Stonehaven Bay Coastal Flood Protection Study

Final Report

December 2019

www.jbaconsulting.com

JBA Project Manager

Nicci Buckley BSc MSc CSci MCIWEM C.WEM
Unit 2.1 Quantum Court
Research Avenue South
Heriot Watt Research Park
Riccarton
Edinburgh
EH14 4AP

Revision History

Revision Ref/Date	Amendments	Issued to
P01 / 5 December 2019	-	Lee Watson and Graeme McCallum, Aberdeenshire Council
P02 / 19 December 2019	Comments from Aberdeenshire Council	Lee Watson and Graeme McCallum, Aberdeenshire Council

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. The work was commissioned via Dougall Baillie. Dougall Baillie's representative for the contract was Scott Macphail and Aberdeenshire Council's representative for the contract was Graeme McCallum. Johnny Coyle, Hannah Otton, Douglas Pender, Johan Skanberg-Tippen and Nicci Buckley of JBA Consulting carried out this work.

Prepared by .... Hannah Otton BSc

Assistant Analyst

.... Douglas Pender MEng PhD MCIWEM C.WEM

Chartered Senior Engineer

.... Nicci Buckley BSc MSc CSci MCIWEM C.WEM

Principal Analyst

Reviewed by .... David Bassett BSc MSc CEnv MCIWEM C.WEM

Director

Purpose

This document has been prepared as a Final Report for Aberdeenshire Council. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

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

Acknowledgements

JBA would like to thank Aberdeenshire Council, SEPA and Stonehaven Flood Action Group for the provision of data and information to support this work.

Copyright

© Jeremy Benn Associates Limited 2019.

Carbon Footprint

JBA is aiming to reduce its per capita carbon emissions.

Executive summary

JBA were commissioned in April 2018 to undertake a coastal flood study for Stonehaven Bay, encompassing the town of Stonehaven and the village of Cowie. This report is the culmination of this work and explains the steps carried out to identify a preferred set of interventions that offer sustainable flood risk management whilst also seeking to improve the environment and benefit the local community.

Stonehaven has a history of coastal flooding and a review of historical events formed the first step in the modelling of coastal flood risk and the development of options. The modelling undertaken included the assessment of still water levels, wave overtopping, flood inundation modelling and erosion modelling both for present day conditions and with an assessment for climate change. Models were calibrated against historic events for which anecdotal evidence was available and developed to understand a range of scenarios.

A long list of potential flood protection options was developed, and subsequently screened using a multi-criteria approach in order to form a short list of options for each section of the frontage. The short-listed options have been developed to a concept design level, with full economic assessment.

The preferred option being presented for prioritisation can be summarised as follows:

- **North** – Raise the existing defences immediately and adapt to a new sea wall when the residual life of the current defences is exceeded in year 30;
- **Central** – Implement an adaptive beach recharge scheme with associated wall raising immediately and replace Cowie Water defences in year 30;
- **Harbour** – Manage the medium-term risk through PFR and construct new defences when the residual life of the current defences is exceeded in year 30.

This fits in with the Scottish Government's 'managed adaptive approach', giving due consideration in the differences between present day and future risk as the effects of climate change are realised.

The table below highlights the preferred option for each zone through time:

Location	Year 0	Year 30	Additional	Maintenance
North	Raise existing wall	New sea wall	-	Annual maintenance of sea walls
Central	Raise existing wall and new recharge scheme including control structures	New walls along Cowie tidal reach	Adapt recharge volume over time to meet end of period design life. 4 instalments every 20 years	Annual maintenance of wall, control structures and beach. 5 yearly recharge to offset sediment losses. Beach monitoring.
Harbour	PFR	New rock revetment at harbour carpark; new stepped revetment in inner harbour; managed realignment of south harbour	-	Annual maintenance of PFR and new structures

The present value damages for the entire study area are **£28.3 million**. The preferred option has a present value cost of **£22.7 million**, with year 0 capital costs of **£9.5 million**. Present value benefits for the preferred option are estimated to be **£26.6 million**, resulting in a BCR of **1.17**.

Whilst the primary benefit of a scheme would be to provide flood protection to the residents and businesses within Stonehaven, the following additional benefits would also be realised:

- Improved public health and well-being.
- Reduction in risk to life following a number of previous evacuations of seafront properties.
- Provide protection to a population with a high proportion of vulnerable and elderly residents.
- Provide recreational and tourism benefits by enhancing the central portion of the beach.
- Recreational and tourism benefits through minimising adverse short-term impact of new structures.
- Construction of significant new defence structures is delayed until the residual life of the existing structures are exceeded. This provides Aberdeenshire Council with valuable time to mitigate some of the public perceptions of the FPS.
- The delayed investment in future defences makes the scheme adaptable to the uncertainty surrounding climate change and sea level rise projections.
- The promotion of natural flood management and working with natural processes through beach recharge and management.

A series of short-term recommendations are also made; these aim to address existing coastal risk prior to the design and construction of a Flood Protection Scheme (FPS).

Contents

List of Figures

List of Tables

Abbreviations

1D	One Dimensional (modelling)
AEP	Annual Exceedance Probability
BZ	Benefit Zone
FPS	Flood Protection Scheme
FRM	Flood Risk Mapping
PV	Present Value
RBMP	River Basin Management Plan
RMSE	Root Mean Square Error (objective function)
SEPA	Scottish Environment Protection Agency
SSSI	Site of Special Scientific Interest
Tp	Wave Period
TUFLOW	Two-dimensional Unsteady FLOW (a hydraulic model)

1 Introduction

JBA Consulting were commissioned by Dougall Baillie on behalf of Aberdeenshire Council to undertake a coastal flood study for Stonehaven Bay.

1.1 Study extent

Stonehaven is a coastal town located approximately 20 km 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).

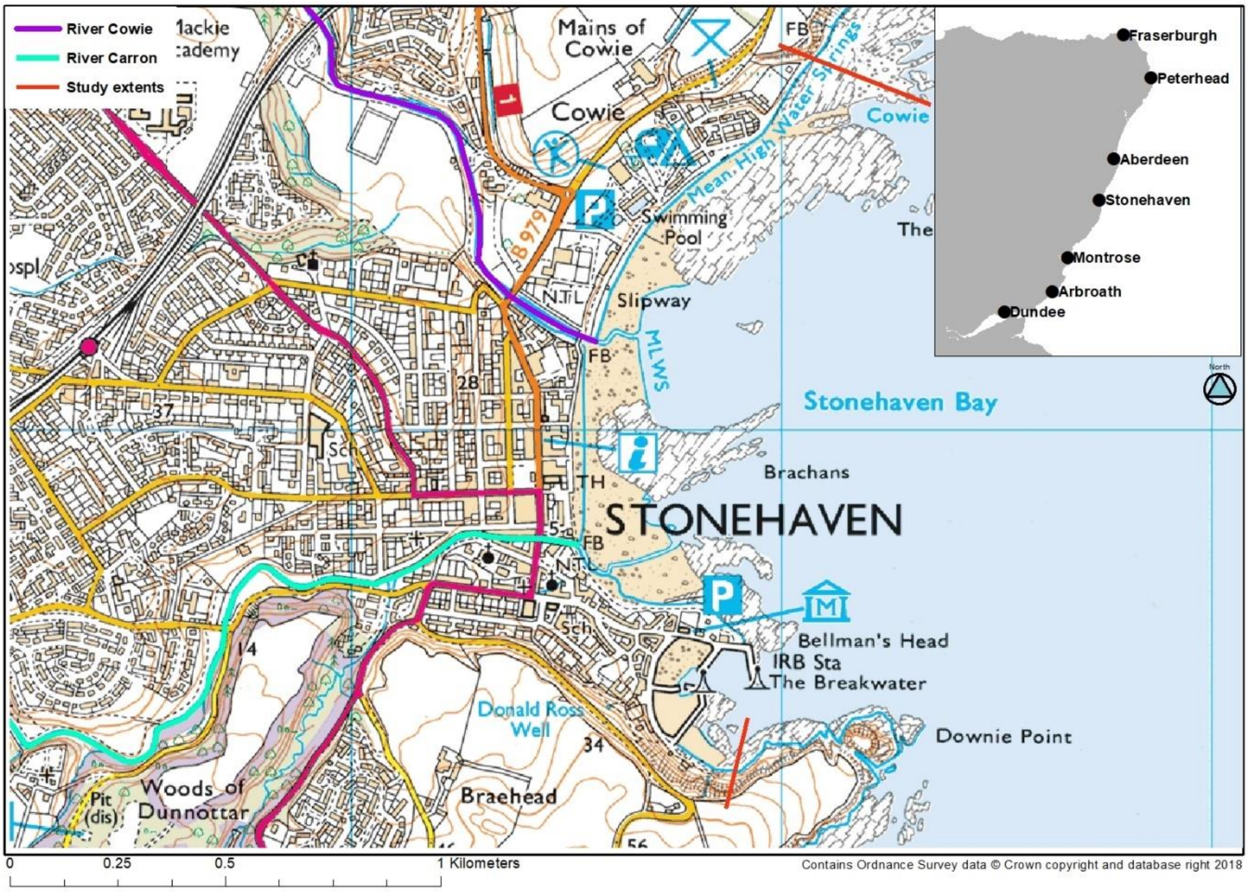


Figure 1-1: Location plan

1.2 Objective

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 is designated 06/23 and is deemed to be at risk of flooding from pluvial, fluvial and coastal sources. Cowie was not included within the original PVA, although this was 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. The values will be updated following the study being undertaken herein.

1.3 Guidance

Scottish Government guidance specifies that an "adaptive" rather than "precautionary" approach to flood risk should be considered[1]. This is to combat the uncertainties surrounding the changes in flood risk in the future (i.e. climate change, natural processes, demographics, etc.) where the design of climate change upfront (precautionary) may not prove to be the best option[2]. This entails looking at a long-term solution that could be changed as the implications of climate change are realised. Managed adaptive approaches enable risk to be monitored at periodic intervals, and responses adapted to respond to changes in risk and can provide more sustainable and adaptable solutions. The flexibility surrounding a managed adaptive approach allows for new innovations to be utilised to help cope with future climate change projections and provide flexibility for capital and maintenance expenditure.

1.4 Report overview

This report is laid out so as to follow the process undertaken for the project:

Chapter 2 – Information Review and Baseline Studies

Chapter 3 – Flood Modelling and Geomorphology Assessment

Chapter 4 – Long List of Options and Multi-Criteria Analysis

Chapter 5 – Short Listed Options and Appraisal

Chapter 6 – Preferred Option, Environmental Screening and Business Case

[1] Scottish Government (2016). Options appraisal for flood risk management: Guidance to support SEPA and the responsible authorities. First Edition.

[2] SEPA (2018) Local Authority Flood Study Checklist. Version 3.

2 Information review and baseline studies

An information review was undertaken to identify gaps in information regarding coastal flooding in Stonehaven and Cowie. Baseline studies were then undertaken in areas where more information was required.

2.1 Information review

Coastal flooding in Stonehaven and Cowie is dominated by waves overtopping the existing defences, with risk associated with still water levels alone being limited to the harbour area. SEPA's coastal flood mapping suggests that risk is limited; however, this mapping does not currently include risk from wave overtopping. Previous assessments of flood risk within Stonehaven Bay have been carried out and are discussed within the Information Review report in **Appendix A**, along with a comprehensive review of historic flood events.

Historical flood information is important to develop an understanding of local flood mechanisms, as well as providing an evidence base for model development and calibration. The most significant events in recent years are those of December 2012 and October 2014, both of which resulted in the flooding of properties, structural damage and risk to life.

Figure 2-1: December 2012 – damage to central wall section following event[3] (left) and overtopping at Cowie promenade[3] (right)

Figure 2-2: October 2014 – flooding of Cowie promenade[4] (left) and waves crashing over the harbour breakwater[5] (right)

The bay is fronted by a range of coastal defences, including a sea walls, stepped revetment and rock armour. Full details, including photographs and location maps are included within the Information Review report in **Appendix A**.

[3] Photograph supplied by Aberdeenshire Council.
[4] https://www.youtube.com/watch?v=V82zGT6-J0g
[5] http://www.bbc.co.uk/news/uk-scotland-tayside-central-29519440

2.2 Baseline studies

A number of baseline studies were undertaken to fill gaps in the information available. A summary of each of these studies is provided below, with full details available in the relevant appendices.

2.2.1 Survey

JBA undertook a 3D laser scan survey of the Stonehaven and Cowie frontages coastline producing a point cloud at a density of 15cm in May 2018. This was augmented with a series of cross sections, aligned with the locations where survey had previously been undertaken. The data was utilised within the flood modelling, geomorphological assessment, and within the concept design and appraisal process. Threshold surveys of relevant buildings, for which data was not already held, were also undertaken and levels used within the economic analysis. The figures in **Appendix B** show the extent of the 3D scan, locations of the cross sections and properties included within the threshold survey.

2.2.2 Structural inspection reports

A series of reports into the condition of assets, ascertained through visual inspections, are provided within **Appendix C**. The reports assess each defence along the frontage, assigning it an overall condition score grade, which is then converted into the predicted lifespan of that defence. A log of defects and recommendations for repairs to defences are also detailed within the reports.

2.2.3 Baseline environmental report

A desk-based investigation into the presence and importance of different habitats within the coastal frontage within Stonehaven Bay was undertaken within the Desktop Environmental Baseline Report, provided in **Appendix D**.

Of particular note is that Garron Point SSSI which is located to the northern extent of the bay. Garron Point Special Area of Conservation and Fowlsheugh Special Protection Area are also located within 2km of the study area. These designations relate to the local geology, habitats, bird species and the presence of the Narrow-mouthed Whorl snail.

Recommendations and considerations for future work are provided within the report.

2.2.4 Baseline NFM and RBMP report

The baseline Natural Flood Management (NFM) and River Basin Management Plan (RBMP) report, which assesses the current condition of the watercourses and coastal water bodies located within the study extent as well as considering the potential NFM options relevant to the study area is provided within **Appendix E**.

The Stonehaven Bay coastal waters, as well as the River Carron and Cowie Water, are classified as being in Good physical condition. There are however a number of morphological constraints along both the coastline and fluvial channels. Opportunities to improve the morphological status are detailed within the report.

Three primary NFM opportunities are also detailed within the report; coastal beach recharge, shingle restoration and fluvial sediment management.

2.2.5 Baseline geotechnical report

An assessment of the geotechnical and geo-environmental risk within the study area is included in the Geotechnical Desk Study Report provided in **Appendix F**.

The report recommends undertaking a targeted ground investigation to determine the ground conditions, the classification of soils and identify the risk of contaminated land, obstructions, dense strata and settlement. As near surface deposits of granular material are anticipated, the extent of seepage and soakaway performance should also be recorded. Service plans have also been obtained for the coastal frontage.

2.2.6 Baseline landscape report

A report reviewing landscape policies and character assessments can be found within **Appendix G**. This includes a review of national and local policies, a landscape character assessment, and assesses landscape, historical and cultural designations.

2.2.7 Baseline heritage report

The Baseline Heritage Assessment report can be found within **Appendix H**.

The Stonehaven Conservation Area includes the Old and New Towns of Stonehaven, including the historic structures of the harbour and the grid-plan of the 18th Century New Town. The report notes that the key area where the design of new defences may impact on the historic character is within the old town, specifically the harbour area, which is category B listed.

There are a number of the other listed buildings, designated and non-designated assets noted, and these are spread throughout the study area. A number of wreck sites are also noted to be located within Stonehaven Bay, although the precise locations are not detailed.

3 Flood modelling and geomorphology assessment

3.1 Flood modelling

The flood modelling process involved multiple steps to develop and combine a suite of numerical models in order to simulate coastal flood risk effectively. A summary of these steps is provided below, with a detailed report of the flood modelling methodology found within **Appendix I**. SEPA's feedback on the interim modelling report is provided within **Appendix J**; the report has been updated to reflect this feedback. Technical Review Certificates from the modelling are included at the end of Appendix I.

3.1.1 Multivariate statistics

SEPA's offshore multivariate (MV) dataset, which consists of more than 2 million discrete events expressed as a combination of wave height, wave direction, wave steepness, directional spreading, wind speed, wind direction and water level was used to produce dependence models that describe the relationships between offshore waves, wind and still water levels; joint probability point 2 (JP2) was used within this study.

The size of the extreme multivariate condition datasets meant it was unfeasible to run the wave transformation model for each condition. The dataset was initially screened to remove events that would not result in the overtopping of the defences in the study area, climate change values (UKCP18 RCP 4.5 95th percentile)[6] were then added so that the dataset was representative of all possible conditions, and a sub-set then derived using a maximum difference algorithm (MDA). This sub-set was run through the wave model, with the results used to train emulator functions.

3.1.2 Still water level transformations

The multivariate water levels are based on the BODC A class gauge at Aberdeen. For use in this study these values required transformation to Stonehaven. To achieve this a water level equation was generated by fitting a function to the 1 in 50 year return period water levels from the Coastal Flood Boundary Dataset (CFBD) using the northing coordinate and based on the distance from Aberdeen. The updated CFBD was used within this study. The still water level values used within the study, with and without an allowance for climate change are provided in Table 3-1.

Table 3-1: Present day and climate change still water levels

Return Period (years)	Present day (2018) SWL (mAOD)	Climate change (2118) SWL (mAOD)
2	2.82	3.55
5	2.92	3.65
10	2.99	3.72
30	3.11	3.83
50	3.16	3.89
100	3.23	3.96
200	3.30	4.03
1000	3.66	4.18

[6] It is noted that this climate change scenario results in slightly lower future still water levels than the advised level for the north east in SEPA's guidance; this guidance was released subsequent to the analysis being undertaken. The implications of this difference could be considered at the detailed design stage.

3.1.3 Wave transformation

SEPA's existing SWAN model developed for the Angus and Aberdeenshire coastal (AnAc) flood forecasting system and used within SEPA's coastal flood map updates was used as the basis of a cut-down SWAN model, used to transform the offshore data to the nearshore. The SWAN model included a varying water level grid, derived via the methodology outlined above.

To improve the accuracy of the model and provide confidence in outputs a calibration process was undertaken using observed data at the Aberdeenshire Council wave buoy located within Stonehaven Bay. Eight events were considered, comparing the percentage RMSE (Route Mean Squared Error) of Hs, Tp and Dir for each potential model setup.

3.1.4 Emulation

90% of the MDA was run through the calibrated SWAN model, with the results used to train emulators at the toe of each defence, as well as at the wave buoy. These emulators describe the relationship between the input variables and the nearshore wave conditions. The remaining 10% of the MDA was subsequently used to validate the emulator functions. The emulators were then used to provide nearshore conditions for the full multivariate dataset, as well as running through hindcast data from WaveWatch III in order to provide nearshore data for historical events.

3.1.5 Wave overtopping

The wave overtopping modelling considers how the waves at the toe of the defences interact with the beach and structures to provide estimates of overtopping volume.

The defences within Stonehaven and Cowie were schematised using the Neural Network within EurOtop II[7]. The schematisations were calibrated, initially assessing the modelled rates for 13 historical events, and secondly for the events in December 2012 and October 2014 in more detail. Following the calibration of the schematisations, the full multivariate dataset was run through the models in order to provide overtopping rates for a range of return periods, including with a climate change allowance. The overtopping locations can be viewed within Figure 3-1, with the results summarised in Table 3-2. It can be seen that the increase in overtopping values due to climate change is significant, with the rates increasing my several orders of magnitude, and what is currently a 200 year event becoming an annual event in 2118.

It should be noted that the overtopping values calculated are relevant to the beach profile, as was present when the topographic survey was undertaken. Natural variation in beach levels means that the overtopping rates will vary for similar storm events depending upon the beach profile at the time.

[7] EurOtop – Manual on wave overtopping of sea defences and related structures, Second Edition, 2016

Figure 3-1: Overtopping profile locations

Table 3-2: Overtopping rates for a range of return periods (l/s/m)

Return Period (years)	SH02	SH06	SH12	SH17	SH20	SH25	SH28	SH29	SH_H_01a	SH_H_01b	SH_H_02
Present day (2018)											
2	0.52	0.58	1.36	0.76	0.22	43.90	0.03	0.08	-	-	0.47
5	1.00	1.09	1.99	1.26	0.37	67.90	0.07	0.11	-	0.04	0.58
10	1.63	1.74	2.57	1.81	0.56	91.70	0.14	0.15	-	0.07	0.70
30	3.56	3.57	3.89	3.11	1.00	140.00	0.36	0.25	<0.01	0.10	1.02
50	4.85	4.78	4.68	4.01	1.33	171.00	0.54	0.33	<0.01	0.11	1.21
100	7.60	7.48	5.91	5.77	1.95	217.00	0.97	0.50	0.01	0.12	1.77
200	11.60	11.60	8.19	8.12	2.99	271.00	1.64	0.76	0.02	0.13	2.72
1000	25.10	26.40	14.30	13.10	6.00	419.00	5.86	1.77	0.05	0.22	9.11
Climate change (2118)											
2	18.50	17.20	10.70	10.20	3.46	511.00	3.71	1.01	0.01	0.06	4.14
5	29.50	27.10	14.80	14.60	5.32	632.00	7.32	1.59	0.03	0.10	7.48
10	41.50	37.60	18.50	18.60	7.13	733.00	11.90	2.35	0.04	0.12	11.40
30	65.30	58.70	25.70	27.00	11.30	911.00	25.00	4.33	0.06	0.15	24.10
50	77.90	69.30	29.70	32.20	14.30	1000.00	32.20	5.60	0.07	0.16	32.80
100	100.00	89.90	37.10	41.20	19.60	1150.00	45.10	8.47	0.08	0.19	53.20
200	127.00	116.00	46.60	52.70	25.50	1310.00	66.30	12.50	0.10	0.21	89.80
1000	201.00	176.00	69.70	81.10	46.90	1850.00	156.00	26.70	0.17	0.34	268.00

3.1.6 Inundation modelling

An existing TUFLOW model developed for SEPA's coastal flood map updates was used as the basis of a detailed flood inundation model. This was forced by an offshore tidal graph in conjunction with overtopping inflows so as to produce a single flood extent that represents the risk from both mechanisms. The model was validated using the December 2012 flood event, with the modelled flood extent compared to photographic evidence within Figure 3-2.

Figure 3-2: Modelled flood extent for 15th December 2012 event, along with photographic evidence from Aberdeenshire Council

3.1.7 Tidal reaches of Carron and Cowie

The Cowie Water and River Carron both discharge into the North Sea within Stonehaven Bay. The configuration of the two watercourses at the coast was historically very different, with the Cowie Water running south along the front behind a large shingle bar, merging with the River Carron prior to discharging out into the bay.

In the present day the Cowie Water discharges into the North Sea to the south of Cowie promenade and to the north of Turners Court. The Cowie Water is tidally influenced up to the weir beneath the B979 road bridge. The mouth of the Cowie Water consists of concrete lined banks, with a training wall extending out from the left (northern) bank, a small amount of rock armour present at the end of the right bank, and a footbridge crossing the channel. Flow beneath the footbridge and out onto the beach is constricted by the deposition of shingle, which also extends further upstream along the right bank.

A comparison of still water levels with the top of banks showed that for both banks there is no risk from coastal flooding due to still water levels alone for up to and including the 200 year plus climate change event (to 2118 using the RCP (Representative Concentration Pathway) 4.5 95th percentile data from UKCP18). For the left bank there is a freeboard of 0.81m and for the right bank there is a freeboard of 0.53m compared to the lowest point along each.

During storm conditions, it is understood that waves propagate into the mouth of the Cowie Water. Video footage, provided by Aberdeenshire Council and dated 16 March 2018, shows waves breaking on the shingle bank, resulting in splash over the right hand bank of the river, with smaller waves then running along the right bank revetment and breaking on the weir beneath the B979 road bridge. As a result, a wave overtopping input was included within the inundation model at this location.

The River Carron discharges into the North Sea to the north of the harbour and south of the main central beach. The tidal reach of the river is influenced by both still water levels (SWL) and waves. Construction of the fluvial flood protection scheme for the River Carron and its tributary the Glaslaw Burn commenced in summer 2019.

It is understood that Aberdeenshire Council are happy with the freeboard allowance provided within the downstream reach in order to account for coastal risk. Should the coastal options potentially effect levels within the Carron, the implications for the fluvial scheme will need to be investigated in future design phases. Otherwise, it was agreed that no further work to consider still water levels or waves in the tidal reach of the River Carron was required as part of this study.

3.1.8 Still water level impacts on sewer network flooding

As well as considering potential flood risk directly from the coast, it is important to consider the interaction between coastal flooding and other flood sources, especially with regard to climate change. To this end, an assessment of the impact of extreme sea levels on the drainage network within Stonehaven and Cowie has been undertaken. Multiple outfalls connect to the sea directly, as well as into the lower reaches of the watercourses.

To this end, Scottish Water's Integrated Catchment Model (ICM) was utilised to assess the effect of both present day and climate change tidal levels on the local sewer network. An example output for the 200 year event in 2118 is provided in Figure 3-3.

The interaction between coastal and surface water flood risk will need to be considered in future design phases, with the impact of sea level rise on surface water risk being accounted for within the Surface Water Management Plan, and the potential impacts on surface water risk due to the construction of coastal defences being considered in the design of a coastal scheme; additional details on this are provided within Section 6.3.2.

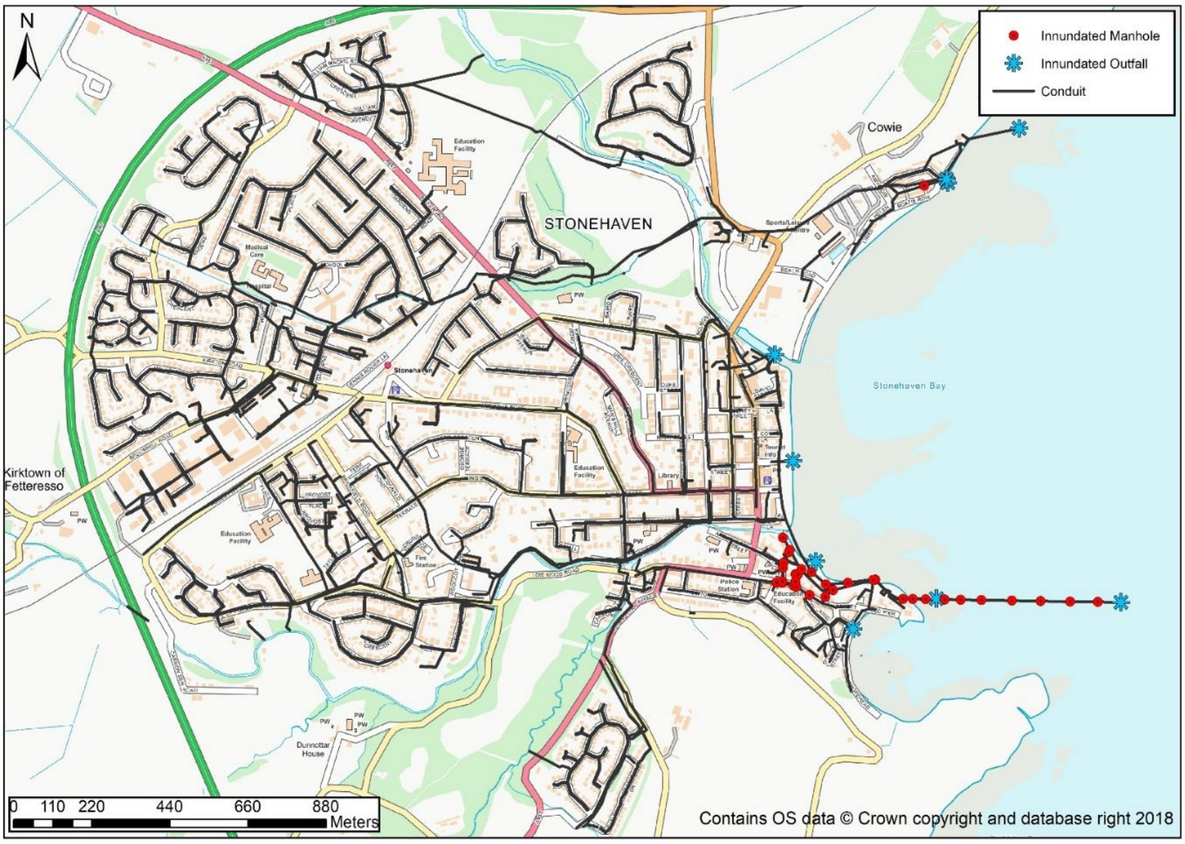


Figure 3-3: Assessment of 200 year 2118 still water levels on sewer network

3.2 Geomorphology assessment

To understand the morphological processes within the bay and how they contribute to flood risk, an assessment of the local coastal geomorphology was undertaken. The aim was to evaluate the historical trends in shoreline position and beach volume, and thus provide an indication on the controlling mechanisms and influences these have on flood risk and erosion.

An assessment of future erosion was subsequently undertaken through numerical modelling of short-term storm response, with the objective being to better understand the potential future risk to critical assets after failure of the current coastal defences.

A summary of the work undertaken is provided below, with further details available within the modelling report provided in **Appendix I**.

3.2.1 Topographic analysis

Topographic survey data was available from 2008, 2013 and 2018 which allowed a medium-term beach volume trend to be established. Sediment characteristics vary significantly across the bay from sand in the north to shingle and coarse sand in the south. Cross-shore transport is the primary control mechanism, leading to berm building and the burying of the defences during extreme events. While this renders the sea wall obsolete as an overtopping defence, anecdotal evidence supports the theory that a higher, steeper beach provides more protection by dissipating energy further offshore. A longshore gradient also exists, as can be seen from the general increase in beach width from north to south. The control structures at the mouths of both the Cowie and Carron appear to be inefficient at retaining beach sediment, with the volume of sediment to the south of the Carron outfall less than that placed there manually by Aberdeenshire Council (historically

Aberdeenshire Council have removed material from the mouth of the Cowie and placed this to the south of the mouth of the River Carron). The data used for the analysis was not available at the frequency required to fully understand the performance and changes in the beach during extreme conditions, however the morphology of the beach is clearly a key component in the protection against and exacerbation of flood risk within the bay.

3.2.2 XBeach modelling

To better understand the morphological response of the beach during extreme conditions, numerical modelling was undertaking using the XBeach suite of morphodynamic models. During small storm events, the main section of beach has a tendency to accumulate across the upper beach and erode below the MHWS, as was also seen within the topographic analysis.

The general pattern is a steepening of the beach and the dynamic response during storm events will have impacts on the overtopping rates along the beach front. The beach recycling that takes place annually does not influence the overall sediment budget as sediment is consistently lost to the south of the mouth of the River Carron but naturally replenished at the mouth of the Cowie Water.

In a scenario where the coastal defences have failed, the upper beach in the north of the bay is predicted to significantly erode, leading to a retreat in the HAT position. The lower beach will experience accumulation from the eroded sediment further up the profile, which demonstrates the opposite trend to normal conditions. The defences currently in place play a major role in preventing landward erosion.

The middle and southern sections of the bay are predicted to experience an accumulation of sediment across the whole profile in a scenario without defences indicating the defences do not play a significant role in controlling sediment movement.

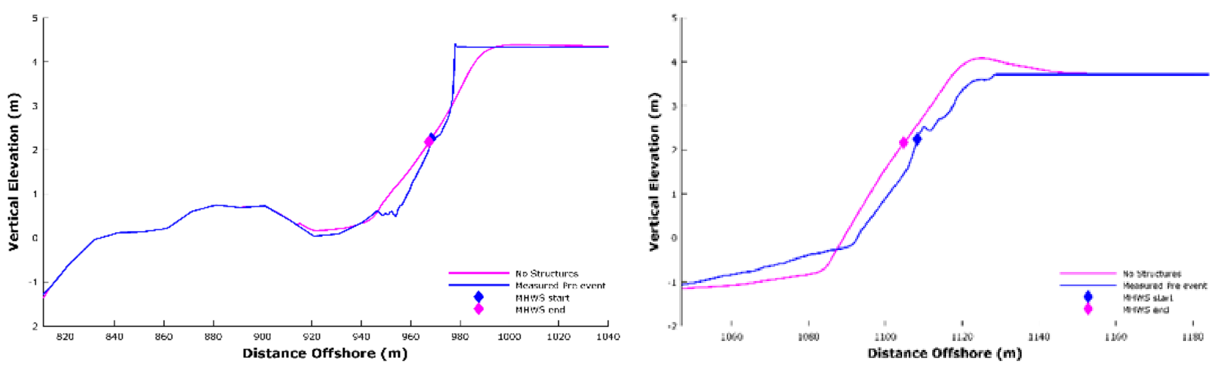


Figure 3-4: Undefended erosion profiles at the north (left) and middle (right) of Stonehaven Bay

Multiple storm events with varying combinations of Hs and SWL were modelled for each return period, and the average HAT retreat rate was annualised. The north of the bay is predicted to experience an annual retreat rate of up to 1.66m/year. For profiles where advancement of the beach was seen in the south of the bay, the minimum values from each event were analysed to model the maximum extent of landward erosion (maximum retreat rate of 0.5m/year), however it is more likely that the south of the bay will experience HAT advancement.

4 Long list and multi-criteria analysis

In order to consider options that may be appropriate to reduce coastal flood risk, the frontage of the study area was split into three benefit zones (BZs) (Figure 4-1); North, Central and Harbour. The River Cowie sits within the Central BZ due to the primary flood risk mechanism being associated with overtopping of the southern bank. A long list of potential flood risk management options was drawn up and the validity of the options for each of the zones assessed; this provided an initial screening of the options (Table 4-1). Further analysis was subsequently undertaken to assess the remaining options against a series of technical, economic, environmental, social, political and legal criteria (Table 4-2), with each option/category assigned a score (Table 4-3) based on whether the option met the aims of the assessment criteria.

The full analysis is provided in **Appendix K**, with those taken forward to the short list phase for further assessment denoted by two ticks within Table 4-1. Note: Property Flood Resilience (PFR) has been taken forward as a short-term recommendation for all benefit zones.

In order to incorporate stakeholder views into the multi-criteria analysis a public consultation event was held at Mackie Academy on 29 January 2019. Aberdeenshire Council and JBA Consulting introduced the study and the aims of the meeting via a presentation, with posters then available for discussion and questionnaires so that feedback could be provided. Stonehaven Flood Action Group (SFAG) submitted a formal document in response to the event, with a copy of this included within **Appendix L**; the additional suggestions made by SFAG were incorporated into the multi-criteria analysis spreadsheets.

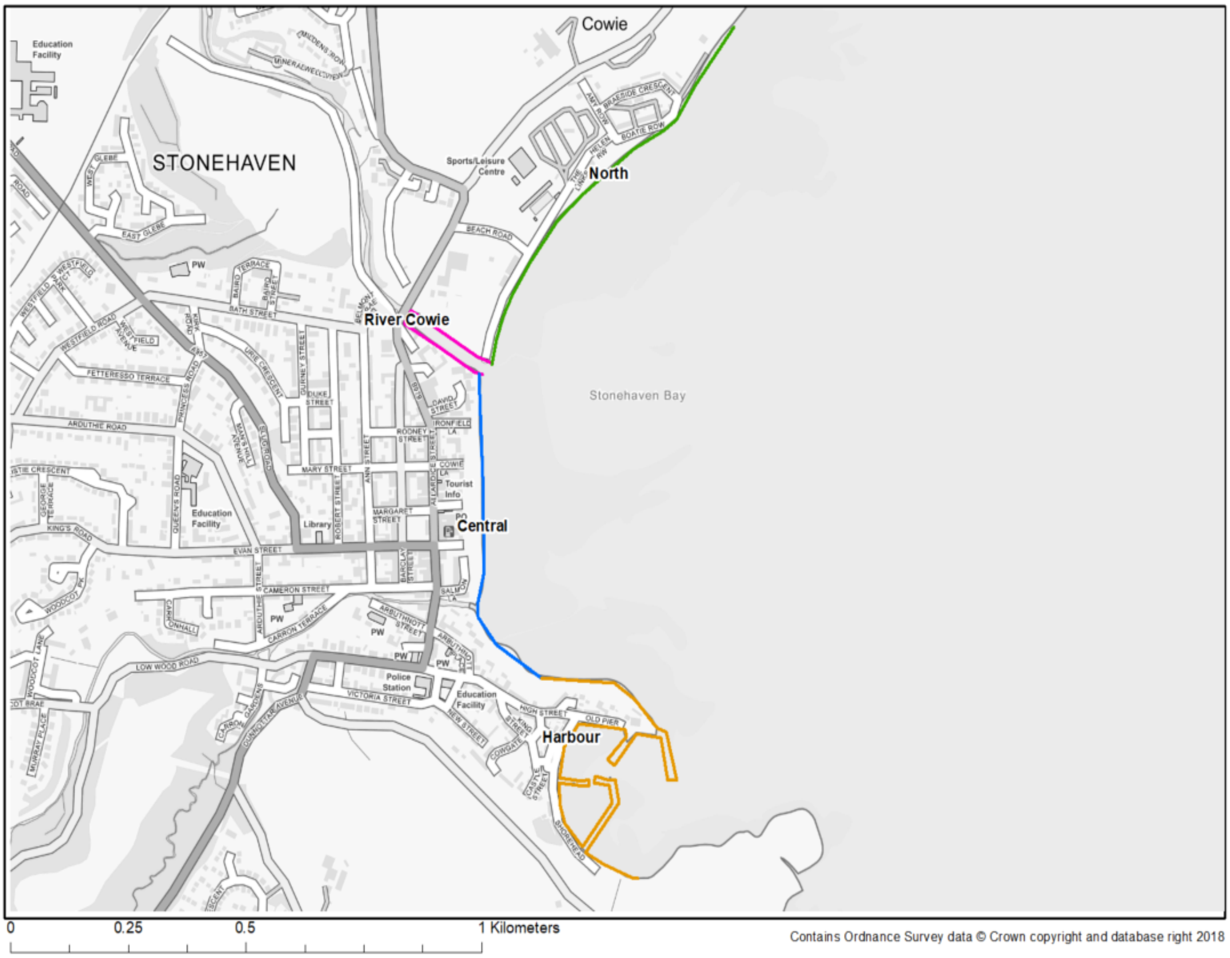


Figure 4-1: Stonehaven Bay benefit zones

Table 4-1: Long list of options considered

Option and Description	Benefit zone		
	North	Central	Harbour
Do nothing No maintenance of existing defences.	✔	✔	✔
Do minimum Maintain existing defences.	✔✔	✔✔	✔✔
Replace sea wall A new wall could be built of concrete, steel piles or masonry. This option would seek to replace the existing defence or be built seaward of the existing wall. To adapt to climate change, the wall would need to be taller than the current defence, which may require raising the promenade and footpath area behind.	✔✔	✔✔	
Raise existing sea wall Raising the existing wall would increase the flood protection performance of the defence in the short to mid-term. However, as this option relies on the existing structure it can only practically be raised so far without a complete re-build. In addition, without raising the promenade, sea views could be affected and therefore the wall could only be raised so far. In areas where the existing structures are currently in poor condition a concrete 'shroud' would be used to encase the existing defence to prevent premature failure of the new raised defence.	✔✔	✔	
Rock armour revetment Rock armour could be installed at the base of the existing sea wall to increase flood protection performance. As this solution does not increase the height of the defence it is only viable in the short to mid-term without the full effects of sea level rise. The rock armour would encroach onto the amenity beach (or into the mooring zone within the harbour), but it would not affect line-of-site from the town.	✔		✔
Setback walls with flood gates Flood protection walls could be installed set-back from the existing coastal defences, these would run parallel to the roads and private property boundaries. In some instances, it is envisioned that private properties may require integrating into the defence line to ensure flood wall continuity; this would require waterproofing or shrouding of vulnerable areas. This option would help prevent flooding to the town through a secondary defence line; while it does not help reduce wave overtopping, it would prevent flood water from inundating properties. In the long-term this option will be less effective due to the extreme sea levels expected and it does not seek to improve the condition of existing defences. However, if used in conjunction with other defence improvements it could effectively work into the long-term scenario.	✔	✔	

Option and Description	Benefit zone		
	North	Central	Harbour
Offshore breakwater An offshore breakwater would seek to reduce the flood risk by dissipating wave energy within Stonehaven Bay. The size of the structure (height and width) would determine how much wave energy is dissipated. For this reason, a breakwater could be designed to be submerged such that it is not visible, creating a reef-like structure to break the largest waves offshore. As this option does not increase the height of the existing defences it may only offer limited protection in the long-term, however coupled with other defence options it could aid in reducing the size of other required defences.	✔	✔	
Wall extension with rock armour revetment The existing defence could be increased in height with the addition of rock armour installed on its seaward face. The rock armour would serve as protection to the wall whilst also significantly reducing wave overtopping making it an effective coastal flood defence in the long-term scenario. To adapt to climate change, the wall would need to be taller than the current sea wall, which may require raising the promenade and footpath area behind the defence. In areas where the existing structures are currently in poor condition a concrete 'shroud' would be used to encase the existing defence to prevent premature failure of the new raised defence.	✔✔		
New stepped or sloping revetment The existing defences could be replaced by a new stepped revetment (as currently seen along the Cowie promenade), or by a similar modular blockwork structure or rock armour structure. All solutions could be designed such that their wave overtopping performance is suitable into the long-term scenario. Given the present-day overtopping risk, a higher crest level than existing will be required. To adapt to climate change, the wall would need to be raised further, which may require raising the promenade and footpath area behind the defence.	✔	✔	✔✔
Beach recharge and control structures The beach within Stonehaven could be recharged increasing the beach crest width and height. To prevent the beach mobilising and moving around within the bay beach control structures would also likely be required. With a large enough beach in both height and width this option could be a solution in the long-term, however it would also require replenishment over time if it is shown that material is lost offshore or the beach migrates shoreward through "roll-over". This option could also be coupled with other options to limit the size of hard defences required.	✔✔	✔✔	

Option and Description	Benefit zone		
	North	Central	Harbour
Foreshore recharge Similar to beach replenishment, this would look to have large quantities of beach material dumped near the centre of Stonehaven Bay, effectively making a very large beach / sand bar. Over time this material would move around within the bay, replenishing the existing beaches. This option would reduce the water depths within the bay and thus create a large area in which wave action would be dissipated across. This option would be suitable up until the long-term scenario given sufficient material deposition. It is possible that the beach would need replenishing by mid-century.	✔	✔	
Beach and river realignment Within the central section, the beach could be moved seaward with a view to redirect the Cowie Water south towards the Carron, as it flowed historically. As the beach is moved seaward, it would effectively act as type of breakwater to the hard coastal defences, however this realignment would likely require nourishment along with control structures to make sure the system is stable in extreme events and not breached. This option would be suitable into the mid-term scenario, but exposing the toe of the hard defences for the realigned river may require additional strengthening and repair works to ensure integrity against fluvial and coastal processes.		✔	
Managed realignment – Cowie Partial realigning the defence in the northern benefit area (Helen Row and Boatie Row) could be considered due to the flood risk and lower number of residential and businesses in this area. Within a partial realignment scenario, a secondary defence, potentially in the form of a vegetated earth bund, would be built set-back from the existing coastal defences; this would be required to prevent flooding to the remaining properties.	✔		
Ground raising The flood risk in the northern benefit area is a result of the low ground level, meaning that any wave overtopping will flow down and flood this area. An option to consider instead of realigning the defence would be to raise the ground level immediately behind the defences such that flood water can only flow back out to sea. While this option is a large undertaking, it could secure the flood risk beyond the long-term scenario if coupled with repairs or replacements of the existing defences to manage erosion risk.	✔		
Managed realignment – harbour As there is limited development at risk in the south harbour, managed realignment could be considered. This option would likely also require a setback wall with flood gate at the edge of the existing harbour arm to limit wave overtopping into the inner basin.			✔✔

Option and Description	Benefit zone		
	North	Central	Harbour
River Cowie training wall / groyne extension The existing concrete structure could be extended further out and southward to shelter the river mouth from waves. The structure could be an extension of the concrete structure or be formed of rock armour. As this defence does not increase the height of the existing river banks, it is only effective to the mid-term scenario, however coupled with existing defence improvements would make it a long-term solution.	✔	✔	
Rock armour revetment extension The existing rock armour structures located to the north of the harbour have very narrow crest widths; extending the rock armour crest width would effectively improve their performance against wave overtopping. In the long-term scenario, with the higher extreme sea levels, it might be that the defence would require a raised parapet wall at the rear of the rock armour profile.			✔✔
Advance the line with new vertical wall Within the harbour a new wall alignment could be built at the toe of the existing defence without effectively increasing the footprint of the structure. The defence would likely be made from sheet piles, which could be clad with timber to aid with mooring and improve the appearance of this option. Concrete or masonry would also be suitable materials for construction, though may have a larger footprint. This option would also widen the promenade/road making better access for pedestrians.			✔✔
Extension of harbour breakwater arm The existing outer breakwater arm could be extended to further shelter the middle basin from wave overtopping. This defence could be an extension of the concrete structure or a rock armour structure. This option would have to carefully take into account the navigation routes for vessels and might require dredging to maintain the required navigation channel width.			✔
New breakwater arm A new southern breakwater arm could be built further out from the harbour and connected to the headland. This option would provide additional shelter to the harbour, potentially protecting the inner and outer areas of the harbour and could increase the active harbour space allowing a new mooring basin to be designed by the South Pier and old lifeboat house. The form of this new breakwater arm would likely be of rock armour, but a concrete caisson structure could also be viable.			✔
Advance the line To maximise the benefits from improving the coastal defences in the south of the harbour, advancing the line with a new defence would create a new area in which additional businesses could be built on. As this option widens the defence it will prevent overtopping flow into the inner basin. This option could re-use the existing rock armour into a new defence, or alternatively an extension of the South pier could be considered in the form of a masonry or concrete sea wall.			✔

Option and Description	Benefit zone		
	North	Central	Harbour
Property relocation Properties at immediate flood risk behind the current coastal defences could be relocated, reducing potential flood damages while also providing additional space for flood protection improvement schemes behind the existing defences. While this option does not seek to reduce wave overtopping it could be coupled with other mid to long-term strategies to reduce flood risk damages.	✔	✔	✔
Property Flood Resilience and Resistance (PFR) A short-term option to address flooding in less severe storm events, PFR measures could be a valuable option to incorporate into those properties at risk of flooding. For more severe storms and with increasing sea levels, the level of resilience will be limited and is therefore not considered to be a mid-term option, unless coupled with improvements to the coastal defences.	✔	✔	✔

Table 4-2: Multi-criteria assessment

Category	Assessment criteria	Aims
Technical	**Technical performance and adaptability**	Provides desired standard of protection throughout the design life of the scheme or is easily adaptable to allow for modifications for climate change through time. Provides protection to full extent of benefit zone.
	Buildability	Safe to construct, local sources of appropriate material for construction, suitable ground conditions and would not conflict with existing services, primarily the sewer main along the front.
Economic	**Capital cost**	Low capital cost.
	Maintenance and monitoring	Minimal ongoing maintenance and/or monitoring requirements and costs.
Environmental	**Ecology and environment**	No environmental impact on local habitats, geology and ecology, including local designations.
	NFM and RBMP	Works with nature to provide natural protection and does not downgrade the existing classifications.
Social	**Landscape and Heritage**	Works with the existing landscape and is sensitive to listed buildings and heritage designations.
	Tourism	Maintains access to beaches, considers local views and provides connectivity along the frontage.
Political	**Strategic alignment**	Aligns with local strategies.
	Stakeholder views	Supported by stakeholders and the local community.
Legal	**Waste management and contamination**	Minimal waste disposal requirements or contamination risks.
	Regulatory consenting and approvals	Regulatory framework would be readily achievable.

Table 4-3: Multi-criteria assessment scoring

Score	Description
1	Option has significant potential to negatively affect achievement of aims
2	Option likely to conflict with aims
3	Option not likely to contribute or conflict with aims
4	Option likely to contribute to achieving aims
5	Option has significant potential to meet aims

5 Short list and appraisal

The short-listed options underwent a detailed appraisal to test the economic viability of each, with the appraisal processes implemented for each benefit zone (BZ) individually. Outcomes were subsequently combined to form the most appropriate option for an FPS for the frontage as a whole. The modelling shows that in terms of coastal flood risk, the BZs are independent of one another. As such, no residual risk of backdoor flooding is expected, should the decision be taken not to progress with a scheme at any of the respective BZs.

It should be noted that short-term recommendations that could be implemented prior to a formal Flood Protection Scheme are detailed within Chapter 6.

5.1 Baseline scenario

The baseline scenario for this assessment is the Do Minimum. Under this scenario, it is assumed that the existing defences will be maintained at their current level of investment, with a residual life as indicated in the visual asset condition surveys undertaken as part of this study. In this scenario, when the residual life is exceeded, the defences are assumed to have failed.

Analysis and modelling of the undefended scenarios indicates that there is no inherent benefit in attempting to incorporate these into the damage calculations. However, the economic cost of exposure and erosion of critical assets after failure is considered conceptually and used to support the case for long-term investment (Section 0). The loss of the beach is included in the recreational benefits assessment for each option individually.

5.2 Short list options

The below sections provide a summary of the short-listed options for each Benefit Zone.

Although there is no design standard required to receive government grant, options have initially been developed and appraised for a 200-year standard of protection (SoP). This aligns with the current planning guidance and will therefore allow for additional wider benefits in terms of long-term regeneration of Stonehaven and Cowie. Options have also been tested against the 200-year SoP with an allowance for climate change (CC) to help consider the long term needs for flood protection and to highlight the implications of sea level rise on the defence designs.

Table 5-1: North benefit zone short-listed options and timescale over which they are applicable

Option	SoP	Timescale
Sea Wall 1	200-year	Medium
Sea Wall 2	200-year + CC	Long
Rock Revetment 1	200-year	Medium
Rock Revetment 2	200-year + CC	Long
Beach Recharge 1	200-year	Medium
Beach Recharge 2	200-year + CC	Long
Raise Existing Walls	200-year	Medium*
*This is not considered a long-term option as it is limited to the residual life of the current defences		

Table 5-2: Central benefit zone short-listed options and timescale over which they are applicable

Option	SoP	Timescale
River Cowie Walls	200-year + CC	Long*
Sea Wall 1	200-year	Medium
Sea Wall 2	200-year + CC	Long
Beach Recharge 1	200-year	Medium
Beach Recharge 2	200-year + CC	Long
*Limited wave action in the Cowie means that the difference in present day and climate change designs are such that there is no considerable benefit in an adaptive approach on the Cowie.		

Table 5-3: Harbour benefit zone short-listed options and timescale over which they are applicable

Option	SoP	Timescale
North Rock (NR)	200-year + CC	Long
Inner Revetment (IR)	200-year + CC	Long
Inner Walls (IW)	200-year + CC	Long
South Rock (SR)	200-year + CC	Long
South MRL (MRL)	200-year + CC	Long

It should be noted that no medium terms options have been considered for the harbour for the following reasons:

1. The profile required to achieve the 200-year + CC standard for the north rock revetment is not sufficiently increased from the existing that it would benefit from an adaptive approach.
2. The overtopping rates and depths in the inner harbour are such that the flood risk may be adequately managed through PFR.
3. There is estimated to be 30 years' residual life in the current structures which, combined with PFR can manage risk in the short to medium term.
4. The levels required to achieve the 200-year + CC standard for the inner harbour is not sufficiently increased from the existing profile that it would benefit from an adaptive approach.

5.3 Concept designs

Concept designs were developed for the above short-listed options to assess their feasibility. These included the general arrangement of defences, typical section, engineering materials and key structure dimensions and are included in full in **Appendix M**, along with the design risk assessment and supporting technical note. The defence geometries have been optimised by extreme wave conditions and extreme sea levels.

The medium options have been designed to a 200-year event standard of protection, with the long term options including allowance for climate change up to 2118. Where applicable, both are shown within the drawings provided.

The Environment Agency (2017) freeboard guidance[8] has been adopted wherein you can choose a standard based on risk. At this stage a 4-star confidence rating has been assumed to be achieved during the future detailed design stage. As such, a minimum 450mm freeboard

8 Environment Agency. 2017. Accounting for residual uncertainty - updating the freeboard guide (SC120014)

has been designed to achieve zero still water level flooding during the design event, and events with lower return periods.

The tolerable overtopping discharge threshold proposed for all shortlist options is to be less than 1 l/s/m for the 0.5% AEP event as this is considered to be safe for pedestrians, according to the European Wave Overtopping Manual[9].

No allowance for settlement and consolidation has been made within the designs, and therefore all the levels presented in the concept designs represent post-settlement and post-consolidation levels.

All of the shortlisted options have been optimised to achieve the best balance between the required design performance standards and minimising material usage and, hence, carbon footprint as to develop a sustainable design.

The shortlist options have been designed to protect from tidal inundation and from the risk of wave overtopping. The typical sections were assessed within the latest release of the Artificial Neural Network overtopping tool. A range of revetment crest levels, wall crest levels, crest widths and revetment slopes were assessed. The wave climate data used to develop the shortlist designs was the 2018 and 2118 0.5% AEP overtopping for the medium- and long-term options respectively. The final defence geometries are included in **Appendix M**.

5.4 Options appraisal

The appraisal has considered a combination of the above options to allow for the appraisal in each benefit zone to be implemented with the aim of satisfying the following concepts:

1. Demonstrate the business case for best use of the current defences until failure then replace with CC allowance (delayed approach).
2. Demonstrate the business case for replacing the current defences now and adapting to CC over the appraisal period (adaptive approach).
3. Demonstrate the business case for replacing the current defences now including a CC allowance (precautionary approach).

The above satisfies the requirements of both Aberdeenshire Council and Scottish Government and will allow for the most appropriate preferred option in the medium and long-term to be identified and proposed for FPS funding.

Table 5-4: North BZ – appraised options; timescales over which they are applicable; approach and investment

Option	Start	Mid	Approach	Investment
1	Sea wall 1	Sea wall 2	Adaptive	Upfront and delayed
2	Rock Revetment 1	Rock Revetment 2	Adaptive	Upfront and delayed
3	Recharge 1	Recharge 2	Adaptive	Upfront and delayed
4	Sea wall 2	Sea wall 2	Precautionary	Upfront
5	Rock Revetment 2	Rock Revetment 2	Precautionary	Upfront
6	Raise Wall	Sea wall 2	Adaptive	Upfront and delayed
7	Raise Wall	Rock Revetment 2	Adaptive	Upfront and delayed
8	Raise Wall	Recharge 2	Adaptive	Upfront and delayed
9*	Raise Wall	NA	Non-compliant	Upfront
*Option 9 has been considered to demonstrate the potential benefit of adapting the current defences in the medium-term. This has been assessed over the residual life of the defences and it may not be suitable for government grant in isolation. It does however provide an assessment of the benefit in investing now should the FPS process be delayed, or the scheme not be prioritised in the next cycle.				

9 EurOtop. 2018. Manual on wave overtopping of sea defences and related structures.

Table 5-5: Central BZ – appraised options; timescales over which they are applicable; approach and investment

Option	Start	Mid	Approach	Investment
1	Sea wall 1 and River Cowie Walls	Sea wall 2 and River Cowie Walls	Adaptive	Upfront and delayed
2	Recharge 1 and River Cowie Walls	Recharge 2 and River Cowie Walls	Adaptive	Upfront and delayed
3	Sea wall 2 and River Cowie Walls	Sea wall 2	Precautionary	Upfront
4	Recharge 2 and River Cowie Walls	Rock Revetment 2	Precautionary	Upfront
5*	Recharge 1	NA	Non-compliant	Upfront
*Option 5 has been considered to demonstrate the potential benefit of working with the current defences in the medium-term. This has been assessed over the residual life of the defences and it may not be suitable for government grant in isolation. It does however provide an assessment of the benefit in investing now should the FPS process be delayed, or the scheme not be prioritised in the next cycle.				

Table 5-6: Harbour BZ– appraised options; timescales over which they are applicable; approach and investment

Option	Start	Mid	Approach	Investment
1	NR + IR + SR	NR + IR +SR	Precautionary	Upfront
2	NR + IW +SR	NR + IW +SR	Precautionary	Upfront
3	NR + IR +MRL	NR + IR +MRL	Precautionary	Upfront
4	NR + IW +MRL	NR + IW +MRL	Precautionary	Upfront
5*	NR + PFR	NR + Best 1-3	Adaptive	Upfront and delayed
6**	PFR	NR + Best 1-3	Adaptive	Upfront and delayed
7	PFR	NA	Non-compliant	Upfront
NR = North Revetment; IR = Inner Revetment; SR = South Revetment; IW = Inner Wall; MRL = Managed Realignment *Option 5 will accept that the risk to the inner and southern harbour can be managed through PFR and the existing defence condition in the medium-term. ** Given the lack of damages in the harbour, Option 6 will manage the risk in the medium-term through PFR and test the benefit of delaying all capital investment until year 30 in the appraisal period.				

Table 5-7: Approach summary

Benefit Zone	Medium-term Option	Long-term Option	Adaptive approach	Precautionary approach
North	✓	✓	✓	✓
Central	✓	✓	✓	✓
Harbour	✓	✓	✓	✓

Upon completion of the appraisal process a preferred option for SEPA prioritisation must be presented. This will require the following additional considerations:

1. The implications of an adaptive approach in terms of availability/guarantee of delayed capital investment;
2. The implications of having an adaptive approach that only includes upfront capital investment to improve the existing defences / beach;

3. Providing a balance between public perception of future risk and the visual impact of implementing a precautionary design;
4. The requirement to have a consistent investment strategy and design standard across the study area.

5.5 Public consultation

A public consultation was held at Stonehaven Town Hall on 13 June 2019 to gather feedback on the short-listed options. For each benefit zone the long list, short list, flood extents and proposed defence designs were displayed for discussion.

Following the meeting in excess of 100 responses were received from the public, with most of these submitting comments in support of SFAG's formal response. The document received from SFAG, along with any additional comments are provided in **Appendix N**.

Given the strength of the public response, Aberdeenshire Council commissioned some additional analysis with regard to the performance of the existing beach profile and proposed beach recharge option within the central benefit zone. The main question was whether a larger beach, e.g. the long-term profile, could provide and appropriate level of protection in the present day without the need to raise the wall at the rear.

This analysis was presented at a meeting with the Council and representatives from SFAG, held at the Council offices in Stonehaven on 27 August 2019. The additional analysis is detailed within **Appendix O**.

Following the meeting, a further response was prepared to demonstrate how SFAG's comments had been incorporated into the study; this is provided within **Appendix P**.

5.6 Costs

Costs of construction for the options have been developed from the JBA design drawings by McLaughlin Harvey; the principal contractor for the River Carron FPS. Contractor derived costs give more confidence in the overall total, particularly the mobilisation and construction components.

Outcomes from these have been used to develop unit costs for each option, which are then applied across the length of frontage being considered.

In addition to the construction costs, the following uplifts are applied:

- On-costs – 19% of construction costs to account for:
    - Designer fees
    - Aberdeenshire Council staff costs
    - Contract supervision
    - Cost consultants fee
    - Legal costs
    - Land purchase
- Optimism bias – 60% to account for concept design stage

For each option, maintenance costs were estimated using Environment Agency databases[10]. The costs used assume efforts are made to maintain assets at condition grade 2 (Good) using the grading system described in the Environment Agency's asset condition assessment manual[11]. Higher estimates have been used to account for the fact the defences will suffer direct wave loading.

[10] Appendix B Maintenance Standards – SC060078 FRCM Assets: Deterioration Modelling and WLC Analysis

[11] Condition Assessment Manual (CAM) (Environment Agency, 2012)

Whole life (present value) costs have been estimated based on the above enabling, capital and maintenance costs. The following assumptions have been made:

- The life span of the scheme and appraisal period is 100 years.
- Discounting of costs are based on the standard Treasury discount rates as recommended by the 2018 revision to the HM Green Book.
- Initial capital costs are assumed to occur in year 0.
- Delayed and adaptive costs are assumed to occur in year 30 (residual life of the majority of existing defences).

5.7 Flood damages

Flood damages have been estimated using the best practice approach outlined in the Multi-Coloured Manual[12] (MCM) using 2017 depth damage curves, uplifted to 2018. It includes quantification of the economic costs associated with:

- Direct property damages
- Indirect property damages
- Intangible damages including increased vulnerability
- Risk to life
- Recreational losses

Flood damages will increase over time in response to rising sea levels and this has explicitly been accounted for in the analysis. Annual Average Damages (AAD) have been estimated using the modelled results for 2018 and 2118 and interpolated linearly through the appraisal period.

Table 5-8 shows a breakdown of AAD and the total present value damages (PVD) for each benefit zone, and the study area. Figure 5-1 and Figure 5-2 demonstrate the breakdown in AAD for each BZ and the contribution of each BZ to the total.

A total PVD of £25.8 million is estimated for the entire study area, based on a 100-year appraisal period.

Table 5-8: Average Annual Damages and Present Value Damages

Benefit Zone	2018 AAD (£k)	2118 AAD (£k)	Total PvD (£k)
Harbour	£50	£93	£1,836
Central	£233	£927	£12,595
North	£225	£798	£11,360
All	£508	£1,817	£25,791

[12] Penning-Rowsell el al., 2013. Flood and Coastal Erosion Risk Management – A Manual for Economic Appraisal

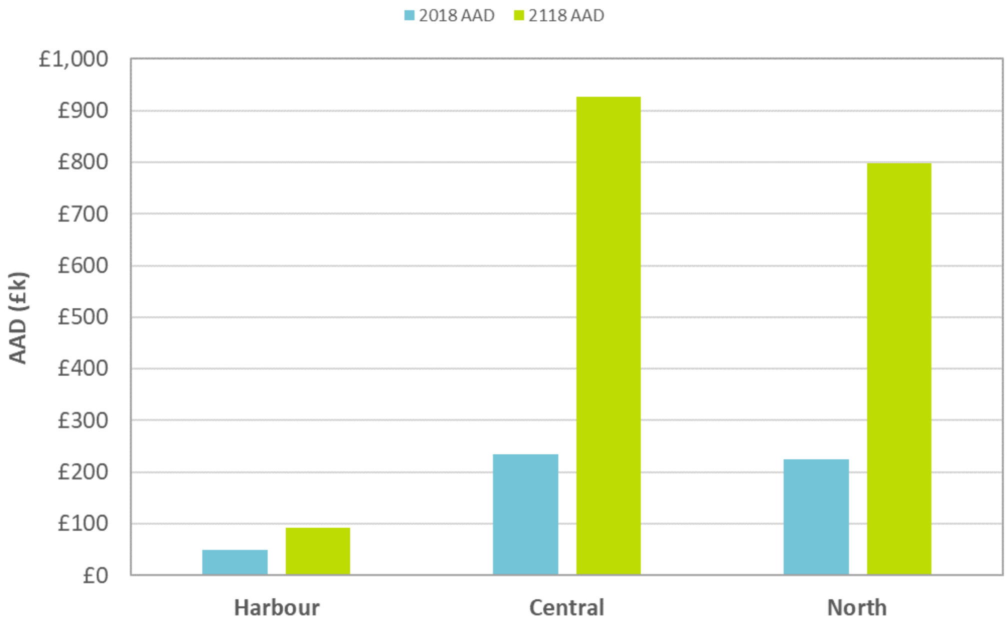


Figure 5-1: Present Day and 2118 Annual Average Damages

Recreational losses have been estimated based on a "*Willingness to Pay*" approach. From this, it is estimated that an additional **£2.5 million** of benefit can be achieved by investing in an FPS to protect the frontage.

This has been divided evenly across each BZ along with the following assumptions for realisation of the benefit.

- 100% can be claimed for the Recharge option
- 90% can be claimed for Sea Wall options
- 80% can be claimed for Rock Armour options

This is based on the feedback from the public and stakeholders as to how much they believed these options would affect the "*attractiveness*" of the frontage.

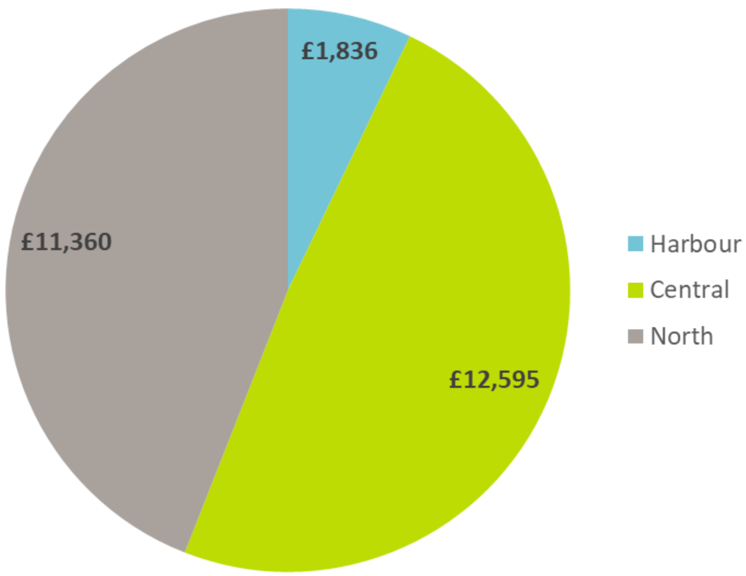


Figure 5-2: AAD breakdown for each BZ

Adding in the recreational losses results in total present day damages of **£28.3 million**.

5.8 Economic analysis

Details of the economic analysis undertaken for each benefit zone, and subsequently considering a range of combinations of the options are presented below. Calculation sheets are provided within **Appendix Q**.

5.8.1 North benefit zone

The options outlined in the tables in Section 5.4 were appraised in order to establish their economic viability. The table below provides a summary of the options, with the subsequent tables outlining the results from the appraisal.

Table 5-9: North benefit zone options

Option	Name	Description
1	**Do Minimum**	Continue with current maintenance and reactive repairs of defences.
2	**Wall Adaptive**	New sea wall constructed present day and adapted (year 30) in response to climate change.
3	**Rock Adaptive**	New rock revetment constructed present day and adapted (year 30) in response to climate change. Will also include wall raising.
4	**Recharge Adaptive**	New recharge scheme constructed present day and adapted in response to climate change. Will also include wall raising.
5	**Wall Precautionary**	New sea wall constructed present day that includes 2118 climate change allowance.
6	**Rock Precautionary**	New rock revetment constructed present day that includes 2118 climate change allowance. Will also include wall raising.
7	**Wall Delayed**	Existing walls raised and new sea wall constructed (with climate change allowance) in year 30.
8	**Rock Delayed**	Existing walls raised and new rock revetment constructed (with climate change allowance) in year 30.
9	**Recharge Delayed**	Existing walls raised and new recharge scheme constructed (with climate change allowance) in year 30.
10	**Wall Raise**	Existing walls raised until design life is exceeded - 30 year appraisal only.

The results from this analysis are presented in the table below, with the economically viable options highlighted in green.

Table 5-10: North Benefit Zone Economic Analysis

Option	Name	PV Costs (£k)	PV Benefits (£k)	BCR
2	**Wall Adaptive**	12,022	11,583	0.96
3	**Rock Adaptive**	13,479	11,498	0.85
4	**Recharge Adaptive**	34,386	11,667	0.34
5	**Wall Precautionary**	13,533	11,739	0.87
6	**Rock Precautionary**	14,414	11,655	0.81
7	**Wall Delayed**	6,898	11,583	1.68
8	**Rock Delayed**	7,212	11,498	1.59
9	**Recharge Delayed**	17,131	11,667	0.68
10	**Wall Raise**	2,076	5,597	2.70

From the results presented above, only the delayed investment in new structures achieve a BCR > 1. All options that consider a new structure in year 0 are shown to be not economically viable. Of the delayed investment options, construction of a new sea wall in year 30 is shown to give the highest **BCR (1.68).**

The medium-term option of only wall raising for 30 years has the highest **BCR (2.70)** and demonstrates the case for immediate investment in some form.

5.8.2 Central benefit zone

The options outlined in the tables in Section 6.3 were appraised in order to establish their economic viability. The table below provides a summary of the options, with the subsequent tables outlining the results from the appraisal.

It should be noted that, for any options to achieve a BCR > 1.0, investment in new defences along Cowie must be delayed to year 30. In the medium-term the residual risk here will either have to be accepted or managed through PFR.

Table 5-11: Central benefit zone options

Option	Name	Description
1	**Do Minimum**	Continue with current maintenance and reactive repairs of defences.
2	**Wall Adaptive + River Cowie Walls**	New sea wall constructed present day and adapted (year 30) in response to climate change. New walls along River Cowie in year 30.
3	**Wall Precautionary + River Cowie Walls**	New sea wall constructed present day that includes 2118 climate change allowance. New walls along River Cowie in year 30.
4	**Recharge Adaptive + River Cowie Walls**	New recharge scheme constructed present day and adapted in response to climate change. New walls along River Cowie year 30. Will also include wall raising.
5	**Recharge medium-term**	New recharge scheme implemented until the life of structures in the north is exceeded - 30 year appraisal only. Will also include wall raising.

The results from this analysis are presented in the table below, with the economically viable options highlighted in green.

Table 5-12: Central benefit zone economic analysis

Option	Name	PV Costs (£k)	PV Benefits (£k)	BCR
2	**Wall Adaptive + River Cowie Walls**	12,740	12,675	0.99
3	**Wall Precautionary + River Cowie Walls**	14,362	12,976	0.90
4	**Recharge Adaptive + River Cowie Walls**	12,468	12,759	1.02
5	**Recharge medium-term**	7,601	6,056	0.80

From the results presented above, only the beach recharge is economically viable with a **BCR > 1 (1.02).** All options that consider a new structure in year 0 are shown to be not economically viable.

For the sea wall it is shown that there is no significant economic benefit in adapting the design over the appraisal period.

Unlike the North BZ, the medium-term option of only recharging for 30 years is shown not to be cost effective (**BCR = 0.80**).

5.8.3 Harbour benefit zone

The options outlined in the tables in Section 6.4 were appraised in order to establish their economic viability. The table below provides a summary of the options, with the subsequent tables outlining the results from the appraisal.

Table 5-13: Harbour benefit zone options

Option	Name	Description
1	**Do Minimum**	Continue with current maintenance and reactive repairs of defences.
2	**North Rock + Inner Revetment + South Rock**	New rock revetments (north and south) and stepped revetment (inner) constructed present day that includes 2118 climate change allowance.
3	**North Rock + Inner Wall + South Rock**	New rock revetments (north and south) and wall (inner) constructed present day that includes 2118 climate change allowance.
4	**North Rock + Inner Revetment + South MRL**	New rock revetment (north), stepped revetment (inner), and managed realignment (south) constructed present day that includes 2118 climate change allowance.
5	**North Rock + Inner Wall + South MRL**	New rock revetment (north), wall (inner), and managed realignment (south) constructed present day that includes 2118 climate change allowance.
6	**PFR + North Rock + Delayed Inner Revetment + South MRL**	PFR and rock revetment (north) implemented present day with new stepped revetment (inner), and managed realignment (south) constructed in year 30 with a climate change allowance.
7	**PFR + Delayed North Rock + Inner Revetment + South MRL**	PFR implemented present day with new rock revetment (north), stepped revetment (inner), and managed realignment (south) constructed in year 30 with a climate change allowance.
8	**PFR - 30 years**	PFR resilience implemented present day – 30-year appraisal period only.

The results from this analysis are presented in the table below, with the economically viable options highlighted in green.

Table 5-14: Harbour Benefit Zone Economic Analysis

Option	Name	PV Costs (£k)	PV Benefits (£k)	BCR
2	**North Rock + Inner Revetment + South Rock**	10,506	2,650	0.25
3	**North Rock + Inner Wall + South Rock**	13,766	2,565	0.19
4	**North Rock + Inner Revetment + South MRL**	8,202	2,650	0.32
5	**North Rock + Inner Wall + South MRL**	11,462	2,565	0.22
6	**PFR + North Rock + Delayed Inner Revetment + South MRL**	5,734	2,650	0.46
7	**PFR + Delayed North Rock + Inner Revetment + South MRL**	3,381	2,301	0.68
8	**PFR - 30 years**	442	1,084	2.45

From the results presented above, all the new structural options fail to achieve a BCR > 1. This is the case regardless of whether investment is delayed or not.

The medium-term option of only considering PFR for 30 years has the highest **BCR (2.45)** and demonstrates the case for immediate investment in some form.

Despite having a BCR < 1, options 6 and 7 have the highest BCR of the structural options considered, and as such have been taken forward; this ensures that there are medium and long term options for the full study extent considered within the combinations below.

5.8.4 Combination

Upon analysis of the individual BZ results, the most economically viable were taken forward to assess as options across the entire bay. Options considered are:

- **North 7** – Wall raise and delayed new sea wall
- **North 8** – Wall raise and delayed new rock revetment
- **North 9** – Wall raise and delayed beach recharge
- **Central 4** – Adaptive recharge with sea wall raise and River Cowie walls
- **Harbour 6** – PFR and north rock armour; with delayed inner revetment and south MRL
- **Harbour 7** – PFR and delayed north rock armour, inner revetment and south MRL

In addition to these, a Medium-term option (30-year) was appraised. This combines:

- **North 5** - Wall raising
- **Central 4** – Recharge and sea wall raise
- **Harbour 8** - PFR

The aim of this is to support the case for long-term investment through an adaptive approach by highlighting the immediate short to medium-term benefit.

The table below provides a summary of the options, with the subsequent tables outlining the results from the appraisal.

Table 5-15: Combined Benefit Zones Options

Combination	Name	Description
	Do Minimum	Continue with current maintenance and reactive repairs of defences
A	North 7 + Central 4 + Harbour 7	Wall raise and new wall in year 30 - North Adaptive recharge - Central PFR and new rock revetment (north), stepped revetment (inner) and MRL (south) in year 30 - Harbour
B	North 8 + Central 4 + Harbour 7	Wall raise and new rock revetment in year 30 - North Adaptive recharge - Central PFR and new rock revetment (north), stepped revetment (inner) and MRL (south) in year 30 - Harbour
C	North 9 + Central 4 + Harbour 7	Wall raise and new recharge in year 30 - North Adaptive recharge - Central PFR and new rock revetment (north), stepped revetment (inner) and MRL (south) in year 30 - Harbour
D	North 7 + Central 4 + Harbour 6	Wall raise and new wall in year 30 - North Adaptive recharge - Central Rock revetment (north) year 0; stepped revetment (inner) and MRL (south) in year 30 - Harbour
E	North 8 + Central 4 + Harbour 6	Wall raise and new rock revetment in year 30 - North Adaptive recharge - Central Rock revetment (north) year 0; stepped revetment (inner) and MRL (south) in year 30 - Harbour
F	North 9 + Central 4 + Harbour 6	Wall raise and new recharge in year 30 - North Adaptive recharge - Central Rock revetment (north) year 0; stepped revetment (inner) and MRL (south) in year 30 - Harbour
G	North 10 + Central 5 + Harbour 8 (30-years)	Wall raise - North Recharge - Central PFR - Harbour
H	North 7 + Central 4	Wall raise and new wall in year 30 - North Adaptive recharge – Central Do Minimum - Harbour

The results from this analysis are presented in the tables below, with the economically viable options highlighted in green.

Table 5-16: Combined Benefit Zones Economic Analysis

Combination	Name	PV Costs (£k)	PV Benefits (£k)	BCR
A	North 7 + Central 4 + Harbour 7	22,748	26,643	1.17
B	North 8 + Central 4 + Harbour 7	23,062	26,559	1.15
C	North 9 + Central 4 + Harbour 7	32,980	26,727	0.81
D	North 7 + Central 4 + Harbour 6	25,101	26,991	1.08
E	North 8 + Central 4 + Harbour 6	25,415	26,907	1.06
F	North 9 + Central 4 + Harbour 6	35,334	27,075	0.77
G	North 10 + Central 5 + Harbour 8 (30-years)	10,120	12,737	1.26
H	North 7 + Central 4 + Do Min Harbour	19,367	27,018	1.40

Of the long-term options applicable to the full study extent, the following combination (A) is shown to be the most cost beneficial, with a **BCR of 1.17**.

- North BZ: raising the existing defences then constructing a new sea wall in year 30.
- Central BZ: adaptive beach recharge scheme with associated wall raising.
- Harbour BZ: PFR for the first 30 years followed by the construction an extended rock revetment to the north of the harbour, a stepped revetment in the inner harbour and managed realignment to the south of the harbour.

A higher BCR can be achieved by managing all flood risk in the harbour BZ with PFR until year 30 (combination A compared to D, and combination B compared to E).

The medium-term option of only considering a 30-year appraisal period (combination G) has a BCR of 1.26 and demonstrates the case for immediate investment in some form.

Due to the options for the Harbour BZ not proving to be economically viable in their own right, a combination was also considered where the do minimum option is taken forward for the harbour. This results in the highest BCR of 1.40.

The economic analysis of the short-listed options was reviewed twice by SEPA; a review of the initial calculations was undertaken in June 2019 and a subsequent review of the final analysis was undertaken in December 2019. Both of these consultation responses are provided within **Appendix R**.

6 Preferred option

6.1 Short-term recommendations

As part of the "managed adaptive approach", a number of short-term recommendations are outlined below in order to manage existing flood risk prior to an FPS being implemented.

6.1.1 Property level resistance and resilience

Property flood resistance and resilience (PFR) measures, resistance measures are also widely known as Property Level Protection (PLP) provide property owners and professional partners with practical and cost-effective steps to help lower flood risk through the use of a range of products.

It is understood that a number of properties within Stonehaven and Cowie already have PFR measures implemented or available to use during an event. However, this could be improved upon and it is recommended that advice is sought from the Scottish Flood Forum on this. Measures implemented at this stage would be the responsibility of individual property owners.

The modelling undertaken as part of this project has provided high resolution flood risk maps for present day and 2118. It is recommended that these be used as reference by relevant departments within Aberdeenshire Council (e.g. Planning and Building Control) to promote the adoption of resilience measure when undertaking any building works within the flood zone.

6.1.2 Sediment management

There is a history of sediment recycling within Stonehaven Bay. Generally, this has seen the movement of shingle from within the mouth of the Cowie Water to just south of the River Carron. However, analysis undertaken as part of this study, and supported by accounts of local residents, suggests that the material placed to the south of the Carron does not stay in place for long, and is removed by natural processes. This is despite the presence of a small rock groyne to trap material within this area of the beach. As such, this is not considered to be a sustainable management strategy.

It is recommended that a full beach monitoring strategy is developed by Aberdeenshire Council, and that this is used to inform future sediment management practices; see section 6.1.3 below for further information on beach monitoring. Prior to this information being available, it is recommended that sediment is only removed from the mouth of the Cowie Water and placed within the central beach area in response to particular events that have removed material; this is the area where the analysis undertaken as part of this study has shown that the beach plays a crucial role in the functioning of the defences. The requirement for short term replenishment of the beach in front of Cowie promenade should be limited by the presence of the rock armour that was installed in 2006. The crucial role that the beaches play in Stonehaven and Cowie highlights the importance of working with natural processes, and also have the added benefit of providing recreational amenity value.

6.1.3 Beach monitoring

Within this study it has been shown that the beaches in both the north and central benefit zones form an important part of the defences. The analysis undertaken herein was based on three beach surveys, each approximately 5 years apart, and with the data gathered in different seasons. In order to develop an informed beach management plan, it is recommended that a beach monitoring programme be established; this would provide a clearer picture of sediment movements within the bay with regard to seasonal changes and post storm responses. This would be used to determine short term sediment management practices, the future design of beach recharge within a scheme, and the maintenance of such a scheme.

As an extension to this study a trial of CoastSnap is being setup at the mouth of the Cowie Water. This is in the form of a mount and information board located at the mouth of the Cowie Water, which members of the public can use to take images of the beach. Images taken from the fixed photo frame are then submitted to be aligned and rectified using a number of Ground Control Points.

It is recommended that Aberdeenshire Council establish a full beach monitoring programme in addition to the CoastSnap trail.

6.1.4 Flood warning service

SEPA's coastal flood forecasting system for Aberdeenshire and Angus was launched in autumn 2018. Within Stonehaven Bay this provides a still water level forecast for the bay as a whole, as well as wave overtopping forecasts at both Cowie and Stonehaven.

It is recommended that all residents and business within the coastal flood risk zone are signed up to the forecasting system in order to provide advanced notice of conditions, and lead in time to allow any demountable PFR measures to be put in place.

6.1.5 Repairs and maintenance

The coastline with Cowie and Stonehaven is already fronted by a range of defences. As part of this study two visual structural assessments; one for the harbour and one for the rest of the frontage, were undertaken. These include the condition of each of the sections of defence, provide information on the residual life of the structures and identify any existing defects. It is recommended that information contained within these reports is used to supplement Aberdeenshire Council's existing inspection and maintenance procedures.

6.2 Medium to long term options

6.2.1 Business case

The results and analysis presented within Chapter 5 have demonstrated how the short-listed options have been developed and appraised for Stonehaven Bay. It has been shown how these comply with the requirements of both Aberdeenshire Council and Scottish Government.

The results demonstrate that the most economically viable approach is to implement an adaptive approach to flood and erosion risk management, which can be summarised as follows for each benefit zone:

- **North** – Improve the existing defences immediately and adapt to a new sea wall when the residual life is exceeded;
- **Central** – Implement an adaptive beach recharge scheme and associated wall raising immediately and replace Cowie defences in year 30;
- **Harbour** – Manage the medium-term risk through PFR and construct new defences when the residual life of the current defences is exceeded (year 30).

Should this be progressed forward as an FPS in the next Scottish Government funding cycle, this would result in the following schedule of works.

Table 6-1: Schedule of works for each BZ

Location	Year 0	Year 30	Additional	Maintenance
North	Raise existing wall	New sea wall	-	Annual maintenance of sea walls
Central	Raise existing wall and new recharge scheme including control structures	New walls along Cowie tidal reach	Adapt recharge volume over time to meet end of period design life. 4 instalments every 20 years.	Annual maintenance of wall, control structures and beach. 5 yearly recharge to offset sediment losses. Beach monitoring.
Harbour	PFR	New rock revetment at harbour carpark; new stepped revetment in inner harbour; managed realignment of south harbour	-	Annual maintenance of PFR and new structures

The above option provides a 1 in 200 year standard of protection whilst also adapting to the impact of climate change in an optimised way; in that expenditure on flood defences is applied when it is needed rather than up-front. This has two key benefits – upfront cost savings, and time to manage or offset the potential negative impacts of raised defences in Stonehaven.

The preferred option was presented to the Kincardine and Mearns Area committee on 19 November 2019 and was subsequently approved at the Infrastructure Services committee on 28 November 2019. It was recognised there is a potential need for an increase in sea wall height as a result of projected sea level increases. However, it is requested that all defences at sea are maximised in order to ensure that the sea wall height is optimised at the lowest achievable level such that the promenade need not be raised. It is further requested that the provision of an offshore reef, i.e. extension of the Brachans rock platform (as discussed within Appendix P) and the effective use of fishtail groynes to both retain sediment and reduce wave action in the most exposed locations is considered.

It is therefore recommended that these details are considered in full during any future design phases.

6.3 Preferred option benefits

The present value cost of the preferred option has been estimated to be **£22.7 million**, including a 60% optimism bias. This is broken down as follows:

- North - £6.9 million
- Central - £12.4 million
- Harbour - £3.4 million

In terms of overall cash contributions required, this is estimated to be £56 million over the 100-year appraisal period. Much of this spend is delayed until after the residual life of the existing structures (year 30).

Figure 6-1 provides a breakdown of the cumulative cash contributions for the preferred option over the 100-year appraisal period.

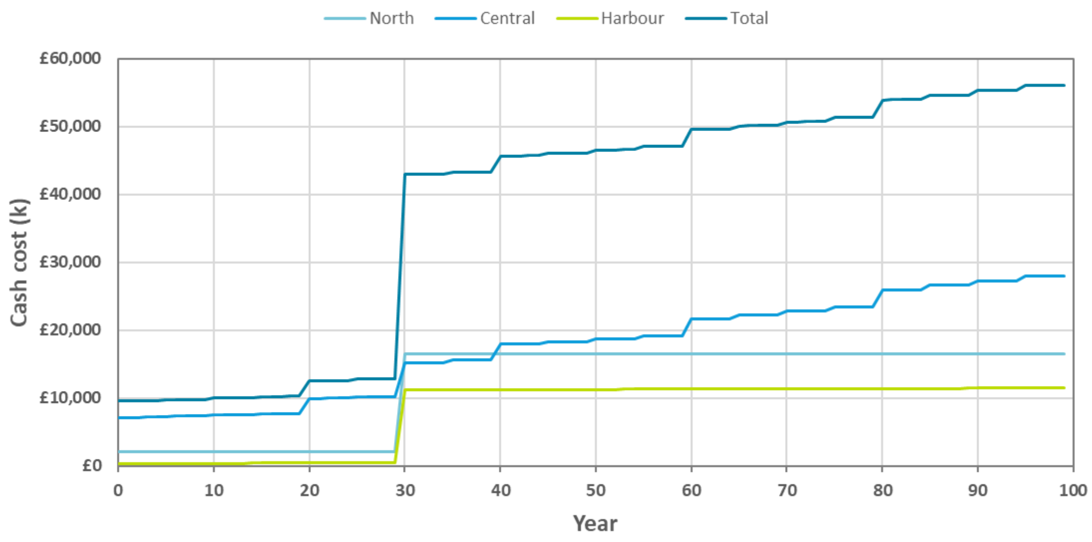


Figure 6-1: Cumulative cash contributions over the 100 year appraisal period

Although the Scottish Government guidance promotes and adaptive approach, at the time of writing there is not definitive information as to how such FPS will be funded. There is therefore the risk that the full spend required for the preferred option may not be met through Government grant.

Should only the year 0 costs receive grant, £9.5 million would be eligible, which, assuming the same contribution as the first cycle, would mean £7.6 million of Government investment.

As discussed previously, the primary form of benefit of the scheme is in the way of providing flood protection to residents and businesses within Stonehaven.

In addition, it is proposed that the following additional benefits will be realised:

- Public health and well-being.
- Reduce risk to life following a number of previous evacuations of seafront properties.
- Provide protection to a population with a high proportion of vulnerable and elderly residents.
- Recreational and tourism benefits by enhancing the central portion of the beach.
- Recreational and tourism benefits through minimising adverse short-term impact of new structures.
- Construction of significant new defence structures is delayed until the residual life of the existing structures are exceeded. This provides Aberdeenshire Council with valuable time to mitigate some of the public perceptions of the FPS.
- The delayed investment in future defences makes the scheme adaptable to the uncertainty surrounding climate change and sea level rise projections.
- The promotion of natural flood management and working with natural processes through beach recharge and management.

In total the PV estimates of these are estimated to be **£26.6 million**, resulting in a BCR of **1.17**.

6.3.1 Additional considerations

Immediate case for investment

The uncertainty in the funding mechanism for adaptive schemes mean that there is a risk that the required contribution is not met by Scottish Government over the lifetime of the scheme. To demonstrate the case for immediate investment a 30-year appraisal was also conducted. The schedule of works for this is provided below with the appraisal results demonstrating the immediate need for investment with a BCR = **1.24**.

This demonstrates that the scheme is viable based on the immediate and shorter-term risk, and does not solely rely on the uncertainty surrounding sea level rise over a 100-year appraisal period.

Table 6-2: Schedule of works for 30-year appraisal

Location	Year 0	Additional	Maintenance
North	Raise existing wall	-	Annual maintenance of sea walls.
Central	Raise existing wall and new recharge scheme including control structures	Adapt recharge volume over time to meet end of period design life. 1 instalment at 20 years	Annual maintenance of wall, control structures and beach. 5 yearly recharge to offset sediment losses.
Harbour	PFR	-	Annual maintenance of PFR and new structures.

Harbour

The individual BZ appraisals conducted demonstrated that no option results in an economic case for investment in the harbour. Should the harbour be removed from the business case and future FPS, the overall BCR increases to **1.40**, over a 100-year appraisal period.

If it should come down to maximising the BCR to provide the best chance for prioritisation, removal of the harbour from the analysis could be considered.

The planning implications of an adaptive approach, where by the standard of protection may vary through time, will also need to be considered by Aberdeenshire Council.

Erosion protection

The work undertaken to assess the potential erosion (Section 3.2 and Appendix I) has shown that failure of the defences may result in severe unchecked erosion and future (after 30 years) risk to properties and critical infrastructure.

As there is a high degree of uncertainty in the estimates, the financial implications of this were not estimated so as to not skew the business case. However, should, for example, the sewer main become exposed in the North BZ, the cost of repair or replacement would likely considerably outweigh that to improve the sea defences after 30 years.

This provides further support for implementing an adaptive scheme over the next 100 years.

Social deprivation and vulnerability

During the assessment it was found that, on average, properties within a 20m buffer of the 1,000-year flood extent had a higher *Vulnerability Index* than the remainder of Stonehaven (based on SEPA receptor datasets). This is particularly true for the most at risk areas of the Central BZ (e.g. Turners Court) where most properties are sheltered accommodation.

The financial impacts of flooding on health is largely thought to be underestimated in most financial assessments, with the impact to the most vulnerable considerably greater than the rest of the population. The impacts on health are estimated through the MCM's *Intangible Damages*. Here the MCM guidance varies from applying £286/household/year to £2,315/household/year.

Through initial consultation with SEPA it was requested that the lower (£286) value was used when developing the business case in order to provide consistency with other studies. However, a higher value for Stonehaven (particularly the Central BZ) could be justified.

Intangible Damages account for approximately 5% of the total PVD for the Central BZ and if the value was increased to the MCM average £1,300, the Do Minimum PVD increases by 8% to **£28 million**.

This further supports the case for immediate investment in improved defences in Stonehaven Bay, particularly in the Central BZ.

6.3.2 Residual risk

The flood study undertaken herein has focused on coastal risk, and it should be acknowledged that the preferred coastal scheme could have an impact on surface water. The coastline is already fronted by a range of defences, which could result in the ponding of surface water. However, following the optimisation of wall heights, should the promenade need to be raised, this could result in the displacement of surface water. It is therefore recommended that the implications of the design on surface water be considered at the detailed design stage, including the potential for storage to be integrated within a raised promenade and the construction of additional drainage to the landward side of any promenade. No such measures have been included within the costs at present.

6.4 Environmental screening

The process of Environmental Impact Assessment (EIA) ascertains the likely significant environmental effects from a proposal. An EIA screening opinion for the preferred option will be prepared and submitted to Aberdeenshire Council since the proposal comprises a project described in Annex II of the 2011/92/EU 'EIA' Directive - "10(f) Inland-waterway construction not included in Annex I, canalisation and flood-relief works' and "10(k) Coastal work to combat erosion and maritime works capable of altering the coast through the construction, for example, of dykes, moles, jetties and other sea defence works, excluding the maintenance and reconstruction of such works".

There are several sets of EIA Regulations which transpose the Directive and proposed developments should be considered in relation to the most applicable regulations. The powers within the Marine (Scotland) Act 2010 for management of Scotland's seas extend from the Mean High Water Spring (MHWS) to the seaward limits of the Scottish territorial waters. Since, at the time of preparation of the screening report, the drawings for the preferred option includes works at the coast which extend beyond MHWS, the Stonehaven Flood Study will be screened under both The Flood Risk Management (Flood Protection Schemes, Potentially Vulnerable Areas and Local Plan Districts) (Scotland) Amendment Regulations 2017 and The Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017.

Appendices

A Information Review Report

JBA consulting

Stonehaven Bay Coastal Flood Protection Study

Information Review Report

Final Report

September 2018

www.jbaconsulting.com

Aberdeenshire COUNCIL

JBA Project Manager

Nicci Buckley BSc MSc CSci MCIWEM C.WEM
Unit 2.1 Quantum Court
Research Avenue South
Heriot Watt Research Park
Riccarton
Edinburgh
EH14 4AP

Revision history

Revision Ref/Date	Amendments	Issued to
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.

Prepared by .... Douglas Pender MEng PhD MCIWEM

Senior Engineer

Prepared by .... Nicci Buckley BSc MSc CSci MCIWEM C.WEM

Chartered Senior Analyst

Reviewed by .... David Bassett BSc MSc CEnv MCIWEM C.WEM

Director

Purpose

This document has been prepared as a Final Report for Aberdeenshire Council. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

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.

Copyright

© Jeremy Benn Associates Limited 2018.

Carbon footprint

A printed copy of the main text in this document will result in a carbon footprint of 58g if 100% post-consumer recycled paper is used and 73g if primary-source paper is used. These figures assume the report is printed in black and white on A4 paper and in duplex.

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).

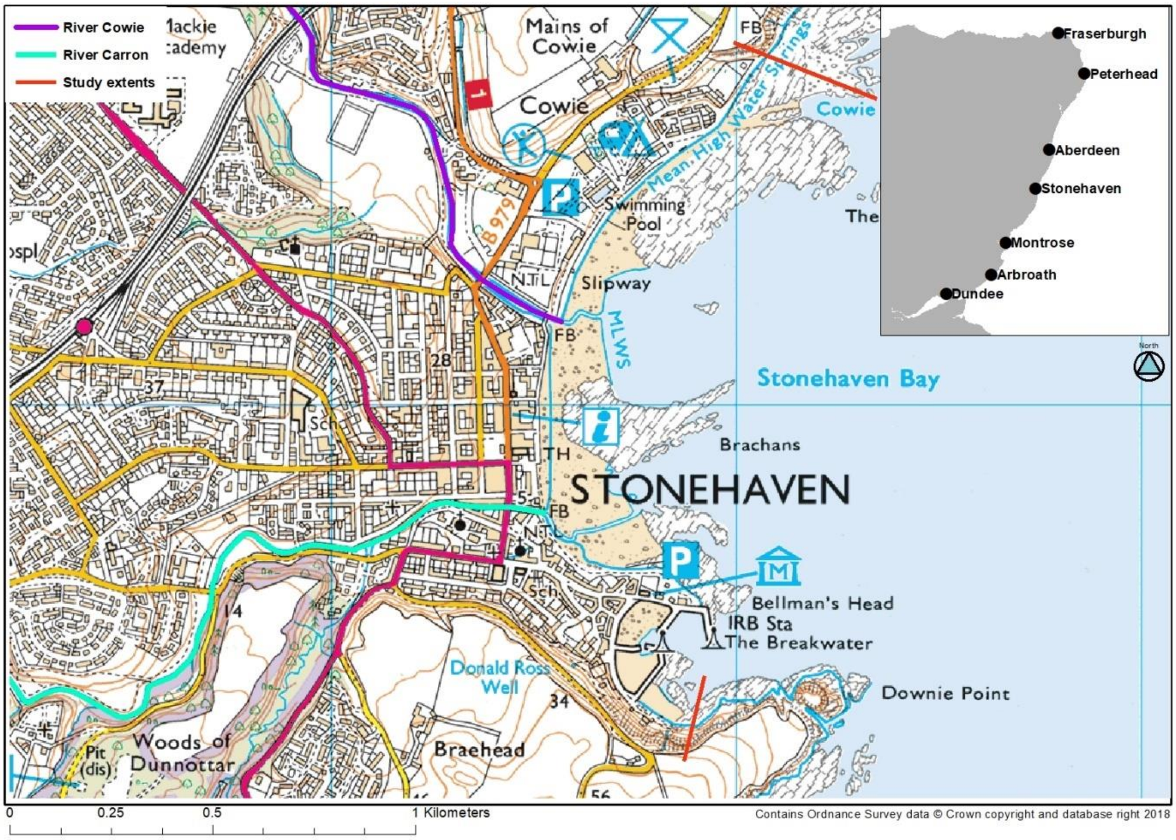


Figure 1-1: Location plan

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.

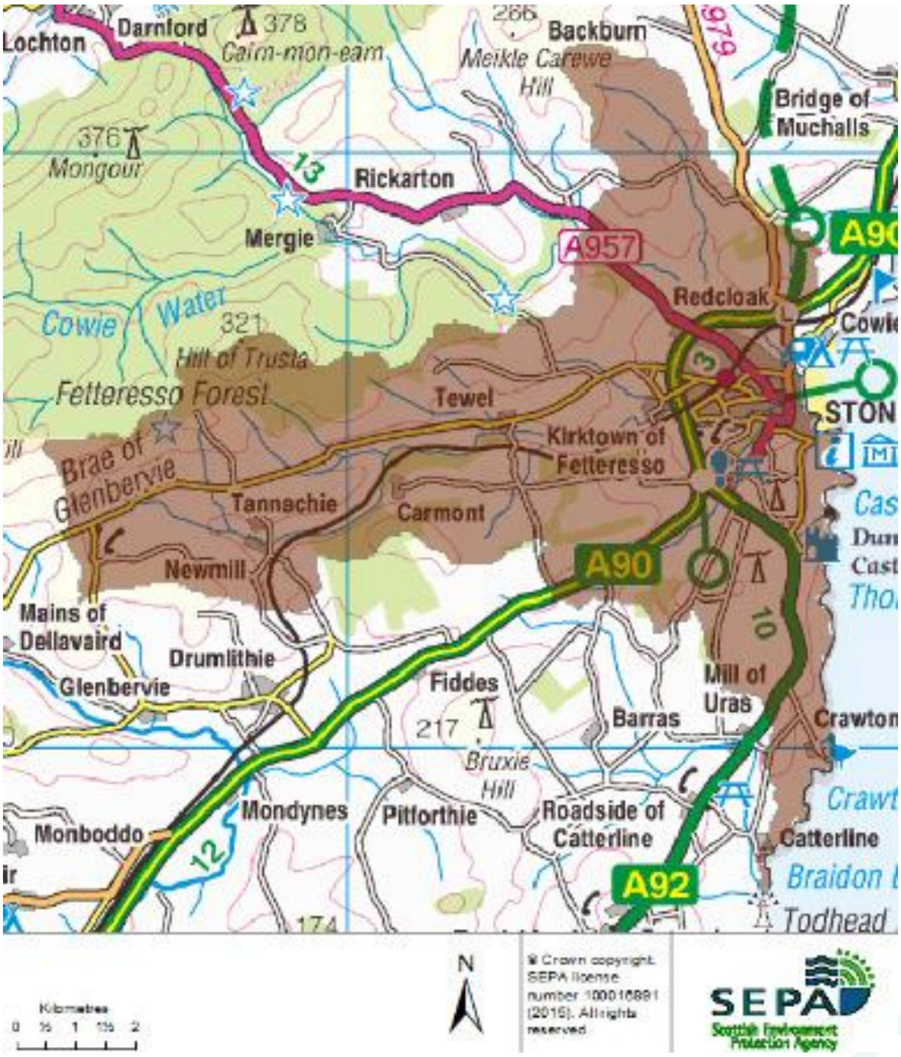


Figure 1-2: Stonehaven PVA from the Local FRM Plan

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.

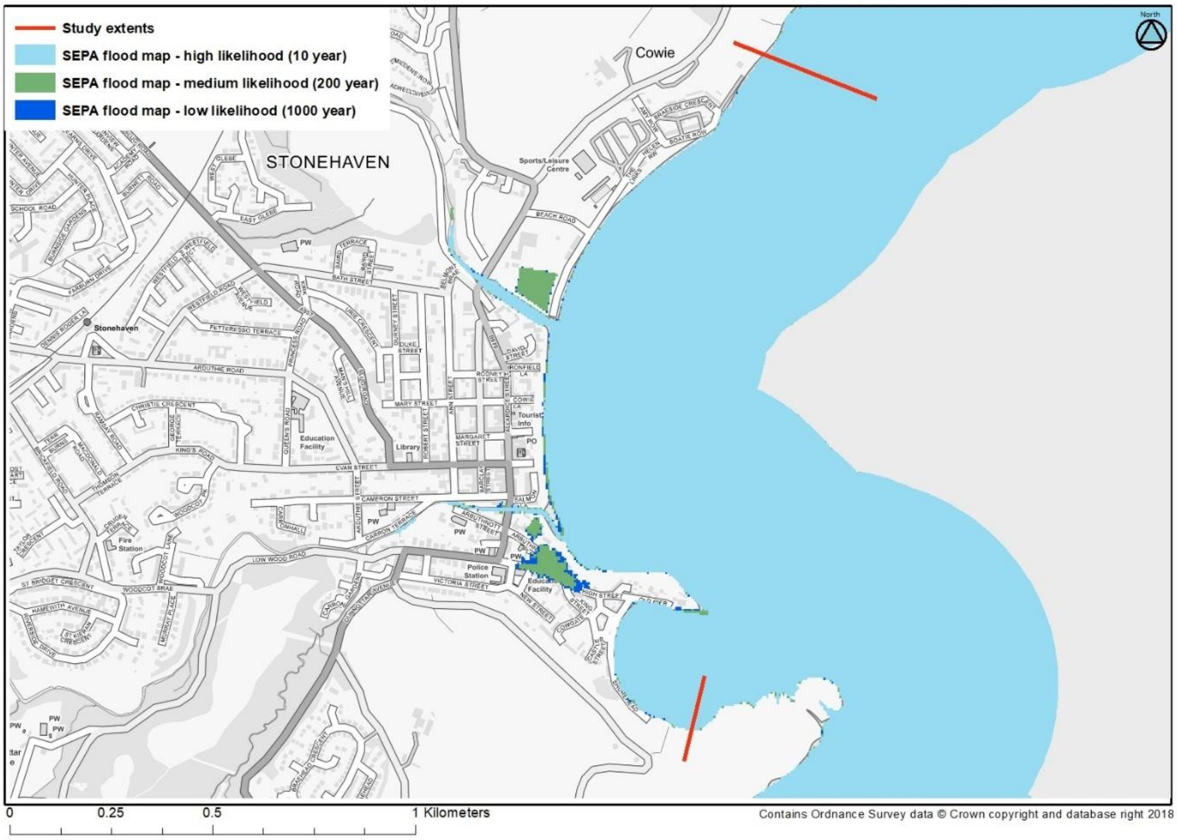


Figure 3-1: SEPA coastal flood extents

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.

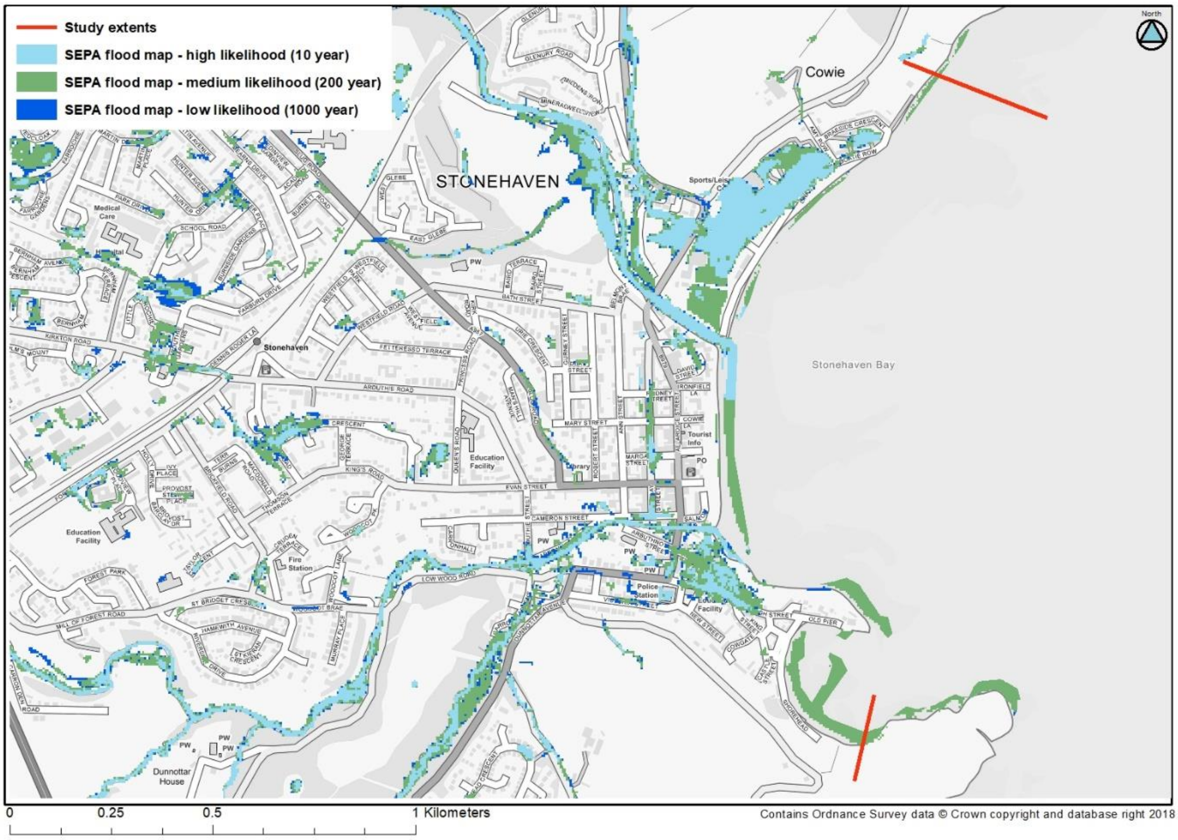


Figure 3-2: SEPA pluvial flood extents

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.

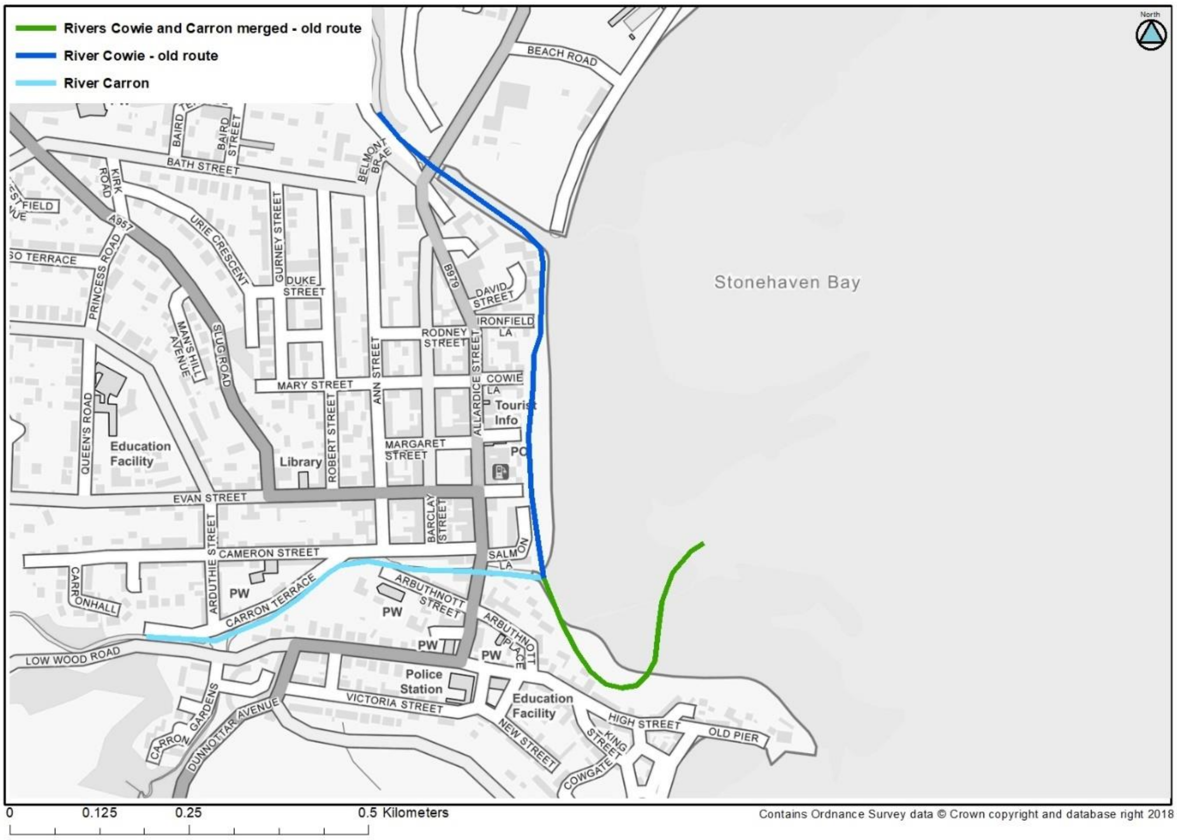


Figure 3-3: Historical configuration of the Rivers Cowie and Carron at the coast

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.

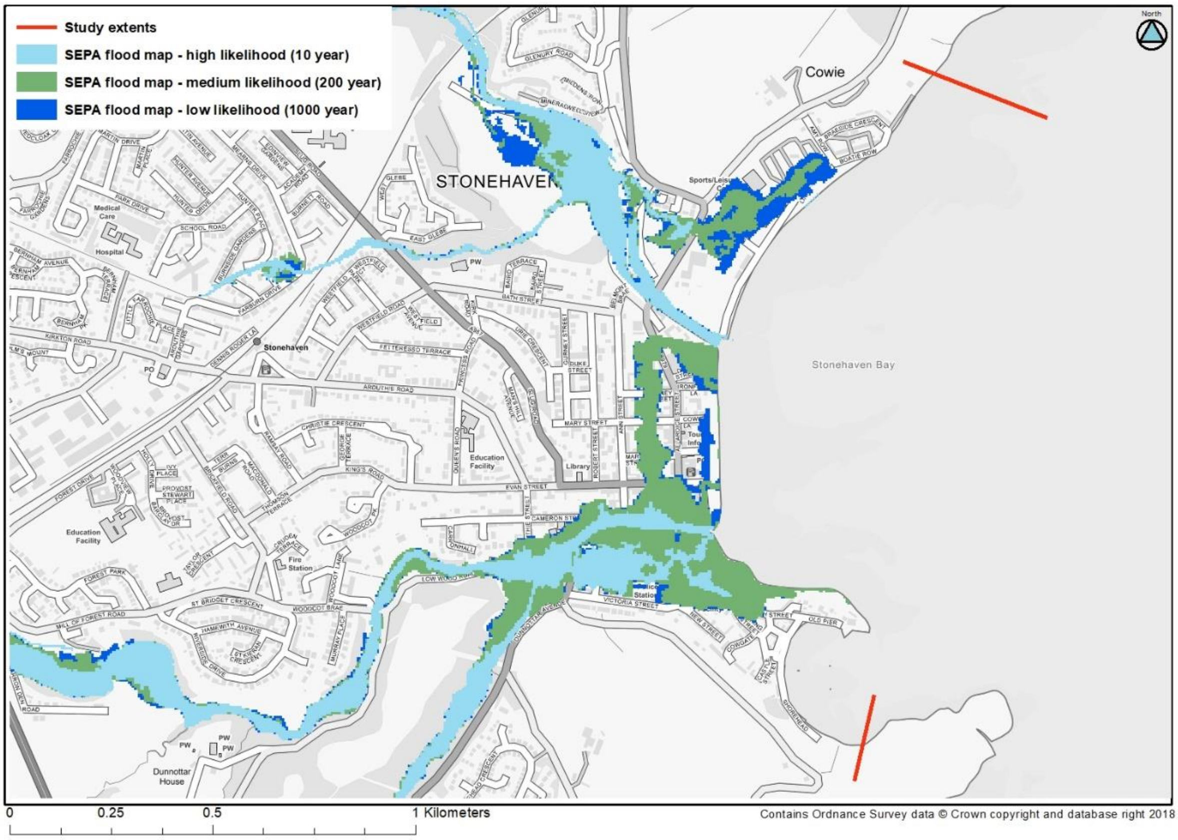


Figure 3-4: SEPA fluvial flood extents

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.

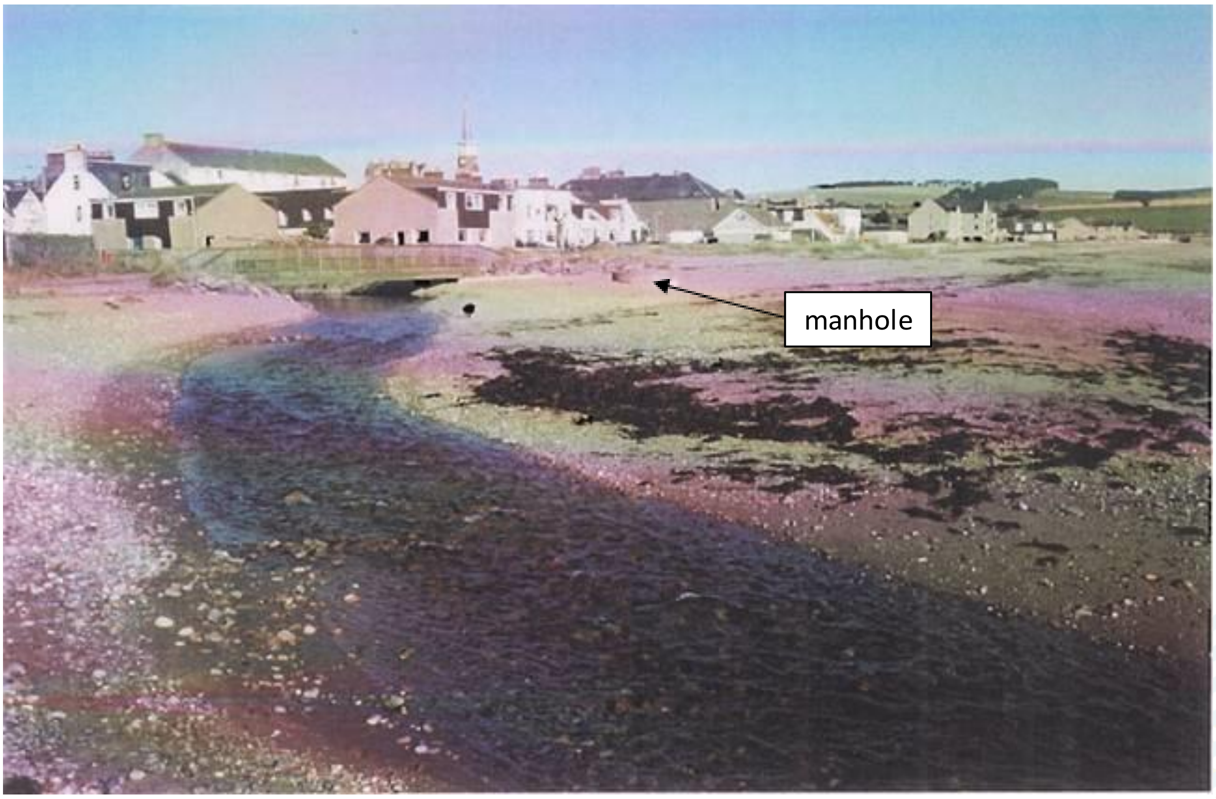


Figure 4-5: Historical natural outfall of the River Carron

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

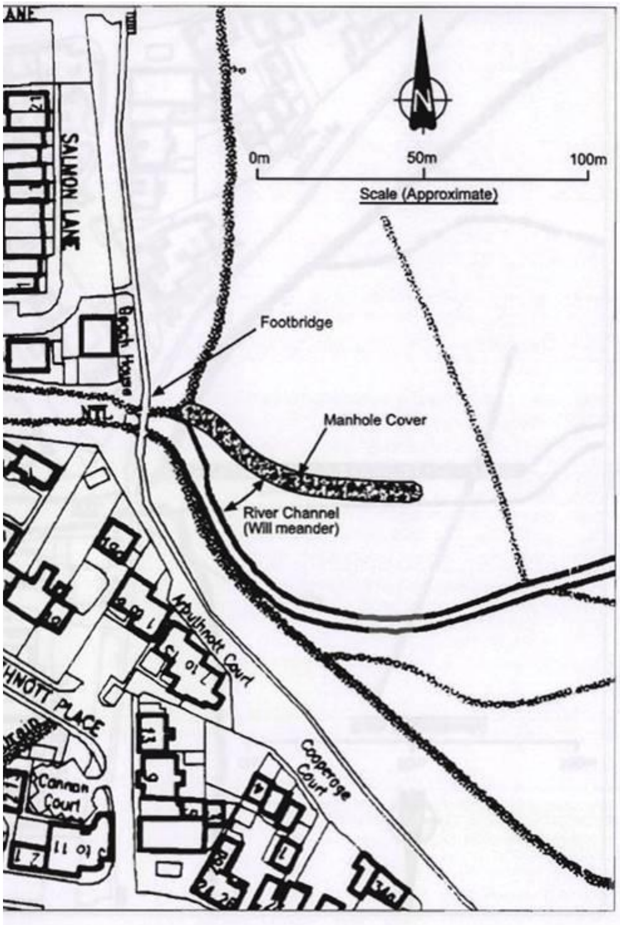


Figure 4-6: Recommended training wall option from HR Wallingford report

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.

0 0.05 0.1 0.2 Kilometers

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.

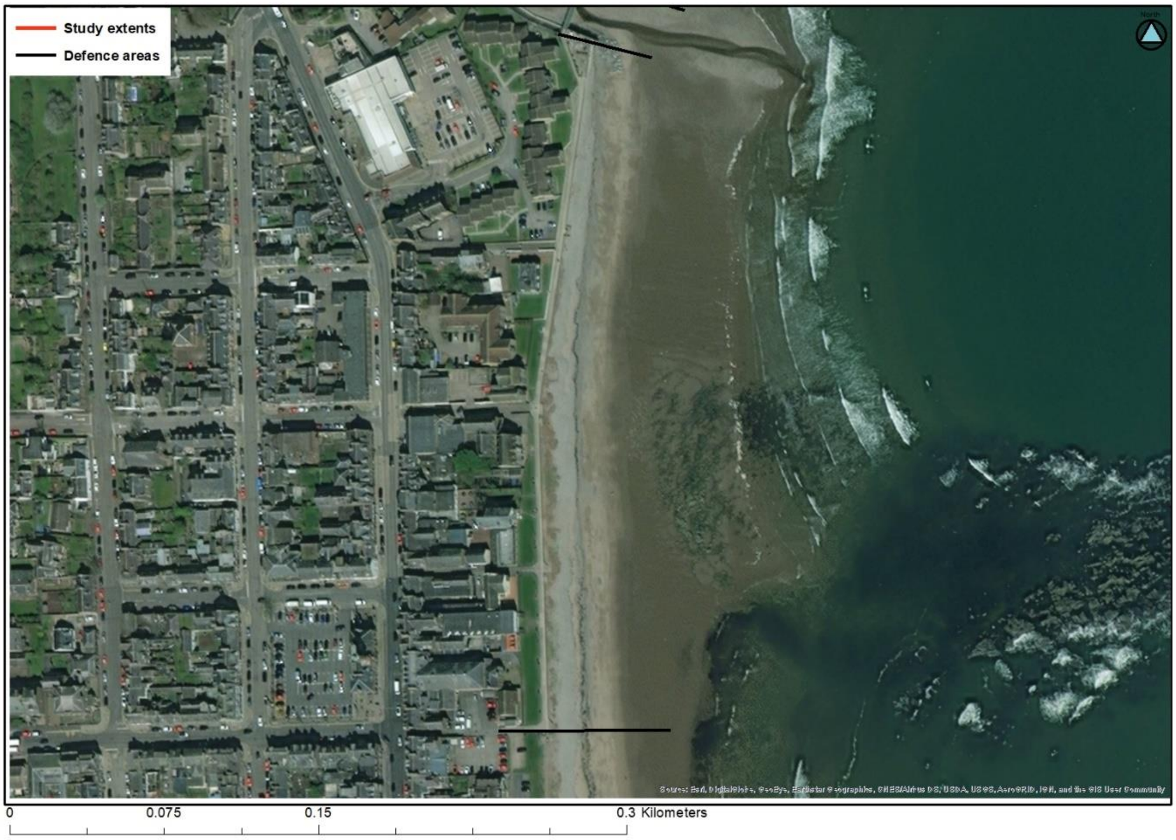


Figure 4-8: Aerial image of central section

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.

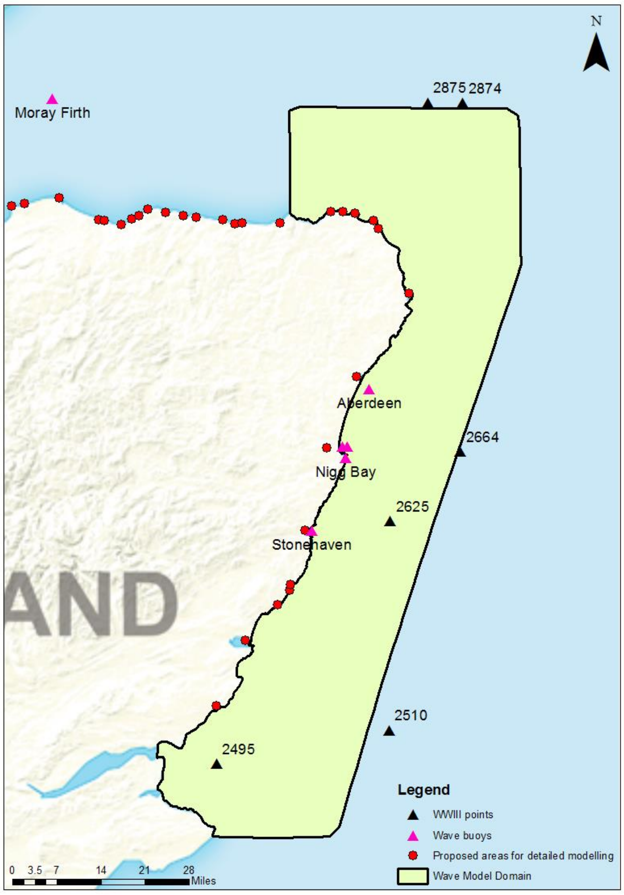


Figure 6-1: SEPA SWAN model and WW3 points used for developing the offshore multivariate datasets

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.

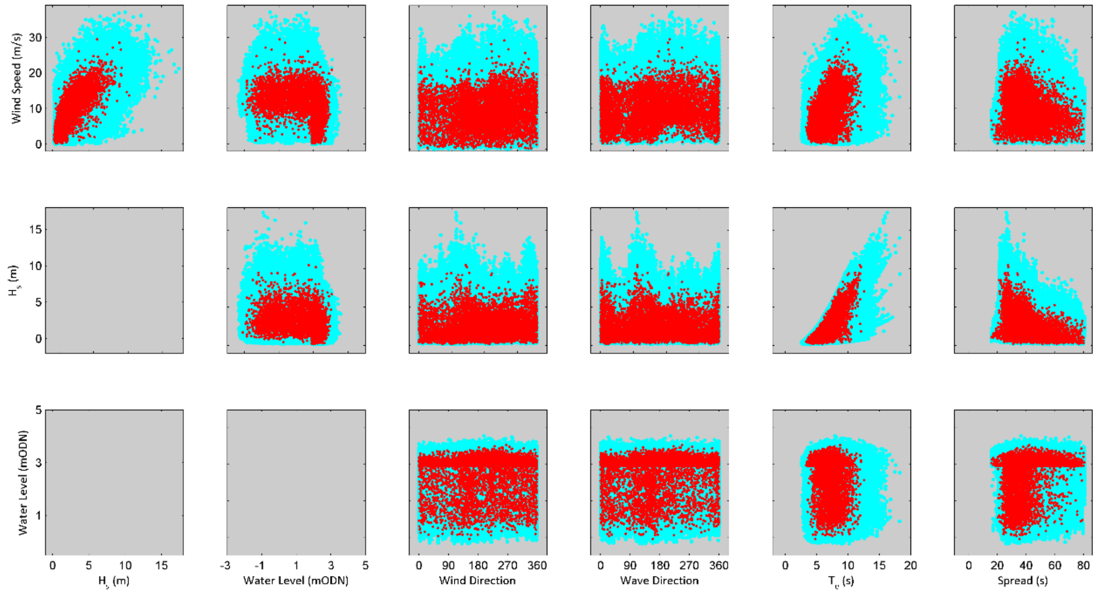


Figure 6-2: Summary of SEPA offshore multivariate dataset events relevant to Stonehaven. Red data points show the observed events from WW3, with the turquoise points indicated the simulated data that will inform the wave conditions and overtopping risk

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.

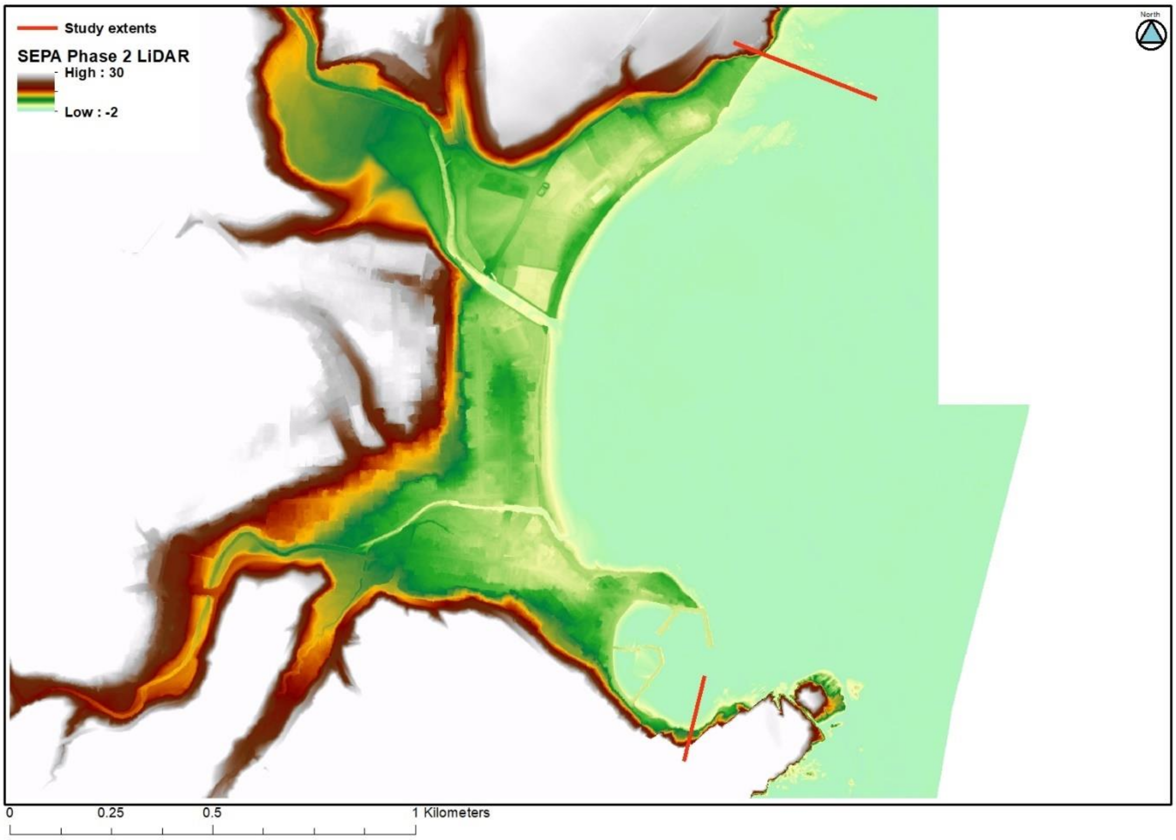


Figure 6-3: SEPA Phase 2 LiDAR coverage

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.

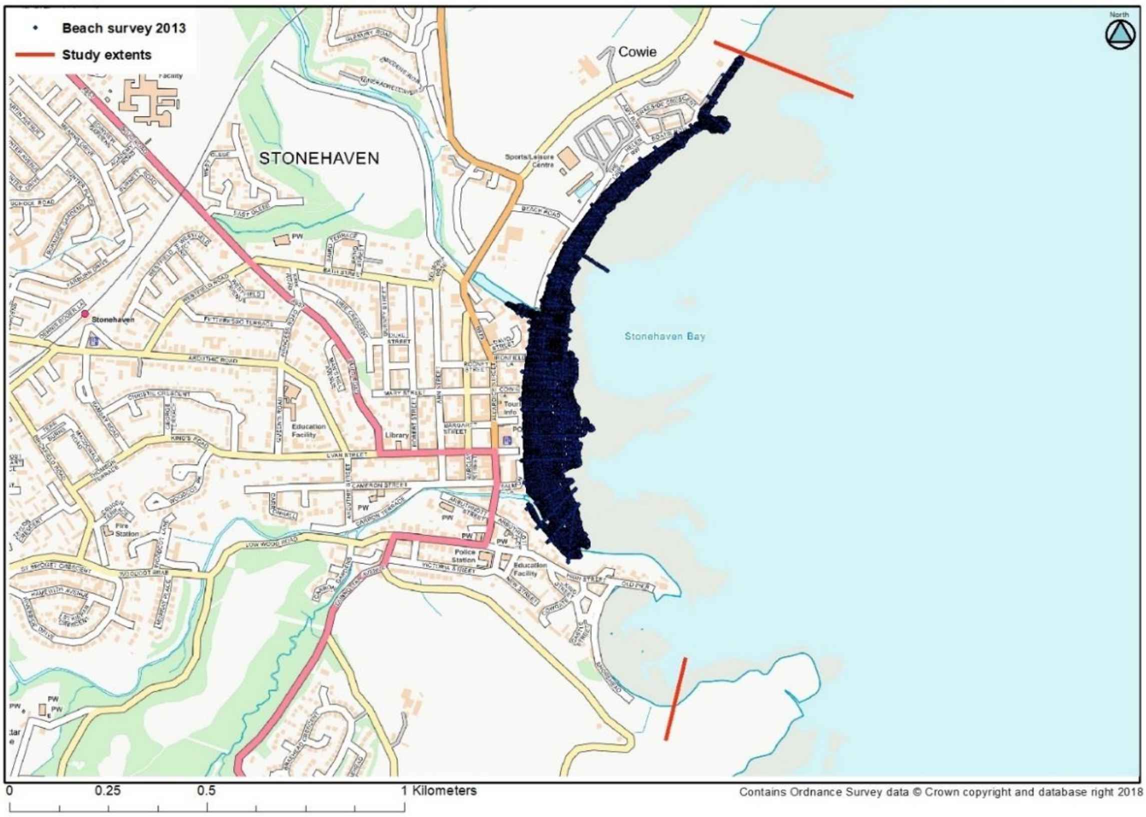


Figure 6-4: Extent of the 2013 beach survey

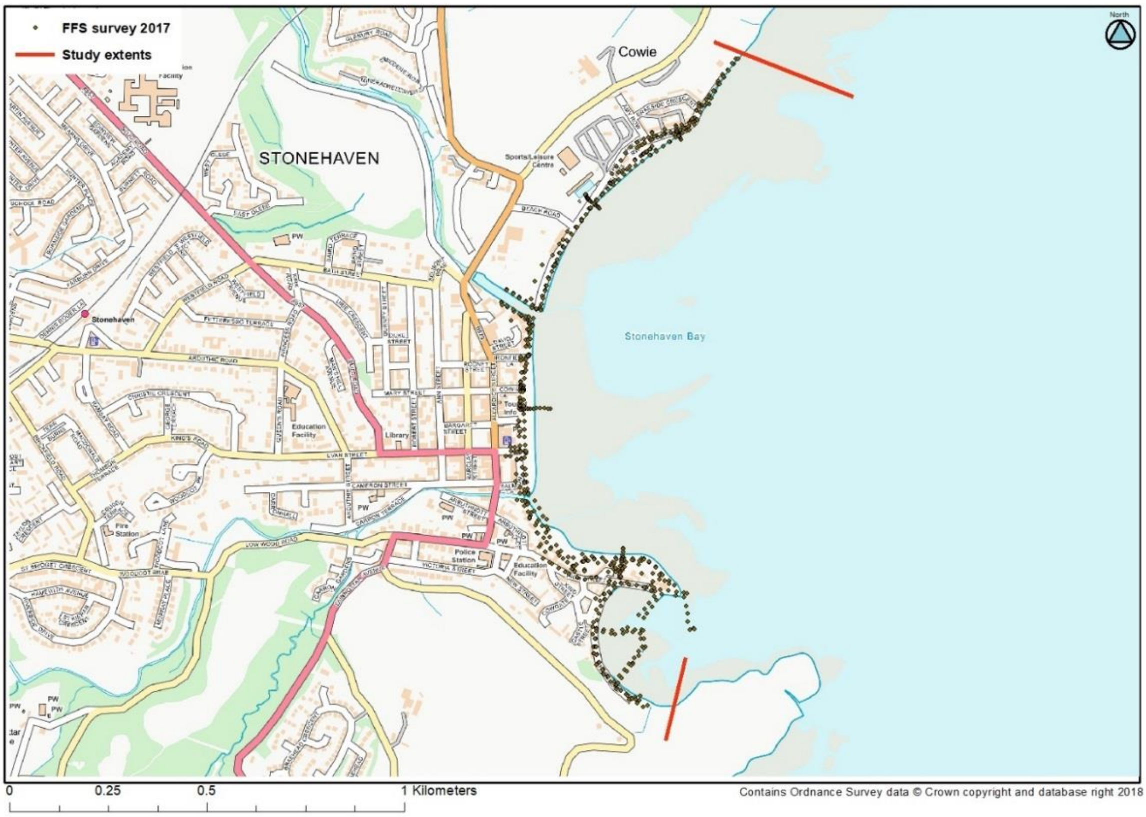


Figure 6-5: Extent of the 2017 FFS survey

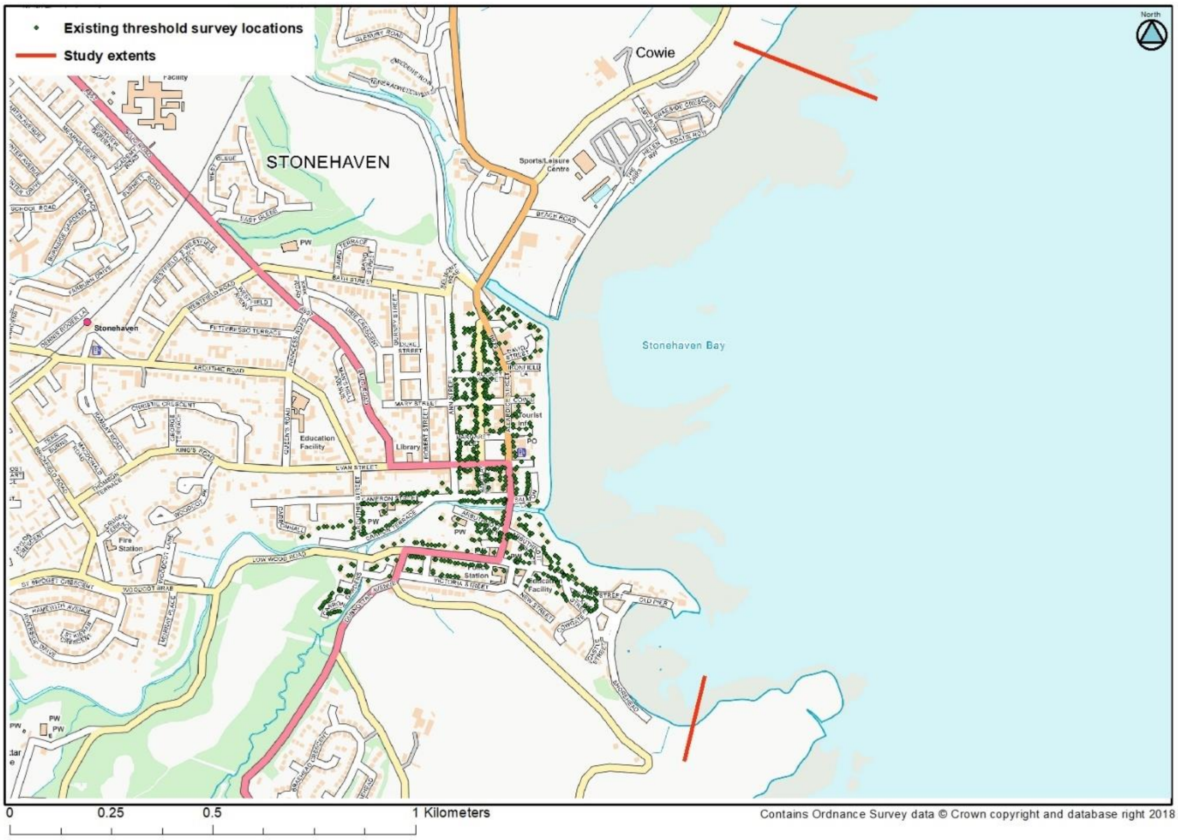


Figure 6-6: Locations of the existing threshold survey levels

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

JBA consulting

Offices at

Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Glasgow
Haywards Heath
Isle of Man
Limerick
Newcastle upon Tyne
Newport
Peterborough
Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

Registered Office
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE
United Kingdom

+44(0)1756 799919
info@jbaconsulting.com
www.jbaconsulting.com
Follow us:

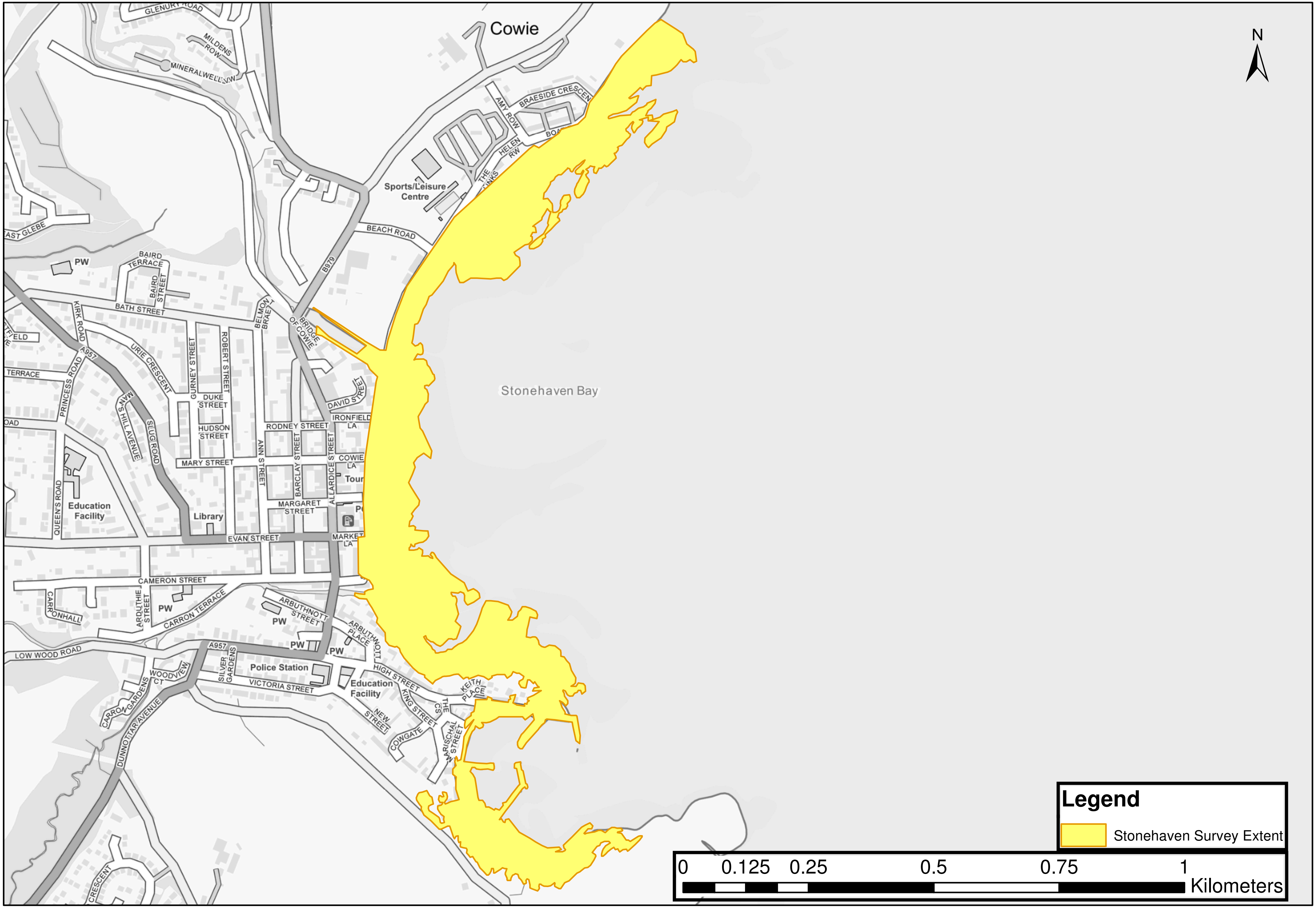
Jeremy Benn Associates Limited

Registered in England 3246693

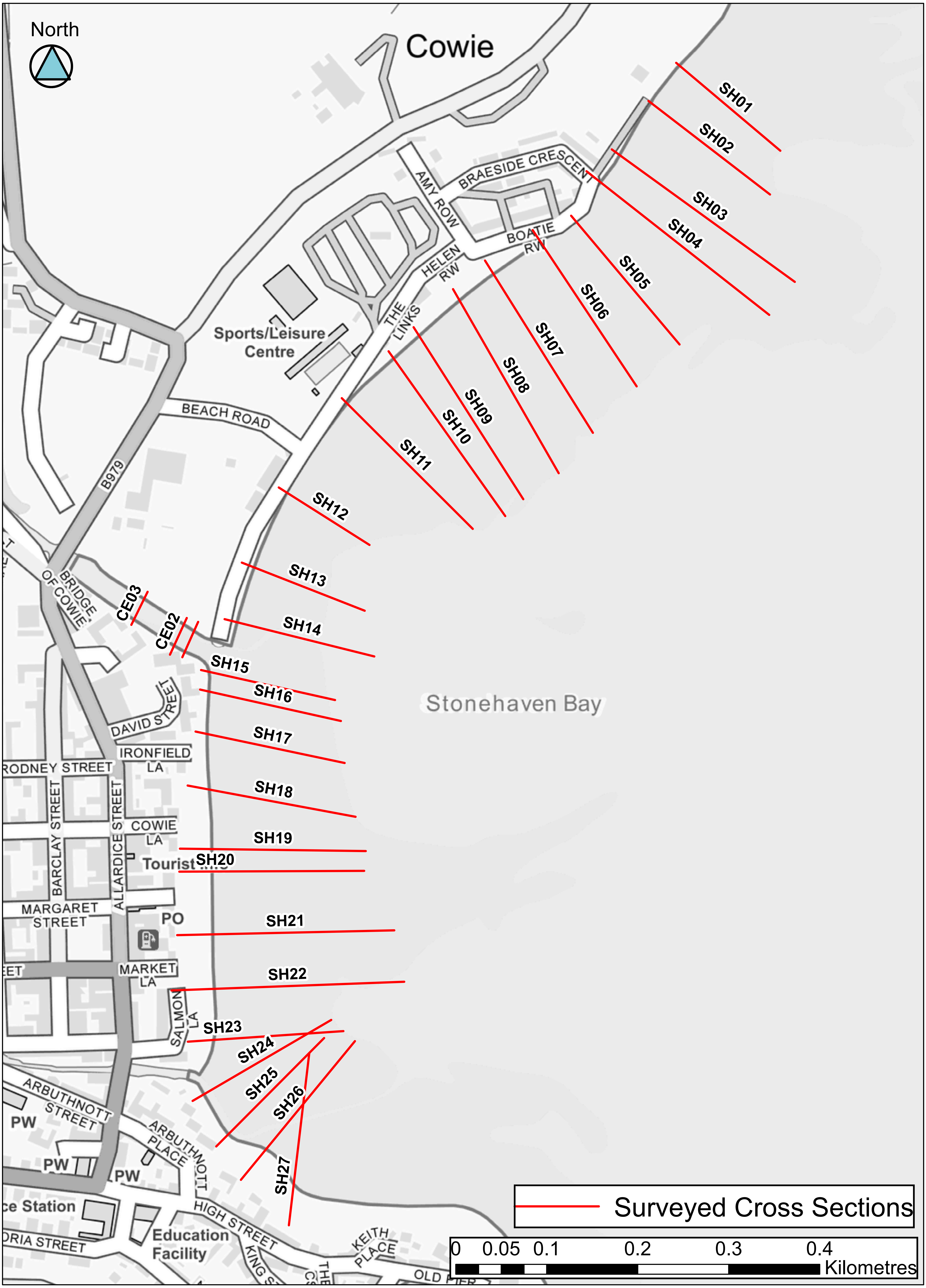
JBA Group Ltd is certified to:
ISO 9001:2015
ISO 14001:2015
OHSAS 18001:2007

New Civil Engineer TechFest Awards FESTIVAL OF INNOVATION AND TECHNOLOGY 2017 WINNER
New Civil Engineer 100 COMPANIES OF THE YEAR 2016 WINNER
New Civil Engineer 100 COMPANIES OF THE YEAR 2017 RANKED COMPANY
CHAS® Accredited Contractor CHAS.co.uk

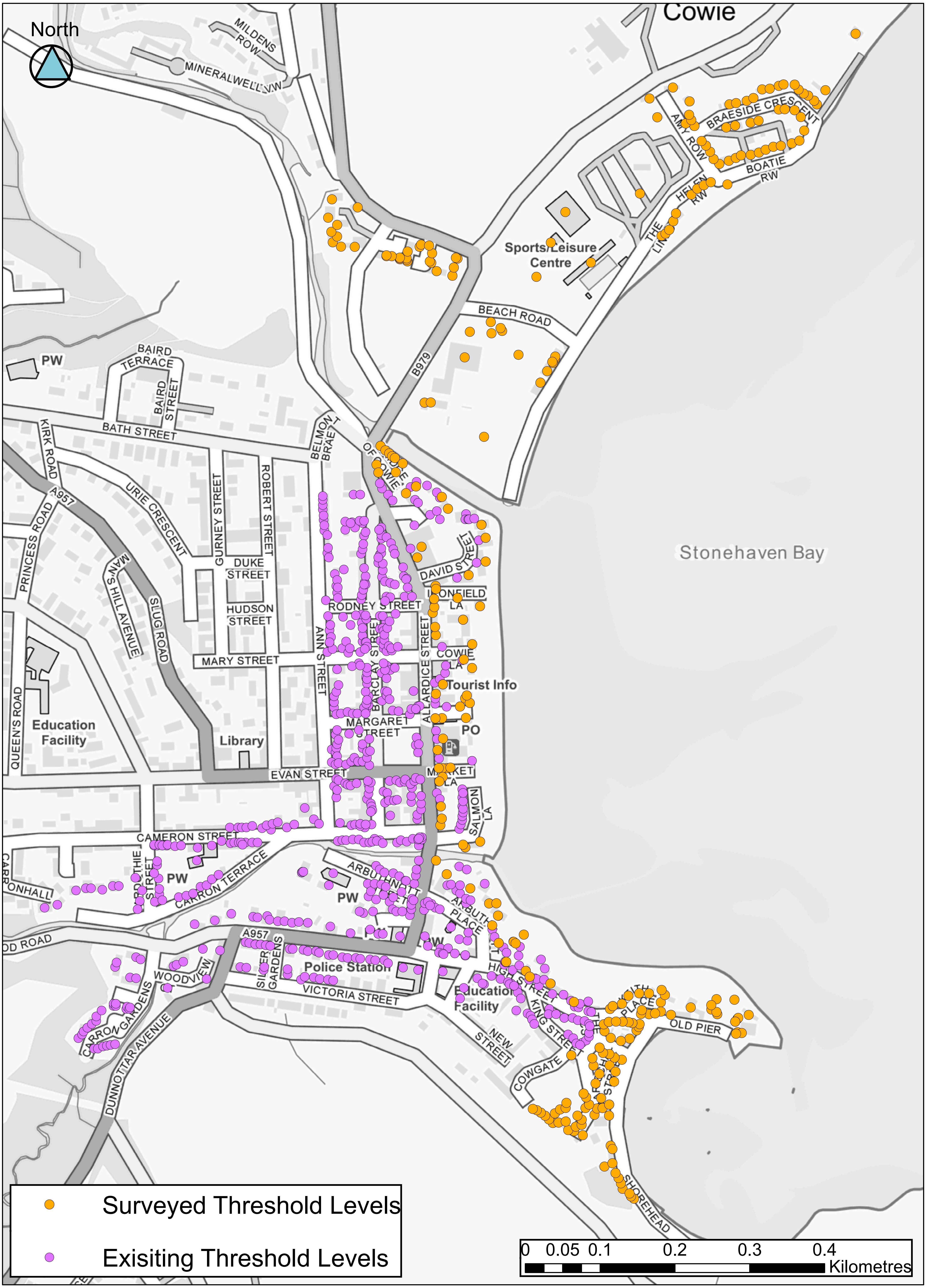
B Survey



Contains ordnance Survey (C) Crown Copyright and database right 2018. Licence No 10002002498



Contains OS data © Crown copyright and database right 2019



Contains OS data © Crown copyright and database right 2019

C Structural Inspection Reports

1. General information

Location Plan:	Stonehaven coastal defences Assessment Date: 14/05/2018	
	Exam Type:	**Detailed**
	Complete Survey:	Yes
	Structure Ref:	**1**
	OS Ref:	387570 , 786291
	Survey Unit:	N/A
	Governing SMP2:	N/A
	SMP2 Policy Unit:	N/A
	SMP2 Policy:	N/A

NOTE: This document has been prepared as an Asset Condition Survey Report for Aberdeenshire Council. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

1.1. Type of structure and general description (to include key components and materials)

Stonehaven coastal defences are located in Stonehaven Bay, Aberdeenshire. The defence has been split into six sections corresponding to a change in defence combination.

- Stonehaven coastal defence A: A masonry/concrete wall with a concrete toe, fronted by a sand/shingle beach.
- Stonehaven coastal defence B: A concrete sea wall, with a sort span of sheet piles connecting it to Section C, fronted by a sand/shingle beach.
- Stonehaven coastal defence C: A concrete stepped revetment with a large recurve splash wall, fronted by a shingle beach.
- Stonehaven coastal defence D: A sheet piles structure with sloping concrete pitching training walls on the mouth of the River Cowie.
- Stonehaven coastal defence E: A concrete sea wall, varying in width, fronted by a shingle beach.
- Stonehaven coastal defence F: A shingle beach with rock armour protection on the mouth of the River Carron.

At the northern end of the asset, Section A ties into the natural cliffline by Cowie village. The southern extent of the defence, Section F ties-into a rock armour revetment forming part of Stonehaven harbour. Access to the beach and foreshore is available via access steps in several locations across the beach and directly from the footpath between Section E and Section F.

1.2. Summary of condition and critical defects

Section A is considered to be in poor condition having several defects which could significantly reduce the performance of the asset and warrants further investigation. Sections B, C, D and E are considered to be in fair condition with defects that could potentially reduce performance of the assets. Section F is considered to be in good condition with only minor defects. The defects that are believed to be significant and require immediate attention are as follows:

Section A:

- The concrete toe of the masonry wall is being undermined in places, providing reduced protection to the sea wall.
- There are signs of voiding behind the blockwork.
- H&S - Access to the structure through the poor condition slipway is considered to be a health and safety hazard.
- The access to the rear of the masonry wall at the north end is in poor condition. Further deterioration may compromise protection to the rear of the wall.

Section B:

- The concrete wall in general is in good condition, however there are numerous outfalls which require flap valves. The exposed sheet piled face is heavily corroded and with some complete loss of section though the piles. Following the survey the local council informed that a sink hole appeared in the crest of the wall, on top of the sheet pile section of the wall due to voiding in the sheet piles. The depression in vegetated crest is believed to be due to wave overtopping and wear from pedestrian and vehicle access.

Section C:

- H&S - The beach access steps have broken or poorly fixed hand railings. In general the steps are in poor condition, most notably one access point is missing 3 tiers of steps and has exposed dowel bars protruding from the concrete providing a severe health and safety hazard. It is recommended that these steps are closed to public access until remedial works are completed.
- Extensive damage to the concrete recurve wall was observed from the reinforcement corrosion.

Section D:

- The river training wall piles are corroded, but the severity of which is unknown. It is known that a section of approximately 5-10m is undermined and there is no piling. Multiple drainage points require maintenance and possibly new flap valves.

Section E:

- No significant defects, but multiple expansion joints require re-sealing for a watertight seal.

Section F:

- The rock armour protecting the river Carron appeared overly steep, along its length, and could be subject to collapse under extreme wave loads.

Note that this is a condition assessment of the existing structures and does not assess the performance of the structures as flood defences, which will be assessed elsewhere.

1.3. Access considerations

Third party/adjacent landowner permissions:	None
Nearest public highway:	B979
Local guidance:	Parking available at the top of the sea wall on Section C on the promenade. Alternatively, in the town centre.
Tide state during survey:	Spring (Low)
Equipment required for access and examinations:	Standard survey equipment.

2. Structure information

Defence Hierarchy	Type	Sub Types	Elements	Material Type
Section A	Defence	Wall	Exposed face	Masonry (open joints, missing blockwork, voiding)
	Defence	Wall	Seaward toe	Concrete (dilapidated repairs, cracks)
	Defence	Wall	Access strip	Concrete (undermined, uneven and damaged surface, health and safety hazard)
Section B	Defence	Wall	Exposed face	Concrete wall (vertical cracks, damaged recurve, exposed reinforcement, loss of concrete cover)
	Defence	Wall	Crest	Vegetated (large depression in earth surface, sinkhole(observed following the visual inspection))
	Defence	Wall	Exposed face	Steel (heavily corroded, localised complete loss of section, damaged capping beam)
Section C	Defence	Embankment	Exposed face	Concrete (abraded concrete surface, some exposed reinforcement)
	Defence	Embankment	Splash wall	Concrete (heavily corroded reinforcement, extensive damage to concrete recurve, cracking)
	Defence	Embankment	Rock armour	Rock armour buried and seems to be in good condition. Unable to survey any defects.
Section D	Defence	Embankment	Channel side	Concrete (some cracking and damage to concrete, vegetation growth, concrete toe undermined and piling missing)
	Defence	Embankment	Piling	Steel (corroded, some anchor plates lost, concrete toe undermined and piling missing (not observed during survey))
	Defence	Embankment	Exposed face	Concrete (cracking, exposed reinforcement, general dilapidation)
Section E	Defence	Wall	Exposed face	Concrete (cracking, exposed reinforcement)
Section F	Defence	Embankment	Exposed face	Beach (shallow, possibly narrow for wave attenuation)
	Defence	Embankment	Rock armour	Rock (undersized at mouth of river Carron, overly steep)
	Defence	Embankment	Splash wall	Masonry (only acting as defence in extreme events)

Approx. defence length (m):	2000		
Approx. co-ordinates from:	387616, 785618	To:	388472, 787211
As built drawing available:	No		
Linked to other Asset Types:	The defence ties into a natural cliff on the northern side and into Stonehaven harbour on the southern side.		
Infrastructure protected:	Asset protects approximately 2000m road infrastructure as well as nearby properties and business immediately at risk of flooding.		
Assets type and ownership that the defence ties into at either end:	The defence ties into the natural cliff to the north and the harbour's rock armour revetment to the south, both under local council ownership.		

2.1 Topographic level information

Section A	Value	Method of calculation
Crest level of primary defence (mAOD)	4.58	Topo Survey
Toe level of primary defence (mAOD)	N/A	N/A
Approx. defence height above beach (m)	1.75 (Varies)	N/A
Upper beach level (mAOD)	3.253	Laser scan
Lower beach level (mAOD)	0.844	Laser scan
Approx. total beach height (m)	Varies	N/A
Beach crest width (m)	Varies	N/A
Approx. beach gradient (1 in ...)	Varies	N/A
Beach Cross Sectional Area (m2)	Varies	N/A
Beach composition	N/A	N/A

Section B	Value	Method of calculation
Crest level of primary defence (mAOD)	4.59	Topo Survey
Toe level of primary defence (mAOD)	N/A	N/A
Approx. defence height above beach (m)	2.1	N/A
Upper beach level (mAOD)	3.279	Laser scan
Lower beach level (mAOD)	-0.841	Laser scan
Approx. total beach height (m)	Varies	N/A
Beach crest width (m)	Varies	N/A
Approx. beach gradient (1 in ...)	Varies	N/A
Beach Cross Sectional Area (m2)	Varies	N/A
Upper Beach composition	Sand	N/A
Lower Beach composition	N/A	N/A

Section C	Value	Method of calculation
Crest level of primary defence (mAOD)	6.02	Topo Survey
Toe level of primary defence (mAOD)	N/A	N/A
Approx. defence height above beach (m)	5.8	Topo Survey
Upper beach level (mAOD)	2.624	Laser scan
Lower beach level (mAOD)	-1.145	Laser scan
Approx. total beach height (m)	Varies	N/A
Beach crest width (m)	Varies	N/A
Approx. beach gradient (1 in ...)	Varies	N/A
Beach Cross Sectional Area (m2)	Varies	N/A
Beach composition	N/A	N/A

Section D	Value	Method of calculation
Crest level of primary defence (mAOD)	5.23	Topo Survey
Toe level of primary defence (mAOD)	N/A	N/A
Approx. defence height above beach (m)	5	Topo Survey
Upper beach level (mAOD)	N/A	N/A
Lower beach level (mAOD)	N/A	N/A
Approx. total beach height (m)	N/A	N/A
Beach crest width (m)	N/A	N/A
Approx. beach gradient (1 in ...)	N/A	N/A
Beach Cross Sectional Area (m2)	N/A	N/A
Beach composition	N/A	N/A

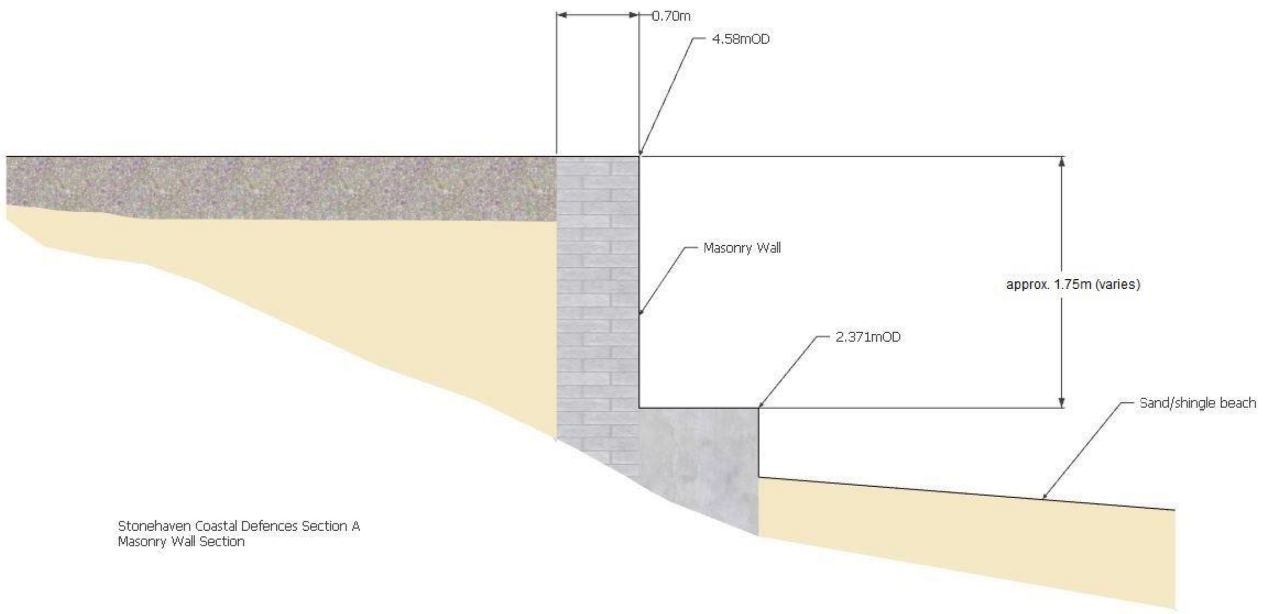
Section E	Value	Method of calculation
Crest level of primary defence (mAOD)	4.78	Topo Survey
Toe level of primary defence (mAOD)	N/A	N/A
Approx. defence height above beach (m)	Varies	Topo Survey
Upper beach level (mAOD)	4.613	Laser scan
Lower beach level (mAOD)	-1.359	Laser scan
Approx. total beach height (m)	Varies	N/A
Beach crest width (m)	Varies	N/A
Approx. beach gradient (1 in ...)	Varies	N/A
Beach Cross Sectional Area (m2)	Varies	N/A
Beach composition	Shingle	N/A

Section F	Value	Method of calculation
Crest level of primary defence (mAOD)	4.515	Topo Survey
Toe level of primary defence (mAOD)	N/A	N/A
Approx. defence height above beach (m)	Varies	N/A
Upper beach level (mAOD)	4.118	Laser scan
Lower beach level (mAOD)	-0.951	Laser scan
Approx. total beach height (m)	Varies	N/A
Beach crest width (m)	Varies	N/A
Approx. beach gradient (1 in ...)	Varies	N/A
Beach Cross Sectional Area (m2)	Varies	N/A
Upper Beach composition	Shingle	N/A
Lower Beach composition	N/A	N/A

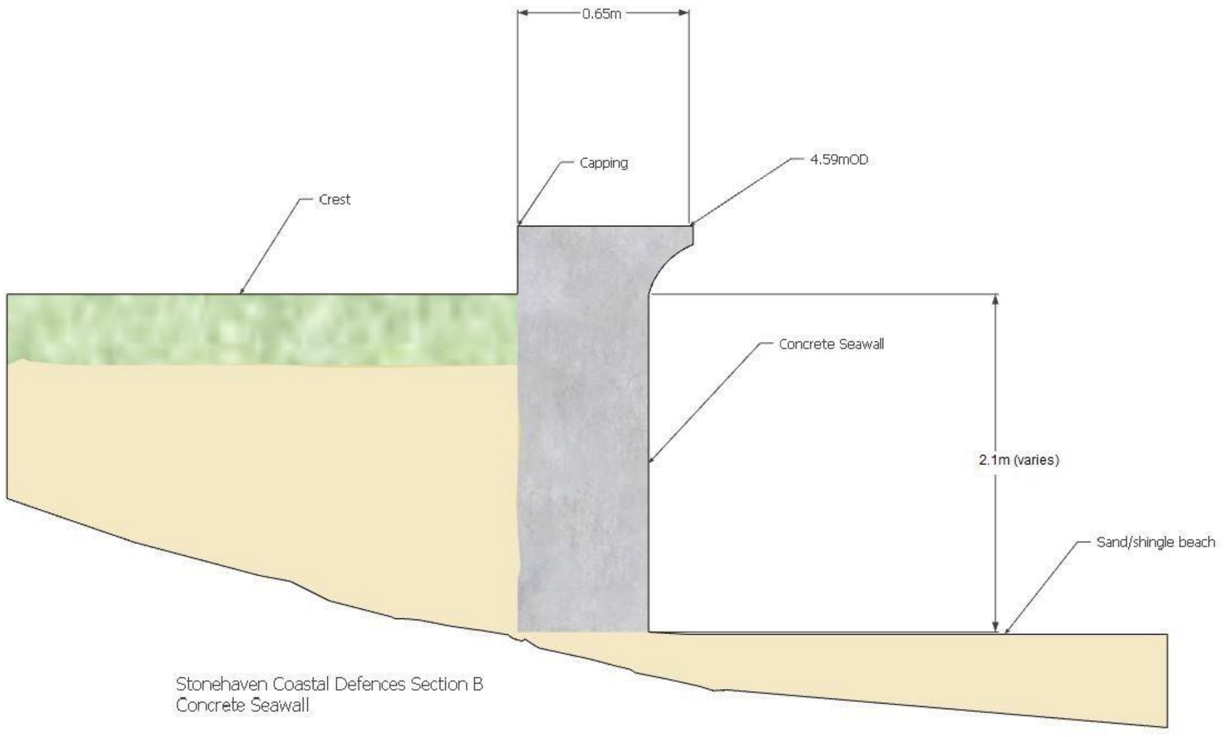
3. Asset site sketch

Plan:

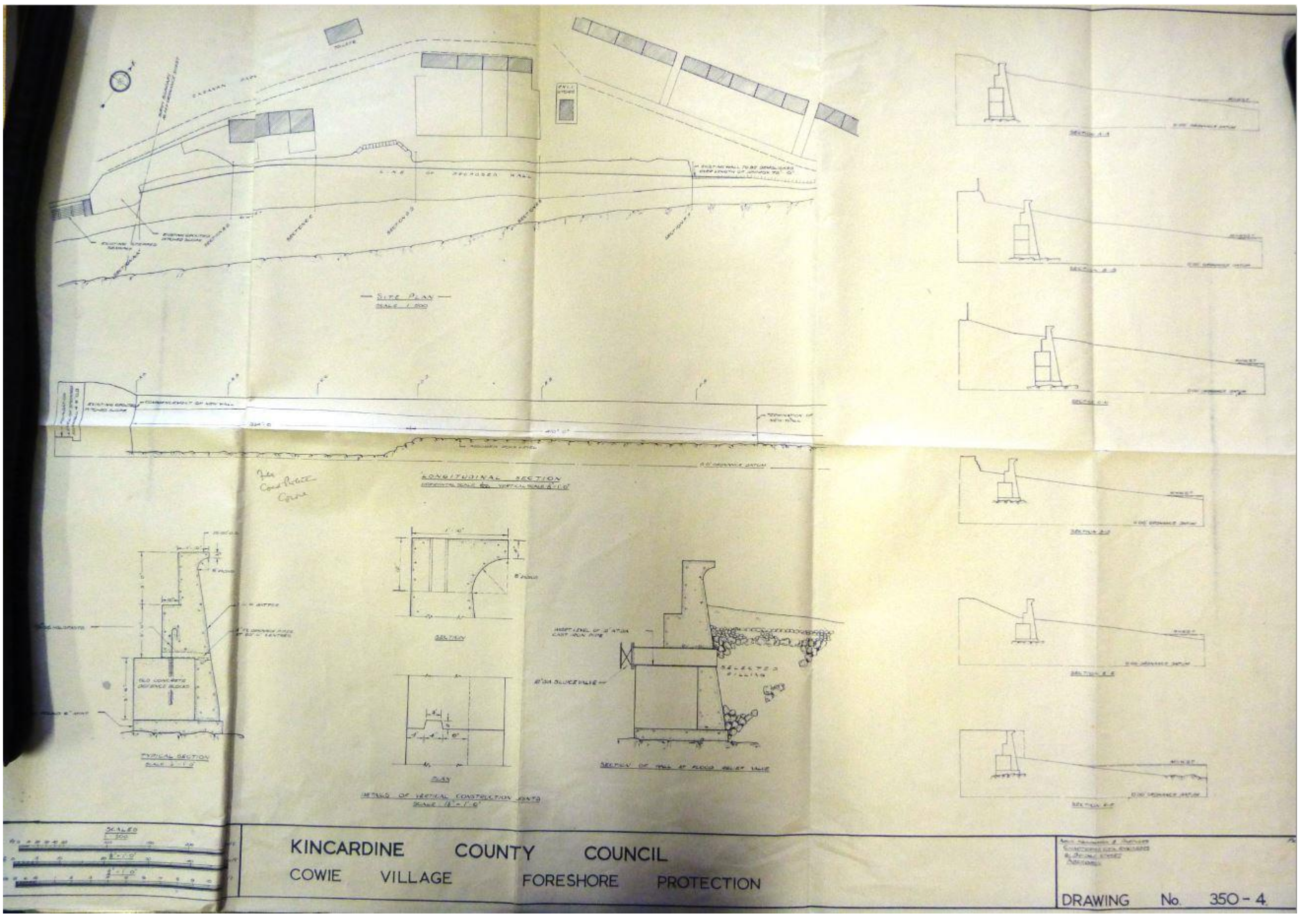
Sketch: Section A



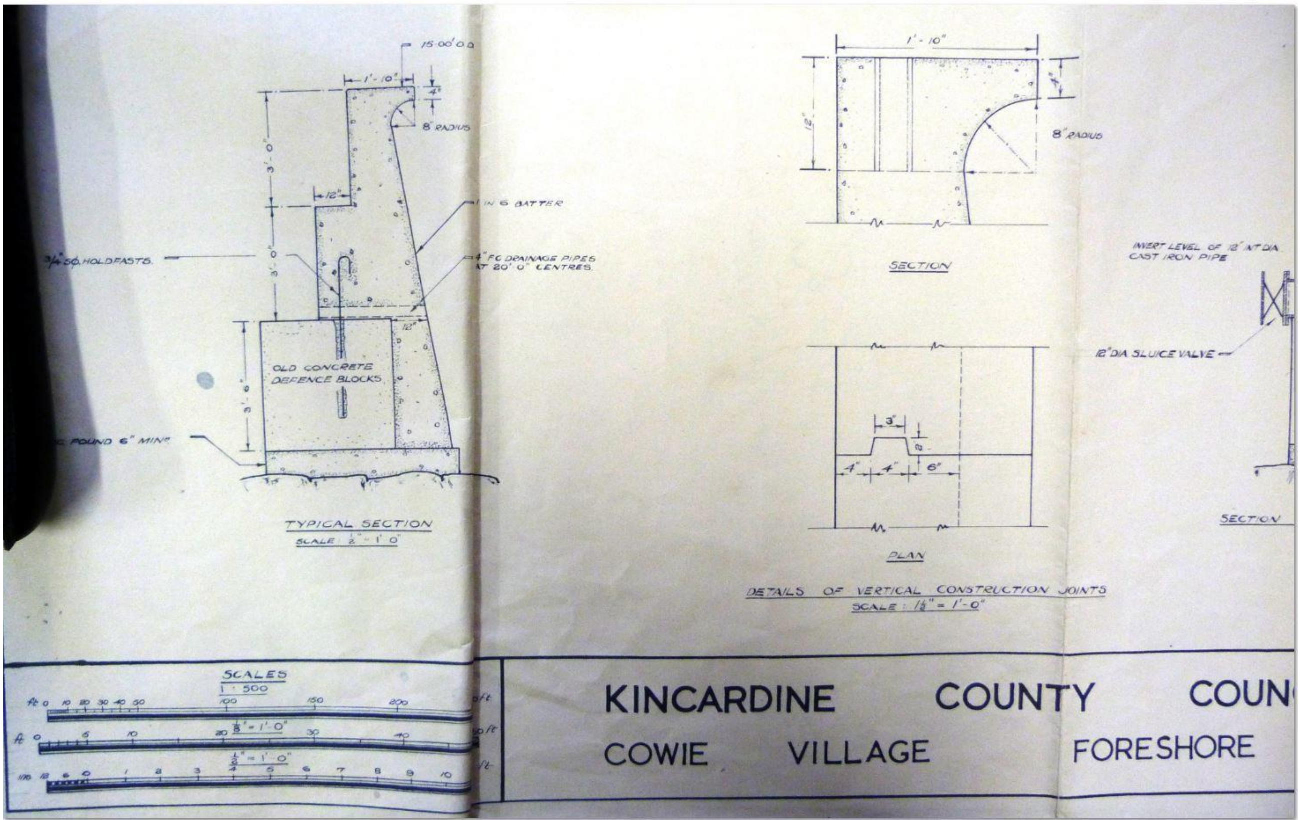
Sketch: Section B



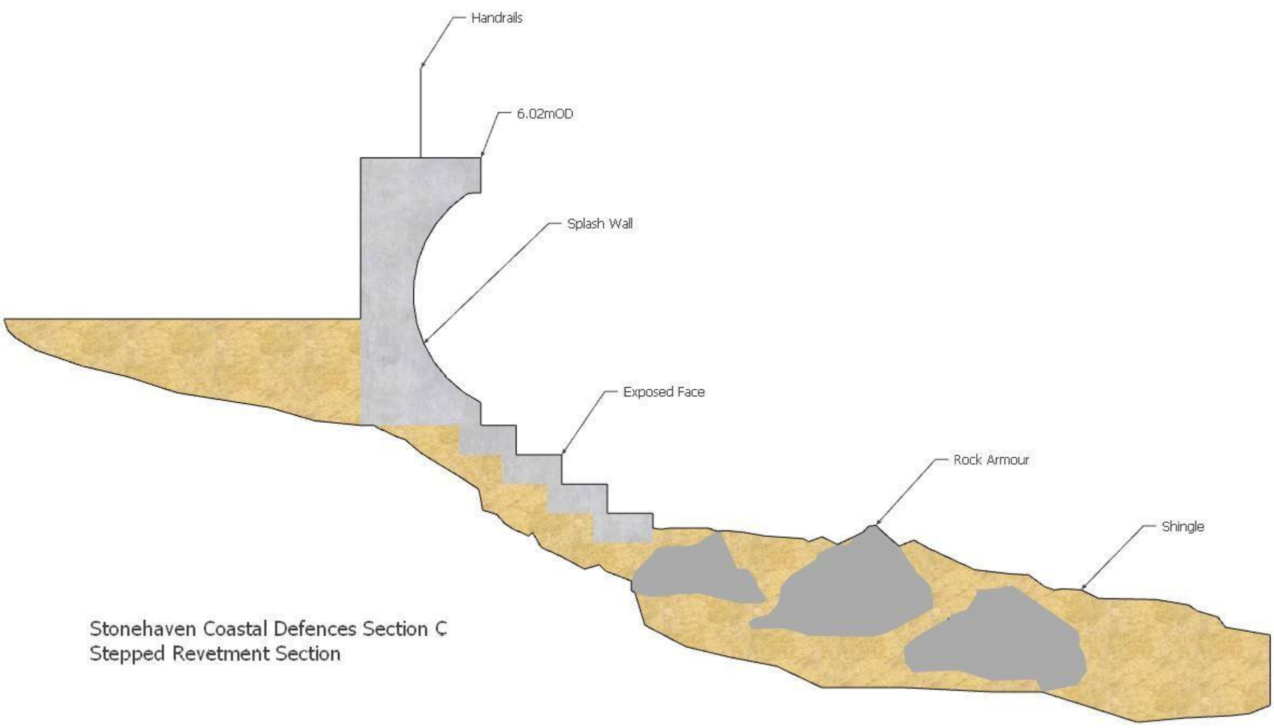
Sketch: Flood Protection Works at Cowie - Seawall Plan and Sections - Section B



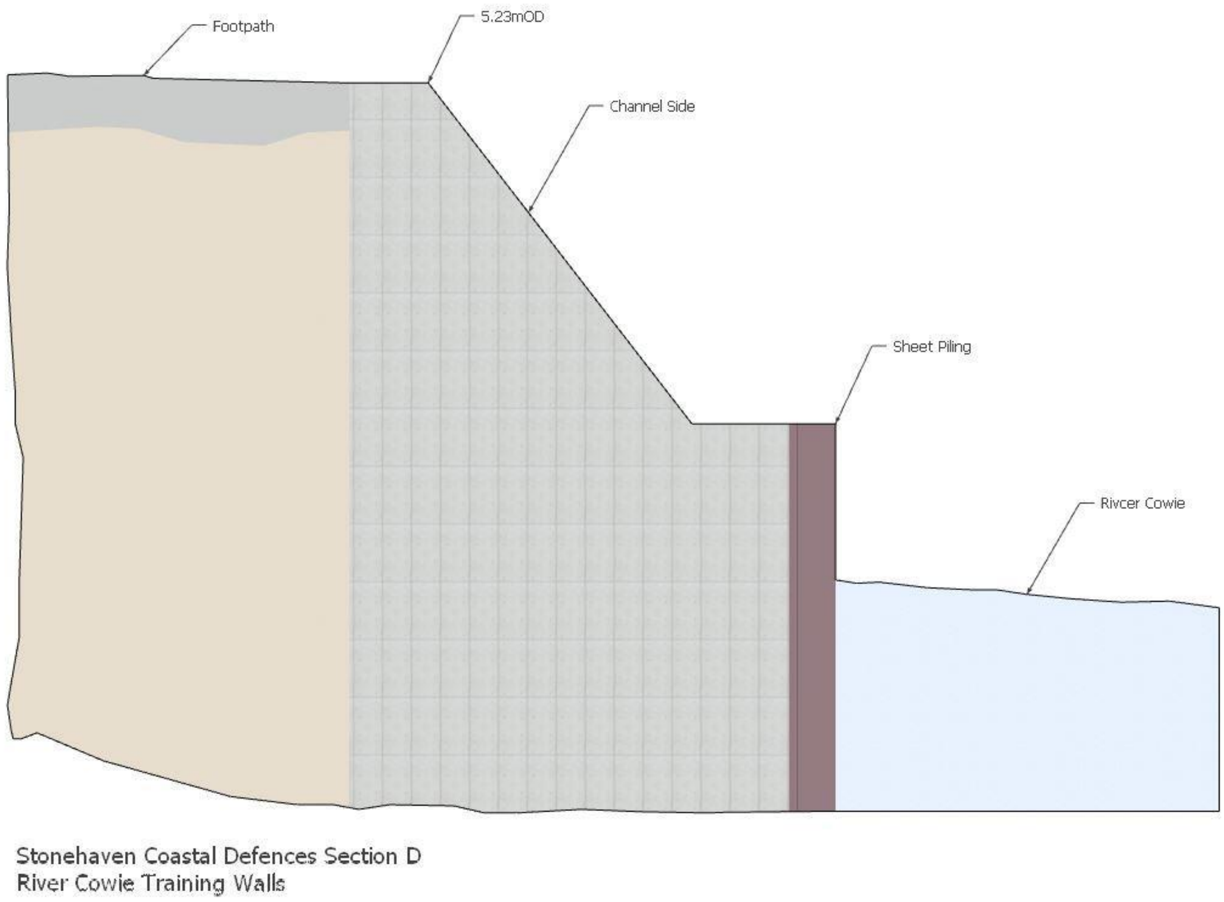
Sketch: Flood Protection Works at Cowie - Seawall Sections - Section B



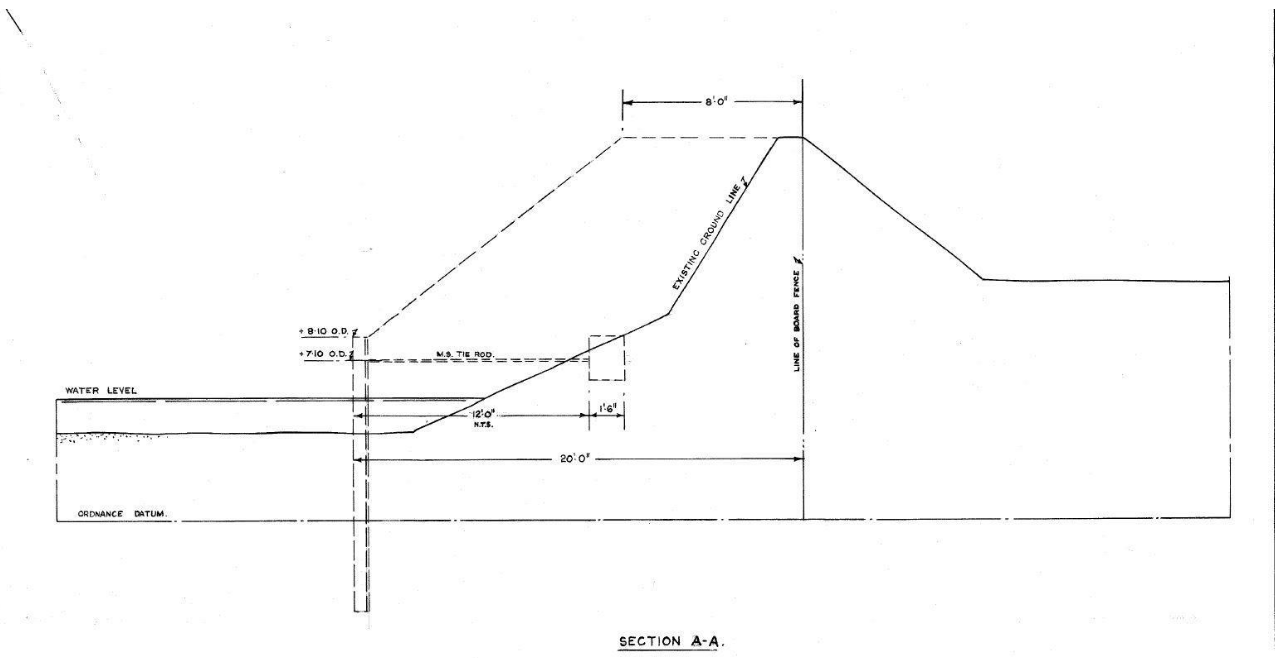
Sketch: Section C



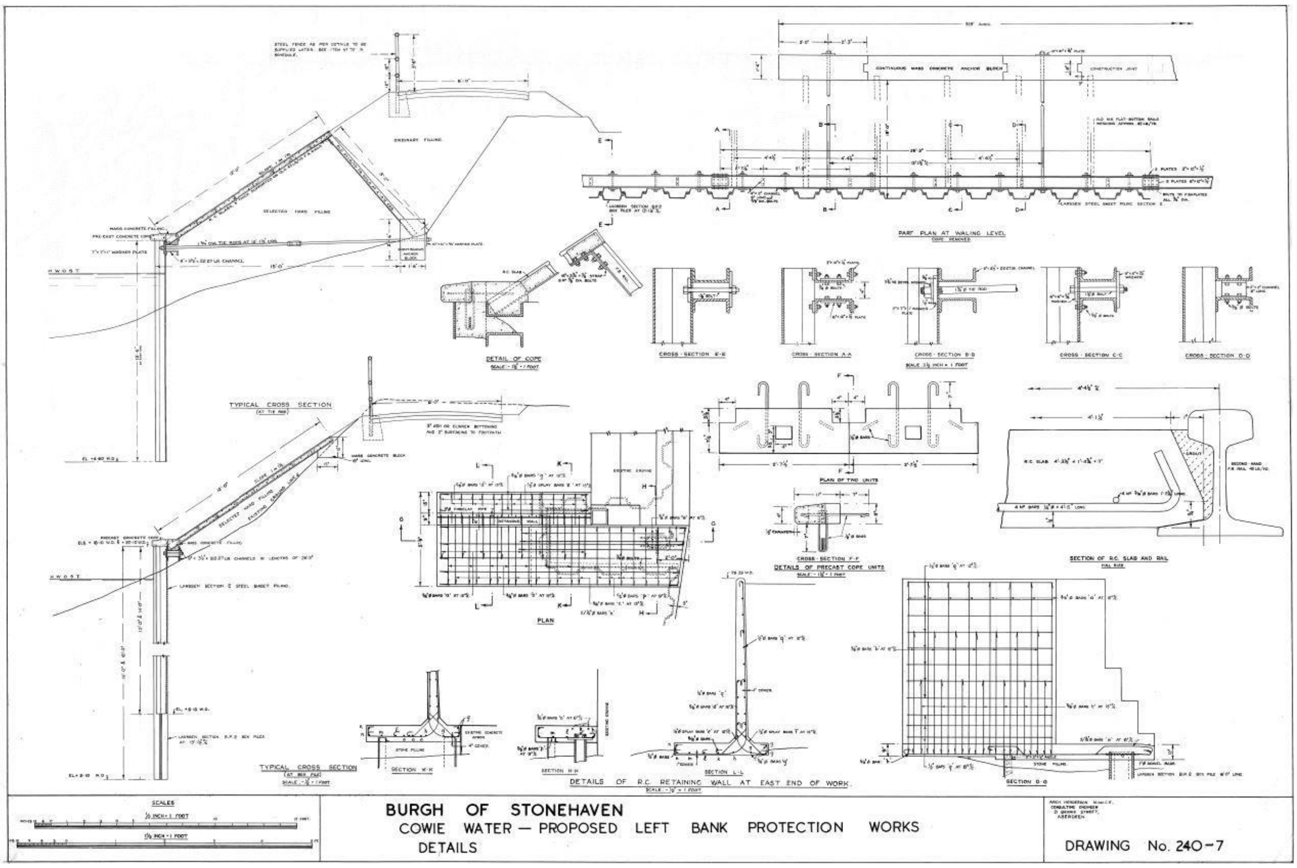
Sketch: Section D



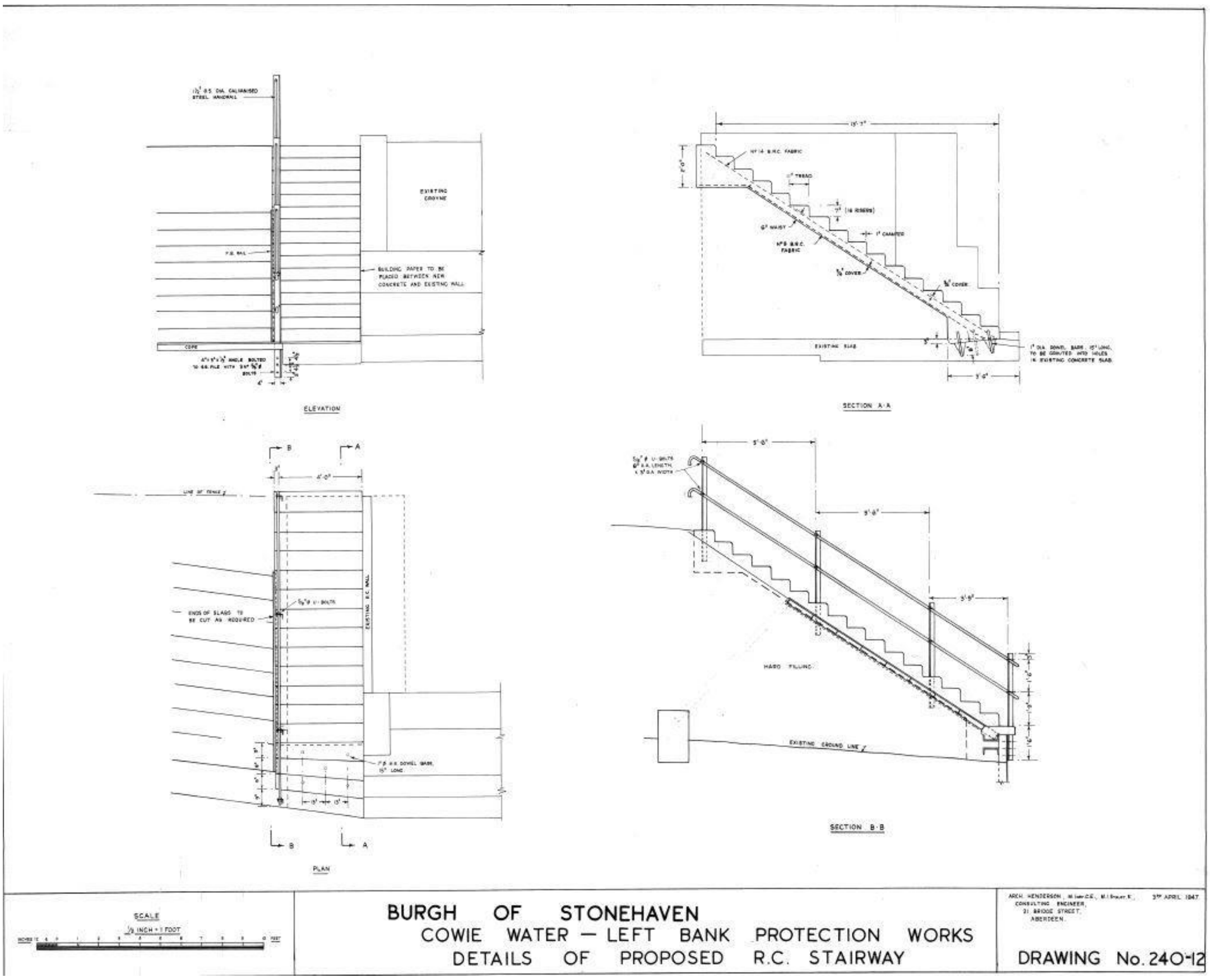
Sketch: Cowie Water - Section D



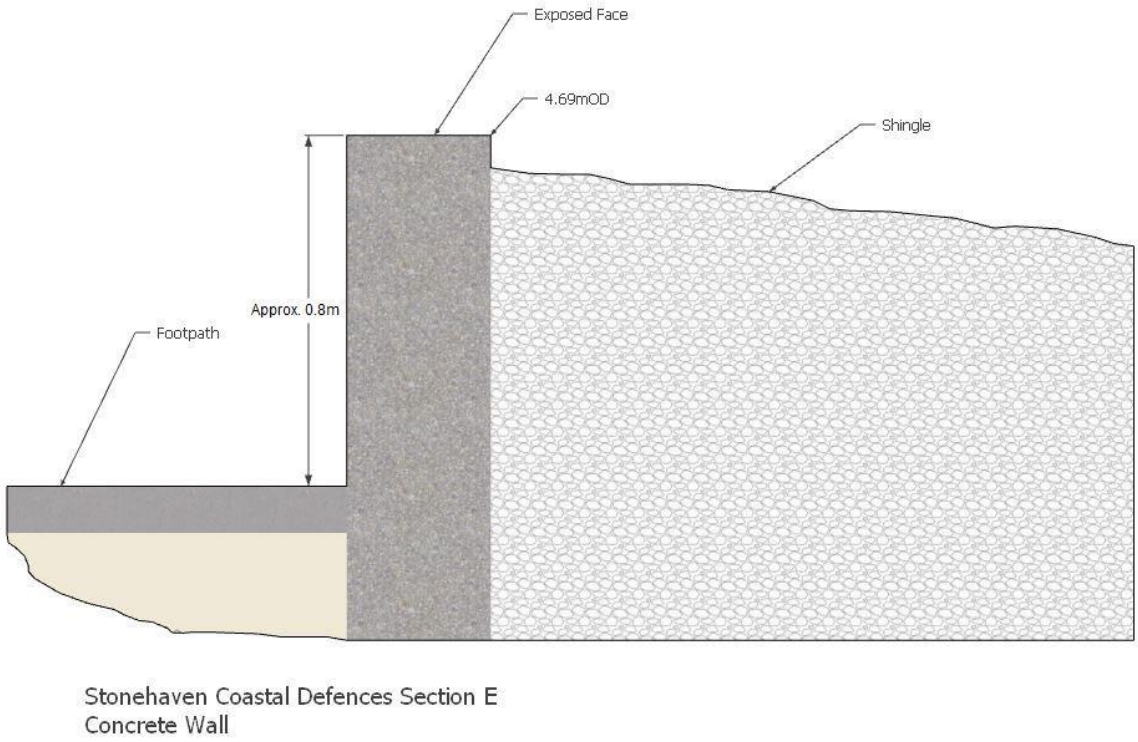
Sketch: Cowie Water Left Bank Protection Works - Section D Details



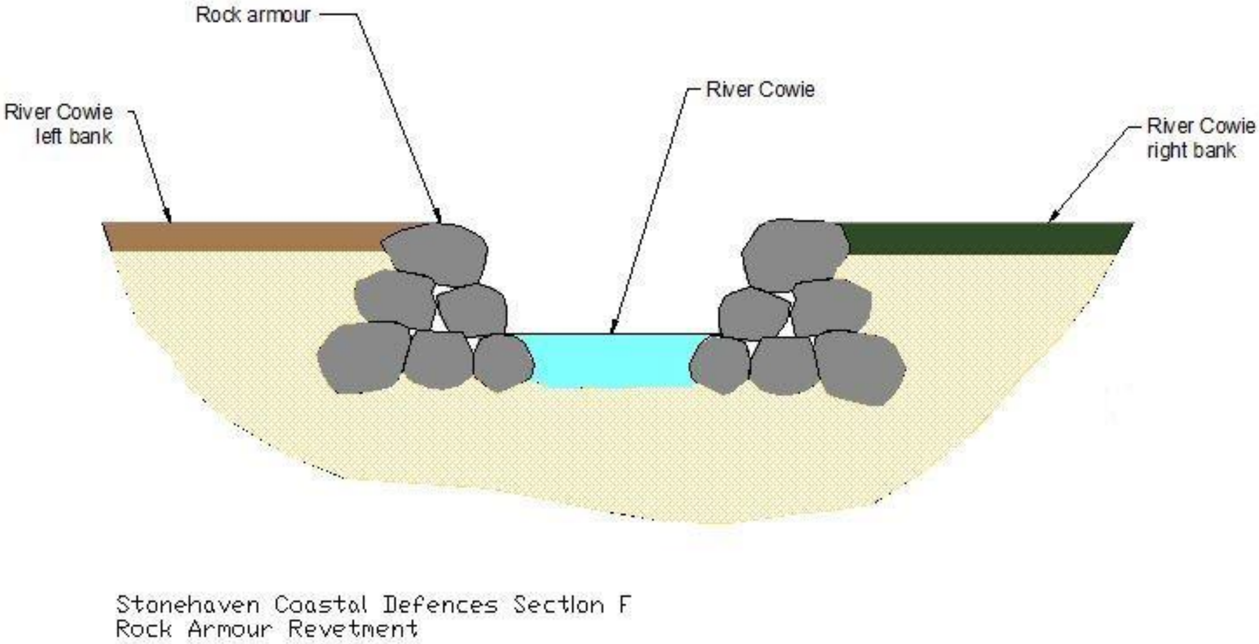
Sketch: Cowie Water Left Bank Protection Works - Section D Details



Sketch: Section E



Sketch: Section F



4. Visual Condition Survey

4.1 Section A

Main Asset

The main asset is broken down into its constituent parts (elements) and assigned a condition score. This condition score of each element is weighted according to its importance in the functioning of the defence.

