Stonehaven Bay Coastal Flood Protection Study

Information Review Report

Final Report

September 2018

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Aberdeenshire COUNCIL

JBA Project Manager

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Revision history

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P01 / May 2018	Draft Report	G McCallum L Watson S McFarland
P02 / June 2018	Updated following comments from Aberdeenshire Council.	G McCallum L Watson S McFarland
P03 / June 2018	Updated following comments from Aberdeenshire Council.	G McCallum L Watson S McFarland
P04 / September 2018	Updated following comments from Stonehaven Flood Action Group	G McCallum L Watson S McFarland

Contract

This report describes work commissioned by Gavin Penman on behalf of Aberdeenshire Council by a letter dated 27 February 2018 and Purchase Order number 1002287. Dougall Baillie's representative for the contract was Scott Macphail and Aberdeenshire Council's representative for the contract was Graeme McCallum. Douglas Pender and Nicci Buckley of JBA Consulting carried out this work.

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Purpose

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JBA Consulting has no liability regarding the use of this report except to Aberdeenshire Council.

Acknowledgements

JBA thank SEPA and Aberdeenshire Council for the supply of data and the Stonehaven Flood Action Group (SFAG) for meeting JBA representatives during the site walkover.

Carbon footprint

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JBA is aiming to reduce its per capita carbon emissions.

Contents

1 Introduction

1.1 Study extent

Stonehaven is a coastal town located approximately 20 km to south of Aberdeen, with the village of Cowie located immediately to the north. The two communities sit within Stonehaven Bay on the shore of the North Sea, with the Rivers Carron and Cowie discharging into the bay (Figure 1-1).

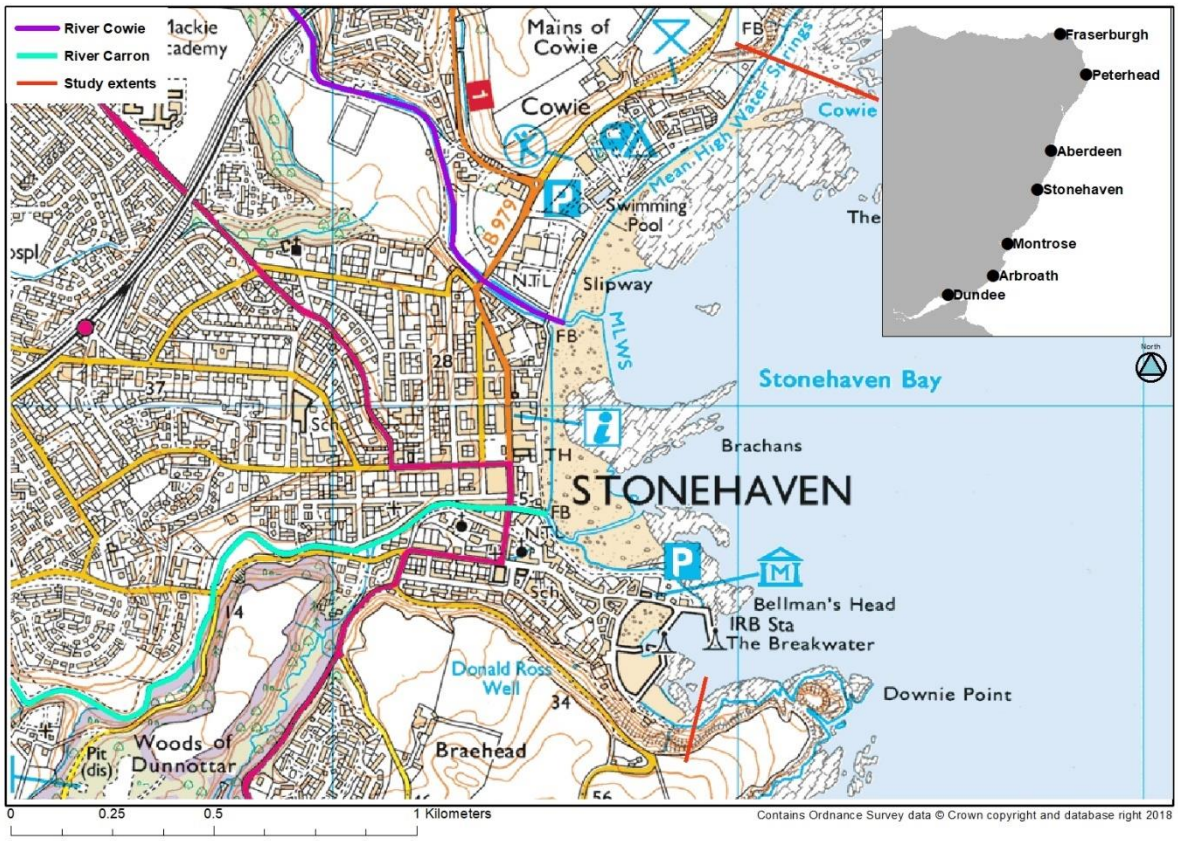

Figure 1-1: Location plan

1.2 Project aims

In terms of flood risk management, Stonehaven is part of the North East Local Plan District (NELPD), with Aberdeenshire Council designated the Lead Local Authority. The North East Local Flood Risk Management Plan (LFRMP) for 2016-2022, which supplements the local Flood Risk Management Strategy (FRMS) developed by the Scottish Environment Protection Agency (SEPA), identifies Stonehaven as a Potentially Vulnerable Area (PVA), being at risk of flooding from multiple sources.

The Stonehaven PVA (Figure 1-2) is designated 06/23 and is deemed to be at risk of flooding from pluvial, fluvial and coastal sources. At present Cowie is not included within the PVA, although it is proposed that this is revised to form an extended Stonehaven PVA within the NFRA2 (National Flood Risk Assessment 2) consultation process. Of concern to this study is the risk from coastal flooding, which the FRM plan identifies as having the potential to affect 110 people with Annual Average Damages (AAD) of £30,100. These values are based on generalised approaches which are typically used where detailed overtopping flood mapping is not available; details are available within JBA's 2014 Stonehaven Coastal Frontage Assessment report. The values will be updated following the study being undertaken herein.

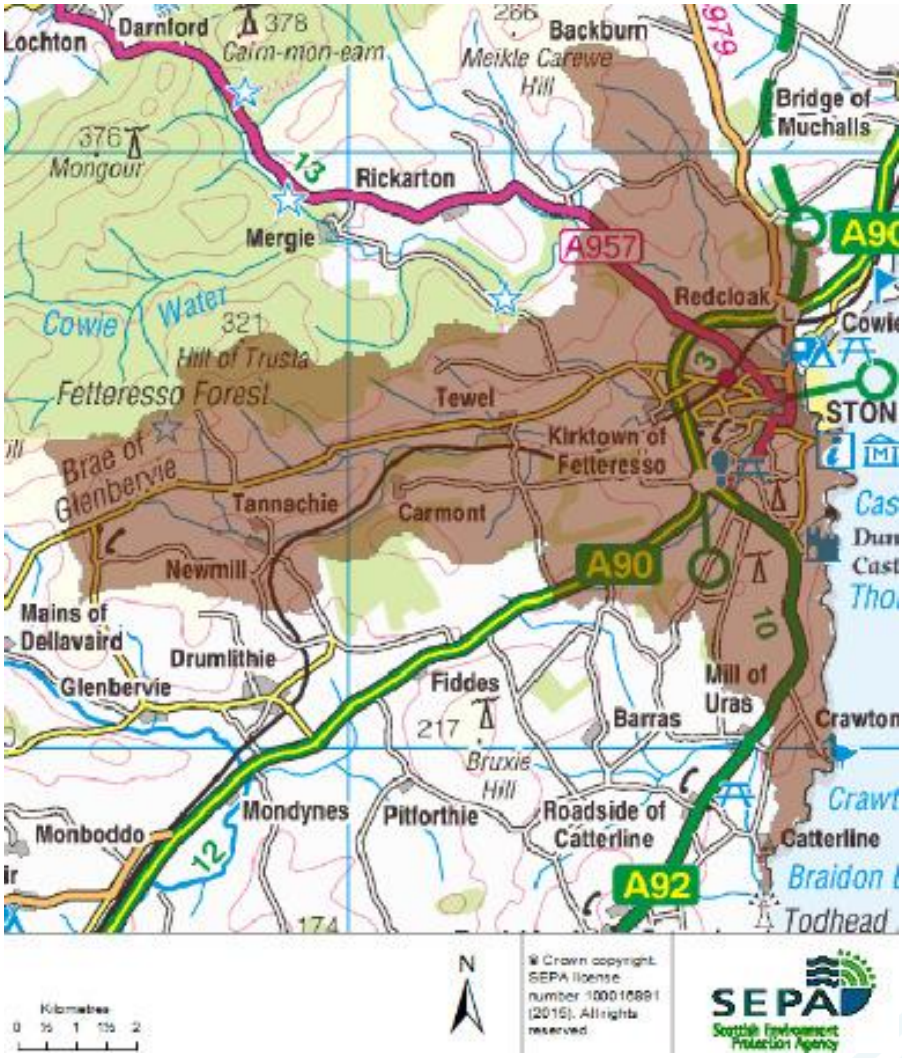

Figure 1-2: Stonehaven PVA from the Local FRM Plan

The objective of this project is to deliver a flood protection study to consider options to reduce coastal flood risk within the PVA (Table 1-1). The study will consider both existing and future flood and erosion risk to Stonehaven and Cowie and see the development of a 'long list' of potential options to mange this risk. The long list will be screened to a 'short list' of short, medium and long term options using multi-criteria analysis; this type of analysis allows for the consideration of more than just the engineering based pros and cons of each option, incorporating socio-economic, environmental, built heritage, landscape and tourism issues into the mix. Benefit-cost calculations based upon the short list options will subsequently reduce the list to a preferred option, which will aim to bring all of the important issues within Stonehaven and Cowie together.

