Economics Baseline

Sidmouth and East Beach Management Plan

Prepared for

East Devon District Council

January 2016

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Document history

Economics Baseline Report

Sidmouth & East Beach Management Plan

East Devon District Council (EDDC)

This document has been issued and amended as follows:

Version	Date	Description	Created by	Verified by	Approved by
1.0	31/03/2015	Initial Draft for EDDC comment	Alan Frampton	Jonathan Rogers	Jonathan Rogers
1.1	16/07/2015	Draft for comment	Alan Frampton	Jonathan Rogers	Jonathan Rogers
1.2	24/08/2015	Revised Draft for comment	Alan Frampton	Jonathan Rogers	Jonathan Rogers
1.3	26/01/2016	Final	Alan Frampton	Jonathan Rogers	Jonathan Rogers

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Contents

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1 Introduction

This document provides details of the economic basis (i.e. the economic benefits) for both ongoing and future beach management and coastal flood and risk management activities along the Sidmouth frontage, within the extent of the Sidmouth and East Beach Management Plan (BMP) extent defined in Figure 1-1.

This economic basis is developed from new assessment of flood and erosion risk (Section 3), but set in context by comparing the findings of the new analysis with previous economic assessments used to provide the case for past coastal protection and flood defence schemes along the BMP frontage (Section 2).

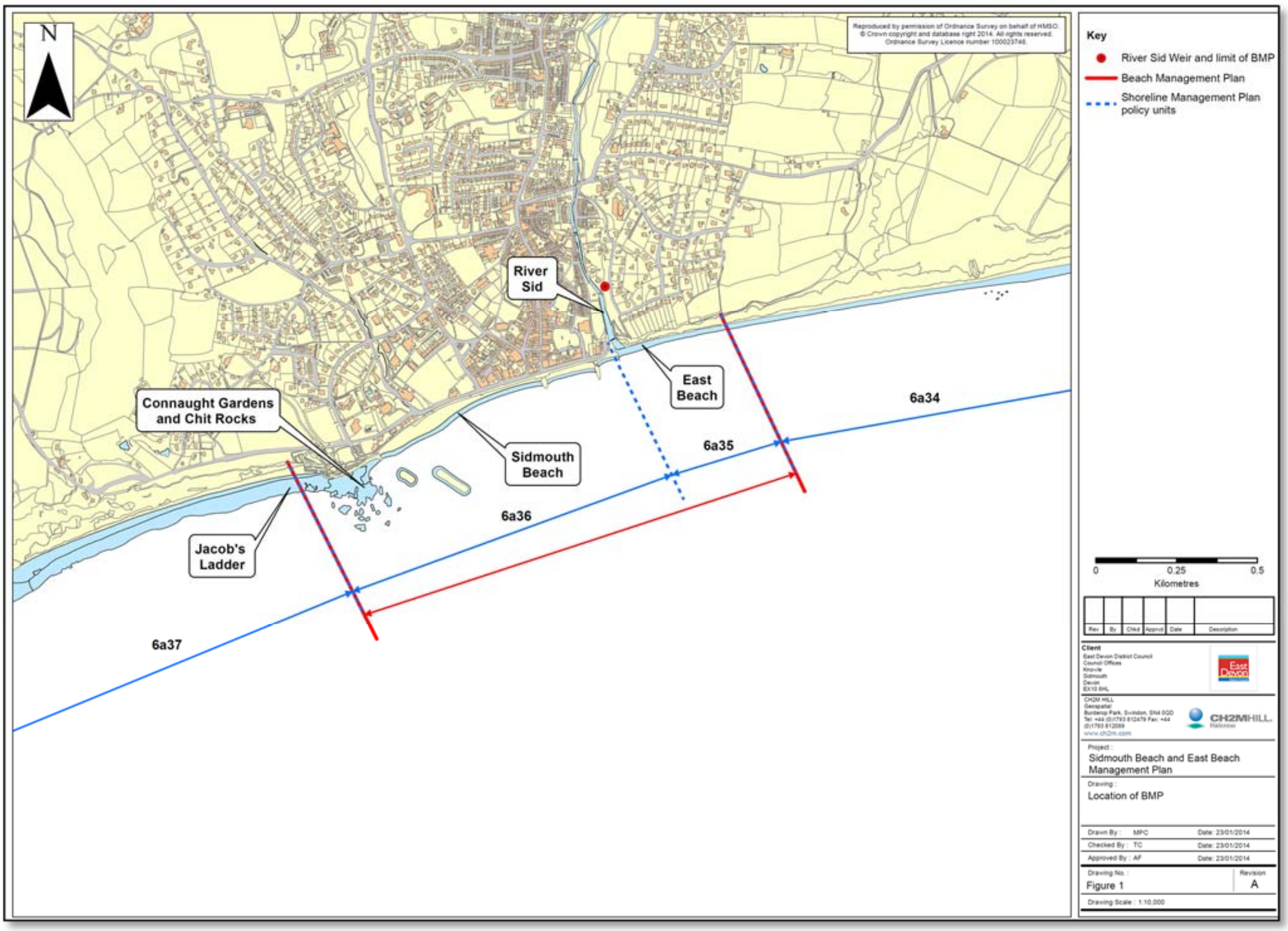

Figure 1-1 Sidmouth & East Beach Management Plan extent

2 Economic Appraisals from Previous Studies

There has been a number of previous studies that have produced economic appraisal to demonstrate the value of continued investment in coastal flood and erosion risk management measures along the Sidmouth BMP frontage. This section provides a summary of the economic case put forward by those previous studies between 1990 and 2011. The purpose of this is to provide understanding of the economic case upon which the previous coast protection works at Sidmouth were justified.

2.1 Coast Protection at Sidmouth Benefit Cost Analysis (May, 1990)

The *Coast Protection at Sidmouth Benefit Cost Analysis* (Posford Duvivier, 1990) provides the economic justification for the Phase 1 coast protection works at Sidmouth. This stated the economic benefits as being £500k (promenade and roadway) plus £17,500k (Hotel and other seafront property). These benefits stemmed only from expected coastal erosion losses should the Sidmouth seawall fail and thus allow erosion to impact these assets no coastal flood losses were considered. A 6% discount factor was applied (as per national guidance at that time) to the combined £18,000k benefits, giving rise to Present Value (PV) benefits of between £11,743k (if assets are lost in years 5-7) and £14,307k (if assets are lost in years 2-4); these reflecting the expectation that the seawall was already damaged and in imminent danger of failing completely.

The costs of the Phase 1 coast protection works to repair the seawall are stated at £350k. Therefore, given the range of benefits, the range of benefit:cost ratios for the Phase 1 works were assessed to be between 1:34 (if assets are lost in years 2-4) and 1:41 (if assets are lost in years 5-7).

2.2 Coast Protection at Sidmouth: Report on Phase 2 Works and Benefit Cost Analysis (January, 1992)

The *Coast Protection at Sidmouth: Report and Phase 2 Works and Benefit Cost Analysis* (Posford Duvivier, 1992a) contains, in Appendix A of that report, calculation of the amenity benefits of undertaking coast protection works along the Sidmouth frontage. This assessment of amenity benefits was based upon the Flood Hazard Research Centre (FHRC) Yellow Manual (FHRC, 1992), which was best-practice guidance at the time the analysis was done.

The basis for the assessment was estimates of visitor numbers to Sidmouth as no site specific survey was undertaken at the time. These were based on the following assumptions:

- 100% of day-visits based on visitor numbers derived from car parking data (100,837 visitors over a 150 day summer season).
- 10% of staying visitors based on hotel booking data (50,500 staying visitors assumed from 505,000 hotel bookings over a 150 day summer season).
- In lieu of actual data, local visitor numbers assumed to be 75 visitors/day over 150 day summer season (therefore 11,250 visitors over a season).

These visitor numbers were then multiplied by values from the FHRC Yellow Manual based on stated value of the damage that would be caused if the coastal defences were allowed to fail and the beach lost, as follows:

- £2.37 per adult day visitor
- £5.55 per adult staying visitor
- £1.58 per adult local visitor.

In addition, the FHRC Yellow Manual values for perceived value gained (i.e. benefit) of protecting the coast with a new scheme were also applied, as follows:

- £1.80 per adult day visitor
- £1.31 per adult staying visitor
- £1.04 per adult local visitor.

The amenity benefits from damages avoided (i.e. by not allowing the coastal defence to fail and beach to be lost) combined with the benefit gained from a new scheme were calculated over a 50 year appraisal period (as was required by national guidance at that time; note, currently a 100 year appraisal period is used), and are summarized in Table 2-1.

Table 2-1 Summary of amenity benefits for the Phase 2 coast protection scheme (from Posford Duvivier, 1992a)

Visitor Type	No. Visitors per 150 day summer season	Loss per 150 day summer season (£k)	Total loss over 50 years (£k)	Gain per 150 day summer season (£k)	Total gain over 50 years (£k)	TOTAL Benefits over 50 Years (£k)
Day	100,837	238.98	11,949.00	66.16	3,308.00	15,257.00
Staying	50,500	280.23	14,011.50	181.51	9,075.50	23,087.00
Local	11,250	17.78	889	11.7	585	1,474.00
TOTALS	**162,587**	**536.99**	**26,849.50**	**259.37**	**12,968.50**	**39,818.00**

The total benefits from amenity over 50 years of providing new coast protection measures at Sidmouth were therefore assessed to be £39,818k. Applying a 6% discount factor to these gave a total PV Benefit of £12,552.71k. This is split between PV losses (£8,464.68k) and PV gains (£4,088.03k).

2.3 Coast Protection at Sidmouth Phase 2: Engineers Report (October, 1992)

The *Coast Protection at Sidmouth Phase 2: Engineers Report* (Posford Duvivier, 1992b) provided the economic case for implementing the present coast protection scheme at Sidmouth in the form of rock groynes, beach recharge and two detached breakwaters. In doing so it presented the total Present Value (PV) benefits from properties at risk of erosion only (i.e. the property damages incurred under a 'Do Nothing' scenario) should the seawall that existed at the time collapse in 10, 15 or 20 years' time. No flood damages were calculated.

The outputs of the assessment are presented in Table 2-2 alongside estimated scheme costs (assuming a 50 year scheme life) and benefit:cost ratios.

Table 2-2 Summary of economic case in 1992 (from Posford Duvivier, 1992)

Assumed Year of Seawall Collapse	Total Present Value (PV) Property Benefit (£k)	Total Scheme Cost (£k)	Benefit:Cost Ratio
10	9,020.90	4,400	2.05
		5,300	1.70
15	6,740.90	4,400	1.53
		5,300	1.27
20	5,037.10	4,400	1.14
		5,300	0.95

In addition to assessing property damages, this report also included assessment of the impacts of providing increased amenity benefit to beach users through a scheme that included beach recharge. This beach user benefit was based upon a beach user survey carried out at Sidmouth[1] and provided an estimated beach amenity PV benefit of £4,088k in January 1992 (refer to Section 2.2). The impact of including this amenity beach user benefit in the economic case is demonstrated in Table 2-3.

Table 2-3 Impact of including beach user benefit on the economic case in 1992 (from Posford Duvivier, 1992)

Assumed Year of Seawall Collapse	Total Present Value (PV) Property Benefit (£k)	Beach User (Amenity) Benefit (£k)	Total Benefits (£k)	Total Scheme Cost (£k)	Benefit:Cost Ratio (excluding amenity gain)	Benefit:Cost Ratio (with amenity gain)
10	9,020.90	4,088	13,108.90	4,400	2.05	2.98
				5,300	1.70	2.47
15	6,740.90	4,088	10,828.90	4,400	1.53	2.46
				5,300	1.27	2.04
20	5,037.10	4,088	9,125.10	4,400	1.14	2.07
				5,300	0.95	1.72

It should be noted that the total outturn cost of the Phase 2 scheme (excluding ongoing beach management costs) was £7,100k (Posford Duvivier, 1998). This is £1,800k greater than estimated in 1992 as shown in Tables 2-2 and 2-3. Applying this outturn cost of the scheme to the benefits stated in those above tables would indicate the scheme had an outturn benefit:cost ratio of between 1.27 and 0.71 (excluding amenity benefits), and between 1.85 and 1.29 (including amenity benefits).

2.4 Sidmouth – Emergency Works: Engineers Report (November, 1993)

The *Sidmouth – Emergency Works: Engineers Report* (Posford Duvivier, 1993) provides economic justification for construction of emergency 400m length of rock revetment to reduce the risk of seawall collapse due to low beach levels. The cost of these works is stated as being £550k. These are assessed against the benefits already calculated for the Phase 2 Coast Protection Scheme (refer to Section 2.3), to give benefit:cost ratios of between 1:25 and 1:28.

2.5 Coast Protection Connaught Gardens: Revised Engineers Report (August, 1994)

The *Coast Protection Connaught Gardens: Revised Engineers Report* (Posford Duvivier, 1994) provided the economic case for the construction of the rock revetment around Chit Rocks to support and protect the existing seawall that already ran around the base of the cliffs in this area, such that the land above the cliffs (Connaught Gardens) would continue to be protected for the next 60 years (the scheme design life).

The scheme benefits were based upon cliff erosion that would be expected to occur should the existing seawall collapse in 10, 15 or 20 years' time. Such erosion could impact up to 10 properties (though the term 'properties' in this case includes the value of the promenade, Jacobs Ladder stairways, public shelters, kiosks, walls, pergolas and gates) with a market (capital) value at the time of £583k.

The amenity benefit of continuing to protect Connaught Gardens atop the cliff for 60 years was also calculated for each seawall failure scenario, based on an estimate of 25,000 visitors per annum.