Sub-Type	Elements	Attributes and General Notes	Condition Grade	Weighting (1-9)	Overall (CG x W)
Wall	Exposed face	Masonry (open joints, missing blockwork, voiding)	4	9	36
Wall	Seaward toe	Concrete (dilapidated repairs, cracks)	3	8	24
Wall	Access strip	Concrete (undermined, uneven and damaged surface, health and safety hazard)	5	1	5
Sum				18	65
Overall condition score Grade*					**4**

Sum of (Weightings x Condition Grades) / (Sum of Weightings)
Unless a weighting of 9 is given for any element, in which case, the condition of this element should be taken as the overall condition grade.

4.2 Section B

Main Asset

The main asset is broken down into its constituent parts (elements) and assigned a condition score. This condition score of each element is weighted according to its importance in the functioning of the defence.

Sub-Type	Elements	Attributes and General Notes	Condition Grade	Weighting (1-9)	Overall (CG x W)
Wall	Exposed face	Concrete wall (vertical cracks, damaged recurve, exposed reinforcement, loss of concrete cover)	3	9	27
Wall	Crest	Vegetated (large depression in earth surface, sinkhole(observed following the visual inspection))	3	7	21
Wall	Exposed face	Steel (heavily corroded, localised complete loss of section, damaged capping beam)	4	7	28
Sum				23	76
Overall condition score Grade*					**3**

Sum of (Weightings x Condition Grades) / (Sum of Weightings)
Unless a weighting of 9 is given for any element, in which case, the condition of this element should be taken as the overall condition grade.

4.3 Section C

Main Asset

The main asset is broken down into its constituent parts (elements) and assigned a condition score. This condition score of each element is weighted according to its importance in the functioning of the defence.

Sub-Type	Elements	Attributes and General Notes	Condition Grade	Weighting (1-9)	Overall (CG x W)
Embankment	Exposed face	Concrete (abraded concrete surface, some exposed reinforcement)	3	7	21
Embankment	Splash wall	Concrete (heavily corroded reinforcement, extensive damage to concrete recurve, cracking)	3	7	21
Embankment	Rock armour	Rock armour buried and seems to be in good condition. Unable to survey any defects.	2	6	12
Sum				20	54
Overall condition score Grade*					**3**

Sum of (Weightings x Condition Grades) / (Sum of Weightings)
Unless a weighting of 9 is given for any element, in which case, the condition of this element should be taken as the overall condition grade.

4.4 Section D

Main Asset

The main asset is broken down into its constituent parts (elements) and assigned a condition score. This condition score of each element is weighted according to its importance in the functioning of the defence.

Sub-Type	Elements	Attributes and General Notes	Condition Grade	Weighting (1-9)	Overall (CG x W)
Embankment	Channel side	Concrete (some cracking and damage to concrete, vegetation growth, concrete toe undermined and piling missing)	3	7	21
Embankment	Piling	Steel (corroded, some anchor plates lost, concrete toe undermined and piling missing (not observed during survey))	4 (Condition Grade was 3 previously, now classified as Condition Grade 4 after council's information on missing piling for approximately 10m)	8	32
Embankment	Exposed face	Concrete (cracking, exposed reinforcement, general dilapidation)	3	7	21
Sum				22	74
Overall condition score Grade*					**3**

Sum of (Weightings x Condition Grades) / (Sum of Weightings)
Unless a weighting of 9 is given for any element, in which case, the condition of this element should be taken as the overall condition grade.

4.5 Section E

Main Asset

The main asset is broken down into its constituent parts (elements) and assigned a condition score. This condition score of each element is weighted according to its importance in the functioning of the defence.

Sub-Type	Elements	Attributes and General Notes	Condition Grade	Weighting (1-9)	Overall (CG x W)
Wall	Exposed face	Concrete (cracking, exposed reinforcement)	3	7	21
Sum				7	21
Overall condition score Grade*					**3**

Sum of (Weightings x Condition Grades) / (Sum of Weightings)
Unless a weighting of 9 is given for any element, in which case, the condition of this element should be taken as the overall condition grade.

4.6 Section F

Main Asset

The main asset is broken down into its constituent parts (elements) and assigned a condition score. This condition score of each element is weighted according to its importance in the functioning of the defence.

Sub-Type	Elements	Attributes and General Notes	Condition Grade	Weighting (1-9)	Overall (CG x W)
Embankment	Exposed face	Beach (shallow, possibly narrow for wave attenuation)	2	7	14
Embankment	Rock armour	Rock (undersized at mouth of river Carron, overly steep)	2	7	14
Embankment	Splash wall	Masonry (only acting as defence in extreme events)	3	4	12
Sum				18	40
Overall condition score Grade*					**2**

Sum of (Weightings x Condition Grades) / (Sum of Weightings)
Unless a weighting of 9 is given for any element, in which case, the condition of this element should be taken as the overall condition grade.

4.7 Asset condition grade summary

	Section A	Section B	Section C	Section D	Section E	Section F
Target condition grade	2	2	2	2	2	2
Overall surveyed condition grade	4	3	3	3	3	2
Total time taken to reach CG1	0	0	0	0	0	0
Total time taken to reach CG2	0	0	0	0	0	0
Total time taken to reach CG3	0	0	0	0	0	15 years
Total time taken to reach CG4	0	15 years	15 years	25 years	15 years	35 years
Total time taken to reach CG5	15 years	30 years	30 years	35 years	30 years	45 years

4.8 Additional information

General description and effect of any coastal erosion noted:	None noted during asset inspection.
General description and effect of any wave overtopping noted:	Depression in vegetated crest on Section B may be a result of overtopping damage. No observable evidence of damage from wave overtopping was noted during asset inspection.
General description and effect of any longshore / cross-shore sediment transport noted:	Evidence of beach transport into the River Cowie mouth. Variability of beach noted on Section B and to lesser degree to Section C.

5. Identification of defects and recommendations

5.1. Main asset defect register

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D1	387886, 786644	Wall	Crest	63	Poorly vegetated / worn crest.	Resurface vegetated crest.	29
D2	387867, 786632	Wall	Crest	64	Depression of crest.	Resurface vegetated crest.	29
D3	387925, 786664	Wall	Exposed face	48	Cracked and spalling concrete between wall types	Repoint / patch repair damaged concrete.	5
D4	387925, 786663	Wall	Exposed face	49	Spalling concrete approximately 1 x 0.3m.	Consider refacing spalling repairs.	13
D5	387904, 786656	Wall	Exposed face	50	Broken flap valve	Replace flap valve.	21
D6	387903, 786654	Wall	Exposed face	51	Loss of cover exposing corroded steel evenly spaced in the frontage.	Breakout and repair corroded area.	23
D7	387898, 786648	Wall	Exposed face	52	No. 12 missing flap valves.	Consider installing flap valves.	21
D8	387891, 786642	Wall	Exposed face	53	Spalling of concrete along the construction joint.	Reface spalling concrete.	6
D9	387885, 786640	Wall	Exposed face	54	Damaged recurve approximately 0.5m x 0.3m.	Patch repair damaged recurve.	17
D10	387815, 786593	Wall	Exposed face	55	Damaged recurve approximately 0.3m long.	Patch repair damaged recurve.	17
D11	387809, 786587	Wall	Exposed face	56	Minor crack 1m long approx.	Repoint fracture and monitor wall for signs of movement.	18

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D12	387774, 786562	Wall	Exposed face	57	Vertical fracture in wall.	Repoint vertical fracture and monitor wall for signs of movement.	7
D13	387774, 786562	Wall	Exposed face	58	Damaged recurve in two places, approximately 1m long	Patch repair concrete recurve.	7
D14	387767, 786557	Wall	Exposed face	59	Vertical crack in wall.	Repoint cracks and monitor wall for signs of movement.	10
D15	387762, 786550	Wall	Exposed face	60	Vertical crack in wall.	Repoint vertical fracture and monitor wall for signs of movement.	10
D16	387734, 786524	Wall	Exposed face	61	Missing pointing between recurve units.	Repoint open joints.	13
D17	N/A	Wall	Exposed face	62	Blocked drainage pipes.	Unblock pipes and consider installing flap valves.	17
D18	N/A	Wall	Exposed face	65	Corroded sheet piles.	Monitor and undertake further survey to determine pile thickness. Consider replacing sheet piles with an alternative coastal defence solution.	2
D19	387725, 786516	Wall	Exposed face	66	Cracking in the capping beam approximately 0.5m long.	Repoint crack.	18
D20	387719, 786511	Wall	Exposed face	67	Section loss of sheet piles.	Monitor and undertake further survey to determine pile thickness. Consider replacing sheet piles with an alternative coastal defence solution.	1
D21	387714, 786507	Wall	Exposed face	68	Cracking in the capping beam.	Repoint crack.	11
D22	387714, 786501	Embankment	Exposed face	69	Missing handrailing.	Replace timber handrails with a more durable solution.	1
D23	387714, 786503	Embankment	Exposed face	70	Corroded handrailing support.	Replace timber handrails with a more durable solution.	19

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D24	387712, 786500	Embankment	Splash wall	71	Cracking of concrete.	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	14
D25	387712, 786501	Embankment	Splash wall	72	Corroded reinforcement	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	16
D26	387708, 786499	Embankment	Splash wall	73	Chipped concrete exposing reinforcement.	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	9
D27	387706, 786496	Embankment	Splash wall	74	General abrasion of steps	Monitor and consider replacing rendering to prevent further deterioration.	21
D28	387703, 786492	Embankment	Splash wall	75	Vertical crack.	Repoint vertical crack.	16
D29	387702, 786491	Embankment	Splash wall	79	Exposed corroded reinforcement.	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	6
D30	387699, 786491	Embankment	Splash wall	76	Open joints.	Replace missing mastic.	17
D31	387696, 786488	Embankment	Splash wall	77	Cracking in upper radius of recurve throughout defence length.	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	12
D32	387692, 786477	Embankment	Splash wall	78	1 x 0.3 m exposed reinforcement and damaged concrete. Crack propagating along by the side of recurve.	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	6
D33	387678, 786462	Embankment	Splash wall	80	Open joints.	Replace missing mastic.	17

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D34	387676, 786462	Embankment	Splash wall	81	24No. outfalls missing flap valves. Some outfalls are blocked.	Unblock blocked outfalls. Consider installing flap valves.	20
D35	387669, 786455	Embankment	Splash wall	82	Loss of concrete and exposed reinforcement approx. 0.5 x 0.3m with vertical crack exposing more reinforcement	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	6
D36	387667, 786451	Embankment	Splash wall	83	Long horizontal crack, approximately 5m and crack in buttress wall.	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	12
D37	387670, 786447	Embankment	Splash wall	84	Difference in crest level.	None.	11
D38	387657, 786431	Embankment	Splash wall	85	20m long cracks.	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	12
D39	387647, 786423	Embankment	Splash wall	86	Timber handrailing missing.	Replace timber handrails with a more durable solution.	1
D40	387647, 786424	Embankment	Splash wall	87	Corroded handrail supports.	Consider replacing corroded supports	23
D41	387646, 786423	Embankment	Splash wall	88	Cracks in concrete on steps.	Repoint fractures.	12
D42	387664, 786450	Embankment	Splash wall	89	Corroded handrailing supports.	Consider replacing corroded supports.	23
D43	387671, 786462	Embankment	Splash wall	90	Loss of concrete cover and corroding reinforcement.	Reface concrete cover.	24

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D44	387642, 786419	Embankment	Splash wall	91	Approximately 20m longitudinal crack along the recurve exposing corroding reinforcement .	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	7
D45	387625, 786391	Embankment	Splash wall	92	Damaged concrete exposing reinforcement approximately 0.3x 0.2m and long crack approximately 10m.	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	13
D46	387620, 786386	Embankment	Splash wall	93	Damaged concrete with exposed corroding reinforcement, approx. 2x0.3m	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	5
D47	387618, 786380	Embankment	Splash wall	94	Damaged concrete with exposed corroding reinforcement approximately 1 x 0.3m.	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	5
D48	387605, 786361	Embankment	Splash wall	95	Loss of concrete on top of recurve cover exposing reinforcement.	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	6
D49	387601, 786351	Embankment	Splash wall	96	Damaged concrete on top of recurve.	Replace damaged concrete.	20
D50	387592, 786332	Embankment	Splash wall	97	Vertical crack on recurve.	Repoint vertical fracture and repair recurve damage.	9
D51	387593, 786323	Embankment	Splash wall	98	Health and Safety - major loss of steps, exposed dowels.	Cordon off step access, replace missing steps and cover exposed dowels.	1
D52	387595, 786325	Embankment	Splash wall	99	Signs of rot on timber handrailing.	Replace timber handrails with a more durable solution.	30
D53	387594, 786329	Embankment	Splash wall	100	Corroded handrail supports.	Replace timber handrails with a more durable solution.	23

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D54	387592, 786326	Embankment	Splash wall	101	Horizontal cracks.	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	10
D55	387568, 786260	Embankment	Exposed face	102	Corrosion of handrailing supports.	Replace timber handrails with a more durable solution.	25
D56	387558, 786221	Embankment	Splash wall	103	Health and Safety - Missing handrails.	Replace timber handrails with a more durable solution.	1
D57	387556, 786229	Embankment	Splash wall	104	Distorted handrails.	Replace timber handrails with a more durable solution.	29
D58	387487, 786216	Embankment	Piling	105	Corrosion of piles.	Monitor and consider corrosion protection of piles.	2
D59	387486, 786218	Embankment	Piling	106	Missing flap valve	Replace flap valve.	20
D60	387491, 786215	Embankment	Channel side	107	Drainage points blocked.	Unblock drainage points, consider installing flap valves.	20
D61	387383, 786311	Embankment	Channel side	122	Vegetation growth on top of concrete	Develop vegetation clearance plan.	26
D62	387499, 786208	Embankment	Channel side	108	Broken slab, potential for scour behind protected face	Patch repair damaged slab.	11
D63	387499, 786208	Embankment	Piling	109, 143	Damaged concrete capping beam exposing reinforcement .	Patch repair damaged slab.	11
D64	387514, 786217	Embankment	Piling	110	Anchor missing, possibly more than one	Investigate whether missing anchors require replacing.	3
D65	387532, 786197	Embankment	Exposed face	111	Open joints.	Repoint open joints	17

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D66	387532, 786198	Embankment	Exposed face	112	Cracked and broken concrete approximately 0.5m.	Reface concrete and repoint fracture.	13
D67	387532, 786213	Embankment	Piling	113	Chipped capping beam	Replace damaged concrete.	22
D68	387549, 786214	Embankment	Exposed face	114	Broken parapet.	Fix horizontal guarding.	27
D69	387567, 786212	Embankment	Exposed face	115	Abrasion of concrete exposing reinforcement.	Reface concrete cover.	14
D70	387557, 786206	Embankment	Exposed face	116	Damaged concrete, approximately 1.5m long, exposing reinforcement heavily corroded.	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	3
D71	387554, 786207	Embankment	Exposed face	117	Chipping concrete and cracks along the river face of the wall.	Reface concrete and repoint fractures.	27
D72	387551, 786208	Embankment	Exposed face	118	Vertical crack on recurve approximately 1m long	Repoint vertical fracture.	28
D73	387544, 786207	Embankment	Exposed face	119	Flap valves missing.	Consider installing flap valves.	23
D74	387405, 786265	Embankment	Channel side	120	Delaminating concrete repairs.	Reface concrete repairs.	18
D75	387403, 786265	Embankment	Channel side	121	Horizontal crack. Poor condition of upper concrete slope.	Repoint fracture.	18
D76	388077, 786860	Wall	Exposed face	123	Improper design/repairs.	Monitor and consider replacing with a more formal coastal protection.	15
D77	388062, 786848	Wall	Exposed face	124	Blocks missing from masonry wall.	Replace missing blockwork.	4

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D78	388057, 786846	Wall	Exposed face	125	Open joints.	Repoint open joints.	4
D79	388028, 786814	Wall	Exposed face	126	Voiding behind blockwork.	Repoint and fill voids.	4
D80	388021, 786802	Wall	Exposed face	127	Dilapidated concrete repairs.	Reface concrete repairs.	8
D81	388014, 786789	Wall	Exposed face	128	Voiding around loose blockwork.	Repoint and fill voids.	4
D82	387970, 786723	Wall	Exposed face	129	5No. missing flap valves.	Consider installing flap valves.	21
D83	387959, 786699	Wall	Access strip	130, 144	Very poor condition of concrete slipway including severe undermining and extensive cracking of slipway surface.	Consider rebuilding slipway if still in use.	8
D84	387948, 786682	Wall	Exposed face	131	Cracking of concrete approximately 2m long.	Repoint vertical cracking. Monitor wall for further deterioration.	12
D88	387534, 786173	Wall	Exposed face	132, 146, 150, 154, 158, 161, 163, 165	Open joints.	Replace missing mastic.	13
D89	387535, 786169	Wall	Exposed face	133, 145, 149, 153, 157, 160, 162, 164, 166, 167, 168, 169, 170, 171, 172, 173, 174	Chipped concrete by expansion joint with exposure of reinforcement.	Reface concrete cover to prevent further damage and repoint fractures.	21
D90	387525, 786097	Wall	Exposed face	134	Flood gate possibly needed.	Consider installing flood gate.	21
D91	387508, 786007	Wall	Exposed face	135	Distortion of parapet	Consider replacing parapet.	29

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D92	387508, 786001	Wall	Exposed face	136	Chipped concrete by the expansion joint approximately 0.4x0.2m.	Reface concrete.	17
D93	387506, 785982	Wall	Exposed face	137, 147, 151, 155	Vertical crack in concrete.	Repoint vertical crack.	14
D94	387509, 785970	Wall	Exposed face	138	Damaged concrete	Reface damaged concrete.	17
D95	387528, 785743	Embankment	Rock armour	139	Overly steep rock armour profile, at risk of collapse under extreme wave loading.	Consider reprofiling rock armour profile.	31
D96	387555, 785675	Embankment	Rock armour	140	Duckbill outfall valves heavily silted.	Clear area surrounding valves.	20
D97	388018, 786803	Wall	Seaward toe	141	Undermining and damage to the concrete toe.	Repair damaged concrete, while extending toe protection further down into the beach .	3
D98	387717, 786512	Wall	Crest	142, 148, 152, 156, 159	Sinkhole in crest (observed following initial inspection).	Fix the sinkhole and fill the depression. Consider replacing the sheet piles in the exposed face to prevent further erosion (Sinkhole observed following initial inspection□Council has undertaken repairworks).	1

6. Health and safety check

Health and Safety Check (Defence - Section A)

	Y or N	Photo No.	Notes
Handrails			No handrails present.
Are handrails necessary	N		
Are handrails present	N		
Are handrails secured	-		
Handrail construction material	-		
Are handrails corroded	-		
Is handrail paint in good condition	-		
Ladders / Steps			
Are ladders / steps necessary for access	N		
Are ladder / steps present	N		
Steps construction material	-		
Are steps in good condition	-		
Are steps free of algae growth	-		
Are ladders secured	-		
Are ladders corroded	-		
Is ladder paint in good condition	-		
Ramps and walkways			The ramp has uneven surface with major holes on the top and undermined on one side.
Are ramps and walkways necessary for access	Y		
Are ramps and walkways present	Y		
Ramp construction material			Concrete
Are ramps in good condition	N		
Are ramps free of algae growth	Y		
Safety Harness Attachments			
Are attachments necessary for inspection	N		
Are attachments present	N		
Are attachments in good condition	-		

Summary of health and safety items

No summary details entered

Health and Safety Check (Defence - Section B)

	Y or N	Photo No.	Notes
Handrails			Handrails only present on top of the sheet pile wall - 90 of the wall without handrailing.
Are handrails necessary	N		
Are handrails present	N		
Are handrails secured	-		
Handrail construction material	-		
Are handrails corroded	-		
Is handrail paint in good condition	-		
Ladders / Steps			
Are ladders / steps necessary for access	N		
Are ladder / steps present	N		
Steps construction material	-		
Are steps in good condition	-		
Are steps free of algae growth	-		
Are ladders secured	-		
Are ladders corroded	-		
Is ladder paint in good condition	-		
Ramps and walkways			
Are ramps and walkways necessary for access	N		
Are ramps and walkways present	N		
Ramp construction material	-		
Are ramps in good condition	-		
Are ramps free of algae growth	-		
Safety Harness Attachments			
Are attachments necessary for inspection	N		
Are attachments present	N		
Are attachments in good condition	-		

Summary of health and safety items

Access to Section B is via steps on the south side of the wall and at the beginning of Section C.

Health and Safety Check (Defence - Section C)

	Y or N	Photo No.	Notes
Handrails			Handrails are present throughout Section C, on top of the revetment and the access steps. Some missing elements and corroded supports were found during inspection.
Are handrails necessary?	Y		
Are handrails present?	Y		
Are handrails secured?	Y		
Handrail construction material			Timber
Are handrails corroded?	Y		
Is handrail paint in good condition?	N		
Ladders / Steps			Access to the toe of the defence is available via steps in four different locations. Some dilapidated and hazardous access steps are present to the south side of Section C and exposed dowel bars are causing tripping hazards (removed after initial visual inspection).
Are ladders / steps necessary for access?	Y		
Are ladder / steps present?	Y		
Steps construction material			Concrete
Are steps in good condition?	Y		
Are steps free of algae growth?	N		
Are ladders secured?	N		
Are ladders corroded?	N		
Is ladder paint in good condition?	N		
Ramps and walkways			
Are ramps and walkways necessary for access?	N		
Are ramps and walkways present?	N		
Ramp construction material	-		
Are ramps in good condition?	-		
Are ramps free of algae growth?	-		
Safety Harness Attachments			
Are attachments necessary for inspection?	N		
Are attachments present?	N		
Are attachments in good condition?	-		

Summary of health and safety items

- There are exposed dowels bars on the access steps causing immediate hazard and they should be covered.
- There are access steps missing causing falling hazard.
- Due to the falling hazard at the crest of the sea wall, the missing handrailing section should be repaired.

Health and Safety Check (Defence - Section D)

	Y or N	Photo No.	Notes
Handrails			Handrails generally in good condition. Fixings missing off a parapet panel on top of the exposed face of the structure.
Are handrails necessary	Y		
Are handrails present	Y		
Are handrails secured	Y		
Handrail construction material			Steel
Are handrails corroded	N		
Is handrail paint in good condition	Y		
Ladders / Steps			
Are ladders / steps necessary for access	N		
Are ladder / steps present	N		
Steps construction material	-		
Are steps in good condition	-		
Are steps free of algae growth	-		
Are ladders secured	-		
Are ladders corroded	-		
Is ladder paint in good condition	-		
Ramps and walkways			
Are ramps and walkways necessary for access	N		
Are ramps and walkways present	N		
Ramp construction material	-		
Are ramps in good condition	-		
Are ramps free of algae growth	-		
Safety Harness Attachments			
Are attachments necessary for inspection	N		
Are attachments present	N		
Are attachments in good condition	-		

Summary of health and safety items

No major health and safety hazards. Parapet suggested to be repaired.

Health and Safety Check (Defence - Section E)

	Y or N	Photo No.	Notes
Handrails			
Are handrails necessary□	N		
Are handrails present□	N		
Are handrails secured□	-		
Handrail construction material	-		
Are handrails corroded□	-		
Is handrail paint in good condition□	-		
Ladders / Steps			
Are ladders / steps necessary for access□	Y		
Are ladder / steps present□	Y		
Steps construction material			Concrete
Are steps in good condition□	Y		
Are steps free of algae growth□	Y		
Are ladders secured□	N		
Are ladders corroded□	N		
Is ladder paint in good condition□	N		
Ramps and walkways			Access to the defence is available via Section E.
Are ramps and walkways necessary for access□	N		
Are ramps and walkways present□	N		
Ramp construction material	-		
Are ramps in good condition□	-		
Are ramps free of algae growth□	-		
Safety Harness Attachments			
Are attachments necessary for inspection□	N		
Are attachments present□	N		
Are attachments in good condition□	-		

Summary of health and safety items

No summary details entered

Health and Safety Check (Defence - Section F)

	Y or N	Photo No.	Notes
Handrails			
Are handrails necessary	N		
Are handrails present	N		
Are handrails secured	-		
Handrail construction material	-		
Are handrails corroded	-		
Is handrail paint in good condition	-		
Ladders / Steps			
Are ladders / steps necessary for access	N		
Are ladder / steps present	N		
Steps construction material	-		
Are steps in good condition	-		
Are steps free of algae growth	-		
Are ladders secured	-		
Are ladders corroded	-		
Is ladder paint in good condition	-		
Ramps and walkways			
Are ramps and walkways necessary for access	N		
Are ramps and walkways present	N		
Ramp construction material	-		
Are ramps in good condition	-		
Are ramps free of algae growth	-		
Safety Harness Attachments			
Are attachments necessary for inspection	N		
Are attachments present	N		
Are attachments in good condition	-		

Summary of health and safety items

No summary details entered

7. Asset assessment

7.1. Recommended works

Band A: Emergency works
Defect posing an immediate safety hazard. Immediate action required.

Defect Recommendation	Defect
Unblock pipes and consider installing flap valves.	D17
Monitor and undertake further survey to determine pile thickness. Consider replacing sheet piles with an alternative coastal defence solution.	D20
Replace timber handrails with a more durable solution.	D22
Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	D35
Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	D44
Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	D46
Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	D47
Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	D48
Cordon off step access, replace missing steps and cover exposed dowels.	D51
Replace timber handrails with a more durable solution.	D56
Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	D70
Clear area surrounding valves.	D96
Fix the sinkhole and fill the depression. Consider replacing the sheet piles in the exposed face to prevent further erosion (Sinkhole observed following initial inspection Council has undertaken repair works).	D98

Replace timber handrails with a more durable solution.	D39
Consider replacing corroded supports	D40
Repoint fractures.	D41
Consider replacing corroded supports.	D42
Reface concrete cover.	D43
Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	D45
Replace damaged concrete.	D49
Repoint vertical fracture and repair recurve damage.	D50
Replace timber handrails with a more durable solution.	D53
Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete recurve.	D54
Replace timber handrails with a more durable solution.	D55
Monitor and consider corrosion protection of piles.	D58
Replace flap valve.	D59
Unblock drainage points, consider installing flap valves.	D60
Develop vegetation clearance plan.	D61
Patch repair damaged slab.	D62
Patch repair damaged slab.	D63
Investigate whether missing anchors require replacing.	D64
Repoint open joints	D65
Reface concrete and repoint fracture.	D66
Replace damaged concrete.	D67
Fix horizontal guarding.	D68
Reface concrete cover.	D69
Reface concrete and repoint fractures.	D71
Repoint vertical fracture.	D72
Consider installing flap valves.	D73
Reface concrete repairs.	D74
Repoint fracture.	D75
Replace missing blockwork.	D77
Repoint open joints.	D78
Repoint and fill voids.	D79

Reface concrete repairs.	D80
Repoint and fill voids.	D81
Repoint vertical cracking. Monitor wall for further deterioration.	D84
Replace missing mastic.	D88
Reface concrete cover to prevent further damage and repoint fractures.	D89
Consider installing flood gate.	D90
Reface concrete.	D92
Repoint vertical crack.	D93
Reface damaged concrete.	D94
Repair damaged concrete, while extending toe protection further down into the beach .	D97

Band C: Short-term remedial works

Defect posing a potential safety hazard. Work recommended within 12 to 30 month period.

Defect Recommendation	Defect
Resurface vegetated crest.	D1
Resurface vegetated crest.	D2
Breakout and repair corroded area.	D6
Consider installing flap valves.	D7
Patch repair damaged recurve.	D9
Patch repair damaged recurve.	D10
Repoint crack.	D19
Monitor and consider replacing rendering to prevent further deterioration.	D27
None.	D37
Replace timber handrails with a more durable solution.	D52
Replace timber handrails with a more durable solution.	D57
Monitor and consider replacing with a more formal coastal protection.	D76
Consider installing flap valves.	D82
Consider rebuilding slipway if still in use.	D83
Consider replacing parapet.	D91
Consider reprofiling rock armour profile.	D95

Band D: Long-term maintenance works

Defect resulting in long-term deterioration of structure or affecting performance. Work recommended within 30 to 48 month period.

No defects identified in this band

7.2. Report sign-off

Prepared and Completed by:	Johan Skanberg-Tippen BSc, MSc (Eng)
Signed:	
Date:	02/07/2018
Checked and Approved by:	Graham Kenn CEng, MICE, C.WEM, CIWEM – Technical Director – Coastal Engineering
Signed:	
Date:	02/07/2018

Appendix 1 – Photographs

Section Photos	
Section A **Description:** View of Section A (looking south) Asset Type: Defence Sub Type: Wall Elements: Exposed face, seaward toe and access strip **Photo number: 1**	
Section A **Description:** View of Section A (looking south) Asset Type: Defence Sub Type: Wall Elements: Exposed face, seaward toe and access strip **Photo number: 7**	

Section B **Description:** View of Section B (looking south) Asset Type: Defence Sub Type: Wall Elements: Exposed face (concrete), exposed face (sheet piles) and crest **Photo number: 2**	
Section C **Description:** View of Section C (looking north) Asset Type: Defence Sub Type: Revetment Elements: Exposed face, sea wall and rock armour **Photo number: 6**	

Section D **Description:** View of Section D (looking west) Asset Type: Defence Sub Type: Training Walls Elements: Channel side, exposed face and piling **Photo number: 3**	
Section E **Description:** View of Section E (looking south) Asset Type: Defence Sub Type: Wall Elements: Exposed face **Photo number: 4**	

Section F **Description:** View of Section F (looking south) Asset Type: Defence Sub Type: Embankment Elements: Beach and rock armour **Photo number: 5**	
Section F **Description:** View of Section F (looking south) Asset Type: Defence Sub Type: Embankment Elements: Beach and rock armour **Photo number: 8**	

Defect Photos	
Section B **Crest** **Defect Ref: D1** **Description:** D1 - Poorly vegetated and eroded crest **Photo number: 63**	
Section B **Crest** **Defect Ref: D2** **Description:** D2 - Depression of crest **Photo number: 64**	

Section B **Exposed face** **Defect Ref: D3** **Description:** D3 - Cracked and spalling concrete **Photo number: 48**	
Section B **Exposed face** **Defect Ref: D4** **Description:** D4 - Spalling concrete **Photo number: 49**	

Section B **Exposed face** **Defect Ref: D5** **Description:** D5 - Broken flap valve **Photo number: 50**	
Section B **Exposed face** **Defect Ref: D6** **Description:** D6 - Cover loss exposing corroded reinforcement **Photo number: 51**	

Section B **Exposed face** **Defect Ref: D7** **Description:** D7 - 12 missing flap valves **Photo number: 52**	
Section B **Exposed face** **Defect Ref: D8** **Description:** D8 - Spalling concrete **Photo number: 53**	

Section B **Exposed face** **Defect Ref: D9** **Description:** D9 - Damaged recurve **Photo number: 54**	
Section B **Exposed face** **Defect Ref: D10** **Description:** D10 - Damaged recurve **Photo number: 55**	

Section B **Exposed face** **Defect Ref: D11** **Description:** D11 - Vertical crack **Photo number: 56**	
Section B **Exposed face** **Defect Ref: D12** **Description:** D12 - Vertical fracture **Photo number: 57**	

Section B **Exposed face** **Defect Ref: D13** **Description:** D13 - Damaged recurve **Photo number: 58**	
Section B **Exposed face** **Defect Ref: D14** **Description:** D14 - Vertical crack **Photo number: 59**	

Section B **Exposed face** **Defect Ref: D15** **Description:** D15 - Vertical fracture **Photo number: 60**	
Section B **Exposed face** **Defect Ref: D16** **Description:** D16 - Missing pointing between recurve units **Photo number: 61**	

Section B **Exposed face** **Defect Ref: D17** **Description:** D17 - Blocked drainage pipes **Photo number: 62**	
Section B **Exposed face** **Defect Ref: D18** **Description:** D18 - Corroded sheet piles **Photo number: 65**	

Section B **Exposed face** **Defect Ref: D19** **Description:** D19 - Cracking in the capping beam **Photo number: 66**	
Section B **Exposed face** **Defect Ref: D20** **Description:** D20 - Section loss of sheet piles **Photo number: 67**	

Section B **Exposed face** **Defect Ref: D21** **Description:** D21 - Crack in the capping beam **Photo number: 68**	
Section C **Exposed face** **Defect Ref: D22** **Description:** D22 - Missing handrailing **Photo number: 69**	

Section C **Exposed face** **Defect Ref: D23** **Description:** D23 - Corroded handrailing support. **Photo number: 70**	
Section C **Splash wall** **Defect Ref: D24** **Description:** D24 - Cracking of concrete **Photo number: 71**	

Section C **Splash wall** **Defect Ref: D25** **Description:** D25 - Corroded reinforcement **Photo number: 72**	
Section C **Splash wall** **Defect Ref: D26** **Description:** D26 - Chipped concrete exposing reinforcement **Photo number: 73**	

Section C **Splash wall** **Defect Ref: D27** **Description:** D27 - General abrasion of steps **Photo number: 74**	
Section C **Splash wall** **Defect Ref: D28** **Description:** D28 - Vertical crack **Photo number: 75**	

Section C **Splash wall** **Defect Ref: D29** **Description:** D29 - Exposed corroding reinforcement **Photo number: 79**	
Section C **Splash wall** **Defect Ref: D30** **Description:** D30 - Open joints **Photo number: 76**	

Section C **Splash wall** **Defect Ref: D31** **Description:** D31 - Cracking in upper radius of recurve **Photo number: 77**	
Section C **Splash wall** **Defect Ref: D32** **Description:** D32 - Exposed reinforcement and damaged concrete **Photo number: 78**	

Section C **Splash wall** **Defect Ref: D33** **Description:** D33 - Open joints **Photo number: 80**	
Section C **Splash wall** **Defect Ref: D34** **Description:** D34 - 24 outfalls missing flap valves **Photo number: 81**	

Section C **Splash wall** **Defect Ref: D35** **Description:** D35 - Loss of concrete exposing reinforcement **Photo number: 82**	
Section C **Splash wall** **Defect Ref: D36** **Description:** D36 - Horizontal crack on sea wall and buttress wall **Photo number: 83**	

Section C **Splash wall** **Defect Ref: D37** **Description:** D37 - Difference in crest level **Photo number: 84**	
Section C **Splash wall** **Defect Ref: D38** **Description:** D38 - 20m long cracks **Photo number: 85**	

Section C **Splash wall** **Defect Ref: D39** **Description:** D39 - Handrailing missing **Photo number: 86**	
Section C **Splash wall** **Defect Ref: D40** **Description:** D40 - Corroded handrail supports **Photo number: 87**	

Section C **Splash wall** **Defect Ref: D41** **Description:** D41 - Cracks in concrete on steps **Photo number: 88**	
Section C **Splash wall** **Defect Ref: D42** **Description:** D42 - Corroded handrail supports **Photo number: 89**	

Section C **Splash wall** **Defect Ref: D43** **Description:** D43 - Cover loss and corroding reinforcement **Photo number: 90**	
Section C **Splash wall** **Defect Ref: D44** **Description:** D44 - Crack exposing corroding reinforcement **Photo number: 91**	

Section C **Splash wall** **Defect Ref: D45** **Description:** D45 - Chipped concrete exposing reinforcement **Photo number: 92**	
Section C **Splash wall** **Defect Ref: D46** **Description:** D46 - Chipped concrete exposing reinforcement **Photo number: 93**	

Section C **Splash wall** **Defect Ref: D47** **Description:** D47 - Chipped concrete exposing reinforcement **Photo number: 94**	
Section C **Splash wall** **Defect Ref: D48** **Description:** D48 - Chipped concrete exposing reinforcement **Photo number: 95**	

Section C **Splash wall** **Defect Ref: D49** **Description:** D49 - Damaged concrete on top of recurve **Photo number: 96**	
Section C **Splash wall** **Defect Ref: D50** **Description:** D50 - Vertical crack on recurve **Photo number: 97**	

Section C **Splash wall** **Defect Ref: D51** **Description:** D51 - Loss of steps and exposed dowels **Photo number: 98**	
Section C **Splash wall** **Defect Ref: D52** **Description:** D52 - Signs of rot on timber handrailing **Photo number: 99**	

Section C **Splash wall** **Defect Ref: D53** **Description:** D53 - Corroded handrail supports **Photo number: 100**	
Section C **Splash wall** **Defect Ref: D54** **Description:** D54 - Horizontal crack in sea wall **Photo number: 101**	

Section C **Exposed face** **Defect Ref: D55** **Description:** D55 - Corrosion of handrailing supports **Photo number: 102**	
Section C **Splash wall** **Defect Ref: D56** **Description:** D56 - Missing handrails **Photo number: 103**	

Section C **Splash wall** **Defect Ref: D57** **Description:** D57 - Distorted handrails **Photo number: 104**	
Section D **Piling** **Defect Ref: D58** **Description:** D58 - Corrosion of piles **Photo number: 105**	

Section D **Piling** **Defect Ref: D59** **Description:** D59 - Missing flap valve **Photo number: 106**	
Section D **Channel side** **Defect Ref: D60** **Description:** D60 - Drainage points blocked **Photo number: 107**	

Section D **Channel side** **Defect Ref: D61** **Description:** D61 - Vegetation growth on top of concrete **Photo number: 122**	
Section D **Channel side** **Defect Ref: D62** **Description:** D62 - Broken slab, potential for scour behind protected face **Photo number: 108**	

Section D **Piling** **Defect Ref: D63** **Description:** D63 - Damaged concrete capping beam exposing reinforcement **Photo number: 109**	
Section D **Piling** **Defect Ref: D63** **Description:** D63 - Damaged concrete capping beam exposing reinforcement **Photo number: 143**	

Section D **Piling** **Defect Ref: D64** **Description:** D64 - Anchor missing, potentially more than one **Photo number: 110**	
Section D **Exposed face** **Defect Ref: D65** **Description:** D65 - Open joints **Photo number: 111**	

Section D **Exposed face** **Defect Ref: D66** **Description:** D65 - Cracked and broken concrete approximately 0.5m **Photo number: 112**	
Section D **Piling** **Defect Ref: D67** **Description:** D67 - Chipped capping beam **Photo number: 113**	

Section D **Exposed face** **Defect Ref: D68** **Description:** D68 - Broken parapet **Photo number: 114**	
Section D **Exposed face** **Defect Ref: D69** **Description:** D69 - Abrasion of concrete exposing reinforcement **Photo number: 115**	

Section D **Exposed face** **Defect Ref: D70** **Description:** D70 - Damaged concrete approximately 1.5m long, e posing heavily corroded reinforcement **Photo number: 116**	
Section D **Exposed face** **Defect Ref: D71** **Description:** D71 - Chipping concrete and cracks along the river face of the wall **Photo number: 117**	

Section D **Exposed face** **Defect Ref: D72** **Description:** D72 - Vertical crack on recurve approximately 1m long **Photo number: 118**	
Section D **Exposed face** **Defect Ref: D73** **Description:** D73 -Flap valves missing **Photo number: 119**	

Section D **Channel side** **Defect Ref: D74** **Description:** D74 - Delaminating concrete repairs **Photo number: 120**	
Section D **Channel side** **Defect Ref: D75** **Description:** D75 - Horizontal crack - poor protection of upper concrete slope **Photo number: 121**	

Section A **Exposed face** **Defect Ref: D76** **Description:** D76 - Improper design / repairs **Photo number: 123**	
Section A **Exposed face** **Defect Ref: D77** **Description:** D77 - Missing blockwork **Photo number: 124**	

Section A **Exposed face** **Defect Ref: D78** **Description:** D78 - Open joints **Photo number: 125**	
Section A **Exposed face** **Defect Ref: D79** **Description:** Voiding behind blockwork. **Photo number: 126**	

Section A **Exposed face** **Defect Ref: D80** **Description:** D80 - Dilapidated concrete repairs **Photo number: 127**	
Section A **Exposed face** **Defect Ref: D81** **Description:** D81 - Voiding around blockwork **Photo number: 128**	

Section A **Exposed face** **Defect Ref: D82** **Description:** D82 - Missing flap valves **Photo number: 129**	
Section A **Access strip** **Defect Ref: D83** **Description:** D84 - Undermined slipway **Photo number: 130**	

Section A **Access strip** **Defect Ref: D83** **Description:** D83 - Holes on top of the slipway **Photo number: 144**	
Section A **Exposed face** **Defect Ref: D84** **Description:** D84 - Cracking of concrete **Photo number: 131**	

Section E **Exposed face** **Defect Ref: D88** **Description:** D88 - Open joints **Photo number: 132**	
Section E **Exposed face** **Defect Ref: D88** **Description:** D88 - Open joints **Photo number: 146**	

Section E **Exposed face** **Defect Ref: D88** **Description:** D88 - Open joints **Photo number: 150**	
Section E **Exposed face** **Defect Ref: D88** **Description:** D88 - Open joints **Photo number: 154**	

Section E **Exposed face** **Defect Ref: D88** **Description:** D88 - Open joints **Photo number: 158**	
Section E **Exposed face** **Defect Ref: D88** **Description:** D88 - Open joints **Photo number: 161**	

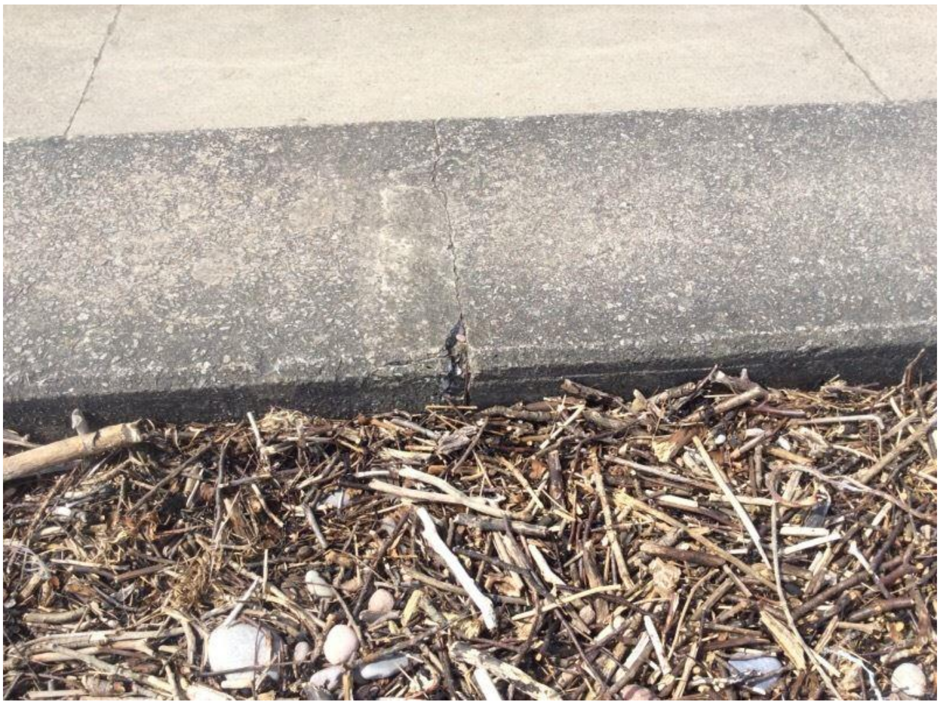
Section E **Exposed face** **Defect Ref: D88** **Description:** D88 - Open joints **Photo number: 163**	
Section E **Exposed face** **Defect Ref: D88** **Description:** D88 - Open joints **Photo number: 165**	

Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 133**	
Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 145**	

Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 149**	
Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 153**	

Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 157**	
Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 160**	

Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 162**	
Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 164**	

Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 166**	
Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 167**	

Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 168**	
Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 169**	

Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 170**	
Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 171**	

Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 172**	
Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 173**	

Section E **Exposed face** **Defect Ref: D89** **Description:** D89 - Chipped concrete by expansion joint with exposure of reinforcement **Photo number: 174**	
Section E **Exposed face** **Defect Ref: D90** **Description:** D90 - Flood gate possibly needed **Photo number: 134**	

Section E **Exposed face** **Defect Ref: D91** **Description:** D91 - Distortion of parapet **Photo number: 135**	
Section E **Exposed face** **Defect Ref: D92** **Description:** D92 - Chipped concrete by the expansion joint approximately 0.4x0.2m **Photo number: 136**	

Section E **Exposed face** **Defect Ref: D93** **Description:** D93 - Vertical crack in concrete **Photo number: 137**	
Section E **Exposed face** **Defect Ref: D93** **Description:** D93 - Vertical crack in concrete **Photo number: 147**	

Section E **Exposed face** **Defect Ref: D93** **Description:** D93 - Vertical crack in concrete **Photo number: 151**	
Section E **Exposed face** **Defect Ref: D93** **Description:** D93 - Vertical crack in concrete **Photo number: 155**	

Section E **Exposed face** **Defect Ref: D94** **Description:** D94 - Damaged concrete **Photo number: 138**	
Section F **Rock armour** **Defect Ref: D95** **Description:** D95 - Overly steep rock armour profile **Photo number: 139**	

Section F **Rock armour** **Defect Ref: D96** **Description:** D96 - Duckbill valves blocked up **Photo number: 140**	
Section A **Seaward toe** **Defect Ref: D97** **Description:** D97 - Poor protection of the toe **Photo number: 141**	

Section B **Crest** **Defect Ref: D98** **Description:** Sinkhole in crest (observed following initial inspection) **Photo number: 142**	
Section B **Crest** **Defect Ref: D98** **Description:** Sinkhole in crest (observed following initial inspection) **Photo number: 148**	

Section B **Crest** **Defect Ref: D98** **Description:** Sinkhole in crest (observed following initial inspection) **Photo number: 152**	
Section B **Crest** **Defect Ref: D98** **Description:** Sinkhole in crest (observed following initial inspection) **Photo number: 156**	

Section B **Crest** **Defect Ref: D98** **Description:** Sinkhole in crest (observed following initial inspection) **Photo number: 159**	

Appendix 2 – Asset descriptors

Asset Type	Sub Type	Element
Defence	Wall	Exposed face
		Landward face
		Crest
		Berm
		Channel side
		Landward toe
		Capping wall
		Access strip
		Core
		Drainage ditch
		Seaward toe
		Rock armour
	Embankment	Exposed face
		Landward face
		Crest
		Berm
		Channel side
		Landward toe
		Access strip
		Splash deck
		Splash wall
		Seaward toe
		Rock armour
		Piling
		Gabions
	Quay	Quay face
		Deck
		Capping
		Piling
		Planking
		Stem
		Roundhead
		Sheet piling
		Seaward face
		Face protection
	Dune	Stabilised zone
		Active zone
	Cliff	Seaward face
		Cliff top
		Seaward toe
		Face protection
		Drainage

Asset Type	Sub Type	Element
Beach Structure	Groyne	Crest
		Left face
		Right face
		Piling
		Planking
		Waling
		Roundhead
		Fishtail
		Stem
		Sheet piling
		Capping beam
	Breakwater	Crest
		Seaward face
		Landward face
		Sheet piling
		Bedding layer
		Face protection
		Roundhead
		Fishtail
		Capping beam
		Waling

Appendix 3 – EA Condition Grades

10 Environment Agency Condition Assessment Manual

2.0 Visual inspection condition grades

The condition grading and descriptions given below are the standards adopted by the Environment Agency. The five condition grades, ranging from 'very good' to 'very poor', remain as before. However, the descriptions have been redefined, compared to the previous versions of the Condition Assessment Manual, to reflect condition according to flood defence performance.

2.1 General assessment

Grade	Rating	Description
1	Very Good	Cosmetic defects that will have no effect on performance
2	Good	Minor defects that will not reduce the overall performance of the asset
3	Fair	Defects that could reduce performance of the asset
4	Poor	Defects that would significantly reduce the performance of the asset. Further investigation needed
5	Very Poor	Severe defects resulting in complete performance failure

Appendix 4 – Deterioration times – EA Guidance

Table A.1 Deterioration times (years) to different condition grades for different asset types and exposures

Asset class	Environment	Material	AIMS asset classification	Narrow/ wide*	Maintenance Regime	Expected deterioration times (years) to specified CG from new														
						Medium deterioration					Fastest deterioration					Slowest deterioration				
						1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Vertical wall	Fluvial	Concrete	Defence/ wall	N/A	1	0	15	35	50	60	0	5	20	30	40	0	20	50	70	80
					2	0	20	45	70	90	0	10	30	50	60	0	25	60	100	120
					3	0	25	55	90	120	0	15	40	70	80	0	30	70	130	160
		Brick/ masonry		N/A	1	0	15	35	50	60	0	5	20	30	40	0	20	50	70	80
					2	0	20	45	70	90	0	10	30	50	60	0	25	60	100	120
					3	0	25	55	90	120	0	15	40	70	80	0	30	70	130	160
		Timber		N/A	1	0	5	10	12	15	0	3	5	7	10	0	7	15	18	21
					2	0	10	20	25	30	0	5	10	12	15	0	15	30	35	40
					3	0	15	30	35	42	0	7	15	17	20	0	23	45	52	60
		Gabion	Defence/ wall/ gabions	N/A	1	0	5	10	22	26	0	4	8	15	18	0	5	10	25	30
					N/A															
					N/A															
	Coastal/ estuarine	Concrete	Defence/ wall	N/A	1	0	10	30	40	50	0	5	15	25	30	0	15	45	60	80
					2	0	15	40	55	70	0	10	20	30	40	0	20	60	80	100
					3	0	20	50	70	90	0	15	25	35	50	0	25	75	100	120
		Brick/ masonry		N/A	1	0	10	30	40	50	0	5	15	25	30	0	15	45	60	80
					2	0	15	40	55	70	0	10	20	30	40	0	20	60	80	100
					3	0	20	50	70	90	0	15	25	35	50	0	25	75	100	120
		Timber		N/A	1	0	4	8	10	14	0	2	4	6	8	0	5	13	16	20
					2	0	8	18	23	28	0	4	8	10	13	0	14	28	33	38
					3	0	13	28	33	38	0	5	13	15	18	0	21	42	48	55
		Gabion	Defence/ wall/ gabions	N/A	1	0	3	8	15	20	0	1	5	10	13	0	3	8	20	25
					N/A															
					N/A															

Asset class	Environment	Material	AIMS asset classification	Narrow/ wide*	Maintenance Regime	Expected deterioration times (years) to specified CG from new														
						Medium deterioration					Fastest deterioration					Slowest deterioration				
						1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Sheet piles	Fluvial	Cantilevered steel	Defence/ wall/ piling	N/A	1	0	15	20	40	50	0	10	15	20	25	0	20	30	60	70
					2	0	20	30	50	60	0	15	20	30	35	0	25	40	70	80
					3	0	25	40	60	70	0	20	30	40	45	0	30	50	80	90
		Anchored steel		N/A	1	0	15	20	40	50	0	10	15	20	25	0	20	30	60	70
					2	0	20	30	50	60	0	15	20	30	35	0	25	40	70	80
					3	0	25	40	60	70	0	20	30	40	45	0	30	50	80	90
	Coastal/ estuarine	Cantilevered steel		N/A	1	0	10	15	30	40	0	5	10	15	20	0	15	30	50	60
					2	0	15	25	50	60	0	10	15	25	30	0	20	40	60	70
					3	0	20	35	60	70	0	15	20	35	40	0	25	50	70	80
		Anchored steel		N/A	1	0	10	15	30	40	0	5	10	15	20	0	15	30	50	60
					2	0	15	25	50	60	0	10	15	25	30	0	20	40	60	70
					3	0	20	35	60	70	0	15	20	35	40	0	25	50	70	80
Demount-able defences	Fluvial	Metal	Defence/ demount-able	N/A	1	0	1	3	4	5	0	1	2	3	4	0	2	4	5	7
					2	0	5	10	45	55	0	2	5	35	45	0	10	20	60	70
					3	0	8	15	55	65	0	5	10	45	55	0	15	25	70	80
		Wood		N/A	1	0	1	3	4	5	0	1	2	3	4	0	2	4	5	7
					2	0	3	5	23	28	0	1	3	18	23	0	5	10	30	35
					3	0	4	8	28	33	0	3	5	23	28	0	8	13	35	40
Earth dykes or embank-ments	Fluvial	Varying core material	Defence/ embankment	Narrow	1	0	3	6	25	40	0	1	3	5	7	0	5	10	40	60
					2	0	15	30	60	80	0	2	5	7	10	0	20	40	70	110
					3	0	16	33	70	90	0	3	6	8	11	0	22	44	90	130
				Wide	1	0	3	6	25	40	0	2	6	10	14	0	5	10	40	60
					2	0	15	30	60	80	0	4	10	14	20	0	20	40	70	110
					3	0	16	33	70	90	0	5	10	14	20	0	22	44	90	130
	Coastal/ estuarine			Narrow	1	0	3	6	22	30	0	1	2	4	5	0	5	10	40	60
					2	0	14	28	40	50	0	2	4	6	8	0	20	40	60	80

Asset class	Environment	Material	AIMS asset classification	Narrow/ wide*	Maintenance Regime	Expected deterioration times (years) to specified CG from new – Medium deterioration					Fastest deterioration					Slowest deterioration				
						1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
					3	0	15	30	45	60	0	3	5	8	10	0	22	45	80	110
				Wide	1	0	4	6	22	30	0	2	5	9	12	0	5	10	40	60
					2	0	14	30	50	60	0	4	9	12	18	0	20	40	70	90
					3	0	20	35	55	70	0	5	10	14	20	0	22	44	85	120
	Fluvial	With slope/toe protection		Narrow	1	0	15	25	35	40	0	3	8	10	12	0	20	40	60	80
					2	0	20	30	70	90	0	3	8	10	15	0	25	50	80	130
					3	0	25	45	80	100	0	15	20	30	40	0	30	60	90	140
				Wide	1	0	15	25	35	40	0	8	15	20	25	0	20	40	60	80
					2	0	20	30	70	90	0	12	20	30	40	0	25	50	100	130
					3	0	25	45	80	110	0	15	30	40	50	0	30	60	110	150
	Coastal/ estuarine			Narrow	1	0	9	19	31	40	0	3	7	10	12	0	10	20	40	60
					2	0	15	30	50	60	0	3	8	10	15	0	20	50	75	100
					3	0	20	40	60	80	0	10	20	25	30	0	30	60	100	130
				Wide	1	0	9	19	31	40	0	8	15	20	25	0	20	40	60	80
					2	0	15	30	50	60	0	12	20	30	40	0	25	50	90	120
					3	0	20	40	60	80	0	15	30	40	50	0	30	60	100	140
Sloping walls with slope protection or revetment	Fluvial	Turf	Defence/ embankment	Narrow	1	0	3	6	25	40	0	1	3	5	7	0	5	10	40	60
					2	0	15	30	60	80	0	2	5	7	10	0	20	40	70	110
					3	0	16	33	70	90	0	3	6	8	11	0	22	44	90	130
				Wide	1	0	3	6	25	40	0	2	6	10	14	0	5	10	40	60
					2	0	15	30	60	80	0	4	10	14	20	0	20	40	70	110
					3	0	16	33	70	90	0	5	10	14	20	0	22	44	90	130
	Coastal/ estuarine			Narrow	1	0	3	6	22	30	0	1	2	4	5	0	5	10	40	60
					2	0	14	28	40	50	0	2	4	6	8	0	20	40	60	80
					3	0	15	30	45	60	0	3	5	8	10	0	22	45	80	110
				Wide	1	0	4	6	22	30	0	2	5	9	12	0	5	10	40	60

Asset class	Environment	Material	AIMS asset classification	Narrow/ wide*	Maintenance Regime	Expected deterioration times (years) to specified CG from new – Medium deterioration					Fastest deterioration					Slowest deterioration				
						1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
					2	0	14	30	50	60	0	4	9	12	18	0	20	40	70	90
					3	0	20	35	55	70	0	5	10	14	20	0	22	44	85	120
	Fluvial	Permeable[2]		Narrow	1	0	15	25	35	40	0	3	8	10	12	0	20	40	60	80
					2	0	20	30	70	90	0	3	8	10	15	0	25	50	80	130
					3	0	25	45	80	100	0	15	20	30	40	0	30	60	90	140
				Wide	1	0	15	25	35	40	0	8	15	20	25	0	20	40	60	80
					2	0	20	30	60	90	0	12	20	30	40	0	25	50	100	130
					3	0	25	45	80	110	0	15	30	40	50	0	30	60	110	150
	Coastal/ estuarine			Narrow	1	0	9	19	31	40	0	3	7	10	12	0	10	20	40	60
					2	0	15	30	50	60	0	3	8	10	15	0	20	50	75	100
					3	0	20	40	60	80	0	10	20	25	30	0	30	60	100	130
				Wide	1	0	9	19	31	40	0	8	15	20	25	0	20	40	60	80
					2	0	15	30	50	60	0	12	20	30	40	0	25	50	90	120
					3	0	20	40	60	80	0	15	30	40	50	0	30	60	100	140
	Fluvial	Impermeable[3]		Narrow	1	0	15	25	35	40	0	3	8	10	12	0	20	40	60	80
					2	0	20	30	70	90	0	3	8	10	15	0	25	50	80	130
					3	0	25	45	80	100	0	15	20	30	40	0	30	60	90	140
				Wide	1	0	15	25	35	40	0	8	15	20	25	0	20	40	60	80
					2	0	20	30	60	90	0	12	20	30	40	0	25	50	100	130

[2] Permeable revetments: These are flexible revetments including rip rap, turf, natural stone and concrete blocks.

[3] Impermeable revetments: These are continuous sloping structures of concrete or stone blockwork, asphalt or mass concrete. They tend to be grouted in bitumen or concrete, making them inflexible.

Asset class	Environment	Material	AIMS asset classification	Narrow/ wide*	Maintenance Regime	Expected deterioration times (years) to specified CG from new														
						Medium deterioration					Fastest deterioration					Slowest deterioration				
						1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
					3	0	25	45	80	110	0	15	30	40	50	0	30	60	110	150
	Coastal/ estuarine			Narrow	1	0	9	19	31	40	0	3	7	10	12	0	10	20	40	60
					2	0	15	30	50	60	0	3	8	10	15	0	20	50	75	100
					3	0	20	40	60	80	0	10	20	25	30	0	30	60	100	130
				Wide	1	0	9	19	31	40	0	8	15	20	25	0	20	40	60	80
					2	0	15	30	50	60	0	12	20	30	40	0	25	50	90	120
					3	0	20	40	60	80	0	15	30	40	50	0	30	60	100	140
Pipe culverts	Fluvial	Concrete	Channel/ simple OR complex culvert	N/A	1	0	10	30	45	55	0	5	10	20	30	0	20	50	65	80
					2	0	30	55	80	90	0	20	40	60	70	0	40	70	100	115
					3	0	50	80	115	125	0	35	70	100	110	0	60	90	135	150
		Masonry/ brick		N/A	1	0	10	30	45	55	0	5	10	20	30	0	20	50	65	80
					2	0	20	40	70	80	0	10	20	35	45	0	30	60	90	110
					3	0	30	50	95	115	0	15	30	50	65	0	40	70	115	135
		Steel (corrugated galvanised)		N/A	1	0	10	30	45	55	0	5	10	20	25	0	20	50	65	75
					2	0	20	40	60	75	0	10	20	30	40	0	30	60	85	100
					3	0	30	50	75	95	0	15	30	40	50	0	40	70	105	130
		Plastic		N/A	1	0	10	30	45	55	0	5	10	20	25	0	20	50	65	75
					2	0	30	55	70	80	0	20	40	50	60	0	40	70	90	110
					3	0	50	80	95	105	0	35	70	80	90	0	60	90	115	135
		Clay		N/A	1	0	10	30	45	55	0	5	10	20	25	0	20	50	65	75
					2	0	30	55	80	90	0	20	40	60	70	0	40	70	100	115
					3	0	50	80	115	130	0	35	70	100	115	0	60	90	135	155
Beaches with and without beach control	Coastal	Shingle/sand	Defence/ beach		1	0	9	13	25	35	0	4	7	9	13	0	15	38	75	100
					2	0	16	30	50	75	0	7	10	13	20	0	27	50	150	200
					3	0	20	55	90	120	0	12	20	25	40	0	27	75	200	250

Asset class	Environment	Material	AIMS asset classification	Narrow/ wide*	Maintenance Regime	Expected deterioration times (years) to specified CG from new														
						Medium deterioration					Fastest deterioration					Slowest deterioration				
						1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
structures																				
Control structures	Coastal	Rock groynes	Beach structure/ groyne		1	0	19	57	114	124	0	10	30	59	67	0	44	131	262	273
					2	0	19	114	190	200	0	10	59	99	108	0	44	262	437	450
					3	0	57	190	266	285	0	30	99	139	150	0	131	437	612	635
		Timber groynes			1	0	6	13	17	20	0	2	5	8	10	0	10	20	25	30
					2	0	10	25	30	34	0	5	10	13	15	0	15	40	45	50
					3	0	14	37	43	48	0	8	15	18	20	0	20	60	65	70
		Offshore breakwaters (rock)	Beach structure/ breakwater		1	0	19	57	114	124	0	10	30	59	67	0	44	131	262	273
					2	0	19	114	190	200	0	10	59	99	108	0	44	262	437	450
					3	0	57	190	266	285	0	30	99	139	150	0	131	437	612	635
		Breastwork (timber)			1	0	11	18	22	25	0	7	10	13	15	0	15	25	30	35
					2	0	15	30	35	40	0	10	15	18	20	0	20	45	50	60
					3	0	19	42	48	55	0	13	20	23	25	0	25	65	70	80
		Crib walls (timber)			1	0	11	18	22	25	0	7	10	13	15	0	15	25	30	35
					2	0	15	30	35	40	0	10	15	18	20	0	20	45	50	60
					3	0	19	42	48	55	0	13	20	23	25	0	25	65	70	80
Dunes with or without holding structures	Coastal	All	Defence/ dunes		1	0	10	15	30	40	0	5	8	10	15	0	20	40	110	150
					2	0	15	35	60	80	0	7	10	13	20	0	27	60	150	200
					3	0	20	60	100	130	0	12	20	25	40	0	30	80	190	250
Saltmarsh-es, saltings and warths with or without holding structures	Coastal	All	Land/ saltmarsh		1	0	12	25	40	45	0	8	14	20	25	0	20	40	110	150
					2	0	18	40	75	90	0	10	16	25	30	0	27	60	150	200
					3	0	22	80	130	150	0	14	25	30	50	0	30	80	190	250
Maintained	Fluvial	Earth (e.g.	Channel/		1	0	1	2	5	8	0	1	2	3	6	0	1	2	6	10

Asset class	Environment	Material	AIMS asset classification	Narrow/ wide*	Maintenance Regime	Expected deterioration times (years) to specified CG from new: Medium deterioration 1	2	3	4	5	Fastest deterioration 1	2	3	4	5	Slowest deterioration 1	2	3	4	5
channels		regraded channels)	open channel		2	0	2	150	250	350	0	1	140	150	200	0	3	180	300	400
					3	0	150	200	300	400	0	120	150	200	300	0	170	220	350	450
Maintained channels	Fluvial	Concrete/ brick		N/A	1	0	15	35	50	60	0	5	20	30	40	0	20	50	70	80
					2	0	20	45	70	90	0	10	30	50	60	0	25	60	100	120
					3	0	25	55	90	120	0	15	40	70	80	0	30	70	130	160
Weirs	Fluvial	All	Structure/ weir	N/A	1	0	15	20	40	60	0	10	15	30	40	0	20	30	50	70
					2	0	30	50	70	90	0	20	30	50	60	0	40	70	90	110
					3	0	45	80	100	120	0	30	45	70	80	0	60	110	130	150
Outfalls	Fluvial	All	Structure/ outfall	N/A	1	0	15	35	50	60	0	5	20	30	40	0	20	50	70	80
					2	0	20	45	70	90	0	10	30	50	60	0	25	60	100	120
					3	0	25	55	90	120	0	15	40	70	80	0	30	70	130	160
	Coastal/ estuarine	All		N/A	1	0	10	15	30	40	0	5	10	15	20	0	15	30	50	60
					2	0	15	25	50	60	0	10	15	25	30	0	20	40	60	70
					3	0	20	35	60	70	0	15	20	35	40	0	25	50	70	80
Flap valves	Fluvial	Cast iron and coplastic	Structure/ control gate	N/A	1	0	8	13	17	20	0	5	9	12	15	0	10	17	21	25
					2	0	10	17	21	25	0	8	13	17	20	0	12	20	25	30
					3	0	12	21	25	30	0	11	17	22	25	0	14	23	29	35
	Coastal/ estuarine	Cast iron and coplastic		N/A	1	0	5	9	12	15	0	3	6	8	10	0	8	13	17	20
					2	0	8	13	17	20	0	5	9	12	15	0	10	17	21	25
					3	0	11	17	22	26	0	7	12	16	20	0	12	21	25	30
Moveable gates (manually operated)	Fluvial	All	Structure/ control gate	N/A	1	0	12	25	32	38	0	5	12	16	20	0	15	32	41	50
					2	0	18	34	42	50	0	10	22	30	35	0	20	40	50	60
					3	0	24	43	52	62	0	15	32	44	50	0	25	48	59	70
	Coastal/ estuarine	All		N/A	1	0	10	14	16	18	0	4	7	9	10	0	13	22	26	30
					2	0	15	23	27	30	0	7	11	13	15	0	18	29	35	40
					3	0	20	32	38	42	0	10	15	17	20	0	23	36	44	50

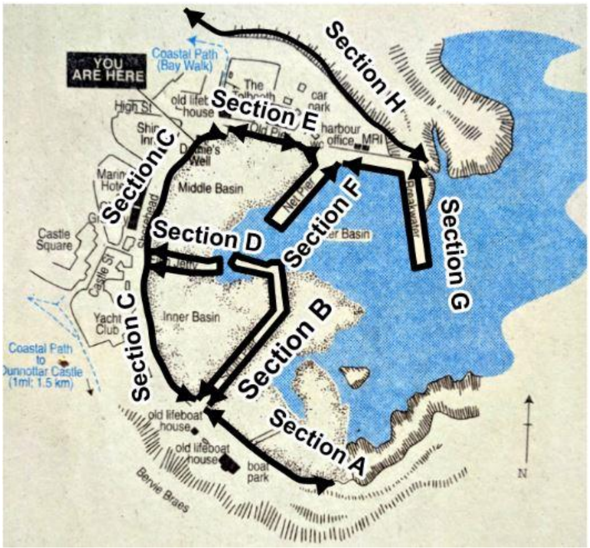
Asset class	Environment	Material	AIMS asset classification	Narrow/ wide*	Maintenance Regime	Expected deterioration times (years) to specified CG from new: Medium deterioration 1	2	3	4	5	Fastest deterioration 1	2	3	4	5	Slowest deterioration 1	2	3	4	5
Moveable gates (electrically operated)	Fluvial	All	Structure/ control gate	N/A	1	0	12	20	24	28	0	5	10	13	15	0	15	27	33	38
					2	0	18	29	35	40	0	10	17	21	25	0	20	33	39	45
					3	0	24	35	42	49	0	15	24	29	35	0	25	39	45	52
	Coastal/ estuarine	All		N/A	1	0	10	14	16	18	0	4	7	9	10	0	13	16	18	20
					2	0	15	20	23	25	0	7	11	13	15	0	18	24	27	30
					3	0	20	26	30	33	0	10	15	17	20	0	23	32	36	40
Debris screens	Fluvial	All	Structure/ screen	N/A	1	0	5	14	21	25	0	2	10	17	20	0	7	20	25	30
					2	0	7	20	32	40	0	5	15	25	30	0	10	25	40	50
					3	0	9	26	43	55	0	8	20	33	40	0	13	30	55	70
Flood gates and barriers	Fluvial	Metal	Structure/ control gate	N/A	1	0	12	25	32	38	0	5	12	16	20	0	15	32	41	50
					2	0	18	34	42	50	0	10	22	30	35	0	20	40	50	60
					3	0	24	43	52	62	0	15	32	44	50	0	25	48	59	70
	Coastal/ estuarine			N/A	1	0	10	14	16	18	0	4	7	9	10	0	13	22	26	30
					2	0	15	23	27	30	0	7	11	13	15	0	18	29	35	40
					3	0	20	32	38	42	0	10	15	17	20	0	23	36	44	50
	Fluvial	Wood		N/A	1	0	6	13	16	19	0	3	6	8	10	0	8	16	21	25
					2	0	9	17	21	25	0	5	11	15	18	0	10	20	25	30
					3	0	12	22	26	31	0	8	16	22	25	0	13	24	30	35
	Coastal/ estuarine			N/A	1	0	5	7	8	9	0	2	4	5	6	0	7	11	13	15
					2	0	8	12	14	15	0	4	6	7	8	0	8	15	18	20
					3	0	10	16	19	21	0	5	8	9	10	0	12	18	22	25

Narrow assets defined as <4 m crest width, wide assets defined as 4 m or greater crest width

AssetCoast JBA consulting

1. General information

Location Plan:



Stonehaven harbour

Assessment Date: 15/05/2018

Exam Type:	**Detailed**
Complete Survey:	Yes
Structure Ref:	**1**
OS Ref:	387867 , 785378
Survey Unit:	N/A
Governing SMP2:	N/A
SMP2 Policy Unit:	N/A
SMP2 Policy:	N/A

NOTE: This document has been prepared as an Asset Condition Survey Report for Aberdeenshire Council. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

1.1. Type of structure and general description (to include key components and materials)

Stonehaven Harbour is located at the southern end of Stonehaven Bay, connecting to the coastal defences in the north and tying into the natural cliff headland in the south. The defence has been split into 8 sections correlating to a change in structure type and to match the local naming convention.

- Section A - A rock armour revetment fronting the old lifeboat house and Bervie Braes cliff-line to the south.
- Section B - South Pier - A masonry harbour arm, with a seaward facing wall, landward facing mooring, and sheet piled roundhead.
- Section C - Shorehead - A sloped masonry quay wall, running along shorehead road.
- Section D - Fish Jetty - A masonry jetty separating the inner and middle basins, with a sheet piled roundhead.
- Section E - Old Pier - A masonry quay face running along Old Pier road.
- Section F - Net Pier - A masonry pier with two-sided moorings and a sheet piled roundhead.
- Section G - Breakwater - A concrete harbour breakwater arm with landward facing moorings.
- Section H - A rock armour revetment fronting the Stonehaven Harbour Office.

1.2. Summary of condition and critical defects

Section A has defects that could significantly reduce performance of the asset and warrant further investigation. Sections B, C, D, E, F, G and H are considered to be in fair condition with some defects that could potentially reduce performance of the assets. The defects that are believed to be significant and require immediate attention are as follows: Section A: - The rock armour units are expelled and undersized and the access path is in poor condition with missing planks. Section B: - There are signs of voiding behind the blockwork on the seaward and quay face. - The sheet piles are heavily corroded with some complete loss of section through the piles. - Corroded ladders. Section C: - The toe is undermined along the seaward face for approximately 30m. - Several drainage points possibly need flap valves. Section D: - There are signs of undermining scour on the toe of the quay face. - The sheet piles are heavily corroded with some complete loss of section through the piles. - Corroded ladders. Section E: - No significant defects - cracking on slipway. Section F: - There are signs of undermining scour on the toe of the quay face. - There are anchor plates missing from the sheet piles. Section G: - There is exposed reinforcement corroding due to cover loss. Section H: - The rock armour protecting the harbour appeared overly steep and could be subject to collapse under extreme wave loads.

1.3. Access considerations

Third party/adjacent landowner permissions:	The harbour is open to public access, however an area of the breakwater arm is fenced off and requires private access through the Survitec Survival Craft Marine Training Academy.
Nearest public highway:	A957
Local guidance:	A complete survey requires a low tide to examine the harbour in full detail. Boat access is required if survey of the seaward face of the breakwater and south pier is required.
Tide state during survey:	Spring (Low)
Equipment required for access and examinations:	High-Vis, life jackets.

2. Structure information

Defence Hierarchy	Type	Sub Types	Elements	Material Type
Section A	Defence	Embankment	Rock armour	Rock (undersized, non-uniform, expelled rock armour)
	Defence	Embankment	Access strip	Slipway (uneven, damaged)
	Defence	Embankment	Splash wall	Masonry/ Concrete capping (dilapidated, damaged)
Section B	Defence	Quay	Seaward face	Masonry (voiding, open joints)
	Defence	Quay	Quay face	Masonry (small cracks, open joints)
	Defence	Quay	Capping	Masonry (cracking and spalling of buttress elements, weathering of repairs)
	Defence	Quay	Piling	Steel (corroded piles, missing anchors)
	Defence	Quay	Deck	Concrete (insufficient handrailing)
Section C	Defence	Wall	Access strip	Concrete (cracking and loss of concrete, algae growth)
	Defence	Wall	Exposed face	Masonry (undermining scour, cracking, loose blockwork)
	Defence	Wall	Capping wall	Mix of concrete and masonry units (cracks, spalling and honeycombing of concrete)
Section D	Defence	Quay	Sheet piling	Steel (corroded piles and ladder)
	Defence	Quay	Quay face	Masonry (undermining scour, delaminated surfacing)
	Defence	Quay	Deck	Cobbles (Insufficient handrailing)
Section E	Defence	Wall	Access strip	Concrete (extensive cracking)
	Defence	Wall	Exposed face	Masonry (no major defects)
Section F	Defence	Quay	Sheet piling	Steel (holes in piles, missing anchor plates)

	Defence	Quay	Quay face	Masonry (undermining scour on toe, cracking, delaminated concrete repairs)
	Defence	Quay	Deck	Concrete (displaced timber beam, insufficient handrailing)
Section G	Defence	Quay	Capping	Concrete (delaminating repairs, open joints)
	Defence	Quay	Seaward face	Concrete (cracking of concrete, exposed steel corroding, corroded / damaged handrails)
	Defence	Quay	Face protection	N/A
	Defence	Quay	Deck	Concrete (insufficient handrailing, damaged surfacing)
	Defence	Quay	Quay face	Concrete (undermining scour, cracking, spalling and delaminating concrete)
Section H	Defence	Embankment	Rock armour	Rock armour (undersized, overly steep, narrow crest)
	Defence	Embankment	Splash wall	Masonry (missing blockwork)

Approx. defence length (m):	900m		
Approx. co-ordinates from:	387627 , 785605	To:	387854 , 785220
As built drawing available:	No		
Linked to other Asset Types:	The defence ties into the council owned coastal defences in the north.		
Infrastructure protected:	The harbour protects the old town area of Stonehaven from coastal erosion and coastal flooding, it also protects harbour infrastructure (harbour masters office, survival craft marine training centre and multiple amenity features).		
Assets type and ownership that the defence ties into at either end:	The defence ties into the natural cliff-line to the south and the rock armour coastal protection to the north, both under local council ownership.		

2.1 Topographic level information

Section A	Value	Method of calculation
Crest level of primary defence (mAOD)	5.323	Laser Scan
Toe level of primary defence (mAOD)	0.476	Laser Scan
Approx. defence height above beach (m)	4.886	Laser Scan
Upper beach level (mAOD)	N/A	N/A
Lower beach level (mAOD)	N/A	N/A
Approx. total beach height (m)	N/A	N/A
Beach crest width (m)	N/A	N/A
Approx. beach gradient (1 in ...)	N/A	N/A
Beach Cross Sectional Area (m2)	N/A	N/A
Beach composition	N/A	N/A

Section B	Value	Method of calculation
Crest level of primary defence (mAOD)	6.043	Laser scan
Toe level of primary defence (mAOD)	0.526	Laser scan
Approx. defence height above beach (m)	5.506	Laser scan
Upper beach level (mAOD)	N/A	N/A
Lower beach level (mAOD)	N/A	N/A
Approx. total beach height (m)	N/A	N/A
Beach crest width (m)	N/A	N/A
Approx. beach gradient (1 in ...)	N/A	N/A
Beach Cross Sectional Area (m2)	N/A	N/A
Beach composition	N/A	N/A

Section C	Value	Method of calculation
Crest level of primary defence (mAOD)	5.053	Laser scan
Toe level of primary defence (mAOD)	1.432	Laser scan
Approx. defence height above beach (m)	2.68	Laser scan
Upper beach level (mAOD)	N/A	N/A
Lower beach level (mAOD)	N/A	N/A
Approx. total beach height (m)	N/A	N/A
Beach crest width (m)	N/A	N/A
Approx. beach gradient (1 in ...)	N/A	N/A
Beach Cross Sectional Area (m2)	N/A	N/A
Beach composition	N/A	N/A

Section D	Value	Method of calculation
Crest level of primary defence (mAOD)	3.849	Laser scan
Toe level of primary defence (mAOD)	0.345	Laser scan
Approx. defence height above beach (m)	3.945	Laser scan
Upper beach level (mAOD)	N/A	N/A
Lower beach level (mAOD)	N/A	N/A
Approx. total beach height (m)	N/A	N/A
Beach crest width (m)	N/A	N/A
Approx. beach gradient (1 in ...)	N/A	N/A
Beach Cross Sectional Area (m2)	N/A	N/A
Beach composition	N/A	N/A

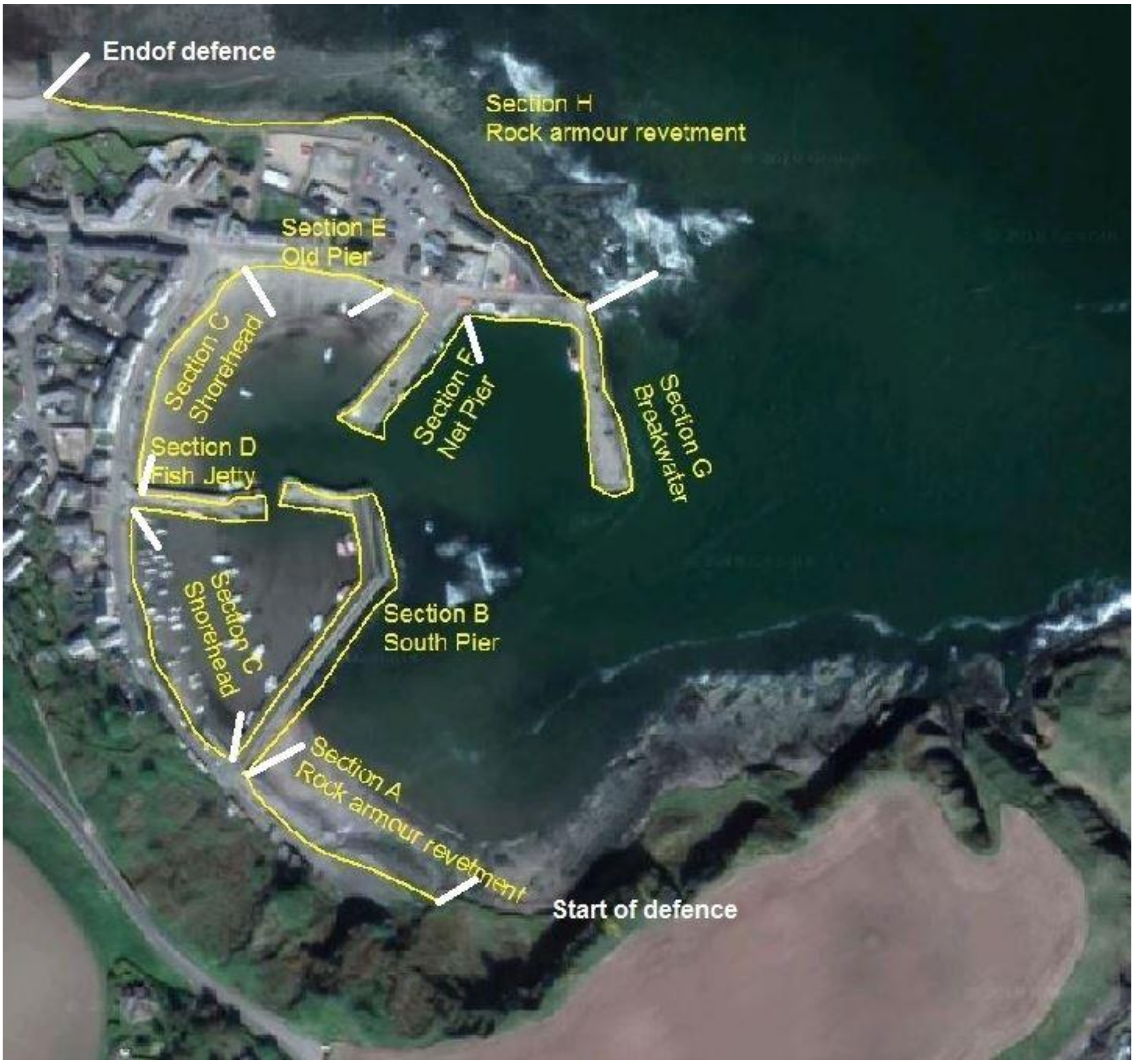
Section E	Value	Method of calculation
Crest level of primary defence (mAOD)	3.890	Laser scan
Toe level of primary defence (mAOD)	2.080	Laser scan
Approx. defence height above beach (m)	2.609	Laser scan
Upper beach level (mAOD)	N/A	N/A
Lower beach level (mAOD)	N/A	N/A
Approx. total beach height (m)	N/A	N/A
Beach crest width (m)	N/A	N/A
Approx. beach gradient (1 in ...)	N/A	N/A
Beach Cross Sectional Area (m2)	N/A	N/A
Beach composition	N/A	N/A

Section F	Value	Method of calculation
Crest level of primary defence (mAOD)	4.089	Laser scan
Toe level of primary defence (mAOD)	0.608	Laser Scan
Approx. defence height above beach (m)	2.525	Laser Scan
Upper beach level (mAOD)	N/A	N/A
Lower beach level (mAOD)	N/A	N/A
Approx. total beach height (m)	N/A	N/A
Beach crest width (m)	N/A	N/A
Approx. beach gradient (1 in ...)	N/A	N/A
Beach Cross Sectional Area (m2)	N/A	N/A
Beach composition	N/A	N/A

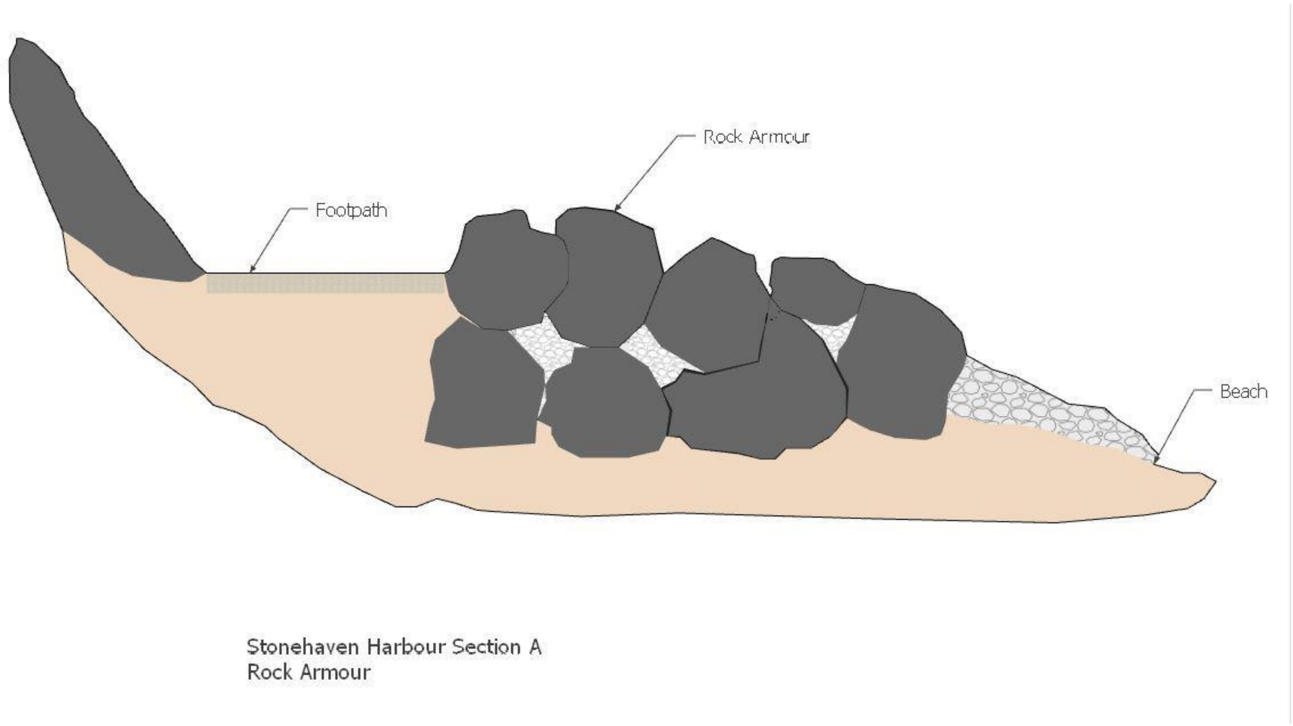
Section G	Value	Method of calculation
Crest level of primary defence (mAOD)	7.437	Laser scan
Toe level of primary defence (mAOD)	0.646	Laser Scan
Approx. defence height above beach (m)	3.276	Laser Scan
Upper beach level (mAOD)	N/A	N/A
Lower beach level (mAOD)	N/A	N/A
Approx. total beach height (m)	N/A	N/A
Beach crest width (m)	N/A	N/A
Approx. beach gradient (1 in ...)	N/A	N/A
Beach Cross Sectional Area (m2)	N/A	N/A
Beach composition	N/A	N/A

Section H	Value	Method of calculation
Crest level of primary defence (mAOD)	6.016	Laser Scan
Toe level of primary defence (mAOD)	0.663	Laser Scan
Approx. defence height above beach (m)	6.00	Laser Scan
Upper beach level (mAOD)	N/A	N/A
Lower beach level (mAOD)	N/A	N/A
Approx. total beach height (m)	N/A	N/A
Beach crest width (m)	N/A	N/A
Approx. beach gradient (1 in ...)	N/A	N/A
Beach Cross Sectional Area (m2)	N/A	N/A
Beach composition	N/A	N/A

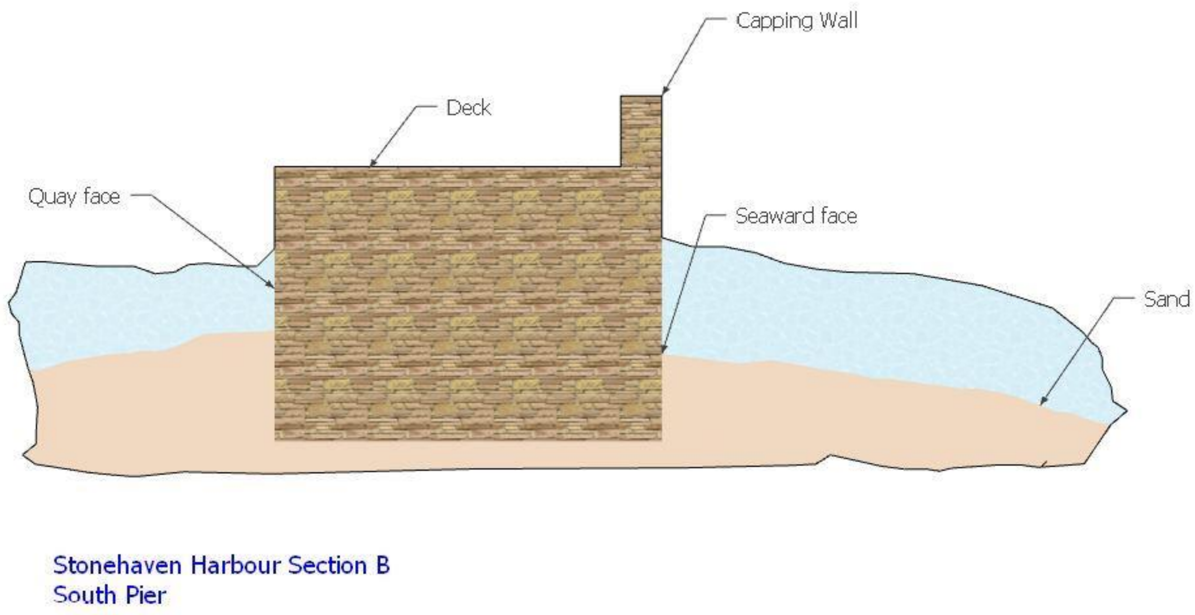
Asset site sketch

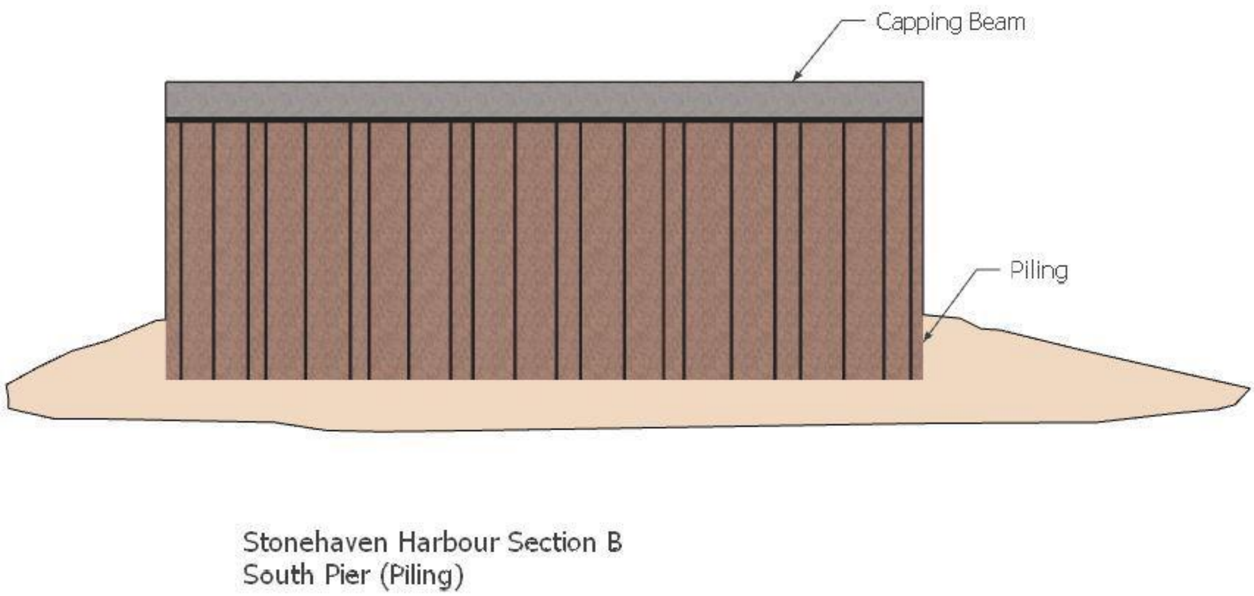
Plan:


Sketch: Section A

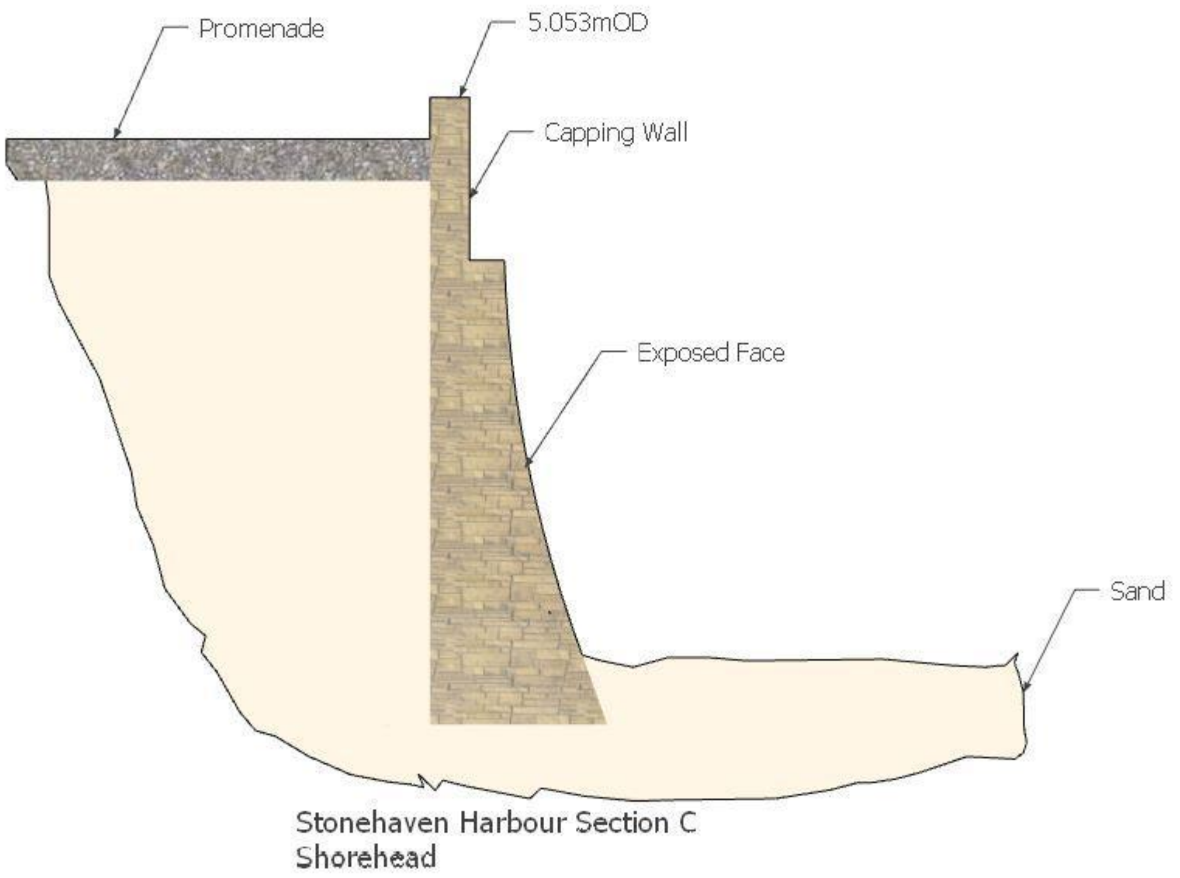


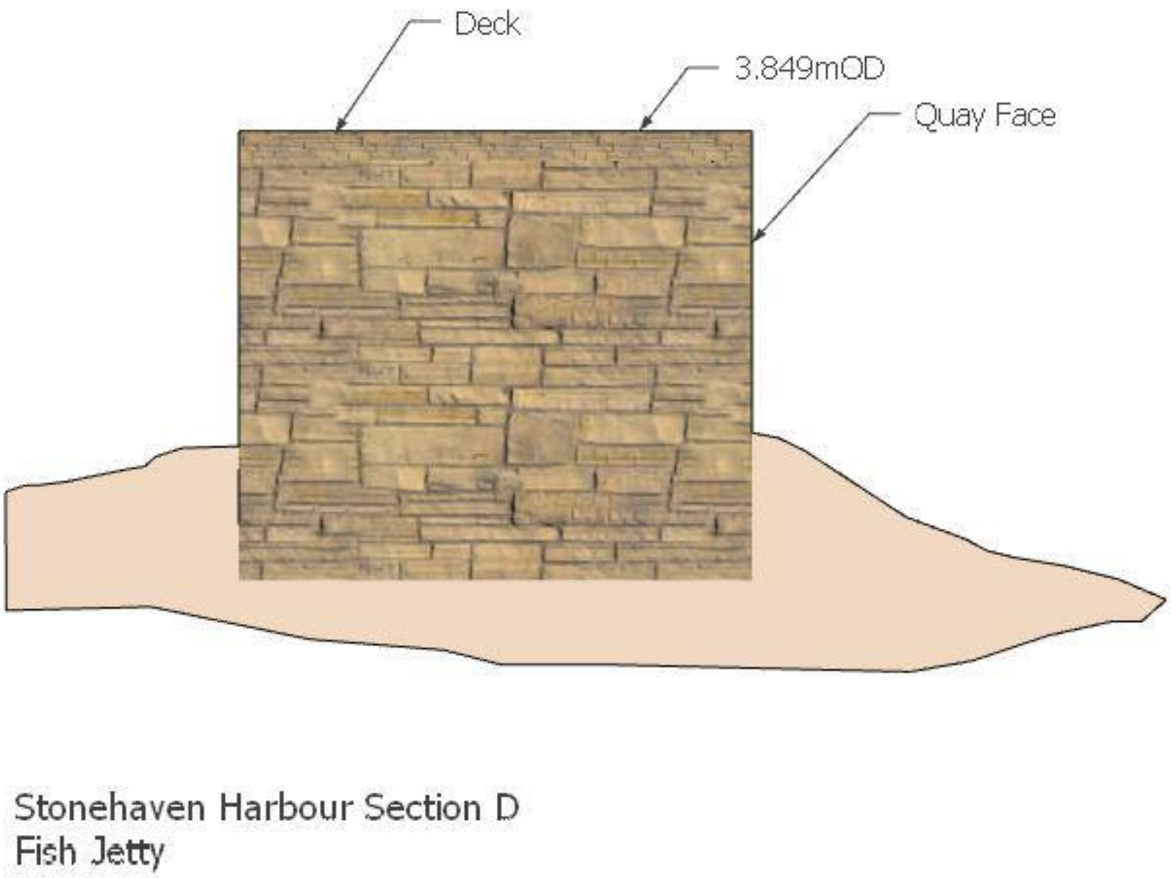
Sketch: Section B

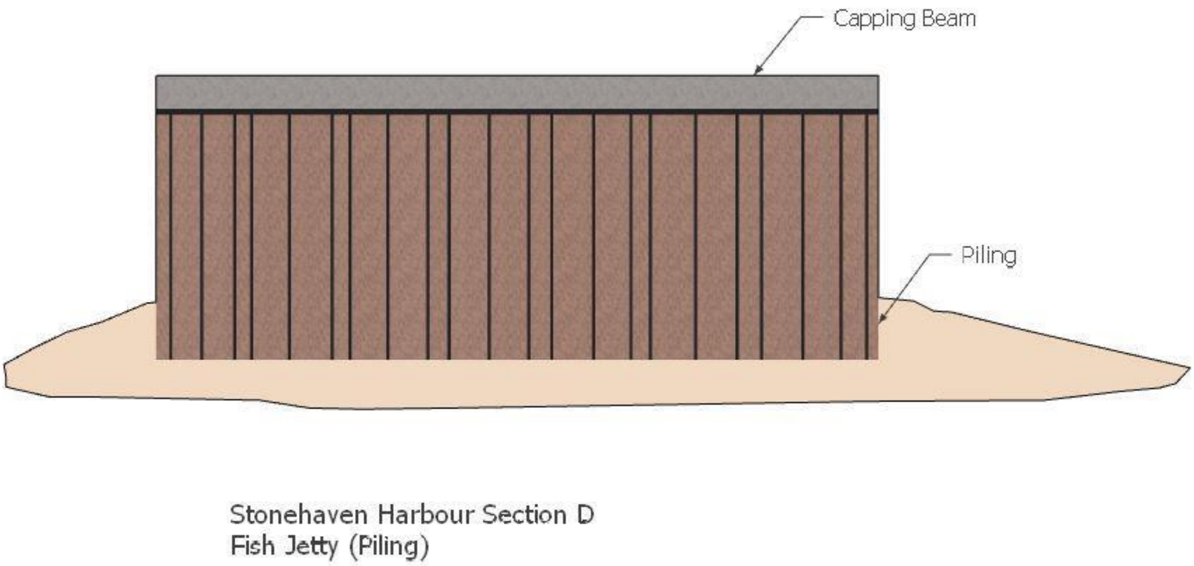


Sketch: Section B - Piling


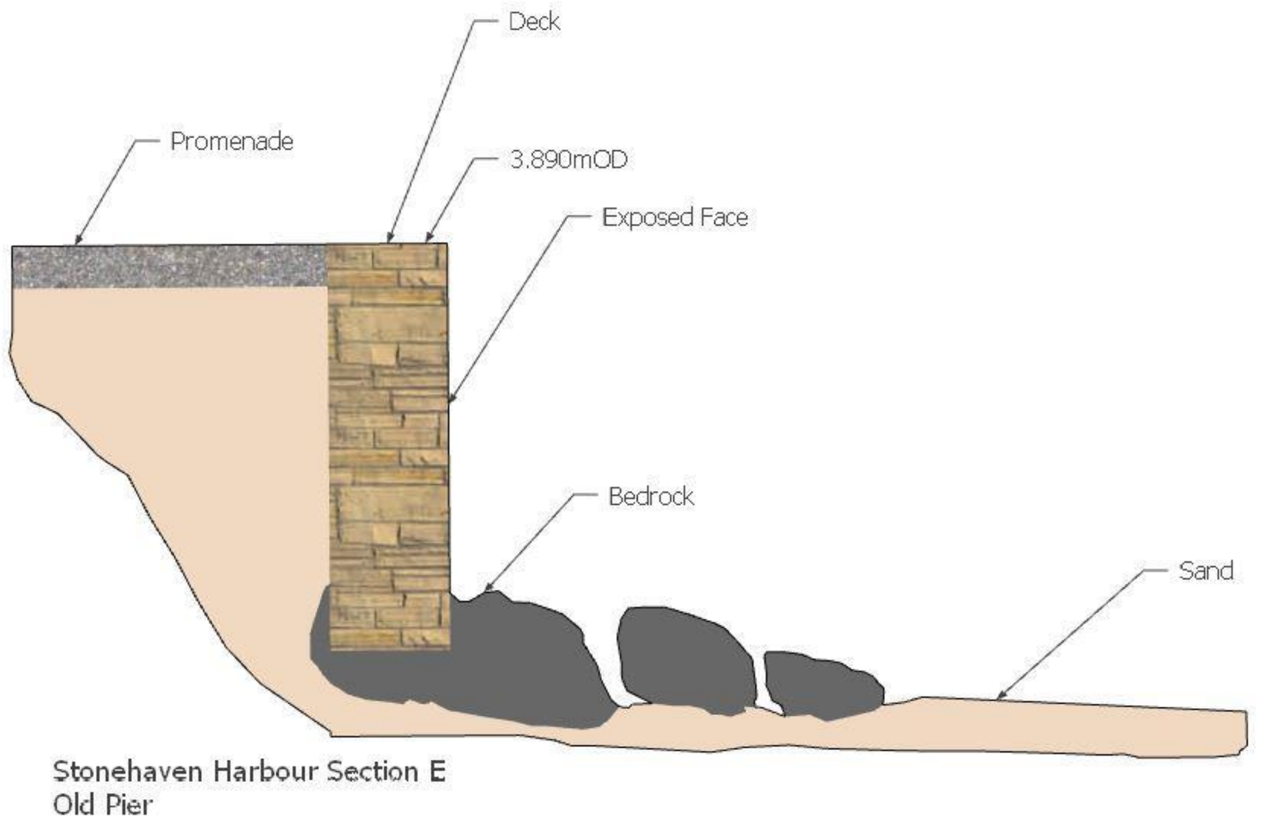
Sketch: Section C



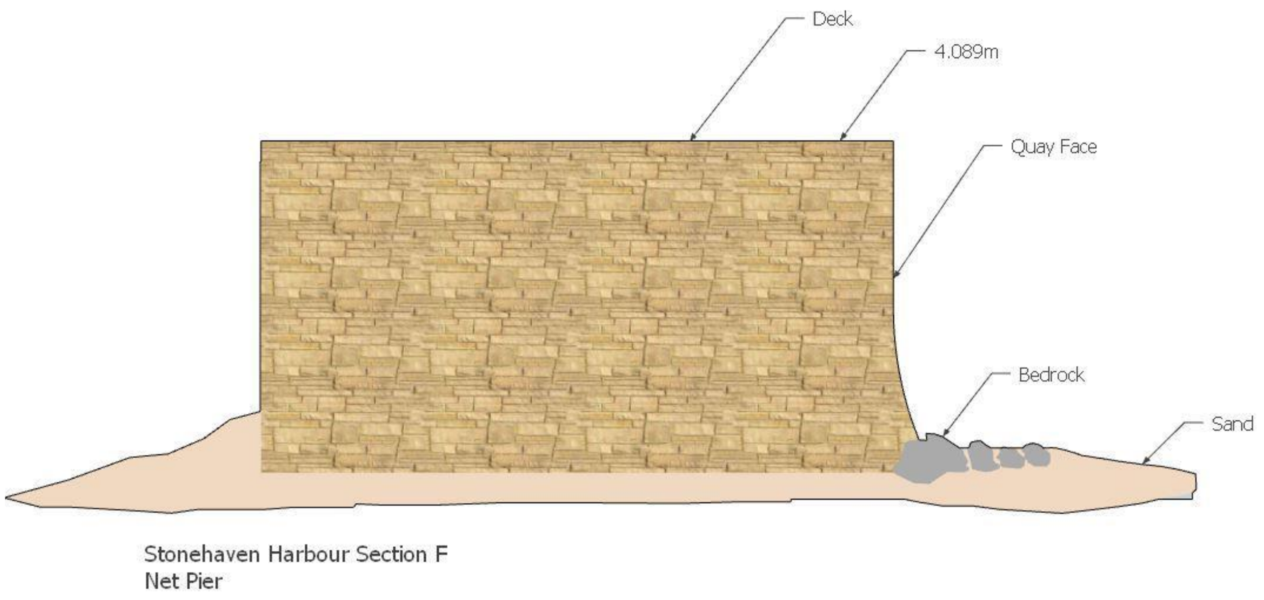
Sketch: Section D


Sketch: Section D - Piling


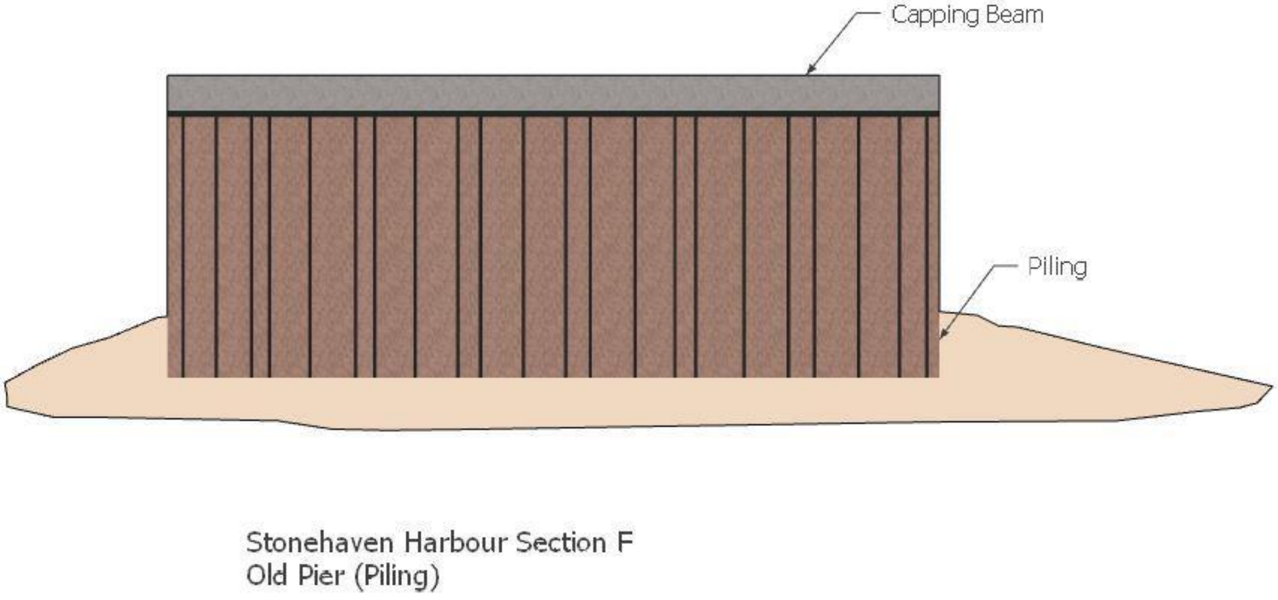
Sketch: Section E



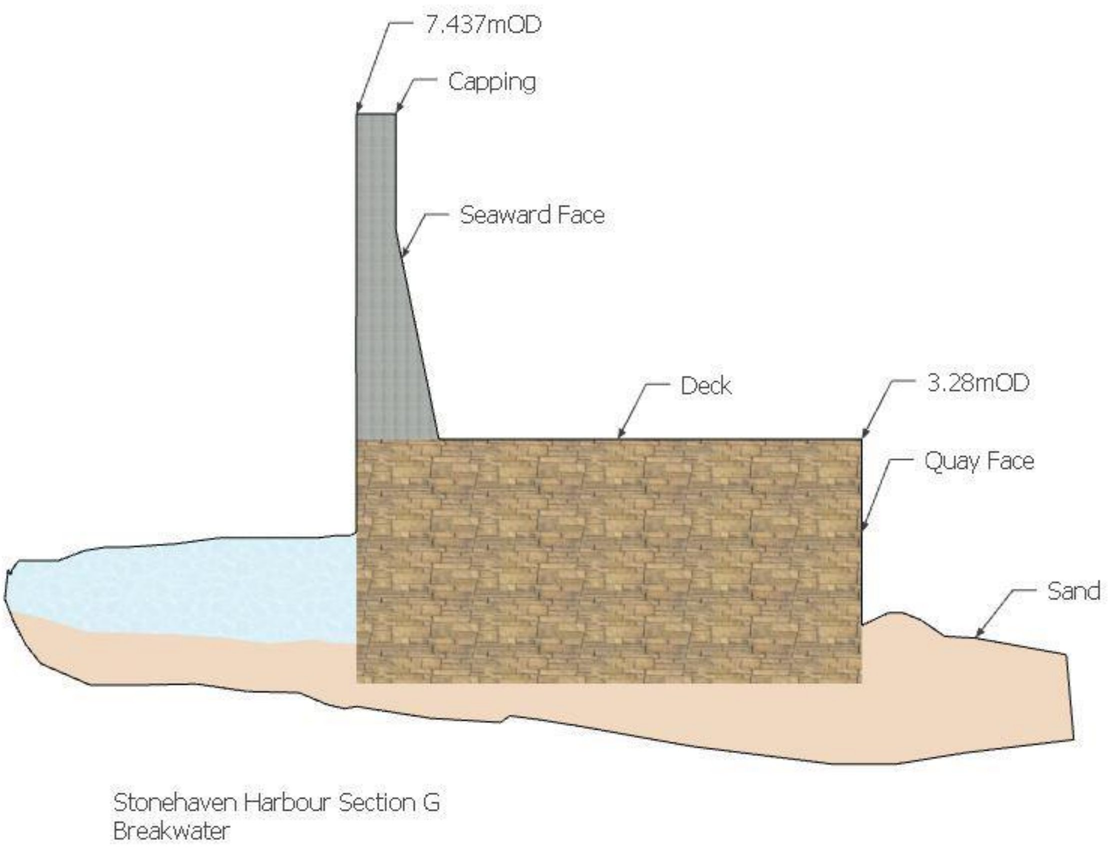
Sketch: Section F



Sketch: Section F - Piling



Sketch: Section G



3. Visual Condition Survey

3.1 Section A

Main Asset

The main asset is broken down into its constituent parts (elements) and assigned a condition score. This condition score of each element is weighted according to its importance in the functioning of the defence.

Sub-Type	Elements	Attributes and General Notes	Condition Grade	Weighting (1-9)	Overall (CG x W)
Embankment	Rock armour	Rock (undersized, non-uniform, expelled rock armour)	4	7	28
Embankment	Access strip	Slipway (uneven, damaged)	3	5	15
Embankment	Splash wall	Masonry/ Concrete capping (dilapidated, damaged)	4	4	16
Sum				16	59
Overall condition score Grade*					**4**

Sum of (Weightings x Condition Grades) / (Sum of Weightings)
Unless a weighting of 9 is given for any element, in which case, the condition of this element should be taken as the overall condition grade.

3.2 Section B

Main Asset

The main asset is broken down into its constituent parts (elements) and assigned a condition score. This condition score of each element is weighted according to its importance in the functioning of the defence.

Sub-Type	Elements	Attributes and General Notes	Condition Grade	Weighting (1-9)	Overall (CG x W)
Quay	Seaward face	Masonry (voiding, open joints)	3	9	27
Quay	Quay face	Masonry (small cracks, open joints)	3	7	21
Quay	Capping	Masonry (cracking and spalling of buttress elements, weathering of repairs)	4	7	28
Quay	Piling	Steel (corroded piles, missing anchors)	4	8	32
Quay	Deck	Concrete (insufficient handrailing)	3	5	15
Sum				36	123
Overall condition score Grade*					**3**

Sum of (Weightings x Condition Grades) / (Sum of Weightings)
Unless a weighting of 9 is given for any element, in which case, the condition of this element should be taken as the overall condition grade.

3.3 Section C

Main Asset

The main asset is broken down into its constituent parts (elements) and assigned a condition score. This condition score of each element is weighted according to its importance in the functioning of the defence.

Sub-Type	Elements	Attributes and General Notes	Condition Grade	Weighting (1-9)	Overall (CG x W)
Wall	Access strip	Concrete (cracking and loss of concrete, algae growth)	3	5	15
Wall	Exposed face	Masonry (undermining scour, cracking, loose blockwork)	4	7	28
Wall	Capping wall	Mix of concrete and masonry units (cracks, spalling and honeycombing of concrete)	3	7	21
Sum				19	64
Overall condition score Grade*					**3**

Sum of (Weightings x Condition Grades) / (Sum of Weightings)
Unless a weighting of 9 is given for any element, in which case, the condition of this element should be taken as the overall condition grade.

3.4 Section D

Main Asset

The main asset is broken down into its constituent parts (elements) and assigned a condition score. This condition score of each element is weighted according to its importance in the functioning of the defence.

Sub-Type	Elements	Attributes and General Notes	Condition Grade	Weighting (1-9)	Overall (CG x W)
Quay	Sheet piling	Steel (corroded piles and ladder)	4	8	32
Quay	Quay face	Masonry (undermining scour, delaminated surfacing)	3	7	21
Quay	Deck	Cobbles (Insufficient handrailing)	3	5	15
Sum				20	68
Overall condition score Grade*					**3**

Sum of (Weightings x Condition Grades) / (Sum of Weightings)
Unless a weighting of 9 is given for any element, in which case, the condition of this element should be taken as the overall condition grade.

3.5 Section E

Main Asset

The main asset is broken down into its constituent parts (elements) and assigned a condition score. This condition score of each element is weighted according to its importance in the functioning of the defence.

Sub-Type	Elements	Attributes and General Notes	Condition Grade	Weighting (1-9)	Overall (CG x W)
Wall	Access strip	Concrete (extensive cracking)	3	5	15
Wall	Exposed face	Masonry (no major defects)	3	7	21
Sum				12	36
Overall condition score Grade*					**3**

Sum of (Weightings x Condition Grades) / (Sum of Weightings)
Unless a weighting of 9 is given for any element, in which case, the condition of this element should be taken as the overall condition grade.

3.6 Section F

Main Asset

The main asset is broken down into its constituent parts (elements) and assigned a condition score. This condition score of each element is weighted according to its importance in the functioning of the defence.

Sub-Type	Elements	Attributes and General Notes	Condition Grade	Weighting (1-9)	Overall (CG x W)
Quay	Quay face	Masonry (undermining scour on toe, cracking, delaminated concrete repairs)	3	7	21
Quay	Deck	Concrete (displaced timber beam, insufficient handrailing)	3	5	15
Quay	Sheet piling	Steel (holes in piles, missing anchor plates)	4	8	32
Sum				20	68
Overall condition score Grade*					**3**

Sum of (Weightings x Condition Grades) / (Sum of Weightings)
Unless a weighting of 9 is given for any element, in which case, the condition of this element should be taken as the overall condition grade.

3.7 Section G

Main Asset

The main asset is broken down into its constituent parts (elements) and assigned a condition score. This condition score of each element is weighted according to its importance in the functioning of the defence.

Sub-Type	Elements	Attributes and General Notes	Condition Grade	Weighting (1-9)	Overall (CG x W)
Quay	Capping	Concrete (delaminating repairs, open joints)	3	7	21
Quay	Seaward face	Concrete (cracking of concrete, exposed steel corroding, corroded / damaged handrails)	3	9	27
Quay	Deck	Concrete (insufficient handrailing, damaged surfacing)	3	5	15
Quay	Quay face	Concrete (undermining scour, cracking, spalling and delaminating concrete)	3	7	21
Sum				28	84
Overall condition score Grade*					**3**

Sum of (Weightings x Condition Grades) / (Sum of Weightings)
Unless a weighting of 9 is given for any element, in which case, the condition of this element should be taken as the overall condition grade.

3.8 Section H

Main Asset

The main asset is broken down into its constituent parts (elements) and assigned a condition score. This condition score of each element is weighted according to its importance in the functioning of the defence.

Sub-Type	Elements	Attributes and General Notes	Condition Grade	Weighting (1-9)	Overall (CG x W)
Embankment	Rock armour	Rock armour (undersized, overly steep, narrow crest)	3	8	24
Embankment	Splash wall	Masonry (missing blockwork)	3	7	21
Sum				15	45
Overall condition score Grade*					**3**

Sum of (Weightings x Condition Grades) / (Sum of Weightings)
Unless a weighting of 9 is given for any element, in which case, the condition of this element should be taken as the overall condition grade.

3.9 Asset condition grade summary

	Section A	Section B	Section C	Section D	Section E	Section F	Section G	Section H
Target condition grade	2	2	2	2	2	2	2	2
Overall surveyed condition grade	4	3	3	3	3	3	3	3
Total time taken to reach CG1	0	0	0	0	0	0	0	0
Total time taken to reach CG2	0	0	0	0	0	0	0	0
Total time taken to reach CG3	0	0	0	0	0	0	0	0
Total time taken to reach CG4	0	15 years	15 years	15 years	15 years	15 years	15 years	20 years
Total time taken to reach CG5	10 years	30 years	30 years	30 years	30 years	30 years	30 years	30 years

3.10 Additional information

General description and effect of any coastal erosion noted:	None noted.
General description and effect of any wave overtopping noted:	None observed. Anecdotal evidence suggests that severe wave overtopping occurs over the outer harbour breakwater arm, lower but more severe volumes of wave overtopping occur along shorehead road but are still considered significant.
General description and effect of any longshore / cross-shore sediment transport noted:	None noted.

4. Identification of defects and recommendations

4.1. Main asset defect register

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D1	387852, 785224	Embankment	Rock armour	102	Nonuniform rock armour profile, insufficient protection to timber footbridge.	Consider re-profiling rock armour slope with existing and new rock.	19
D2	387848, 785228	Embankment	Rock armour	103	Undersized rock armour.	Consider rebuilding rock armour revetment with suitably sized armourstone, extending the protection to the harbour arm.	13
D3	387851, 785224	Embankment	Rock armour	104, 187	Expelled rock armour, also present on slipway blocking access.	Remove armour blocking slipway□replace armourstone back into profile.	13
D4	387833, 785234	Embankment	Rock armour	105	Poorly placed and non-interlocking rock profile.	Consider rebuilding rock armour revetment with suitably sized armourstone, extending the protection to the harbour arm.	13
D5	387804, 785235	Embankment	Access strip	106	Open joints between granite blocks.	Repoint open joints between blocks.	26
D6	387829, 785212	Embankment	Rock armour	107	Poor condition of rock armour crest, too narrow under design guidance and provides insufficient protection to the timber walkway.	Consider rebuilding rock armour revetment with suitably sized armourstone, extending the protection to the harbour arm.	27
D7	387804, 785225	Embankment	Access strip	108, 188	Health and Safety - Uneven and damaged access path, with missing planking.	Consider replacing access path.	5
D8	387786, 785236	Embankment	Rock armour	109	Insufficient rock armour protection at tie-in with harbour arm.	Consider rebuilding rock armour revetment with suitably sized armourstone, extending the protection to the harbour arm.	20
D9	387756, 785248	Embankment	Splash wall	110, 189, 221	General dilapidation and damaged capping repairs.	Reface concrete repairs.	10
D10	387759, 785270	Quay	Seaward face	111	Open joints.	Repoint open joints.	21

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D11	387783, 785305	Quay	Seaward face	112, 190	Voiding behind seaward face.	Repoint and injection grout voids.	1
D12	387788, 785311	Quay	Capping	113, 192	Open joints.	Repoint open joints.	11
D13	387747, 785276	Quay	Quay face	114, 191, 224	Small cracks in masonry blocks.	Monitor cracking and consider repointing repairs.	12
D14	387748, 785290	Quay	Quay face	168	Open joints.	Repoint open joints.	11
D15	387771, 785306	Quay	Deck	115	Dilapidated tarmac surface.	Consider resurfacing concrete repairs.	28
D16	387780, 785310	Quay	Capping	116	Weathering of repairs.	Monitor and consider replacing weathered blockwork.	11
D17	387788, 785318	Quay	Capping	117, 194, 223	Corroding piping in masonry joints.	Remove old corroded piping and repoint joints.	15
D18	387797, 785330	Quay	Capping	118	Cracking and spalling concrete rendering throughout section.	Breakout and replace concrete rendering.	20
D19	387811, 785353	Quay	Capping	119, 193, 222	Spalling, cracking and honeycombing of buttress elements of the wall.	Reface concrete repairs.	7
D20	387813, 785400	Quay	Capping	120	Settlement of the wall.	As part of annual inspection, monitor wall for signs of movement.	3
D21	387776, 785404	Quay	Sheet piling	121	Corrosion of sheet piles.	Monitor and consider options for replacing the sheet pile structure.	4
D22	387776, 785404	Quay	Sheet piling	122, 216	Health and Safety - Heavily corroded ladder.	Replace the ladder.	2
D23	387774, 785404	Quay	Sheet piling	123	Capping beam cracked.	Repoint crack.	13

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D24	387774, 785404	Quay	Deck	124	Insufficient hand railing.	Consider installing handrails.	29
D25	387774, 785404	Quay	Deck	125	Loose handrailing.	Fix loose handrailing.	23
D26	387808, 785391	Quay	Quay face	126, 213	Weathering of blockwork.	Monitor and consider surfacing repairs to weathered blockwork.	14
D27	387808, 785391	Quay	Quay face	127, 212	Corroded ladder.	Replace ladder.	9
D28	387732, 785287	Wall	Access strip	128	Cracking and loss of concrete on the slipway.	Reface concrete repairs.	24
D29	387729, 785289	Wall	Exposed face	129, 195	Cracking of pointing along the entire length and loose blockwork.	Repoint cracks.	11
D30	387731, 785288	Wall	Access strip	130	Health and Safety - algae growth on slipway.	Remove vegetation to avoid slipping hazards.	22
D31	387712, 785307	Wall	Exposed face	131, 197, 226	Missing flap valve.	Consider installing a flap valve.	30
D32	387711, 785310	Wall	Exposed face	132, 196, 225, 233	Undermining scour of exposed face approximately 10m.	Consider options for installing scour protection for the seawall. Monitor wall for signs of settlement and further deterioration.	1
D33	387697, 785353	Wall	Exposed face	133	Undermining scour of exposed face approximately 2m long.	Consider scour protection of the toe. Monitor wall for signs of settlement and further deterioration.	2
D34	387696, 785373	Wall	Exposed face	134	Sealant material missing between blockwork.	Replace missing sealant material.	11
D35	387697, 785384	Wall	Exposed face	135	Possibly blocked outfall.	Unblock outfall, consider installing flap valve.	16

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D36	387733, 785392	Quay	Deck	136	H&S Insufficient handrailing around the landing quay roundhead.	Consider installing handrails.	29
D37	387763, 785395	Quay	Piling	137	Corrosion of sheet piles.	Monitor and consider options for repairing/replacing the sheet pile structure.	4
D38	387763, 785395	Quay	Piling	138	Chipping of capping beam.	Consider repairing damaged concrete.	16
D39	387761, 785403	Quay	Piling	139	Missing sheet pile tie-back anchors.	Monitor and consider options for repairing/replacing the sheet pile structure.	5
D40	387694, 785406	Wall	Exposed face	140	Dilapidated concrete repairs exposing open joints in old masonry blockwork of the exposed face and the crest.	Reface concrete repairs.	12
D41	387690, 785409	Wall	Capping wall	141, 198	Large horizontal cracks in capping wall. Cracking also visible on landward side.	Repoint cracks and monitor for further movement.	15
D42	N/A	Wall	Capping wall	144	Spalling and honeycombing concrete approximately 10m long.	Reface concrete repairs.	17
D43	387713, 785410	Quay	Quay face	174, 215	Health and Safety - Corroded and loose ladder.	Replace ladder.	9
D44	387709, 785406	Quay	Quay face	142	Delaminating concrete repairs.	Reface concrete repairs.	14
D45	387703, 785408	Quay	Quay face	143	Approximately 1m x 0.3 m scour.	Extend concrete toe beneath scour depth.	2
D46	387699, 785411	Wall	Exposed face	145, 199	Delaminating repairs on toe and potential for undermining scour, approximately 30m.	Consider scour protection of the toe. Monitor wall for signs of settlement and further deterioration.	2
D47	387700, 785424	Wall	Exposed face	146, 200, 227, 234	Voiding behind the structure. Approximately 1m deep behind the structure in 5 locations.	Fill voids. Monitor wall for signs of settlement and further deterioration.	1

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D48	387708, 785452	Wall	Capping wall	147, 201	Drainage points on capping wall may need flap valves.	Consider installing flap valves.	30
D49	387730, 785490	Wall	Capping wall	148, 202	Open joints between blockwork.	Repoint open joints.	7
D50	387744, 785510	Wall	Access strip	149, 203	Extensive cracking on slipway.	Repoint cracks and patch repair damaged concrete.	10
D51	387750, 785511	Wall	Access strip	150, 204	Cracking on side of slipway.	Repoint cracks and patch repair damaged concrete.	17
D52	387829, 785499	Quay	Quay face	151, 205	Longitudinal cracks approximately 8m.	Repoint cracks and monitor structure for signs of movement.	13
D53	387831, 785502	Quay	Quay face	152	Long cracks approximately 3m.	Repoint cracks.	13
D54	387839, 785489	Quay	Deck	153	Health and Safety - insufficient handrailing.	Consider installing handrails.	29
D55	387812, 785431	Quay	Deck	154	Displaced timber beam.	Replace beam.	24
D56	N/A	Quay	Quay face	173	Delaminated concrete repairs along harbour face.	Reface concrete repairs.	12
D57	387805, 785441	Quay	Quay face	155	Health and Safety - Algae and seaweed growth on steps. Slipping hazard.	Remove algae and seaweed to prevent slipping hazards.	19
D58	387892, 785492	Quay	Capping	156	Delaminating concrete repairs.	Reface concrete.	25
D59	387883, 785494	Quay	Capping	157	Open joints.	Repoint open joints.	13
D60	387894, 785492	Quay	Capping	158	Missing element, exposed pipe.	Replace missing block.	18

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D61	387919, 785479	Quay	Seaward face	159, 206	Stains from corroding reinforcement.	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete structure.	6
D62	387922, 785484	Quay	Seaward face	160, 207, 228	Cracking of concrete.	Repoint cracks.	9
D63	387931, 785440	Quay	Seaward face	161, 208	Cracking of walls. Repairs displaced.	Reface concrete repairs.	8
D64	387937, 785422	Quay	Seaward face	162	Damage of concrete around pipe.	Patch repair damaged concrete.	8
D65	387940, 785406	Quay	Seaward face	163, 209, 229	Exposed steel corroding.	Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete structure.	5
D66	387944, 785403	Quay	Seaward face	164	Corroded handrails.	Consider replacing corroded handrails.	18
D67	387927, 785422	Quay	Seaward face	165, 210	Health and Safety - Damaged handrailing around stepped access.	Replace damaged handrails.	7
D68	387921, 785482	Quay	Deck	166, 211	Insufficient handrailing	Consider installing handrails.	29
D69	387902, 785489	Quay	Deck	167	Damaged surfacing of deck.	Resurface concrete.	31
D72	387778, 785397	Quay	Sheet piling	169, 214, 230, 235	Two holes in piles, approximately 0.3x0.1m and 0.3x0.3.	Monitor and consider options for replacing the sheet pile structure.	1
D73	387815, 785402	Quay	Sheet piling	170	6No. holes corroded through piles.	Monitor and consider options for repairing/replacing the sheet pile structure.	1
D74	387811, 785430	Quay	Sheet piling		General corrosion.	Monitor and consider options for repairing/replacing the sheet pile structure.	4

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D75	387811, 785401	Quay	Sheet piling	171	Missing sheet pile tie-back anchor plates.	Monitor and consider options for repairing/replacing the sheet pile structure.	5
D76	387813, 785400	Quay	Quay face	172	Delaminating concrete repairs .	Reface concrete repairs.	15
D77	387815, 785455	Quay	Quay face	175, 217	Undermining scour on old concrete toe repairs.	Install concrete protection beyond depth of scour. Monitor wall for signs of movement and further deterioration.	1
D78	387819, 785457	Quay	Quay face	176, 218	Loss of sealant material between blockwork.	Replace missing sealant material.	5
D79	387814, 785432	Quay	Seaward face	177	Protective apron possibly undermined - not long enough to provide protection to full wall length.	Consider repairing and extending concrete apron.	3
D80	387856, 785489	Quay	Quay face	180	Concrete cracking.	Repoint cracks.	14
D81	N/A	Quay	Quay face	178, 219, 231	Spalling, delaminating concrete.	Reface concrete repairs.	15
D82	387858, 785489	Quay	Quay face	179	Area of rock wall possibly undermined.	Monitor wall for signs of movement. Consider toe protection of the wall.	3
D83	387920, 785480	Quay	Quay face	181	Possible undermining scour.	Monitor wall for signs of movement. Consider toe protection of the wall.	3
D84	387874, 785492	Quay	Quay face	182	Undermining scour on the seaward facing side.	Provide scour protection on toe. Monitor wall for signs of movement and further deterioration.	1
D85	387654, 785600	Embankment	Rock armour	183, 220, 232	Undersized rock armour units.	Consider replacing rock armour with suitably sized units.	25
D86	387816, 785579	Embankment	Rock armour	186	Overly steep rock armour profile, at risk of collapse under extreme wave loading.	Consider reprofiling rock armour profile.	31

Defect Ref No.	Defect Location (NGR)	Sub Type	Element	Photo Ref	Defect Description	Recommendations	Defect Priority
D87	387833, 785560	Embankment	Splash wall	184	Blockwork missing.	Replace missing blockwork.	24
D88	387841, 785562	Embankment	Rock armour	185	Narrow rock armour crest width.	Consider increasing the width of the crest.	27

5. Health and safety check

Health and Safety Check (Defence - Section A)

	Y or N	Photo No.	Notes
Handrails			
Are handrails necessary□	N		
Are handrails present□	N		
Are handrails secured□	-		
Handrail construction material	-		
Are handrails corroded□	-		
Is handrail paint in good condition□	-		
Ladders / Steps			
Are ladders / steps necessary for access□	N		
Are ladder / steps present□	N		
Steps construction material	-		
Are steps in good condition□	-		
Are steps free of algae growth□	-		
Are ladders secured□	-		
Are ladders corroded□	-		
Is ladder paint in good condition□	-		
Ramps and walkways			The ramp has uneven surface and there are planks missing.
Are ramps and walkways necessary for access□	Y		
Are ramps and walkways present□	Y		
Ramp construction material			Timber
Are ramps in good condition□	N		
Are ramps free of algae growth□	Y		
Safety Harness Attachments			
Are attachments necessary for inspection□	N		
Are attachments present□	N		
Are attachments in good condition□	-		

Summary of health and safety items

There are planks missing from the pathway. It is recommended that they be replaced.

Health and Safety Check (Defence - Section B)

	Y or N	Photo No.	Notes
Handrails			Handrails suggested to be installed.
Are handrails necessary	Y		
Are handrails present	N		
Are handrails secured	-		
Handrail construction material	-		
Are handrails corroded	-		
Is handrail paint in good condition	-		
Ladders / Steps			Corroded ladders.
Are ladders / steps necessary for access	Y		
Are ladder / steps present	Y		
Steps construction material			-
Are steps in good condition	N		
Are steps free of algae growth	N		
Are ladders secured	N		
Are ladders corroded	Y		
Is ladder paint in good condition	N		
Ramps and walkways			
Are ramps and walkways necessary for access	N		
Are ramps and walkways present	N		
Ramp construction material	-		
Are ramps in good condition	-		
Are ramps free of algae growth	-		
Safety Harness Attachments			
Are attachments necessary for inspection	N		
Are attachments present	N		
Are attachments in good condition	-		

Summary of health and safety items

The access ladders are corroded and there is insufficient handrailing on the deck.

Health and Safety Check (Defence - Section C)

	Y or N	Photo No.	Notes
Handrails			
Are handrails necessary	Y		
Are handrails present	N		
Are handrails secured	-		
Handrail construction material	-		
Are handrails corroded	-		
Is handrail paint in good condition	-		
Ladders / Steps			
Are ladders / steps necessary for access	N		
Are ladder / steps present	N		
Steps construction material	-		
Are steps in good condition	-		
Are steps free of algae growth	-		
Are ladders secured	-		
Are ladders corroded	-		
Is ladder paint in good condition	-		
Ramps and walkways			There is algae growth on top of the slipway.
Are ramps and walkways necessary for access	Y		
Are ramps and walkways present	Y		
Ramp construction material			Concrete
Are ramps in good condition	N		
Are ramps free of algae growth	N		
Safety Harness Attachments			
Are attachments necessary for inspection	N		
Are attachments present	N		
Are attachments in good condition	-		

Summary of health and safety items

There is algae growth on the slipway causing slipping hazards.

Health and Safety Check (Defence - Section D)

	Y or N	Photo No.	Notes
Handrails			
Are handrails necessary□	N		
Are handrails present□	N		
Are handrails secured□	-		
Handrail construction material	-		
Are handrails corroded□	-		
Is handrail paint in good condition□	-		
Ladders / Steps			Corroded and loose ladders.
Are ladders / steps necessary for access□	Y		
Are ladder / steps present□	Y		
Steps construction material			-
Are steps in good condition□	N		
Are steps free of algae growth□	N		
Are ladders secured□	N		
Are ladders corroded□	Y		
Is ladder paint in good condition□	N		
Ramps and walkways			
Are ramps and walkways necessary for access□	N		
Are ramps and walkways present□	N		
Ramp construction material	-		
Are ramps in good condition□	-		
Are ramps free of algae growth□	-		
Safety Harness Attachments			
Are attachments necessary for inspection□	N		
Are attachments present□	N		
Are attachments in good condition□	-		

Summary of health and safety items

There are corroded and loose ladders and insufficient handrailing on the deck.

Health and Safety Check (Defence - Section E)

	Y or N	Photo No.	Notes
Handrails			
Are handrails necessary□	N		
Are handrails present□	N		
Are handrails secured□	-		
Handrail construction material	-		
Are handrails corroded□	-		
Is handrail paint in good condition□	-		
Ladders / Steps			
Are ladders / steps necessary for access□	N		
Are ladder / steps present□	N		
Steps construction material	-		
Are steps in good condition□	-		
Are steps free of algae growth□	-		
Are ladders secured□	-		
Are ladders corroded□	-		
Is ladder paint in good condition□	-		
Ramps and walkways			Some cracking present on top and on the side of the slipway.
Are ramps and walkways necessary for access□	Y		
Are ramps and walkways present□	Y		
Ramp construction material			Concrete
Are ramps in good condition□	N		
Are ramps free of algae growth□	N		
Safety Harness Attachments			
Are attachments necessary for inspection□	N		
Are attachments present□	N		
Are attachments in good condition□	-		

Summary of health and safety items

No summary details entered

Health and Safety Check (Defence - Section F)

	Y or N	Photo No.	Notes
Handrails			
Are handrails necessary□	Y		
Are handrails present□	N		
Are handrails secured□	-		
Handrail construction material	-		
Are handrails corroded□	-		
Is handrail paint in good condition□	-		
Ladders / Steps			Algae and seaweed growth on access steps.
Are ladders / steps necessary for access□	Y		
Are ladder / steps present□	Y		
Steps construction material			Concrete
Are steps in good condition□	N		
Are steps free of algae growth□	N		
Are ladders secured□	N		
Are ladders corroded□	N		
Is ladder paint in good condition□	N		
Ramps and walkways			
Are ramps and walkways necessary for access□	N		
Are ramps and walkways present□	N		
Ramp construction material	-		
Are ramps in good condition□	-		
Are ramps free of algae growth□	-		
Safety Harness Attachments			
Are attachments necessary for inspection□	N		
Are attachments present□	N		
Are attachments in good condition□	-		

Summary of health and safety items

There is insufficient handrailing on the deck

Health and Safety Check (Defence - Section G)

	Y or N	Photo No.	Notes
Handrails			The handrails around the stepped access are damaged and displaced.
Are handrails necessary?	Y		
Are handrails present?	Y		
Are handrails secured?	N		
Handrail construction material			Steel
Are handrails corroded?	Y		
Is handrail paint in good condition?	N		
Ladders / Steps			
Are ladders / steps necessary for access?	N		
Are ladder / steps present?	N		
Steps construction material	-		
Are steps in good condition?	-		
Are steps free of algae growth?	-		
Are ladders secured?	-		
Are ladders corroded?	-		
Is ladder paint in good condition?	-		
Ramps and walkways			
Are ramps and walkways necessary for access?	N		
Are ramps and walkways present?	N		
Ramp construction material	-		
Are ramps in good condition?	-		
Are ramps free of algae growth?	-		
Safety Harness Attachments			
Are attachments necessary for inspection?	N		
Are attachments present?	N		
Are attachments in good condition?	-		

Summary of health and safety items

The handrails are damaged around the stepped access.

Health and Safety Check (Defence - Section H)

	Y or N	Photo No.	Notes
Handrails			
Are handrails necessary□	N		
Are handrails present□	N		
Are handrails secured□	-		
Handrail construction material	-		
Are handrails corroded□	-		
Is handrail paint in good condition□	-		
Ladders / Steps			
Are ladders / steps necessary for access□	N		
Are ladder / steps present□	N		
Steps construction material	-		
Are steps in good condition□	-		
Are steps free of algae growth□	-		
Are ladders secured□	-		
Are ladders corroded□	-		
Is ladder paint in good condition□	-		
Ramps and walkways			
Are ramps and walkways necessary for access□	N		
Are ramps and walkways present□	N		
Ramp construction material	-		
Are ramps in good condition□	-		
Are ramps free of algae growth□	-		
Safety Harness Attachments			
Are attachments necessary for inspection□	N		
Are attachments present□	N		
Are attachments in good condition□	-		

Summary of health and safety items

No summary details entered

6. Asset assessment

6.1. Recommended works

Band A: Emergency works

Defect posing an immediate safety hazard. Immediate action required.

Defect Recommendation	Defect
Remove armour blocking slipway replace armourstone back into profile.	D3
Repoint and injection grout voids.	D11
Monitor and consider options for replacing the sheet pile structure.	D21
Remove vegetation to avoid slipping hazards.	D30
Consider options for installing scour protection for the seawall. Monitor wall for signs of settlement and further deterioration.	D32
Consider scour protection of the toe. Monitor wall for signs of settlement and further deterioration.	D33
Monitor and consider options for repairing/replacing the sheet pile structure.	D37
Monitor and consider options for repairing/replacing the sheet pile structure.	D39
Monitor and consider options for replacing the sheet pile structure.	D72
Monitor and consider options for repairing/replacing the sheet pile structure.	D73
Monitor and consider options for repairing/replacing the sheet pile structure.	D74
Monitor and consider options for repairing/replacing the sheet pile structure.	D75
Install concrete protection beyond depth of scour. Monitor wall for signs of movement and further deterioration.	D77
Monitor wall for signs of movement. Consider toe protection of the wall.	D82
Monitor wall for signs of movement. Consider toe protection of the wall.	D83
Provide scour protection on toe. Monitor wall for signs of movement and further deterioration.	D84

Band B: Urgent Works

Defect posing a potential safety hazard. Work recommended within 12 month period.

Defect Recommendation	Defect
Consider replacing access path.	D7
Reface concrete repairs.	D9
Repoint open joints.	D10
Repoint open joints.	D12
Monitor cracking and consider repointing repairs.	D13
Repoint open joints.	D14
Consider resurfacing concrete repairs.	D15
Monitor and consider replacing weathered blockwork.	D16
Remove old corroded piping and repoint joints.	D17
Reface concrete repairs.	D19
Replace the ladder.	D22
Repoint crack.	D23
Fix loose handrailing.	D25
Reface concrete repairs.	D28
Repoint cracks.	D29
Replace missing sealant material.	D34
Unblock outfall, consider installing flap valve.	D35
Reface concrete repairs.	D40
Repoint cracks and monitor for further movement.	D41
Reface concrete repairs.	D42
Replace ladder.	D43
Reface concrete repairs.	D44
Extend concrete toe beneath scour depth.	D45
Consider scour protection of the toe. Monitor wall for signs of settlement and further deterioration.	D46
Fill voids. Monitor wall for signs of settlement and further deterioration.	D47
Repoint open joints.	D49
Repoint cracks and patch repair damaged concrete.	D50
Repoint cracks and patch repair damaged concrete.	D51
Repoint cracks and monitor structure for signs of movement.	D52
Repoint cracks.	D53

Reface concrete repairs.	D56
Remove algae and seaweed to prevent slipping hazards.	D57
Repoint open joints.	D59
Replace missing block.	D60
Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete structure.	D61
Repoint cracks.	D62
Reface concrete repairs.	D63
Patch repair damaged concrete.	D64
Replace damaged handrails.	D67
Reface concrete repairs.	D76
Replace missing sealant material.	D78
Repoint cracks.	D80
Reface concrete repairs.	D81
Replace missing blockwork.	D87

Band C: Short-term remedial works

Defect posing a potential safety hazard. Work recommended within 12 to 30 month period.

Defect Recommendation	Defect
Consider rebuilding rock armour revetment with suitably sized armourstone, extending the protection to the harbour arm.	D2
Consider rebuilding rock armour revetment with suitably sized armourstone, extending the protection to the harbour arm.	D4
Repoint open joints between blocks.	D5
Breakout and replace concrete rendering.	D18
Consider installing handrails.	D24
Monitor and consider surfacing repairs to weathered blockwork.	D26
Replace ladder.	D27
Consider installing a flap valve.	D31
Consider repairing damaged concrete.	D38
Consider installing flap valves.	D48
Consider installing handrails.	D54
Replace beam.	D55
Reface concrete.	D58
Breakout damaged area of concrete, remove and replace corroded reinforcement as required and reform concrete structure.	D65
Consider replacing corroded handrails.	D66
Consider installing handrails.	D68
Resurface concrete.	D69
Consider repairing and extending concrete apron.	D79

Band D: Long-term maintenance works

Defect resulting in long-term deterioration of structure or affecting performance. Work recommended within 30 to 48 month period.

Defect Recommendation	Defect
Consider re-profiling rock armour slope with existing and new rock.	D1
Consider rebuilding rock armour revetment with suitably sized armourstone, extending the protection to the harbour arm.	D6
Consider rebuilding rock armour revetment with suitably sized armourstone, extending the protection to the harbour arm.	D8
As part of annual inspection, monitor wall for signs of movement.	D20
Consider installing handrails.	D36
Consider replacing rock armour with suitably sized units.	D85
Consider reprofiling rock armour profile.	D86
Consider increasing the width of the crest.	D88

6.2. Report sign-off

Prepared and Completed by:	Johan Skanberg-Tippen BSc, MSc (Eng)
Signed:	
Date:	17/05/2018
Checked and Approved by:	Graham Kenn CEng, MICE, C.WEM, CIWEM – Technical Director – Coastal Engineering
Signed:	
Date:	05/07/2018

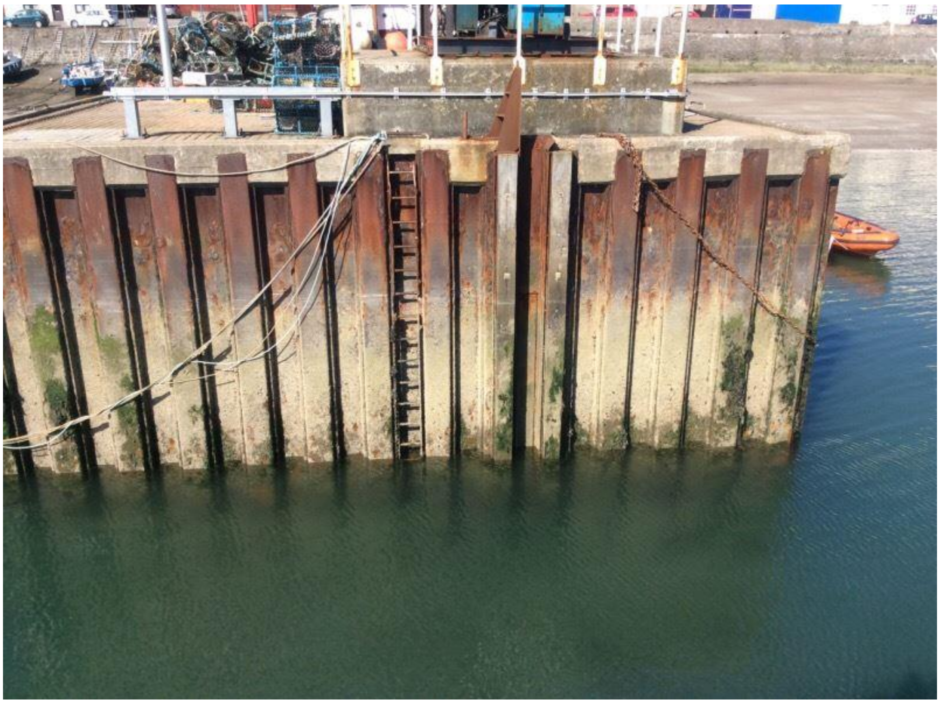
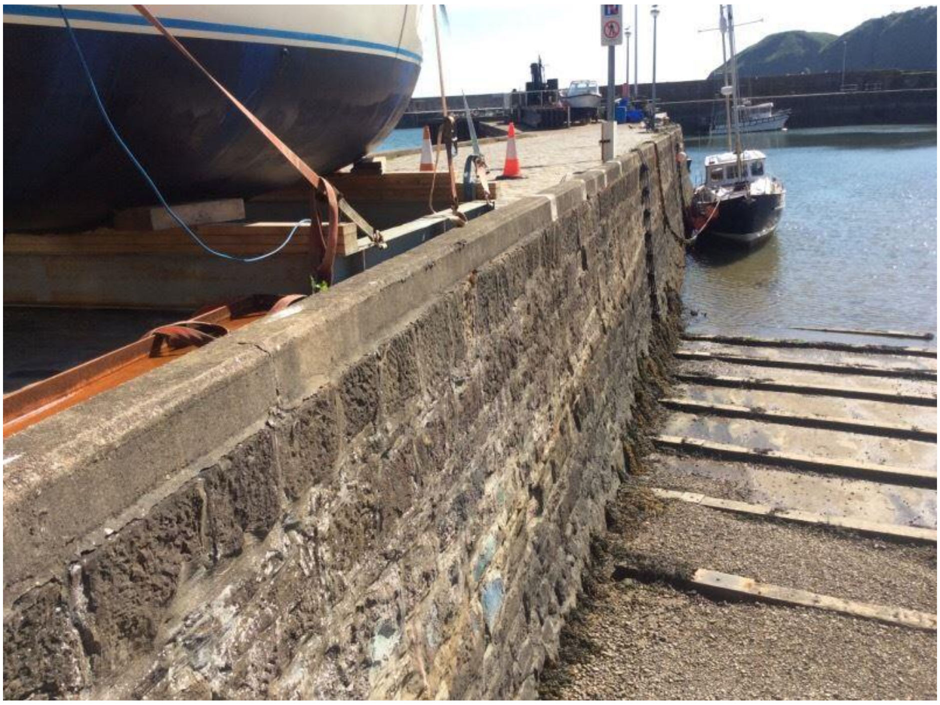
Appendix 1 – Photographs

<table>
<tr><th colspan="2">Section Photos</th></tr>
<tr><td>Section A
Description: Viewer Section A (looking northwest).
Asset Type: Defence
Sub Type: Embankment
Elements: Rock armour, access strip and splash wall.