Table 1-1: Local FRM Plan action

PVA	Agreed action	National and Local Authority ranks	Action description
PVA 06/23 Stonehaven	Flood Protection Study (FPS) Action ID 6023020005	National rank: 86 of 168 Local Authority rank: 4 of 12	A flood protection study is required to consider flood protection works to reduce the risk of coastal flooding in Stonehaven. The flood protection study should consider wave attenuation (beach management / recharge), coastal management actions (revetments), the construction of direct defences, relocation of properties and property level protection. Other actions may also be considered to develop the most sustainable range of options. The number of properties at risk of flooding from wave overtopping will be confirmed as part of the study. The estuary of the River Cowie up to the A957 road bridge will be included in this study.

2 Historical flooding

A review of historical flood events is crucial to provide context and develop an understanding of local flood mechanisms, as well as providing an evidence base for model development and calibration.

A review of coastal flood events was undertaken using data collected from:

- Aberdeenshire Council, including Biennial reports
- SEPA historical flooding database
- SNIFFER report[1]
- British Hydrological Society (BHS) Chronology of British Hydrological Events[2]
- Internet search

The coastal historical flood record for Stonehaven has been documented within Table 2-2, with a selection of photographs presented within Figure 2-1. The events range from waves overtopping the outer harbour wall with no effect on roads or properties, to large scale events that resulted in flooding to multiple properties and evacuations. In reality, overtopping of the outer harbour wall happens far more frequently than is recorded herein; a number of events have been included where good imagery is available, primarily for completeness of the record of coastal mechanisms that occur within the study area.

Table 2-1 summarises the number of flood events per year. From this, it is evident that better records of flooding exist for recent years (post 2005). This is due to the increased availability of online resources (e.g. YouTube videos) and the inclusion of coastal flood events in the Local Authority's Biennial Reports.

1 FRM10: Coastal Flooding in Scotland: A Scoping Study, SNIFFER, Final Report, August 2008
2 BHS Chronology of British Hydrological Events http://cbhe.hydrology.org.uk/ [Accessed February 2018]

Table 2-1: Summary of flood events by year

Year	No. of events
2018	2
2017	1
2016	3
2015	5
2014	6
2013	1
2012	3
2011	1
2010	2
2009	1
2008	3
2007	5
2006	0
2005	1
Pre 2005	4

Of all the historic events special consideration will be given to those of December 2012 and October 2014 when developing the modelling method and options appraisal. These have been the most significant in recent years resulting in major flooding to properties, structural damage and risk to life.

Table 2-2: Historical flooding events in Stonehaven

Date	Location	Details	Source
16/03/2018		Overtopping of wall at Cowie village, stepped revetment at Cowie promenade, central wall section and waves propagating up the River Cowie.	Details and photographs provided by Aberdeenshire Council.
02/03/2018		Sea high and causing some minor overtopping at promenade, reaching to shop fronts and shingle over road.	SEPA database
13/01/2017		Overtopping and shingle along The Links. Road inundated.	Aberdeenshire and Angus Coast FFS - Photograph supplied by Aberdeenshire Council
16/10/2016		Overtopping of outer harbour wall but no impact to roads or properties.	https://www.youtube.com/watch?v=9QRBcyQO500
09/01/2016		Overtopping of defences along The Links.	https://www.youtube.com/watch?v=uFe302knyVI
		Overtopping outside Turners Court and along the promenade, with shingle and seaweed debris across the road. Surge up the Cowie Water.	SEPA database
04/01/2016		Overtopping of outer harbour wall but no impact to roads or properties.	Metro http://metro.co.uk/2016/01/04/uk-weather-flood-warnings-in-place-across-country-as-more-rain-heads-our-way-5599685/
30/12/2015	Stonehaven harbour	High seas and wave action.	SEPA database
24/12/2015		Overtopping and shingle along The Links. Shingle along road.	AnAc FFS - Photograph supplied by Aberdeenshire Council
29/10/2015	Cowie village and promenade	Minor overtopping on to public road and green area at Boatie Row, Cowie, Stonehaven. Note seawall crest level = approx. 4.4mAOD. Minor overtopping and shingle deposited on public road at Beach Promenade, Stonehaven. Note seawall crest level = approx. 5.8.	SEPA database
19/10/2015	Cowie village	Overtopping of Boatie Row.	AnAc FFS - Photograph supplied by Aberdeenshire Council
24/02/2015		Overtopping of frontage and shingle strewn across road.	AnAc FFS - Historic photograph supplied by SEPA

Date	Location	Details	Source
09/10/2014	Stonehaven harbour	Large waves crashing over the barrier into the sheltered harbour behind. Substantial swell within harbour.	SEPA database
07/10/2014	Turners Court on the sea front (4 buildings with 54 units of sheltered accommodation)	Police evacuated a nursing home and houses in Stonehaven.	SEPA database
		Evacuation of homes in Stonehaven.	BBC News http://www.bbc.co.uk/news/uk-scotland-tayside-central-29519440
		Significant overtopping along Stonehaven harbour wall and along promenade.	https://www.youtube.com/watch?v=A2LG_zCA9cM
04/02/2014		Overtopping of defences.	AnAc FFS - Photograph supplied by Aberdeenshire Council
30/01/2014		Outer and inner harbour walls overtopping.	https://www.youtube.com/watch?v=5OeSmFLqFDw
29/01/2014		Overtopping of defences. Mostly foam drive.	AnAc FFS - Photograph supplied by Aberdeenshire Council
19/01/2014		Overtopping of outer and inner harbour walls. Overtopping also observed at the Marine Hotel.	https://www.youtube.com/watch?v=oeFolQcMmcA
05/12/2013		High SWL and overtopping of small waves	AnAc FFS - Historic photograph supplied by SEPA
15/12/2012		High tides and strong winds led to coastal flooding.	SEPA database
	Ironfield Lane, Stonehaven AB39 2AG	Debris inc. trees, bins and parts of walls blocking the driveways of properties in Ironfield Lane. Many residents are pensioners and are blocked in. Info source; Report to SCC.	SEPA database
	Boatie Row, Cowie, Stonehaven AB39 2RN	House and gardens along with neighbouring properties flooding from the sea. Water coming over the sea wall and running along backs of properties. Fire service attempted to pump water for 1.5 hours but unsuccessful. Info source; Report to SCC.	SEPA database
		Significant overtopping and damage to shorefront properties.	https://www.youtube.com/watch?v=_-UhH0ImdX0
13/10/2012		Overtopping of outer harbour wall.	https://www.youtube.com/watch?v=_jgoXTrrGAY

Date	Location	Details	Source
25/09/2012		Overtopping of outer and inner harbour walls. Overtopping also observed at the Marine Hotel.	https://www.youtube.com/watch?v=02qhjbzYvE4
21/01/2011		Significant overtopping of outer harbour wall.	https://www.youtube.com/watch?v=cGH4G1JrpV4
08/11/2010		Overtopping of promenade, Boatie Row and Cowie shorefront.	AnAc FFS - Photograph supplied by Aberdeenshire Council
08/09/2010		Significant overtopping and wrack marks along Beach Road.	https://www.youtube.com/watch?v=Ma_QNYR5UUM
		Overtopping along The Links and debris across the road.	https://www.youtube.com/watch?v=XDo3OrBxofc
12/01/2009		Overtopping of promenade, Boatie Row and Cowie shorefront.	AnAc FFS - Photograph supplied by Aberdeenshire Council
13/12/2008		Wave overtopping and flooding of seafront businesses.	Aberdeenshire Council 7th annual report
20/03/2008		Wave overtopping at Stonehaven and Cowie – flooding of seafront property. Sandbags issued.	SEPA database
10/03/2008		Seafront properties and amenity land flooded, especially towards Cowie from overtopping water. Shingle and rock armour thrown over sea wall, damage to Cowie sea wall copings.	SEPA database
		Overtopping of Cowie Promenade.	AnAc FFS - Photograph supplied by Aberdeenshire Council
		Stonehaven and Cowie – flooding to seafront business	Aberdeenshire Council 7th annual report
22/11/2007		Overtopping at Turners Court and Promenade	SEPA database
13/04/2007		Overtopping at Turners Court and Promenade	SEPA database
06/03/2007		Overtopping and significant overland flow at Beach Road/The Links.	https://www.youtube.com/watch?v=kbi1QedxQ7A
05/03/2007		Overtopping of Cowie Promenade.	AnAc FFS - Photograph supplied by Aberdeenshire Council
21/02/2007		Overtopping of Stonehaven and Cowie Promenade.	AnAc FFS - Photograph supplied by Aberdeenshire Council
26/04/2005	Cowie	Emergency repairs needed on Cowie sea wall. Sea wall at Cowie undermined.	SEPA database
		Coastal erosion and collapse of sea wall foundations	Aberdeenshire Council 5th annual report

Date	Location	Details	Source
1996	Cowie	Overtopping of Cowie promenade occurred several times in the first 3 months of 1996.	HR Wallingford 1998 report
1982	Stonehaven: Beach front	Looking towards the seawall (from the north side) near the bridge over the Cowie Water. Beyond the south side of the river, evidence of beach erosion by the large volume of shingle has been piled up against the breakwater.	SEPA database
		Looking towards the seawall (from the south side) near the bridge over the Cowie Water. Beyond the seawall is being overtopped by high waves, and the promenade is covered with shingle and other debris.	SEPA database
		Looking towards the seawall (from the south side) near the bridge over the Cowie Water. The promenade to the rear of the seawall has been flooded, the top of the seawall has been adorned with seaweed.	SEPA database
30/01/1956		Engineering works at Stonehaven flooded. Water pouring through main breakwater in harbour - minor damage.	SEPA database
31/01/1953		Engineering works flooded (6 inches depth). Minor damage to breakwater.	Documentary records of coastal storms in Scotland 1500-1991 A.D. Volume 2

Figure 2-1: Example photographs of historical flooding

10 March 2008

Overtopping of wall at Cowie village. Photograph supplied by Aberdeenshire Council.

