also be discounted to present day values. Discount rates are taken from the Treasury's 'Green Book' (HM Treasury, 2022), as shown in Table 1.10.

Table 1.10: The Green Book's Long Term Discount Rate

Period of Years	0 - 30	31 - 75	76 - 125
Discount Rate	3.5%	3.0%	2.5%

This results in factoring the AAD by 29.813. The AAD and PvD are calculated for the direct damages. Table 1.11 outlines the details that are recorded within the damage assessment shapefile attribute tables:

Table 1.11: AAD and PVD Data

Data type	Attribute name	Data details
Annual Average Damage for direct damages, intangible damages	AAD	The equation to calculate the AAD is as follows: (([Q2_EvDam]+[Q5_EvDam])/2*(0.5-0.2)+ ([Q5_EvDam]+[Q10_EvDam])/2*(0.2-0.1)+ ([Q10_EvDam]+[Q30_EvDam])/2*(0.1-0.03333)+ ([Q30_EvDam]+[Q50_EvDam])/2*(0.03333-0.02)+ ([Q50_EvDam]+[Q100_EvDam])/2*(0.02-0.01)+ ([Q100_EvDam]+[Q200_EvDam])/2*(0.01-0.005)+ ([Q200_EvDam]+[Q1000_EvDam])/2*(0.005-0.001))
Present value damage	PvD	The AAD factored by 29.813.

1.10 Capping Damages

It is recognised that for certain properties the overall damage associated with it can far exceed the market value of the property. This can be due to either the depth to which it floods or the frequency with which it floods or a combination of both factors. Where such a situation occurs, it is necessary to cap the damages at the market value.

When capping damages for residential properties, RPS sourced house price statistics tables from Registers of Scotland to find the regional average market value. For a non-residential property its capping value is calculated by its rateable value multiplied by a factor which reflects the added value of percentage rental yield from that property is used. The methods used to acquire robust values for capping damages are recommended in the FCERM Manual 2013 and the MCM 2022. Research is carried out to identify both the rateable value and the average rental yield for commercial properties in the region. For percentage rental yield, an average for Scotland of around 6% is identified using data produced by Savills, 2017, therefore using MCM guidance a multiplier of 16.7 would be appropriate.

The approach taken by RPS, in line with MCM guidance, is to cap the direct damages and to leave the intangible flood impacts uncapped before totalling up the overall damages. This process is outlined in Section 1.13.

The following details in Table 1.12 and Table 1.13 are incorporated within damage assessment shapefile attribute tables:

Table 1.12: Commercial Capping Damages Data

MCM_Code	Property Type	Capping Value /m^2
2	Shops	£148.45 x 16.7 = £2,479.12
3	Offices	£102.77 x 16.7 = £1,716.26
4	Warehouses	£38.21 x 16.7 = £638.11

MCM_Code	Property Type	Capping Value /m²
5	Leisure & Sport	£43.04 x 16.7 = £718.77
51	Leisure	
52	Sport	
521	Playing Field	
523	Sports Centre	
525	Sports Stadium	
526	Marina	
9	Miscellaneous	
910	Car park	
960	Substation	
6	Public Buildings	£61.93 x 16.7 = £1,034.23
8	Industry	£30.30 x 16.7 = £506.01

Table 1.13: Capping Damages Data

Data type	Attribute name	Data details
Capped direct damages (baseline scenario)	PvD_BL_Cap	Residential property damages over capping value are set equal to this value. Commercial property damages capping value = rateable value x % rental yield.
Capped direct damages (defended scenario)	PvD_Df_Cap	The direct damages in the defended scenario are also capped using the same capping data for the baseline.

1.11 Intangible Impacts of Flooding

Apart from the material damages to the building structure and the goods inside the property, it is recognised that there are monetary damages associated with stress, health effects and loss of memorabilia, which can be as important as direct material damage to householders. The MCM guidance assesses these impacts as intangible benefits that are associated with flood defence improvements. For analysis of intangible benefits Defra's risk reduction matrix is commonly used (Defra, 2004), as shown in Table 1.14. The calculated intangible benefits are summed with the benefits derived from direct damage avoided to provide the total benefit; this is discussed in more detail later. In line with the Defra methodology, the intangible benefit is not capped.