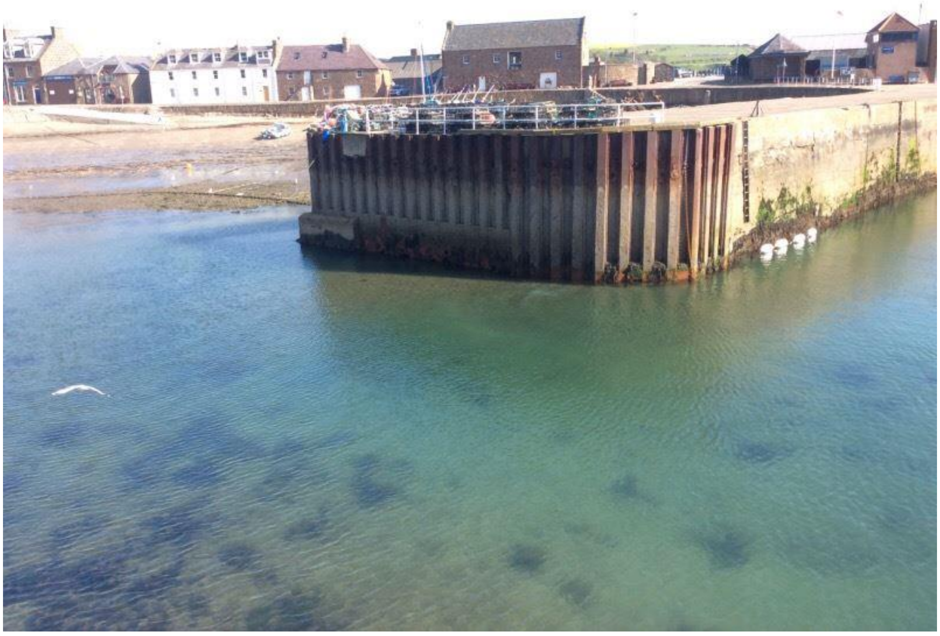
Photo number: 1</td><td></td></tr>
<tr><td>Section B
Description: View of Section B
(looking north)
Asset Type: Defence
Sub Type: Quay
Elements: Seaward face, Quay face, capping, piling, deck.
Photo number: 2</td><td></td></tr>
</table>

Section B **Description:** View of Section B (looking north) Asset Type: Defence Sub Type: Quay Elements: Seaward face, Quay face, capping, piling, deck. **Photo number: 10**	
Section B **Description:** View of Section B (looking north) Asset Type: Defence Sub Type: Quay Elements: Seaward face, Quay face, capping, piling, deck. **Photo number: 12**	

Section B **Description:** View of Section B (looking north) Asset Type: Defence Sub Type: Quay Elements: Seaward face, Quay face, capping, piling, deck. **Photo number: 14**	
Section C **Description:** View of Section C (looking north) Asset Type: Defence Sub Type: Wall Elements: Access strip, exposed face, capping wall. **Photo number: 4**	

Section D **Description:** View of Section D (looking west) Asset Type: Defence Sub Type: Quay Elements: Sheet piling, quay face, deck. **Photo number: 3**	
Section D **Description:** View of Section D (looking west) Asset Type: Defence Sub Type: Quay Elements: Sheet piling, quay face, deck. **Photo number: 9**	

Section D **Description:** View of Section D (looking west) Asset Type: Defence Sub Type: Quay Elements: Sheet piling, quay face, deck. **Photo number: 13**	
Section E **Description:** View of Section E (looking north) Asset Type: Defence Sub Type: Wall Elements: Access strip, exposed face. **Photo number: 5**	

Section F **Description:** View of Section F (looking north) Asset Type: Defence Sub Type: Quay Elements: Quay face, deck, sheet piling. **Photo number: 7**	
Section F **Description:** View of Section F (looking north) Asset Type: Defence Sub Type: Quay Elements: Quay face, deck, sheet piling. **Photo number: 11**	

Section G **Description:** View of Section G (looking east) Asset Type: Defence Sub Type: Quay Elements: Capping, seaward face, deck, quay face. **Photo number: 6**	
Section H **Description:** View of Section H (looking northwest) Asset Type: Defence Sub Type: Embankment Elements: Rock armour, splash wall. **Photo number: 8**	

Defect Photos	
Section A **Rock armour** **Defect Ref: D1** **Description:** D1 - Nonuniform rock armour profile, insufficient protection to timber footbridge. **Photo number: 102**	
Section A **Rock armour** **Defect Ref: D2** **Description:** D2 - Undersized rock armour. **Photo number: 103**	

Section A **Rock armour** **Defect Ref: D3** **Description:** D3 - Expelled rock armour, also present on slipway blocking access. **Photo number: 104**	
Section A **Rock armour** **Defect Ref: D3** **Description:** D3 - Expelled rock armour, also present on slipway blocking access. **Photo number: 187**	

<table>
<tr><td>Section A
Rock armour
Defect Ref: D4
Description: D4 - Poorly placed and non-interlocking rock profile.
Photo number: 105</td><td></td></tr>
<tr><td>Section A
Access strip
Defect Ref: D5
Description: D5 - Open joints between granite blocks.
Photo number: 106</td><td></td></tr>
</table>

Section A **Rock armour** **Defect Ref: D6** **Description:** D6 - Poor condition of rock armour crest, too narrow under design guidance and provides insufficient protection to the timber walkway. **Photo number: 107**	
Section A **Access strip** **Defect Ref: D7** **Description:** D7 - H&S uneven and damaged access path, with missing planking. **Photo number: 108**	

Section A **Access strip** **Defect Ref: D7** **Description:** D7 - H&S uneven and damaged access path, with missing planking. **Photo number: 188**	
Section A **Rock armour** **Defect Ref: D8** **Description:** D8 - Insufficient rock armour protection at tie-in with harbour arm. **Photo number: 109**	

Section A **Splash wall** **Defect Ref: D9** **Description:** D9 - General dilapidation and damaged capping repairs **Photo number: 110**	
Section A **Splash wall** **Defect Ref: D9** **Description:** D9 - General dilapidation and damaged capping repairs **Photo number: 189**	

Section A **Splash wall** **Defect Ref: D9** **Description:** D9 - General dilapidation and damaged capping repairs **Photo number: 221**	
Section B **Seaward face** **Defect Ref: D10** **Description:** D10 - Open joints. **Photo number: 111**	

Section B **Seaward face** **Defect Ref: D11** **Description:** D11 - Voiding behind seaward face **Photo number: 112**	
Section B **Seaward face** **Defect Ref: D11** **Description:** D11 - Voiding behind seaward face **Photo number: 190**	

Section B **Capping** **Defect Ref: D12** **Description:** D12 - Open joints **Photo number: 113**	
Section B **Capping** **Defect Ref: D12** **Description:** D12 - Open joints **Photo number: 192**	

Section B **Quay face** **Defect Ref: D13** **Description:** D13 - Small cracks of masonry blocks. **Photo number: 114**	
Section B **Quay face** **Defect Ref: D13** **Description:** D13 - Small cracks of masonry blocks. **Photo number: 191**	

Section B **Quay face** **Defect Ref: D13** **Description:** D13 - Small cracks of masonry blocks. **Photo number: 224**	
Section B **Quay face** **Defect Ref: D14** **Description:** D14 - Open joints. **Photo number: 168**	

Section B **Deck** **Defect Ref: D15** **Description:** D15 - Dilapidated tarmac surface. **Photo number: 115**	
Section B **Capping** **Defect Ref: D16** **Description:** D16 - Weathering of repairs **Photo number: 116**	

Section B **Capping** **Defect Ref: D17** **Description:** D17 - Corroding piping joints. **Photo number: 117**	
Section B **Capping** **Defect Ref: D17** **Description:** D17 - Corroding piping joints. **Photo number: 194**	

Section B **Capping** **Defect Ref: D17** **Description:** D17 - Corroding piping joints. **Photo number: 223**	
Section B **Capping** **Defect Ref: D18** **Description:** D18 - Cracking and spalling of concrete rendering throughout section. **Photo number: 118**	

Section B **Capping** **Defect Ref: D19** **Description:** D19 - Spalling, cracking and honeycombing of buttress elements of the wall. **Photo number: 119**	
Section B **Capping** **Defect Ref: D19** **Description:** D19 - Spalling, cracking and honeycombing of buttress elements of the wall. **Photo number: 193**	

Section B **Capping** **Defect Ref: D19** **Description:** D19 - Spalling, cracking and honeycombing of buttress elements of the wall. **Photo number: 222**	
Section B **Capping** **Defect Ref: D20** **Description:** D20 - Settlement of the wall. **Photo number: 120**	

Section D **Sheet piling** **Defect Ref: D21** **Description:** D21 - Corrosion of sheet piles. **Photo number: 121**	
Section D **Sheet piling** **Defect Ref: D22** **Description:** D22 - Health and Safety - Heavily corroded ladder. **Photo number: 122**	

Section D **Sheet piling** **Defect Ref: D22** **Description:** D22 - Health and Safety - Heavily corroded ladder. **Photo number: 216**	
Section D **Sheet piling** **Defect Ref: D23** **Description:** D23 - Capping beam cracked. **Photo number: 123**	

Section B **Deck** **Defect Ref: D24** **Description:** D24 - Insufficient hand railing **Photo number: 124**	
Section B **Deck** **Defect Ref: D25** **Description:** D25 - Loose handrailing **Photo number: 125**	

Section B **Quay face** **Defect Ref: D26** **Description:** D26 - Weathering of blockwork. **Photo number: 126**	
Section B **Quay face** **Defect Ref: D26** **Description:** D26 - Weathering of blockwork. **Photo number: 213**	

Section B **Quay face** **Defect Ref: D27** **Description:** D27 - Corroded ladder **Photo number: 127**	
Section B **Quay face** **Defect Ref: D27** **Description:** D27 - Corroded ladder **Photo number: 212**	

Section C **Access strip** **Defect Ref: D28** **Description:** D28 - Cracking and loss of concrete on the slipway **Photo number: 128**	
Section C **Exposed face** **Defect Ref: D29** **Description:** D29 - Cracking of pointing along the entire length and loose blockwork. **Photo number: 129**	

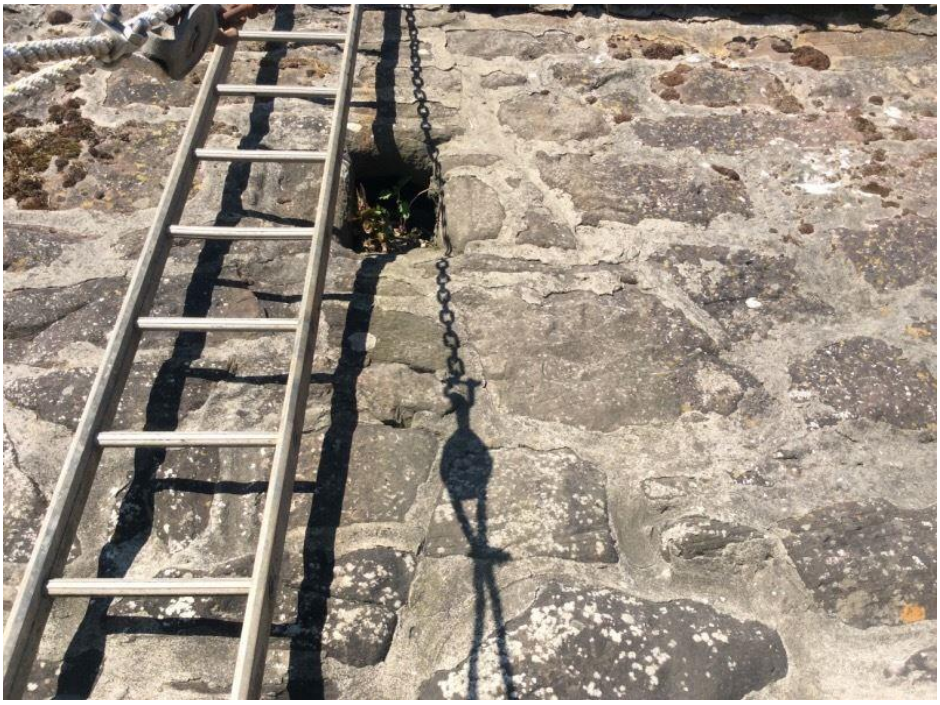
Section C **Exposed face** **Defect Ref: D29** **Description:** D29 - Cracking of pointing along the entire length and loose blockwork. **Photo number: 195**	
Section C **Access strip** **Defect Ref: D30** **Description:** D30 - Algae growth on slipway **Photo number: 130**	

Section C **Exposed face** **Defect Ref: D31** **Description:** D31 - Missing flap valve **Photo number: 131**	
Section C **Exposed face** **Defect Ref: D31** **Description:** D31 - Missing flap valve **Photo number: 197**	

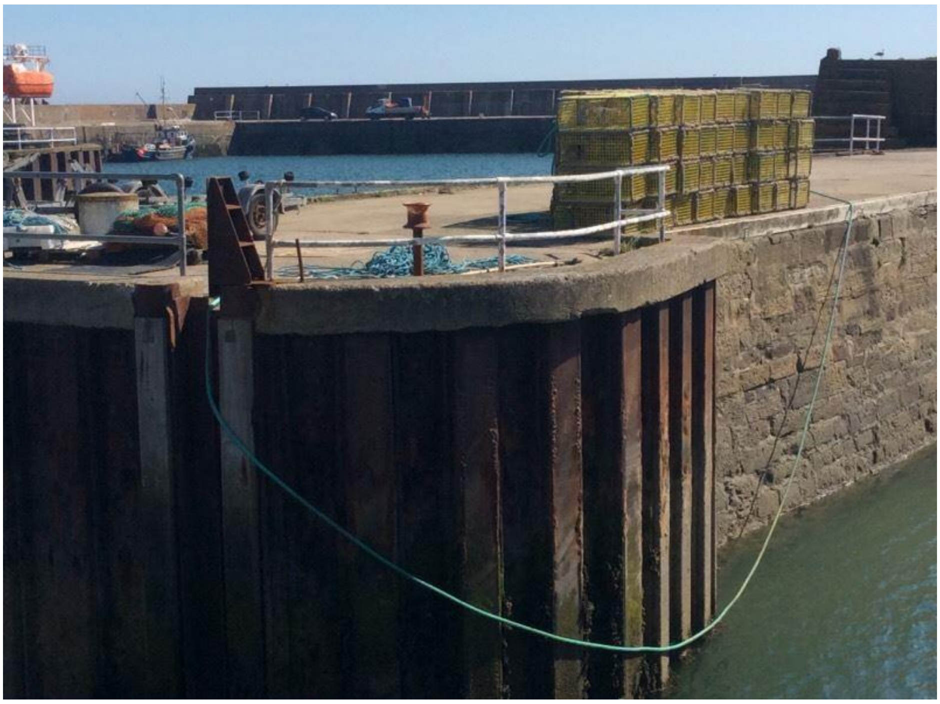
Section C **Exposed face** **Defect Ref: D31** **Description:** D31 - Missing flap valve **Photo number: 226**	
Section C **Exposed face** **Defect Ref: D32** **Description:** D32 - Undermining scour of exposed face approximately 10m **Photo number: 132**	

Section C **Exposed face** **Defect Ref: D32** **Description:** D32 - Undermining scour of exposed face approximately 10m **Photo number: 196**	
Section C **Exposed face** **Defect Ref: D32** **Description:** D32 - Undermining scour of exposed face approximately 10m **Photo number: 225**	

Section C **Exposed face** **Defect Ref: D32** **Description:** D32 - Undermining scour of exposed face approximately 10m **Photo number: 233**	
Section C **Exposed face** **Defect Ref: D33** **Description:** D33 - Undermining scour of exposed face approximately 2m long. **Photo number: 133**	

Section C **Exposed face** **Defect Ref: D34** **Description:** D34 - Open joints **Photo number: 134**	
Section C **Exposed face** **Defect Ref: D35** **Description:** D35 - Possibly blocked outfall. **Photo number: 135**	

Section D **Deck** **Defect Ref: D36** **Description:** D36 - H&S Insufficient handrailing. **Photo number: 136**	
Section B **Piling** **Defect Ref: D37** **Description:** D37 - Corrosion of sheet piles. **Photo number: 137**	

Section B **Piling** **Defect Ref: D38** **Description:** D38 - Chipping of capping beam. **Photo number: 138**	
Section B **Piling** **Defect Ref: D39** **Description:** D39 - Missing anchors **Photo number: 139**	

Section C **Exposed face** **Defect Ref: D40** **Description:** D40 - Dilapidated concrete repairs exposing open joints in old masonry blockwork of the exposed face and the crest. **Photo number: 140**	
Section C **Capping wall** **Defect Ref: D41** **Description:** D41 - Large horizontal cracks. Cracking also visible on landward side **Photo number: 141**	

Section C **Capping wall** **Defect Ref: D41** **Description:** D41 - Large horizontal cracks. Cracking also visible on landward side **Photo number: 198**	
Section C **Capping wall** **Defect Ref: D42** **Description:** D42 - Spalling and honeycombing of concrete approx. 10m **Photo number: 144**	

Section D **Quay face** **Defect Ref: D43** **Description:** D43 - Health and Safety - Corroded and loose ladder. **Photo number: 174**	
Section D **Quay face** **Defect Ref: D43** **Description:** D43 - Health and Safety - Corroded and loose ladder. **Photo number: 215**	

Section D **Quay face** **Defect Ref: D44** **Description:** D44 - Delaminated surfacing **Photo number: 142**	
Section D **Quay face** **Defect Ref: D45** **Description:** D45 - Approximately 1m x 0.3 m scour. **Photo number: 143**	

Section C **Exposed face** **Defect Ref: D46** **Description:** D46 - Delaminating repairs on toe and potential for undermining scour, approximately 30m. **Photo number: 145**	
Section C **Exposed face** **Defect Ref: D46** **Description:** D46 - Delaminating repairs on toe and potential for undermining scour, approximately 30m. **Photo number: 199**	

Section C **Exposed face** **Defect Ref: D47** **Description:** D47 - Voiding behind the structure. Approximately 1m behind the structure in 5 locations. **Photo number: 146**	
Section C **Exposed face** **Defect Ref: D47** **Description:** D47 - Voiding behind the structure. Approximately 1m behind the structure in 5 locations. **Photo number: 200**	

Section C **Exposed face** **Defect Ref: D47** **Description:** D47 - Voiding behind the structure. Approximately 1m behind the structure in 5 locations. **Photo number: 227**	
Section C **Exposed face** **Defect Ref: D47** **Description:** D47 - Voiding behind the structure. Approximately 1m behind the structure in 5 locations. **Photo number: 234**	

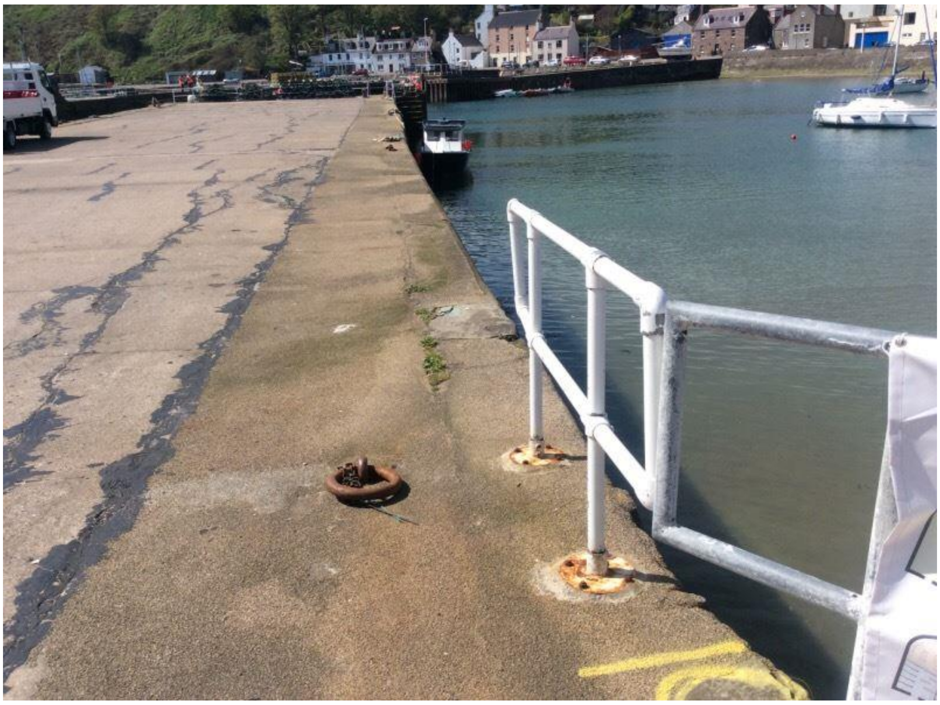
Section C **Capping wall** **Defect Ref: D48** **Description:** D48 - Drainage points on capping wall may need flap valves **Photo number: 147**	
Section C **Capping wall** **Defect Ref: D48** **Description:** D48 - Drainage points on capping wall may need flap valves **Photo number: 201**	

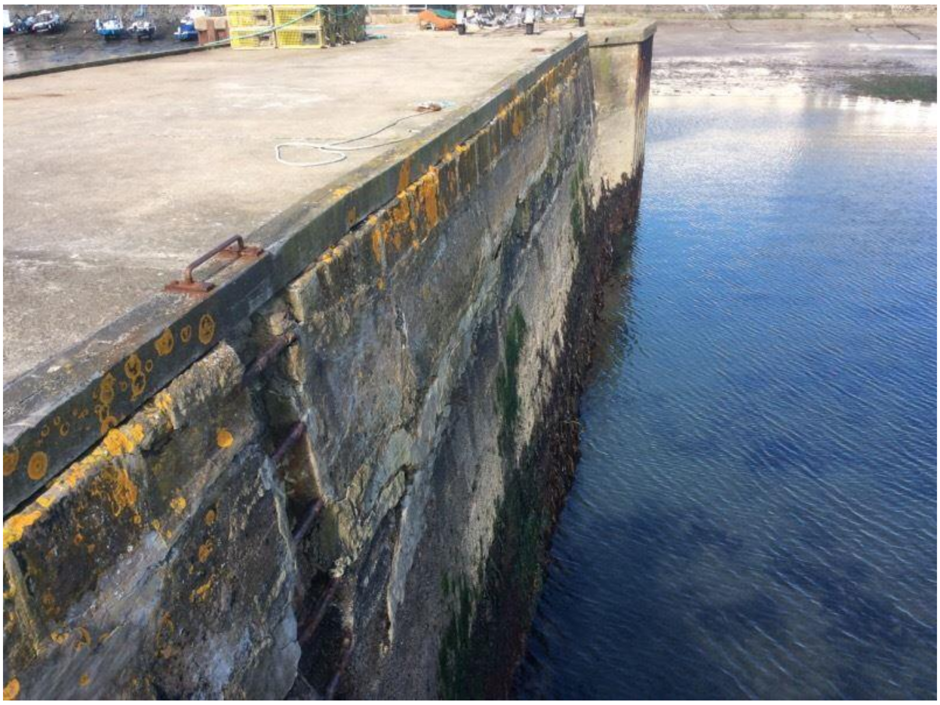
Section C **Capping wall** **Defect Ref: D49** **Description:** D49 - Open joints **Photo number: 148**	
Section C **Capping wall** **Defect Ref: D49** **Description:** D49 - Open joints **Photo number: 202**	

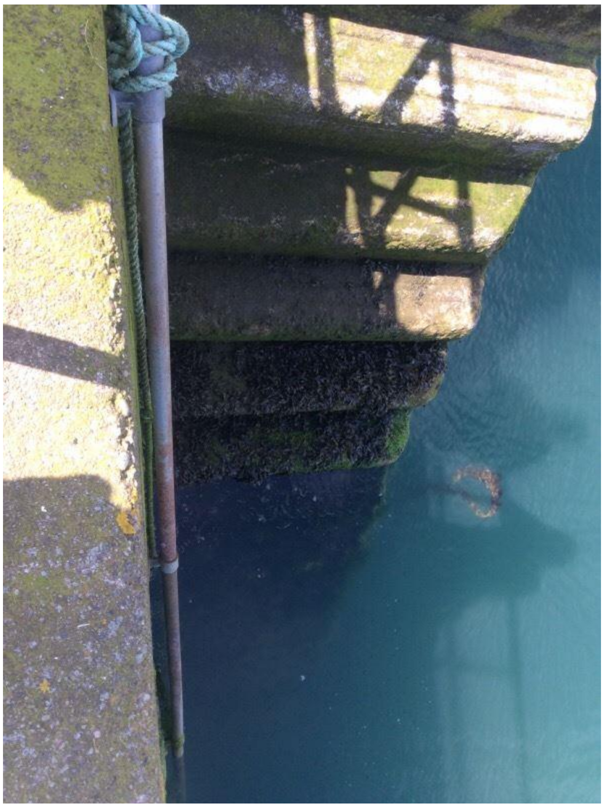
Section E **Access strip** **Defect Ref: D50** **Description:** D50 - Extensive cracking on slipway **Photo number: 149**	
Section E **Access strip** **Defect Ref: D50** **Description:** D50 - Extensive cracking on slipway **Photo number: 203**	

Section E **Access strip** **Defect Ref: D51** **Description:** D51 - Cracking on side of slipway. **Photo number: 150**	
Section E **Access strip** **Defect Ref: D51** **Description:** D51 - Cracking on side of slipway. **Photo number: 204**	

Section F **Quay face** **Defect Ref: D52** **Description:** D52 - Longitudinal cracks approximately 8m. **Photo number: 151**	
Section F **Quay face** **Defect Ref: D52** **Description:** D52 - Longitudinal cracks approximately 8m. **Photo number: 205**	

Section F **Quay face** **Defect Ref: D53** **Description:** D53 - Long cracks approximately 3m **Photo number: 152**	
Section F **Deck** **Defect Ref: D54** **Description:** D54 - H&S insufficient handrailing **Photo number: 153**	

Section F **Deck** **Defect Ref: D55** **Description:** D55 - Displaced timber beam. **Photo number: 154**	
Section B **Quay face** **Defect Ref: D56** **Description:** D56 - Delaminated concrete repairs along harbour face. **Photo number: 173**	

Section F **Quay face** **Defect Ref: D57** **Description:** D57- Algae and seaweed growth on steps. Slipping hazard. **Photo number: 155**	
Section G **Capping** **Defect Ref: D58** **Description:** D58 - Delaminating concrete repairs **Photo number: 156**	

Section G **Capping** **Defect Ref: D59** **Description:** D59 - Open joints **Photo number: 157**	
Section G **Capping** **Defect Ref: D60** **Description:** D60 - Missing element, exposed pipe. **Photo number: 158**	

Section G **Seaward face** **Defect Ref: D61** **Description:** D61 - Stains of corroding reinforcement. **Photo number: 159**	
Section G **Seaward face** **Defect Ref: D61** **Description:** D61 - Stains of corroding reinforcement. **Photo number: 206**	

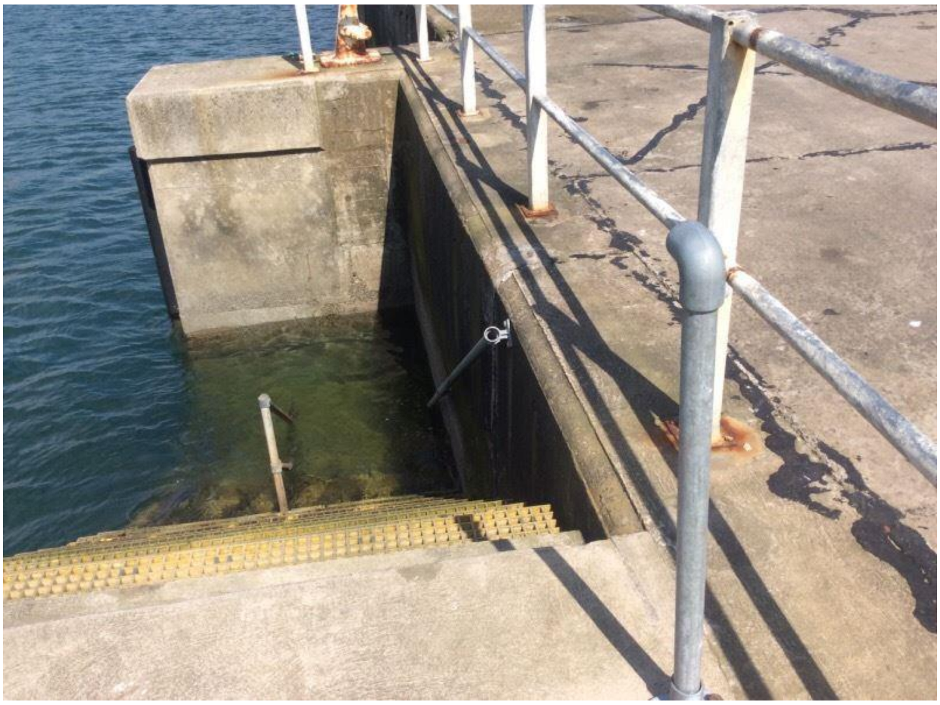
Section G **Seaward face** **Defect Ref: D62** **Description:** D62 - Cracking of concrete **Photo number: 160**	
Section G **Seaward face** **Defect Ref: D62** **Description:** D62 - Cracking of concrete **Photo number: 207**	

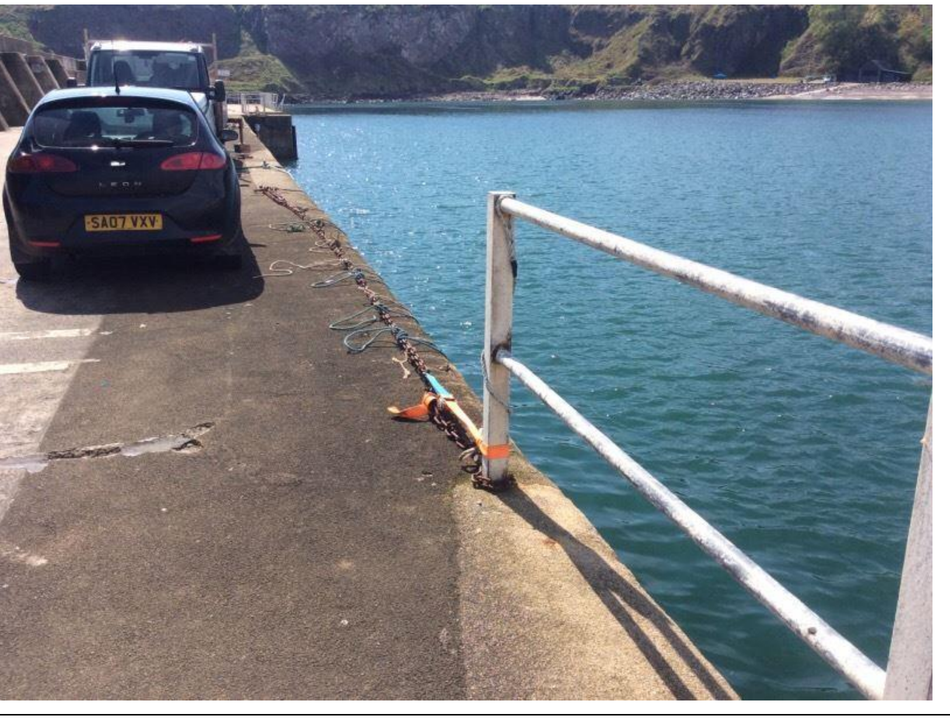
Section G **Seaward face** **Defect Ref: D62** **Description:** D62 - Cracking of concrete **Photo number: 228**	
Section G **Seaward face** **Defect Ref: D63** **Description:** D63 - Cracking of walls. Repairs coming off. **Photo number: 161**	

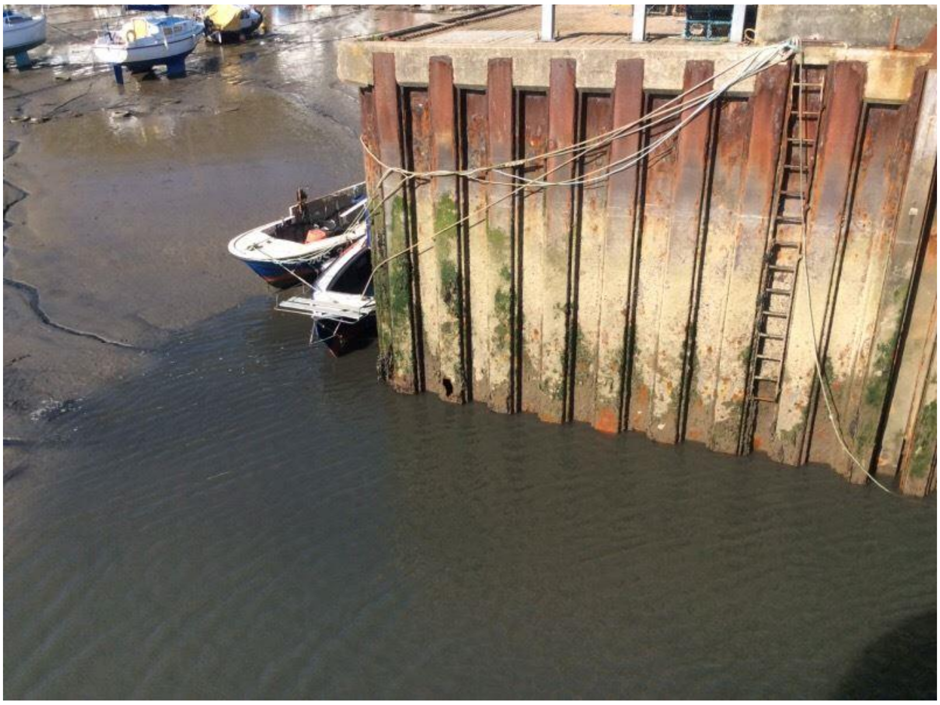
Section G **Seaward face** **Defect Ref: D63** **Description:** D63 - Cracking of walls. Repairs coming off. **Photo number: 208**	
Section G **Seaward face** **Defect Ref: D64** **Description:** D64 - Damage of concrete around pipe. **Photo number: 162**	

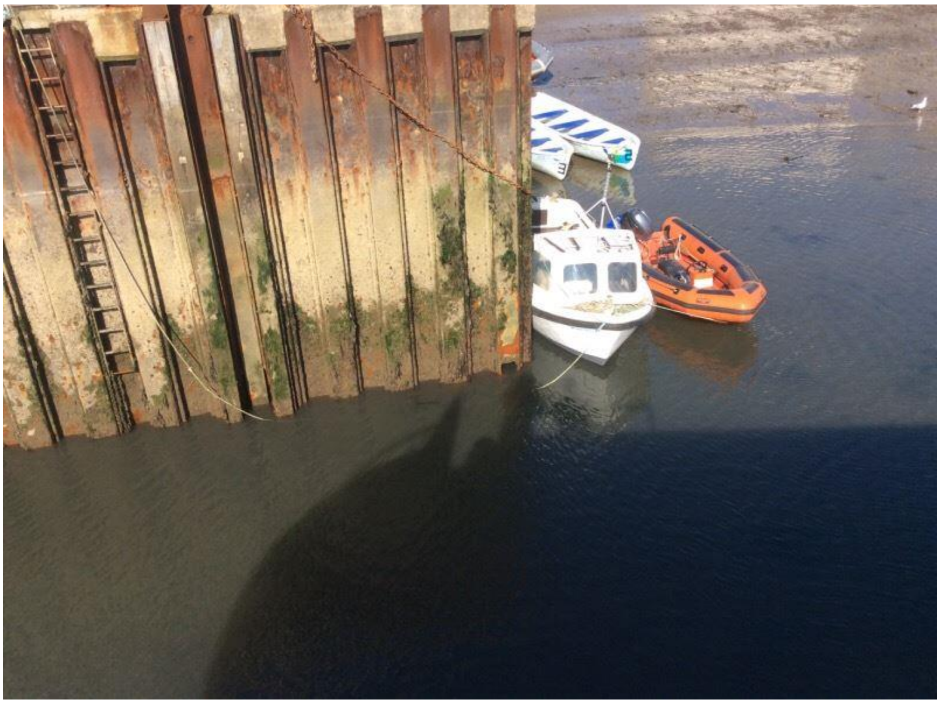
Section G **Seaward face** **Defect Ref: D65** **Description:** D65 - Exposed steel corroding. **Photo number: 163**	
Section G **Seaward face** **Defect Ref: D65** **Description:** D65 - Exposed steel corroding. **Photo number: 209**	

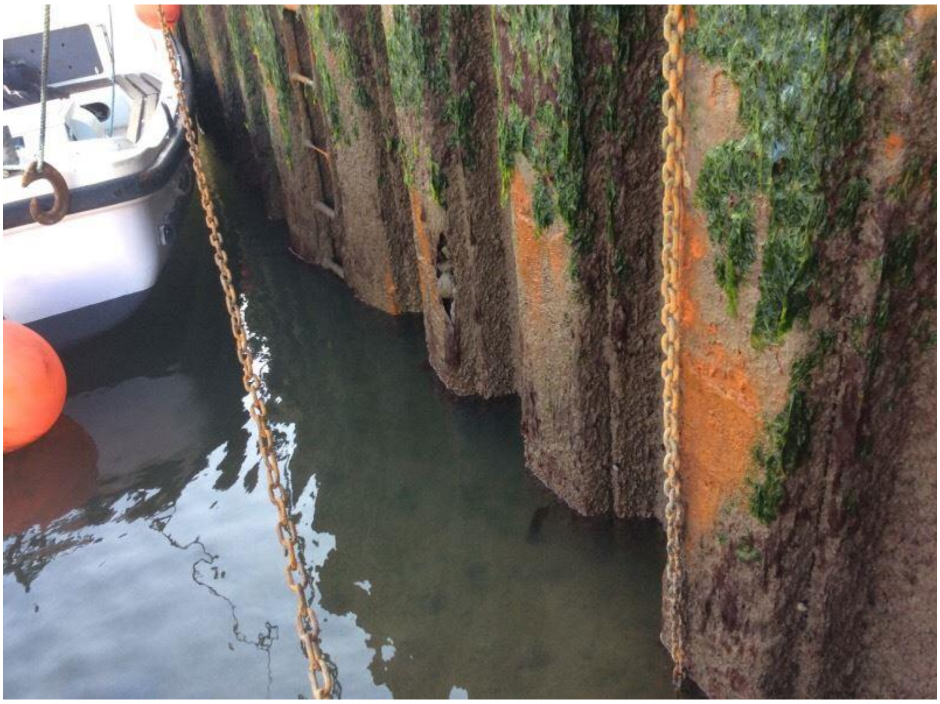
Section G **Seaward face** **Defect Ref: D65** **Description:** D65 - Exposed steel corroding. **Photo number: 229**	
Section G **Seaward face** **Defect Ref: D66** **Description:** D66 - Corroded handrails **Photo number: 164**	

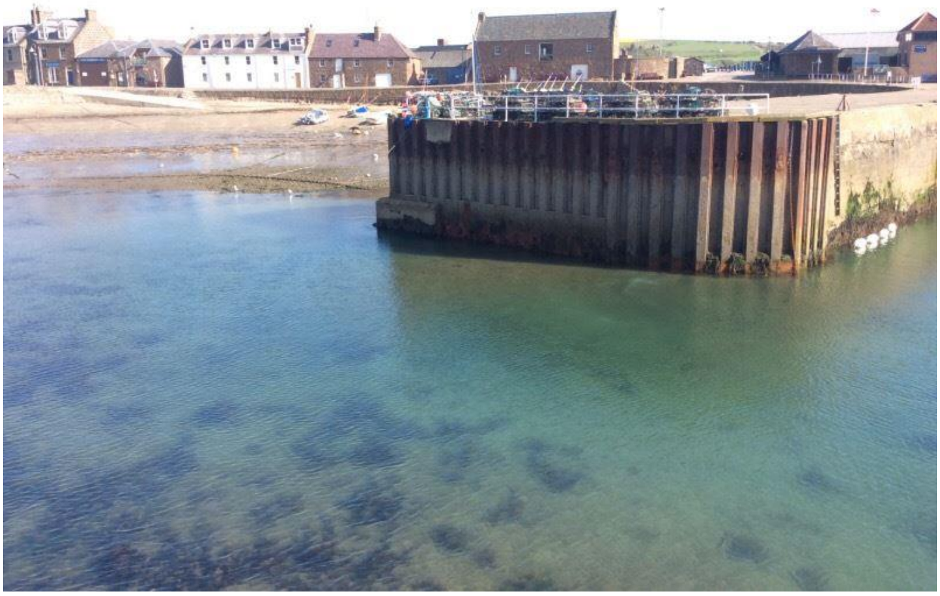
Section G **Seaward face** **Defect Ref: D67** **Description:** D67 - Health and Safety - Damaged handrailing around stepped access. **Photo number: 165**	
Section G **Seaward face** **Defect Ref: D67** **Description:** D67 - Health and Safety - Damaged handrailing around stepped access. **Photo number: 210**	

Section G **Deck** **Defect Ref: D68** **Description:** D68 - Insufficient handrailing **Photo number: 166**	
Section G **Deck** **Defect Ref: D68** **Description:** D68 - Insufficient handrailing **Photo number: 211**	

Section G **Deck** **Defect Ref: D69** **Description:** D69 - Damaged surfacing of deck **Photo number: 167**	
Section D **Sheet piling** **Defect Ref: D72** **Description:** D72 - Two holes in piles, approximately 0.3x0.1m and 0.3x0.3 **Photo number: 169**	

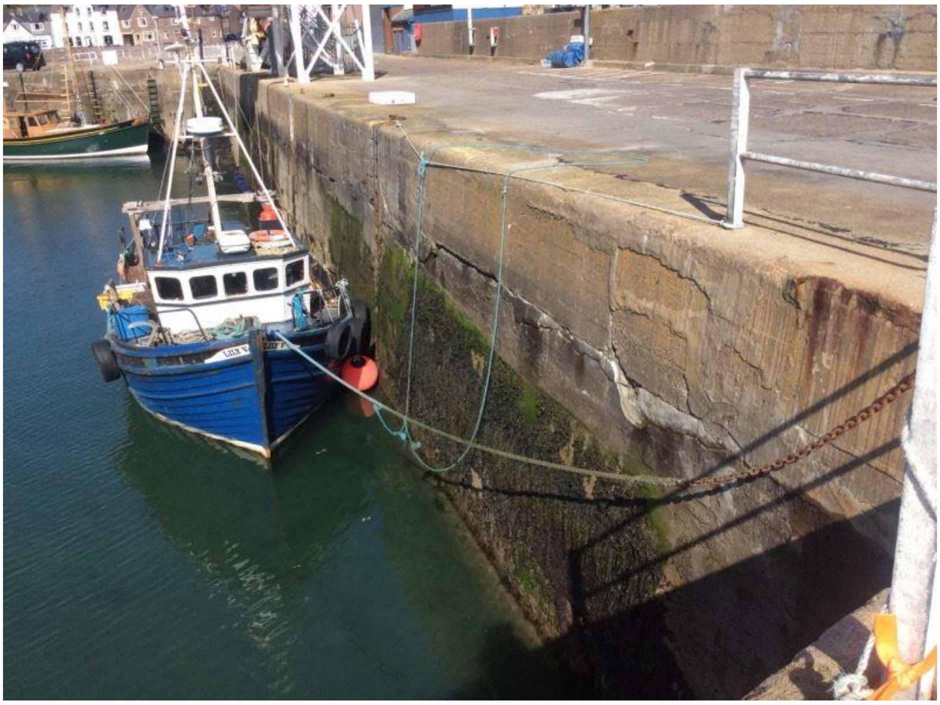
Section D **Sheet piling** **Defect Ref: D72** **Description:** D72 - Two holes in piles, approximately 0.3x0.1m and 0.3x0.3 **Photo number: 214**	
Section D **Sheet piling** **Defect Ref: D72** **Description:** D72 - Two holes in piles, approximately 0.3x0.1m and 0.3x0.3 **Photo number: 230**	

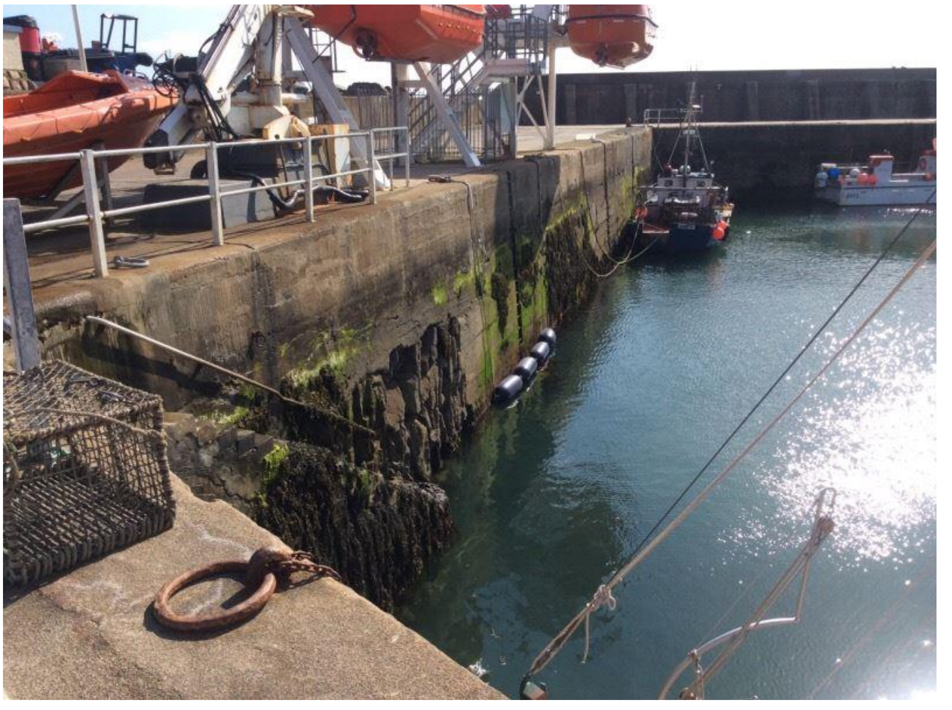
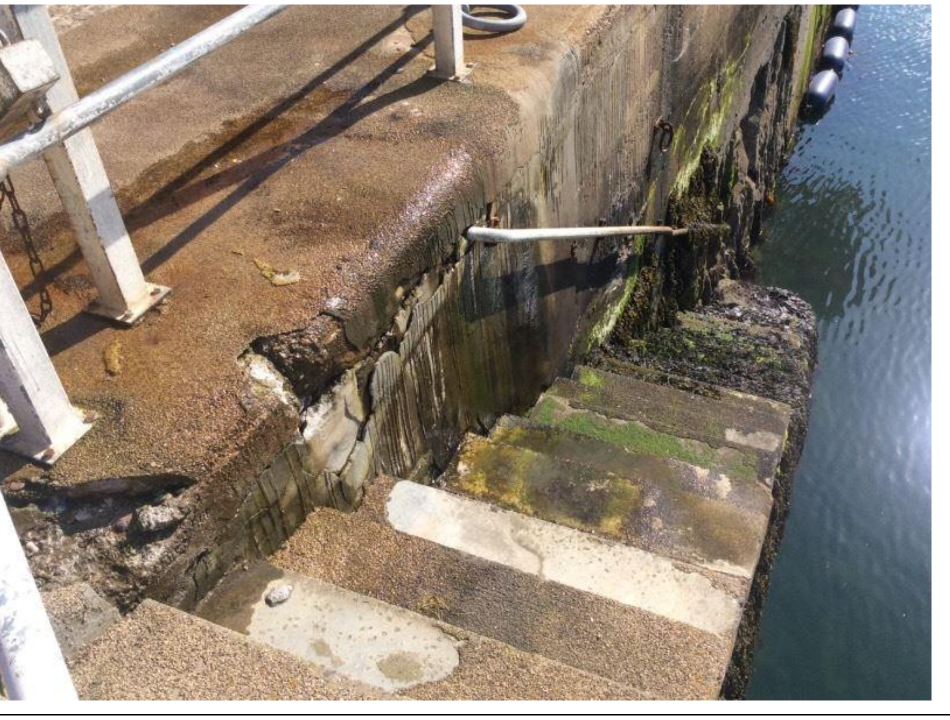
Section D **Sheet piling** **Defect Ref: D72** **Description:** D72 - Two holes in piles, approximately 0.3x0.1m and 0.3x0.3 **Photo number: 235**	
Section F **Sheet piling** **Defect Ref: D73** **Description:** D73 - 6 no of holes corroded through piles. **Photo number: 170**	

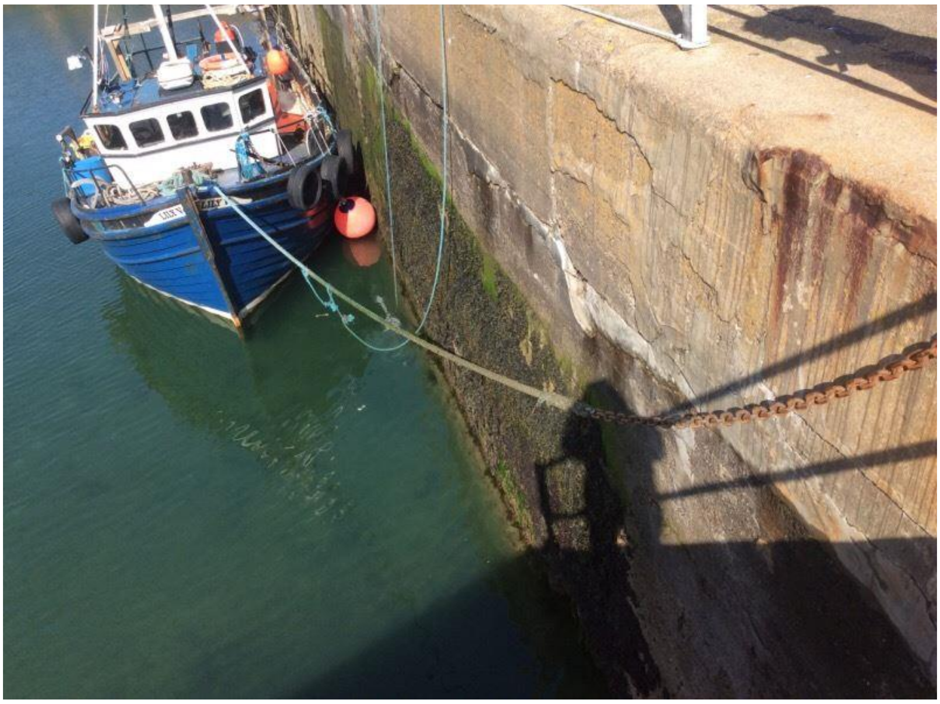
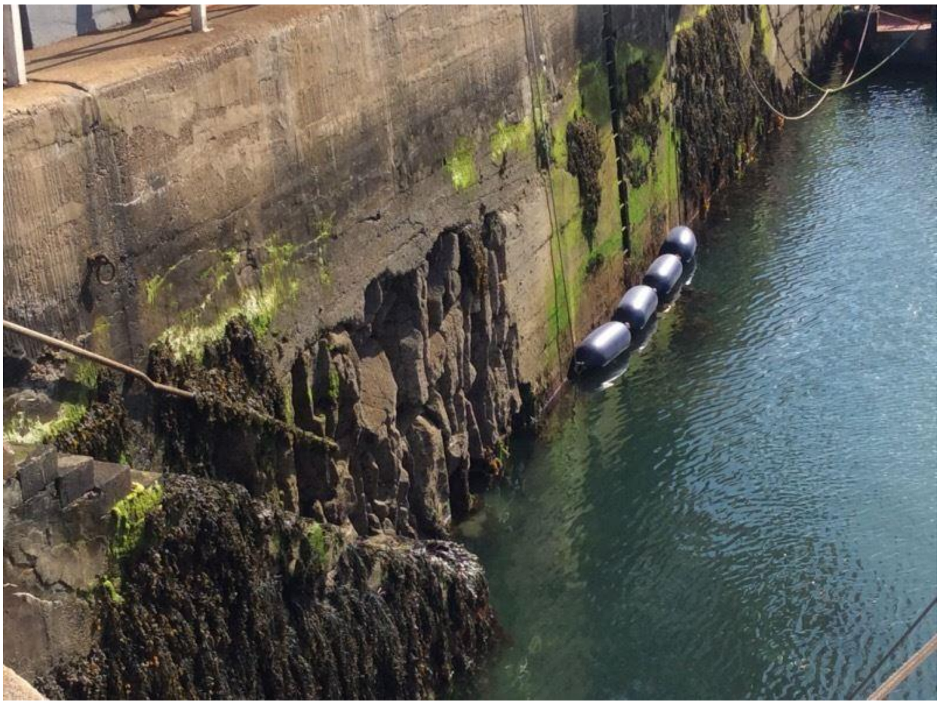
Section F **Sheet piling** **Defect Ref: D75** **Description:** D75 - Missing anchor plates. **Photo number: 171**	
Section F **Quay face** **Defect Ref: D76** **Description:** D76 - Delaminating concrete repairs **Photo number: 172**	

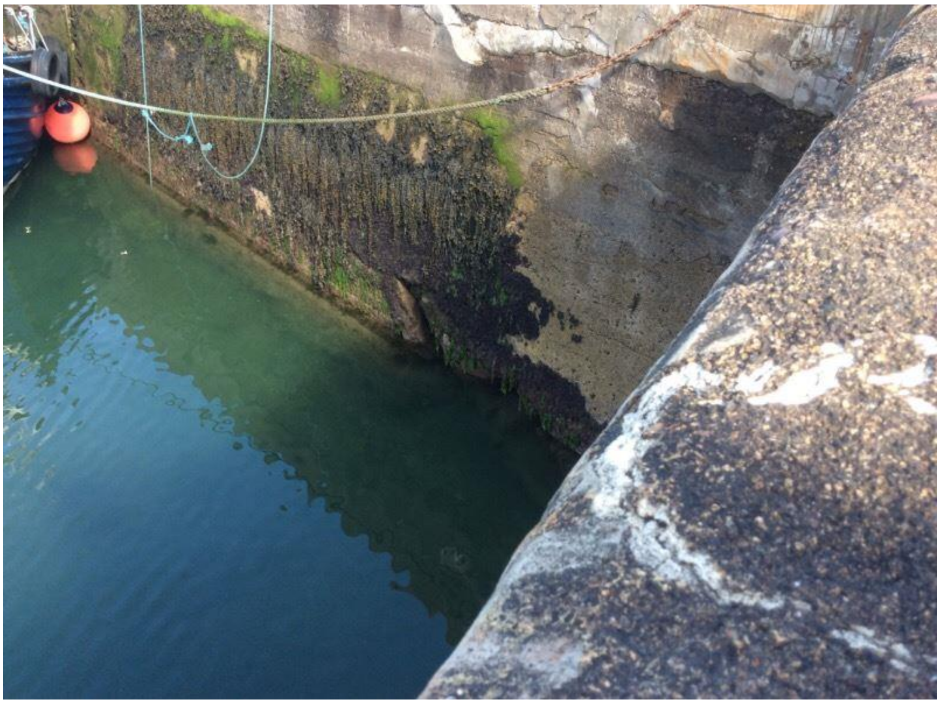
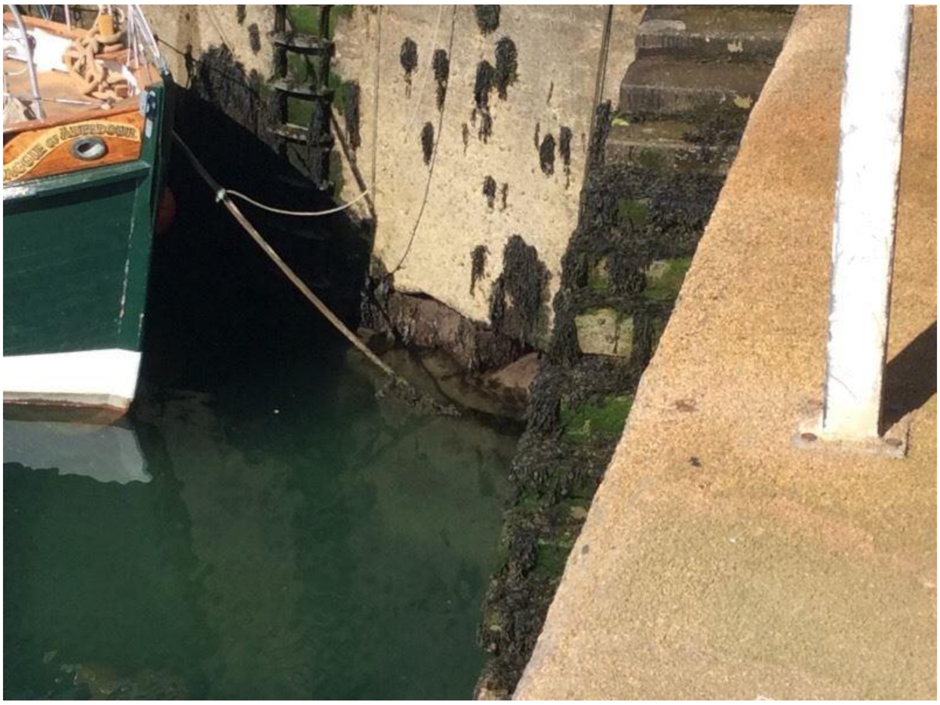
Section F **Quay face** **Defect Ref: D77** **Description:** D77 - Undermining scour on toe of old concrete toe repairs. **Photo number: 175**	
Section F **Quay face** **Defect Ref: D77** **Description:** D77 - Undermining scour on toe of old concrete toe repairs. **Photo number: 217**	

<table>
<tr><td>Section F
Quay face
Defect Ref: D78
Description: D78 - Open joints
Photo number: 176</td><td></td></tr>
<tr><td>Section F
Quay face
Defect Ref: D78
Description: D78 - Open joints
Photo number: 218</td><td></td></tr>
</table>

Section B **Seaward face** **Defect Ref: D79** **Description:** D79 - Protective apron possibly undermined - not long enough to provide protection to that face **Photo number: 177**	
Section G **Quay face** **Defect Ref: D80** **Description:** D80 - concrete cracking **Photo number: 180**	

Section G **Quay face** **Defect Ref: D81** **Description:** D81 - Spalling , delaminating concrete **Photo number: 178**	
Section G **Quay face** **Defect Ref: D81** **Description:** D81 - Spalling , delaminating concrete **Photo number: 219**	

Section G **Quay face** **Defect Ref: D81** **Description:** D81 - Spalling , delaminating concrete **Photo number: 231**	
Section G **Quay face** **Defect Ref: D82** **Description:** D82 - Area of protection rock possible undermined. **Photo number: 179**	

Section G **Quay face** **Defect Ref: D83** **Description:** D83 - Possible undermining scour. **Photo number: 181**	
Section F **Quay face** **Defect Ref: D84** **Description:** D84 - Undermining scour on the seaward facing side **Photo number: 182**	

Section H **Rock armour** **Defect Ref: D85** **Description:** D85 - Undersized rock armour units **Photo number: 183**	
Section H **Rock armour** **Defect Ref: D85** **Description:** D85 - Undersized rock armour units **Photo number: 220**	

Section H **Rock armour** **Defect Ref: D85** **Description:** D85 - Undersized rock armour units **Photo number: 232**	
Section H **Rock armour** **Defect Ref: D86** **Description:** D86 - Overly steep rock armour profile **Photo number: 186**	

Section H **Splash wall** **Defect Ref: D87** **Description:** D87 - Blockwork missing **Photo number: 184**	
Section H **Rock armour** **Defect Ref: D88** **Description:** D88 - Narrow rock armour crest width **Photo number: 185**	

Appendix 2 – Asset descriptors

Asset Type	Sub Type	Element
Defence	Wall	Exposed face
		Landward face
		Crest
		Berm
		Channel side
		Landward toe
		Capping wall
		Access strip
		Core
		Drainage ditch
		Seaward toe
		Rock armour
	Embankment	Exposed face
		Landward face
		Crest
		Berm
		Channel side
		Landward toe
		Access strip
		Splash deck
		Splash wall
		Seaward toe
		Rock armour
		Piling
		Gabions
	Quay	Quay face
		Deck
		Capping
		Piling
		Planking
		Stem
		Roundhead
		Sheet piling
		Seaward face
		Face protection
	Dune	Stabilised zone
		Active zone
	Cliff	Seaward face
		Cliff top
		Seaward toe
		Face protection
		Drainage

Asset Type	Sub Type	Element
		Crest
		Left face
		Right face
		Piling
		Planking
	Groyne	Waling
		Roundhead
		Fishtail
		Stem
		Sheet piling
Beach Structure		Capping beam
		Crest
		Seaward face
		Landward face
		Sheet piling
		Bedding layer
	Breakwater	Face protection
		Roundhead
		Fishtail
		Capping beam
		Waling

Appendix 3 – EA Condition Grades

2.0 Visual inspection condition grades

The condition grading and descriptions given below are the standards adopted by the Environment Agency. The five condition grades, ranging from 'very good' to 'very poor', remain as before. However, the descriptions have been redefined, compared to the previous versions of the Condition Assessment Manual, to reflect condition according to flood defence performance.

2.1 General assessment

Grade	Rating	Description
1	Very Good	Cosmetic defects that will have no effect on performance
2	Good	Minor defects that will not reduce the overall performance of the asset
3	Fair	Defects that could reduce performance of the asset
4	Poor	Defects that would significantly reduce the performance of the asset. Further investigation needed
5	Very Poor	Severe defects resulting in complete performance failure

D Baseline Environment Report

Stonehaven Bay Coastal Flood Protection Study

Desktop Environmental Baseline Report

Final Report

September 2018

www.jbaconsulting.com

Aberdeenshire COUNCIL

JBA Project Manager

Nicci Buckley BSc MSc CSci MCIWEM C.WEM
Unit 2.1
Quantum Court
Research Avenue South
Riccarton
EDINBURGH
EH14 4AP

Revision history

Revision Ref/Date	Amendments	Issued to
P01 / 2 July 2018	Draft Report	G McCallum L Watson S McFarland
P02 / 27 September 2018	Final Report	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 Graeme McCallum. Anissia Halwyn and Sarah King of JBA Consulting carried out this work.

Prepared by .... Anissia Halwyn BSc PhD

Eco-geomorphologist

.... Sarah King BSc MSc GradCIEEM

Assistant Ecologist

Reviewed by .... Dorian Latham BA PhD CEnv MIEEM

Technical Director - Environment

Purpose

This document has been prepared as a Final Report for Aberdeenshire Council. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared. 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.

Copyright

© Jeremy Benn Associates Limited 2018.

Carbon footprint

JBA is aiming to reduce its per capita carbon emissions.

Contents

List of Figures

List of Tables

Abbreviations

CIEEM	Chartered Institute of Ecology and Environmental Management
EPS	European Protected Species
HRA	Habitats Regulations Assessment
INNS	Invasive Non-Native Species
JNCC	Joint Nature Conservation Committee
LNCS	Local Nature Conservation Site
LNR	Local Nature Reserve
MCZ	Marine Conservation Zone
NESBReC	North East Scotland Biological Records Centre
NNR	National Nature Reserve
PEA	Preliminary Ecological Appraisal
PVA	Potentially Vulnerable Area
SAC	Special Area of Conservation
SNH	Scottish Natural Heritage
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
WANE Act	Wildlife and Natural Environment (Scotland) Act
W&CA	Wildlife and Countryside Act

Executive Summary

JBA Consulting was commissioned by Aberdeenshire Council to undertake a desktop ecological assessment of Stonehaven Bay, Aberdeenshire. The results of this study will be used to inform the development of options for Stonehaven Bay Coastal Flood Protection Scheme.

A desk study was undertaken in June 2018 to review existing ecological baseline information available in the public domain and to obtain ecological records held by third parties.

Garron Point SSSI is within the northern area of the site extent in Stonehaven Bay. The proposed coastal flood protection scheme should be designed so as to minimise any effects on the geology, habitats and species for which the SSSI is designated.

Garron Point Special Area of Conservation and Fowlsheugh Special Protection Area are within 2km of the site. The options appraisal will need to consider the ecological impacts to the designated sites at an early stage. Any proposed works will need to aware of the presence of qualifying bird species from the SPA and if works take place within the northern extent of the site, the presence of Narrow-mouthed Whorl Snail *Vertigo angustior* in Garron Point SAC will need to be considered. The proposed works will need to ensure there are no changes in groundwater run-off or the flooding regime within the SAC to the north.

It is recommended that a Preliminary Ecological Appraisal survey and report is conducted when the scope and extent of works are known. Recommendations for protected species surveys may also be made within the PEA report.

When a final option for the works is known and detailed method statements are available, a Marine Licence will need to be obtained from Marine Scotland. A Habitats Regulations Appraisal and SSSI assent from SNH will be obtained as part of this procedure.

1 Introduction

1.1 Overview

JBA Consulting was commissioned by Aberdeenshire Council to undertake a desktop environmental baseline assessment of Stonehaven Bay, Aberdeenshire. The results of this survey will be used to inform the development of options for Stonehaven Bay Coastal Flood Protection Scheme.

This report identifies the likely ecological and geological constraints associated with the proposed scheme. The report will present the actions required to develop the ecological impact assessment and, in turn the required mitigation and potential opportunities for enhancement.

The approach to this appraisal follows best practice guidance published by the Chartered Institute of Ecology and Environmental Management (CIEEM) including Guidelines for Ecological Report Writing (CIEEM, 2015). The report follows standard biotope methodologies in the Marine Monitoring Handbook (Davies *et a*l., 2001), designed to assess the condition of marine Special Areas of Conservation (SACs) in the UK, which fulfil the UK's common standards for monitoring.

1.2 Site Location and Description

Stonehaven and Cowie are located approximately 20km south of Aberdeen. They sit within Stonehaven Bay on the North Sea, with the Rivers Carron and Cowie flowing through the town and discharging into the bay. The area has been identified as a Potentially Vulnerable Area (PVA) and is at risk of coastal flooding.

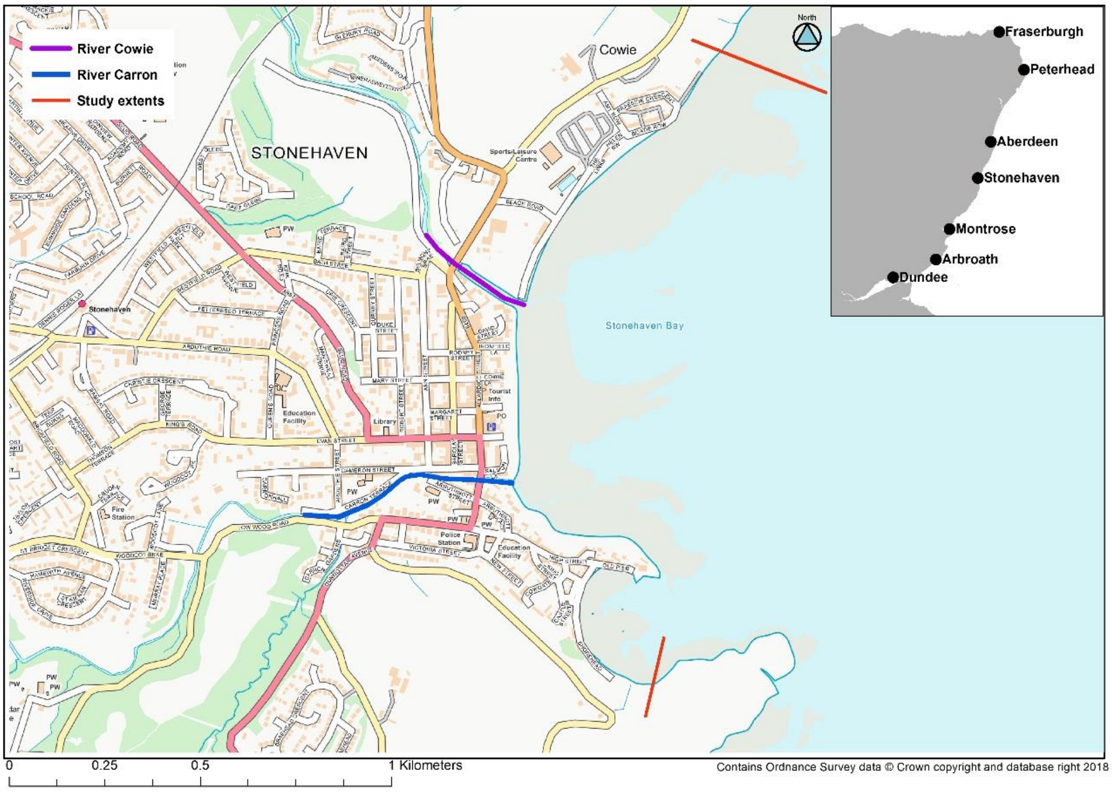


Figure 1-1: Location Plan

1.3 Proposed Works

This report will inform the development of options to provide a coastal flood protection scheme for Stonehaven Bay. Works are expected to take the form of coastal flood defences in Stonehaven Bay.

Details of the proposed works are not currently known; however, they are likely to involve some, or all of the following measures:

- Coastal beach recharge;
- Shingle restoration (coastal sediment recycling);
- Fluvial sediment management and morphological improvements;
- Hard engineering, e.g. raising sea walls; rock armour.

The first three measures are recommended and detailed in the Natural Flood Management and River Basin Management Plan report (JBA Consulting, 2018).

2 Legislation and Planning Policy

The primary legislation in Scotland covering nature conservation and wildlife protection is outlined below. The legislation makes it an offence to kill or capture certain animals including birds, or to remove certain native plants. The law also protects certain animals from disturbance including disturbance of their nests and/ or resting places. This section is not intended as a detailed appraisal of wildlife legislation, or provision of a legal opinion, but aims to provide a summary context to support the desktop ecology report.

2.1 Habitats Directive and Conservation (Natural Habitats, &c.) Regulations 1994

In Scotland, the EU Habitats Directive is transposed through a combination of the Habitats Regulations 2010 (in relation to reserved matters) and the 1994 Regulations. These Regulations afford protection to certain species identified in the Habitats Directive, including those requiring strict protection (European Protected Species (EPS)). Section 2.5 below provides further details on specific species.

The Habitats Regulations 1994 (as amended in Scotland) implement the species protection requirements of the Habitats Directive in Scotland on land and inshore waters (0-12 nautical miles). There are various Schedules attached to the Habitats Regulations including Schedule 2 and 4 which relate to European protected species (fauna and flora, respectively) and Schedule 3 with relates to those animals in Annex V of the Habitats and Species Directive whose natural range includes Great Britain.

The designation and protection of domestic sites, e.g. Sites of Special Scientific Interest (SSSI), and European sites e.g. Special Protection Areas (SPA) and Special Areas of Conservation (SAC) falls within these Regulations.

Public bodies (including the Local Planning Authority) have a duty to have regard to the requirements of the Habitats Directive in carrying out their duties, i.e. when determining a planning application.

The Habitats Regulations Appraisal (HRA) requirements protect European sites by requiring that any plan or project which may have a 'likely significant effect (LSE)' on a site (either individually or in combination with other plans or projects) must be subject to an Appropriate Assessment of its implications for the site in view of the site's conservation objectives. The HRA process is mandatory under the Habitats Directive implemented through The Conservation (Natural Habitats, &c.) Regulations 1994. As part of the process Scottish Natural Heritage (SNH) must be consulted.

The HRA is a multi-stage process through which Appropriate Assessment (AA) is carried out, if in the primary Screening stage of the HRA it is determined that the project may have an adverse impact upon a Natura 2000 site. Such plans or projects may only proceed if they will not adversely affect the integrity of the European site concerned, without the decision of the over-riding public interest. HRA Screening will be required for the site once a preferred option(s) has been selected and the likely scope and extent of works have been planned.

2.2 Wildlife and Countryside Act 1981 (as amended)

The Wildlife and Countryside Act (W&CA) 1981 (as amended) constitutes an important statute relating to the protection of flora, fauna and the countryside within Great Britain. Part 1 of the Act deals with the protection of wildlife. Most

EPS are now covered under the Conservation of Habitats and Species Regulations (as amended; see section 2.1) however certain species and activities are still covered by the W&CA. The W&CA also covered possession of species listed in the various schedules. In Scotland, the W&CA is amended by The Nature Conservation (Scotland) Act 2004 and The Wildlife and Natural Environment (Scotland) Act 2011.

2.3 Nature Conservation (Scotland) Act 2004

The Act serves to make provisions in relation to the conservation of biodiversity; to make further provision in relation to the conservation and enhancement of Scotland's natural features; to amend the law relating to the protection of certain birds, animals and plants; and for connected purposes. Under Section 2(4) of the Act a Scottish Biodiversity List, a list of animals, plants and habitats that Scottish Ministers consider to be of principal importance for biodiversity conservation in Scotland, was compiled.

2.4 Wildlife and Natural Environment (Scotland) Act 2011

The Wildlife and Natural Environment (Scotland) Act (WANE Act) is an Act of the Scottish Parliament to make provision in connection with wildlife and the natural environment; and for connected purposes.

2.5 Protected Species

Certain species and species groups are afforded specific protection under the Conservation (Natural Habitats, &c.) Regulations 1994 and the W&CA 1981 (as amended). Furthermore, under these laws provisions are made for control of spread of non-native invasive species. Relevant species and levels of protection in Scotland are detailed below (Scottish Natural Heritage, 2018).

2.5.1 Badger

Badgers *Meles meles* and their setts are protected by the Protection of Badgers Act 1992. This Act has been supplemented by the WANE Act, making it illegal to kill, injure or take a Badger, or to interfere with an active sett, including blocking an active entrance or allowing a dog to enter the sett. Furthermore, under this legislation, it is illegal to dig for, cruelly ill-treat, or tag a Badger.

2.5.2 Red Squirrel

Red Squirrels *Sciurus vulgaris* are listed on Schedule 5 of the Wildlife and Countryside Act 1981 (as amended). It is an offence to intentionally or recklessly:

- kill, injure or take a Red Squirrel;
- damage, destroy or obstruct access to any structure or place which a Red Squirrel uses for shelter or protection (a drey);
- disturb Red Squirrel when it is occupying a structure or place for that purpose; and
- possess or control, sell, offer for sale or possess or transport for the purpose of sale any live or dead Red Squirrel or any derivative of such an animal.

2.5.3 Otter

The European Otter *Lutra lutra* is a EPS protected under the Conservation (Habitats &c) Regulations 1994, making it an offence to:

- deliberately capture, injure or kill an Otter;
- deliberately disturb an Otter such as to affect local populations or breeding success;
- damage or destroy an Otter holt, possess or transport an Otter or any part of an Otter; and
- sell or exchange an Otter.

Otters also receive protection under the Wildlife and Countryside Act 1981 (as amended), this makes it an offence to:

- intentionally or recklessly disturb any Otter whilst within a damage or destroy a breeding site (holt) or resting place of such an animal; and
- intentionally or recklessly obstruct access to a holt or other structure or place otters use for shelter or protection, or otherwise deny the animal use of that place.

2.5.4 Water Vole

The Water Vole *Arvicola amphibious* is protected under the Wildlife and Countryside Act 1981 (as amended). This makes it an offence to:

- intentionally kill, injure or capture a Water Vole;
- possess or control a Water Vole, living or dead, or any part of a Water Vole;
- intentionally or recklessly damage, destroy or obstruct access to any place of shelter, or disturb a Water Vole within such a place; and
- sell or offer for sale a Water Vole living or dead, or part of a Water Vole.

2.5.5 Bats

All UK bat species are EPS under the Conservation (Habitats &c) Regulations 1994. It is an offence to:

- deliberately kill, injure or capture any bat;
- intentionally or recklessly disturb a bat, or deliberately disturb a group of bats;
- damage or destroy, or intentionally or recklessly obstruct access to, a bat roosting place; and
- possess, or sell (living or dead) any bat or part of a bat.

Furthermore, amendments to the Regulations (2007-2012) include, under Regulation 40, that it is no longer a defence to state that killing, capture or disturbance of bats or the destruction of their roosts was an incidental or unavoidable result of a lawful activity.

2.5.6 Breeding Birds

All wild birds (with certain exceptions listed in Schedule 2) are protected under the Wildlife and Countryside Act 1981 (as amended). This makes it an offence to intentionally:

- kill, injure, or take any wild bird;
- take, damage or destroy the nest of any wild bird whilst it is in use or being built; and
- take, destroy or possess the egg of any wild bird.

Furthermore, certain species receive additional protection under Schedule 1, which makes it an offence to disturb these species while they are nest building, or at a nest containing eggs or young, or disturb the dependent young of such birds.

Those species listed on Schedules A1 and 1A receive additional protection which makes it an offence to intentionally or recklessly:

- at any time take, damage, destroy or otherwise interfere with any nest habitually used by any wild bird, when not in use, included in Schedule A1; and
- at any time harass any wild bird included in Schedule 1A.

2.5.7 Reptiles and Amphibians

Legal protection varies considerably for different species. Smooth Snake *Coronella austriaca*, Sand Lizard *Lacerta agilis* and Natterjack Toads *Epidalea calamita* are EPS receiving the same protection as Great Crested Newt. Under the Wildlife and Countryside Act 1981 (as amended) Adder *Viperus berus*, Grass Snake *Natrix natrix*, Common Lizard *Zootoca vivipara* and Slow Worm *Anguis fragilis* are protected from intentional killing or injuring, additionally Common Frogs *Rana temporaria*, Common Toads *Bufo bufo* and other newt species are prohibited from sale.

2.5.8 Wildcat

The Wildcat is a EPS under the Conservation (Habitats &c) Regulations 1994. It is an offence to deliberately or recklessly:

- Capture, injure, kill or harass a wildcat;
- Disturb a wildcat in a den or any other structure or place it uses for shelter or protection;
- Disturb a wildcat while it is rearing or otherwise caring for its young;
- Obstruct access to a den or other structure or place wildcats use for shelter or protection or otherwise deny the animal use of that place;
- Disturb a wildcat in a manner or in circumstances likely to significantly affect the local distribution or abundance of the species;

Disturb a wildcat in a manner or in circumstances likely to impair its ability to survive, breed or reproduce, or rear or otherwise care for its young.

It is also an offence to damage or destroy a breeding site or resting place of such an animal whether or not intentionally or recklessly.

2.5.9 Cetaceans

All species of dolphin, whale and porpoise found in Scottish territorial waters are protected under the Conservation (Natural Habitats, &c.) Regulations 1994. This makes it an offence to intentionally or recklessly:

- Kill, injure or capture a cetacean;
- Disturb or harass a cetacean; and
- Damage or destroy a breeding site or resting place of such an animal (whether or not deliberately or recklessly).

2.5.10 Seal

The main legislation that protects seals in Scottish waters is the Marine (Scotland) Act 2010. Seals are also protected under the Conservation (Natural Habitats, &c) Regulations 1994 and the Protection of Seals (Designation of Haul-Out Sites) (Scotland) Order 2014.

It is an offence to intentionally or recklessly kill, injure or take a seal at any time of year, except:

- To alleviate suffering
- Where Marine Scotland has issued a licence to do so

It is also an offence to intentionally or recklessly harass seals at significant haul-out sites under the Protection of Seals (Designation of Haul-out Sites) (Scotland) Order 2014

2.5.11 Invasive Non-native Species (INNS)

Schedule 9 of the Wildlife and Countryside Act 1981 (as amended) lists 62 plant species, or groups of plants, and 69 animal species. The major amendment to this Act in Scotland is found in the WANE Act (2011). It is an offence to release or cause to spread in the wild any of these species. Of particular note are Japanese Knotweed *Fallopia japonica*, Himalayan Balsam *Impatiens glandulifera*, Giant Hogweed *Heracleum mantegazzanum* and Signal Crayfish *Pacifastacus leniusculus*.

2.6 Planning Policy

2.6.1 Aberdeenshire Local Development Plan 2017

The Aberdeenshire Local Development Plan (Aberdeenshire Council, 2017) contains Policy E1 Natural Heritage, which sets out what development can be permitted in relation to nature conservation sites, protected species and wider biodiversity and geodiversity. The following details of Policy E1 are relevant to the proposed coastal flood protection scheme at Stonehaven:

- New development will not be allowed where it may have an adverse effect on a nature conservation site, except in the case of:
    - an internally designated site where there are imperative reasons of overriding public importance and there is no alterative solution;
    - for nationally designated sites where a thorough assessment has demonstrated that the overall integrity of the site will not be comprised;
    - for local nature conservation sites where the proposal's public benefits clearly outweigh the nature conservation value of the site;
    - In all cases impacts must be suitably mitigated and suitable compensatory measures must be implemented;
- Development should seek to avoid detrimental impact on protected species through the carrying out of surveys and submission of protection plans describing appropriate mitigation where necessary;
- A baseline ecological survey should be prepared for all major development and for smaller proposals where there is evidence that a habitat, geological feature or species of importance may exist on the site; and

- All developments should identify measures that will be taken to improve biodiversity and geodiversity in proportion to the potential opportunities available and the scale of the development.

3 Methodology

3.1 Desk Study

A desk study was undertaken in June 2018 to review existing ecological baseline information available in the public domain and to obtain ecological records held by third parties.

For the purposes of the desk study, the study area was defined to be the site and a 1km radius around it. Information was requested from North East Scotland Biological Records Centre (NESBReC) including records of non-statutory designated nature conservation sites and notable and protected species. Historic records (those preceding 2000) of species whose habitat are considered not to be relevant to the site have been excluded from this report. The full data search results can be provided upon request.

In addition, the MAGIC database (a UK Government website that provides authoritative geographic information about the natural environment) was searched for statutory designated sites within 2km of the site including Marine Conservation Zones (MCZ), Sites of Special Scientific Interest (SSSI), National Nature Reserves (NNR), Local Nature Reserves (LNR), European designated Natura 2000 sites (SACs, SPAs) and internationally designated Ramsar sites.

3.2 Data Limitations

Data from biological records centres, or on-line databases, is historical information and datasets might be incomplete, inaccurate or missing. It is important to note that even where data is held, a lack of records for a defined geographical area does not necessarily mean that the species is absent; the area may simply be under-recorded.

4 Desk Study Results

4.1 Statutory Designated Sites

A search of the MAGIC database identified one SSSI within the site boundary and one SAC and one SPA within 2km of the site (see Appendix A) these are detailed below.

4.1.1 Garron Point SAC

Garron Point SAC is approximately 850m to the north east of the site (see Appendix A). The SAC is designated for the population of Narrow-mouthed Whorl Snail *Vertigo angustior* which has very specific habitat requirements, needing marshy, coastal turf, high and even humidity and flowing groundwater, but no deep or prolonged flooding or desiccation (Joint Nature Conservation Committee (JNCC), 2015). At Garron Point it is found in two small areas of damp, free-draining Red Fescue grassland. This is the most northerly population of the species in the UK. This snail species is the only qualifying interest feature for Garron Point SAC. Communication with SNH or a specialist is required to determine the exact distribution of Narrow-mouthed Whorl Snail at Garron Point.

4.1.2 Fowlsheugh SPA

Fowlsheugh SPA is located approximately 1.7km to the south of the site at Stonehaven (see Appendix A). The site is designated as it supports populations of the following species during the breeding season (JNCC, 2001):

- Guillemot *Uria aalge*, 40,140 pairs representing at least 1.8% of the breeding East Atlantic population (Count as at 1992);
- Kittiwake *Rissa tridactyla*, 34,870 pairs representing at least 1.1% of the breeding Eastern Atlantic - Breeding population (Count, as at 1992).

The site also qualifies as containing a seabird assemblage of international importance by regularly supporting 170,000 individual seabirds during the breeding season, including Razorbill *Alca torda*, Herring Gull *Larus argentatus*, Fulmar *Fulmarus glacialis*, Guillemot *Uria aalge* and Kittiwake *Rissa tridactyla*.

Birds from Fowlsheugh SPA are likely to use surrounding habitats, such as littoral sediment present within the site extent (Appendix B) for foraging.

4.1.3 Garron Point SSSI

Garron Point SSSI overlaps with Garron Point SAC and is located to the north of Stonehaven and is within the site extent for this study (see Appendix A). The SSSI is designated for its geology as well as its biological interest. The site supports maritime cliff habitat with large areas of cliff grassland and smaller areas of sand dune, saltmarsh and shingle (SNH, 2005).

Geology

Garron Point SSSI is of national and international importance for a number of geological formations. The coastal outcrop of the Highland Boundary Fault marks the southern geological boundary of the Scottish Highlands. The site demonstrates the structural relationship between the Dalradian, Highland Border Complex and Old Red Sandstone, which are major subdivisions in the geological history of the British Isles. The largest extent of igneous outcrops in the Highland Border Complex lie between Garron Point and Slug Head (approximately 500m to the south of the promontory). The complex is composed of remnants of ocean crust, consisting mainly of metamorphosed tholeiitic pillow lavas with intercalated cherts, siltstones and mudstones. Subordinate gabbroic and doleritic intrusions also lie within the complex. Associated spatially with these rocks is a carbonated and silicified serpentinite with nodules of serpentinized gabbroic rocks.

South of Slug Head, 'Old Red Sandstone' occurs. This section of the SSSI overlaps with the most northern part of the study extent. These rocks are primarily non-marine Devonian, part of the Cowie Sandstone Formation and the Carron Sandstone Formation. They formed from fluvial deposits, with the exception of the Cowie Harbour Siltstone Member, which formed from lacustrine deposits. At the Toutties, the Cowie Harbour Siltstone Member includes a mudstone containing freshwater fish fossils (Cowie Harbour Fish Bed). This site is unique as being the only one of this age in the Scottish-Baltic fish province.

Biology

The cliff grassland is dominated by species typical of this habitat, such as False Oat-grass *Arrhenatherum elatius*, Red Fescue *Festuca rubra* and Yorkshire Fog *Holcus lanatus*. Other species present include Thrift *Armeria maritima*, Sea Plantain *Plantago maritima*, Sea Campion *Silene uniflora* and Common Scurvygrass *Cochlearia officinalis*. Several species that are uncommon in Aberdeenshire are also present in the cliff grassland, these are Purple Milk-vetch *Astragalus danicus*, Meadow Saxifrage *Saxifraga granulata*, Carline Thistle *Carlina vulgaris* and Bloody Crane's-bill *Geranium sanguineum* (SNH, 2005). The habitats map in Appendix B indicates that most biological interest within the SSSI would be found outside the study extent, on maritime cliffs or grassland.

Garron Point SSSI is also designated as it supports populations of Narrow-mouthed Whorl Snail *Vertigo angustior* and Northern Brown Argus butterfly *Aricia Artaxerxes*, which are rare species of invertebrate.

SNH has produced a list of operations requiring consent within Garron Point SSSI (SNH, 2009). Those operations requiring consent that may be relevant to the proposed coastal flood protection works at Stonehaven are:

- Application of pesticides, including herbicides (weedkillers);
- Dumping, spreading or discharge of any materials;
- The destruction, displacement, removal or cutting of any plant or plant remains, including e.g. shrub, herb, turf;
- Erection of sea defences or coast protection works, including cliff or landslip drainage or stabilisation measures;
- Extraction of minerals including peat, shingle, sand and gravel, topsoil, sub-soil, shells and spoil;
- Construction, removal or destruction of roads, tracks, walls, fences, hardstands, banks, ditches or other earthworks, or the laying, maintenance or removal of pipelines and cables, above or below ground;
- Erection of permanent or temporary structures, or the undertaking of engineering works, including drilling; and
- Modification of natural or man-made features (including cave entrances), clearance of boulders, large stones, loose rock or scree and battering, buttressing, grading or seeding rock faces or outcrops.

4.2 Non-Statutory Designated Sites

The Muchalls to Stonehaven Bay Local Nature Conservation Site (LNCS) lies within the site, covering the area to the seaward side of mean high water (Appendix C). This designation reflects the biological and geological importance of the area at a regional level. The site has a diversity of coastal habitats on the cliffs and cliff top grasslands, including heathland on some of the headlands dominated bell heather Erica cinerea; maritime grassland on the more exposed coastal cliffs with species such as thrift *Armeria maritima* and wood vetch *Vicia sylvatica*; netural grassland dominated by false oat-grass *Arrhenatherum elatius*. Species associated with base-rich soils are present along this stretch, including carline thistle *Carlina vulgaris*. High plant diversity supports high insect diversity, especially insects suited to lime habitats. Along the shore, sand dune, flush and salt marsh habitats are present. Wave-cut platforms around the Garron Point-Skatie Shore coastline support diverse populations of algae. The cliff grasslands in the southern part of the sites are important habitat for the narrow-mouthed whorl snail, as detailed in section 4.1.1.

Downie Point to Todhead Coast LNCS is immediately outside the southern extent of the site. The LNCS is important for breeding seabirds and supports a range of coastal flora with some base rich areas and a good diversity of invertebrates. The site also contains features of geological and geomorphological interest, including a blowhole, hanging valley and unusual platform weathering forms.

4.3 Habitats

North East Scotland Biological Records Centre (NESBReC) habitat data is available for the area for the time periods 2004-2007, 2008-2009, 2010-2012 and 2013-2015. Data for habitats within the site was only recorded between 2004- 2007 (Appendix B). This indicates that the majority of the coastal habitat within the site is comprised of littoral sediment and littoral rock, with a small area of supralittoral sediment. The surrounding area is predominantly comprised of improved grassland and arable land.

4.4 Protected Species

The data search from NESBReC returned many recent and historical records for protected species within 1km of the site. Details of these records including key legislative protection and proximity of the record to the site is given in the following sections. Due to the large amount of data returned, the record closest to the site and the most recent record for each species (post-2000) was given greatest consideration.

4.4.1 Mammals

Protected mammal species returned in the data search are listed in Table 4-1. Wildcat is unlikely to be present on a highly disturbed coastal strip and are therefore not considered any further in this report. Although Badger and Red Squirrel have been observed within 1km of the site, there is unlikely to be habitat suitable for both species within the site extent.

The data search returned records of Water Vole within the River Carron. Water Vole is unlikely to be present on the coastal frontage but could be present within the final reaches of the Rivers Carron which is included in the site extent.

Otter records were also returned in the data search. There could be suitable habitat for Otter present in the River Carron and a previous ecological walkover conducted in 2011 confirms this (JBA Consulting 2011).

The data search returned records of bat species. Bats could be present in the wider area, if suitable habitat is present.

Table 4-1: Records of protected mammal species within 1km of the site (from NESBReC)

Common Name	Scientific Name	UK protection	Distance from Site and Date
Common Pipistrelle	*Pipistrellus pipistrellus*	Conservation (Habitats &c) Regulations 1994 Schedule 2 Wildlife and Countryside Act 1981 (as amended) Schedule 5	Within the site (2011)
Soprano Pipistrelle	*Pipistrellus pygmaeus*	Conservation (Habitats &c) Regulations 1994 Schedule 2 Wildlife and Countryside Act 1981 (as amended) Schedule 5 UKBAP Scottish Biodiversity List	Within the site River Carron (2011)
Hedgehog	*Erinaceus europaeus*	UKBAP Scottish Biodiversity List	50m N (2015)
Water Vole	*Arvicola terrestris*	Wildlife and Countryside Act 1981 (as amended) Schedule 5 UKBAP Scottish Biodiversity List	80m W and within River Carron (2014)
Otter	*Lutra lutra*	Conservation (Habitats &c) Regulations 1994 Schedule 2 Wildlife and Countryside Act 1981 (as amended) Schedule 5 UKBAP Scottish Biodiversity List	350m S (2013)
Red Squirrel	*Sciurus vulgaris*	Wildlife and Countryside Act 1981 (as amended) Schedule 5 UKBAP Scottish Biodiversity List	500m W (2012)
Badger	*Meles meles*	Protection of Badgers Act 1992 (as amended)	600m N (2015)
*Key: UKBAP= Priority Species in the UK Biodiversity Action Plan; WCA= Wildlife and Countryside Act with schedule number; BoCC= Birds of Conservation Concern Red or Amber listed			

4.4.2 Breeding and wintering birds

A number of bird species were returned in the data search, with protected species records presented in Table 4-2. The majority of these records were of songbirds and waders. It is likely that waders forage on the littoral sediment shown in the habitat maps in the appendices, although due to the disturbed nature of the habitats around the site, there may be low potential for ground-nesting birds to nest within the site.

Table 4-2: Records of protected bird species within 1km of the site (from NESBReC)

Common Name	Scientific Name	UK protection	Distance from Site and Date
Peregrine	*Falco peregrinus*	WCA 1 UKBAP Scottish Biodiversity List	Within the site (2015)
Swift	*Apus apus*	BoCC Amber Scottish Biodiversity List	Within the site (2015)
Redshank	*Tringa totanus*	BoCC Amber	Within the site (2014)
House Sparrow	*Passer domesticus*	BoCC Red UKBAP Scottish Biodiversity List	Within the site (2012)
Dunlin	*Calidris alpina*	BoCC Amber Scottish Biodiversity List	Within the site (2005)
Red-throated Diver	*Gavia stellata*	BoCC Amber Scottish Biodiversity List	Adjacent to south of site (2008)
Yellowhammer	*Emberiza citrinella*	BoCC Red UKBAP Scottish Biodiversity List	300m S (2016)
Tree Sparrow	*Passer montanus*	BoCC Red UKBAP Scottish Biodiversity List	300m S (2016)
Ring Ouzel	*Turdus torquatus*	BoCC Red UKBAP Scottish Biodiversity List	300m S (2016)
Eider	*Somateria mollissima*	BoCC Amber	650m S (2011)
Curlew	*Numenius arquata*	BoCC Red UKBAP Scottish Biodiversity List	700m NE (2013)
Skylark	*Alauda arvensis*	BoCC Red Scottish Biodiversity List	750m NE (2008)
Snow Bunting	*Plectrophenax nivalis*	WCA 1 Scottish Biodiversity List	800m S (2010)
*Key: UKBAP= Priority Species in the UK Biodiversity Action Plan; WCA= Wildlife and Countryside Act with schedule number; BoCC= Birds of Conservation Concern Red or Amber listed			

4.4.3 Amphibians and reptiles

No records of amphibians and reptiles were returned in the data search. Amphibians and reptiles are considered extremely unlikely to be present on a coastal strip and are therefore not considered any further in this report

4.4.4 Marine mammals

Records of Bottle-nosed Dolphin and Minke Whale were returned in the desk study and are likely to be found in the sea close to the study extent (Table 4-3).

Table 4-3: Records of protected marine mammal species within 1km of the site (from NESBReC)

Common Name	Scientific Name	UK protection	Distance from Site and Date
Bottle-nosed Dolphin	*Tursiops truncatus*	Conservation (Natural Habitats, &c.) Regulations 1994 Wildlife and Countryside Act 1981 (as amended) UKBAP Scottish Biodiversity List	650m SE (2012)
Minke Whale	*Balaenoptera acutorostrata*	Conservation (Habitats &c) Regulations 1994 UKBAP Scottish Biodiversity List	550m E (2011)
*Key: UKBAP= Priority Species in the UK Biodiversity Action Plan; WCA= Wildlife and Countryside Act with schedule number; BoCC= Birds of Conservation Concern Red or Amber listed			

4.4.5 Invertebrates

Records of Grayling *Hipparchia semele* and Northern Brown Argus *Aricia artaxerxes* were returned in the desk study (Table 4-3). Northern Brown Argus can be found on alkaline ground in coastal valleys, where its larval foodplant, Common Rock-rose *Helianthemum nummularium* grows. Grayling is found in dry, infertile habitats, occurring on poor, dry grasslands, dry heaths and in dunes on the coast. According to the habitat map in Appendix B, suitable habitat for these species is likely to be present in the wider area, but not within the study extent

Table 4-4: Records of protected invertebrate species within 1km of the site (from NESBReC)

Common Name	Scientific Name	UK protection	Distance from Site and Date
Grayling	*Hipparchia semele*	UKBAP Scottish Biodiversity List	Within the site (2003)
Northern Brown Argus	*Aricia artaxerxes*	UKBAP Scottish Biodiversity List	Adjacent to north of site (2016)
*Key: UKBAP= Priority Species in the UK Biodiversity Action Plan; WCA= Wildlife and Countryside Act with schedule number; BoCC= Birds of Conservation Concern Red or Amber listed			

4.4.6 Fish

A number of fish species in the River Carron were returned in the data search (Table 4-5: Records of protected fish species within 1km of the site (from NESBReC) The River Carron and its tributaries are known to be prized Trout and Salmon nurseries.

Table 4-5: Records of protected fish species within 1km of the site (from NESBReC)

Common Name	Scientific Name	Distance from Site and Date
Atlantic Salmon	*Salmo salar*	Within the site in River Carron (2010)
Brown/Sea Trout	*Salmo trutta*	Within the site in River Carron (2010)
European Eel	*Anguilla anguilla*	In River Carron (2010)
*Key: UKBAP= Priority Species in the UK Biodiversity Action Plan; WCA= Wildlife and Countryside Act with schedule number; BoCC= Birds of Conservation Concern Red or Amber listed		

4.5 Invasive Non-Native Species

Numerous records of INNS were returned in the data search these are summarised in Table 4-6 below.

Table 4-6: Records of INNS within 2km of the site

Common Name	Scientific Name	Distance from Site and Date
Purple Laver seaweed	*Porphyra umbilicalis*	Within the site (2008)
Himalayan Balsam	*Impatiens glandulifera*	On banks of River Cowie and Carron (2017)
Japanese Knotweed	*Fallopia japonica*	Adjacent to west of site (2014)
Giant Hogweed	*Heracleum mantegazzianum*	Adjacent to west of site (2017)

5 Conclusions and Recommendations

5.1 Statutory Designated Sites

When a final option for the works is known and detailed method statements are available, a **Marine Licence** will need to be obtained from Marine Scotland. A **Habitats Regulations Appraisal** and **SSSI consent** from SNH will be obtained as part of this procedure. However, the proposed coastal flood protection scheme should be designed to minimise any effects on the habitats and species for which the statutory sites are designated. Therefore, a **Preliminary Ecological Appraisal (PEA) should be commissioned as soon as possible, when the scope and extent of the preferred option is known** to establish which, if any, of the designated habitats and species could be affected by the works.

A HRA screening will need to be conducted to establish whether the works have the potential to have a likely significant effect on either Garron Point SAC or Fowlsheugh SPA.

Any proposed works within the northern extent of the site will need to be especially aware of the presence of Narrow-mouthed Whorl Snail in Garron Point SAC. The proposed works will need to ensure there are no changes in groundwater run-off or the flooding regime within the SAC to the north. If the preferred option includes works in the northern section of the study extent, communication with SNH or a specialist is required to determine the exact distribution of Narrow-mouthed Whorl Snail at Garron Point. This information will support the HRA screening assessment.

Birds from Fowlsheugh SPA are likely to use surrounding habitats for foraging. The potential impact on breeding birds must be considered so that a preferred option can be developed to minimise any effects on breeding birds. A site visit will record areas of habitat with the potential to support breeding birds. Such an assessment focuses principally on the vegetative habitats present, but also any aquatic, man-made, or other features that could support nesting birds, and will determine the need for further bird surveys. This information will support the HRA screening, which will assess the potential impacts on designated features of the SPA. Fowlsheugh is also an RSPB reserve. Therefore, discussions with the RSPB will be required once further details on the extent and nature of works are available.

Garron Point SSSI is within the northern area of the site extent in Stonehaven Bay. The proposed coastal flood protection scheme should be designed to minimise any effects on the habitats and species for which the SSSI is designated. The habitats map in Appendix B indicates that most biological interest within the SSSI would be found outside the study extent, on maritime cliffs or grassland. However, Garron Point SSSI is of national and international importance for a number of geological formations which are present within the study site. Of particular note are the Old Red Sandstone formations within the northern part of the FPS site extent, including the Cowie Harbour Siltstone Member containing freshwater fish fossils. The construction and operation of Stonehaven FPS will need to be designed to avoid any impacts on this unique geological formation within the site extent, but also to avoid impacts on the wider coast as a result of modified coastal processes.

5.2 Non-Statutory Designated Sites

The Muchalls to Stonehaven Bay Local Nature Conservation Site (LNCS) lies within the site, covering the area to the seaward side of mean high water and

Downie Point to Todhead Coast LNCS is immediately outside the southern extent of the site. The sites are important for a range of ecological, geological and geomorphological features, similar to the statutory designated sites described in section 5.1. The proposed coastal flood protection scheme should be designed to minimise any effects on the features for which the non-statutory sites are designated. Therefore, a Preliminary Ecological Appraisal (PEA) should be commissioned following confirmation of the preferred option, to establish which, if any, of the non-statutory designated sites could be affected by the works.

5.3 Habitats

The desk study identified that the habitats present within the site between 2004 and 2007 were littoral sediment and rock, with a small area of supralittoral sediment. As this information is over 10 years old the habitats on site may have changed. Once the preferred option for the coastal flood protection scheme are known, a detailed PEA survey is recommended of the areas to be affected by the proposed works. This will include a Phase 1 Habitat Survey (including Marine Habitat Classification) to broadly categorise the habitat types present on the site.

This will allow a more detailed assessment of the potential ecological constraints and opportunities to inform the detailed design.

5.4 Protected Species

The desk study identified numerous records of common bird species both within the site and in the wider area. There are no records of the seabird species for which Fowlsheugh SPA is designated. However, the lack of records does not indicate that these species are absent from the area. During an ecological walkover following confirmation of the scope and extent of the works, habitats will be assessed for their potential to support protected bird species and any incidental bird sightings during the survey will be recorded. Recommendations for further bird surveys will be made if necessary.

There are known populations of Common and Soprano Pipistrelle bats within the site. During an ecological walkover following confirmation of the scope and extent of works, trees and structures within the site will need to be inspected for their bat roost potential in line with good practice guidelines (Collins, 2016).

The River Carron had a population of Water Voles in 2014, and there were numerous reported sightings of Otter in the area in 2013. A PEA will be required following confirmation of the scope and extent of the works, where habitats will be assessed for their potential to support Otter and any field signs discovered during the survey will be recorded. The PEA survey will identify any potential Water Vole burrows or Otter holts or resting places within the proposed works area. Recommendations for further surveys for Water Vole and Otter will be made if necessary.

The River Carron also supports populations of Atlantic Salmon, Sea/ Brown Trout and European Eels. Consideration should be given to these species if any in-channel working is proposed in the River Carron, and the proposed works should be designed to maintain fish passage for these migratory species.

Marine mammals such as Minke Whale and Bottle-nosed Dolphin are present close to the site extent. These species are sensitive to underwater noise from development activity, such as piling and blasting. When the scope and nature of the works have been confirmed, communication with SNH will be required to assess the need for targeted species surveys and mitigation measures.

5.5 Invasive Non-Native Species

Records of four INNS in close proximity to the site were returned in the data search. The PEA survey will identify whether any of these species are within the area to be affected by the proposed works. Further recommendations will then be made to minimise the risk of spreading these species during works.

5.6 Summary of Recommendations

Recommendations for surveys and assessments are summarised in Table 5-1 below, along with a suggested programme. Further recommendations for any additional protected species surveys will be made in the PEA report, if necessary.

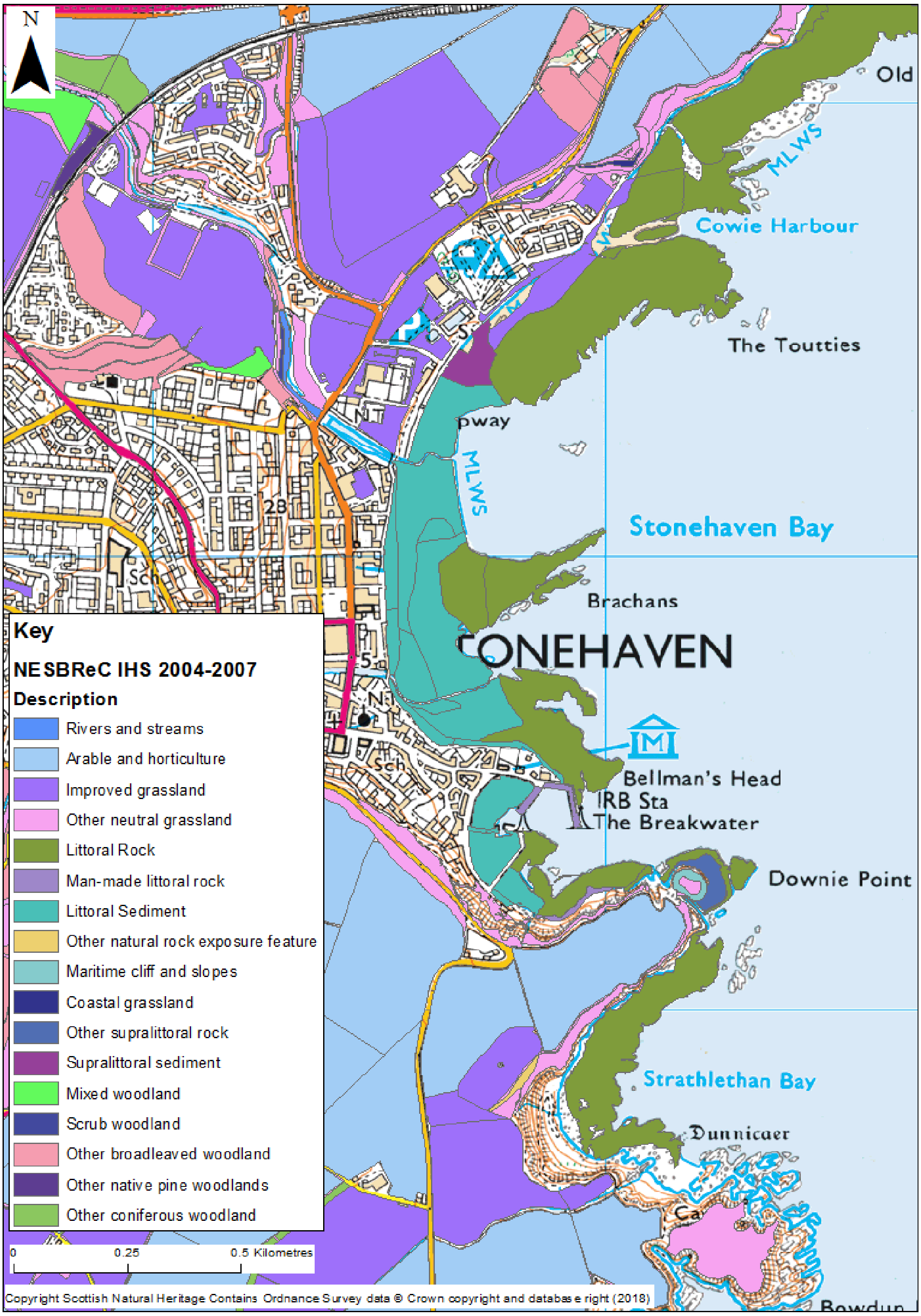
Table 5-1: Summary of Recommendations

Recommendation	Suggested Timings
PEA survey and report	When scope and extent of preferred option is known
Marine Licence	When final option is known
HRA Screening Assessment	When final option is known, as part of Marine Licence procedure. Likely to assess impact on SPA, possibly SAC if works are planned to the north of study extent.
SSSI consent	When final option is known, as part of Marine Licence procedure

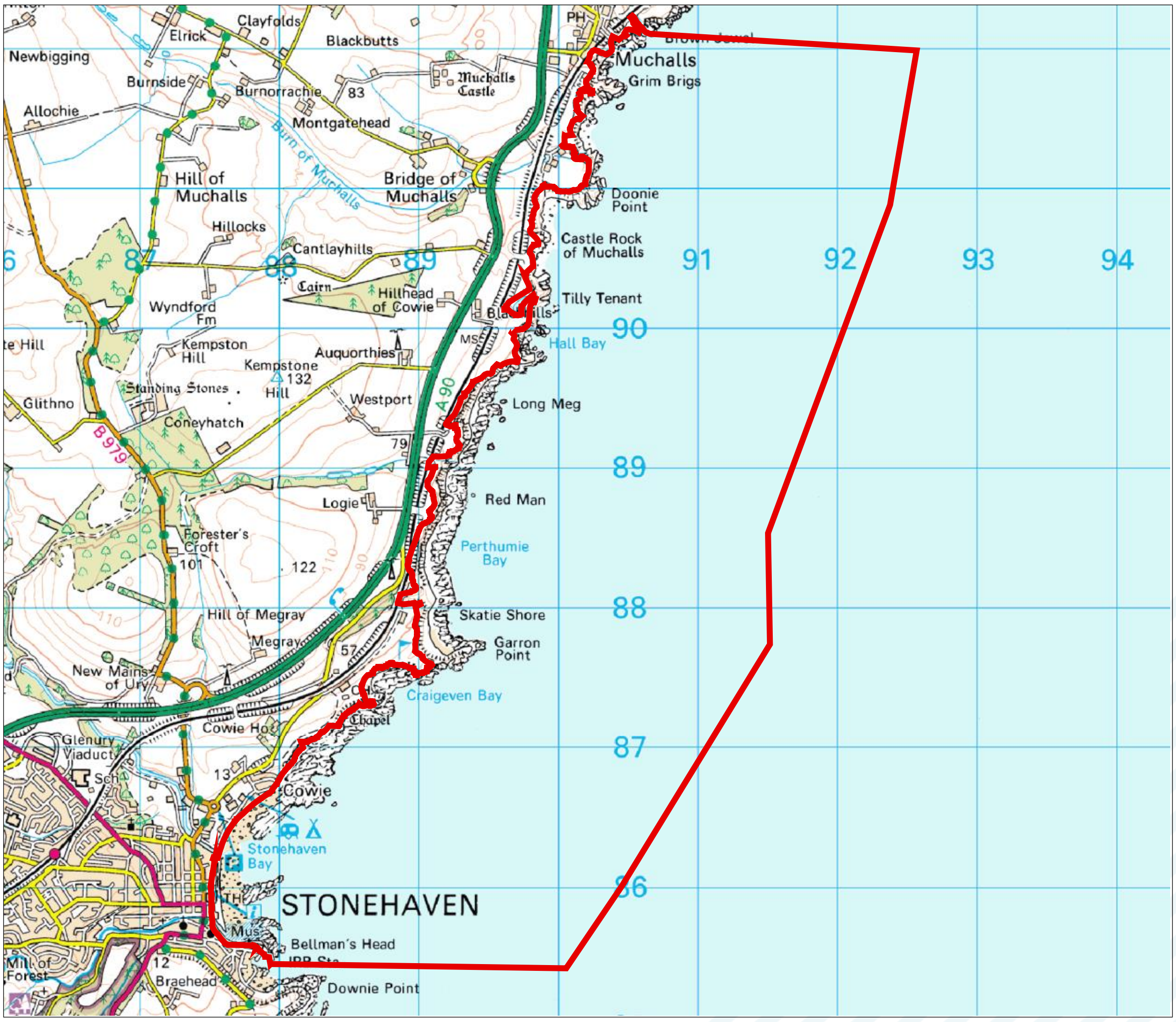
Appendices

A Designated Sites within 2km of Stonehaven Bay

B NESBReC habitats survey 2004-2007



C Muchalls to Stonehaven Bay LNCS Boundary



References

Aberdeenshire Council (2017) Aberdeenshire Local Development Plan 2017 [online] Accessed 29/06/2018 Available at: https://www.aberdeenshire.gov.uk/media/20616/local-development-plan-2017-part-1.pdf

JBA Consulting (2011) Stonehaven River Carron Flood Alleviation Study

JBA Consulting (2018) Stonehaven Bay Coastal Flood Protection Study – Natural Flood Management and River Basin Management Plan Report

JNCC (2001) Fowlsheugh SPA [online] Accessed 28/06/2018 Available at: <http://jncc.defra.gov.uk/default.aspx?page=1912>

Joint Nature Conservation Committee (JNCC) (2015) Garron Point SAC [online] Accessed 28/06/2018 Available at: http://jncc.defra.gov.uk/ProtectedSites/SACselection/sac.asp?EUcode=UK0030356

Mott MacDonald (2017) Stonehaven Flood Protection Scheme: Geomorphology Detailed Design Review

Scottish Natural Heritage (SNH) (2005) Garron Point Site of Special Scientific Interest Citation [online] Accessed 28/06/2018 Available at: <http://gateway.snh.gov.uk/sitelink/siteinfo.jsp?pa_code=674>

SNH (2009) Garron Point SSSI Operations Requiring Consent from SNH [online] Accessed 29/06/2018 Available at: http://gateway.snh.gov.uk/sitelink/siteinfo.jsp?pa_code=674

SNH (2018) Legal Framework [online] Accessed 29/06/2018 Available at: <https://www.nature.scot/professional-advice/safeguarding-protected-areas-and-species/protected-species/legal-framework>

UK Butterflies (2018) Northern Brown Argus [online] Accessed 29/06/2018 Available at: <http://www.ukbutterflies.co.uk/species.php?species=artaxerxes>

Offices at

Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Glasgow
Haywards Heath
Isle of Man
Limerick
Newcastle upon Tyne
Newport
Peterborough
Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

Registered Office
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE
United Kingdom

+44(0)1756 799919
info@jbaconsulting.com
www.jbaconsulting.com
Follow us:

Jeremy Benn Associates Limited

Registered in England 3246693

JBA Group Ltd is certified to:
ISO 9001:2015
ISO 14001:2015
OHSAS 18001:2007

E Baseline NFM and RBMP Report

JBA consulting

Stonehaven Bay Coastal Flood Protection Study

Natural Flood Management and River Basin Management Plan Report

Final Report

December 2018

www.jbaconsulting.com

Aberdeenshire COUNCIL

JBA Project Manager

Nicci Buckley BSc MSc CSci MCIWEM C.WEM
Unit 2.1 Quantum Court
Research Avenue South
Heriot Watt Research Park
Riccarton
Edinburgh
EH14 4AP

Revision history

Revision Ref/Date	Amendments	Issued to
P01 / 05 July 2018	Draft Report	G McCallum L Watson S McFarland
P02 / 26 September 2018	Aberdeenshire Council comments addressed.	G McCallum L Watson S McFarland
P03 / 11 December 2018	Stonehaven Flood Action Group comments addressed.	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. Briony McIntosh and Douglas Pender of JBA Consulting carried out this work.

Prepared by .... Briony McIntosh MEarthSci

Assistant Analyst

Reviewed by .... Douglas Pender MEng PhD MCIWEM

Senior Engineer

.... Caroline Anderton BSc MSc CEnv CSci MCIWEM C.WEM

Technical Director

Purpose

This document has been prepared as a Final Report for Aberdeenshire Council. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

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

Acknowledgements

JBA thank SEPA for supplying the natural flood management, morphological pressures and river basin management plan datasets. JBA also thank Aberdeenshire Council for the supply of data.

Copyright

© Jeremy Benn Associates Limited 2018.

Carbon footprint

A printed copy of the main text in this document will result in a carbon footprint of 57g if 100% post-consumer recycled paper is used and 72g if primary-source paper is used. These figures assume the report is printed in black and white on A4 paper and in duplex.

JBA is aiming to reduce its per capita carbon emissions.

Executive summary

Under the Flood Risk Management Act 2009, this report forms part of the appraisal study for Stonehaven and Cowie commissioned by Aberdeenshire Council. The purpose of this report is to assess the current physical condition of the Stonehaven Bay coastline based on parameters set out in the River Basin Management Plan (RBMP), in particular considering any morphological constraints. In addition, the purpose of this report is to identify opportunities for Natural Flood Management (NFM).

Stonehaven Bay is located on the shore of the North Sea and lies within sediment cell 2 (Fife Ness to Cairnbulg Point)[3], sub-cell 2c (Milton Ness to Girdle Ness). The Bay is fronted by a relatively narrow sand and shingle beach with a rocky foreshore to the north. Sediment movement is generally from north to south. Storm wave action is understood to erode beach material and during high energy wave events gravel from the foreshore appears to be transported landward depositing material along, and in some cases nearly burying the sea wall. The River Carron and the River Cowie discharge into Stonehaven Bay at the southern and northern extents of the Bay respectively. Both are tidally influenced and shingle is deposited at the mouth of the River Cowie as a result of wave action; historically this has periodically been recycled and placed in the Bay to the south of the River Carron.

The Stonehaven Bay coastal waters as well as the River's Carron and Cowie are classified as being in 'Good' physical condition according to the 2016 RBMP classifications. There are however a number of morphological constraints along both the coastline and fluvial channels. These include:

- The Stonehaven coastal defences, which vary in form and height along the frontage.
- The banks of the River Carron are urbanised and a stone wall lines the channel upstream and downstream of the Bridgefield Road bridge. The mouth of the River Carron has also been engineered to direct flow south along the shoreline as a result of the installation of a breakwater feature.
- The River Cowie downstream of the B979 road bridge is concrete lined and sediment accumulation is high due to the combination of fluvial and tidally deposited material, which has narrowed the channel outlet.

Suggested RBMP actions to be considered during the options appraisal, specifically with respect to morphology are as follows:

- Opportunities to improve the physical condition of the coastline are limited. Removal of the coastal defences and/or managed realignment to set-back defences is not a viable option. The hard defences are the primary source of flood protection to Stonehaven and Cowie and should not be removed. Consideration should be given to limiting future additional hard-engineered structures to retain the 'Good' morphological status and limit disruption to natural coastal processes. Where additional defences are required use of 'green' materials should be considered, as are being developed for the Catterline coastal erosion project.
- Morphological improvements to the River Carron to encourage sediment transport to the foreshore area are also limited. A flood defence scheme is due to be constructed along the Carron from August 2018 which will likely change the morphological characteristics and RBMP status of the watercourse.
- The morphology of the River Cowie downstream of the B979 road bridge could be improved to increase velocities and outflux of accumulated sediment to naturally recharge the Stonehaven foreshore.

NFM opportunities at Stonehaven have also been considered and the three primary opportunities identified are:

1. **Coastal beach recharge.** Large-scale recharge to increase the shingle beach width and height along the shorefront to break wave energy. Detailed sediment modelling and analysis of Stonehaven Bay is however crucial in order to identify sediment sources, sinks and pathways to inform the suitability and location of any recharge. It is also suggested recharge be undertaken in conjunction with maintaining the existing hard defences, and additional groynes may be required to hold sediment within the Bay.
2. **Shingle restoration (coastal sediment recycling).** In addition to long-term recharge, short-term sediment recycling to maintain the restored beach profiles should be considered. Recycling involves redistribution of sediment within the local area (sediment cell) from areas of deposition to areas of erosion.
3. **Fluvial sediment management and morphological improvements.** Sediment deposition in the mouth of both the River Carron and River Cowie are indicated within the SEPA NFM potential mapping. Fluvial sediment deposition combined with the coastal influx of material reduces channel capacity and can increase the risk of flooding. Sediment management measures such as morphological alterations to the channel to increase velocities and flush sediment back into the foreshore are should be considered during options appraisal and has the multi-benefit of maintaining the 'Good' RBMP morphological status.

Contents

List of Figures

List of Tables

Abbreviations

BGS	British Geological Survey
FRM	Flood Risk Mapping
ID	Identifier
RBMP	River Basin Management Plan
SEPA	Scottish Environment Protection Agency
SSSI	Site of Special Scientific Interest
WFD	Water Framework Directive

1 Introduction

The purpose of this report is to summarise the desk-based assessment of Stonehaven Bay to determine the current condition of the coastline based on parameters set out in the River Basin Management Plan (RBMP). In particular, the study aims to identify all morphological pressures on the coastline and fluvial waterbodies within the study area and potential to improve the RBMP status of these waterbodies. In addition, the purpose of this report is to summarise potential opportunities for Natural Flood Management (NFM).

1.1 RBMP

1.1.1 Legislation

The River Basin Management Plan forms part of the European Water Framework Directive (WFD) 2000. The WFD is currently in its second cycle (2015 - 2027) and sets out the objectives for protecting and improving the water environment; balancing the environmental, societal and economic costs and benefits. The Scottish Environment Protection Agency (SEPA) are responsible for managing this within Scotland.

The RBMP defines and classifies the environmental condition of water bodies, with the overall condition graded from poor to high based on a number of categories. For fluvial waterbodies these include: access for fish migration; water flows and levels; freedom from invasive species; water quality; ecology and physical condition. For coastal waterbodies overall condition is based on water quality, ecology and morphology.

1.1.2 Aim

The aim of this RBMP assessment was to consider the current overall status of the Stonehaven Bay coastal waters, as well as the morphological condition of the coastline and identify opportunities to improve morphology. In addition, the physical condition of the final reaches of the two fluvial watercourses discharging into Stonehaven Bay was assessed to identify opportunities to improve morphology. The results are discussed in further detail in the following chapters.

1.2 NFM

1.2.1 Legislation

The Flood Risk Management (Scotland) Act 2009 requires SEPA and Responsible Authorities to consider sustainable approaches to managing flood risk. This includes considering the role that NFM has in reducing flood risk, where NFM was defined by SAIFF (2011)[1] as follows:

'Natural Flood Management can be defined as those techniques that aim to work with natural hydrological and morphological processes, features and characteristics to manage the sources and pathways of flood waters. These techniques include the restoration, enhancement and alteration of natural features and characteristics, but exclude traditional flood defence engineering that works against or disrupts these natural processes.'

1.2.2 Aim

In the past, coastal flood management has typically focused on traditional methods of mitigating flood risk, such as the use of sea walls, groynes and revetments. Disruption to natural coastal processes because of 'hard' engineering, for example modification of natural sediment supply and transport as a result of groynes, potentially reduces the level of protection and design life offered, and such an approach is not considered to

---

1 Scottish Advisory and Implementation Forum for Flooding (SAIFF, 2011)

be sustainable on its own. Increased water depths as a result of sea level rise and the consequent increase in wave energy predicted to impact Scotland due to climate change further undermines the protection offered.

In contrast, NFM measures work together with the natural characteristics and processes of the landscape to help manage flooding. In isolation NFM measures may be more effective for smaller scale events, meaning traditional hard-engineering options are still typically required and have a role in terms of the level of protection offered and cost benefit analysis with respect to large magnitude events. Incorporation of NFM within the overall Flood Protection Scheme may however reduce the impact of large scale events and extend the design life of coastal defences.

NFM measures vary in scale and type depending on local conditions. The SEPA Natural Flood Management Handbook[2], Chapter 3, provides guidance on coastal based NFM measures. The goal of coastal NFM is to restore the coastline and stabilise coastal features to buffer wave energy and minimise its impact on existing defences, or provide a natural buffer in cases where no defences exist. Coastal processes and therefore NFM recommendations are highly site specific. There is also an interconnection between fluvial and coastal processes with fluvial flow and sediment potentially influencing beach sediment volumes. For areas such as Stonehaven Bay, it is therefore important to consider the impact of catchment based NFM measures. Types of coastal NFM measures considered in the NFM Handbook are given in Table 1-1.

Table 1-1 – Types of coastal NFM measures

Type of NFM measure	Example
Managed realignment	Breaching or removal of existing hard defences or creation of 'set-back' protection.
Saltmarsh and mudflat restoration	Habitat restoration to create an area of wave energy dissipation.
Sand dune restoration	Planting to restore stability, increasing their ability to dissipate wave energy.
Shingle restoration	Sediment nourishment in the foreshore to dissipate wave energy.
Recharge (beach or intertidal)	Placement of sediment in the foreshore to dissipate wave energy.

NFM measures often offer several multiple benefits (such as improvements in water quality or increased access to nature) and can be used in conjunction with traditional engineering approaches to reduce flood risk where appropriate.

The aim of this NFM assessment is to consider the current state of the coastline and identify locations where coastal NFM may be appropriate. Potential opportunities for NFM are discussed in further detail in the following chapters.

2 https://www.sepa.org.uk/media/163560/sepa-natural-flood-management-handbook1.pdf [Chapter 3. Page 38].

2 Stonehaven Bay

2.1 Geology, coastal and fluvial processes

The town of Stonehaven and village of Cowie are located approximately 20 km to the south of Aberdeen. They sit within Stonehaven Bay on the shore of the North Sea, which lies within sediment cell 2 (Fife Ness to Cairnbulg Point)[3], sub-cell 2c (Milton Ness to Girdle Ness, Figure 2-1). According to the British Geological Survey (BGS) 1:625,000 scale geological map of Britain[4] the coastline consists of sandstone bedrock (Figure 2-1) with small bands of volcanic lavas to the north of Stonehaven; with overlying glacial sand and gravel deposits. The northern foreshore of the bay is rocky with a small sandy beach, while the central-southern extent of Stonehaven is fronted by a moderately large sand and shingle beach (Figure 2-1). No significant littoral drift is believed to occur within sediment sub-cell 2c[3] and cliff erosion is low but general sediment distribution is from north to south and as such beach heights increase southwards.

Two rivers, the Carron and Cowie, flow through Stonehaven and discharge into Stonehaven Bay (Figure 2-1). Both rivers are tidally influenced and during storm conditions waves can propagate up the mouth of the River Cowie and break at the B979 road bridge. Shingle is also deposited in the mouth of the River Cowie and is periodically recycled and placed in the boardwalk region (Figure 2-1) in an attempt to reduce erosion. Engineering of a breakwater feature at the mouth of the River Carron has realigned the mouth of watercourse and appears to have directed flow south longshore towards the boardwalk area of the Bay. A flood defence scheme is scheduled for construction along the River Carron from August 2018.

Storm wave action is known to erode beach material at Stonehaven, with the timber walkway at the southern extent of the Bay (Figure 2-1) washed away in the December 2012 event. From observations during the site visits it and discussions with local residents, it is indicated that during high energy wave events the shingle from the foreshore is transported landward and is deposited in front of, and over, the sea wall between the River Carron and Cowie outlets, almost completely burying the seaward face (Figure 3-1, C). This appears to have resulted in a significant steepening of the beach face allowing for large waves to break closer to the shore and an increase in wave runup and overtopping. Sedimentation patterns will be investigated further in the erosion assessment report.

2.2 Review of Historical Mapping and Information

A review of historical mapping[5] as well as information provided by local resident Ian McDonald[6] indicated the shingle beach fronting Stonehaven was historically far more extensive than present. Pre-1930s no sea wall was present along the bay and the shingle beach appeared greater in both width and height, with shingle present up to road level. In addition, the River Cowie historically flowed south towards the River Carron (Figure 2-2), with historical maps showing its former course in 1950 and its present-day course in 1967. The exact date when it changed course is unknown but it is understood that the river broke through the shingle bar that was present during a storm event in 1948[6] and has run its present-day course into Stonehaven Bay since.

Historical accounts suggest shingle loss from Stonehaven Bay was rapid post-1940 when large quantities of material were excavated from the beach to cast concrete tank traps within the Kincardineshire region and form the foundations of the runways at

---

3 H.R.Wallingford. 1997. Coastal cells in Scotland. Scottish Natural Heritage Research, Survey & Monitoring Report. No. 56.

4 British Geological Survey http://mapapps.bgs.ac.uk/geologyofbritain/home.html [Accessed: June 2018]

5 National Library of Scotland. OS 25 Inch Scotland, 1892-1949. OS 1:25,000 maps of Great Britain, 1937-1961. http://maps.nls.uk/geo/explore/#zoom=17&lat=56.9643&lon=-2.2064&layers=10&b=1 [Accessed: June 2018]

6 Report on the history of Stonehaven Bay containing historical photographs and maps provided on 22 June 2018 by local resident Ian McDonald.

Fordoun aerodrome[6]. Additionally, the breakthrough of the Cowie is believed to have increased the rate of shingle loss due to increased fluvial velocities increasing the north south longshore drift velocities[6].

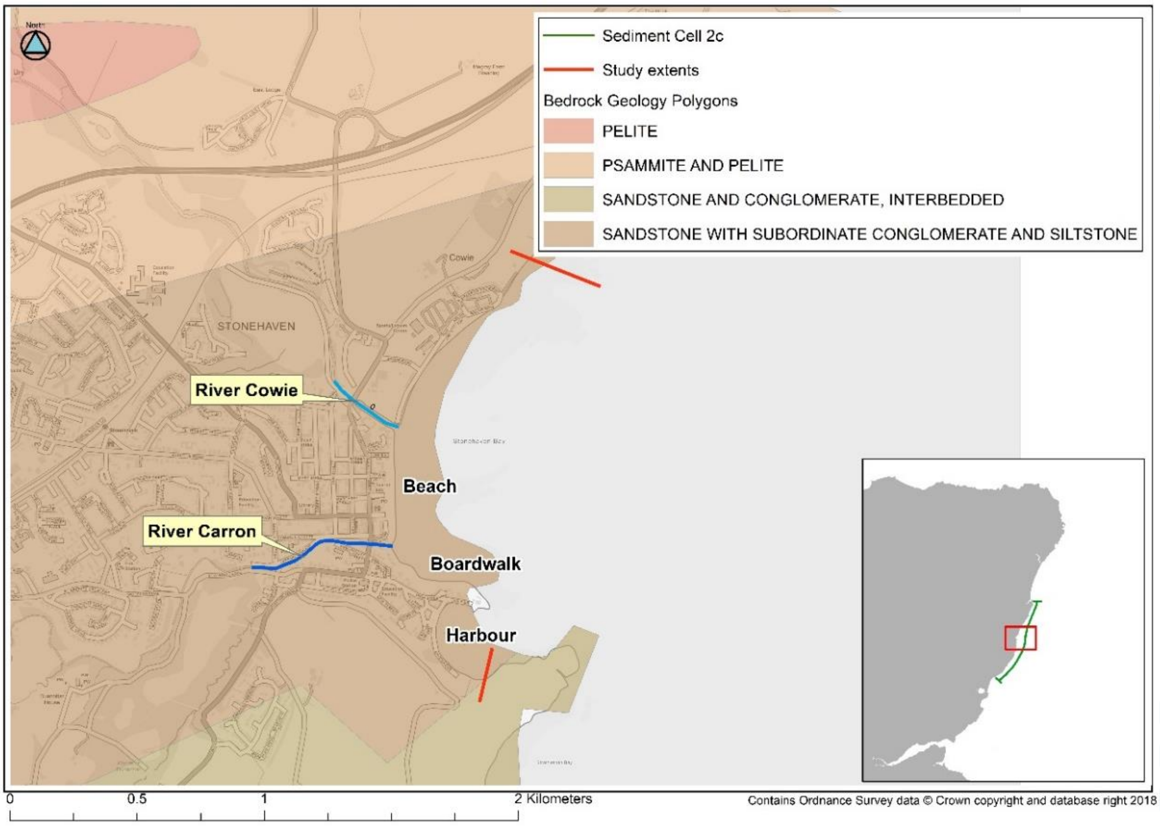


Figure 2-1: Stonehaven study area

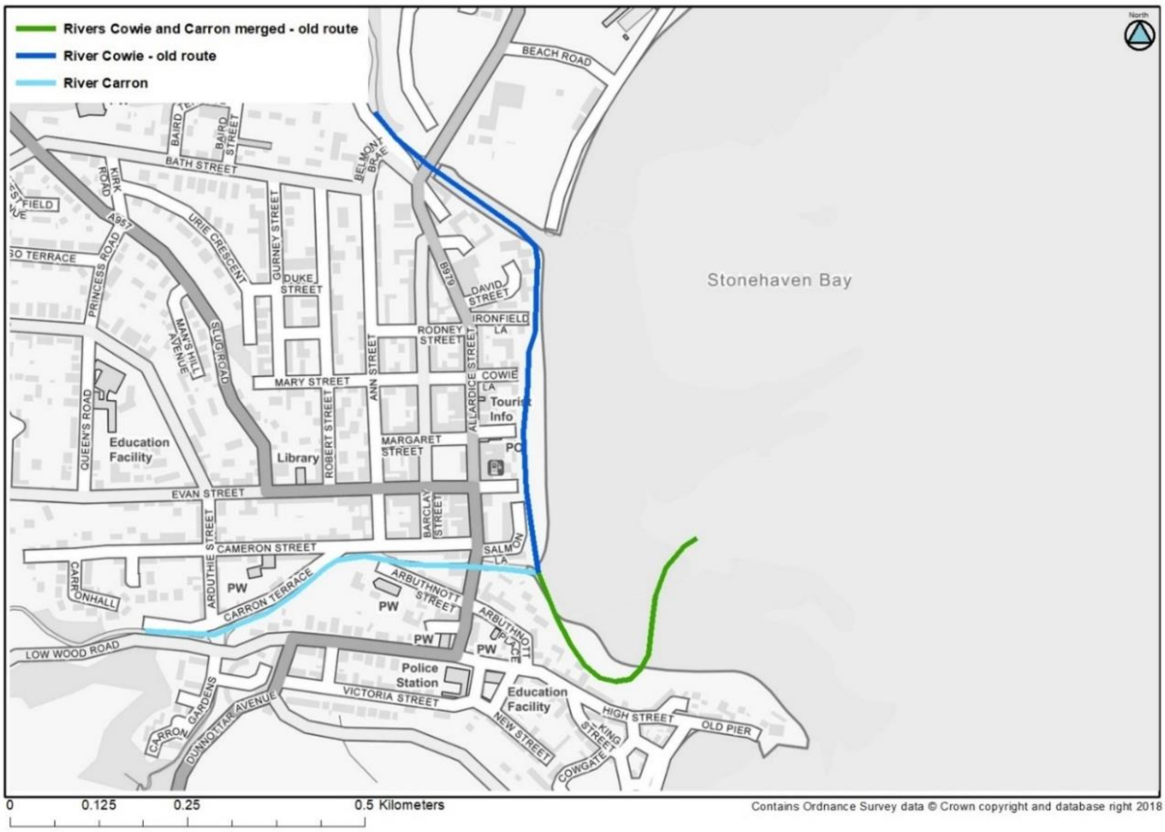


Figure 2-2: Historical configuration of the Rivers Cowie and Carron at the coast

2.3 Coastal defences

There are several formal and informal coastal defences within the study area which include (south to north, Figure 2-3):

- Stonehaven Harbour which contains rock armour revetments, a breakwater, piers and quay walls.
- A large rock armour revetment to the north of Stonehaven harbour.
- A boardwalk section north of the harbour consisting of rock armour and a shingle beach which suffers erosion and damage during storm events. The Carron outfalls within this area.
- A concrete wall and shingle beach area fronting the Stonehaven properties.
- The outlet of the River Cowie consists of a combination of concrete walls, concrete revetments, and steel sheet piles.
- Stepped revetments between the mouth of the River Cowie and open air pool form the main coastal defence along the south Cowie frontage. It consists of a stepped concrete revetment with small wave return wall at the crest.
- A concrete and masonry wall defends the coast north of the pool, in front of Cowie village.
- It is understood that construction of the River Carron fluvial flood protection scheme is due to commence from August 2018.

Figure 2-3: Area and defence types within Stonehaven Bay

2.4 Land management

2.4.1 Land use

Figure 2-4 illustrates land cover types in the Stonehaven Bay area based on the Land Cover Map 2012[7]. Land use to the northern and southern extents of the study area is pastural land, while the remaining coastline is backed by the urban extent of Stonehaven. The banks of the River Carron and Cowie are constrained through their lower reaches as a result of urbanisation. The coastal reach of the study area is classified as beaches, dunes and sands; however, no sand dunes are present, with Stonehaven fronted by a relatively narrow sand and shingle beach.

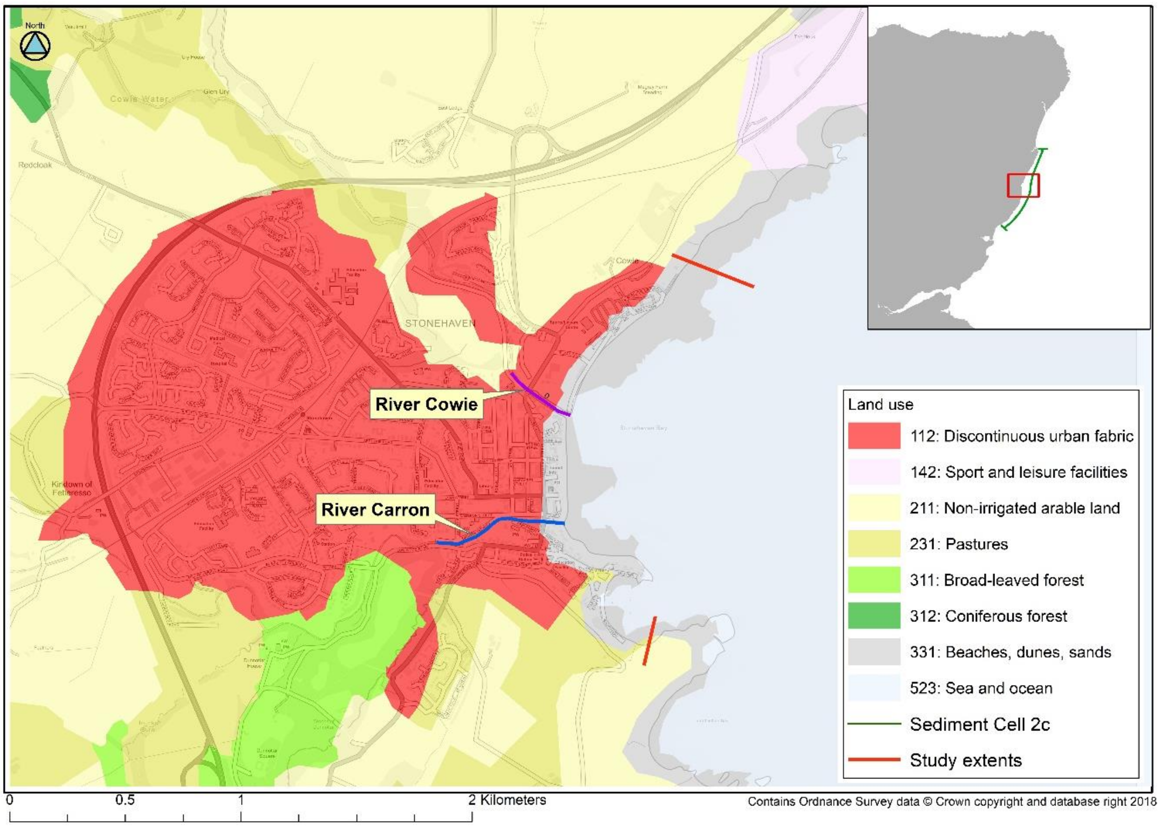


Figure 2-4: Land use

7 Corine Land Cover European seamless vector database. Release v18_5 (02/2016) http://land.copernicus.eu/pan-european/corine-land-cover

2.4.2 Scottish Natural Heritage Landscape Designations

Scottish Natural Heritage (SNH) datasets indicate within the study area north of the River Cowie outlet, by the open air swimming pool, Stonehaven Bay northwards falls under the Garron Point Site of Special Scientific Interest (SSSI) which is of both geological and botanical interest. In addition, Stonehaven Bay is part of the Muchalls to Stonehaven Bay Local Nature Conservation Site (LNCS)[8], which reflects the biological and geological importance of the site at a regional level. Castle of Cowie scheduled monument lies just outwith the study area to the north of Stonehaven, but several listed buildings are located within the study area including Stonehaven Harbour.

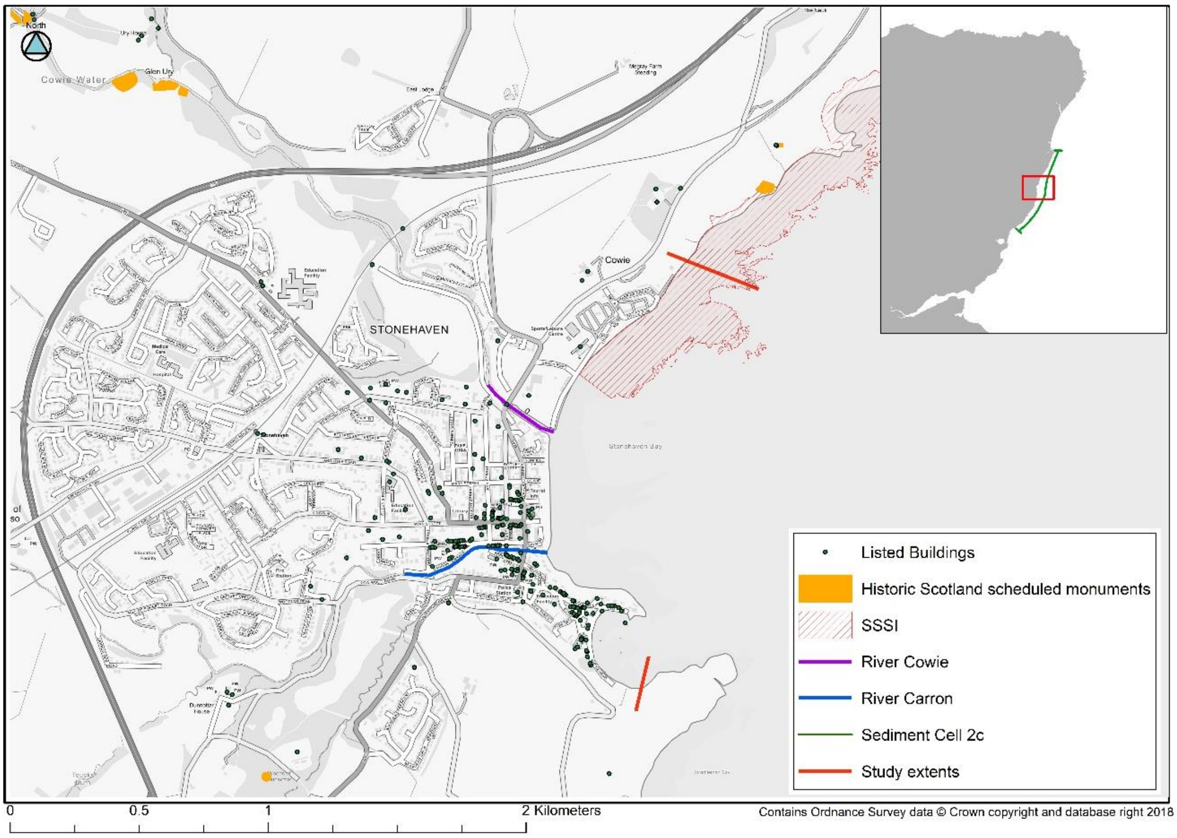


Figure 2-5: Landscape designations

8 Aberdeenshire Local Development Plan. April 2017. Supplementary Guidance. Local Conservation Sites. https://www.aberdeenshire.gov.uk/media/20028/5a-local-nature-conservation-sites-index.pdf [Accessed: June 2018]

3 RBMP Review

3.1 Introduction

RBMP data were examined using the Water Environment Hub[9] and RBMP datasets supplied by SEPA. Coastal and fluvial waterbodies are classified in the RBMP based on several parameters (detailed in Chapter 1). This report will focus on morphological pressures affecting the Stonehaven coastline and fluvial watercourses downstream of the Bridgefield Road and B979 road bridges.

Morphological pressures which can result in the downgrade in status of coastal and fluvial waters include:

- Hard engineering of the coastline. For example, groynes which can exacerbate erosion downstream of the defence as well as modify natural sediment supply and transport pathways; sea walls and revetments.
- Land claim. Numerous intertidal or sub-tidal areas have been claimed for agriculture, housing, industry, ports and harbours which have reduced the capacity of intertidal systems to buffer flooding from the sea.
- Channel realignment and constraint e.g. straightening and canalisation of fluvial watercourses.

Measures to restore and improve the physical condition of coastlines and fluvial watercourses therefore include:

- Removing redundant or setting back coastal structures i.e. managed realignment.
- Land reclamation and habitat restoration to restore saltmarshes, mudflats, sand dunes and increase the foreshore area for wave energy dissipation.
- Restoring channel sinuosity, habitats and flows.

3.2 Coastal Morphological Pressures and Recommendations

Stonehaven Bay is located within the Garron Point to Downie Point (Stonehaven) coastal water body, ID 200517, with an area of approximately 17 km^2. The water body is classified as being in 'Good' overall and physical condition (2016 classification), and this overall status has been consistent every year from 2008 to 2016.

Despite being of 'Good' morphological condition the coastline has been highly modified with coastal defences present along the entire study extent. These include a sea wall in Stonehaven Harbour (Figure 3-1, A), rock armour north of the harbour (Figure 3-1, B) stepped revetments with a small wave return wall at the crest through the centre and northern extent of Stonehaven Bay (Figure 3-1, C and E) and a sea wall at Cowie village (Figure 3-1, F).

Removal of the defences is not a viable option as they are the primary source of protection to the town, and managed realignment to set-back defences is not viable as land claim means the town backs directly onto the coastline. Limiting future additional hard-engineering along the coastline to maintain the 'Good' morphological RBMP status should be considered during the options appraisal. Where additional defences are required use of 'green' materials could be considered. For example, as is being developed through the EU funded Catterline coastal erosion project which is aiming to use trees, reclaimed timber, debris and biodegradable material to shore up the bay's defences to protect it from coastal erosion and landslides[10].

---

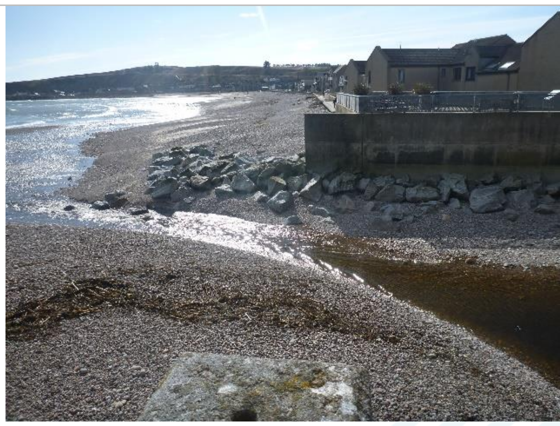
9 SEPA Water Environment Hub https://www.sepa.org.uk/data-visualisation/water-environment-hub/ [Accessed: June 2018]
10 The Press and Journal. Catterline to benefit from £10.8 million eco-friendly coastal erosion project. 17 May 2018. https://www.pressandjournal.co.uk/fp/news/aberdeenshire/1476762/catterline-to-benefit-from-10-8million-eco-friendly-coastal-erosion-project/ [Accessed@ June 2018]

Figure 3-1: Coastal morphological pressures

A: Stonehaven Harbour backed by a sea wall.

B: Rock armour and boardwalk north of the harbour.

C: Sea wall almost buried by sediment deposited during storm events.



D: Outlet of the River Cowie. Sedimentation from coastal waters evident which has narrowed the fluvial channel. Small groyne feature on the southern right bank.

E: Concrete revetments fronting the northern extent of Stonehaven Bay.

F: Northern rocky foreshore with small sandy beach and defence wall.

3.3 Fluvial Morphological Pressures and Recommendations

3.3.1 River Carron

The Carron Water (ID 23257) is classified as being in 'Poor' overall condition, downgraded based on its ecology and pollutants but is of 'Good' morphological condition. The banks of the Carron are however heavily constrained through Stonehaven due to urbanisation, and upstream and downstream of the Bridgefield Road bridge the channel is lined by masonry walls on either side (Figure 3-3, A), as indicated by the grey-bank reinforcement in the SEPA morphological pressures dataset[11], which also indicates the lower reach of the River Carron has undergone high impact realignment (Figure 3-2). Additionally, the mouth has been engineered to direct flow longshore in a rock sided channel towards the boardwalk area of the bay. Redirection of fluvial flows may be exacerbating erosion in this region in addition to inhibiting fluvial sediment redistribution to the area because of the 'dog-legged' channel potentially reducing velocities.

Removal of the final engineered section of channel is ultimately suggested to improve the RBMP status and encourage sediment outflux to the foreshore. However, the structure was built with the aim of trapping shingle on the beach to the north and to allow the Carron to drain freely across the beach. There are also issues surrounding waves propagating up the channel of the Carron[12]. A sewage conduit located under the channel mouth also constrains any channel redesign[12]. In addition, construction of a flood defence scheme is scheduled for August 2018 along the Carron which is likely to change the morphological characteristics and RBMP status of the watercourse.

3.3.2 River Cowie

The Cowie Water (Rickarton to sea, ID 23253) is classified as being in 'Good' overall and physical condition. This has been the case since 2007 except for 2015 when it was classified as being in 'Moderate' condition on the basis of its ecology.

The morphology of the Cowie Water at its downstream extent has been highly modified. Downstream of the B979 road bridge the watercourse flows in a straightened, wide, flat, concrete and sheet-piled channel, as indicated by the grey-bank reinforcement in the SEPA morphological pressures dataset (Figure 3-2). Sediment accumulation within the channel is observed to be high due to the tidal influx of material as well as deposition of fluvial material as the channel slope decreases in the lower reaches. Over time this may increase the risk of fluvial flooding from the Cowie through a reduction in channel capacity (Figure 3-3, B). Fluvial sediment transport when the river is in spate may however remove a proportion of the accumulated material. Fluvial flood risk is considered greater from the River Carron which has a longer and more extensive flood history dating back to 1829[13]. Sediment accumulation has also narrowed the fluvial outlet of the channel (Figure 3-3, C). These characteristics would suggest sediment is not easily, naturally transported back into Stonehaven Bay, with the main mechanism of re-distribution being periodic dredging of material that is then recycled in Stonehaven Bay, south of the River Carron. It is suggested the morphology of the channel could be improved to encourage fluvial transport of material by increasing velocities. This could be achieved through engineering the channel further or a store and release mechanism to naturally recharge the Stonehaven foreshore. In addition, consideration could be taken of measures that may limit the coastal influx of material to the mouth of the channel.

---

11 Only the significant morphological pressures have been considered which are defined as: impoundments; set back embankments; embankments with and without reinforcement; green and grey bank reinforcement; high and low impact realignment and culverts. It should also be noted the SEPA morphological pressures mapping does not necessarily follow the watercourses as they are plotted as straight lines based on their start and end point.

12 JBA Consulting. River Carron Rock Armour Study. Final Report. January 2015.

13 SEPA North East Local Plan District Stonehaven Potentially Vulnerable Area 06/23 http://apps.sepa.org.uk/frmstrategies/pdf/pva/PVA_06_23_Full.pdf [Accessed: July 2018]

Figure 3-2: SEPA fluvial morphological pressures

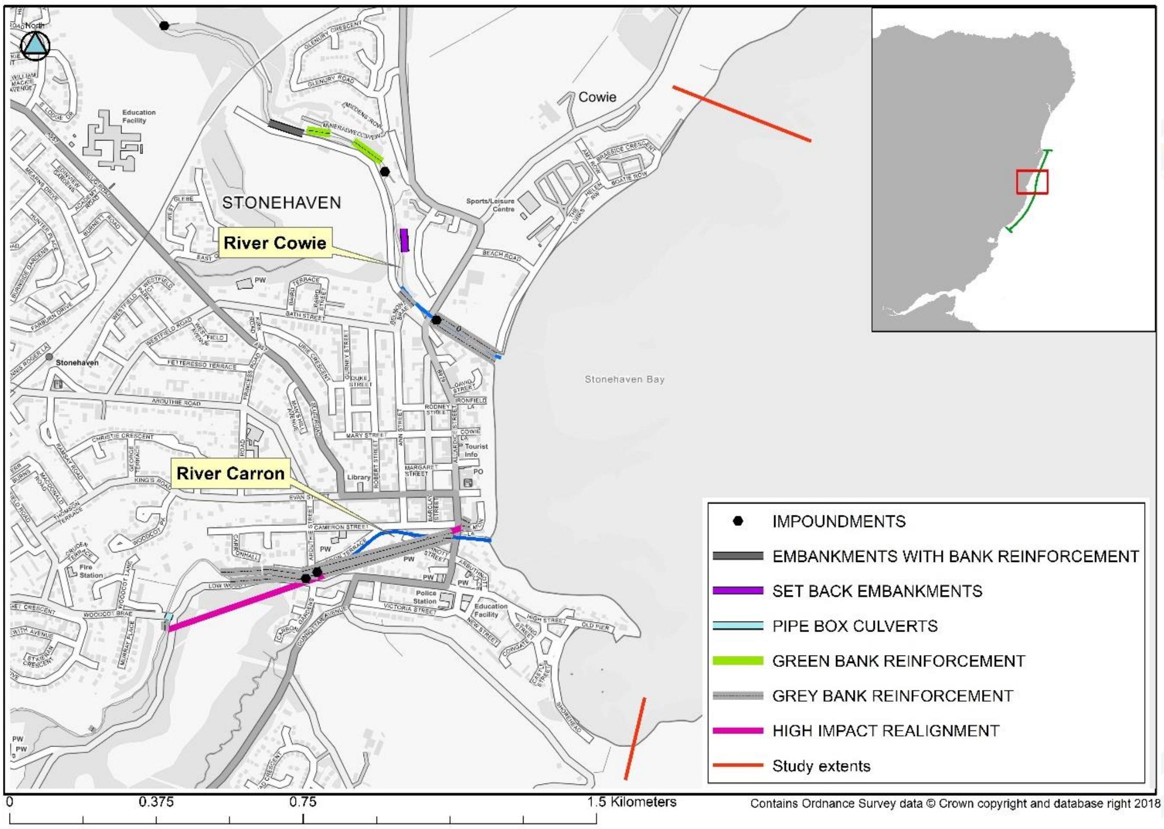
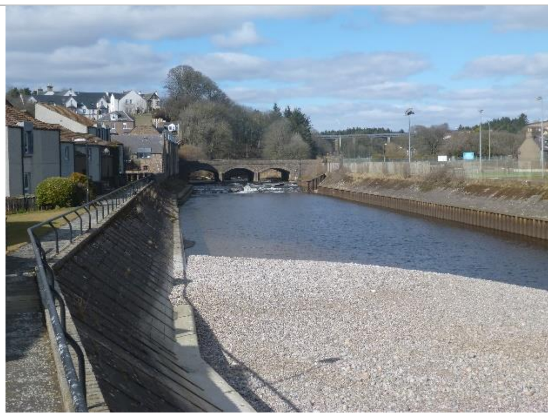


Figure 3-3: Fluvial morphological pressures - photographs

	
A: Looking upstream along the Carron Water. The channel is constrained on both banks by a large stone wall. A flood defence scheme is scheduled for construction along this reach in August 2018.	B: Looking upstream along the River Cowie. Flat, wide channel constrained by concrete walls and sheet-pile along both banks. Sediment accumulation is high (evident in the foreground) reducing channel capacity.
	
C: Looking downstream across the River Cowie. Narrowing of the channel outlet due to sedimentation.	

4 Opportunities for Natural Flood Management

SEPA, as part of the FRM Act Section 20 screening process, has undertaken a high-level strategic analysis of Scotland to determine the areas in which NFM measures could be most effective[14]. As the priority for this study is to reduce coastal flood risk at Stonehaven in particular, this broad-scale analysis has demonstrated where opportunities exist for the following:

- Coastal wave energy dissipation.
- Fluvial sediment management.

4.1 Coastal Wave Energy Dissipation

SEPA has produced a map identifying areas with potential to dissipate wave energy arriving at the shore. The mapping was generated by considering the fetch (distance over which wind blows to create waves) as a proxy for wave power and the space available (the distance between Mean High Water Spring and Mean Low Water Spring) to attenuate it.

Areas with high and medium potential for wave energy dissipation are shown in Figure 4-1. It can be seen that high potential is indicated along most of the Stonehaven coastline with the exception of Stonehaven Harbour where medium potential is indicated. Means to achieve wave energy dissipation include:

- Managed realignment.
- Saltmarsh and mudflat restoration.
- Sand dune restoration.
- Shingle restoration.
- Recharge.

Based on the constraints identified previously, shingle restoration and recharge are the only appropriate options.

4.2 Fluvial Sediment Management

SEPA has also produced a map identifying areas of sediment erosion, deposition and transport within Scottish rivers, thus identifying where sediment management measures may be appropriate for implementation to decrease flood risk. This was achieved using a model to estimate the amount of sediment entering and leaving a given reach and calculating the overall sediment balance.

A sediment management potential map for the River Carron and River Cowie is also illustrated in Figure 4-1. It can be seen the lower reaches of both watercourses are indicated to be depositing material as they approach the coast. This is combined with the wave driven influx of material (Figure 3-3, B) making sediment management a key consideration along the final reaches of both watercourses to reduce fluvial flood risk and in terms of sediment loss from the coastal sediment cell.

---

14 Nutt, N. 2012. Flood Risk Management (Scotland) Act 2009. Methods to screen and quantify natural flood management effects. Report commissioned by SEPA and Forestry Commission Scotland, May 2012.

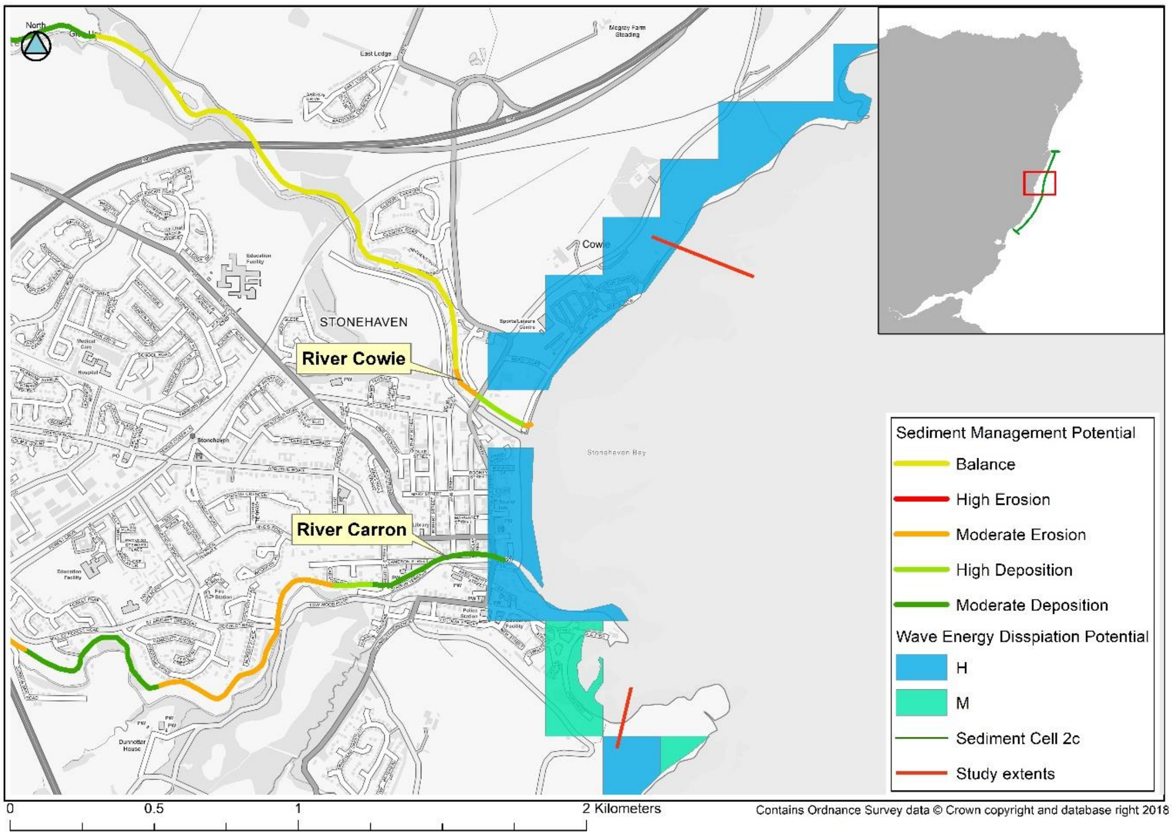


Figure 4-1: Stonehaven NFM potential mapping

4.3 NFM Recommendations

4.3.1 Beach Recharge

The SEPA NFM mapping indicates the potential to reduce wave energy is high along most of the Stonehaven coastline within the study area. Beach recharge is one mechanism of wave energy dissipation and involves the large-scale placement of sediment on the intertidal foreshore. Sediment is imported from an offshore source and particle size and composition should be like that of the existing foreshore. It is often undertaken alongside hard engineering to limit sediment loss from the system and is most appropriate where loss of sediment is the root cause of coastal flood risk.

Beach profiles at Stonehaven are actively evolving, with sediment generally moving north to south but also believed to be being transported landward during storm events. Sediment is being lost from the system, with a previous report by JBA Consulting[15] indicating the entire foreshore of Stonehaven Bay was eroding. There is also believed to be ongoing erosion of the beach south of the River Carron. Sediment loss reduces the wave energy reduction potential of the foreshore and natural beach profiles requires continued sediment supplies to remain effective at dissipating energy. During storm events, landward movement of sediment appears to have naturally steepened beach profiles north of the River Carron and in some cases nearly buried the sea wall. This natural steepening of the beach profile is acting as a means for waves to runup and overtop the defences; the proximity of the defences to the properties results in the potential for an increased risk of flooding.

Given wave overtopping is the primary source of flood risk to Stonehaven, large scale shingle recharge is one option for reducing this. The beach at Stonehaven has historically been far more extensive with significant reductions in shingle volumes

15 JBA Consulting. Stonehaven Coastal Frontage Assessment. Final Report. September 2014.

appearing to be a result of historical excavation[6]. Therefore, recharge to restore beach width and height could restore the natural wave energy buffering capacity of the shoreline. More detailed modelling and analysis within Stonehaven Bay is however crucial to identify the sources, sinks and transport mechanisms within the Bay to inform the suitability, appropriate locations and volumes required for a recharge scheme. Consideration should also be given to maintaining/repair of the existing hard defences along with new defence control measures that may be required to retain sediment on the beach.

4.3.2 Shingle restoration (coastal sediment recycling)

Supplementary to large scale beach nourishment, short term shingle restoration (sediment recycling) to maintain beach volumes at Stonehaven could also be used to widen the beach and shallow the slope and should be considered further in the options appraisal. Recycling involves the movement of sediment within the same coastal cell from areas of accumulation to areas of erosion. Sediment sources and the appropriate location(s) for deposition will be considered should beach management be taken forward as an option.

There is a history of recycling shingle at Stonehaven Bay with sediment from the mouth of the River Cowie periodically excavated and placed in the boardwalk area south of the River Carron. Recycling operations have been undertaken since 2001 and are summarised in Table 4-1[17]. The latest recycling operation occurred in March 2016 when 3000 tonnes of material was excavated from the mouth of the River Cowie and deposited south of the River Carron[18]. Continuation of sediment recycling in Stonehaven to maintain beach width, particularly if a large-scale beach recharge scheme is carried forward is suggested as a potential option. As with the recharge, sediment redistribution at Stonehaven would however benefit from a more detailed analysis to better understand the coastal processes responsible for sediment transport. Particularly as local residents note that during storm events the recycled material south of the River Carron is often washed offshore[6].

17 JBA Consulting. Stonehaven Coastal Frontage Assessment. Final Report. September 2014.
18 Information provided by Aberdeenshire Council. Stonehaven Beach Recycling Works – March 2016. Liam Rochford 6 April 2016.

Table 4-1 – Stonehaven beach recycling operations

	Collected (tonnes)		Deposited (tonnes)		
Year	From mouth of Cowie	From mouth of Carron	South of mouth of Carron	North of stepped seawall	South of mouth of Cowie
2001	2000	0	2000	0	0
2002	2000	0	2000	0	0
2003	2000	0	2000	0	0
2004	2000	0	2000	0	0
2005	2000	0	2000	0	0
2006	2000	0	500*	2000	0
2007	2000	150	2150	0	0
2008	2000	150	2150	0	0
2009	4350	0	4000	0	350!
2010	3000	0	3000	0	0
2011	1500	0	1500	0	0
2012	1000	0	1000	0	0
2013	0	0	0	0	0
2014	2500	0	2500	0	0
2015	0	0	0	0	0
2016	3000	0	3000	0	0
2017	3250	0	3250	0	0

Notes:

* Shingle placed over manhole cover just north of groyne at Carron.

t c150 tonnes of rock armour transferred from groyne at the mouth of the Cowie to improve groyne at mouth of the Carron.

! Shingle placed c50m south of the mouth of the Cowie.

4.3.3 Fluvial Sediment Management

The SEPA NFM mapping indicated fluvial sediment deposition is dominant in the lower reaches of both the River Cowie and Carron. This is in addition to the material supplied from coastal sources during high tide and storm events. Sediment accumulation in the channel may increase the risk of fluvial flooding through a reduction in channel capacity, and the current morphology of both watercourses inhibit sediment outflux to the foreshore impacting coastal processes. Effective management of the fluvial sediment should therefore be considered in the appraisal of options.

As discussed in Section 3.3, alterations to the watercourses to increase fluvial velocities and thus sediment outflux to the foreshore, as well as continued dredging of the channels to re-deposit local material back into the coastal sediment cell for short term recycling should be considered during the appraisal phase.

5 Conclusions and recommendations

5.1 RBMP

Stonehaven Bay is classified as being in 'Good' overall and physical condition (2016 classification). The coastline has however been modified and is backed by a range of coastal defences. Removal of these defences and/or managed realignment are not viable options, with the hard defences providing the primary form of coastal flood protection to the town.

The Carron Water is classified as being in 'Poor' overall condition, downgraded based on its ecology and pollutants, but is of 'Good' morphological condition. The mouth of the Carron has been engineered to direct flow south longshore in a rock sided channel towards the boardwalk area of Stonehaven Bay. This channel realignment is believed to have restricted sediment redistribution to the foreshore and redirection of fluvial flows may be exacerbating erosion of the foreshore south of the Carron outlet. Alterations to the channel should be considered during the appraisal phase to improve sediment transport potential at the mouth. Flood protection scheme works are scheduled to be undertaken from August 2018 along the River Carron which is likely to change the morphological characteristics and RBMP status of the watercourse.

The Cowie is classified as being in 'Good' overall and physical condition. Downstream of the B979 road bridge the watercourse flows in a wide, flat, concrete and sheet-piled sided channel. Sediment accumulation is high due to the combination of the fluvial and tidal influx of material and has narrowed the channel outlet. This may increase the risk of fluvial flooding from the Cowie due to a reduction in channel capacity resulting in an increased risk of overtopping of the concrete lined banks. Redistribution of material back into the coastal sediment cell is observed to be limited and requires periodic dredging of the channel. The options appraisal phase should therefore consider improvements to the morphology of the River Cowie to encourage fluvial outflux of material naturally recharging the Stonehaven foreshore. Channel improvements such as improving morphological diversity also works towards achieving the RBMP objectives and maintaining a 'Good' status.

5.2 NFM

Three NFM opportunities at Stonehaven Bay have been identified. These are: (i) beach recharge, (ii) shingle restoration (recycling) and (iii) fluvial sediment management to maintain beach profiles and thus encourage wave energy dissipation. Large-scale recharge would be the primary NFM measure with short-term sediment recycling undertaken to maintain the recharge volumes.

Detailed sediment modelling and analysis of Stonehaven Bay is however crucial in informing re-charge suitability, locations and volumes. In addition, the suggested NFM measures above are made in conjunction with maintaining the existing hard defences, not as an alternative. Additional groynes may be required to hold sediment within the Bay. Use of 'green' materials in construction should be considered as are being developed in the EU funded Catterline coastal erosion project[10].

JBA consulting

Offices at

Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Glasgow
Haywards Heath
Isle of Man
Limerick
Newcastle upon Tyne
Newport
Peterborough
Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

Registered Office
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE
United Kingdom

+44(0)1756 799919
info@jbaconsulting.com
www.jbaconsulting.com
Follow us:

Jeremy Benn Associates Limited

Registered in England 3246693

JBA Group Ltd is certified to:
ISO 9001:2015
ISO 14001:2015
OHSAS 18001:2007

New Civil Engineer TechFest. Awards FESTIVAL OF INNOVATION AND TECHNOLOGY 2017 WINNER
New Civil Engineer 100 COMPANIES OF THE YEAR 2016 WINNER
New Civil Engineer 100 COMPANIES OF THE YEAR 2017 RANKED COMPANY
CHAS® Accredited Contractor CHAS.co.uk

F Baseline GI Report

JBA consulting

Stonehaven Bay Coastal Flood Protection Study

Geotechnical Desk Study Report

Final Report

September 2018

www.jbaconsulting.com

Aberdeenshire COUNCIL

JBA Project Manager

Nicci Buckley
Unit 2.1 Quantum Court
Research Avenue South
Heriot Watt Research Park
Riccarton
Edinburgh
EH14 4AP

Revision history

Revision Ref/Date	Amendments	Issued to
P01 / 05 July 2018	Draft Report	G McCallum L Watson S McFarland
S2 / 26 September 2018	Final Report	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. Callum Hanson of JBA Consulting carried out this work.

Prepared by .... Callum Hanson BSc FGS

Assistant Engineer

Reviewed by .... Steven Thomson BSc (Hons) MSc

Engineer

Approved by .... James Howard BSc MSc PhD FGS CGeol

Principle Geotechnical Engineer

Purpose

This document has been prepared as a Final Report for Aberdeenshire Council. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

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

Copyright

© Jeremy Benn Associates Limited 2018.

Carbon footprint

JBA is aiming to reduce its per capita carbon emissions.

Contents

List of Figures

List of Tables

Abbreviations

FM	Formation
FRMS	Flood Risk Management Strategy
LFRMP	Local Flood Risk Management Plan
LTD	Limited
NELPD	North East Local Plan District
NVZ	Nitrate Vulnerable Zone
PVA	Potentially Vulnerable Areas
SAC	Special Areas of Conservation
SEPA	Scottish Environment Protection Agency
SFAG	Stonehaven Flood Action Group
SFDAD	Scottish Flood Defence Asset Database
SNH	Scottish Natural Heritage
SPT	Standard Penetration Test
SSSI	Sites of Specific Scientific Interest
UXO	Unexploded Ordnance

1 Introduction

1.1 Overview

Coastal mapping and historical flood records show that there is a high risk of flooding due to wave overtopping throughout Stonehaven and Cowie. Flooding is well documented, particularly in recent years, with significant events having occurred in December 2012 and October 2014 resulting in major flooding to properties, structural damage and risk to life.

The Stonehaven and Cowie frontage are protected by a wide variety of defences, such as concrete sea walls (both main and rear), stepped revetments, rock structures and beach. A Coastal Frontage Assessment report [1] undertaken by JBA Consulting identified issues regarding the sustainability and economic viability of maintaining the current Stonehaven coastal defences.

With regard to 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 Northeast 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. Of concern to this study is the risk from coastal flooding throughout Stonehaven and Cowie.

1.2 Aims and objectives

This report is a Phase 1 Geo-environmental Desk Study undertaken on behalf of Aberdeenshire Council. The aim of this document is to inform the feasibility of options for the Stonehaven Bay Coastal Protection Scheme.

The objectives of the desk study were to make preliminary assessments of the likely geotechnical constraints which may be encountered and affect the location and design of the flood defences, on the basis of the historical and current land use of the site and its environs.

The report is based upon archival research. It includes a search and assessment of likely ground conditions which has been undertaken with reference to the Local Authority, The Coal Authority, the British Geological Survey, the Scottish Environmental Protection Agency and Landmark Envirocheck. In addition, a review of web-based information from the Archaeological Services database has been undertaken, as well as the Council records and the Scottish Flood Defence Asset Database (SFDAD) aiming to identify any details of the defences, supported by structure surveys undertaken as part of the present study. However, it should be noted that not all of the structural inspections available have been reviewed in detail as part of this report.

The findings and opinions conveyed via this report are based on information obtained from a variety of sources as detailed within this report, which JBA believe are reliable. Nevertheless, JBA cannot and does not guarantee the authenticity or reliability of the information it has relied upon. The findings of this study should be regarded as preliminary to be confirmed or otherwise by intrusive site investigation works.

This report has been prepared by JBA with all reasonable skill, care and attention within the terms of the Contract with the Client and taking account of the information made available by the Client, as well as the manpower and resources

[1] 2014s0926 Stonehaven Coastal Frontage Assessment Final Report September 2014 v2.1

devoted to it by agreement with the Client. JBA disclaims any responsibility to the Client and others in respect of any matters outside the scope of the above Contract.

2 Site information

2.1 Site location

Stonehaven and Cowie are located approximately 20km to the south of Aberdeen. They sit within Stonehaven Bay on the shore of the North Sea. The Rivers Carron and Cowie flow through the town of Stonehaven and discharge into the bay (Figure 2-1).

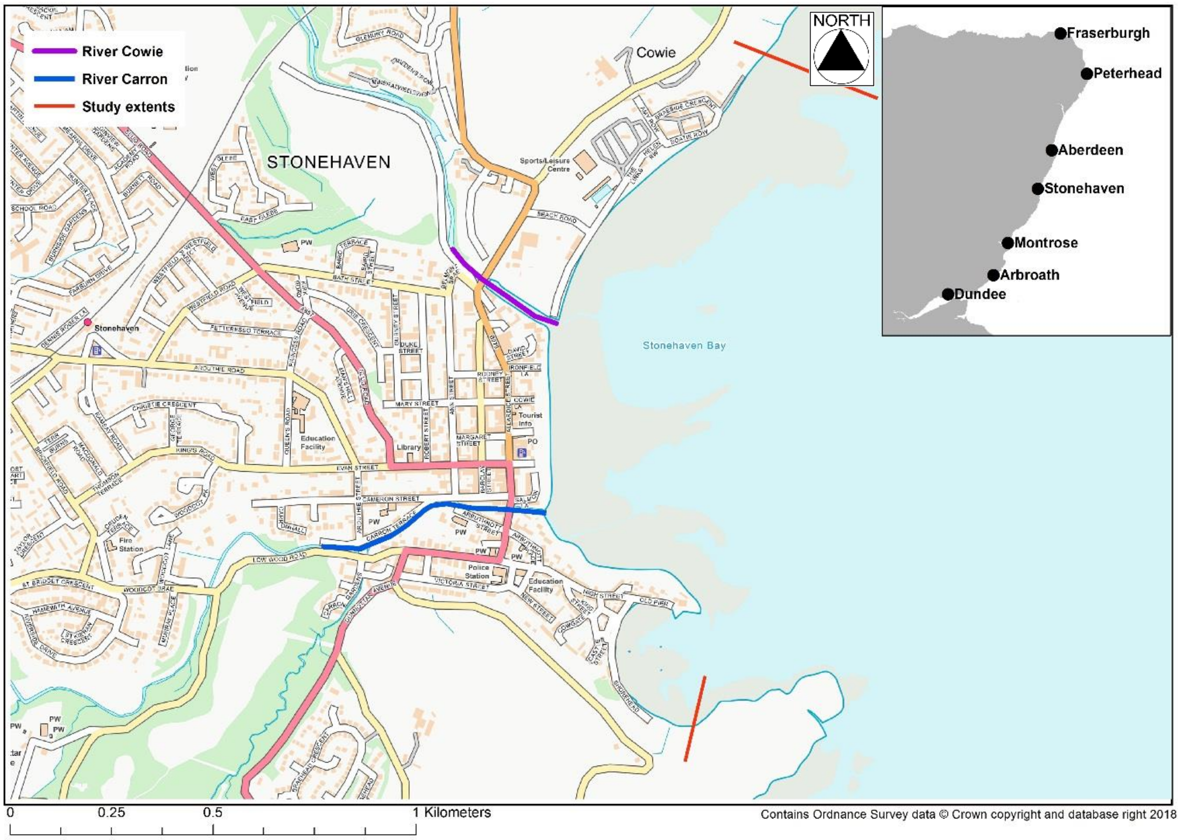


Figure 2-1: Location plan

2.2 Site description

The area is protected by existing sea defences along the Stonehaven and Cowie frontage. The general arrangement of the different defences within Stonehaven Bay is shown on Figure 2-2 below.

Figure 2-2: Subdivision of existing sea defences in Stonehaven Bay

Each of these areas are summarised below, running from south to north.

A Coastal Asset Condition Survey was carried out using Asset Coast in May 2018. More detail on the condition of the defences and any defects can be found in the Structural Condition Assessment Reports.

2.2.1 Harbour area

The harbour area of the sea front is prone to flooding from a combination of high sea levels and the action of waves that can enter the harbour mouth and run along the walls of the inner basin. This area is extended from the red line to the black line, on the outer side of breakwater. A review of the historic flood records shows that the properties along Shorehead have flooded in the past as well as several near misses when sandbags have been deployed as a precaution.

Figure 2-3: Aerial image of harbour area

2.2.2 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 extending from the outer breakwater into the bay.

Figure 2-4: Aerial image of the rock armour section

2.2.3 Boardwalk section

The boardwalk section is a mixture of shingle beach to the north and a rock armour structure to the south. The beach is understood to be prone to erosion and the timber walkway washed away during the Dec 2012 event. Shingle deposited in the mouth of the River Cowie to the north is periodically recycled and redeposited along the beach of the Boardwalk section as a coastal protection measure.

The section also includes the outfall of the River Carron; the mouth of which is trained by rock armour structures.

Figure 2-5: Aerial image of the boardwalk section

2.2.4 Central wall section

The central wall section dominates the frontage for properties in Stonehaven. It is a combination of a concrete sea wall and a shingle beach. Construction drawings 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.

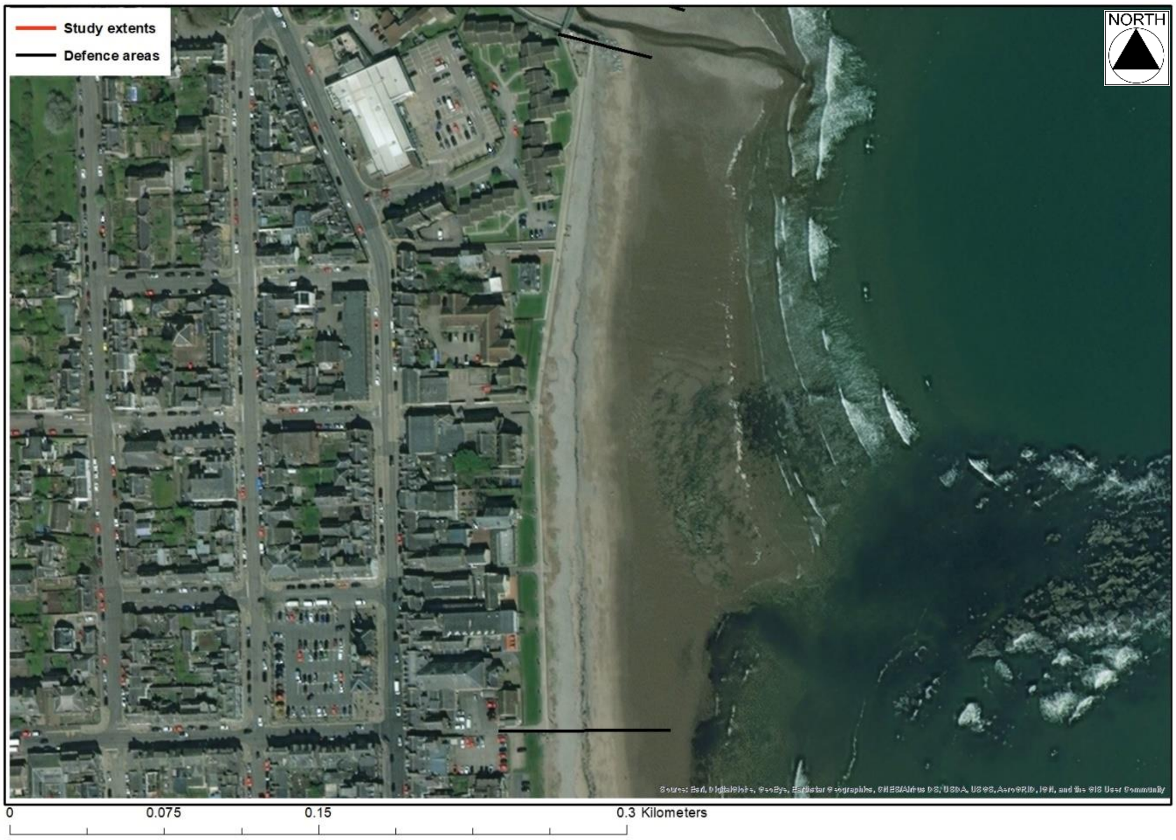


Figure 2-6: Aerial image of the central section

2.2.5 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 that is approximately 200m upstream. During storm events, waves can propagate into the mouth of the river and break on the weir beneath the B979 road bridge. The south bank of the river is also at risk from overtopping from oblique waves that enter the mouth and roll along the revetment.

It is understood that the section of wall on the north bank has been undermined in the past and will likely require engineering works to stabilise it.

Figure 2-7: Aerial image of the River Cowie section

2.2.6 Stepped revetment section

The stepped revetment section forms the main coastal defence along Cowie promenade. It runs from the mouth of the River Cowie to the northern end of the open-air pool. It consists of a stepped concrete revetment with a wave return wall at the crest; a rock armour toe was added to the defence in 2006. There is also a short steel piled section at the north, in front of the parking spaces opposite the swimming pool. The sheet piles were recently undermined, with a sink hole opening up behind; this has been rectified, with concrete now backing the defence.

Over the years there has been significant damage to the structure from undermining and scour at the toe, as well as the high frequency of overtopping causing significant damage to the shorefront commercial properties due to the local topography.

Figure 2-8: Aerial image of the stepped revetment section

2.2.7 Cowie wall section

The Cowie wall section runs from the open-air pool to north of the pumping station in Cowie. There is a concrete wall for part of the length, the height and construction of which varies. At the north end there is a masonry wall and in the middle a short section of exposed steel sheet piling. The natural rocky foreshore provides a degree of protection from incoming wave energy, but frequent overtopping occurs and results in flooding of properties during the more extreme events.

Figure 2-9: Aerial image of the Cowie wall section

2.3 Historical land use

Stonehaven has a history as an industrial town. The majority of trading in the early 19th century relates to the fishing industry and its auxiliary trades such as curing. Cotton and linen weaving were also significant sectors at that time, with several large mills constructed along the River Carron. Other industries were also operating in the town, such as a bark-mill, a tannery and a gasworks, manufacturing coal gas, Invercarron works, as well as a small brewery and a distillery[15].

At present, the town's primary industries are marine services and tourism, with Dunnottar Castle, a local landmark located outside of the study area, being one of the main attractions.

The historic maps show that most of the shoreline in Stonehaven and Cowie has not significantly changed since 1907. However, in the central section the configuration of the Carron and the Cowie was historically very different, with the Cowie running along the front and merging with the Carron prior to discharging into the bay (Figure 2-10). It is understood that the Cowie changed to run along its present day course sometime between 1950 and 1967.

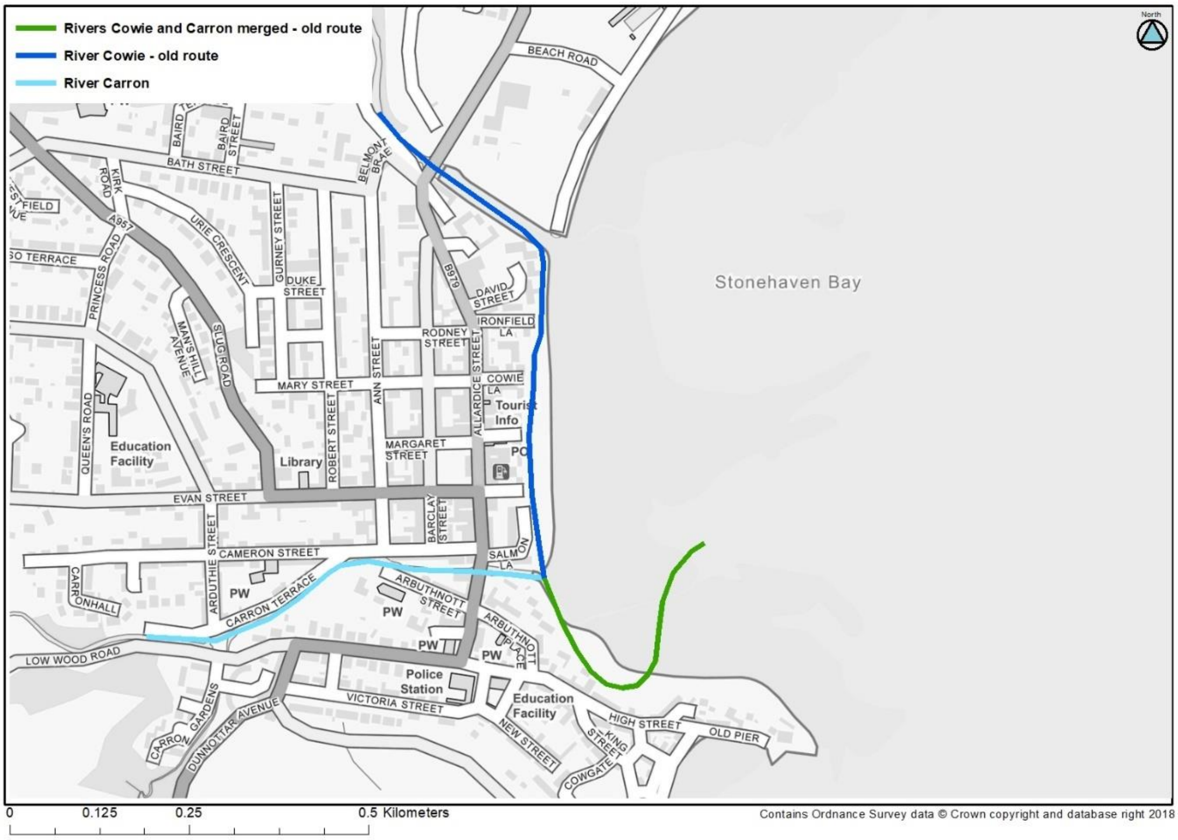


Figure 2-10: Historical configuration of the Rivers Cowie and Carron at the coast

2.4 Designated Sites

The site forms part of several designated environmental zones; these are presented in Appendix A and summarised below.

Garron Point Site of Special Scientific Interest (SSSI) covers much of the northern section of Stonehaven Bay. It is notified as an SSSI to protect a combination of geological and biological features. The Garron Point Special Area for Conservation (SAC) is a site of European importance and lies approximately 2.4km north of the site covering Garron Point and northwards past Skatie Shore. The SAC has been designated to ensure the narrow-mouthed whorl snail population is maintained in the long term. Stonehaven Bay is also 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.

Fowlsheugh SSSI and SPA is located 3.1km to the south along the coast from Stonehaven, overlooking the North Sea. The sheer cliffs, between 30-60 m high, are cut mostly in basalt and conglomerate of Old Red Sandstone age. They form a rock face with diverse structure providing ideal nesting sites for seabirds, especially gulls and auks.

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. SEPA identify the local groundwater inland of the site as a Drinking Water Protected Area, however the site is not designated as a Drinking Water Protected Area.

Any scheduled works to be undertaken below the mean high-water spring will require consent by the Marine Management Organisation (MMO). A Marine Licence is to be obtained if activities involve a deposit or removal of material in the UK marine area.

2.5 Habitats and land use

A sperate ecological survey has been undertaken as part of this project the results of which can be found in the Ecological Report.

2.6 Archaeology and Pre-History

Stonehaven also features many historical buildings including Grade A listed churches and castles. Additionally, Prehistoric (Neolithic) artefacts have been found across the town. A fossil of the oldest known terrestrial organism that had adaptations to breath air, Pneumodesmus newmani (existed during the Late Silurian), a species of Millipede, was found at Cowie beach in 2004[2].

2.7 Built landscape and heritage

Separate built landscape and heritage studies have been undertaken as part of this project, the results of which can be found in the Built Landscape and Heritage reports respectively.

Figure 2-11 presents locations for 312 listed buildings in the town (pink dots) and 31 scheduled monuments (Blue dots). The hatching outlines Stonehaven Conservation Area (CA437). Further assessment can be found in the Heritage Report.

[2] http://news.bbc.co.uk/1/hi/scotland/3427499.stm

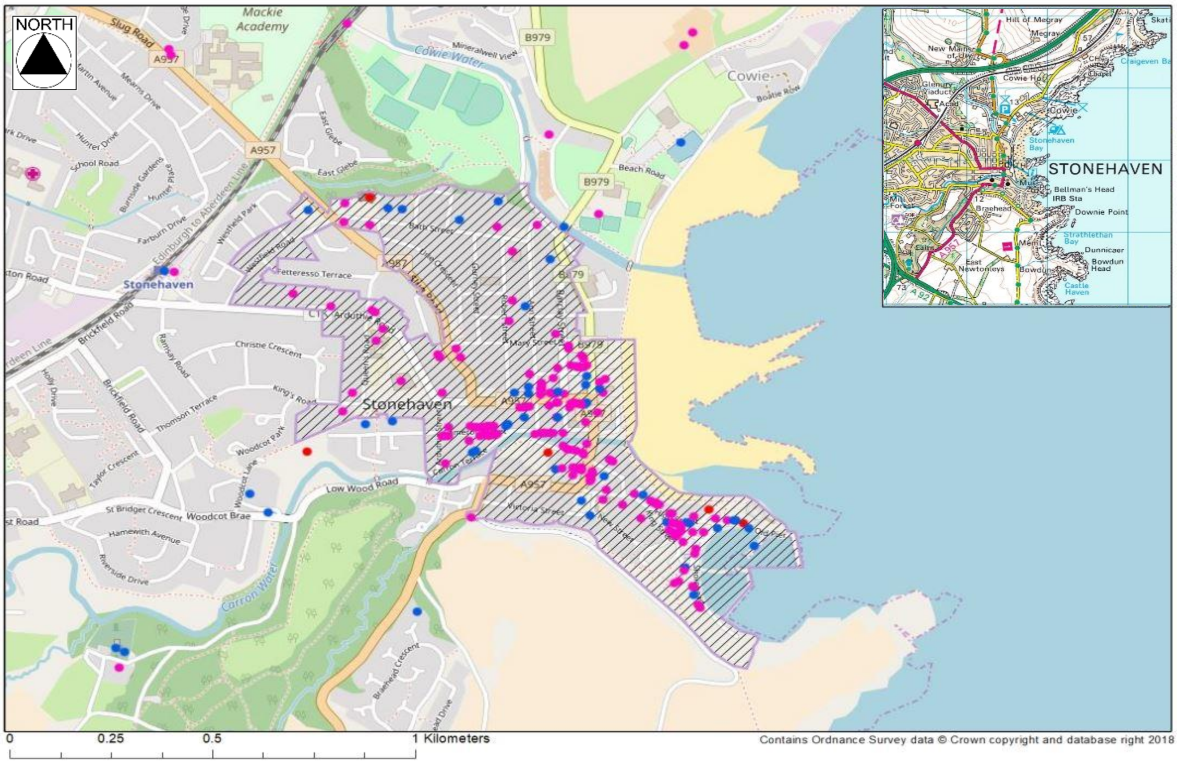


Figure 2-11: Listed building plan for Stonehaven and Cowie. (Blue - scheduled monuments; Pink - listed buildings; Hatching – Stonehaven Conservation Area).

3

3 Geohazards

3.1 Hydrology and hydrogeology

Aquifer productivity has been defined in the BGS groundwater report for Scotland, from which the site bedrock aquifer productivity is considered to be high to very high and superficial aquifer productivity to be moderate. In the report, surface water and groundwater are also considered part of the Nitrate Vulnerable Zone (NVZ)[12].