Overtopping of central wall section. Photograph supplied by Aberdeenshire Council.

Flooding of car park behind swimming pool due to overland flow from overtopping of Cowie promenade. Photograph supplied by Aberdeenshire Council.

12 January 2009

Overtopping of wall at Cowie village. Photograph supplied by Aberdeenshire Council.

5 March 2007

Overland flow due to overtopping at Cowie promenade. Photograph supplied by Aberdeenshire Council.

8 November 2010

Flooding in Cowie village due to overtopping. Photograph supplied by Aberdeenshire Council.

7 October 2014

Waves crashing on the outer breakwater, Stonehaven harbour. Photograph source: http://www.bbc.co.uk/news/uk-scotland-tayside-central-29519440

Photograph from drone footage showing wave overtopping along Cowie promenade. Photograph source: https://www.youtube.com/watch?v=V82zGT6-J0g

15 December 2012

Aftermath along central wall section due to wave overtopping. Photograph supplied by Aberdeenshire Council.

Overtopping of stepped revetment at Cowie promenade. Photograph supplied by Aberdeenshire Council.

16 March 2018

Overtopping of central wall section. Photograph supplied by Aberdeenshire Council.

Overtopping at Cowie promenade. Photograph supplied by Aberdeenshire Council.

Wave action within the harbour. Photograph supplied by Aberdeenshire Council.

3 Flood Mechanisms

3.1 Coastal flooding

The current SEPA coastal mapping (Figure 3-1) was produced by GIS projection modelling of still water levels alone (tidal levels plus storm surge), and as such does not include the potential risk due to wave overtopping. The current mapping suggests that there is limited risk from coastal flooding within Stonehaven and Cowie; however, this is not supported by the historical record presented above, which shows that there is a high risk of flooding due to wave overtopping. SEPA's coastal flood mapping is currently being updated along this stretch of coastline to include wave overtopping.

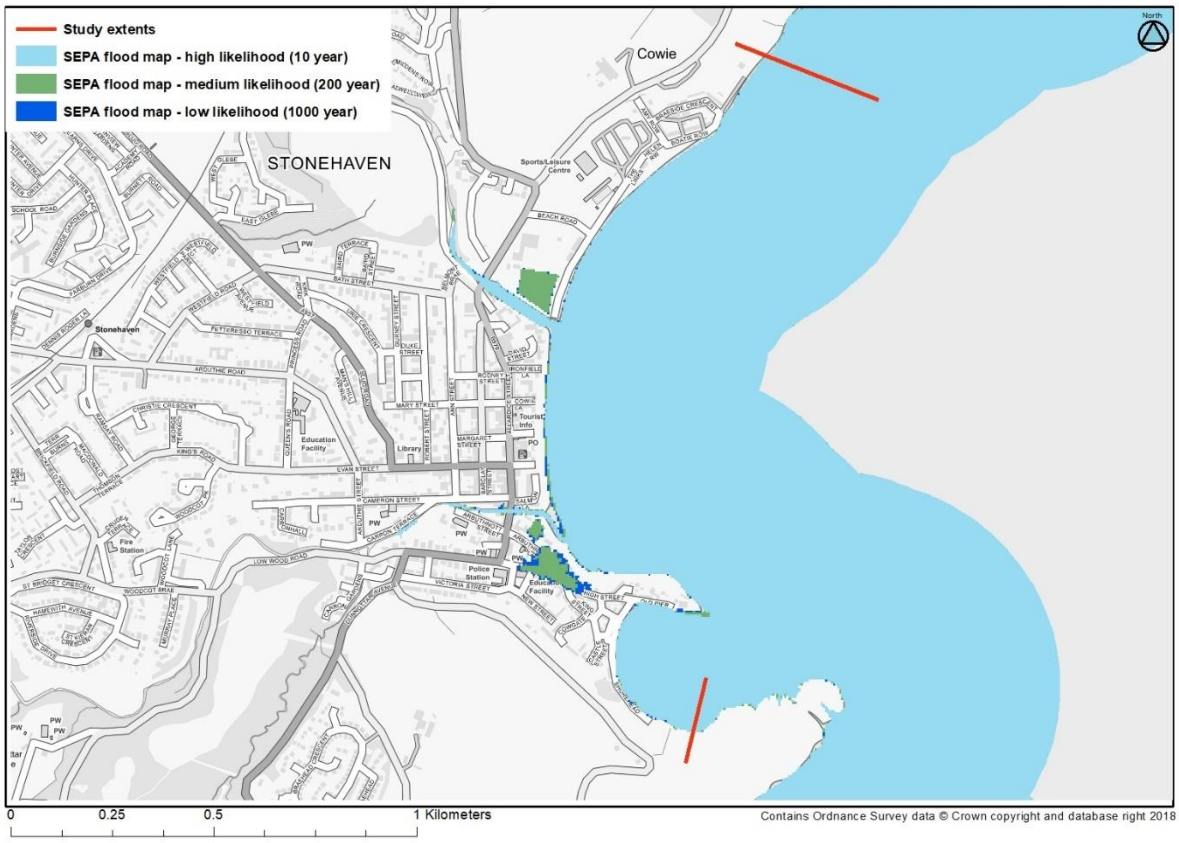

Figure 3-1: SEPA coastal flood extents

3.2 Surface water (pluvial) flooding

Although surface water flooding is not the focus of this study, the potential impacts of options on surface water flood risk need to be considered. Comment will also be made on the potential for sea level rise due to climate change to impact upon the local drainage network.

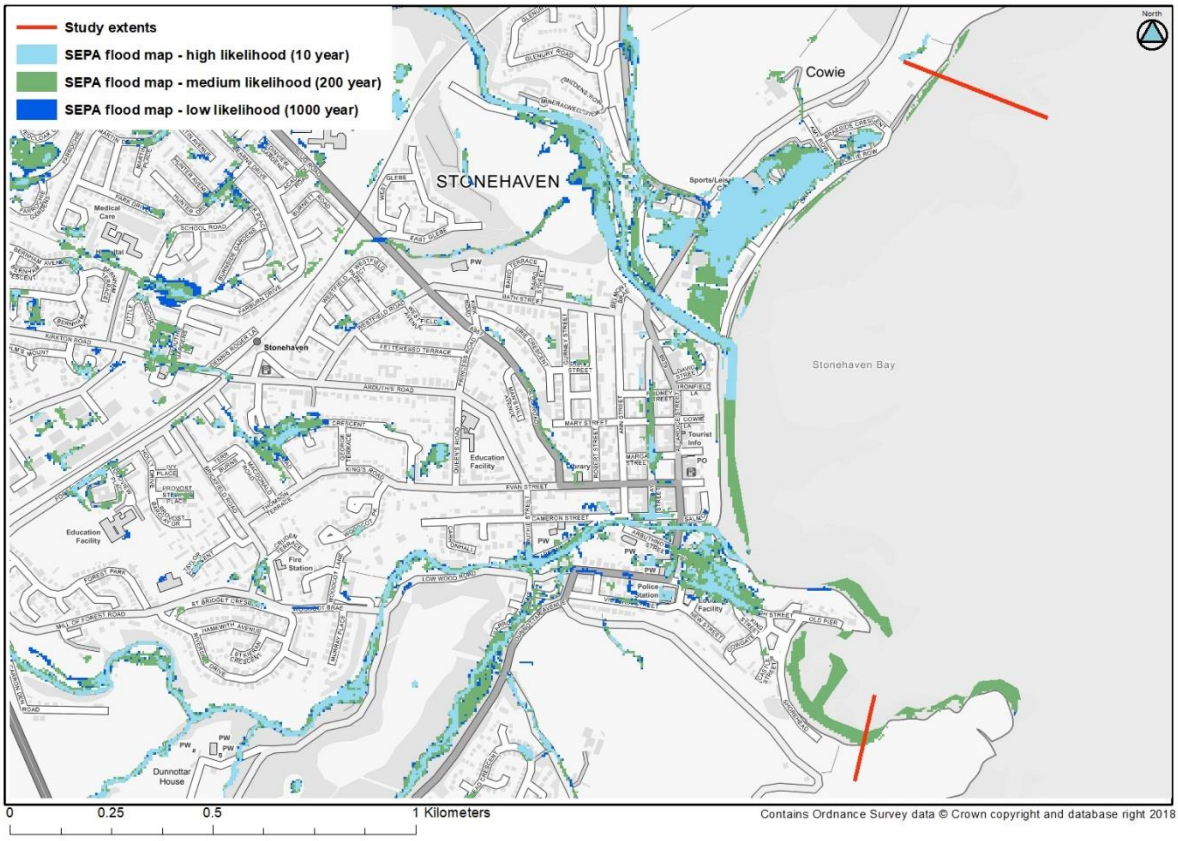

Figure 3-2: SEPA pluvial flood extents

3.3 Fluvial flooding

The Rivers Carron and Cowie both outfall to the North Sea within Stonehaven Bay. The River Carron is tidal up to the A957 road bridge and the Cowie up to the B979 road bridge. The configuration of the two watercourses at the coast was historically very different, with the River Cowie running along the front and the two merging prior to discharging out into the bay (Figure 3-3). It is understood that the River Cowie broke through the shingle bar that was present during a storm event and has run its present day course since. Historical maps show the River Cowie running its former course in 1950 and its present day course in 1967, with the exact date when it changed unknown.