[1] The date of the beach user survey at Sidmouth is unknown. Details are reported to be included in Appendix D of the Engineers Report (Posford Duvivier, 1992), but this appendix is not included in the data provided for this project from East Devon District Council.

Table 2-4 summarises the benefits presented in this report of August 1994, along with the estimated costs of the preferred rock revetment scheme and associated benefit:cost ratios.

Table 2-4 Summary of the economic case for rock revetment at Chit Rocks (from Posford Duvivier, 1994)

Assumed Year of Seawall Collapse	Total Property Benefit (£k)	Amenity Benefit (£k)	Total Benefits (£k)	Total Scheme Cost (£k)	Benefit:Cost Ratio (excluding amenity)	Benefit:Cost Ratio (with amenity)
10	268	790	1,058	250	1.07	4.20
15	200	580	780	250	0.80	3.10
20	150	420	570	250	0.60	2.30

2.6 Sidmouth Phase 2 Coast Protection Scheme: Beach Management Plan (October, 1996)

The *Sidmouth Phase 2 Coast Protection Scheme: Beach Management Plan* (Posford Duvivier, 1996) restates the scheme benefits from the Engineers Report (refer to Section 2.3), which in turn draws upon the assessment of amenity benefits (refer to Section 2.2). It also states that since sufficient benefits to justify the coast protection scheme were provided by the combination of potential erosion losses to seafront properties and amenity benefits, no further analysis of damages to properties landwards of Sidmouth esplanade was carried out (i.e. no flood damages were calculated).

This 1996 BMP also provides economic justification for the construction of an additional rock groyne opposite Bedford Road – the Bedford Groyne. The cost of this additional rock groyne is stated as being £692k. This cost was added to the total PV cost of the Phase 2 scheme (refer to Section 2.3), giving an overall scheme cost of £7,800k for the Sidmouth Coast Protection Scheme Phase 2.

2.7 Sidmouth Phase 2 Coast Protection Scheme: Revised Beach Management Plan (July, 1998)

The *Sidmouth Phase 2 Coast Protection Scheme Revised Beach Management Plan* (Posford Duvivier, 1998) provides the economic case for a third phase of the Sidmouth Coast Protection Scheme, to construct an additional rock groyne along the frontage adjacent to the Bedford Hotel (the 'Bedford Groyne') and undertaking annual beach management works over a 50 year period.

The economic case was based upon the 1992 economic case (refer to Section 2.1), with the benefit values being inflated by the Retail Price Index inflation between May 1992 and May 1997 (a multiplier of 1.37). The economic case was also updated to reflect greater amenity benefit from both avoidance of loss of beach and amenity gain through introducing beach recharge; this gave a revised and inflated amenity benefit of £17,847.50k in 1998.

In addition, a revised retrospective calculation was undertaken based on the assumption that the seawall could, in 1992 calculations, have potentially failed within 5 years; resulting in a calculated PV benefit of £14,545.50k from property damages.

These revised property and amenity benefits gave total benefits in 1998 of £32,393k. When compared to combined Phase 2 outturn costs of £7,100k and estimated costs for rock groyne construction and ongoing beach management activity over a 50 year scheme life of £730k – giving a total 50 years scheme cost in 1998 of £7,843k – the benefit:cost ratio for the third phase of coast protection works at Sidmouth was calculated to be 1.86 (excluding amenity benefit) and 4.13 (including amenity benefit). As with preceding economic assessments (refer to Sections above) the benefits were based only on coastal erosion losses and no consideration was given to coastal flood damages.

2.8 Pennington Point Coastal Study (August, 2001)

The *Sidmouth – Pennington Point Coastal Study* (Posford Duvivier, 2001) included an economic appraisal of 4 options for the introduction of coast protection measures to the east of the River Sid (East Beach) to reduce the risk of coastal erosion to cliff top properties above Pennington Point along Cliff Road. The economic case was also based upon the need to protect the western river wall of the River Sid against the risk of it becoming exposed to coastal wave action as the adjacent Pennington Point eroded further back in the future.

The 4 scheme options appraised were:

- Scheme Option 1: River Sid Wall Upgrading
- Scheme Option 2: Rock Groyne constructed at Pennington Point
- Scheme Option 3: Rock Revetment constructed at Pennington Point
- Scheme Option 4: Rock Revetment constructed at Pennington Point and extended eastwards to protect Cliff Road.

The economic benefits identified in this study included:

- Property losses along Cliff Road due to erosion give Present Value (PV) benefits under a 'Do Nothing' scenario of between £128k (assuming an erosion rate of 1m/year) and £640k (assuming an erosion rate of 2m/year). These values are based upon properties with a 2001 capital value of £3,291k.
- The western river wall of the River Sid protects a South West Water pumping station located (buried) immediately behind the wall and associated ancillary assets (i.e. outfall) with an estimated value of £6,000k.
- Other tangible benefits of a scheme in this area were identified as including £30k costs avoided that would otherwise be incurred to implement a permanent diversion along Beatlands Road to the Ford Footbridge once the Alma Bridge was lost to erosion.
- Intangible benefits from amenity value of the South West Coast Path and Alma Bridge valued at £250k per annum (£3,940k PV benefits over 50 years).[2]

Table 2-5 summarises the economic case for each of the 4 scheme options described above.

Table 2-5 Summary of the economic case for 4 scheme options for the River Sid and Pennington Point (from Posford Duvivier, 2001)

Scheme Option	PV Cost (£k)	River Wall Benefits (tangible) (£k)	Cliff Road Benefits (tangible) (£k)	Alma Bridge Benefits (intangible) (£k)	Total Benefits (tangible) (£k)	Total Benefits (tangible + intangible) (£k)	Benefit: Cost Ratio (tangible only)	Benefit: Cost Ratio (tangible + intangible)
1	190	3,170	0	0	3,170	3,170	16.7	16.7
2	346	3,170	157	290	3,327	3,617	9.6	10.5
3	360	3,170	157	290	3,327	3,617	9.2	10.1
4	1,016	3,170	640	290	3,810	4,100	3.8	4.0

The conclusion of this study was that only Scheme Option 1 was likely to attract Defra grant-in aid funding to implement. This economic assessment was further developed as part of the 2003 Project Appraisal Report (refer to Section 2.9).

[2] Since this study, it is no longer possible to include 'benefit' of protecting the South West Coast Path in economic appraisal. The policy of the South West Coast Path is to work with nature and move the path inland where it is lost to erosion. This is reflected in the SMP2 policy decisions referred to in Section 2.5.

2.9 Coast Protection – Pennington Point: Project Appraisal Report (February, 2003)

The *Coast Protection – Pennington Point: Project Appraisal Report* (Posford Haskoning, 2003) further developed the economic case of the preferred option identified in the 2001 coastal study (refer to Section 2.8).

The PV costs of the preferred option were further developed for construction of a 210m long rock revetment along East Beach, set 5-15m away from the base of the cliff, and totaled £810k. These costs also included repairs to the river wall in years 10 (2013) and 25 (year 2028).

These PV costs were compared to the benefits calculated in the 2001 coastal study (refer to Section 2.8), giving a range of benefit:cost ratios of between 1:4.4 and 1:5.7; depending on whether or not amenity benefits are included, and if a discount factor of 6% or 3.5% is applied.

These benefit:cost ratios were in turn used to calculate a priority score that had been introduced by that time for allocating Flood Defence Grant in Aid to coastal defence schemes in England. For this proposed Pennington Point scheme, the priority scores ranged between 7.5 and 9.5.

2.10 South Devon and Dorset Shoreline Management Plan Review (SMP2) (June, 2011)

The *South Devon and Dorset SMP2* (Halcrow, 2011) is a high level shoreline management policy document and covers a large length of coastline. As such the economic analysis contained within it (in Appendix H) is high level and determines if the shoreline management policy is:

- Clearly economically viable;
- Clearly not economically viable; or
- Potentially economically viable and in need of further study.

The following datasets were used for the economic review within the SDAD SMP2:

- National Property Dataset (second edition, 2005) – for property locations and property prices;
- RICS Rural Land Market Survey (H2 2008) – for agricultural land values;
- SMP Guidance and Environment Agency Unit Cost Manual – for defence costs;
- SDAD SMP2 Appendix C (Baseline Processes Understanding) – for details of erosion rates; and,
- Environment Agency Flood Zone 2 – for flood mapping extents.

The SMP2 policy for the Sidmouth BMP extent is in two parts, or Policy Units (PUs); namely PU 6a35 and PU 6a36 (refer to Figure 1-1). The policy for the section east of the River Sid (i.e. East Beach) is stated in PU 6a35 as being for Managed Realignment over the next 100 years. No economic benefits were identified for PU 6a35 in the SMP2 which, having evaluated all erosion rate data, concluded a lower rate of erosion for the cliffs in this area compared to the estimates made in the Pennington Point Study (refer to Section 2.8). The economic case for the Managed Realignment policy in 6a35 is based upon the need to manage the future recession of the cliffs along this section of coast such that the risk of flooding to the rest of Sidmouth by outflanking of the defences from the east is managed in the long term (i.e. to manage the defences along the western side of the River Sid much as argued in the economic case presented in the Pennington Point Study discussed in Section 2.8).

The economic case presented in the SMP2 for protecting the Sidmouth frontage that is subject of this BMP, was therefore based upon the economic benefits of protecting property assets only along the main Sidmouth frontage in PU 6a36. The assessment made in the SMP2 identified a total of 244 residential and 100 commercial properties as being at risk of flooding over a 100 year period, with a capital value of £50,340k and a Present Value (PV) benefit of £49,110k.

In total, the SMP2 estimated costs over 100 years (as per with current guidance) for managing coastal flood and erosion risk along the combined frontages of PU 6a35 and PU 6a36 as being £4,810k. Using this estimated cost with the PV benefit stated above, the benefit:cost ratio for continued intervention at Sidmouth was calculated to be 10.21.

3 Economic Appraisal for this BMP

3.1 Introduction

As the defence assessment carried out as part of developing this Sidmouth & East Beach Management Plan (CH2M HILL, 2015) indicates that the seawall along the Sidmouth town frontage is in good condition and unlikely to fail any time soon, provided the seawall is maintained appropriately, the main benefit of the seawall and associated coastal defences along the Sidmouth frontage is to reduce wave overtopping and so the risk of coastal flooding. As such, for this beach management plan it is considered more appropriate for the Sidmouth town frontage to assess the flood risk to property rather than the risk to properties from erosion as a result of failure of the seawall. This is counter to the basis for the Sidmouth Coast Protection Scheme constructed in the 1990’s which was justified only on coastal erosion losses with no consideration of coastal flood damages (refer to Section 2). Coastal erosion risk to the area above East Beach (i.e. Pennington Point/East Cliff) is, however, appraised for this beach management plan.

The following sections describe the approach taken to assessing potential flood and erosion risk damages along the BMP extent.

3.2 Flood Risk Damages

As the scale of coastal flood damages has not been investigated in any substantial way before, to inform the development of the BMP a preliminary flood risk modelling exercise was carried out. The purpose of this preliminary modelling was to provide an initial assessment of the scale of flood damages that exist along the BMP frontage, thus providing coastal flood risk economic benefits to inform benefit:cost assessment of future management options as part of later stages of the BMP development.

Flood risk damages along the Sidmouth town frontage have been determined using a 2D TUFLOW flood propagation model, driven by wave overtopping rates derived for this BMP along the seafront (CH2M HILL, 2015) and extreme water levels ranging between 1:1 year and 1:200 year return periods along the River Sid, for both the present day (2014) and allowing for 50 and 100 years of sea level rise. The flood modelling was conducted for two wave overtopping cases:

- design beach profile; and
- lowest beach profile.

Appendix A provides full details of the modelling approach and presents the flood extents derived.

The flood extents derived have been used to calculate Annual Average Damages (AAD) and total Present Value damages (PVd) over 100 years; PVd values taking into account future discounting. These damage calculations were carried out using residential and commercial property data from the National Receptor Database (NRD) and CH2M HILL’s *damage calculator* software, which utilizes depth-damage curves derived from Multi-Coloured Manual, MCM (FHRC, 2013) and assumes a property threshold level of 0.15m for all properties as well as a coastal saline factor adjustment. The AAD and PVd values are presented in Table 3-1.

Table 3-1 Annual Average Damages and Whole Life PV Damages

	Annual Average Damage, AAD (£k) by Future Year for sea level rise			Whole Life Present Value Damages. PVd (£k)
Scenario	**2014**	**2065**	**2115**	
Lowest Beach Profile	1,934	3,517	6,066	85,383
Design Beach Profile	0	0	0	0

From the results shown in Table 3-1, it is evident that the flood risk under the 'lowest beach profile' case is much more extensive, and so damaging economically, compared to the 'design beach profile' case. The 'lowest beach profile' case giving 100-year PVd of £85,383k (based on flood risk to up to 108 residential and 80 non-residential properties under the 1:200 year return period event in year 100; note, the 1:200 year event in year 0 poses flood risk to 86 residential and 57 non-residential properties), compared to £0k (and 0 property at risk) for the 'design beach case', indicating the potential benefits for flood risk reduction to be gained by providing the 'design beach profile' along the Sidmouth town frontage. This demonstrates the value of retaining the 'design beach profile' in its ability to significantly reduce the scale of wave overtopping along the seafront (by reducing wave breaking directly against the seawall) and thus the extent of flood risk to Sidmouth town.

It should be noted that these values are based on available data in the NRD and that the analysis does not include upper flood properties, basements, and properties with MCM code '999'. The analysis also assumes that a property is only flooded when flooding envelops the properties centroid. As such, the results presented in Table 3-1 (and Appendix A) are considered to be on the low-side of total flood damages for both cases, and that with further work, the flood damages for Sidmouth would be calculated to be higher than the £85,383k determined already. This is something that could be investigated further at a later date.