3.2 Ground stability

The Envirocheck Report identifies the site as at low risk from potential ground instability. This includes the risk from landslides and ground dissolution. Despite this, in 2009, approximately 65 homes were evacuated after a series of landslips in the Bervie Braes. The Bervie Braes lies immediately to the south of Stonehaven Harbour and extend for approximately 850m and reach a maximum height of 55m. The landslips came after a very wet October and with the melting of heavy snow that activated areas of slope instability. In 2012, Aberdeenshire Council commissioned stabilisation works to the slope, comprising the installation of landslip prevention soil nails at the toe of the slope. It is anticipated that this has significantly reduced the risk of landslides at Stonehaven.

The Envirocheck Report has also recorded a very low to low risk of running sands or shrinking and swelling clays on the site.

3.3 Mining

Scotland's long history of mining has left a legacy across much of the central belt, with minimal mining activities taking place around the East Coast. Shallow mining has been mainly for coal and metalliferous mineral extraction. No evidence of coal mining has been identified on historic maps of Stonehaven. However, one location for metal extraction at Steel Pade, 500m west of Stonehaven Harbour, is recorded by the BGS.

3.4 Contamination

The possible contaminants on site depend largely on the industrial history of the site and surrounding area. Several historic industries frequently associated with contamination of land or groundwater have been recorded on or near the site. A former gas works used for manufacturing coal gas was located adjacent to Stonehaven Harbour until 1928. Waste associated with gas manufacture includes coal tars, oil, sludges, ash, coal dust and coke, which may still exist in the soil matrix or groundwater adjacent to the site.

A tannery is recorded adjacent to the Carron until 1959. Tanneries are considered to be a major source of pollution, with the associated waste-water commonly leaving a contamination legacy in the building, subsurface and nearby watercourses.

Stonehaven harbour is recorded to have been built prior to the 17th Century, and has periodically been repaired due to the damages caused by storms. Previously used as a fish market, the harbour is now designated for recreational purpose with over 130 regular moorings fully occupied. It is to be expected that accidental oil spills (petrol/diesel) from boats may have occurred.

The unexploded ordnance (UXO) risk map identifies the site to be at low risk of UXO.

Overall, the risk of encountering contamination is high due to the intense industrial heritage of Stonehaven.

4 Ground conditions

4.1 Artificial ground

The town of Stonehaven has a long history and is anticipated to overlie large areas of made ground. It is likely these extend beyond those areas outlined in the BGS archives and the Landmark Report. Figure 4-1 shows areas of artificial ground recorded on the BGS website.

Stonehaven Harbour marks the southern extent of the site and consists of four piers first constructed in 1607 that remained relatively unchanged until 1812. JBA were unable to access any historical construction or survey information with regards to the artificial deposits mapped at this area.

Figure 4-1: Site location with BGS artificial ground indicated

4.2 Superficial geology

Superficial deposits on site vary significantly with the proximity to the fluvial or marine environment in which they were deposited. Marine beach deposits are expected to outcrop across the foreshore, with raised marine beach deposits comprising the backshore. The thickness of beach deposits is likely to vary as sands and gravels are exposed to variable maritime conditions.

At the estuaries of the River Carron and River Cowie, alluvium is anticipated to outcrop, comprising clay, silts, sands and gravels. The alluvium is likely to consist of weathered Liry Silt Formation and Drumlithe Sands and Gravel Formation, which are expected to subcrop at the site. Glacial Till (Diamicton), known locally as the Mill of Forest Till Formation, subcrops inland of the site, particularly northwards towards Cowie.

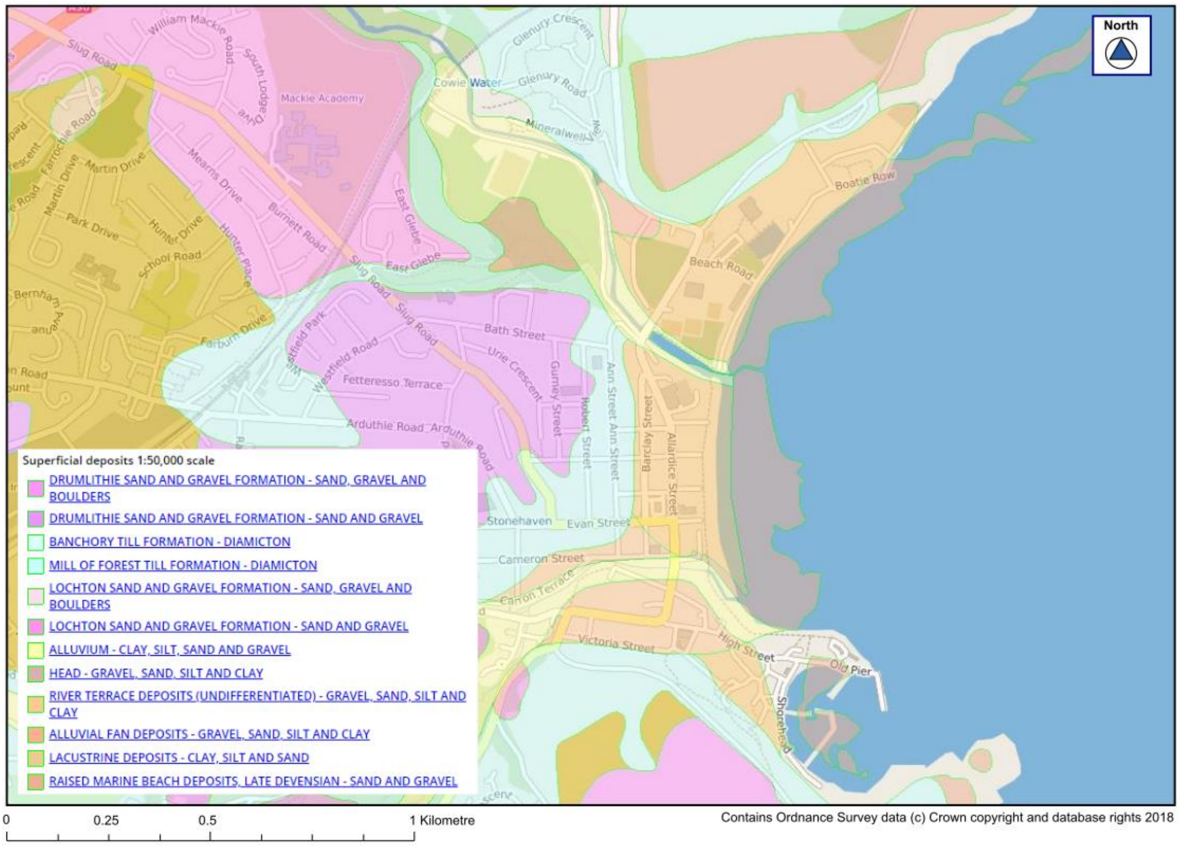


Figure 4-2: Site location with BGS superficial deposits overlay

4.3 Bedrock geology

The bedrock geology at Stonehaven is deformed by a series of northwest southeast trending faults. Lateral and normal displacement of the Carron Sandstone and Dunnottar Castle Conglomerate Formation has formed a local half graben.

The north of the site is geologically complex. The fault-emplaced Cowie sedimentary series, consisting of a seaward dipping succession of Cowie Harbour Conglomerates under Cowie Sandstones and Cowie Harbour Siltstones, outcrops adjacent to Boatie Row. Cross cutting the Cowie and Carron Sandstones at Craigeven Bay are the North Britain Siluro-Devonian Calc Alkaline Dyke Suite, consisting of a porphyry quartz-feldspar dyke.

Bedrock is well mapped for the region on the Geological Survey of Scotland 1:50,000 Geological Map Solid and Drift (1999) and the British Geological Survey GeoIndex. The maps show bedrock outcrops at the surface, approximately 75m east of the coastline. Bedrock is mapped to be dipping approximately 80^{o} to the southeast. It is expected therefore that bedrock will be at shallow levels on site with limited superficial cover.

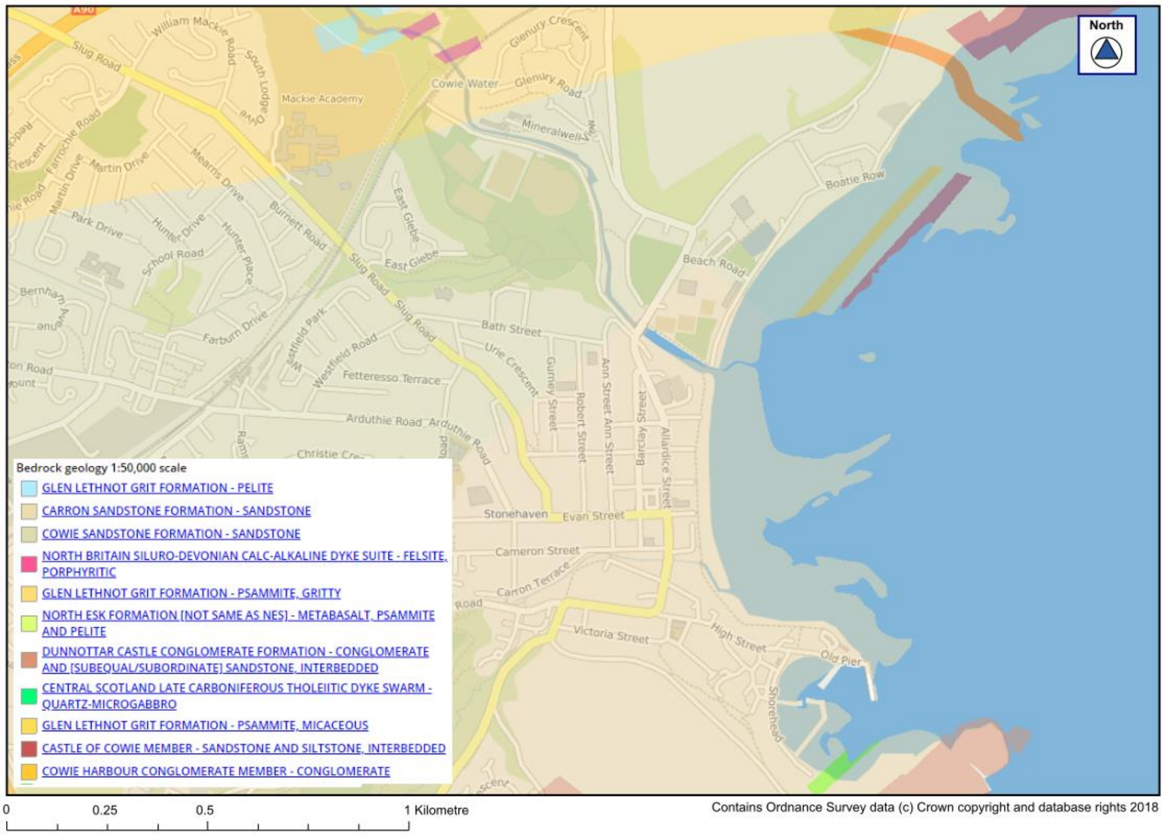


Figure 4-3: Site location with BGS bedrock geology indicated

4.4 Previous ground investigations

There have been several historic Ground Investigations (GI) conducted within 50m of the site and recorded within the BGS archives. Nine Grampian Soil Survey LTD cable percussive borehole logs have been obtained from the BGS database and are summarised below. This information was the only open-source, non-confidential data on the site. Aberdeenshire Council have provided GI reports completed during the River Carron fluvial scheme and additional existing information about the geology of the area, is available through a Landmark Envirocheck report[11].

4.4.1 Grampian Soil Survey LTD Phase I

Grampian Soil Survey LTD were commissioned to conduct five cable percussive boreholes (BH1 to BH5) in 1984 to a maximum depth of 5.50mbgl along Salmon Lane and onto the foreshore at the boardwalk. BH3, BH4 and BH5 were carried out on the site adjacent to the Carron estuary and on the beach in the boardwalk section.

BH3 was conducted on the beach to the north of the outfall of the River Carron. It encountered dense sands and gravels to 3.20mbgl over cobble and boulder gravel to 3.8mbgl. Weathered laminated sandy peaty silt was recorded to termination at 5.5mbgl. Water entry at 2.10m depth rose to 1.90m after 20 minutes due to tidal response. SPT 'N' results ranged from 18 to 50 in the sands and gravels and 14 in the laminated silts.

BH4 was conducted 30m southeast of BH3 and found dense sands and gravels to 3.10mbgl over cobbles and boulders to 3.60mbgl. Traces of laminations in sandy silts were recorded from 3.60mbgl to termination at 5.5mbgl. SPT 'N' values ranged from 14 to 55 in the sands and gravels, and 16 in the sandy silts.

BH5 is located along the River Carron estuary approx. 30m southeast of BH4. At surface to 2.80mbgl the records show medium to coarse sand and gravels with cobbles and boulders with an SPT 'N' value of 21. Underlaying the sands are partially weathered strong to very strong red sandstone to depths of 4.00mbgl.

4.4.2 Grampian Soil Survey LTD Phase II

Following completion of works adjacent to the River Carron, Grampian Soil Survey LTD completed four cable percussive boreholes to a maximum depth of 6.50mbgl at 2 locations along Old Pier in 1984. Details of the investigation are discussed below.

BH1 was terminated at 1.70mbgl due to the close proximity of a water pipe and moved to BH1A position. BH2A replaces BH2 following refusal on a concrete obstruction. BH1A and BH2A encountered embankment fill to 3.50mbgl and 3.80mbgl respectively described as 'dirty sand, gravel; with reworked boulder clay, cobbles and boulders.' Boreholes terminated at 6.50mbgl and 4.00mbgl respectively after chiselling through 'brown/red sandstone (boulders/bedrock).'

4.4.3 Costain Ground Investigation

As part of the River Carron Phase I Flood Alleviation works, Costain were commissioned by Aberdeenshire Council to carry out a ground investigation in the town of Stonehaven under technical direction of JBA Consulting. A factual report (SH-JBA-00-00-RP-GE-0004) and a geotechnical interpretative report (SH-JBA-00-00-RP-GE-0003_P3.0) were produced following the investigation. No boreholes were conducted on the existing sea defence. The closest boreholes, BH26 and BH27, were formed adjacent to Arbuthnott Place, approximately 40m west of the existing frontage.

BH26 encountered granular made ground to 0.80mbgl over superficial deposits of mixed gravels to 2.30mbgl that are underlain by sandy silts then clays to 7.00mbgl. Between 7.00 to 13.00mbgl is sandstone bedrock, weathered throughout the top 0.5m, and experiencing significant core loss between 8.00 and 11.00mbgl. Groundwater strikes were recorded between 2.00 and 1.30mbgl.

BH27 records granular made ground to 0.5mbgl over cohesive made ground to 1.20mbgl. Fine to coarse sand to 2.4mbgl overlies silts to 3.40mbgl and clay to 9.00mbgl. Clay varies in composition from silty sandy to very sandy with depth. Between 8.50 and 9.00mbgl friable sandy clay includes interbeds of fine to medium sandstone. From 9.00mbgl to termination at 15.00mbgl strong, coarse grained sandstone core was recorded. Groundwater was struck at 1.20mbgl and rose to 1.1mbgl after 20 minutes.

4.5 Anticipated on site geology

A summary of the likely succession of geological strata is described in the Table 5-1. This information has been extracted from BGS borehole records, BGS GeoIndex, and from the aforementioned ground investigations undertaken to the south of the site (boardwalk and rock armour sections), which do not cover the whole of the site. Hence, it should be noted that the geological strata vary from south to north of the site area.

4.5.1 Groundwater

Groundwater is likely shallow (between 1.00mbgl and 4.00mbgl) and may be perched within the marine beach deposits with the alluvial clay/glacial till acting as the aquiclude.

Table 4-1: Anticipated site geology

GeoIndex name	Top depth (mbgl)	Base depth	Description
Made ground	Ground level	3.80	Sandy gravelly embankment fill
Marine beach (MB) Raised MB	Ground level (where made ground absent)	3.20	Dense sands and gravels Cobbles and boulder gravels
*Alluvium	2.30	5.50	Silty peats
Glacial till	3.40	9.00	Silty sandy clay
*Drumlithe	unknown		
Carron Sandstone Fm.	4.00	15.00 unproven	Strong, coarse grained sandstone

5 Geotechnical Risk Register

Table 5-1: Risk matrix

Probability	(P)		Impact	(I)		Risk	(R)
Very likely	5	x	Very high	5	=	Severe	20-25
Likely	4		High	4		Substantial	15-19
Plausible	3		Medium	3		Moderate	10-14
Unlikely	2		Low	2		Minor	5-9
Very Unlikely	1		Very low	1		None	1-4

Table 5-2: Geotechnical risk register

Item	Site and Ground Conditions	Hazard	Probability	Impact	Risk	Consequence	Control Measure	Probability	Impact	Risk
Contaminated Land	Tannery Old gas works	Contamination hotspots Unsuitable material for reuse	2	5	10	Health impact to site operatives and general public. Construction delays	Adequate groundwater and soil testing during GI for potential contaminants. Remedial works to contaminated land.	1	5	5
Drainage and Flooding	High groundwater	Instability of excavations below the water table	4	5	20	Collapse of excavation causing injury or death Damage to machinery	Desktop study outlined risk. Ground investigation and monitoring required to confirm ground model and strata properties. Identify requirement for drainage / support structures during works.	1	5	5
	Tides	Insufficient attenuation for soakaway Access constraints	4	4	16	Inefficient drainage resulting in flooding	Drainage designs to accommodate expected drainage from earthworks slopes and cutting drains. Ground Investigation is required to confirm the ground model and strata properties. Adequate time provided for construction between tides and access route confirmed prior to mobilisation.	1	5	5
	Fast seepage	Groundwater inflow into excavations	4	4	16	Seepage beneath flood defences Increased uplift pressures on excavation floor and beneath defence structures	Adequate site investigation to determine strata permeabilities. Pumping water out of excavations as required. Appropriate geotechnical design.	2	4	8
Temporary Works and Construction Issues	Loose or unstable strata at shallow depth	Excavation instability	3	4	12	Collapse or support required. H&S.	Near surface granular strata, to be confirmed by ground investigation and controlled by support during construction phase.	1	4	4
	Cohesive strata	Settlement of temporary and permanent works	3	4	12	Collapse of structure. Delays to works.	Appropriate GI and design works	1	4	4
	Hard strata / obstructions at shallow depth	Hard digging / driving	1	4	4	Increase cost and delay	Ground investigation to confirm bedrock at depth and identify potential obstructions in near sub-surface	1	4	4
	Unrecorded underground services	Damage during works posing risk to H&S of personnel and public	2	5	10	Increased cost of delay and for unplanned diversions, protection or repair.	Vigilance throughout works. Ensure up to date service drawings are obtained. GPR survey prior to works CAT scan excavations prior to works.	1	5	5

6 Summary and recommendations

The BGS Geoindex and historical borehole records identify a likely geological succession of superficial deposits comprising marine and raised beach deposits over glacial till. Alluvium may be present adjacent to the River Cowie and River Carron and local areas of made ground are expected along the flood defence frontage. The bedrock is anticipated to comprise of sandstones of the Carron Sandstone Formation. Due to localised intrusive geological records, this geological succession cannot be applied across the entire site.

The main geotechnical risks associated with the predicted geology underlying the site are:

- High groundwater levels – this could have a significant impact on constructing geotechnical trial pits and could impact on any construction works along the coastline;
- Fast seepage though granular deposits – this could cause difficulties forming excavations, particularly on the beach where sands are likely to wash in;
- Contaminated land – associated with the old tannery and gas works situated in proximity to the site;
- Settlement – of cohesive deposits within the alluvium deposits adjacent to the estuaries of the River Carron and Cowie;
- Shallow bedrock – early termination of intrusive investigations on the site due to limited superficial cover.

6.1 Recommendations

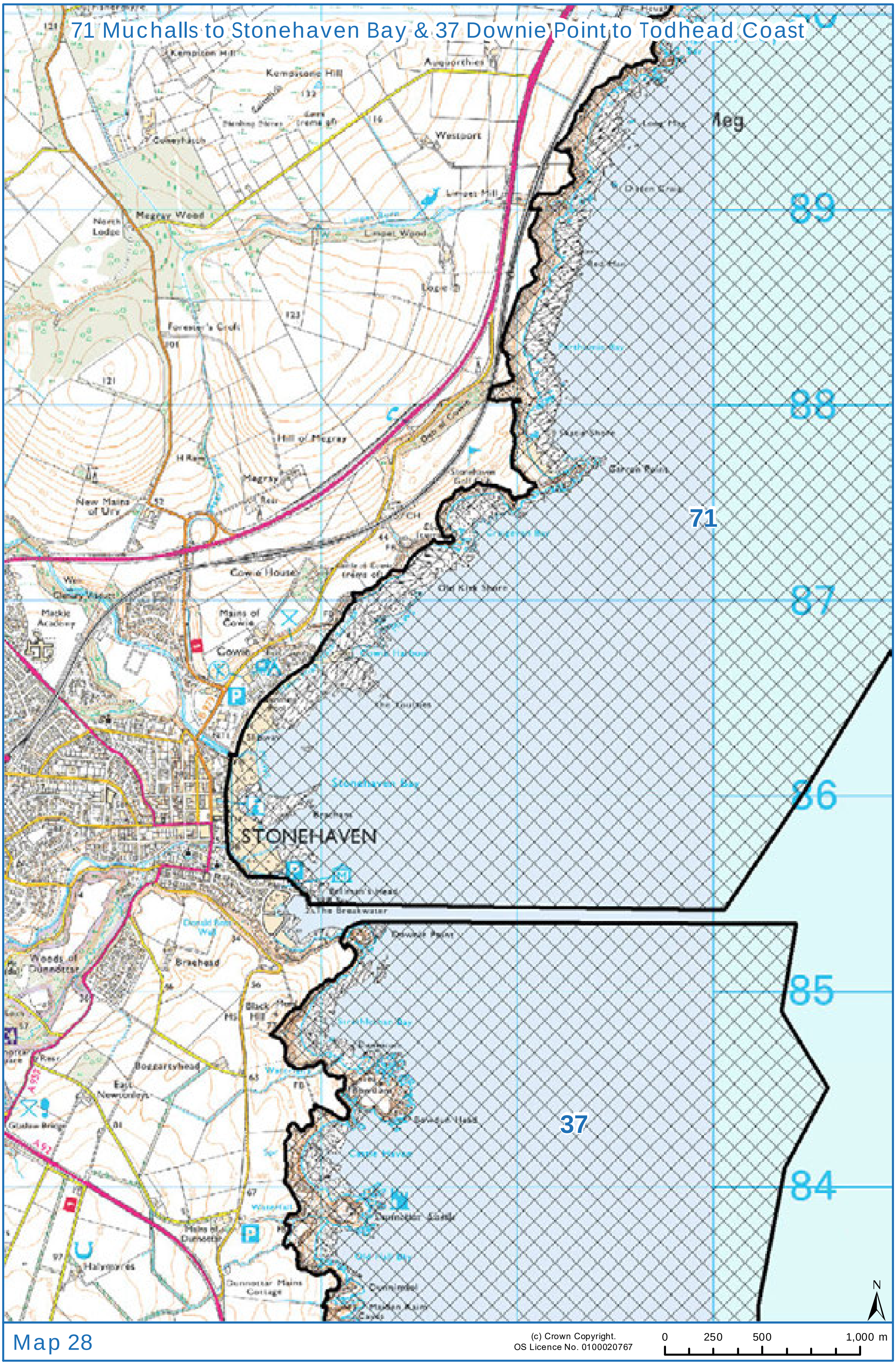
In order to inform design of the proposed improvements to flood defences along the Stonehaven frontage, a GI is recommended to determine shallow ground conditions and quantify geotechnical risk. As near surface deposits of granular material are anticipated, the extent of seepage into excavation works and high groundwaters leading to poor soakaway performance should be targeted and recorded during the GI. This will enable risks identified (Table 5-2) to be quantified and subsequently mitigated during design and construction.

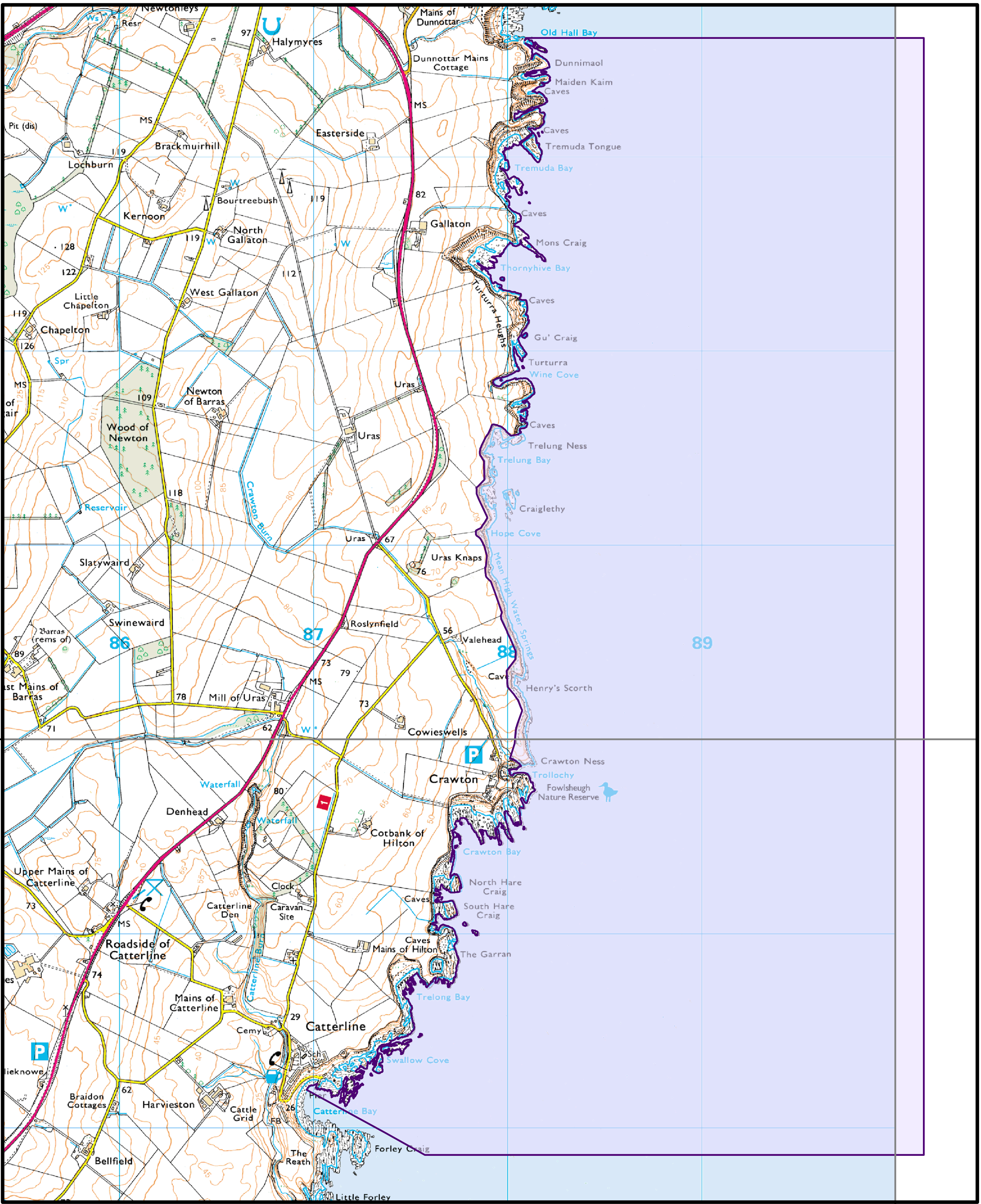
Therefore, The GI should record the following geotechnical characteristics:

- Strata conditions with testing for bearing capacity;
- Consolidation and plasticity to define maximum acceptable loading that can be applied to the ground;
- Soakaway testing.

Appendix

A Scottish Natural Heritage (SNH) Designated Sites in Stonehaven


71 Muchalls to Stonehaven Bay & 37 Downie Point to Todhead Coast
71
37
89
88
87
86
85
84
STONEHAVEN
Map 28
(c) Crown Copyright.
OS Licence No. 0100020767
0 250 500 1,000 m
N



Fowlsheugh

Special Protection Area

EC Site Code: UK9002271

Site boundary

0 0.375 0.75 1.5 km

0 375 750 1,500 m

Scale 1:25,000

This is an updated representation of the classified site boundary. Any apparent small differences are due to changes to the OS backdrop.

N

OS backdrop map is 1:25,000

Produced by: Geographic Information Group, SNH, 2011
© Reproduced by permission of Ordnance Survey on behalf of HMSO. © Crown copyright and database right 2011. All rights reserved. Ordnance Survey Licence number SNH 100017908.

Fowlsheugh

Site of Special Scientific Interest

Site Code: 660

Site boundary

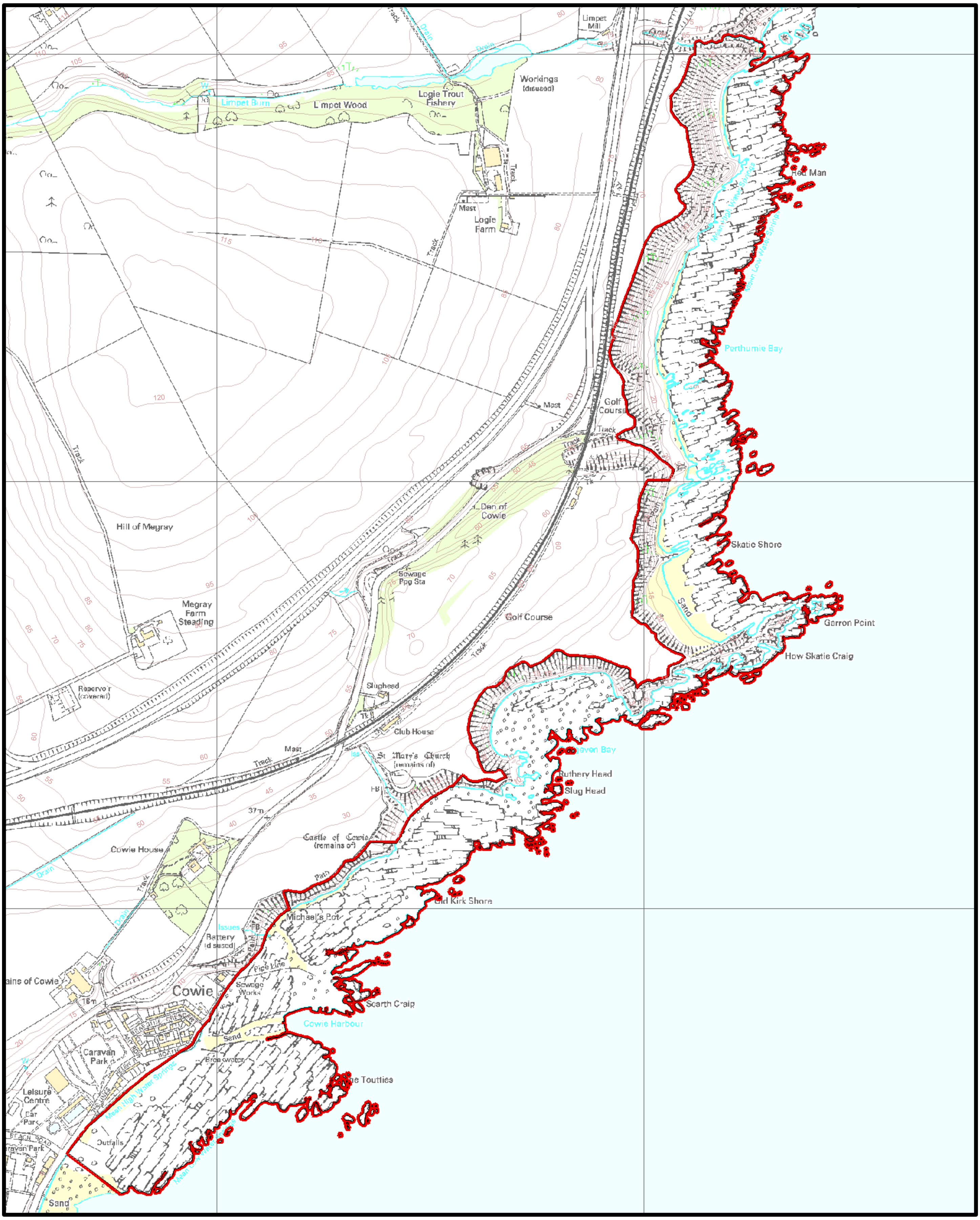
Produced by: Geographic Information Group, SNH, 2010

© Reproduced by permission of Ordnance Survey on behalf of HMSO. © Crown copyright and database right 2010. All rights reserved. Ordnance Survey Licence number SNH 100017908.

This is an updated representation of the notified site boundary. Any apparent small differences are due to changes to the OS backdrop.

N

Scale 1:8,000



Garron Point

Site of Special Scientific Interest

Site Code: 674

Site boundary

Produced by: Geographic Information Group, SNH, 2010

© Reproduced by permission of Ordnance Survey on behalf of HMSO. © Crown copyright and database right 2010. All rights reserved. Ordnance Survey Licence number SNH 100017908.

The seaward boundary of the SSSI follows MLWS and includes the offshore rocks and skerries

This is an updated representation of the notified site boundary. Any apparent small differences are due to changes to the OS backdrop.

N

Scale 1:12,000

References

[1] BGS GeoIndex http://www.bgs.ac.uk/geoindex/
[2] BHS Chronology of British Hydrological Events http://cbhe.hydrology.org.uk/
[3] Environment Agency. Magic Map http://www.natureonthemap.naturalengland.org.uk/magicmap/
[4] Environment Agency. What's in your backyard. http://apps.environment-agency.gov.uk/wiyby/default/
[5] FRM10: Coastal Flooding in Scotland: A Scoping Study, SNIFFER, Final Report, August 2008
[6] HR Wallingford. 1998. Stonehaven Seawall, Aberdeenshire. Feasibility Study of Improvements. Report EX3731.
[7] JBA Consulting. 2013. Stonehaven River Carron and Burn of Glaslaw Flood Protection Scheme. Site Investigation – Desk Study. Final Report for Aberdeenshire Council.
[8] JBA Consulting. 2013. Stonehaven River Carron & Burn of Glaslaw Flood Protection Scheme. Ground Investigation Interpretive Report. Final Report for Aberdeenshire Council. SH-JBA-00-00-RP-GE-0003_P3.0.
[9] JBA Consulting. 2014. Stonehaven Coastal Frontage Assessment. Final Report for Aberdeenshire Council.
[10] JBA Consulting. 2018. Stonehaven Bay Coastal Protection Study – Information Review Report. Draft Report for Aberdeenshire Council.
[11] Landmark. 2018. Envirocheck Report. 44862644_1_1.
[12] Macdonald et al. 2005. An overview of groundwater in Scotland. British Geological Survey. 1-29.
[13] Mott Macdonald. 2015. Phase 1 Preliminary Contaminated Land Risk Assessment Report.
[14] PJ Consulting & Associates. Stonehaven Harbour Development Feasibility Report.
[15] https://maps.nls.uk/townplans/background/stonehaven.html.

JBA consulting

Offices at

Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Glasgow
Haywards Heath
Isle of Man
Limerick
Newcastle upon Tyne
Newport
Peterborough
Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

Registered Office
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE
United Kingdom

+44(0)1756 799919
info@jbaconsulting.com
www.jbaconsulting.com
Follow us:

Jeremy Benn Associates Limited

Registered in England 3246693

JBA Group Ltd is certified to:
ISO 9001:2015
ISO 14001:2015
OHSAS 18001:2007

New Civil Engineer TechFest. Awards FESTIVAL OF INNOVATION AND TECHNOLOGY 2017 WINNER
CHAS Accredited Contractor CHAS.co.uk
IEMA Transforming the world to sustainability - EIA -

G Baseline Landscape Report

Stonehaven Bay Coastal Flood Protection Study

Landscape Impact Scoping Report

Final Report

September 2018

www.jbaconsulting.com

JBA Project Manager

Nicci Buckley BSc MSc CSci MCIWEM C.WEM
Unit 2.1 Quantum Court
Research Avenue South
Heriot Watt Research Park
Riccarton
Edinburgh
EH14 4AP

Revision History

Revision Ref/Date	Amendments	Issued to
P01 / 4 June 2018	Draft Report	G McCallum L Watson S McFarland
P02 / 26 September 2018	Final Report	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. Matthew Thirsk and Peter Harrison of JBA Consulting carried out this work.

Prepared by .... Matthew Thirsk, BA (Hons)

Assistant Landscape Architect – Landscape Architecture & Urban Design

Reviewed by .... Peter Harrison, BA (Hons), Grad Dip, CMLI, MAPM

Technical Director – Landscape Architecture & Urban Design

Purpose

This document has been prepared as a Final Report for Aberdeenshire Council. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

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.

Copyright

© Jeremy Benn Associates Limited 2018.

Carbon Footprint

A printed copy of the main text in this document will result in a carbon footprint of 58g if 100% post-consumer recycled paper is used and 73g if primary-source paper is used. These figures assume the report is printed in black and white on A4 paper and in duplex.

JBA is aiming to reduce its per capita carbon emissions.

Executive summary

JBA Consulting was commissioned to undertake a Landscape Impact Scoping Report as part of the Stonehaven Bay Coastal Flood Protection Study. The overall objective of the project is to deliver a flood protection study to consider options to reduce coastal flood risk.

This Landscape Impact Scoping Report reviews existing national and local policy, landscape character assessment, landscape designations and historical and cultural landscape designations considered applicable to the location of the proposed interventions as well as to the wider area.

Contents

List of Figures – Appendix A

1 Introduction

1.1 Scope of Appraisal

JBA Consulting Ltd is instructed by Aberdeenshire Council to prepare this Landscape Impact Scoping Report relating to the range of potential interventions proposed within the Stonehaven Bay Coastal Flood Protection Study.

Stonehaven is identified as a Potentially Vulnerable Area (PVA) being at risk from pluvial, fluvial and coastal sources.

The Landscape Impact Scoping Report considers the policies and designations that apply to Stonehaven.

1.2 Site Location

The study encompasses the coastal town of Stonehaven and village of Cowie, which are located within Stonehaven Bay approximately 20km south of Aberdeen. The National Grid Reference for Stonehaven is OS X (Eastings) 387439, OS Y (Northings) 784854.

The study extents are shown on the accompanying Figures 1 and 2.

2 Planning Policy

This section provides an overview of policy relevant to the application site. National policy sets the wider context of landscape, whilst local policy provides a framework that informs the sensitivity of key elements, highlights issues specific to the site and how these may be considered in relation to the overall planning balance.

The planning authority is Aberdeenshire Council.

2.1 National Planning Policy

2.1.1 National Planning Framework for Scotland 3 (NPF3)

NPF3 was published in June 2014 and sets the spatial strategy for Scotland's development for the following 20 to 30 years. It includes the Scottish Government's policy commitments on sustainable economic growth and is a material consideration in the determination of planning applications. NPF3 includes reference to the importance of green infrastructure and landscape and cultural heritage, including the Central Scotland Green Network (CSGN). Planning authorities must also take NPF3 into account in the preparation of Local Development Plans.

2.1.2 Scottish Planning Policy (SPP)

SPP is the statement of Scottish Government's policy on nationally important land use planning matters. It sets the core principles, key objectives and intended outcomes of the planning system.

Several *Subject Policies* are listed within the document including *A Successful, Sustainable Place* and *A Natural, Resilient Place* which each have several sub-headings of relevance to this report:

A Successful, Sustainable Place - Promoting Town Centres states *NPF3 reflects the importance of town centres as a key element of the economic and social fabric of Scotland. Much of Scotland's population lives and works in towns, within city regions, in our rural areas and on our coasts and islands. Town centres are at the heart of their communities and can be hubs for a range of activities. It is important that planning supports the role of town centres to thrive and meet the needs of their residents, businesses and visitors for the 21st century.*

A Successful, Sustainable Place - Promoting Rural Development states that with regards to Coastal Planning *The planning system should support an integrated approach to coastal planning to ensure that development plans and regional marine plans are complementary. Terrestrial planning by planning authorities overlaps with marine planning in the intertidal zone. On the terrestrial side, mainland planning authorities should work closely with neighbouring authorities, taking account of the needs of port authorities and aquaculture, where appropriate. On the marine side, planning authorities will need to ensure integration with policies and activities arising from the National Marine Plan, Marine Planning Partnerships, Regional Marine Plans, and Integrated Coastal Zone Management, as well as aquaculture.*

A Natural, Resilient Place - Valuing the Natural Environment states that the planning system should *facilitate positive change while maintaining and enhancing distinctive landscape character [and] promote protection and improvement of the water environment, including rivers, lochs, estuaries, wetlands, coastal waters and groundwater, in a sustainable and co-ordinated way.*

A Natural, Resilient Place – Managing Flood Risk and Drainage gives context on how *NPF3 supports a catchment-scale approach to sustainable flood risk management. The spatial strategy aims to build the resilience of our cities and towns, encourage sustainable land management in our rural areas, and to address the long-term vulnerability of parts of our coasts and islands. Flooding can impact on people and businesses. Climate change will increase the risk of flooding in some parts of the country. Planning can play an important part in reducing the vulnerability of existing and future development to flooding.*

2.2 Local Planning Policy

Preparation of a Local Development Plan (LDP) is a requirement of the Planning etc. (Scotland) Act 2006. The LDP sets out detailed policies and proposals for the area which, together with supplementary planning guidance, will inform decisions on future development when the council assesses planning applications. The Town and Country Planning (Scotland) Act 1997 requires that decisions on planning applications should be made in accordance with the development plan unless material considerations indicate otherwise.

The development plan for Aberdeenshire is part of a suite of documents including the Aberdeen City and Shire Strategic Development Plan and statutory supplementary guidance.

2.2.1 Aberdeenshire Local Development Plan 2017

The Aberdeenshire Local Development Plan was adopted in April 2017. It sets out the policies to guide development in Aberdeenshire from 2017 to 2022. It includes a series of maps that form part of the plan.

The plan will direct decision-making on all land-use planning issues and planning applications in Aberdeenshire. The Plan's overall strategic vision is to develop a strong and resilient economy, maintain a high quality of life and an exceptional environment through sustainable development that takes into account the important issues of climate change and reducing carbon.

The following policies of the Aberdeenshire LDP have relevance to landscape and visual issues.

Policy R1 Special rural areas relates to how development opportunities will be significantly restricted in coastal zones to reflect the special nature of these areas:

We will approve proposals for coastal protection works if an assessment of the implications of the works shows that they work with natural processes and there will be no significant adverse impact on coastal processes or habitats, and that the development will not result in increased coastal erosion or flooding elsewhere on the coastline. The full range of management options should be *considered over the lifetime of the development and against appropriate climate change projections.*

Policy E1 Natural Heritage advises that new development will not be allowed where it may have an adverse effect on a nature conservation site designated for its biodiversity or geodiversity importance, except where the following circumstances apply:

For nationally designated sites a thorough assessment must demonstrate that the objectives of designation and the overall integrity of the site will not be compromised, or that any significant adverse effects on the qualities for which the site has been designated are clearly outweighed by social, environmental or economic benefits of national importance. In all cases, any impacts must be suitably mitigated.

For other recognised nature conservation sites (such as Local Nature Conservation Sites, nature reserves, designated wetlands, woodland in the Scottish Natural Heritage Ancient Woodland Inventory and the Native Woodland Survey of Scotland the proposal's public benefits must clearly outweigh the nature conservation value of the site. In all cases, impacts must be suitably mitigated and, for any proposals involving the removal of woodland, the Scottish Government Control of Woodland Removal Policy will apply.

Policy E2 Landscape states:

We will refuse development that causes unacceptable effects through its scale, location or design on key natural landscape elements, historic features or the composition or quality of the landscape character. These impacts can be either alone or cumulatively with other recent developments. Development should not otherwise significantly erode the characteristics of landscapes as defined in the Landscape Character Assessments produced by Scottish Natural Heritage or have been identified as Special Landscape Areas of local importance.

Policy C4 Flooding states:

We will not approve development that may contribute to flooding issues elsewhere.

2.2.2 Supplementary Guidance

The Aberdeenshire LDP references 9 elements of Supplementary Guidance (SG), with the following of relevance to this report:

- 4 The Coastal Zone
- 5a Local Nature Conservation Sites – Index
- 5b Local Nature Conservation Sites – Coastal Sites
- 9a Special Landscape Areas

SG 4 presents a map of Coastal Zones that is referenced in Policy R1. The zone runs in from Newtonhill in the north and stops just before Cowie Park on the north of Stonehaven Bay. It doesn't include the majority of Stonehaven Bay and re-commences at Downie Point at the southern end of the bay continuing further south to Inverbervie. Despite the continuity break at Stonehaven Bay, the Coastal Zone is classed as *Kincardine & Mearns*.

SG 5a and 5b provide information on the Coastal Sites designated as Local Nature Conservation Sites, of which there are two in Stonehaven Bay; *71 Muchalls to Stonehaven Bay* runs into the north of the bay and *37 Downie Point to Todhead Coast* continues on to the south of Stonehaven.

SG 9a is explored in more detail in Section 3.1.3 (below).

3 Landscape baseline and assessment of effects

This section provides a description of the baseline conditions for key landscape receptors, along with an assessment of the potential effects of the proposed development.

The landscape character of the area under consideration can be assessed at a variety of different scales, from national to site-based. Desk-based and site-based studies considering these differing scales are outlined below. A number of existing published studies relate to the area under consideration and provide a basis for the assessment of the landscape character and impacts.

3.1 Landscape character: baseline

3.1.1 National – Landscape Character Assessment

Scottish National Heritage (SNH) coordinated a national programme of regional landscape character assessment studies from 1994-1998 which classified Scotland into 28 Landscape Character Types (LCT) and 372 Landscape Character Areas (LCA). These reports were generally based on local authority districts, many of which were completed prior to local government reorganisation in 1996. The assessments were compiled independently by different consultants, contractors and SNH staff to broadly similar briefs.

Environmental Resources Management was responsible for the production of the South and Central Aberdeenshire Landscape Character Assessment 102 (SCALCA), which was produced in 1997.

The report was intended to provide the landscape context for SNH staff responding to planning and land use related casework as well as of use to Aberdeenshire Council in the production of its local and structure plans.

The site lies within LCT **ABS1, Coastal Strip**, a narrow band along the whole of the coast between Whinnyfold in the north and Montrose in the south, although this can be sub-divided into 3 smaller areas defined by their different shorelines and lithology. The site is located within LCA *Kincardine Cliffs,* a 30km section of coastline from Aberdeen in the north to Inverbervie in the south. The key characteristics of Kincardine Cliffs that are particularly relevant to the study area are:

- *Major communications corridor behind the cliffs notably the A90 and east coast railway.*
- *Expansive views out to sea provide vast sense of scale.*
- *Weather is fundamental to character; coast is often windswept or lashed by rain and spray; resulting sense of exposure is great.*

Under Pressures and Sensitivities, it notes *the open and exposed character of the landscape on cliffs is sensitive to changes in land use and scale of development*.

3.1.2 Aberdeenshire Council Local Landscape Designations Review (2016)

This landscape characterisation study was undertaken by Land Use Consultants (LUC) and published in March 2016 and provides a consistent classification for the whole of the unitary authority area. The overall purpose of the project was:

- *to identify Aberdeenshire landscapes which have particular value and merit special attention as designated local landscapes in the Aberdeenshire Local Development Plan;*
- *to inform an Aberdeenshire wide 'all-landscapes' approach and future landscape objectives;*
- *to inform the preparation of the forthcoming Local Development Plan 2016, specifically the development of robust and meaningful landscape policy and associated supplementary guidance.*

The review builds on the SNH study described in Section 3.1.1, utilising the same Landscape Character Types (LCT) but now referring to Landscape Units (LU) rather than Landscape Character Areas. There are 37 individual Landscape Units identified within the review.

The site lies within **LCT Coastal Strip** and **LU 34 Kincardine Cliffs** and is the same geographical extent as defined in Section 3.1.1.

The review evaluates each LU by 12 criteria including built heritage assets, wildness, scenic qualities and naturalness and natural heritage assets. A pre-determined question is then answered by one of three pre-determined responses that rank the outcome as High / Medium / Low.

Kincardine Cliffs is a high-scoring Landscape Unit and is ranked as high. An analysis of the Landscape Unit is classed as Consistency, Relationships and Search areas identified and summarised as:

- Consistency - A distinctive stretch of coastline with a strong sense of place, centred on Stonehaven;
- Relationships - Has a relationship with the sea and sky, but is otherwise self-contained;
- Search areas identified - Included in a search area which captures the south east Aberdeenshire coast, and extends inland south of Stonehaven where adjacent farmland forms a backdrop to the coast.

Ten Special Landscape Areas (SLA), consisting of a combination of the high and medium scoring Landscape Units, have been created and are now defined within Supplementary Guidance documents that are part of the Aberdeenshire Local Development Plan.

3.1.3 Special Landscape Areas (SLAs)

There are three separate Supplementary Guidance (SG) documents that cover the ten Special Landscape Areas. The purpose of the Supplementary Guidance is to support Policy E2 "Landscape" of the Aberdeenshire Local Development Plan (2017).

A Statement of Importance for each of the SLAs is provided within the SG which is broken in to four sections - Location and Boundaries, Designation Statement, Forces for Change and Management Recommendations

The site sits within *South East Aberdeenshire Coast Special Landscape Area* and is detailed in SG *9a Special Landscape Areas*.

Location and Boundaries

- *Covers the coast from south of Aberdeen City to the mouth of the North Esk in the south,*
- *This narrow but continuous strip has been defined to include areas with strong coastal influence, the landward extent of which is generally restricted due to the high cliffs that separate the hinterland from the sea,*

- *Designation of this area recognises the importance of its rugged scenery of weathered coastal cliffs and atypical raised beach features, which form an important setting to the numerous coastal villages and towns as well as an important natural habitat.*

Designation Statement

- *The South East Aberdeenshire coast is unified by its general south east facing orientation onto the North Sea.*
- *The SLA contains many settlements, the largest of which is Stonehaven, framed by cliffs and featuring a working harbour, and strong cultural elements,*
- *This area is visible from the A90 and A92 coastal routes, National Cycle Network Route 1, east coast railway and coastal footpaths, and sea views are fundamental to its character,*
- *Coastal routes include the A92, A90, east coast railway, footpaths and National Cycle Network (Route 1), all offering expansive views out to sea*.

Forces for Change

- *Impact of proposals which effect the integrity of natural and historic features within the SLA, particularly development seeking to take advantage of sand dunes and beaches.*

Management Recommendations

- *Development which may impact on the headlands, beaches and landmarks in the area should be carefully considered in order to ensure that the panoramic views within are not negatively impacted,*
- *Development should conserve the coastal characteristics associated with towns in this area,*
- *Assess the potential impact on the sea views from significant roads, paths and visitor sites, particularly seeking to ensure that the ragged and wild nature of the coastal cliff tops and open vista of St Cyrus Bay are maintained.*

3.2 Zones of Theoretical Visibility (ZTV)

ZTV's are used to examine issues of visibility and inter-visibility in a landscape. No ZTV has been undertaken for this project, although one may be considered at a later stage once a final design solution has been selected.

Examination of a ZTV informs initial judgement as to which landscape and visual receptors should be either scoped out or subject to further assessment.

It should be noted that the ZTVs display only theoretical visibility. The screened ZTV accounts for the effects of screening through built form and woodland.

3.3 Selection of viewpoints

Viewpoints are used as part of an assessment of impacts. Since any change in the landscape is yet to be determined no viewpoints have been selected as part of this document. Potential viewpoints will be selected through desk and field-based research once the final design solution has been selected.

3.4 Site and Settlement Character – Baseline

Site Character

Site character will be assessed once the design solution has been selected.

Heritage Designations

A large section of Stonehaven is within a conservation area and there are many listed buildings found within the boundary of the conservation area as well as several more outside of the boundary. There are no Scheduled Ancient Monuments or World Heritage Sites within the study area.

Ecological Designations

The southern end of Garron Point Site of Special Scientific Interest (SSSI) is just within the northern extent of the study area. A SSSI is a national conservation designation. There are two Local Nature Conservation Sites that are within the study extents. These are locally designated sites and are referenced in *Policy E1 Natural Heritage* of the Aberdeenshire Local Development Plan 2017.

3.4.1 Landscape Character Assessment of Effects

The extent of the proposed interventions are within a Special Landscape Area designation.

3.4.2 Heritage Designations

A full cultural heritage assessment, including assessment of significance, is not provided within this Landscape Impact Scoping Report. A separate cultural heritage assessment is being produced by FAS Heritage.

3.4.3 Landscape designations

The extent of the proposed interventions are within a Special Landscape Area designation. There are no National Scenic Areas, Gardens and Designed Landscapes, Historic Marine Protected Areas, within the study area.

3.5 Visual baseline and assessment of effects

The visual baseline and assessment of effects will be considered as part of a Landscape Visual Assessment (LVA) once a final design solution has been selected.

3.5.1 Visual Qualities of the Proposal Site

The proposed development site is currently within Stonehaven Bay, Stonehaven, Aberdeenshire and the visual qualities will be considered as part of an LVA once a final design solution has been selected.

3.5.2 Recreational routes and Core Paths

Core Paths and National Cycle Network (Route 1) may offer expansive views out to sea and will be considered as part of an LVA once a final design solution has been selected.

3.5.3 Road and rail routes

Coastal routes include the A92, A90, east coast railway and local roads will be considered as part of an LVA once a final design solution has been selected.

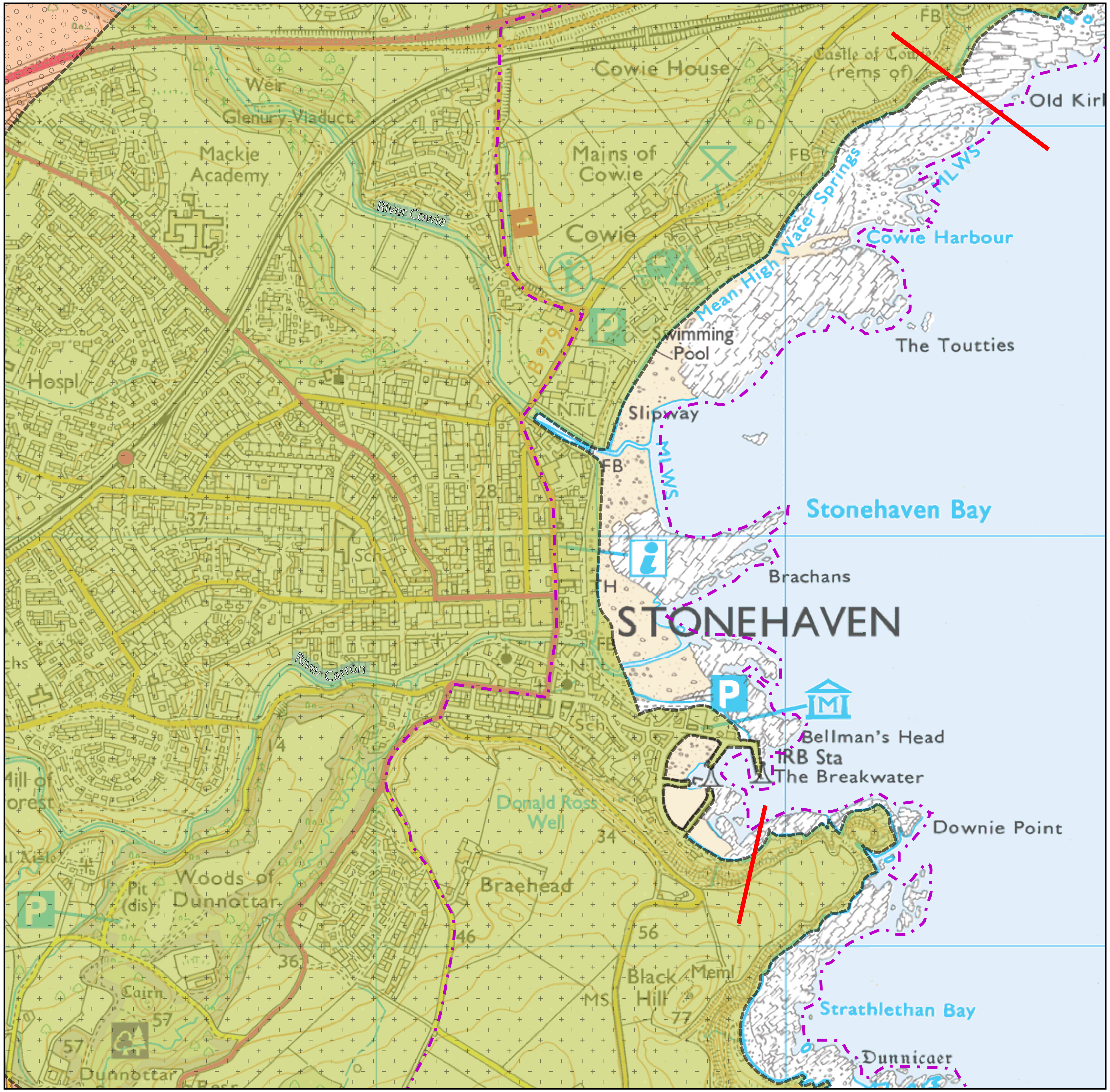
4 Conclusions

Following review of landscape policies and designations above, the following locally specific designations and issues will be considered further within the appraisal and the future assessment of landscape and visual effects:

- Consideration of the Special Landscape Area designation;
- Consideration of Core paths and National Cycle Network route;
- The consideration of other designated sites which will inform the overall landscape character, quality and value, include; listed buildings, Conservation Area, SSSI and Local Nature Conservation Sites;
- Consideration of the policies in the Aberdeenshire Local Development Plan 2017 as provided in section 2.2.1.

Appendices

A Figures



Key

Flood Study Extents

Landscape Designations

Scottish Natural Heritage Landscape Character Assessment:

Landscape Character Type - ABS1Coastal Strip
Landscape Character Area - Kincardine Cliffs

Landscape Character Type - ABS2 Agricultural Heartlands
Landscape Character Area - Garvock & Glenbervie

Aberdeenshire Council Local Landscape Designations Review:

Landscape Character Type - Coastal Strip
Landscape Unit - 34 Kincardine Cliffs

Landscape Character Type - Agricultural Heartlands
Landscape Unit - 35 Garvock & Glenbervie

Special Landscape Area:

South East Aberdeenshire Coast

NORTH

0 160 320 480 640
Metres

Stonehaven Bay Coastal Flood Protection Study
Project 2018s0343
LVA
Figure 1:
Landscape Designations

Reproduced from Ordnance Survey mapping with the permission of the controller of Her Majesty's Stationery Office © Crown Copyright and database rights 2018 Ordnance Survey 0100031673

JBA Consulting
Salts Mill, Victoria Road
Saltaire, Shipley
BD18 3LF
(01274) 714269
www.jbaconsulting.com

Key

Flood Study Extents

Heritage Designations

Listed Buildings

Scheduled Monument

Stonehaven Conservation Area

Ecological Designations

SSSI

Aberdeenshire Local Development Plan 2017

Policy E1 Natural Heritage:

Local Nature Conservation Site

Policy R1 Special rural areas:

The Coastal Zone

Recreational Routes

The Aberdeenshire Core Paths Plan

Existing Core Paths

On Road Links

National Cycle Network

Route 1 - Coast and Castles North (Edinburgh to Aberdeen)

NORTH

0 160 320 480 640
Metres

Stonehaven Bay Coastal Flood Protection Study
Project 2018s0343
LVA
Figure 2:
Local Designations and Recreational Routes

Reproduced from Ordnance Survey mapping with the permission of the controller of Her Majesty's Stationery Office © Crown Copyright and database rights 2018 Ordnance Survey 0100031673

JBA Consulting
Salts Mill, Victoria Road
Saltaire, Shipley
BD18 3LF
(01274) 714269
www.jbaconsulting.com

Offices at
Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Glasgow
Haywards Heath
Isle of Man
Limerick
Newcastle upon Tyne
Newport
Peterborough
Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

Registered Office
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE
United Kingdom

+44(0)1756 799919
info@jbaconsulting.com
www.jbaconsulting.com
Follow us:

Jeremy Benn Associates Limited

Registered in England 3246693

JBA Group Ltd is certified to:
ISO 9001:2015
ISO 14001:2015
OHSAS 18001:2007

H Baseline Heritage Report

STONEHAVEN COASTAL STUDY

STONEHAVEN

ABERDEENSHIRE

HERITAGE ASSESSMENT

REPORT

AUGUST 2018

HERITAGE ASSESSMENT

STONEHAVEN COASTAL STUDY

ABERDEENSHIRE

SITE CODE: SHV18

REPORT CODE: FAS2018 743 SHV717

NGR: NO 875 861

REPORT

August 2018

Version 2.0

FAS HERITAGE

Unit 8 Fulford Business Centre
35 Hospital Fields Road
York
YO10 4DZ

Tel (01904) 652000
Fax (01904) 749014
mail@fas-heritage.co.uk
www.fas-heritage.co.uk

ON BEHALF OF	JBA CONSULTING Port Neuk 1 Longcraig Road South Queensferry Edinburgh EH30 9TD
PROJECT TEAM	Justin Garner-Lahire BA Nicola Toop BA MA PhD MCIfA
REPORT PREPARED BY	Nicola Toop BA MA PhD MCIfA
REPORT REVIEWED BY	Cecily Spall BSc MA MCIfA ----------------------------------
REPORT AUTHORISED BY	Justin Garner-Lahire BA ----------------------------------

LIST OF CONTENTS

Appendices

Plates

Figures

Summary

This document presents the results of a Heritage Assessment (HA), prepared to inform proposals for coastal flood defences at Stonehaven, Aberdeenshire. The assessment was undertaken by FAS Heritage on behalf of JBA Consulting during May and June 2018. Currently no design has been proposed, and so the assessment considers only the potential impact of development along the coastline.

The assessment considers designated and non-designated heritage assets within a 250m buffer along the coastline. Searches of the Aberdeenshire Sites and Monuments Record (SMR) and Historic Environment Scotland data were undertaken for this area, and a scoping exercise undertaken to identify those heritage assets that would potentially be affected by works along the coastline.

The key area of potential impact on setting and historic character is the Old Town, specifically the harbour area. A harbour is known to have existed from at least the 17th century, and buildings in the area date from this period onwards. The form of the harbour as it exists is the result of 18th and 19th-century developments. The harbour is Category B Listed, and this area provides the historic setting for a large number of Listed granaries, wharves, townhouses and other historic features, including an 18th-century sundial and 19th-century Duthie's Well. Any work that erodes the legibility of the historic harbour or affects its wider character could affect the setting and therefore significance of these buildings. It is recommended that the design of any work in the vicinity of the harbour is sympathetic to the historic character of the Old Town.

To the north of the harbour, a Category A Listed former textile yard of 17th-century date occupies a site on Keith Place. A historic seawall to the north represents a key element of the form and character of this site. It is recommended that physical impact on this heritage asset is avoided, and that the design of any works in this area is sympathetic to the historic character of this heritage asset.

Buildings along the eastern edge of the New Town are generally oriented towards the town rather than the bay. Historically, the Cowie Water flowed to the rear of properties and discharged into the bay after meeting the Carron. The current character of this part of the seafront was achieved in the 20th century and makes a limited contribution to the setting of heritage assets in the immediate area. Changes to the appearance and form of the coast would not significantly harm the significance of this part of the Conservation Area or the setting of designated heritage assets.

The bay is known to have been occupied from prehistory onwards, with remains of short and long cists recorded in the area of the Tolbooth in the Old Town and at Beachgate in the New Town. Much of the seafront, however, is not considered to be of high archaeological potential. The area to the rear of the Tolbooth is known to be modern infill, with a small strip of archaeological potential surviving closer to the historic buildings. Change to the form of the seafront by the New Town is likely to represent significant modern infill also, having previously been host to a continuation of the Cowie Water and a gravel spit.

Few known heritage assets are recorded along the area of potential development. A displaced anti-tank cube is the only securely located non-designated heritage asset along the seafront. This feature is not *in situ*, but should be retained in any proposed scheme. A historic jetty is recorded at Cowie Harbour and is legible today. A number of wreck sites are included in the SMR records for Stonehaven bay, including adjacent to the harbour, but are not located precisely.

Acknowledgements

FAS Heritage would like to thank Nicci Buckley (JBA Consulting) and Claire Herbert (Aberdeenshire Archaeologist) for assistance during the preparation of this report.

1.0 INTRODUCTION

This document presents the results of a Heritage Assessment (HA), prepared to inform proposals for coastal flood defences at Stonehaven, Aberdeenshire. The assessment was undertaken by FAS Heritage on behalf of JBA Consulting during May and June 2018.

1.1 LOCATION AND LAND USE

Stonehaven lies on the east coast of Aberdeenshire and is the county town of Kincardineshire. The study focuses on the coastline of Stonehaven Bay, where proposals for coastal flood defences are being considered (central NGR: NO 875 861)(Figure 1; Plate 1).

Plate 1 Aerial view of Stonehaven

Stonehaven comprises the Old Town – a historic settlement that centres on the harbour to the south of the bay, and the New Town, a planned settlement constructed in the 18th and 19th centuries. Two rivers – the Cowie Water and the Carron Water discharge into the sea to the north and south of the New Town respectively.

Plate 2 Modern view of Stonehaven, looking south

The northern part of the study area, beyond the Cowie Water, contains the settlement of Cowie and is host to modern caravan parks and an early 20th-century open air pool; a road and modern concrete seawall follow the coast in this area. Between the Cowie Water and Carron Water lies the eastern edge of the New Town. A modern seawall flanks a concrete footpath that extends along the seafront, accessed from the east-west streets of the New Town and ending at Market Lane. The footpath continues across the shore, crossing a bridge over Carron Water and continuing towards the Old Town and the harbour (Plate 2); here the edge of the townscape varies with low walls, car parks, and modern and historic buildings (Plate 3). The harbour comprises two basins and an outer haven, and is host to numerous historic buildings.

Plate 3 Northern edge of Old Town, looking west

Location map and study area	Scale 1:25000		Figure 1

1.2 STUDY AREA

The study area defined represents a 250m buffer from the coastline along Stonehaven Bay (see Figure 1).

1.3 AIMS AND OBJECTIVES

The aim of the assessment is to set out the heritage baseline for the study, to identify those heritage assets that would potentially be affected by a new coastal defence scheme, to describe their significance, and make recommendations to ensure minimal impact on heritage significance.

1.4 LEGAL FRAMEWORKS AND PLANNING GUIDANCE

1.4.1 Legal frameworks

The following legal frameworks, planning policy and guidance apply to this assessment:

- Ancient Monuments and Archaeological Areas Act, 1979
- Planning (Listed Buildings and Conservation Areas)(Scotland) Act, 1997
- Town and Country Planning (Scotland) Act 1997
- Scottish Planning Policy (SPP)(2014)
- Historic Environment Scotland Policy Statement (HESPS)(2016)

Guidance

- Planning Advice Note 71 (PAN71) – Conservation Area Management
- Managing change in the Historic Environment: Setting, 2016

2.0 METHODOLOGY

The HA has been prepared with reference to the Chartered Institute for Archaeologists (2014) *Standard and Guidance for Historic Environment Desk-Based Assessment*.

2.1 DESK-BASED RESEARCH

2.1.1 Sources

The following were consulted as part of the assessment:

- Aberdeenshire Sites and Monuments Record (SMR)
- National Record of Historic Environment
- Historic maps and plans (online at nls.ac.uk)

2.1.2 Gazetteer

SMR data was provided for a 250m buffer along the coast of Stonehaven (see Figure 1 for study area). This provided information on:

- Scheduled Monuments
- Listed Buildings
- Conservation Areas
- Non-designated heritage assets

2.1.3 Site visit

A site visit was undertaken during the 11th to 13th June 2018.

2.2 ASSESSMENT OF SIGNIFICANCE AND IMPACT

An initial scoping exercise was undertaken to identify those heritage assets that would potentially be affected by coastal defence works along the Stonehaven coastline, either directly or through impact on setting. These have been the subject of further assessment of significance and potential impact.

2.2.1 Assessment of significance

Heritage significance has been assessed taking into account:

- archaeological interest
- architectural interest
- artistic interest
- historic interest

The following grades of significance have been employed:

- **Exceptional significance** - resources which can be demonstrated to have international or national significance, special relevance to British history or culture, and/or are of extraordinary or unique archaeological, architectural, artistic or historic merit. This will include World Heritage Sites, Scheduled Monuments (or those monuments which otherwise meet scheduling criteria) all Listed Buildings Category A and M, sites on the Inventory of Gardens and Designed Landscapes, and or Inventory of Historic Battlefields
- **Considerable significance** - resources with importance within a national or regional context, due to special archaeological, architectural, artistic or historic interest. This category will include Conservation Areas, Category B Listed Buildings
- **Moderate significance** - resources of local importance. This might include heritage assets with archaeological, architectural, historic or artistic interest, but which do not meet the criteria for designation
- **Some significance** - resources of limited local importance, due to their high frequency, lack of provenance or limited survival. This might include resources of local significance

that have been partially destroyed by past land use, whether by agricultural activity or built development

- **Unknown significance** - resources of uncertain importance based upon their type or condition.

2.2.2 Assessment of impact

The impact of any development upon the significance of a heritage asset may be adverse or beneficial. The significance of a heritage asset might be affected by direct physical impact, including destruction, demolition and alteration, but may also be affected by changes to its setting. This could include changes to the historic character of an area, alterations to views to and from a site, accidental damage from construction work, temporary loss of amenities (largely arising during development work and including air and noise pollution, visual intrusion, increased traffic, changes in the character of a landscape or townscape).

Categories of impact have been graded thus:

- **Substantial** - the heritage asset is totally altered, including change to most or all of the archaeological features or historic building fabric complete or comprehensive alteration to the setting of the heritage asset
- **Moderate** - the heritage asset is clearly altered, including change to many archaeological features or much of the historic building fabric the setting of the heritage asset is obviously altered
- **Slight** - the heritage asset is altered slightly, including change to some archaeological features or part of the historic building fabric there is a slight change to the setting of the heritage asset
- **Negligible** - the heritage asset or its setting are changed in a barely distinguishable way
- **Beneficial** - the condition of the heritage asset, or its setting is improved
- **No change** - no change

Following consideration of the value of the heritage asset and likely magnitude of the impact of development on that asset, an assessment can be made of the overall effect of the proposed work on each resource and on the area as a whole. This is broadly based on the assumption that the most significant effect will result in circumstances where the very highest impact occurs to very important remains.

2.3 DEFINITIONS

2.3.1 Heritage assets

Those parts of the historic environment that have significance because of historic, archaeological, architectural or artistic significance can be termed heritage assets. Heritage assets can include any form of building, monument, site, place, area or landscape identified as having a degree of significance because of its heritage interest.

Heritage assets may be formally designated, but also include those sites or monuments which are identified through documentary research or fieldwork but which have not been formally designated.

3.2.2 Setting

SPP 2014 (Glossary) describes setting as:

> □ more than the immediate surroundings of a site or building, and may be related to the function or use of a place, or how it was intended to fit into the landscape or townscape, the view from it or how it is seen from around, or areas that are important to the protection of the place, site or building.

The setting of a historic asset can incorporate a range of factors, not all of which will apply to every case. These are set out in Historic Environment Scotland□s Managing Change in the Historic Environment and can include:

- current landscape or townscape context□
- visual envelope, incorporating views to, from and across the historic asset or place□
- key vistas, framed by rows of trees, buildings or natural features that give an asset or place a context, whether intentional or not□
- the prominence of the historic asset or place in views throughout the surrounding area□
- character of the surrounding landscape□
- general and specific views including foregrounds and backdrops□
- relationships between both built and natural features□
- aesthetic qualities
- other non-visual factors such as historical, artistic, literary, linguistic, or scenic associations, intellectual relationships (e.g. to a theory, plan or design), or sensory factors□
- a □Sense of Place□: the overall effect formed by the above factors.

Factors to be considered in assessing impact on the setting of a historic asset or place include:

- the visual impact of the proposed change relative to the scale of the historic asset or place and its setting□
- the visual impact of the proposed change relative to the current place of the historic asset or place in the landscape□
- the presence, extent, character and scale of the existing built environment within the surroundings of the historic asset or place and how the proposed development compares to this□
- the magnitude and cumulative effect of the proposed change □ sometimes relatively small changes, or a series of small changes, can have a major impact on our ability to appreciate and understand a historic asset or place□
- the ability of the landscape, which comprises the setting of a historic asset or place, to absorb new development without eroding its key characteristics□
- the effect of the proposed change on qualities of the existing setting such as sense of remoteness, evocation of the historical past, sense of place, cultural identity, spiritual responses.

3.0 SUMMARY HISTORICAL AND ARCHAEOLOGICAL BACKGROUND

The background is not intended to represent a comprehensive history of the town, but aims to provide sufficient detail to allow the heritage impact of coastal developments to be considered. In the following, monuments recorded in the gazetteer are cross-referenced using heritage asset numbers (eg. HA 1).

3.1 PRE-MEDIEVAL

Within the study area, a number of findspots and heritage assets have been recorded which pre-date the medieval settlement and provide an indication of early activity in the area. The earliest material recorded in the study area was a fragment of copper-alloy blade found to the south of the town and dated to the Bronze Age (HA 3). Of possible Bronze Age date is the reported short cist found at Stonehaven market cross (HA 7).

Stonehaven is said to have been a focal point for settlement in the Iron Age. To the south of Stonehaven, Downie Point has been identified as the site of a possible dun, a fortified site of probable late Iron Age to early medieval date. Further burials, identified as long cists, have been recorded, including at a site close to the Tolbooth on the harbour (HA 109, 110, 111) and a site on Beachgate east of the New Town. Human remains of unspecified date and burial tradition are also noted in the Historic Environment Record (HA 108).

Although fragmentary and not securely dated, the evidence from the study area indicates that the bay formed a focal point for activity, and particularly burial, through prehistory.

3.2 MEDIEVAL AND POST-MEDIEVAL SETTLEMENT

Early settlement lay to the south of Carron Water, around the area of the harbour, in what is now Old Town. Medieval activity is represented primarily outside the town to the north and south of the study area at St Mary's Chapel, Castle of Cowie and Dunottar Castle.

Cowie is documented as 'village of Cowy' in the 14th century (HA 114) and was erected a burgh in 1540. Stonehaven became a burgh of barony in the 16th century, and subsequently superseded Kincardine as the county town of Kincardineshire in the early 17th century (HA 113).

3.3 18TH TO 20TH CENTURY

The Old Town focuses on the harbour to the south, while the northern New Town was laid out and developed in the late 18th to early 19th century. At Cowie, to the north, the small hamlet expanded during this period.

3.3.1 Old Town

A harbour is known to have existed in the 17th century, when in 1698 grants were made for its repair (HA 88); the Tolbooth at the end of the pier is the oldest building in Stonehaven and dates to the 16th century (HA 86). Structures of 17th-century date are noted in the harbour area including a house (HA 100), textile yard (HA 77) and plague burial ground (HA 106).

The early form of the harbour is not known. In 1794 improvements were made and the open-ended basin was enclosed by one pier extended outwards and a second extended towards it. The usefulness of the pier was limited by a large rock called 'Craig-ma-cair' which lay south of the pier and tended to silt up after storms (www.stonehaven-heritage.org)(shown on Wood's map of 1823 – Plate 4). Robert Stevenson drew up plans in 1811, and an Act of Parliament in 1825 allowed the quarrying and blasting of Craig-ma-Cair and the construction of the new South Pier. In 1877, the old pier was extended to create an inner harbour, and the breakwater was subsequently completed in 1908, which extended the harbour to accommodate larger vessels (www.stonehaven-heritage.org). This breakwater was damaged in the late 20th century and was rebuilt.

3.3.2 New Town

In 1759, Robert Barclay of Ury purchased the estate of Arduthie for £1500, with the intention of developing a New Town at Stonehaven, to the north of the Old Town and separated from it by the Carron water, bounded to the north by the Water of Cowie. The town was designed by his son, Robert, on an irregular grid-iron plan, and development commenced in 1797. The streets were named after family members, with Allardice, Barclay and Ann running north-south and Cameron, Evan and Mary running east-west. The Market House (later Buildings) is sited in Barclay Square (later Market Square). Further minor streets extend to the north and west. The first house, built on the north bank of the Carron and now demolished, was soon followed by those facing the square and main streets. The majority of heritage assets identified in the study area – designated and non-designated – relate to buildings of 18th, 19th and 20th-century date that developed within the town (see Appendix A).

In the 1930s, Stonehaven enjoyed popularity as a seaside town, represented architecturally by structures such as the Art Deco restaurant and the open air swimming pool (HA 8). A bowling pavilion and other leisure facilities were developed in the area north of the Cowie Water (HA 9).

Wartime structures are also represented in the study area, with the site of a former drill hall noted in the High Street (HA 132). In 1940, the Cowie Line was hastily constructed (HA 133), comprising five groups of anti-tank cubes. Most have been removed, with the surviving remains including a line of 12 anti-tank cubes in their original location west of Cowie Bridge, and one that has been relocated to the edge of the breakwater at the end of the Cowie Water.

Plate 4 Extract from John Wood's plan of 1823 (nls.ac.uk)

3.3.3 Historic map regression

The plan of the town by John Wood in 1823 shows the extent to which the town had developed at that time (see Plate 4). The New and Old Towns were much more distinct than today□apart from the early housing along Arbuthnott Street, and the mill complex, few houses existed south of the Carron Water and the water formed a much more distinctive boundary within the landscape. At this time, a spinning mill was sited south of the Cowie Water. The Cowie Water/Cowie Burn flowed behind a gravel bank to meet the Carron Water before discharging into the bay.

South of the Carron Water, a mill leat served a corn mill and spinning mill (HA 118). Buildings in the New Town did not extend fully to the frontage, in contrast to the buildings of the Old Town and Harbour to the south where the built fabric of the town extended to the waterfront. The form of the harbour is shown at this time, prior to improvements of 1825□Craig na Cair is depicted and labelled adjacent to the pier. Wood□s map shows no detail north of Cowie Water.

Late 19th-century Ordnance Survey editions provide further information on the layout of the area. The first edition Ordnance Survey map of 1866 shows the new form of the harbour, with a lifeboat station to the south (Plate 5). The central pier divides the harbour into two docks. The seawall to the rear of Keith Place appears to have been constructed at this time. The Tollbooth was at this time the limit of built development on the north side of the harbour.

The 1868 1:10560 edition (Plate 6) shows the open character of land north of Cowie Water, with Cowie itself representing a small settlement on the coast, with Cowie House and Mains of Cowie shown. A gun battery is depicted north of Cowie (HA 131), and a boat building yard labelled on the shore.

By 1903, a jetty had been constructed at Cowie Harbour□elements of this are still extant ()HA 157)(Plate 7). In the Old Town harbour, the breakwater had been constructed perpendicular to the northern part of the harbour (Plate 9) and by 1924, land to the north and east of the Tollbooth had been made-up and reclaimed to create the larger area developed today.

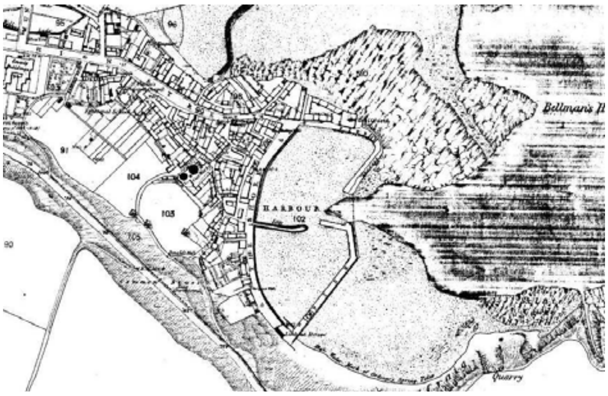


Plate 5 Extract from Ordnance Survey 1866

Plate 6 Extract from Ordnance Survey 1868

Plate 7 Cowie harbour, with jetty visible

The historic maps show buildings of an industrial nature on the eastern edge of the New Town, including warehouses to the north and a tannery to the south. An aerial view of 1932 shows the town at this time, including the channel of the Cowie Burn, and the industrial nature of many buildings (Plate 10).

Comparison of the historic Ordnance Survey and current aerial views allows the change that occurred in the latter part of the 20th century to be appreciated (Plate 8).

The 1950 Ordnance Survey edition (surveyed 1938) shows that the Cowie Water still flowed south to meet the Carron Water□a series of footbridges extended across the channel to access the gravel spit. An aerial view of 1948 show that the Cowie Burn no longer flowed into the Carron, but had breached the gravel spit further north.

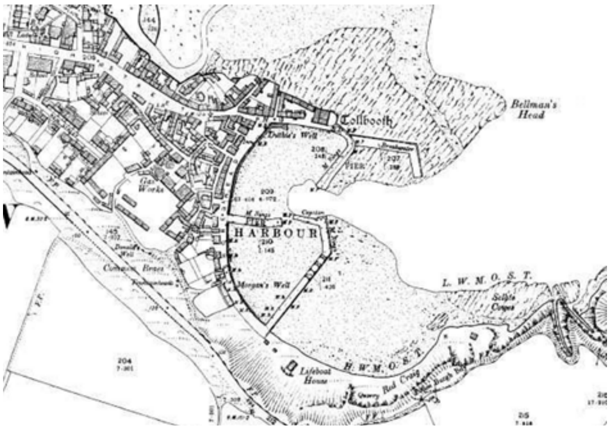


Plate 9 Extract from Ordnance Survey 1903

Plate 10 Extract from aerial view, 1932 (SPW040485) □ Historic Environment Scotland

Plate 8 Aerial view and 1868 OS overlay

By 1957 the coastline of Stonehaven had been considerably altered□the Cowie Water discharged directly into the sea and the north-south channel is no longer depicted, although the footbridges are still labelled. This would have significantly altered the setting of the properties along the frontage of the New Town.

More recent activity has involved the creation of the existing sea wall, and the construction of rock armour to protect the town.

4.0 BASELINE CONDITIONS

The following sets out known heritage assets within the study area. Designated heritage assets are shown on Figure 2 and Figure 3, and non-designated heritage assets in Figure 4.

4.1 DESIGNATED HERITAGE ASSETS

4.1.1 Scheduled Monuments

Scottish Planning Policy states that:

> 145. Where there is potential for a proposed development to have an adverse impact on the scheduled monument or on the integrity of its setting, permission should only be granted where there are exceptional circumstances

There are no Scheduled Monuments within the study area but three have been considered in this assessment, as they occupy relatively prominent coastal positions north and south of Stonehaven. These include St Mary's Chapel, Castle of Cowie and Dunottar Castle

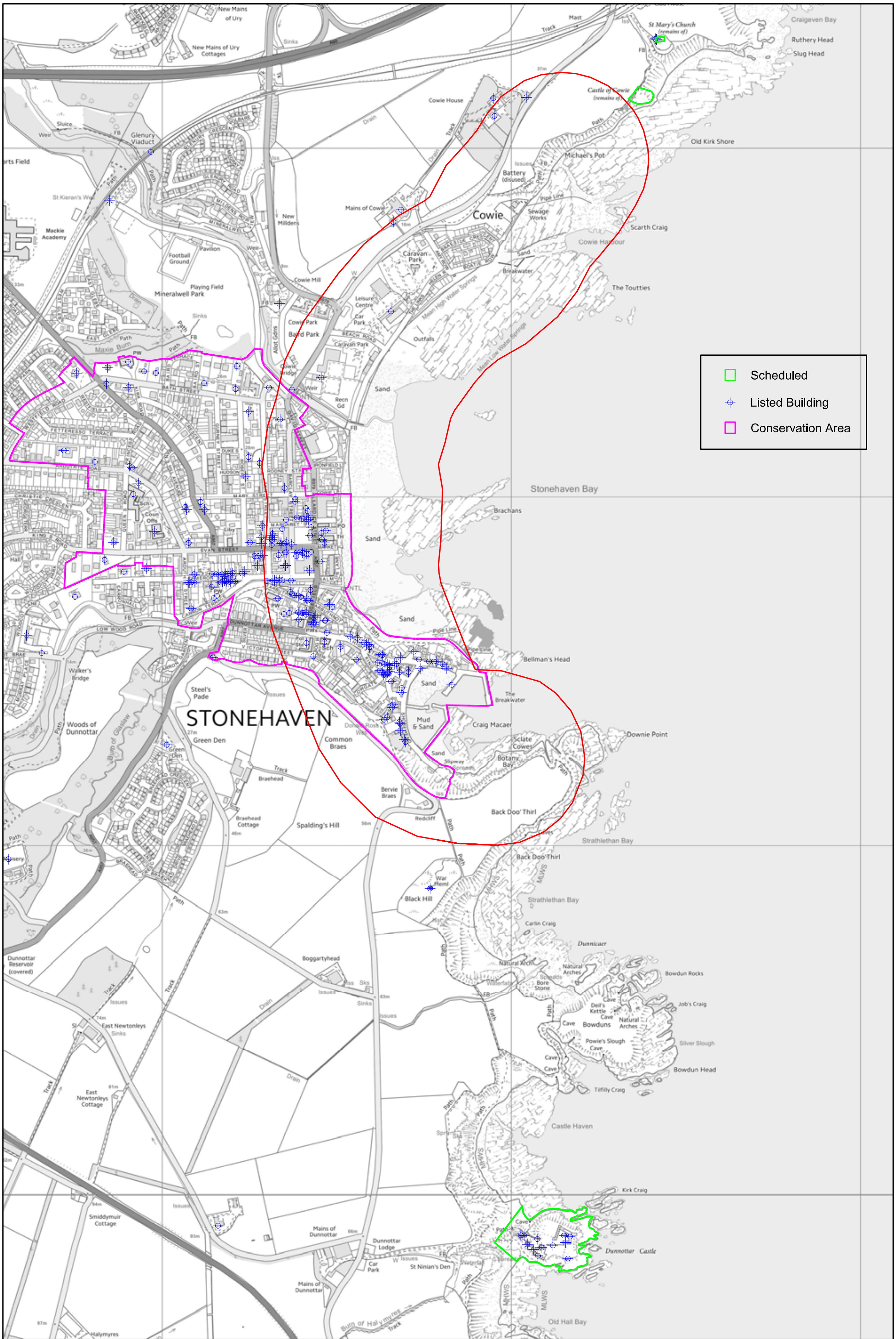
These were visited during the site visit to establish whether the development would affect the setting of these monuments, and the conclusions are set out below.

4.1.2 Listed Buildings

Listed buildings are protected under the Planning (Listed Buildings and Conservation Areas) (Scotland) Act 1997. This establishes that any work which affects the character of a Listed Building will require listed building consent.

Scottish Planning Policy sets out the following relating to Listed Buildings (SPP, para 141).

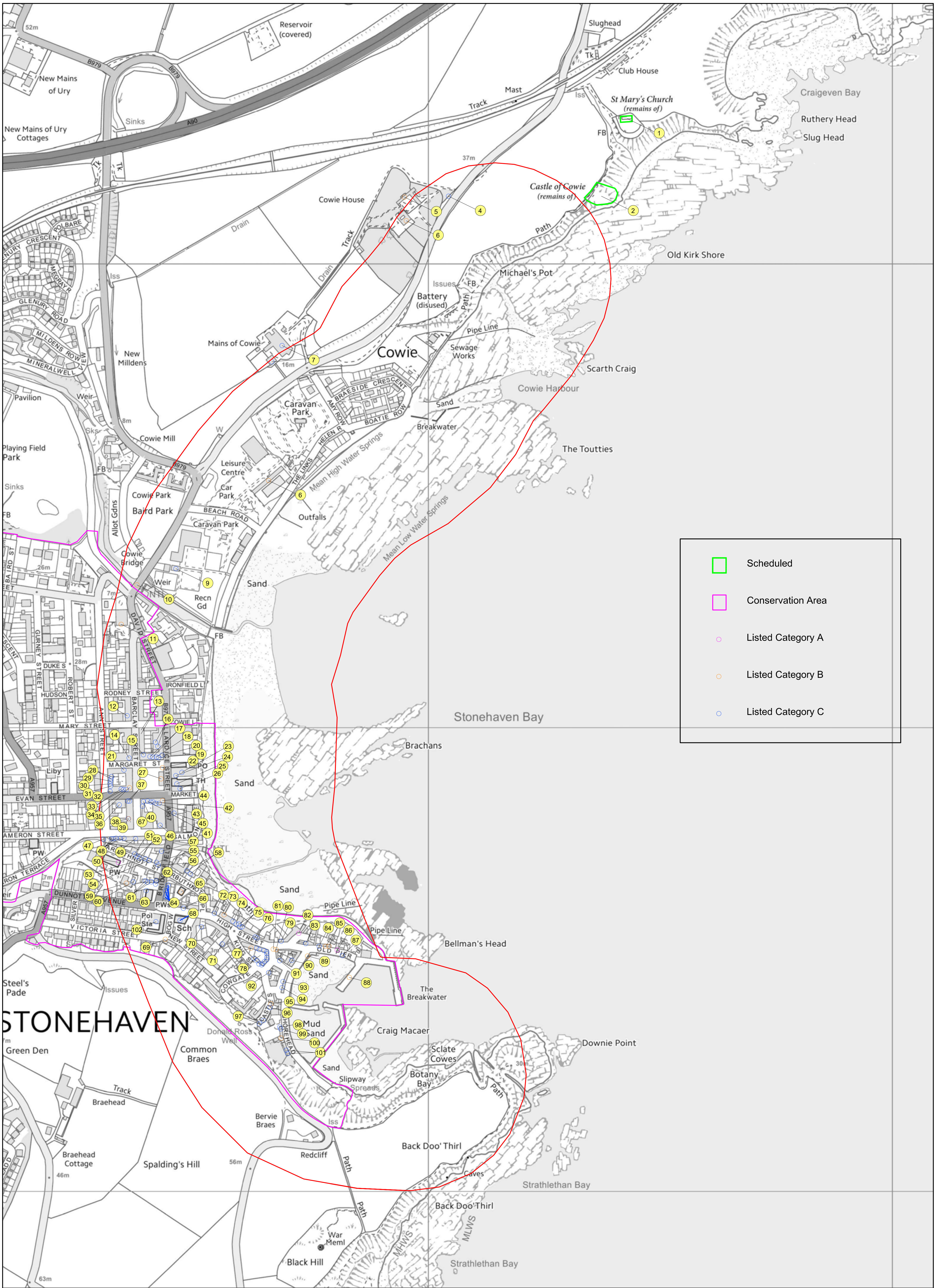
> 141. Change to a listed building should be managed to protect its special interest while enabling it to remain in active use. The layout, designs, materials, scale, siting and use of any development which will affect a listed building or its setting should be appropriate to the character and appearance of the building or setting. There is a presumption against demolition or other works that will adversely affect a listed building or its setting□



Reproduced from Ordnance Survey with the permission of The Controller of HM Stationery Office © Crown copyright

Field Archaeology Specialists Ltd Unit 8 Fulford Business Centre 35 Hospital Fields Road York YO10 4DZ Licence No AL100005790

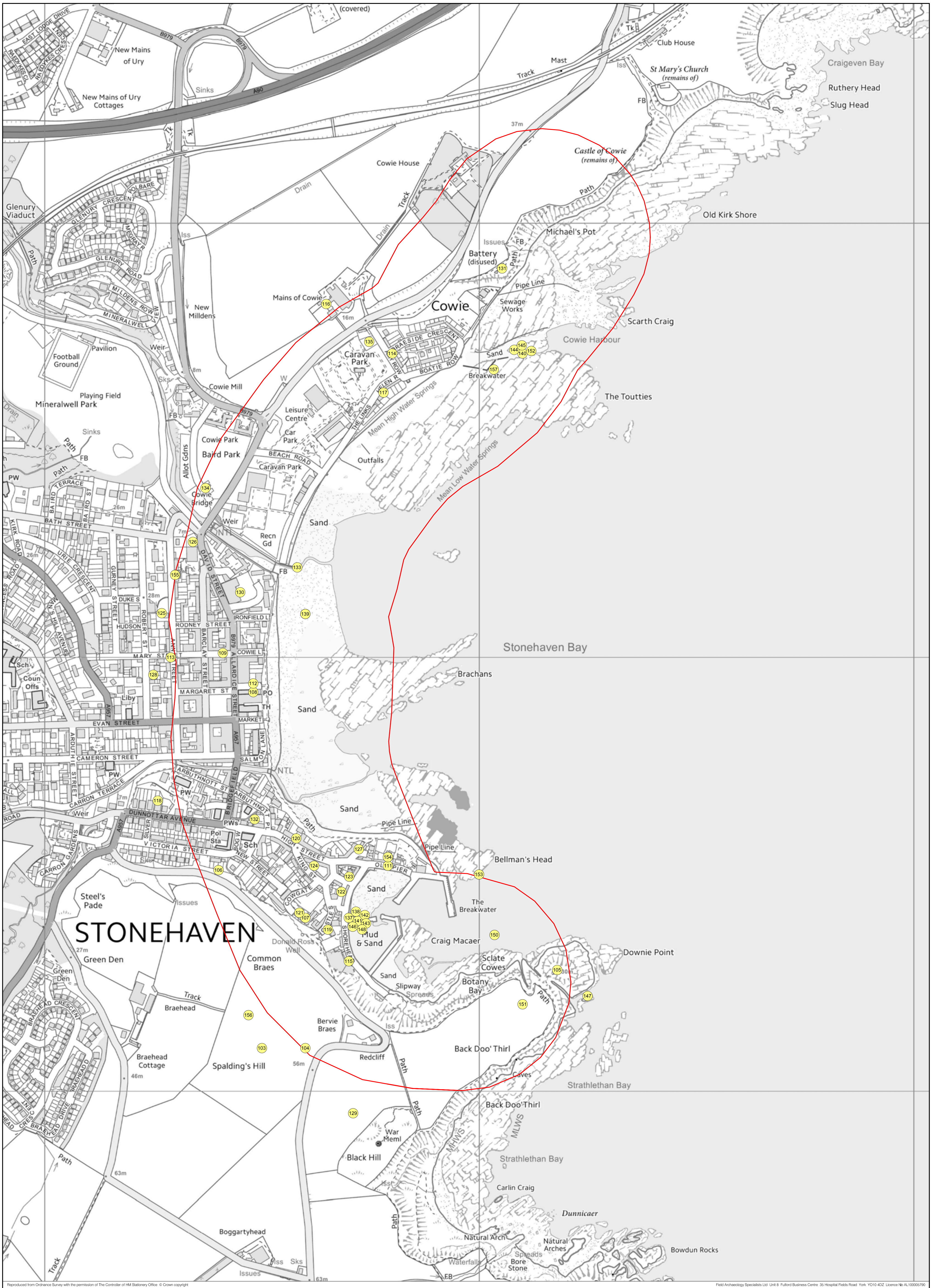
Location of designated heritage assets	Scale 1:15000	Figure 2



Location of designated heritage assets (north)

Scale 1:7500

Figure 3



Reproduced from Ordnance Survey with the permission of The Controller of HM Stationery Office © Crown copyright

Field Archaeology Specialists Ltd Unit 8 Fulford Business Centre 35 Hospital Fields Road York YO10 4DZ Licence No AL100005790

Location of non-designated heritage assets | Scale 1:5000 | Figure 4

FAS HERITAGE

A total of 99 Listed Buildings were identified in the study area, including three Category A Listed Buildings□28 Category B Listed Buildings, and 68 Category C Listed Buildings (HA 4-102)(see Figure 2).

4.1.3 Conservation Area

Conservation Areas are defined in the Planning (Listed Buildings and Conservation Areas) (Scotland) Act 1997 as

> areas of special architectural or historic interest, the character or appearance of which it is desirable to preserve or enhance.

PAN 71 (p1) states that

> The designation of a conservation area is a means to safeguard and enhance the sense of place, character and appearance of our most valued historic places. Buildings of character, listed buildings, scheduled monuments, trees, historic street patterns, open spaces and designed gardens and landscapes are important components of these areas. The overall layout and pattern of development may be just as important to the character as individual buildings.

PAN 71 (p4) states that

> Physical change in conservation areas does not necessarily need to replicate its surroundings. The challenge is to ensure that all new development respects, enhances and has a positive impact on the area. Physical and land use change in conservation areas should always be founded on a detailed understanding of the historic and urban design context.

Scottish Planning Policy (2014) states that

> 143. Proposals for development within conservation areas and proposals outwith which will impact on its appearance, character or setting, should preserve or enhance the character or appearance of the conservation area. Proposals that do not harm the character or appearance of the conservation area should be treated as one which preserves that character or appearance. Where the demolition of an unlisted building is proposed through Conseration Are Consent, consideration should be given to the contribution the building makes to the character and appearance of the conservation area. Where a building makes a positive contribution the presumption should be to retain it.

The Stonehaven Conservation Area includes the Old and New Towns of Stonehaven, encompassing the historic structures of the harbour and the grid-plan of the 18th-century new town. No Conservation Area Appraisal is available for the town.

The Old Town focuses around the old harbour, with an irregular street pattern and numerous historic buildings, items of street furniture and monuments. The significance of the New Town is enhanced by its integrity□the historic layout is still legible in the wide streets of the grid plan, and many buildings retain their historic character, which reflect the construction of the new town in the 18th- and 19th-century, with vernacular styles joined by more occasional, grander structures. 1930s architecture is represented by rarer, notable structures which include the Carron Restaurant.

4.2 NON-DESIGNATED HERITAGE ASSETS

A further 54 non-designated heritage assets were identified from searches of the Aberdeenshire SMR. These range in date from prehistory to the modern day and are mapped on Figure 3. SMR records include a number of wreck sites, the locations for which are not precisely recorded (HA 136 to HA 153).

5.0 ASSESSMENT OF SIGNIFICANCE AND SETTING

An initial scoping exercise was undertaken, to identify those heritage assets that would potentially be affected by development along the coast, and to consider the contribution that the coastline makes to their setting and significance.

5.1 SCOPING EXERCISE

5.1.1 Scheduled Monuments

Scheduled Monuments considered in this assessment lie outside the main study area, to the north and south.

St Mary's Chapel and burial ground (HA 1) lie in a cliff top position to the north of Stonehaven. The church and burial ground are of exceptional significance, due to archaeological and historical interest. The site has extensive views along the coastline, including the southern part of Stonehaven bay; works within the southern part of the bay may be visible in views from the site (Plate 11).

Plate 11 View from St Mary's Chapel and burial ground

Castle of Cowie (HA 2) is said to have been a medieval hunting lodge. The site occupies a promontory north of the bay; there are no upstanding remains and few visible earthworks of the site, but the archaeological value of the site is reflected in its Scheduled status, reflecting exceptional value. Understanding the historic setting of the site includes the views that would be afforded to and from the site, which include the coastline of the bay (Plate 12).

Plate 12 View towards Cowie Castle and the coast of Stonehaven

Dunottar Castle (HA 3) lies some distance to the south of Stonehaven Bay. The site has exceptional historic, archaeological and artistic value. The site visit indicated that there would be no intervisibility with the bay, and there would be no impact.

5.1.2 Listed Buildings

Moving from north to south, the following scoping observations were made.

A group of Listed Buildings at Cowie House are screened entirely by vegetation, and no views are achieved of the coast, and these are not considered further (HA 4, 5, 6).

At Mains of Cowie (Cat C□HA 7) the farm and associated building lie on the western side of the road and overlook at the coast. The house occupies an elevated location above the road oriented towards the sea□views are achieved towards Stonehaven bay but these are distant, and the intervening landscape characterised by a modern caravan park. As such, any changes to the seafront and coastal zone along the bay are unlikely to affect the quality of views of and from this Listed property.

Stonehaven open air swimming pool (Cat B, HA 8) occupies a location on the coast, and was constructed at a time when Stonehaven was becoming increasingly popular as a tourist destination (Plate 13). As such, this forms an significant element of the historic town, representing a key phase in its development. The coast provides the immediate physical setting of the structure but here the landscape is modern in character. The seafront is heavily engineered and the pool lies adjacent to a modern car park and caravan park. Development along the coast may affect the physical and visual setting of this monument, but this is unlikely to represent harm to appreciation of the architectural and historic significance of the building.

Plate 13 Open air pool, Stonehaven

The Bowling Club and pavilion (Cat C, HA 9) lie in relatively open ground. The key aspect of setting contributing to significance is association with the sports ground. Development along the coast would not affect the setting and significance of this heritage asset and it is not considered further (Plate 14).

Plate 14 Pavilion

Cowie Bridge (Cat B□HA 10) is a 19th-century road bridge□views are afforded along the Cowie Water towards the coast, which could be affected by coastal defences. This is already a heavily engineered watercourse and is not sensitive to new development (Plate 15).

Plate 15 View from Cowie Bridge, looking east

Within the New Town of Stonehaven, the majority of Listed Buildings lie within the grid-plan streets. The built form of the town prevents views out to the coast from the main north-south streets, with occasional rare glimpses through the east-west thoroughfares. Within the Old Town too, many Listed Buildings lie within the streetplan and do not have views to and from the coastline. Their setting would therefore be unaffected by the introduction of new coastal defences and are not considered further (HA 11-22□27-69, 102).

Plate 16 Rear of the Crown Hotel from the sea front

Some buildings are constructed on plots that extend to the seafront, including properties on Allardice Street (Royal Hotel, Nos. 38-40, Town Hall and Crown Hotel□HA 23-26), and Arbuthnott Street (HA 58)(Plate 16). These properties are oriented towards the town, and their architectural value appreciated from the main streets. The seafront makes limited impact to setting and significance, and development in this area is unlikely to result in harm to the historic environment. To the rear of these plots, historically, ran the channel of the Cowie Water before it met the Carron. The former location of the footbridge parapets can be identified, but these are modern in character and as they lack historic context they are not readily identifiable as such.

Plate 17 View along High Street, looking east

In the Old Town, properties on High Street also extend to the seafront (HA 72-76, 79, 82). Properties fronting onto High Street are terraced and are not viewed with a coastal backdrop (Plate 17).

Plate 18 View of the rear of High Street

To the rear, stone boundary walls reflect historic character but the outbuildings and rear yards are varied in character, with modern boundaries and structures. These do not make a significant contribution to appreciation of architectural value or historic context of the Listed Buildings (Plate 18). Development to the rear is unlikely to affect heritage significance.

Plate 19 View of Keith Place

At Keith Place (HA 82), a 17th-century former textile yard has a historic seawall to the rear that contributes to the historic character of this area and is clearly visible when walking along the seafront to the rear of these properties. This area is more permeable in terms of views towards the coast, and the seawall contributes significantly to the setting and character of these buildings (Plate 19 and Plate 20). The wall is included in the Listing.

Plate 20 View of seawall to rear of Keith Place

More direct setting on the seafront is noted for those properties and heritage assets which front the harbour (HA 84-90, 93-4, 99-101). These include in particular the Tolbooth (HA 86). The building is best appreciated from the harbour, which provides its historic context and contributes to heritage value (Plate 21). Designated heritage assets in the area include granaries, tenements, houses, a sundial and Duthie's well. Some early structures survive, most notably the Tolbooth, but the majority are 19th century, and as such the largely 19th-century form of the harbour (HA 88) contributes to historic context and significance.

Plate 21 View of harbour towards Tolbooth

5.1.3 Non-designated heritage assets and archaeological potential

Few non-designated heritage assets are recorded along the coastal zone.

To the south of the harbour, the site of a possible dun (HA 105) occupies elevated land. This would not be directly affected, and ability to appreciate the strategic topographic location would not be harmed.

Three long cists were recorded (HA 111) in the vicinity of the Tolbooth, indicating archaeological potential for burial along the coastal strip. Burials were also recorded at Beachgate (HA 108, 112). Archaeological investigation north of the Tolbooth has, however, corroborated the interpretation of historic maps in demonstrating that this area is infill, indicating low archaeological potential, and land east of Beachgate has been altered considerably.

Undesignated townhouses are recorded in the SMR but no further information provided (HA 115, 120, 122, 123).

At 7 Keith Place, a vaulted cellar was identified and destroyed (HA 127). This reflects archaeological potential close to these buildings but would not be affected by coastal works.

North of the town, a 19th-century gun battery occupies an elevated location on the coast (HA 131). While long distance views are possible, these are unlikely to be affected by the proposed works.

Plate 22 Anti-tank cube on breakwater

One of a series of anti-tank cubes (HA 133) survives on the breakwater at the end of the Cowie Water□a further twelve survive upstream of Cowie Bridge (Plate 22). This could potentially be affected by flood defence works, and mitigation should be in place if this is the case. As the feature is *ex situ*, significance would not be harmed by relocation to a suitable position in the immediate vicinity.

The historic map regression identified that a jetty was constructed at Cowie Harbour before 1903, the form of which is partly legible today (HA 157). This feature could potentially be affected if works are undertaken in this area.

5.2 ASSESSMENT OF SIGNIFICANCE AND POTENTIAL IMPACT

The following table summarises those heritage assets that would potentially be affected directly or indirectly by coastal defence works. For each heritage asset the table provides a summary statement of heritage significance, the attributes of setting that contribute to significance, and the potential impact of works along the coast.

Table 1 Summary of significance and potential impact

HA	Site	Status	Significance	Setting	Potential impact
1	Chapel of St Mary	SM	Exceptional □ archaeological, architectural and historical	Topographic setting contributes to aesthetic value, views of and from the site allow the significance to be appreciated.	Slight impact on distant views of bay□unlikely to harm heritage significance
2	Castle of Cowie	SM	Exceptional □ archaeological and historical	Topographic setting contributes to aesthetic value.	Slight impact on distant views of bay□unlikely to harm heritage significance
82	6 Keith Place	LB Cat A	Exceptional □ historical, architectural, archaeological and aesthetic	Historic context reflected in coastal location, and contributes to heritage significance	Potential impact on views of and from this property, and possible direct impact on the seawall. Listed Building Consent would be needed if direct impact is anticipated

HA	Site	Status	Significance	Setting	Potential impact
84	1-2 Old Pier, Stonehaven	LB Cat C	Considerable □ historical and architectural value	Group value contributes to significance. Setting on harbour and with other buildings reflects historic and socio-economic context of buildings.	Development could potentially affect historic character of the harbour and views of and from these buildings
85	3-5 Old Pier, Stonehaven	LB Cat B	Exceptional □ historical and architectural value		
86	Stonehaven Tolbooth□ standing structure	LB Cat A	Exceptional □ historical and architectural value		
87	Old Tolbooth, Old Pier, Stonehaven	LB Cat B	Exceptional □ historical and architectural value		
88	Stonehaven Harbour	LB Cat B	Exceptional □ historical and architectural value		
89	Duthie's Well, Shorehead, Stonehaven	LB Cat B	Exceptional □ historical and architectural value		
90	Ship Inn, 5 Shorehead, Stonehaven	LB Cat C	Considerable □ historical and architectural value		
93	Marine Hotel, Shorehead, Stonehaven	LB Cat C	Considerable □ historical and architectural value		
94	The Granary, Shorehead, Stonehaven	LB Cat C	Considerable □ historical and architectural value		
99	Stonehaven	LB Cat C	Considerable □ historical and architectural value		
100	19 Shorehead, Stonehaven	LB Cat B	Exceptional □ historical and architectural value		
101	23-24 Shorehead, Stonehaven	LB Cat C	Considerable □ historical and architectural value		
131	Remains of a gun battery to the northeast of the village of Cowie	Non-des	Moderate □ archaeological and historical value	Setting on elevated location will reflect strategic choice of site	No impact anticipated. Any change to views will be slight and will not harm ability to appreciate topographic location
133	Cowie Line	Non-des	Moderate □ historical value	Not in situ □ general location contributes to significance but specific situation does not reflect historic context or enhance legibility	Direct impact possible if element is removed or masked. Sympathetic relocation required if necessary
157	Jetty at Cowie	Non-des	Slight-moderate □ historical value	Topographic setting reflects intended function and historic context.	Direct impact possible if works extend into this area

5.3 ARCHAEOLOGICAL POTENTIAL

Archaeological discoveries along the Stonehaven coast have indicated that there is the potential for remains of prehistoric to modern date close to the seafront. However, existing coastal defences and changes to the coastline in the 20th century are likely to have truncated surviving remains along the existing seafront. The heritage assessment has identified some areas of known low potential, including the 20th-century made ground to the rear of the Tolbooth. The former route of the Cowie Water channel and gravel spit are also likely to represent infill or modern landscaping and is therefore of limited archaeological potential. The potential for encountering wreck sites within the bay is noted, but cannot be easily assessed.

6.0 SUMMARY AND RECOMMENDATIONS

The initial assessment identified few heritage assets that would potentially be affected by proposed works.

The key area of potential impact on setting and historic character is the Old Town, specifically the harbour area. A harbour is known to have existed from at least the 17th century, and buildings in the area date from this period onwards. The form of the harbour as it exists is the result of 18th and 19th-century developments. The harbour is Category B Listed, and this area provides the historic setting for a large number of designated granaries, wharves, townhouses and other historic features, including an 18th-century sundial and 19th-century Duthie's Well. Any work that erodes the legibility of the historic harbour or affects its wider character could potentially harm the setting and therefore significance of these buildings. It is recommended that the design of any work in the vicinity of the harbour is sympathetic to the historic Character of the Old Town.

To the north of the harbour, a Category A Listed former textile yard of 17th-century date occupies a site on Keith Place. A historic seawall to the north represents a key element of the form and character of this site. It is recommended that physical impact on this heritage asset is avoided, and that the design of any works in this area is sympathetic to the historic character of this heritage asset. Listed Building Consent may be required for works in this area, if they extend as far as the historic seawall.

Buildings along the eastern edge of the New Town are generally oriented towards the town rather than the bay. Historically, the Cowie Water flowed to the rear of properties and discharged into the bay after meeting the Carron. The current character of this part of the seafront was achieved in the 20th century and makes a limited contribution to the setting of heritage assets in the immediate area. Glimpsed views of the sea along the east-west streets of the New Town may potentially be affected, but unless proposed developments totally obscure these views they are unlikely to significantly affect the character of the area. Changes to the appearance and form of the coast would not significantly harm the significance of this part of the Conservation Area or the setting of designated heritage assets.

The bay is known to have been occupied from prehistory onwards, with remains of short and long cists recorded in the area of the Tolbooth in the Old Town and at Beachgate in the New Town.

Much of the seafront, however, is not considered to be of high archaeological potential. The area to the rear of the Tolbooth is known to be modern infill, with a small strip of archaeological potential surviving closer to the historic buildings. Changes to the form of the seafront by the New Town are likely to have resulted in significant infill, having previously been host to a continuation of the Cowie Water and a gravel spit. Any final designs should be assessed in terms of archaeological impact and appropriate mitigation designed if appropriate□the Aberdeenshire Archaeologist should be consulted.

Few known heritage assets are recorded along the area of potential development. A displaced anti-tank cube is the only securely located non-designated heritage asset along the seafront. This feature is not *in situ*, but should be retained in any proposed scheme. The remains of a late 19th-early 20th-century jetty are legible at Cowie Harbour and mitigation may be required if this is to be affected. A number of wreck sites are included in the SMR records for Stonehaven bay, including adjacent to the harbour, but are not precisely located.

7.0 REFERENCES

Cartographic sources

1823 John Wood plan of Stonehaven

1866 Ordnance Survey, 1:2500

1868 Ordnance Survey, 1:10560

1903 Ordnance Survey, 1:2500

1924 Ordnance Survey, 1:2500

APPENDIX A GAZETTEER

Key

NHLE	National Heritage List for England
SM	Scheduled Monument
LB	Listed Building
GI/GII*/GII	Grade I, II*, II
SE12SE 0	NMR Number
NMR 00000	Unique identifier in English Heritage Archives/NMR records
MST	Stoke-on-Trent Historic Environment Record
DST	HER designation number
LB	Listed Building number

HA No	NGR	Reference numbers	Status	Name	Description	Date
Scheduled Monuments						
1	NO 88425 87313	SM5584	SM	Chapel of St Mary	Roofless chapel in a curvilinear raised graveyard. Originally dedicated to St Nechtan, but later rededicated to the Virgin Mary in 1276. Suppressed in 1560s. 19th century barrel vaulted chamber added to W gable.	Medieval
2	NO 8836 8714	SM 9742	SM	Castle of Cowie	Cowie Castle, said to have been a royal hunting castle. The remains of Cowie Castle stand on a sheer-sided coastal promontory 180m SSW of Cowie Chapel	Medieval
3			SM	Dunottar Castle		Medieval
Listed Buildings						
4	NO 88044 87146	NO88NE0314 NRHE 229958 HES LB 9386	LB Cat C	Cowie House	18th century. Rubble built with 2 pairs of ashlar gatepiers, those at NE circular and banded with cornices with conical coping stones on 2 steps.	18th C
5	NO 87949 87144	NO88NE0313 Canmore 229946 HES LB No 9385	LB Cat B	Cowie House Offices	18th century. L-plan single storey and loft stepped in slope, coursed squared rubble 2 segmentally arched coach houses with single gabled dormer above to court at lower section hay barn at N with large double arched doors in NE gable. Slated roofs with straight skews and skewputts	18th C
6	NO 87953 87093	NO88NE0114 NRHE 183561 HES LB 9384	LB Cat B	Cowie House	Large composite plain vernacular mansion, asymmetrically grouped round court, 3-storey on south, taller single storey and attic on west, single storey on north and S single storey on east with 2 storey pavilion at SE	19th C
7	NO 87685 86824	NO88NE0115 NRHE 229985 HES LB 9349	LB Cat C	Mains Of Cowie	Farmstead still in use. It is depicted on the first edition OS map of 1867 as an L-shaped steading with enclosed courtyard to the south which has a small rectangular building in its southern corner.	19th C

HA No	NGR	Reference numbers	Status	Name	Description	Date
8	NO 8765 8652	NO88NE0120 NRHE 185161 HES LB 50183	LB Cat B	Stonehaven Open Air Pool	Open air heated salt-water swimming pool, still in use. Built in 1934 to the designs of Gregory and Gall. Water heating, circulation, filtering and disinfecting systems were installed in 1935, and the gents changing room extended 1936. Art Deco	20th C
9	NO 87456 86343	NO88NE0278 HES LB 50271	LB Cat C	Bowling Club Pavilion, Stonehaven Recreation Grounds	Sports pavilion, still in use, built in the early 20th century. It is a single-storey and part-raised basement, seven-bay, roughly rectangular plan, timber sports pavilion	20th C
10	NO 87372 86308	NO88NE0247 NRHE 36946 HES LB 41613	LB Cat B	Cowie Bridge	Road bridge, still in use, probably built by John Smith of Aberdeen in 1827. Re-using the original facing, the north approach was widened during the early 20th century.	19th C
11	NO 87338 86223	NO88NE0234 NRHE 185028 HES LB 41570	LB Cat B	Invercowie House, Barclay Street, Stonehaven	Villa, still in use, built before 1804, probably incorporating 18th century fabric and with later alterations. It is a two-storey with attic and raised basement, three-bay, symmetrical, rectangular-plan harled villa with ashlar margins, an eaves cornice and stone mullions	19th C
12	NO 87351 86026	NO88NE0238 HES LB 50272	LB Cat C	60-62 Barclay Street, Stonehaven	Commercial building with flatted dwelling above, built in the 1890s. It is a tall, two-storey and attic, two-bay building in an irregular terrace to the south. The building is constructed from stugged red sandstone ashlar	19th C
13	NO 87381 85987	NO88NE0249 NRHE 265518 HES LB 41561	LB Cat C	43-45 Barclay Street, Stonehaven	Terraced houses, now also in commercial use, built in the late 18th to early 19th century with later alterations. They are a two-storey and attic, six-bay terraced pair of dwellings constructed from large blocks of squared and coursed sandstone rubble	19th C
14	NO 87355 85935	NO88NE0242 NRHE 185042 HES LB 41569	LB Cat C	32 Barclay Street, Stonehaven	Shop and house, still in use as such, built in the late 18th century with later alterations. It is a two-storey and attic, terraced corner shop with a dwelling above, constructed from ashlar with stugged and droved margins and a first-floor cill band	18th C
15	NO 87386 85942	NO88NE0252 NRHE 179689 HES LB 41651	LB Cat C	26-27 Market Square, Stonehaven	Former bank, now in use by The Royal British Legion, built by Peddie and Kinnear in 1862 with later additions. It is a two-storey, three-bay, piend-roofed simple Italianate bank building constructed from narrow bands of coursed rubble	19th C
16	NO 87412 85969	NO88NE0260 NRHE 184971 HES LB 50239	LB Cat C	45-47 Allardice Street, Stonehaven	Shop and flat, still in use as such, built in the late 19th century. It is a three-storey, two-bay building constructed of sandstone with squared rubble, moulded cill courses, eaves course, corniced dormerheads and stone mullions.	19th C

HA No	NGR	Reference numbers	Status	Name	Description	Date
17	NO 87400 85938	NO88NE0257 NRHE 185279 HES LB 41652	LB Cat C	28-30 Market Square, Stonehaven	Shop and flat, still in use, built in the early 19th century with later alterations. It is a two-storey and attic, three-bay, terraced building constructed from painted machine-stugged ashlar with contrasting stone margins and a deep base course.	19th
18	NO 87414 85937	NO88NE0265 NRHE 244051 HES LB 41653	LB Cat C	31-32 Market Square, Stonehaven	Shop with dwelling above, still in use, built in the early 19th century with later alteration. It is a two-storey and attic, two-bay terraced building that is stuccoed and lined out as ashlar. The grey slate roof has tall, coped ashlar and brick stacks w	19th C
19	NO 87419 85936	NO88NE0267 NRHE 185280 HES LB 41654	LB Cat C	33-35 Market Square, Stonehaven	Dwelling and shop, still in use, built in the earlier 19th century with later alterations. It is a two-storey and attic, three-bay, terraced building that is rendered and painted with ashlar margins and bracketed and corniced fascias.	19th C
20	NO 87426 85941	NO88NE0271 HES LB 50238	LB Cat C	31-33 Allardice Street, Stonehaven	House, now also in use as a shop, probably built before 1823. It is a two-storey and attic, two-bay terraced dwelling with a later shop at the ground	19th C
21	NO 87344 85909	NO88NE0235 NRHE 185278 HES LB 51028	LB Cat C	24 Market Square, Stonehaven	Shop and dwelling, still in use, dated 1882 although in an earlier 19th century traditional manner, with few alterations. It is a tall two-storey and attic, three-bay, terraced ashlar building with squared and snecked rubble to the side with some Aberdeen bond.	19th C
22	NO 87427 85914	NO88NE0273 NRHE 185238 HES LB 41641	LB Cat B	Market Square Fountain, Stonehaven	Fountain, built in 1897. It is a small, free-standing polished granite gothic drinking fountain with a baptismal font style circular bowl on an octagonal pier with scroll supports at the splayed faces. Above is a corniced, open square columned canopy, ea	19th C
23	NO 87469 85904	NO88NE0283 NRHE 184961 HES LB 41536	LB Cat C	Royal Hotel, Allardice Street, Stonehaven	Hotel, still in use, built in circa 1900 at a time when Stonehaven was gaining a growing reputation as a seaside resort, with later alterations and additions. It is a three-storey and attic, two-bay, terraced finely droved sandstone ashlar hotel with pol	20th C
24	NO 87456 85897	NO88NE0277 NRHE 184960 HES LB 41535	LB Cat C	38-40 Allardice Street, Stonehaven	Shop with flatted dwelling, still in use, built in circa 1900. It is a three-storey and attic, narrow gable-fronted building in an irregular terrace, constructed from red sandstone ashlar.	20th C
25	NO 87458 85879	NO88NE0279 NRHE 184963 HES IB 41534	LB Cat B	Town Hall, 32-36 Allardice Street, Stonehaven	Town hall, still in use, built by Matthews and Lawrie (Inverness) in 1879, with additions by D and J R McMillan in 1903. It is a two-storey and attic, six-bay Renaissance style Town Hall with a five-bay, piend-roofed hall to the rear.	19th C
26	NO 87465 85869	NO88NE0281 NRHE 184959 HES LB 41533	LB Cat C	Crown Hotel, 30 Allardice Street, Stonehaven	Former hotel, now in residential and commercial use, built in circa 1900 incorporating earlier fabric (probably late 18th century), and converted to flatted dwellings in 2004.	18th/ 20th C

HA No	NGR	Reference numbers	Status	Name	Description	Date
27	NO 87424 85890	NO88NE0269 NRHE 184956 HES LB 41640	LB Cat B	Market Buildings, Market Square, Stonehaven	Market building, in commercial use, built by Alexander Fraser in 1826-27 with the tower built in 1827 and the spire completed in 1856, with later alterations. It was originally called The Market House and was commissioned by Captain Barclay-Allardice.	19th C
28	NO 8732 8589	NO88NE0229 NRHE 184997 HES LB 50241	LB Cat C	23-25 Ann Street, Stonehaven	Early 20th century. 2-storey and attic, mirrored pair of 3-bay houses with gated entrance recess and well-detailed interiors. Stugged squared and snecked rubble with droved margins.	20th C
29	NO 87315 85885	NO88NE0228 NRHE 230536 HES LB 41539	LB Cat C	21 Ann Street, Stonehaven	House, possibly formerly a shop, in residential use and built in the earlier 19th century. It is a two-storey and attic, two-bay terraced house constructed from coursed squared rubble	19th C
30	NO 87314 85879	NO88NE0226 NRHE 230537 HES LB 41538	LB Cat C	19 Ann Street, Stonehaven	House, possibly also with an earlier use as a shop, in residential use, built in the earlier 19th century. It is a two-storey and attic, two-bay, terraced building constructed from coursed squared rubble with projecting stone cills.	19th C
31	NO 87315 85874	NO88NE0227 NRHE 184988 HES LB 41537	LB Cat C	17 Ann Street, Stonehaven	House, still in use, built in the early 19th century. It is a two-storey and attic, three-bay, terraced stuccoed house with projecting stone cills to the first floor. The grey slate roof has coped brick stacks with some cans and thackstane and an ashlar-coped skew to the north	19th C
32	NO 87314 85863	NO88NE0225 NRHE 185188 HES LB 41621	LB Cat C	23-27 Evan Street, Stonehaven	Shops with flats above, still in use, built in the early 19th century. They are a pair of two-storey and attic, three-bay, terraced ashlar shops	19th C
33	NO 87343 85867	NO88NE0233 NRHE 268629 HES LB 41620	LB Cat C	7-11 Evan Street, Stonehaven	Shops and flats, still in use, built in the early 19th century. It is a two-storey and attic, three-bay, terraced flatted dwelling with shops at the ground	19th C
34	NO 87349 85867	NO88NE0237 NRHE 185185 HES LB 41619	LB Cat C	1-5 Evan Street, Stonehaven	Shop with dwellings above, still in use, built in the early 19th century. It is a two-storey and attic, four-bay, terraced building constructed of coursed squared rubble and continuous in design to Numbers 7 ・11 (NO88NE0233).	19th C
35	NO 87356 85871	NO88NE0243 NRHE 185276 HES LB 41647	LB Cat B	12-16 Market Square, Stonehaven	Shop, now also in residential use, built in the early 19th century with a 1920s shopfront carried out by the Ramsay family. It is a three-storey and attic, six-bay, finely-detailed terraced granite ashlar building on a corner site.	19th C
36	NO 87334 85834	NO88NE0232 HES LB 50256	LB Cat C	10-12 Evan Street, Stonehaven	Shop and flatted dwelling, still in use as such, built in the earlier 19th century and altered in the 1920s. It is a two-storey and attic, two-bay terraced ashlar building retaining unusual 1920s fittings.	19th C

HA No	NGR	Reference numbers	Status	Name	Description	Date
37	NO 87352 85842	NO88NE0239 NRHE 185190 HES LB 41623	LB Cat C	2-6 Evan Street, Stonehaven	Shop and tenement, still in use, built in the earlier 19th century with later alteration. It is a two-storey with part basement and later attic, five-bay terraced building constructed from dressed sandstone ashlar	19th C
38	NO 87353 85804	NO88NE0240 NRHE 185036 HES LB 41563	LB Cat C	Larik Lounge, 8 Barclay Street, Stonehaven	Shop and flatted dwelling, still in use, built in the earlier 19th century. It is a two-storey, three-bay building in an irregular terrace, and is constructed from colourwashed stugged ashlar with stone cills to the ground, a banded first floor cill course and eaves lintel course	19th C
39	NO 87354 85804	NO88NE0241 NRHE 185037 HES LB 41564	LB Cat B	Alexandra Hotel, 10 Barclay Street, Stonehaven	Former hotel, converted to a public house with flatted dwellings above, built in circa 1830. It is a three-storey building in an irregular terrace with a five-bay ground floor with four-bays above, with an arcaded channelled ashlar ground floor.	19th C
40	NO 87386 85841	NO88NE0251 NRHE 244046 HES LB 41646	LB Cat C	11 Market Square And 23 Barclay Street, Stonehaven	Flat and shop, still in use, built in the mid-19th century with later alterations. It is a two-storey and attic, three-bay, terraced, flatted dwelling with an altered shop at the ground floor	19th C
41	NO 87395 85842	NO88NE0258 NRHE 265587 HES LB 41645	LB Cat C	8-10 Market Square, Stonehaven	Shop and flats, still in use, rebuilt in circa 1875. It is a tall two-storey and attic, three-bay, terraced building constructed from ashlar	19th C
42	NO 87407 85840	NO88NE0259 NRHE 244029 HES LB 41644	LB Cat C	6-7 Market Square, Stonehaven	Shop and house, still in use, built in the early to earlier 19th century with later alterations. It is a two-storey, two-bay, terraced ashlar building with droved margins and chamfered arrises. The grey slate roof has coped ashlar stacks	19th C
43	NO 87413 85837	NO88NE0263 NRHE 185272 HES LB 41643	LB Cat C	4-5 Market Square, Stonehaven	House, now also in use as a shop, built in the early 19th century with later alterations. It is a low two-storey and attic, three-bay, terraced ashlar building.	19th C
44	NO 87427 85843	NO88NE0272 NRHE 185271 HES LB 41642	LB Cat B	1-3 Market Square, Stonehaven	Shops and flats, still in use as such, built in the mid-19th century. It is a two-storey and attic, three-bay stugged ashlar building with finely droved margins, a first floor cill course and an eaves course.	19th C
45	NO 87452 85816	NO88NE0276 HES LB 50240	LB Cat C	8 Allardice Street, Stonehaven	House, still in use, built in circa 1800 with later alterations. It is a two-storey and attic, three-bay traditional terraced house constructed from large blocks of squared and coursed rubble with deep-set openings.	19th C
46	NO 87422 85790	NO88NE0268 NRHE 184958 HES LB 41532	LB Cat C	Queen's Hotel, 9 Allardice Street, Stonehaven	Hotel, still in use as such, built in the earlier 19th century and reworked in the early 20th century. It was formerly named the Commercial Hotel, and is a two-storey and attic, three-bay hotel that has been Edwardianised in an English Tudor manner	19th C

HA No	NGR	Reference numbers	Status	Name	Description	Date
47	NO 8730 8576	NO88NE0223 NRHE 36949 HES LB 41553	LB Cat C	White Bridge	Footbridge, still in use, built in 1879 by G S Hird engineer and Blaikie Brothers, makers, replacing an earlier timber bridge. It is a single-span, shallow segmental-arched, cast-iron footbridge over Carron Water that has been cast in three sections.	19th C
48	NO 87344 85762	NO88NE0230 NRHE 243934 HES LB 41587	LB Cat C	29-37 Cameron Street, Stonehaven	Terraced row of cottages, still in use, built in the earlier 19th century. They are single-storey and attic, traditional harled cottages with later polygonal-roofed canted dormer windows, a grey slate roof, coped harled ridge	19th C
49	NO 87369 85761	NO88NE0246 HES LB 50254	LB Cat C	19 Cameron Street, Stonehaven	Tenement, still in residential use, built in the late 19th century. It is a tall two-storey and attic, two-bay above ground, small tenement constructed from red sandstone ashlar with projecting cills and some stugged margins.	19th C
50	NO 87332 85710	NO88NE0231 NRHE 185010 HES LB 41552	LB Cat A	St James The Great Episcopal Church, Arbuthnott Street	Church, still in ecclesiastical use. The nave was built by Sir Robert Rowand Anderson in 1875-77, Work began on 21 September 1875, with the foundation stone laid by Rev Alexander Penrose Forbes, rector of the old Episcopal Church and subsequently Bishop. Regionally Significant	19th C
51	NO 87367 85728	NO88NE0245 NRHE 185009 HES LB 41551	LB Cat C	11-13 Arbuthnott Street, Stonehaven	House, still in use, built in circa 1800 with later alterations at the ground. It is a two-storey, four-bay house closing a regular terrace to the north-west and constructed from roughly coursed and squared rubble with raised margins at the first floor.	19th C
52	NO 87378 85719	NO88NE0248 NRHE 185008 HES LB 41550	LB Cat C	7-9 Arbuthnott Street, Stonehaven	Houses, still in use, built in the late 18th century. It is a two-storey, three- and two-bay pair of houses closing a regular terrace to the south-east, and constructed from roughly squared, snecked rubble with similar roughly squared dressings.	18th C
53	NO 87390 85718	NO88NE0253 Canmore 185007 HES LB No 41549	LB Cat C	5 Arbuthnott Street, Stonehaven Standing structure	House, still in use, built in the early 19th century. It is a two-storey with attic, three-bay terraced house constructed from rough red ashlar with ashlar dressings.	19th C
54	NO 87398 85714	NO88NE0256 NRHE 185006 HES LB 41548	LB Cat C	3 Arbuthnott Street, Stonehaven	House, still in use, built in the early 19th century with later alterations. It was returned to its original layout in the late 20th century with ground floor window reinserted after the opening had been enlarged to form a garage entrance.	19th C
55	NO 87414 85710	NO88NE0264 NRHE 185005 HES LB 41547	LB Cat C	1 Arbuthnott Street, Stonehaven	House, still in use, built in the early 19th century but possibly incorporating earlier fabric. It is a tall three-storey and attic, three-bay house	19th C

HA No	NGR	Reference numbers	Status	Name	Description	Date
56	NO 87418 85704	NO88NE0266 NRHE 185119 HES LB 41581	LB Cat C	11 Bridgefield, Stonehaven	House, now also in part-use by a charitable organisation, built in the late 18th century with later additions. It is a two-storey, three-bay, rectangular-plan end terrace harled house with ashlar to the side and a base course to the gable.	18th C
57	NO 87425 85734	NO88NE0270 HES LB 50251	LB Cat C	19 Bridgefield, Stonehaven	Former joiner's workshop, now in use as a shop and offices, built in the mid to later 19th century and extended in the 1920s by Robert Thomson and Sons.	19th C
58	NO 87487 85685	NO88NE0285 NRHE 185004 HES LB 41545	LB Cat C	Bowmont House, 19-23 Arbuthnott Place, Stonehaven	House, still in use, built in the early 19th century with later alterations. It is a two-storey with attic, four-bay house with flanking two-storey pavilion wings, and is constructed from red sandstone ashlar with contrasting long and short quoins	19th C
59	NO 87349 85665	NO88NE0236 NRHE 185166 HES LB 41618	LB Cat B	Mill Inn, Dunnottar Avenue, Stonehaven	Former coaching inn and temperance hotel, now in residential use, built in the late 18th century and circa 1830. After fire damage in 1997, it was converted to flats in 1998. Its name derives from the meal mill which stood to the west of the building	19th C
60	NO 87364 85668	NO88NE0244 HES LB 50253	LB Cat C	4 Bridgefield Terrace, Stonehaven	Former coach house, now in residential use, built before 1823 as part of the adjacent Mill Inn (NO88NE0236). It is a two-storey, three-bay, T-plan building with a further lower bay altered to a garage. The building is constructed from whitewashed rubble	19th C
61	NO 87403 85668	NO88NE0255 HES LB 50252	LB Cat C	1-3 Bridgefield Terrace, Stonehaven	Cottages, still in use, built in the early 20th century with later 20th century alterations, and thought to have been built as housing for mill workers alongside 1-3 Bridgefield (NO88NE0262).	20th C
62	NO 87412 85663	NO88NE0262 HES LB 50250	LB Cat C	1-3 Bridgefield, Stonehaven	Cottages, still in use, built in the early 20th century and thought to have been built as housing for mill workers alongside 1, 2 and 3 Bridgefield Terrace (NO88NE0255). They are a linked and characterful pair of two-storey, two-bay, rectangular-plan buildings	20th C
63	NO 87392 85649	NO88NE0254 NRHE 185122 HES LB 41584	LB Cat C	St Bridget's Hall, Dunnottar Avenue, Stonehaven	Church, now in use as a church hall, built by G P K Young of Perth in 1886 with later additions and alterations, including a later added hall. It was opened on January 25, 1888, and was rededicated in 1970 after conversion to a church hall. It is an Arts and Crafts style church buildings	19th C
64	NO 87434 85648	NO88NE0275 NRHE 265358 HES LB 41585	LB Cat C	1-5 Rickarton Cottages, Bridgefield, Stonehaven	Cottages, still in use, built in 1875-76 with 20th century additions. The rear walls form a boundary with the Church of the Immaculate Conception (NO88NE0282) to the east, and were formerly all owned by the church, with Number 3 having been the Presbytery	19th C

HA No	NGR	Reference numbers	Status	Name	Description	Date
65	NO 87467 85646	NO88NE0282 NRHE 185003 HES LB 41546	LB Cat B	RC Church of The Immaculate Conception, Arbuthnott Place	Church, still in ecclesiastical use, built by J Russell Mackenzie in circa 1875-77. The funds for the church and the nearby Rickarton Cottages (NO88NE0275), which were formerly owned by the church, were provided by Mrs Hepburn of Rickarton as a memorial	19th C
66	NO 87472 85611	NO88NE0284 NRHE 185222 HES LB 41627	LB Cat C	8 High Street, Stonehaven	House, still in use, built in circa 1800 with later alterations. It is a two-storey, three-bay, traditional harled house with painted margins and quoin strips	19th C
67	NO 87384 85831	NO88NE0250 NRHE 185031 HES LB 41557	LB Cat C	15-19 Barclay Street, Stonehaven	House, now also in use as shops, built in the earlier 19th century with later alterations. It is a two-storey and attic, three-bay flatted dwelling with later shops at the ground floor in an irregular terrace	19th C
68	NO 87465 85585	NO88NE0280 NRHE 185154 HES LB 50260	LB Cat C	Dunnottar Primary School, High Street, Stonehaven	School, still in use, dated 1889. It is a tall two-storey, five-bay, rectangular plan, monumental school with narrow bands of stugged ashlar with polished ashlar margins and stugged quoins to the frontage and stugged, squared and snecked rubble to sides.	19th C
69	NO 87433 85544	NO88NE027 NRHE 36909 HES LB 50249	LB Cat B	Bogwell Lane, Stonehaven	Pair of 17th century inscribed graveslabs set in later cement-faced rubble wall, said to have been found at the site of an old plague burial ground (SMR Ref NO88NE0003). The stone to the north is dated 1608, and has death's head and shield incorporating	17th C
70	NO 87511 85571	NO88NE0286 NRHE 185240 HES LB 50261	LB Cat C	9 High Street, Stonehaven	House, still in use, built in the late 18th century. It is a two-storey and attic, three-bay, rectangular-plan traditional house, set back from street and constructed from roughly squared and snecked rubble with ashlar dressings and small windows.	18th C
71	NO 87556 85534	NO88NE0288 HES LB 50259	LB Cat C	Sea Cadet Hall, High Street, Stonehaven	Former school, now in use as a Sea Cadet hall, built in 1851 and extended in 1897 by J A Souttar, Aberdeen, builder Messrs Smith and Co, Stonehaven and joiner R Mitchell and Sons, Stonehaven.	19th C
72	NO 87539 85600	NO88NE0287 NRHE 185223 HES LB 41628	LB Cat C	24-26 High Street, Stonehaven	Tenement, still in residential use, built in the mid 19th century with later alterations. It is a three-storey and attic, three-bay plain tenement constructed from roughly coursed and snecked rubble with tooled ashlar dressings	19th C
73	NO 87560 85597	NO88NE0065 NRHE 185224 HES LB 41629 NO88NE0289	LB Cat B	Christian's House Old Stonehaven	Site of townhouse stood at 28-32 High Street. Three-storey-and-attic, five window, ashlar-fronted house. Surviving building built in 1712 as a private dwelling, using from 1746 as a place of worship for Episcopalian services by Rev Aleaxander Greig, when government legislation forbade congregations larger than five due to their support of the Jacobite cause.	18th C

HA No	NGR	Reference numbers	Status	Name	Description	Date
74	NO 87579 85583	NO88NE0290 Canmore 265371 HES LB 41630	LB Cat C	36-42 HIGH STREET, STONEHAV EN	Shops and dwellings, now converted to fully residential, built in the later 19th century with later alterations. It was originally known as Victoria Buildings. The Scots style terraced tenement is two-storey and attic and four-bay, and is constructed from stugged, squared and snecked rubble.	19th C
75	NO 87599 85571	NO88NE0291 NRHE 185226 HES LB 41631	LB Cat C	44-48 High Street, Stonehaven	Tenement, in residential and commercial use, built in circa 1800 with later alterations. It is a three-storey and attic, three-bay, rectangular-plan, harled terraced tenement	19th C
76	NO 87631 85547	NO88NE0293 NRHE 265366 HES LB 41632	LB Cat C	58-60 High Street, Stonehaven	House, still in use, built in the early 19th century but possibly incorporating 17th century fabric, and renovated in 1975. It is a two-storey and attic, three-bay terraced harled house with stone margins and a base course.	19th C
77	NO 87618 85525	NO88NE0292 NRHE 80422 HES LB 41626	LB Cat B	51 High Street, Stonehaven	Townhouse, still in residential use, built in the early 17th century with later alterations, including a slightly raised wallhead. It is a three-storey, four-bay, L-plan, harled terraced town house with painted ashlar margins.	17th C
78	NO 87642 85492	NO88NE0295 HES LB 50237	LB Cat C	Albert Lane, High St, King St, The Cross, Stonehaven	A small housing development covering 2-4 Albert Lane, 53-59 High Street, 11A-19 King Street and 4-6 The Cross, still in residential use, built in 1938-42. In 1944 a mine exploded in the harbour, sufficiently damaging the houses to force residents to leave, and not return for 2 years	20th C
79	NO 87683 85540	NO88NE0303 NRHE 185229 HES LB 41635	LB Cat C	82 High Street, Stonehaven	Shops and house, now fully in residential use, built in the later 19th century with later alterations. It is a tall two-storey and attic, four-bay house with the ground floor converted from shops, and a lower two-storey, single bay at the east.	19th C
80	NO 87672 5522	NO88NE0076 NRHE 36953 HES LB 41615	LB Cat B	Stonehaven Clock Tower	Clock tower, dated 1790 with later alterations and additions. It is thought to be the work of Aberdeen mason James Rhind, built by public subscription and known locally as Old Town Steeple. The original clock (now on display in the Tolbooth Museum)	18th C
81	NO 87666 85523	NO88NE0004 NRHE 36920 HES LB 41616	LB Cat B	Stonehaven Market Cross	Site of market cross□the cross was removed from its original site to its present site at NO8765 8551 some time before 1864. It is a simple stone-shafted cross, square at base but splayed above, resting on an octagonal base.	19th C
82	NO 87721 85557	NO88NE0102 NRHE 80421 HES LB 41638	LB Cat A	6 Keith Place, Stonehaven	17th century former textile yard with an enclosing seawall which pre-dates the 18th century harbour improvements. The interior stonework retains evidence of a large fireplace to the west gable at basement	17th C

HA No	NGR	Reference numbers	Status	Name	Description	Date
83	NO 87736 85535	NO88NE0308 NHRE 185237 HES LB 41637	LB Cat C	94-96 High Street, Stonehaven	House and shop, still in use as such, built in the mid 19th century. It is a two-storey and attic, three-bay terraced building constructed from stugged ashlar.	19th C
84	NO 87765 85529	NO88NE0310 NRHE 185976 HES LB 41657	LB Cat C	1-2 Old Pier, Stonehaven	Houses, still in use, built in the early 19th century. They are a pair of two-storey and attic, five-bay, rectangular-plan part-terraced rendered and painted houses with projecting cills.	19th C
85	NO 87779 85529	NO88NE0311 NRHE 265394 HES LB 41658	LB Cat B	3-5 Old Pier, Stonehaven	House, still in use, built in the 18th century house with later additions and alterations. It is a two-storey, four-bay, L-plan, piend-roofed house with two stone forestairs in an irregular terrace overlooking the harbour.	18th C
86	NO 87804 85521	NO88NE0018 NRHE 36899 HES LB 41655	LB Cat A	Stonehaven Tolbooth standing structure	Former storehouse and tolbooth, now in use as a museum. It was built in the late 16th century as a storehouse by the Earl Marischal, but became the Tolbooth when Stonehaven became the county town in about 1600 as it was the strongest building in town. By 1897 it had reverted to its original use	Post-med
87	NO 87815 85509	NO88NE0312 NRHE 185283 HES LB 41656	LB Cat B	Old Tolbooth, Old Pier, Stonehaven	Sundial, dated 1710. It is a free-standing sundial with a cubic sandstone head with chamfered angles, a horizontal dial with wrought-iron gnomon and a short square-section shaft, also with chamfered angles, off-set below.	18th C
88	NO 87830 85462	NO88NE0029 NRHE 36938 HES LB 41625	LB Cat B	Stonehaven Harbour	Harbour, still in use, built in place of an earlier harbour. A harbour existed here certainly by the early 17th century though as to its size it is not known. Grants were made to repair the harbour in 1698. By 1794 it consisted of nothing more than an open-ended basin, when it was enclosed by the one pier being extended and another pier being built out towards it. It was not until 1825 that improvements were made. A natural harbour improved by two curving piers which with smaller later piers form two basins and an outer haven. Original rubble works have been modified with steel sheet piling	17th C onwards
89	NO 87740 85508	NO88NE0309 NRHE 80426 HES LB 41659	LB Cat B	Duthie's Well, Shorehead, Stonehaven	Well, built in the early 19th century. The Duthie family, who made their money from ship building and the manufacture of rope, helped fund the building of the well. A square ashlar structure encloses the well	19th C
90	NO 87706 85499	NO88NE0307 Canmore 185965 HES LB 41660	LB Cat C	Ship Inn, 5 Shorehead, Stonehaven	Inn, still in use, built in the mid 19th century, probably incorporating 1771 fabric, with later alterations. It is a three-storey, four-bay, rectangular-plan, terraced hotel with a crowstepped nepus gable. whitewashed coursed rubble with polished ashlar margins	18th C

HA No	NGR	Reference numbers	Status	Name	Description	Date
91	NO 87680 85498	NO88NE0301 HES LB 50262	LB Cat C	4 John Street, Stonehaven	House, still in residential use, built in the early 19th century. The east access from the house to the port suggests it was probably formerly a merchant house. It is a two-storey, three-bay traditional house with large squared rubble, red sandstone blocks with stone margins and snecked rubble to sides and read	19th C
92	NO 87656 85472	NO88NE0296 NRHE 184977 HES LB 41530	LB Cat C	1 Albert Lane, Stonehaven	House, still in use, built in the late 18th century with later additions. It is a traditional two-storey, harled house, with painted ashlar margins and deep-set windows. The west (principal) elevation has bays grouped to left.	18th C
93	NO 87687 85453	NO88NE0305 NRHE 185973 HES LB 41662	LB Cat C	Marine Hotel, Shorehead, Stonehaven	Hotel, still in use, dated 1884 with later additions and alterations. It is a three-storey and attic, five-bay, near-symmetrical, rectangular-plan hotel in an irregular terrace, constructed from stugged, squared and snecked rubble with ashlar dressings, painted at ground floor.	19th C
94	NO 87685 85440	NO88NE0304 NRHE 121571 HES LB 41663	LB Cat C	The Granary, Shorehead, Stonehaven	Former granary, now in residential use, built in the early 19th century, converted to a dwelling with a new roof installed 1976-78. It is a four-storey, four-bay, rectangular-plan, terraced, harled former granary with snecked, roughly coursed rubble and squared rubbed dressings to rear	19th C
95	NO 87661 85405	NO88NE0298 NRHE 185152 HES LB 41609	LB Cat B	1 Castle Street, Stonehaven	House, still in use, built in the mid 18th century. It is a two-storey, lined stucco terraced house, with three bays at the ground floor and a base course. The timber sash and case windows have two upper sash and plate glass glazing patterns.	18th C
96	NO 87659 85397	NO88NE0297 NRHE 243887 HES LB 41610	LB Cat C	3 Castle Street, Stonehaven	House, still in use, built in the early 19th century. It is a two-storey, three-bay, traditional terraced house with stucco lined-out as ashlar, a base course and raised cills. The grey slate roof has two small later rooflights, coped stuccoed stacks wit	19th C
97	NO 87636 85362	NO88NE0294 NRHE 243873 HES LB 41612	LB Cat C	7-11 Castle Street, Stonehaven	Houses, still in use, built in the 18th century and altered to the rear. It is a two-storey, seven-bay, rectangular-plan, short terrace of harled houses with painted margins and snecked rubble to the side.	18th C
99	NO 87682 85351	NO88NE0032 NRHE 185975 HES LB 41667	LB Cat C	Stonehaven	Former warehouse/granary, dating from the early 19th century, now the Aberdeen and Stonehaven Yacht Club. It is 4-storey, 3-window, rendered at ground level and harled above. The northern windows have been loading doors□3rd floor openings are small oblongs	19th C

HA No	NGR	Reference numbers	Status	Name	Description	Date
100	NO 87683 85331	NO88NE0302 NRHE 80423 HES LB 41668	LB Cat B	19 Shorehead, Stonehaven	House, still in use, built in the late 17th century with later alterations. At some time it was in use as a pub with a beer cellar. It is a two-storey and cellar, three-bay, rectangular-plan house with its gable to the harbour.	17th C
101	NO 87694 85305	NO88NE0306 NRHE 265381 HES LB 41670	LB Cat C	23-24 Shorehead, Stonehaven	Tenement, in residential use, built in the early and mid 19th century with various later alterations. The southern area of Number 24 was formerly housed a net-making workshop. It is a plain two-storey, five-bay, rectangular-plan terraced small tenement	19th C
102	NO 87413 85583	HES LB 41617	LB Cat B	Stonehaven Sheriff Court House and Police Station including boundary walls	James Campbell Walker 1863-65, incorporating 18th C fabric and additions by John Smith in 1822. 2 storey and basement, 11-bay, symmetrical neo-classical court house with slightly advanced end bays.	18th-19th C
Non-designated heritage assets						
103	NO 875 851	NO88NE0041 NRHE 118772	-	Braehead Crop Mark (includes soil mark)	Field system□banks and blobs visible on air photograph. Regionally significant	Unknown
104	NO 876 851	NO88NE0155	-	Spalding's Hill Findspot	Fragment of a copper alloy blade found during metal detecting, 2013. The blade of a sword or possibly rapier, has a tapering end and prominent mid rib. Claimed as Treasure Trove (2013/352)	Bronze Age
105	NO 8818 8528	NO88NE0074 NRHE 36897	-	Downie Point Crop Mark (Includes Soil Mark)	Possible site of a Dun. There is a reputed dun on Downie Point (the name is thought to be corruption of 'Dunie' i.e. little fort□thought to have stood on the flat, grass-covered summit of the peninsula centred at NO 8818 8528 measuring about 43m NW-SE by 20m	□
106	NO 8740 8551	NO88NE0003 NRHE 36909	-	Stonehaven	Supposed site of plague burial-ground, now occupied by modern buildings and gardens. Two gravestones were found about 1842 and are now set into the E wall of a public footpath at NO8741 8552 (SMR ref NO88NE0274).	17th C
107	NO 876 854	NO88NE0013 NRHE 36892	-	Old Stonehaven □short cists	Documentary Reference Only Short cists□two short cists were found near Stonehaven market cross while the causeway was being relaid c1880. The following week similar finds were made 20yds away beside the local gasworks. 'Many such finds had previously been made on the triangle of sandy soil on which Old Stonehaven stnads□	
108	NO 8748 8592	NO88NE0143	-	Beachgate, Stonehaven	Bones found by workmen during building works on Beachgate House in 2003. Some of the bones were human - fragmented clavicle, two ribs, and mandible, probably from a young adult female. Animal bone from a dog was also recovered, probably from a later deposit. Bones undated	Unknown

HA No	NGR	Reference numbers	Status	Name	Description	Date
109	NO 8741 8601	NO88NE0002 NRHE 36898	-	Stonehaven	Long cists□two long cists containing extended inhumations were found near the E end of Mary Street. The cists, which lay about 3.6m apart, were aligned from NE -SW□one measured 1.65m by 0.41m and 0.36m in depth.	Early medieval
110	NO 876 854	NO88NE0059 NRHE 36935	-	Albert Lane, Stonehaven	Site of a long cist, uncovered during road works in August 1983. Excavation determined that the remains were oriented roughly north-south, but had been disturbed prior to their 1983 discovery and were incomplete. The remains were re-examined by AOC	Unknown
111	NO 8779 8552	NO88NE0048 NRHE 36918	-	Stonehaven Tolbooth	Three long cists□a skeleton and a skull are preserved in Marischal College Museum. Said to have been found during roadworks.	Unknown
112	NO 8748 8594	NO88NE0103	-	Beachgate Lane	During utility work on an area of derelict land just off Beachgate Lane a cist was uncovered.	Unknown
113	NO 8729 8600	NO88NE0055 NRHE 36934	-	Stonehaven	Burgh□Stonehaven was erected a burgh of barony in the 16thC and superseded Kincardine as the county town of Kincardineshire in the early 17thC. The town first developed to the S of the Carron Water, the area now known as Old Stonehaven, where the harbour, the tolbooth and the market cross are. In the later 18th C the area known as New Stonehaven was laid out to the N of the Carron Water	Medieval
114	NO 878 867	NO88NE0054 NRHE 36951		Cowie	Village of Cowie, which was erected a burgh in 1540-1, although the 'village of Cowy' is recorded in the 14th Century. The medieval castle and chapel of Cowie lie to the North East of the present village.	Medieval
115	NO 877 853	NO88NE0062	-	Shorehead, Stonehaven	Site of townhouse. No further information.	-
116	NO 87648 86814	NO88NE0069 NRHE 80425	-	Old Stonehaven	Site of a possible fortified inn□no further information.	-
117	NO 8778 8661	NO88NE0366	-	4 Helen Row, Cowie	Cottage, still in use, depicted on the 1st and 2nd edition OS maps as a rectangular building at the western end of a row of four terraced cottages. Current maps show it has been altered to T-plan. A photographic survey was carried out in 2016 prior to proposed alterations	19th C
118	NO 8726 8567	NO88NE0133	-	Invercarron	Site of a corn mill. On the 1st edition OS map (c.1867) it is shown as having a pond with mill dam to the west and a lade passing the mill building and heading east to the harbour. By the 2nd edition OS map (c.1888) the lade has been covered.	Post med

HA No	NGR	Reference numbers	Status	Name	Description	Date
119	NO 87652 85373	NO88NE0153 NRHE 185153	-	5 Castle Street, Stonehaven	Remains of a fisherman's cottage dating from the early 19th century. Single storey with attic, and two windows and a door to the street. It formerly had a canted dormer to the sea and pantiled roof. Rubble built with a harled seaward elevation.	19th C
120	NO 87579 85583	NO88NE0064 NRHE 265371		Old Stonehaven	Site of townhouse□called Cumberland House□no further information.	
121	NY 8759 8541	NO88NE0068	-	Old Stonehaven	Site of townhouse□stood at Water Yett. No further information. Documentary Reference Only	-
122	NO 87683 8546	NO88NE0067	-	Old Stonehaven	Site of townhouse□stood at 5 Shorehead□no further information.	Post med
123	NO 87701 85495	NO88NE0061 NRHE 36953		Shorehead, Stonehaven	Site of townhouse. No further information.	-
124	NO 8762 8552	NO88NE0066 NRHE 80422	-	Old Stonehaven	Site of townhouse□stood at 51 High Street. The earliest 'smart house' in town, built for William Ogilvy of Lumgair. Three storeys, harled, tall and narrow, bolection-moulded doorpiece with traces of interlace ornament. No longer extant	-
125	NO 87279 86098	NO88NE0218 NRHE 184993 HES LB 41543		Harley House, 56 Ann Street, Stonehaven	House, still in use, built in the early 19th century. It is a two-storey and attic, three-bay house with stugged ashlar with droved margins, coursed rubble and a base course. The grey slate roof has coped ashlar gablehead stacks with a full-complement of cans and thackstanes and ashlar-coped skews	19th C
126	NO 87341 86266	NO88NE0036 NRHE 36941	-	Belmont Brae, Stonehaven	Brewery□remains of old brewery represented by 2 barrel-vaulted chambers with rough sandstone and mortar walls, which lie beneath the main road. A stump of a chimney lies in the corner of an adjacent garden.	
127	NO 87723 85558	NO88NE0035 NRHE 80420	-	7 Keith Place, Stonehaven	Vaulted cellar. The top half of barrel-vaulting (red sandstone blocks) was exposed and destroyed during demolition of an overlying building. The cellar had been backfilled with sand, pebbles and earth and clearly predates a now demolished building. Survives beneath the lane immediate N of demolition and may relate to foundations of early structures, which are visible in the garden immediate N of lane	Post-med
128	NO 8725 8596	NO88NE0106	-	5 Robert Street	Rectangular cottage that is depicted on the 1867 1st edition OS map.	19th C
129	NO 8771 8495	NO88SE0095		Black Hill	A number of metal, pottery and glass objects were found in the fields around the Black Hill war memorial by a metal detectorist in April 2011. These include 17th - 19th Century lead weights and coins□18th - 19th Century copper alloy buttons□a 19th Cent	17th C onwards
130	NO 8745 8615	NO88NE0031 NRHE 121570		Stonehaven	Bonded warehouses□mid 19thc□a range of 7 bays of 1- and 2-storey rubble buildings.	19th C

HA No	NGR	Reference numbers	Status	Name	Description	Date
131	NO 88053 86896	NO88NE0085 NRHE 36954	-	Cowie	The remains of a gun battery lie to the north-east of the village of Cowie. It is depicted as having three guns on the 1st edition OS maps of 1867-74 but disused by the 1889-1915 editions. It was re-built and used during the 2nd World War but is now disused	19th C
132	NO 87483 85627	NO88NE0146 NRHE 331410		High Street, Stonehaven	Site of a drill hall, used in World War I and World War II, and which is shown on 3rd edition OS 1:2500 map, behind the buildings on the street frontage. It was the base of 'C' Company, 7th battalion Gordon Highlanders in 1914. Now demolished, new housing occupies the site	20th C
133	NO 87135 86630 NO 8732 8633 to NO 8735 8630	NO88NE0130 NRHE 204699	-	Cowie Line	Remains of five groups of anti-tank cubes part of the Cowie Stop Line. The ground east of the Glenury Viaduct drops to a floodplain which was fortified by five sections of anti-tank cubes which are visible on vertical aerial photographs taken by the RAF in 1946. Only 13 survive, one on the breakwater at the mouth of the Cowie Water and a line of 12 still in their original location to the west of Cowie Bridge	20th C
134	NO 8737 8639	NO88NE0094	-	Baird Park	A World War II Nissen hut, currently being used by the local authority.	20th C
135	NO 87747 86727	NO88NE0140	-	Cowie Telephone Exchange	Former telephone exchange, dating from the early 20th century. A photographic survey was carried out in 2015 ahead of proposed development.	20th C
136	NO c. 876 861	NO88NE0317 NRHE 195852	-	Nancy, Sands of Cowie Wreck site	The schooner NANCY, carrying a cargo of deals, logs and planks, was wrecked on the Sands of Cowie, Stonehaven, on the 31st October 1774.	18th C
137	NO c.877 854	NO88NE0357 NRHE 274080	-	Ellen, Stonehaven Harbour Wreck site	The barque ELLEN, in ballast, was wrecked near Stonehaven on the 23rd November 1869. The crew were lost. Wrecked at the back of the new pier	19th C
138	NO c.877 854	NO88NE0334 NRHE 198593	-	Corsair, Stonehaven Harbour	The iron steamship CORSAIR was wrecked at Stonehaven harbour in March 1881. No further information.	19th C
139	NO c.876 861	NO88NE0340 NRHE 247538	-	Nancy, Cowie Beach	The sloop NANCY, carrying a cargo of herring from Aberdeen to Leith, under Captain Christie, was wrecked at the entrance to Stonehaven harbour, on Cowie beach, on the 19th November 1850.	19th C
140	NO 881 867	NO88NE0360 NRHE 275942	-	Louise, Cowie	The schooner LOUISE, under Captain Jansen, carrying a cargo of flax and cedilla from St. Petersburg to Dundee, was stranded at Cowie during a dense fog on the 8th October 1859. The crew were saved.	19th C
141	NO 877 854	NO88NE0354 NRHE 271725	-	Martha, Stonehaven Harbour	The sloop MARTHA, under Captain Sharp, carrying a cargo of lime from Sunderland to Findhorn, was wrecked at the back of Stonehaven quay on the 7th October 1822 after her cargo ignited. The crew were saved.	19th C

HA No	NGR	Reference numbers	Status	Name	Description	Date
142	NO 877 854	NO88NE0323 NRHE 199918	-	Roslin Castle, Stonehaven Harbour	The wooden lugger ROSLIN CASTLE, in ballast, under Captain Leiper, was stranded at the back of the South pier, Stonehaven harbour, on the 26th December 1899.	19th C
143	NO 877 854	NO88NE0361 NRHE 282459	-	Olive, Stonehaven Harbour	The schooner OLIVE, under Captain Targoose, travelling from Hull to Stonehaven, was wrecked near the South Pier, Stonehaven, on the 4th April 1849.	19th C
144	NO 881 867	NO88NE0318 NRHE 196485	-	Ann And Isabella, Cowie Wreck Site	The sloop ANN AND ISABELLA, under Captain Anderson, was stranded at Cowie, Stonehaven, on the 9th May 1881.	19th C
145	NO c.881 867	NO88NE0364 NRHE 285517	-	Isabella Forbes, Cowie	The wooden schooner ISABELLA FORBES, under Captain Kennedy, carrying a cargo of coal from Sunderland to Aberdeen, was stranded at Cowie, Stonehaven, on the 30th July 1867.	18th C
146	NO 877 854	NO88NE0341 NRHE 248559	-	Christina, Stonehaven Harbour	The schooner CHRISTINA, with a crew of 6 under Captain Smith, carrying a cargo of barley from Montrose to London, was wrecked at the back of the North harbour at Stonehaven on the 25th November 1852. The crew were saved.	19th C
147	NO 8825 8522	NO88NE0330 NRHE 198264	-	Downie Point	Supposed site of wreck.	-
148	NO c.877 854	NO88NE0356 NRHE 273884	-	Isabella, Stonehaven Harbour	The schooner ISABELLA, under Captain Smith, travelling from Morrison's Haven to Arbroath, was stranded at the South Pier, Stonehaven, on the 7th November 1835. The crew were saved.	19th C
149	-	NO88NE0365 NRHE 298192	-	North Sea	A Norwegian schooner is reported to have been wrecked about 10 miles South of Aberdeen on the 22nd December 1870. No further information.	
150	NO 88036 85361	NO88NE0322 NRHE 199774	-	Oxford Eight, Stonehaven Harbour	The wooden ketch OXFORD EIGHT, with a crew of 4 under Captain J. Lamb, carrying a cargo of coal from Bridgeness to Stonehaven, was stranded at the entrance to Stonehaven harbour on the 5th May 1898.	
151	NO c.881 852	NO88NE0342 NRHE 250279		Felix, Downie Point	The wooden barquentine FELIX (formerly names as FELIX BRANDT, and EASTERN PRINCE), with a crew of 10 under Captain G. Andersen, carrying a cargo of coal from East Hartlepool to Malmo, was stranded on Throng Neck, near Downie Point, on the 20th October 1898. Three of the crew were lost	19th C
152	NO c. 881 867	NO88NE0325 NRHE 200455		Welcome Home, Cowie Creek, Stonehaven	The wooden lugger WELCOME HOME, in ballast, under Captain Taylor, was driven from her moorings and stranded at Cowie Creek, Stonehaven, on the 10th February 1904.	20th C

HA No	NGR	Reference numbers	Status	Name	Description	Date
153	NO 880 855	NO88NE0331 NRHE 198283	-	Foldin, Bellman's Head, Stonehaven	The wooden barque FOLDIN, with a crew of 6 under Captain Andersen, carrying a cargo of iron, was stranded on Bellman's Head, 150 yards from Stonehaven Harbour, on the 22nd December 1876.	19th C
154	NO 8779 8554	NO88NE0124		Backies, Stonehaven	An evaluation was carried out at this site in 2006 by Murray Archaeological Services in advance of a proposed wastewater treatment scheme and pumping station. An evaluation trench excavated in the central area of the site appears to show that was deep infill in the recent past. Concluded that only the narrow strip on the S of the site is the area of archaeological importance.	-
155	NO 8730 8619	NO88NE0138	-	Invercowie House, Stonehaven	A watching brief was carried out at this site in March 2008 in advance of a proposed housing development. Part of the site lies within the former walled garden of Invercowie House (NO88NE0234). No archaeological features or finds were evident in the soil strip	-
156	NO 87469 85176	NO88NE0136	-	Bervie Braes, Stonehaven	Archaeological monitoring was undertaken by Rathmell Archaeology during the boring of test pits by Jacobs in respect of groundworks on the cliff top above the Bervie Braes road south of Stonehaven. This was due to the close proximity to a crop mark site. No archaeological features were recorded	-
157	NO 8803 8668	-	-	Jetty	Jetty marked on 1903 historic map in Cowie Harbour and legible on the seafront today	19th C e20th C

I Interim Modelling Report and Technical Review Certificates

Stonehaven Bay Coastal Flood Protection Study

Interim Modelling Report

Final Report

January 2019

www.jbaconsulting.com

JBA Project Manager

Nicci Buckley BSc MSc CSci MCIWEM C.WEM
Unit 2.1 Quantum Court
Research Avenue South
Heriot Watt Research Park
Riccarton
Edinburgh
EH14 4AP

Revision history

Revision Ref/Date	Amendments	Issued to
P01 / 02 November 2018	-	G McCallum L Watson S McFarland
P02 / 18 January 2019	Climate change modelling added and comments from SEPA and Aberdeenshire Council addressed.	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. Johnny Coyle, Hannah Otton, Douglas Pender and Nicci Buckley of JBA Consulting carried out this work.

Prepared by .... Johnny Coyle BSc MSc

Analyst

Prepared by .... Hannah Otton BSc

Assistant Analyst

Reviewed by................................. Douglas Pender MEng PhD MCIWEM

Senior Engineer

Reviewed by .... Nicci Buckley BSc MSc CSci MCIWEM C.WEM

Principal Analyst

Approved by .... David Bassett BSc MSc CEnv MCIWEM C.WEM

Director

Purpose

This document has been prepared as a Draft Report for Aberdeenshire Council. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

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

Acknowledgements

JBA would like to thank Aberdeenshire Council, SEPA and the Stonehaven Flood Action Group for the provision of data and information to support this work.

Copyright

© Jeremy Benn Associates Limited 2018.

Carbon footprint

JBA is aiming to reduce its per capita carbon emissions.

Executive summary

This Interim Modelling Report was undertaken by JBA Consulting for Aberdeenshire Council as part of a Flood Protection Study (FPS) to consider options to reduce coastal flood risk within Stonehaven and Cowie. The report consists of three sections: flood modelling; geomorphological assessment; and baseline economics.

The flood modelling process used SEPA's offshore multivariate dataset in conjunction with still water levels from the Coastal Flood Boundary dataset to estimate flood risk to Stonehaven from both wave overtopping and extreme sea levels. Testing of the methodology using hindcast data was undertaken to provide confidence in the modelling outputs, with the results giving good agreement with historic observed overtopping and flooding. Modelling of the extreme conditions shows that there are multiple properties at risk of flooding within the study area, even at low return periods.

The geomorphological assessment showed that there are high levels of variability in local beach levels and volumes. Cross-shore transport is the primary control mechanism, leading to berm building and the burying of the defences during extreme events. While this renders the sea wall obsolete as an overtopping defence, anecdotal evidence supports the theory that a higher, steeper beach provides more protection by dissipating energy further offshore. A longshore gradient also exists, as can be seen from the general increase in beach width from north to south. The control structures at the mouths of both the Cowie and Carron appear to be inefficient at retaining beach sediment, with the volume of sediment to the south of the Carron outfall less than that placed there manually by Aberdeenshire Council. The data used for the analysis was not available at the frequency required to fully understand the performance and changes in the beach during extreme conditions, however the morphology of the beach is clearly a key component in the protection against and exacerbation of flood risk within the bay.

Present value damages calculated from the baseline economical appraisal are approximately £12.6 million. The high frequency of flooding and number of properties at risk during low return periods has significantly capped these. Overall the damages without capping are over £50 million suggesting that without intervention, set back or change of use of the properties there is significant potential for ongoing losses within the community.

Recreational losses through erosion of the beach; risk to life from wave overtopping; critical infrastructure at risk from erosion and sea level rise and climate change will be incorporated into the damage assessment prior to full options appraisal and will cause overall present value damages to increase for the appraisal period.

Contents

List of Figures

List of Tables

Abbreviations

1D	One Dimensional (modelling)
2D	Two Dimensional (modelling)
AAD	Annualised Average Damages

CFBD	Coastal Flood Boundary Dataset
DEFRA	Department of the Environment, Food and Rural Affairs (formerly MAFF)
DTM	Digital Terrain Model
FCERM	Flood and Coastal Erosion Risk Management (R&D programme)
FPS	Flood Protection Scheme
HR	Hydraulic Research, Wallingford
Hs	Significant Wave Height
LiDAR	Light Detection And Ranging
mAOD	metres Above Ordnance Datum
MDA	Maximum Difference Algorithm
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MSL	Mean sea level
NCCA	National Coastal Change Assessment
OS	Ordnance Survey
PvD	Present Value Damages
RMSE	Root Mean Square Error (objective function)
SEPA	Scottish Environment Protection Agency
Tp	Wave Period
TUFLOW	Two-dimensional Unsteady FLOW (a hydraulic model)

1 Introduction

1.1 Overview

Stonehaven is a coastal town located approximately 20 km to the 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).

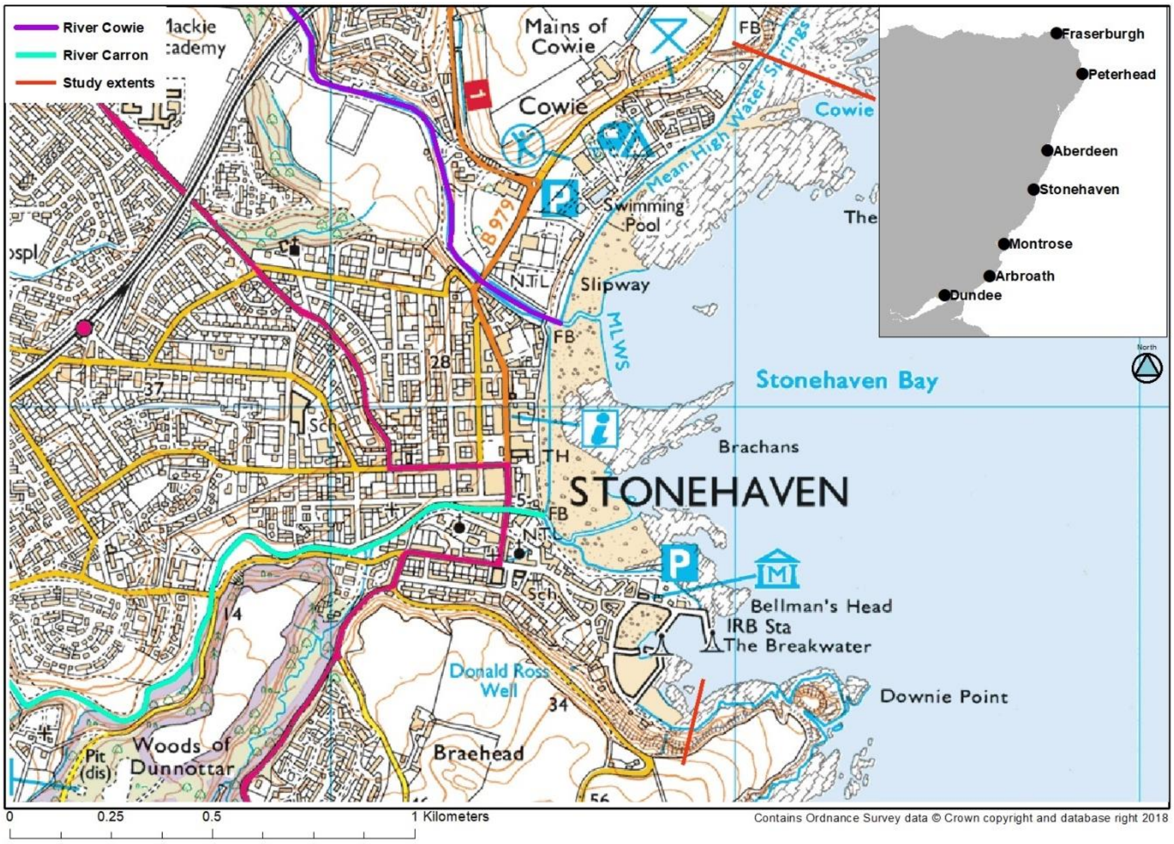


Figure 1-1: Location plan

JBA were commissioned by Aberdeenshire Council to undertake a coastal Flood Protection Study (FPS) to consider options to reduce coastal flood risk within Stonehaven and Cowie. The key project stages, and where this Interim Modelling Report fits into the context of the wider project are summarised below:

Information Review Report	Complete
Supplementary studies	Complete
Modelling and baseline economics	Interim Modelling Report
Engineering and options appraisal	Underway

This report has been prepared to present the modelling methodology for review purposes. It is split into three main chapters covering (i) flood modelling, (ii) geomorphological assessment, and (iii) baseline economics.

2 Flood modelling

2.1 Coastal flood risk drivers

The first stage in coastal flood modelling involves consideration of the local coastal processes and key mechanisms of flooding, as it is essential that the modelling accounts for these processes in as realistic manner as possible.

Figure 2-1 illustrates the main components that contribute to coastal flooding during a storm event. Historical events have shown that flood risk due to still water levels (SWL) alone is limited within Stonehaven and Cowie, with wave overtopping being the primary mechanism that results in coastal inundation.

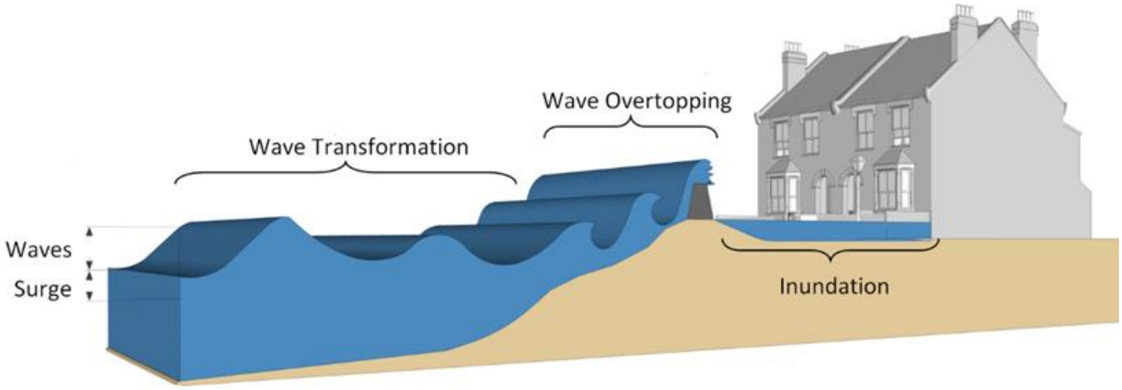


Figure 2-1: Components of coastal flood risk

2.2 Historical flood events

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 historical events in Stonehaven and Cowie was undertaken within the Information Review Report[1], with the events documented ranging from waves overtopping the outer harbour walls with no effect on roads or properties, to large scale events that resulted in flooding to multiple properties and evacuations.

The most significant event in recent years occurred in December 2012. This resulted in significant flooding, structural damage and risk to life. The December 2012 event has formed the main focus of model calibration herein.

2.3 Modelling schematisation

There is no one modelling package available that can simulate all of the elements of coastal flood risk simultaneously. As such, the modelling undertaken herein required the development and coupling of a suite of numerical models. The steps are outlined below:

Multivariate statistics – SEPA's offshore multivariate (MV) dataset was used to produce dependence models that describe the relationships between offshore waves, wind and still water levels. The size of the extreme multivariate condition datasets (ca. 2 million iterations of offshore conditions) meant it was unfeasible to run the wave transformation model for each condition. A sub-set of the full MV dataset was therefore derived using a maximum difference algorithm (MDA); this was taken

[1] Stonehaven Bay Coastal Flood Protection Study, Information Review Report, Final Report, September 2018

forward to the wave model, with the results used to train emulator functions and provide results for the full multivariate dataset in the nearshore.

Still water level transformations – Still water level elevations for a range of return periods were readily available from the updated (2018) Coastal Flood Boundary Dataset (CFBD).

Wave transformation - SEPA's existing SWAN model developed for the AnAc coastal flood forecasting system and used within SEPA's coastal flood map updates was used as the basis of a cut-down SWAN model, used to transform the offshore waves to the nearshore. The model was calibrated using the Stonehaven wave buoy.

Emulation – The MDA was run through the calibrated SWAN model, with the results used to train emulators at the toe of each defence. The emulators were subsequently used to provide nearshore conditions for the full multivariate dataset.

Wave overtopping – The defences within Stonehaven and Cowie were schematised using the Neural Network within EurOtop II. The schematisations were calibrated using historical events and the full multivariate dataset run through the models to provide overtopping rates for a range of return periods.

Flood inundation – SEPA's existing TUFLOW model developed for SEPA's coastal flood map updates was used as the basis of a detailed flood inundation model. This was forced by an offshore tidal graph in conjunction with overtopping inflows so as to produce a single flood extent that represents the risk from both mechanisms.

Each of these steps is discussed in detail below.

2.4 Multivariate datasets

In 2017, SEPA developed offshore multivariate datasets for offshore wave, wind and water level conditions across Scotland. Here, point JP2 has been used. This combines wind from point 2625 and waves from point 2664 of CEFAS' WavewatchIII offshore wave model. The location of this can be seen in Figure 2-2.

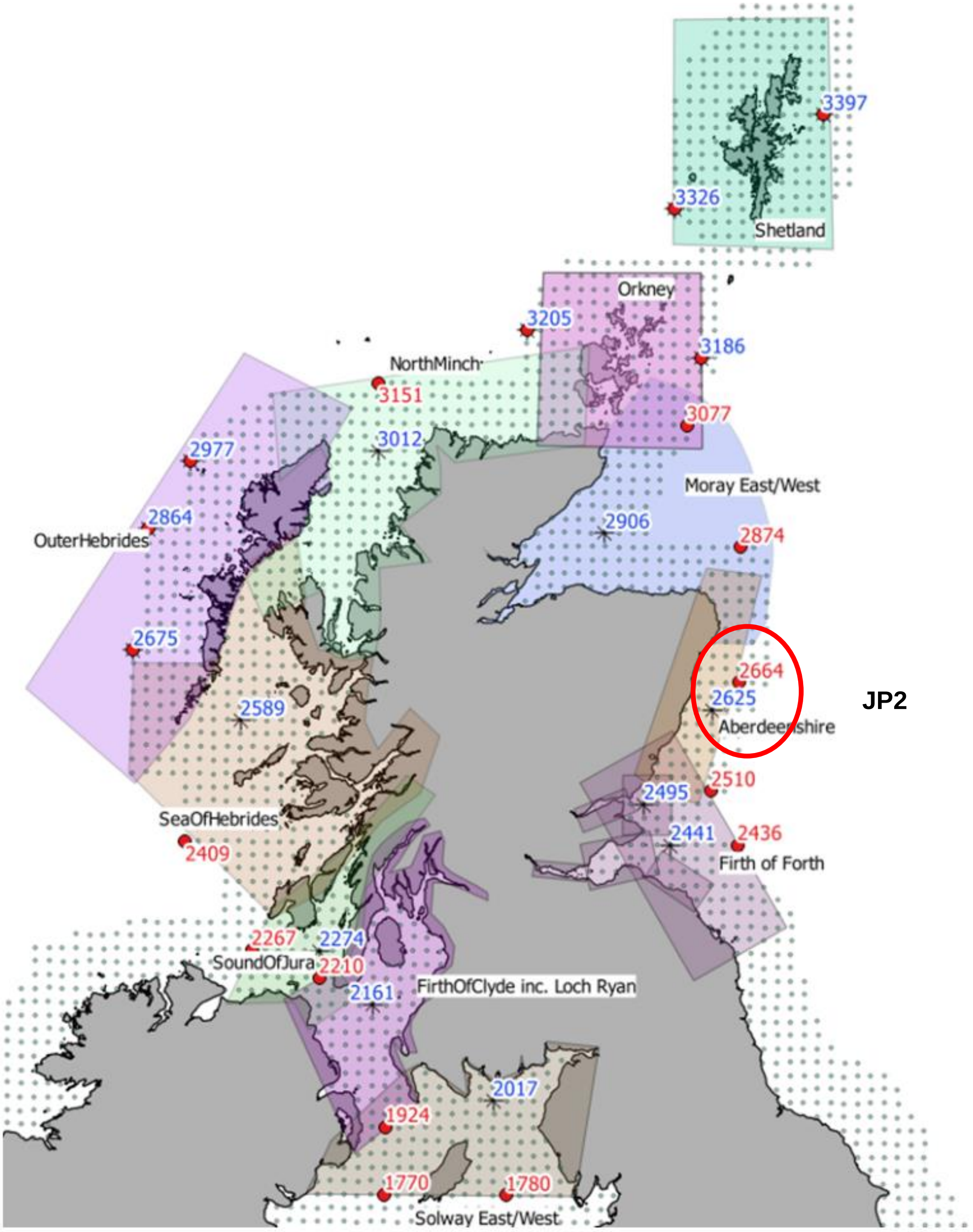


Figure 2-2: Scottish offshore multivariate datasets

The JP2 offshore multivariate dataset provided by SEPA consists of 2,038,804 discrete events expressed as a combination of wind speed, wind direction, wave height, wave direction, wave steepness, directional spreading and water level. This dataset is representative of 10,000 years of events at the offshore location, with water levels based off Aberdeen.