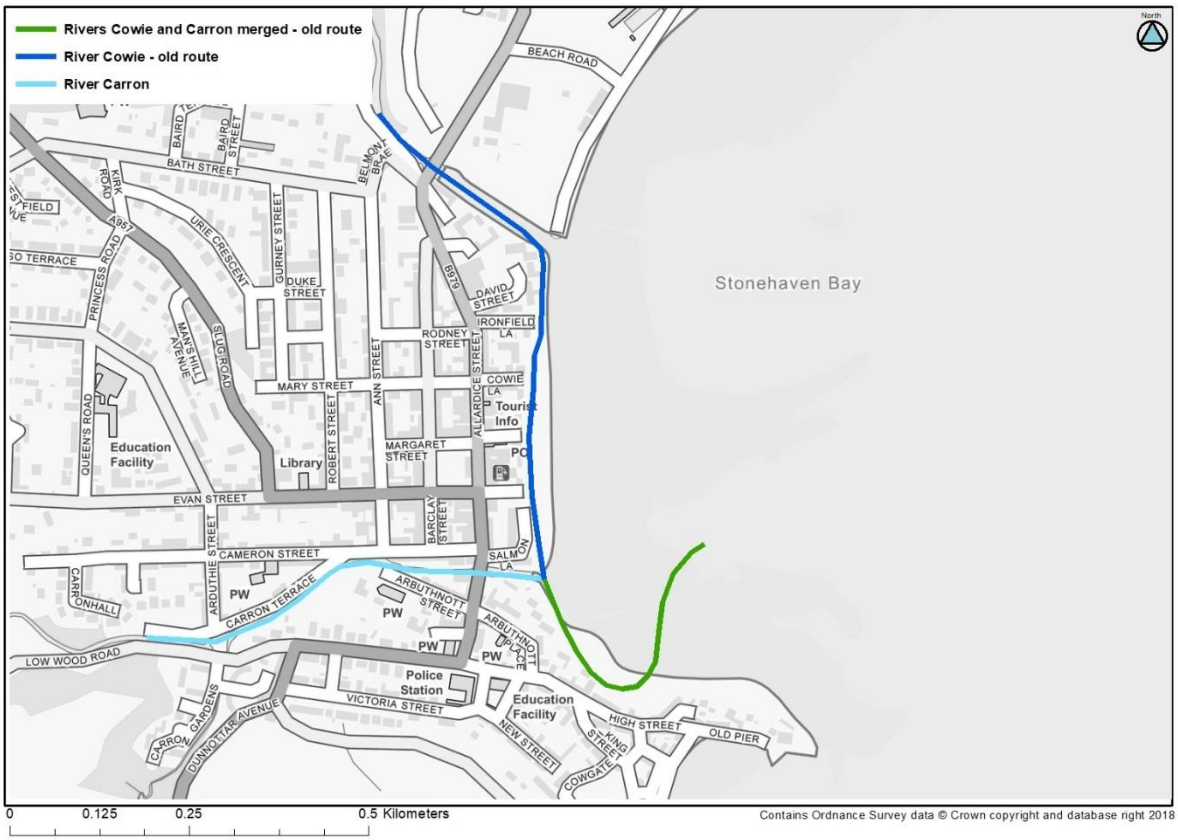

Figure 3-3: Historical configuration of the Rivers Cowie and Carron at the coast

Although fluvial flooding is not the primary focus of this study, both watercourses have tidal reaches at their downstream extents. Still water levels and waves will be considered on the Cowie up to the B979 road bridge and the impacts of sea level rise will be assessed for the tidal reach of the River Carron. It is understood that construction of the River Carron fluvial flood protection scheme is due to commence in August 2018.

SEPA's existing fluvial flood extents are presented within Figure 3-4.

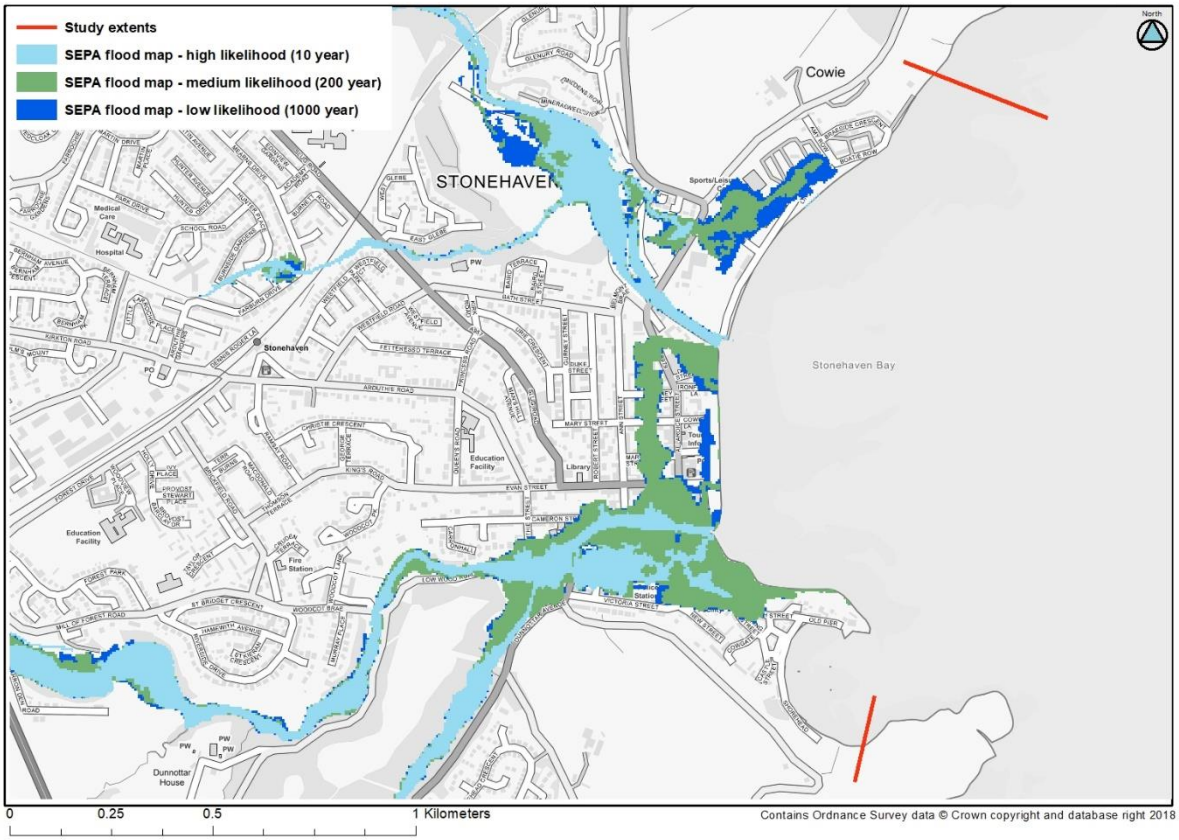

Figure 3-4: SEPA fluvial flood extents

4 Existing defences

The frontage varies through Stonehaven and Cowie, with the general areas denoted within Figure 4-1 below.

Figure 4-1: Areas and defence types within Stonehaven Bay

Each of these areas/defence types is summarised below, running from south to north.

Aberdeenshire Council's records and the Scottish Flood Defence Asset Database (SFDAD) website were checked for any details of any of the defences.

Harbour area

The harbour area of the town is prone to flooding from a combination high sea levels and wave action from waves that can enter the mouth and run along the walls of the inner basin. Review of the historic flood records show that the properties along Shorehead have flooded in the past as well as several near misses when sandbags have been deployed as a precaution.

In 2017, Aberdeenshire Council commissioned an inspection of the structural assets within the harbour. This concluded that several of the elements are in very poor condition with multiple structural defects. The content and recommendations made here will be reviewed in detail during the structural surveys, with a focus on any defects or works likely flood risk. It is understood that the diver inspection was repeated in May 2018; this up to date information is to be provided by Aberdeenshire Council once available.

No other drawings or details are available.

Figure 4-2: Aerial image of harbour area

Rock armour section

To the north of the harbour is a public car park that is fronted by a substantial rock armour revetment. This is placed along the headland from the outer breakwater to within the bay.

No drawings or details have been made available and the condition of this will be reviewed during the structural surveys. The outcomes and recommendations of this will be used to inform the options appraisal and any further engineering works required.

Figure 4-3: Aerial image of rock armour section

Boardwalk section

The boardwalk section is a mixture of rock armour and a shingle beach and also includes the mouth of the River Carron; the Carron outfall is considered in its own right below.

South of the Carron, the beach is prone to erosion with the timber walkway washed away during the December 2012 event. This is likely a combination of wave energy and the influence of the mouth of the River Carron, which directs flow longshore towards the area. Shingle deposited in the mouth of the River Cowie is periodically recycled and placed here to reduce erosion, with limited success.

No drawings or details of the boardwalk are available.