In addition, the preliminary modelling work undertaken for this BMP does not consider the in-combination flood risk of high fluvial flows and extreme tides, nor surface water impacts on flood risk. Nor does it assess the potential implications of increased wave overtopping along the River Sid western wall should it become exposed by retreat of the cliffs to the east (refer to Section 3.3). These are also areas where further investigation could be undertaken to develop the economic case further.

3.3 Erosion Risk Damages

Assessment of future erosion risk potential has been made as part of cliff analysis presented in the Coastal Processes Baseline (CH2M HILL, 2016) produced alongside this economics baseline for the Sidmouth & East Beach Management Plan.

That assessment concluded that for East Cliff (CBU7 in assessment), over 100 years total cliff top recession is predicted to be between 20.9m and 30.9m. For Peak Hill (CBU4 in assessment), total cliff top recession over 100 years is predicted to be between 16.5m and 21.5m. These 100 year recession predictions are shown plotted in Figure 3-1 (for East Cliff) and Figure 3-2 (for Peak Hill).

It is important to note that the projections show the cumulative impact 100 years erosion and no attempt has been made to determine annual cliff losses or erosion rates. The actual erosion experienced in a given year is determined by the level of the beach, which is itself determined by the direction of waves that determines net drift direction; the timing, intensity and frequency of storms; and the amount of rainfall, none of which can be confidently predicted. Due to the current low beach levels, it is likely that the high rates of erosion seen in recent years will continue for several years, but that erosion will reduce in the near future once sediment has drifted back towards the west and a beach has accumulated.

The timing of a future reduction in cliff recession rate is uncertain, but several feedback mechanisms dictate that a continuation of a high rate of cliff recession for 100 years is not credible. Consistent accelerated erosion along a short section of coast would lead to formation of a set-back section of the cliff line where the cliff would become progressively further away from breaking waves causing erosion to reduce. Furthermore, a set-back section of coast would allow a pocket beach to accumulate, which would absorb wave energy and reduce erosion (CH2M HILL, 2016).

From these projections of future erosion risk, it is evident that based on the assessments made, that no property assets are predicted to be at direct risk from coastal erosion in the next 100 years.

For Peak Hill, no direct erosion risk damages to properties have therefore been calculated as part of this new analysis. It should be noted that there is a potential risk in 100 years to the cliff top road that provides local access in this area; no valuation of this impact to highways is made in this new analysis.

For East Cliff, although the 100 year projection indicates no loss of cliff top property, due to uncertainty about the future extent of cliff top recession (refer to CH2M HILL, 2016), a sensitivity test is justified based on the assumption that an additional 10m of cliff top recession could potentially occur (i.e. total recession over 100 years would then be up 40.9m). The probability that such an additional 10m of erosion loss were to occur is estimated to be 5%. Should this occur, then it is evident from Figure 3-3 that up to five cliff top properties along Cliff Road (atop East Cliff) could be lost to erosion.

Following the approach recommended in the Flood Hazard Research Centre (2013) guidance, local property valuations (assuming no coastal erosion risk) were obtained for these five properties (Overthorpe, Shimoda, Uplands, Derby Cottage and Cliffe Cottage) from Fulfords Estate Agents in Sidmouth; the total market valuation determined as a result was £3,470k (refer to Appendix B). This valuation was used with the assumption that property loss would occur in year 100 (i.e. apply discount factor for year 100) with a 5% probability of loss occurring to determine PVd for coastal erosion losses. The resulting PVd for coastal erosion losses is therefore £9k.

Whilst the potential erosion losses along East Cliff (CBU7) described above are calculated to be relatively small (in comparison to the flood damages described in Section 3.2) based on current projections, ongoing monitoring of cliff recession (as recommended in the Coastal Processes Baseline (CH2M HILL, 2016) will allow regular review of this economic risk.

It should also be noted that as East Cliff recedes over the next 100 years (as indicated in Figure 3-1), the Alma Bridge would become unsustainable in its current position whilst the western wall of the River Sid, that provides fluvial flood defence at the present time, will become increasingly exposed to full coastal conditions (particularly during south-easterly storm events). Such exposure, which will start to occur if East Cliff receded by about a further 10-15m from its 2015 position, will increase the likelihood of defence failure and thus incurrence of flood damages discussed in Section 3.2 over time; this would also impact critical infrastructure located behind the western wall of the River Sid that serves the wider area, notably the Sewage Pumping Station operated by South West Water located immediately upstream of western Alma Bridge abutment. This serves to demonstrate that whilst measures along the Sidmouth Town frontage to reduce flood risk from wave overtopping are appropriate (i.e. reduce economic damages as evidenced in Section 3.2), this benefit would be for nought if the risk posed by outflanking from the east is not also addressed at the same time.

The fluvial defences will therefore need to be upgraded to full coastal standard in advance of them becoming exposed by erosion of the cliffs and/or there is a different approach to managing coastal erosion risk implemented along East Beach/East Cliff. The trigger for commencing the planning of such upgrades would prudently be when a further 5m of erosion occurs in the vicinity of Alma Bridge over a 30-50m length of open coast extending eastwards form Alma Bridge. Based on the assessments made for East Cliff, as described in the Coastal Processes Baseline (CH2M HILL, 2016), and factoring the potential uncertainty with regards timing of recession, this increased exposure could potentially occur within the next 20 years (i.e. by 2035). Again, this risk of outflanking can be kept under regular review if informed by regular ongoing monitoring of cliff recession and beach levels in front of the cliffs as recommended in the Coastal Processes Baseline (CH2M HILL, 2016).

As noted above, this risk of outflanking is also dependent upon the measures implemented along the open coast around the mouth of the River Sid, and so monitoring of cliff recession and beach levels along

East Cliff/East Beach in the future will also inform assessment of the impact of any measures upon cliff erosion and so outflanking risk to the western wall of the River Sid.

As described in Section 3.2, further analysis, including numerical modelling, is required to better understand the wave and water level conditions that could be expected to occur along an exposed western wall of the River Sid defences, and in turn the associated wave overtopping potential and associated flood risk that would result should erosion continue as projected (i.e. no measures implemented along the open coast to reduce erosion risk).

Figure 3-1 Cliff recession projection for 100 years at East Cliff (CBU7). Note the projection is made from the 2015 cliff top, but are overlain on the 2012 image for presentation purposes.

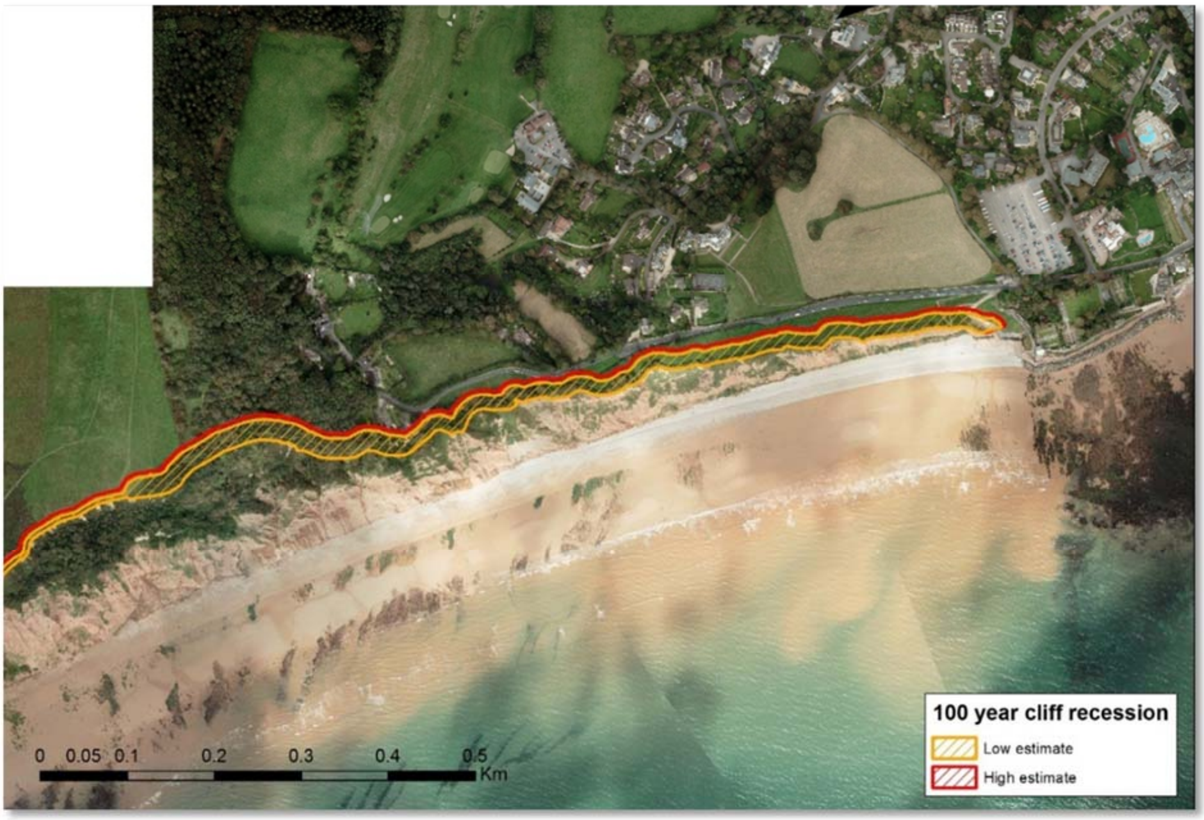

Figure 3-2 Cliff recession projection for 100 years at Peak Hill (CBU4). Note the projection is made from the 2012 cliff top and overlain on the 2012 image.

Figure 3-3 5m cliff recession intervals from 2015 for East Cliff (CBU7)

3.4 Amenity Damages

In addition to calculating update flood and erosion risk damages (Sections 3.2 and 3.3), the 1992 calculation of amenity benefit has also been updated to provide an indication of the potential level of amenity benefits that could be realized along the Sidmouth frontage. This achieved using the values presented in Section 2.2 adjusted as followed:

(a) Inflated to present day (2014) prices using the Retail Prices Index (RPI) inflation values from the Office of National Statistics (2015) between Q1 1992 (130.8) and Q4 2014 (257.4) – giving inflation of 196%; and

(b) Extended from a 50 year to 100 year assessment horizon.

The result of applying these two updates is presented in Table 3-2. This shows that the potential Present Value losses from visitors to the Sidmouth Seafront if coastal defences were allowed to deteriorate and fail is likely to be of the order of £31,431k over 100 years, allowing for application of discount factors. If defences are maintained (or improved), there is potential Present Value gain over 100 years of about £15,181k on top of avoiding the loss of £31,431k (i.e. total benefit of £46,612k over 100 years).

Table 3-2 Summary of amenity benefits based on data from Phase 2 (refer to Table 2-1) updated using RPI inflation of 196% between Q1 1992 (130.8) and Q4 2014 (257.4) and extended to 100 years.

Visitor Type	No. Visitors per 150 day summer season	Loss per 150 day summer season (£k)	*Total Present Value loss over 100 years (£k)* [A]	Gain per 150 day summer season (£k)	*Total Present Value gain over 100 years (£k)* [B]	*Total Present Value benefits over 100 Years (£k)* [A+B]
Day	100,837	468.40	*13,988*	129.67	*3,872*	*17,860*
Staying	50,500	549.25	*16,402*	355.76	*10,624*	*27,026*
Local	11,250	34.85	*1,041*	22.93	*685*	*1,726*
TOTALS	**162,587**	**1,0520.50**	***31,431***	**508.36**	***15,181***	***46,612***

This provides an indication of the potential value of amenity to Sidmouth to be gained from retaining coastal defence and a beach along the Sidmouth frontage, which is sufficient for appraising the economics benefits of potential future options as part of this project. Further research could be undertaken in the future to revise the visitor numbers assumed and/or values visitors assigned (via a contingent valuation survey).

3.5 Summary of 'Do Nothing' Economic Damages

The analysis presented in this section indicates that the potential Present Value (PV) economic damages to the Sidmouth BMP frontage from coastal flood risk to approximately 188 residential and commercial properties is at least £85,383k, and that this is considered to be a low-estimate given limitations of the analysis and the NRD data that underpins it. In addition, up to five residential properties are considered to be at potential risk of coastal erosion in the very long-term (i.e. 100 years); the PV economic damages for these erosion losses is calculated to be £9k.

In addition to property risks, the potential impact of not maintaining coastal defences at Sidmouth in upon the amenity value of the town is calculated to be of the order of £31,431k over 100 years.

Combining the property and amenity damages over 100 years gives total Present Value damages of £116,823k against which costs of future management can be assessed as part of the options development stage of the Sidmouth and East Beach Management Plan. Without amenity damages, the total PV damages is £85,392k.