Prior to use of the dataset, wave steepness and Hs were used to estimate peak period (Tp). This was done buy first estimating Te (peak energy period) from Hs and Steepness (*s*) using the equation below, with Tp then estimated using a standard JONSWAP spectrum.

$$Te = \sqrt{\frac{2\pi Hs}{sg}}$$

The dataset was subsequently assessed to remove events that do not result in overtopping of the defences. Events were removed if they satisfied the following criteria:

- The water level was below a level that would not produce extreme (1yr) overtopping. Testing of depth limited waves showed the onset of overtopping to be aligned with water levels above 1mAOD.
- If both wind and waves were originating from the west sector (200º-360º).
- If the water level was below Mean High Water Springs (MHWS) (2.07mAOD), offshore Hs was below 2.25m and wind speed was below 15m/s; these values were selected through SWAN modelling and overtopping calculations.

This reduced dataset constituted the starting point for present day extreme conditions. The same filtering was then applied to the 2118 event set, with uplifted water levels for future scenarios.

2.4.1 MDA generation

The datasets (2018 and 2118) defined above were taken as the basis from which to create the MDA dataset of ca. 1,000 events for use in the SWAN model and emulator training and validation. The MDA and the combined multivariate datasets are provided in Figure 2-3. The figure clearly shows the filtering applied for water level and direction.

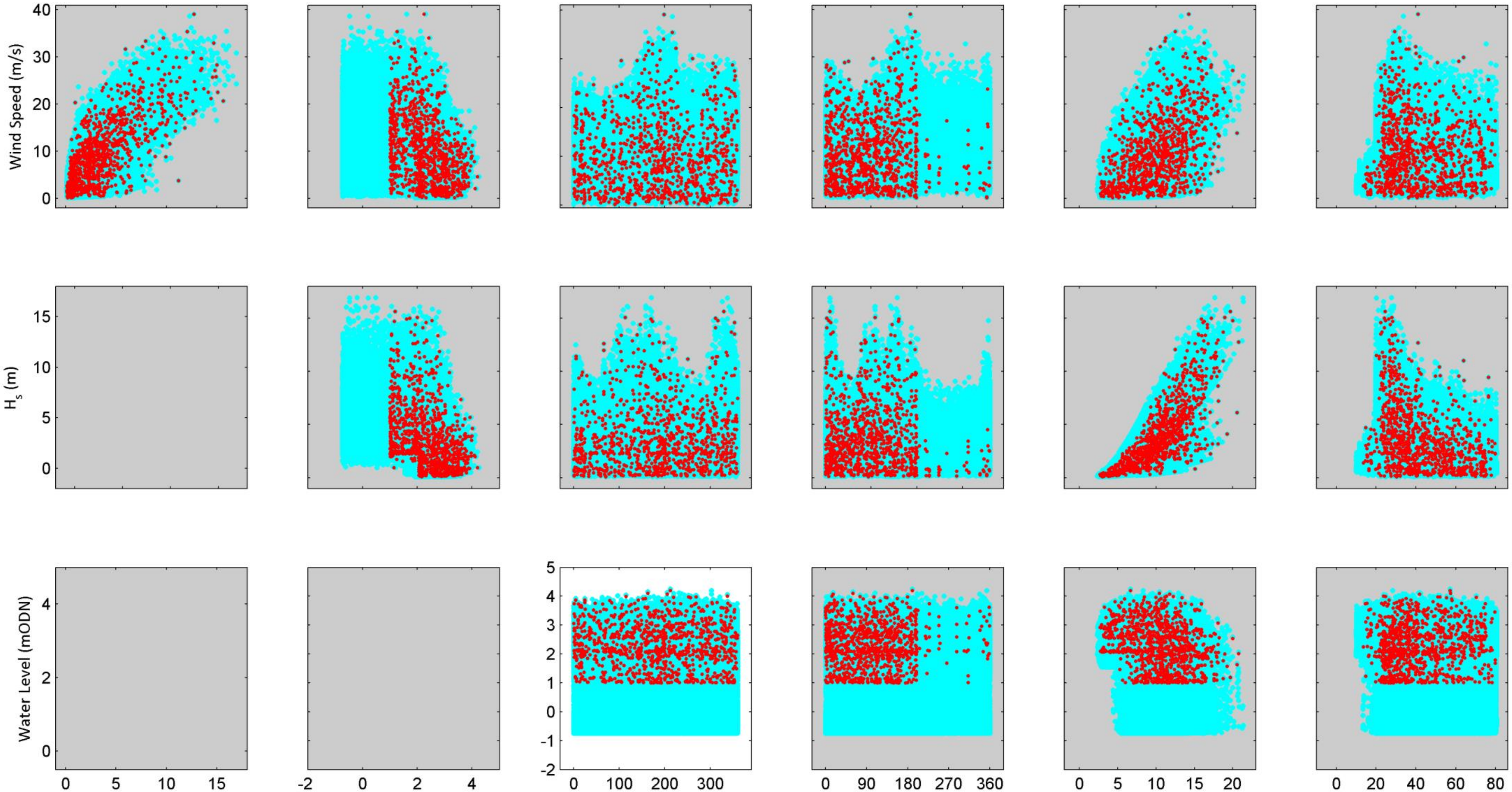


Figure 2-3: Multivariate data (turquoise) vs MDA data (red)

2.5 Water level transformations

The multivariate water levels are based on the BODC A class gauge at Aberdeen. For use in this study these values required transformation to Stonehaven. To achieve this a water level equation was generated by fitting a function to the 1 in 50 year return period water levels from the Coastal Flood Boundary Dataset (CFBD) using the northing coordinate and based on the distance from Aberdeen. This fitting and equation can be seen in Figure 2-4.

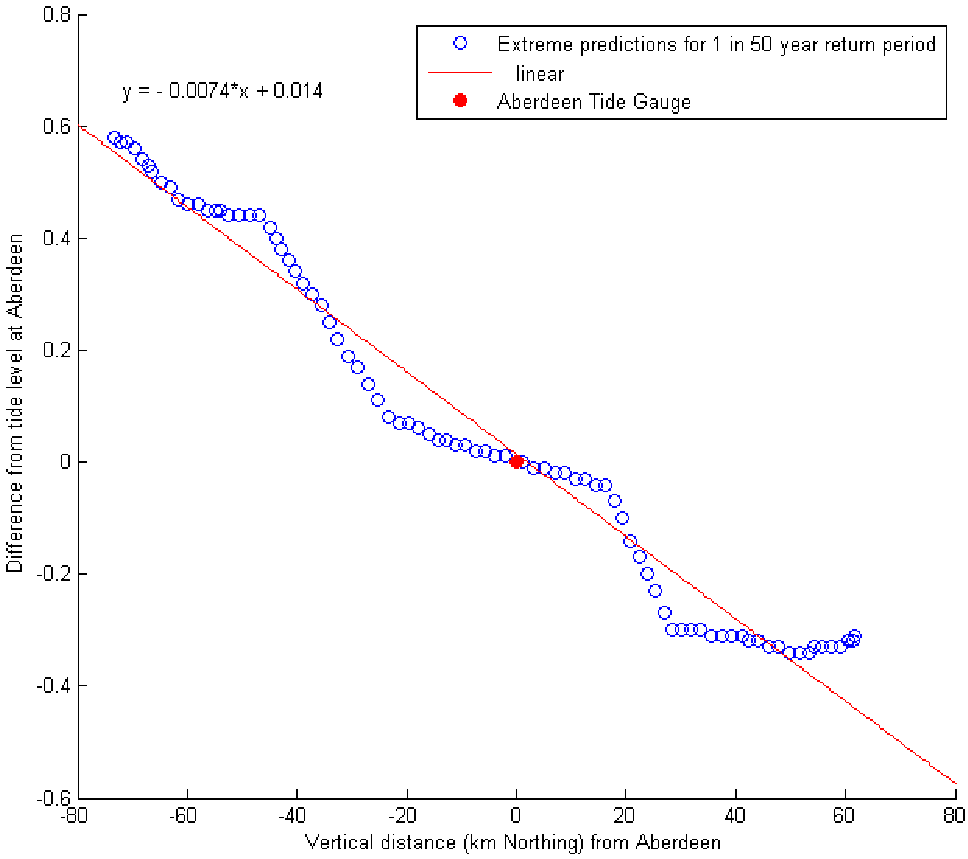


Figure 2-4: Extreme still water level equation for the model domain, based on Northing change relative to Aberdeen

This method of water level transformation was used within the SWAN modelling, creating a varying water-level grid within the model domain. This method was also used in the AnAc FFS system and the coastal flood mapping update, and has been found to be appropriate for locations along the coastline.

2.6 Wave transformation

Wave action is a complex process controlled by a number of factors. Waves are generated in deep water and then propagate towards land. As they do so, they enter shallower bathymetry where wave transformation processes occur, including shoaling, diffraction, refraction, depth limitation and breaking. The waves are also subject to the additional influence of wind. The consequence of these processes is that the properties of the waves when they reach the base of coastal defences are quite different to those in deep water. In terms of coastal flood risk, it is the nearshore waves that are of the greatest importance, as it is these that interact with beaches and defences and ultimately lead to wave overtopping and inundation.

To simulate the nearshore wave characteristics at the defences along the study frontage, a wave transformation model was developed using the industry standard SWAN (Simulating Waves Nearshore) modelling software. SWAN is a third-generation wave model capable of simulating the following nearshore wave transformation processes:

- Wind-wave interactions - the transfer of wind energy into wave energy, leading to the growth of waves.
- Shoaling - the build-up of energy as a wave enters shallow water, causing an increase in wave height.
- Refraction - the change in wave speed as waves propagate through areas of changing depth, causing a change in wave direction.
- Wave breaking - the destabilisation of a wave as it enters shallow water, causing broken waves with the characteristic whitewash or foam on the crest.
- Wave dissipation - limits the size of waves through white-capping, bottom friction and depth-induced breaking.

SWAN calculates stationary wave statistics for specific inputs of wave height, period and direction at an offshore boundary, and wind speed and direction applied across the model domain.

2.6.1 Model domain

The SWAN model domain covers the coastline from Montrose in the south to Aberdeen in the north and extends offshore to SEPA's JP2 multivariate point (Figure 2-5).

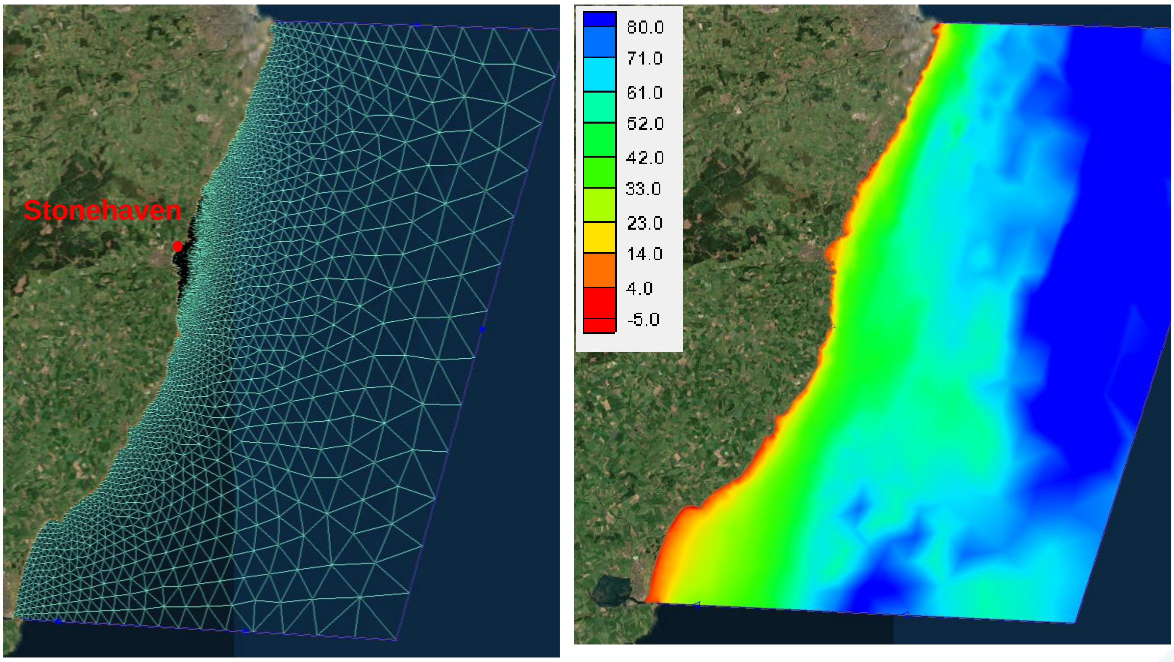


Figure 2-5: SWAN wave model mesh (left) and bathymetry (right)[2]

[2] Background imagery from SMS World Imagery (2018). All depths in SWAN model given in meters Below Ordnance Datum.

2.6.2 Topography representation

The coastline and bathymetry within Stonehaven Bay is complex, with 40m high cliffs to the north and to the south and extensive shore platforms and other rocky features controlling the underlying geometry of the sea bed within the bay. To effectively model wave transformation here, these features were included within the mesh through appropriate refinement (Figure 2-6). Of particular interest is the feature in the centre of the bay (The Brachans) and the extensive shore platforms fronting Cowie and Bellman's head due to their influence on the shoaling and diffraction/refraction of incoming waves. These features are well represented within the model mesh.

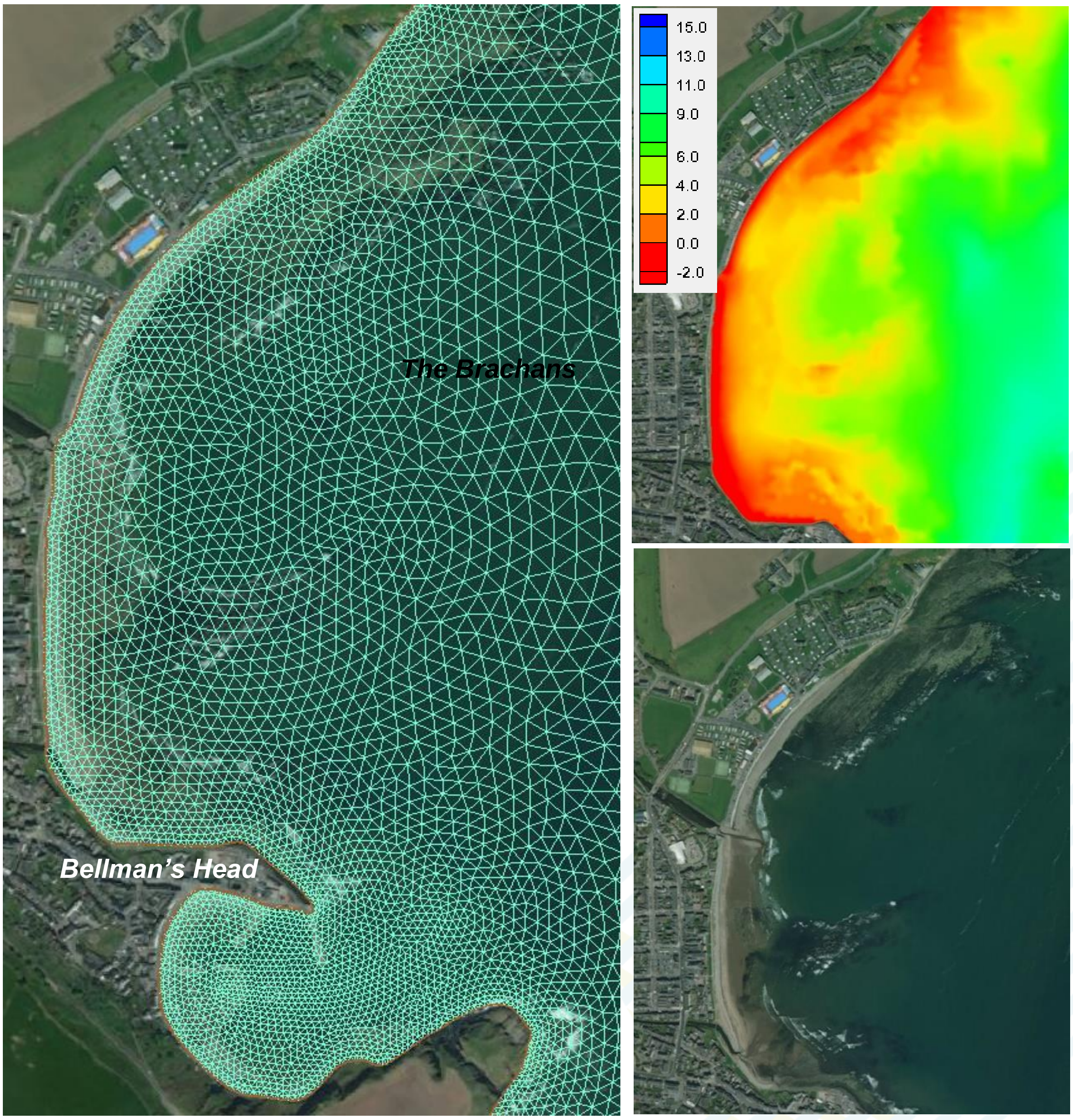


Figure 2-6: SWAN wave model mesh within Stonehaven Bay[2], depths in meters below ODN

2.6.3 Harbour representation

SWAN is a phase averaging wave transformation model and does not resolve the sea surface, rather the overall statistics. As such, in areas where significant wave transformation occurs over a small distance (such as around a breakwater or within a harbour) SWAN cannot accurately represent wave conditions. These environments are better represented by phase resolving models. However, the computational requirements of these calculations make them unfeasible for the approach adopted here. Whilst the representation of processes is somewhat poor within SWAN, two wave overtopping output locations are required within the harbour (Figure 2-7) to effectively represent observed inundation. To assist model convergence within the harbour, only the outer harbour wall was represented within SWAN; the remaining three breakwaters were not represented within the mesh.

Initially, results for along Shorehead (SH_H_01) were extracted at point a below. However, results at this location did not represent the level of risk that has been observed historically, likely due to the limitations of the SWAN model within the harbour environment. As such, results for along Shorehead were subsequently extracted at the centre of the harbour (point b), resulting is greater correlation between the model results and historical events. Results at the southern extent of the harbour are extracted at point SH_H_02.

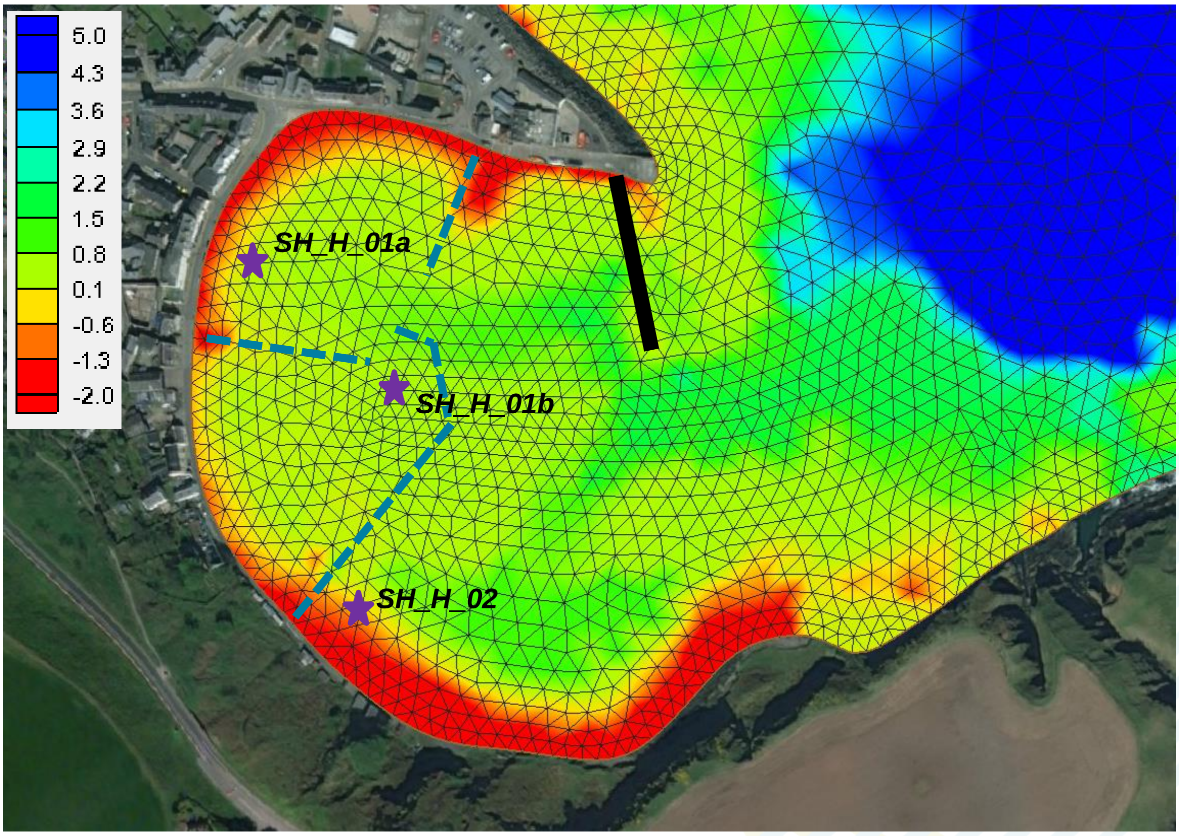


Figure 2-7: SWAN representation of Stonehaven Harbour[2]

2.6.4 Calibration

To improve the accuracy of the model and provide confidence in outputs a calibration process was undertaken using observed data at the Aberdeenshire Council wave buoy within Stonehaven Bay. Eight events were considered, comparing the percentage RMSE (Route Mean Squared Error) of Hs, Tp and Dir for each potential model setup. These results are presented in Table 2-1.

Table 2-1: Calibration RMSE scores of different model setups, given as a percentage of observed spectra

Model setup parameters				
Wind growth	Friction	RMSE Hs (%)	RMSE Tp (%)	RMSE Dir score
JANS	JSWP	**12.62%**	**9.90%**	**9.83**
JANS	Coll	**12.38%**	**9.90%**	**9.81**
JANS	Mads	**13.04%**	**9.81%**	**9.76**
Kom	JSWP	**13.08%**	**9.82%**	**9.31**
Kom	Coll	**12.78%**	**9.82%**	**9.30**
Kom	Mads	**13.18%**	**9.73%**	**9.22**
Westh	JSWP	**13.57%**	**9.53%**	**9.26**
Westh	Coll	**13.40%**	**9.53%**	**9.25**
JANS	JSWP	**12.62%**	**9.90%**	**9.83**
JANS	Coll	**12.38%**	**9.90%**	**9.81**

The final model set up uses the Komen wind growth model and Collins friction model with a bias correction for hindcast conditions identified by HR-Wallingford and Royal Haskoning DHV as part of the development of the multivariate data. The performance of this setup can be seen in Figure 2-8. This was found to be the best performing model setup based on the results of the calibration.

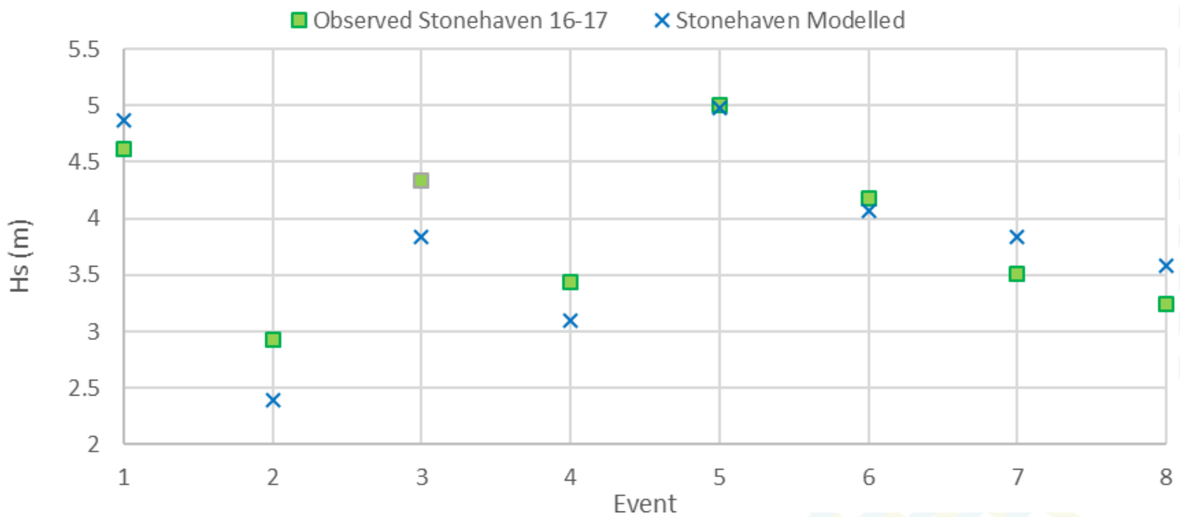


Figure 2-8: Modelled vs observed Hs for final SWAN model set up

2.7 Emulation

2.7.1 Emulator locations

The offshore wave conditions for the MDA sample were transformed to the nearshore using the SWAN wave model. Results were output at ten nearshore toe locations as well as at the wave buoy. The output locations are provided in Table 2-2 and can be seen graphically in Figure 2-9.

Table 2-2: SWAN output locations

Cross section ref.	SWAN model node	Easting	Northing
SH02	4264	387995.9	786750.3
SH06	4421	387912.3	786646
SH12	4446	387618.7	786327.9
SH17	5579	387573.6	786089.7
SH20	6055	387568.0	785941.2
SH25	6564	387624.3	785668.7
SH28	7402	387557.0	785662.0
SH29	7778	387883.5	785575.1
SH_H_01a	8796	387709.5	785437.8
SH_H_01b	8958	387777.5	785397.4
SH_H_02	9088	387786.6	785253.8
Cal_Buoy	6316	388669.9	786159.2

Figure 2-9: SWAN model output locations

2.7.2 Emulator training

The MDA events were used to derive functions that describe the relationship between the input variables (water level, offshore wave spectra, wind speed and wind direction) and modelled nearshore wave conditions. In order to produce a dataset for training the emulators and a separate, independent dataset for validation, the modelled SWAN results were divided, with 90% of the results used to create the emulators (training data) and the remaining 10% used for validation of these emulation functions (validation data).

The training data was used to select the empirical function that best describes the relationships between offshore and nearshore wave conditions, specifically the wave height, period and direction. A range of functions and coefficients are fitted to SWAN outputs with the validation dataset then being used to establish a Nash-Sutcliffe (NS) score (using the equation below) for the function.

$$E = 1 - \frac{\sum_{t=1}^{T} \left(Q_m^t - Q_o^t\right)^2}{\sum_{t=1}^{T} \left(Q_o^t - \overline{Q_o}\right)^2}$$

The error stat measures the accuracy of the model predictions, with a value of 1 indicating a perfect match, 0 indicating that the function is as accurate as the mean of the modelled data, and < 0 indicating that the mean of the modelled data is a better estimate than the function. The results are presented in Table 2-3.

Table 2-3: Best performing emulator scores and functions

Toe Ref.	Hs Func	Hs NS	Tp Func	Tp NS	Dir Func	Dir NS
SH02	Cubic	0.628	Cubic	0.960	Thin Plate	0.840
SH06	Cubic	0.707	Cubic	0.969	Thin Plate	0.852
SH12	Cubic	0.799	Thin Plate	0.941	Thin Plate	0.836
SH17	Cubic	0.787	Cubic	0.962	Thin Plate	0.860
SH20	Cubic	0.760	Default	0.967	Thin Plate	0.817
SH25	Cubic	0.759	Thin Plate	0.937	Thin Plate	0.708
SH28	Cubic	0.603	Thin Plate	0.972	Thin Plate	0.875
SH29	Cubic	0.739	Thin Plate	0.970	Thin Plate	0.919
SH_H_01a	Linear	0.831	Thin Plate	0.872	Linear	0.743
SH_H_01b	Cubic	0.925	Thin Plate	0.809	Linear	0.283
SH_H_02	Cubic	0.791	Thin Plate	0.808	Thin Plate	0.129
Cal_Buoy	Cubic	0.985	Cubic	0.964	Thin Plate	0.906

Generally, the emulation performs better for the deeper toe locations. This is due to these having a greater number of events available with which to train the emulation functions. For toes that are located at a higher elevation, the number of events available is reduced as the toe is essentially 'dry' for events with a lower water level.

The NS scores for Hs mostly rest between 0.70 and 0.93 with the exception of select higher level toes (SH02 and SH28). These similarly score lower for direction. As does the higher toe (SH_H_02) within the harbour. This can be attributed to the lower number of training runs and the complex shore bathymetry present at the toe of these structures. Overall, the emulators perform well for wave period, only dropping below 0.90 within the harbour.

Emulator diagnostics plots for all toes are provided in Appendix A. Potential sources of errors for the poorest performing emulation locations are outlined below, with diagnostic plots provided in Table 2-4.

Toe SH02

The NS score for Hs emulation at SH02 is 0.63, with an R^2 value of 0.70. The emulation function here improves as the modelled wave heights increase; lower wave heights (below 0.6m) show the greatest scatter in modelled vs emulated wave heights. The larger errors in this dataset come from runs with dissonance between wave and wind directional forcing. Period and direction emulate well, scoring above 0.80.

It is considered that the emulation of large waves is appropriate for use in overtopping modelling of extreme events and the low NS score can be predominantly attributed to a poor performance of small waves or non-standard events (opposing wind /wave directions). Such events are unlikely to significantly impact extreme overtopping.

Toe SH28

The NS score for Hs emulation at SH28 is 0.60, with an R^2 value of 0.67. The wave and wind roses displayed in Table 2-4 show that for events with large waves (greater than 0.6m) there is a high degree of divergence between input wave and wind directions (waves from the SE and wind form the NNE). The remainder of the dataset appears to perform well with relatively low errors between emulated and modelled. Emulated wave period and direction performed well with both scoring above 0.87.

It is considered that the emulation of large waves is appropriate for use in overtopping modelling of extreme events and the low NS score can be predominantly attributed to a poor performance of small waves, or offshore wind conditions. Such events are unlikely to significantly impact extreme overtopping

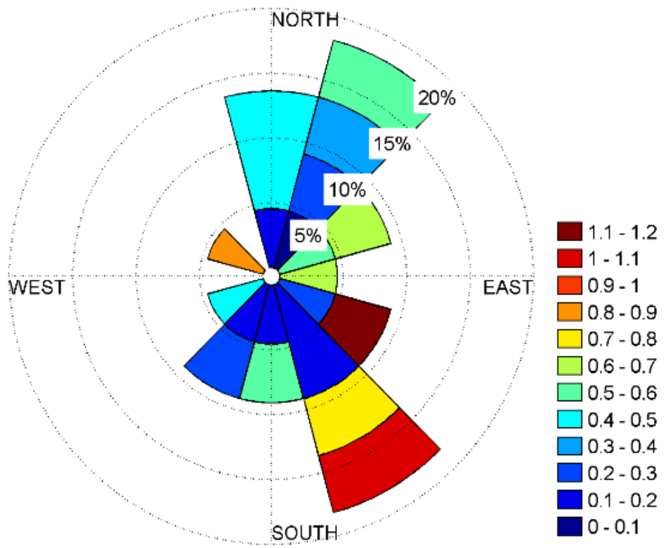
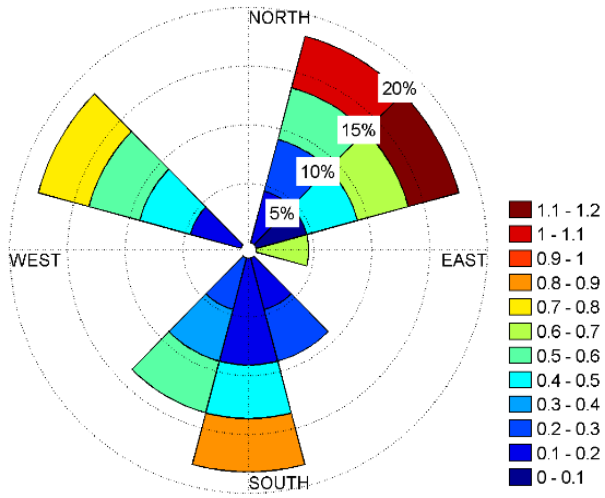
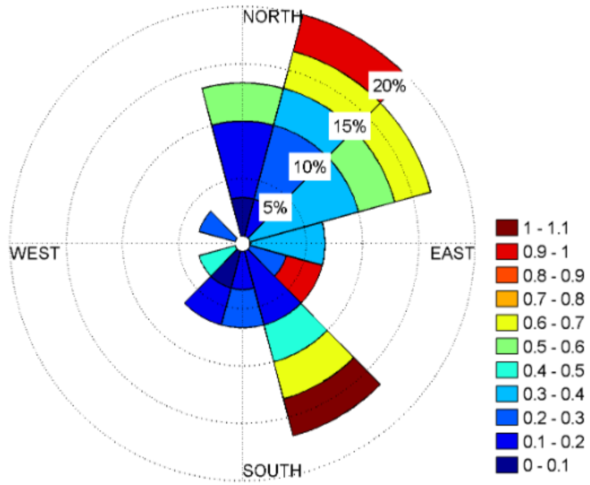
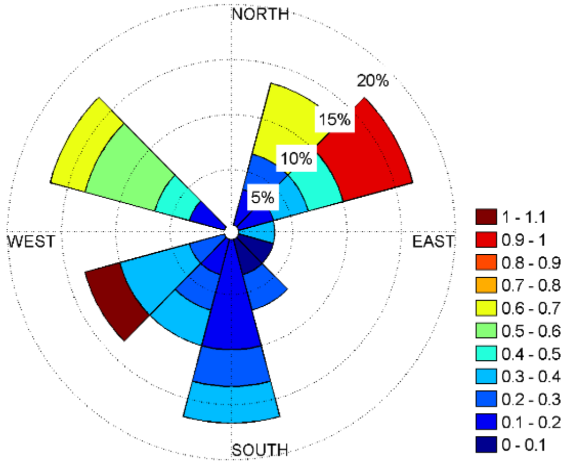
Toes SH_H_01a, SH_H_01b and SH_H_02

Both nearshore toes within the harbour have poor directional emulation scores, particularly SH_H_02. Both SH_H_01 and SH_H_02 output toes are at high elevations and, despite only the harbour curtain wall being included within modelling, within areas of complex bathymetry. This poor emulation is attributed to variance in the phase averaging method of wave modelling of SWAN within harbours and the small variation in the direction of incoming waves. This is a limitation of the method and highlights that there is a greater uncertainty associated with modelling waves within the harbour.

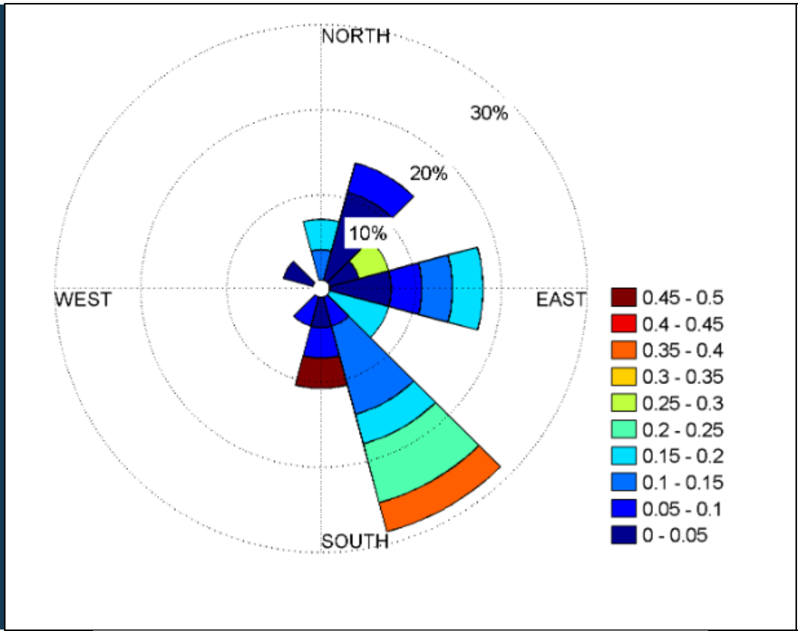
Toe SH_H_1b is an additional wave output point for crossection SH_H_01 with greater exposure and in deeper water. This output location was included to mitigate short fallings in the phase averaging approach to wave transformation in SWAN and poor representation of non-linear interactions within the harbour. This is confirmed with greater wave heights simulated within both hindcast and multivariate datasets.

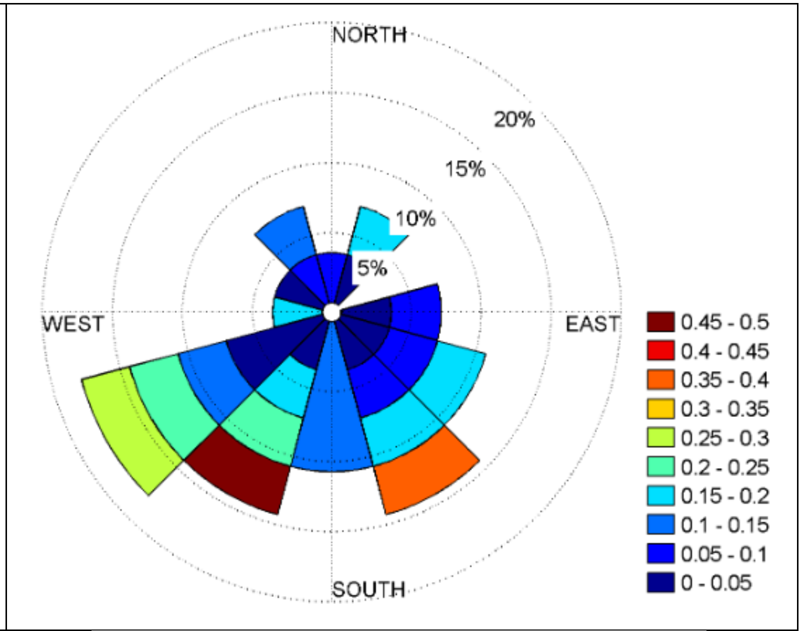
This uncertainty is inherent in the modelling of this section and is a limitation of the wave transformation methodology. This uncertainty has been mitigated by the calibration of overtopping rates in the hindcast (discussed in section 2.8). This, however does not eliminate the potential for computational inaccuracies within the modelling and it is accepted that the rates for these sections are more uncertain than the other output locations.

Table 2-4: Diagnostic plots for locations with poor emulation performance

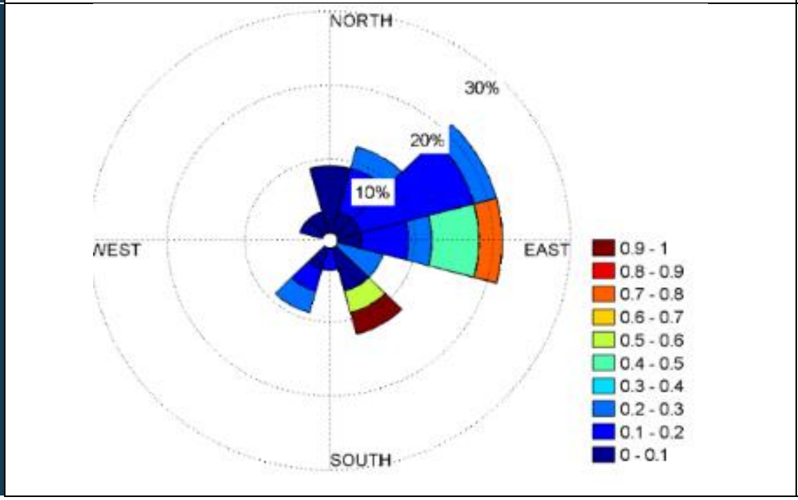
<table>
<tr><th>Output Location</th><th>Offshore wave direction for high Hs errors</th><th>Offshore wind direction for high Hs errors</th></tr>
<tr><td>SH02</td><td></td><td></td></tr>
<tr><td>SH28</td><td></td><td></td></tr>
</table>

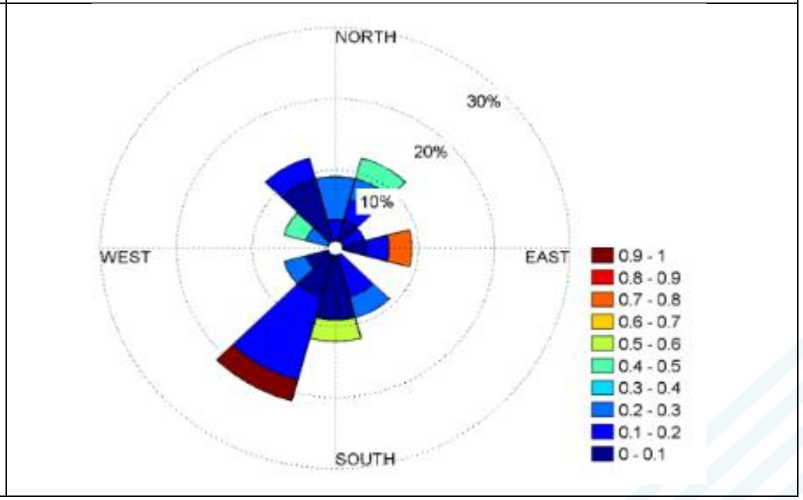
SH_H_01a





SH_H_02





2.7.3 Emulated datasets

The preferred emulator functions were used to transform the offshore wave and wind conditions to the nearshore for both the present day and future datasets. The full, unfiltered, dataset was transformed to the wave buoy location to inform the complete climate here.

In addition, hindcast data from CEFAS WaveWatch III was estimated at all locations. This dataset was then used to provide validation against recorded wave heights at the buoy and historic overtopping events at the defences.

2.7.4 Emulation validation and performance and wave buoy

The emulated data at the buoy was validated against three observed events at the wave buoy in Stonehaven Bay. These events can be seen below in Figure 2-10 to Figure 2-12. They show good performance of wave transformation at the wave buoy with regard to wave heights, timings and the duration of the events.

Figure 2-10: Emulator performance at wave buoy - mid Oct 2016 event

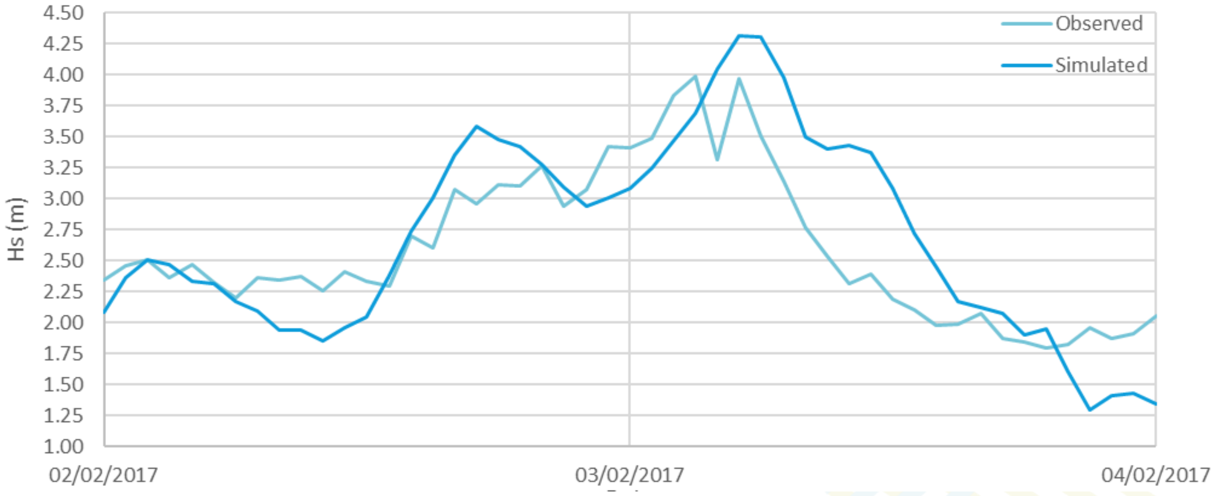


Figure 2-11: Emulator performance at wave buoy - early Feb 2017 event

Figure 2-12: Emulator performance at wave buoy - mid Feb 2017 event

2.7.5 Integration

To provide consistency between the SWAN wave model and the overtopping models, the level of the SWAN output node and the schematised toe depths within the overtopping models must be at a similar depth. Table 2-5 shows the depths of each of these, while Figure 2-13 shows their location. The majority of the toe depths match the SWAN toes, with the exception of toes that have been elevated to calibrate with observed overtopping rates (SH02, SH28 and SH29). Wave conditions forcing SH_H_01 are taken at deeper water depths to maximise wave heights. The difference seen at these toes is discussed further within section 2.8.

Table 2-5: Comparison between SWAN and EurOtop toe elevations

Profile Ref.	EurOtop toe depth (mAOD)	SWAN toe depth (mAOD)	Difference (m)
SH02	1.0	1.44	-0.44
SH06	1.0	0.98	-0.02
SH12	-0.30	-0.26	-0.04
SH17	-0.30	-0.31	0.01
SH20	0.20	0.26	-0.06
SH25	1.0	1.18	0.18
SH28	-0.07	-0.71	0.64
SH29	0.50	0.01	0.49
SH_H_01a	1.50	0.91	-0.59
SH_H_01b	1.50	-0.27	1.16
SH_H_02	1.50	1.51	-0.01

2.8 Wave overtopping

The wave overtopping modelling considers how the waves at the toe of the defences interact with the beach and structures to provide estimates of overtopping volume.

This was undertaken using the industry standard EurOtop II[3] Neural Network tool. This is considered the most suitable method to assess complex multi-component defence structures, such as those present within the study area.

The Neural Network model uses nearshore wave characteristics at the toe of a defence structure, defence geometry and sea level data to quantify a mean overtopping discharge rate. This rate is expressed in terms of litres per second, per metre length of defence (l/s/m).

Estimates of wave overtopping have large levels of uncertainty associated with them. As such, the focus of the work undertaken herein is on the calibration of results using the historical flood information available. The following sections present the schematisation of the defences as well as the results from the overtopping modelling undertaken.

2.8.1 Wave overtopping schematisations

The Neural Network tool requires several inputs, including the nearshore wave conditions and a defence 'schematisation', based on the geometry, orientation, height and structure material. Schematising the wave overtopping profiles with respect to defence geometry has the following steps:

1. Identification of suitable locations for the profiles
2. Schematisation of the defences at these locations

The locations themselves are provided in Figure 2-13; these are deemed sufficient to quantify the variation in risk, exposure and structure type within the bay. Table 2-6 presents these more specifically along with the Neural Network schematisations developed from the JBA survey.

[3] EurOtop – Manual on wave overtopping of sea defences and related structures, Second Edition, 2016

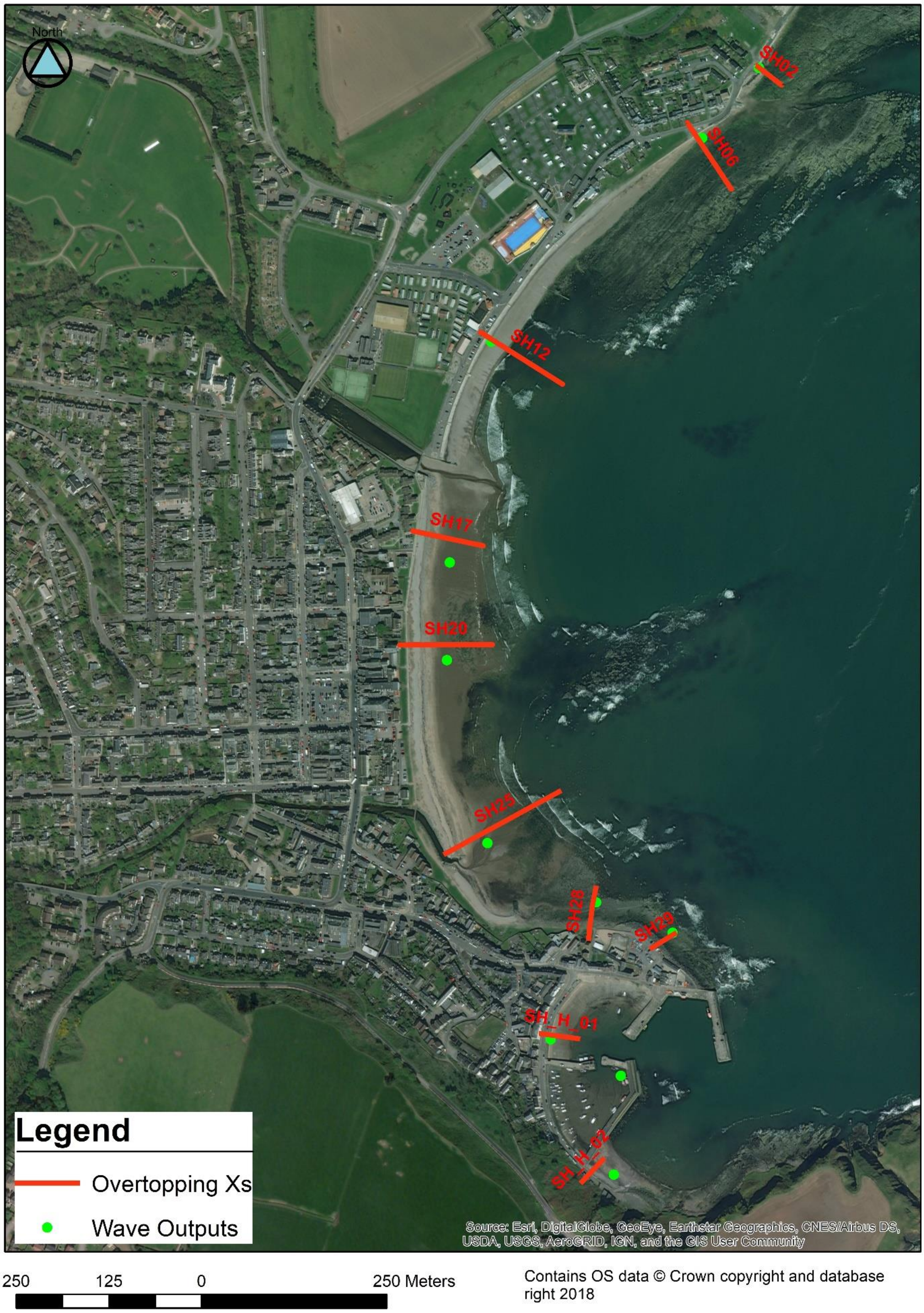
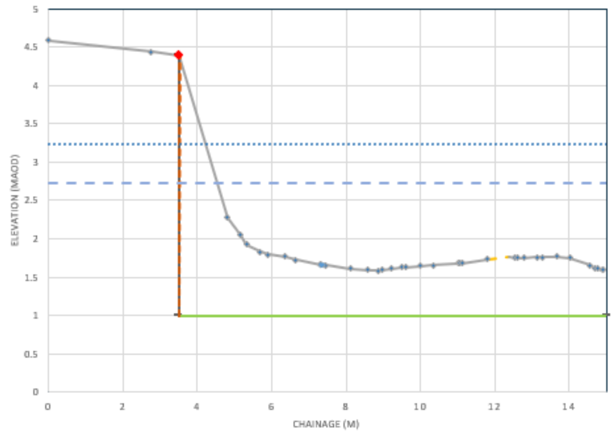
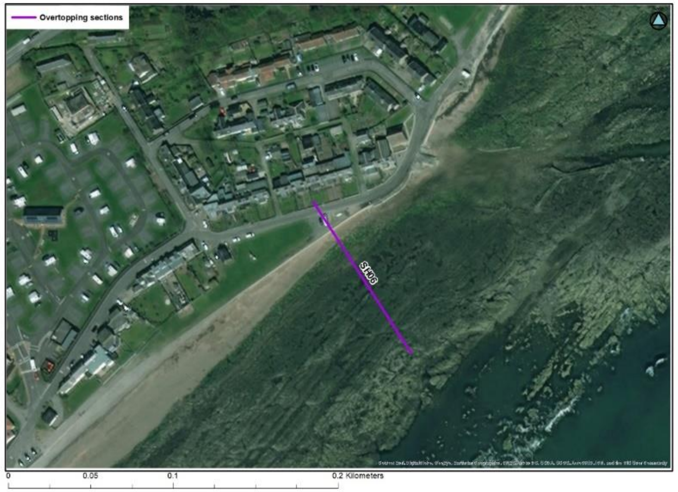
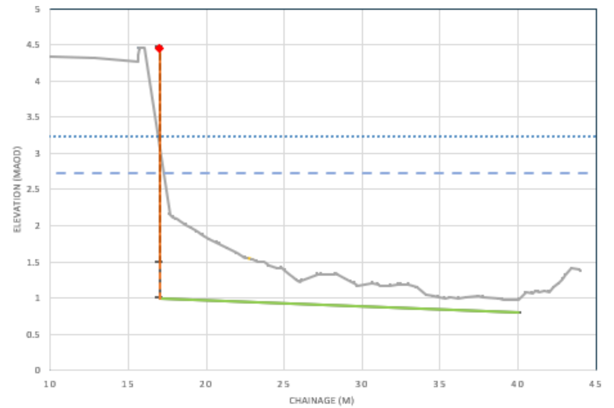
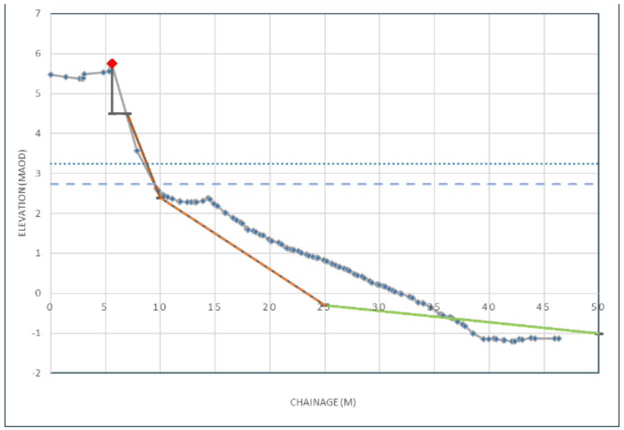
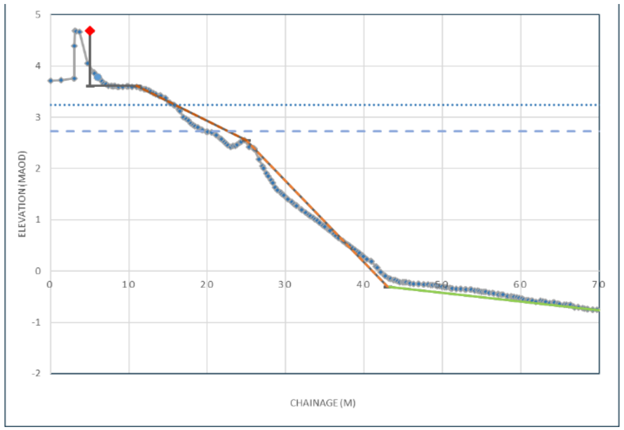


Figure 2-13: Overtopping profile locations

Measured Profile | Schematised Profile | foreshore slope | Structure lower slope
Structure upper slope | Crest Level | T1 | T200

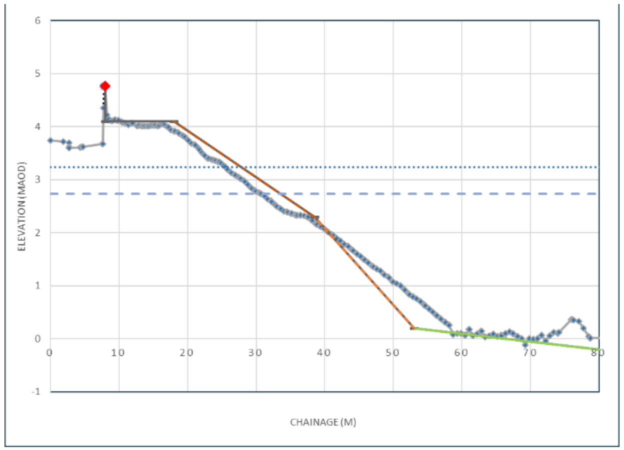
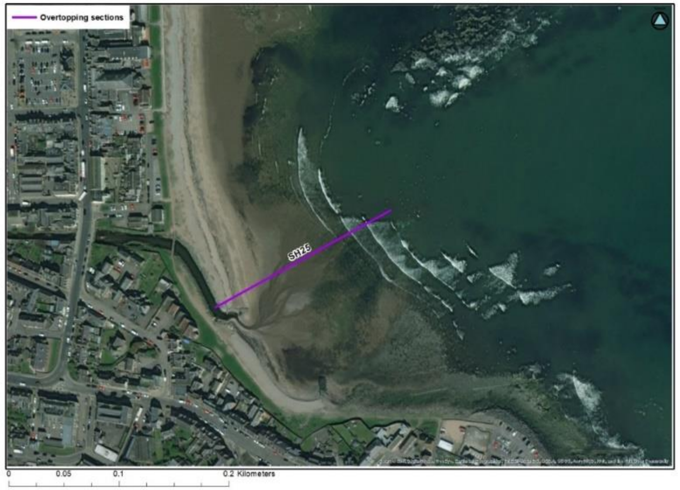
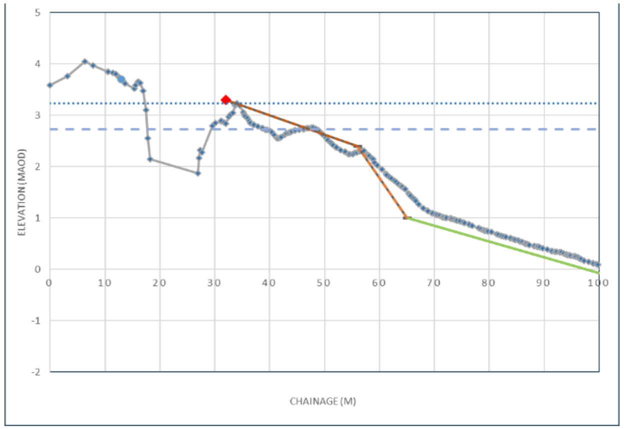
Table 2-6: Wave overtopping cross sections

XS Ref.	Location on aerial imagery	Photograph	Schematised and measured cross section
SH02			
SH06			

<table>
<tr><td>SH12</td><td>
</td><td></td><td>
</td></tr>
<tr><td>SH17</td><td>
</td><td></td><td>
</td></tr>
</table>

Measured Profile   Schematised Profile   foreshore slope   Structure lower slope

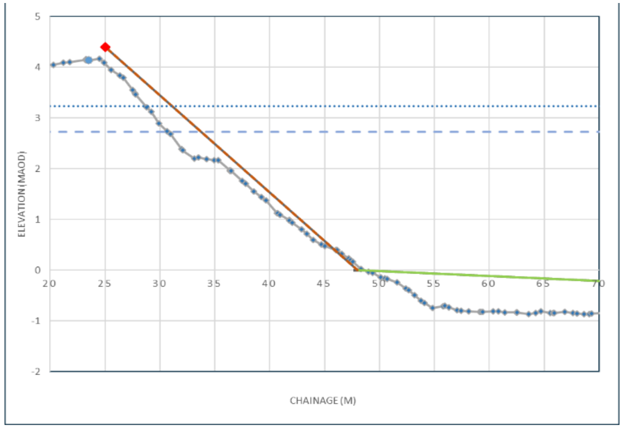
Structure upper slope   Crest Level   T1   T200

SH20			
SH25			

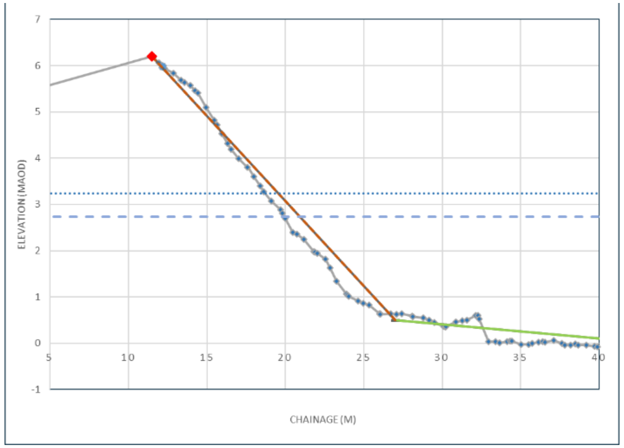
Measured Profile   Schematised Profile   foreshore slope   Structure lower slope

Structure upper slope   Crest Level   T1   T200

SH28

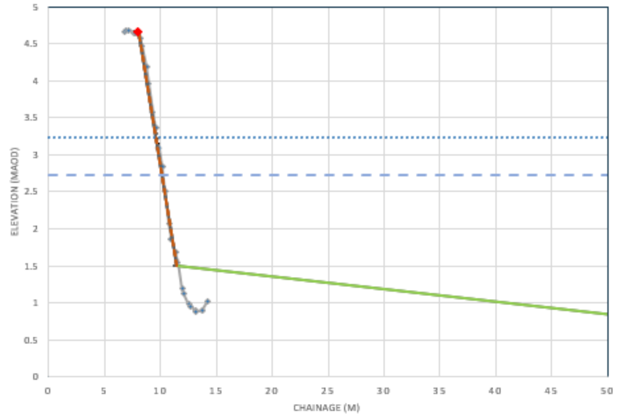
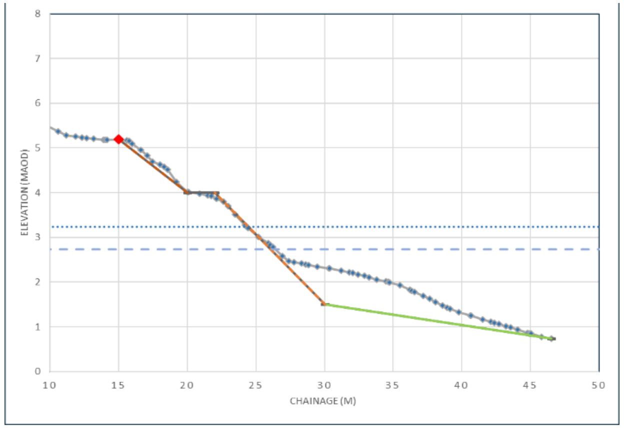


SH29



Measured Profile | Schematised Profile | foreshore slope | Structure lower slope

Structure upper slope | Crest Level | T1 | T200

SH_H_01			
SH_H_02			

Measured Profile   Schematised Profile   foreshore slope   Structure lower slope

Structure upper slope   Crest Level   T1   T200

2.8.2 Wave overtopping calibration

The emulated hindcast data (discussed in Section 2.6) was applied to the Neural Network and used to calibrate the schematisations so that appropriate overtopping rates were obtained. To do this, overtopping rates for thirteen known events were assessed at the 10 defences, with calibration being conducted to fulfil the following objectives:

1. The peak overtopping rates are within the order of magnitude expected given the observed overtopping and damage.
2. The variation in rates within the bay is representative of the differences in observed risk (e.g. SH12 > SH17 > SH20).
3. The annual average overtopping rates are plausible given the observed risk.

Calibration of these overtopping cross sections was undertaken by the modification of the schematised profile whilst keeping the schematisation relevant to the observed defences at each frontage. This constituted the inclusion/omission of berm features (SH28), the modification of crest widths (SH20, to simulate different widths of beach) and the manipulation of toe levels (SH06, SH_H_01 and SH_H_02). It should also be noted that cross sections were taken along a typical defensive profile for each defence whereas wave output locations are situated at an appropriate depth within the model. This is anticipated to have minimal impact on incoming wave spectra.

The events and a brief description of the impacts are presented in Table 2-8. The hindcast boundary conditions used to drive emulation can be seen in Table 2-7. All events, with the exception of 29/10/2014 had a water level in excess of 2mAOD and incoming wave directions from 044 to 176, impacting the shoreline. Events can all be considered extreme considering the MHWS level 2.05m AOD, the average modelled Hs (1.5m) and Tp (7.2 sec) over the hindcast period.

It should be noted that the 1 in 20 year SWL event observed in Aberdeen on 5/12/2013 has been omitted from the analysis. This is due to erroneous WaveWatch III hindcast data for this event showing high offshore waves coming onshore; photographic evidence and buoy records do not corroborate this in the nearshore and so this event was removed from the analysis. Similarly, the event on the 12/01/2009 predicted long period waves and large water levels from the south, these combined with the opposing hindcast wind and wave directions confounded emulation, predicting larger waves than observed within the nearshore. This is a source of uncertainty that is inherent in the approach to the modelling, in that the hindcast data can be inconsistent with observed conditions and so overtopping may not match observed values for all events. For reference, the input values used for each event (observed water levels and wind and wave data from the hindcast model) are provided within Table 2-7, with a summary of the impacts of each event within Table 2-8.

For the December 2012 event, both the early morning and the afternoon tide were run through the modelling, with the early morning tide providing the highest rates, as occurred during the event.

Crest elevations from each cross sections were taken from surveyed data obtained by JBA in 2018.

Table 2-7: Hindcast maximum boundary conditions for events

Date	WL, AOD (max)	Hs (max)	Tp (max)	Dir (mean)
01/04/2006	2.40	1.95	10.20	44
20/02/2007	2.60	2.13	7.04	152
06/03/2007	2.50	5.18	9.62	161
10/03/2008	2.66	5.11	10.20	153
12/01/2009	2.81	3.63	9.90	176
08/09/2010	2.26	3.96	9.62	103
08/11/2010	2.38	5.32	10.10	144
15/12/2012	2.58	8.36	13.51	93
29/01/2014	1.65	5.90	10.87	108
03/02/2014	2.28	4.13	8.62	160
07/10/2014	2.29	5.53	12.50	80
24/12/2015	2.50	4.88	10.10	169
10/01/2016	2.05	3.77	10.99	92

Table 2-8: Historical overtopping events in Stonehaven

Event date	Description of impact
01/04/2006	Coastal erosion and collapse of sea wall foundations.
21/02/2007	Overtopping of Stonehaven and Cowie promenade.
06/03/2007	Overtopping and significant overland flow at Beach Road/The Links.
10/03/2008	Shingle and rock armour thrown over sea wall, damage to Cowie sea wall copings. Seafront properties and amenity land flooded, particularly towards Cowie.
12/01/2009	Overtopping of promenade, Boatie Row and Cowie shorefront.
08/09/2010	Overtopping at Boatie Row and along The Links. Flooding behind.
08/11/2010	Outer and inner harbour walls overtopping with overtopping along Stonehaven shorefront.
15/12/2012	Significant overtopping and damage to shorefront properties as well as evacuations.
29/01/2014	Outer and inner harbour walls overtopping. Mostly foam.
04/02/2014	Overtopping at swimming pool and Boatie Row.
07/10/2014	Significant overtopping at Stonehaven harbour wall and along the promenade.
24/12/2015	Overtopping of frontage and shingle strewn across road.
10/01/2016	Overtopping of defences along The Links.

The hindcast modelling shows overtopping for at most cross sections for each event considered. Following an initial review, some schematisations were adjusted to modify overtopping rates to better match the anecdotal impacts.

The modelled overtopping rates at each cross section are presented in

Table 2-9. It should be noted that the values presented are average overtopping rates; in some locations the damage observed could have resulted from large infrequent waves, versus some areas where small volumes overtop frequently.

The rates are considered appropriate for the events selected given the records available and evidence of flooding, with each section along the frontage discussed below.

Table 2-9: Modelled overtopping rates for historical events (l/s/m)[4]

Event date	SH02	SH06	SH12	SH17	SH20	SH25	SH28	SH29	SH_H_01a	SH_H_01b	SH_H_02
01/04/2006	0.27	0.15	0.29	0.09	0.05	6.50	0.01	0.03	-	-	-
20/02/2007	0.42	0.95	0.13	0.03	0.02	0.14	-	0.07	-	-	-
06/03/2007	0.49	0.46	0.75	0.32	0.05	6.90	□0.01	0.03	-	-	-
10/03/2008	1.43	0.89	2.94	1.94	0.47	18.70	0.02	0.05	-	0.13□	0.75
12/01/2009	3.14	2.15	3.67	2.27	0.44	30.30	□0.01	0.12	-	-	-
08/09/2010	0.16	0.13	0.37	0.16	0.06	6.79	□0.01	0.05	-	-	-
08/11/2010	0.27	0.22	0.92	0.51	0.12	14.50	0.01	0.05	-	0.16□	-
15/12/2012	1.10	0.59	4.92	3.86	0.77	56.70	0.19	0.10	-	0.171	0.77
29/01/2014	-	-	0.09	0.01	0.01	□0.01	0.01	-	-	-	-
04/02/2014	0.18	0.16	0.53	0.21	0.06	6.02	□0.01	0.04	-	-	-
07/10/2014	0.25	0.33	1.18	0.52	0.10	13.40	0.07	0.04	-		-
24/12/2015	0.54	0.44	1.77	0.96	0.19	2.58	□0.01	0.03	-		-
10/01/2016	0.22	0.15	0.51	0.13	0.03	1.84	0.01	-	-	-	-

[4] □indicates poor representation within neural network training data – rates not reliable.

Harbour cross sections

Initially, with the toe location at SH_H_01a, the cross section within the inner harbour showed no overtopping for the events assessed. As SWAN is known to be poor within confined harbours this is not unexpected. Overtopping from events in the multivariate data exist but it is likely that the risk was underestimated at this location. As a result of this under-performance at the toe, the larger waves simulated at output location SH_H_01b were used to generate overtopping. This produced more appropriate overtopping for observed events and so was taken forward within the modelling.

Emulators found wave heights at this location to be largely independent of depth and predicted generally small waves (<0.8m) with longer periods which were used to produce overtopping. Figure 2-14 shows the small number of simulated hindcast events that satisfy filtering applied for toe SH_H_01b (Crest freeboard : Hs < five, RC/Hs), plotted against the CLASH training data. Approximately five records in the training database have a RC/Hs ratio greater than four, with none of these being in the range of our hindcast data. Subsequently, much of the simulated events undergo high degree of interpolation/ extrapolation to produce overtopping rates. To mitigate this, a lower RC/Hs ratio of four was selected for this location as, although waves with a ratio of between four and five produced overtopping, these were not considered accurate.

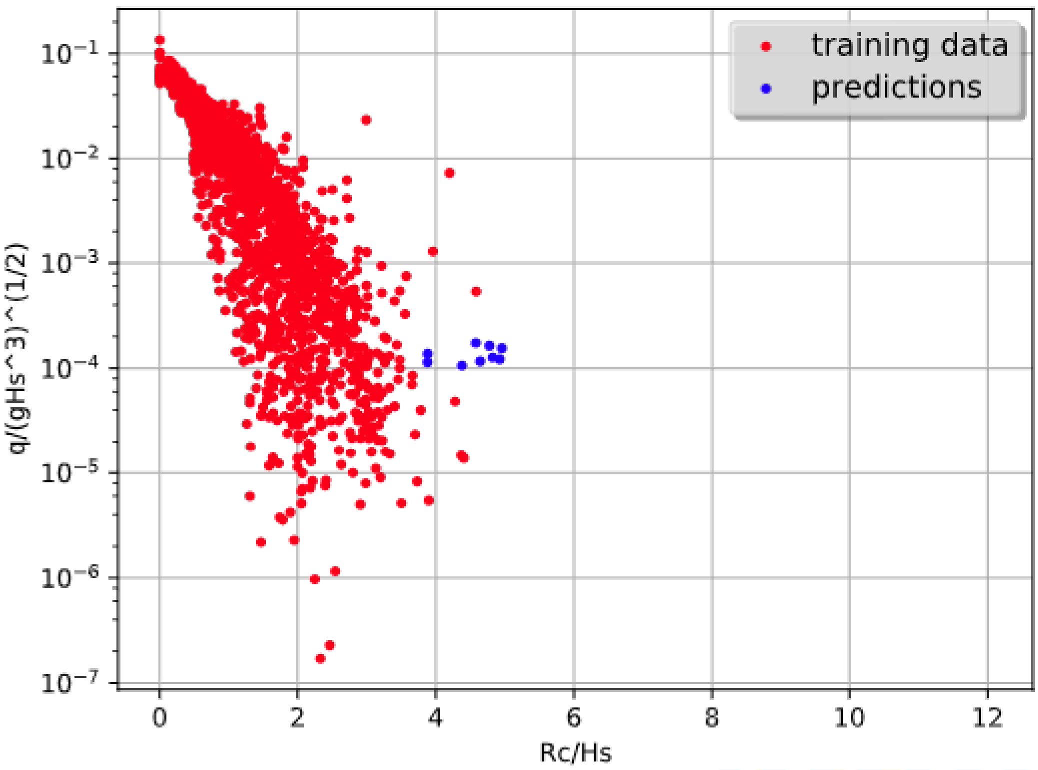


Figure 2-14: Overtopping output of forcing conditions with overtopping training data. Output from Overtopping.ing.unibo.it.

The cross-section to the south of the harbour overtops to a greater magnitude than the more sheltered cross section located within the harbour, and notably is modelled to overtop on 15/12/12, when anecdotal evidence exists of damage to the sheds situated here.

Bellman's Head cross sections

For cross-section SH28 it was necessary to elevate the schematised toe level from -0.71 to -0.07 to reduce the incoming wave heights, similar limitations were applied to SH29 (0.0m to 0.5m). This is not inconsistent with levels along the frontage however it does deviate from the SWAN node depth. An additional depth-limitation check shows this to have minimal impact on integration with SWAN/emulated outputs.

The cross-sections at Bellman's Head show consistently moderate levels of overtopping for all events. The rates are considered appropriate as large waves rarely propagate from a northerly direction, directly impacting SH28, and SH29 is largely protected by bathymetric features fronting the section.

River Carron mouth

Cross-section SH_25 is situated at the mouth of the River Carron. The overtopping rates are included here to address concerns over wave impacts within the river channel and are considered largely appropriate for the lower crest level of the defence.

Central wall cross sections

Two cross-sections are present along the central frontage of Stonehaven. Both consist of similar beach morphology and defence but are impacted by differing wave conditions. SH20 is more sheltered (from the Brachans) with SH17 being more exposed. This is reflected in the outputs for these cross-sections, with SH20 consistently having lower overtopping rates than SH17.

Cowie cross sections

Three overtopping cross-sections exist within Cowie, with SH12 estimating overtopping at Cowie Pool and shops, and SH6 and SH2 calculating overtopping at Boatie Row and to the north of Stonehaven Bay. These cross-sections have consistently high rates for events where there are reports of significant overtopping at Cowie (e.g. 24/12/2015, 04/02/2012 and 08/09/2010).

2.8.3 Extreme overtopping rates

The overtopping rates for a range of return periods for the present day (2018) and future (2118) are outlined in Table 2-10 and Table 2-11. These rates were estimated by ranking the overtopping rate for all of the multivariate dataset events and assigning probabilities of occurrence based on it being representative of 10,000 years. Again, the variation in risk typically observed along the frontage is evident (e.g. SH12 > SH17 > SH 20).

It should be noted that the overtopping rates for SH25 are not used in the inundation modelling and rather provide an indication of the potential volume of water entering the Carron mouth under extreme conditions.

Table 2-10: 2018 overtopping rates for a range of return periods (l/s/m)

Return Period (years)	SH02	SH06	SH12	SH17	SH20	SH25	SH28	SH29	SH_H_01a	SH_H_01b	SH_H_02
2	0.52	0.58	1.36	0.76	0.22	43.90	0.03	0.08	-	-	0.47
5	1.00	1.09	1.99	1.26	0.37	67.90	0.07	0.11	-	0.04	0.58
10	1.63	1.74	2.57	1.81	0.56	91.70	0.14	0.15	-	0.07	0.70
30	3.56	3.57	3.89	3.11	1.00	140.00	0.36	0.25	<0.01	0.10	1.02
50	4.85	4.78	4.68	4.01	1.33	171.00	0.54	0.33	<0.01	0.11	1.21
100	7.60	7.48	5.91	5.77	1.95	217.00	0.97	0.50	0.01	0.12	1.77
200	11.60	11.60	8.19	8.12	2.99	271.00	1.64	0.76	0.02	0.13	2.72
1000	25.10	26.40	14.30	13.10	6.00	419.00	5.86	1.77	0.05	0.22	9.11

Table 2-11: 2118 overtopping rates for a range of return periods (l/s/m)

Return Period (years)	SH02	SH06	SH12	SH17	SH20	SH25	SH28	SH29	SH_H_01a	SH_H_01b	SH_H_02
2	18.50	17.20	10.70	10.20	3.46	511.00	3.71	1.01	0.01	0.06	4.14
5	29.50	27.10	14.80	14.60	5.32	632.00	7.32	1.59	0.03	0.10	7.48
10	41.50	37.60	18.50	18.60	7.13	733.00	11.90	2.35	0.04	0.12	11.40
30	65.30	58.70	25.70	27.00	11.30	911.00	25.00	4.33	0.06	0.15	24.10
50	77.90	69.30	29.70	32.20	14.30	1000.00	32.20	5.60	0.07	0.16	32.80
100	100.00	89.90	37.10	41.20	19.60	1150.00	45.10	8.47	0.08	0.19	53.20
200	127.00	116.00	46.60	52.70	25.50	1310.00	66.30	12.50	0.10	0.21	89.80
1000	201.00	176.00	69.70	81.10	46.90	1850.00	156.00	26.70	0.17	0.34	268.00

2.9 Flood inundation modelling

A 2D flood inundation model was constructed in the TUFLOW modelling package for Stonehaven and Cowie. The model extends from the mouth of the bay to high ground as well as along the rivers Carron and Cowie (Figure 2-15). It has been used to estimate flood extents and depths for extreme events from a combination of still water levels and wave overtopping.

The following sections provide a breakdown of the key model components, calibration and model outputs.

Figure 2-15: TUFLOW model domain and inflows

2.9.1 Digital terrain model

The base digital terrain model (DTM) was generated from four datasets. These were overlain in an appropriate order to make best use of the data available.

- Cross sectional survey of the River Carron. This data was available along the length of the River Carron from the previous fluvial assessments.
- Terrestrial Laser Scanned (TLS) topography of the beach, coastal frontage and areas within the harbour.
- Phase 2 1m LiDAR data provided by SEPA. This was filtered to remove the representation of the water surface within the model domain.
- Oceanwise bathymetry data within the bay. This was used for the area within the bay beyond the extents of the LiDAR and TLS data.

2.9.2 Feature representation

Not all features within the domain were accurately represented within the combined model DTM. As such, modifications to the DTM were applied; these are detailed below:

Coastal defences

The crest elevations and extents of the defences were not accuracy represented within the DTM. These features have been added to the model by enforcing crest elevations from topographic survey. Defences were also added along the banks of the River Carron, thus assuming that the fluvial scheme is in place; these are only required to prevent SWL flooding under the climate change scenarios. Further details of the fluvial-coastal interactions are provided within section 0.

Buildings

Buildings within the model domain were defined from MasterMap data. Elevations for the buildings were taken from threshold survey data, collected either as part of the fluvial scheme or as part of this project. Where threshold data was unavailable a level was identified by the average LiDAR level plus two standard deviations. The levels were used to represent the buildings as 'stubby buildings'; this means that shallow flooding can flow around the buildings, whereas deeper flood depths are able to enter the building and flow through. This will have an impact on the accuracy of the inclusion of these buildings within the economic assessment (discussed in section 4). However, buildings without threshold data were predominately setback from the coastline.

River channels

The channel of the River Carron was included by interpolating bed levels from the fluvial survey data, with the channel of the Cowie Water represented as accurately as possible from available data.

Nearshore rock platforms

The extensive shore platforms along the frontage are uneven and impacted model stability. As the representation of these features was not important to the assessment of flood outlines, these features were smoothed out within the inundation model.

Roughness

The roughness (Mannings's *n* value) representation of features within the domain was varied according to land use classifications within the OS MasterMap, with the values used presented in Table 2-12.

Table 2-12: Feature Manning's *n* classification

Manning's n	Land use classification
0.030	Default floodplain value
0.300	Buildings
0.100	Structures
0.030	Inland and coastal water
0.070	Natural surface and gardens
0.025	Manmade surface, roads and paths
0.100	Trees
0.046	Marsh

2.9.3 Model files

Table 2-13 details the TUFLOW files used within the calibration and extreme event model runs.

Table 2-13: Details of TUFLOW model files

File type	File name	Comments
TUFLOW control file	*Stonehaven_~e1~_~s~.tcf*	- Specifies model start and end times (35h simulation for extreme events) - Specifies timestep of 1.5 sec - Calls all other model control files
TUFLOW general file	*Stonehaven_General_Commands_001.trd*	- Specifies model output parameters and locations - Includes standard wetting and drying depths, velocity cut offs, etc.
TUFLOW geometry file	*Stonehaven_001.tgc*	Specifies grid construction and modifications including: - Cell size (4m) and domain extent - DTM mosaic - Defense reinforcement (ZSH files) - Topography roughness - Stability smoothing patches
TUFLOW event file	*Stonehaven_Events_001.tef*	- Defines all events considered - Sets the initial water level for all events - Sets the file path for model checks
TUFLOW boundary file	*Stonehaven_Boundary_Control_001.tbc*	Specifies the boundary condition locations (OT and SWL) used in all simulations

2.9.4 TUFLOW model validation

The event on the 15th of December 2012 is documented as the most severe coastal flood event in Stonehaven's recent history. This was used as the validation event for the overtopping and inundation modelling as the most information exists for observed inundation.

The performance of the emulation and calibration of the overtopping models is presented in the preceding sections and was found to tie in well with historical events. Whilst the focus of the validation of the inundation model is to compare the modelled flood extents and depths to records from the Dec 2012 event, by extension this will also provide additional validation of the overtopping rates and nearshore wave heights.

For reference, examples of the observed overtopping during Dec 2012 are presented in Figure 2-16. The photographs were provided by Aberdeenshire Council.

Figure 2-16: Observed overtopping during the December 2012 event

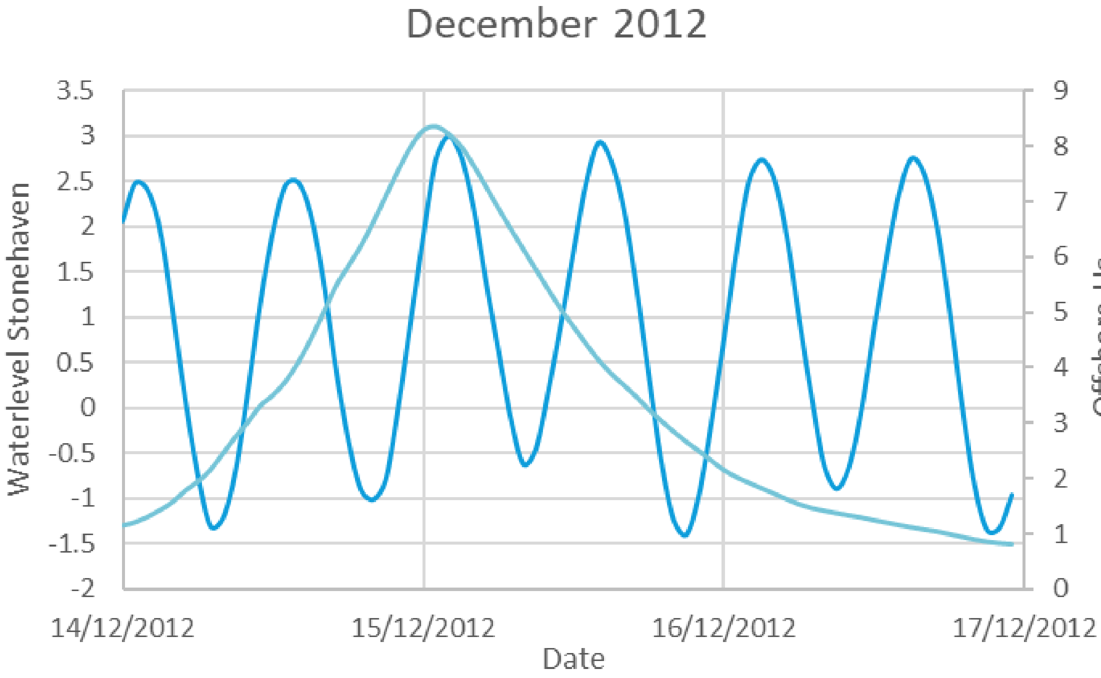


Figure 2-17: Offshore Hs (light blue) and SWL (dark blue) at Stonehaven for December 2012

This event caused evacuations of the sheltered housing along the frontage following to the onset of overtopping. Observations for this event report significant overtopping occurred over two high tides with the tide early in the morning of the 15th having the largest overtopping rate due to the highest offshore waves (Figure 2-17). The next high tide also produced overtopping albeit, at lower rates.

Along the Stonehaven frontage reports indicate that more overtopping occurred at the northern section (around SH_17) than at the middle and lower sections of the frontage. This is supported by the modelled results with higher rates and greater flood extents observed just south of the Cowie. This is considered appropriate and consistent with event observations.

The flood extent for this event can be seen in Figure 2-18 are shown to match well to observed inundation. This is particularly true in the sheltered housing (south of the Cowie) and the area surrounding the leisure centre. At Boatie Row, no photos of inundation are available although overtopping was reported along the Cowie frontage. Given the extent of previous flooding in the area, the modelled extent is appropriate for an event of this magnitude.

The output flood extent for this event can be seen in Figure 2-18 with modelled water levels output in Figure 2-19. Modelled levels at these points match well the onset of inundation and the approximate flood levels.

Observations also indicate a flow of inundated defences from south to north. This is corroborated by modelling which shows a watershed between Ironfield Lane and Cowie Lane from where water flows north toward Turners Court and ponds in the area to the south, surrounding Beachgate Lane.

Figure 2-18: Modelled flood extent for 15th December 2012 event, along with photo evidence from Aberdeenshire Council

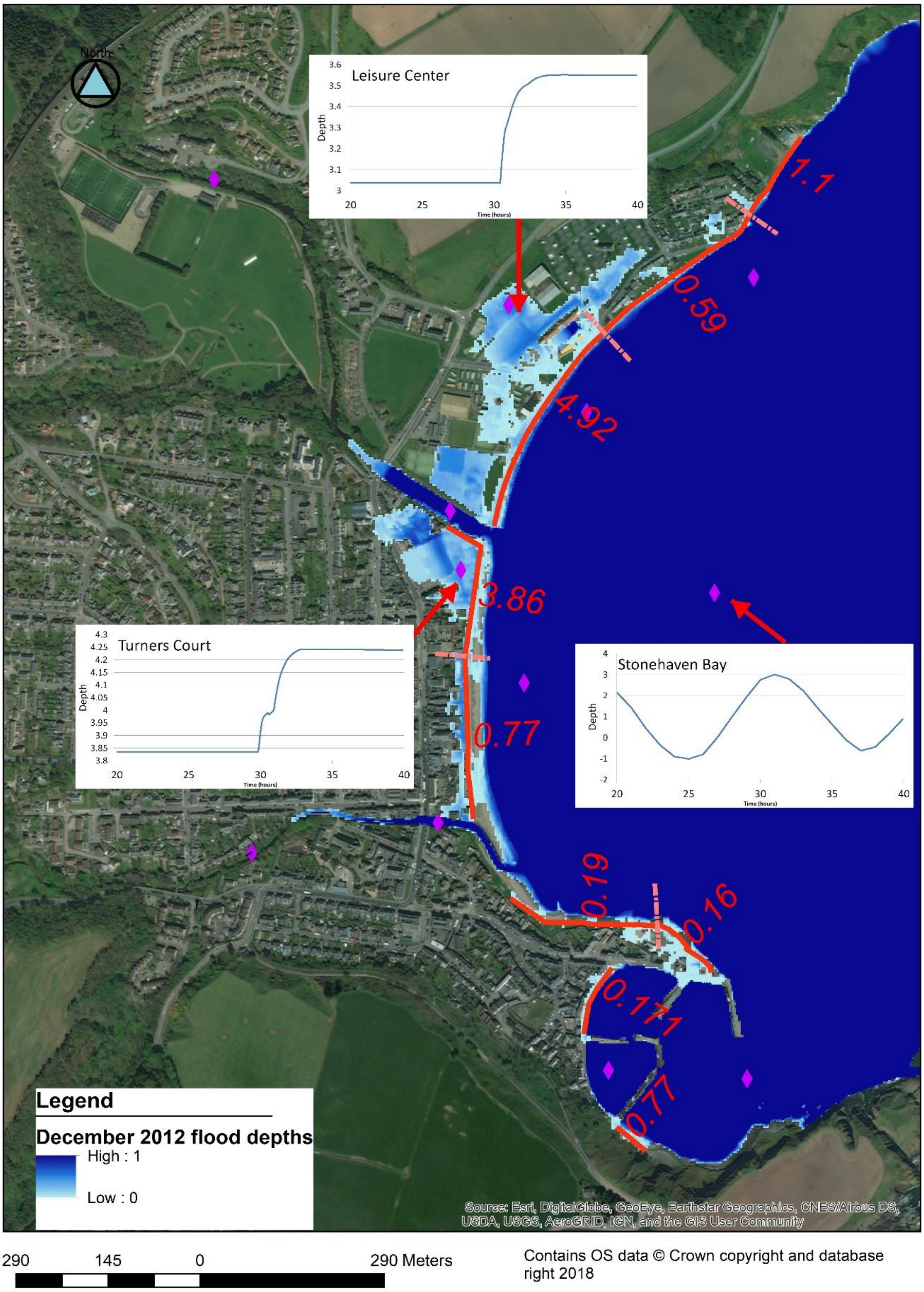


Figure 2-19: Modelled flood extent for 15th December 2012 event, along with overtopping rates and estimated water depths at key locations

Extreme events

Inundation extents and depths for the extreme events are required to inform the baseline economic assessment and the options appraisal. For coastal flood risk, inundation is typically represented as a composite risk from both SWL and wave overtopping. This means that each return period simulation is forced with the corresponding SWL and overtopping rate.

For communities where there is variation in the risk mechanism (e.g. SWL flooding within an estuary and overtopping at the sea) this allows for both to be accounted for. However, when SWL overtopping exists at the coastal defences, this can lead to double counting of flood volume as this will be included in the overtopping rates and simulated in TUFLOW from the tidal graphs. To account for this an additional check is made, where an approximate overtopping volume from the extreme tidal graph (using a broad crested weir equation) is removed from the overtopping rates.

It should be noted that, for all the defences where overtopping is applied in TUFLOW, none are predicted to overtop from SWL alone for present day conditions. Still water levels are anticipated to be close to the defensive crests (particularly within Cowie) for higher return periods in 2118.

Overtopping rates

The peak extreme overtopping rates estimated previously (section 2.8.3) were used to generate a variable rate based on a tidal curve using the underlying peak water level. The same wave conditions are applied throughout, with the wave heights used for overtopping being depth limited based on the water at the toe of the defences throughout the cycle.

The duration of the extreme event conditions is something that is not considered in the multivariate model. As such, it has been assumed that these persist over a single tidal cycle (12 hours). Figure 2-20 provides an example of the extreme overtopping rates at various locations.

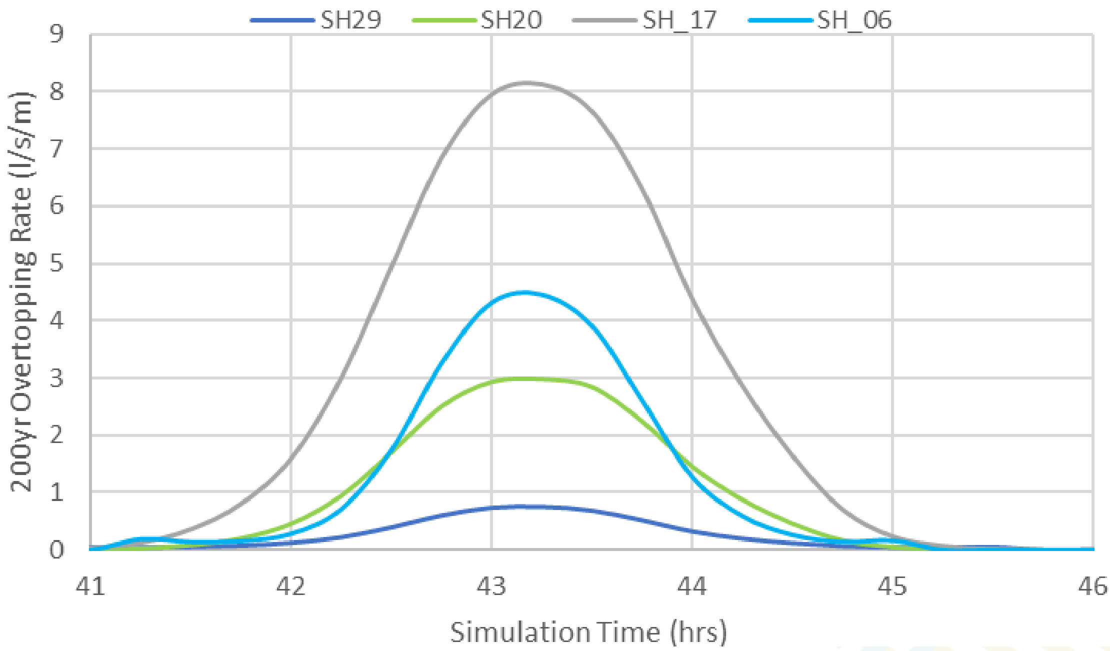


Figure 2-20: Overtopping rate for four selected cross sections for a 1 in 200 year event

SWL tidal graphs

The generation of the extreme SWL tidal graphs follows the CFB methodology[5]. It combines a base astronomical series at Stonehaven from Admiralty Total Tide, a surge shape from Aberdeen and extreme sea levels from the 2018 update to the CFB.

As specified in the guidance, the base astronomical tide has a peak level between MHWS and HAT (2.35mAOD). The surge peak is applied to the preceding trough of the astronomical tide to maximise the flood volume. Given that limited SWL flooding occurs and there are no large estuaries in Stonehaven, it is likely that the positioning of the surge has very little influence on extreme flood depths.

Sea level rise has been considered using the UKCP18 medium emissions, 95th percentile scenario. For climate change scenarios, the extreme sea level and base astronomical tide will be uplifted to 2118 levels. This gives an increase of 0.73m from present day (2018) conditions. Figure 2-21 provides examples of the 200-year tidal graphs for 2018 and 2118.

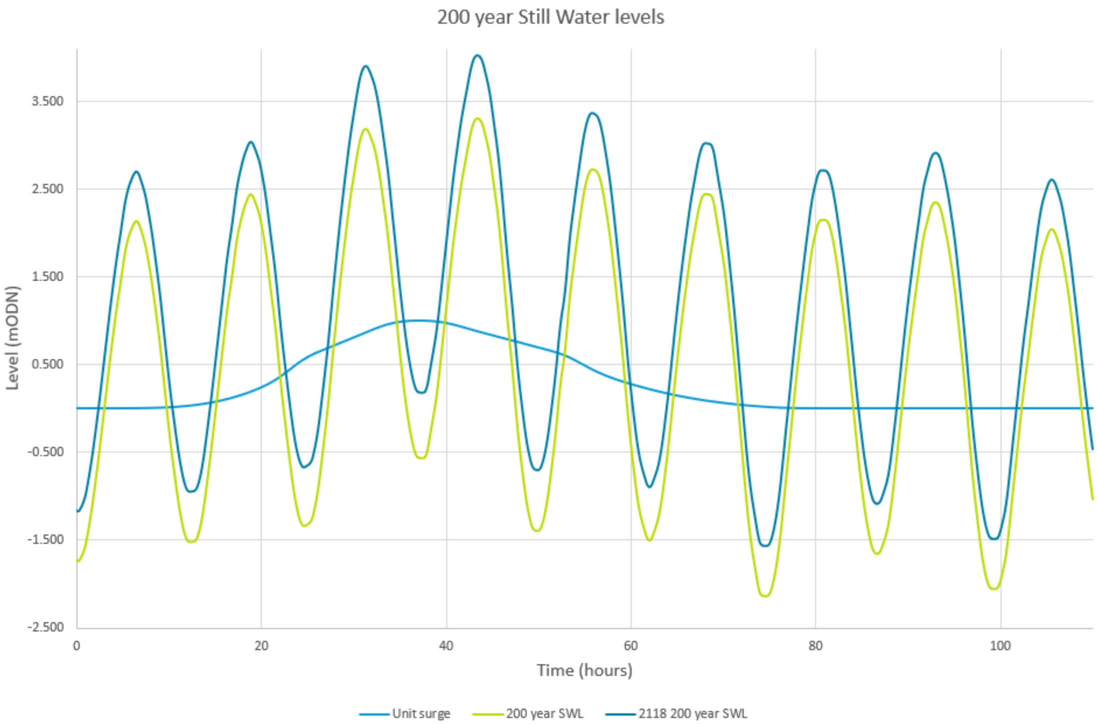


Figure 2-21: Example tidal graphs for 2018 and 2118 200-year events

Table 2-14 shows the still water levels for a range of return periods at Stonehaven. These levels are based on the nearest Coastal Flood Boundary (CFB) dataset node (3250) an represent the peak water level input into the TUFLOW model for each run.

---

[5] DEPARTMENT FOR ENVIRONMENT FOOD AND RURAL AFFAIRS. 2011. Technical Report Design sea levels. R&D Report SC060064. Defra/Environment Agency.

Table 2-14: Present day and climate change still water levels for a range of return periods

Return Period (years)	Present day (2018) SWL (mAOD)	2118 SWL (mAOD)
2	2.824	3.548
5	2.924	3.648
10	2.994	3.718
30	3.108	3.832
50	3.164	3.888
100	3.234	3.958
200	3.304	4.028
1000	3.664	4.178

Extents

As part of this baseline assessment, extreme events for a range of return periods have been modelled. Flood depths and extents for the present day 2-year, 30-year, 100-year and 200-year events are provided in Appendix E along with 2118 flood extents for the 30-year and 200-year events. Section 4 provides a breakdown of the number of properties flooded at each return period.

2.10 Tidal reach of the Cowie Water

The Cowie Water discharges into the North Sea the south of Cowie promenade and to the north of Turners Court. The Cowie Water is tidally influenced up to the weir beneath the B979 road bridge.

2.10.1 Historical configuration

The configuration of the two watercourses at the coast was historically very different, with the Cowie Water running south along the front behind a large shingle bar, and the two merging prior to discharging out into the bay (Figure 2-22). It is understood that the Cowie Water broke through the shingle bank during a storm event in 1948. Anecdotal evidence suggests that large volumes of shingle were removed from the frontage during the 1940s, resulting in a reduced width of shingle[6].

The photograph presented in Figure 2-23 was taken in 1932 and shows the historical flow path of the Cowie Water behind the shingle bar[7], whereas Figure 2-24, which was taken in 1948, shows that the two rivers have separate outfalls onto the beach[8].

---

[6] Stonehaven beach shingle loss document supplied by Ian McDonald, Stonehaven resident

[7] Extract from aerial view, 1932 (SPW040485) Historic Environment Scotland

[8] Photo extracted from YouTube video by Ian McDonald, Stonehaven resident

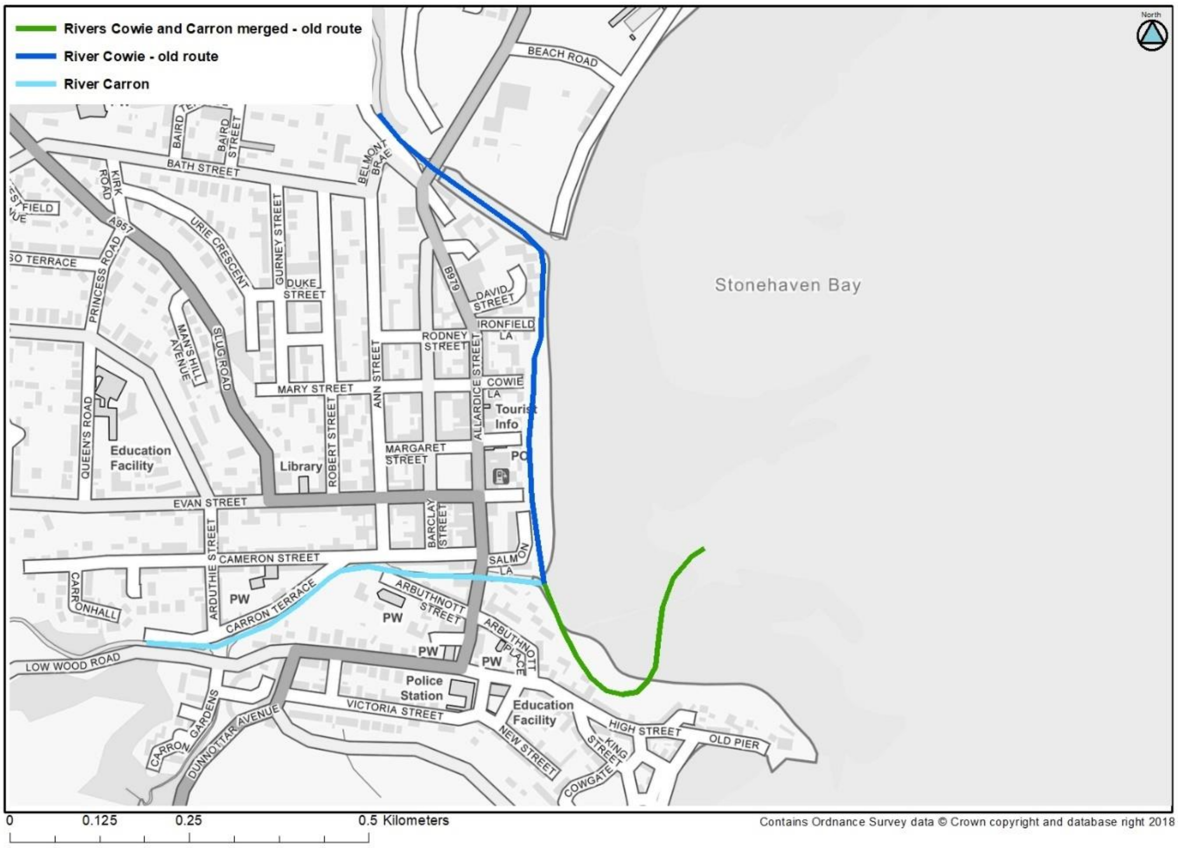


Figure 2-22: Historical configuration of the Cowie Water and River Carron at the coast

Figure 2-23: Image showing historical path of the Cowie Water, River Carron and the shingle bar

Figure 2-24: Image showing the river mouths in 1948 following the Cowie breaking through the shingle bank

2.10.2 Present day configuration

The mouth of the Cowie Water consists of concrete lined banks, with a training wall extending out from the left (northern) bank, a small amount of rock armour present at the end of the right bank, and a footbridge crossing the channel. Flow beneath the footbridge and out onto the beach is constricted by the deposition of shingle, which also extends further upstream along the right bank. Upstream of the footbridge the channel sides are formed by sheet piles topped with a sloped concrete revetment (Figure 2-26). The current configuration can be seen within the aerial image presented in Figure 2-25; however, it should be noted that the path of the river at the mouth and across the beach does vary.

During storm conditions, it is understood that waves propagate into the mouth of the river. Video footage, provided by Aberdeenshire Council and dated 16 March 2018, shows waves breaking on the shingle bank, resulting in splash over the right hand bank of the river, with smaller waves then running along the right bank revetment and breaking on the weir beneath the B979 road bridge.

Figure 2-25: Aerial image showing the present day mouth of the Cowie Water

Figure 2-26: Looking upstream from the mouth of the Cowie Water to the weir and B979 road bridge

Figure 2-27: Right bank and footbridge at the mouth of the Cowie Water

Figure 2-28: Left bank training wall at the mouth of the Cowie Water

2.10.3 Coastal flood risk in the tidal reach

Potential coastal flood risk within the tidal reach of the Cowie Water exists from both still water levels (SWL) and wave action; each of these are considered in turn below.

Still water levels

Due to the lack of a hydraulic model along the Cowie Water, the bank levels have been compared directly with tidal levels. Figure 2-29 and Figure 2-30 show the top of bank levels along the left and right hand banks of the Cowie downstream of the B979 road bridge respectively, and compare this to the extreme sea levels from the updated Coastal Flood Boundary Dataset (CFBD).

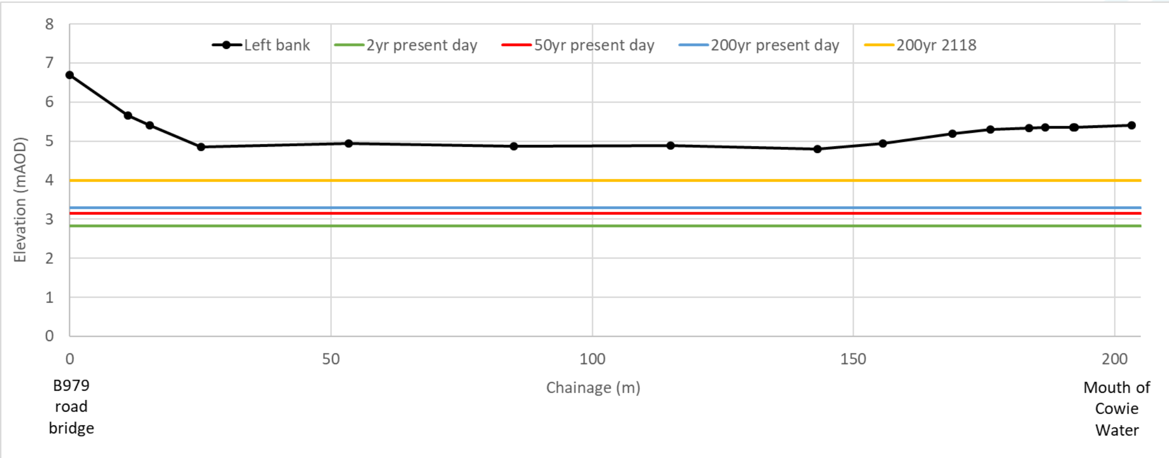


Figure 2-29: SWL compared to top of bank levels; left bank

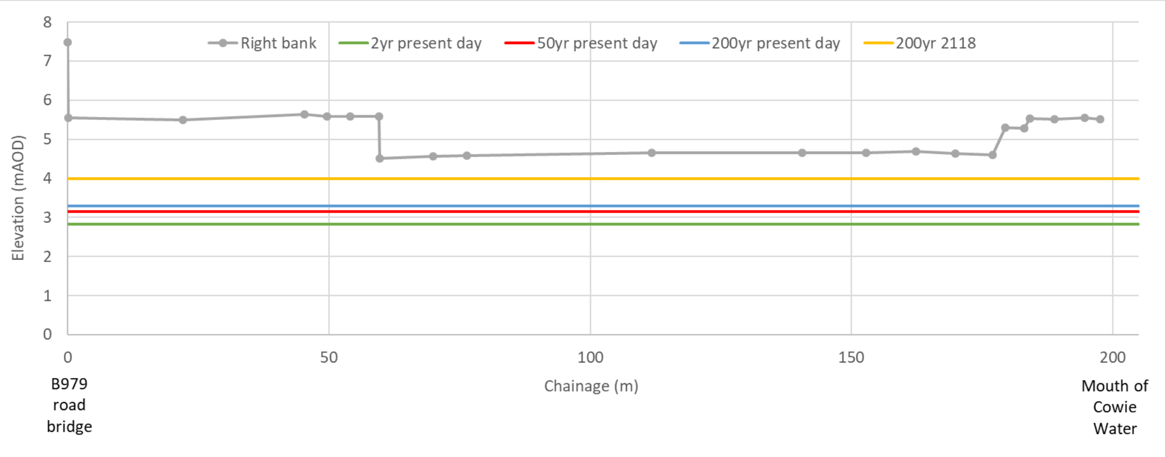


Figure 2-30: SWL compared to top of bank levels; right bank

It can be seen that for both banks, there is no risk from coastal flooding due to still water levels alone for up to and including the 200 year plus climate change event (to 2118 using the medium emissions 95th percentile data from UKCP18). For the left bank there is a freeboard of 0.81m and for the right bank there is a freeboard of 0.53m compared to the lowest point along each.

Waves

Additional coastal risk exists in the form of waves, and there is anecdotal evidence that waves can overtop the right hand bank of the Cowie within the tidal reach and then roll along the revetment, finally breaking on the weir beneath the B979 road bridge.

A video of waves at the mouth of the Cowie that was filmed on 16 March 2018 was provided by Aberdeenshire Council. The video shows waves breaking on the shingle bank, resulting in splash over the right hand bank of the river, with smaller waves then running along the right bank revetment and breaking on the weir beneath the B979 road bridge.

In order to model waves propagating up the channel of the Cowie Water, a phase resolving wave model would need to be developed; however, this is outwith the scope of the current project. As such, a methodology has been derived in order to undertake a simplified assessment of wave risk within the tidal reach of the Cowie.

Due to the presence of large volumes of shingle at the mouth of the river as well as upstream of the footbridge, waves entering the channel would become depth limited.

Topographic levels around the river mouth, taken from the laser scan data, are presented in Figure 2-31.

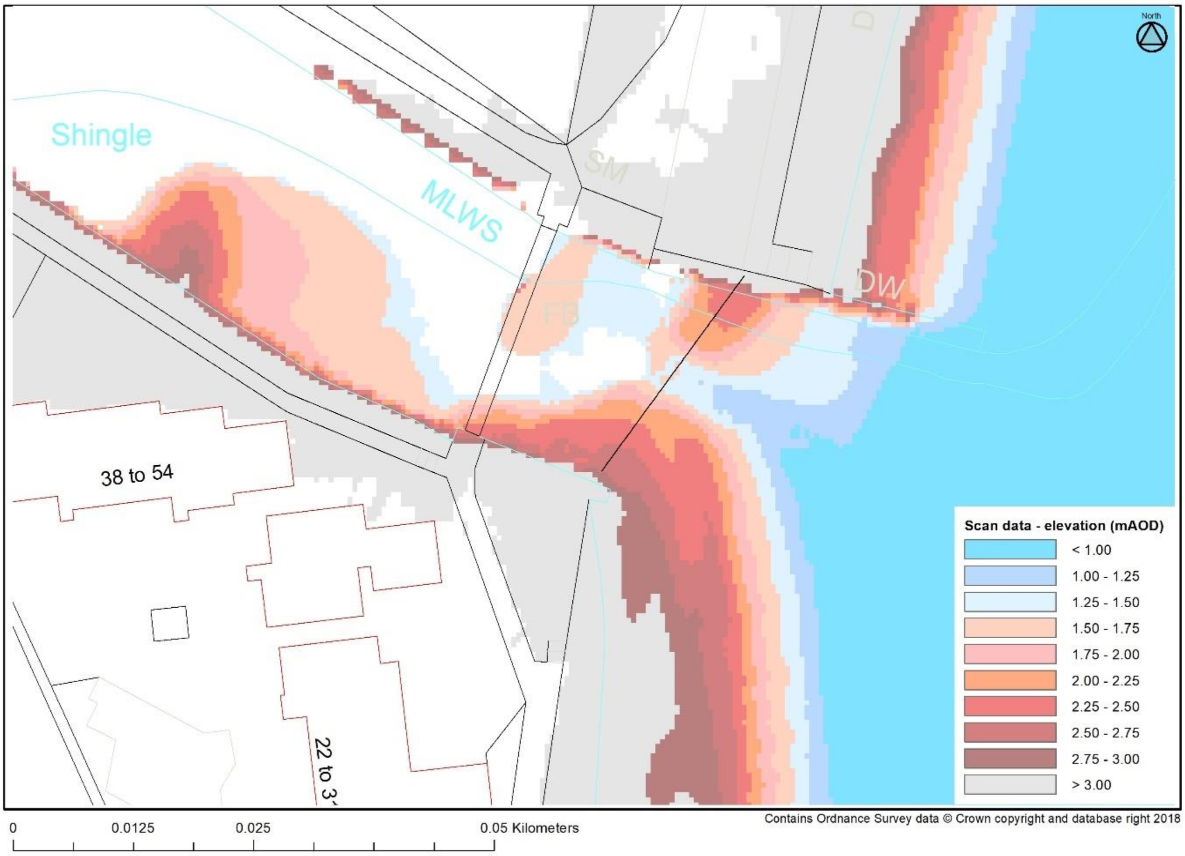


Figure 2-31: Elevations at mouth of Cowie Water from scan data

Based on the concept that waves entering the Cowie Water will become depth limited, the maximum height that a wave in the channel could be can be considered.

Depending on the options that are considered, the level to depth limit waves to could vary (e.g. if an option includes removing the shingle); for the purpose of this assessment a conservative value of 1.5mAOD has been taken. Based on the extreme sea levels from the updated CFBD, the maximum depth limited wave heights that could occur within the channel are as presented within Table 2-15. The depth limited wave heights are based on a conservative factor of 0.8 of the water depth. Half of the wave height has subsequently been added onto the SWL to give a total height, and these are presented in comparison to the top of bank levels within Figure 2-32 and Figure 2-33.

Table 2-15: Maximum depth limited wave heights for a range of SWL

SWL return period	SWL (mAOD)	Depth limited wave height (m)	Total height (mAOD)
2 year	2.82	1.06	3.35
50 year	3.16	1.33	3.82
100 year	3.23	1.38	3.92
200 year	3.30	1.44	4.02
200 year 2118	3.99	1.99	4.99

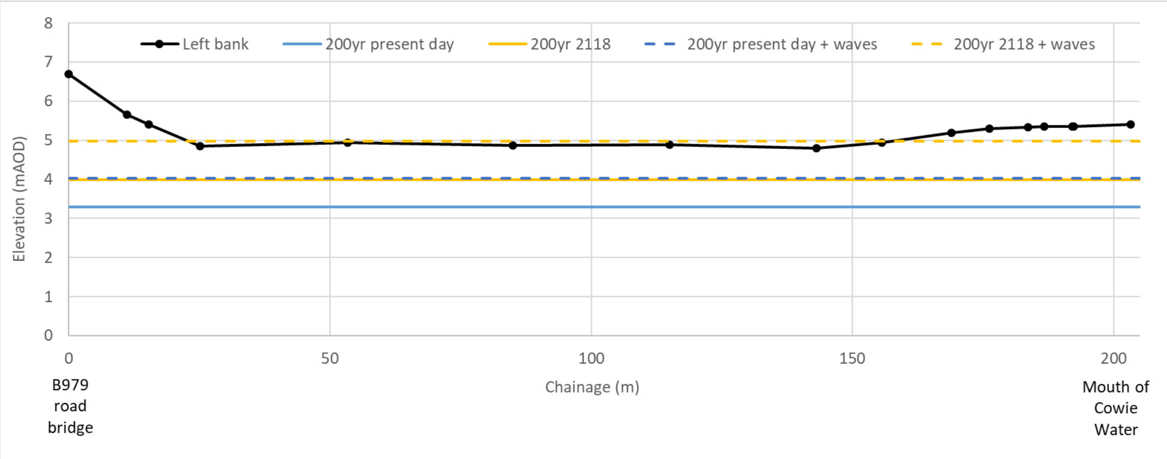


Figure 2-32: SWL plus waves compared to top of bank levels; left bank

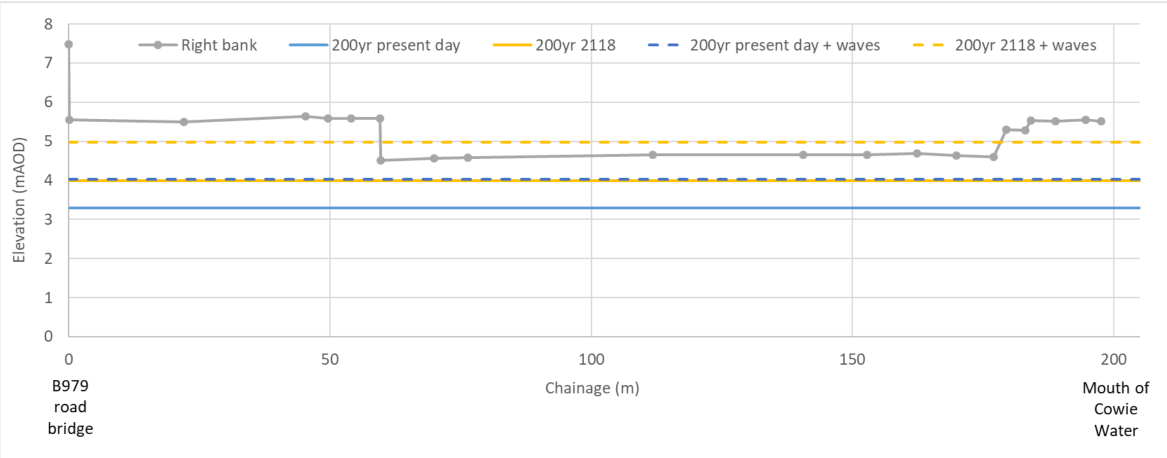


Figure 2-33: SWL plus waves compared to top of bank levels; right bank

It can be seen that, waves within the channel are only likely to become an issue for future extreme events. This is based on a conservative estimate of potential wave heights within the channel and this would vary according to the options that are progressed. Present day risk is deemed to be limited to the most seaward section, where oblique waves run up the shingle and result in some element of overtopping of the right bank. This has been accounted for within the modelling by extending the inflow in the TUFLOW model around the corner of the Cowie, and will be accounted for within the conceptual design by considering the depth limitation in conjunction with runup calculations.

2.11 Tidal reach of the River Carron

The River Carron discharges into the North Sea to the north of the harbour and south of the main central beach. The tidal reach of the river is influenced by both still water levels (SWL) and waves. Construction of the fluvial flood protection scheme for the River Carron and its tributary the Glaslaw Burn is due to commence in 2019.

2.11.1 Historical configuration

The mouth of the River Carron prior to any training works being constructed can be seen in Figure 2-34.

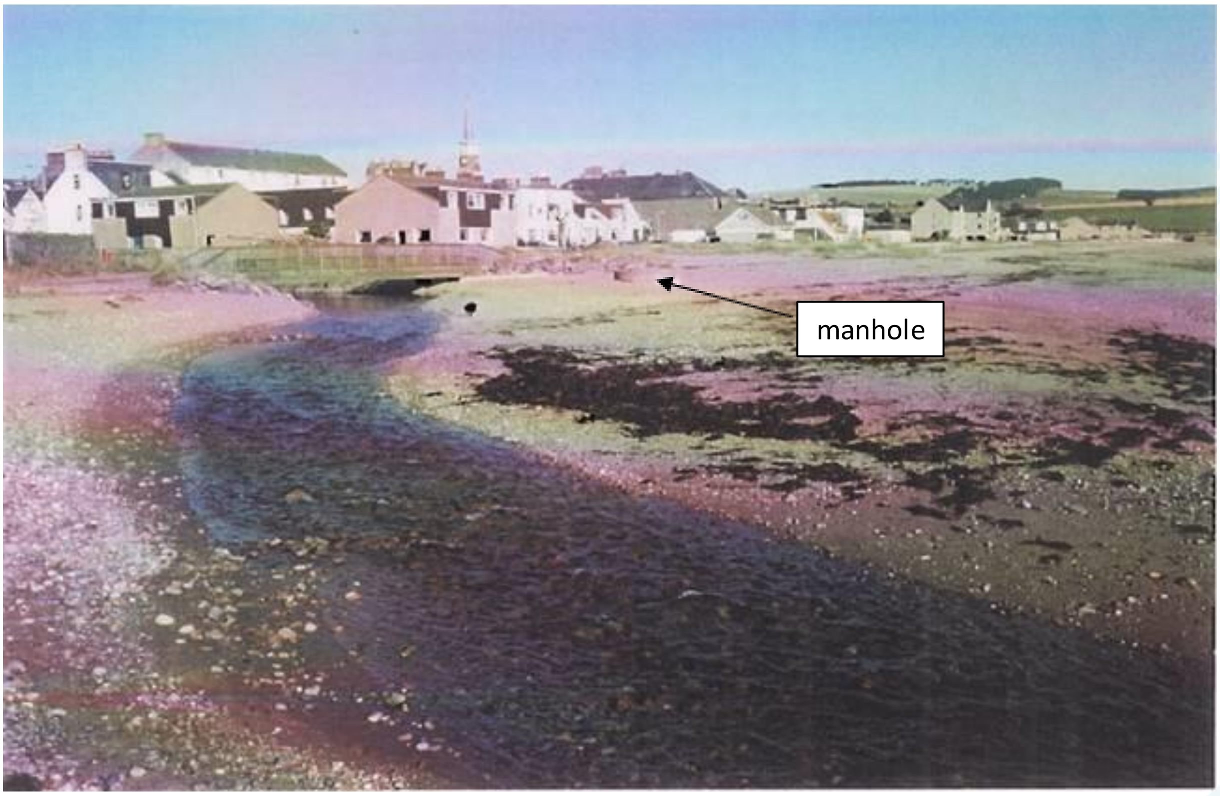


Figure 2-34: Historical natural outfall of the River Carron

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 as well as the deflection and partial siltation of the channel across the beach. The report[9] considered a number of training wall configurations, with the recommended option presented within Figure 2-35.

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

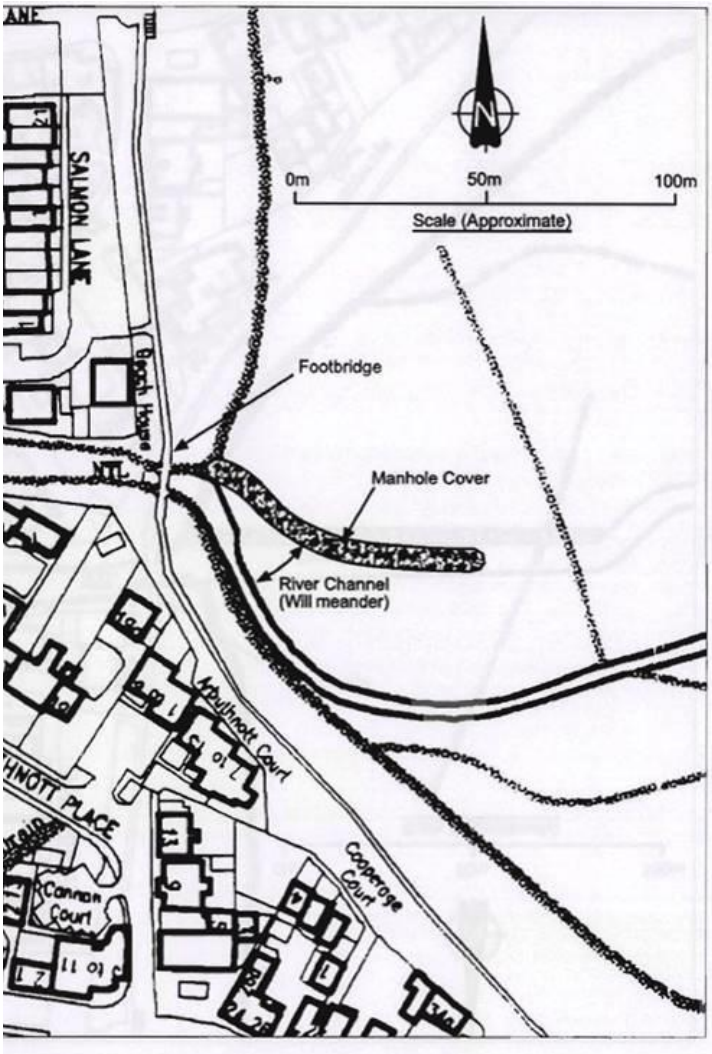


Figure 2-35: Recommended training wall option from HR Wallingford report

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, however the information available is limited. It is understood that initial training structures were built between 1998 and 2006, with these were then extended in 2008 (Figure 2-36).

Figure 2-36: Proposed extension to the training structures, 2007

2.11.2 Present day configuration

The present day configuration at the mouth of the Carron can be seen in Figure 2-37.

Figure 2-37: Current configuration at the mouth of the River Carron

2.11.3 Coastal flood risk in the tidal reach

Potential coastal flood risk within the tidal reach of the River Carron exists from both still water levels (SWL) and wave action; each of these are considered in turn below.

Still water levels

A number of hydraulic models are available for the River Carron. In 2011 JBA were commissioned by Aberdeenshire Council to undertake a Flood Alleviation Study, and as part of this constructed a 1D-2D linked model of the River Carron and Glaslaw Burn in InfoWorks-RS. The model was calibrated to the flood event that occurred on 1 November 2009 and was subsequently used by JBA to develop the outline design of the fluvial scheme. The downstream boundary of the model was in the form of a tidal graph, and this was timed so that the peak tidal level coincided with peak flows at the downstream limit of the model.

Sensitivity analysis undertaken as part of the original study with regard to the downstream boundary showed that for a 2 year fluvial event, the tidal downstream boundary effects flood levels up as far as White Bridge, and for a 200 year fluvial event this is limited to as far as Bridgefield Bridge (Figure 2-38).

Whilst the analysis shows that the combination of a high fluvial flow (Q200) with a lower return period tidal level (T2) results in the highest overall water levels, the dependency between the two was not assessed. As such, the report recommends that joint probability analysis between fluvial flows and tidal levels be undertaken at the detailed design phase. However, it should be noted that the combination of Q200 and T200 shows only a small difference in stage between Bridgefield and Beach bridges; becoming minimal at Bridgefield bridge.

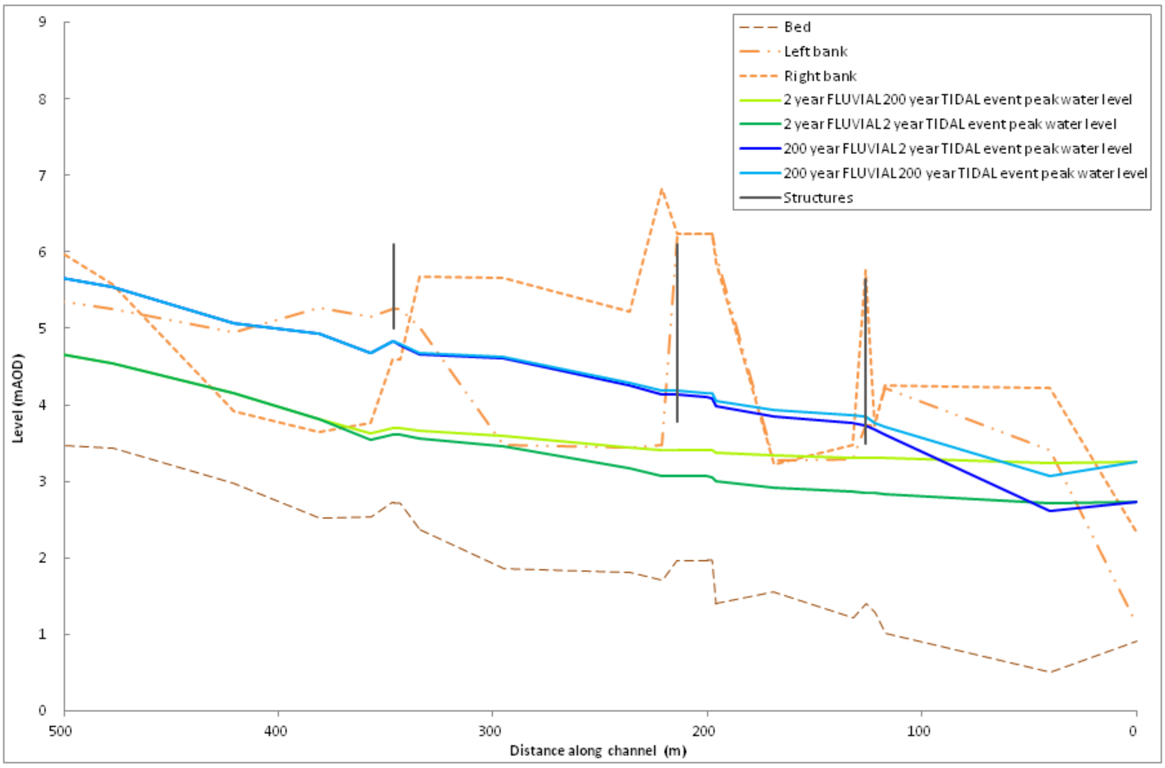


Figure 2-38: Long section of the River Carron – downstream boundary sensitivity analysis

The 2011 JBA report also considered the effect of the rock armour at the mouth of the River Carron on tidal levels within the channel. Specifically, this looked at the change in the tidal level within the rock armour section of the channel downstream of Beach Bridge (Figure 2-39). The report concluded that due to the water level downstream of Beach Bridge being relatively constant, should the reach length downstream of the bridge be reduced, there will be little change in water levels further upstream.

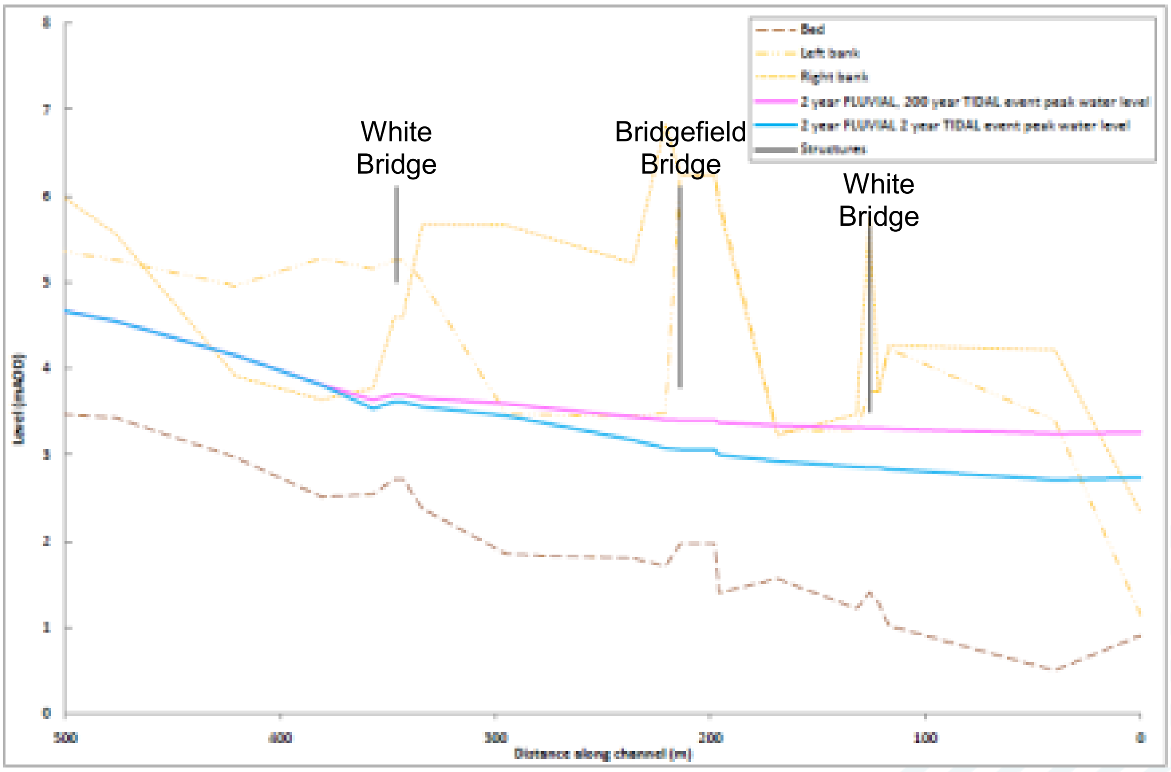


Figure 2-39: Long section of River Carron – SWLs in rock armour section of channel

The detailed design of the fluvial scheme was awarded to Mott MacDonald Limited, with their Hydrology and Hydraulic modelling report being released in June 2015[10], supplemented by two addendums dated December 2015[11,12].

As part of the detailed design Mott MacDonald developed a 2D in-channel TUFLOW model of the River Carron and the Glaslaw Burn. The downstream boundary of this model is in the form of a HT boundary, with the peak level corresponding to a 1-year tide. However, the peak flow in the Carron is not aligned with the peak tidal level (Figure 2-40). It is aligned with the minimum cut off value of 1.5mAOD, which is between MHWS (2.07mAOD) and MHWN (1.17mAOD). As part of the modelling, sensitivity analysis was undertaken by increasing the downstream boundary by 0.5m, with the report concluding that the effects were negligible. It is assumed that the timing in the peaks was unaltered for the sensitivity testing, and as such a tidal level of 2.0mAOD was applied at the timing of the peak flow.

---

[10] Stonehaven Flood Protection Scheme, Hydrology and Hydraulic Modelling, June 2015
[11] Stonehaven Flood Protection Scheme, Hydrology and Hydraulic Modelling - Addendum A to Revision A, December 2015
[12] Stonehaven Flood Protection Scheme, Hydrology and Hydraulic Modelling - Addendum B to Revision A, December 2015

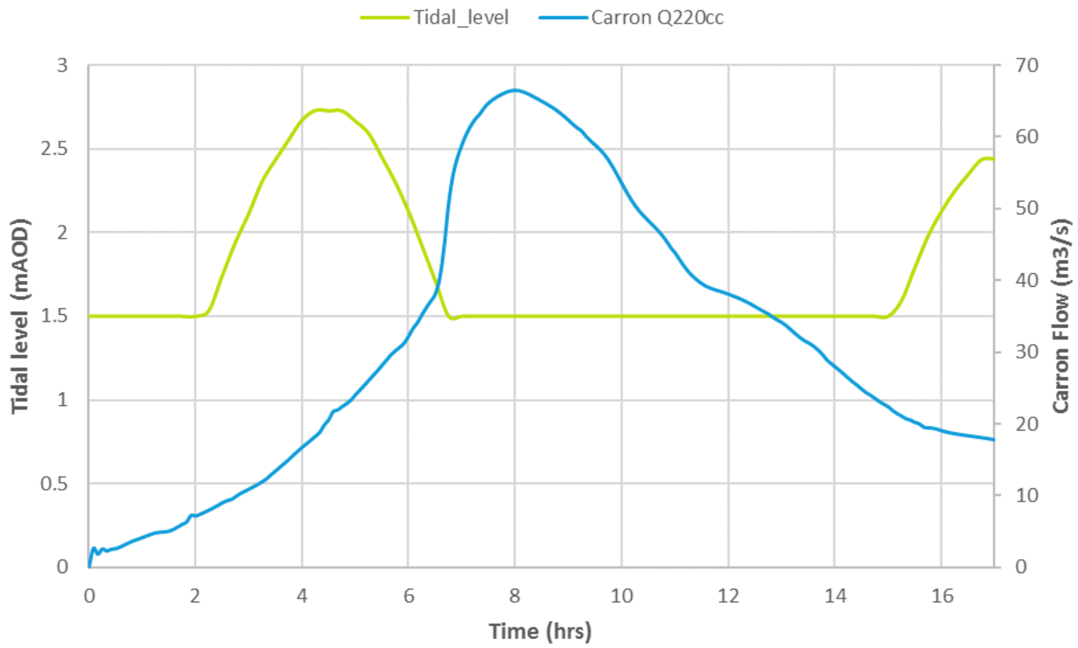


Figure 2-40: Tidal and fluvial boundaries for Q200cc design run from Mott MacDonald model

Whilst it is clear that the fluvial flows dominate flood levels within the Carron, the tide can affect levels within the downstream reach. It is understood that Aberdeenshire Council are happy with the freeboard allowance provided within the downstream reach in order to account for tidal levels. Should the coastal options being considered potentially effect levels within the Carron, the implications for the fluvial scheme will need to be investigated. Otherwise, no further work to consider still water levels in the tidal reach of the River Carron is required as part of this study.

Waves

In 2014 JBA were commissioned by Aberdeenshire Council to undertake a study to investigate wave propagation up the River Carron, as has been observed historically, e.g. as shown in Figure 2-41. The study combined information gathered from historical events with numerical modelling to assess potential wave heights within the downstream reach of the Carron and discuss the potential implications of this on the design of the fluvial scheme.

Figure 2-41: Wave propagation up the River Carron on 15 December 2012[13]

The report looks at a number of options to reduce wave heights within the channel and outlines high-level cost estimates of both a breakwater and the raising of the walls proposed as part of the fluvial scheme to account for wave action. The report details that in order to maintain a suitable freeboard, the walls would need to be raised by 0.9m.

It is understood that Aberdeenshire Council are satisfied with the freeboard provided by the proposed fluvial scheme and accept any residual risk from occasional wave overtopping. Should the coastal options being considered potentially increase waves within the Carron, the implications for the fluvial scheme will need to be investigated. Otherwise, no further work to consider waves in the tidal reach of the River Carron is required as part of this study.

2.12 Impacts of sea level rise on sewer network flood risk

As well as considering potential flood risk directly from the coast, it is important to consider the interaction between coastal flooding and other flood sources, especially with regard to climate change. To this end, an assessment of the impact of extreme sea levels on the drainage network within Stonehaven and Cowie has been undertaken. Multiple outfalls connect to the sea directly as well as into the lower reaches of the watercourses. During a coastal flood event, high sea levels can exacerbate flood risk in the drainage network through backup of the system and inability to discharge effectively; with the impact of climate change this risk is likely to increase.

To assess the implications of climate change on the local sewer system from tidal sources, Scottish Water's Integrated Catchment Model (ICM) has been utilised for surrounding drainage and sewer system of Stonehaven.

[13] Photograph taken by Ian McDonald, Stonehaven resident

The network geometry used for this assessment is:

"STW001527_STW001543:NEEDS_MODEL:22_3_2017".

The ICM model contains the drainage and sewer network system of Stonehaven. Data was provided by Scottish Water and is part of the Aberdeen ICS catchment, which incorporates Stonehaven.

For this assessment the 1 in 30 year and 1 in 200 year flood events were considered. To gain an understanding of the impact of sea level rise these were assessed for the present day and the 2118 epoch, using the UKCP18 medium emission 95th percentile scenario. Table 2-16 shows the associated flood levels.

Table 2-16: Still water levels for key return periods at Stonehaven

Return Period	Level (mAOD)
30 (2018)	3.11
200 (2018)	3.30
30 (2118)	3.83
200 (2118)	4.03

ICM model STW001527_STW001543:NEEDS_MODEL:22_3_2017 was exported into shapefile format and assessed within ArcGIS. An assessment of the network indicated that some isolated manholes and conduits are located within the model (i.e. pipes discharging to soakaways). These features were excluded from consideration as this study is to assess the implications of climate change on the local sewer system from tidal sources. A schematic of the network is shown in Figure 2-42.

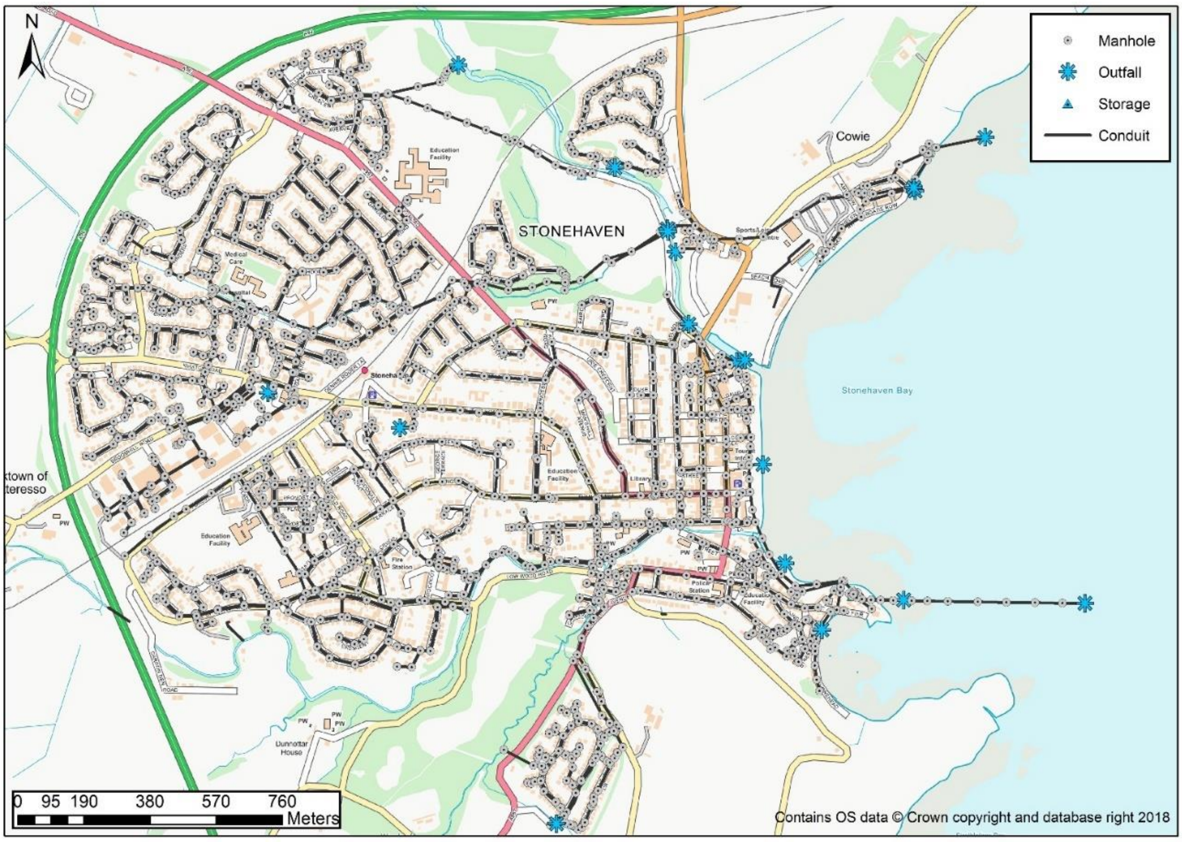


Figure 2-42: Local drainage network from ICM

In total, the following number of drainage features were identified within the drainage network of Stonehaven:

Outfalls: 19

Manholes: 2280

Storage features: 4

Within the ICM model, each node has a designated 'flood level'. This the level at which flooding could occur from a node via the manhole opening or connected gullies; whichever is lower.

The outfalls that would be impacted during each flood event were identified. Using the 'at risk' outfalls as a starting point, 'at risk' manholes and storage features were identified by assessing those that have a flood level less than the associated tidal peak for each scenario. A sense check was subsequently undertaken on the identified attributes by tracing their location, via the plotted conduit lines, to an 'at risk' outfall.

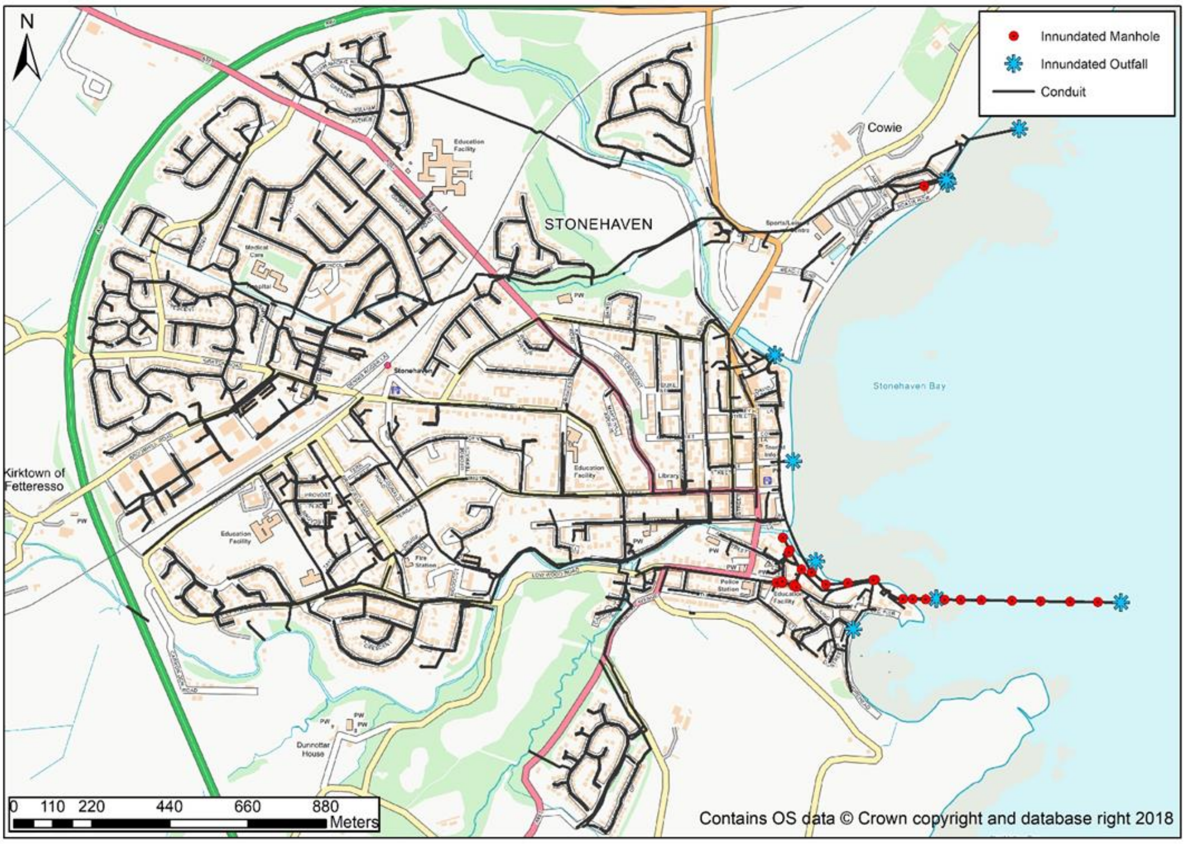


Figure 2-43: 30 year tidal flood event (2018)

During a present day 30-year tidal flood event, inundated outfalls and manholes are largely located where the Carron Water flows into Stonehaven Bay. Six manholes located along High Street are potentially at risk of flooding along with manholes located to the rear of the development, which backs onto the coastline. Isolated 'at' risk' manholes are also located in Cowie, along a side street of Boatie Row.

A summary of 'at risk' drainage features identified during a present day 30-year tidal flood event is provided in Table 2-17.

Table 2-17: At risk assets - 30 year, 2018

Drainage Features.	Number identified as 'at risk'.	Percentage of drainage network considered 'at risk'.
Outfall	9	47.4%
Manholes	26	1.1%
Storage features	0	0%

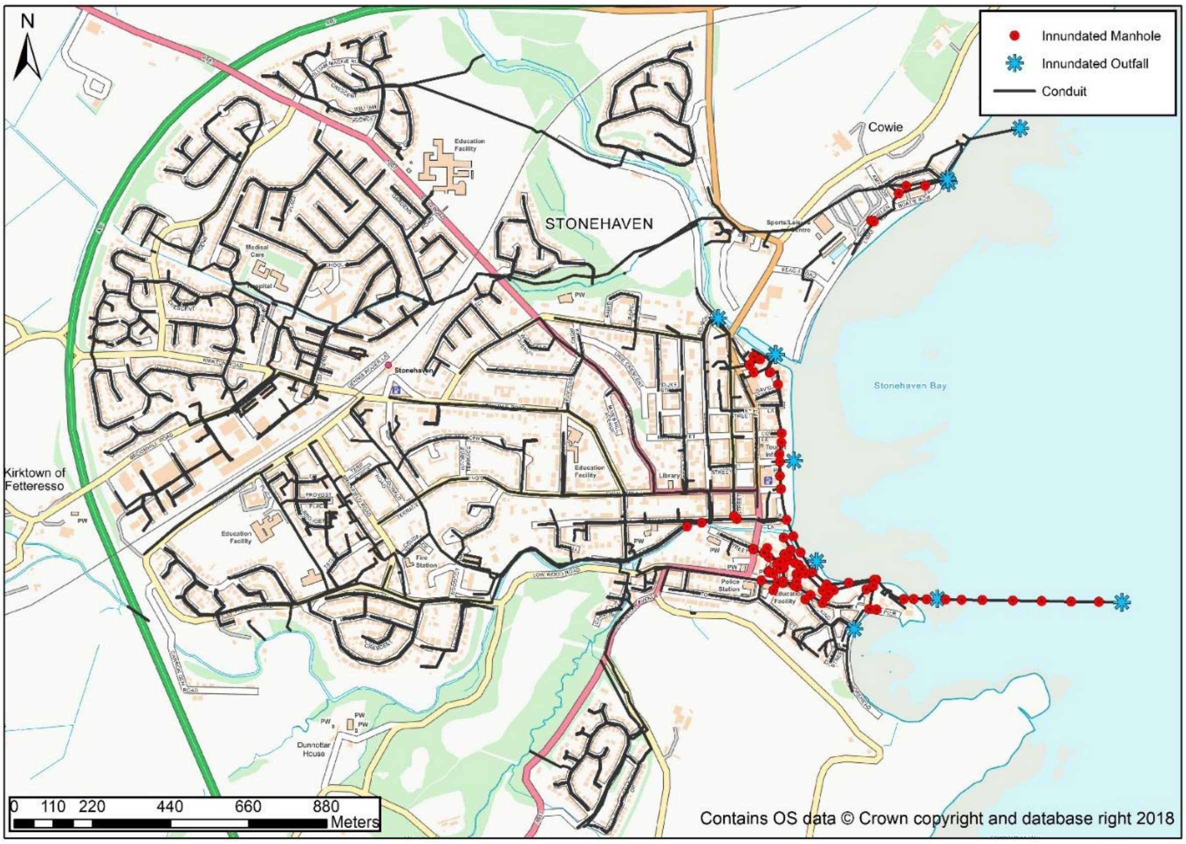


Figure 2-44: 30 year tidal flood event (2118)

During a 30-year tidal flood event which takes into consideration climate change (2118), the areas and number of drainage features identified to be 'at risk' increases. Areas located at the mouth of the Carron Water are likely to be the worst effected during a flood event of this magnitude, with risk spreading to the east along Arbuthnott Street, Arbuthnott Place, High Street, Old Pier and Cameron Street (to the west) where a number of residential properties could be impacted during surcharging of the sewer system. The number of vulnerable manholes in has also increased along The Links and Helen Row.

A summary of 'at risk' drainage features identified during a 30-year tidal flood event which takes into account climate change (2118) is provided in Table 2-18.

Table 2-18: At risk assets - 30 year, 2118

Drainage Features.	Number identified as 'at risk'.	Percentage increase from present day 30-year tidal flood event.	Percentage of drainage network considered 'at risk'.
Outfall	10	11.1%	52.6%
Manholes	90	246.2%	3.9%
Storage features	0	0%	0%

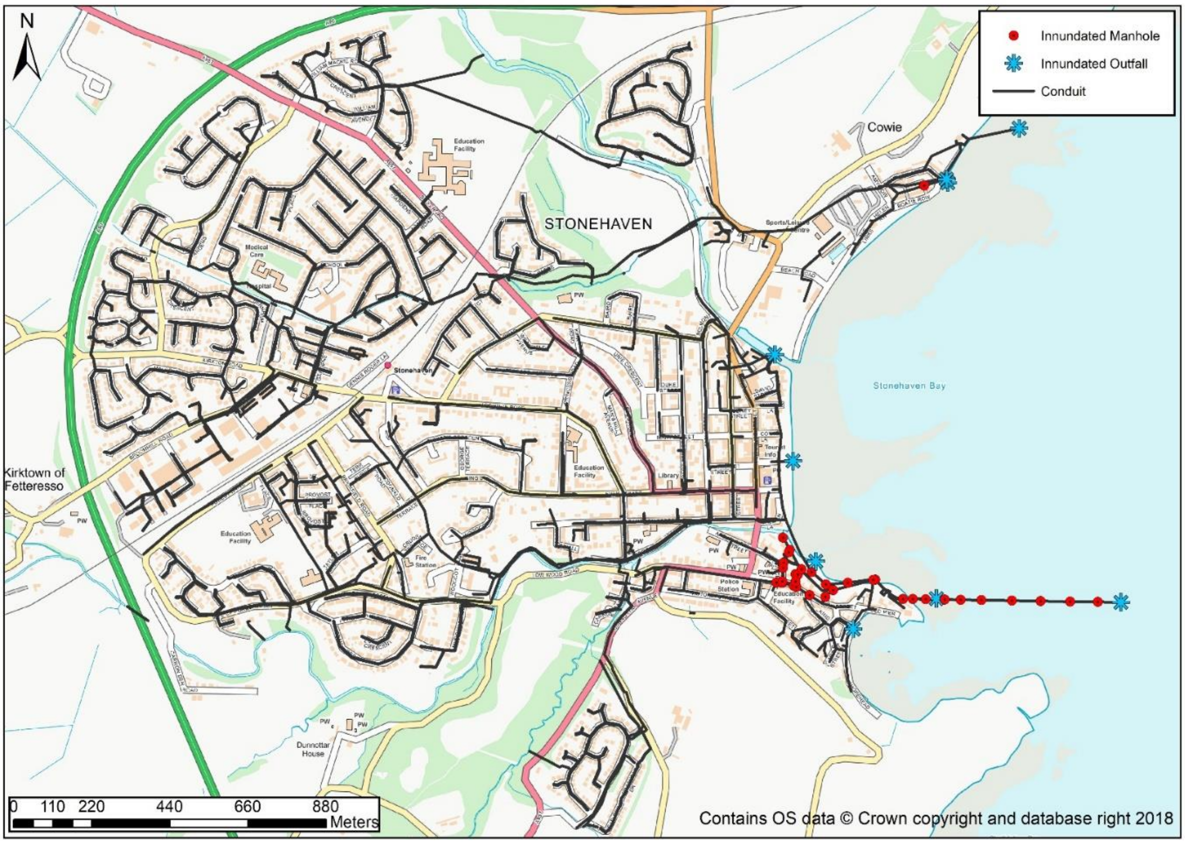


Figure 2-45: 200 year tidal flood event (2018)

During a present day 200-year tidal flood event, areas and drainage features identified to be 'at risk' largely follow the patterns identified during the present day 30-year tidal flood event scenario. The number of risk outflow locations has not changed but the number of potentially vulnerable manhole locations has increased.

A summary of 'at risk' drainage features identified during a present day 200-year tidal flood event is provided in Table 2-19.

Table 2-19: At risk assets - 200 year, 2018

Drainage Features.	Number identified as 'at risk'.	Percentage increase from present day 30-year tidal flood event.	Percentage of drainage network considered 'at risk'.
Outfall	9	0%	47.4%
Manholes	34	30.1%	1.5%
Storage features	0	0%	0%

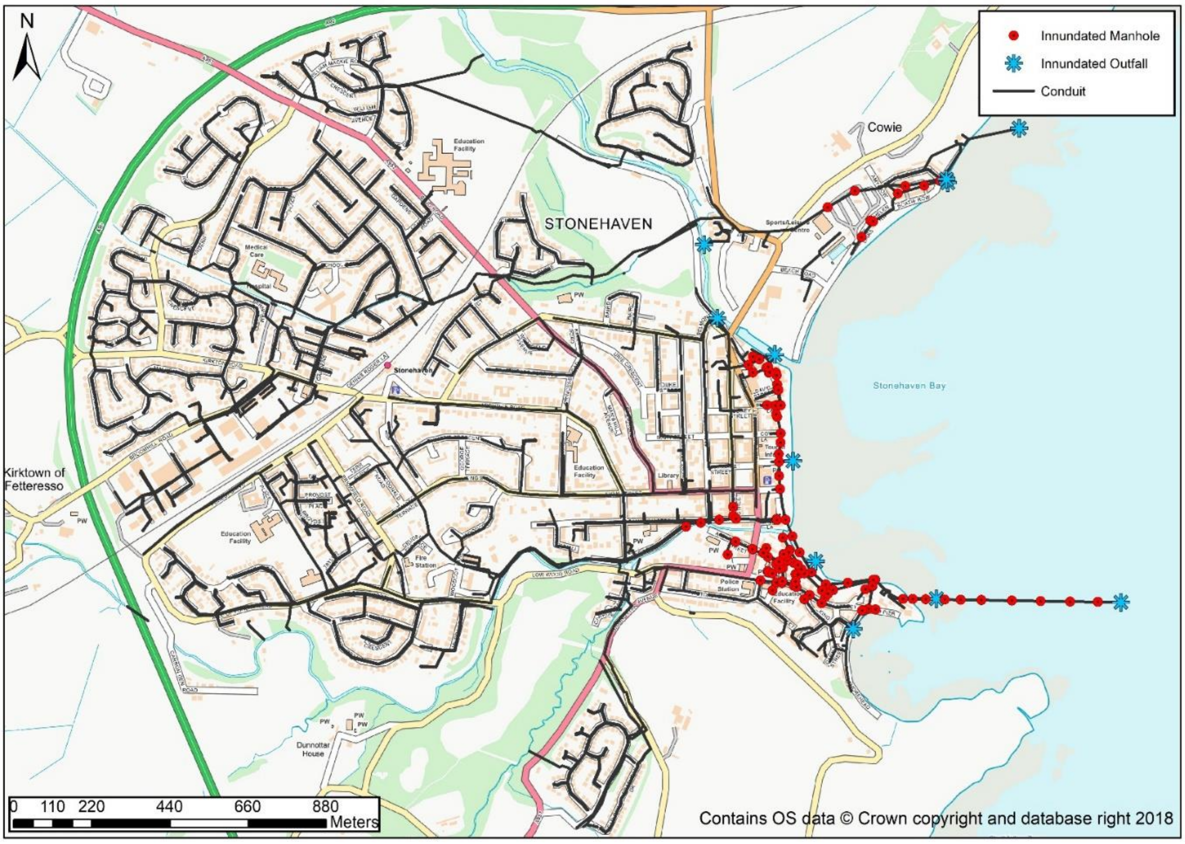


Figure 2-46: 200 year tidal flood event (2118)

During a 200-year tidal flood event which takes into consideration climate change (2118), the areas and number of drainage features identified to be 'at risk' increases. Areas located along the River Carron are likely to be the worst effected during a flood event of this magnitude, with risk spreading to the east along Arbuthnott Street, Arbuthnott Place, High Street, Old Pier and Cameron Street (to the west) where a number of residential properties could be impacted during surcharging of the sewer system. In addition, built development which back up onto the coastline to the east of Allardice Street and associated roads could also be impacted. Vulnerable manhole extents to the north have also spread to manholes along The Links and Helen Row.

A summary of 'at risk' drainage features identified within Stonehaven during a present day 200-year tidal flood event is presented in Table 2-20.

Table 2-20: At risk assets - 200 year, 2118

Drainage Features.	Number identified as 'at risk'.	Percentage increase from present day 200-year tidal flood event.	Percentage increase from 2118 30-year tidal flood event.	Percentage of Stonehaven drainage network considered 'at risk'.
Outfall	10	11.1%	0%	52.6%
Manholes	107	214.7%		4.7%
Storage features	0	0%	0%	0%

3 Geomorphology Assessment

To understand the morphological processes within the bay and how they contribute to flood risk, an assessment of the local coastal geomorphology has been undertaken. The aim of this is to evaluate the historical trends in shoreline position and beach volume, and thus provide an indication on the controlling mechanisms and influences these have on flood risk and erosion.

Assessment of future erosion is subsequently considered through numerical modelling of short-term storm response, with the objective to better understand the potential future risk to critical assets after failure of the current coastal defences.

3.1 Overview

The exposed position of Stonehaven on the coastline and the direct exposure to storm surges and extreme wave conditions historically led to the construction of multiple formal and informal coastal defences along the shore. These include a large rock armour revetment to the north of Stonehaven harbour; a boardwalk section consisting of rock armour and shingle; a concrete wall fronting the properties within the central section of the bay; stepped revetments with a small wave return wall at the crest between the mouth of the Cowie Water and the open-air pool; and sea walls along the frontage at Cowie village. All of these features enforce the current shoreline of the bay to a largely stationary position.

3.2 Geology

The arrangement of the bay and geological features has resulted in complex morphology and sediment transport patterns. The Highland Boundary Fault appears on the coastline at Stonehaven and the bedrock consists of Old Red Sandstone[14] with subordinate conglomerate and siltstone formed around 420 Ma. Ice covered Stonehaven and the surrounding area from the Strathmore Ice Stream that flowed northwards depositing reddish brown deposits[15]. Stonehaven is built on a raised beach that was created when glaciers retreated with glacial sand and gravel dominating the superficial deposits in the area, having been reworked over time resulting in the beaches that are present today.

3.3 Sediment transport and morphology

The volume of erodible sediment in the bay is limited due to the coastal defences and underlying geology. The headlands at either end of the bay prevent continuous longshore drift, and the dominant process appears to be cross-shore movement of shingle, with the elevation of the beach varying considerably with a fluctuating wave climate. Whilst cross-shore processes dominate, there is a general north to south trend in sediment movement. This occurs due to the northern headland providing less sheltering and is exacerbated by its finer sediment and longer offshore rock platform. Transport of material to the north is constrained by the mouth of the Cowie Water and training walls which trap transported material in the channel. Periodic beach recycling of this trapped material takes place with this being deposited south of the River Carron, to minimise erosional losses here.

---

[14] Ramsay and Brampton, 2000. Coastal Cells in Scotland: Cell 2 – Fife Ness to Cairnbulg Point. Scottish Natural Heritage Research, Survey and Monitoring Report No 144.

[15] A Landscape Fashioned by Geology: Northeast Scotland. Jon Merritt and Graham Leslie. https://www.nature.scot/sites/default/files/2017-06/Publication%202009%20-%20Landscape%20fashioned%20by%20geology%20-%20Northeast%20Scotland.pdf [Accessed 28 August 2018]

3.4 Current sediment management practices

Periodic sediment recharge occurs, where sediment is removed from within the mouth of the Cowie Water and redeposited to the south of the River Carron. Table 3-1 summarises the data available from Aberdeenshire Council on previous sediment movements.

This data has been used utilised within the long term trend analysis (Section 3.5).

Table 3-1: Summary of historical beach recycling operations

	Collected (tonnes)		Deposited (tonnes)		
Year	**From mouth of Cowie**	**From mouth of Carron**	**South of mouth of Carron**	**North of stepped seawall**	**South of mouth of Cowie**
2001	2000	0	2000	0	0
2002	2000	0	2000	0	0
2003	2000	0	2000	0	0
2004	2000	0	2000	0	0
2005	2000	0	2000	0	0
2006	2000	0	500*	2000	0
2007	2000	150	2150	0	0
2008	2000[t]	150	2150	0	0
2009	4350	0	4000	0	350□
2010	3000	0	3000	0	0
2011	1500	0	1500	0	0
2012	1000	0	1000	0	0
2013	0	0	0	0	0
2014	2200	0	2500	0	0
2015	0	0	0	0	0
2016	3000	0	3000	0	0
2017	3250	0	3250	0	0

Notes:

* Shingle placed over manhole cover just north of groyne at Carron.

[t] c150 tonnes of rock armour transferred from groyne at the mouth of the Cowie to improve groyne at mouth of the Carron.

□Shingle placed c50m south of the mouth of the Cowie.

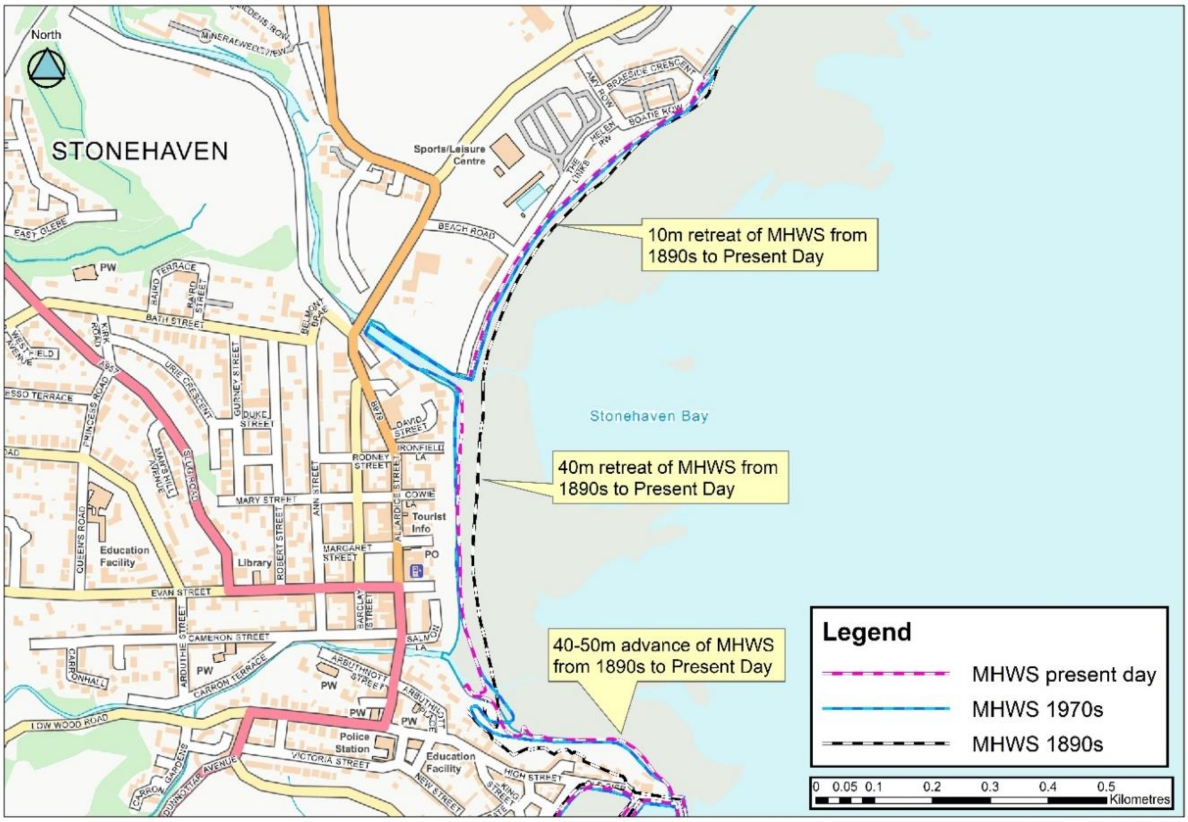
3.5 Long term trends

In 2015 the Scottish Government commissioned the National Coastal Change Assessment (NCCA) to provide an evidence base to understand morphological changes that have happened along the coast and how man-made interventions have shaped these changes. The datasets generated from this include historic MHWS contours from 1890s to present day and estimates of future erosion for 2050 and 2100.

The MHWS position is shown in Figure 3-1, and it can be seen that this has retreated along the northern and middle sections of the bay from 1890s to present day. Over the period the north of the bay has experienced a 10 m retreat of MHWS. The middle of the bay, between the Cowie and Carron, has retreated ca. 40 m. Historically, the Cowie Water flowed south along the front and joined with the River Carron before discharging into the sea (Figure 3-2). The Cowie broke through the shingle bar in 1948 following a large storm event and has run its present-day course since. Additionally, this breach event coincided with an increasing loss of shingle from the beach, when it is reputed that large volumes of sediment were removed in 1940-1950. It is likely that the combination of these two processes has contributed to the retreat of MHWS observed between 1890s and 1970s.

This has potentially caused the rate of shingle loss of the main beach to increase as the river discharges towards the south east and so velocity of the river discharge contributes to the increase in velocity of the natural north to south sediment drift.

The south of the bay, at the mouth of the Carron, has experienced large fluctuations in MHWS position (Figure 3-3). In the 1890s, the larger beach width forced the river to flow further south before discharging into the sea. In the 1970s the river discharged at approximately the same location, however north of the mouth, the area of sediment had increased and caused the MHWS to advance ca. 20 m. Rock armour was put in place on each side of the River Carron mouth in 2006 to stabilise its course and reduce sediment movement across the channel, which forced the river to discharge at a more northerly location than at previous years. This explains the loss of beach observed between 1970 and present day. Beach recharge takes place south of the Carron, and has done since the early 2000s, which accounts for the increase in beach in this location compared to 1970s. At the south of the bay, north of the harbour, the MHWS has advanced since the 1890s between 40 – 50 m as land has been reclaimed, for car parking and the shoreline is now constrained.



Contains Ordnance Survey data (c) Crown copyright and database right 2018

Figure 3-1: MHWS fluctuations from NCCA data

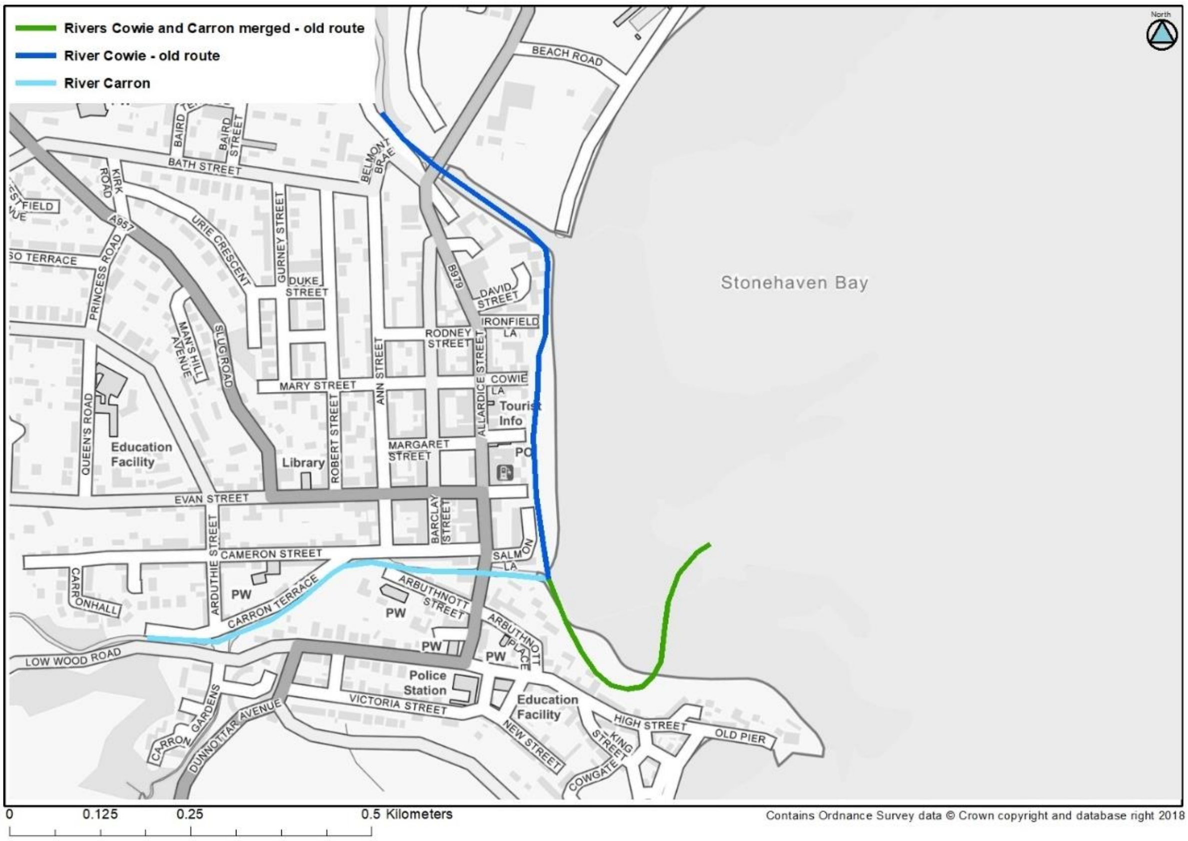


Figure 3-2: Historical fluvial flow routes

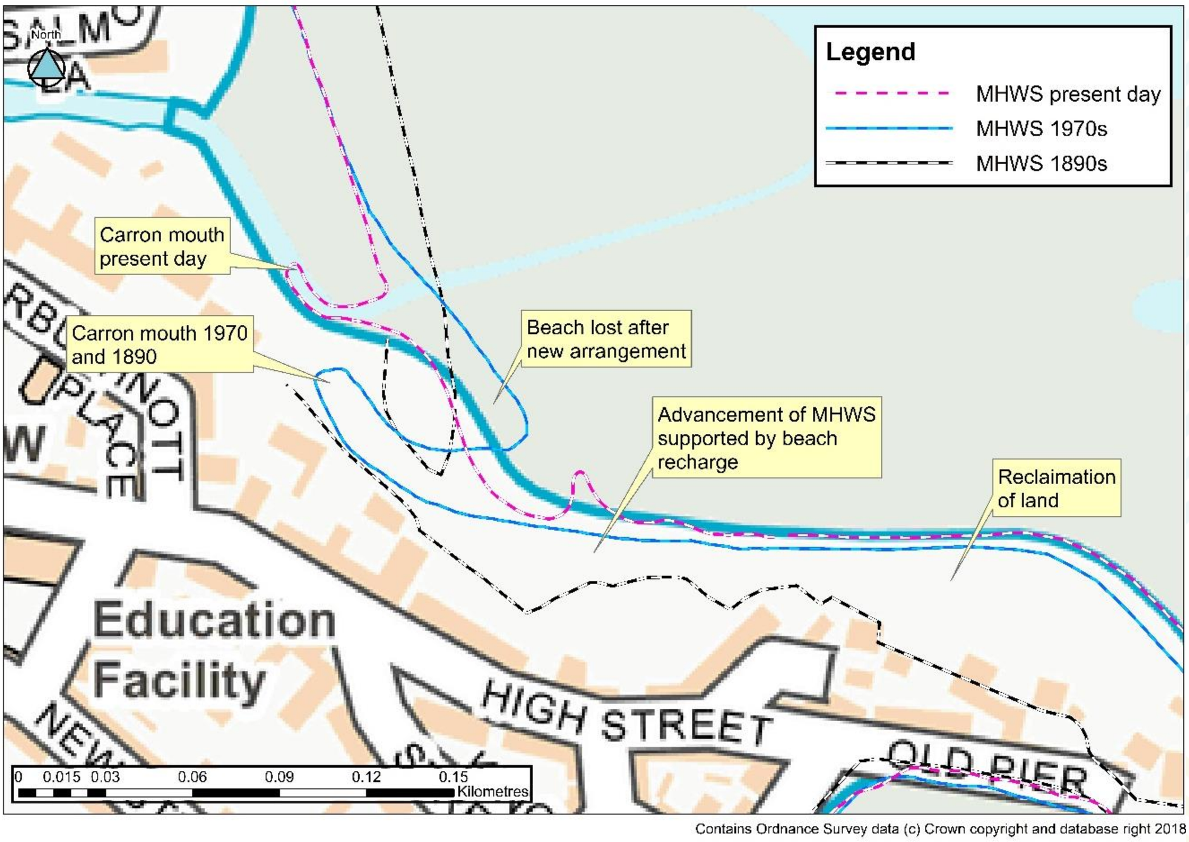


Figure 3-3: MHWS fluctuations at the mouth of the River Carron

3.6 Topographic Analysis

Topographic analysis was undertaken to understand the trends in and impacts of sediment movement in Stonehaven Bay, and to identify what controls these variations have on the coastal defences.