Figure 4-4: Aerial image of boardwalk section

River Carron outfall

Historically the River Carron discharged freely across the beach (Figure 4-5). In 1998 HR Wallingford were commissioned by Aberdeenshire Council to consider options for maintaining a channel for the River Carron across the beach; concerns were that the discharge of floodwater was being hampered by the low clearance of the footbridge crossing the channel and the deflection and partial siltation of the channel across the beach. The report[3] considered a number of training wall configurations, with the recommended option presented within **Figure** 4-6.

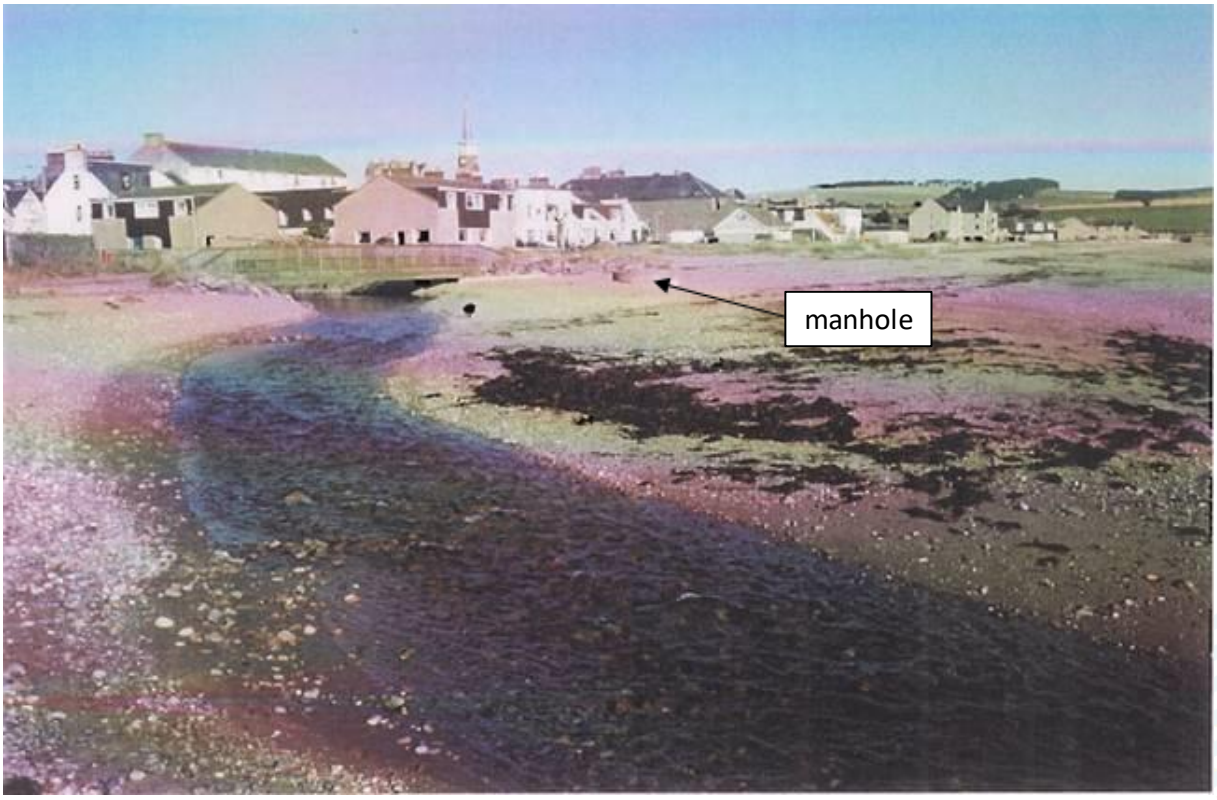

Figure 4-5: Historical natural outfall of the River Carron

[3] Stonehaven Seawall, Aberdeenshire – Feasibility Study of Improvements, Report EX3731, November 1998

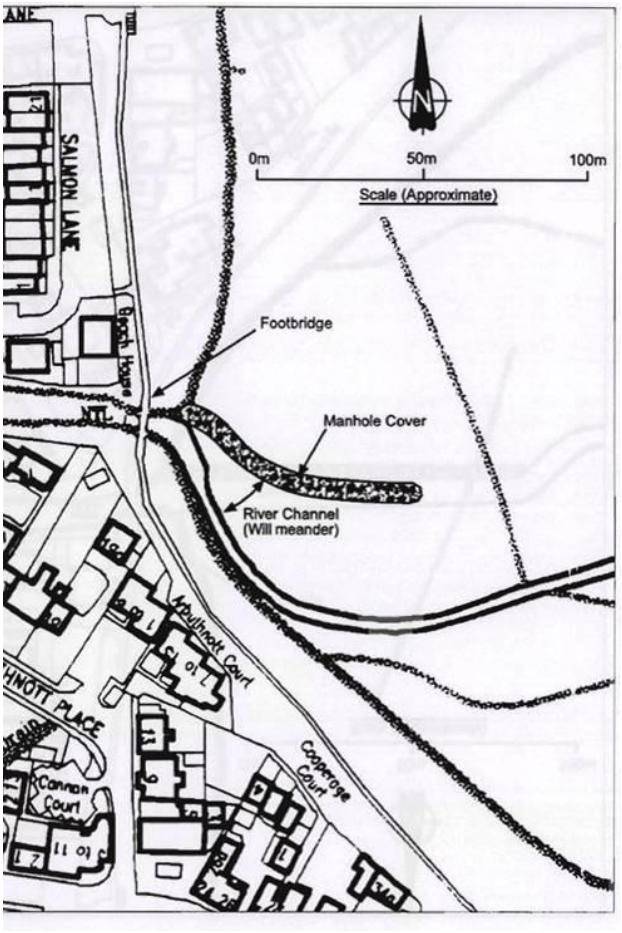

Figure 4-6: Recommended training wall option from HR Wallingford report

The configuration of the rock armour training structure that was built at the mouth of the Carron differs from that shown above. Details of the final design and the date of construction have been requested from Aberdeenshire Council, and these details will be incorporated into future phases of the study once they are made available. The current configuration at the mouth of the Carron can be seen in **Figure** 4-7.

Figure 4-7: Current configuration at the mouth of the River Carron

Central wall section

The central wall section is a combination of a concrete sea wall and a shingle beach. Construction drawings of the northern half of the sea wall have been provided by A Turner of the Stonehaven Flood Action Group (SFAG) and will be reviewed as part of the options appraisal and engineering design phases, during which the risk of failure and potential for undermining of the wall will be assessed.

During high energy wave events, it appears that gravel from the foreshore is transported landward and has deposited in front of the wall, almost completely burying the seaward face; this results in a change of beach profile, essentially creating a ramp for the waves run up. Sediment movement patterns between 3 beach surveys, undertaken in 2008, 2013 and 2018, will be assessed as part of a wider erosion assessment within the modelling phase of this study.

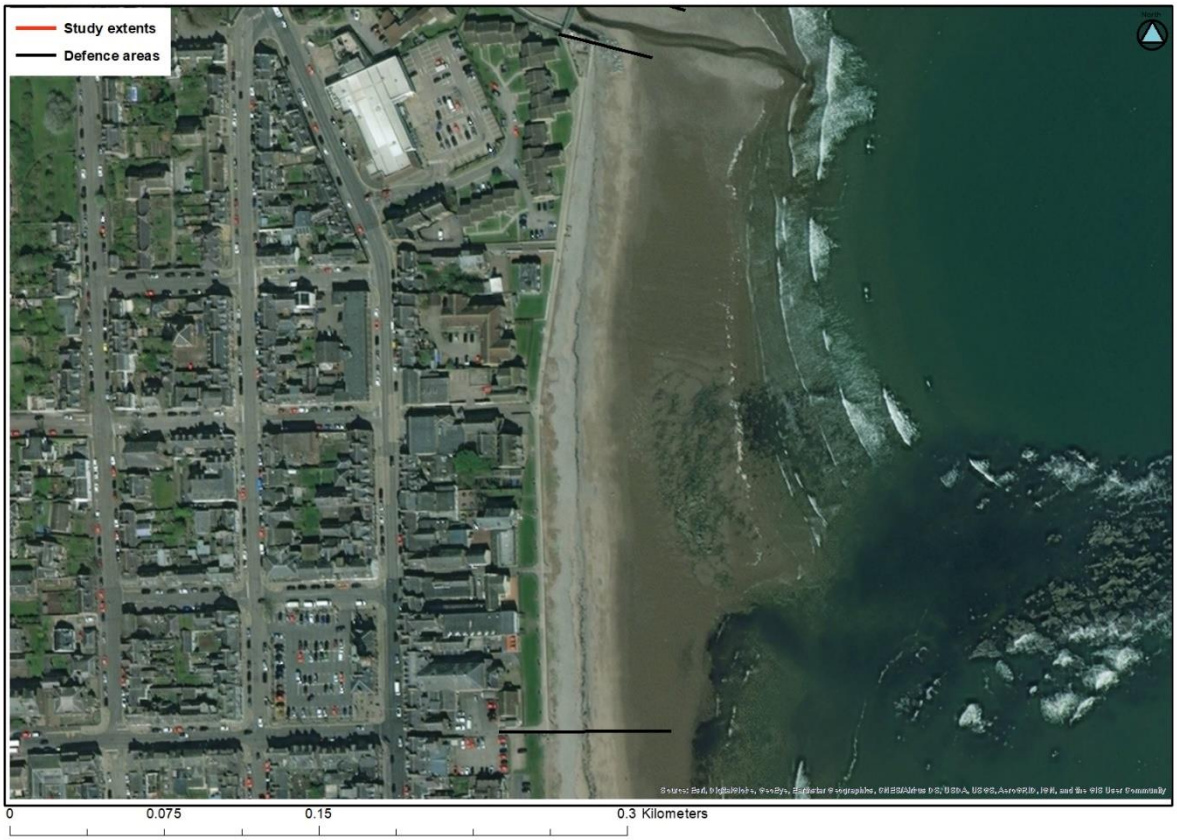

Figure 4-8: Aerial image of central section

River Cowie section

The River Cowie section consists of a combination of concrete walls, concrete revetments, and steel sheet piles. The defences extend from the mouth of the River to the B979 road bridge, 200m upstream. During storm conditions, waves can propagate into the mouth of the river and break on the weir at the road bridge. The south bank of the river is also at risk from overtopping from obliques waves that enter the mouth and roll along the revetment.