4 Conclusions

The findings of the economics baseline assessment are:

- The Sidmouth Coastal Protection Scheme constructed in the 1990s was based on:
  - A 50 year scheme appraisal period. *NB: current guidance is now to use a 100 year appraisal period.*
  - Application of flat 6% discount factor over the appraisal period to derive Present Value damages (PVd). *NB: the new analysis in Section 3 is based upon a variable discount factor that changes over a 100 year appraisal period.*
  - Erosion losses of (up to 10no.) seafront properties with PVd calculated to be between £5,037k and £9,021k.
  - Amenity losses over the appraisal period calculated to be £12,553k.
  - No account was made of flood damages over the appraisal period.
- Assessments made as part of this BMP has determined that coastal erosion risk along the Sidmouth town frontage is not the main issue to be addressed given that the defences are assessed as being in good condition with significant residual life remaining. Rather, it is the coastal flood risk to the low-lying areas of Sidmouth town, as a result of wave overtopping of the seafront, that are the main issue to focus on.
- The SMP2 (Halcrow, 2011) was the first attempt to value flood damages along the Sidmouth frontage. This broad assessment which did not account for annual average damages based on impact of different return period events, calculated that up to 244 residential and 100 commercial properties lie within the flood zone defined by the Environment Agency, with PVd calculated to be £49,110k over a 100 years appraisal period.
- The flood damages calculated in for this BMP identify up to 108 residential and 80 commercial properties at risk of flooding, with PVd calculated over a 100 year appraisal period to be £85,383k based on a lowest beach profile scenario. This is based on a more detailed assessment than the SMP2 and is considered to be a low estimate of flood damages given the limitations of the analysis and the NRD data that underpins it.
- Updated assessment of amenity losses from the 1990's analysis that is also extended to a 100 year appraisal period amenity, are calculated to be £31,431k.
- The assessment of options for Pennington Point/East Beach in 2001-2003 was based upon:
  - A 50 year scheme appraisal period. *NB: current guidance is now to use a 100 year appraisal period.*
  - Application of flat 6% discount factor over the appraisal period to derive Present Value damages (PVd). *NB: the new analysis in Section 3 is based upon a variable discount factor that changes over a 100 year appraisal period.*
  - Erosion losses of cliff top properties with PVd calculated to be between £128k and £640k.
  - Potential loss of South West Water infrastructure along the western wall of the River Sid as it becomes exposed to coastal conditions by erosion of Pennington Point/East Cliff valued at £6,000k.
- Assessment as part of the SMP2 (Halcrow, 2011) and this BMP both identify that the erosion risk to cliff top properties over the next 100 years is considered to be less than the assessment made in 2001-2003. There are, however, up to five properties at risk of coastal erosion along the top of East Cliff (Cliff Road) in the very long term (100 years). The PVd calculated for these erosion losses is £9k.

- Combining the property flood and erosion damages with the amenity damages over 100 years gives total PVd of £116,823k against which costs of future management can be assessed as part of the options development stage of the Sidmouth and East Beach Management Plan. Without amenity damages included, the total PVd reduces to £85,392k.
- The main risk from erosion of Pennington Point/East Cliff over the next 100 years is (a) the loss of the Alma Bridge (in its current position), and (b) the exposure of the western wall of the River Sid to full coastal conditions, which would pose increased risk of wave overtopping and potentially structural failure of this wall leading to widespread flooding and loss of critical infrastructure (e.g. sewage pumping station) that serves the wider area, unless the wall is upgraded to full coastal design standards and/or there is a different approach to managing coastal erosion risk implemented along East Beach/East Cliff. This exposure is predicted to occur within the next 20 years (i.e. by 2035) based upon the current situation, and so planning to implement any wall upgrade is likely to be required within this time-frame; though that depends on what is done along the open coast of East Cliff/East Beach to reduce erosion and so outflanking risk to the low-lying area of Sidmouth town centre. Such measures are justifiable on that basis as otherwise investment to reduce flood risk along Sidmouth town frontage would be for nought if nothing was done to address potential future increased flood risk from the River Sid due to ongoing erosion of East Cliff.
- Along the Connaught Gardens (Chit Rocks) and Jacob’s Ladder Beach sections of the BMP frontage, previous economic cases have all been based upon preventing coastal erosion to the benefit of amenity assets of economic value to Sidmouth. In 1994 these were estimated to have a capital value of £583k. However, given present funding rules for flood and coastal defence, future funding to maintain these assets, and/or to recycle beach sediment from the promenade area at Jacob’s Ladder Beach back westwards when it causes an amenity use issue, is likely to require full 100% funding contributions from third-party (i.e. non-FCERM Grant in Aid) sources.

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Appendix A Coastal Flood Inundation Modelling Technical Note

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Technical Note

Project	Sidmouth Beach Management	**Date**	12th March 2015
Subject	Coastal Flood Inundation Modelling	**Ref**	Khairulanwar Abdul Jami/Matthew Kennedy

1 Introduction

This report provides a baseline assessment of the coastal flooding along the Sidmouth and East Beach Management Plan (BMP) frontage (Figure 1). The purpose of this assessment is to provide inundation maps and economic analysis for Sidmouth. As such, this report includes:

- Information about the data used for setting up the model (Sections 2 and 3).
- Methodology on how the assessment is done (Section 4).
- Assessment of TUFLOW 2D model results and economic analysis calculation (Section 5).
- Conclusions and recommendation for further investigation and possible mitigation in terms of reducing flood damages (Section 6).

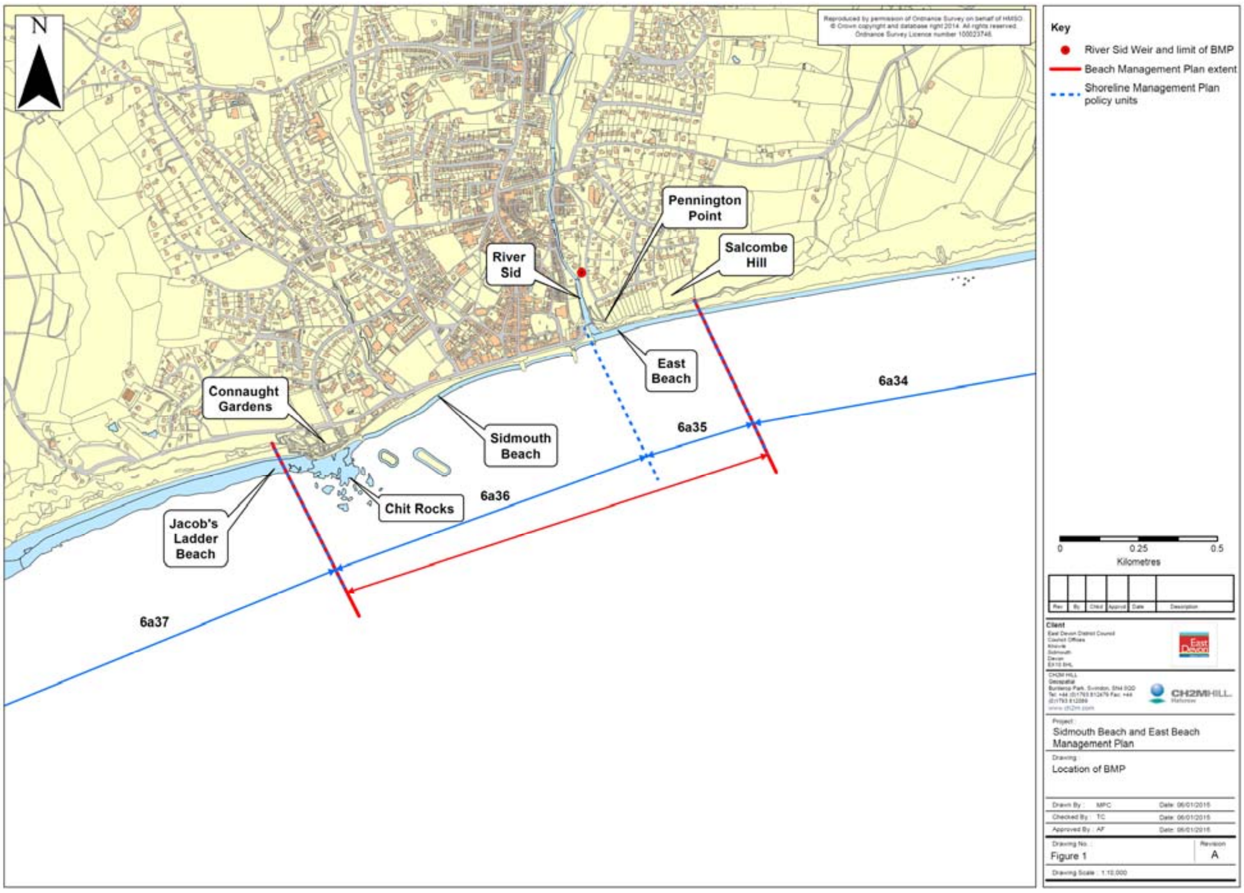


Figure 1 – Sidmouth BMP extent

2 Data Information

The purpose of this section is to highlight the input data used for this project. Input data includes a Digital Terrain Model (DTM), overtopping rates for cases to be modelled along the open coast, tide curves to be modelled along the River Sid, defence crest level survey, and OS Master Map.

2.1 LiDAR DTM

DTMs are usually used to define topography for a certain extents or locations. For this project, the DTM received, cover the area of interest for this project and is used to define the topography of Sidmouth. The DTM comes in ascii file format that and was provided by the Environment Agency's Geomatics Group.

2.2 Overtopping Rates

Overtopping rate is the rate of water that flows over the top of the sea defences as a result of waves breaking against a sea defence. Overtopping rates are used as the input for the 2D model boundary condition which represent the overtopping of the Sidmouth defences along the coastline. The overtopping rates for cases to be modelled were derived from the Defence Assessment Report produced as part of the development of the Sidmouth and East Beach Management Plan. The rates used for this flood modelling study were defined for the following two categories:

(a) design beach; and

(b) lowest beach profile.

Each category then assesses three different scenarios:

(i) Present Day scenario (2014);

(ii) 50 years climate change scenario (year 2065) and

(iii) 100 years climate change scenario (year 2115).

Each scenario is assessed for five different return period events:

1) 1 in 1 year (100% AEP);
2) 1 in 5 years (20% AEP);
3) 1 in 50 years (2% AEP);
4) 1 in 100 years (1% AEP); and
5) 1 in 200 years (0.5% AEP).

2.3 Tide Curve

The tide curve predicts the times and heights of the high and low tides for a given location. The tide curve is used for the 2D model boundary condition which represent water that coming from the confluence of the river Sid and the sea. Event data that are used for the model are the 1 in 1 year (100% AEP), 1 in 5 years (20% AEP), 1 in 50 years (2% AEP), 1 in 100 years (1% AEP), and 1 in 200 years (0.5% AEP) events for present day, climate change 50 years and climate change 100 years.

2.4 Crest Level Survey

The Crest Level Survey came in CSV files and included the elevation of the crest, and coordinate of the defences. The survey data were used to locate the position of the defences and to determine the location of overtopping boundary for the 2D model.

2.6 Master Map

OS Mastermap information was downloaded from CH2M Hill’s internal servers for use with this project.

3 Data Review

3.1 LiDAR Data Review

From the data sent, there is few of pre-merged DTM data and around 195 files of unmerged DTM tiles with 4m cell size.

3.1.1 Pre-Merged DTM

Finding of the pre-merged DTM shows that the data is not suitable to be used for 2D modelling. Since the merged DTM consist of unfiltered data and filtered data together in the same file. The unfiltered data include together the elevation of building on the area will impact the results for the flood map.

The pre-merged DTM will not be used for modelling.

3.1.2 Unmerged DTM

From preliminary checking of 195 files of unmerged DTM tiles, it seems that it can be categorized into two (2) different types, which is:

a) Unfiltered data, and

b) Filtered data.

Unfiltered data will not be used for modelling

3.1.3 Filtered DTM

After a thorough investigation, it comes out that the filtered unmerged DTM had its own different version dependent on the time it was taken (this was the same for the unfiltered data). The version is as follow:

i) Taken on 17th April 2007; this LiDAR data covers our area of interest, but it was taken on 2007.

ii) Taken on 31st January 2010; the LiDAR data had missing area on the northern part of Sidmouth, however this was outside the study area.

iii) Taken on 4th April 2010; Data did not cover area of interest.

iv) Taken on 20th March 2007; this LiDAR data does not cover our area of interest greatly as the data above, but it extend to the eastern part of Sidmouth where it does not include in our model.

After comparing each available unfiltered data, it was determined that filtered data taken on 31st of January 2010 will be used for the data taken on 17th of April 2007 may be useful for further study as the 2010 data does not cover the whole of Sidmouth.

All the data selected was then merged into one (1) ascii file using MapInfo.

3.2 Tide Curves Data Review

The tide curves data received was in excel spreadsheet format.

From review it is found that the data in the spreadsheet contained more events than required modelling. Since there are less events needed for this assessment as mentioned in Section 2.3, the necessary curves were selected and the highest peak of each curve was selected to model the extreme tidal scenarios. The tidal curves used are available in Annex A.

3.3 Crest Level Survey Data Review

The elevation and location of the crest level survey was reviewed against the DTM and found to be consistent with other data sources including mapping.

4 Methodology

4.1 2D Model Set Up and Runs

TUFLOW software (2013-12-AC-iSP-w64) was used to set up and run the 2D Model for this project. The simulations carried out are as below:

4.1.1 Boundary Conditions

For the 2D model, two boundary conditions have been used, one to represent wave overtopping along the defences (an inflow boundary-ST in TUFLOW) and a second to represent tidal incursion up the River Sid (a water level boundary- HT in TUFLOW). The locations of these boundaries can be seen in the model schematic in Annex B.

For the wave overtopping 4 ST Boundaries were used as indicated on the plans in Annex B. These are:

1) West Pier,

2) Bedford Steps,

3) York Steps Groyne, and

4) East Pier Groyne

Two wave overtopping boundaries (Clifton Walkway and Jacobs Ladder) were removed from the model as these was at the foot of the western cliffs and did not contribute to flooding.

The size and magnitude of the wave overtopping for each event is shown on the plans in Annex B and also tabulated in Annex A. For the wave overtopping, these values were divided by 1000 to represent that wave overtopping rates are not constant and are dependent on the wave period. Wave overtopping was applied as a triangular hydrograph with a duration of two hours and peaking after 1 hour. The initial and final wave overtopping rates were considered to be zero.