Table 1.14: Intangible benefits associated with flood risk management improvements (2020/21 prices) (FRHC, 2020)

			Standard of Protection After – AFP (RP in years)							
Standard of protection before – AFP (RP in years)			0.007	0.008	0.01	0.013	0.02	0.033	0.05	0.1
			-150	-125	-100	-75	-50	-30	-20	-10
	1	-1	£321	£316	£294	£225	£108	£37	£17	£7
	0.1	-10	£315	£309	£287	£218	£100	£31	£12	£0
	0.05	-20	£302	£297	£277	£207	£88	£20	£0	-
	0.03	-30	£284	£278	£257	£188	£70	£0	-	-
	0.02	-50	£213	£209	£187	£118	£0	-	-	-
	0.01	-75	£96	£92	£70	£0	-	-	-	-
	0.01	-100	£27	£22	£0	-	-	-	-	-
	0.01	-125	£6	£0	-	-	-	-	-	-

AFP = Annual Flood Probability

RP = Return Period

Annual Benefits = Damages (before) - Damages (after)

No intangible damages are assigned to commercial properties as these costs do not apply at the same level.

1.12 Damage Assessment Review

A review of the damage assessment files is carried out to quality check the data being used. Some basic checks carried out by the damage assessors include reviewing the properties that contribute over 1% of the capped PvD, checking the area and thresholds of large commercial buildings and spot-checking depth damage data is correctly applied. Checks are also carried out by the modeller, to ensure the model is calibrated to historic events and to inform the optioneering process.

1.13 Calculation of Total Benefit

The total economic benefit for study areas is calculated as the sum of the direct and intangible benefits. Damages are assessed up the 0.1% AEP, protecting all properties in the assessment within the 0.5% AEP extent. The intangible benefit is uncapped as discussed previously. The relevant fields in the economic risk shapefile are provided in Table 1.15.

Table 1.15: Benefits and Related Fields in the Economic Damage Assessment

Data Type	Attribute Name	Data Details
Present value damage (PvD) in baseline scenario	PvD_BL	Damages assessed up to 0.1% AEP.
PvD in baseline scenario (capped)	PvD_BL_Cap	Any present value damage greater than CapVal is capped at the CapVal. Any damage less than the CapVal is let equal to the original present value damage.
PvD in defended scenario	PvD_Df	Residual damages with properties protected up to 0.5% AEP (only 0.1% AEP damages remain).
PvD in defended scenario (capped)	PvD_Df_Cap	Capping applied similar to PvD_BL_Cap.
Present value benefit (PvB) derived from direct damage avoided (capped)	PvB_Cap	Calculated by the following: PvD_BL_Cap - PvD_Df_Cap
PvB relating to intangible impacts avoided	PvB_Int	Derived from Defra Intangible Matrix. Intangible benefits are not capped.
Final PvB for the study area	PvB_Final	Calculated by the following: PvB_Cap + PvB_Int

2 BALLATER FPS DAMAGE ASSESSMENT OUTPUTS

The outputs of the update Ballater FPS updated 2022 study damage assessment have been presented below. A comparison was drawn against the previous 2018 results, to further understand the impacts of the various changes in the hydraulic regime as set out in the Ballater Additional Flood Study Feasibility Report.

The present value damages were found to have increased significantly in the 2022 study, leading to the potential benefits of a 0.5% AEP Standard of Protection scheme rising from £33.1m to £53.3m. The damage assessment summary for both the 2018 and 2022 studies are presented in Table 2.1.

Table 2.1: Damage Assessment Summary

Study	Properties at risk in 0.5% AEP event		Baseline	Defended	Capped Benefit (0.5% AEP SoP)
	Residential	Commercial	PvD	PvD	PV Benefit
2018	474	108	£ 49,261,432	£ 4,574,151	£ 33,154,655
2022	475	108	£ 107,386,696	£ 4,903,609	£ 53,366,103

It is evident from a comparison of the 2018 and 2022 assessment outputs that the flood risk increases notably in the higher frequency / lower magnitude events in the 2022 study model. In the previous 2018 model, properties were identified to be at risk from the 20% AEP event, however 18 properties were identified to be at risk in the 2022 study scenario from the 50% AEP event. For various return period it is the case that additional properties are identified at risk of flooding in the 2022 study compared to the 2018 baseline. In Table 2.2 the number of properties accruing flood damages in each AEP event have been collated.

Table 2.2: Properties at Risk in 2018 Study and 2022 Study

Flood Frequency		Properties at Risk		Difference
Annual Exceedance Probability	Return Period	2018 Study	2022 Study	
50%	Q2	0	18	+18
20%	Q5	11	90	+79
10%	Q10	60	135	+75
3.33%	Q30	180	383	+203
2%	Q50	416	490	+74
1%	Q100	530	540	+10
0.5%	Q200	582	583	+1
0.1%	Q1000	611	614	+3

The event damages calculated for the 2022 study exceed the damages in the 2018 study for all AEP events, as shown by the loss probability curve presented in Figure 2.1. These observations explain the significant increases in damages and potential benefits for the 2022 study summarised in Table 2.1.