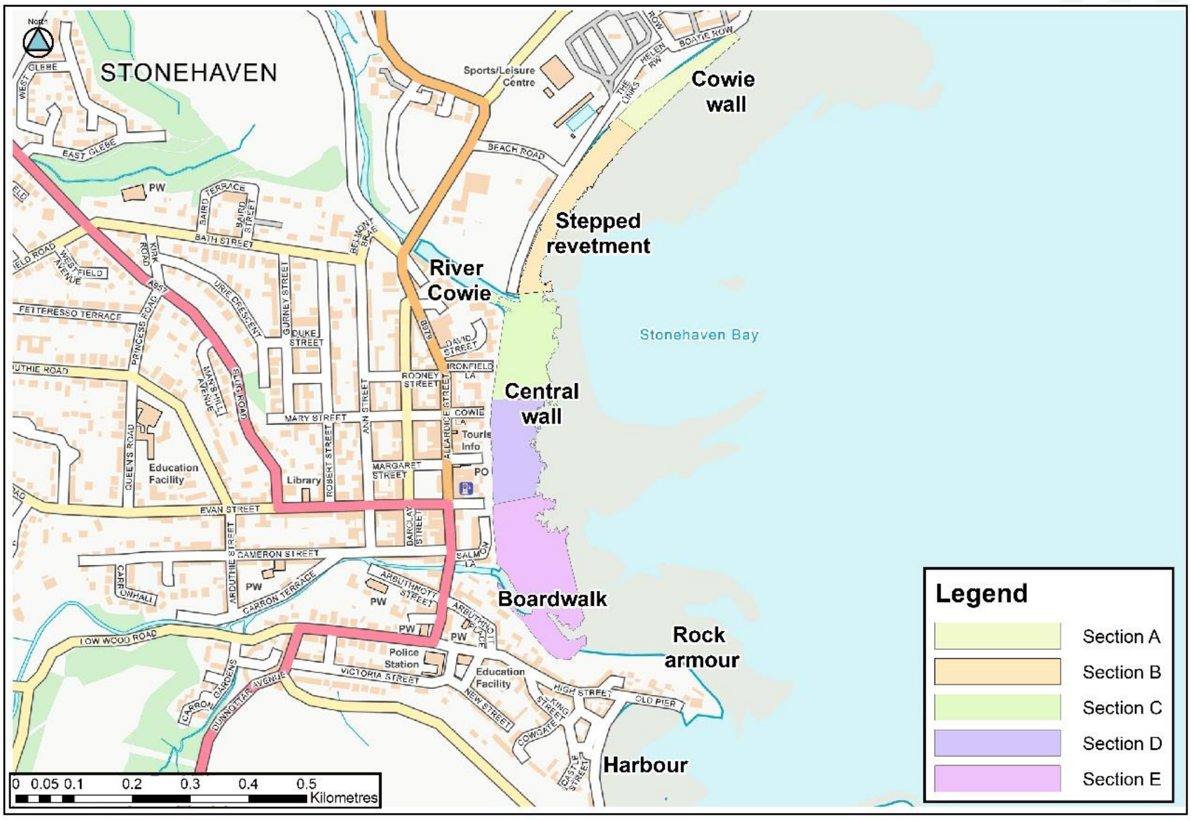
3.6.1 Data

Detailed topographic data of the beach is available for December 2008, May 2013 and May 2018 and has been used to assess the volumetric changes within the bay. A five year gap in data makes it hard to identify definitive trends. A medium term trend can be defined, however a seasonal variability trend cannot with this interval between surveys. The survey dates may also impact the analysis, as a December beach profile will be significantly different to a May beach profile. The 2013 and 2018 May beach profiles and resulting sediment budgets will reflect the previous winters' storms, whilst the 2008 December profile is pre-winter storm season and therefore will potentially show larger variations when compared with the other two datasets.

In isolation, this data is potentially insufficient to draw definitive conclusions on the erosion/accretion patterns. However, in the absence of more frequent surveys, it will be analysed with the aim of establishing medium-term beach stability.

3.6.2 Sections

There is considerable variability in both the defence types and sediment characteristics within Stonehaven Bay. To effectively manage the analysis, the length of the beach was divided into a number of sections based on the defence and sediment type. It was decided that five different sections best described Stonehaven Bay (Figure 3-4) and allows variation in erosion and sediment movement to be identified along the beach.



Contains Ordnance Survey data © Crown copyright and database right 2018

Figure 3-4: Division of Stonehaven Bay into sections

Table 3-2: Stonehaven Bay sections summary

Section	Defence type	Predominant sediment type	Approx. D50 (mm)	Offshore platform
A	**Vertical wall**	**Coarse sand**	**1**	**Yes**
B	**Stepped revetment**	**Coarse sand/shingle**	**10**	**No**
C	**Buried revetment**	**Shingle**	**50**	**No**
D	**Buried revetment**	**Shingle**	**50**	**Yes**
E	**Shingle beach**	**Shingle**	**50**	**No**

The general characteristics of the beach and defences at each section are shown in the figures below.

Figure 3-5: Section A/XS08: Vertical sea wall and sandy beach

Figure 3-6: Section B/XS12: Stepped revetment and shingle beach

Figure 3-7: Cowie Water estuary from the south with sediment accumulation

Figure 3-8: Section C/XS17: Seawall with sediment build up and shingle beach

Figure 3-9: Section D/XS20: Seawall with sediment build up. Shingle and coarse sand beach.

Figure 3-10: Section E/XS26: Boardwalk at the top of the beach; River Carron discharging into the sea across the beach

3.6.3 MHWS variations

The MHWS contour line (2.07 mAOD) was extracted as a contour for each of the three datasets to track shoreline movement over the last 10 years (Figure 3-11). The showed MHWS has advanced in Section A by 5 m from 2008 to 2018.

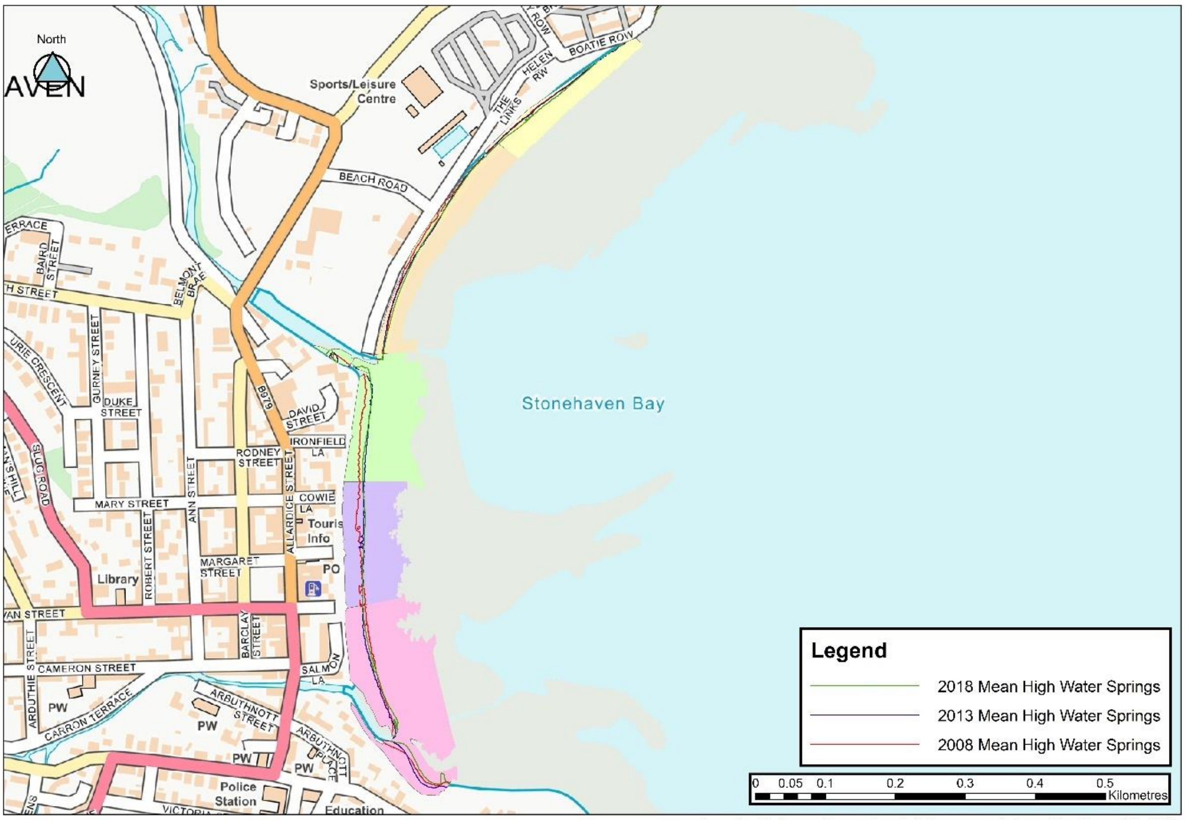
Section B also sees an advance of the MHWS by an average of 3 m along the section.

Within Section C, the 2013 MHWS position is the most seaward, 3 m beyond the position of the 2018 MHWS. However, from 2008 to 2018, the MHWS has advanced 8 m within this section.

The MHWS in Section D has advanced at the north, by over 12 m, whilst it has retreated at the south by 3 m.

In Section E this has retreated at the north by 3 m, and advanced in the south by 5 m.

The overall trend is that of MHWS advancement, and therefore sediment accumulation in the upper beach.



Contains Ordnance Survey data (c) Crown copyright and database right 2018

Figure 3-11: MHWS fluctuations from 2008, 2013 and 2018

3.6.4 Volumetric Analysis

Within each section of the beach, overall volume change and volume change above and below the MHWN (1.17mODN) was calculated between 2008, 2013 and 2018 in ArcGIS. It should be noted that MHWN was chosen over MHWS as the proximity of MHWS to the existing defences made it unsuitable for establishing volumetric changes. The results are presented in Table 3-3, Table 3-4 and Table 3-5.

Table 3-3: Volumetric changes within each section (2008 to 2013)

Section	Volume change above MHWN (m^3)	Volume change below MHWN (m^3)	Net Sediment Budget (m^3)
A	436	659	1095
B	1198	1319	2517
C	2868	-3092	-230
D	1881	-2964	-1083
E	-1129	-2328	-3457

Table 3-4: Volumetric changes within each section (2013 to 2018)

Section	Volume change above MHWN (m^3)	Volume change below MHWN (m^3)	Net Sediment Budget (m^3)
A	666	194	860
B	329	-314	15
C	708	-296	412
D	1842	-1866	-24
E	3466	-780	2686

Table 3-5: Volumetric changes within each section (2008 to 2018)

Section	Volume change above MHWN (m^3)	Volume change below MHWN (m^3)	Net Sediment Budget (m^3)
A	1102	854	1956
B	1527	1019	2546
C	3663	-3386	277
D	3725	-4807	-1082
E	2332	-3103	-771

Section A

A steady increase in volume across the whole beach, both above and below MHWN, of 1,956 m^3 was seen in Section A from 2008 to 2018. The section contains the lowest volume of active sediment across the bay.

Section B

A large increase in volume of 2,517 m^3 above and below the MHWN is observed in Section B between 2008-2013 (Table 3-3). However, although the overall change is positive, there is an area of significant sediment loss north of the Cowie Water training wall. Whilst longshore drift is north to south, cross-shore sediment movement is likely to dominate the beach profile, and the training wall appears to interfere with the natural sediment movement patterns. Between 2013-2018, the volume of sediment transported is much reduced to 300 m^3 (Table 3-4). Volume increases above MHWN and decreases below MHWN resulting in a negligible net sediment budget of 15 m^3. Overall, there is a significant sediment gain across the section over the period (Table 3-5).

Section C

Sediment volume within Section C is very variable, and much larger than at the two northern sections. Whilst there is a large gain above MHWN, there is also a significant loss below MHWN, making the overall volume change within the cell negative between 2008 – 2013 (Table 3-3). Between 2013-2018, sediment gain above MHWN outweighs the sediment loss happening below MHWN and so the overall change is positive (Table 3-4).

South of the Cowie Water training wall (Figure 3-14), there is a large accumulation of sediment building up both within the river channel and south along the main beach. This indicates the current training wall arrangement is insufficient for sediment retention in Section B.

Across the 10-year time period, Section C experiences a very large gain above MHWN, 3,663 m^3, and a very large loss below MHWN, -3,386 m^3, (Table 3-5), leading to only a slight increase in sediment across the section overall.

Section D

Section D experiences a significant gain of sediment above MHWN between 2008 and 2013, however a large loss below MHWN is seen, making the overall sediment budget negative (Table 3-3). The same pattern is seen between 2013- 2018 (Table 3-4) meaning the overall change in sediment within this cell from 2008 – 2018 is negative: -1,082 m^3 (Table 3-5). The positive gain above MHWN is also significant (3,725 m^3), however does not outweigh the large amount of sediment that is lost from the lower beach.

Section E

Section E covers the mouth of the River Carron and experiences negative sediment movement, both above and below the MHWN from 2008 – 2013 (Table 3-3). Between 2013-2018, a significant sediment gain within the cell is seen, caused by a large increase in sediment above MHWN of 3,466 m^3 (Table 3-4). Section E has seen an overall loss in sediment from 2008 – 2018 (Table 3-5), despite the large accumulation observed between 2013 and 2018, potentially following a recharge event. The River Carron is partially responsible for the large fluctuations in sediment balance at the south of the bay. Whilst beach recharge takes place within this cell, the sediment deposited does not accumulate further and is slowly lost offshore due to combined river and wave processes. The sediment accumulation seen in Figure 3-14 may be due to a combination of sediment within the watercourse being flushed down during high flows, creating a bar across the beach, and the rock armour arrangement directing flow further south.

Overall, there was a net sediment gain in the north of the bay (Sections A – C), and a net sediment loss in the south (Sections D and E). Each section of the beach experienced sediment accumulation above MHWN, and the three southern sections (C – E) experienced sediment erosion below MHWN. The changes seen between 2013 – 2018 were much smaller in volume than those seen the previous 5 years, which could be due to the survey dates as the difference between 2008 December and 2013 May beach profiles are more significant that differences between May 2013 May and May 2018 beach profiles.

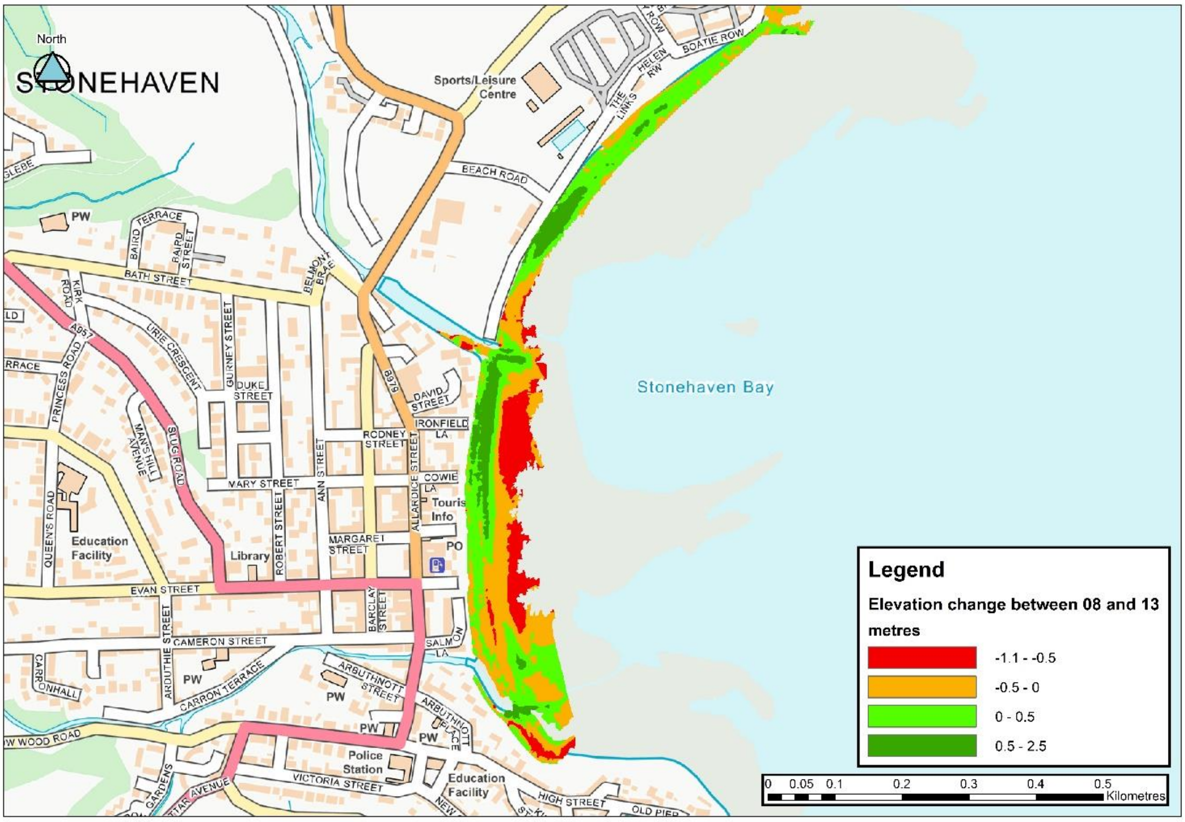


Figure 3-12: Elevation change from 2008 to 2013 across Stonehaven Bay

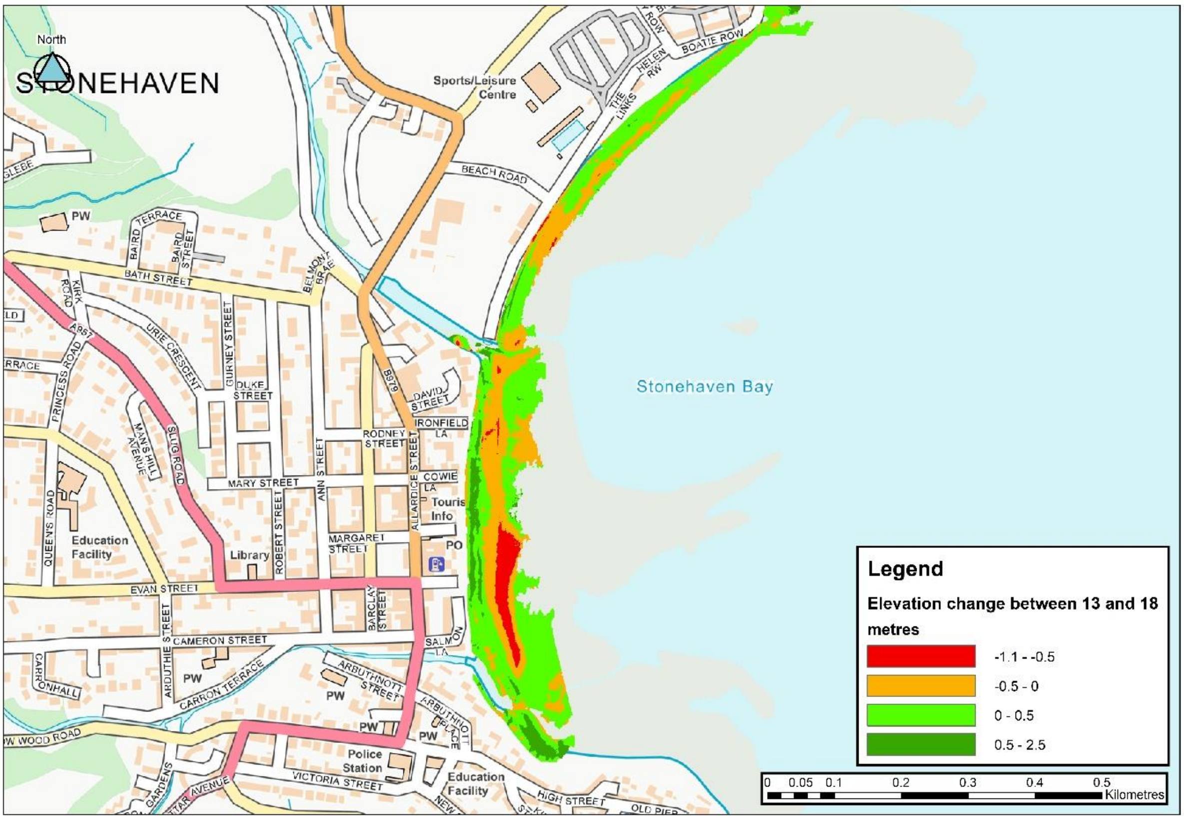


Figure 3-13: Elevation change from 2013 to 2018 across Stonehaven Bay

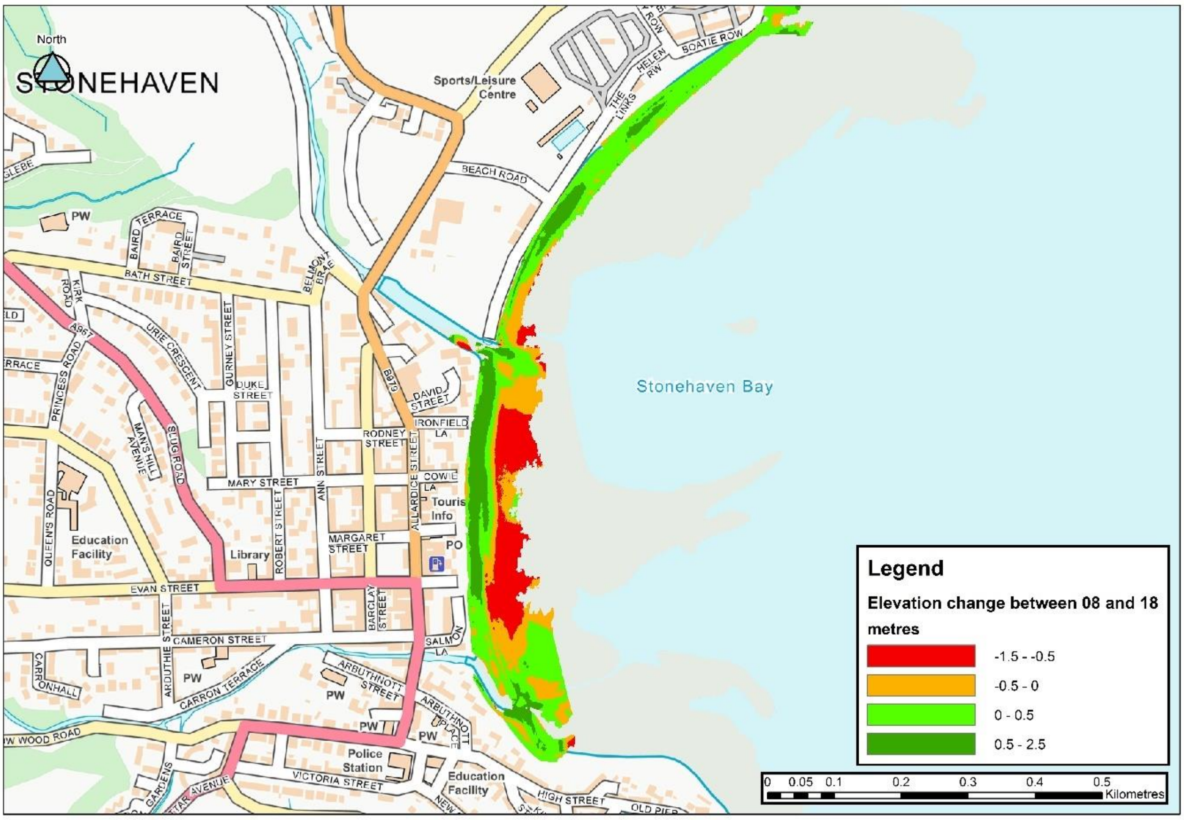


Figure 3-14: Elevation change from 2008 to 2018 across Stonehaven Bay

3.6.5 Cross sectional analysis

As part of the earlier surveys, cross-sectional profiles were taken at 26 locations along the beach (Figure 3-15).

These were replicated for the May 2018 survey and have been used to provide additional analysis of the volumetric changes in the beach.

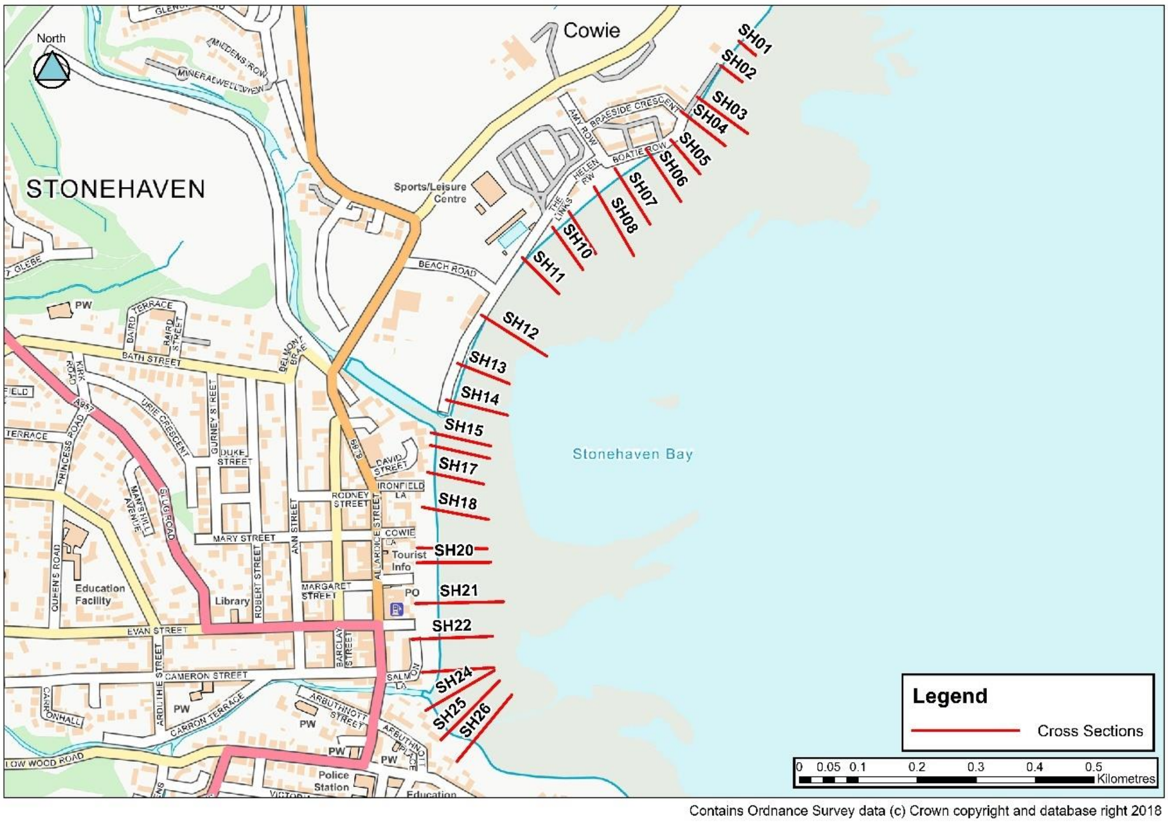


Figure 3-15: Cross sections at Stonehaven Bay

Figure 3-16 shows a general increase in sediment volume from 2008 to 2018 above MHWN. An overall summary of volume changes is provided in Appendix B, with profile plots from each year in Appendix D. Between 2008 and 2013, the majority of cross sections gained volume, with the largest volume gain seen between XS15-XS20. Between 2013 and 2018, the volume variations are much smaller and more varied, with some sections that had been gaining volume previously seeing a loss in volume, e.g. XS15 and XS17. The cross sections with the largest variability from 2008 to 2018 are XS14 - XS21 and XS26. Overall, there is a general increase in sediment volume towards the south of the bay (Figure 3-16) and significant volume losses are present predominantly north of the River Carron estuary (XS22-XS24), whilst the most significant volume gains are south of the Cowie Water estuary in the middle of the bay (XS15-XS21). XS04, XS05, XS07, XS08, XS09, XS19, XS20, XS21, XS25 and XS26 are always gaining sediment above MHWN whilst XS22, XS23 and XS24 are consistently losing sediment.

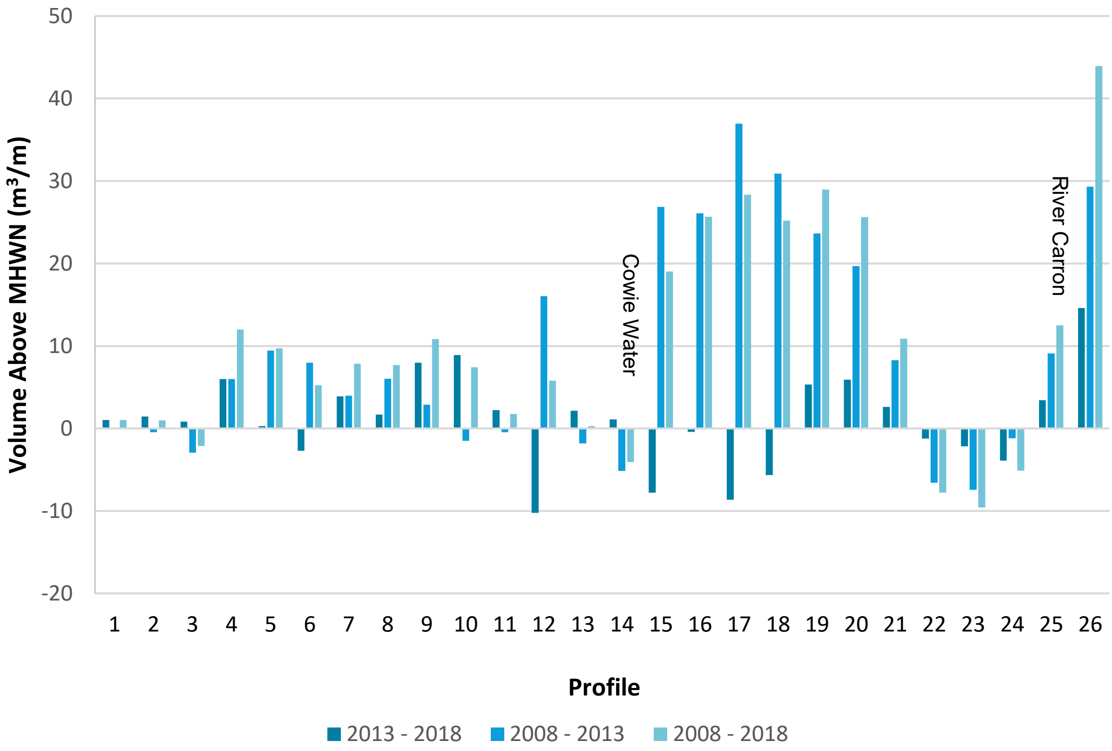


Figure 3-16: Sediment volume below MHWN from 2008 to 2018

3.6.6 Volumetric trends

Overall, the volume above MHWN increases north to south due to the increasing width of the beach and therefore sediment available. This supports the predominant sediment movement findings from previous studies.

Generally, variations between 2008 and 2013 are larger than those between 2013 and 2018. It is hypothesised that this is primarily due to the timings of the surveys with the 2008 being undertaken before the storm season, and the 2013 and 2018, after.

To support this, an analysis of "storm" event frequency was undertaken. This was based on the emulated hindcast dataset at the buoy location and an Hs threshold of the 99th percentile. Independent events were generated when Hs exceeded this threshold, assuming a 24-hour independence. This resulted in 21 events for 2008-2013, and 20 events for 2013-2018.

This supports the fact that there is no physical reason for such large variation between 2008-2013 and 2013-2018 and the date of the survey, may heavily influence the trends evident in the data.

The three northern sections are experiencing a net volume gain, whilst southern sections have experienced a net loss of volume. The composition of the beach and presence of a rock platform varies throughout the bay, explaining the different patterns seen. The Cowie Water supplies fine sediment to Section C, within the river channel and to the beach to the south of the watercourse. An overall gain of sediment is seen within the cell, and across the profiles in the area, which is inconsistent with the volume of sediment removed periodically through recharge.

The largest variation is seen in the sections south of the Cowie Water and the beach is seen to accumulate near the defences and erode near the sea, leading to a steepening of the whole beach. This eroded sediment contributes to the increase in volume above MHWN. This is typical of a storm response in gravel beaches and is more pronounced between 2008 and 2013.

3.6.7 Coastal structure performance

Cowie Water training wall

The sediment bar within the Cowie Water channel has considerably increased in volume since 2013 and significant sediment build up within the channel at the mouth of the Cowie Water is also present (Figure 3-17). The Cowie runs along the south of the training wall in a narrowed channel before discharging into the sea. The training wall was installed to prevent sediment from the north blocking the mouth of the Cowie and help maintains beach volume to the north.

Table 3-6: Volumetric changes above the toe of the Cowie training wall

Profile	2008	2013	2018
	Volume above toe of the wall (m^3/m)		
14	65.44	60.38	60.74
15	68.25	87.39	76.89

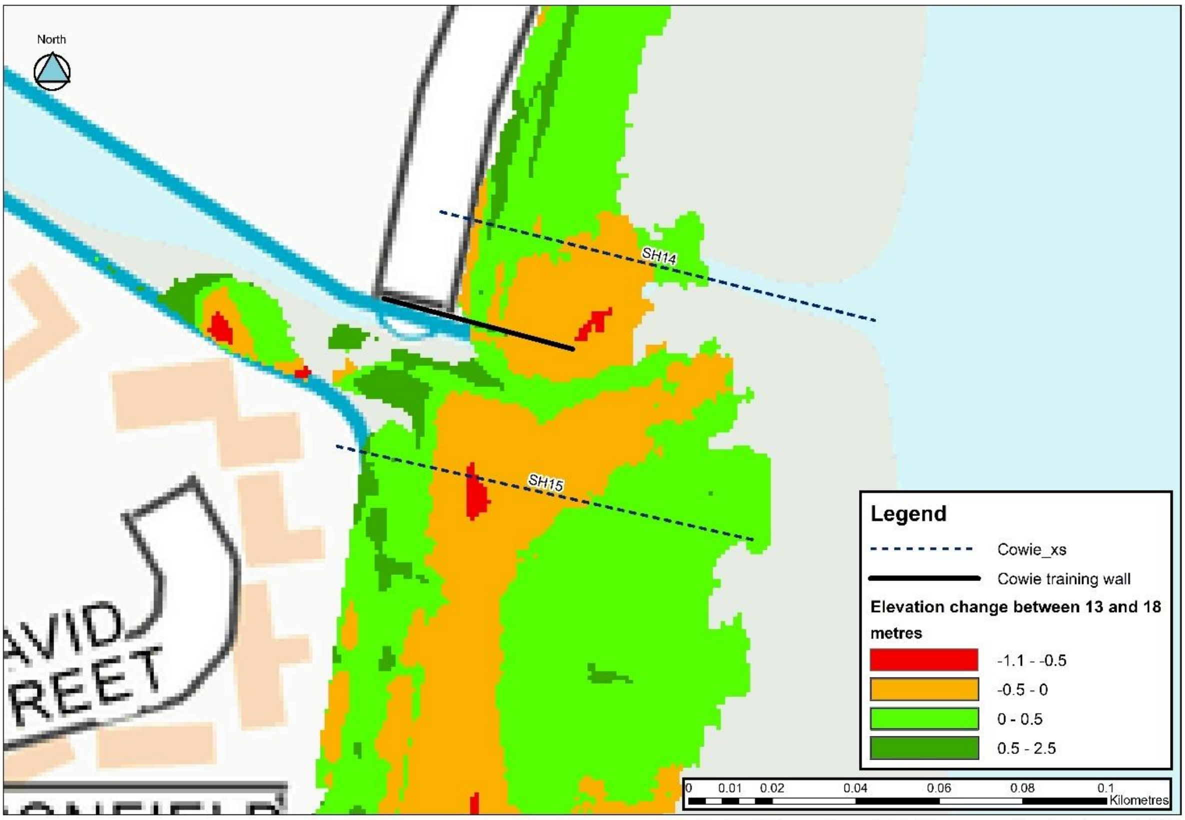


Figure 3-17: Cowie Water: elevation change from 2013 to 2018

In an attempt to assess the performance of the structure a refined topographic and profile analysis was undertaken.

The wall ends at approximately 0.55 mAOD in 2018, and volume change was analysed above and below this level.

Between 2008 and 2013, the volume at Profile 14 decreased from 65.44 m^3 to 60.38 m^3 (Table 3-6). Between 2013 and 2018, the volume change was very little, gaining only 0.4 m^3/m. In both time periods an area of significant sediment loss is present behind the training wall (Figure 3-18) suggesting the north to south longshore drift movement of sediment is not the dominant process at this location. It is possible that cross-shore transport during extreme events dominates here and is responsible for the erosion at the structure.

Profile 15 experienced the opposite sediment patterns to those at Profile 14, increasing in volume from 2008 to 2013, from 68.25 m^3 to 87.39 m^3. Between 2013 and 2018, the volume change was less and a loss of 10 m^3 was evident.

The highest volume at Profile 14 was experienced in 2008, which is the same year that Profile 15 experienced its lowest sediment volume (Table 3-6 and Figure 3-16). The lowest volume at Profile 14 coincided with the highest volume at Profile 15, in 2013. The largest volume change at both profiles occurred in the period between 2008 – 2013, and the following five years experienced less sediment variation. It may be that Profile 14 is more prone to erosion from extremes when the training wall is at full capacity, and additional sediment bypasses the wall and accumulates within the Cowie channel.

Removal of sediment through beach recycling in this area does not appear to have a large influence on the overall sediment budget of this section, or the flood risk to assets shoreward, as the beach is naturally replenished from river discharge and longshore sediment movement.

The training wall at the Cowie is effective at reducing sediment transport south to an extent, however when it is at full capacity, sediment bypasses it and contributes to build up in the Cowie Water channel.

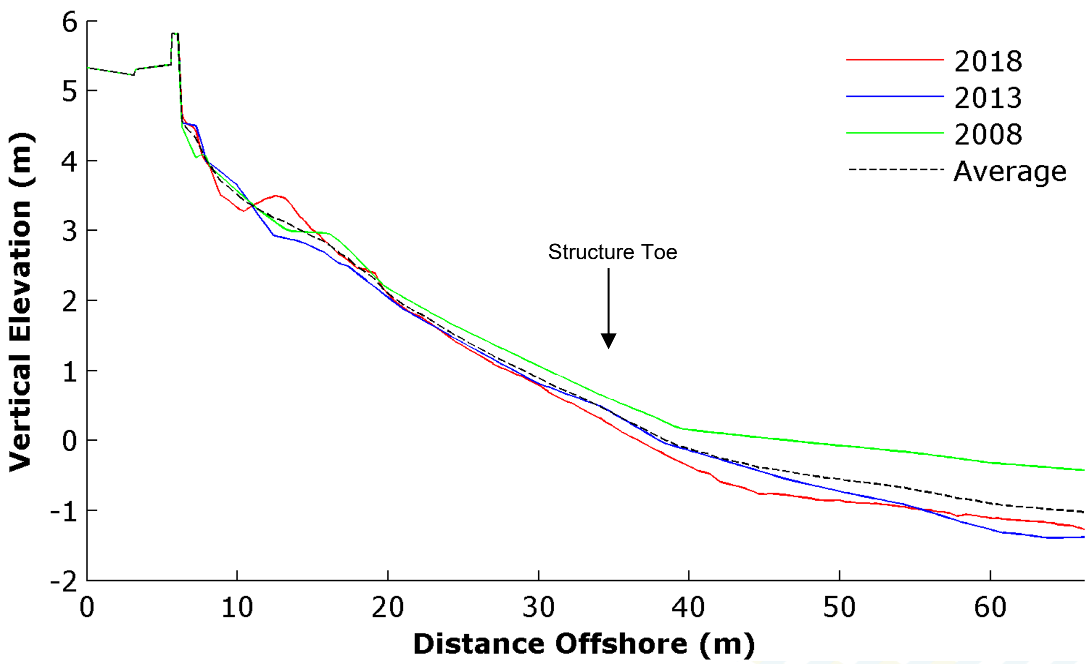


Figure 3-18: Profile 14

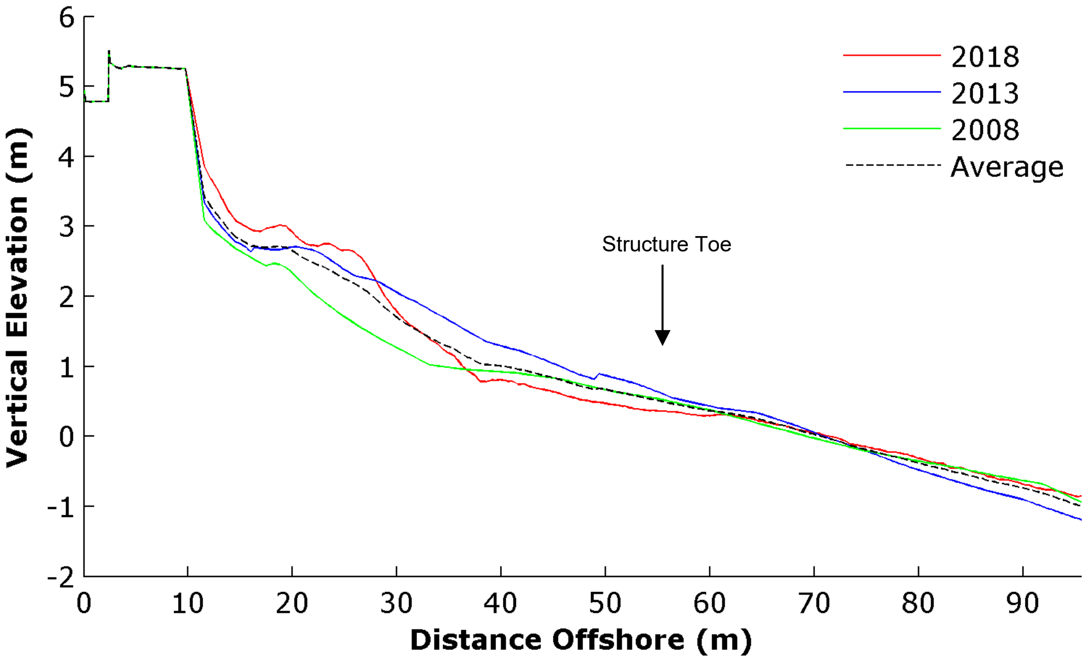


Figure 3-19: Profile 15

River Carron rock armour

Figure 3-20 shows the area considered for detailed analysis and this shows while sediment has eroded at the mouth of the river, there are large areas of accumulation present to the north and south. North of the mouth, significant erosion in the middle beach is seen. The lower beach of both profiles has consistently gained sediment throughout the time period. The overall volume above MHWN has steadily increased from 2013 to 2018, following a decrease from the previous 5 years. Profile 25 (Figure 3-21) remains relatively steady, with a slight increase in volume across the profile, from 66.4 m^3 to 78.9 m^3. Profile 26 (Figure 3-22) also sees accumulation of sediment almost throughout the profile, which may be explained by deposition from the River Carron, or as a result of the sediment recharge that takes place.

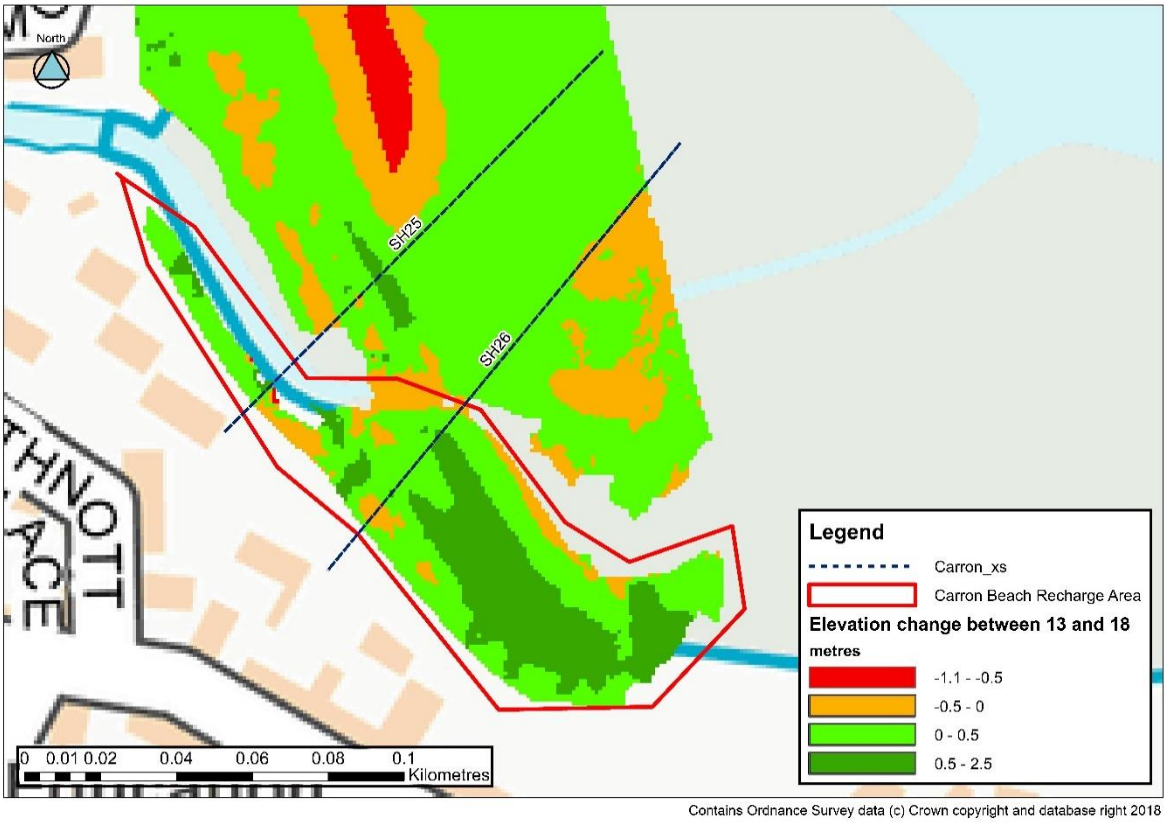


Figure 3-20: River Carron: Elevation change from 2013 to 2018 (NB: the area of no data is the current course of the River Carron which was not included in the topographic survey from 2018.)

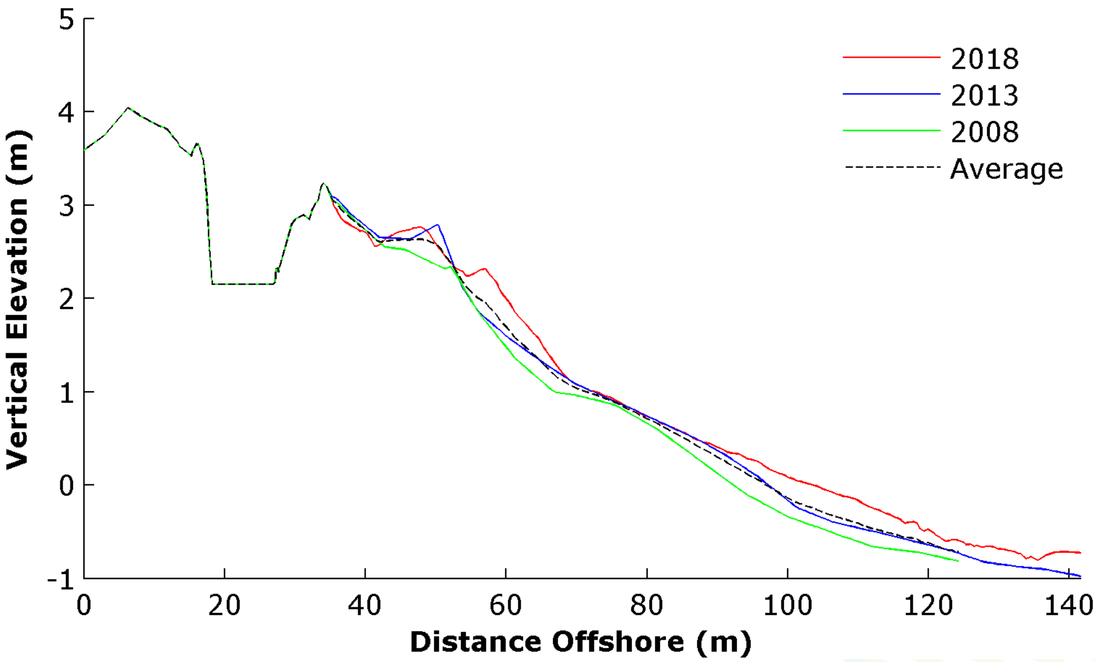


Figure 3-21: Profile 25

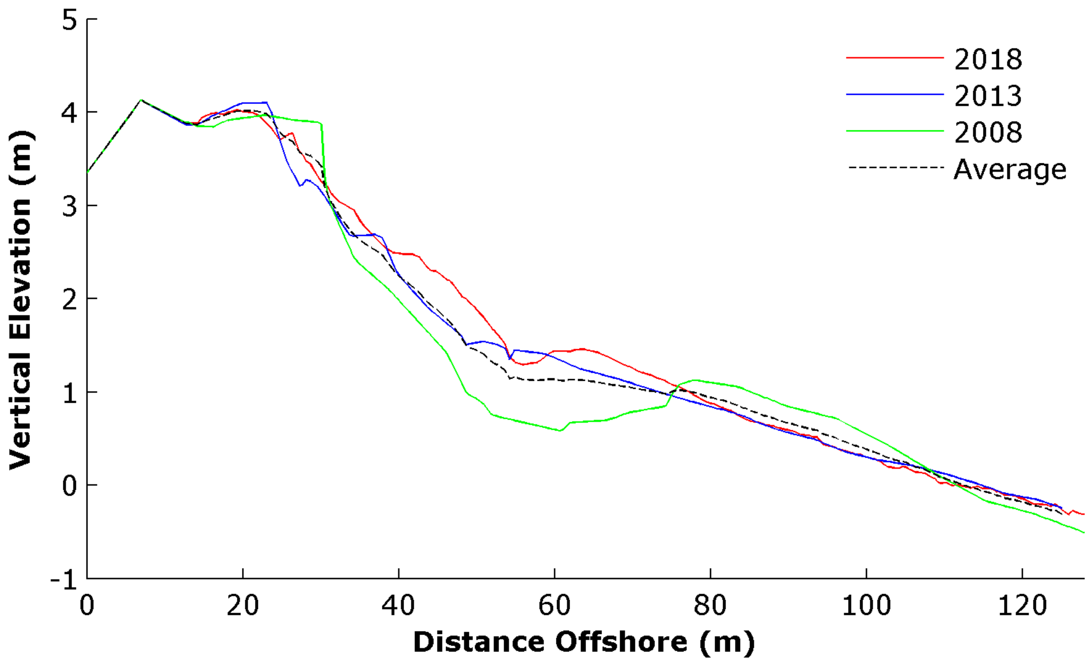


Figure 3-22: Profile 26

Specific analysis of the area of beach recharge (south of the Carron estuary outlined in Figure 3-20) undertaken and the overall volume change from 2008 to 2018 was calculated (Table 3-7). The first five years analysed return a negative value of -810 m^3. During this time period, 5,825 m^3 (11650 tonnes, converted at 2000kg/m^3) of sediment was deposited in this area, and this analysis supports the observations that sediment from the beach recycling is consistently being lost from this area. From 2013 to 2018, the topographic analysis estimated a volume gain of 2,101 m^3, which is less than was deposited during the period (4,375 m^3). This again supports observations that sediment is lost offshore from this area, despite the ongoing beach recharge.

Table 3-7: Volumetric changes within Carron recharge area

	2008 - 2013	2013 - 2018	2008 - 2018
Volume change within Carron recharge area (m^3)	**-810**	**2101**	**1291**
Volume deposited through beach recycling (m^3)	**5,825**	**4,375**	**10,200**
% sediment retained from recharge	**-13.9%**	**48%**	**12.7%**

Although there is a high degree of uncertainty in the analysis (both in survey data and extent), this demonstrates that the current practice is ineffective. Despite sediment being lost from the recharged area, the overall analysis shows that it may not be completely lost from the Stonehaven Bay sediment cell and is rather redistributed within the bay. To better understand this redistribution, detailed monitoring (e.g. tracers) or 2D modelling of combined waves and currents, would be required.

3.7 Erosion modelling

To better understand the morphological response of the beach during extreme conditions, a numerical modelling assessment was undertaken. This used the XBeach suite of morphodynamic models and will be used to:

- Provide an understanding of storm responses;
- Identify critical assets at risk of erosion.

The division of the beach presented previously was retained for the XBeach modelling, leading to the creation of five 1D models. These were extended offshore to the approximate location of the buoy.

The details of the models are explained in the following sections, with each being set up to best represent the characteristics of the section of the beach being modelled.

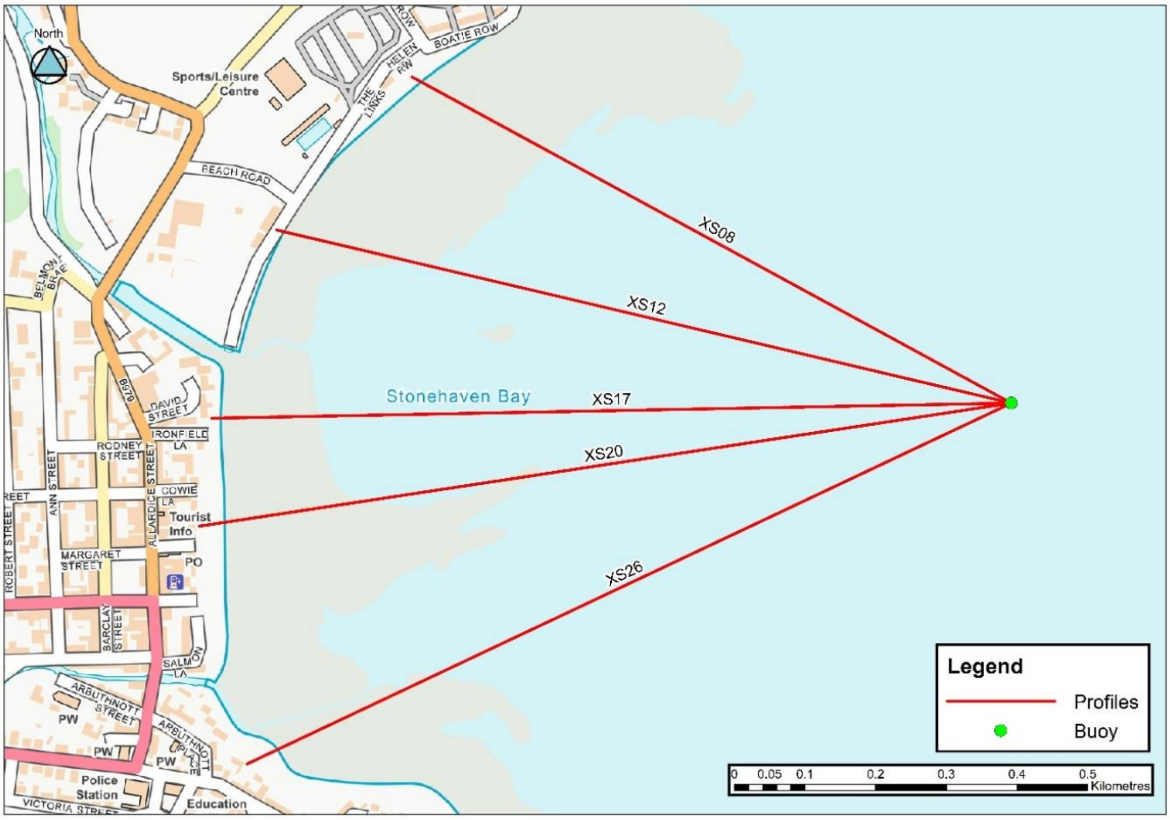


Figure 3-23: Topographic profiles extended to nearest wave buoy

3.7.1 XBeach requirements

Bathymetry and beach profiles

The full cross-section profiles were compiled using the topographic data from the 2018 survey and OceanWise data to extend them to wave buoy.

The location of any structures and offshore rock platforms were identified and included in the model bathymetry as unerodable sections.

Section A/XS08

This location is characterised by a small sandy beach fronted by a large rock platform that protrudes over 100 metres into the bay, protecting the shore from erosion to some extent. There is a vertical seawall at the top of the beach, landward of which is a grass bank leading to properties at a lower level. Figure 3-24 shows a schematised cross section of the profile.

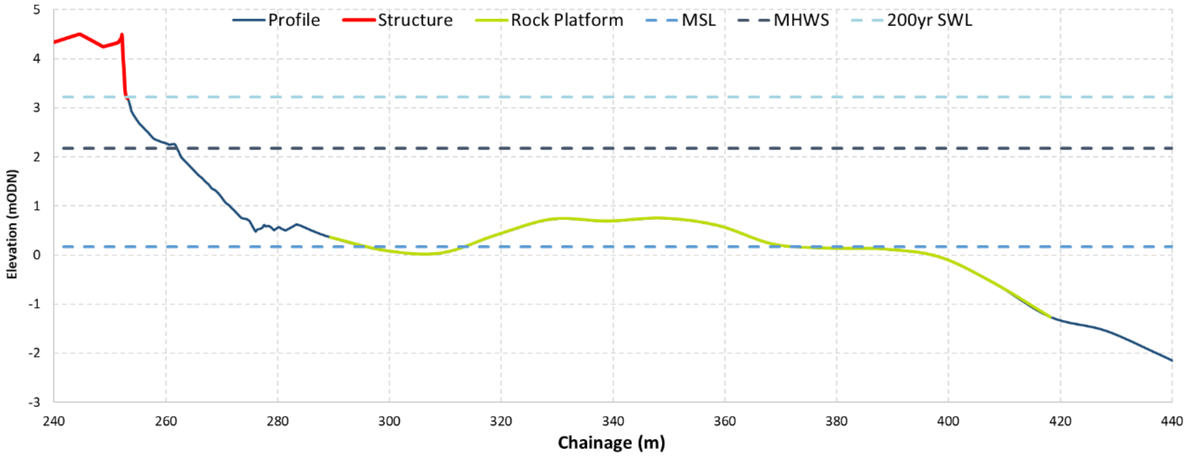


Figure 3-24: XS08 topographic profile

Section B/XS12

This location is predominantly shingle but mixed with coarser sand lower on the beach. There is no offshore rock platform. A stepped revetment with recurve wall is present at the top of the beach (Figure 3-25) which backs directly onto the Links esplanade.

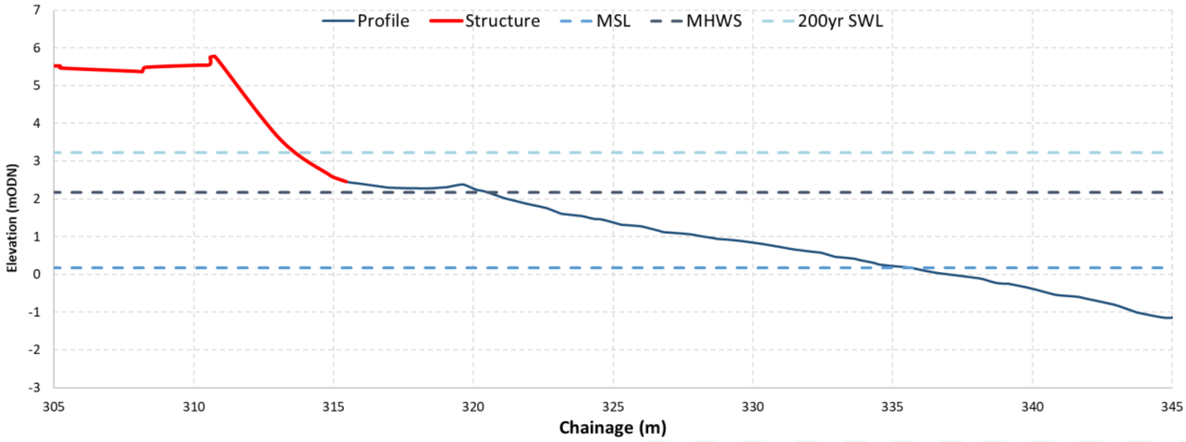


Figure 3-25: XS12 topographic profile

Section C/XS17

The beach at this location is again a mix of coarse sand and shingle and is much wider than the previous two sections. The seawall present (Figure 3-26) is becoming buried underneath accumulated beach sediment from the predominant landward movement of the beach.

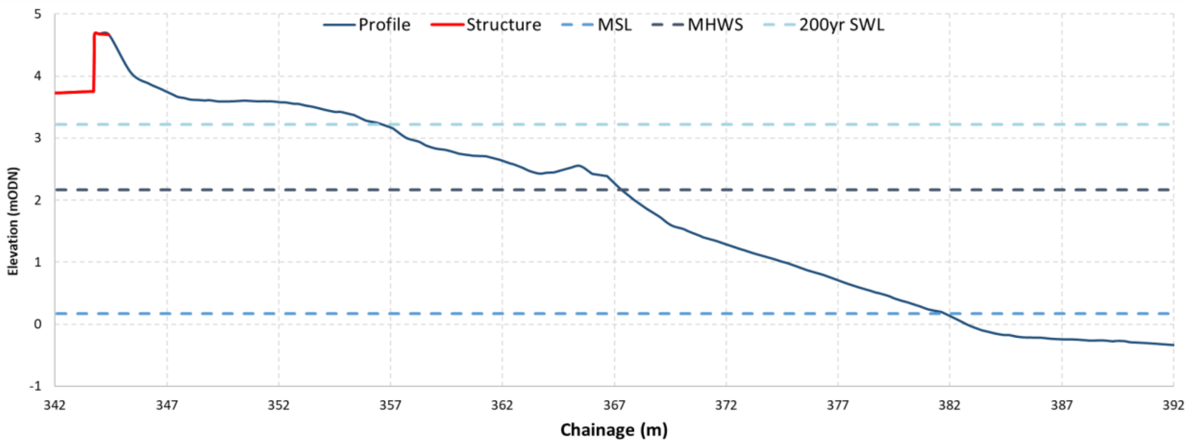


Figure 3-26: XS17 topographic profile

Section D/XS20

The beach at this location is similar to Section C, however the seawall is more visible from the shore. There are multiple rock platforms present offshore of this profile just below MSL (Figure 3-27). It is likely that these will dissipate wave energy, explaining why less accumulation of sediment has occurred compared to Section C.

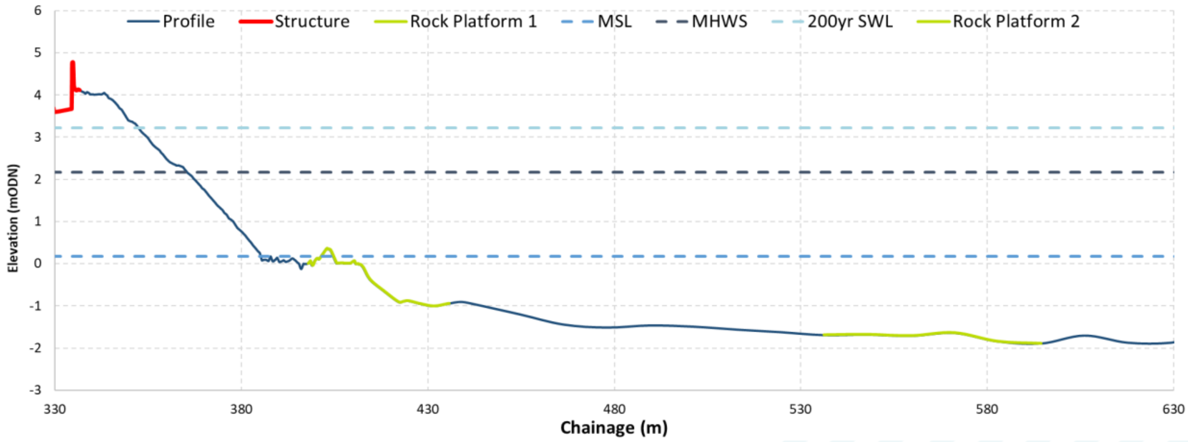


Figure 3-27: XS20 topographic profile

Section E/XS26

There are no defences in place at this location, and there is a boardwalk at the crest of the beach (Figure 3-28). The beach is predominantly shingle with sand present where the River Carron discharges into the sea.

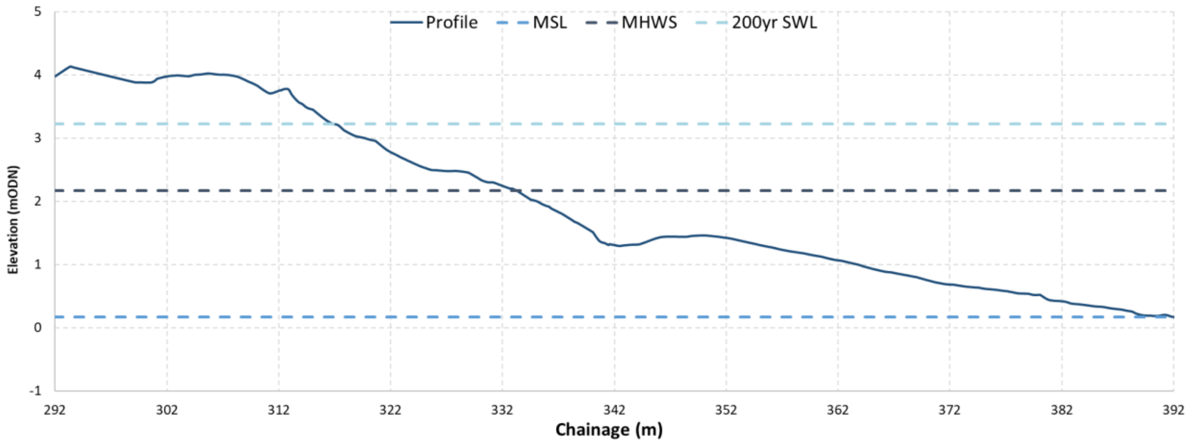


Figure 3-28: XS26 topographic profile

Sediment availability

The quantity and depth of erodible material present across the section is required for XBeach modelling to be realistic. The majority of the profile was set to 10 metres of erodible material, except for the rock platform and coastal defences which had 0 metres of erodible material. Depth was transitioned between 0 and 10 to create a smooth slope. The hardbed locations were identified from aerial imagery and topographic data.

Sediment size was estimated through aerial imagery and photographs and is outlined in Table 3-2.

3.7.2 Modelling of the 2017 event

Morphodynamic modelling of beaches is an extremely complex process with a high degree of uncertainty. To have greatest confidence in model outputs and behaviour it is preferable to have pre- and post-event profiles to calibrate and validate the model. In the absence of this here, the models have been sense checked based on the predicted behaviour during the peak of the highest recorded wave event in the offshore buoy record (February 2017).

The XBeach suite of models consists of XBeach (for sandy beaches) and XBeach-G (for gravel beaches). These represent the key physical process that control morphology (e.g. hydrodynamics, undertow, groundwater flow and sediment transport) on different beach types using different numerical approximations.

Based on the characteristics of each section, the most appropriate model was determined and set up accordingly (Table 3-8).

Table 3-8: Preferred model setups for each section

Section	Model	Wave solver
A / X08	**XBeach**	**Non-hydrostatic**
B / XS12	**XBeach-G**	**Non-hydrostatic**
C / XS17	**XBeach-G**	**Non-hydrostatic**
D / XS20	**XBeach-G**	**Non-hydrostatic**
E / XS26	**XBeach-G**	**Non-hydrostatic**

The non-hydrostatic wave solver allows for the estimation of the short-wave shape and runup. This is used as default in XBeach-G as it is the short waves that are responsible for shaping the morphology.

However, by default the XBeach models uses a surfbeat wave solver, where the infragravity wave shape is fully solved and the short-wave component estimated through energy balance. For exposed sandy beaches with wide surf zones, infragravity waves are the predominant control on erosion. This approach allows for the approximation of wave undertow and will always result in a net offshore movement of sediment.

To provide a comparison to the preferred model setup, a second model using the original XBeach in surfbeat mode was made. This is used to highlight the differences between approaches and give confidence that the preferred set-up is appropriately replicating the expected morphological response.

Boundary Conditions

The event on the 7th February 2017 was identified as the largest in the wave buoy record and was extracted from the data. This was combined with the recorded water level at the Class-A tidal gauge at Aberdeen to form the boundary conditions for the modelling. The dominant wave direction within the event was from the east, ~107°, with wave heights exceeding 5m, and periods over 10s. The 12 hours encompassing high tide was used in the modelling (Figure 3-29); with the waves assumed to be approaching each profile perpendicularly.

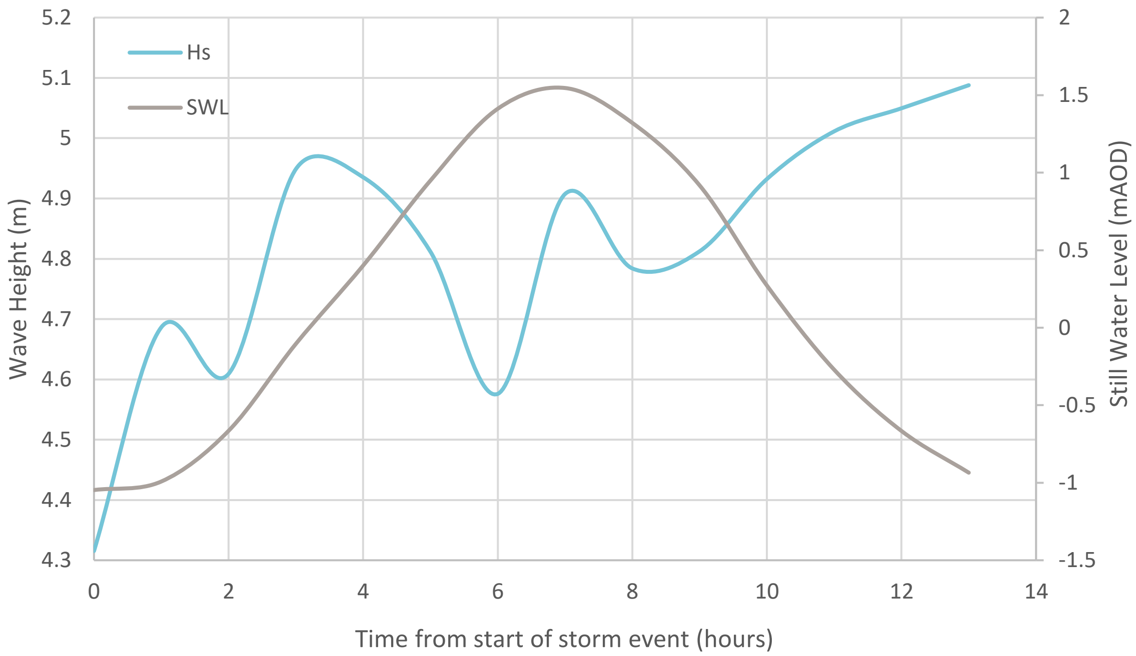


Figure 3-29: February 2017 event Wave Height and SWL

Results

The results from the modelling of the February 2017 event are provided in the following sections. These present the estimated change in the beach profile post-event and the change in level at the defence toe level throughout the event.

XS08

The preferred model setup demonstrates accumulation of sediment at the toe of the defences and an overall landward movement of the beach.

As a comparison the default surfbeat model predicts significant erosion at the toe and offshore deposition.

At the peak water level recorded in the event (~1.5mODN) the rock platform is likely to provide substantial sheltering from the larger offshore waves. It is likely that this would influence sediment movement at this location, with the smaller waves in the lee of the platform promoting onshore transport of the beach sediment.

While scour at the toe of the defences has been observed in the past, it is likely that this is attributed to events with larger SWL.

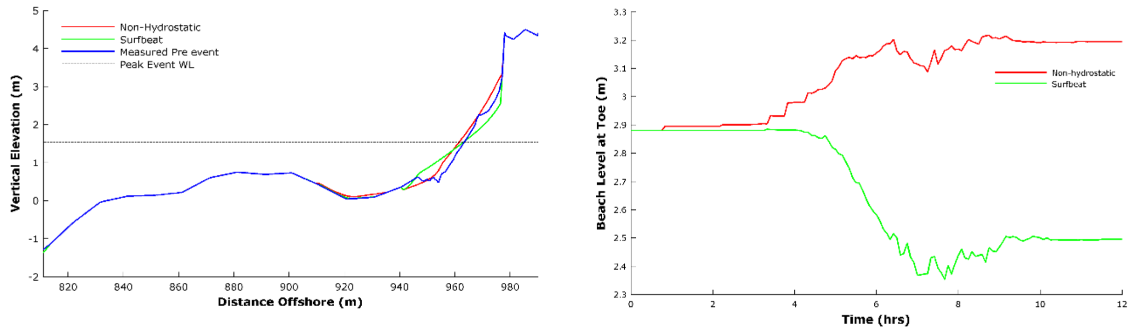


Figure 3-30: XS08 modelled profile and beach level at the defence toe

XS12

The level at the toe stays similar in the preferred model setup, as accumulation of the beach takes place predominantly below the toe level.

In the XBeach surfbeat model a substantial portion of the beach below the defence becomes eroded and is deposited offshore.

The beach here is predominantly gravel meaning the use of XBeach is inappropriate and the predicted erosion is unrealistic.

Given the peak water level of the event, the modelled accumulation of the beach using the preferred model setup is considered realistic.

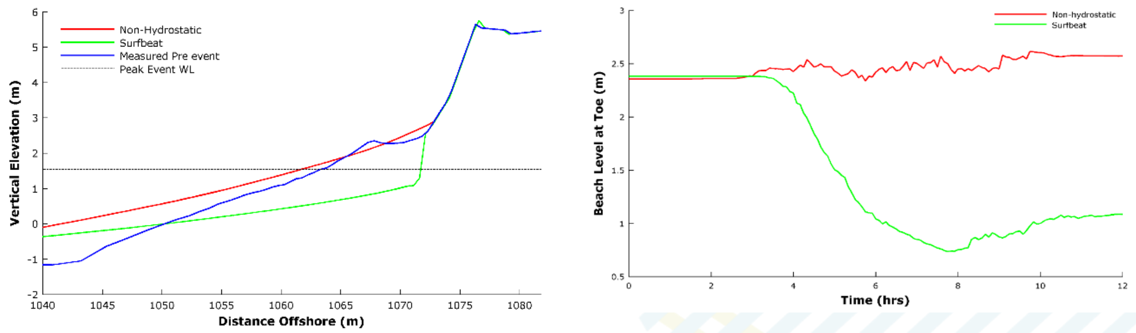


Figure 3-31: XS12 modelled profile and beach level at the defence toe

XS17

Accumulation of sediment is predicted across the whole beach at XS17 for the preferred model setup, as well as some sediment depositing landward of the defences.

Modelling erosion with surfbeat shows unrealistic erosion of the beach above SWL.

These sediment changes are mirrored in the change in beach level at the defence toe; taken as the crest of the beach in front of the sea wall.

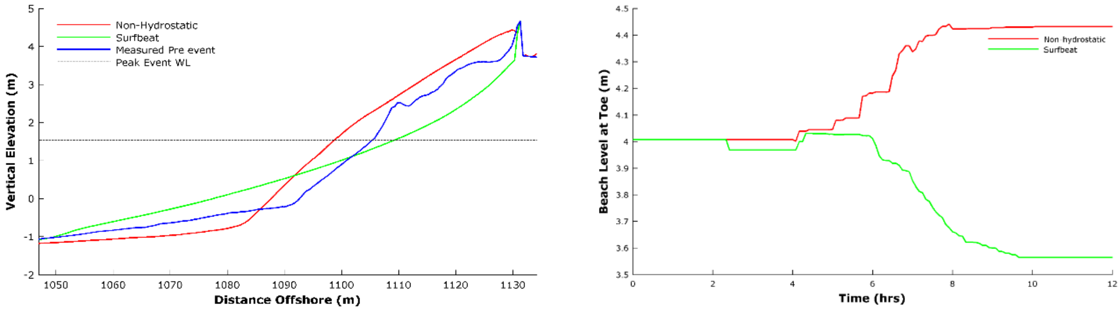


Figure 3-32: XS17 modelled profile and beach level at defence toe

XS20

Accumulation of sediment is predicted across the whole beach at XS20 for the preferred model setup, as well as some sediment depositing landward of the defences.

The XBeach surfbeat model results in unrealistic erosion of the beach.

Compared to XS17, the sheltering provided by the rock platform reduces wave energy resulting in less accumulation.

The level at the toe (taken as the top of the beach at the sea wall) varies very slightly with preferred model setup. Again, this is a reflection in the reduction in wave energy and runup attributed to the rock platform. The XBeach surfbeat model estimates a greater level of deposition at the toe, primarily due the to the sediment size and the undertow being insufficient to return all transported material offshore.

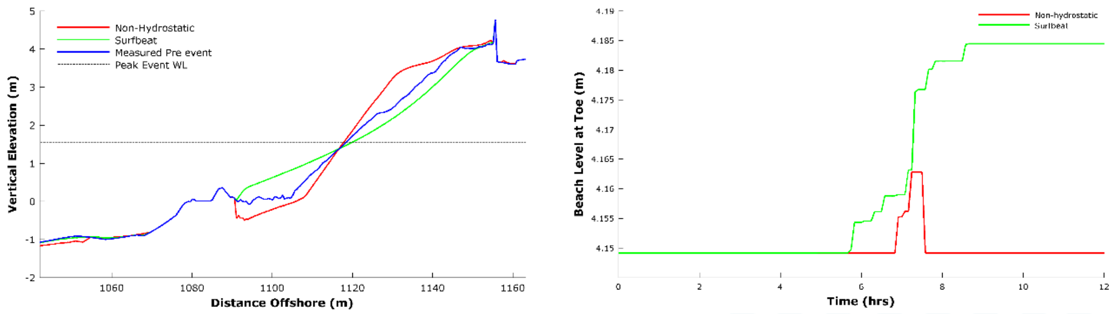


Figure 3-33: XS20 modelled profile and beach level at toe

XS26

Accumulation of a large amount of sediment above the high tide level is predicted by the preferred model setup. Given the coarseness of the beach material, and the relatively low SWL, this behaviour is expected. Shingle is also deposited landward of the boardwalk.

Little to no erosion is predicted by the XBeach surfbeat model as the undertow is insufficient to transport such large shingle.

The level of the beach crest decreases slightly in both models.

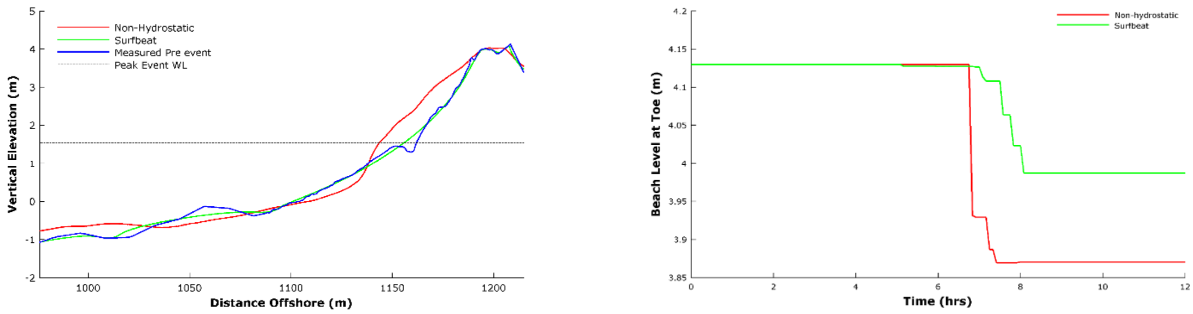


Figure 3-34: XS26 modelled profile and beach level at defence toe

Summary

Historical data in the form of photographs and topographic survey has shown that sediment moves steadily shoreward and the upper beach builds.

While there is anecdotal evidence of scour at defence toes, this suggest that predominantly the nearshore beach steepens and the upper beach gains in volume during extreme events.

During the February 2017 event, it is likely that the low water level was the controlling mechanism on the beach morphology, and during such conditions the predicted net movement of sediment would be landward, resulting in an increase in volume of the upper beach and deposition at defence toes.

It is proposed that the preferred model setups replicate this expected behaviour and are suitable for use in the more detailed erosion modelling.

3.8 Undefended erosion modelling

In Stonehaven Bay, the coastal defences are critical to preventing the exposure and damage of key infrastructure. Should these defences fail, the land behind will be exposed to direct wave attack resulting in erosion and associated economic damage. To estimate the likely assets at risk of erosion throughout the appraisal period, undefended modelling will be undertaken.

The complex nature of the morphological response of beaches (particularly shingle) means that no model (empirical or numerical) has been developed or tested for long-term profile response with most focusing on estimating response to individual events. While certain attempts have been made to use XBeach (Original) for long-term simulations, these have been met with varying success and are limited both by computational effort and the accumulation of errors through time.

It is therefore proposed that the following methodology be used to establish future erosion scenarios:

- Create XBeach models with defence structures removed to replicate failure of the defences;
- Generate joint-probability extreme boundary conditions for a range of events (1yr to 1000yr RPs);
- Model profile response for each event and establish an "average" eroded profile for each RP;
- Estimate the retreat of the HAT (Highest Astronomical Tide, 2.57m) for each from the "average" profile response;
- Use these to establish and Annual Average Retreat (m/year);
- Identify the failure year of the defences;

- Based on the failure year, project HAT at 2050, 2080 and 2118 to estimate potential erosion and assets at risk.

Different profiles will respond differently to different forcing conditions and it was therefore decided that the change in HAT was most appropriate for use here. This is consistent with what has been used in the National Coastal Change Assessment and prevents unrealistic erosive response during the highest wave events, particularly at the finer sediment profiles in Cowie.

It should be acknowledged that this type of analysis is highly uncertain and that progression of erosion, in the event of defence failure, will likely occur at different rates along the front. None-the-less, the analysis presented here is useful in that it helps identify the potential risk of unchecked erosion which can be carried forward to develop the business case for investment in the frontage.

Given the inherent uncertainty of the method, attempts to include climate change in the analysis will have no additional benefit.

3.8.1 Coastal defence conditions and residual life

The coastal defences' lifespan and condition were assessed in a separate report (Coastal Asset Condition Survey Report[16]). The defences were all graded at CG3 as some defects were present. It was predicted that within 30 years, the defences present at XS08, XS12, XS17 and XS20 will have degraded to CG5, which results in complete failure of the defences. The wall north of Section A, at profiles 1-4, was graded at a CG4, indicating failure is predicted within 15 years. As there is no beach present here, the results from XS08 will be applied to this location. As no defences were in place at XS26, a condition assessment had not been undertaken at this location and the beach is free to advance and retreat from the present day.

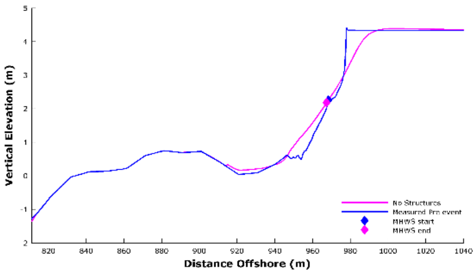
3.8.2 2017 event

To demonstrate the concept, the models were run again for the 2017 event to simulate a situation where all the coastal defences have failed, to demonstrate the extent of erosion/sediment movement that may occur.

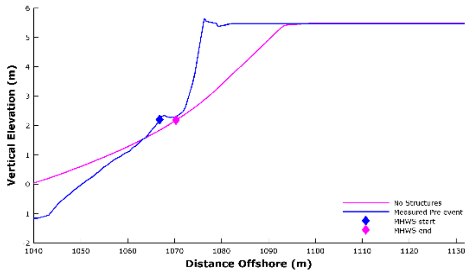
The movement of the MHWS was analysed by identifying the corresponding chainage of the 2.17mODN contour (MHWS for Stonehaven) at the start and end of the simulation.

The results are presented in the following section.

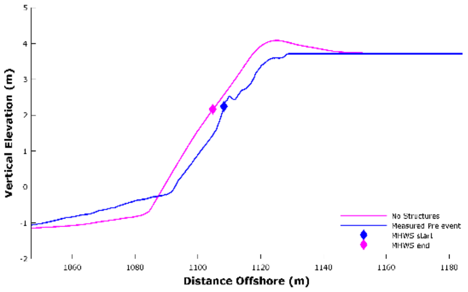
[16] JBA Consulting. Coastal Asset Condition Survey Report. Final Report. July 2018.



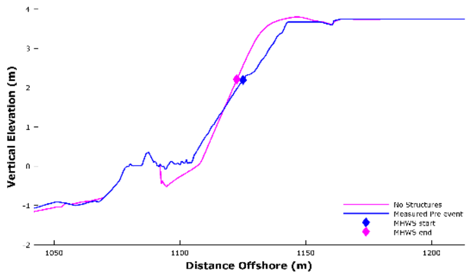
XS08/Section A



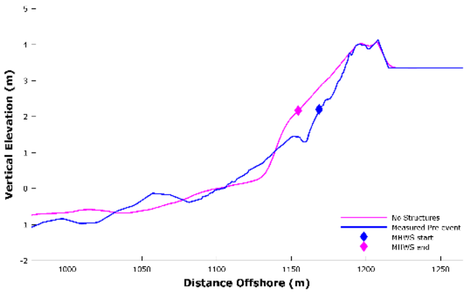
XS12/Section B



XS17/Section C



XS20/Section D



XS26/Section E

Figure 3-35: Undefended modelled profiles

- At XS08, the coastal defences erode whilst the lower half of the beach accumulates sediment. The MHWS line moves 1m towards the sea due to accumulation of sediment.
- At XS12, similarly to XS08, the defences get completely eroded away, and the MHWS line moves 3.5m landward.
- XS17 is subject to further accumulation across the whole beach, and erosion of the small seawall. The MHWS line moved 3.5m seaward.
- At XS20, without the seawall, erosion has little effect on the assets behind the defences however the beach advances, as seen by the 3.5m advance of the MHWS line.
- At XS26, given that no defences or hardbed was present, the sediment movement profile is identical to the original non-hydrostatic mode model run and the MHWS line advances by 14m.

Summary

At XS08 and XS12, the coastal defences are predicted to erode, which differs from the sediment patterns seen in the modelled scenario (Figure 3-30 and Figure 3-31) and in the topographic analysis (Section 3.6) that see accumulation of sediment above the MHWN. The defences in this location are preventing the landward erosion of sediment, holding the beach in place.

Without defences in place at XS17, XS20 and XS26, the upper beach is predicted to accumulate sediment, with some beach erosion occurring below MHWN. This is similar to the sediment trends seen from topographic analysis (Section 3.6) and the modelling of the February 2017 event, suggesting the defences are not playing a major role in controlling sediment movement.

3.8.3 Design Events

Boundary conditions

For the wave overtopping analysis SEPA's offshore multivariate dataset has been used. This involves the modelling and emulation of a dataset containing approximately 2 million "events". As part of this process the dataset was emulated at the buoy location for use in the erosion modelling.

Analysis of this dataset allows for the generation of joint-dependency curves of any variable at any return period. Here we have used this to estimate joint-dependency Hs and SWL for 1yr, 2yr, 10yr, 30yr, 50yr, 100yr, 200yr and 1000yr events. This is like the standard DEFRA 2003 joint-probability methodology but makes use of the modelled dependency between the parameters from the analysis undertaken to develop the MV data.

The wave period was estimated based on developing a relationship of the average value within ranges of Hs in the emulated MV data. This relationship is shown below and was used to estimate T_p for the design events.

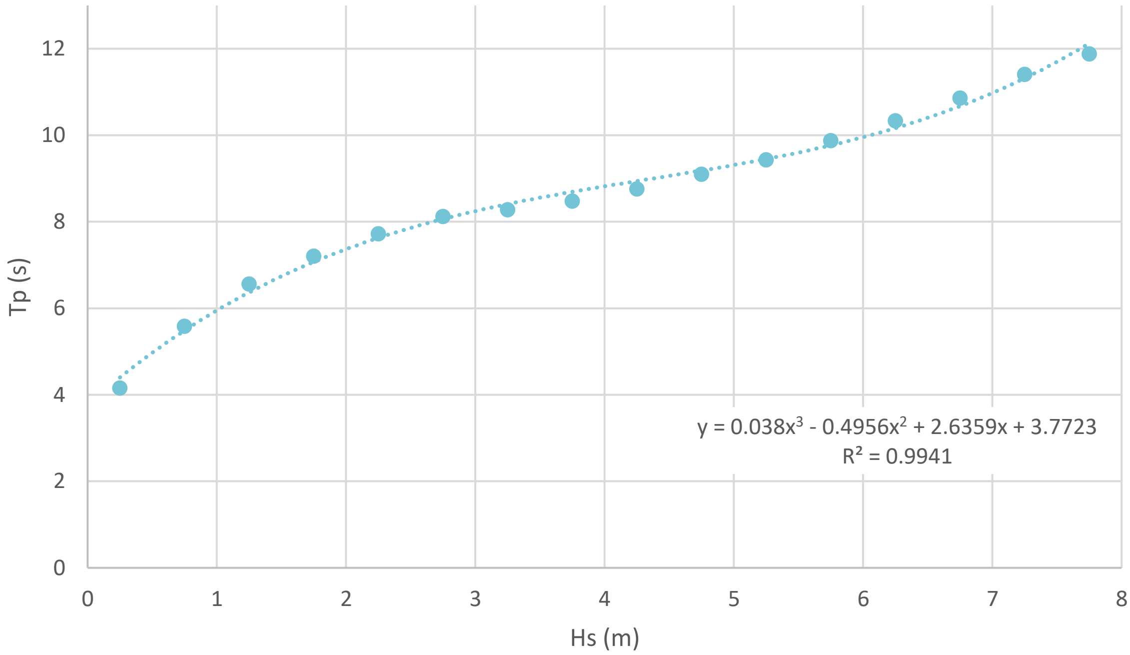


Figure 3-36: Relationship between Hs and Tp

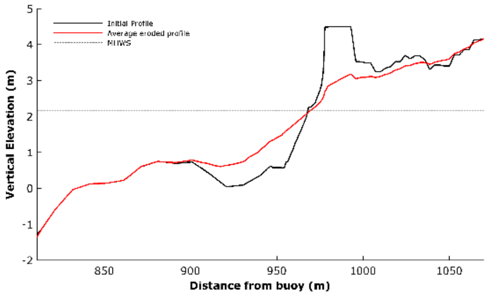
Events have been modelled for the 12 hours encompassing high tide, with the offshore wave conditions assumed to stay constant throughout. The combinations of Hs, Tp and SWL for all events are presented in Appendix C.

Results

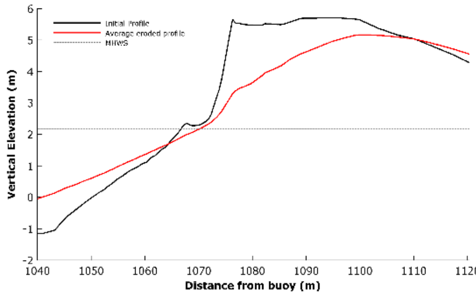
The input files for the design events were the same as for the undefended runs above, however 150m of LiDAR data behind the coastal defences was added onto the profiles to estimate realistic sediment movement at different return periods.

The movement of the HAT for the average eroded profile for each return period at each cross section was estimated.

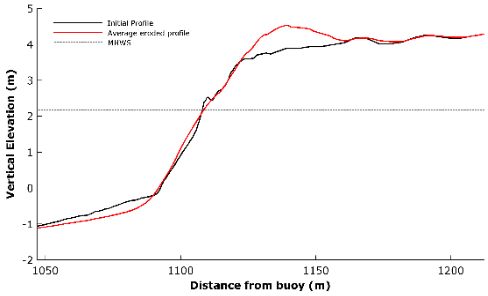
Overall, the amount of potential sediment movement increases with increasing return period. Cross sections 08 and 12 have the potential to be subject to significant erosion, including erosion of the crest of the defence, whilst the other three cross sections are predicted to experience accumulation, especially at the crest of the beach.



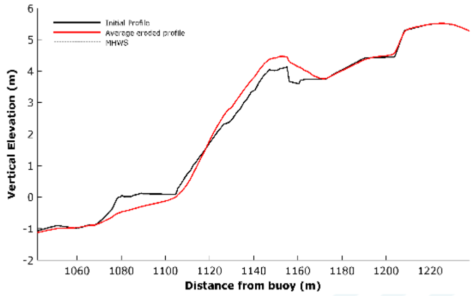
XS08



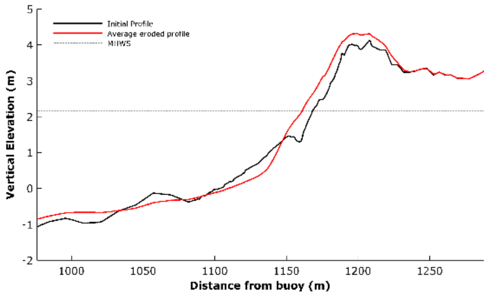
XS12



XS17



XS20



XS26

Figure 3-37: 0.5% AP (200 year) profiles

HAT movement

Movement of the HAT contour was estimated by annualising the average profile movement for each return period. For profiles where advancement of the beach was seen, the minimum values from each event were analysed to model the maximum extent of landward erosion. The results of this are provided in Table 3-9.

Table 3-9: Annual Average Retreat (m/year) for each profile

Profile	Annual Average Retreat (m/year)
XS08	1. 66
XS12	1.59
XS17	0.36
XS20	0.50
XS26	0.27

In the northern section of Stonehaven Bay (Cowie), sediments are predicted to significantly erode, and therefore a retreat of the HAT line will be seen. The HAT average retreat near the Cowie Water has been identified as c. 50 metres by 2080, and c. 110 metres by 2118. The shaded area highlights the maximum area at risk of erosion between 2018, 2080 and 2118 (Figure 3-38), if all defences were to fail at the end of their given lifespan. Assuming a similar erosion pattern at XS01-04 as at XS08, and given the failure of the defences 15 years earlier, by 2080 a retreat of c. 75 metres is seen and by 2118, a retreat of c. 138 metres at the north of the bay is predicted. The assets within this erosional zone are therefore potentially at risk.

The southern end of Stonehaven Bay is predicted to experience little retreat of the HAT position, with a maximum retreat of 15 metres by 2080, and 34 metres by 2118, within section D. The number of assets within the erosion zone here is significantly less than in the north of the bay. It is more likely that the southern end of the bay will experience HAT advancement.

Events with lower water level and high wave heights cause the largest erosion.

An A3 figure of HAT predictions is in Appendix F.

This modelling and analysis approach have an extremely high degree of uncertainty and assumes that the backshore consist of fill material similar to the beach. In reality, the: slow failure of the defences, man-made surfaces, buildings and other materials will significantly influence the erosion rates.

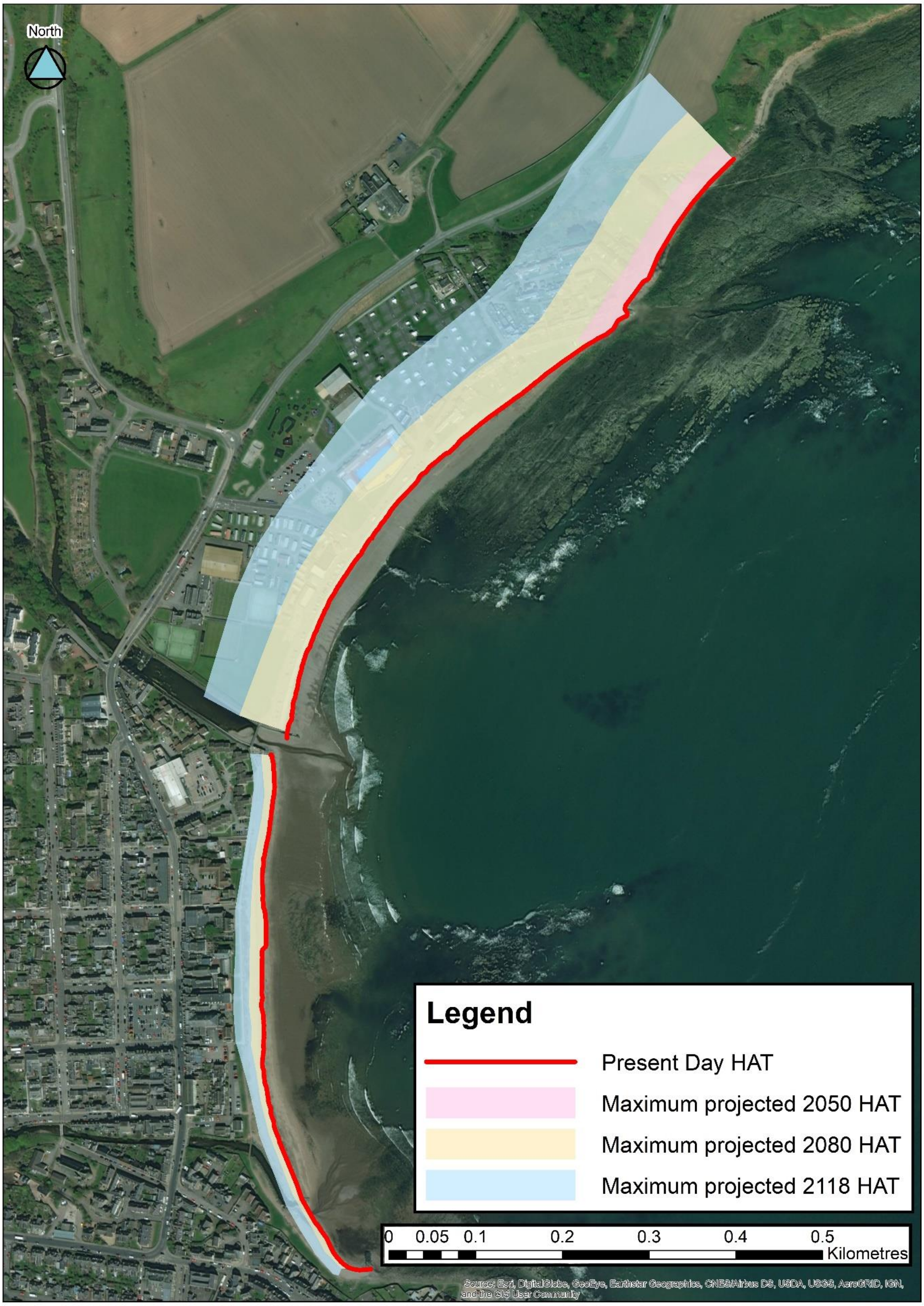


Figure 3-38: Projected HAT retreat by 2050, 2080 and 2118.

Erosion enhanced flooding

North of the Cowie Water, the Promenade and Links area provide a high ground buffer to the lower areas to the rear. Should defences fail, erosion of these "buffer" area will result in significant exposure to the lower lying areas to inundation from future extreme sea levels.

To provide an indicative assessment of this future risk, crest elevation changes, predicted by XBeach, were annualised, to establish when these low-lying areas would become at risk from SWL flooding.

The crest was taken as the top of the coastal defence and compared to the highest elevation point on the eroded profile, not including the ground beyond the defence. Crest elevation drop is shown in Figure 3-39 and analysed further in Table 3-11.

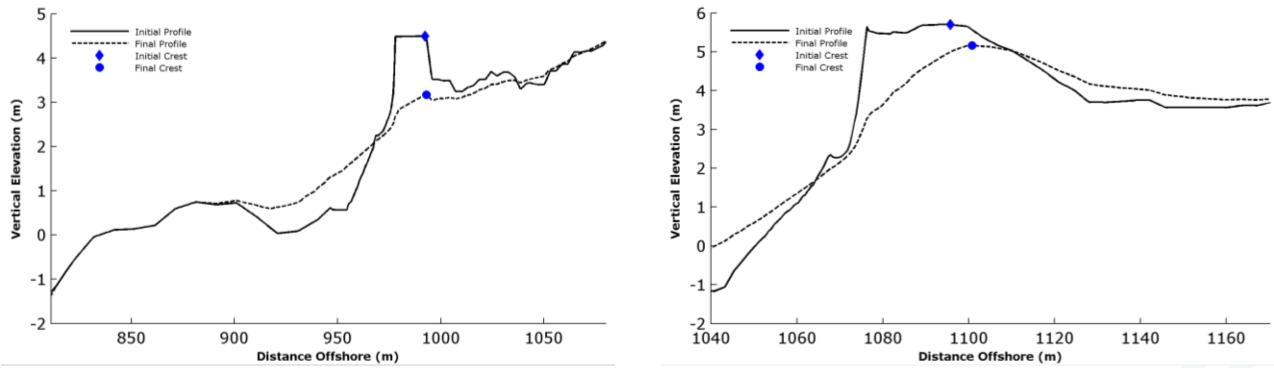


Figure 3-39: Crest changes from the 200-year event (XS08 on left, XS12 on right)

Table 3-10: Extreme Sea Levels from UKCP18

RP	2080	2118
30	3.51	3.83
200	3.71	4.03

Table 3-11: Crest elevation variation

	Crest Level	Ground Level	2080	2118
XS08	4.49	3.49	Crest < Ground Ground < 30yr and 200yr	Crest < Ground Ground < 30yr and 200yr
XS12	5.65	3.75	Crest < Ground Ground > 30yr and 200yr	Crest < Ground Ground < 30yr and 200yr

At XS08, a drop of 0.77m/year is estimated. The top of the coastal defence is 4.5 mAOD and the ground level behind the defences is 3.49 mAOD. Following the predicted degradation of the defences in 2050 at this profile, and assuming the crest level would not drop below ground level, by 2052, the crest level would be at ground level and the area would be at risk of flooding from SWLs. In 2080 and 2118 at both the 30-year and 200-year return periods (Table 3-10).

At XS12, the estimated crest elevation drop is 0.14m/year. The crest of the defences at this location is 5.65 mAOD with ground level of 3.75 mAOD. The defences are predicted to have degraded by 2050, and by 2064 the crest level would be at ground level of the backshore, and the area would be at risk from SWL The 2080 SWLs are not sufficient to inundate but at 2118 the 30-year and 200-year return periods (Table 3-10) will flood the backshore area.

To estimate flooding impacts of this erosion, these "buffers" were removed from the TUFLOW model and simulations of the 30 and 200-year events at 2118 were undertaken. The results of these are presented in Appendix F and show the predicted extent of SWL flooding alone for these events.

It should be noted that, a comparison between the defended 2118 extents (Appendix E) shows less inundation occurring for the erosion enhance maps. This is a product of the modelling method and occurs for the following reasons:

- No wave action has been accounted for in the erosion enhanced flooding;
- SWLs alone do not exceed the average backshore level to the north (XS08).

3.9 Erosion assessment summary

North of the Cowie Water the sediment is fine sand, and a rock platform is present. The beach is subject to large variations in volume, however the topographic surveys indicate that the upper beach has accumulated in the past 10 years. Given the uncertainty in the analysis due to the survey frequency, it is not possible to say whether this demonstrates long-term accretion or is a product of short-term fluctuations captured by the survey. Anecdotal evidence and local observations suggest extreme short-term fluctuations in beach levels exist here, and that the frequency of the survey is unable to capture this behaviour. The analysis does however show that the sediment balance within the bay can be considered relatively stable over this period. This is supported by the long-term MHWS analysis which shows minimal variation.

Modelling has shown this area has a tendency to accumulate across the upper beach and erode at the lower beach during small storm events such as the February 2017 event, however in a scenario without coastal defences in place, this area is projected to significantly erode, leading to a retreat of the HAT location. The lower beach is predicted to increase in volume from the eroded sediment further up the profile, in a scenario with no coastal defences, demonstrating the opposite trend to normal conditions. Coastal defences are playing a role in holding the line, preventing loss of assets and restricting sediment movement landward. South of the Cowie Water, sediment increases in diameter, and therefore behaves differently. The general pattern is a steeping of the beach, through accumulation near the defences and erosion of the lower beach. This dynamic response during extreme events will have implications on the wave overtopping rates along the front. Considerations of the impacts and management of this response will be investigated during the concept design of the preferred option.

Modelling of the February 2017 event in this area mirrors the general sediment movement patterns over the past 10 years. Without defences, the beach is predicted to accumulate sediment across the whole profile, causing a seaward movement of HAT. The defences do not appear to be influencing the general sediment movement trends in the lower three sections of the beach. The beach recycling that takes place annually does not appear to have a large influence in the overall sediment budget of the beach as sediment is naturally replenished near the Cowie Water and sediment is consistently lost offshore south of the River Carron.

3.10 Erosion assessment recommendations

Morphodynamic modelling is attributed with a high degree of uncertainty and so recommendations are proposed to increase certainty of future analysis. Better topographic data is recommended, both at more frequent intervals and from the same time of year so post-storm analysis can be made. If possible, this should be targeted to capture pre- post-storm changes in beach levels to allow for quantification of anecdotal evidence of rapidly varying beach levels in the bay.

Monitoring of the gravel bar within the Cowie would allow for detailed analysis of sediment recycling to be made. Data regarding the volume of shingle "cleaned up" following storm events from the coastal footpath and other areas would allow for a more accurate analysis.

4 Baseline economic assessment

To assess the present-day economic impact for coastal flood events a baseline economic assessment was undertaken. These results, presented above, are used to estimate the damage associated with given coastal events at specified return periods.

It should be noted that, although the available modelling results have been utilised in the most appropriate manner, the representation of the baseline scenario may change through consultation with stakeholders, and the monetary values presented here may change as the project develops. Attention should therefore primarily be focused on the approach that is being recommended to ensure there is agreement going forward.

4.1 Estimation of flood damages

4.1.1 Damage calculations

The SEPA receptor dataset has been used in this initial economic assessment to give an estimate of flood damages. At this stage, only corrections have been applied to the floor areas of properties. Prior to the full options appraisal, a detailed analysis (including ground truthing) will be undertaken to assess the quality of this receptor database. This will include:

- Checking of property types against MCM code;
- Checking for basements;
- Assessment of vulnerability.

Flood damages were estimated by linking the receptor points to the building footprints and estimating the water depth at each from flood extents generated by TUFLOW model. These analyses use 2017 depth-damage curves from the Multi-Coloured Handbook (MCM) associated with coastal flooding.

The above determines the direct damages due to property inundation. In addition to these further indirect damages were added to the total. Below is a summary of all damage and additional benefits considered here.

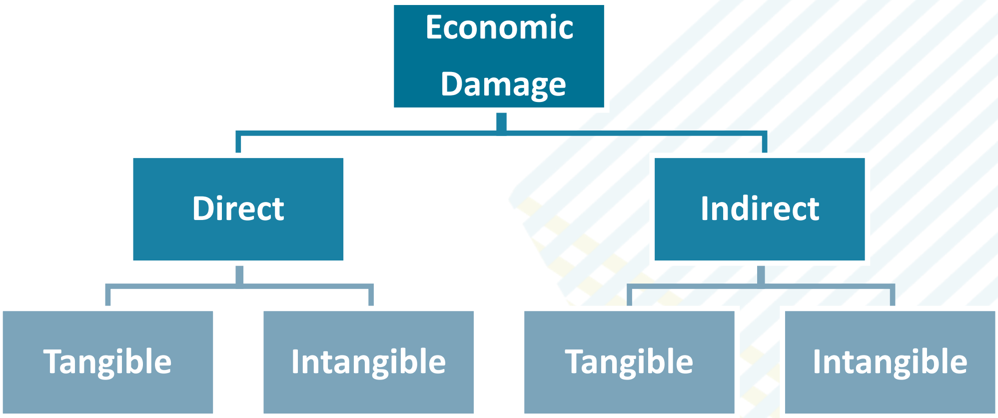


Figure 4-1: Aspects of flood damage

- Direct damages due to property inundation
- Indirect non-residential damages at 3% of direct damages

Evacuation and temporary accommodation costs

- Emergency services costs at 5.6% of total residential direct damages
- Intangible damages (e.g. health)

For calculation of damages the analyses consider a building threshold level for each property, derived from surveyed levels, which is common in FCERM appraisals and provides an accurate assessment of property inundation depths at each return period.

The following assumptions and additional data were used to improve and provide the necessary information to supplement the above datasets. Comments on the quality of the data have also been listed.

Should the ground truthing exercise not support of these assumptions, the options appraisal analysis will be adapted as required.

Table 4-1: Direct flood damage assumptions

Data type	Data and any assumptions used
Depth Damage data	Long Duration Multi-Coloured Manual for coastal (wave damage) sources used.
Flood levels	Flood levels derived from inundation modelling for the 2, 5, 10, 50, 100, 200 and 1000 year return periods for present day.
Threshold level	Threshold levels used where available. Remaining data taken from LiDAR. Visual assessment using Google Streetview conducted.
Basements	Not considered
Residential property types	Defined by property types (Detached, Semi-Detached, Terraced, Flat).
Non-residential property types	Defined by SEPA Receptor Database. Assumed as sector average where no data available
Property areas	Defined by SEPA Receptor Database or as building areas
Residential market values for capping	Zoopla market values used.
Non-residential market values for capping	Market values determined from bulk class rateable values per m^2. uplifted to 2018 by CPI
Flood duration	Assumed to be more than 12 hours as overtopping occurs over at least a single tidal cycle
Updating of MCM damage data	2017/18 damage data used. No updating necessary.

4.1.2 Depth damage curve

The FHRC MCM provides standard flood depth/direct damage datasets for a range of property types, both residential and commercial. This standard depth/damage data for direct and indirect damages has been utilised in this study to assess the potential damages that could occur under each of the options. Flood depths within each property have been calculated from the inundation modelling by comparing predicted water depths at each property to threshold levels.

The following FHRC depth damage curve was selected for this baseline assessment:

Long Duration with Warning (Without Cellar), Wave and Salt Water Damage

4.1.3 Threshold levels

Threshold levels used within the damage calculations were obtained from topographic survey available and from LiDAR levels (as outlined in TuFlow modelling, Section 2.9.2) and applied to building footprint in modelling as well as to the receptor points for estimating flood depths in the damage calculations.

4.1.4 Residential property capping

In line with the guidance in the MCM, the property damages are capped to market value. For residential properties, the capped values have been taken from Zoopla and are presented in Table 4-2.

Table 4-2: Average property for Stonehaven (prices taken from Zoopla, Sept. 2018)

Property	Market Value
Detached	£302,671
Semi-detached	£214,556
Terraced	£227,140
Flat	£140,938

4.1.5 Non-residential property capping

Market values for non-residential properties can be estimated from a properties rateable value. The rateable value is used, together with an equivalent yield to estimate market value for damage capping using the following relationship:

Estimated Capital Valuation = Factor x Rateable Value

The 'Factor' reflects the added value or percentage rental yield from that property. This is typically recommended to be a value of 10-12.5 for flood defence purposes[17], although the MCH recommends a value of 16.7[18]. A value of 16.7 was used.

Non-residential properties have been capped based on the Valuation Office Agency rateable values (RV) for bulk classes. These have been assigned to non-residential receptors within the study area and vary between properties. Table 4-3 summarises the rateable values used for the non-residential within Stonehaven these have been uplifted from 2008 to 2018 using the CPI (Consumer Price Index)

17 Environment Agency (2009). Flood and Coastal Erosion Risk Management - Appraisal Guidance.

Table 4-3: Rateable values applied to non-residential receptors

Bulk Class	2018 CPI (£/m²)
All Bulk Classes	83
Retail premises	164
Total Offices	153
Commercial Offices	162
'Other' Offices	107
Factories3	37
Warehouses3	50
Other bulk premises	40
Non-bulk premises	-
Non-bulk premises with floorspace	59

The capped value for non-residential properties was therefore determined from the following relationship in line with the MCH guidance:

$$Value = Floor\ area\ \times\ RV\ \times\ 16.7$$

4.1.6 Intangible damages (Health)

Intangible damages for each property, and each return period have been estimated using the following equation[19]

$$\text{Damages (£ per yr per household)} = 286\ \times \left\{1.026 - (1/(1 + 37.5e^{-0.06/AFP}\right\}$$

Typically, a value of £286 is used in the calculations. For assessment of baseline damages and to appraise the damage associated with given options at a later stage this approach is used.

However, there is debate as to whether the methodology used to determine this value underestimates the adverse health impacts of flooding. This may be particularly relevant in Stonehaven where there is high risk of flooding combined with a high concentration of vulnerable people.

Through consultation with SEPA, it has been agreed that the typical value (£286) be applied as part of the appraisal to allow for consistent national comparison of economic viability of proposed FPSs. This value has therefore been used for the calculations presented here and will be carried forward to the appraisal.

None-the-less, the vulnerability of the local community at risk of flooding is extremely important in Stonehaven. To emphasise this when developing the business case for the preferred option, we will test the sensitivity of the Benefit Cost Ratio by assigning a "vulnerability index" to each receptor based on the information

[19] Environment Agency, 2004, The Appraisal of Human Related Intangible Impacts of flood, R&D Technical Report FD2005/TR, Environment Agency

available in the SEPA's strategic receptor dataset. This combines over 75 and vulnerable people scores, with higher scores indicating higher levels of vulnerability. The average vulnerability index for residential properties within 20m of the present day 1,000-year coastal inundation extent was found to be 38.8, significantly greater than the average score within Stonehaven (14.63). The classification of vulnerable properties at risk of flooding from the present-day 1000-year event in Figure 4-2.

For the inclusion of vulnerability, we will use the average vulnerability index of 38.8 to determine a cut off, above which a higher monetary value has been applied.

This will likely be taken as £1,340/yr/household based on the typical (£286) and higher (£2513) values presented in the MCM.

Figure 4-2: Property vulnerability index for properties in Stonehaven

4.2 Indirect damages

4.2.1 Local authority and emergency services losses

The multi coloured manual provides guidance on the assessment of indirect damages for emergency services and other third party costs. It recommends that a value between 5.6% and 10.7% of the direct property damages is used to represent emergency costs. These include the response and recovery costs incurred by organisations such as the emergency services, the Local Authority and SEPA.

The 5.6% value is more representative of flooding to a smaller community, whereas the 10.7% value is more representative of a more widespread regional flood scenario. This led to a value of 5.6% being considered most appropriate Indirect commercial damages

Obtaining accurate data on indirect flood losses is difficult. Indirect losses are of two kinds:

- losses of business to overseas competitors, and
- the additional costs of seeking to respond to the threat of disruption or to disruption itself which fall upon firms when flooded.

The first of these losses is unusual and is limited to highly specialised companies which are unable to transfer their productive activities to a branch site in this country, and which therefore lose to overseas competitors. The second type of loss is likely to be incurred by most Non-residential Properties (NRPs) which are flooded. They exclude post-flood clean-up costs but include the cost of additional work and other costs associated with inevitable efforts to minimise or avoid disruption. These costs include costs of moving inventories, hiring vehicles and costs of overtime working. These costs also include the costs of moving operations to an alternative site or branch and may include additional transport costs.

Chapter 5, Section 5.7 of the MCM[20] recommends estimating and including potential indirect costs where these are the additional costs associated with trying to minimise indirect losses. This is assessed by calculating total indirect losses as an uplift factor of 3% of estimated total direct NRP losses at each return period included within the damage estimation process.

4.2.2 Evacuation losses

The MCM (2013) provides guidance on the losses associated with evacuation (getting people safely out of homes during an event and temporary accommodation costs whilst properties are repaired). Costs recommended are based on flood depths and property type.

4.3 Modelling Results

To inform the baseline assessment, only present day flood extents have been used. The water surface was used in conjunction with the receptor dataset and threshold datasets to identify the properties inundated (i.e. water level above threshold) at each return period. These are presented in Table 4-4. A total of 68 properties are expected to be inundated during a 200-year event. Most of these properties are situated to the South of the River Cowie, in Stonehaven and Boatie Row.

20 Penning-Rowsell et al., 2013. Flood and Coastal Erosion Risk Management - A Manual for Economic Appraisal

Table 4-4: Count of inundated properties for Present day scenarios

Event	2yr	5yr	10yr	30yr	50yr	100yr	200yr	1000 yr
Residential	14	21	29	37	48	54	57	64
Commercial	2	2	3	6	7	9	11	19
Total	16	23	32	43	55	63	68	83

Figure 4-3: Two year flood extent with impacted properties

Figure 4-4: 200 year flood extent with impacted properties

4.3.1 Flood damages

Baseline flood damage calculations were undertaken following the methodology defined in the previous sections. This has assumed a 100-year appraisal period using the standard Treasury discount rates outlined in the Green Book.

This results in a total estimate of Present Value Damages (PvD) of £12.6 million. Table 4-5 and Figure 4-5 provide a breakdown of the contribution from each component considered at this stage, both in terms of Annual Average Damages (AAD) and PvD.

Table 4-5: Breakdown of 2018 flood damages

Component	AAD (£k)	PvD (£k)
Direct Residential	□261.86	□7,806.79
Direct Commercial	□84.81	□2,528.36
Indirect Commercial	□2.54	□75.85
Emergency Services	□20.80	□620.11
Evac. And Temp Accom	□28.87	□860.81
Intangibles (Health)	□20.38	□607.70
Vehicles	□3.47	□103.30
Total	**£422.73**	**£12,602.92**

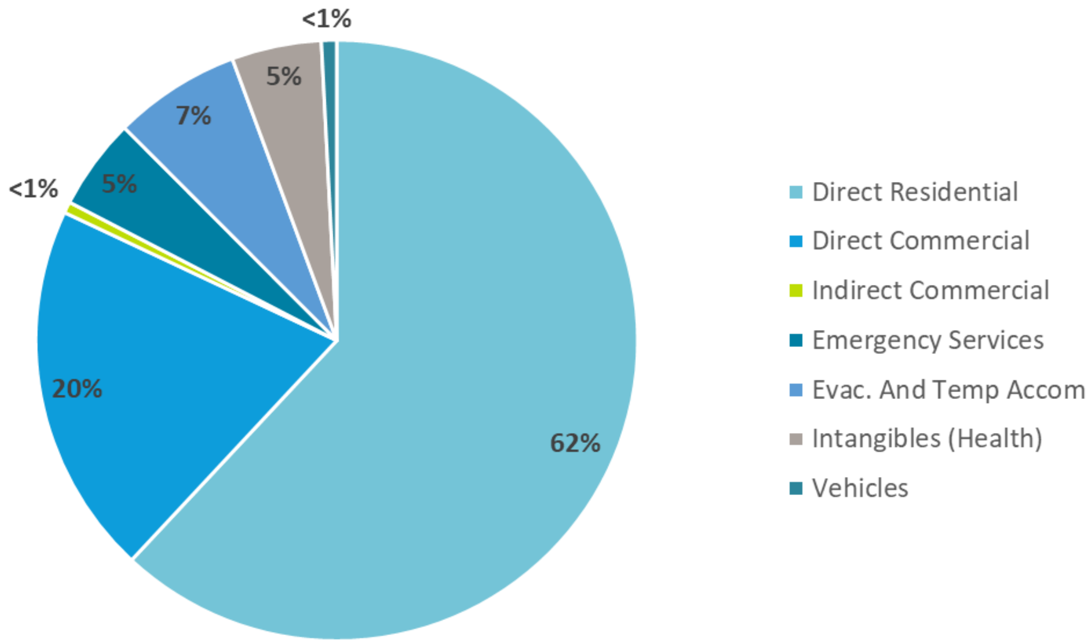


Figure 4-5: Proportion of components contributing to 2018 flood damages

It should be noted that, given the high risk of flooding and large depth that can accumulate behind the defences, the values reported above are significantly influenced by the capping of PvD to property values. Out of all the properties flooded, 55% of residential, and 21% of non-residential properties have their AAD capped at market value. If no capping was considered, the total PvD would increase to £54.7 million.

5 Conclusions and recommendations

5.1 Flood modelling

The methodology for developing and assessing flood risk has been demonstrated and shown to have the following phases:

- Processing of SEPA's offshore multivariate data into an MDA sample;
- Wave transformation modelling of the MDA sample to provide nearshore conditions;
- Fitting of emulators to the wave transformation results;
- Emulation for the entire multivariate dataset and corresponding WaveWatch III hindcast data;
- Estimation of overtopping for hindcast wave conditions using EurOtop Neural Network 2;
- Calibration and sense checking of overtopping schematisations using historic flood information;
- Estimation of extreme overtopping rates using the full multivariate dataset and EurOtop Neural Network 2;
- TUFLOW inundation modelling of the December 2012 event as a validation of the entire modelling framework;
- TUFLOW inundation modelling of extreme events to inform baseline flood damage calculations.

The results presented, and checks undertaken have demonstrated that the methodology is robust and effectively captures the baseline flood risk to Stonehaven from wave overtopping and extreme sea levels.

As part of this interim reporting, baseline flood risk has been considered. This assessment will be used to inform the options appraisal, allowing for a managed adaptive approach to flood risk for Stonehaven to be undertaken.

The main source of uncertainty in the results has been shown to be within the harbour where the SWAN modelling and emulators have the largest errors. While, the methodology presented is considered sufficient to estimate flood risk as part of this study, should the outcomes demonstrate the requirement for the re-design of defences at the rear of the harbour, it is recommended that more detailed (phase-resolving) wave modelling be considered at a later stage.

It has been shown that, sea level rise due to climate change has the potential to significantly affect additional parts of the drainage network. This is primarily concentrated on assets south of the Carron.

The increase in flood risk on the watercourses has not been considered at this stage. This will be assessed throughout the options appraisal to make sure that any alterations to the banks and defences include sufficient levels and freeboard, given the combined fluvial-coastal risk.

5.2 Erosion Modelling

The erosion risk at Stonehaven has been analysed and assessed using the following steps:

- Review of the baseline processes that influence sediment transport and erosion;
- Analysis of national datasets (NCCA) to establish the long-term trends in shoreline position;

- Analysis of available topographic survey data to establish medium-term term (10 year) volumetric variations in the beach;
- Numerical modelling of the beach to estimate erosion rates after defence failure and identify any critical assets at risk.

The results presented show that there is a high level of variability in the beach levels and volumes. The primary control mechanism is cross-shore transport during extreme events which lead to berm building and burying of the defences. This particularly evident south of the River Cowie, where the revetment is almost completely buried, and the beach now forms the primary defence to the properties behind. Anecdotal evidence from local residences suggests that this improves dissipation of wave energy further offshore, reducing overtopping. This will be considered further during the option development.

Although the cross-shore processes are thought to dominate, a longshore gradient exists. This is likely to do with the higher exposure of the northern section of the bay (Cowie) and explains the increase in beach width from north-to south.

The assessment of the performance of the control structures at the Cowie and Carron mouths have shown them to be inefficient at retaining beach sediment, with the Carron mouth arrangement possibly exacerbating the loss of sediment that is recycled to the area. Overall, the volume increase around the Carron mouth, is less that the volume placed by Aberdeenshire Council.

While the analysis undertaken has been useful to give an overall picture of the changes in the beach, these are not available at the frequency required to fully understand the performance and changes in the beach during extreme conditions. This is exacerbated by the trends potentially being skewed by the timing of the surveys undertaken (i.e. 2008 was before/during the storm season and 2013 and 2018 were after). These data are insufficient to fully understand the morphological behaviour of the system and to assess the implications that these changes may have on flood risk (i.e. there is no evidence of toe scour in the available data, which has been discussed in previous studies). Although, the numerical modelling undertaken in XBeach helps to understand the short-term changes during storms, this is again limited with a lack of recorded pre-storm profiles to give confidence that the range of processes are adequately captured.

The morphology of the beach is clearly a key component in the protection against, and exacerbation of, flood risk within the bay. Should the study undertaken here lead to the design and construction of a new FPS, it is recommended that regular beach monitoring and survey be undertaken in the intervening period to support the management decisions and ongoing processes.

The area south of the Carron mouth is a key area of interest in terms of erosion and morphological change. While it has been hypothesised that the discharge from the river increases erosion in this location by altering the longshore gradient this is only anecdotal. Some further detailed modelling of 2D velocity gradients and vectors within the bay (including river discharges) should be considered in the future to better understand the overall processes during extreme events.

5.3 Baseline economic appraisal

The results from the baseline economic appraisal has shown that the present-day damages have a present value of approximately £12.6 million. The main contribution to this is through direct residential property damages. The high frequency of flooding and number of properties at risk during low return periods has resulted in significant capping of the damages to market value. Without this capping the present value damages are estimated to be £54.7 million, further highlighting the high level of risk at lower return periods.

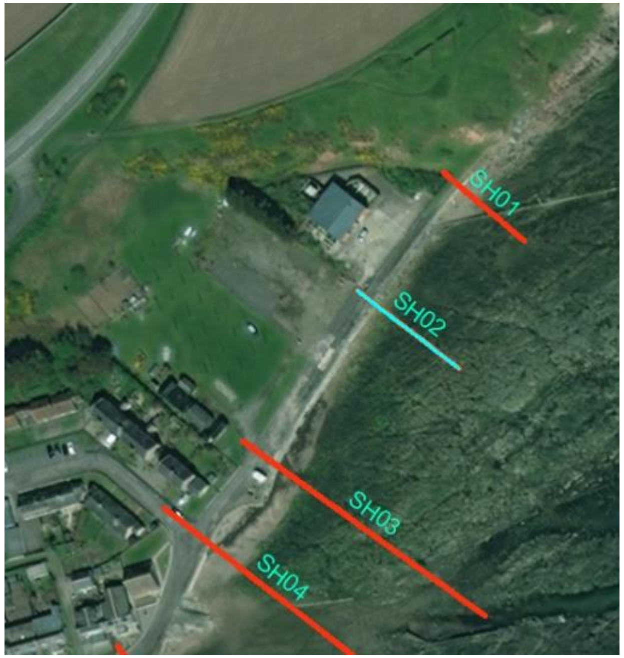
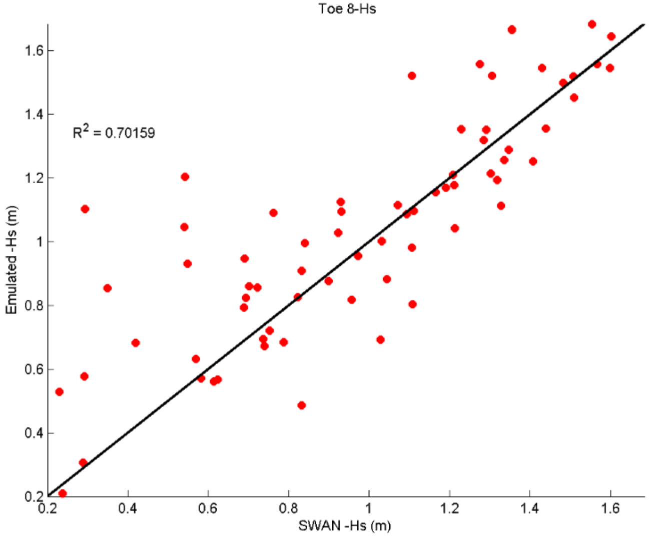
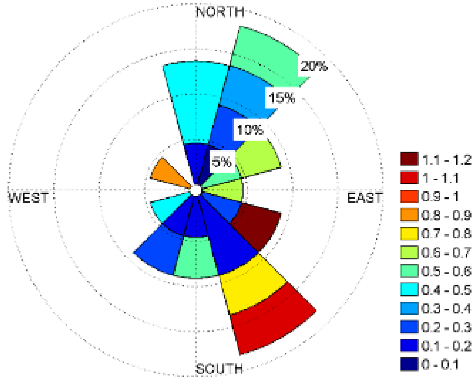
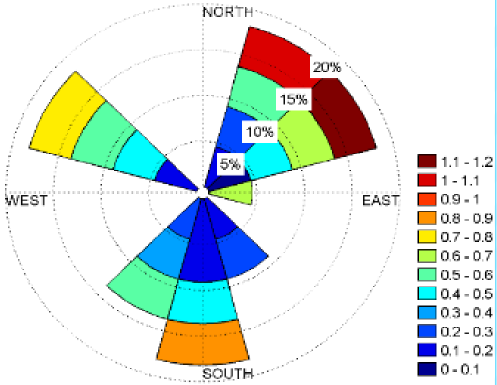
Prior to full options appraisal the following will be incorporated into the damage assessment:

- Recreational losses through erosion of the beach;
- Risk-to-life from wave overtopping;
- Critical infrastructure at risk from erosion;
- Sea level rise and climate change.

Inclusion of these will increase the overall present value damages for the appraisal period.

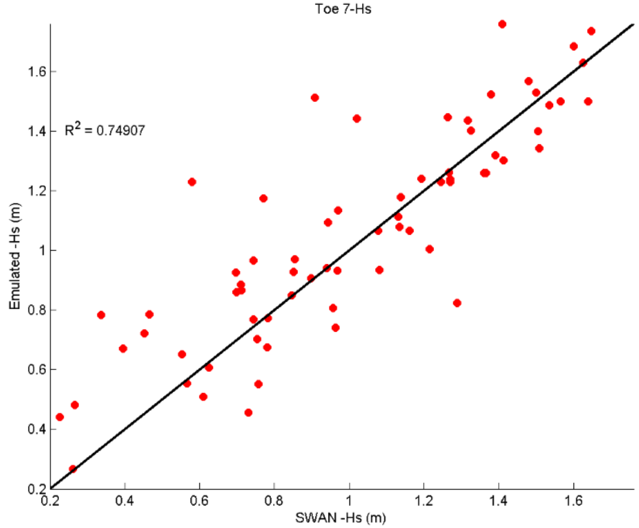
Appendices

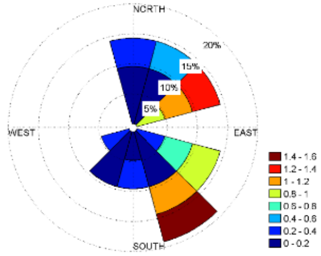
A Emulator function diagnostics

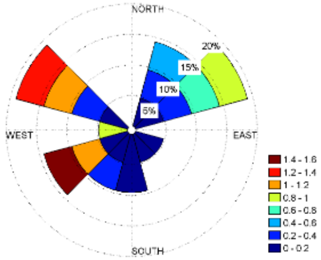
Output Location	Function scores (top) and chosen function Hs prediction (bottom)	Hs errors for offshore wind direction (top) and wave direction (bottom)
SH_02 		 

SH_06


SH04
SH05
SH06
SH07
SH08
SH09

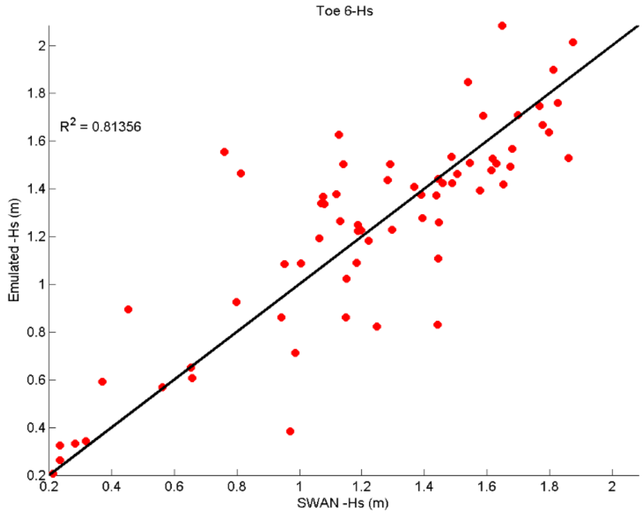

Toe 7-Hs
R^2 = 0.74907
Emulated -Hs (m)
SWAN -Hs (m)

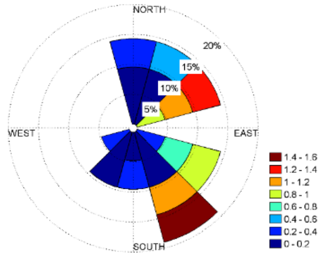

NORTH
WEST
EAST
SOUTH
5%
10%
15%
20%
1.4 - 1.6
1.2 - 1.4
1 - 1.2
0.8 - 1
0.6 - 0.8
0.4 - 0.6
0.2 - 0.4
0 - 0.2

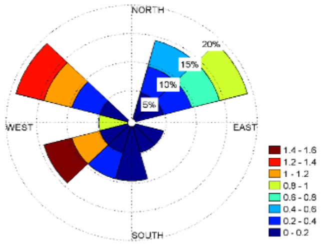

NORTH
WEST
EAST
SOUTH
5%
10%
15%
20%
1.4 - 1.6
1.2 - 1.4
1 - 1.2
0.8 - 1
0.6 - 0.8
0.4 - 0.6
0.2 - 0.4
0 - 0.2

SH_12

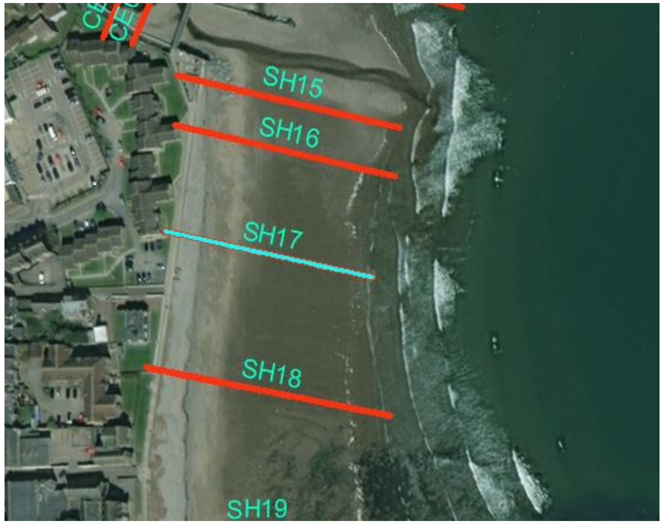

SH10
SH11
SH12
SH13
SH14
CE02

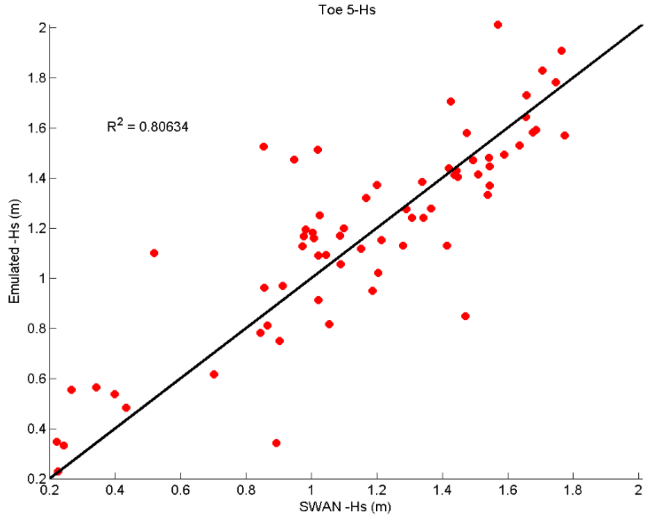

Toe 6-Hs
R^2 = 0.81356
Emulated -Hs (m)
SWAN -Hs (m)

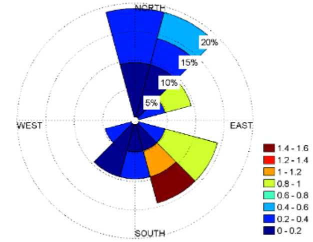

NORTH
WEST
EAST
SOUTH
5%
10%
15%
20%
1.4 - 1.6
1.2 - 1.4
1 - 1.2
0.8 - 1
0.6 - 0.8
0.4 - 0.6
0.2 - 0.4
0 - 0.2

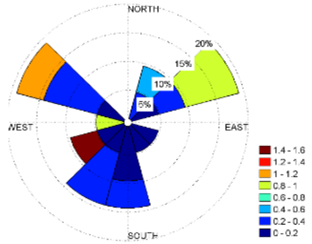

NORTH
WEST
EAST
SOUTH
5%
10%
15%
20%
1.4 - 1.6
1.2 - 1.4
1 - 1.2
0.8 - 1
0.6 - 0.8
0.4 - 0.6
0.2 - 0.4
0 - 0.2

SH_17


SH15
SH16
SH17
SH18
SH19

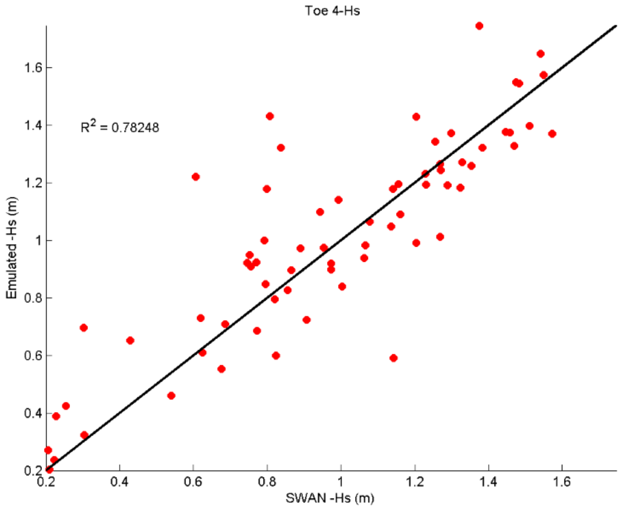

Toe 5-Hs
R^2 = 0.80634
Emulated -Hs (m)
SWAN -Hs (m)

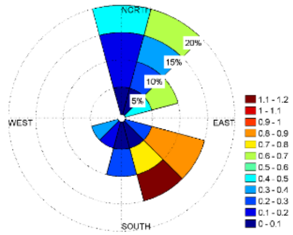

NORTH
WEST
EAST
SOUTH
20%
15%
10%
5%
1.4 - 1.6
1.2 - 1.4
1 - 1.2
0.8 - 1
0.6 - 0.8
0.4 - 0.6
0.2 - 0.4
0 - 0.2

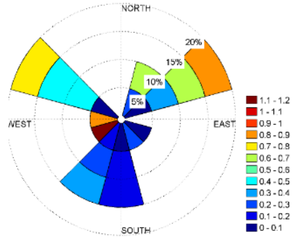

NORTH
WEST
EAST
SOUTH
20%
15%
10%
5%
1.4 - 1.6
1.2 - 1.4
1 - 1.2
0.8 - 1
0.6 - 0.8
0.4 - 0.6
0.2 - 0.4
0 - 0.2

SH_20

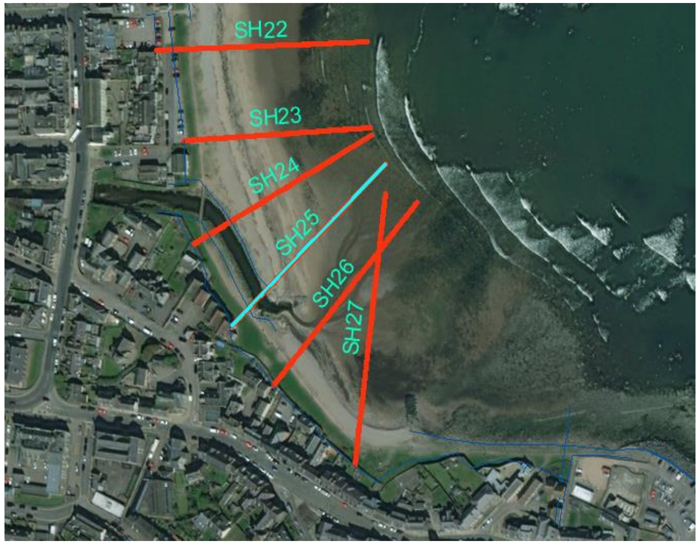

SH18
SH19
SH20
SH21
SH22

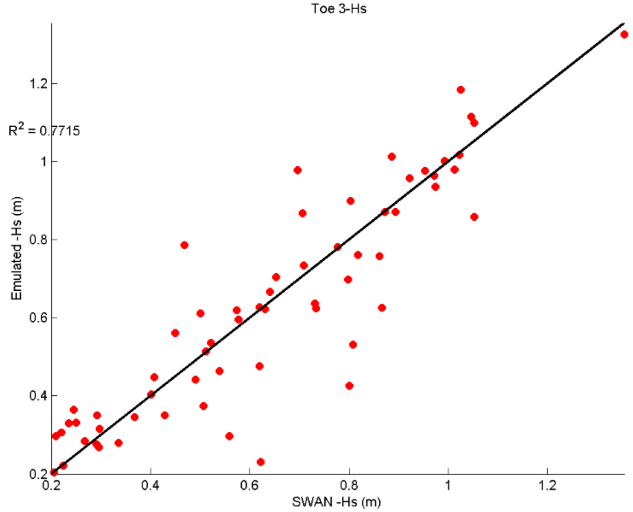

Toe 4-Hs
R^2 = 0.78248
Emulated -Hs (m)
SWAN -Hs (m)

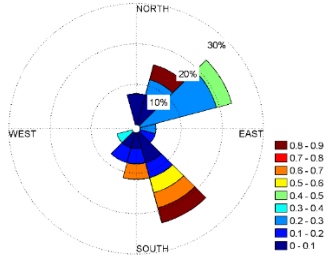

WEST
EAST
SOUTH
20%
15%
10%
5%

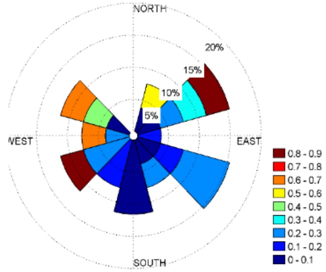

NORTH
WEST
EAST
SOUTH
20%
15%
10%
5%

SH_25


SH22
SH23
SH24
SH25
SH26
SH27

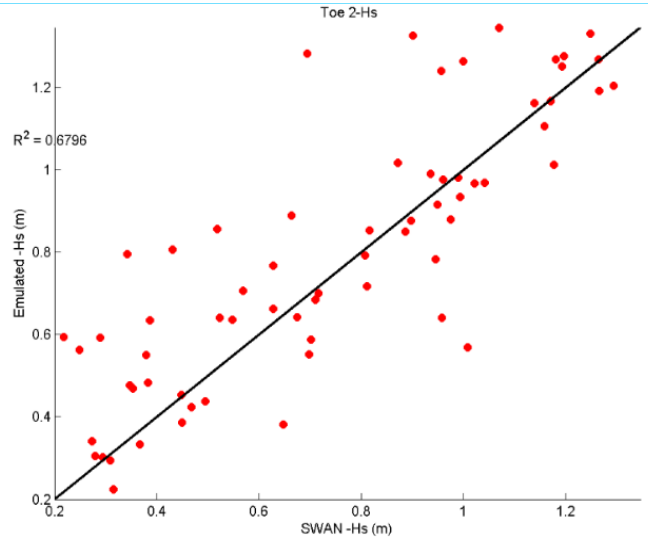

Toe 3-Hs
R^2 = 0.7715
Emulated -Hs (m)
SWAN -Hs (m)

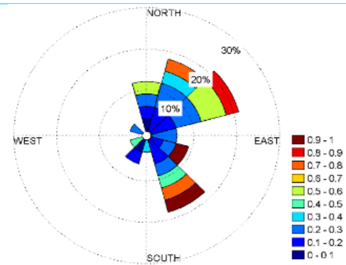

NORTH
SOUTH
WEST
EAST
10%
20%
30%
0.8 - 0.9
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
0.4 - 0.5
0.3 - 0.4
0.2 - 0.3
0.1 - 0.2
0 - 0.1

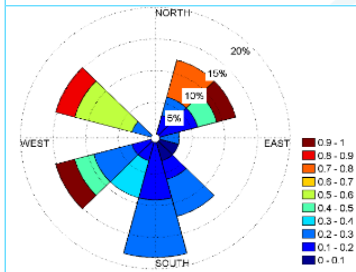

NORTH
SOUTH
WEST
EAST
5%
10%
15%
20%
0.8 - 0.9
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
0.4 - 0.5
0.3 - 0.4
0.2 - 0.3
0.1 - 0.2
0 - 0.1

SH_28


SH28
SH29

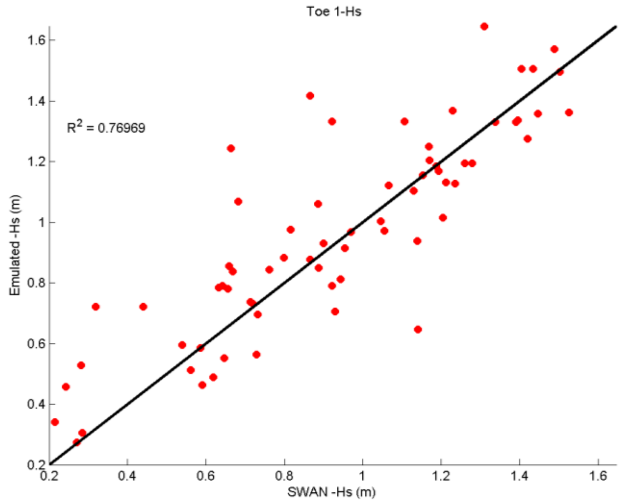

Toe 2-Hs
R^2 = 0.6796
Emulated -Hs (m)
SWAN -Hs (m)

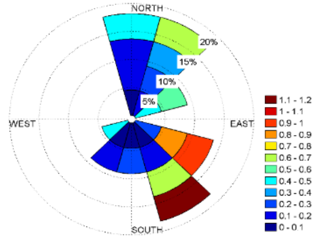

NORTH
SOUTH
WEST
EAST
10%
20%
30%
0.9 - 1
0.8 - 0.9
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
0.4 - 0.5
0.3 - 0.4
0.2 - 0.3
0.1 - 0.2
0 - 0.1

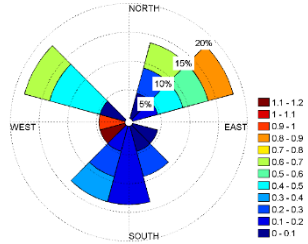

NORTH
SOUTH
WEST
EAST
5%
10%
15%
20%
0.9 - 1
0.8 - 0.9
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
0.4 - 0.5
0.3 - 0.4
0.2 - 0.3
0.1 - 0.2
0 - 0.1

SH_29

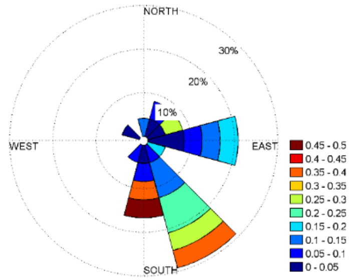

SH28
SH29


Toe 1-Hs
R^2 = 0.76969
Emulated -Hs (m)
SWAN -Hs (m)

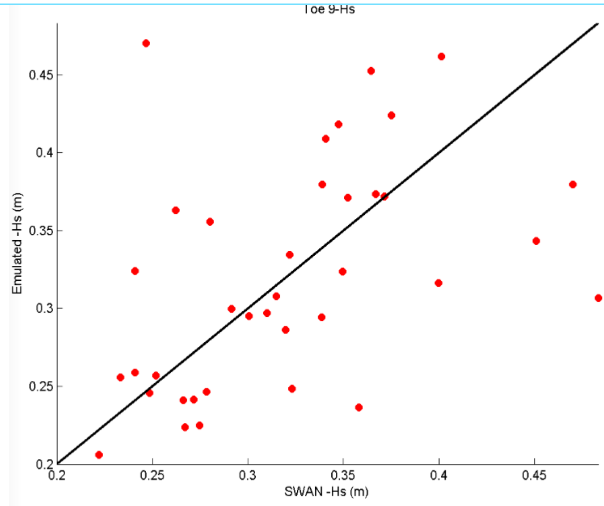

NORTH
WEST
EAST
SOUTH
5%
10%
15%
20%
1.1 - 1.2
1 - 1.1
0.9 - 1
0.8 - 0.9
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
0.4 - 0.5
0.3 - 0.4
0.2 - 0.3
0.1 - 0.2
0 - 0.1

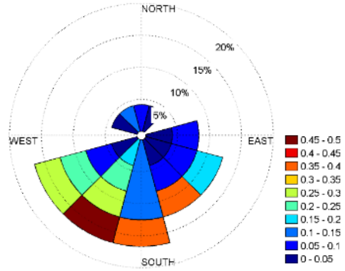

NORTH
WEST
EAST
SOUTH
5%
10%
15%
20%
1.1 - 1.2
1 - 1.1
0.9 - 1
0.8 - 0.9
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
0.4 - 0.5
0.3 - 0.4
0.2 - 0.3
0.1 - 0.2
0 - 0.1

SH_H_01

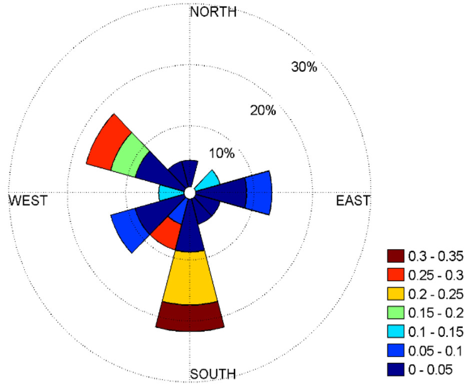

NORTH
WEST
EAST
SOUTH
10%
20%
30%
0.45 - 0.5
0.4 - 0.45
0.35 - 0.4
0.3 - 0.35
0.25 - 0.3
0.2 - 0.25
0.15 - 0.2
0.1 - 0.15
0.05 - 0.1
0 - 0.05

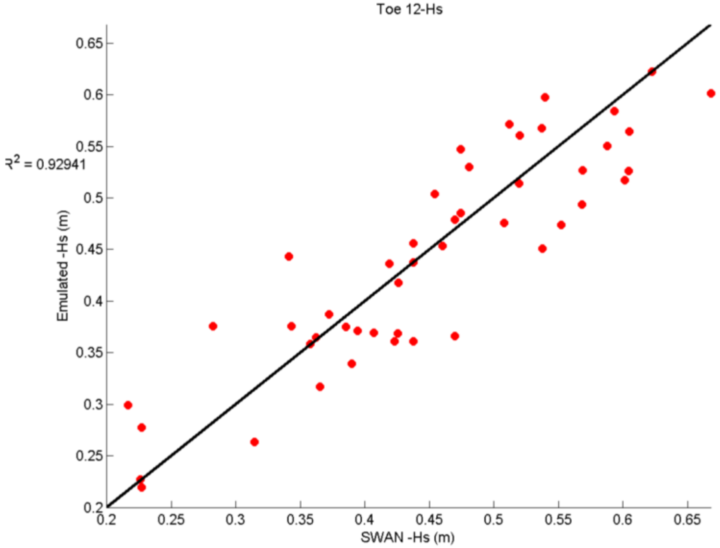

SH_H_01
SH_H_02

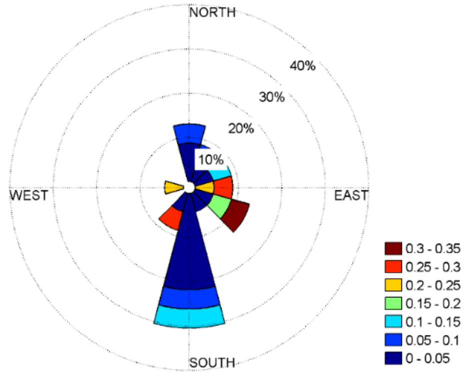

Toe 9-Hs
Emulated -Hs (m)
SWAN -Hs (m)
0.2
0.25
0.3
0.35
0.4
0.45


NORTH
WEST
EAST
SOUTH
5%
10%
15%
20%
0.45 - 0.5
0.4 - 0.45
0.35 - 0.4
0.3 - 0.35
0.25 - 0.3
0.2 - 0.25
0.15 - 0.2
0.1 - 0.15
0.05 - 0.1
0 - 0.05

SH_H_01b

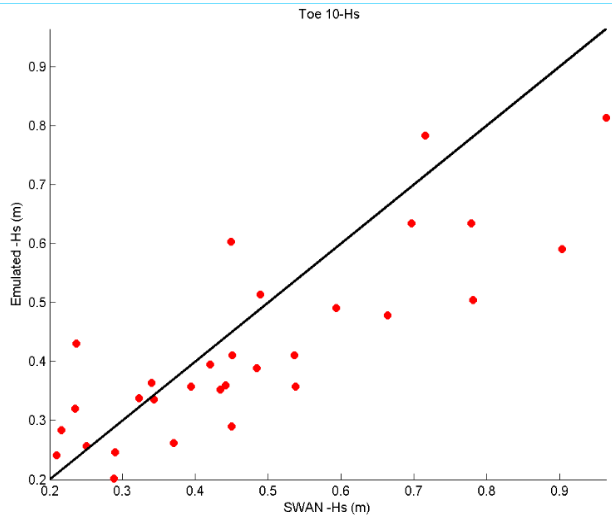

NORTH
WEST
EAST
SOUTH
10%
20%
30%
0.3 - 0.35
0.25 - 0.3
0.2 - 0.25
0.15 - 0.2
0.1 - 0.15
0.05 - 0.1
0 - 0.05

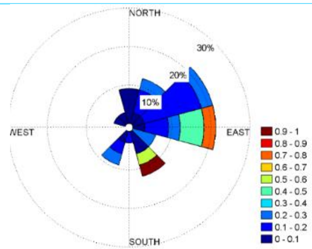

Toe 12-Hs
R^2 = 0.92941
Emulated -Hs (m)
SWAN -Hs (m)

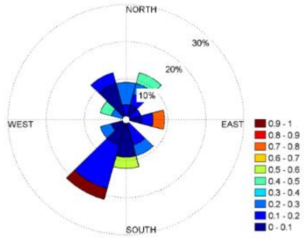

NORTH
SOUTH
EAST
WEST
10%
20%
30%
40%
0.3 - 0.35
0.25 - 0.3
0.2 - 0.25
0.15 - 0.2
0.1 - 0.15
0.05 - 0.1
0 - 0.05

SH_H_02

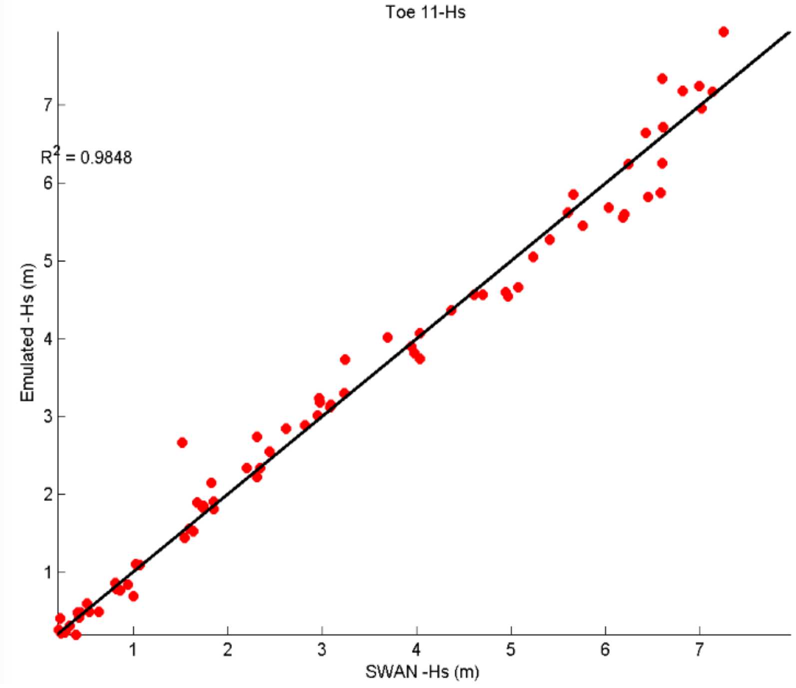

SH_H_01
SH_H_02

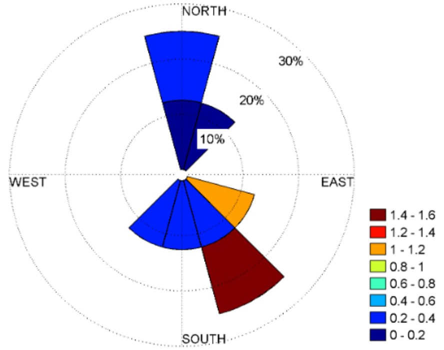

Toe 10-Hs
Emulated -Hs (m)
SWAN -Hs (m)

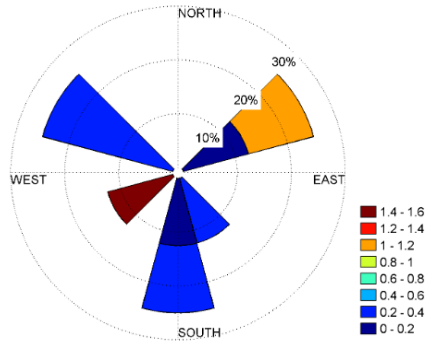

NORTH
SOUTH
EAST
WEST
10%
20%
30%


NORTH
SOUTH
EAST
WEST
10%
20%
30%

Calibration Buoy (Cal_buoy)







B Volumetric Analysis

Table B-1: Volumetric changes above MHWN in Stonehaven Bay

Profile	Volume in 2008 (m3/m)	Volume in 2013 (m3/m)	Volume in 2018 (m3/m)	Volume change 2008-2013 (m3/m)	Volume change 2013-2018 (m3/m)	Total volume change 2008-2018 (m3/m)
1	34.06	34.06	35.07	0.00	1.01	1.01
2	20.72	20.26	21.72	-0.46	1.46	1.00
3	32.31	29.38	30.19	-2.93	0.81	-2.12
4	43.76	49.76	55.74	6.00	5.99	11.99
5	16.22	25.65	25.93	9.43	0.28	9.71
6	18.87	26.82	24.10	7.95	-2.71	5.24
7	24.47	28.42	32.32	3.95	3.90	7.85
8	31.26	37.29	38.95	6.03	1.66	7.69
9	32.78	35.65	43.61	2.87	7.97	10.84
10	28.38	26.88	35.78	-1.50	8.90	7.41
11	39.01	38.56	40.78	-0.45	2.22	1.77
12	33.67	49.70	39.45	16.03	-10.24	5.78
13	41.05	39.22	41.35	-1.83	2.14	0.30
14	60.09	54.93	56.02	-5.16	1.10	-4.06
15	48.78	75.63	67.82	26.85	-7.80	19.04
16	50.87	76.94	76.54	26.07	-0.40	25.66
17	53.85	90.80	82.17	36.95	-8.63	28.32
18	73.22	104.10	98.43	30.88	-5.67	25.21
19	96.65	120.29	125.62	23.64	5.33	28.97
20	94.21	113.91	119.83	19.70	5.92	25.62
21	94.35	102.62	105.23	8.27	2.61	10.88
22	135.81	129.24	128.01	-6.57	-1.23	-7.80
23	99.27	91.83	89.68	-7.44	-2.15	-9.58
24	103.71	102.50	98.61	-1.21	-3.90	-5.10
25	66.40	75.49	78.91	9.08	3.42	12.50
26	127.40	156.72	171.32	29.32	14.60	43.92

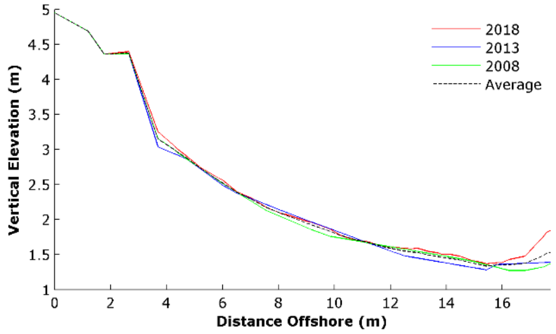
C XBeach Joint Probability Runs

Table C-1: Joint probability boundary conditions for XBeach modelling

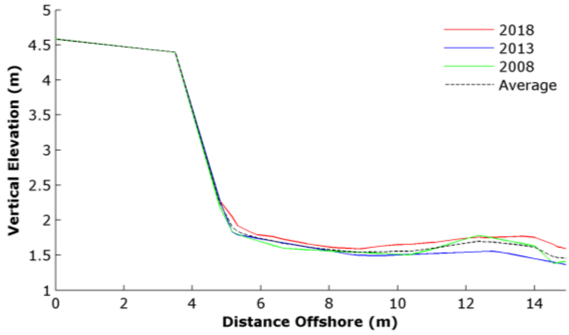
Event	1 year	2 year	10 year	30 year	50 year	100 year	200 year	1000 year
1								
Hs (m)	0.617	0.653	0.716982	0.753	0.768	0.785	0.802	0.859
SWL (mAOD)	2.859	2.859	2.859	2.859	2.859	2.859	2.859	2.859
Tp (s)	5.741	5.822	5.964	6.041	6.074	6.110	6.147	6.264
2								
Hs (m)	1.234	1.306	1.434	1.505	1.537	1.570	1.605	1.7176
SWL (mAOD)	2.764	2.835	2.999	3.107	3.156	3.226	3.282	3.449
Tp (s)	6.976	7.099	7.310	7.422	7.469	7.520	7.571	7.733
3								
Hs (m)	1.851	1.958	2.151	2.258	2.305	2.355	2.407	2.576
SWL (mAOD)	2.680	2.747	2.151	3.027	3.070	3.146	3.209	3.354
Tp (s)	7.914	8.051	2.151	8.399	8.448	8.501	8.553	8.716
4								
Hs (m)	2.468	2.611	2.868	3.011	3.073	3.141	3.209	3.435
SWL (mAOD)	2.594	2.659	2.822	2.935	2.987	3.056	3.132	3.273
Tp (s)	8.613	8.748	8.967	9.078	9.125	9.173	9.222	9.371
5								
Hs (m)	3.085	3.264	3.585	3.764	3.841	3.926	4.012	4.294
SWL (mAOD)	2.477	2.558	2.701	2.814	2.863	2.941	3.034	3.133
Tp (s)	9.134	9.259	9.464	9.568	9.612	9.659	9.707	9.857
6								
Hs (m)	5.554	3.917	4.302	4.516	4.610	4.711	4.814	5.153
SWL (mAOD)	2.35	2.388	2.576	2.666	2.707	2.763	2.849	2.950
Tp (s)	10.598	9.655	9.862	9.9755	10.025	10.080	10.137	10.33
7								
Hs (m)		3.976	4.621	4.777	4.853	4.942	5.046	5.369
SWL (mAOD)		2.370	2.514	2.610	2.654	2.713	2.770	2.900
Tp (s)		9.687	10.03	10.117	10.1589	10.209	10.270	10.471
8								
Hs (m)		5.873	5.019	5.269	5.378	5.496	5.617	6.011
SWL (mAOD)		2.35	2.386	2.526	2.566	2.611	2.649	2.712

Tp (s)		10.842	10.254	10.407	10.477	10.557	10.643	10.960
9								
Hs (m)			6.453	6.776	6.914	7.068	6.419	6.870
SWL (mAOD)			2.35	2.35	2.35	2.35	2.395	2.518
Tp (s)			11.391	11.770	11.952	12.168	11.354	11.893
10								
Hs (m)							7.224	7.738
SWL (mAOD)							2.35	2.35
Tp (s)							12.404	13.310

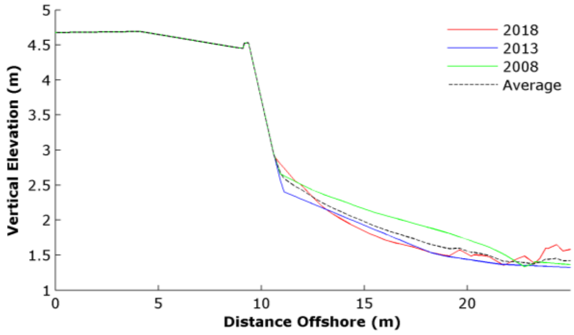
D Profile Plots



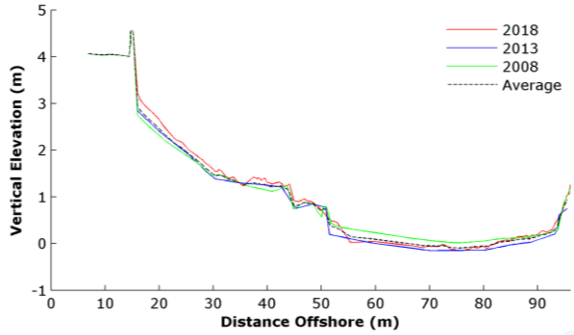
XS01



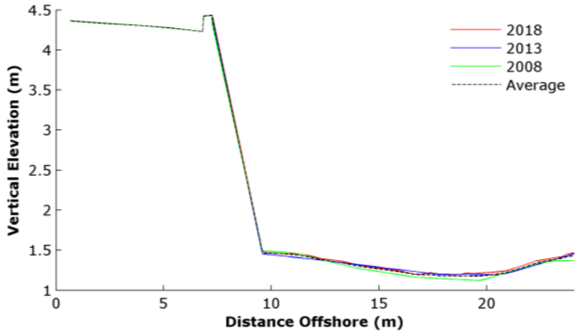
XS02



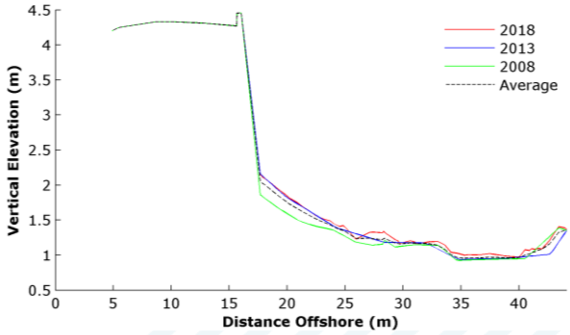
XS03



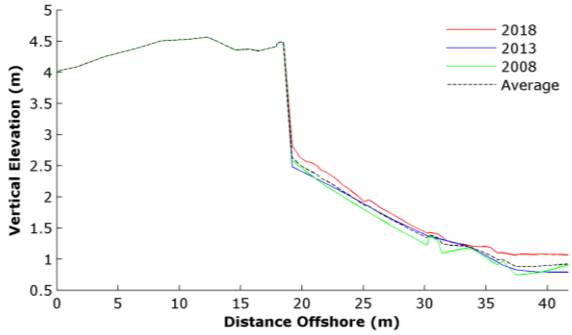
XS04



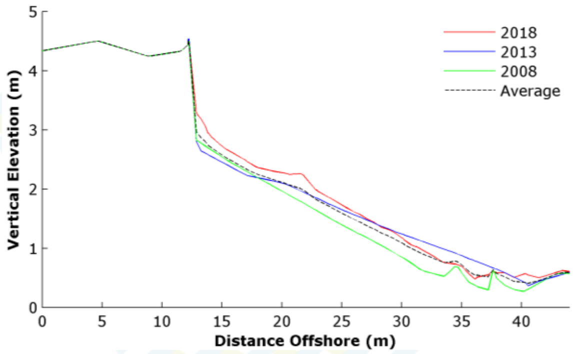
XS05



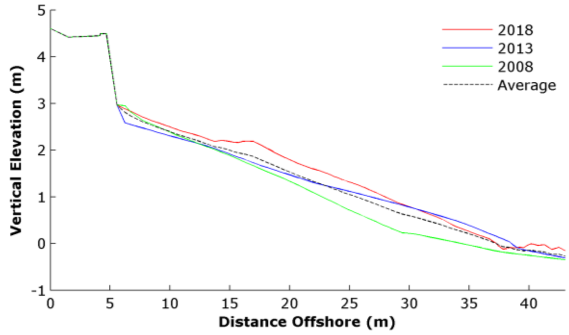
XS06



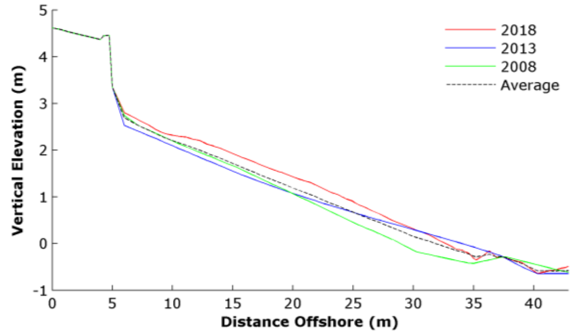
XS07



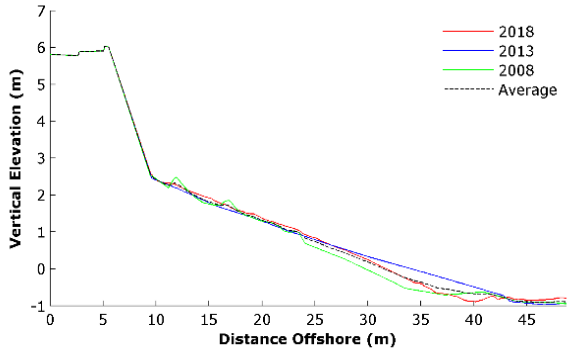
XS08



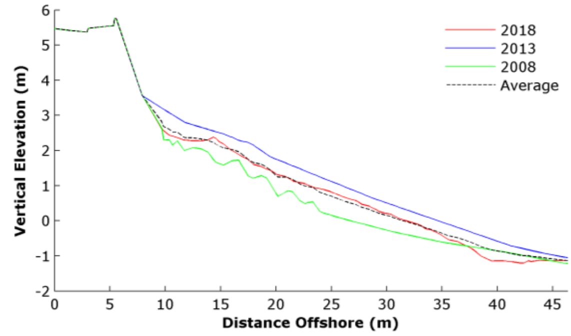
XS09



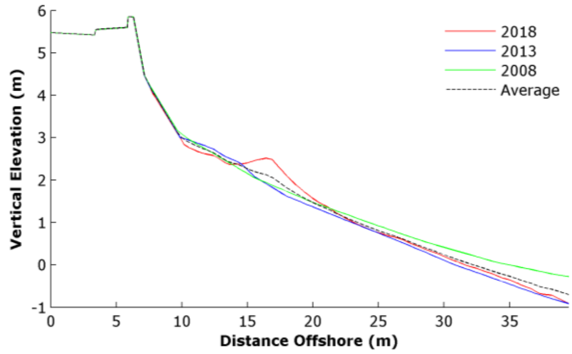
XS10



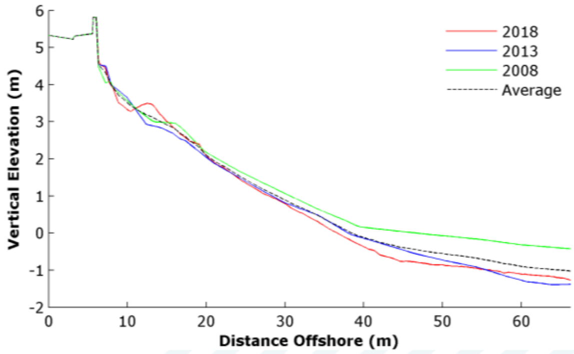
XS11



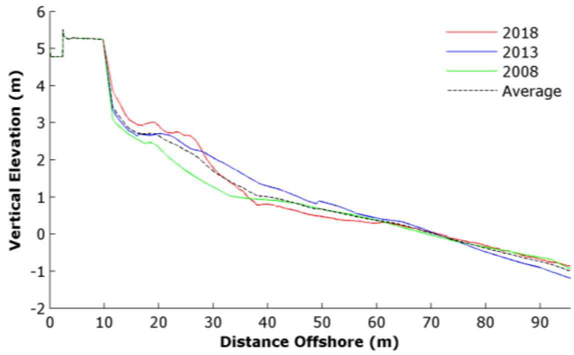
XS12



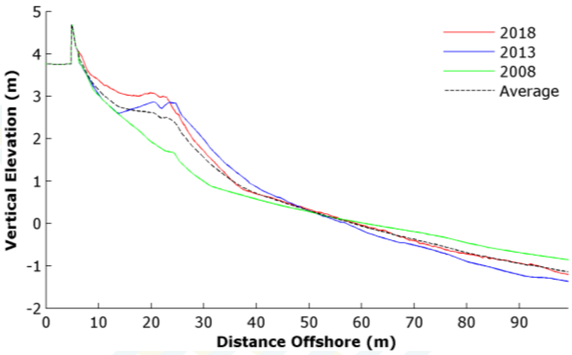
XS13



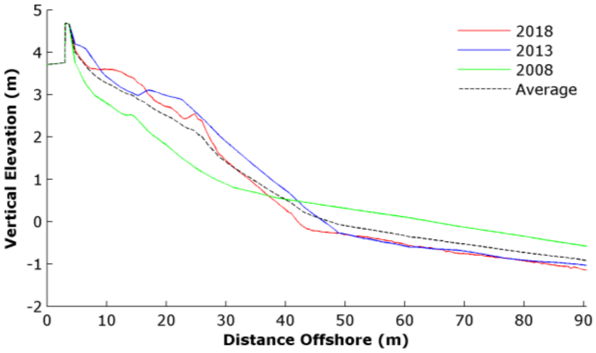
XS14



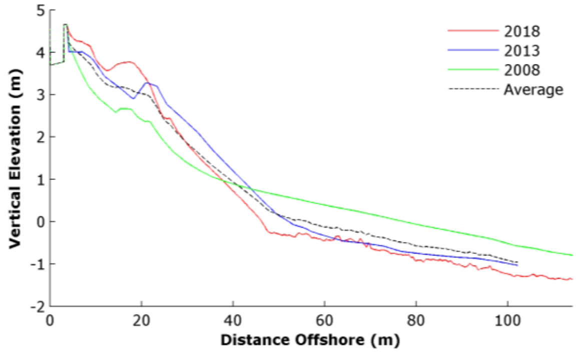
XS15



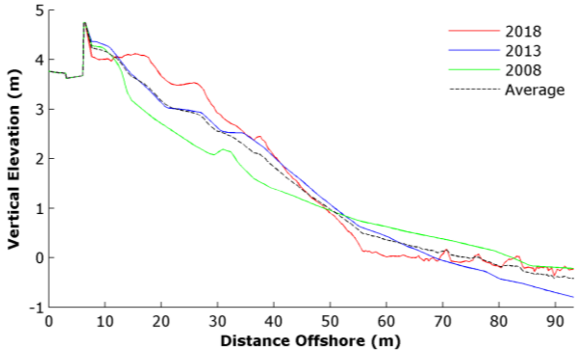
XS16



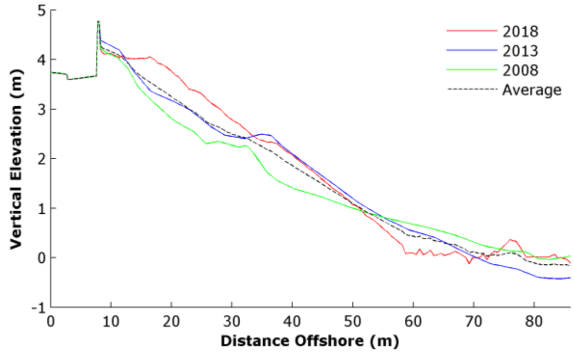
XS17



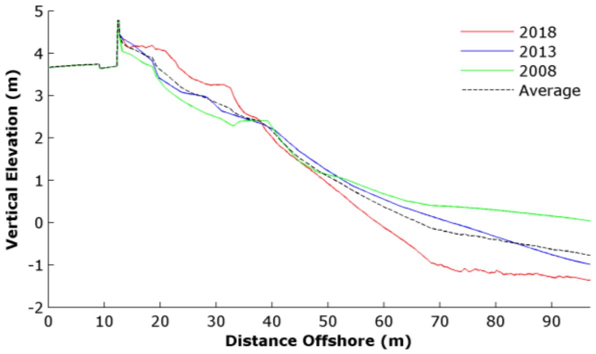
XS18



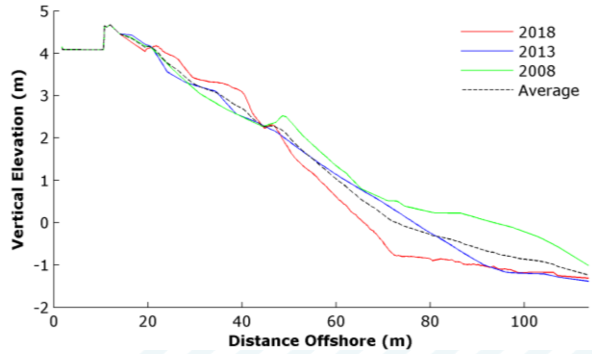
XS19



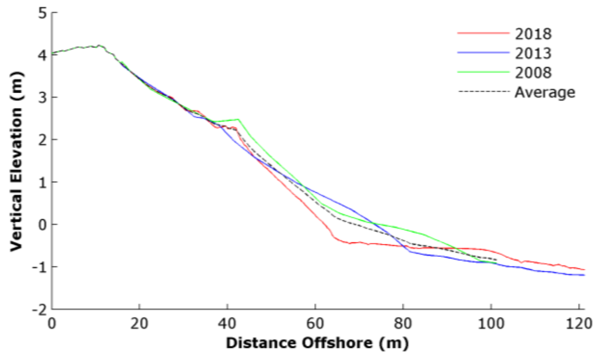
XS20



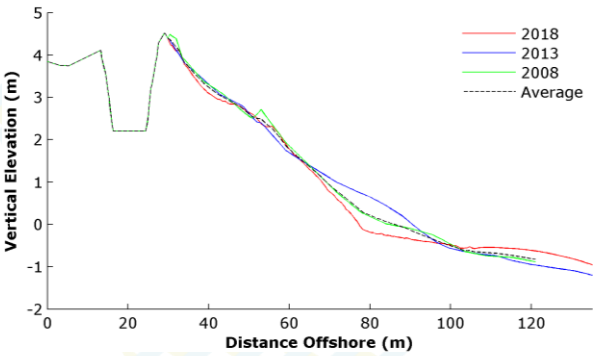
XS21



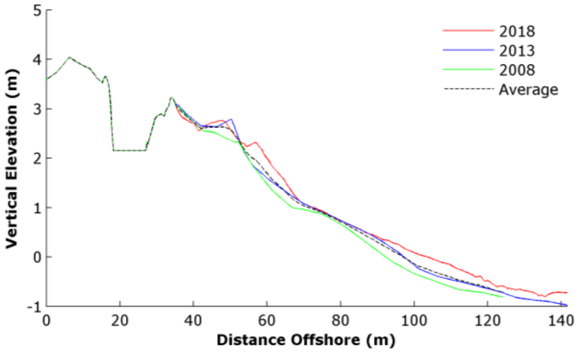
XS22



XS23

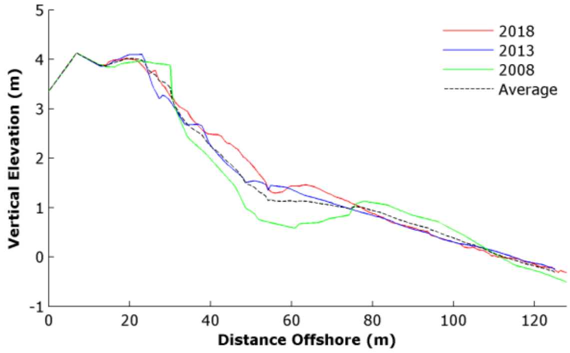


XS24



Vertical Elevation (m)
Distance Offshore (m)
2018
2013
2008
Average

XS25



Vertical Elevation (m)
Distance Offshore (m)
2018
2013
2008
Average

XS26

E Inundation extent

Contains OS data © Crown copyright and database right 2018

Contains OS data © Crown copyright and database right 2018

250 125 0 250 Meters

Contains OS data © Crown copyright and database right 2018

Contains OS data © Crown copyright and database right 2018

260 130 0 260 Meters

Contains OS data © Crown copyright and database right 2018

Contains OS data © Crown copyright and database right 2018

F Erosion map


North
Legend
Present Day HAT
Maximum projected 2050 HAT
Maximum projected 2080 HAT
Maximum projected 2118 HAT
0 0.05 0.1 0.2 0.3 0.4 0.5
Kilometres
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Contains OS data © Crown copyright and database right 2018

Contains OS data © Crown copyright and database right 2018

JBA consulting

Offices at:

Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Glasgow
Haywards Heath
Isle of Man
Limerick
Newcastle upon Tyne
Newport
Peterborough
Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

Registered Office
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE
United Kingdom

+44(0)1756 799919
info@JBA - consulting.com
www.JBA - consulting.com
Follow us:

Jeremy Benn Associates Limited

Registered in England 3246693

JBA - Group Ltd is certified to:
ISO 9001:2015
ISO 14001:2015
OHSAS 18001:2007

New Civil Engineer TechFest Awards WINNER
New Civil Engineer 100 COMPANIES OF THE YEAR 2016 WINNER
New Civil Engineer 100 COMPANIES OF THE YEAR 2017 RANKED COMPANY
CHAS Accredited Contractor CHAS.co.uk

WAVE TRANSFORMATION QA LOG

Project: 2018s0343 –Stonehaven FPS – Wave model
Filename: AKI-JBAU-00-00-AU-HM-0001-S2-P01.01
Modeller/Analyst: Johnny Coyle
Independent Reviewer: Fay Fishford
Project Manager/Team Leader: Nicola Buckley

1 Introduction

This document summarises the model checks that were performed with respect to the wave transformation modelling undertaken for the above study. The document summarises the series of checks undertaken by the Modeller, the Independent Reviewer and the Project Manager / Team Leader. Reviewer comments are provided in a traffic light system of colours in line with the following:

Use the following colour scheme to record recommendations:

Green – suggestion for improved / good practice but which is unlikely to change the project outcomes.