The water levels for the HT boundary to be applied along the River Sid were taken from a spreadsheet provided to the modelling team. The peak value for each return period is summarised in Table 1 below:

Table 1 – Peak Sea Levels

	Peak Level (mAOD)				
	1 in 1 Year	1 in 5 Years	1 in 50 Years	1 in 100 Years	1 in 200 Years
2014	2.7	2.86	3.1	3.16	3.24
2065	2.9	3.06	3.27	3.36	3.44
2115	3.15	3.31	3.52	3.61	3.69

4.1.2 Model Domain and parameters

The area modelled can be seen in the model schematic in Annex B. The domain was modelled using a 4m cell size and a 1 second time-step.

4.1.3 Model Geometry

4.1.3.1 Model topography

The merge DTM from section 3.1.3 was used to define model topography. However, since the DTM had a small hole due to a small lake that exist within the tiles, a z shape polygon was used in TUFLOW to fill this hole.

4.1.3.2 Buildings

From the Master Map, building polygons were extracted, and raised in elevation to 0.2m as an additional elevation to the DTM. In addition a high roughness value of 0.5 was used to ensure that water preferentially flowed around buildings.

4.1.3.3 Defining Roughness

Roughness values were based upon OS Mastermap land use classifications and followed the values outlined in the Table 2 below:

Table 2 – 2D Model Roughness Values

Code	Roughness Value	Type
10000	0.04	default
10021	0.5	building
10053	0.04	general surface ; residential yards
10054	0.025	general surface ; step
10056	0.03	general surface ; grass,parkland
10062	0.5	building ; glass house
10076	0.5	land heritage and antiquities
10089	0.035	water ; inland
10111	0.1	natural environment (confierous/non coniferous trees)
10119	0.02	roads tracks and paths ; manmade
10123	0.025	roads tracks and paths ; tarmac or dirt tracks
10167	0.05	rail
10172	0.02	roads tracks and paths ; tarmac
10183	0.02	roads tracks and paths(roadside) ; pavement
10185	0.03	structures ; roadside structure
10187	0.5	structures ; generally on top of buildings
10203	0.04	water ; foreshore
10210	0.035	water ; tidal water
10217	0.035	land (unclassified)
10096	0.04	slope
10193	0.04	pylon
10093	0.04	Land, assume grass
10099	0.04	Cliff, assumed step

4.2 Damage Calculation

Damage calculations have been carried out using ISIS damage calculator. This software utilizes damage curves derived from MCM 2013 and damage estimates have been made assuming a property threshold level of 0.15m for all properties and a coastal saline factor adjustment.

Further to this all upper flood properties and properties with MCM code '999' have been excluded from the analysis. The methodology also follows that a property is only flooded when flooding envelops the properties centroid.

5 Results

5.1 Flood Extents

Flood extents for each scenario and return period can be seen in Annex C. Each map also includes the damage estimates for each scenario. Results show a significant amount of flooding for low return periods. This is a result of large overtopping volumes of the eastern most defence near the River Sid estuary.

5.2 Damages and flooded properties

As a result of frequent flooding originating from the eastern flood defence, Annual Average Damage is high as seen in Table 3. Assessing whole life damages by interpolating between the damage figures for 2014, 2065 and 2115 gives a present value of damages of £85,383k.

Table 3 – Annual Average Damages and Whole Life PV Damages

	Annual Average Damage (£k) by Future Year for sea level rise			Whole Life Damages. Present Value (£k)
Scenario	**2014**	**2065**	**2115**	
Lowest Beach	1,934	3,517	6,066	85,383
Design Beach	0	0	0	0

6 Conclusions and Recommendations

6.1 Conclusions

Flood extents show that the area most at risk from wave overtopping in Sidmouth is concentrated along the west bank of the River Sid at the eastern end of the esplanade. Lower land elevations in this area means that even wave overtopping at the western end of the esplanade flows towards this area.

6.1.1 Lowest Beach Overtopping Rate

Flooded area and overtopping rate are shown to be directly proportional, leading to an increase in flooded area with climate change. Mapped flood extents in Annex C show that the area of Sidmouth along the west bank of the River Sid is most at risk, with topography directing flows to this area. Significant flooding occurs for even the 1 in 1 year return period as a result of the volume of wave overtopping. Whilst higher return period events and the impact of climate change increase the volume of overtopping, the flooded area still remains to the south east of Sidmouth bounded by the River Sid.

6.1.2 Design Beach Overtopping Rate

Compared to the lowest beach profile, flood extents for the design beach show a marked decrease in flooded area. This is due to overtopping rates that are orders of magnitude lower along all of the frontage with the exception of the East Pier (defence length 6). Overtopping rates here are not so significantly reduced and this is the main source of flooding under the design beach scenario. Even with this notable reduction, flooding still occurs for the 1 in 1 year event. However, the area affected is shallow and is not shown to impact property. Since overtopping rates are minimized elsewhere, flood extents are limited to the eastern end of the Esplanade. Even for climate change in 2115 extents only reach to York Street and East Street behind the esplanade where they largely affect the Ham Park and York Street Car Park.

6.2 Recommendations

The design beach scenario shows a marked decrease in wave overtopping rates and consequently, flood extents. From a flood risk perspective this would be the preferred option, however it would be also recommended to make amendments to the East pier such that wave overtopping here is also reduced.

From a modelling perspective the results shown are a reflection of the volume of water resulting from the wave overtopping calculations. Improvements to the model could be made by calculating wave overtopping over the entire course of a design event as it is considered unlikely that the extent of flooding observed in the model for the 1 in 1 year event occurs. At present the model is considered to represent a conservative estimate of flooding.

Damage calculations have been kept simple to give a broad understanding of the impacts of flooding on Sidmouth. However, if more detail is added to the hydraulic model, a more detailed damage assessment approach is recommended that takes into account the onset of flooding for properties that does not solely include when the property centroid is enveloped by the flood extent. Further to this some extra analysis using google streetview or a site visit is recommended to classify those properties with MCM code 999 that appear to be legitimate residential or commercial properties.

Annex A Model Boundary Conditions

A.1 Tide curve data

	2014 Water Level (mAOD)				
Time (H)	1 in 1 Year	1 in 5 Years	1 in 50 Years	1 in 100 Years	1 in 200 Years
75.5	-0.35	-0.22	-0.01	0.04	0.11
75.67	-0.25	-0.11	0.1	0.15	0.22
75.83	-0.15	-0.01	0.2	0.26	0.32
76	-0.04	0.1	0.31	0.36	0.43
76.17	0.06	0.2	0.42	0.47	0.54
76.33	0.26	0.41	0.62	0.68	0.75
76.5	0.47	0.61	0.83	0.88	0.96
76.67	0.57	0.72	0.94	0.99	1.06
76.83	0.77	0.92	1.14	1.2	1.27
77	0.98	1.13	1.35	1.4	1.48
77.17	1.18	1.33	1.55	1.61	1.69
77.33	1.38	1.53	1.76	1.82	1.89
77.5	1.58	1.74	1.96	2.02	2.1
77.67	1.79	1.94	2.17	2.23	2.3
77.83	1.99	2.14	2.37	2.43	2.51
78	2.09	2.24	2.48	2.54	2.61
78.17	2.29	2.45	2.68	2.74	2.82
78.33	2.39	2.55	2.78	2.84	2.92
78.5	2.49	2.65	2.89	2.95	3.03
78.67	2.5	2.65	2.89	2.95	3.03
78.83	2.6	2.76	2.99	3.05	3.13
79	2.6	2.76	3	3.06	3.13
79.17	2.7	2.86	3.1	3.16	3.24
79.33	2.7	2.86	3.1	3.16	3.24
79.5	2.7	2.86	3.1	3.16	3.24
79.67	2.7	2.86	3.1	3.16	3.24
79.83	2.7	2.86	3.1	3.16	3.24
80	2.7	2.86	3.1	3.16	3.24
80.17	2.6	2.76	3	3.06	3.14
80.33	2.6	2.76	3	3.06	3.14
80.5	2.5	2.66	2.9	2.96	3.04
80.67	2.5	2.66	2.9	2.96	3.03
80.83	2.4	2.56	2.79	2.85	2.93
81	2.3	2.45	2.69	2.75	2.83
81.17	2.1	2.25	2.49	2.55	2.63
81.33	1.99	2.15	2.39	2.45	2.53
81.5	1.79	1.95	2.19	2.24	2.32
81.67	1.69	1.85	2.08	2.14	2.22
81.83	1.49	1.65	1.88	1.94	2.02

	2014 Water Level (mAOD)				
Time (H)	1 in 1 Year	1 in 5 Years	1 in 50 Years	1 in 100 Years	1 in 200 Years
82	1.29	1.45	1.68	1.74	1.82
82.17	1.09	1.24	1.48	1.54	1.61
82.33	0.89	1.04	1.27	1.33	1.41
82.5	0.59	0.74	0.97	1.03	1.11
82.67	0.39	0.54	0.77	0.83	0.91
82.83	0.19	0.34	0.57	0.63	0.7
83	-0.12	0.04	0.27	0.32	0.4
83.17	-0.32	-0.16	0.06	0.12	0.2
83.33	-0.52	-0.37	-0.14	-0.08	-0.01
83.5	-0.72	-0.57	-0.34	-0.28	-0.21
83.67	-0.92	-0.77	-0.54	-0.49	-0.41
83.83	-1.12	-0.97	-0.74	-0.69	-0.61
84	-1.32	-1.17	-0.95	-0.89	-0.81
84.17	-1.42	-1.27	-1.05	-0.99	-0.92
84.33	-1.62	-1.47	-1.25	-1.19	-1.12
84.5	-1.72	-1.58	-1.35	-1.3	-1.22
84.67	-1.73	-1.58	-1.36	-1.3	-1.23
84.83	-1.83	-1.68	-1.46	-1.4	-1.33
85	-1.83	-1.68	-1.46	-1.41	-1.33
85.17	-1.83	-1.68	-1.47	-1.41	-1.34
85.33	-1.73	-1.59	-1.37	-1.32	-1.24
85.5	-1.73	-1.59	-1.37	-1.32	-1.25

	2065 Water Level (mAOD)				
Time (H)	1 in 1 Year	1 in 5 Years	1 in 50 Years	1 in 100 Years	1 in 200 Years
75.5	-0.18	-0.05	0.13	0.21	0.28
75.67	-0.08	0.06	0.24	0.32	0.39
75.83	0.03	0.17	0.35	0.43	0.5
76	0.13	0.27	0.46	0.54	0.61
76.17	0.24	0.38	0.57	0.65	0.72
76.33	0.44	0.59	0.77	0.86	0.93
76.5	0.65	0.79	0.98	1.06	1.14
76.67	0.75	0.9	1.09	1.17	1.25
76.83	0.96	1.1	1.3	1.38	1.46
77	1.16	1.31	1.51	1.59	1.66
77.17	1.36	1.51	1.71	1.8	1.87
77.33	1.57	1.72	1.92	2	2.08
77.5	1.77	1.92	2.12	2.21	2.29
77.67	1.98	2.13	2.33	2.42	2.49
77.83	2.18	2.33	2.54	2.62	2.7
78	2.28	2.44	2.64	2.73	2.81

	2065 Water Level (mAOD)				
Time (H)	1 in 1 Year	1 in 5 Years	1 in 50 Years	1 in 100 Years	1 in 200 Years
78.17	2.48	2.64	2.85	2.93	3.01
78.33	2.59	2.74	2.95	3.04	3.12
78.5	2.69	2.85	3.05	3.14	3.22
78.67	2.69	2.85	3.06	3.15	3.22
78.83	2.79	2.95	3.16	3.25	3.33
79	2.79	2.95	3.16	3.25	3.33
79.17	2.9	3.06	3.26	3.35	3.43
79.33	2.9	3.06	3.27	3.36	3.44
79.5	2.9	3.06	3.27	3.36	3.44
79.67	2.9	3.06	3.27	3.36	3.44
79.83	2.9	3.06	3.27	3.36	3.44
80	2.9	3.06	3.27	3.36	3.44
80.17	2.8	2.96	3.17	3.26	3.34
80.33	2.8	2.96	3.17	3.26	3.34
80.5	2.7	2.86	3.06	3.15	3.23
80.67	2.69	2.85	3.06	3.15	3.23
80.83	2.59	2.75	2.96	3.05	3.13
81	2.49	2.65	2.86	2.95	3.03
81.17	2.29	2.45	2.66	2.74	2.82
81.33	2.19	2.35	2.55	2.64	2.72
81.5	1.99	2.14	2.35	2.44	2.52
81.67	1.89	2.04	2.25	2.34	2.41
81.83	1.68	1.84	2.05	2.13	2.21
82	1.48	1.64	1.84	1.93	2.01
82.17	1.28	1.44	1.64	1.73	1.8
82.33	1.08	1.23	1.44	1.52	1.6
82.5	0.78	0.93	1.13	1.22	1.3
82.67	0.58	0.73	0.93	1.02	1.1
82.83	0.38	0.53	0.73	0.82	0.89
83	0.07	0.23	0.43	0.51	0.59
83.17	-0.13	0.02	0.22	0.31	0.39
83.33	-0.33	-0.18	0.02	0.11	0.18
83.5	-0.53	-0.38	-0.18	-0.1	-0.02
83.67	-0.73	-0.58	-0.38	-0.3	-0.22
83.83	-0.93	-0.78	-0.59	-0.5	-0.43
84	-1.14	-0.99	-0.79	-0.7	-0.63
84.17	-1.24	-1.09	-0.89	-0.81	-0.73
84.33	-1.44	-1.29	-1.09	-1.01	-0.94
84.5	-1.54	-1.39	-1.2	-1.11	-1.04
84.67	-1.54	-1.39	-1.2	-1.12	-1.04
84.83	-1.64	-1.5	-1.3	-1.22	-1.15
85	-1.65	-1.5	-1.31	-1.23	-1.15