Drawings of the structures are available from Aberdeenshire Council and will be reviewed in detail during the options appraisal and engineering phases. It is understood that the section on the north bank has been undermined in the past and will likely require additional engineering works.

Figure 4-9: Aerial image of River Cowie section

Stepped revetment section

The stepped revetment section forms the main coastal defence along Cowie promenade; this section has as a number of commercial properties. It runs from the mouth of the Cowie to the northern end of the open air pool. It consists of a stepped concrete revetment with a small wave return wall at the crest. A drawing of the defences has been extracted from the Aberdeenshire Council archive. Although these are considered formal sea defences, from and engineering point, there is no entry in the Scottish Flood Defence Asset Database (SFDAD).

Over the years there has been significant damage to the structure from undermining and scour at the toe. Currently most of the toe is buried under a considerable depth of sediment. The sediment here is much finer than further south in the bay, with rock armour installed along the toe of the defences in 2006.

Overtopping here happens regularly, with significant damage to the shorefront commercial properties occurring in recent years. The local topography means that when significant overtopping occurs water will flow west, flooding the leisure centre car park, caravan park, and bowling club.

Figure 4-10: Aerial image of stepped revetment section

Cowie wall section

The Cowie wall section runs from the open-air pool to the limit of the residential properties in Cowie. It is a vertical concrete wall that experiences extremely variable sediment depths at the toes. The natural rocky foreshore provides a degree of protection from incoming wave energy, but frequent overtopping exists. Flooding to properties here also occurs during the more extreme events.

Drawings are available from Aberdeenshire Council archives for the southern half of this section.

Figure 4-11: Aerial image of Cowie wall section

Recommendation: It is recommended that a visual structural survey to classify the defences, assess their condition, record defects, assess residual life and where possible assess toe depth (through excavations during site walkover) is undertaken.

5 Environmental background

5.1 Environmental designations and data

The study will need to consider international, national and local designated sites. It is understood that the Garron Point Site of Special Scientific Interest (SSSI) covers much of the northern half of Stonehaven Bay and is of both geological and botanical interest. The Garron Point Special Area for Conservation (SAC) covers Garron Point and northwards past Skatie Shore and is a site of European importance. In addition, Stonehaven Bay is part of the Muchalls to Stonehaven Bay Local Nature Conservation Site (LNCS), which reflects the biological and geological importance of the site at a regional level.

NESBReC habitat data is available for the area for the time periods 2004-07, 2010-12 and 2013-15, as well as designated species and bat survey information. Details on Invasive Non-native Species (INNS) have also been requested.

Environmental reporting for the River Carron fluvial scheme has also been provided by Aberdeenshire Council.

Recommendation: It is recommended that a baseline ecology report including site walkover is undertaken in order to ensure all potential environmental constraints are considered within the optioneering. However, it is understood that Aberdeenshire Council only wish to undertake a desktop study at this stage and will consider the need for site surveys at the options stage.

5.2 River Basin Management Plan

Stonehaven Bay is located within the Garron Point to Downie Point (Stonehaven) coastal water body, ID 200517. The water body has 'Good' overall status, and this has been consistent every year from 2008 to 2016. In 2014, this was split down into 'Good' for physical condition, 'High' for freedom from invasive species and 'high' for water quality.

Recommendation: It is recommended that a desktop baseline report be prepared, which can be used to assess the potential options and ensure the classification of the water body would not be downgraded due to any proposed works.

5.3 Natural Flood Management

Natural Flood Management (NFM) and morphology pressures data has been requested from SEPA but was not available at the time of writing.

Recommendation: It is recommended that a baseline natural flood management desktop report be prepared; this will review the SEPA data and recommend any options that could feed into the appraisal process.

5.4 Built landscape and heritage

It is understood that there are a number of issues that will need to be considered in reference to the wider build environment and heritage. This includes scheduled monuments, shipwrecks, the potential for buried features due to the medieval origins of Cowie village, and a range of listed buildings.

Existing information includes the reporting from the River Carron fluvial scheme and the Historic Environment Scotland map search facility.

Recommendation: It is recommended that a built landscape and heritage baseline report be prepared, which can be used to assess the potential options in reference to the wider built environment.

5.5 Geotechnical Investigation

A range of information is available from previous Geotechnical Investigations (GI); reports from the River Carron fluvial scheme have been provided by Aberdeenshire Council, any data Scottish Water hold from the construction of the sewer main along the front has been requested, and additional existing information may be available through Envirocheck.

Recommendation: It is recommended that a geotechnical engineering desk study be prepared in order to collate and review the existing information in the context of a coastal flood protection scheme.

6 Modelling

There have been several previous assessments focused along the shorefront at Stonehaven; these are summarised below along with a summary of ongoing projects and the proposals for modelling as part of this study.

6.1 Previous assessments

Several previous assessments of the flood and erosion risk along the frontage have been undertaken in the last 20 years. These have primarily been high-level with the intended outcomes to provide recommendations for future management and mitigation options that can be considered during a detailed study.

A summary of these is provided below with detailed consideration of the findings being used to inform the options appraisal and engineering components of the detailed study being undertaken here.

River Carron Rock Armour Study – JBA Consulting (January 2015)

JBA undertook a study to investigate wave propagation within the River Carron and the implications this could have in relation to the proposed fluvial defences. The study included wave modelling, an assessment of the geometry of the river training wall and high level cost estimates of options to reduce the risk.

Stonehaven Coastal Frontage Assessment – JBA Consulting (September 2014)

JBA consulting undertook a high-level assessment of the flood risk from wave overtopping along the coastal frontage. This involved the assessment of overtopping rates for historic storms and potential extreme conditions.

The approach adopted was simplified and allowed for high-level recommendations for future management practices to be made. This included beach nourishment to increase width in front of critical sections, sediment recycling practices, and a high-level cost-benefit analysis.

The main recommendation was that different solutions were required for different sections of the frontage, and a detailed numerical modelling and options appraisal is required.

Stonehaven Topographic Baseline Survey Report 2013 – Canterbury City Council (June 2013)

The report provides an overview of the topographic survey work undertaken in May 2013; this survey was a repeat of that undertaken in December 2008. The report goes on to summarise analysis undertaken to assess the changes in beach volume that had occurred between the 2 surveys. This analysis split the frontage into 4 sections as well as differentiating between the beach and the foreshore.

Stonehaven, Inverbervie and Rosehearty Beach Management – HR Wallingford (April 2009)

This study focused on the use of the 2008 topographic survey to understand whether there was any change to the flood and erosion risk along the front due to the changes

in beach levels. Considering the survey, no changes to the recommendations of the 2006 study (discussed below) were made. Further recommendations regarding the increased frequency of monitoring to better understand the effect of sediment and shingle levels on the overtopping of the stepped revetment at Cowie were made.

Aberdeenshire Topographic Survey Programme, Stonehaven – Canterbury City Council (December 2008)

The report provides an overview of the topographic survey work undertaken in December 2008. The survey included levels across the beach and 27 cross sections.

Coastal Management Plan NESFLAG Region, Scotland – HR Wallingford (May 2007)

This document provided a recommendation for how to implement an effective Coastal Management Plan (CMP) for the northeast of Scotland. This included discussions on how data should be collected and managed to inform management practices. As the aim of the report was to provide effective guidance, the flood and erosion problems at Stonehaven were not considered specifically.

Wave Overtopping, Crovie, Whitehills and Stonehaven – HR Wallingford (May 2006)

This study provided a high-level assessment of the extreme wave conditions and overtopping risk to the stepped revetment along the Cowie promenade. Consideration was given to various beach levels that highlighted the importance of maintaining high beach levels to reduce overtopping.

Mitigation methods to reduce overtopping and erosion at the toe of the structure were proposed. These considered an increase in beach level, rock armour toe protection, and raising of the wave return wall.

The combinations considered showed that, to reduce overtopping rates to within a tolerable limit would require substantial modification to the toe and crest of the structure.

Stonehaven Bay, Aberdeenshire – A Strategic Review of Beaches and Coastal Defences – HR Wallingford (July 1999)

This study provided a review of the coastal defences at Stonehaven and provided recommendations for future coastal management practices that could reduce the flood and erosion risk. The main recommendations were structural repairs to existing defences that would prevent undermining. Again, the importance of maintaining constant beach levels along the critical defences was highlighted.

Stonehaven Seawall, Aberdeenshire – Feasibility Study of Improvements – HR Wallingford (November 1998)

This study reviewed the flooding and erosion problems that were being regularly observed along the front. This highlighted the maintain a high beach level was critical to reduce overtopping and limit the potential for the seawall being undermined. Consideration was given to measures that could be employed along the Cowie stepped revetment to maintain a high beach level and reduce erosion at the toe. This included the construction of a rock berm as the maintenance of levels through beach nourishment was not considered a sensible option.