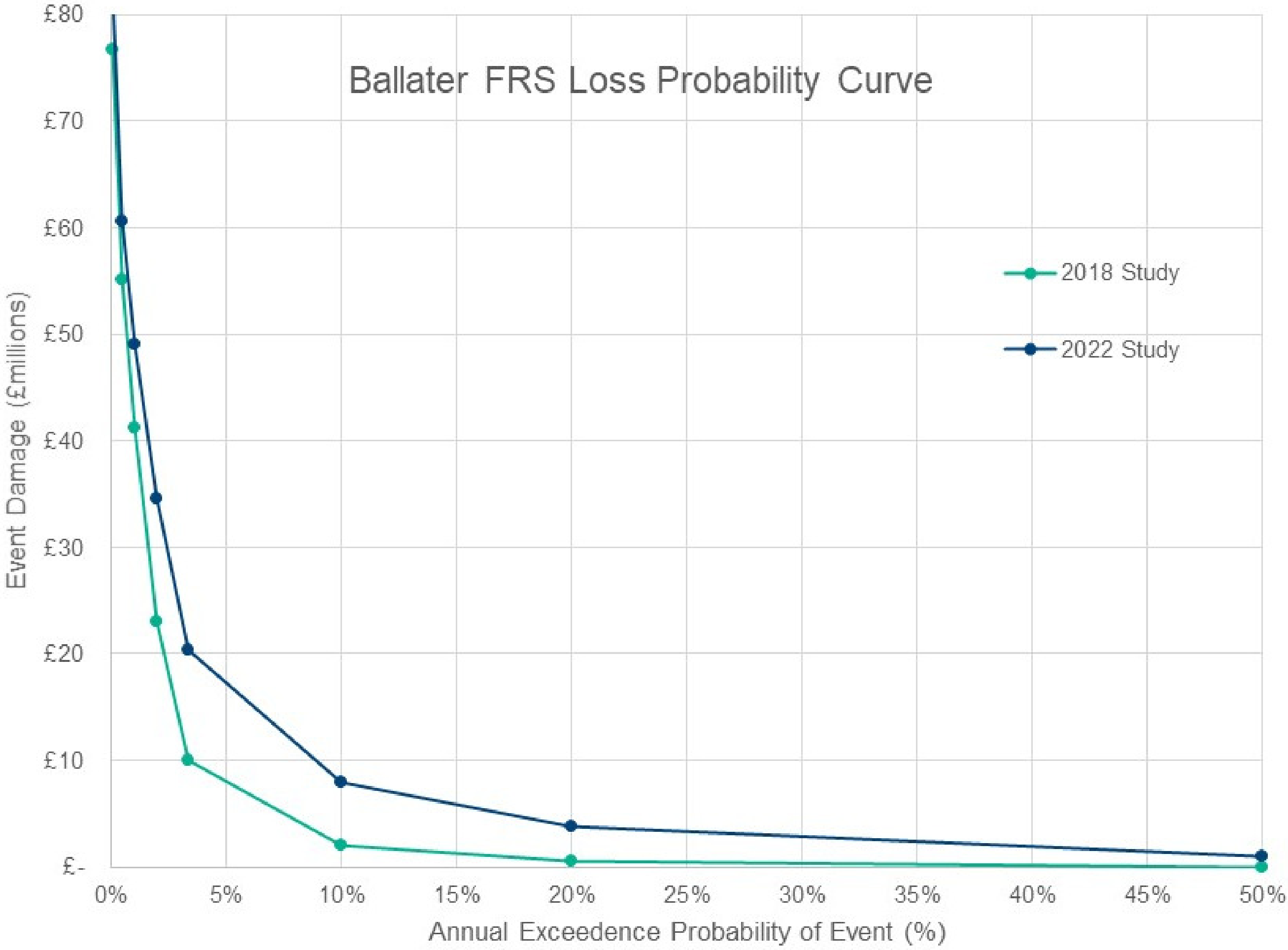


Figure 2.1: Ballater FRS Loss Probability Curves for the 2018 and 2022 Studies

2.1 Alternative Standards of Protection

An assessment was undertaken to provide the potential benefits afforded by alternative standards of protection for the 2022 study modelling outputs. The potential Present Value Benefits and the number of properties this would involve providing protection for are summarised in Table 2.3.

Table 2.3: Present Value Benefits Associated with Various Standards of Protection for Ballater 2022 Study

Standard of Protection		Present Value Benefit (2022 Study)	Properties Protected
Annual Exceedance Probability	Return Period		
50%	Q2	£ 3,943,821	18
20%	Q5	£ 4,448,395	90
10%	Q10	£ 9,602,579	135
3.33%	Q30	£ 25,984,269	383
2%	Q50	£ 34,957,190	490
1%	Q100	£ 45,248,821	540
0.5%	Q200	£ 53,366,103	583
0.1%	Q1000	£ 58,269,711	614