	2065 Water Level (mAOD)				
Time (H)	1 in 1 Year	1 in 5 Years	1 in 50 Years	1 in 100 Years	1 in 200 Years
85.17	-1.65	-1.5	-1.31	-1.23	-1.16
85.33	-1.55	-1.41	-1.22	-1.14	-1.06
85.5	-1.56	-1.41	-1.22	-1.14	-1.07

	2115 Water Level (mAOD)				
Time (H)	1 in 1 Year	1 in 5 Years	1 in 50 Years	1 in 100 Years	1 in 200 Years
75.5	0.03	0.17	0.35	0.42	0.49
75.67	0.14	0.28	0.46	0.53	0.6
75.83	0.25	0.39	0.57	0.65	0.72
76	0.35	0.49	0.68	0.76	0.83
76.17	0.46	0.6	0.79	0.87	0.94
76.33	0.67	0.81	1	1.08	1.15
76.5	0.88	1.02	1.21	1.29	1.37
76.67	0.98	1.13	1.32	1.4	1.48
76.83	1.19	1.34	1.53	1.61	1.69
77	1.4	1.54	1.74	1.82	1.9
77.17	1.6	1.75	1.95	2.03	2.11
77.33	1.81	1.96	2.16	2.24	2.32
77.5	2.01	2.16	2.36	2.45	2.53
77.67	2.22	2.37	2.57	2.66	2.74
77.83	2.42	2.58	2.78	2.87	2.94
78	2.53	2.68	2.89	2.97	3.05
78.17	2.73	2.89	3.09	3.18	3.26
78.33	2.83	2.99	3.2	3.28	3.36
78.5	2.94	3.09	3.3	3.39	3.47
78.67	2.94	3.1	3.31	3.39	3.47
78.83	3.04	3.2	3.41	3.5	3.58
79	3.05	3.2	3.41	3.5	3.58
79.17	3.15	3.31	3.52	3.61	3.68
79.33	3.15	3.31	3.52	3.61	3.69
79.5	3.15	3.31	3.52	3.61	3.69
79.67	3.15	3.31	3.52	3.61	3.69
79.83	3.15	3.31	3.52	3.61	3.69
80	3.15	3.31	3.52	3.61	3.69
80.17	3.05	3.21	3.42	3.51	3.59
80.33	3.05	3.21	3.42	3.51	3.59
80.5	2.95	3.11	3.32	3.4	3.48
80.67	2.95	3.1	3.31	3.4	3.48
80.83	2.84	3	3.21	3.3	3.38
81	2.74	2.9	3.11	3.2	3.28
81.17	2.54	2.7	2.9	2.99	3.07

	2115 Water Level (mAOD)				
Time (H)	1 in 1 Year	1 in 5 Years	1 in 50 Years	1 in 100 Years	1 in 200 Years
81.33	2.44	2.59	2.8	2.89	2.97
81.5	2.23	2.39	2.6	2.69	2.76
81.67	2.13	2.29	2.49	2.58	2.66
81.83	1.93	2.09	2.29	2.38	2.46
82	1.73	1.88	2.09	2.17	2.25
82.17	1.53	1.68	1.88	1.97	2.05
82.33	1.32	1.48	1.68	1.77	1.85
82.5	1.02	1.18	1.38	1.46	1.54
82.67	0.82	0.97	1.17	1.26	1.34
82.83	0.62	0.77	0.97	1.06	1.13
83	0.31	0.47	0.67	0.75	0.83
83.17	0.11	0.26	0.46	0.55	0.63
83.33	-0.09	0.06	0.26	0.35	0.42
83.5	-0.29	-0.14	0.06	0.14	0.22
83.67	-0.49	-0.34	-0.15	-0.06	0.01
83.83	-0.7	-0.55	-0.35	-0.26	-0.19
84	-0.9	-0.75	-0.55	-0.47	-0.39
84.17	-1	-0.85	-0.66	-0.57	-0.5
84.33	-1.2	-1.05	-0.86	-0.77	-0.7
84.5	-1.31	-1.16	-0.96	-0.88	-0.8
84.67	-1.31	-1.16	-0.97	-0.88	-0.81
84.83	-1.41	-1.27	-1.07	-0.99	-0.91
85	-1.42	-1.27	-1.08	-0.99	-0.92
85.17	-1.42	-1.27	-1.08	-1	-0.93
85.33	-1.32	-1.18	-0.99	-0.91	-0.83
85.5	-1.33	-1.19	-1	-0.91	-0.84

A.2 Wave overtopping rates for design beach profile scenarios

Design Beach Profile with Present Day Wave and Water Levels (2014)

	OT Rate (l/s/m) by Frontage					
Return Period	**1**	**2**	**3**	**4**	**5**	**6**
1 in 1	17	0	0	0	0	67
1 in 5	34	1	0	0	1	93
1 in 50	84	10	1	0	2	143
1 in 100	103	16	1	0	2	166
1 in 200	135	32	1	1	3	193

Design Beach Profile with Present Day Wave and Water Levels increased for sea level rise to 2065

	OT Rate (l/s/m) by Frontage					
Return Period	**1**	**2**	**3**	**4**	**5**	**6**
1 in 1	41	3	1	0	1	102
1 in 5	75	12	1	0	2	139
1 in 50	169	79	3	1	4	221
1 in 100	204	123	4	1	5	249
1 in 200	260	222	5	2	7	292

Design Beach Profile with Present Day Wave and Water Levels increased for sea level rise to 2115

	OT Rate (l/s/m) by Frontage					
Return Period	**1**	**2**	**3**	**4**	**5**	**6**
1 in 1	106	28	2	0	2	169
1 in 5	180	96	3	1	5	231
1 in 50	370	552	8	3	11	374
1 in 100	437	837	11	4	14	424
1 in 200	542	1440	14	5	19	502

A.3 Wave overtopping rates for lowest beach profile scenarios

Lowest Beach Profile with Present Day Wave and Water Levels (2014)

	OT Rate (l/s/m) by Frontage					
Return Period	**1**	**2**	**3**	**4**	**5**	**6**
1 in 1	17	33	3	57	84	82
1 in 5	34	75	6	78	114	108
1 in 50	84	216	13	124	179	166
1 in 100	103	275	16	139	200	185
1 in 200	135	373	20	163	232	214

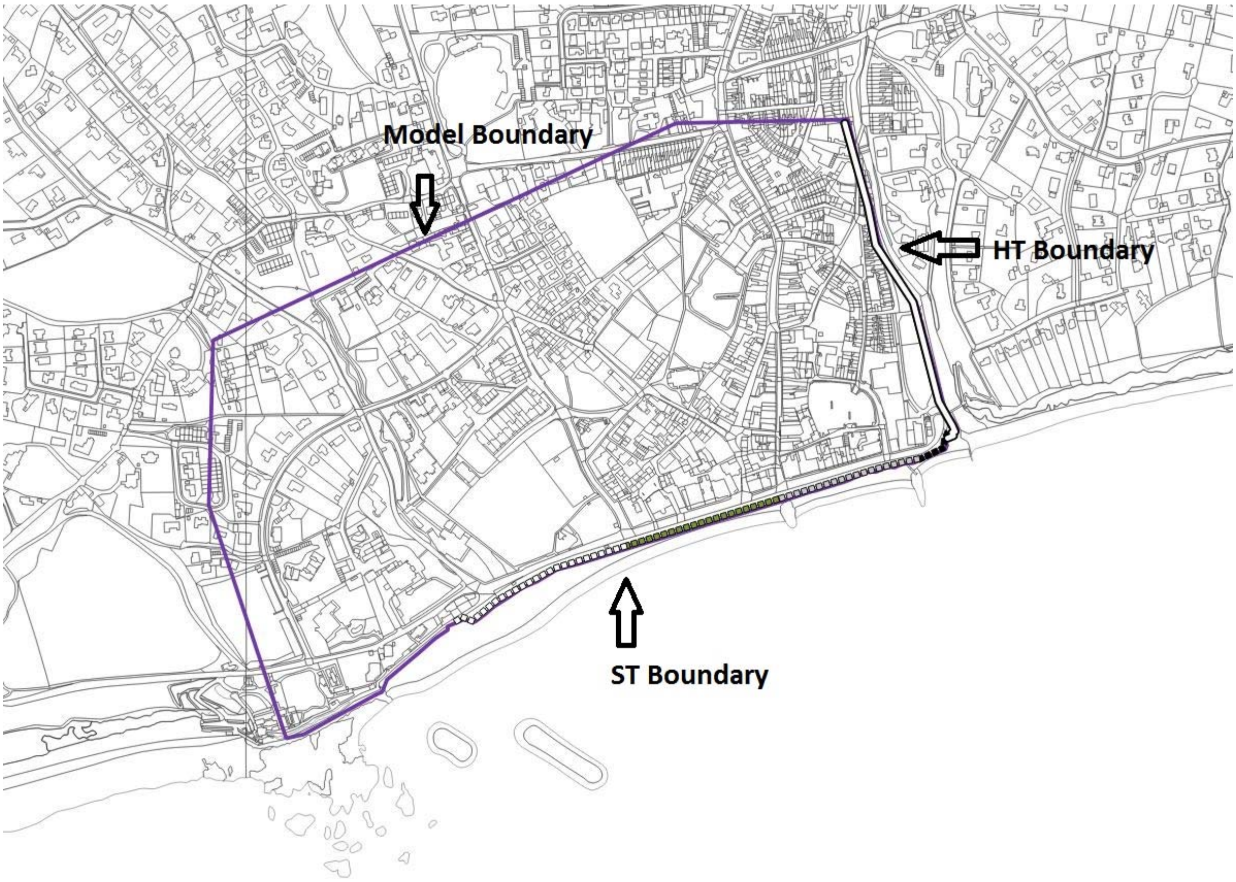
Lowest Beach Profile with Present Day Wave and Water Levels increased for sea level rise to 2065

	OT Rate (l/s/m) by Frontage					
Return Period	**1**	**2**	**3**	**4**	**5**	**6**
1 in 1	41	94	7	86	125	118
1 in 5	75	192	12	117	169	157
1 in 50	169	485	25	187	265	244
1 in 100	204	599	30	211	298	274
1 in 200	260	783	37	247	348	319

Lowest Beach Profile with Present Day Wave and Water Levels increased for sea level rise to 2115

	OT Rate (l/s/m) by Frontage					
Return Period	**1**	**2**	**3**	**4**	**5**	**6**
1 in 1	106	289	16	142	204	188
1 in 5	180	527	27	195	277	254
1 in 50	370	1163	53	318	444	406
1 in 100	437	1395	63	361	503	459
1 in 200	542	1759	79	428	593	541

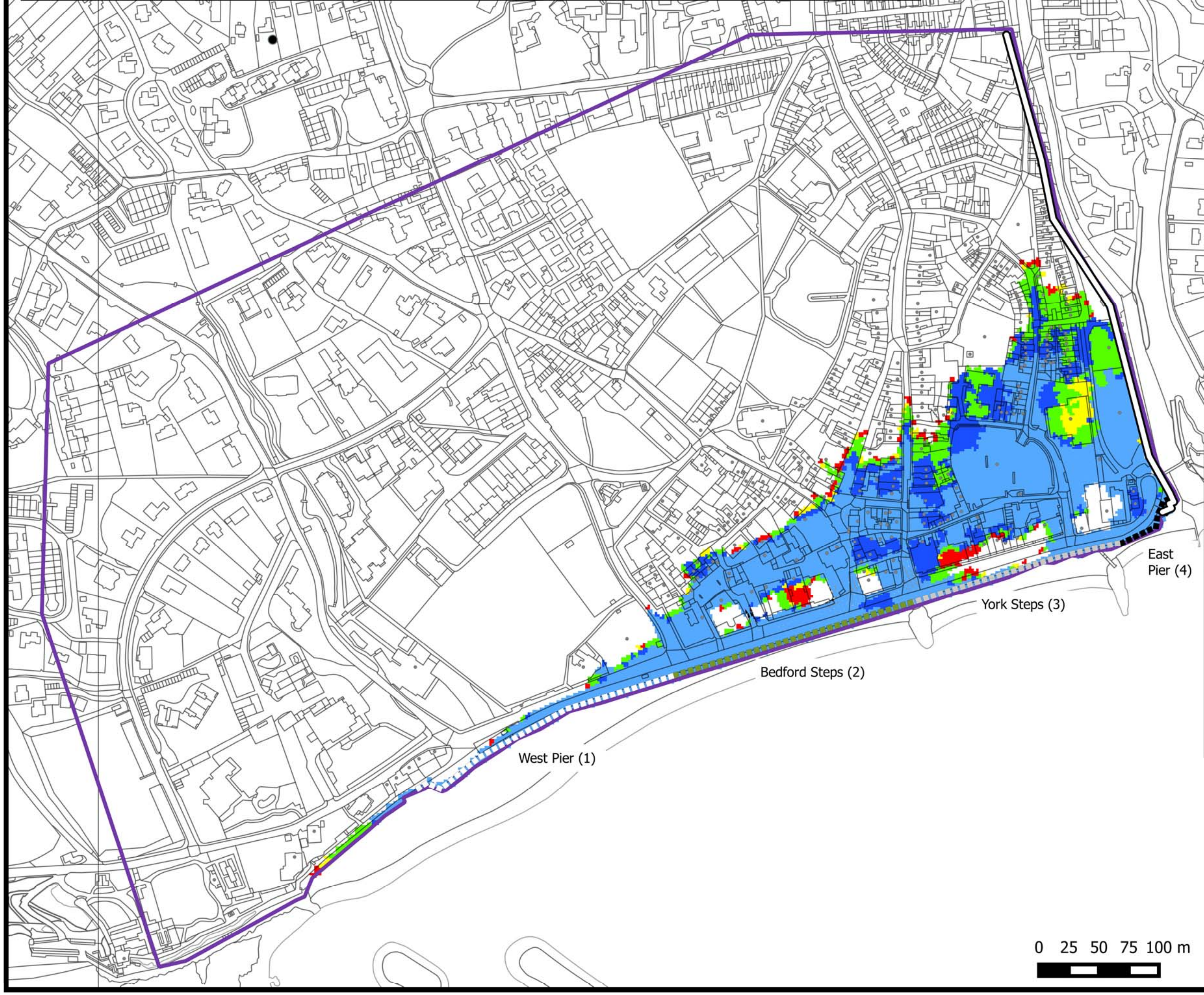
Annex B Model Schematic



Annex C Maps

C.1 Flood maps based on lowest beach levels

Calculated Property Damage (£)											
Event	1 in 1 Year		1 in 5 Years		1 in 50 Years		1 in 100 Years		1 in 200 Years		
Prop. Type	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	AAD
Residential	316811	19	758125	36	1568722	64	1782471	69	2151434	86	677661
Non-Residential	756438	9	1355834	19	2549042	49	2873416	52	3299944	57	1256459
Total	1073248	28	2113959	55	4117765	113	4655888	121	5451377	143	1934120