6.2 Ongoing Studies

SEPA Coastal Flood Mapping Update – Phase 1 (2017 – 2018)

JBA are currently updating SEPA's coastal flood maps for the north east of Scotland, including the Orkney islands. When complete, these maps will include the risk of coastal flooding from, SWL, wave overtopping and wave runup. The methodology and

datasets being used are the same that are proposed for this study so much of the modelling practices will already have been tried and tested.

Stonehaven is one of the locations where the risk of flooding is being assessed using detailed, wave, overtopping and inundation modelling. The individual components developed as part of this will be used as the starting point for this flood study, with refinements made if necessary.

SEPA Coastal Flood Forecasting System (2017 – 2018)

JBA are currently developing a coastal flood forecasting system for SEPA for the Aberdeenshire and Angus Coastline (AnAc). Stonehaven is one of the communities to receive detailed forecasts of wave overtopping. The information and experience gained here has fed into the Coastal Flood Mapping Update and will therefore also be incorporated into the modelling developed here.

6.3 Proposed modelling

The modelling proposed as part of this study includes a wave transformation model, wave overtopping modelling, a TuFlow inundation model and erosion modelling. This modelling will require a range of input data; this is summarised below.

Coastal Flood Boundary Dataset (CFBD)

The CFBD provides estimates of extreme sea levels at a 2km chainage around the entire UK coast. The levels are obtained through statistical analysis of surge residuals at A-Class and intermediate gauges throughout the UK, with areas between estimated from a combination of interpolation and hydrodynamic modelling.

These levels were first provided by Defra in 2011 but have recently been updated to make use of longer historical records. This update is scheduled for release imminently and will form the SWL component of the flooding analysis and design of defence options.

Multi-variate offshore wind and wave data

SEPA have recently developed offshore multivariate wind and wave datasets for use in coastal flood studies. These provide 10,000 years' of statistically representative extreme events and will allow for the AEPs required to develop the options appraisal and engineering design to be undertaken.

Figure 6-1 shows the location of these points within the SEPA wave model of the Aberdeenshire and Angus Coast, with point WW3 point 2664 (only wind comes from 2625) being the most relevant to estimating flood risk from waves at Stonehaven.

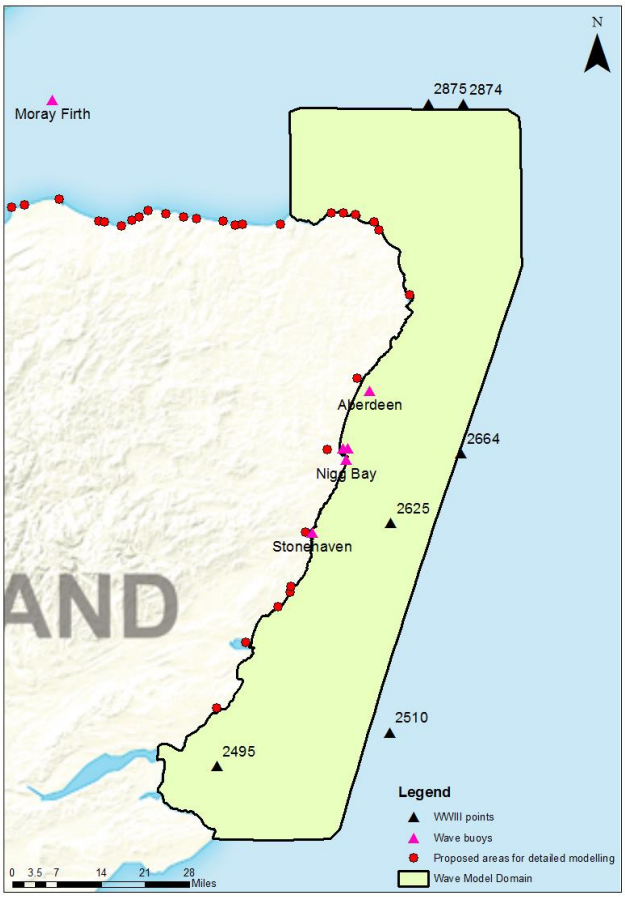

Figure 6-1: SEPA SWAN model and WW3 points used for developing the offshore multivariate datasets

The dataset contains approximately 2 million events and will be reviewed in detail to maximise efficiency during the modelling and analysis phase. Figure 6-2 provides a summary of the event dataset, comparing the observed and simulated parameters considered in the multivariate analysis.

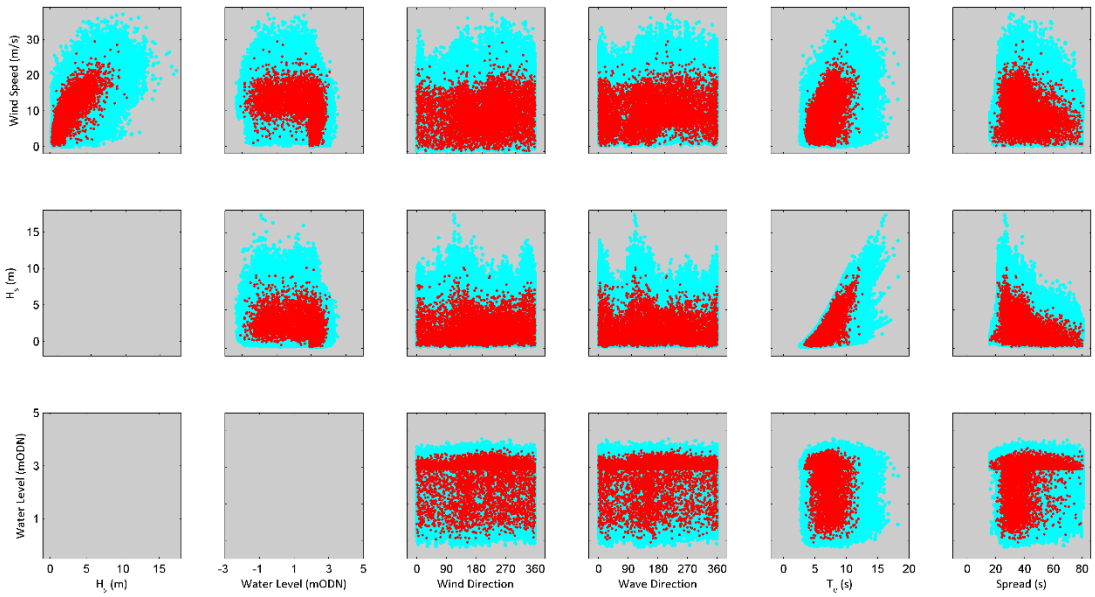

Figure 6-2: Summary of SEPA offshore multivariate dataset events relevant to Stonehaven. Red data points show the observed events from WW3, with the turquoise points indicated the simulated data that will inform the wave conditions and overtopping risk

Climate change

The UK Climate Projections (UKCP) provides the relative sea level rise scenarios that will be used in the study. The current datasets were released in 2009 (UKCP09) but new estimates are scheduled to be released in November 2018 (UCKP18). The appropriate dataset (and emissions scenarios) will be confirmed through consultation with SEPA as it is important to ensure a nationally consistent approach across all coastal flood studies that are to be considered during the July 2019 prioritisation exercise. Should SEPA advise on the use of the UKCP18 data, this could lead to a delay in delivery.

Should the UKPC09 dataset be used to inform the options appraisal, the Council should be aware that they will need to run models again for the new climate change predictions as part of any detailed design process.

Topographic data

The SWAN wave transformation model will require bathymetry data to represent the ocean floor offshore. OceanWise data was used in the existing wave model for the area; licencing arrangements for the use of this data are currently being finalised by SEPA and Aberdeenshire Council.

SEPA's Phase 2 LiDAR covers the full extent of Stonehaven (Figure 6-3) and is at 1m resolution. This is appropriate to use as a base DTM within the modelling.