Amber – non-standard method or method not following guidance but unlikely to have impacted on results

Red – omission that could make the findings subject to challenge and which requires correction/further work

2 Summary of modelling and analysis

Modeller's summary of modelling undertaken:

A wave model has been constructed for the Aberdeenshire and Angus coastline on the east coast of Scotland, specifically Stonehaven Bay with mesh spacing between 4,000m offshore and 7.5m in nearshore areas of interest. The wave model is designed to transform a 10,000 year offshore multivariate event dataset (Not available at the time of calibration). This data is based on WaveWatch III wave data from point 2664 and wind data from point 2625 along with historic water levels from Aberdeen. The modelled nearshore waves will be used, in conjunction with emulator functions to provide inputs into overtopping calculations to compute defensive overtopping rates.

Due to the limited number of high wave events available in the recorded period only calibration of the model has been undertaken for a limited date range (2016-17) within Stonehaven Bay . Validation of the modelling suite as a whole (i.e. waves, overtopping and inundation) will be performed during the EurOtop and TUFLOW model developments.

3 Modeller checks

Modeller to provide summary of their own checking routines and audit trail	**The model inputs and outputs have been checked as each stage during the model development process.**
Modeller to state why they believe that the results are reasonable and fit for purpose (e.g. validation results, historical evidence, sensitivity testing)	**The model is deemed fit for purpose as the results have been compared to three geographically independent time series of wave buoy observations and lie within accepted RMSE error scores. Additionally, the complete modelling suite (waves, overtopping, inundation) will be validated against recorded flood history, where available.**
Modeller to provide link to any related process documents or spreadsheets	N:\2018\Projects\2018s0343 - Dougall Baillie Associates - Stonehaven Bay Coastal FPS\AKI-HM\Non-graphical\00\AKI-JBAU-00-00-M2-HM-0006-S0-P01.01-SWAN_Modelling

4 Wave model set-up

This modelling has been performed with SWAN v41.01A.

4.1 Modelling overview

This modelling has required the construction of a SWAN mesh from Montrose to Aberdeen. The modelling relies on forcing conditions obtained from WW3 points 2664 (boundary wave conditions) and 2625 (wind field conditions). The SWAN model will transform the offshore conditions to 6-10 overtopping cross sections (locations TBC) in the nearshore of Stonehaven Bay and Harbour.

4.2 Boundary conditions

Offshore boundary conditions for the FFS will be provided by two WaveWatch III (WWIII) points (2664, wave, and 2625, wind). This data is obtained from a course grid wave transformation model run by the Met Office and forced by atmospheric conditions: outputs exists for 37 years. WWIII data will be input into the SWAN model and transformed to the nearshore toes for use in the calibration of overtopping models and the wave model itself.

As part of the development of the MV dataset, RHDHV/HR Wallingford recommended that bias corrections be applied to the WWIII data based on comparative analysis at the CEFAS Wavenet buoys and an uplift on offshore wave heights at WaveWatch output 2664 to agree with observed data using the formula and constants displayed below. Tp was also modified to maintain steepness with hindcast WW3 conditions.

$$H_{s,corr} = a\, H_{s,model}^{b}$$

Point ID	Model	*a*	*b*
P2	Aberdeenshire	1.051	1.081

Given the location of the available wave observations, calibration will be performed with forcing from 2664, using U10 and V10 wind parameters from WWIII location 2625. Following the calibration of the model domain for the AnAc FFS a single uniform boundary was applied along the offshore boundary.

Although point 2664 lies beyond the model boundary it is still the most applicable WWIII multivariate dataset for use within the model domain with point 2510 approximately 30 km to the south of the domain. A wave height from 2664 is considered to have minimal change along the model boundary and appropriate for use within the model.

The model used four boundary nodestrings, one for the northern, one for the eastern and two for the southern boundaries. The northern boundary was set to vary from no wave inshore to full height waves 4Km offshore. At the south the boundary varied from full height to 0 over 5.5km. for the remainder of the southern boundary, a full height wave was applied. It was found through sensitivity testing that an application of a single variable wave boundary at the south caused an instability in Hs application associated with a reversal of node string direction. Subsequently two node strings were used

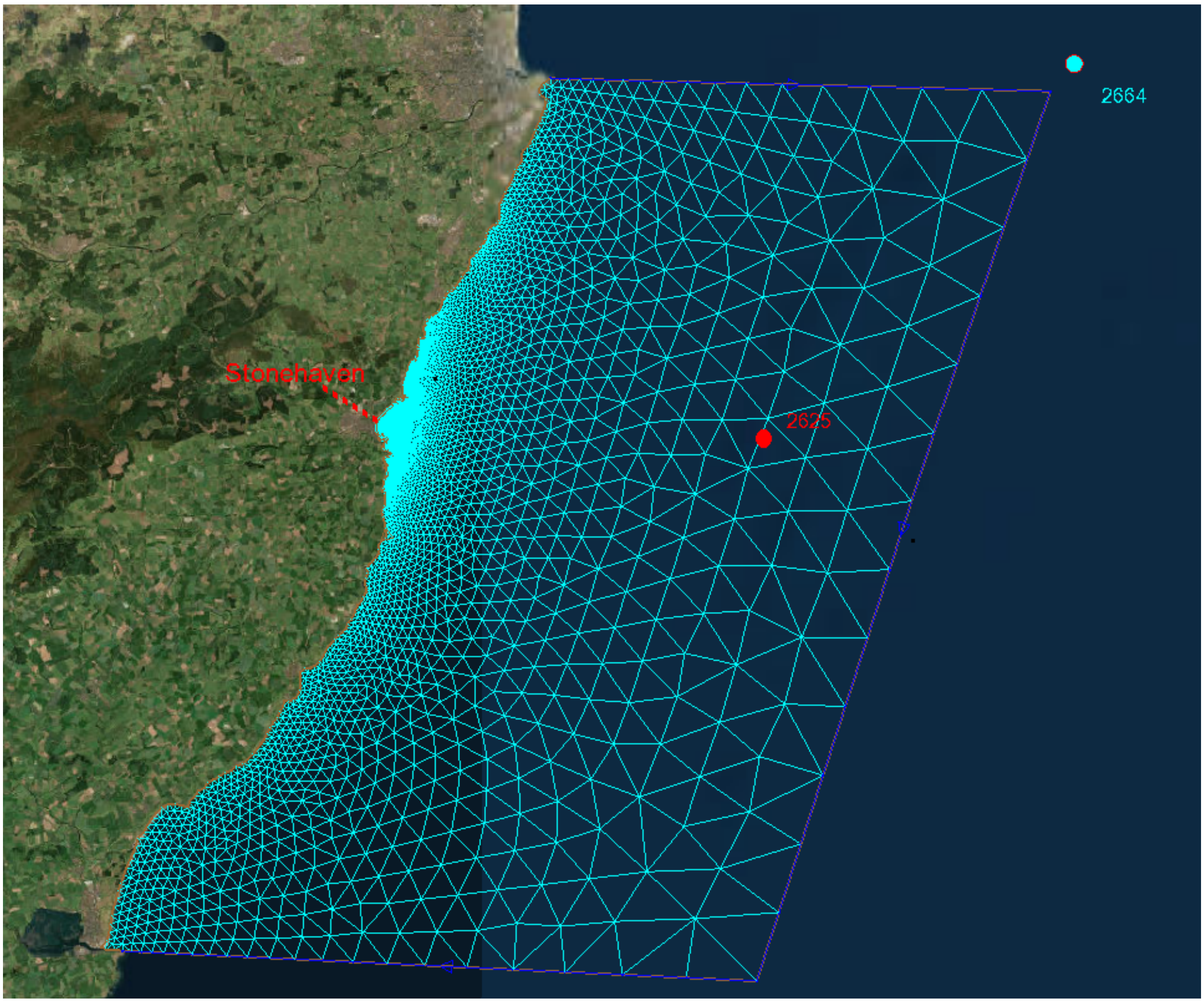


Figure 4-1: Location of WW3 locations in the vicinity of the AnAc FFS model domain. Image obtained from RHDHV/HR Wallingford

Project: 2018s0343 –Stonehaven FPS – Wave model
Filename: AKI-JBAU-00-00-AU-HM-0001-S2-P01.01
Modeller/Analyst: Johnny Coyle
Independent Reviewer: Fay Fishford
Project Manager/Team Leader: Nicola Buckley

4.3 Bathymetry

The offshore bathymetry was obtained from Oceanwise via SEPA. The data was obtained in Chart datum (CD) and transformed to mAOD. This bathymetry covered the entire shoreline with greater definition around ports. Whilst this bathymetry was used in 17-20m raster format as this dataset has high resolution offshore data, supplemented with nearshore bathymetry contours, extracted from charts.

This Oceanwise Data was used as a base condition for the DTM with additional data supplementing the nearshore. These datasets were overlaid in the following order:

- SEPA Phase 2 1m LiDAR (without Stonehaven Harbour)
- Stonehaven Topographic Survey, 2013
- Stonehaven Terrestrial Laser Scan (TLS), 2018

The oceanwise data available varied in format from the datasets used in the origional model. The bathymetry dataset extends to approximately 2.0-2.5mAOD where it plateaued, representing topographical features. These areas were largely covered by terrestrerial datasets and where these datasets intersect preference was given for terresterial datasets due to the higher accuracy and point resolution of data. The datasets were found to agree relativley well seaward of the shoreline.

The terrestrial datasets were found to agree well with coverages varying depending on the time of survey (relative to Low Water). For the LiDAR dataset the representation of the water surface was removed.

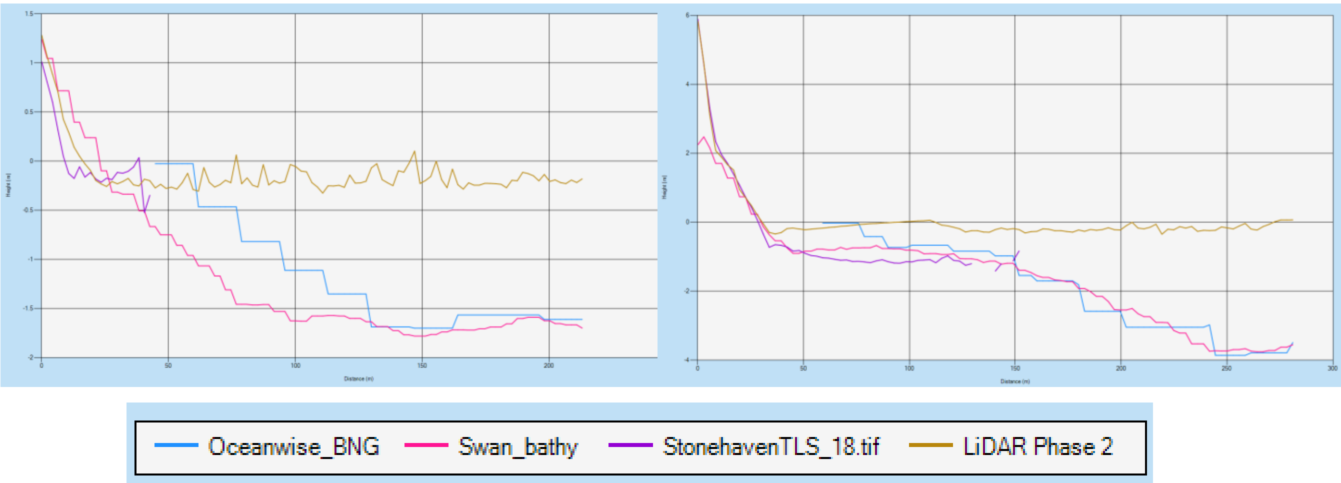


Figure 4-2: Terrestrial Data DTM comparison at Cowie, left and Beachgate Lane, Right

The Terrestrial Datasets do not agree with the Oceanwise datasets in the nearshore, this is most likely due to the low quality of source data in the nearshore (Chart Contours). To address this, Oceanwise data that did not agree with topography or known features within Stonehaven bay was cleaned, allowing smooth integration between datasets.

Bathymetry datasets can be found within the ArcGIS project AKI-JBAU-00-00-M2-HM-0003-S0-p01-Swan_data_review which can be found here

N:\2018\Projects\2018s0343 - Dougall Baillie Associates - Stonehaven Bay Coastal FPS\AKI-HM\Graphical\00\M2\Projects

4.3.1 Toe depths

Ten cross-sections were schematised within Stonehaven Bay from Cowie in the north to the harbour at the south, as can be seen in **Error! Reference source not found.** with cross-sections SG_H_01 in the inner harbour and SH_H_02 to the south of the inner harbour. The toe depths were adapted to match SWAN Bathymetry and the appropriate node for extraction identified. These can be seen in Table 4-1 below with the schematisations seen here in the workbook " 2018s0343-JBA_EurOtopII_calculation2.xlsx"

WAVE TRANSFORMATION QA LOG

Project: 2018s0343 –Stonehaven FPS – Wave model
Filename: AKI-JBAU-00-00-AU-HM-0001-S2-P01.01
Modeller/Analyst: Johnny Coyle
Independent Reviewer: Fay Fishford
Project Manager/Team Leader: Nicola Buckley

N:\2018\Projects\2018s0343 - Dougall Baillie Associates - Stonehaven Bay Coastal FPS\AKI-HM\Non-graphical\00\AKI-JBAU-00-00-M2-HM-0009-S0-P01.01-Wave_Overtopping

Table 4-1: Overtopping crossections and SWAN Nodes

Profile	OT_Prof_ID	Toe_Depth	Node_Id	X	Y	Z	Difference
SH29	1	0	7819	387896.1	785576.5	0.00	0.00
SH28	2	-0.74	7294	387799.2	785732.2	0.75	0.01
SH25	3	1.25	6562	387604.7	785694.3	-1.18	0.07
SH20	4	0.2	6055	387568	785941.2	-0.26	-0.06
SH17	5	-0.3	5700	387571.8	786073.2	0.31	0.01
SH12	6	1.5	4271	387627.7	786371.2	-1.54	-0.04
SH06	7	1.47	3424	387911.7	786656.5	-1.49	-0.02
SH02	8	1.59	3438	387988.9	786740.9	-1.62	-0.03
SH_H_01	9	0.89	8839	387707.8	785429.2	-0.91	-0.02
SH_H_02	10	1.5	9065	387793	785246.5	-1.51	-0.01

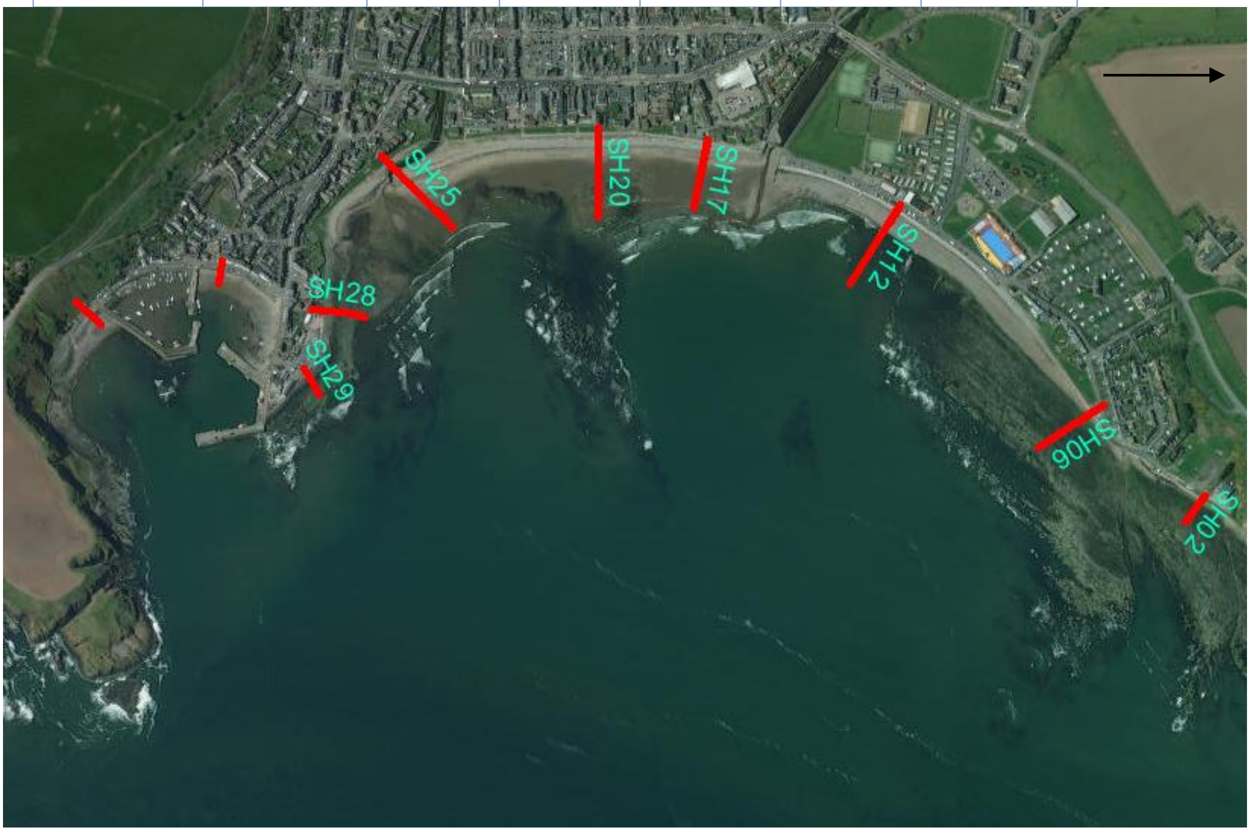
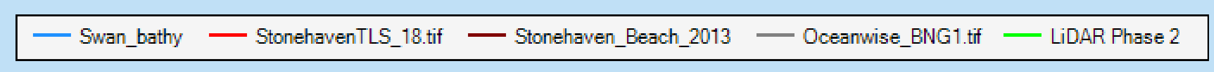
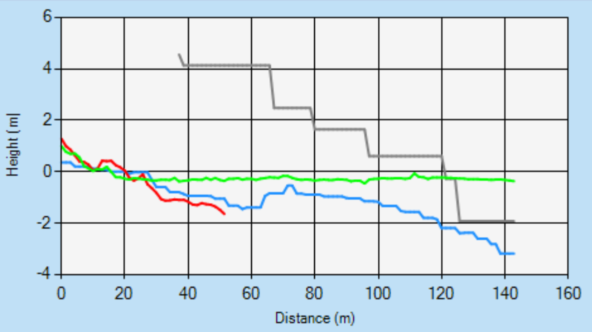
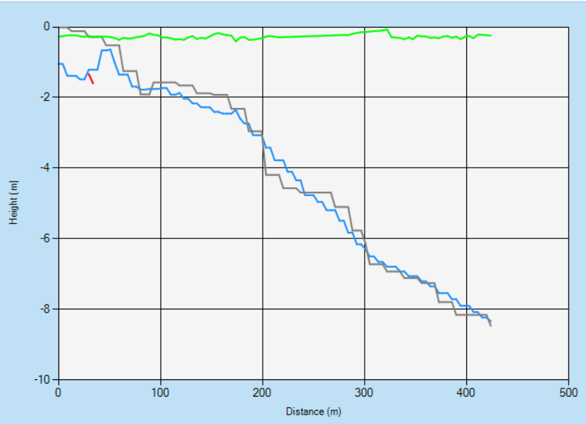
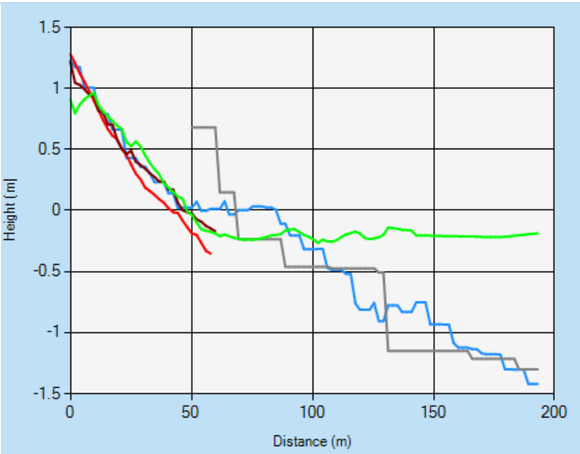


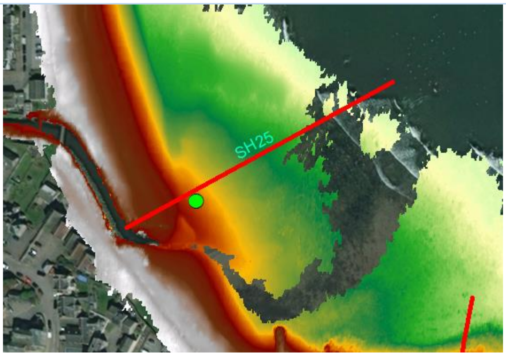
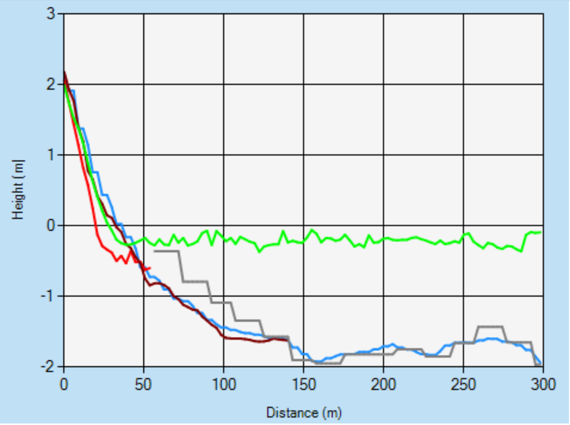
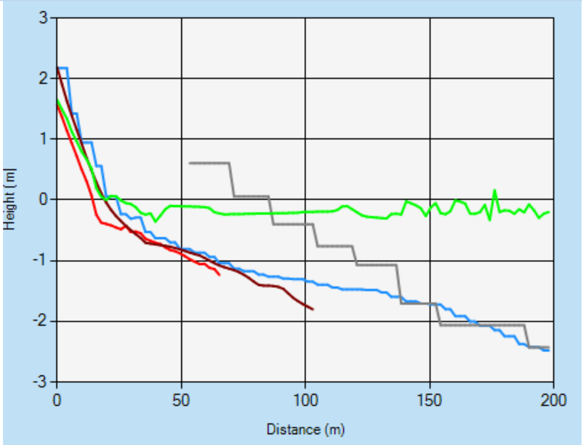
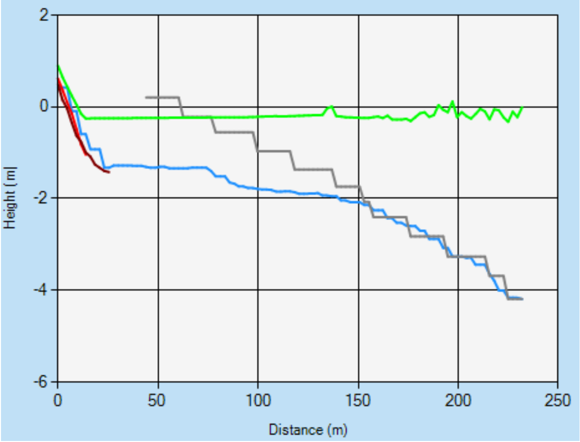
Figure 4-3: Overtopping crossections within Stonehaven Bay

4.3.2 Bathymetry seaward of toes

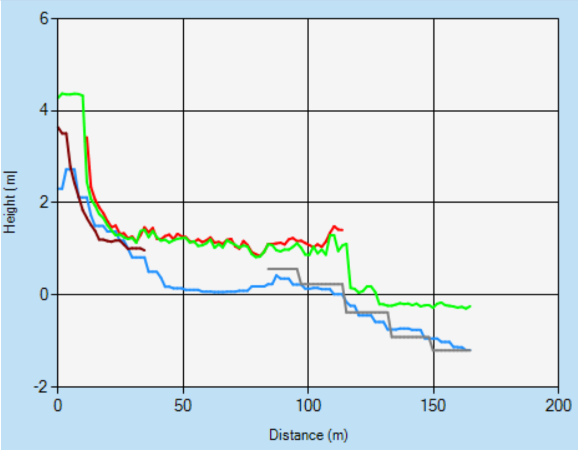
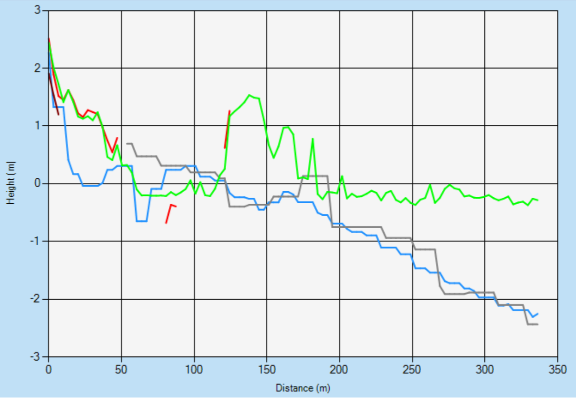
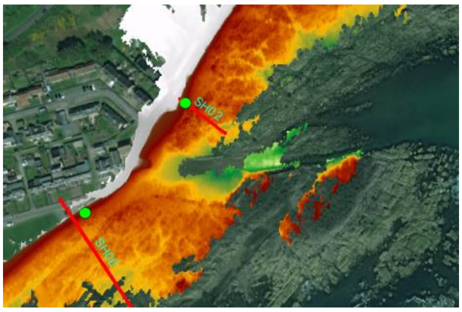
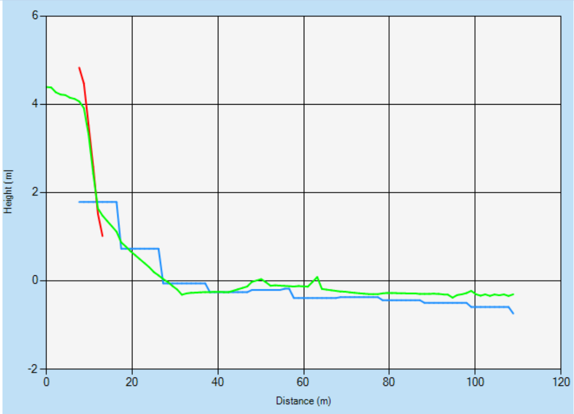
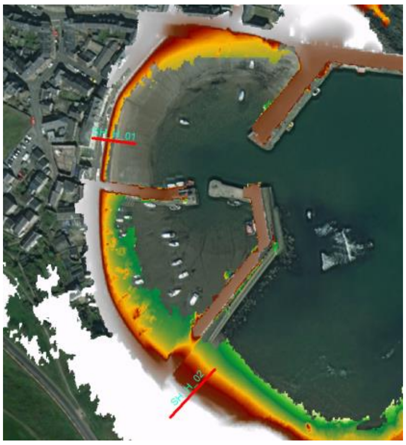
Output profile	Crossections	Comments
		
SH29		Mesh is seen to be appropriate and follows TLS scan of rock armour closely. Beyond this dataset extent there is a slight increase in meshed elevation, due to interpolation techniques picking up high elevations close by. This is appropriate as there is a bathymetric feature offshore of the rock armour frontage.  
SH28		-
SH25		The mesh elevation deviates from the profile at 50-80m. this is due to patchy coverages of TLS in the nearshore that pulls the mesh elevations to higher elevations through interpolation. Mesh levels deemed appropiate. See below

WAVE TRANSFORMATION QA LOG

Project: 2018s0343 –Stonehaven FPS – Wave model
Filename: AKI-JBAU-00-00-AU-HM-0001-S2-P01.01
Modeller/Analyst: Johnny Coyle
Independent Reviewer: Fay Fishford
Project Manager/Team Leader: Nicola Buckley

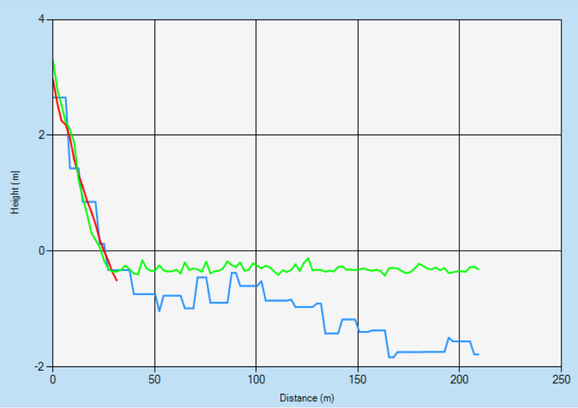
		
SH20		-
SH17		-
SH12		-

Project: 2018s0343 –Stonehaven FPS – Wave model
Filename: AKI-JBAU-00-00-AU-HM-0001-S2-P01.01
Modeller/Analyst: Johnny Coyle
Independent Reviewer: Fay Fishford
Project Manager/Team Leader: Nicola Buckley

SH06		Shoreplatform level ambigious here with scanned levels mixed with water surface. Emergent line of rock 50 offshore. Not extensive, omission considered appropiate
SH02		The feature offshore was identified as a rock outcrop within the mesh. This was removed from the mesh as it was small and did not extend across the defence.In the nearshore a small channel is evident in the nearshore and can be seen in the Swan DTM and below 
SH_H_01		Although this crossections is close to SH_H_02 it is in a distinctly different morphological setting and SH_H_01 is known to be relatively flat at the base of the harbour wall. See image below for location. 

WAVE TRANSFORMATION QA LOG

Project: 2018s0343 –Stonehaven FPS – Wave model
Filename: AKI-JBAU-00-00-AU-HM-0001-S2-P01.01
Modeller/Analyst: Johnny Coyle
Independent Reviewer: Fay Fishford
Project Manager/Team Leader: Nicola Buckley

SH_H_02		No oceanwise bathymetry is present within the harbour. The mesh elevations are interpolated from shoreline levels (extracted from TLS and LiDAR) and approximated charted depths.

Model mesh

The model mesh was generated in SMS to cover Stonehaven bay, extending to the appropriate distance offshore for the WW3 points, and far enough north/south to minimise boundary impacts. The model domain can be seen in Figure |4 SEQ Figure * ARABIC \s 1 |3.

All model data is in British national grid (BNG) coordinate system and meters Below Ordinance Datum (mBOD). Mesh resolution in the vicinity of the areas of interest range from 7 to 10m. The largest cell sizes were situated along the eastern and northern model boundary and were at approximately 4,000m spacing.

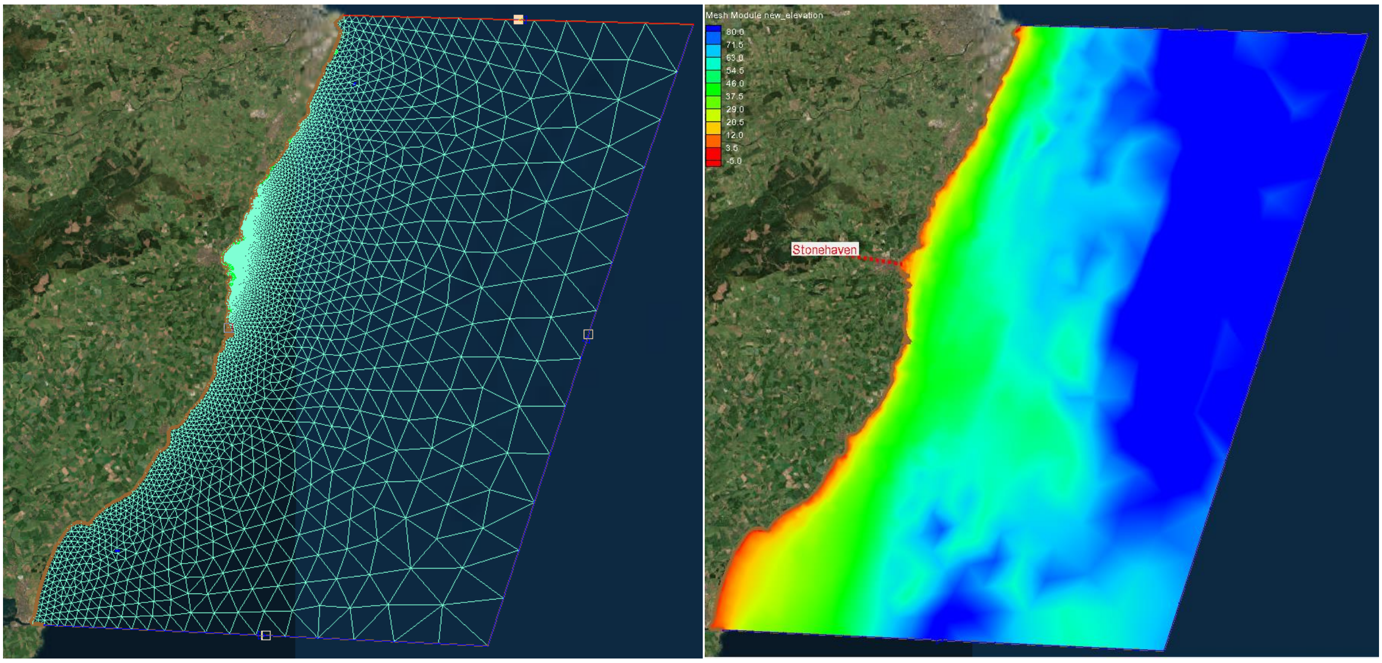


Figure : Model mesh (left) and bathymetry (right).

4.4 Harbour representation

Stonehaven Harbour was included within the mesh with the internal breakwaters removed. It is recognised that the phase averaging computatuional engine does not resolve well within confined, complex wave environments where non-linear wave processes become dominant. The desired output location within the Harbour can be seen in Figure 4-5 along with the representation of the outer breakwater (represented as a Obstical Line within Swan and the toe levels represented within the bathymetry). Figure 4-4 shows an aerial view of the harbour wall. Bathymetric features to the northwest can be seen that are included within the model mesh (Figure 4-5). Areas infront of the wall are known to be shallow and is corroborated by oceanwise (but not charts) and so a representation of the shallow water in the vicinity of the primary harbour wall was left in the mesh

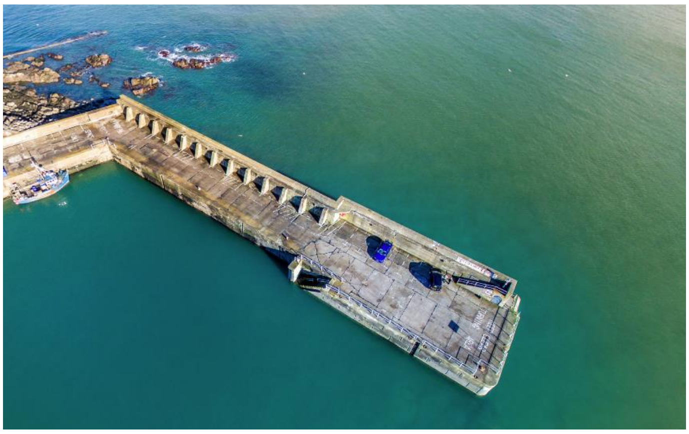


Figure 4-4: Stonehaven Harbour wall and representation within charts

Inner harbour walls were not represented within the mesh as these impact the convergence of the model. This is discussed further in section 0.

Bathymetry within the harbour did not well identify the bathymetric features present, whilst the harbour is relativly understood to be flat there was no representation of important features in the Oceanwise data (Channel, berths). These were incised into the mesh having been aproximated by available chart data in the vicinity of the tip of the harbour wall. These values were then interpolated to LiDAR values at the shoreline or locations where the Oceanwise appeared consistent with charted depths. The incison can also be seen in Figure 4-5: Harbour representation.

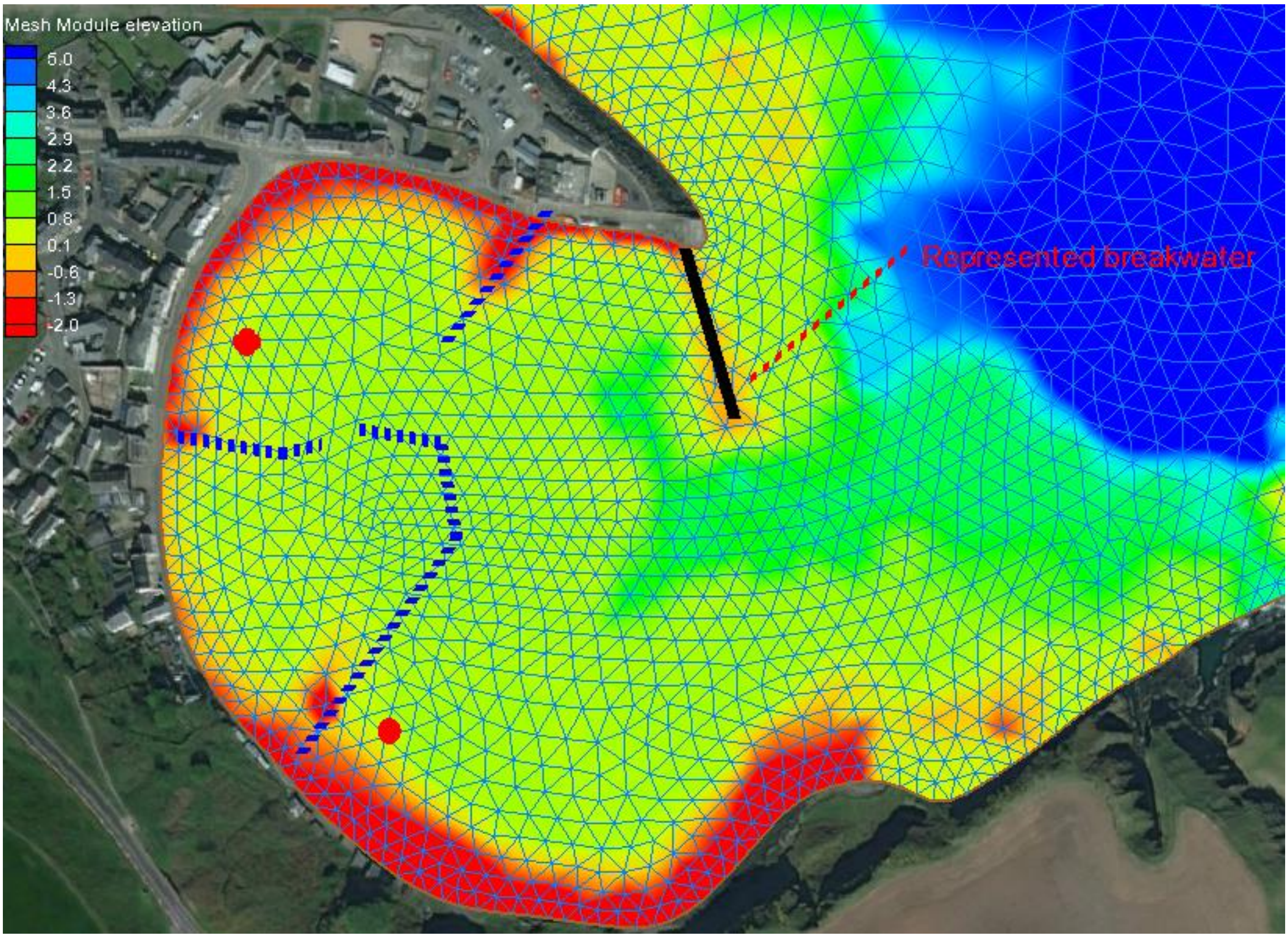


Figure 4-5: Harbour representation within the SWAN mesh. NB: only the main breakwater is represented

4.5 Mesh resolution: sensitivity testing

Mesh sensitivity testing was performed previously to ensure the required mesh resolution was sufficient to accurately model the wave transformation to the nearshore. This was done by generating a x4 mesh resolution. The refined mesh was found to have minimal impact on nearshore Hs within Stonehaven Bay producing a maximum of 5cm increase and an average bias of -0.01m in Hs for the five nearshore points assessed.

The refined mesh was found to cause a significant decrease in Hs for the toe location represented in Figure 4-5 of 0.17m. Due to the computational inaccuracies associated with SWAN and in particular wave breaking, coupled with observational experience of large waves in this section of the harbour, the existing model resolution of 10-15m within the harbour was further refined to replicate the energy dissipation of the refined mesh, as a result mesh resolution was refined to 7.5-10m in the area and 10-13m at the harbour entrance. This was deemed to have an adverse impact on the number of iterations required for model convergence, requiring approximately 120-130 iterations for convergence of north easterly events (all other directions converged between 70-100 iterations). This was deemed acceptable to produce the best possible iterations of nearshore wave heights within the harbour. Model run times remained under six minutes.

Additional refinement was performed, reducing mesh point spacing to 5m. this iteration of the mesh caused convergence to plateau at 95□ and so was abandoned.

4.6 Frequency discretisation

Frequency was discretised into 29 frequencies between 0.04 and 1Hz: corresponding to periods between 1 and 25 seconds, which covers the range of periods expected from wind and swell waves.

4.7 Water level transformations

Given the variation in extreme water level along the coast, variable water level grids were required for every SWAN run. To achieve this a water level equation was generated by fitting a function to the 1 in 50 year return period water levels from the Coastal Flood Boundary Dataset (CFBD) using the northing coordinate and based on the distance from Aberdeen (where the SWL forecast will be received when operational). This fitting and equation can be seen in Figure 4-6.

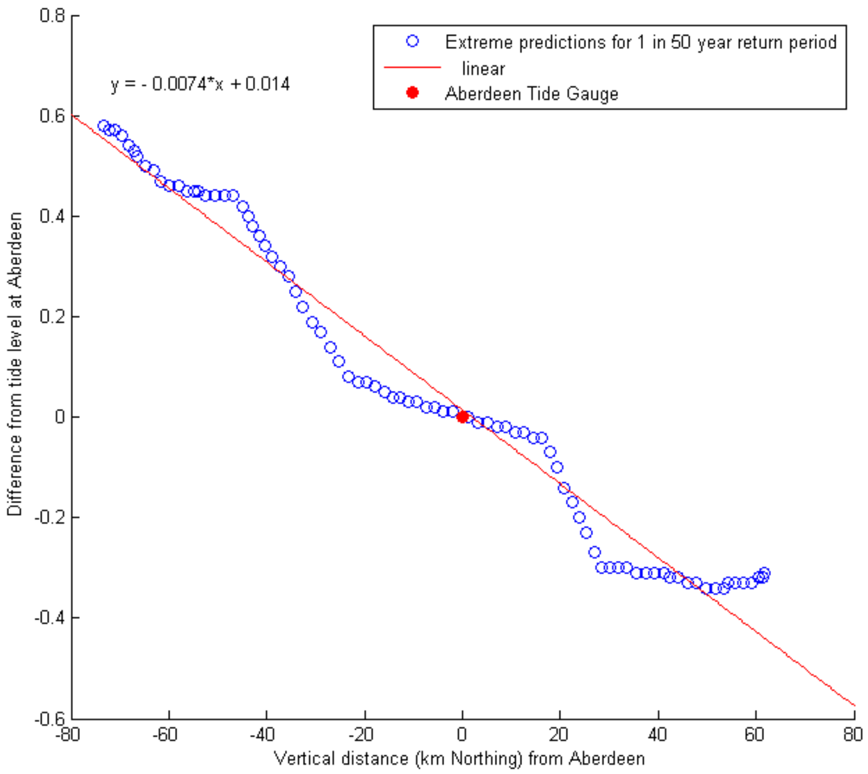


Figure 4-6: Extreme still water level equation for the model domain, based on Northing change relative to Aberdeen

This method of water level grid generation was also used in the FFS system wave model and the coastal flood mapping. It has been found to be appropriate for locations along the coastline

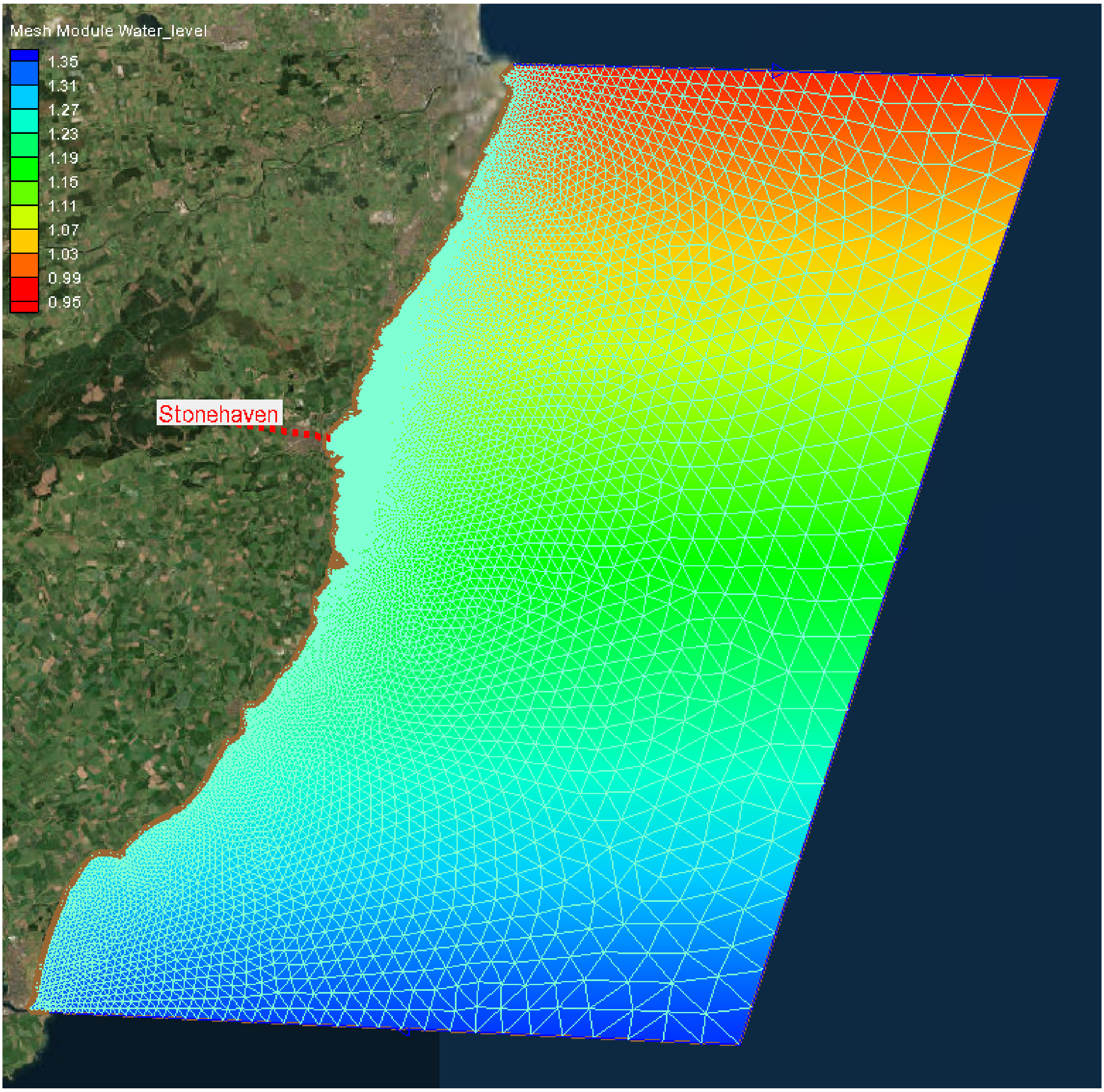


Figure 4-7: Extreme still water level equation for the model domain, based on Northing change relative to Aberdeen

5 Model calibration

For hindcast data the wave model was run using the uplift parameters specified in section 4.2 for Hs, Tp was also scaled using the input wave steepness to ensure relative boundary conditions. Water levels from Aberdeen were used and a variable water level grid generated for the domain.

Diffraction and Triads were computed throughout the wave field. These were considered to be a requirement of the final model to better represent conditions in the lee of Stonehaven harbour breakwater and so were included in computations, although a sensitivity test on the impact of diffraction was undertaken.

5.1 Wind and friction models

Although previous SWAN models have been developed in the area but due to the difference in setup, it was necessary to calibrate the SWAN model to identify the most appropriate model setup. Eight calibration events were selected from the Stonehaven Waverider placed in 2016/17 and used to inform model calibration the location of this buoy can be seen in Figure 5-3. Events 1-4 were used in the calibration of AnAc FFS and Coastal Mapping Swan models. These eight events were selected due to the large Hs observed but also the varying wave directions and a degree of independence (24 hours). These events can be seen in Table 5-1 below.

Table 5-1: Calibration events used and observed wave parameters

		Stonehaven Waverider (2016-2017)		
Event	**Date/time**	*Hs (m)*	*Tp(s)*	*fpdir*
1	**15/10/2016 10:00**	4.62	10.2	91.9
2	**09/11/2016 10:00**	2.93	8.3	111.5
3	**14/10/2016 18:00**	4.33	10.3	94.4
4	**22/11/2016 08:00**	3.43	9.1	87.0
5	**07/02/2017 15:30**	5.01	11.2	100.2
6	**31/01/2017 15:30**	4.18	9.8	136.4
7	**03/02/2017 06:00**	3.51	9.0	131.5
8	**06/03/2017 20:00**	3.24	10.8	87.5

5.1.1 Results of friction and physics calibration

The previous wave transformation models in the area were found to calibrate well to Komen wind growth and JONSWAP friction models, with whitecapping deactivated, or uplift applied to the boundaries, as specified in section 4.2. These model setups could not be directly inferred to this model, subsequently a calibration exercise was undertaken to identify the most appropriate setup for accurate wave transformation modelling within Stonehaven Bay (compared to observed conditions in 2016-17).

The resulting model wave heights for initial calibration (wind growth and friction models) and buoy observations at Stonehaven are plotted in Figure 5-1. The wave model under predicted Hs for four of the eight runs.

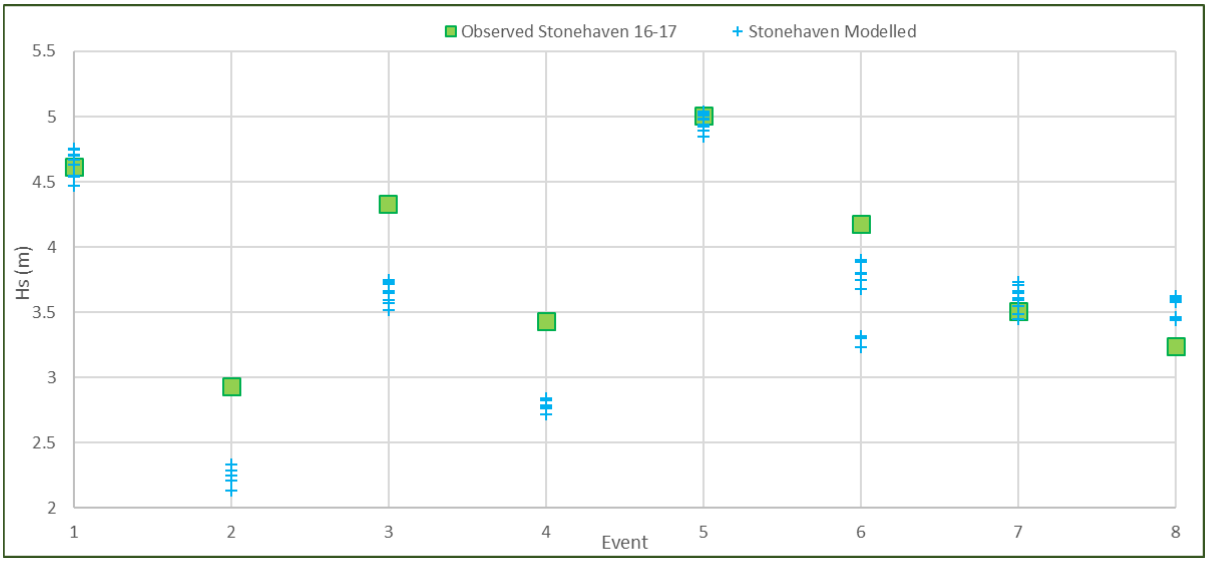


Figure 5-1: Model wave heights plotted against wave buoys at Stonehaven for eight calibration events,

This iteration of wave model setup used an uplifted Hs, as specified above, as well as a Tp input scaled to Hs by steepness. No further modification was made to the model inputs. This produced a best performing model setup of Komen wind growth and Collins friction models Table 5-3, with the lowest RMSE for Hs of 14.76□. For the four underpredicted events the model drastically underpredicted Hs and so it was decided to increase the energy input into the model.

Table 5-2: Calibration results for eight events

		Stonehaven Waverider		
		RMSE Hs (%)	RMSE Tp (%)	Dir RMSE score
JANS	*JSWP*	18.35%	9.79%	10.9
JANS	*Coll*	19.15%	9.82%	11.8
JANS	*Mads*	19.88%	9.73%	10.7
Kom	*JSWP*	14.87%	9.83%	10.0
Kom	*Coll*	14.76%	9.82%	9.9
Kom	*Mads*	16.44%	9.75%	9.8
Westh	*JSWP*	16.46%	9.55%	9.4
Westh	*Coll*	16.44%	9.56%	9.4

Despite the acceptable RMSE scores of the model setup specified above, wave heights at the Stonehaven wave buoy were consistently lower than observed. Consiquently an additional calibration exercise was undertaken to assess the impact of an uplifted windspeed input on wave conditions. The results of this analysis can be seen in Figure 5-2.

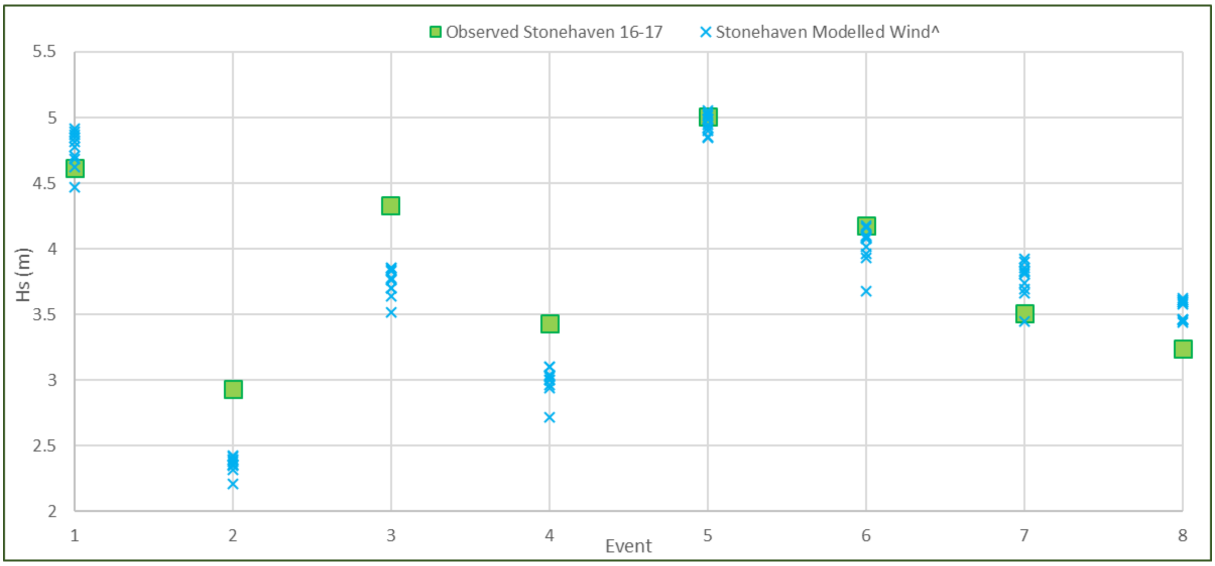


Figure 5-2: Model wave heights plotted against wave buoys at Stonehaven for eight calibration events, for predicted wind +20%

The uplift on windspeed can be seen to increase wave heights for all events, increasing the modelled error for events 1 and 8, which were previously marginally overpredicted. It also allowed events 5 and 7 to be accurately predicted and reduced the bias for the remaining four under-predicted events. Table 5-3 shows the results of the iteration of this model setup. The increased windspeed decreased the RMSE score for direction for all iterations. The setup with uplifted windspeed improved the RMSE percentages for Hs and Tp all setups, with the best improvement in RMSE for Hs observed for the Janssen, Collins setup. This setup however did not perform as well for Tp and Direction with comparatively high Tp and Directional error scores. The best performing setup from the previous setup (Komen and Collins) had the next lowest error score for Hs with considerably better scores for Tp and Direction. This setup was therefore brought forward as the best performing setup.

Table 5-3: Calibration results for eight events with uplifted wind forcing

		Stonehaven Waverider		
		RMSE Hs (%)	RMSE Tp (%)	Dir RMSE Score
JANS	*JSWP*	12.62%	9.90%	9.83
JANS	*Coll*	12.38%	9.90%	9.81
JANS	*Mads*	13.04%	9.81%	9.76
Kom	*JSWP*	13.08%	9.82%	9.31
Kom	*Coll*	12.78%	9.82%	9.30
Kom	*Mads*	13.18%	9.73%	9.22
Westh	*JSWP*	13.57%	9.53%	9.26
Westh	*Coll*	13.40%	9.53%	9.25

5.2 Model sensitivity at toe locations

5.2.1 Sensitivity to parameter selection:

The impact of wave growth and energy dissipation scheme parameter selection on wave heights was assessed in the nearshore of Stonehaven Bay and Harbour (locations shown in Figure 5-3). As the actual toe extraction points were not available, representative nodes were used in the nearshore. The selection of wave growth and energy dissipation scheme parameter was found to have an impact on modelled Hs, generating an average variance of 0.093m for Hs at the four nearshore locations (with a maximum of 0.35m).

Figure 5-3: Nearshore toes used for analysis in leu of final toe depths along with the wave buoy location

This small deviation of wave characteristics at the toe of defences highlights a moderate sensitivity to wave growth and energy dissipation schemes within the nearshore of Stonehaven Bay.

5.2.2 Sensitivity to diffraction:

The model was found to be not sensitive to diffraction with minimal variation (max 0.025m variation in Hs within the harbour for a north easterly event) observed in output at the nearshore toes assessed. Despite this minimal variation in toe wave heights for the event used to assess the impact of diffraction, large variance in Hs was noted adjacent to the output nodes within the harbour (of up to 10cm, 50-100 of the maximum Hs in the harbour). The mesh, particularly within the harbour was found to be sensitive to diffraction and remained on for model runs.

5.2.3 Sensitivity to harbour representation:

The additional two harbour walls within Stonehaven Bay were included within the mesh as a sensitivity test. As anticipated their inclusion impacted model run times, requiring an additional 21 iterations to converge to 99□. The inclusion of these breakwaters (with a reflection coefficient of 0, no reflection). within a refined harbour caused significant decrease in the areas in their lee, while causing a slight increase in Hs adjacent to the breakwater placement. These additional breakwaters were deemed to be too have too great an impact on the number of model iterations required for satisfactory model convergence with relatively limited impact on output locations. They were subsequently identified as a surplus feature within the model and omitted from the domain.

6 Selected set-up

6.1 SWAN wave model setup

The finalised model set up uses the Komen wind growth model and Collins friction model, with an uplift of 20 on input wind speed. This has been found to be the best performing model setup based on the results of the calibration and the calibration factors for boundary wave conditions, advised by RHDHV. While previous SWAN models within the area required the deactivation of whitecapping within the domain, the bias corrections applied to wave spectra at the boundary and winds across the domain produce sufficiently low RMSE scores for model calibration.

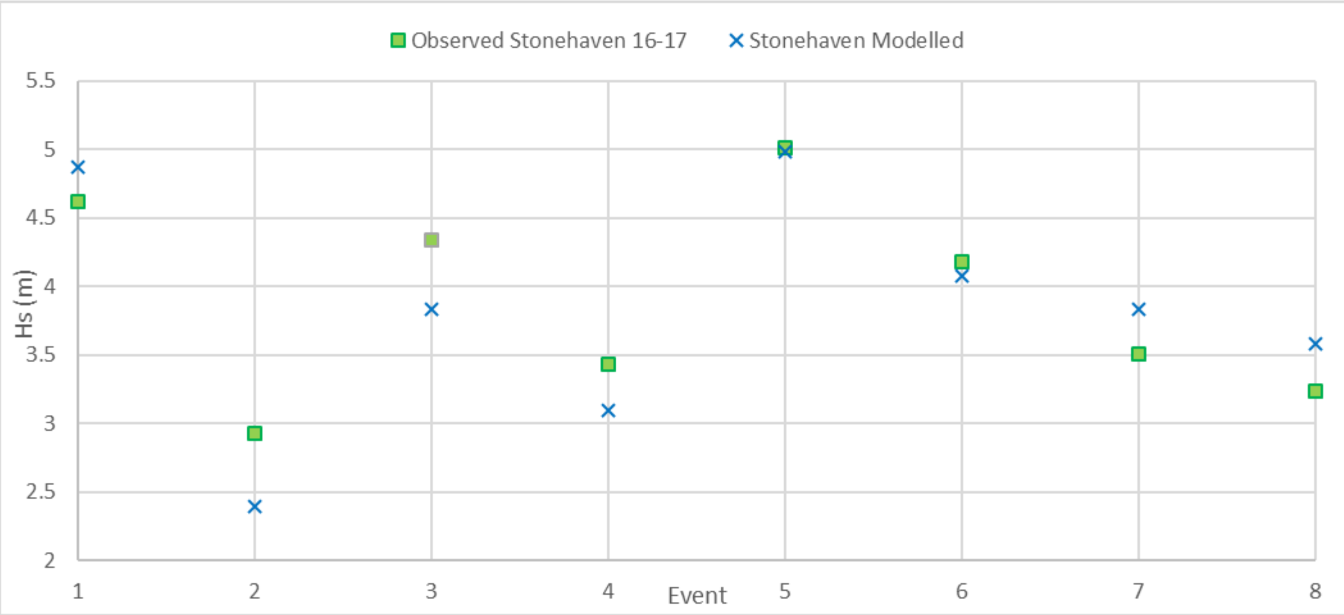


Figure 6-1: Modelled vs Observational Hs for final model set up

6.2 Reality checks on wave propagation and dissipation

The spatial variation of the wave fields was sense checked using the eight calibration events described in Table 5-1. These checks showed that the model produces realistic variations in the wave fields in accordance with the underlying bathymetry. An example of the output wave fields for Hs, direction and TM10 (the output variables that will be used in the overtopping modelling) are shown below along with the representation of the harbour wall (obstacle) on Hs.

The bathymetric feature in the centre of the bay Is clearly visible in Figure 6-2 and Figure 6-3, causing convergence of incoming waves by +/- 30 degree and a decline in Hs as the waves shoal and break. This is deemed appropriate

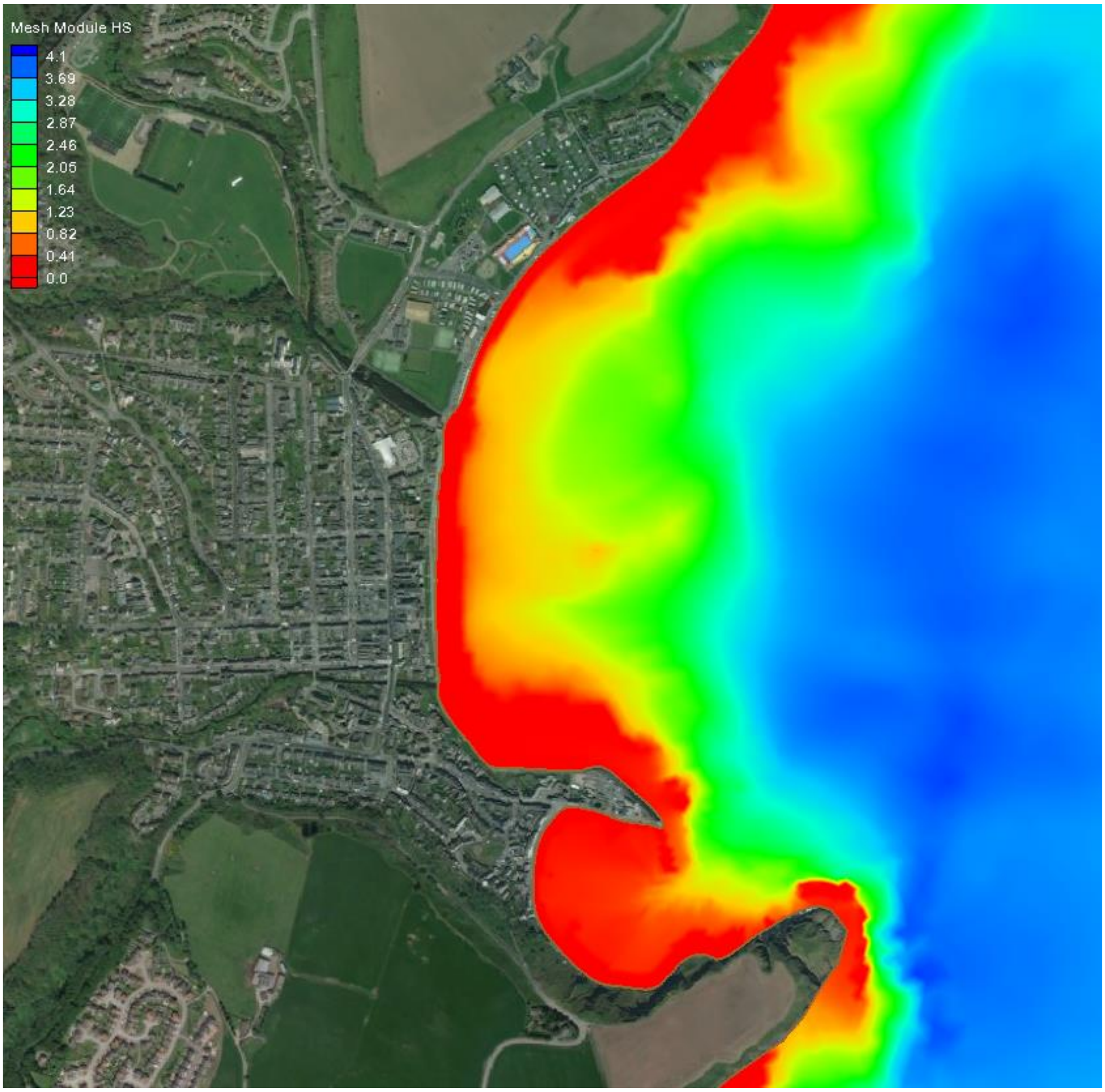


Figure 6-2: Wave heights in Stonehaven for calibration event 8

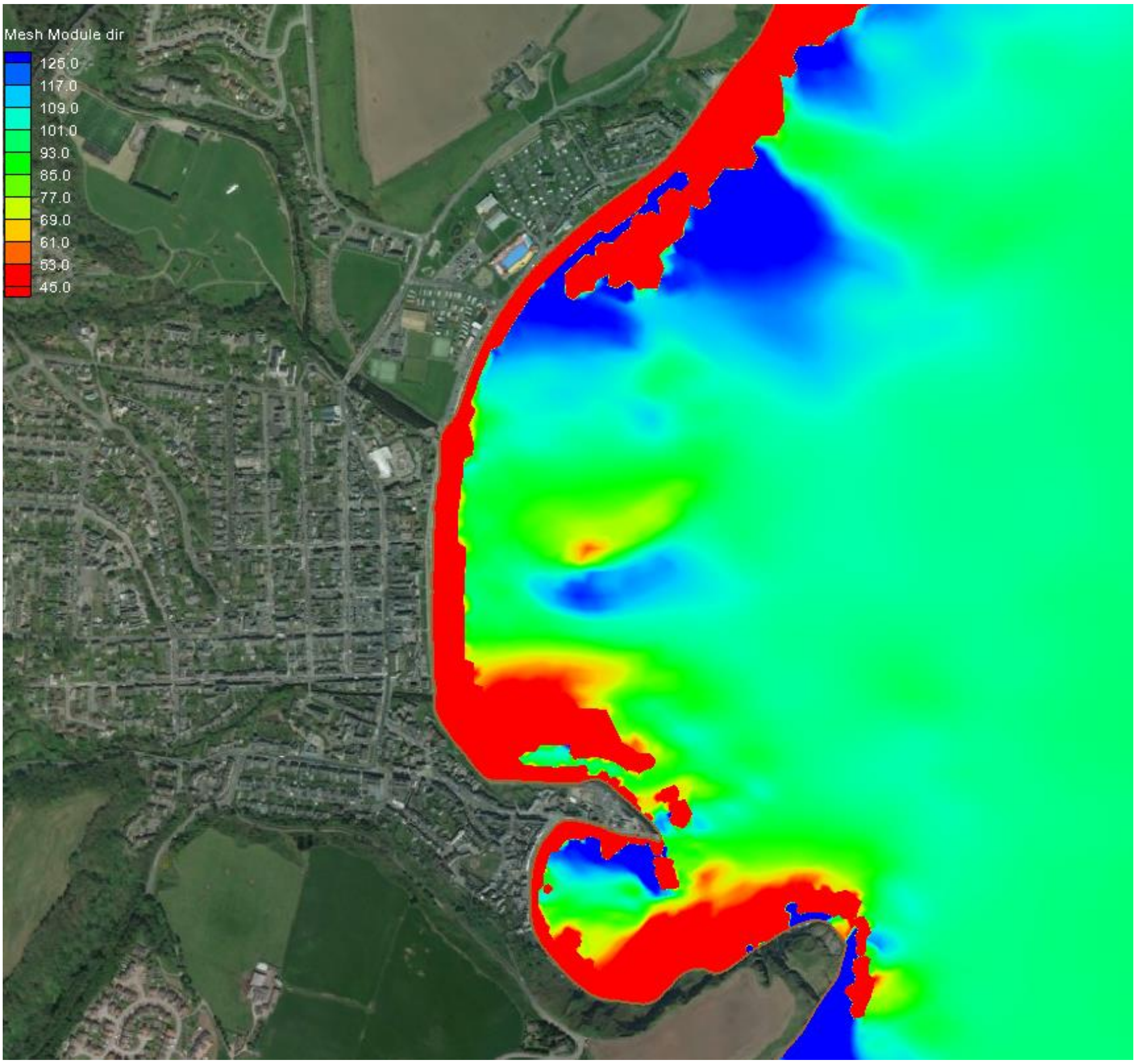


Figure 6-3: Wave direction across the domain for validation event 8

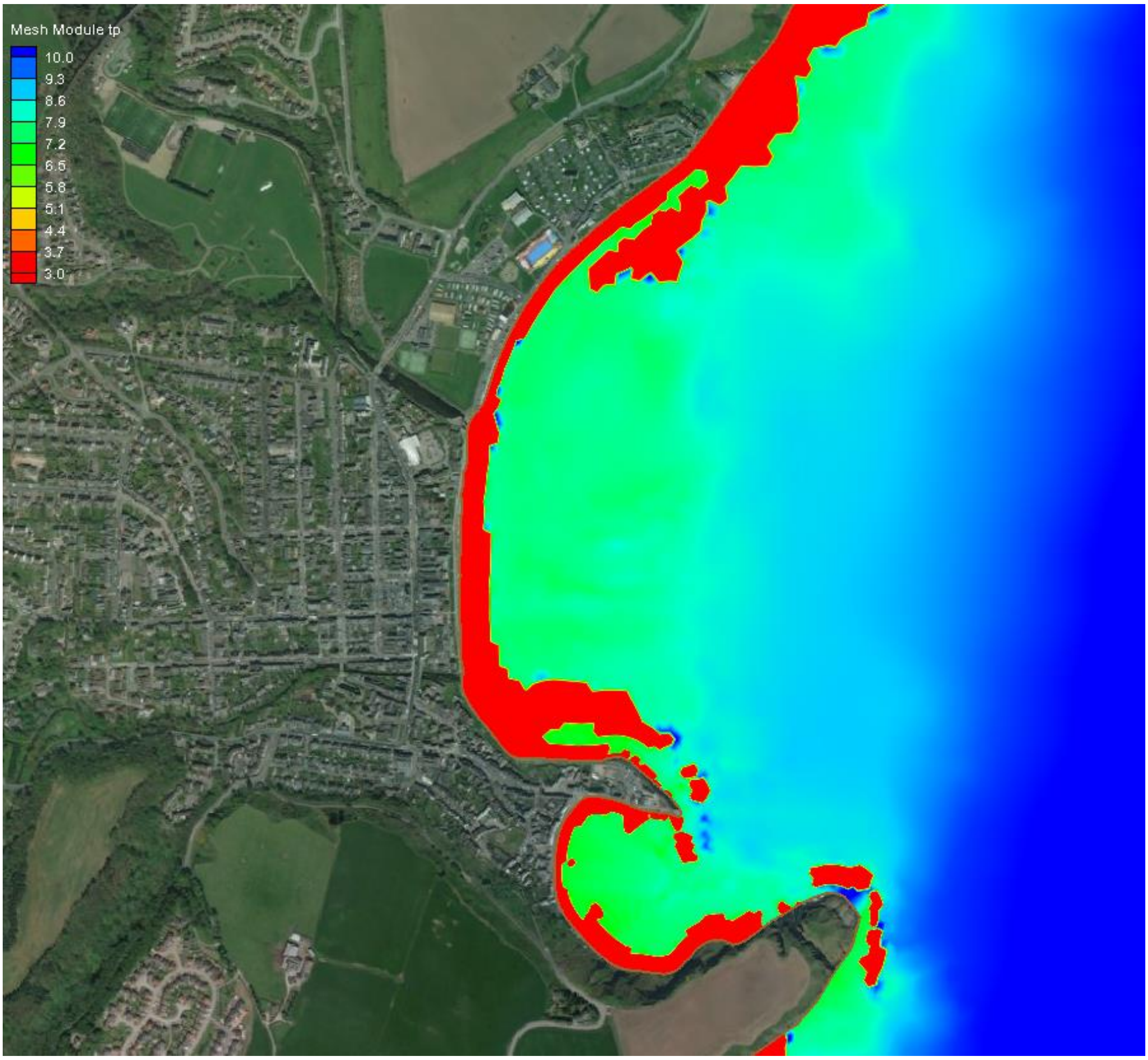


Figure 6-4: Wave period at Stonehaven for validation event 8

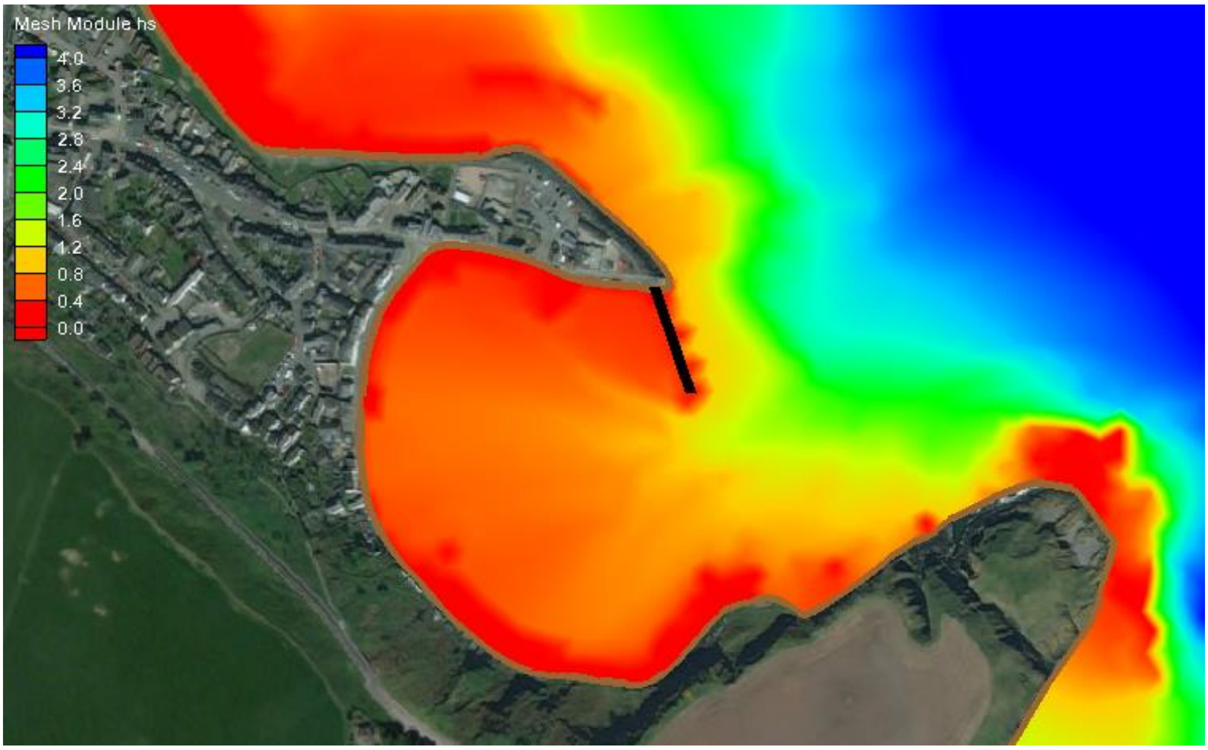


Figure 6-5: Representation of breakwater at Stonehaven Harbour for Hs during event 1

WAVE TRANSFORMATION QA LOG

Project: 2018s0343 –Stonehaven FPS – Wave model
Filename: AKI-JBAU-00-00-AU-HM-0001-S2-P01.01
Modeller/Analyst: Johnny Coyle
Independent Reviewer: Fay Fishford
Project Manager/Team Leader: Nicola Buckley

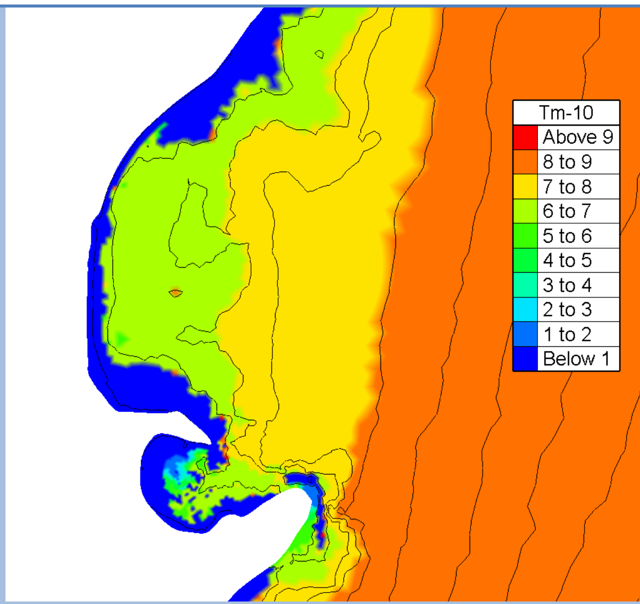
Summary of independent model review

Model Choice	
Does model fit brief (Stationary or non-stationary model required)	**Stationary model suitable for extremes analysis and to create a look-up table.**
Domain	
Does the boundary cover offshore waves from all relevant directions	**Yes**
Does the coastline file represent the coastline to a high enough resolution for the modelling required	**Yes, the coastline around Stonehaven is appropriately represented.**
Are all required output locations offshore of the chosen coastline	**Yes, mesh nodes have been used as the output points.**
Does the model domain extend far enough offshore that computational error close to the model boundary will not affect required results	**Yes**
Does the model domain extend far enough offshore so that wave boundary conditions are accurate for the model boundary	**Yes**
Active and Inactive Boundaries	
Are ocean and land boundaries set	**Yes**
Is the spectral shape to be applied to the ocean boundary appropriate given the geographic location and the boundary conditions available	**Yes, the JONSWAP spectrum being used, which was developed for waves in the North Sea and study site is in the North Sea.**
Bathymetry	
Is the input bathymetry of a high enough resolution for model resolution required	**Yes**
Are bathymetry data available for areas which may dry out at low tide	**Yes**
Are boundaries between different bathymetry data sets smooth	**Yes, but see comment below regarding selected bathymetry dataset.**
Does the model mesh/grid represent the input bathymetry well	**Yes, based on the figures supplied.**
Are bathymetric features close to output locations well represented	**Please update the mesh bathymetry around SH29, SH25, SH02 and SH_H_01. In these locations the mesh bathymetry does not reflect the best bathymetry dataset. Please see the notes in the text.**
Are bathymetric features elsewhere within the model domain well represented if they are expected to alter wave propagation (e.g. offshore sand banks)	**Mesh checked against original Oceanwise bathymetry. Bathymetry suitably represented for wave transformation modelling.**
Water Level	
If model water level has been set constant across the model domain is this a realistic assumption given tidal behaviour across the model domain	**A variable water level grid has been used based on extreme water levels.**

For non-stationary models has underlying tide /surge behaviour been taken into consideration If not is this justifiable	**NA**
If model wind speed and direction has been set constant across the model domain is this realistic	**Yes, the model domain is small compared to low pressure systems.**
Are there any data sets available which could be used to construct a spatially varying wind field	**Not required**
For non-stationary models has an appropriate data set been identified to cover the required model time period	**NA**
Wave Boundary Conditions	
If modelled, wave boundary conditions should come from the same model data source as wind data otherwise there may be inconsistency between the two.	**WWIII data used for wind and waves.**
Is enough information available to generate a wave spectrum	**JONSWAP spectrum has been used, most appropriate as simulating statistical events.**
For non-stationary models has an appropriate data set been identified to cover the required model time period	**NA**
Output Requirements	
Model behaviour checked through output of Hs, Tp, Mdir fields for the entire model domain.	Yes
Water depth at output points checked against real depth (interpolation / lower resolution may result in differing water depth which in shallow water can results in significant change to wave height).	**Table 4.1 shows the differences between the desired and selected toe depths are less than 0.10m.**
Results	
Do errors at the model boundary disappear further into the model domain	**Yes**
Does wind growth occur as expected given the fetch length across the model	**Not possible to assess as simulated events are dominated by the boundary wave not the local wind speed.**
Are changes in wave period easily explained	**Generally yes but there is an isolated error in the centre of the bay. This is deemed acceptable as the error is not affecting the toe locations.**

WAVE TRANSFORMATION QA LOG

Project: 2018s0343 –Stonehaven FPS – Wave model
Filename: AKI-JBAU-00-00-AU-HM-0001-S2-P01.01
Modeller/Analyst: Johnny Coyle
Independent Reviewer: Fay Fishford
Project Manager/Team Leader: Nicola Buckley

	 **Event 7, final model setup**
Is the output wave height within the expected range□	Yes
Calibration	
Has the model been calibrated against appropriate quality controlled measured data.	**Appropriate data has been used for the model calibration. The selected model setup has acceptable RMSEs.**
Do the locations of the calibration data allow calibration close to the required output locations□	**Yes, the wave buoy is located just offshore of the output points.**
Validation	
Has the model been validated against appropriate data independent from the calibration process□	**The model has not been validated. The full modelling suite (waves, overtopping and inundation) will be validated against historical flood events which will be appropriate.**
Sensitivity Testing	
Have sensitivity runs been performed in order to test the sensitivity of the model at the output locations to reasonable variations in the model forcing data (for all boundary parameters)□	**Yes**
Reviewer Summary	
The model has been correctly set up and appropriately calibrated. The model is deemed fit for use subject to checks on the output toe locations, when these become available.	
Issues that require addressing	
• **Please update the mesh bathymetry around SH29, SH25, SH02 and SH_H_01. In these locations the mesh bathymetry does not reflect the best bathymetry dataset. Please see the notes in the text.**	
Provide link to full review document if relevant	

WAVE TRANSFORMATION QA LOG

Project: 2018s0343 –Stonehaven FPS – Wave model
Filename: AKI-JBAU-00-00-AU-HM-0001-S2-P01.01
Modeller/Analyst: Johnny Coyle
Independent Reviewer: Fay Fishford
Project Manager/Team Leader: Nicola Buckley

7 Summary of actions taken by modeller to address review

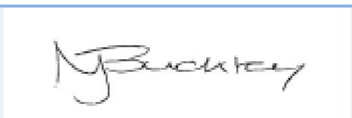
Modeller's comments on issues raised by reviewer and how these have been addressed.	**Wave results are not being used outwith Stonehaven Bay with the final output location being at Cowie, See below. The errors identified by the reviewer to the north of the bay are localised rock features and considered appropriate. No changes were made**  **The isolated error identified within Stonehaven bay for run 7 is a highpoint of elevation, associated with "The Brachans" rock formation at -0.4mAOD (visible offshore of SH20 in the image above). This feature, along with the low waterlevel of the run (-0.39mAOD @ Aberdeen) is attributed to causing the longer period wave identified by the reviewer. The model setup is considered an accurate representation of conditions and no changes were made No output points are proposed to be extracted here.** **Reviewer comments were addressed within the text**
Modeller to summarise the impacts of any changes made on the results.	**Bathymetry outside the harbour (around crossection SH29) was modified due to greater extent of TLS available. This was not near any of the temporary output points used in the analysis and so impact on the results output above is anticipated to be minimal**

8 Reviewer's comments on actions taken

Reviewer to provide comments on the degree to which the actions taken satisfy their concerns	I have updated the review, now the output locations have been selected. To see the original review, to which section 7 refers please consult version 5 of this document. The modeller has addressed all the 'Issues that require addressing' from the original review. This review v06 has highlighted some issues with the nearshore bathymetry which need resolving before the

	QA is signed off. v07: the nearshore bathymetry has been corrected at profile SH29 and differences in the cross-sections have been explained elsewhere. This model is now suitable for use.  23/08/2018

9 Project Manager / Team Leader sign off

Project Manager / Team Leader to comment on the above process and sign off the results	

Technical Review Certificate

Project Name	Stonehaven Bay Coastal FPS
Project Number	2018s0343
Project Manager	Nicci Buckley
Work Carried Out by	Johnny Coyle
Reviewer	Rachel Perks
Subject of Review	Stonehaven TuFlow Model
Date	24/04/2019
Revision	V02
Documents used in Review	
Applicable Standards or Guidance	SEPA Flood Modelling Guidance TUFLOW Manual

Use the following colour scheme to record recommendations:

Green – suggestion for improved / good practice but which is unlikely to change the project outcomes.

Amber – non-standard method or method not following guidance but unlikely to have impacted on results

Red – omission that could make the findings subject to challenge and which requires correction/further work.

SCOPE OF REVIEW

This certificate is intended to cover the review of the TuFlow model developed for Stonehaven as part of the Stonehaven Bay FPS (2018s0343) project.

The purpose of the model is to estimate extreme flood extents from wave overtopping and ESL flooding for multiple return periods and epochs. Results from the 200-year event have been provided to inform the review.

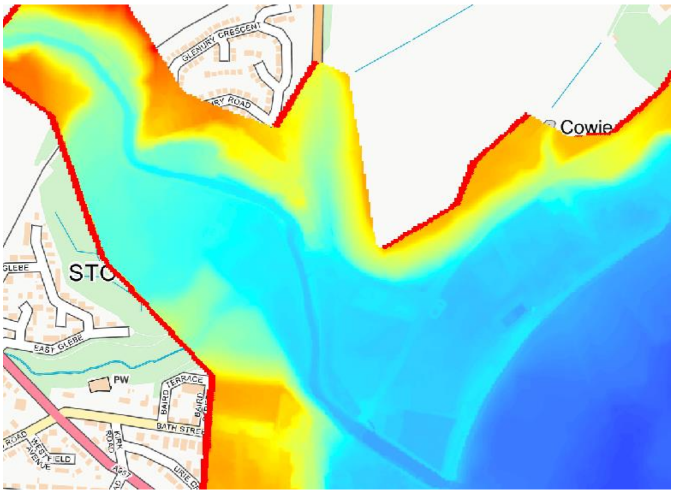
The model files can be found using the link:

\\EDI-RDC03\Live Data\2018\Projects\2018s0343 - Dougall Baillie Associates - Stonehaven Bay Coastal FPS\AKI-HM\Non-graphical\00\AKI-JBAU-00-00-M2-HM-0012-S0-p01.02-Inundation_modelling

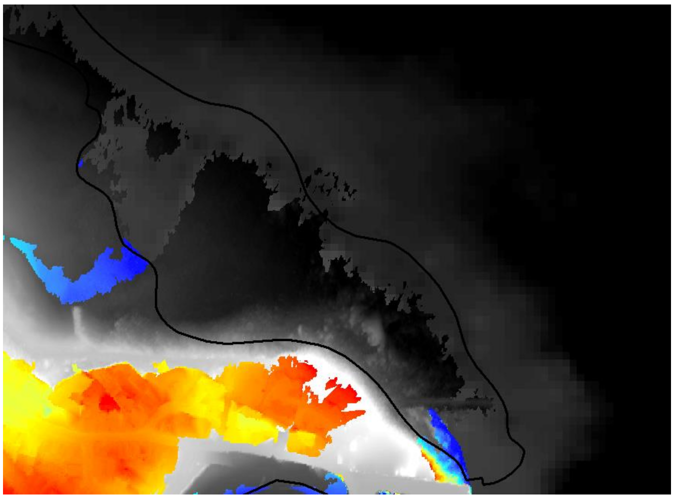
TUFLOW MODEL

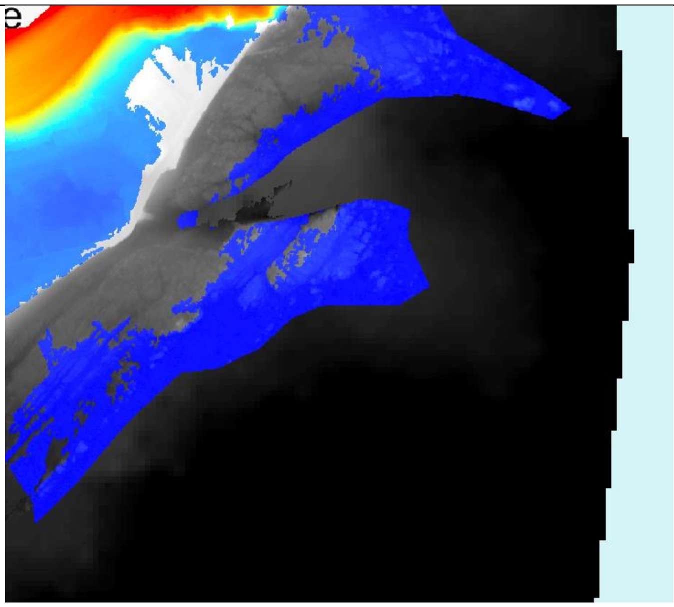
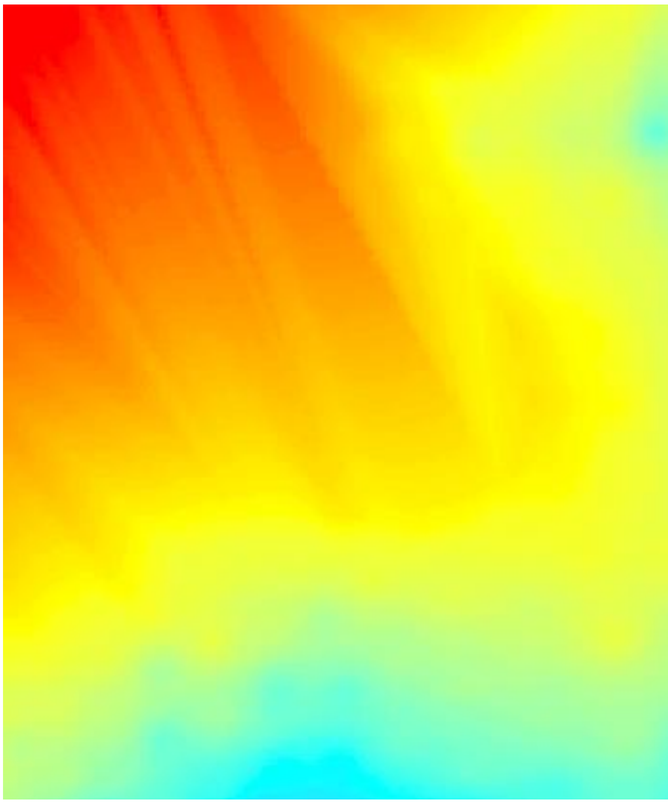
Description and GIS Files	Reviewer comments
The simulations have been conducted using TUFLOW version 2018-03-AA-w64 SP The model is controlled by: *Stonehaven_~s~_~e~_002.tcf* *Stonehaven_Events_002.tef* *Stonehaven_General_Commands_002.trd* *Stonehaven_002.tgc* *Stonehaven_Boundary_Control_002.tbc*	2018 version of TUFLOW used, up to date. Use of the different TUFLOW controls files, scenario and event functions as expected, best practice. Check files written out for every return period (event) which is excessive – check files only required for one return period for each different scenario as only boundary conditions will change. Will have no impact on the model results.

Topo_roughness.tmf It utilises both the scenario and events commands for distinguishing between defended, undefended and roughness tests (Scenarios) and extreme events and epochs (Events). Results, logs and check files are written separately into relevant Scenario and Event folders.	

Model Domain	
Description and GIS Files	Reviewer comments
The model domain is controlled by: *2d_loc_Stonehaven_002_L.shp* *2d_code_Stonehaven_002.shp* The domain is extended sufficiently inland to contain the 200-year 2118 event and laterally at local high points. The grid is orientated approximately parallel to the main the location of interest.	Model orientated appropriately – set up to be in line with the main stretch of coastline, best practice. Model active area is sufficiently large enough - the 2d_code_Stonehaven_002.shp covers the flood extent of the highest event scenario (the 1 in 1000-year event), best practice. Are climate change (sea level rise) simulations being run□ Ensure the model domain is large enough to consider the flood risk associated with this if so. The topographic data doesn't cover the full extent of the current model domain - this leads to the default value of 100m being applied around the edge of the domain. Doesn't appear to be causing an issue as the modelled extents do not reach the edge of the domain but with sea level rise this could be a problem.  Model cell size is 4m and model timestep is 1.5s – in general a flood model timestep should be between □ to □ of the 2D Cell Size in metres, therefore the chosen time step is appropriate based on the cell size. Anything outside of this range would indicate that the model potentially has stability problems.

BASE DTM AND BATHYMETRY

Description and GIS Files	Reviewer comments
The base DTM has been generated from four datasets 1. Cross-sectional survey of the River Carron: this data was available throughout the extent of the River Carron and taken from a previous study assessing fluvial flooding from the River Carron. This was interpolated to a raster within the river channel for the extent of the survey. 2. Terrestrial laser scanned (TLS) Topography of the beach face was also available for the coastal frontage and for areas within the harbour 3. Phase 2 1m LiDAR data provided by SEPA covers most of the terrestrial model extent. This was filtered to remove the representation of water surface within the model domain 4. OceanWise DTM of the bay. This was available in Chart datum and was converted to mAOD using -2.45m. This was used for the area within the bay beyond the extents of the LiDAR and TLS data The data was overlaid with the OceanWise dataset on the bottom and preference given to the more detailed survey. It was necessary to blend the TLS and LiDAR survey into the bathymetry data. This was done using: *2d_zsh_Stonehaven_TLSBLEND_003_R.shp* *2d_zsh_Stonehaven_patch_002_R.shp*	The four datasets that were used to represent the topography of Stonehaven have been read into the model correctly - the lowest resolution data has been read in prior to the higher resolution data. This allows for the more detailed topographic data to overwrite the less detailed data where the data overlaps. These are read into the .tgc file directly as a .txt file, using "Read Grid Zpts ==" command, best practice. The Terrestrial laser scanned Topography shows a spike on the landward extent - this is believed to represent the wall that is also read in as a defence line (see below), as such does not cause any step changes in the DEM_Z. Cross-sectional survey of the River Carron has been used correctly to represent the river - base levels in the survey match the levels in the DEM_Z, differences in these levels are due to the zsh applied at the downstream extent (see below). In some cases, a lot of the topographic data has been ignored - the zshp TIN polygon covers a considerable portion of the data (see image below) particularly at southern end of model. Is the modeller happy that this data has not been used?  The northern section isn't being merged and does lead to some bathymetric step changes. Due to the lack of estuary channel here it is unlikely to impact tidal ingress so modelled water levels and depths should be accurate.

DTM MODIFICATIONS

Defences

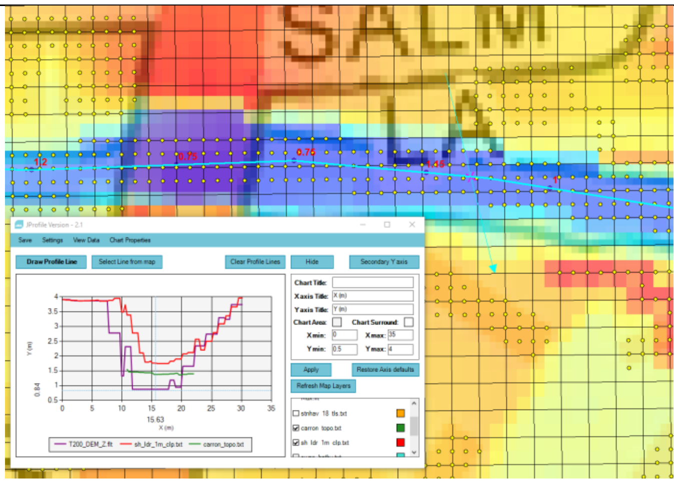
Description and GIS Files	Reviewer comments
The following modifications have been made to the base DTM: *2d_zsh_Stonehaven_Defences_JBA_002_L.shp*	Defences have been read into the model accurately using a single zsh – the THIN function has been used to retain the storage capacity of cells whilst still blocking the flow of water, this is considered appropriate as the zsh

2d_zsh_Stonehaven_Defences_JBA_002_P.shp These provide representations of the defences and top of banks/structures along the frontage. Levels were surveyed in 2016 by JBA as part of a coastal flood forecasting system developed for SEPA. These typically represent wall crests and have therefore been added as **THIN** lines to provide a barrier to flow but not reduce the volume in the domain. Elevations of sections the breakwaters were effectively captured by the base LiDAR, however gaps in the TLS and LiDAR were present. To better represent these features a constant level was extrapolated along their length using the NO MERGE option in the Z shape command. These are read in through the shapefile *2d_zsh_Stonehaven_HarbourWL_002_R.shp*	represents a relatively thin wall along the coastal frontage. There is a gap in the defence line at the end of Ironfield Lane assumption that this is to allow overtopping discharge rates to flow back to sea where this is a beach access point (see image below) – modeller to confirm that this is correct.  Other than the four harbour walls (see below) no additional breakwaters are present in the model, this is appropriate – from inspecting the LIDAR and satellite imagery no breakwaters exist in reality□ modelling is therefore correct, modeller to confirm reason for comment overleaf (is the modeller just referring to the harbour walls in both comments□). The harbour walls have been stamped in at a fixed elevation, this is appropriate as the maximum height and full extent are not picked up accurately in either the Terrestrial laser scanned Topography or Phase 2 1m LiDAR – the resulting DEM_Z shows that the harbour walls are 3.3-3.5m high – modeller to confirm where this level has come from.

	 The model .tgc suggests an undefended scenario, use of a ztin to remove defences – no undefended results are available for review and the ztin does not exist in the model files.

Watercourses/drainage

Description and GIS Files	Reviewer comments
The River Carron was defined formally using interpolated channel cross-sections, however these cross-sections did not extend to the mouth, subsequently it was necessary to enforce the lower section of the watercourse using DTM modification within TUFLOW. The River Cowie was represented as a LiDAR surface as no channel data was available. To improve this representation and to eliminate interpolation errors from the river creating a flow path. Both flowpaths were enforced into the DTM using the GULLY option in the Z Shape command. The width of the watercourses has been estimated from LiDAR and OS mapping and varies within the tidal limit. *2d_zsh_Stonehaven_Channels_002_L.shp* *2d_zsh_Stonehaven_Channels_002_P.shp*	The downstream extent of the River Carron has not been read into the model accurately – the points along the line are not snapped to a node and therefore the model is interpolating the levels between a subset of levels. The example below shows that the DEM_Z has been lowered to 0.87m, but it should have been interpolated between the adjacent points set at 1m and 1.15m. The shape width has been set in the shape file as 8m, the zsh_zpt check file shows that 1.5 x cell width has been adjusted (6m), in general it has still modified the underlying topography and allows flow to pass. Modeller to check they are happy with the width applied. The above issues also apply for The River Cowie.



Buildings

Description and GIS Files

Buildings were represented by modification of the DTM through .zsh files using the NO MERGE option in the Z Shape command. Each structure was uplifted to its surveyed threshold level

Non-surveyed building thresholds have been set to average LiDAR levels within the polygon plus two standard deviations. Review of these buildings using Google Street View suggests there is negligible upstand, and this is appropriate.

These are read in through the zsh file

2d_zsh_Stonehaven_buildings_002_R.shp

Reviewer comments

Buildings represented in the model using the RAISE option, to uplift the underlying Dem_Z by 0.3m. This methodology is appropriate but does not match comment overleaf – modeller to confirm which approach was intended. Approach should have been agreed with client.

Stability

Description and GIS Files

Several stability patches are required for the model domain, mostly relating to unrealistic elevation changes from the differing datasets, generated through interpolation. These were primarily within the harbour domain around the walls where zsh polygons were used to remove these representations and re-interpolate around their boundary.

Additionally, instability along the model boundary was noticed at Downie Point associated with the shore platform and craggy outcrop. To address this the model boundary and inflow was moved to the tip of Downie Point and the platform smoothed to stepped platforms, tapering into the Oceanwise bathymetry. These DTM modifications are read into TuFlow using

2d_zsh_Stonehaven_patch_002_R.shp

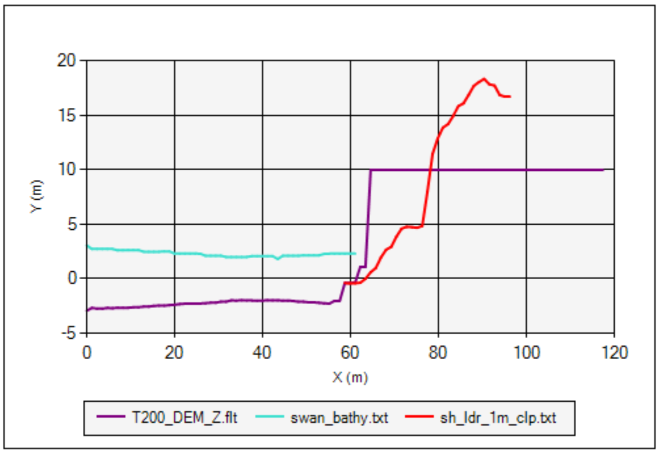
Roughness stability patches were also required along the foreshore of the main frontage between the mouths of the Cowie and Carron and just to the north of the Cowie. Increased roughness in these areas was required to increase stability for higher return periods as water flowed down the beach face on an ebbing tide.

Reviewer comments

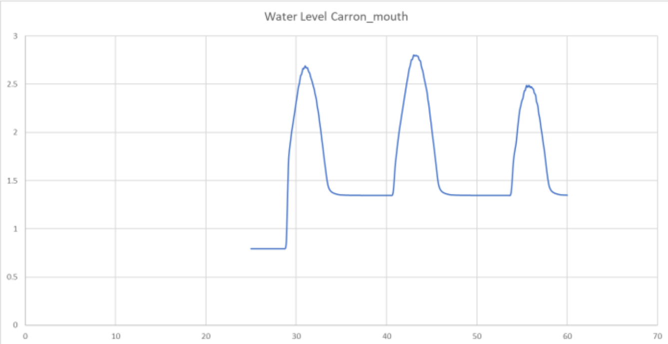
Topographical modifications have been read into the model using 2d_zsh_Stonehaven_patch_002_R.shp. For all except one of the polygons the NO MERGE option has been used, so that all the points lying within the polygon have been adjusted so that the elevation matches that stated in the attribute table. At the boundary this appears to create unrealistic step changes in the DEM_Z (see JProfile plot below), however it is far from the area of interest so will have minimal impact on the results.

Surrounding the harbour walls the NO MERGE option is more appropriate – modeller to check is this was intended.

This document is classified as Commercial

These roughness modifications were read into TuFlow using *2d_Mat_Stonehaven_Patch_002_R.shp*	 For the single polygon where the MERGE option has been selected the datasets have blended appropriately – would describe this as a topographical modification not a stability fix. Two stability fixes have been applied along the coastal frontage using a manning's roughness coefficient of 0.3, this is considered high as it usually represents buildings – modeller to test lower more suitable values.

Other

Description and GIS Files	Reviewer comments
Thirteen PO points were specified for the all runs of the TuFlow model. These output H_ data (water surface elevation) at points of interest around the domain. These include outputs at Turners Close, Carron Terrace, Mineralwell view, Boatie Row, Stonehaven Leisure Centre and Woodcot Brae, as well as at other locations within the bay. These are used for sense checking the calibration event and checking model performance offshore. These are defined through *2d_po_Stonehaven_002_P.shp*	The majority or PO points all show smooth, sensible results. The PO point Carron mouth shows the ide flowing in to the river and on the retreat of the tide a certain amount of the water remains within the channel (below), this is likely due to the early issue of defence point elevations not being snapped to a node on the defence line causing in-channel water to pond and not flow out.  The PO point Woodcot Brae is outside the model domain, as such it has no results – best practice to remove from model, however this will have no impact on the model results.

1D DOMAINS

Description and GIS Files	Reviewer comments
NA	NA

ROUGHNESS

<table>
<tr><th>Description and GIS Files</th><th>Reviewer comments</th></tr>
<tr><td>

A variable roughness has been applied across the domain based on the land use types identified in the OS MasterMap data.

MM_Stonehaven_002.shp

Standard *n* values have been assigned and are provided in

Topo_Roughness.tmf.

Model roughness was varied for +/-20 for the baseline value for the present day 200 year extent. These roughness coefficients had an impact on model extents, with a reduction in Manning’s value increasing flood extents and an increase in Manning’s eliciting a decline in flood extents. The output extents can be seen below. These outputs illustrate step changes between manning’s conditions with a lower manning value having marginally greater flood extents

</td><td>

Model roughness based on OS MasterMap data, sensible coefficients have been used based on Manning’s n values values range from 0.03 to 0.3.

</td></tr>
</table>

This document is classified as Commercial

STILL WATER LEVEL BOUNDARY

Description and GIS Files

Tidal curves have been generated using am Admiralty Total Tide spring tidal cycle for Stonehaven and levels from the calculated return period for the event. The size of the domain means that there is no variation in ESL and a single design tide is applied across the domain.

2018 CFB levels for chainage 3250 have been used.

Uplifts for SLR will be made using the UKCP18 95th percentile of the medium emissions scenario. The calculation of these waterlevels can be found in an XLS workbook in N:\2018\Projects\2018s0343 - Dougall Baillie Associates - Stonehaven Bay Coastal FPS\AKI-HM\Non-graphical\00\AKI-JBAU-00-00-M2-HM-0022-S0-p01.01-Inundation_modelling

Reviewer comments

The model run time for defended is 25 to 60 hours, simulating three tidal peaks. The middle tidal cycle being the peak, the first ensuring that the model is initialised and the last is so that the flood waters have spread to their maximum extent. This is in-line with EA/SEPA guidance, advising models to be run between 3 and 5 tidal cycles.

The event scenario is set to run from 0 to 40 hours, assume this is relating to a calibration run – modeller to confirm.

Water enters the model via a HT boundary applied across the length of the modelled coastline. This head-time boundary has been generated based on the updated CFB chainage 3250\these values are still under review and require approval from SEPA PM – modeller to confirm this approval has been received.

The location of the HT boundary has some inflection points/bends (see image below) - it could have been represented with a straight boundary, which has a tendency to be more stable.

This document is classified as Commercial

	The "Set IWL == " has been used to set the initial water level across the model domain equal to the lowest level of the three tide curves at the start time of the model. This is best practice as it helps to reduce instabilities during model start up as cells get wet.

WAVE OVERTOPPING BOUNDARY

Description and GIS Files	Reviewer comments
Overtopping rates have been estimated for each extreme event using the 2016 EurOtop2 NN tool based on the results of the multivariate modelling. These are applied as an ST boundary factored by 4 to represent the 4m grid resolution. All OT boundaries have been applied landward of the modifications made to enforce the crest levels of the frontage/ defences.	The WO inflows are read into the model to coincide with the central peak tidal cycle (time 43.25 hrs). This is in line with the guidance, which states that overtopping should be applied over a period of 12-24 hours to accurately simulate a storm. The inflow lines are read into the model using the 2d_bc ST (Flow versus Time (m3/s) lines. The flow specified in the boundary file is applied to each cell to which the boundary is connected. The f attribute is set at 4, which is equal to the grid cell size of 4m. These are working as intended. Some WO inflows are orientated slightly misaligned from the model grid - scaling the f parameter based on number of boundary cells actually applied for each OT inflow line would input a more appropriate volume of overtopping into the model along the boundary, modeller to decide if this is necessary.

OTHER BOUNDARIES

Description and GIS Files	Reviewer comments
Two fluvial sources were present within the model domain at the rivers Carron and Cowie. The crest walls here are considered to be to high to be overtopped by high still water levels and normal flows within the river channel. These additional inflows have subsequently not been included in the model domain.	The depth grids for the largest AEP event (0.1) show that floodwaters remain within the river channels. The omission of a fluvial source is therefore sensible.

CALIBRATION AND VALIDATION

Description and GIS Files	Reviewer comments
No recorded flood levels or formal flood extents exist for events at Stonehaven. However, extensive photographic evidence exists for an event on the 15th of December 2012 in which there was extensive flooding from overtopping the output extent as well as the historic photography for this event can be seen below. The modelled flood extents are shown to match up well with post event photography with all impacted areas identified within the flood outline presented below.	Set-up and results for the model calibration look sensible, the focus of this review was for the Def scenario.

The inundation extents around Cowie Pool and the caravan site (image 2 and 3) well represent the inundated extents in this area.

South of the Cowie, the sheltered housing that was evacuated during the event is inundated to an extent similar to that observed during the event.

Along the rest of this frontage, the modelling shows inundation behind the defensive crest which matches post event images of shingle in gardens and along pathways/ roads (images 4,5, and 6).

The inundation modelled at Braeside Crescent was not pictured for the 2012 event but is observed in other similar events (March 2008, November 2010). This coupled with the damage observed in Figure 1 for the December 2012 event is considered appropriate for this area.

From the information available on the extents and depths that occurred during the event, the model can be said to be representing the observed inundation extents and depths.

DESIGN EVENTS AND SCENARIOS

Description

The model has been set up to run the following scenarios and events:

Epoch: Present Day (2018) □Future (2118)

Scenarios: Defended □ Erosion □ Mannings+20 □ Mannings -20

Events: 2yr, 5yr, 10yr, 30yr, 50yr, 100yr, 200yr, 1000yr, 2yr_2118, 5yr_2118, 10yr_2118, 30yr_2118, 50yr_2118, 100yr_2118, 200yr_2118, 1000yr_2118, and December 2012

The defended 200-year event has been provided for review purposes. Additional events have been run and are outlined in detail in

2018s0343 - Stonehaven_TUFLOW_model_log.xlsx

Reviewer comments

The .tef is set up to run 2yr, 5yr, 10yr, 30yr, 50yr, 100yr, 200yr, 1000yr and December 2012 event. There is no indication that climate change has been run for this project – modeller to confirm is this is still to be completed.

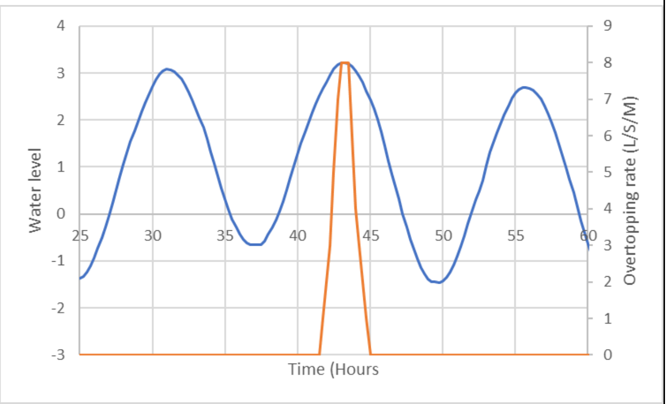
PERFORMANCE AND STABILITY

Description

The model has been run on a constant 4m grid with a 1.5s timestep.

Review of the results show no stability problems. No negative depth warnings exist within the model 200-year defended run that has been used to assess the setup of these models

Plots



Inflows into the model domain for the simulation time (40-60 hrs) can be seen above with the inflows for SH_20. the peak overtopping was set to corrispond to the maximum tidal height.

The model was found to run with no visible stablity issure for the 200 year defended scenario for present day water levels. The Cum Q ME peaks at 0.17□, 15

Reviewer comments

The log files for all Def scenario events (2yr, 5yr, 10yr, 30yr, 50yr, 100yr, 200yr, 1000yr) had zero negative depths warning messages. This indicates that the model is stable.

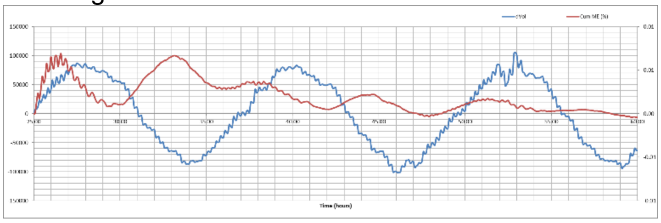
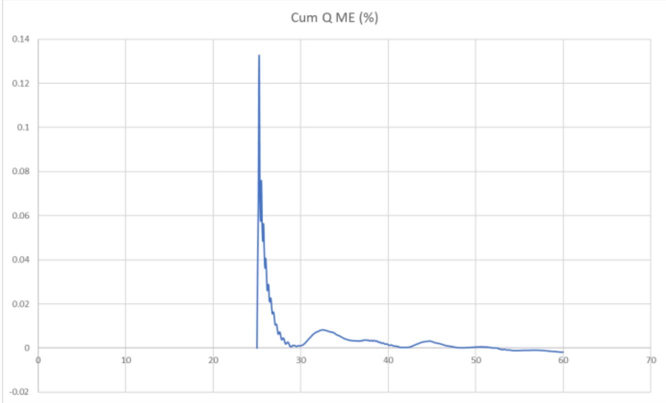
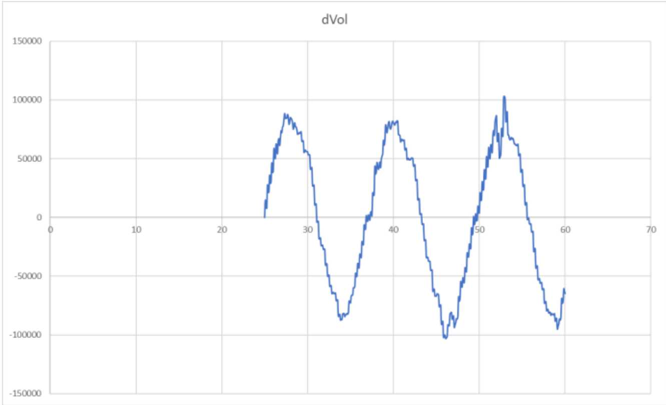
The model head grids generally look sensible, with sensible flood extents for the model domain. There is no glass walling at the model boundary.

There is a slight rise in the head grids from the tide boundary to the shoreline□however there is no indication that the water level causes flooding in the model. The flood extents can be considered a consequence of the wave overtopping discharge rate.

The WO inflows are read into the model to coincide with the central peak tidal cycle, as discussed above.

Cum Q ME

The cumulative mass balance plot, sees an initial spike upon model initialisation, implying a large inflow of water from the model domain. This is short lived and the mass balance reduces to almost zero before the first tidal cycle peak. The peak tide has an accurate mass balance and is well within the acceptable limits throughout the simulation.

minuites into the simulation assoviated with an initial wetting of cells of the water surface present in the DTM and secondarily the shore platform. The MB error then stabilises as additional water is added to the domain, reducing cumulative ME to 0.01.  The dVol shows significant fluctuation, associated primarily wth the tidal inflow boundary, evidenced by the sinusoidal pattern of error. This is common within coastal models and is anticpated to be associated with the wetting and drying of the DTM surface and shore platform. This fluctuation is not anticpated to have a significant impact on modelled flood extents.	 **dVol** The model has been run for 3 tidal cycles. The difference in volume over time (dvol) shows the 3 distinct tidal cycles. The dvol graph is bumpy, which suggests water is moving into and out of the model at the tidal boundary somewhat erratically. This is common in coastal models and shows the general expected volume change. Additionally, there is a slight spike on the final tide curve – modeller to check the reason for this spike as it has the potential to cause instabilities. 

REVIEWER RECOMMENDATIONS:

- Check topographic extent relative to code layer
- Purpose is a gap in the defence line at the end of Ironfield Lane
- Source of level of harbour walls
- Purpose of undefended scenario IF statement in model control files□
- Review levels of zsh along Carron and Cowie
- Review levels at Carron Mouth PO point
- Review Building representation and report
- Review topographical modifications at south eastern model boundary
- Outline purpose of roughness stability fixes and review lower values of n
- Woodcott Brae PO point outside domain

- Outline potential to scale F factor at boundaries
- SWL boundary to confirm review of CFBD and use

MODELLER RESPONSE

- Check topographic extent relative to code layer

  Code layer modified to match landward extent of DTM
- Purpose is a gap in the defence line at the end of Ironfield Lane

  Gap in defence is to allow outflow
- Source of level of harbour walls

  Harbour wall level obtained from approximate road level from LiDAR at shoreward end of structure
- Purpose of undefended scenario IF statement in model control files

  Undefended scenario remained in due to ambiguity of client request. Now Removed
- Review levels of zsh along Carron and Cowie

  Lower of the two spot heights snapped to node.
- Review levels at Carron Mouth PO point

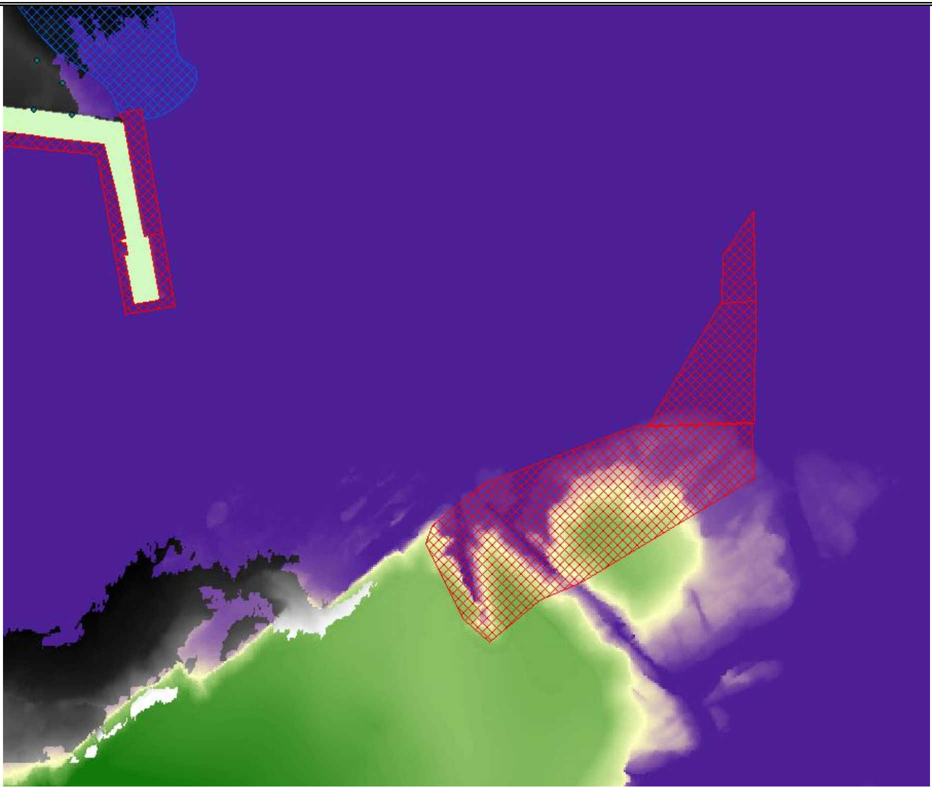
  Topographic representation at the mouth of the Cowie and Carron poor. Levels therefore obtained from LiDAR. The poor drainage outlined at the PO point is due to levels moving from channel survey to water surface representation 0.4m. Given the lack of more appropriate data this was deemed appropriate.
- Review Building representation and report

  TCF pointing to alternative .zsh file with 0.3m uplift. Modified to identify 002 as this has finished floor levels and LiDAR levels
- Review topographical modifications at south eastern model boundary

  Topographic smoothing employed to increase model stability around the boundary and remove uneven shore platform with steep slopes. This is deemed to have no impact on overtopping.
- Question RE: Climate change runs

  Climate change, defended and sensitivity runs have been run and are available.
- Review DVol output and identify source of instability on third tidal peak

  Source of this variation in DVol is unclear. Occurs on tide following overtopping. The instability does not cause any visible influence on results and was not considered to have an impact



- Outline purpose of roughness stability fixes and review lower values of n

  Roughness stability patches put in to stop high velocities flowing between defences following low tide at high return periods. Roughness dropped to 0.1 (buildings and structures)

- Woodcott Brae PO point outside domain

  PO point removed

- SWL boundary to confirm review of CFBD and use

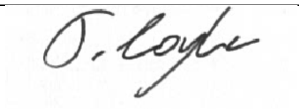
  Client aware of use of CFBD. Climate change scenarios awaiting completion

- Outline potential to scale F factor at boundaries

  Factor modified to increase inflows along appropriate frontages. Text modified

- Cause of spike in tidal inflow

  Inflows amended and spike removed

Signature	
Name	Johnny Coyle
Date	08/04/2019

REVIEWER RECOMMENDATIONS (15/04/2019):

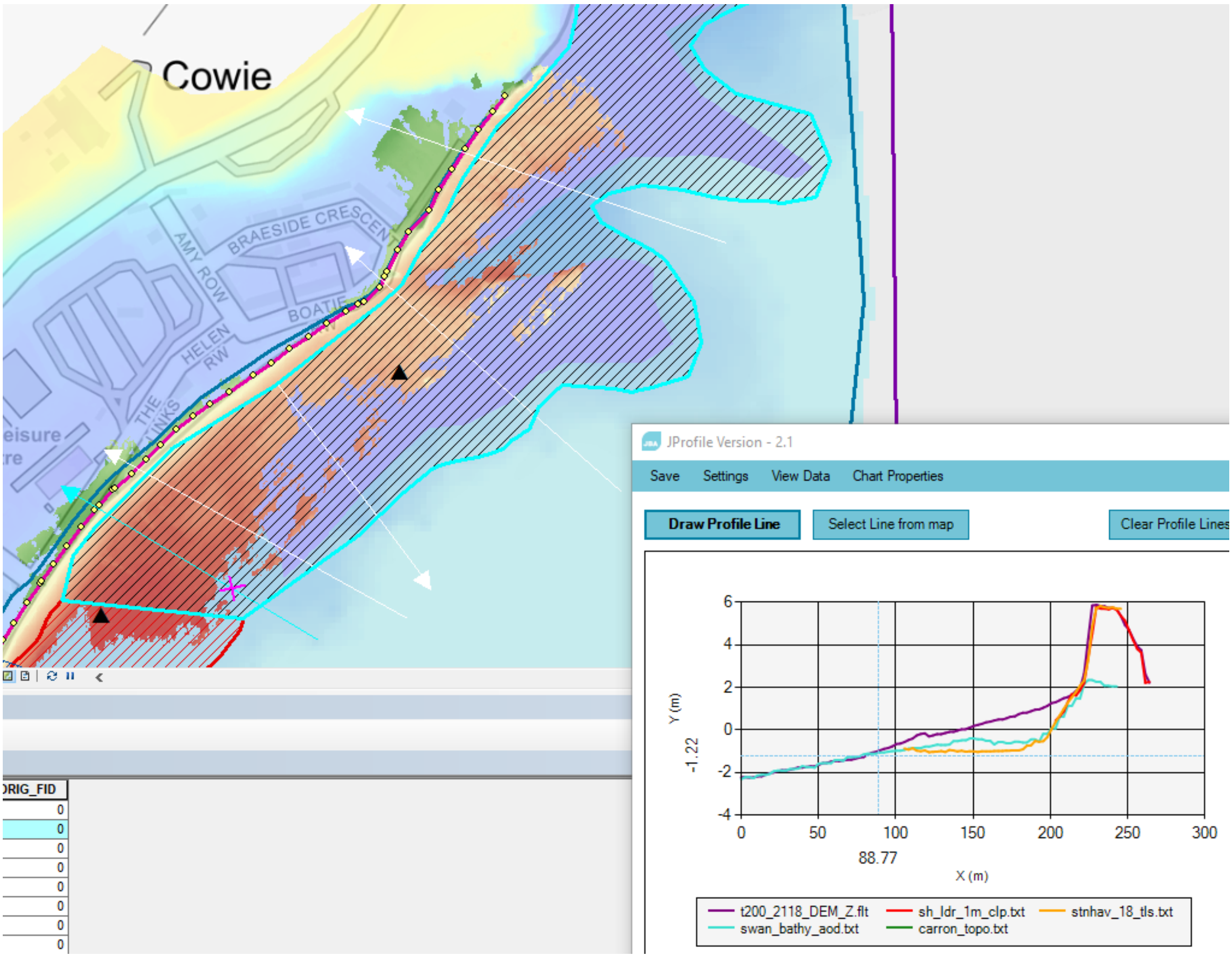
- **The below is only relevant for new comments as of 15/04/2019 or if the modeller response above is not considered suitable (original comment and response has been copied with new review comment).**
- Check topographic extent relative to code layer

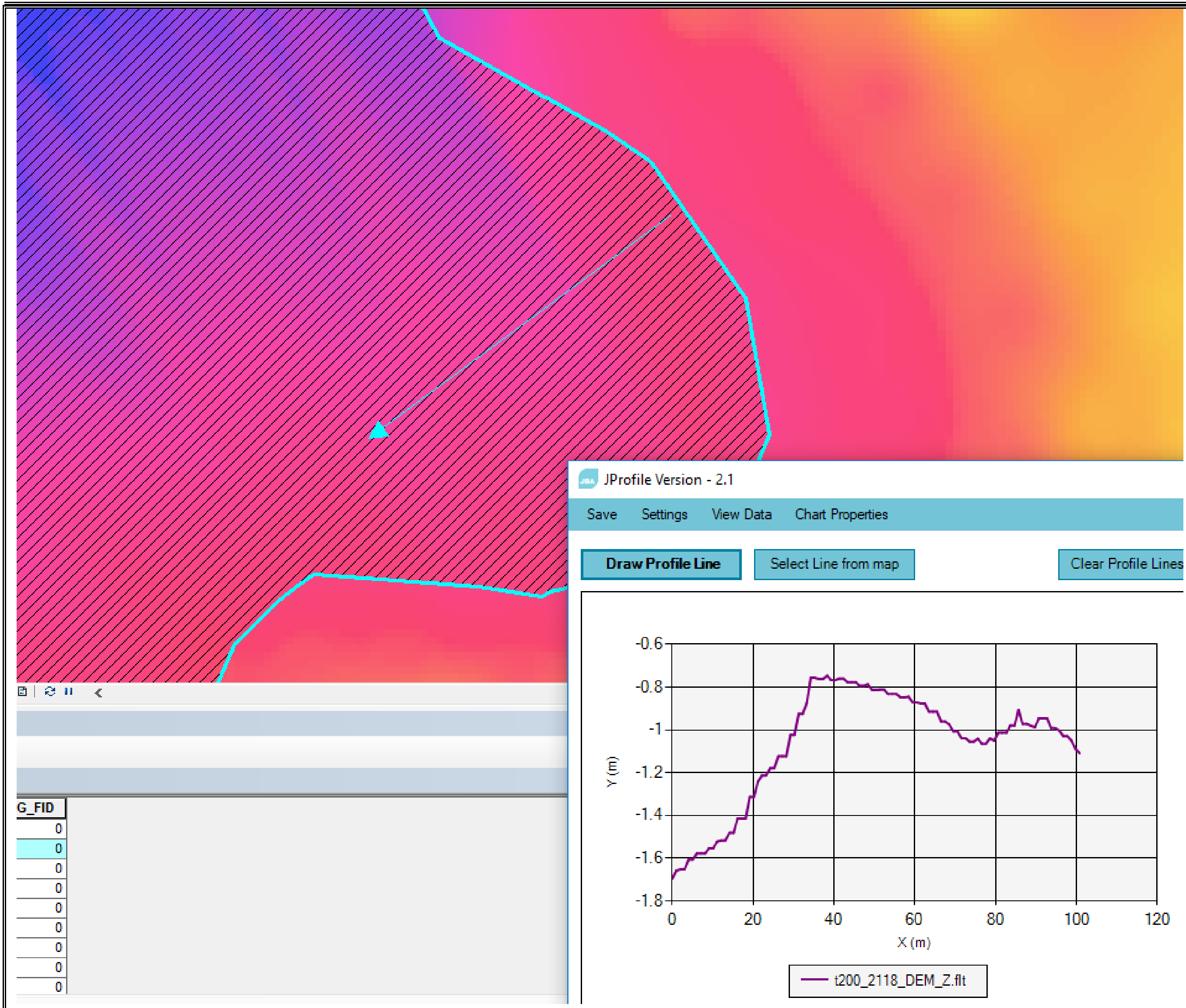
Code layer modified to match landward extent of DTM

The areas that were highlighted in the original review have all been updated and are now correct. There is a small section in the south of the model domain where topographic data doesn't cover the full extent of the current model domain this was filled using 2d_zsh_Stonehaven_patch_001_R.shp. The polygons have a small gap between them, as such the Dem_Z shows a grid cell where the default level was applied. This method seems appropriate, but modeller should update the polygon boundaries so that all the grid cells are adjusted.

Patched

- In some cases, a lot of the topographic data has been ignored - the zshp TIN polygon covers a considerable portion of the data (see image below) particularly at southern end of model. Is the modeller happy that this data has not been used The northern section isn't being merged and does lead to some bathymetric step changes. Due to the lack of estuary channel here it is unlikely to impact tidal ingress so modelled water levels and depths should be accurate. This is in the review above, but the template removed the colour, should have been orange.





These sections of the DTM have been removed from the DTM to improve model stability on the shore platform. Although the DTM is of good quality (TLS data), the representation is highly uneven and caused instability within the domain. This was discussed orally with reviewer at initial review and is considered appropriate.

- Review levels of zsh along Carron and Cowie

  Lower of the two spot heights snapped to node.

  There are still points not snapped to nodes along the channel lines for the River Carron and Cowie (see images below). If modeller does not require the points to represent the channel depth it is best practice to delete them from the shape file.

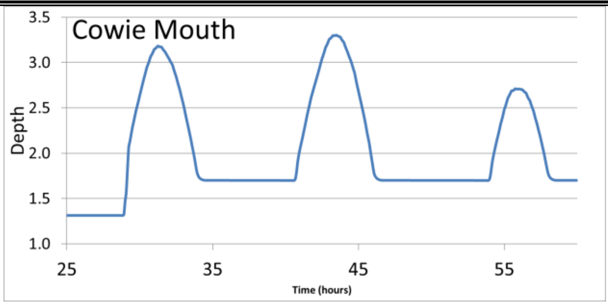
Points snapped to shapefile nodes

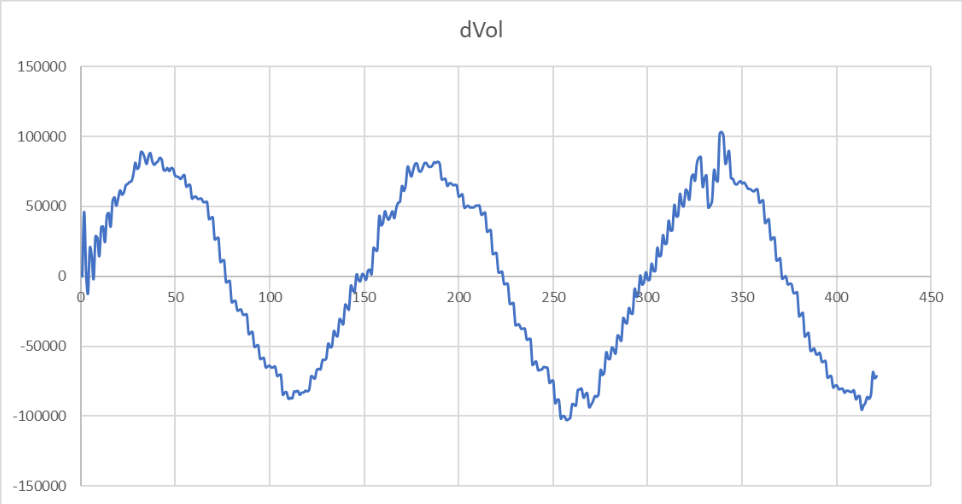
- Review Building representation and report
- TCF pointing to alternative .zsh file with 0.3m uplift. Modified to identify 002 as this has finished floor levels and LiDAR levels

  Reviewed new buildings file and is fit for purpose
- Cause of spike in tidal inflow

  The spike in the dVol graph is still present after the updates.

Cause of fluctuation in DVol unclear. As it occurs on the tidal cycle following inundation it is not anticipated to impact results. As can be seen by the PO point outlined below



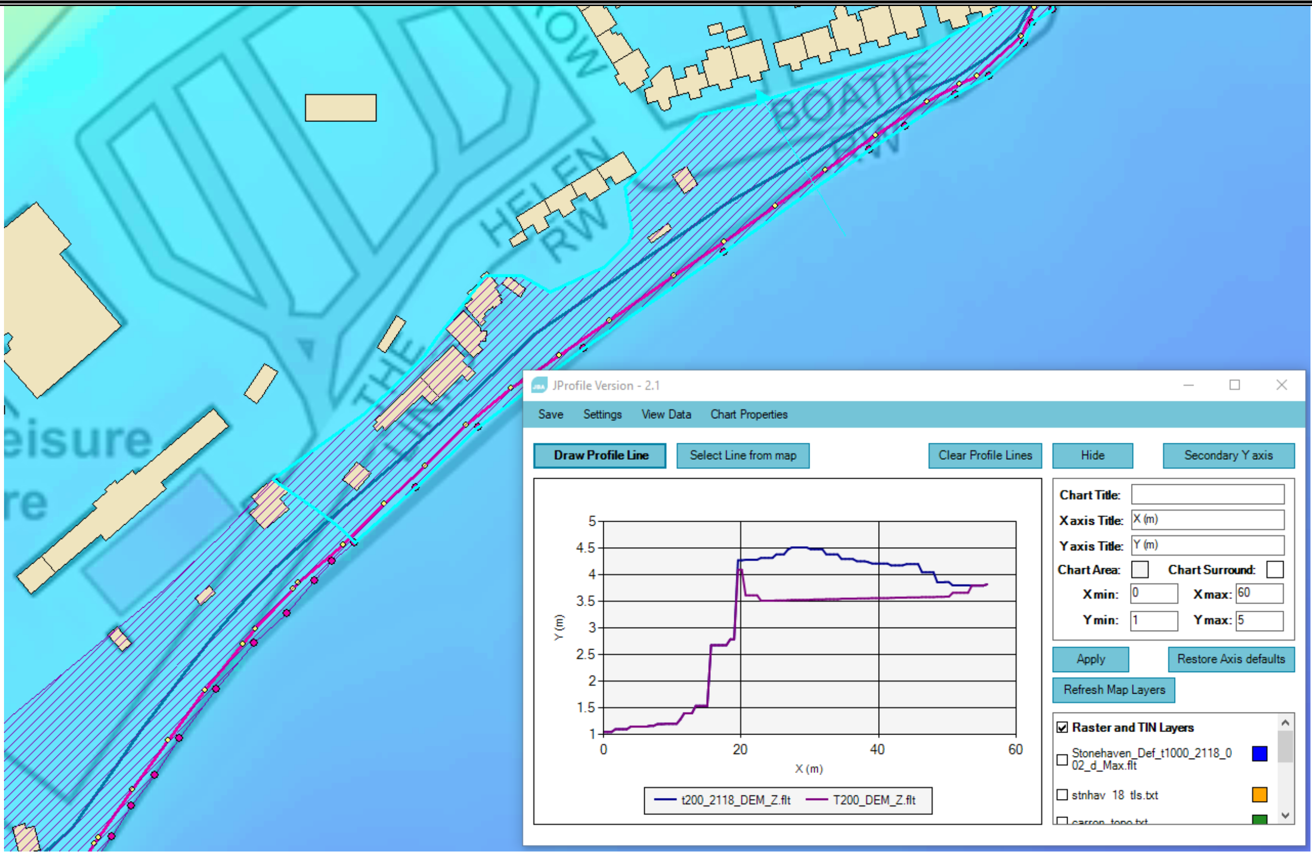


- The 2d_Stonehaven_Erosion_001_L.shp (polygon) and 2d_zsh_Stonehaven_Erosion_001_P.shp files were used to remove the large embankment and stepped revetment in the north of the model domain during the erosion scenario. The two polygons are read into the model using different methods: NO MERGE and using interpolation based on points, modeller to confirm why different methods were used. Additionally the NO MERGE polygon also has points snapped to the boundary so it is not clear which method is intended in this location.

Polygon modified to rely on points and extended.

- The .tgc reads the defence lines into the model, this is then followed by the two shape files that remove the embankment. However, in some locations it looks like there are some cells where the defence line is still applicable (see image below). Modeller to consider removing the defence line in this location for the erosion scenario.

Polygon modified to extend to approximate 2m contour on beach. Removing representation of defences. TGC modified to include IF statement relating to erosion scenario, else stamp defences



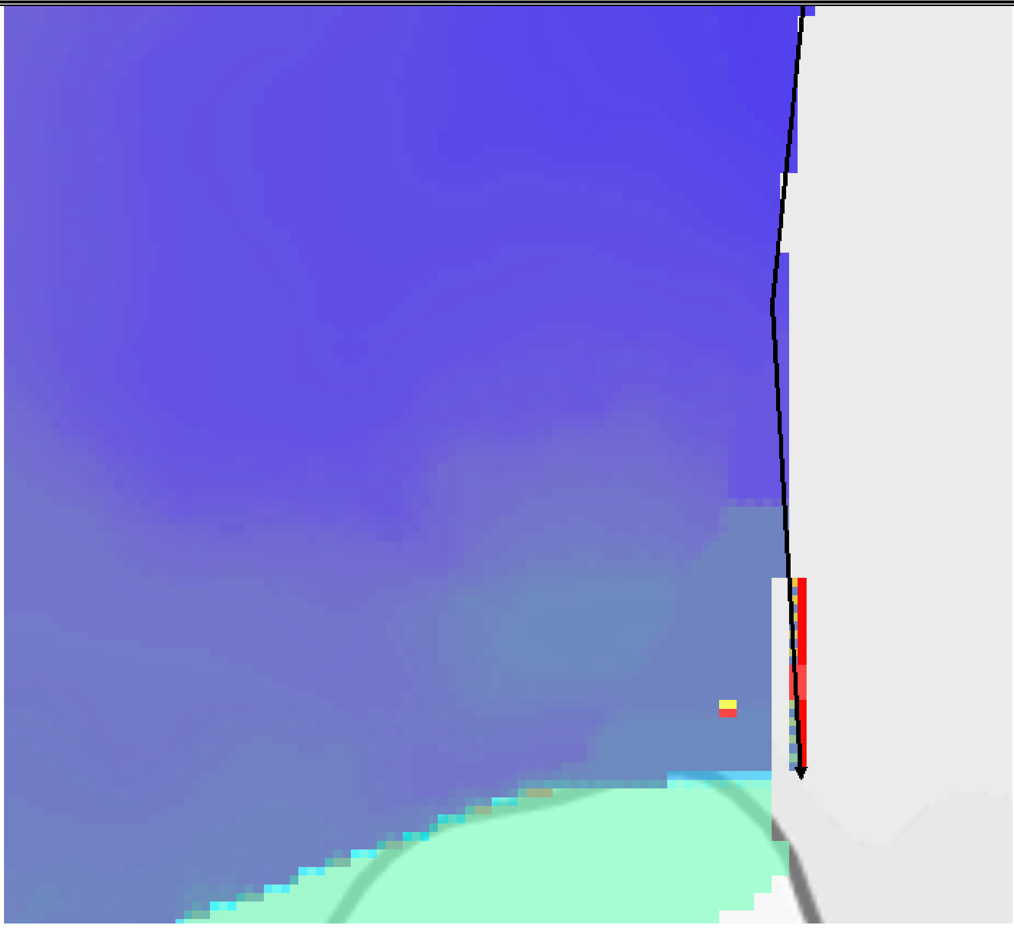
- PO points have been updated and these are now appropriate. One of these points is dry even in the Def T1000_2118, if design runs have not been run yet it would be worth moving this to the maximum extent of the flood grids in the river.

PO point moved and renamed "Glenuy_Cottages"

- The location of the HT boundary has some inflection points/bends (see image below) - it could have been represented with a straight boundary, which has a tendency to be more stable.

  Model boundary has not been updated and still contains inflections points. Additionally modeller to note that the boundary is not snapped to the code layer (see image below)

Inflection points removed from inflow and code layer. Both snapped



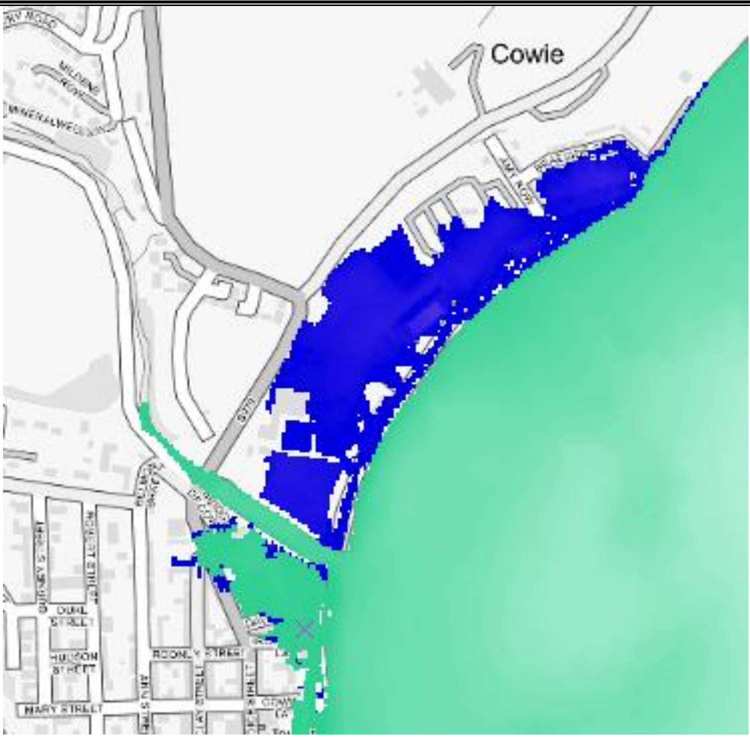
Outline potential to scale F factor at boundaries

Factor modified to increase inflows along appropriate frontages. Text modified

SH29, SH17 and SH_H_02 all have large f parameters considering the model cell size is 4m. Based on the length of the ST boundary and the number of cells this is being applied to (bcc_check) only one of these looks accurate. Modeller to update these and check the remaining ST boundaries to confirm if they are correct.

F factor update omitted following polyline update for 2 inflow lines. Modified to appropriate representation.

- The model extents in the erosion scenario are smaller than the baseline scenario, this is likely because wave overtopping has not been applied (see image below). Modeller to confirm that this approach is producing the results required.



This is considered appropriate for the scope of investigation. The approach will be appropriately caveated in reporting.

FINAL CERTIFICATE

In respect of the project design described above, I have carried out a Review and consider the technical output sound, and any recommendations made have been satisfactorily addressed.

Signature of Reviewer	
Name of Reviewer	Rachel Perks
Date	26/04/2019

J SEPA comments on Interim Modelling Report

Scottish Environment Protection Agency
Buidheann Dìon Àrainneachd na h-Alba

Our ref: PCS/162233
Your ref: Pre app

If telephoning ask for:
Clare Pritchett

29 November 2018

Lee Watson
Aberdeenshire Council
Planning and Environmental Services
Viewmount
Arduthie Road
Stonehaven
AB39 2DQ

By email only to: lee.watson@aberdeenshire.gov.uk

Dear Mr Watson

Stonehaven Bay Coastal Flood Protection Study - Interim Modelling Report

Thank you for your consultation email which SEPA received on 12 November 2018. We welcome the early consultation on the Flood Study, and have reviewed the Interim Modelling Report by JBA dated November 2018 against any information we hold for the area and against our *Modelling Guidance for Responsible Authorities*. We provide our comments below.

1. We note the approach taken around the harbour area and understand the decision process for not representing all of the breakwaters in the bathymetry mesh. We appreciate this is a complex area of the coastline and different in characteristic from most of the frontage in Stonehaven Bay. The model outputs do not seem to be representing observed flooding around the harbour and while we understand some of the modelling reasons why that might be the case, it isn't clear how this will be taken forward in the study. Some discussion on options for improving the model representation here or how the uncertainty is taken forward in the project would be useful.

2. In the section of the report on emulation, there is discussion on overtopping locations where a poorer performance was achieved than across the modelled area as a whole. As expected, the harbour proved a difficult location to represent but two other toe locations were also below average. These locations are both fairly critical in terms of receptors at risk and so it isn't clear what the implications of this are for the outcomes of the study, whether there are any options for improvement or whether these areas of uncertainty need to be reflected in the next stage of the work. In particular it would be useful to provide commentary on whether overtopping would be expected in the region of poor emulator performance.

3. Figure 2-9 shows that the overtopping toe locations for sections SH28 and SH25 to be in different locations to Table 2-6, please confirm which is correct.

4. Where defence/shore profiles have been adjusted so that forecast overtopping rates better

match observed impacts it would be useful to provide an explanation of the physical justification for these changes and, where relevant, link to the erosion/sediment budget analysis later in the report.

5. It is not clear how threshold levels have been identified where threshold survey is not available. Can more details of the approach set out in bullet 3 in section 2.8.2 be provided□

6. Generally, the model outputs have been verified for the calibration events, both against data we hold and with the community. The exception to this being in the harbour area. The report acknowledges the issue around the harbour but it isn't clear how that will be resolved.

7. On that basis, the design outputs for the lower probability events seem representative, but for the more frequent events the risk of flooding seems high compared with flooding experienced on the ground. For the 1 in 2 year event for example 29 properties are said to be flooded but we don't have records of anything like that number of properties flooding so frequently to support that.

8. We welcome the holistic approach taken in the study with the combination of flooding and erosion under consideration, and the inclusion of sediment analysis. Recommendations are given for long term monitoring which we welcome, but the recommendation should possibly extend to the timing of monitoring given the challenges faced with seasonal differences. Consistent timing of surveys seem to be required if the frequency of surveys remains more than a year apart, though there seems to be a case for some more frequent survey to investigate the impact of seasonal changes, or pre and post storm survey in order to provide data for model calibration.

9. Some sediment analysis has been done around the mouth of the Cowie Water, but it isn't clear if the sediment management activities have been reflected in this analysis and it seems likely that there will be some sort of inter-impact. The managed deposition of material at the mouth of the Carron has been looked at in its own right but it isn't clear that the sediment analysis accounts for this in the overall analysis of sediment movement in the bay.

10. There is no reference to any sensitivity testing in the modelling, although we note some is likely to have been carried out as part of the model calibration. We would expect to see sensitivity testing to key parameters and assumptions for the different modelling components and a discussion of the impact on modelling uncertainty. Given the high uncertainties with representing wave overtopping rates in particular, it seems like some sort of sensitivity assessment should be included on some of the parameters used. Given the changes identified with beach profile, this seems like a particular area where there should be testing of probable beach variations and the data seems to be available to do that. As we understand it, only the current beach profile has been modelled so far.

11. To avoid a false implication of the level of uncertainty in the modelling it would be useful to check the report to ensure that all overtopping rates, levels etc. are quoted to the appropriate precision.

12. We note that sea level rise and climate change has yet to be incorporated into the assessment. The report suggest that the UKCP09 medium emissions scenario 95th□ile will be used. It would be useful to provide some commentary on reasons for the choice of emissions scenario and probability level, and whether the assessment is likely to be sensitive to use of the UKCP18 climate change projections, or a different emissions scenario. Can you confirm if sea level rise will also be accounted for in the erosion assessment

13. Advice is specifically sought from SEPA on the approach taken to calculating property vulnerability and damages associated with the concentration of vulnerable people. We agree that the approach is ambiguous and proves challenging in securing appropriate representation while remaining consistent to the methodologies to be applied. The approach to economic assessment is generally in line with guidance subject to the clarifications below:

- Please state the expected impact of not including basements in the damage assessment
- It is understood that detailed topographic survey has been undertaken including property threshold surveys. Please clarify what receptors if any are relying on LiDAR data (as stated in Table 4-1) and what the implications of this are for uncertainty
- The assessment appears to use the SEPA receptor dataset (please clarify which version). This is only suitable for strategic level studies. It’s essential that verification of the property dataset is undertaken for a detailed flood study such as this to ensure that the correct depth damage values are applied. In particular, uncertainties in the non-residential property dataset (including property type and building area) could have significant impacts on damage assessments
- The economic damages related to health impacts should be reported using the standard (lower) value. However we would support recognition of greater health impacts (i.e. due to high vulnerability) being quantified separately for comparison. In doing so, for a detailed study such as this, we would recommend that data used is based on the best locally verified data rather than strategic level datasets such as SEPA’s receptor dataset (based on census datazones)
- A specific query was raised at the Stakeholder meeting on whether the substation had been included in the infrastructure damages and this should be checked.

If you have any queries relating to this letter, please contact me by telephone on 01224 266609 or e-mail at planningaberdeen@sepa.org.uk

Yours sincerely

Clare Pritchett
Senior Planning Officer
Planning Service

Disclaimer
This advice is given without prejudice to any decision made on elements of the proposal regulated by us, as such a decision may take into account factors not considered at this time. We prefer all the technical information required for any SEPA consents to be submitted at the same time as the planning or similar application. However, we consider it to be at the applicant's commercial risk if any significant changes required during the regulatory stage necessitate a further planning application or similar application and/or neighbour notification or advertising. We have relied on the accuracy and completeness of the information supplied to us in providing the above advice and can take no responsibility for incorrect data or interpretation, or omissions, in such information. If we have not referred to a particular issue in our response, it should not be assumed that there is no impact associated with that issue. For planning applications, if you did not specifically request advice on flood risk, then advice will not have been provided on this issue. Further information on our consultation arrangements generally can be found on our website planning pages.

K Multi-criteria analysis

Option	Description	Standard of Protection			Technical		Economic		Environment		Social		Political		Legal		Total	Summary of long list
		Short-term Present day to 2030	Mid-term Present day to 2070	Long-term Present day to 2118	Technical performance and adaptability Aims: Provides desired standard of protection throughout the design life of the scheme or is easily adaptable to allow for modifications for climate change through time. Provides protection to full extent of benefit zone.	Buildability Aims: Safe to construct, local sources of appropriate material for construction, suitable ground conditions and would not conflict with existing services, primarily the sewer main along the front.	Capital cost Aims: Low capital cost.	Maintenance and monitoring Aims: Minimal ongoing maintenance and/or monitoring requirements and costs.	Ecology and environment Aims: No environmental impact on local habitats, geology and ecology, including local designations.	NFM and RBMP Aims: Works with nature to provide natural protection and does not downgrade the existing classifications.	Landscape and Heritage Aims: Works with the existing landscape and is sensitive to listed buildings and heritage designations.	Tourism Aims: Maintains access to beaches, considers local views and provides connectivity along the frontage.	Strategic alignment Aims: Aligns with local strategies.	Stakeholder views Aims: Supported by stakeholders and the local community.	Waste management and contamination Aims: Minimal waste disposal requirements or contamination risks.	Regulatory consenting and approvals Aims: Regulatory framework would be readily achievable.	Short list options in green	Key reason for shortlisting / discounting
1	**Replace sea wall**				4	3	2	4	3	3	3	4	5	3	3	4	41	
	A new wall could be built of concrete, steel piles or masonry. This option would seek to replace the existing defence or be built seaward of the existing wall. To adapt to climate change, the wall would need to be taller than the current defence, which may require raising the promenade and footpath area behind.				+ High standard of protection and long design life. -Potential for increased scour and	working within tidal windows, greater risk in low areas with smaller tidal window.	-High capital costs	manganocene for concrete works and Potential scour and beach loss	take so no impacts on geology and ecology following	+ If the replacement wall has the same extent as the	of existing defence would increase amenity space behind but	to raise land behind walls in Cowie. Access to beach	+ Provides HTL policy with increased SoP		- Waste from demolition of concrete and excavation around wall	- Marine licence required		Option bought forward to short list as it provides flood protection in the long-term by raising the height of the defence. This option may require beach maintenance and replenishment to achieve overtopping requirements.
2	**Raise existing sea wall**				2	5	4	2	3	3	3	4	3	3	5	5	42	
	Raising the existing wall would increase the flood protection performance of the defence in the short to mid-term. However, as this option relies on the existing structure it can only practically be raised so far without a complete re-build. In addition, without raising the promenade, sea views could be affected and therefore the wall could only be raised so far. In areas where the existing structures are currently in poor condition a concrete 'shroud' would be used to encase the existing defence to prevent premature failure of the new raised defence.				+ increased performance - Poor design life as relies on the existing wall - Potential for increased scour	+ works predominantly land-based.	+low / medium capital costs.	+ High maintance costs for existing structures	Shroud increases footprint of defence. Potential impacts on geology of SSSI and non-	+ Raising the existing wall would not increase the area of coastline affected by	Blending of existing and new materials would require consideration. Schedule	Unlikely to need to raise land behind walls in Cowie. Access to beach will need to be	+ Provides HTL in short-medium term only		+ Limited demolition required, utilises existing structures	+ limited consenting required		Option bought forward to short list as it provides flood protection by raising the height of the defence. This option may require beach maintenance and replenishment to achieve overtopping requirements.
3	**Small rock armour revetment**				2	4	4	3	3	2	3	4	3	3	4	4	39	
	Rock armour could be installed at the base of the existing sea wall to increase flood protection performance. As this solution does not increase the height of the defence it is only viable in the short to mid-term without the full effects of sea level rise. The rock armour would encroach onto the amenity beach (or into the mooring zone within the harbour), but it would not affect line-of-site from the town.				+ Increased performance in the mid term + provides scour protection	- Beach based activity - difficulty excavating at toe of defences	+low / medium capital costs.	+ High maintance costs for existing structures	than sea wall so habitat loss would occur. Potential new	+ May alleviate the need to expand defences elsewhere along	on amenity value of beach, but equally could become a feature	space on beach, although also potential to create features.	+ Provides HTL in short-medium term only		- Excavation of beach	- Marine licence required		Discounted due to the limited benefit in mid to long term along while encroaching onto the amenity beach.
4	**Setback walls with flood gates**				4	3	3	2	4	3	3	4	2	2	3	4	37	
	Flood protection walls could be installed set-back from the existing coastal defences, these would run parallel to the roads and private property boundaries. In some instances, it is envisioned that private properties may require integrating into the defence line to ensure flood wall continuity; this would require waterproofing or shrouding of vulnerable areas. This option would help prevent flooding to the town through a secondary defence line; while it does not help reduce wave overtopping, it would prevent flood water from inundating properties. In the long-term this option will be less effective due to the extreme sea levels expected and it does not seek to improve the condition of existing defences. However, if used in conjunction with other defence improvements it could effectively work into the long-term scenario.				+ Mid to long term performance - relies on existing defences for long term performance - does not mitigate scour	+ land based construction	-Medium capital costs	+high maintenance costs for existing structures	on terrestrial habitat. Reduced geological and ecological impacts. Potential to	+ No additional coastal land take which works toward the RBMP objectives. - Not full realignment and therefore still	existing and new materials would require consideration. Schedule monuments to north of Cowie	Potential loss of amenity space on landward side. Access to beach only effected during flood event.	- Allows same or higher level of overtopping of existing defences		- Excavation on land for wall foundations - Possible demolition of existing walls and surfaces	+ Land-based construction		Discounted as the option would not address the large rates of wave overtopping predicted over existing defences resulting in damage to vehicles, infrastructure and presenting a danger to pedestrians during storms
5	**Offshore breakwater**				4	1	2	2	2	4	3	5	4	5	3	2	37	
	An offshore breakwater would seek to reduce the flood risk by dissipating wave energy within Stonehaven Bay. The size of the structure (height and width) would determine how much wave energy is dissipated. For this reason, a breakwater could be designed to be submerged such that it is not visible, creating a reef-like structure to break the largest waves offshore. As this option does not increase the height of the existing defences it may only offer limited protection in the long-term, however coupled with other defence options it could aid in reducing the size of other required defences.				+ long term performance - relies on condition of existing defences	- Difficult to construct, water based activities	- High capital costs for volume of material required and construction	+high maintenance costs for existing structures	significant alteration to coastal processes and downdrift erosion issues,	+ May increase the area of sandy foreshore which would have NFM benefits by	structure would have no impacts on landscape or seascape. Potential impacts	works required along the frontage, thus keeping wall heights down -	+ Allows for HTL to be implemented more effectively through reducing direct		- Possible dredging activities	- Marine licence required - offshore work		Discounted as existing low-lying defences would still be at risk of overtopping from sea level rise in the long term. Option also considered costly and difficult to construct for the scale of breakwater required. Note - offshore breakwater not to be confused with beach control structures as in option 8 which are located close to shore.
6	**New wall extension with a rock armour revetment**				5	3	2	4	3	2	3	2	5	3	4	4	40	
	The existing defence could be increased in height with the addition of rock armour installed on its seaward face. The rock armour would serve as protection to the wall whilst also significantly reducing wave overtopping making it an effective coastal flood defence in the long-term scenario. To adapt to climate change, the wall would need to be taller than the current sea wall, which may require raising the promenade and footpath area behind the defence. In areas where the existing structures are currently in poor condition a concrete 'shroud' would be used to encase the existing defence to prevent premature failure of the new raised defence.				+ High standard of protection - relies on existing defences, though less so than other options + limited risk of scour	- land and beached based activates - disruption to locals - conflict with services	- large volumes of material and scale of construction	+ no maintenance for rock armour	Larger footprint than sea wall alone so habitat loss would occur. Potential new habitats in rock armour.	+ If the overall area of extension is minimal it may not have a significant impact on the existing	on amenity value of beach, but equally could become a feature with rock pools and weathering.	unlikely to require raising of promenade in Cowie. Rock armour would reduce	+ Provides HTL policy with increased SoP		- Excavation of beach	- Marine licence required		Option bought forward to short list as it can efficiently provide flood protection into the long-term.
7	**New stepped or sloping revetment**				5	3	1	4	2	3	3	3	5	3	3	4	39	
	The existing defences could be replaced by a new stepped revetment (as currently seen along the Cowie promenade), or by a similar modular blockwork structure or rock armour structure. All solutions could be designed such that their wave overtopping performance is suitable into the long-term scenario. Given the present-day overtopping risk, a higher crest level than existing will be required. To adapt to climate change, the wall would need to be raised further, which may require raising the promenade and footpath area behind the defence.				+High standard of performance + does not rely on existing structures	- complex construction on beach	- large capital costs	- medium maintenance	footprint of existing defences. Potential impacts on geology of SSSI and non-	+ Replacement of existing defences may not increase the defence footprint thus	defences already present within the bay, so limited impact in terms of visual setting.	already present, but potential loss of amenity space on beach. Need to maintain	+ Provides HTL policy with increased SoP		- Waste from demolition of concrete and excavation around wall	- Marine licence required		Option discounted due to the high capital cost and footprint.
8	**Beach recharge + control structures**				3	3	2	2	2	4	4	5	4	5	3	2	39	
	The beach within Stonehaven could be recharged increasing the beach crest width and height. To prevent the beach mobilising and moving around within the bay beach control structures would also likely be required. With a large enough beach in both height and width this option could be a solution in the long-term, however it would also require replenishment over time if it is shown that material is lost offshore or the beach migrates shoreward through "roll-over". This option may also require the raising of existing hard defences.				- Potential short design life + high standard of protection - relies on existing structures	+ simple construction - added complexity with beach control structures	- Medium / large capital costs	- potential for high maintenance costs depending on beach loss - maintenance of existing structures	Return natural foreshore and potential for ecological benefits if sound practice of beach	+ This is an NFM option which would require limited 'hard-defence' construction	Larger beach would add amenity value and is likely to enhance landscape and	Increase in beach amenity space. Access to beach maintained. No detrimental effects on views.	+ Allows for HTL to be implemented - but maybe not on it's own without being		- offshore dredging for beach sediment - requirement for recharge with suitable sediment - excavation for control structures	- large change to coast and foreshore, licences required		Option taken forward - will need to consider differences between north (rocky foreshore) and south (existing beach) of the zone. Contact with SNH would be helpful to ascertain viability of option in an environmental context.
9	**Foreshore recharge**				2	2	2	1	2	5	4	5	4	5	3	1	36	
	Similar to beach replenishment, this would look to have large quantities of beach material dumped near the centre of Stonehaven Bay, effectively making a very large beach / sand bar. Over time this material would move around within the bay, replenishing the existing beaches. This option would reduce the water depths within the bay and thus create a large area in which wave action would be dissipated across. This option would be suitable up until the long-term scenario given sufficient material deposition. It is possible that the beach would need replenishing by mid-century.				- Potential short design life + high standard of protection - relies on existing structures	+ simple construction - uncertainty around placement	- Medium / large capital costs	- potential for high maintenance costs depending on beach loss - maintenance of existing structures	Working with natural processes sand is transported to where it would accumulate	+ Creation of new foreshore habitats. - Impact of coastal water quality and ecology during	Larger beach and foreshore area - add amenity value and likely to enhance landscape and	Increase in beach amenity space. Access to beach maintained. No detrimental effects on views.	- More similar to ATL given the magnitude of nourishment required		- offshore dredging for beach sediment - requirement for recharge with suitable sediment	- large change to coast and foreshore, licences required		Option discounted due to cost, environmental impact and uncertainty whether the option would work in the long term.
11	**Managed realignment - Cowie**				4	1	1	2	4	4	3	3	1	2	1	3	29	
	Partial realigning the defence in the northern benefit area (Helen Row and Boatie Row) could be considered due to the flood risk and lower number of residential and businesses in this area. Within a partial realignment scenario, a secondary defence, potentially in the form of a vegetated earth bund, would be built set-back from the existing coastal defences; this would be required to prevent flooding to the remaining properties.				+ good standard of protection from reduced risk to properties	- very difficult to relocate properties	- high costs for relocation	- maintenance costs for existing defences	habitat would be increased, resulting in ecological	+ Makes space for coastal habitat development. Would improve	on amenity space, but also potential to make feature and undertake	amenity space. Earth bund could effect views and access would	- Against HTL policy		- Excavation and movement of large volumes of material	- Significant change to land + no maritime licences required		Discounted as not HTL and in stakeholder interest.
12	**Ground raising**				4	1	1	2	2	3	3	3	4	2	1	3	29	
	The flood risk in the northern benefit area is a result of the low ground level, meaning that any wave overtopping will flow down and flood this area. An option to consider instead of realigning the defence would be to raise the ground level immediately behind the defences such that flood water can only flow back out to sea. While this option is a large undertaking, it could secure the flood risk beyond the long-term scenario if coupled with repairs or replacements of the existing defences to manage erosion risk.				+ good standard of protection from reduced risk to properties	- very difficult to relocate properties	- High capital costs	- maintenance costs for existing defences	footprint of defence. Impacts on terrestrial habitats and potential to	+ Opportunity to integrate NFM measures with ground Raising e.g. woodland and vegetation	on amenity space, but also potential to make feature and undertake landscaping. Schedule	Potential impacts on views and access would need to be incorporated.	+ Partial implementation of HTL - without reducing overtopping along the front		- Demolition of buildings - land based excavation	- Significant change to land + no maritime licences required		Discounted as not in stakeholder interest or practical.
20	**Property relocation**				3	2	2	2	2	3	2	3	1	1	1	3	25	
	Properties at immediate flood risk behind the current coastal defences could be relocated, reducing potential flood damages while also providing additional space for flood protection improvement schemes behind the existing defences. While this option does not seek to reduce wave overtopping it could be coupled with other mid to long-term strategies to reduce flood risk damages.				+ Reduces properties at risk - relies on condition of existing defences	- difficult to relocate	- high costs for relocation	- maintenance costs for existing defences	Potential bat habitats in existing buildings. Disruption to terrestrial	No impact.	character of frontage, but also potential to landscape area	character of area could detract from tourism appeal, although	- Against HTL policy		- Demolition of buildings - land based excavation	- Significant change to land + no maritime licences required		Discounted as not in stakeholder interest or practical.
21	**Property Flood Resilience and Resistance (PFR)**				2	5	5	2	3	3	3	5	4	3	5	5		
	A short-term option to address flooding in less severe storm events, PFR measures could be a valuable option to incorporate into those properties at risk of flooding. For more severe storms and with increasing sea levels, the level of resilience will be limited and is therefore not considered to be a mid-term option, unless coupled with improvements to the coastal defences.				- low standard of protection	+ Easy to construct	+ low cost	- low maintenance costs - maintenance costs for existing defences	No impacts.	No impact.	No obvious issues.	No issues.	+ Partially supports HTL - but only in short-term		+ limited waste and disturbance	+ limited consenting		Taken through as 'quick win' instead of short list option.
22	**Do Nothing**				1	5	5	5	2	3	2	1	1	1	2	5	33	
23	**Do minimum**				1	5	5	2	3	3	3	3	3	1	3	3	35	

Option	Description	Standard of Protection: Short-term Present day to 2030	Standard of Protection: Mid-term Present day to 2070	Standard of Protection: Long-term Present day to 2118	Technical: Technical performance and adaptability	Technical: Buildability	Economic: Capital cost	Economic: Maintenance and monitoring	Environment: Ecology and environment	Environment: NFM and RBMP	Social: Landscape and Heritage	Social: Tourism	Political: Strategic alignment	Political: Stakeholder views	Legal: Waste management and contamination	Legal: Regulatory consenting and approvals	Total	Summary of long list
					Aims: Provides desired standard of protection throughout the design life of the scheme or is easily adaptable to allow for modifications for climate change through time	**Aims:** Safe to construct, local sources of appropriate material for construction, suitable ground conditions and would not conflict with existing services, primarily the sewer main along the front	**Aims:** Low capital cost.	**Aims:** Minimal ongoing maintenance and/or monitoring requirements and costs.	**Aims:** No environmental impact on local habitats, geology and ecology, including local designations.	**Aims:** Works with nature to provide natural protection and does not downgrade the existing classifications.	**Aims:** Works with the existing landscape and is sensitive to listed buildings and heritage designations.	**Aims:** Maintains access to beaches, considers local views and provides connectivity along the frontage.	**Aims:** Aligns with local strategies.	**Aims:** Supported by stakeholders and the local community.	**Aims:** Minimal waste disposal requirements or contamination risks.	**Aims:** Regulatory framework would be readily achievable.	Short list options in green	Key reason for shortlisting / discounting
1	**Replace sea wall**				4	3	2	4	3	3	3	4	5	2	3	4	40	
	A new wall could be built of concrete, steel piles or masonry. This option would seek to replace the existing defence or be built seaward of the existing wall. To adapt to climate change, the wall would need to be taller than the current defence, which may require raising the promenade and footpath area behind				+ High standard of protection and long design life. -Potential for increased scour	working within tidal windows, greater risk in low areas with smaller	-High capital costs	manganocene for concrete works and Potential scour and	take so no impacts on geology and	+ If the replacement wall has the same	of existing defence would increase amenity	sea views - need to raise promenade	+ Provides HTL policy with increased SoP	- includes increasing promenade levels	- Waste from demolition of concrete and excavation around wall	- Marine licence required		Option bought forward to shortlist as it provides flood protection in the long-term by raising the height of the defence. This option also includes extending the existing walls as in SFA option D. Note - Replacing wall does not necessarily require demolition of existing, encasement or similar possible.
2	**Raise existing sea wall**				2	5	4	1	3	3	3	2	3	1	5	5	37	
	Raising the existing wall would increase the flood protection performance of the defence in the short to mid-term. However, as this option relies on the existing structure it can only practically be raised so far without a complete re-build. In addition, without raising the promenade, sea views could be affected and therefore the wall could only be raised so far. In areas where the existing structures are currently in poor condition a concrete 'shroud' would be used to				+ increased performance - Poor design life as relies on the existing wall - Potential for increased scour	+ works predominantly land-based.	+low / medium capital costs.	+ High maintained costs for existing structures beach forms primary defence	footprint of defence. Potential impacts on geology of SSSI and non-	+ Raising the existing wall would not increase the area of coastline	existing and new materials would require consideration. Within	could only be raised so far before views become restricted - may need to	+ Provides HTL in short-medium term only		+ Limited demolition required, utilises existing structures	+ limited consenting required		Option discounted as does not address extreme sea levels at southern end of the 'Central' benefit zone. Maintenance of existing defence and beach also required adding to costs.
4	**Setback walls with flood gates**				4	3	4	1	4	3	3	4	2	3	3	4	38	
	Flood protection walls could be installed set-back from the existing coastal defences, these would run parallel to the roads and private property boundaries. In some instances, it is envisioned that private properties may require integrating into the defence line to ensure flood wall continuity; this would require waterproofing or shrouding of vulnerable areas. This option would help prevent flooding to the town through a secondary defence line; while it does not help reduce wave overtopping, it would prevent flood water from inundating properties. In the long-term this option will be less effective due to the extreme				+ Mid to long term performance - relies on existing defences for long term performance - does not mitigate scour	+ land based construction	-Medium capital costs	+ High maintained costs for existing structures beach forms primary defence	on terrestrial habitat. Reduced geological and ecological impacts. Potential to	+ No additional coastal land take which works toward the RBMP objectives. - Not full realignment and therefore still	existing and new materials would require consideration. Within conservation area with numerous	Potential loss of amenity space on landward side. Access to beach only effected during flood event.	- Allows same or higher level of overtopping of existing defences		- Excavation on land for wall foundations - Possible demolition of existing walls and surfaces	+ Land-based construction		Option discounted as it is understood that during previous events the momentum of water as well as deris carried with is unlikely to be stopped by setback walls. Also limited space on where these could be located in some areas.
5	**Offshore breakwater**				4	1	2	2	2	4	3	5	4	5	3	2	37	
	An offshore breakwater would seek to reduce the flood risk by dissipating wave energy within Stonehaven Bay. The size of the structure (height and width) would determine how much wave energy is dissipated. For this reason, a breakwater could be designed to be submerged such that it is not visible, creating a reef-like structure to break the largest waves offshore. As this option does not increase the height of the existing defences it may only offer limited protection in				+ long term performance - relies on condition of existing defences	- Difficult to construct, water based activities	- High capital costs for volume of material required and construction	+high maintenance costs for existing structures	significant alteration to coastal processes and downdrift erosion issues,	+ May increase the area of sandy foreshore which would have NFM benefits by increasing the	structure would have no impacts on landscape or seascape. Potential impacts	works required along the frontage, thus keeping wall heights down.	+ Allows for HTL to be implemented more effectively through reducing direct		- Possible dredging activities	- Marine licence required - offshore work		Discounted as extreme sea levels will still cause flooding in the long term.
7	**New stepped or sloping revetment**				5	3	1	4	2	2	2	2	5	2	3	4	35	
	The existing defences could be replaced by a new stepped revetment (as currently seen along the Cowie promenade), or by a similar modular blockwork structure or rock armour structure. All solutions could be designed such that their wave overtopping performance is suitable into the long-term scenario. Given the present-day overtopping risk, a higher crest level than existing will be required. To adapt to climate change, the wall would need to be raised further, which may				+High standard of performance + does not rely on existing structures	- complex construction on beach	- large capital costs	- medium maintenance	existing defences may not increase the footprint. Potential impacts on geology of	+ Replacement of existing defences may not increase the defence footprint thus minimising	defences already present within the bay, although defences in central section	already present (buried beneath shingle). Need to be higher than current	+ Provides HTL policy with increased SoP		- Waste from demolition of concrete and excavation around wall	- Marine licence required		Option discounted due to the high capital cost and limited difference to sea wall.
8	**Beach recharge + control structures**				3	3	3	2	3	4	4	5	4	5	3	2	41	
	The beach within Stonehaven could be recharged increasing the beach crest width and height. To prevent the beach mobilising and moving around within the bay beach control structures would also likely be required. With a large enough beach in both height and width this option could be a solution in the long-term, however it would also require replenishment over time if it is shown that material is lost offshore or the beach migrates shoreward through "roll-over". This option may				- Potential short design life + high standard of protection - relies on existing structures	+ simple construction - added complexity with beach control structures	- Medium / large capital costs	- potential for high maintenance costs depending on beach loss - maintenance of existing structures	foreshore and potential for ecological benefits if sound practice of beach	+ This is an NFM option which would require limited 'hard-defence' construction	would add amenity value and is likely to enhance landscape and	amenity space. Control structures could detract from beach, but also provide	+ Allows for HTL to be implemented - but maybe not on it's own without being		- offshore dredging for beach sediment - requirement for recharge with suitable sediment - excavation for control structures	- large change to coast and foreshore, licences required		Option bought forward to short list as larger beach can provide flood protection and increases amenity values. Option is the same as SFA option B; same as option C as beach control structures are not defined at this stage (could be timber or rock groynes).
9	**Foreshore recharge**				2	2	2	1	2	5	4	5	4	5	3	1	36	
	Similar to beach replenishment, this would look to have large quantities of beach material dumped near the centre of Stonehaven Bay, effectively making a very large beach / sand bar. Over time this material would move around within the bay, replenishing the existing beaches. This option would reduce the water depths within the bay and thus create a large area in which wave action would be dissipated across. This option would be suitable up until the long-term scenario				- Potential short design life + high standard of protection - relies on existing structures	+ simple construction - uncertainty around placement	- Medium / large capital costs	- potential for high maintenance costs depending on beach loss - maintenance of existing structures	natural processes sand is transported to where it would accumulate	+ Creation of new foreshore habitats. - Impact of coastal water quality and	foreshore area - add amenity value and likely to enhance landscape and	amenity space. Access to beach maintained. No detrimental effects on views.	- More similar to ATL given the magnitude of nourishment required		- offshore dredging for beach sediment - requirement for recharge with suitable sediment	- large change to coast and foreshore, licences required		Option discounted due to the environmental impact on the rocky foreshore and the high capital and maintenance costs.
10	**Beach and river realignment**				4	3	2	2	2	2	3	3	4	2	2	2	31	
	Within the central section, the beach could be moved seaward with a view to redirect the Cowie Water south towards the Carron, as it flowed historically. As the beach is moved seaward, it would effectively act as type of breakwater to the hard coastal defences, however this realignment would likely require nourishment along with control structures to make sure the system is stable in extreme events and not breached. This option would be suitable into the mid-term scenario, but exposing the toe of the hard defences for the realigned river may require				+Good standard of protection + limited design life of existing structures	- difficult construction - risk of destabilising existing defences	- high costs	- high maintenance costs associated with unearthing existing defences and managing the beach	- need to consider habitats that would be lost. Impacts on ecological and RBMP status of	+ Redirecting the Cowie may enhance sediment transport from the fluvial environment to	through re-alignment. Change in character of frontage, although also	format of beach, but potential to create new amenity space with bridges to link promenade to	- More similar to ATL given the magnitude of nourishment required		- Excavation of beach and river mouth, potential contaminants	- Change to coast and foreshore, licences required		Option discounted due to buildability concerns, maintenance costs and stakeholder views.
14	**River Cowie training wall / groyne extension**				4	3	2	3	2	2	3	2	4	2	2	3	32	
	The existing concrete structure could be extended further out and southward to shelter the river mouth from waves. The structure could be an extension of the concrete structure or be formed of rock armour. As this defence does not increase the height of the existing river banks, it is only effective to the mid-term scenario, however coupled with existing defence improvements would make it a				+ would shelter cowie +High standard of protection	- complex construction - impact on cowie mouth	- high / medium cost based upon size of structure	- medium maintenance	and is outwith SSSI boundary. Construction and operation could	+ Sheltering the river mouth may prevent excess sediment	potential impacts on views. Within conservation area	Potential impact on views. No change on access to beach.	- Not an option alone + but aides implementation of HTL	+ SFA additional option A	- Excavation beach and river mouth, potential contaminants	- Change to coast and foreshore, licences required		Discounted as stakeholder concerns on impacts of diverting flow southwards on sediment infront of coastal defences.
20	**Property relocation**				3	2	2	2	2	3	2	3	1	1	1	3	25	
	Properties at immediate flood risk behind the current coastal defences could be relocated, reducing potential flood damages while also providing additional space for flood protection improvement schemes behind the existing defences. While this option does not seek to reduce wave overtopping it could be coupled with other mid to long-term strategies to reduce flood risk damages.				+ Reduces properties at risk - relies on condition of existing defences	- difficult to relocate	- high costs for relocation	- maintanence costs for existing defences	Potential bat habitats in existing buildings. Distruption to terrestrial	No impact.	Impacts on character of frontage. Within conservation area	No impact on sea views or access.	- Against HTL policy		- Demolition of buildings - land based excavation	- Significant change to land + no maritime licences required		Discounted as not in stakeholder interest or practical.
21	**Property Flood Resilience and Resistance (PFR)**				2	5	5	2	3	3	3	5	4	3	5	5		
	A short-term option to address flooding in less severe storm events, PFR measures could be a valuable option to incorporate into those properties at risk of flooding. For more severe storms and with increasing sea levels, the level of resilience will be limited and is therefore not considered to be a mid-term option, unless coupled with improvements to the coastal defences				- low standard of protection	+ Easy to consturct	+ low cost	- low maintanence costs - maintanece costs for existing defences	No impacts.	No impact.	No impact.	No impact.	+ Partially supports HTL - but only in short-term		+ limited waste and disturbance	+ limited consenting		Taken through as 'quick win' instead of short list option.
22	**Do Nothing**				1	5	5	5	2	3	2	1	1	1	2	5	33	Discounted as not inline with HTL policy
23	**Do minimum**				3	5	5	2	3	3	3	3	3	1	3	3	35	Discounted due as it does not address flood risk issues.
SFAG Option A	**Cowie southern training wall**																	Will be considered as part of control structures within option 8.
SFAG Option B	**Central area groynes**																	Will be considered as part of control structures within option 8.
SFAG Option C	**Offshore rock armour**																	Rock armour will be considered as a control structre within option 8.
SFAG Option D	**Sea wall extension**																	Extending the direct defences into this area would be considered within any of the direct defence options above.
SFAG Option E	**Groynes, Cowie southern training wall, rock armour and recharge**																	Will be considered within option 8.