Location Plan

Legend

- 1 in 1 Year Event
- 1 in 5 Year Event
- 1 in 50 Year Event
- 1 in 100 Year Event
- 1 in 200 Year Event
- Model Extent
- Property
- 0.001 -1.000 m/s
- 1.001 -2.000 m/s
- > 2.000 m/s

Scale:

1:3,200

Environment Agency

Halcrow
A CH2M HILL COMPANY

Project Name:

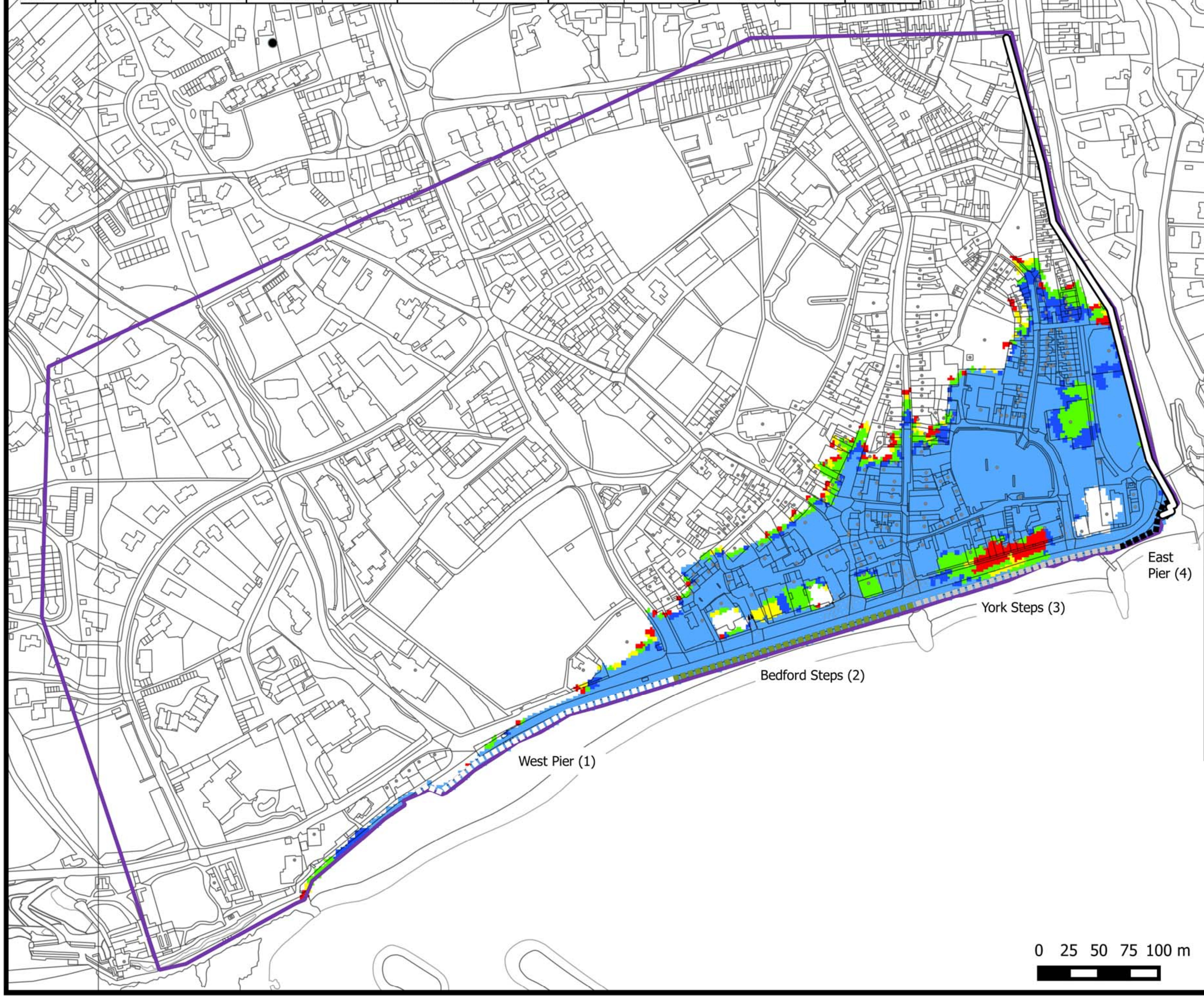
Sidmouth Flood Forecasting Scenarios

Map Title:

Flood Extents: 2014 Lowest Beach Sidmouth

Drawn by : Khairulanwar Jamil Revision : A
Checked by : Matthew Kennedy Date : 02/12/15
Print size : A3

Calculated Property Damage (£)										
Event	1 in 1 Year		1 in 5 Years		1 in 50 Years		1 in 100 Years		1 in 200 Years	
Prop. Type	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	AAD
Residential	882500	41	1467837	63	2473773	90	2707063	95	2993246	98	1350716
Non-Residential	1522263	22	2312931	45	3743399	59	4100966	59	4770441	63	2166074
Total	2404763	63	3780768	108	6217172	149	6808030	154	7763687	161	3516790



Location Plan

Legend

- 1 in 1 Year Event
- 1 in 5 Year Event
- 1 in 50 Year Event
- 1 in 100 Year Event
- 1 in 200 Year Event
- Model Extent
- Property
- 0.001 -1.000 m/s
- 1.001 -2.000 m/s
- > 2.000 m/s

Scale:

1:3,200

Environment Agency

Halcrow
A CH2M HILL COMPANY

Project Name:

Sidmouth Flood Forecasting Scenarios

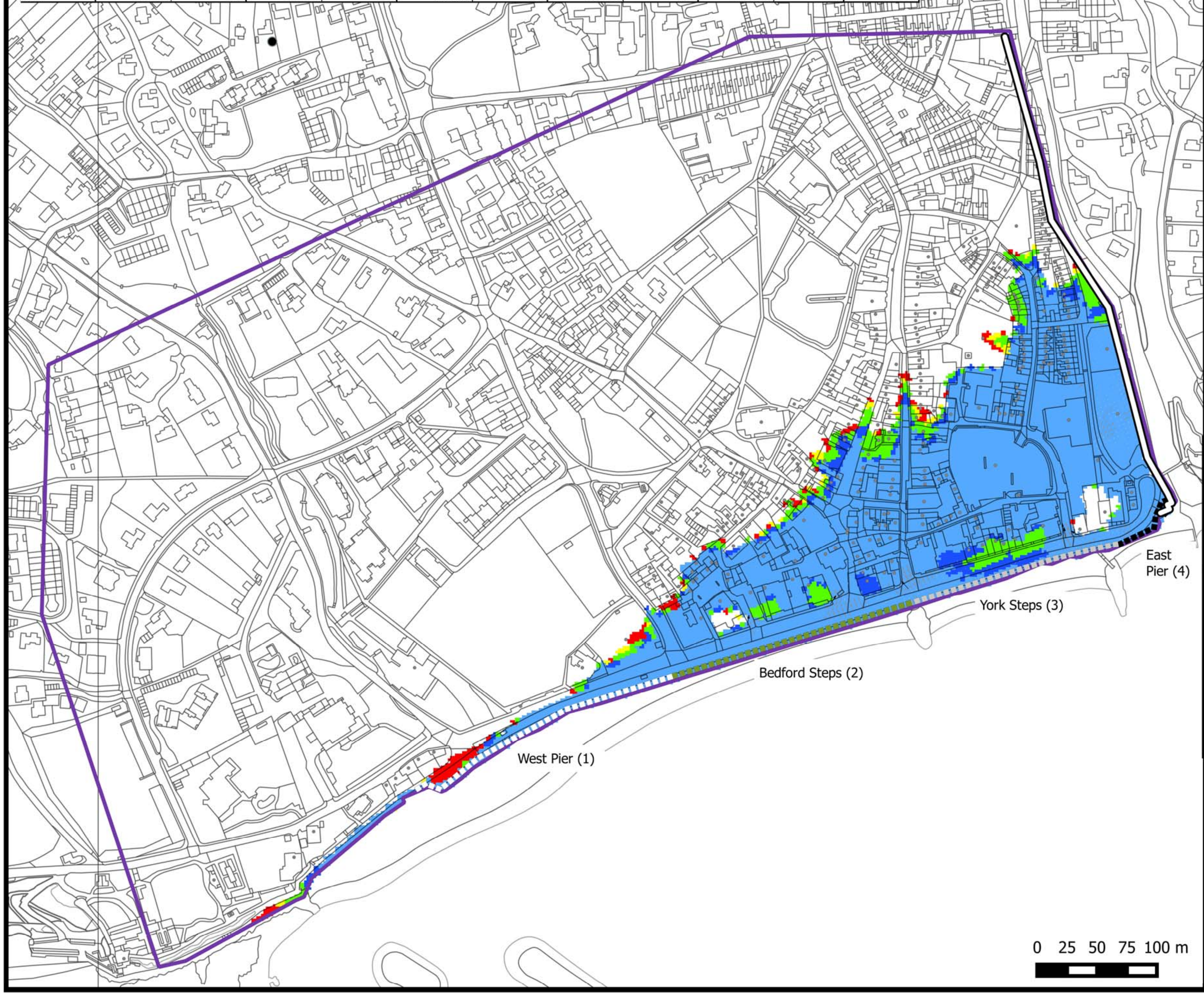
Map Title:

Flood Extents: 2065 Lowest Beach Sidmouth

Drawn by : Khairulanwar Jamil Revision : A
Checked by : Matthew Kennedy Date : 02/12/15
Print size : A3

Calculated Property Damage (£)

Event	1 in 1 Year		1 in 5 Years		1 in 50 Years		1 in 100 Years		1 in 200 Years		
Prop. Type	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	AAD
Residential	1818852	71	2557096	91	3358052	99	3526572	103	3778219	108	2354948
Non-Residential	2921798	52	3870378	59	5728148	68	6195326	68	7058033	80	3710936
Total	4740650	123	6427474	150	9086200	167	9721897	171	10836251	188	6065883



Location Plan

Legend

- 1 in 1 Year Event
- 1 in 5 Year Event
- 1 in 50 Year Event
- 1 in 100 Year Event
- 1 in 200 Year Event
- Model Extent
- Property
- 0.001 -1.000 m/s
- 1.001 -2.000 m/s
- > 2.000 m/s

Scale:

1:3,200

Environment Agency

Halcrow
A CH2M HILL COMPANY

Project Name:

Sidmouth Flood Forecasting Scenarios

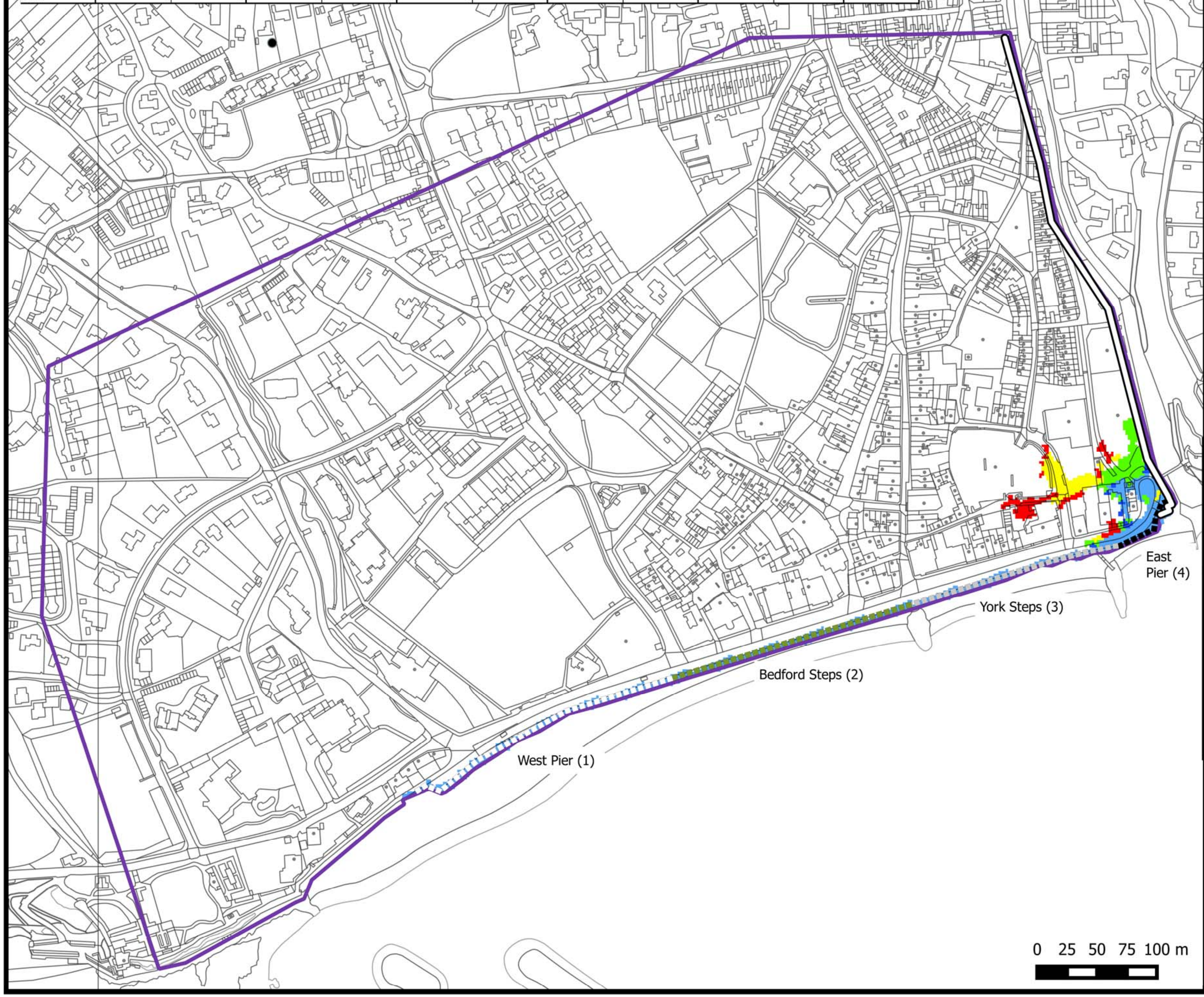
Map Title:

Flood Extents: 2115 Lowest Beach Sidmouth

Drawn by : Khairulanwar Jamil Revision : A
Checked by : Matthew Kennedy Date : 02/12/15
Print size : A3

C.2 Flood maps based on design beach levels

Calculated Property Damage (£)											
Event	1 in 1 Year		1 in 5 Years		1 in 50 Years		1 in 100 Years		1 in 200 Years		
Prop. Type	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	AAD
Residential	0	0	0	0	0	0	0	0	0	0	0
Non-Residential	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0



Location Plan

Legend

- 1 in 1 Year Event
- 1 in 5 Year Event
- 1 in 50 Year Event
- 1 in 100 Year Event
- 1 in 200 Year Event
- Model Extent
- Property
- 0.001 -1.000 m/s
- 1.001 -2.000 m/s
- > 2.000 m/s

Scale:

1:3,200

Environment Agency

Halcrow A CH2M HILL COMPANY

Project Name:

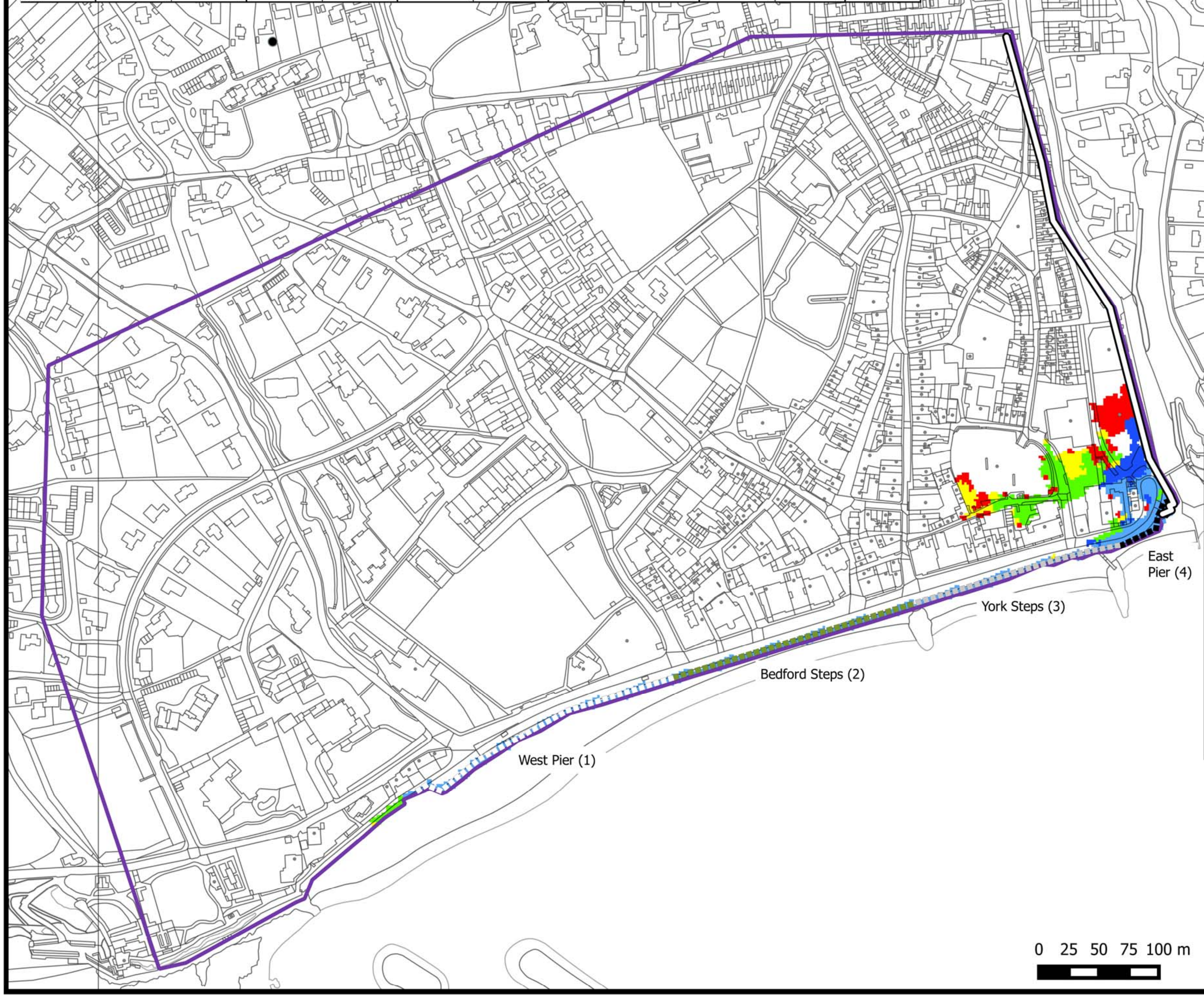
Sidmouth Flood Forecasting Scenarios

Map Title:

Flood Extents: 2014 Design Beach Sidmouth

Drawn by : Khairulanwar Jamil Revision : A
Checked by : Matthew Kennedy Date : 02/12/15
Print size : A3

Calculated Property Damage (£)											
Event	1 in 1 Year		1 in 5 Years		1 in 50 Years		1 in 100 Years		1 in 200 Years		
Prop. Type	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	AAD
Residential	0	0	0	0	0	0	0	0	0	0	0
Non-Residential	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0



Location Plan

Legend

- 1 in 1 Year Event
- 1 in 5 Year Event
- 1 in 50 Year Event
- 1 in 100 Year Event
- 1 in 200 Year Event
- Model Extent
- Property
- 0.001 -1.000 m/s
- 1.001 -2.000 m/s
- > 2.000 m/s

Scale:

1:3,200

Environment Agency

Halcrow
A CH2M HILL COMPANY

Project Name:

Sidmouth Flood Forecasting Scenarios

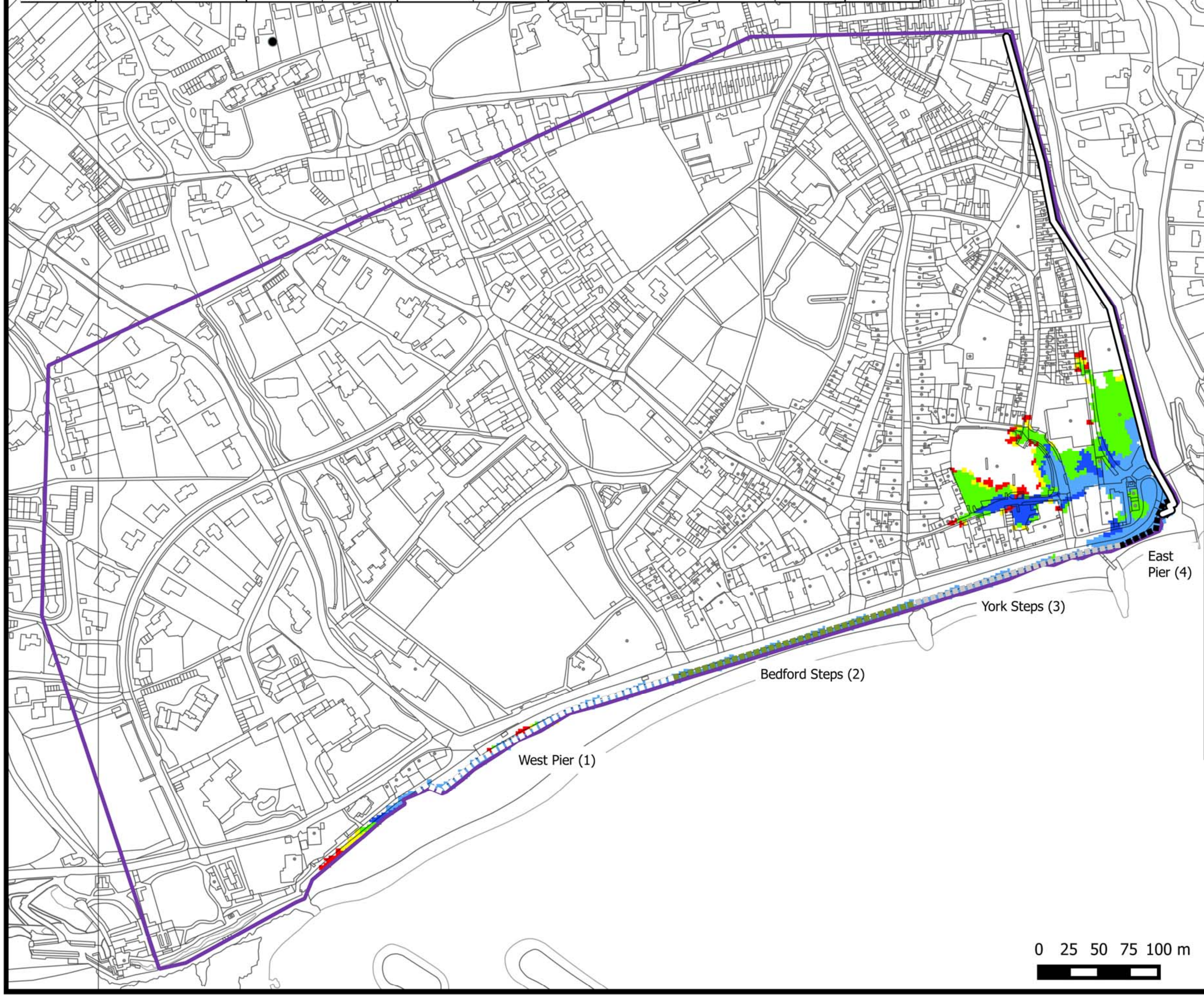
Map Title:

Flood Extents: 2065 Design Beach Sidmouth

Drawn by : Khairulanwar Jamil Revision : A
Checked by : Matthew Kennedy Date : 02/12/15
Print size : A3

Calculated Property Damage (£)

Event	1 in 1 Year		1 in 5 Years		1 in 50 Years		1 in 100 Years		1 in 200 Years		
Prop. Type	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	Cost of Damage	Flooded Prop.	AAD
Residential	0	0	0	0	0	0	0	0	0	0	0
Non-Residential	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0



Location Plan

Legend

- 1 in 1 Year Event
- 1 in 5 Year Event
- 1 in 50 Year Event
- 1 in 100 Year Event
- 1 in 200 Year Event
- Model Extent
- Property
- 0.001 -1.000 m/s
- 1.001 -2.000 m/s
- > 2.000 m/s

Scale:

1:3,200

Environment Agency

Halcrow
A CH2M HILL COMPANY

Project Name:

Sidmouth Flood Forecasting Scenarios

Map Title:

Flood Extents: 2115 Design Beach Sidmouth

Drawn by : Khairulanwar Jamil Revision : A
Checked by : Matthew Kennedy Date : 02/12/15
Print size : A3

Appendix B Cliff Road Property Valuation Data

Property	Valuations provide by Fulfords Estate Agents (Sidmouth), 9th July 2015	
	VALUE WITH EROSION	VALUE WITHOUT EROSION
Overthorpe	£ 375,000.00	£ 575,000.00
Shimoda	£ 500,000.00	£ 725,000.00
Uplands	£ 550,000.00	£ 795,000.00
Derby Cottage	£ 500,000.00	£ 725,000.00
Cliffe Cottage	£ 450,000.00	£ 650,000.00
Kenmore House	£ 525,000.00	£ 750,000.00
The Mynd / The Folly	£ 550,000.00	£ 795,000.00
Southernhay	£ 700,000.00	£ 1,000,000.00
Anthony / Seafield	£ 420,000.00	£ 600,000.00
Southerly	£ 385,000.00	£ 550,000.00
Longwood	£ 500,000.00	£ 650,000.00