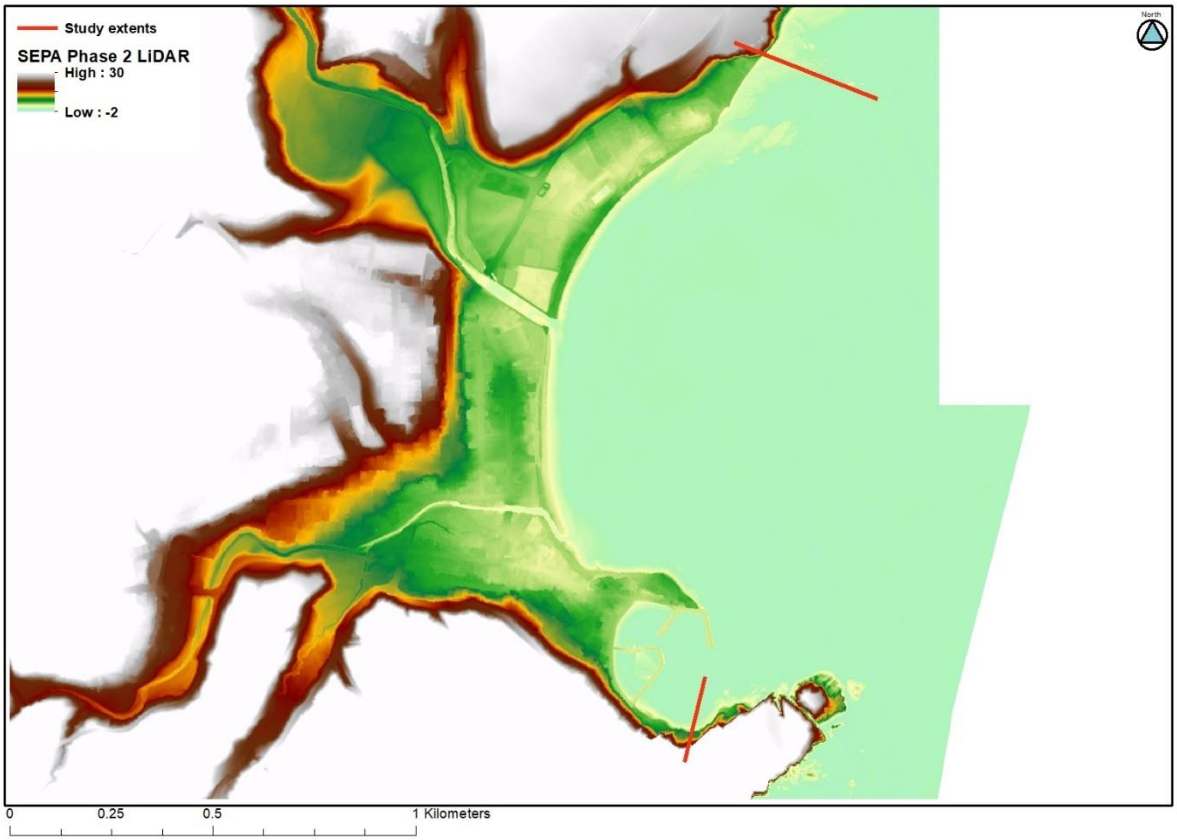

Figure 6-3: SEPA Phase 2 LiDAR coverage

The following topographic survey exists for the study area:

- Beach survey 2008
- Beach survey 2013
- Crest and cross section survey (for FFS) 2017
- Threshold surveys for fluvial scheme

The extent of the two beach surveys are shown in Figure 6-4, the extent of the 2017 FFS survey presented within Figure 6-5 and the locations of the existing threshold surveys shown in Figure 6-6.

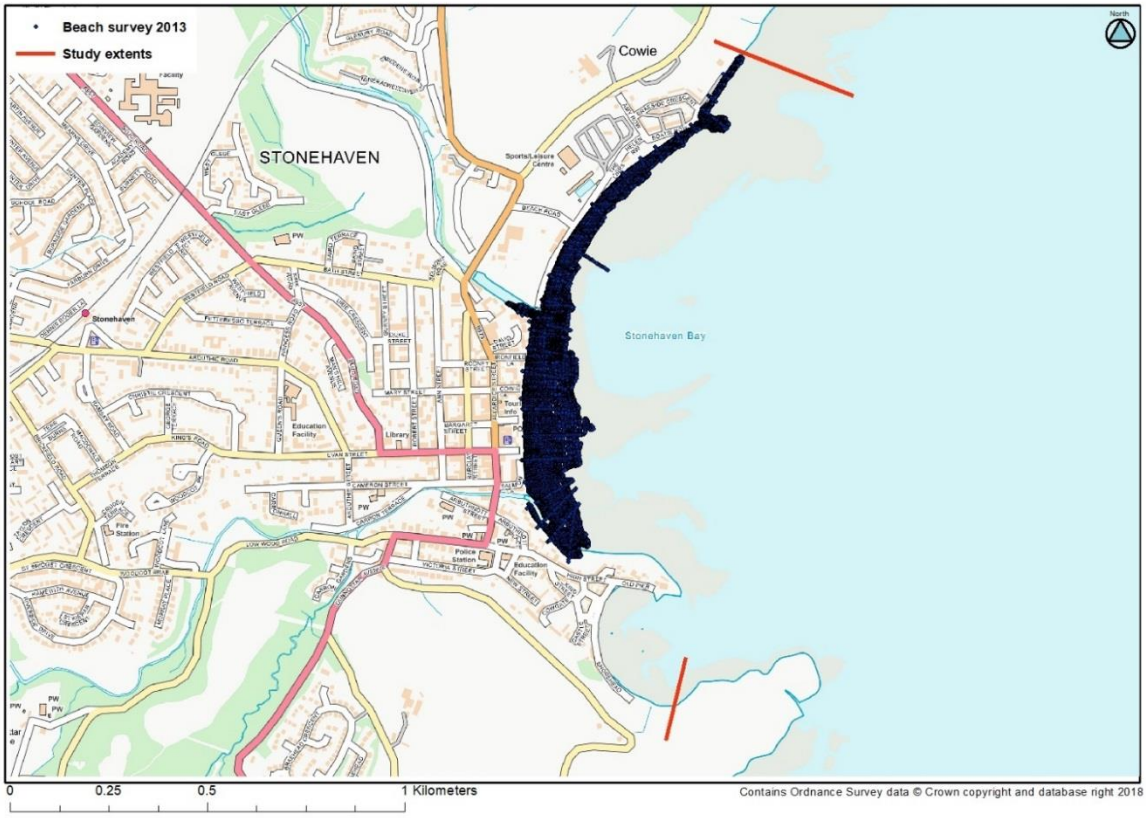

Figure 6-4: Extent of the 2013 beach survey

Figure 6-5: Extent of the 2017 FFS survey

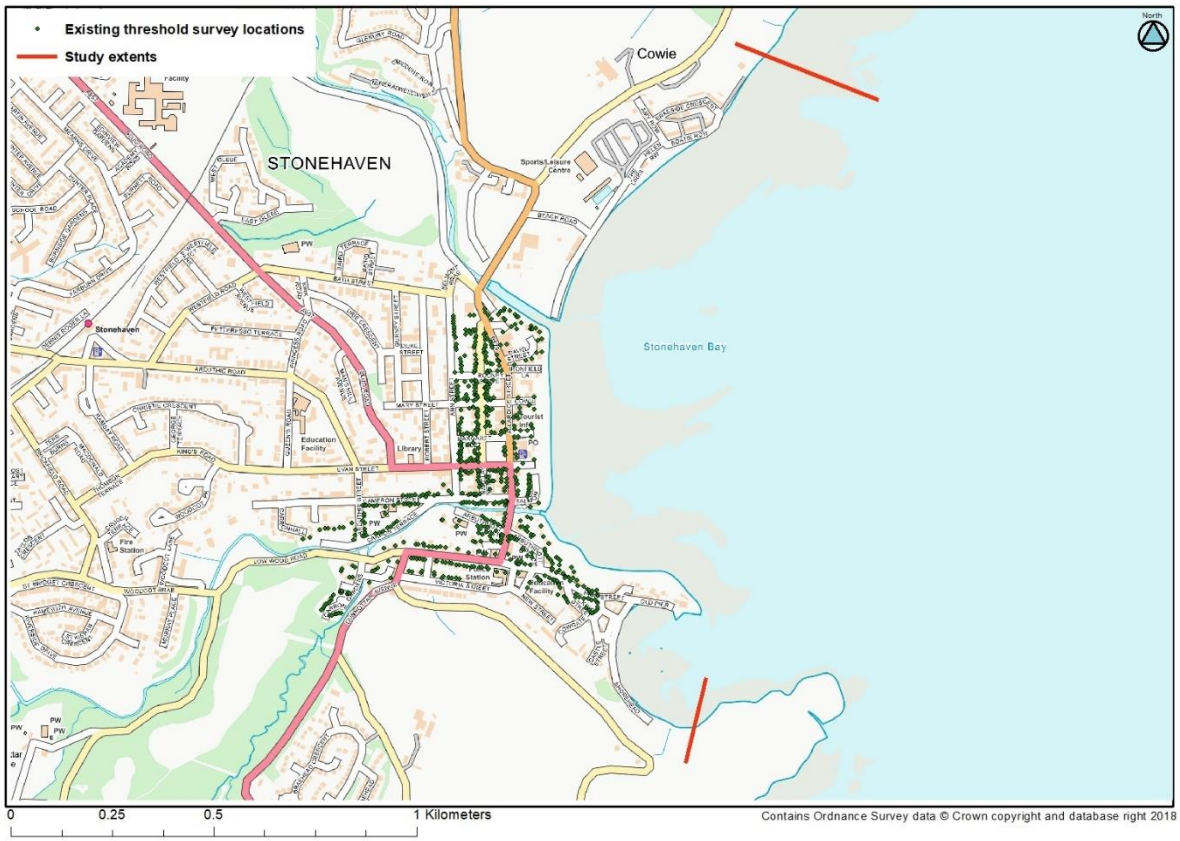

Figure 6-6: Locations of the existing threshold survey levels

Recommendation: It is recommended that the beach plan survey be repeated along with a new survey of the harbour structures and additional threshold levels for areas likely to be affected by flooding due to wave overtopping.

7 Summary of recommendations

Table 7-1: Recommendations for further studies

Recommendations	Currently programmed
Structural survey including visual inspection of all coastal defences. Excavation of toes to assess condition.	Yes
Baseline ecology survey including site walkover	No
Desktop ecology survey	Yes
Desktop baseline RBMP	Yes
Desktop baseline NFM study	Yes
Built landscape and heritage assessment	Yes
Desktop geotechnical desk study	Yes
Beach plan survey and new survey of harbour defences	Yes
Make contact with Stonehaven Town Partnership regarding research on value of tourism to the town.	Yes
Make contact with Stonehaven Flood Action Group (SFAG) regarding information on demographics and vulnerability of residents.	Yes

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