Option	Description	Standard of Protection: Short-term	Standard of Protection: Mid-term	Standard of Protection: Long-term	Technical: Technical performance and adaptability	Technical: Buildability	Economic: Capital cost	Economic: Maintenance and monitoring	Environment: Ecology and environment	Environment: NFM and RBMP	Social: Landscape and Heritage	Social: Tourism	Political: Strategic alignment	Political: Stakeholder views	Legal: Waste management and contamination	Legal: Regulatory consenting and approvals	Total	Summary of long list
		Present day to 2030	Present day to 2070	Present day to 2118	**Aims:** Provides desired standard of protection throughout the design life of the scheme or is easily adaptable to allow for modifications	**Aims:** Safe to construct, local sources of approriate material for construction, suitable ground conditions and would not conflict with existing services.	**Aims:** Low capital cost.	**Aims:** Minimal ongoing maintenance and/or moitoring requirements and costs.	**Aims:** No environmental impact on local habitats, geology and ecology, including local designations.	**Aims:** Works with nature to provide natural protection and does not downgrade the existing classifications.	**Aims:** Works with the existing landscape and is sensitive to listed buildings and heritage designations.	**Aims:** Maintains access to beaches, considers local views and provides connectivity	**Aims:** Aligns with local strategies.	**Aims:** Supported by stakeholders and the local community.	**Aims:** Minimal waste disposal requirements or contamination risks.	**Aims:** Regulatory framework would be readily achievable.	Short list options in green	Key reason for shortlisting / discounting
	INNER HARBOUR																	
3	**Small rock armour revetment**				1	3	3	4	3	2	3	3	3	3	3	4	35	
	Rock armour could be installed at the base of the existing sea wall to increase flood protection performance. As this solution does not increase the height of the defence it is only viable in the short to mid-term without the full effects of sea level rise. The rock armour would encroach onto the amenity beach (or into the mooring zone within the harbour), but it would not affect line-of-site from the town.				+ Increased performance in the mid term + provides scour protection - disrupts mooring and	- Beach based activity - difficulty excavating at toe of defences	+low / medium capital costs.	+ limited maintance costs for rock armour	Larger footprint than sea wall so habitat loss would occur. Potential impacts	- Additional coastal land take which is not inline with the RBMP objectives	Potential impact on amenity value of beach, but equally could become a feature	No impact on views or access.	+ Provides HTL - in short-medium term only		- Disposal of excavated harbour deposits	- Marine licence required		Option discounted as it will impede on harbour operations and not provide sufficient protection into the long-term.
7	**New stepped or sloping revetment**				5	2	2	4	3	2	3	3	5	3	3	4	39	
	The existing defences could be replaced by a new stepped revetment (as currently seen along the Cowie promenade), or by a similar modular blockwork structure or rock armour structure. All solutions could be designed such that their wave overtopping performance is suitable into the long-term scenario. Given the present-day overtopping risk, a higher crest level than existing will be required. To adapt to climate change, the wall would need to be raised further, which may require raising the promenade and				+ High standard of protection and design life	- Difficult construction in harbour	- High capital costs for consturction type and difficulty	- Small maintanence costs	Replacement of existing defences may not increase the footprint. Potential impacts on geology of	- Additional coastal land take which is not inline with the RBMP objectives.	Change in defence type within the harbour - setting of listed harbour will need to be considered.	No impact on views or access.	+ Provides HTL policy with increased SoP		- Limited disposal of excavated harbour deposits - concrete waste	- Marine licence required		Option taken through to short list as it meets the technical requirements and can be designed to have a similar appearance to the existing aligning with heritage aims.
16	**Advance the line with new vertical wall**				4	3	3	3	4	3	3	3	5	3	5	4	43	
	Within the harbour a new wall alignment could be built at the toe of the existing defence without effectively increasing the footprint of the structure. The defence would likely be made from sheet piles, which could be clad with timber to aid with mooring and improve the appearance of this option. Concrete or masonry would also be suitable materials for construction, though may have a larger footprint. This option would also widen the promenade/road making better access for pedestrians				+ High standard of protection and medium to long design life	- Beach based activity - diruptive construction and access	- Medium costs	- Maintenance costs associated with pile corrosion	Relatively localised impact. Outside of SSSI. Change in defence type may have impacts on local	+ No additional coastal land take works towards RBMP objectives.	Increase of amentiy space on landward side without loss of beach. Careful	No impact on views or access.	- Against HTL policy		- limited waste	- Marine licence required		Option progressed to short list as it is practical to construct and cost-effective.
17	**Extension of harbour breakwater arm**				3	2	2	3	2	2	2	2	4	1	2	2	27	
	The existing outer breakwater arm could be extended to further shelter the middle basin from wave overtopping. This defence could be an extension of the concrete structure or a rock armour structure. This option would have to carefully take into account the navigation routes for vessels and might require dredging to maintain the required navigation channel width.				+ Medium standard of protection - residual risk of reflection within harbour still causing	- Difficult construction	- High costs	- Medium maintenance	Relatively localised impact in a heavily modified setting. Outside of SSSI	+ Breakwater arm is not a direct pressure on the physical	Possible impacts on views and setting of listed harbour will need to be considered	Reduction in views. No impact on access.	+ Allows for HTL to be implemented - but may require additional works		- possible dredging activities - concrete waste	- Marine licence required - offshore work		Discounted due to capital cost and stakeholder concerns.
18	**New breakwater arm**				3	2	2	3	2	2	2	2	4	3	3	2	30	
	A new southern breakwater arm could be built further out from the harbour and connected to the headland. This option would provide additional shelter to the harbour, potentially protecting the inner and outer areas of the harbour and could increase the active harbour space allowing a new mooring basin to be designed by the South Pier and old lifeboat house. The form of this new breakwater arm would likely be of rock armour				+ Medium standard of protection - residual risk of reflection within harbour still causing	- Difficult construction	- High costs	- Medium maintenance	Relatively localised impact in a heavily modified setting. Outside of SSSI	+ If inner harbour doesn't require further work the degree of physical alteration may	Possible impacts on views and setting of listed harbour will need to be considered	Reduction in views. No impact on access.	+ Allows for HTL to be implemented - but may require additional works		- possible dredging activities - concrete waste	- Marine licence required - offshore work		Discounted due to capital cost and stakeholder concerns.
20	**Property relocation**				2	1	2	2	2	3	3	3	1	1	1	2	21	
	Properties at immediate flood risk behind the current coastal defences could be relocated, reducing potential flood damages while also providing additional space for flood protection improvement schemes behind the existing defences. While this option does not seek to reduce wave overtopping it could be coupled with other mid to long-term strategies to reduce flood risk damages.				+ Reduced properties at risk - infrasturcture and harbour still at risk	- Difficult to relocate buildings	- Cost associated with relocation	- High cost of mainenance of existing structures	Potential bat habitats in existing buildings. Distruption to terrestrial	No impacts.	Setting of listed harbour will need to be considered.	No impact on views or access.	- Against HTL policy		- Debris from property relocation	- relocation of properties, land-based consenting		Discounted as not in stakeholder interest or practical.
21	**Property Flood Resilience and Resistance (PFR)**				2	5	5	2	3	3	3	3	3	3	5	5		
	A short-term option to address flooding in less severe storm events, PFR measures could be a valuable option to incorporate into those properties at risk of flooding. For more severe storms and with increasing sea levels, the level of resilience will be limited and is therefore not considered to be a mid-term option, unless coupled with improvements to the coastal defences.				- Short term performance and deisgn life - existing harbour walls at risk of failure	+ Simple constrction	+ low cost	- High maintenance of existing walls and properties	No impacts.	No impacts.	Limited visual impacts.	No impact on views or access.	+ Partially supports HTL - but only in short-term		- limited scale of disturbance	+ limited disruption		Taken through as 'quick win' instead of short list option.
22	**Do Nothing**				1	5	5	5	2	3	2	1	1	1	2	5	33	Option discounted as it does not limit wave overtopping and flood risk.
23	**Do minimum**				1	5	5	2	3	3	3	3	3	1	3	3	35	Option discounted as it does not limit wave overtopping and flood risk.
	SOUTHERN HARBOUR																	
13	**Managed realignment**				2	5	5	3	5	5	3	3	1	2	3	5	42	
	As there is limited development at risk in the south harbour, managed realignment could be considered. This option would likely also require a setback wall with flood gate at the edge of the existing harbour arm to limit wave overtopping into the inner basin.				- performance not improved	+ no costs associated with coastal protection - limited costs associated with dismanelling buildings	+ low cost	- increased maintanance for exposed harbour wall in future	Area of coastal habitat would be increased - ecological benefits. Would encourage more natural functioning of the	+ Makes space for coastal habitat development. Would improve the RBMP status of the coastline. - Short term water	Loss of amenity space on landward side. Setting of listed harbour will need to be considered.	Loss of amentiy space in south of harbour. No impact on views or access.	- Against HTL policy		- debris from allowing current defences fail	- no active intervention		Taken through to short list as it is cost-effective.
15	**Rock armour revetment extension**				5	3	3	4	3	3	3	3	4	3	4	4	42	
	The existing rock armour structures located to the north of the harbour have very narrow crest widths; extending the rock armour crest width would effectively improve their performance against wave overtopping. In the long-term scenario, with the higher extreme sea levels, it might be that the defence would require a raised parapet wall at the rear of the rock armour profile.				+ High standard of protection and design life	- Disruptive construction at outer harbour	- Medium cost	+ Limited maintanence of rock armour required	localised impact in heavily modified setting. Outside of SSSI. Increase in defence footprint may impact	+ Similar defence to that already present. - additional coastal land take which is against RBMP objectives.	Same as defence type already present so no impact in terms of townscape. Potential loss of beach amenity space.	No impact on views or access.	+ Provides HTL policy with increased SoP		- Disposal of excavated harbour deposits	- Marine licence required		Taken through to short list to align with stakeholder views.
19	**Advance the line**				5	2	2	4	2	2	3	4	1	2	3	3	33	
	To maximise the benefits from improving the coastal defences in the south of the harbour, advancing the line with a new defence would create a new area in which additional businesses could be built on. As this option widens the defence it will prevent overtopping flow into the inner basin. This option could re-use the existing rock armour into a new defence, or alternatively an extension of the South pier could be considered in				+ High standard of protection and design life	-complex construction	- High capital costs	+ limited maintanence depending upon defence type	Outside of SSSI. Coastal land claim - could impact ecology and geology of the	- Land claim to advance defences does not meet RBMP objectives and may affect	Increase in amenity space on land. Change in views/setting due	Additional amentiy space in south of harbour. No impact on views or access.	- Against HTL policy		- Disposal of excavated harbour deposits	- Marine licence required		Discounted from short list due to costs and against HTL policy.
23	**Do minimum**				2	5	5	2	3	3	3	3	3	1	3	3	36	Discounted due to maintenance requirements and costs.
	NORTH OF HARBOUR																	
15	**Rock armour revetment extension**				5	3	3	4	3	3	3	3	5	3	4	4	43	
	The existing rock armour structures located to the north of the harbour have very narrow crest widths; extending the rock armour crest width would effectively improve their performance against wave overtopping. In the long-term scenario, with the higher extreme sea levels, it might be that the defence would require a raised parapet wall at the rear of the rock armour profile.				+ High standard of protection and design life	- Disruptive construction at outer harbour	- Medium cost	+ Limited maintanence of rock armour required	localised impact in heavily modified setting. Outside of SSSI. Increase in defence footprint may impact	+ Similar defence to that already present. - additional coastal land take which is against RBMP objectives.	Same as defence type already present so no impact in terms of townscape. Potential loss of beach amenity space.	No impact on views or access.	+ Provides HTL policy with increased SoP		- Disposal of excavated harbour deposits	- Marine licence required		Option progressed for northern harbour option to prevent overtopping into carpark. The option will look at a combination of additional rock plus a parapet wall to achieve a cost-effective defence combination.
22	**Do Nothing**				1	5	5	5	2	3	2	1	1	1	2	5	33	Option discounted as it does not limit wave overtopping and flood risk.
23	**Do minimum**				1	5	5	2	3	3	3	3	3	1	3	3	35	Option discounted as it does not limit wave overtopping and flood risk.

L Long-list public consultation feedback

STONEHAVEN
FLOOD
ACTION

Chairman: [redacted] **Treasurer:** [redacted]
Deputy Chairman: [redacted] **Secretary:** [redacted]

13th February 2019

To Stonehaven Bay Coastal Flood Protection Study Team
Carlton House
Stonehaven
Aberdeenshire

On behalf of the Stonehaven Flood Action Group I am pleased to enclose our response to the Coastal Flood Protection Study Consultation held on Tuesday 29th January 2019.

We are grateful for the opportunity to work with the Team and to have been allowed the time to discuss the consultation documents in order to compile our views.

I wish to commend the process, structure and conclusions set out in our attached document and to offer our best wishes as this Study moves into the next phase.

[redacted]
Secretary
Stonehaven Flood Action Group

Executive Summary

In response to Aberdeenshire Council's request for feedback on options to reduce the risk of Coastal flooding along the Stonehaven Coastal Area, the Stonehaven Flood Action Group, SFAG have prepared this document. From the "long List Options", following analysis three have been specifically selected. These are options 5, 8 and 9. In addition, five alternative options have been proposed. Each of these are briefly summarised in this document

Date of Response: 13th Feb 2019.

Reference document - Long list Options

This is part of the STONEHAVEN BAY COASTAL FLOOD PROTECTION STUDY –

Introduction

May we begin by expressing our appreciation of the opportunity to consider and comment on the Long List Options prepared by JBA Consulting and Aberdeenshire Council. These 21 options were first shown at a public meeting on 29th Jan 2019. They were then made available to download on the 30th Jan. At this meeting a request was made by Aberdeenshire Council to the attendees to identify and feedback some options. Those being items which could be put forward to be analysed further.

The approach taken by the Stonehaven Flood Action Group was one of inclusion, with involvement of residents, businesses and other stakeholders in the coast line. After allowing these people some time to read and consider each of the options a meeting was held on 11th Feb 2019. There, as a group we met and collectively discussed each option.

First, and to comply with the request our summary conclusions for those 21 options are given. Each is then discussed individually on its merits and problem areas. In the final section of this feedback five additional options have been included. These were formulated through group discussion and using the initial 21 as a starting point.

Stonehaven Flood Action Group hopes to continue working with Aberdeenshire Council and its consultants in a positive way. In particular, we look forward to discussions as we work towards the Short List.

Lastly, we welcome this paper as representing progress towards giving Stonehaven the protection it needs. It should be remembered though that previous studies into coastal flooding have been commissioned but not followed through. This report will only be of value if acted on timeously and appropriately.

Conclusions

The table below illustrates the summary conclusion on whether each of the 21 options presented in JBA's Long List report should be investigated to improve flood prevention.

Option	Title	Selected	Brief note
1	Replace Sea Wall	No	
2	Raise Existing Seawall	No	Compare with the previous JBA report in 2014.
3	Small Rock Armour Revetment	No	
4	Setback walls with flood gates	No	
5	Offshore Breakwater	Yes	See SFAG Option C
6	Wall Extension with Rock Armour Revetment	No	
7	New Stepped or sloping revetment	No	But note a variation on this – SFAG Option D
8	Beach Recharge & Control Structures	Yes	See SFAG Options B & E
9	Offshore Recharge	Yes	See SFAG Option E
10	Beach & River Realignment	No	
11	Managed realignment - Cowie	No	
12	Ground Raising	No	
13	Managed realignment – south harbour	No	
14	Cowie Water Training wall extension	No	But consider instead SFAG Option A
15	Rock Armour revetment extension	No	
16	Advance the line with new vertical wall	No	
17	Extension of harbour breakwater arm	No	Dangerous for shipping
18	New Breakwater arm	No	
19	Advance the line – south harbour	No	
20	Property relocation	No	
21	Property flood resilience	No	

In conclusion, a combination of measures designed to extend and secure a shingle beach is felt to be more cost effective and less disruptive than some of the major engineering works under consideration. For example, training walls to the south of the Cowie, north of the Carron and groynes suitably placed between these locations would help to reduce the long shore drift of shingle. These measures are illustrated and described more fully.

Offshore breakwaters possibly angled to divert water northwards countering the southerly drift of shingle are also likely to be of benefit. Similar methods have been tried and tested in many areas and are understood to be both effective and cost effective. Indeed, an offshore breakwater (option 5) even though submerged through much of the tide, could still prove valuable in helping dissipate wave energy.

Discussion

In this section of the response each of the 21 options are commented on by the Stonehaven Flood Action Group.

Option 1 – this would be a significant undertaking with much further work to be done in the planning stage. There are several difficulties including the position of the sewage pipe which extends northwards from the Carron. Also, moving the sea wall seaward could result in a narrower beach which in itself would reduce the defence value of such a beach. When the costs of raising the walk-way are added on, it is felt that the costs of this proposal would outweigh any benefits. In addition, raising the height of the sea wall would not be in accordance with residents' wishes and would lessen the amenity value of the sea front.

Option 2 – this option was previously mooted in a JBA report in 2014. The same objections on amenity grounds, as mentioned above, are also valid and it is unlikely in itself to stop over topping. It may in fact aggravate the situation by holding water in and preventing it from running back on the beach. That said, there may be scope for a relatively slight increase in the height of the wall. If this were done sympathetically and in a tasteful, creative manner, it may possibly enhance the appearance of the sea frontage. For this reason, it should not be completely discounted, but the focus for any height increase must be for preventing overtopping. i.e. no point raising the height if the risk of overtopping isn't removed. Then balancing this with the effect to the amenity.

Option 3 – Many parts of the bay are already protected by rock armour revetments. There may be scope for further revetments in front of Cowie village, but digging out sand and shingle there to allow placement of a revetment could do more harm than good. At best it may help protect the sea wall but will do little to stop over topping.

Option 4 – This is a resilience measure already undertaken by residents in some areas and which may again trap water on the landward side of sea wall. Unless it was continuous it may tend to push water onto more vulnerable properties. It would incur ongoing deployment costs, maintenance, etc and as much of the water invading the walkway come from the south and north ends of this section of beach, it is not felt to address the problem.

Option 5 – An offshore breakwater maybe be valuable in a number of ways. It may help retain shingle on the beach and also interfere with wave propagation, hindering it and reducing its amplitude before it reaches the shore. There is potential for discrete areas of breakwater, possible angled to divert waves onto each other or rock revetments similar to those at the north end of the harbour. It would need closer modelling but when considered in conjunction with options 8 and 9 has significant potential. Even a relatively low breakwater, inconspicuous at high tide, could have considerable effect in dispersing waves and reducing their height.

Option 6 – While rock armour may help at this point, raising the sea wall may have little effect on over topping. In any case the proposal should be seen as essential maintenance work and not an improvement to flood defences.

Option 7 – Revetments as described are currently in place from the north end of Cowie to the vicinity of Market Lane. Maintenance may be required, but much of the revetment is presently covered by shingle which is seen as beneficial in helping break waves further to seaward. There needs to be some clarification as to what can be done at the Harbour.

Option 8 – This is seen as a valuable measure, subject of course, to suitable material being used. It would be particularly useful in conjunction with some control structures for example groynes, or the breakwater referred to above. A combination of these measures is likely to be, in our view, effective and represent value for money.

Option 9 – As above, a broad beach or shingle bar is thought to be the best defence, subject to appropriate retaining structures being deployed.

Option 10 – This is not considered viable and the original route of the Cowie passed through what is now a combination of developed land and the sea wall. To fit with the existing structures, it would involve constructing both banks of new Cowie channel on what is the seaward side of the sea wall. i.e. to avoid it undermining the existing sea wall. Bridges would be required to gain access to the shore etc. It is not considered practically feasible.

Option 11 – This proposal is of questionable value and a vegetated earth bund is not felt to offer the quality of defence required. Unless completely continuous, which may not be feasible, it may aggravate flooding by retaining seawater on the landward side. In any case it would be of little value in the long term given the flooding anticipated in the 200 year plan.

Option 12 – Objections as to Option 11 pertain to this option also.

Option 13 – There is little development to the south of the harbour and money spent here could perhaps be better spent elsewhere. Overtopping into the inner harbour is not considered, at present, a significant problem, and the booms and the existing walls provide adequate protection.

Option 14 – This is considered inadvisable and would tend, by diverting the Cowie estuary southwards, to cause erosion in the vicinity of the Crow's Nest and remove shingle from the front of Turners Court. It would aggravate the existing north/south drift along the shore and increase the risk of overtopping.

Option 15 – The existing rock armour at this point seems to work well and although some maintenance may periodically be required it is not felt that an increase in the extent of the armour or a raised parapet wall should be seen as priorities.

Option 16 – This would have a questionable effect on over topping but at the moment cannot be dismissed unless further detail is provided.

Option 17 – Having considered the views of fishermen and other harbour users, this is felt to be a potentially dangerous proposal. By diverting the harbour approach southwards, it would make a difficult entrance even harder and put vessels in danger from rocks on the south shore.

Option 18 – This is likely to prove an expensive option and, as it may only improve protection to the southern extremities of the harbour, is unlikely to be cost effective.

Option 19 – As with option 18, this is not seen as relevant and indeed may even divert waves onto the harbour wall with the possibility of damage there. Money may be better spent protecting areas of greater value.

Option 20 – This option carries huge financial, social and amenity costs. In addition, it would merely move the problem landward while damaging the visual appeal of Stonehaven sea front. It is not thought worthy of further consideration.

Option 21 – Protecting individual properties by resilience methods has already been undertaken by many property owners. Individual property protection should perhaps be left to individuals, and money for flood defences invested in ways that benefit the town overall.

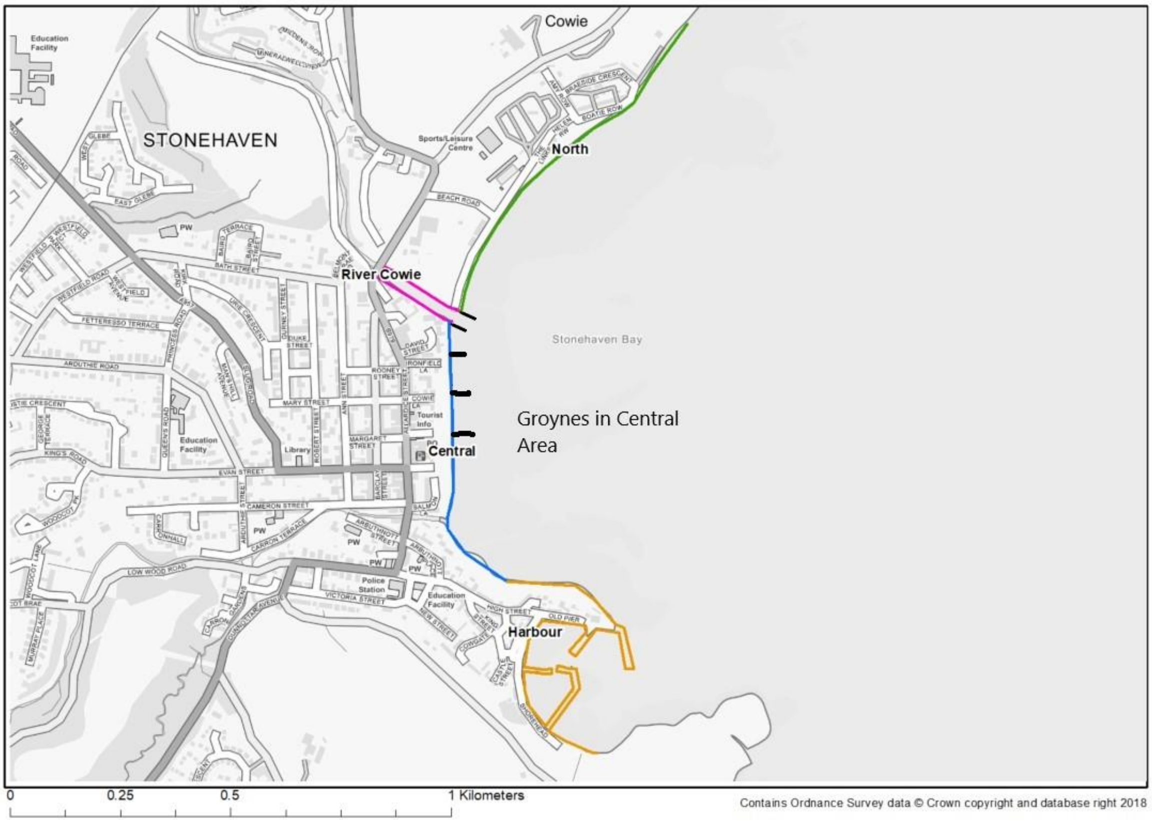
Additional Options

In this section of the response a total of five additional options are presented. It is anticipated that a complete solution for the Stonehaven Bay area could encompass elements from more than one of the options.

Option A - Cowie Estuary Southern Training Wall

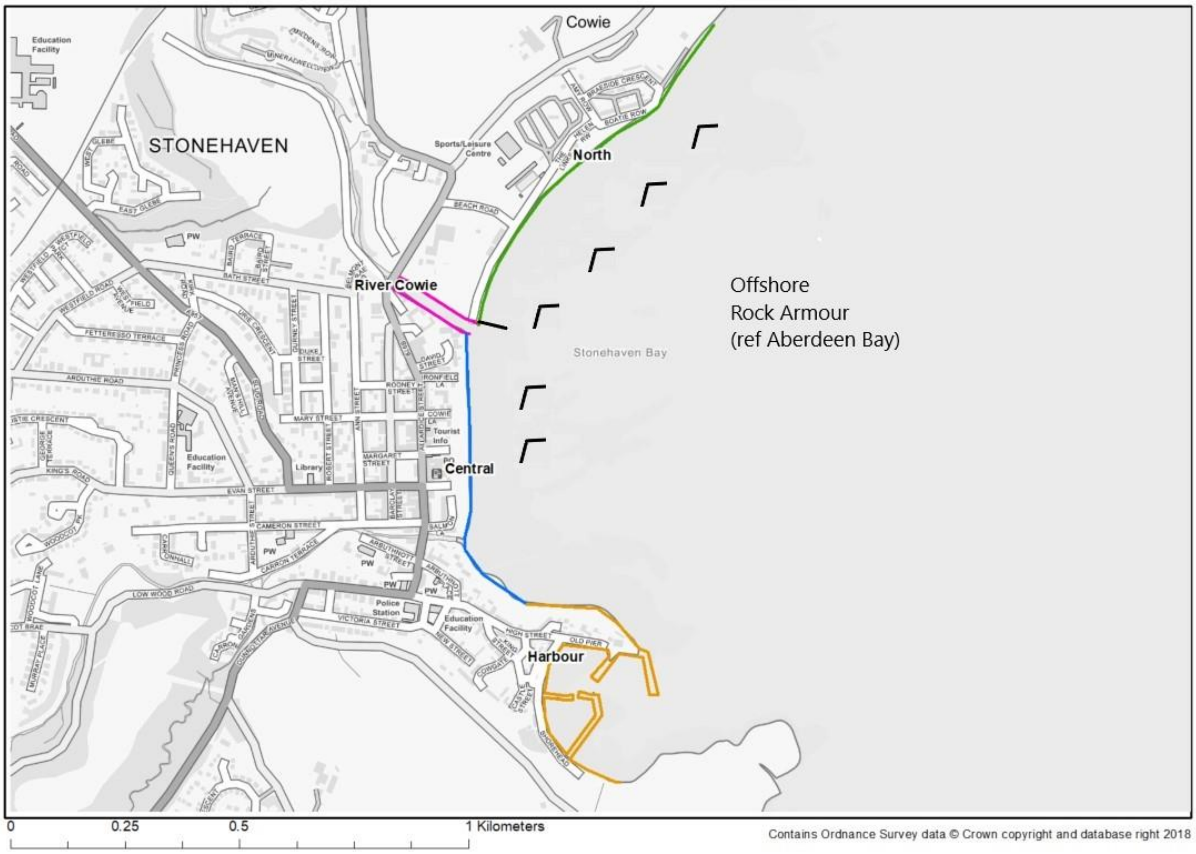
A training wall to the south of the river Cowie, extending seawards, running parallel to the existing training wall may have the effect of moving the river mouth away from the shore and in do so reducing shingle erosion at both the Crow's Nest and along the section in front of Turners Court. We consider this an option worth further consideration.

Option B – Central Area Groynes



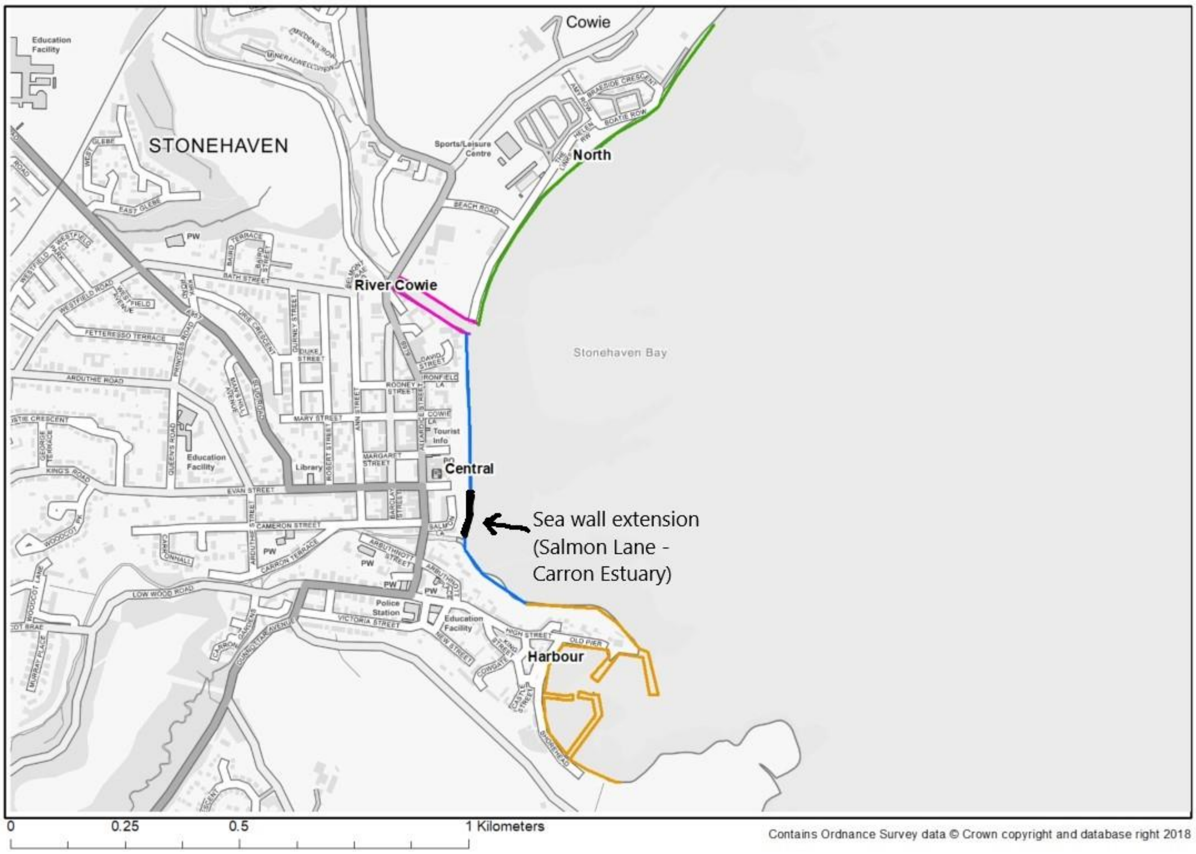
By comparison with JBA's option 8, Option B is the more specific and focused just on the central area. Option B shows the addition of a training wall, (Option A) and three additional Groynes in the central section. While the actual number and position of these groynes should be determined through engineering examination, for clarity in the figure each is shown to be aligned adjacent to an existing beach access road. While not shown in the figure the effect of beach recharge should also be examined.

Option C - Offshore Rock Armour



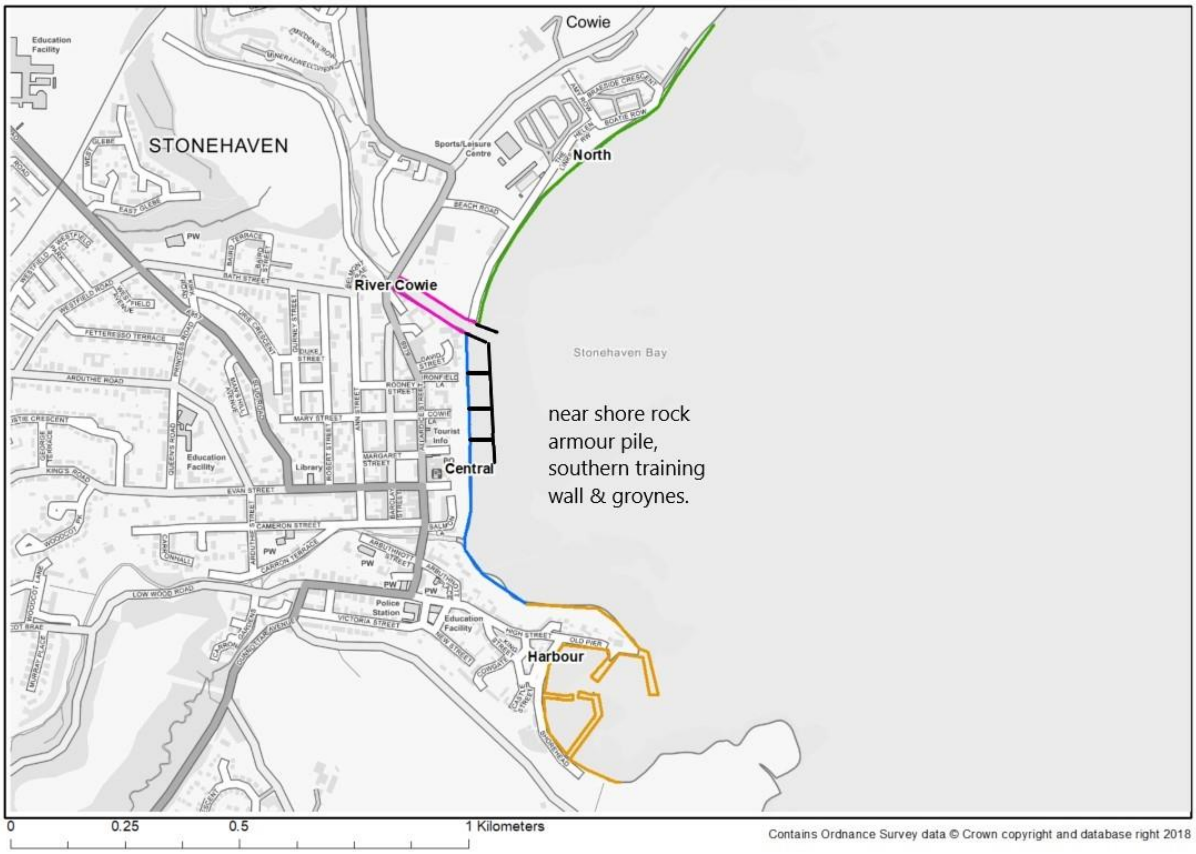
By comparison with JBA's option 5, option B is more specific and looks at the effect of positioning piles of rock armour at various offshore locations. Arranged in a similar manner to that which is used by Aberdeen Council in the Aberdeen City Bay. The figure above shows a total of 4 structures in the northern section and 2 in central section. While the shape of each is shown to be a "V", the actual design and orientation would require engineering modelling. It is also anticipated that these structures will be visible.

Option D – Sea Wall Extension



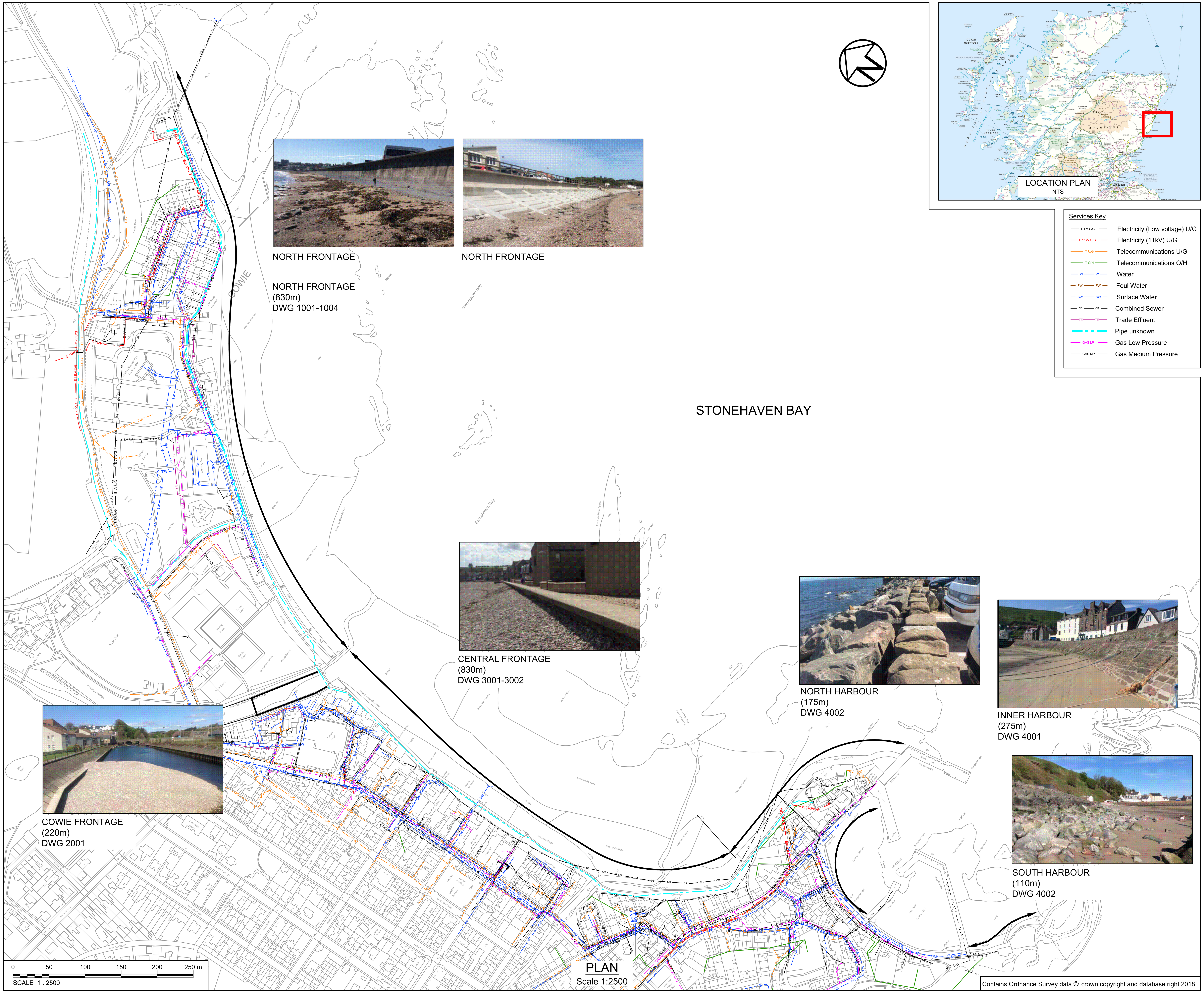
This option is based on extending the existing central sea wall from its current end location to pass in front of Salmon Lane and terminate just short of the northerly bank of the Carron River. The aim is to establish if this will reduce the risk of flooding in that section of the beach front. Note the existing single level would be maintained and the presumption is that the wall could be located east of the sewage pipe and the boardwalk.

Option E – Groynes, Cowie Southern training wall, rock armour, recharge



By comparison with JBA's option 8 & 9, Option E is more specific, and looks at the effect of positioning rock armour to form an extended near shore defence. The addition of groynes and beach recharge have also been included. The focus is the central section from the Cowie estuary to Market Lane. i.e. Beyond the point where the influence of the Brachans aids in dissipating the waves. The near shore position is in the above figure, shown to be comparable to the length of the existing training wall that is located on the northern bank of the Cowie Estuary. It is anticipated that this structure will be visible on the beach. The height though does warrant investigation.

M Engineering Drawings, Technical Note and Designers Risk Assessment



Construction Risks	Public Risks	Environmental Risks
• Unknown foundation depth of existing structures • Unknown ground conditions • Working in tidal conditions • Working at height • Lifting operations • Excavations in soft beach material	• Plant movement on beach and promenade • Disturbance to public by plant noise	• Debris and dust from construction work • Pollution hazards

In addition to the hazards/risks normally associated with the types of work detailed on this drawing take note of the above.
It is assumed that all works detailed on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

General Notes

1. All dimensions shown are in millimetres unless otherwise stated and levels are in metres to Ordnance Datum.
2. Do not scale from this drawing. All dimensions must be checked/verified at detailed design and on site.
3. All levels quoted on drawings were taken from profiles surveyed in May 2018, by JBA Consulting.
4. All works on the coast will be carried out with care to minimise the risk of pollution adhering to Pollution Prevention Guidelines.
5. All works affecting flood defences, main watercourses and/or ordinary watercourses will be subject to Consent for Permanent and Temporary Works under the Land Drainage Act 1991.

	Comments								
Rev.:	Date		Drawn		Designed		Checked		Approved
P02	Comments General updates and medium term levels added								
Rev.:	Date	10/05/19	Drawn	RG	Designed	JST	Checked	AD	Approved	GK

Client Approval
- A - Approved
- B - Approved with Revisions
- C - Do Not Use

Purpose of Issue	Status
For comment	S3

JBA consulting
35 Perrymount Road
HAYWARDS HEATH
West Sussex
RH16 3BW
United Kingdom
www.jbaconsulting.com
t +44 (0)1444 473652
f +44 (0)845 8627772
e info@jbaconsulting.com
Offices at Coleshill, Doncaster, Dublin, Edinburgh, Exeter, Haywards Heath, Limerick, Newcastle upon Tyne, Newport, Saltaire, Skipton, Tadcaster, Thirsk, Wallingford and Warrington

STONEHAVEN BAY COASTAL FPS

GENERAL ARRANGEMENT AND SERVICES

for

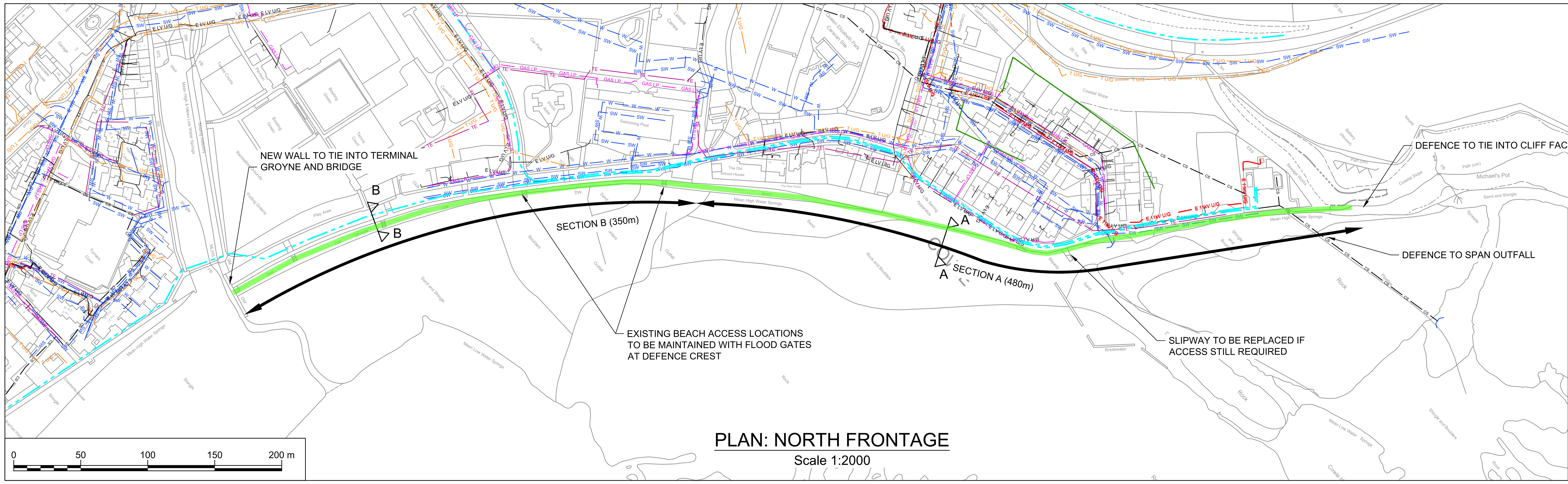
Aberdeenshire Council

This document is the property of Jeremy Benn Associates Ltd. It shall not be reproduced in whole or in part, nor disclosed to a third party, without the permission of Jeremy Benn Associates Ltd.

Scale:	Drawn:	R.Groves	06/03/19
As shown @ A1	Designed:	J. Skanberg-Tippen	06/03/19
	Checked:	A. Dane	10/04/19
	Approved:	G. Kenn	10/04/19

Digital File Name: AKI-JBAU-00-00-DR-C-0001-GA

Drawing Number:	Revision
AKI-JBAU-00-00-DR-C-0001	P02



PLAN: NORTH FRONTAGE

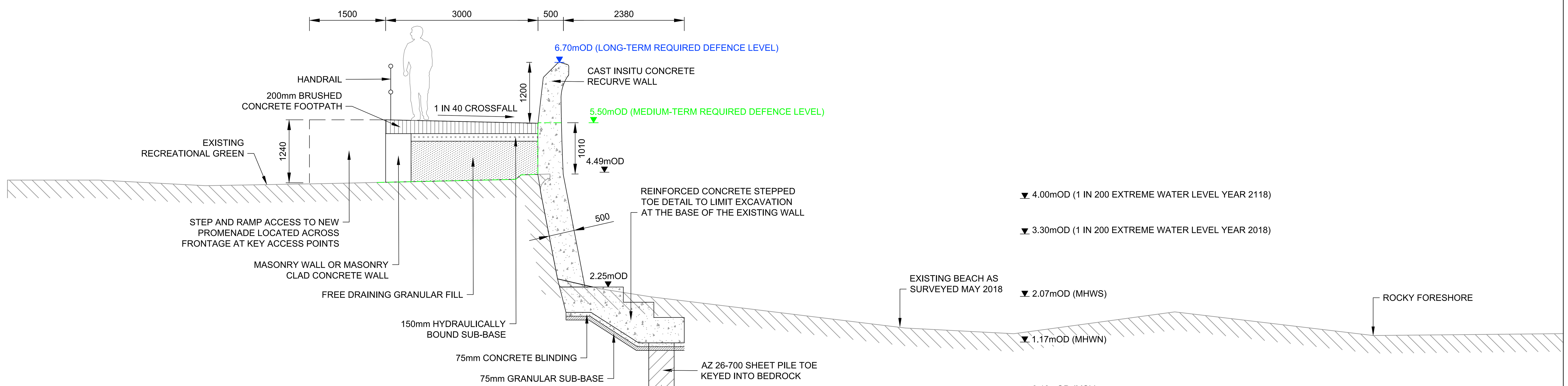
Scale 1:2000

Key

Proposed Frontage Modifications

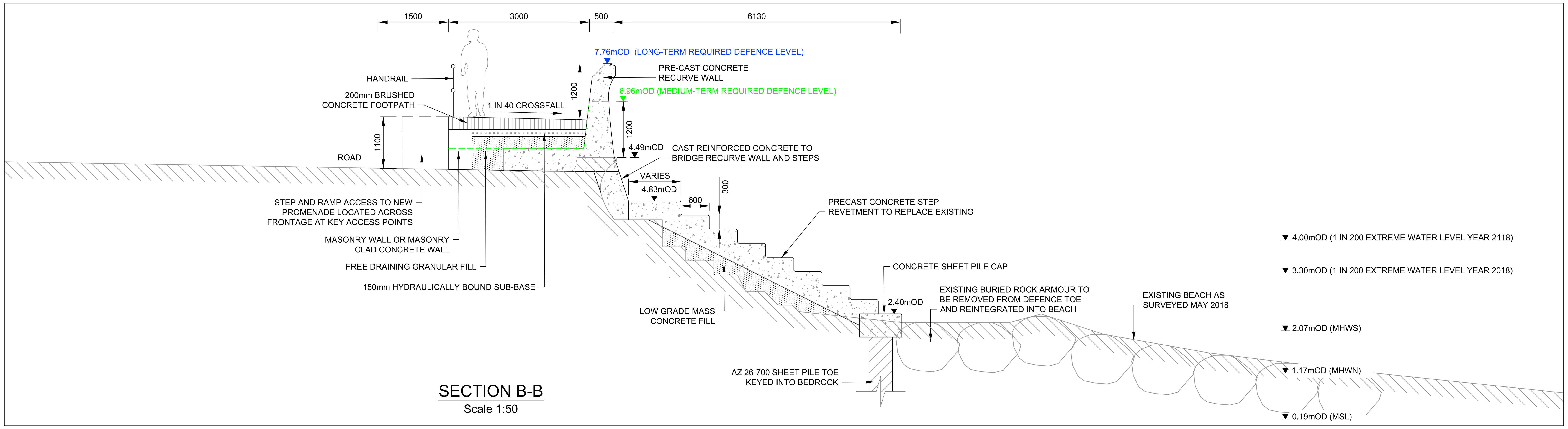
Services Key

- Electricity (Low voltage) U/G
- Electricity (11kV) U/G
- Telecommunications U/G
- Telecommunications O/H
- Water
- Foul Water
- Surface Water
- Combined Sewer
- Trade Effluent
- Pipe unknown
- Gas Low Pressure
- Gas Medium Pressure



SECTION A-A

Scale 1:50



SECTION B-B

Scale 1:50

Construction Risks	Public Risks	Environmental Risks
• Risk of destabilising existing sea wall during excavation at toe • Risk of striking outfalls buried in the beach • Demolition of existing structures	• Working on an Amenity beach • Road closure likely required along frontage • Noise and vibration from piling activities	• Debris and dust from construction work • Pollution hazards associated with working on the open coast

In addition to the hazards/risks normally associated with the types of work detailed on this drawing take note of the above.
It is assumed that all works detailed on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

General Notes

1. All dimensions shown are in millimetres unless otherwise stated and levels are in metres to Ordnance Datum.
2. Do not scale from this drawing. All dimensions must be checked/verified at detailed design and on site.
3. All levels quoted on drawings were taken from profiles surveyed in May 2018, by JBA Consulting.
4. All works on the coast will be carried out with care to minimise the risk of pollution adhering to Pollution Prevention Guidelines.
5. All works affecting flood defences, main watercourses and/or ordinary watercourses will be subject to Consent for Permanent and Temporary Works under the Land Drainage Act 1991.
6. Ground conditions unknown, concept option subject to change upon further investigation.

Structure information

Design life: 100 years

Long-term standard of protection 1 in 200 years, 2118

Medium-term standard of protection 1 in 200 years, 2018

Rev.:	Comments								
	Date		Drawn		Designed		Checked		Approved
P02	General updates and medium term levels added								
	Date	10/05/19	Drawn	RG	Designed	JST	Checked	AD	Approved GK

Client Approval

- A - Approved
- B - Approved with Revisions
- C - Do Not Use

Purpose of Issue	Status
For comment	S3

JBA consulting

35 Perrymount Road
HAYWARDS HEATH
West Sussex
RH16 3BW
United Kingdom

www.jbaconsulting.com

t +44 (0)1444 473652
f +44 (0)845 8627772
e info@jbaconsulting.com

Offices at Coleshill, Doncaster, Dublin, Edinburgh, Exeter, Haywards Heath, Limerick, Newcastle upon Tyne, Newport, Saltaire, Skipton, Tadcaster, Thirsk, Wallingford and Warrington

STONEHAVEN BAY COASTAL FPS

NORTH FRONTAGE
OPTION N1 : NEW SEA WALL

for

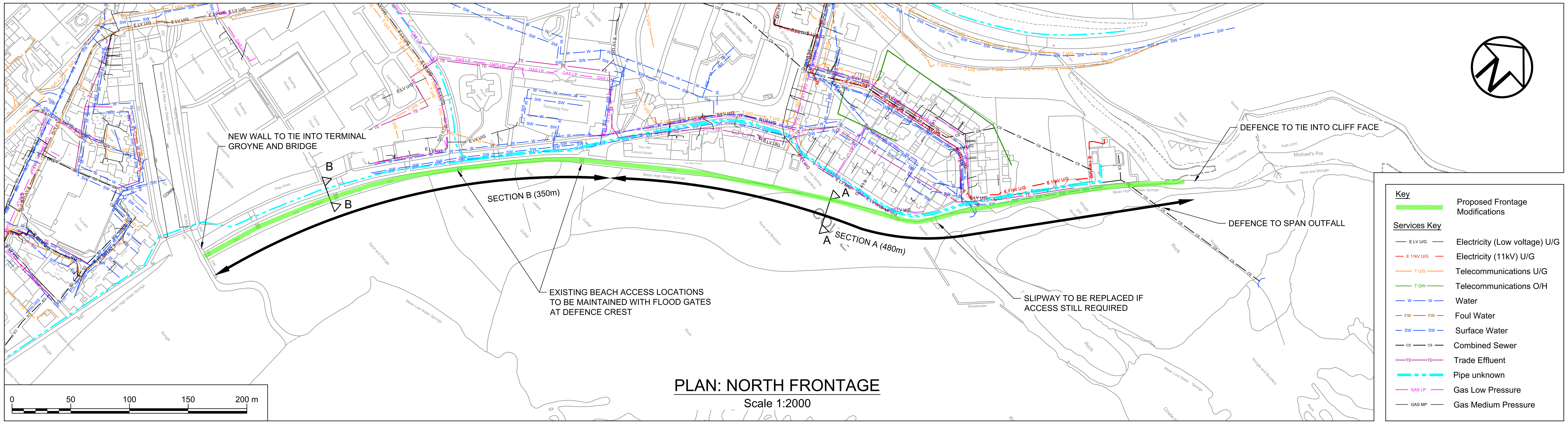
Aberdeenshire Council

This document is the property of Jeremy Benn Associates Ltd. It shall not be reproduced in whole or in part, nor disclosed to a third party, without the permission of Jeremy Benn Associates Ltd.

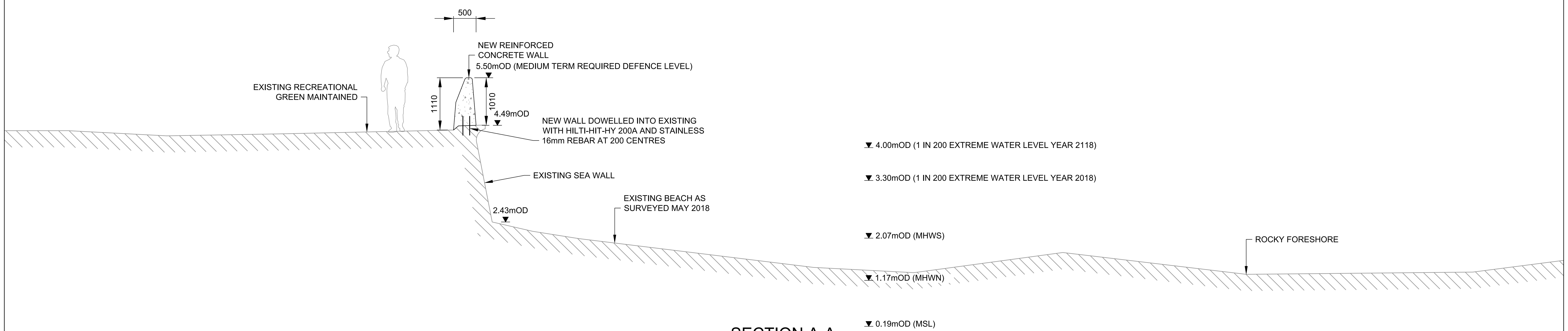
Scale:	Drawn:	R.Groves	06/03/19
As shown @ A1	Designed:	J. Skanberg-Tippen	06/03/19
	Checked:	A. Dane	10/04/19
	Approved:	G. Kenn	10/04/19

Digital File Name: AKI-JBAU-00-00-DR-C-1001_Sections_N1

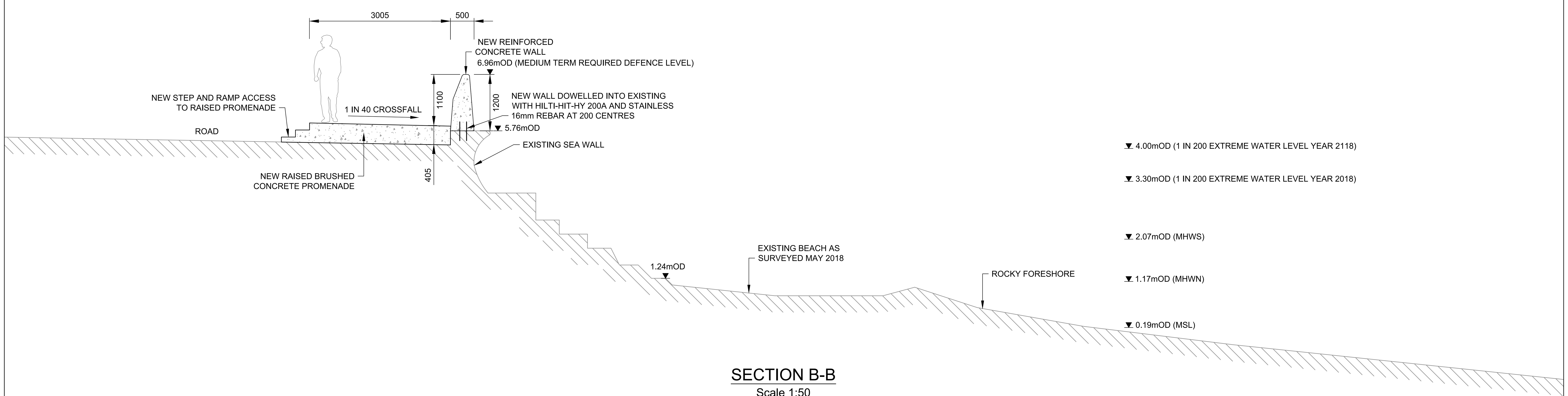
Drawing Number:	Revision
AKI-JBAU-00-00-DR-C-1001	P02



PLAN: NORTH FRONTAGE
Scale 1:2000



SECTION A-A
Scale 1:50



SECTION B-B
Scale 1:50

Construction Risks	Public Risks	Environmental Risks
• Demolition of existing structures	• Working on an Amenity beach • Road closure likely required along frontage	• Debris and dust from construction work • Pollution hazards associated with working on the open coast

In addition to the hazards/risks normally associated with the types of work detailed on this drawing take note of the above.
It is assumed that all works detailed on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

General Notes

1. All dimensions shown are in millimetres unless otherwise stated and levels are in metres to Ordnance Datum.
2. Do not scale from this drawing. All dimensions must be checked/verified at detailed design and on site.
3. All levels quoted on drawings were taken from profiles surveyed in May 2018, by JBA Consulting.
4. All works on the coast will be carried out with care to minimise the risk of pollution adhering to Pollution Prevention Guidelines.
5. All works affecting flood defences, main watercourses and/or ordinary watercourses will be subject to Consent for Permanent and Temporary Works under the Land Drainage Act 1991.
6. Ground conditions unknown, concept option subject to change upon further investigation.

Structure information

Design life: 30 years (based upon residual life of existing defences)

Short-term standard of protection: 1 in 200 years 2018

Rev.:	Comments								
	Date		Drawn		Designed		Checked		Approved
P02	General updates and medium term levels added								
	Date	10/05/19	Drawn	RG	Designed	JST	Checked	AD	Approved GK

Client Approval
A - Approved
B - Approved with Revisions
C - Do Not Use

Purpose of Issue	Status
For comment	S3

JBA consulting

35 Perrymount Road
HAYWARDS HEATH
West Sussex
RH16 3BW
United Kingdom

www.jbaconsulting.com
t +44 (0)1444 473652
f +44 (0)845 8627772
e info@jbaconsulting.com

Offices at Coleshill, Doncaster, Dublin, Edinburgh, Exeter, Haywards Heath, Limerick, Newcastle upon Tyne, Newport, Saltaire, Skipton, Tadcaster, Thirsk, Wallingford and Warrington

STONEHAVEN BAY COASTAL FPS

NORTH FRONTAGE
OPTION N2 : RAISE EXISTING WALLS

for

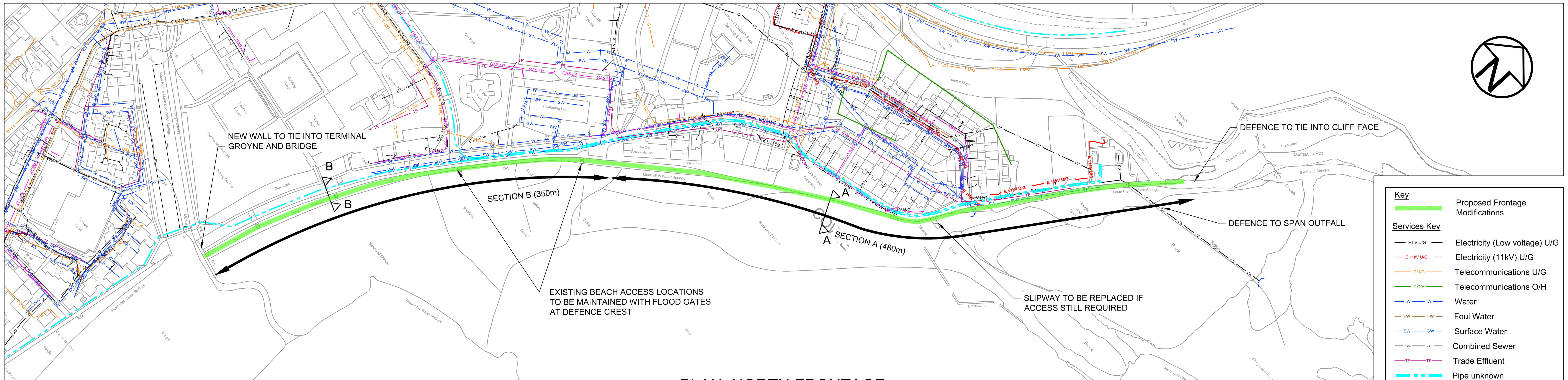
Aberdeenshire Council

This document is the property of Jeremy Benn Associates Ltd. It shall not be reproduced in whole or in part, nor disclosed to a third party, without the permission of Jeremy Benn Associates Ltd.

Scale:			
As shown @ A1	Drawn:	R.Groves	06/03/19
	Designed:	J. Skanberg-Tippen	06/03/19
	Checked:	A. Dane	10/04/19
	Approved:	G. Kenn	10/04/19

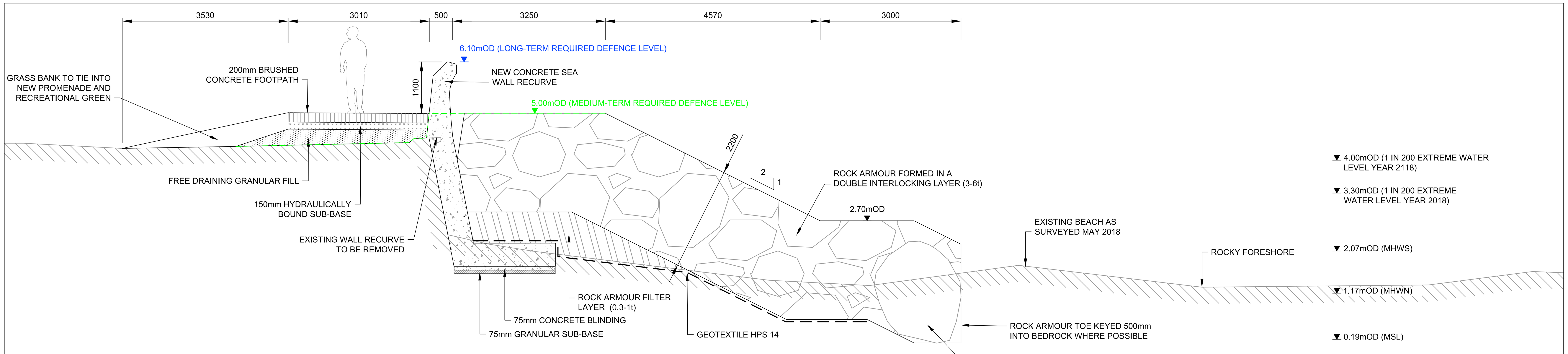
Digital File Name: AKI-JBAU-00-00-DR-C-1002_Sections_N2

Drawing Number:	Revision
AKI-JBAU-00-00-DR-C-1002	P02



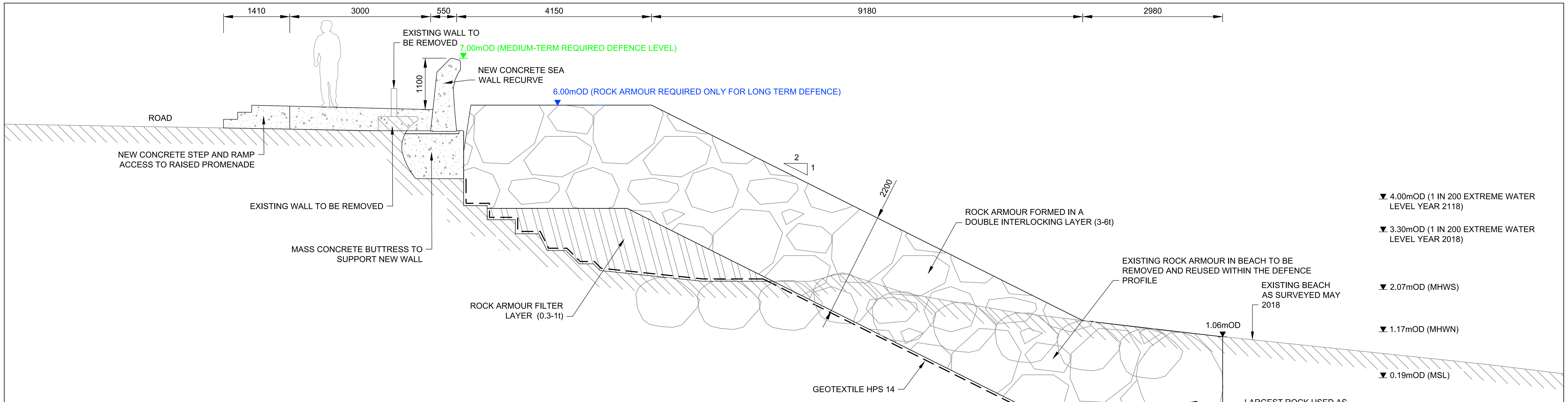
PLAN: NORTH FRONTAGE

Scale 1:2000



SECTION A-A

Scale 1:50



SECTION B-B

Scale 1:50

Construction Risks	Public Risks	Environmental Risks
• Plant movement in intertidal zone • Risk of destabilising existing sea wall during excavation at toe • Risk of striking outfalls buried in the beach • Demolition of existing structures	• Stockpiling of rocks on beach • Working on an Amenity beach • Road closure likely required along frontage • Noise and vibration from rock placement	• Debris and dust from construction work • Pollution hazards associated with working on the open coast

In addition to the hazards/risks normally associated with the types of work detailed on this drawing take note of the above.
It is assumed that all works detailed on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

General Notes

1. All dimensions shown are in millimetres unless otherwise stated and levels are in metres to Ordnance Datum.
2. Do not scale from this drawing. All dimensions must be checked/verified at detailed design and on site.
3. All levels quoted on drawings were taken from profiles surveyed in May 2018, by JBA Consulting.
4. All works on the coast will be carried out with care to minimise the risk of pollution adhering to Pollution Prevention Guidelines.
5. All works affecting flood defences, main watercourses and/or ordinary watercourses will be subject to Consent for Permanent and Temporary Works under the Land Drainage Act 1991.
6. Ground conditions unknown, concept option subject to change upon further investigation.

Structure information

Design life 100 years

Long-term standard of protection 1 in 200 years, 2118

Medium-term standard of protection 1 in 200 years, 2018

Rev.:	Comments				
	Date	Drawn	Designed	Checked	Approved
P02	General updates and medium term levels added				
	Date 10/05/19	Drawn RG	Designed JST	Checked AD	Approved GK

Client Approval
A - Approved
B - Approved with Revisions
C - Do Not Use

Purpose of Issue	Status
For comment	S3

JBA consulting
35 Perrymount Road
HAYWARDS HEATH
West Sussex
RH16 3BW
United Kingdom
www.jbaconsulting.com
t +44 (0)1444 473652
f +44 (0)845 8627772
e info@jbaconsulting.com
Offices at Coleshill, Doncaster, Dublin, Edinburgh, Exeter, Haywards Heath, Limerick, Newcastle upon Tyne, Newport, Saltaire, Skipton, Tadcaster, Thirsk, Wallingford and Warrington

STONEHAVEN BAY COASTAL FPS

NORTH FRONTAGE
OPTION N3 : ARMOUR REVETMENT

for

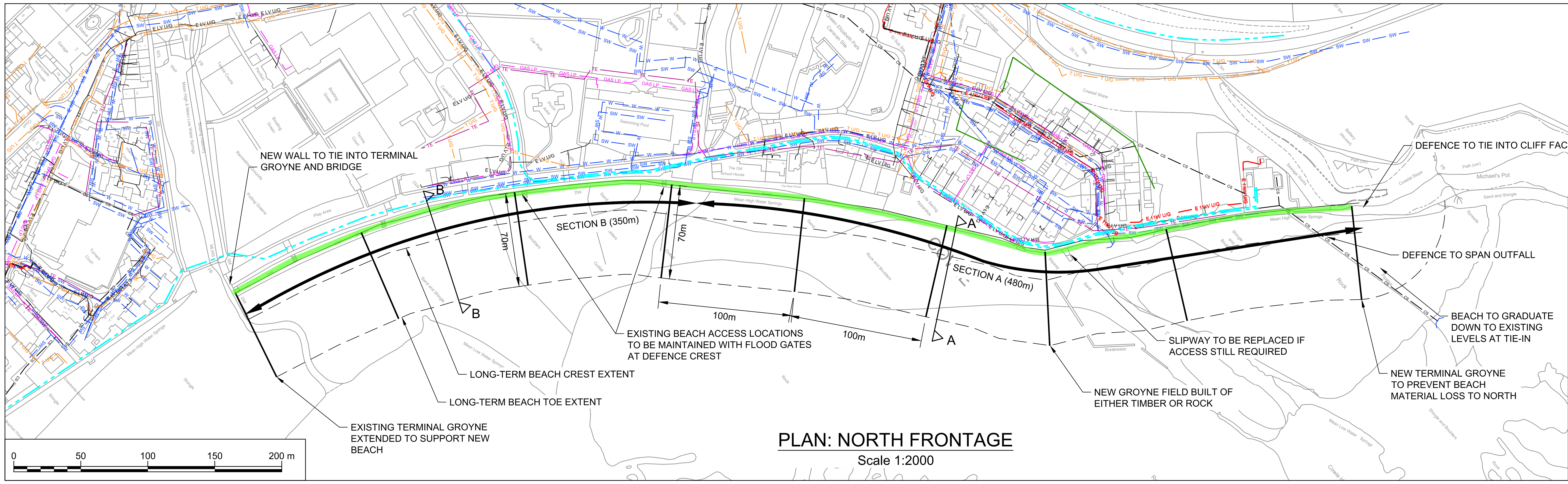
Aberdeenshire Council

This document is the property of Jeremy Benn Associates Ltd. It shall not be reproduced in whole or in part, nor disclosed to a third party, without the permission of Jeremy Benn Associates Ltd.

Scale:			
As shown @ A1	Drawn:	R.Groves	06/03/19
	Designed:	J. Skanberg-Tippen	06/03/19
	Checked:	A. Dane	10/04/19
	Approved:	G. Kenn	10/04/19

Digital File Name: AKI-JBAU-00-00-DR-C-1003_Sections_N3

Drawing Number:	Revision
AKI-JBAU-00-00-DR-C-1003	P02



PLAN: NORTH FRONTAGE

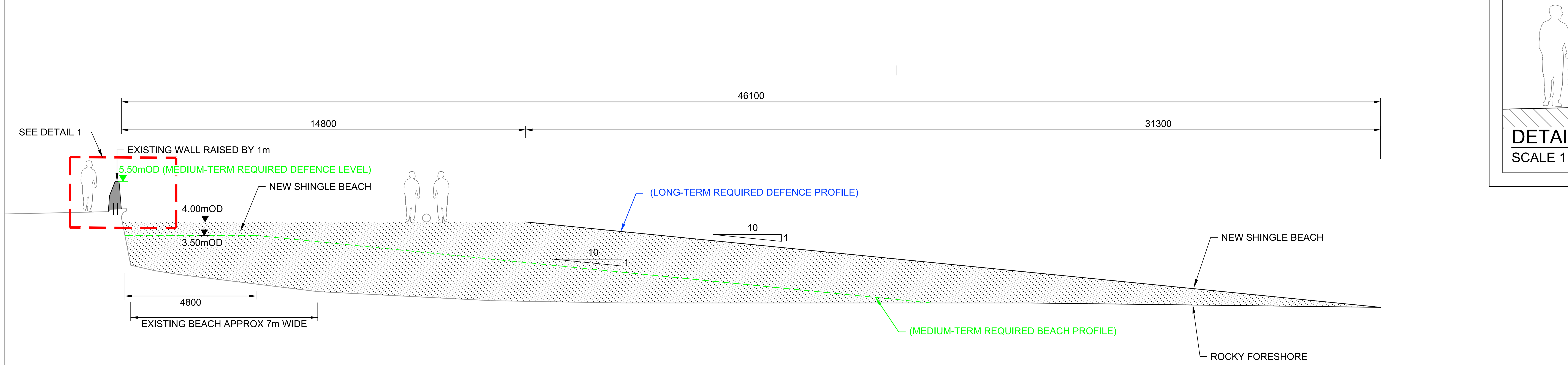
Scale 1:2000

Key

Proposed Frontage Modifications

Services Key

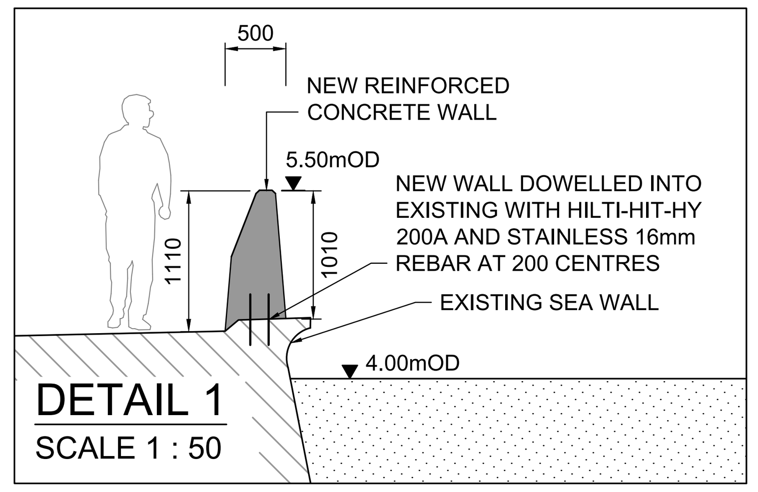
- Electricity (Low voltage) U/G
- Electricity (11kV) U/G
- Telecommunications U/G
- Telecommunications O/H
- Water
- Foul Water
- Surface Water
- Combined Sewer
- Trade Effluent
- Pipe unknown
- Gas Low Pressure
- Gas Medium Pressure



SECTION A BEACH DETAILS	
LENGTH (M)	480
CROSS SECTION AREA (M2)	86.70
ESTIMATED VOLUME (M3)	41620
5-YEAR RECHARGE (M3)	7786

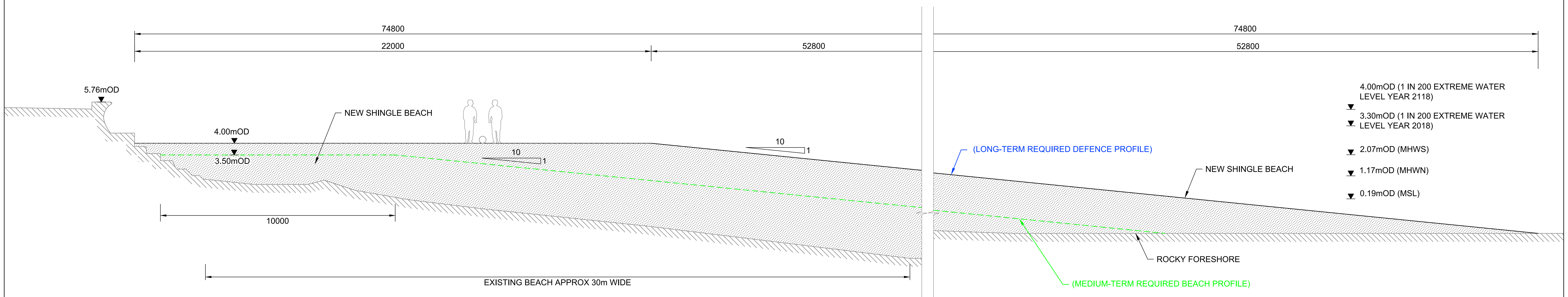
SECTION A-A

Scale 1:100



DETAIL 1

SCALE 1 : 50



SECTION B BEACH DETAILS	
LENGTH (M)	350
CROSS SECTION AREA (M2)	174.20
ESTIMATED VOLUME (M3)	60970
5-YEAR RECHARGE (M3)	11410

SECTION B-B

Scale 1:100

Construction Risks	Public Risks	Environmental Risks
• Risk of striking outfalls buried in the beach • Working within the tidal foreshore • Difficult terrain for plant movement on rocky foreshore	• Plant movement on the beach	• Debris and dust from construction work • Deposition of shingle on beach intertidal rock platform. • Suspended sediment within tidal waters during recharge

In addition to the hazards/risks normally associated with the types of work detailed on this drawing take note of the above.
It is assumed that all works detailed on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

General Notes

1. All dimensions shown are in millimetres unless otherwise stated and levels are in metres to Ordnance Datum.
2. Do not scale from this drawing. All dimensions must be checked/verified at detailed design and on site.
3. All levels quoted on drawings were taken from profiles surveyed in May 2018, by JBA Consulting.
4. All works on the coast will be carried out with care to minimise the risk of pollution adhering to Pollution Prevention Guidelines.
5. All works affecting flood defences, main watercourses and/or ordinary watercourses will be subject to Consent for Permanent and Temporary Works under the Land Drainage Act 1991.
6. Ground conditions unknown, concept option subject to change upon further investigation.

Structure information

Design life: Subject to recharge requirements (estimated 5 yearly)

Long-term standard of protection 1 in 200 years, 2118

Medium-term standard of protection 1 in 200 years, 2018

Rev.:	Comments				
	Date	Drawn	Designed	Checked	Approved
P02	General updates and medium term levels added				
	Date 10/05/19	Drawn RG	Designed JST	Checked AD	Approved GK

Client Approval

- A - Approved
- B - Approved with Revisions
- C - Do Not Use

Purpose of Issue	Status
For comment	S3

JBA consulting

35 Perrymount Road
HAYWARDS HEATH
West Sussex
RH16 3BW
United Kingdom

www.jbaconsulting.com
t +44 (0)1444 473652
f +44 (0)845 8627772
e info@jbaconsulting.com

Offices at Coleshill, Doncaster, Dublin, Edinburgh, Exeter, Haywards Heath, Limerick, Newcastle upon Tyne, Newport, Saltaire, Skipton, Tadcaster, Thirsk, Wallingford and Warrington

STONEHAVEN BAY COASTAL FPS

NORTH FRONTAGE
OPTION N4:
BEACH RECHARGE AND CONTROL STRUCTURES

for

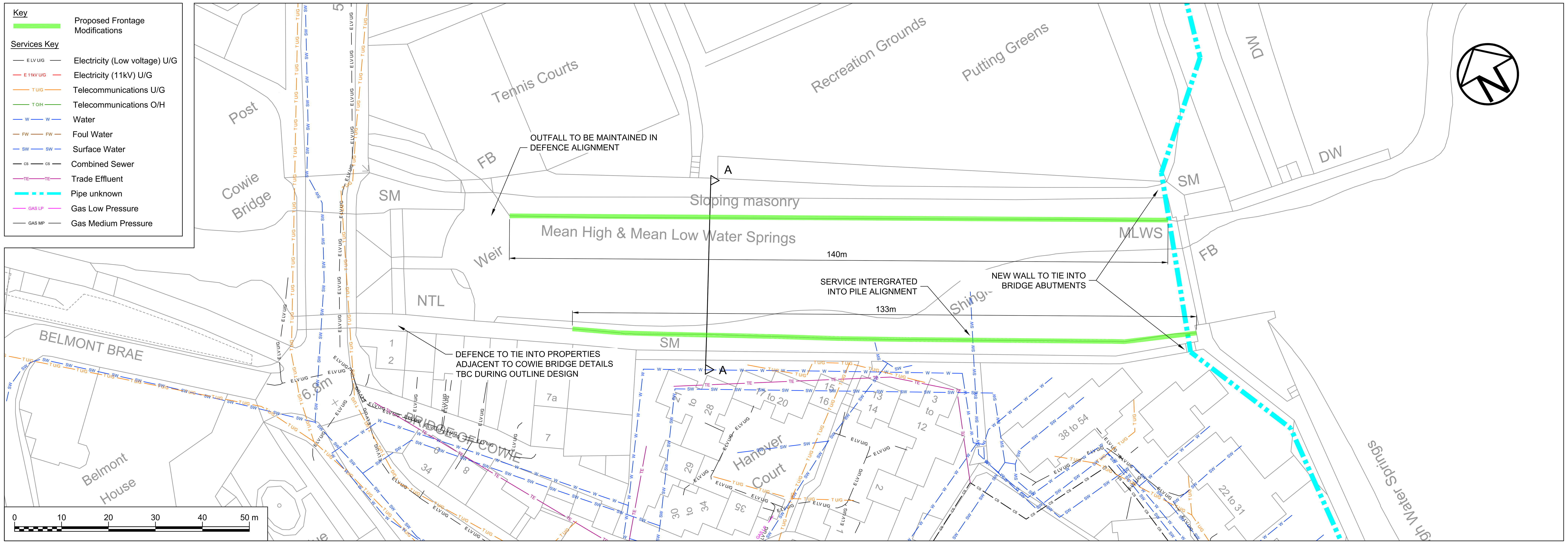
Aberdeenshire Council

This document is the property of Jeremy Benn Associates Ltd. It shall not be reproduced in whole or in part, nor disclosed to a third party, without the permission of Jeremy Benn Associates Ltd.

Scale:			
As shown @ A1	Drawn:	R.Groves	06/03/19
	Designed:	J. Skanberg-Tippen	06/03/19
	Checked:	A. Dane	10/04/19
	Approved:	G. Kenn	10/04/19

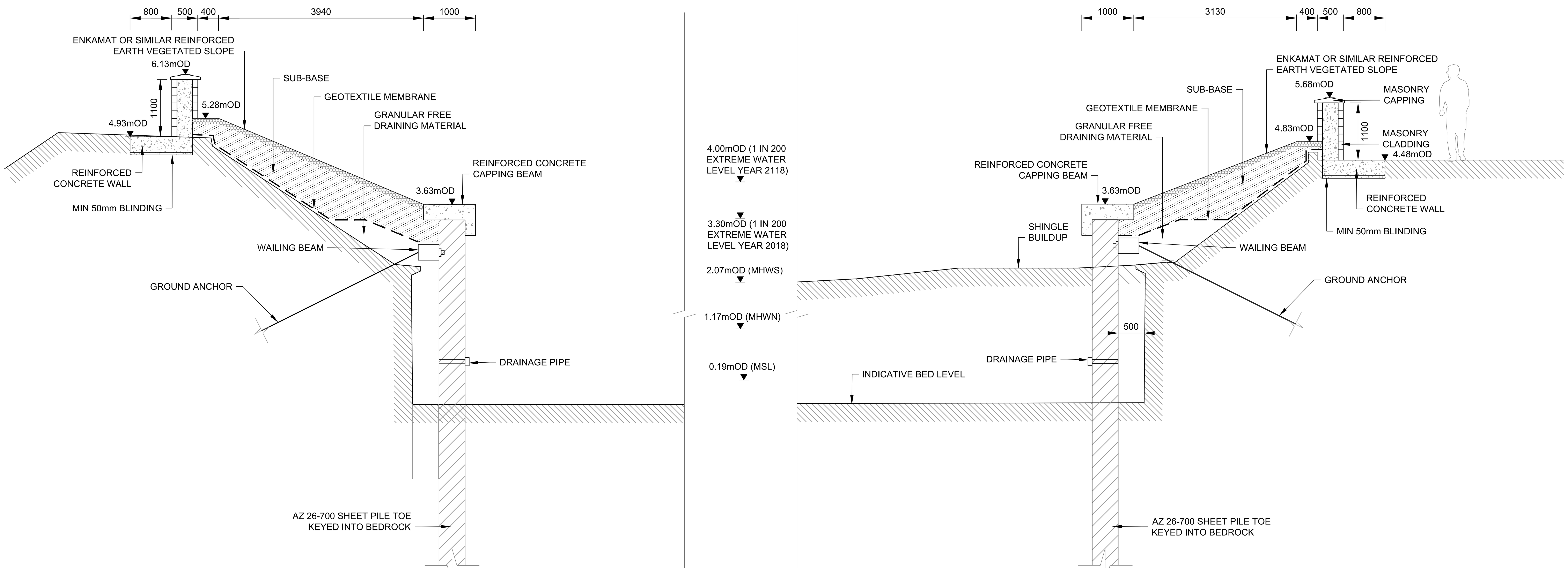
Digital File Name: AKI-JBAU-00-00-DR-C-1004_Sections_N4

Drawing Number:	Revision
AKI-JBAU-00-00-DR-C-1004	P02



PLAN: COWIE FRONTAGE

SCALE 1 : 500



SECTION A-A

Scale 1:50

- Piling in close proximity to properties
- Piling operations in tidal river mouth
- Risk of destabilising existing sea wall during excavation at toe
- Risk of striking outfalls buried in the beach
- Demolition of existing structures

- Road closure likely required along frontage
- Noise and vibration from piling activities

- Debris and dust from construction work
- Pollution hazards associated with working on the open coast

Construction Risks	Public Risks	Environmental Risks

In addition to the hazards/risks normally associated with the types of work detailed on this drawing take note of the above.
It is assumed that all works detailed on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

General Notes

1. All dimensions shown are in millimetres unless otherwise stated and levels are in metres to Ordnance Datum.
2. Do not scale from this drawing. All dimensions must be checked/verified at detailed design and on site.
3. All levels quoted on drawings were taken from profiles surveyed in May 2018, by JBA Consulting.
4. All works on the coast will be carried out with care to minimise the risk of pollution adhering to Pollution Prevention Guidelines.
5. All works affecting flood defences, main watercourses and/or ordinary watercourses will be subject to Consent for Permanent and Temporary Works under the Land Drainage Act 1991.
6. Ground conditions unknown, concept option subject to change upon further investigation.

Structure information

Design life: 100 years standard of protection: 1 in 200 years, 2118

	Comments								
Rev.:	Date		Drawn		Designed		Checked		Approved	
P02	Comments General updates and medium term levels added								
Rev.:	Date	10/05/19	Drawn	RG	Designed	JST	Checked	AD	Approved	GK

Client Approval
- A - Approved
- B - Approved with Revisions
- C - Do Not Use

Purpose of Issue	Status
For comment	S3

JBA consulting
35 Perrymount Road
HAYWARDS HEATH
West Sussex
RH16 3BW
United Kingdom

www.jbaconsulting.com
t +44 (0)1444 473652
f +44 (0)845 8627772
e info@jbaconsulting.com

Offices at Coleshill, Doncaster, Dublin, Edinburgh, Exeter, Haywards Heath, Limerick, Newcastle upon Tyne, Newport, Saltaire, Skipton, Tadcaster, Thirsk, Wallingford and Warrington

STONEHAVEN BAY COASTAL FPS

OPTION CW: COWIE FRONTAGE
NEW TRAINING WALLS

for

Aberdeenshire Council

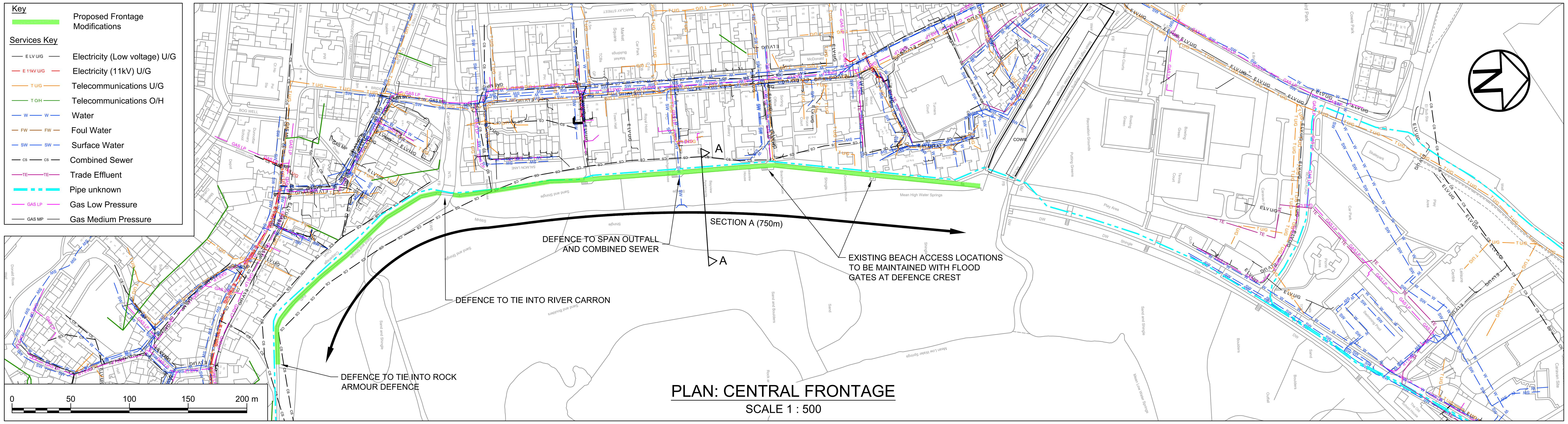
This document is the property of Jeremy Benn Associates Ltd. It shall not be reproduced in whole or in part, nor disclosed to a third party, without the permission of Jeremy Benn Associates Ltd.

Scale:			
As shown @ A1	Drawn:	R.Groves	06/03/19
	Designed:	J. Skanberg-Tippen	06/03/19
	Checked:	A. Dane	10/04/19
	Approved:	G. Kenn	10/04/19

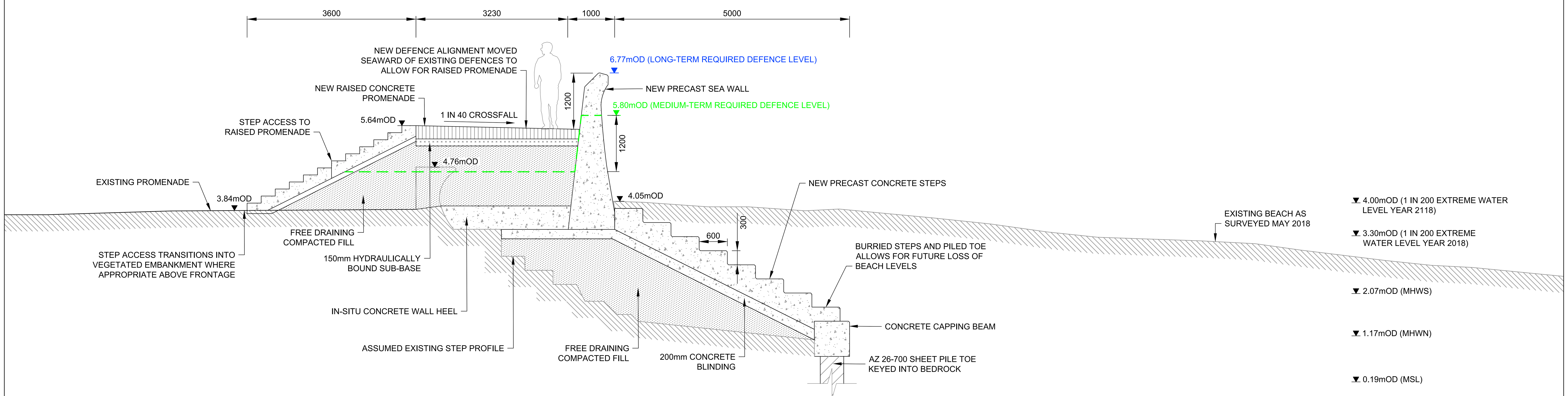
Digital File Name: AKI-JBAU-00-00-DR-C-2001_Section_CW

Drawing Number: AKI-JBAU-00-00-DR-C-2001

Revision: P02



PLAN: CENTRAL FRONTAGE
SCALE 1 : 500



SECTION A-A
Scale 1:50

Construction Risks	Public Risks	Environmental Risks
• Risk of destabilising existing sea wall during excavation at toe • Risk of striking outfalls buried in the beach • Demolition of existing structures	• Working on an Amenity beach • Road closure likely required along frontage • Noise and vibration from piling activities	• Debris and dust from construction work • Pollution hazards associated with working on the open coast

In addition to the hazards/risks normally associated with the types of work detailed on this drawing take note of the above.
It is assumed that all works detailed on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

General Notes

1. All dimensions shown are in millimetres unless otherwise stated and levels are in metres to Ordnance Datum.
2. Do not scale from this drawing. All dimensions must be checked/verified at detailed design and on site.
3. All levels quoted on drawings were taken from profiles surveyed in May 2018, by JBA Consulting.
4. All works on the coast will be carried out with care to minimise the risk of pollution adhering to Pollution Prevention Guidelines.
5. All works affecting flood defences, main watercourses and/or ordinary watercourses will be subject to Consent for Permanent and Temporary Works under the Land Drainage Act 1991.
6. Ground conditions unknown, concept option subject to change upon further investigation.

Structure information

Design life: 100 years

Long-term standard of protection 1 in 200 years, 2118

Medium-term standard of protection 1 in 200 years, 2018

Rev.:	Comments									
	Date		Drawn		Designed		Checked		Approved	
P02	General updates and medium term levels added									
	Date	10/05/19	Drawn	RG	Designed	JST	Checked	AD	Approved	GK

Client Approval
A - Approved
B - Approved with Revisions
C - Do Not Use

Purpose of Issue	Status
For comment	S3

JBA consulting
35 Perrymount Road
HAYWARDS HEATH
West Sussex
RH16 3BW
United Kingdom
www.jbaconsulting.com
t +44 (0)1444 473652
f +44 (0)845 8627772
e info@jbaconsulting.com
Offices at Coleshill, Doncaster, Dublin, Edinburgh, Exeter, Haywards Heath, Limerick, Newcastle upon Tyne, Newport, Saltaire, Skipton, Tadcaster, Thirsk, Wallingford and Warrington

STONEHAVEN BAY COASTAL FPS

CENTRAL FRONTAGE
OPTION C1: NEW SEA WALL

for

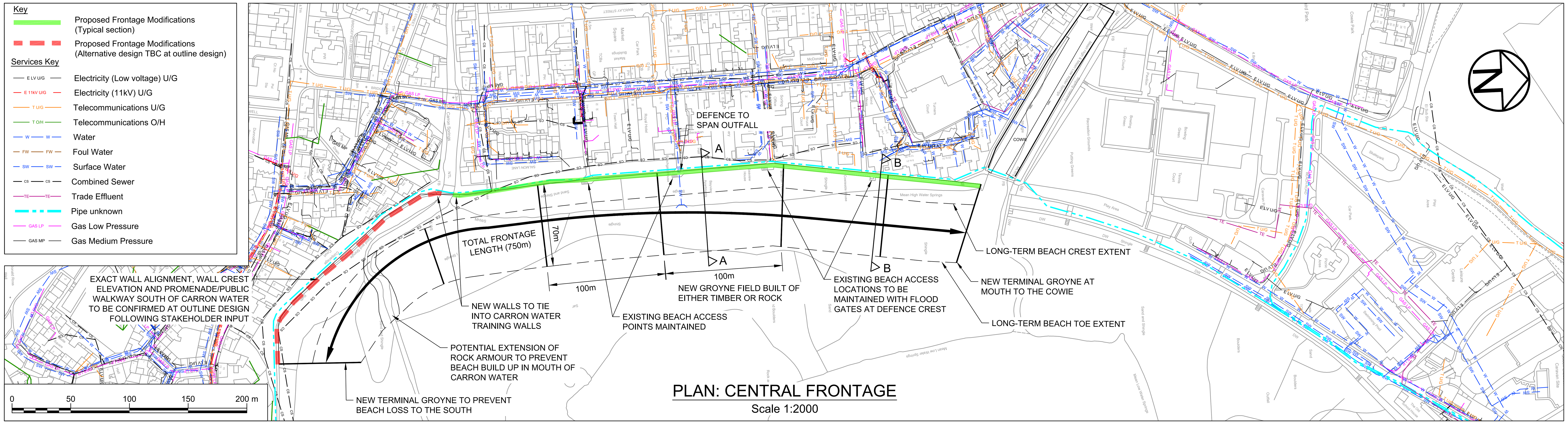
Aberdeenshire Council

This document is the property of Jeremy Benn Associates Ltd. It shall not be reproduced in whole or in part, nor disclosed to a third party, without the permission of Jeremy Benn Associates Ltd.

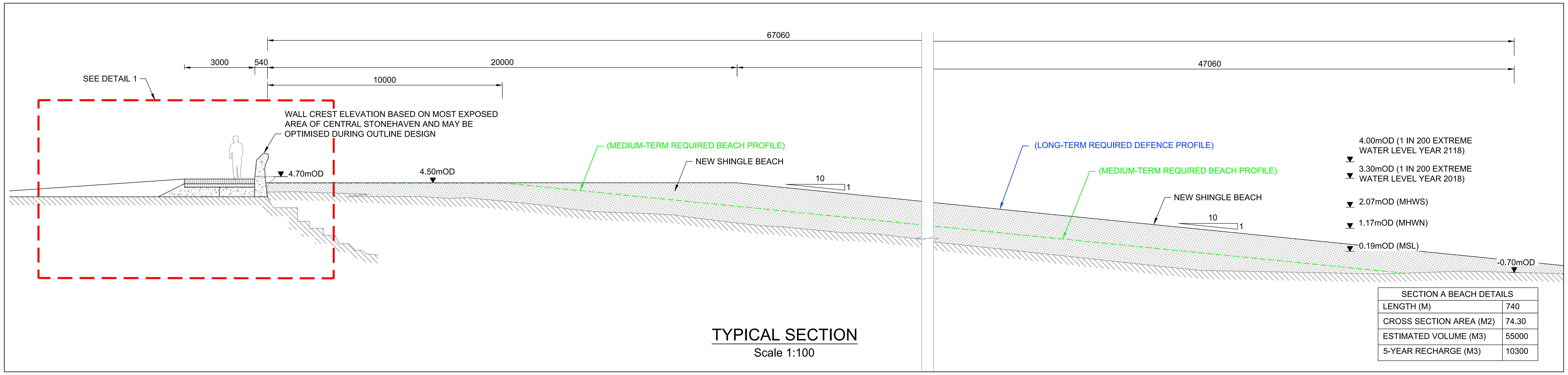
Scale:			
As shown @ A1	Drawn:	R.Groves	06/03/19
	Designed:	J. Skanberg-Tippen	06/03/19
	Checked:	A. Dane	10/04/19
	Approved:	G. Kenn	10/04/19

Digital File Name: AKI-JBAU-00-00-DR-C-3001_Section_C1

Drawing Number:	Revision
AKI-JBAU-00-00-DR-C-3001	P02

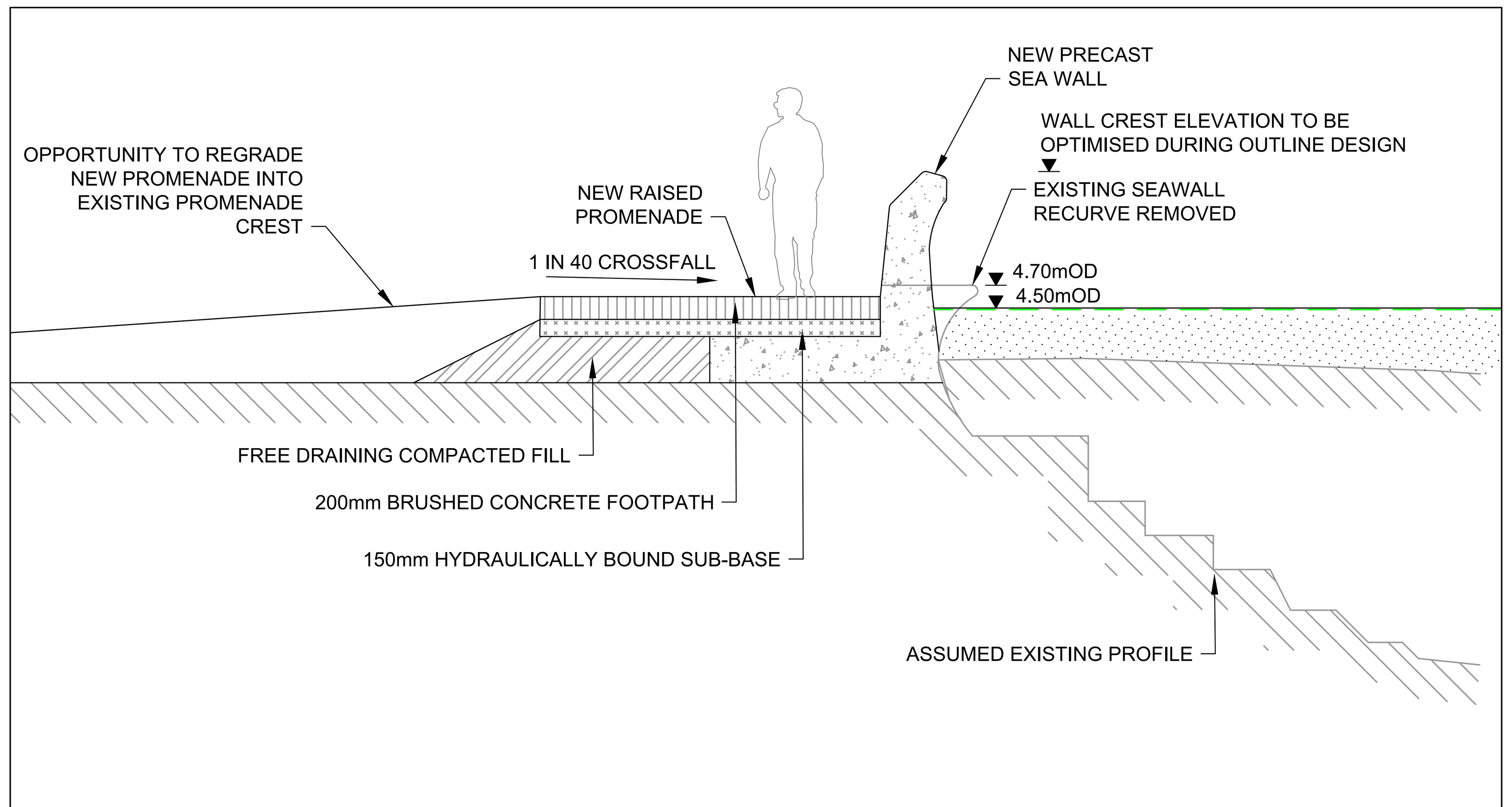


PLAN: CENTRAL FRONTAGE
Scale 1:2000

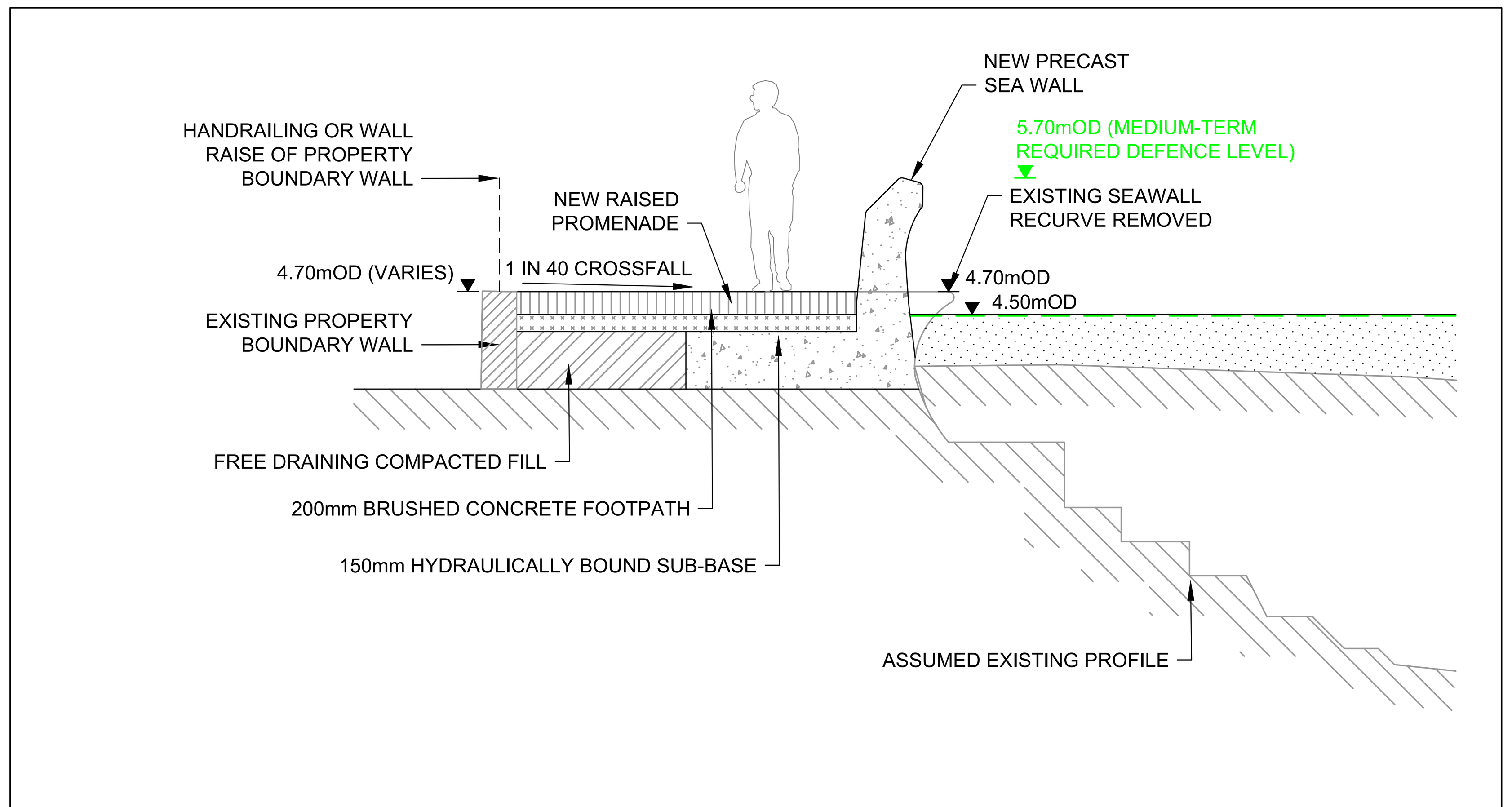


SECTION A BEACH DETAILS	
LENGTH (M)	740
CROSS SECTION AREA (M2)	74.30
ESTIMATED VOLUME (M3)	55000
5-YEAR RECHARGE (M3)	10300

TYPICAL SECTION
Scale 1:100



DETAIL 1
(SECTION A-A)
Scale 1:50



DETAIL 1
(SECTION B-B)
Scale 1:50

Construction Risks	Public Risks	Environmental Risks
• Risk of striking outfalls buried in the beach • Working within the tidal foreshore • Difficult terrain for plant movement on rocky foreshore	• Plant movement on the beach	• Debris and dust from construction work • Deposition of shingle on beach intertidal rock platform. • Suspended sediment within tidal waters during recharge

In addition to the hazards/risks normally associated with the types of work detailed on this drawing take note of the above.
It is assumed that all works detailed on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

General Notes

1. All dimensions shown are in millimetres unless otherwise stated and levels are in metres to Ordnance Datum.
2. Do not scale from this drawing. All dimensions must be checked/verified at detailed design and on site.
3. All levels quoted on drawings were taken from profiles surveyed in May 2018, by JBA Consulting.
4. All works on the coast will be carried out with care to minimise the risk of pollution adhering to Pollution Prevention Guidelines.
5. All works affecting flood defences, main watercourses and/or ordinary watercourses will be subject to Consent for Permanent and Temporary Works under the Land Drainage Act 1991.
6. Ground conditions unknown, concept option subject to change upon further investigation.

Structure information

Design life: 100 years

Long-term standard of protection 1 in 200 years, 2118

Medium-term standard of protection 1 in 200 years, 2018

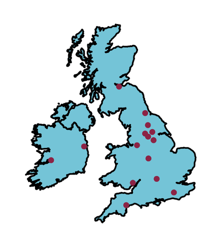
Rev.	Comments	Date		Drawn		Designed		Checked		Approved	
P04	General updates	Date	04/09/19	Drawn	RG	Designed	AW	Checked	JST	Approved	NB
P03	Updates to show additional section and interaction with property boundaries	Date	02/09/19	Drawn	RG	Designed	AW	Checked	JST	Approved	NB
P02	General updates and medium term levels added	Date	10/05/19	Drawn	RG	Designed	JST	Checked	AD	Approved	GK

Client Approval
A - Approved
B - Approved with Revisions
C - Do Not Use

Purpose of Issue	Status
For comment	S3

JBA consulting

35 Perrymount Road
HAYWARDS HEATH
West Sussex
RH16 3BW
United Kingdom
www.jbaconsulting.com
t +44 (0)1444 473652
f +44 (0)845 8627772
e info@jbaconsulting.com



Offices at Coleshill, Doncaster, Dublin, Edinburgh, Exeter, Haywards Heath, Limerick, Newcastle upon Tyne, Newport, Saltaire, Skipton, Tadcaster, Thirsk, Wallingford and Warrington

STONEHAVEN BAY COASTAL FPS

CENTRAL FRONTAGE
OPTION C2: BEACH RECHARGE
AND CONTROL STRUCTURES

for

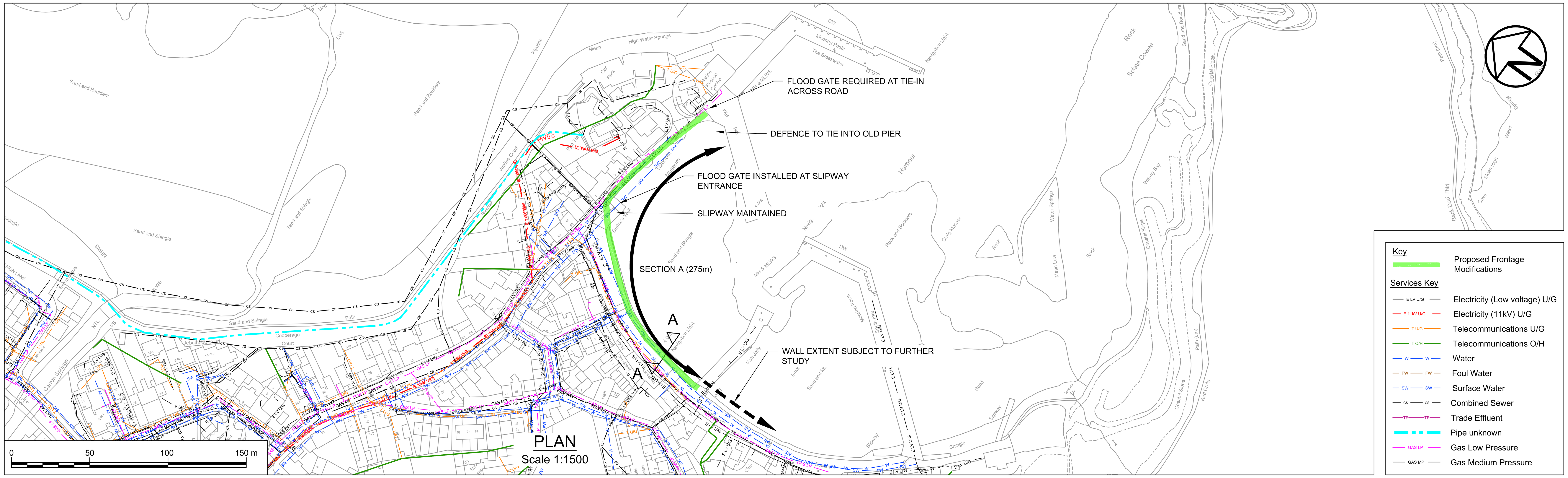
Aberdeenshire Council

This document is the property of Jeremy Benn Associates Ltd. It shall not be reproduced in whole or in part, nor disclosed to a third party, without the permission of Jeremy Benn Associates Ltd.

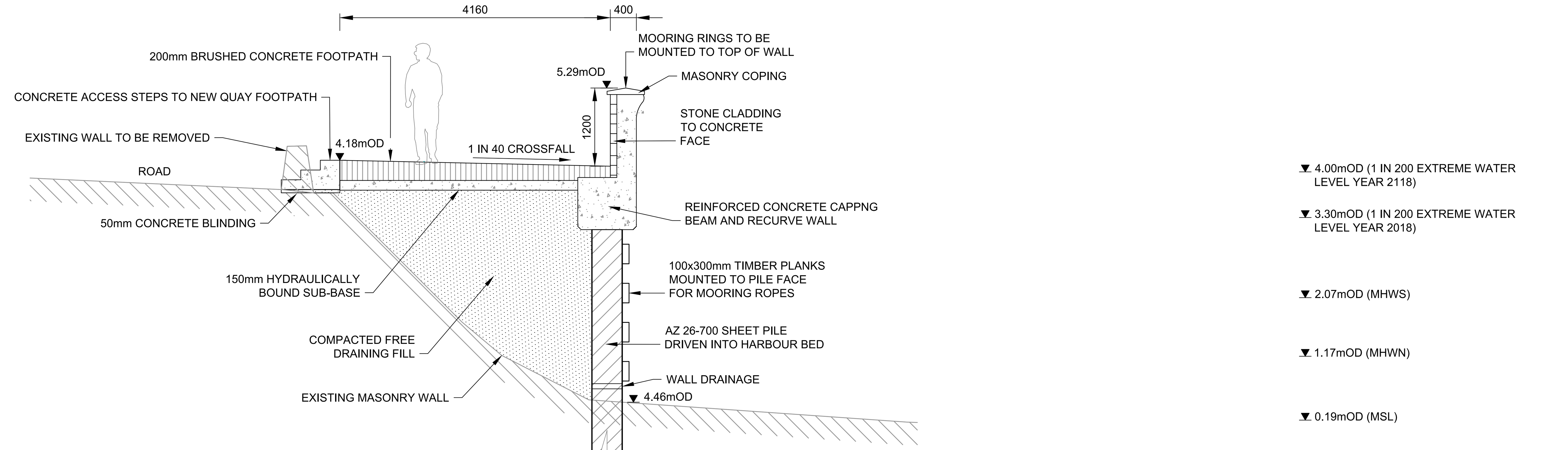
Scale:		
As shown @ A1	Drawn: R.Groves	06/03/19
	Designed: J. Skanberg-Tippen	06/03/19
	Checked: A. Dane	10/04/19
	Approved: G. Kenn	10/04/19

Digital File Name: AKI-JBAU-00-00-DR-C-3002_Section_C2

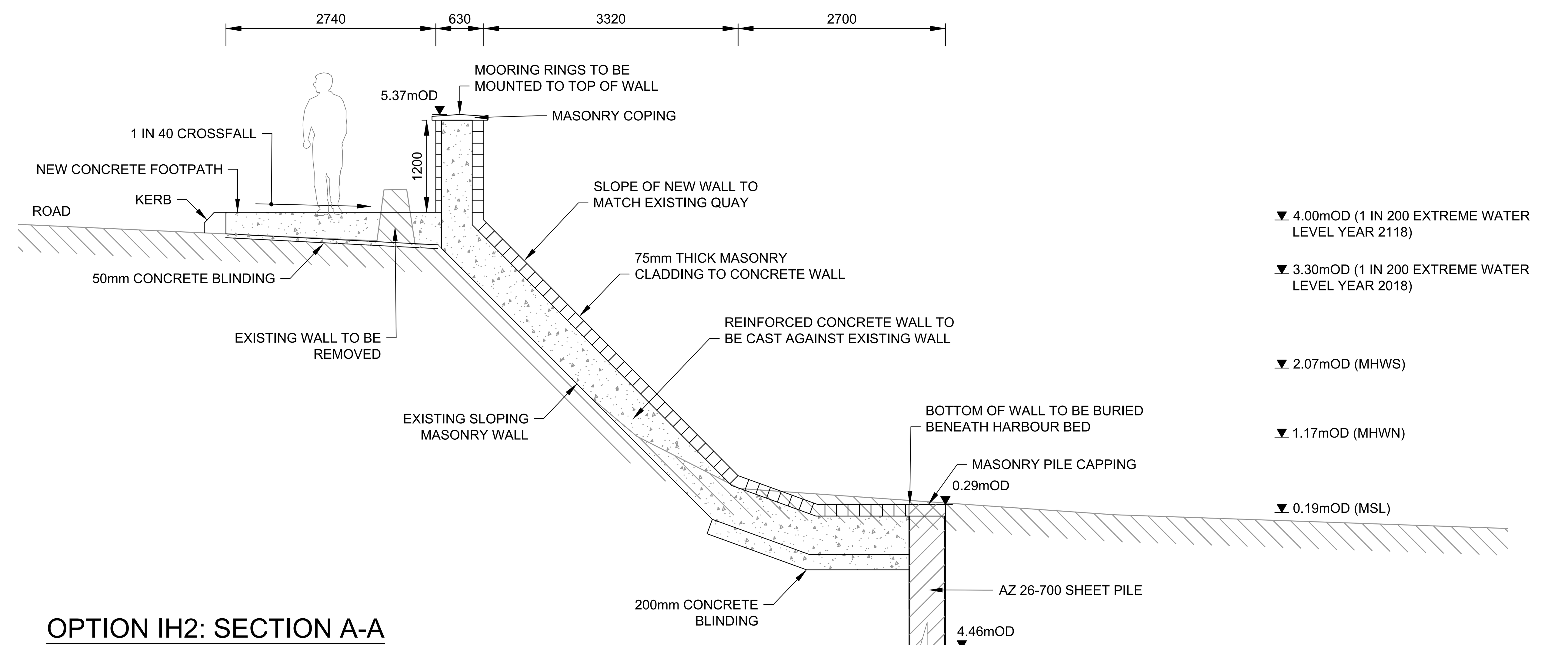
Drawing Number:	Revision
AKI-JBAU-00-00-DR-C-3002	P04



PLAN
Scale 1:1500



OPTION IH1: SECTION A-A
SCALE 1 : 50



OPTION IH2: SECTION A-A
SCALE 1 : 50

Construction Risks	Public Risks	Environmental Risks
• Risk of destabilising existing sea wall during excavation at sea wall toe • Working in an active harbour • RNLI operations not to be disrupted	• Road closure likely required along frontage • Noise and vibration from piling activities	• Debris and dust from construction work • Pollution hazards associated with working within tidal water

In addition to the hazards/risks normally associated with the types of work detailed on this drawing take note of the above.
It is assumed that all works detailed on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

General Notes

1. All dimensions shown are in millimetres unless otherwise stated and levels are in metres to Ordnance Datum.
2. Do not scale from this drawing. All dimensions must be checked/verified at detailed design and on site.
3. All levels quoted on drawings were taken from profiles surveyed in May 2018, by JBA Consulting.
4. All works on the coast will be carried out with care to minimise the risk of pollution adhering to Pollution Prevention Guidelines.
5. All works affecting flood defences, main watercourses and/or ordinary watercourses will be subject to Consent for Permanent and Temporary Works under the Land Drainage Act 1991.
6. Ground conditions unknown, concept option subject to change upon further investigation.

Structure information

Design life: 100 years standard of protection: 1 in 200 years, 2118

Rev.:	Comments							
Rev.:	Date		Drawn		Designed		Checked	Approved
P02	General updates and medium term levels added							
Rev.:	Date 10/05/19		Drawn RG		Designed JST		Checked AD	Approved GK

Client Approval
A - Approved
B - Approved with Revisions
C - Do Not Use

Purpose of Issue	Status
For comment	S3

JBA consulting
35 Perrymount Road
HAYWARDS HEATH
West Sussex
RH16 3BW
United Kingdom
www.jbaconsulting.com
t +44 (0)1444 473652
f +44 (0)845 8627772
e info@jbaconsulting.com
Offices at Coleshill, Doncaster, Dublin, Edinburgh, Exeter, Haywards Heath, Limerick, Newcastle upon Tyne, Newport, Saltaire, Skipton, Tadcaster, Thirsk, Wallingford and Warrington

STONEHAVEN BAY COASTAL FPS

INNER HARBOUR FRONTAGE
OPTIONS IH1 & IH2:
NEW VERTICAL AND SLOPING QUAY WALLS

for

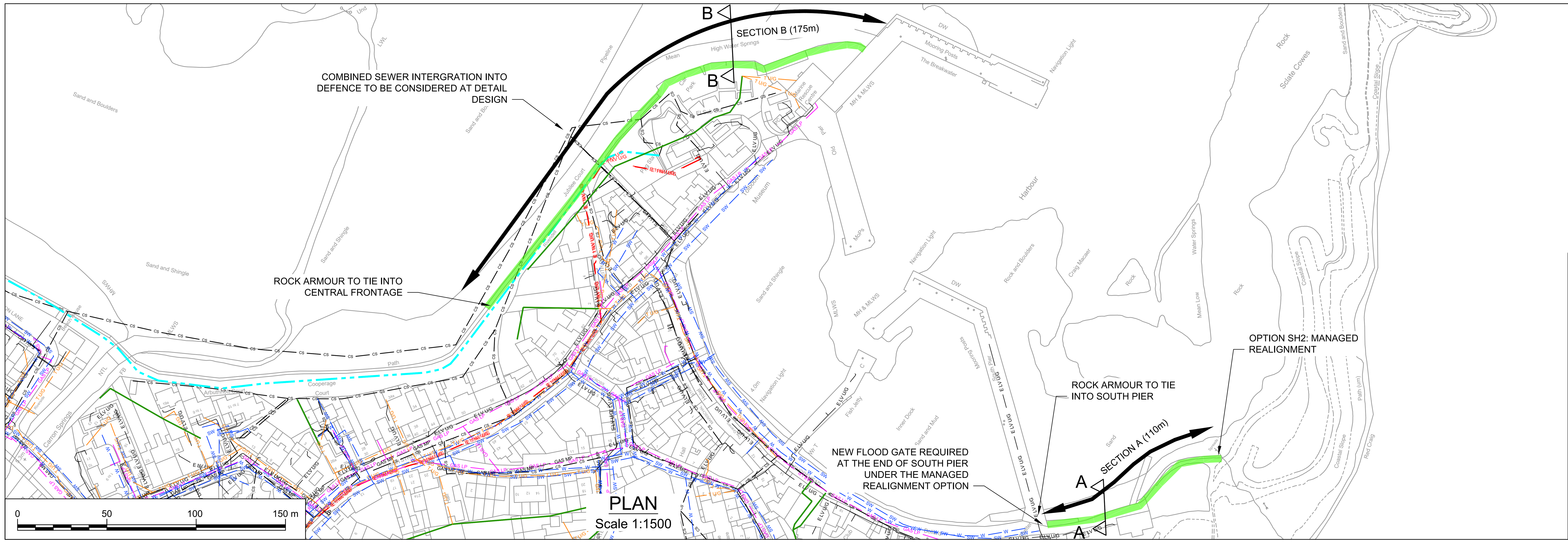
Aberdeenshire Council

This document is the property of Jeremy Benn Associates Ltd. It shall not be reproduced in whole or in part, nor disclosed to a third party, without the permission of Jeremy Benn Associates Ltd.

Scale:			
As shown @ A1	Drawn:	R.Groves	06/03/19
	Designed:	J. Skanberg-Tippen	06/03/19
	Checked:	A. Dane	10/04/19
	Approved:	G. Kenn	10/04/19

Digital File Name: AKI-JBAU-00-00-DR-C-4001_Sections_IH1_&_IH2

Drawing Number:	Revision
AKI-JBAU-00-00-DR-C-4001	P02



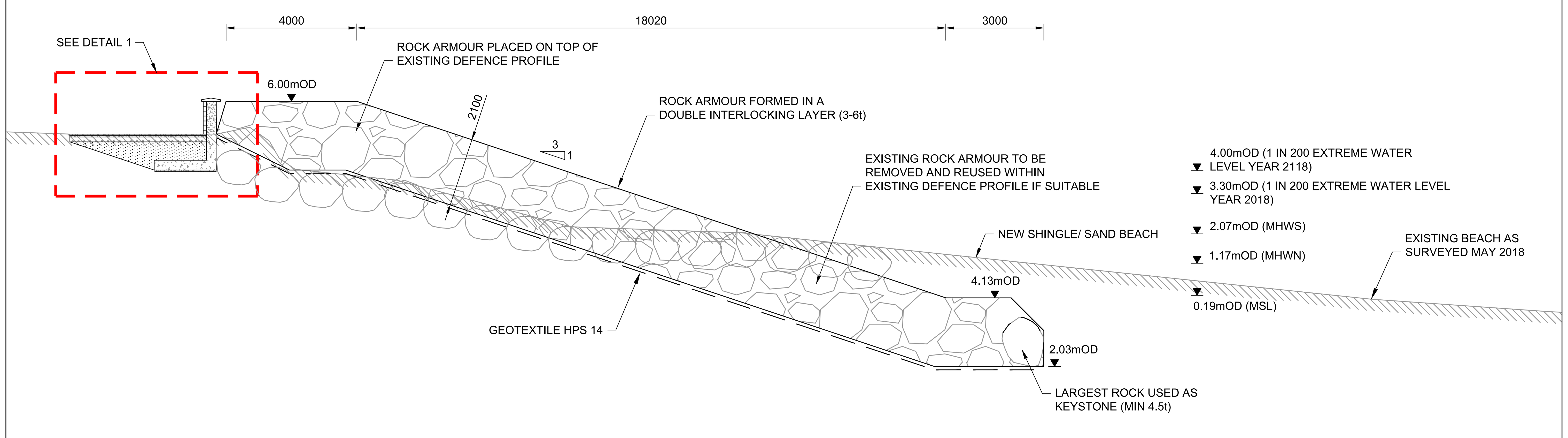
PLAN
Scale 1:1500

Key

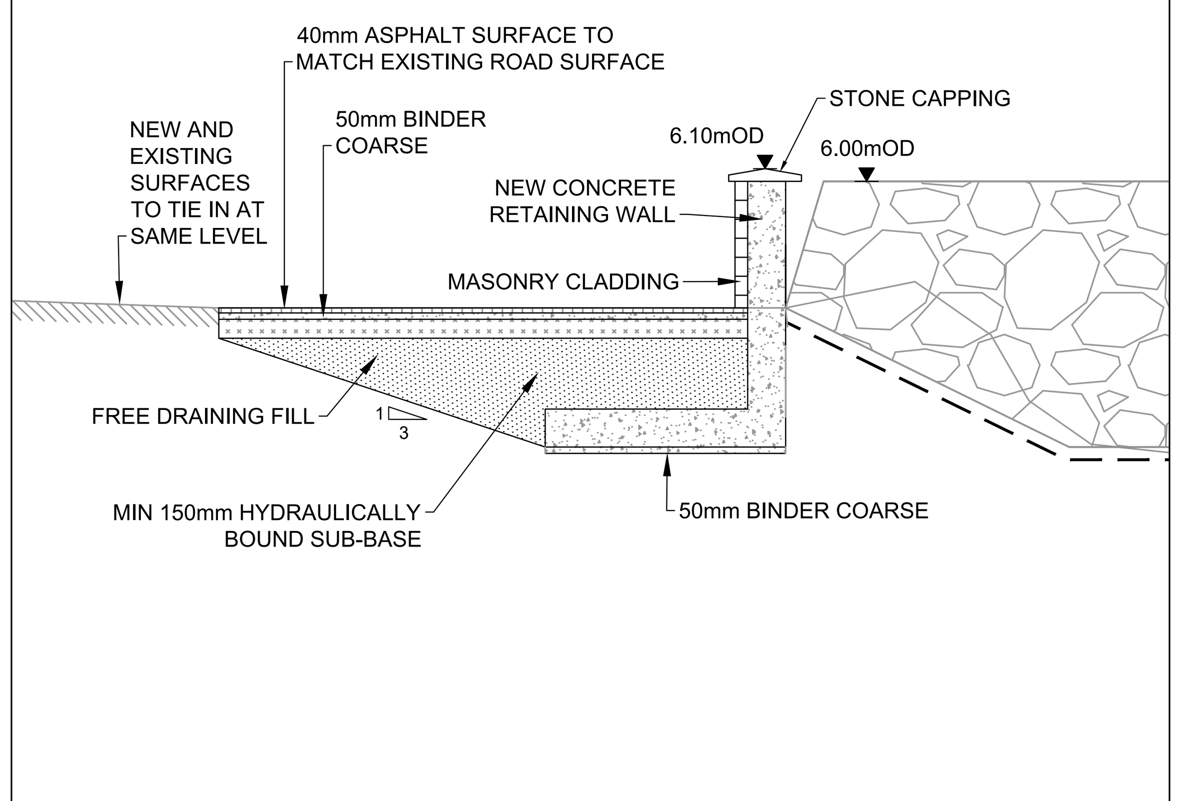
(green line)	Proposed Frontage Modifications

Services Key

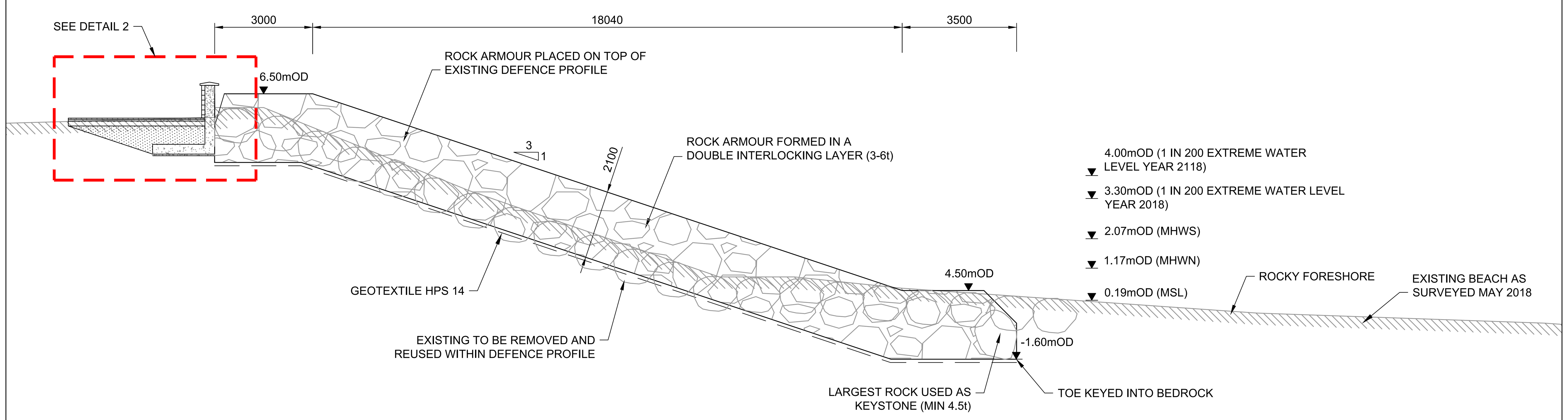
E LV U/G	Electricity (Low voltage) U/G
E 11kV U/G	Electricity (11kV) U/G
T U/G	Telecommunications U/G
T O/H	Telecommunications O/H
W	Water
FW	Foul Water
SW	Surface Water
CS	Combined Sewer
TE	Trade Effluent
	Pipe unknown
GAS LP	Gas Low Pressure
GAS MP	Gas Medium Pressure



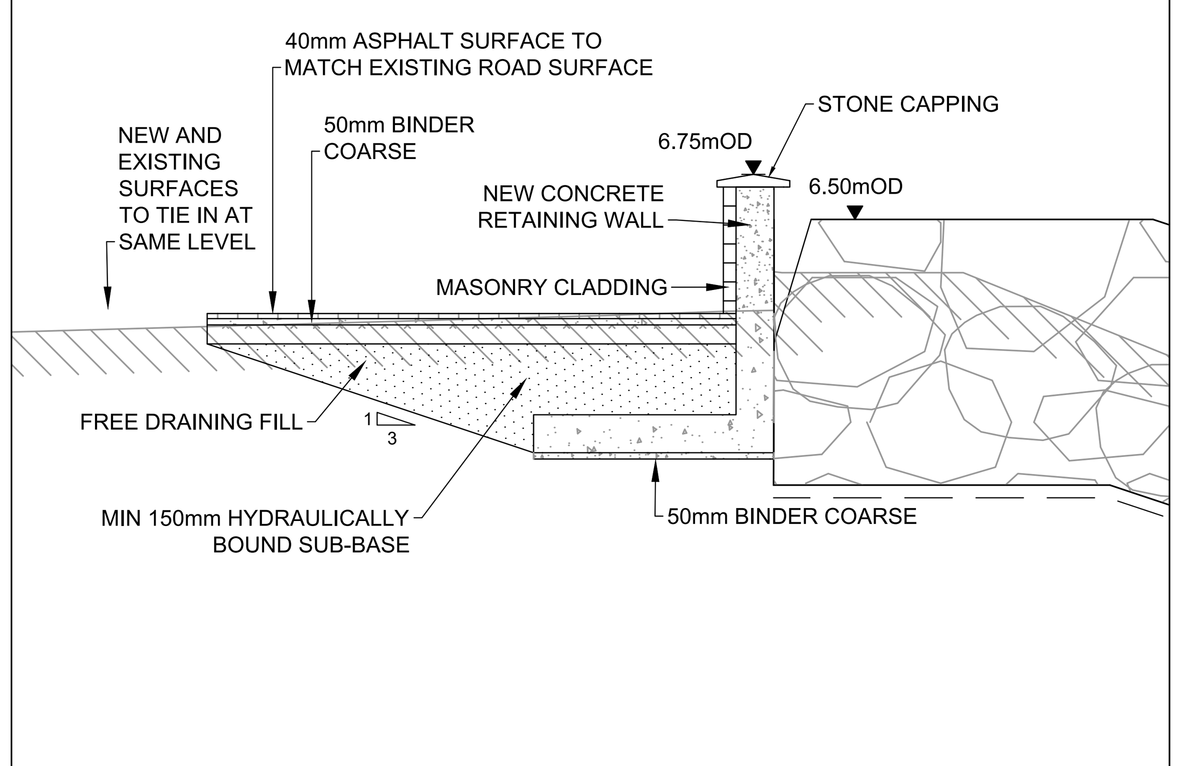
SECTION A-A
SCALE 1 : 100



DETAIL 1
SCALE 1 : 50



SECTION B-B
SCALE 1 : 100



DETAIL 2
SCALE 1 : 50

Construction Risks	Public Risks	Environmental Risks
• Risk of destabilising existing sea wall during excavation at sea wall toe • Working in an active harbour • RNLI operations not to be disrupted	• Road closure likely required along frontage • Noise and vibration from piling activities	• Debris and dust from construction work • Pollution hazards associated with working within tidal water

In addition to the hazards/risks normally associated with the types of work detailed on this drawing take note of the above.
It is assumed that all works detailed on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

General Notes

1. All dimensions shown are in millimetres unless otherwise stated and levels are in metres to Ordnance Datum.
2. Do not scale from this drawing. All dimensions must be checked/verified at detailed design and on site.
3. All levels quoted on drawings were taken from profiles surveyed in May 2018, by JBA Consulting.
4. All works on the coast will be carried out with care to minimise the risk of pollution adhering to Pollution Prevention Guidelines.
5. All works affecting flood defences, main watercourses and/or ordinary watercourses will be subject to Consent for Permanent and Temporary Works under the Land Drainage Act 1991.
6. Ground conditions unknown, concept option subject to change upon further investigation.

Structure information

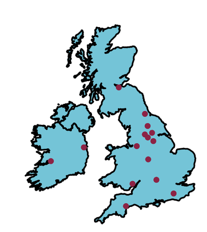
Design life: 100 years standard of protection: 1 in 200 years, 2118

Rev.	Comments										
P03	Added detail 2										
Rev.:	Date	06/06/19	Drawn	RG	Designed		Checked	JST	Approved	GK	
P02	General updates and medium term levels added										
Rev.:	Date	10/05/19	Drawn	RG	Designed	JST	Checked	AD	Approved	GK	

Client Approval
A - Approved
B - Approved with Revisions
C - Do Not Use

Purpose of Issue	Status
For comment	S3

JBA consulting
35 Perrymount Road
HAYWARDS HEATH
West Sussex
RH16 3BW
United Kingdom
www.jbaconsulting.com
t +44 (0)1444 473652
f +44 (0)845 8627772
e info@jbaconsulting.com
Offices at Coleshill, Doncaster, Dublin, Edinburgh, Exeter, Haywards Heath, Limerick, Newcastle upon Tyne, Newport, Saltaire, Skipton, Tadcaster, Thirsk, Wallingford and Warrington



STONEHAVEN BAY COASTAL FPS

HARBOUR FRONTAGE
OPTIONS SH & NH1
ROCK ARMOUR REVETMENT

for

Aberdeenshire Council

This document is the property of Jeremy Benn Associates Ltd. It shall not be reproduced in whole or in part, nor disclosed to a third party, without the permission of Jeremy Benn Associates Ltd.

Scale:			
As shown @ A1	Drawn:	R.Groves	06/03/19
	Designed:	J. Skanberg-Tippen	06/03/19
	Checked:	A. Dane	10/04/19
	Approved:	G. Kenn	10/04/19

Digital File Name: AKI-JBAU-00-00-DR-C-4002_Sections_SH_&_NH1

Drawing Number:	Revision
AKI-JBAU-00-00-DR-C-4002	P03

DESIGN TECHNICAL NOTE

JBA Project Code	2018s0343
Contract	Stonehaven Bay Coastal Flood Protection Study
Client	Dougall Baillie Associates / Aberdeenshire Council
Day, Date and Time	June 2019
Author	Amelia Wright
Reviewer / Sign-off	Johan Skanberg-Tippen / Graham Kenn
Subject	Stonehaven Bay Coastal Flood Protection Study - Concept Design Technical Note for Shortlist Options

1 Introduction

This Design Technical Note details the key assumptions and calculations used in the development of the concept designs of the shortlist options as part of the Stonehaven Bay Coastal Flood Protection Study (FPS).

The Stonehaven Bay Coastal FPS is being developed to investigate the feasibility of a new coastal defence scheme to manage tidal flood risk at Stonehaven Bay. Each option has been designed to protect residential and commercial properties along the Stonehaven frontage between north of Cowie Water and the south of Stonehaven Harbour (see Figure 1-1). The purpose is to increase the protection from the residual risk of wave overtopping, ensuring an appropriate standard of protection (taking climate change into account) and design life of all elements.

Figure 1-1 Frontages assessed within the Stonehaven Bay FPS

DESIGN TECHNICAL NOTE

JBA Project Code	2018s0343
Contract	Stonehaven Bay Coastal Flood Protection Study
Client	Dougall Baillie Associates / Aberdeenshire Council
Day, Date and Time	June 2019
Author	Amelia Wright
Reviewer / Sign-off	Johan Skanberg-Tippen / Graham Kenn
Subject	Stonehaven Bay Coastal Flood Protection Study - Concept Design Technical Note for Shortlist Options

1.1 RIBA Plan of Work

The definition of the RIBA Plan of Work, from project conception to operation, can be summarised is as follows:

- Stage 0 - Strategic Definition - to identify the client's core project requirements.
- Stage 1 - Preparation and Brief - to develop project objectives and initial project brief.
- Stage 2 - Concept Design - to prepare the concept design and preliminary cost information.
- Stage 3 - Developed Design - to prepare the outline design, cost information and project strategies.
- Stage 4 - Technical Design - to prepare the detailed design, to include structural detailing, specialist subcontractor design and specifications.
- Stage 5 - Construction - to manufacture offsite and construction onsite the Technical Design.
- Stage 6 - Handover and Close Out - to handover the finish structures.
- Stage 7 - In use - to utilise the structures as intended.

The Stonehaven Bay FPS has been commission under RIBA Stage 2 Concept Design [1] and thus the concept designs have been produced in accordance with such. Only high-level structural and geotechnical considerations have been made at this stage, with designs having been developed based on a typical profile through each section at Stonehaven, and do not consider access points or tie-ins in detail.

1.2 Design development to shortlist options

As part of the FPS, a range of longlist options have been assessed at a high level via multi-criteria assessments with stakeholder comments. From this some options were eliminated, with the following shortlist options determined and subsequently designed to concept design level:

- North Stonehaven:
  - N1 - New sea wall
  - N2 - Raising the existing sea wall
  - N3 - Rock armour revetment
  - N4 - Beach recharge with control structures
- Cowie Water:
  - CW - New training wall
- Central Stonehaven:
  - C1 - New sea wall
  - C2 - Beach recharge with control structures

1 RIBA. 2013. www.ribaplanofwork.com/About/Concept.aspx

- North Stonehaven Harbour:
  - NH - Rock armour revetment
- Inner Stonehaven Harbour:
  - IH1 - New vertical piled wall
  - IH2 - New sloped quay wall
- South Stonehaven Harbour:
  - SH - Rock armour revetment

All of the options have been designed to reduce the risk of wave overtopping to the corresponding sections of Stonehaven.

2 Input data

The following input data, with listed assumptions, have been adopted during the development of the concept designs for the shortlist options at Stonehaven.

2.1 Datum

All elevations presented in the concept designs are given in metres Above Ordnance Datum (mAOD), based on the Ordnance Survey (OS) GPS Network.

2.2 Topographic data

Topographic data points were surveyed directly by JBA Consulting in May 2018 under the commission of the Stonehaven Bay Coastal FPS. This topographic data contains data on the elevations and schematisations of the existing defences and beach profiles.

Although topographic survey datasets of the beach at Stonehaven were also undertaken in December 2008 and May 2013, this data has not been used in the development of the shortlist designs at Stonehaven.

2.3 Baseline conditions

The coastal defences at Stonehaven are frequently overtopped by waves during storm events. A review of historical flood events indicate that Stonehaven is subject to frequent flooding, ranging from overtopping the harbour wall with no impact to property or roads to large scale overtopping events resulting in flooding to multiple properties and evacuations. A total of 34 events were recorded between 2005-2018.

Inundation modelling, which incorporates wave overtopping rates and subsequent surface water, show that 57 residential and 11 non-residential properties in Stonehaven are at risk of flooding in the present-day 0.5% AEP event.

In order to develop a design which efficiently reduces the flood risk at Stonehaven, it has been crucial to investigate the baseline conditions, which are summarised below.

2.3.1 Existing defences

Stonehaven is approximately 2.4km in length and is formally defended via a range of defence structures. A sand/shingle beach front the defences, although offers little added protection against wave overtopping.

In May 2018, JBA Consulting undertook an asset condition survey of the Stonehaven coastal defences, including the harbour. This concluded that the rock armour at Central Stonehaven is in good condition, and the northern part of North Stonehaven and the South Harbour are in poor condition. The remaining frontage is in fair condition.

Table 2-1 presents the type, condition and estimated residual life (i.e. expected deterioration years to get to a condition where sever defects are present and result in complete performance failure) for each section included within the shortlist concept designs.

Table 2-1 Section details along the Stonehaven frontage

Section	Approx. length (m)	Type	Condition	Residual life (year)
North Stonehaven	830	Part masonry/concrete sea wall and part concrete stepped revetment	3 (fair) - 4 (poor)	15-30
Cowie Water	273	Sheet piles with sloping concrete pitching training walls	3 (fair)	35
Central Stonehaven	750	Part concrete sea wall and part rock armour revetment	2 (good) - 3 (fair)	30-45
North Stonehaven Harbour	175	Rock armour revetment	3 (fair)	30
Inner Stonehaven Harbour	275	Masonry quay wall	3 (fair)	30
South Stonehaven Harbour	110	Rock armour revetment and Bervie Braes cliff-line	4 (poor)	10

2.3.2 Still water level flood risk

The primary defences have varying crest elevations, although the current standard of protection along the Stonehaven frontage is greater than the present day 0.5% AEP event due to the existing structures exceeding 3.96mAOD.

Based on the predicted extreme water levels from the Environment Agency (2011) coastal flood boundary conditions for the UK [2] (see Table 2-2), the Stonehaven frontage would also not experience tidal inundation caused solely by static water and tide levels over the existing defences in the future.

2 Environment Agency. 2011. Coastal flood boundary conditions for UK mainland and islands Project: SC060064/TR2

Table 2-2 Extreme water levels at Stonehaven

Epoch	Event (AEP)	Extreme Water Level (mAOD)
2018 - present-day	0.5%	3.23
2118 - with climate change	0.5%	3.96

Further details on the still water level data, tidal inundation modelling and resulting baseline flood risk are contained within the Interim Modelling Report (AKI-JBAU-00-00-RP-HM-0002-Interim_Modelling_Report) produced as part of the Stonehaven Bay Coastal FPS commission.

2.3.3 Wave overtopping risk

Stonehaven is at risk of flooding caused by wave overtopping as indicated by the tidal inundation modelling. Additionally, historical events, particularly since 2005, evidence frequent flooding of residential properties as a result of waves overtopping the defences. This risk will increase when a 100-year climate change allowance is incorporated due to the increase in water level.

The wave overtopping has been derived from a multivariate approach. All wave climate data (namely water levels, significant water heights and wave periods) for the 0.5% AEP event with and without a 100-year climate change allowance for each typical section has been utilised to develop the shortlist designs.

Further details on the wave data, wave transformation and wave overtopping modelling and resulting baseline risk are contained within the Interim Modelling Report (AKI-JBAU-00-00-RP-HM-0002-Interim_Modelling_Report) produced as part of the Stonehaven Bay Coastal FPS commission.

2.4 Hydrodynamic data

The hydrodynamic data used to develop the options have been sourced from two primary sources:

- Extreme sea levels - the Environment Agency Coastal flood boundary conditions for UK mainland and islands [2] project.
- Extreme wave conditions - calculated using Wave Watch III hindcast wave model time series data.

2.5 Climate change

Climate change projections for Stonehaven have been estimated using the UKCP18 medium emission 95th percentile scenario. Sea level rise is estimated at 0.73m for 100 years resulting in an extreme water level of 3.96mAOD for the 0.5% AEP event. This has been applied for the 2118 epoch representing the end of the 100-year optimal design life within the shortlist options.

2.6 Design life and standard of protection

The design life and standard of protection varies throughout the shortlist options, as summarised in Table 2-3. With the exception of option N2 (North Stonehaven), all options have been designed as long-term options, as such to have a design life of 100 years with a 0.5% AEP event standard of protection, including a 100-year allowance for climate change.

Option N2 has been designed as a medium-term option to a present-day 0.5% AEP event standard of protection and will rely upon the existing sea wall structure as such that maintenance will be required to extend the residual life of the existing structure. The design life of Option N2 is therefore limited to the residual life of the existing sea wall.

Options N1, N3, N4 (all North Stonehaven), C1 and C2 (both Central Stonehaven) have also been developed to allow for the design to be adapted to be a medium-term solution as to reduce the initial capital costs of the scheme. These options will still have a design life of 100 years with a 0.5% AEP event standard of protection although does not account for any climate change allowances.

Table 2-3 Design philosophies at Stonehaven

Option	Long-term option	Medium-term option
N1	X	X
N2		X
N3	X	X
N4	X	X
CW	X	
C1	X	X
C2	X	X
NH	X	
IH1	X	
IH2	X	
SH	X	

2.7 Performance standards

Due to the existing frontage at Stonehaven crest level exceeding extreme water levels, the performance standards for all options is driven solely by wave overtopping.

2.7.1 Still water level

Despite the baseline conditions at Stonehaven indicating that the flood risk is dominated by wave overtopping, it is crucial that all shortlist options should conform to meet the minimum of the 0.5% AEP event with 100-year allowance for climate change, to include a freeboard allowance. Environment Agency (2017) freeboard guidance [3] has been adopted, from which a 4-star confidence rating has been assumed to be achieve during the detailed design. As such, a 450mm freeboard has been accounted for to achieve zero still water level flooding during the design event and events with lower return periods. However, as outlined in Section 2.3.2, the existing defences in Stonehaven already exceed this level and thus the development of the designs are not required to be driven by static water and tide levels.

3 Environment Agency. 2017. Accounting for residual uncertainty - updating the freeboard guidance (SC120014).

2.7.2 Wave overtopping

Table 2-4 summarises the European Wave Overtopping Manual (EurOtop II; 2018) guidance on wave overtopping rates tolerable for pedestrians and vehicles [4]. At this stage, the tolerable discharge threshold proposed for all shortlist options is to be less than 1l/s/m for the 0.5% AEP event as this is considered to be safe for pedestrians. A threshold of up to 5l/s/m may be considered tolerable providing Aberdeenshire Council are willing to take of the risk of lowering this threshold in order to reduce design defence sizes. This latter overtopping threshold is such that all structures will be considered safe for pedestrian access during regular storm events although the council will be required to close the adjacent promenade/pavements in larger events with overtopping rates of over 1l/s/m.

Table 2-4 Wave overtopping limits for pedestrian and vehicles, taken from EurOtop II (2018; pg54).

Hazard type and reason	Mean discharge q (l/s per m)	Max volume V_{max} (l per m)
People at structures with possible violent overtopping, mostly vertical structures	No access for any predicted overtopping	No access for any predicted overtopping
People at seawall / dike crest. Clear view of the sea.		
H_{m0} = 3 m	0.3	600
H_{m0} = 2 m	1	600
H_{m0} = 1 m	10-20	600
H_{m0} < 0.5 m	No limit	No limit
Cars on seawall / dike crest, or railway close behind crest		
H_{m0} = 3 m	<5	2000
H_{m0} = 2 m	10-20	2000
H_{m0} = 1 m	<75	2000
Highways and roads, fast traffic	Close before debris in spray becomes dangerous	Close before debris in spray becomes dangerous

2.8 Ground conditions

As part of the FPS, a Geotechnical Desk Study (AKI-JBAU-00-00-RP-C-0001-Geotechnical_Desk_Study) was undertaken for Stonehaven. This contains full details on the ground conditions along with other geotechnical and geoenvironmental issues associated with the site. The ground conditions at Stonehaven are complex, however, can generally be summarised as follows:

- Bedrock geology - Cowie Sandstone formation (sandstone) and Carron Sandstone Formation (sandstone), with offshore outcrops of Cowie Harbour Conglomerate Member (conglomerate) and Cowie Harbour Siltstone Member (siltstone and sandstone)

4 EurOtop. 2018. Manual on wave overtopping of sea defences and related structures.

- Superficial deposits - Raised Marine Beach Deposits of Holocene Age (sand and gravel), Marine Beach Deposits (gravel), Alluvium (clay, silt, sand and gravel)

No geotechnical analysis has been undertaken at concept design stage in line with RIBA Stage 2.

2.8.1 Contaminated land

The Stonehaven Geotechnical Desk Study (AKI-JBAU-00-00-RP-C-0001-Geotechnical_Desk_Study) investigated pollution incidents and historic, recorded and registered landfills at Stonehaven. The report concluded that there may be significant contamination issues at the site relating to the old tannery and gas works located in close proximity to the frontage.

2.8.2 Structural design

A full structural design has not been undertaken for the design development of the shortlist options, although structural considerations have been made.

No allowance for settlement and consolidation has been made within the designs, and thus all levels presented in the concept design drawings represent the post-settlement and post-consolidation levels. This may need to be revised on the outcome of any ground investigations undertaken prior to detailed design.

2.9 Services data

As part of the FPS, a PAS-128 Type D survey has been undertaken via a desktop utility record search of Stonehaven. The results indicated that at the time of the search, there are a range of services interacting with the frontage. All services have been included within the concept design drawings. Provisions for all services interacting with the frontage and construction zones will need to be made at detailed design.

2.10 Environmental impact

An Ecological Desk Study (AKI-JBAU-00-00-RP-EN-0002-Desktop_Ecology_Report) was undertaken as part of the Stonehaven Bay Coastal FPS. The following are the most significant concluding remarks which may impact the development of the design options:

- North Stonehaven is within the Garron Point Site of Special Scientific Interest (SSSI).
- Numerous protected species can be found within the site, and within 1km of the site extents, and thus targeted species surveys and mitigation measures are likely to be required. This will be aided with a Habitats Regulation Assessment.
- A Preliminary Ecological Assessment will be required as soon as the scope and extent of the preferred way forward is decided upon.

An Environmental Impact Assessment may be required depending on the outcome of these Screening Opinion prior to detailed design.

3 General design development

3.1 Design methodology

The concept designs of shortlist options include the following documents:

- Design drawings showing the general arrangement, cross-sections and any critical details
- Design risk assessment
- Supporting design technical note detailing all assumptions made (i.e. this document)

3.2 Design standards, guidance and reference documents

The following material have been used as the point of reference for all engineering design assumptions:

- BS 6349-1; (2000) Marine Structures Part 1: Code of practice for general criteria
- BS EN 13383-1:2002 Armourstone – Part 1: Specification
- BS EN 13383-2:2002 Armourstone – Part 2: Test methods
- BS EN 1990; (2002) Basis of structural design (+A1:2005)
- BS EN 1997-1:2004 Geotechnical design - General Rules & National Annex (Eurocode 7)
- BS EN 1997-2:2007 Ground investigation and Testing & National Annex (Eurocode 7)
- CERC (1984) Shore Protection Manual
- CIRIA (2007), The Rock Manual: The Use of Rock in Hydraulic Engineering (second edition)
- CIRIA (2010), The Beach Management Manual (second edition
- CIRIA (2010), The use of concrete in maritime engineering – a guide to good practice
- Cobb, F (2015), Structural Engineer's Pocket Book: Eurocodes
- EurOtop II (2018), Manual on wave overtopping of sea defences and related structures, second edition
- Manual of Contract Documents for Highway Works (2019)
- US Army Corp of Engineers (2002), Coastal Engineering Manual

3.3 Key design elements

The key design elements which are transferable between options are described below. Option specific design elements are contained within the subsequent report sections.

All of the shortlist options have been optimised to try and achieve the best balance between the required design performance standards (see Section 2.7) and minimising material usage and, hence, carbon footprint as to develop a sustainable design.

3.3.1 General defence geometry

All of the shortlist options within the Stonehaven Bay Coastal FPS have been designed to protect Stonehaven from the residual risk of wave overtopping, as the frontage is not at still water level risk. The proposed defence geometries have been optimised by wave overtopping, as this methodology also incorporates protection to extreme sea levels. The wave conditions for the 0.5% AEP event have been used for both maximum water levels and wave overtopping, with the present-day 0.5% AEP event being used for the medium-term options and the 0.5% AEP event including an allowance for 100-years climate change has been used to develop the long-term options.

For all options with the exception of CW, a range of defence geometries were tested to determine which structure combination offers the most cost-efficient and sustainable solution for each section and design option, whilst meeting the required wave overtopping performance standard.

For each shortlist option at each section, schematisations for typical sections were assessed within the latest release of the Artificial Neural Network (ANN; 2016) [5]. A range of varying wall crest level, revetment crest level, crest width and revetment slope were assessed. The wave climate data used for each of the typical sections were the 2118 0.5% AEP overtopping event for the long-term options (i.e. N1, N3, N4, CW, C1, C2, NH, IH1, IH2 and SH) and the 2018 0.5% AEP event for the and medium-term options (i.e. N1, N2, N3, N4, C1 and C2).

The outputs from the ANN for each option provided a comprehensive dataset of wave overtopping rates for the design event, defence footprint and above beach level cross-sectional area for each schematisation assessed. To determine the most efficient defence geometry, the following filtering criteria was applied to the dataset:

- Wave overtopping rates to be <1l/s/m, as determined in Section 2.7.
- Exposed height of the wall/freeboard raising to be limited for aesthetic reasons as to not restrict the view.
- Limit the volumes of material as far as reasonably practical whilst still achieving the project aims.

For each shortlist option, the design was developed further based upon the defence geometry obtained through this assessment driven by wave overtopping. The final defence geometry and additional design details are provided in the subsequent sections of this Design Technical Note.

It should be noted, however, that the EurOtop II guidance suggests that this model is only suitable for the development of concept designs. Physical modelling is recommended at detailed design to optimise the design further and to control the key design criteria.

Option CW was developed utilising a separate methodology due to the nature of the Cowie Water site not having a coastal alignment and subsequently has waves acting upon the defence in a different way than all other frontage sections contained within the Stonehaven Bay Coastal FPS.

3.3.2 Access points

At this stage, it is assumed that all access points between the promenade and the beach across the Stonehaven frontage are to be maintained, although design development of these features have not been included within the concept design. Further details on this will require careful consideration during detailed design.

3.3.3 Tie-in details

Tie-ins between sections within the Stonehaven Bay Coastal FPS and at the northern and southern extents of the scheme will require careful consideration at detailed design. It is

5 Artificial Neural Network. 2016. http://overtopping.ing.unibo.it/overtopping/neuronet/net_solve/

recommended that multiple sections are analysed at detailed design to determine the exact location of the defence tie-in and tie-in details specific to each location.

3.4 Design risk and health and safety considerations

All design elements consider design risk as a fundamental requirement of the design process. The foreseen risks and the method of mitigation or risk reduction for each of the shortlist options have been recorded via a Design Risk Assessment (DRA), in line with Construction Design and Management (CDM) Regulations (2015). This identifies any foreseeable potential hazards associated with the design, construction, operation and maintenance and decommissioning of any designed elements for each option. If the risk cannot be eliminated, measures will be considered to minimise the risk so far as reasonably practical. For any risks that cannot be mitigated, these will be described to ensure that they are brought to the attention of any other parties who may become involved in the Stonehaven project.

4 Concrete wall and promenade design philosophy

Several options for the protection of Stonehaven against wave overtopping have been designed as a reinforced concrete retaining wall. A new sea wall has been proposed for options N1 (North Stonehaven), C1 and C2 (both Central Stonehaven), with options N3 (North Stonehaven), NH (North Harbour 1) and SH (South Harbour 1) also incorporating a wall to form the crest level of the design revetments. Additional options CW (Cowie Water) and IH2 (Inner Harbour) include a reinforced concrete setback and sloping wall respectively.

For all wall options, the optimal position and crest level have been determined through the process outlined in Section 3.3.1 for each typical section within each option. The crest level of the walls for these options may vary along the frontage, depending on the option and typical sections used, and with the distance offset from the existing defence line.

Precast concrete has been designed, where appropriate, in order to control the quality of the wall units due to fabrications in accordance with BS EN 13369:2018. A minimum reinforcement cover of 75mm should be achieved due to the exposure to the open coast.

The development of the wall units are to be further analysed during detailed design.

4.1 Concrete walls

4.1.1 Sea walls

The new sea walls within options N1, C1 and C2 have been designed as precast reinforced concrete recurve retaining walls, with a concrete stepped toe detail (or concrete stepped revetment to replace the existing stepped revetment structure) and a concrete capped sheet pile toe keyed into the bedrock.

4.1.2 Impermeable revetment walls

The walls within N3, NH and SH have been designed as precast reinforced concrete retaining walls, as an impermeable backing to the associated designed rock armour revetments.

4.1.3 Setback walls

The new setback wall within option CW has been designed as a precast reinforced concrete retaining wall.

As standard with gravity retaining wall structures, the wall base slab widths have been designed based upon engineering judgement and previous project experience. The base width for the setback walls has been calculated as a stem height (full height of the wall stem from the top of the base slab to the crest level) to base ratio of approximately 1:2, as to be conservative in the design. Due to the nature of the designs, there is no space for a base slab toe.

The wall will be masonry clad and have a masonry coping stone.

4.1.4 Sloping quay wall

The wall within option IH2 has been designed as a precast reinforced concrete wall, to be cast against the existing quay walls as to maintain the existing slope gradient of the quay.

The wall will be masonry cladded and have a masonry coping stone.

4.2 Promenades

As part of options N1, N3, C1 and C2, as new promenade will be constructed. These have been designed to be concrete faced and is to be constructed landward of the sea wall at a minimum of 1.1m lower than the crest height of the new wall. This will require the incorporation of a land raise to achieve the appropriate level.

This raise will predominantly be constructed out of free-draining granular fill material, above which a minimum of 150mm of hydraulically bound sub-base material is required to achieve an appropriate construction surface. The promenade surface will consist of 200mm concrete pavement PAV2 with a brushed finish to tie into the wall unit. The development of this design is in accordance with details contained within the Manual of Contract Documents for Highway Works (MCHW).

A minimum promenade width of 3m is to be achieved to allow for sufficient space for the passing of two wheelchair users, as specified within the MCHW.

It should also be noted that the promenade is to have a cross fall slope of 1 in 40 towards the seaward extent to eliminate the build-up of surface water on the promenade. Further consideration of drainage will be required at detailed design.

4.2.1 Asphalt Extension

Under options NH and SH, a new promenade has not been designed for due to not requiring any land-raising landward of the wall. As such, the existing road surface will be extended to tie into the wall unit. The construction zone required for the heel of the retaining wall will be infilled with free-draining fill material, above which a minimum of 150mm hydraulically bound sub-base material is required to achieve an appropriate construction surface. Above this will lie a 50mm binder coarse layer and a 40mm asphalt surface to match the existing surface. The development of this design is in accordance with details contained within the MCHW.

Consideration of drainage will be required at detailed design.

4.2.2 Pavement

Under option IH2, a new pavement will be constructed. The new pavement will be reinforced concrete with a standard kerb in accordance with the MCHW and is to be constructed landward of the wall at 1.2m lower than the crest height of the new wall. This will incorporate a land raise.

It should be noted that the pavement is to have a cross fall slope of 1 in 40 towards the seaward extent to eliminate the build-up of surface water on the pavement. Further consideration of drainage will be required at detailed design.

5 Concrete stepped revetment design philosophy

Options N1 and C1 incorporate the development of a design to include a concrete stepped revetment where the existing profile is already stepped, in addition to the reinforced concrete walls described in Section 4.1. For the revetment, elements including the crest width and slope gradient have been determined through the process outlined in Section 3.3.1 for the corresponding typical section at North Stonehaven and Central Stonehaven respectively.

Precast concrete has been designed for in order to control the quality of the stepped units due to fabrications in accordance with BS EN 13369:2018, as well as to allow for easier construction and uniformity of steps. A minimum reinforcement cover of 75mm should be achieved due to the exposure to the open coast.

A minimum slope of 1 in 2 is required as to match the existing structure and to continue to allow for access during future beach draw down. As such, the steps have been designed to be 600mm in width with a 300mm rise, for the primary purpose of increasing the roughness coefficient to reduce wave overtopping and not providing public access.

Under option N1, a low-grade mass concrete fill is to occupy the area between the existing and new stepped revetments to enable an appropriate and even construction level. For option C1 this area is much larger and thus a compacted free-draining fill material is to be used above which a 200mm concrete blinding layer has been included within the design to achieve a smooth construction surface for the step units.

6 Sheet pile wall design philosophy

6.1 Option CW

Option CW incorporates a setback wall as defined in Section 4.3, although the development of the design has been extended due to the increased loading of this setback wall on the existing structure. The existing sheet pile has a complex anchor arrangement and thus it would be difficult to pile through the existing embankment. Therefore, the development of the design has included new AZ 26-700 sheet pile to be able to support the additional loading.

The new sheet pile is approximately 500mm offset from the existing sheet pile to allow for construction. The crest level of the concrete capping beam is designed to be as low as possible to reduce the total pile length whilst providing space for the wailing beam and possible anchors required. It is assumed that ground anchors will be required based upon the ground anchor system of the existing structure at Cowie Water.

The area between the existing and proposed sheet piles is to be filled with free-draining granular fill material, with the corresponding embankment between the sheet pile capping beam and the setback wall. The embankment is likely to be an earth embankment constructed of imported fill above which a 150mm thickness of topsoil is proposed, reinforced with a polyamide mat (Enkamat has been recommended at this stage) to minimise the risk of soil erosion.

Consideration of drainage will be required at detailed design.

6.2 Option IH1

Under option IH1, a new quay wall is to be constructed at the toe of the existing masonry wall. The new AZ 26-700 sheet pile wall will have a reinforced concrete capping beam and recurve wall, with the crest level determined by the process outlined in Section 3.3.1. In order to maintain the existing use of the wall within the harbour, the development of the design has incorporated timber planks mounted to the pile face for mooring ropes and mooring rings to be mounted at the crest of the recurve wall.

The area between the existing wall and proposed sheet piles is to be filled with free-draining granular fill material above which a new 200mm brushed faced concrete footpath has been proposed.

It should also be noted that the footpath is to have a cross fall slope of 1 in 40 towards the seaward extent to eliminate the build-up of surface water on the promenade. Further consideration of drainage will be required at detailed design.

7 Rock armour design philosophy

Several options for the protection of Stonehaven against wave overtopping incorporate the development of a design for a rock armour revetment. These include options N3 (North), NH, (North Harbour) and SH (South Harbour).

Elements including the crest level, crest width and slope have been determined through the process outlined in Section 3.3.1 for each typical section within each option.

The crest of the rock may vary along the frontage, depending on the option and typical sections used, although is likely to be above existing beach levels.

7.1 Rock armour sizing

The rock armour has been sized using the Ultimate Limit State (ULS), or the upper limit for the structural stability of the scour protection. The ULS is defined as the worst-case wave height from the 0.5% AEP event with an allowance for climate change within the multivariate analysis. This limit state ensures that the rock armour units will withstand a 0.5% AEP event wave conditions in combination with 0.5% AEP event extreme sea levels, including a climate change allowance for the 100-year appraisal period. The overall likelihood of this magnitude event occurring may have a greater combined probability than a 0.5% AEP event, incorporating a level of conservatism into the critical design elements.

In order to ensure that the correct sizing is used for the rock armour for each option, typical sections through each defence type have been used to calculate the rock armour sizing.

The following are the hydraulic input parameters which have been utilised within the Van der Meer shallow water equations [6]:

- Permeability rating - a permeability rating of 0.1 has been assumed due to being recommended within CIRIA C683 [6; pg. 568] for structures which incorporate a

6 CIRIA. 2007. The Rock Manual: The use of rock in hydraulic engineering.

geotextile between the rock armour and an impermeable surface, thus providing a conservative scenario for this design.

- Slope angle - the slope varies across the options designed. A slope of 1 in 2 has been designed for option N3 and a slope of 1 in 3 for options NH and SH.
- Storm duration - a six-hour storm duration has been assumed. This provides a conservative estimate of the number of waves impacting the structure as in reality the tide range will limit the time waves are breaking against the structure.
- Significant wave height - the significant wave height has been directly extracted from the wave conditions for the 2118 0.5% AEP event at the corresponding typical section.
- Wave period - the wave period has been directly extracted from the wave conditions for the 2118 0.5% AEP event at the corresponding typical section.
- Storm damage level - the storm damage level has been set to 4 (for option N3) and 6 (for options NH and SH) as this is the start of intermediate damage for a 1 in 2 and a 1 in 3 slope respectively [6; pg. 569].
- Rock density - the rock density has been assumed to be 2.65kg/m3.

Using the above parameters, the Van der Meer calculations provided median required rock masses at each typical section for each option. The analysis of these results indicates that 3-6t rock would be sufficient in providing adequate rock stability in which approximately 10% of the rock would be lighter than the median required for stability for all three rock options, as shown in Figure 7-1 for option N3.

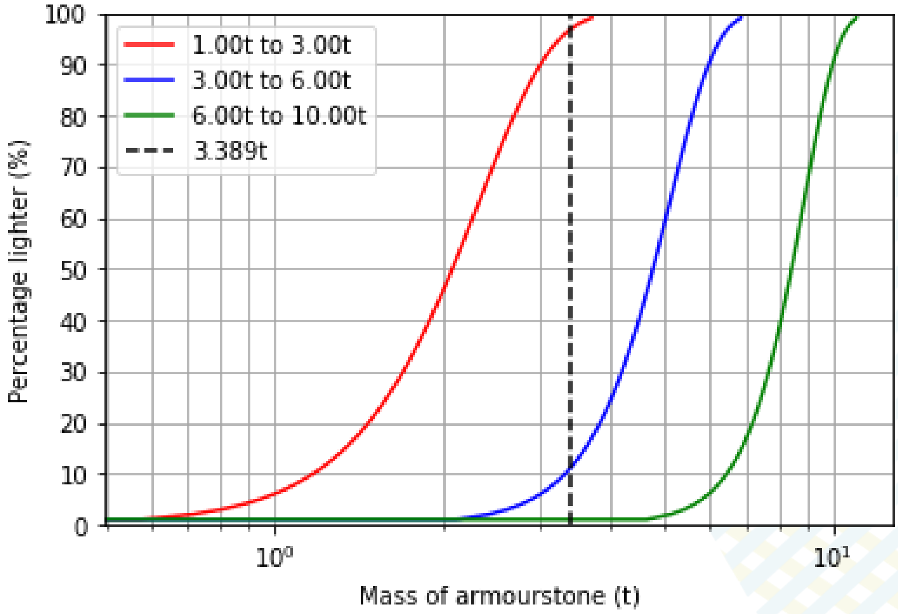


Figure 7-1 Rock grading analysis for option N3, based upon the start of intermediate damage, presenting either 3-6t or 6-10t rock grading would be appropriate

A filter layer is proposed within the design of option N3 only. Additionally, the largest rock at a minimum of 5t to be used as the keystone when geotextiles have been designed for.

It should also be noted that for option N3, part of the frontage has a rocky foreshore platform, with a geotextile underneath. For the remaining section of the north frontage, the rock toe is to be keyed in to increase the stability of the rock armour revetment. This is due to the assumed bedrock being directly underneath the beach.

7.2 Rock armour layer thickness

As recommended within CIRIA C683 [6], the theoretical orthogonal thickness has been calculated to determine the optimal thickness of the rock armour. This utilises the following input parameters:

- Permeability rating - as per Section 7.1.
- Rock density - as per Section 7.1.
- Median diameter - the median diameter for 3-6t rock is 1.21m.
- Number of layers - a double layer of rock armour is assumed for the scour protection.
- Layer thickness coefficient - a value of 0.87 has been used based upon the assumption a double standard or double dense layer with irregular rock.

These calculations resulted in a proposed rock armour thickness of 2.10m for all options.

7.3 Geotextile

Although it is the rock amour which will be directly impacted by the wave climate, critical conditions will occur at the interface between the rock armour and beach material beneath and may result in the failure of the rock armour. As a result, a separation geotextile is required to prevent wash out of the beach material through the rock armour. HPS 14 has been included within the design due to its ability to withstand puncturing from 3-6t rock. It is recommended that further analysis on the mechanical and physical properties of the geotextile required are undertaken at detailed design.

8 Beach recharge and control structures design philosophy

Options N4 (North) and C2 (Central) incorporate the development of a design for beach recharge to a newly designed geometry and accompanying control structures in order to protect Stonehaven against wave overtopping.

The minimum beach geometry required to reduce wave overtopping has been determined through the process outlined in Section 3.3.1 for each typical section within each option. This has defined elements including the required beach crest level and crest width and total cross-sectional area of the designed beach.

It should be noted that although beach profiles at Stonehaven were undertaken in December 2008, May 2013, and May 2018, no beach trends could be concluded from this limited dataset. Therefore, it is assumed that the beach is stable with no net beach loss, although the designs proposed are likely to alter the beach dynamics and thus a conservative approach to the development of the design have been adopted.

8.1 Beach profile and recharge

The process outlined in Section 3.3.1 defined the minimum profile at each section that is required for wave overtopping during the 0.5% AEP event to limit wave overtopping rates to below the 1l/s/m threshold set. However, these results assume that this beach profile remains constant over time.

The beach has been designed as a shingle beach with a slope of 1 in 10, as to reflect the existing beach profile but also as a it is within the typical beach slope for a shingle beach with a median sediment size of 5mm or 10mm [7]. Within the defence geometry testing, a range of crest levels were tested to optimise the design to ensure that shingle is not mobilised and run-up the beach.

From the minimum cross-sectional area of the beach required, a volume of additional material has been calculated for each typical section used. A beach profile smaller than this would result in exceedance of the overtopping threshold. An estimated 20% volume lost for the shingle beach results in the requirement of a 20% uplift on volume, as to account for the loss of material due to wash out and settlement in the first year.

It has been assumed that the annual beach material loss will be approximately 5%. A five-year beach recharge has been designed for, of which will see a total volume reduction of 23% between year one and year five. The development of the design, therefore, also incorporates this reduction based upon the design profile with the 20% uplift, as to ensure that the beach profile will be at the minimum design profile to meet the performance standards of protection of Stonehaven against wave overtopping in between recharge years.

8.2 Control structures

The development of the design for beach recharge also include control structures to increase the stability of the beach, minimise net beach volume change, and maintain the shoreline. A groyne system will be installed perpendicular to the coastline as a physical barrier to limit longshore and cross-shore transport of material.

The groynes will retain enough material to prevent natural beach processes evolving the beach profile or the reorientation away from the designed profile. As such, the groynes have been designed to be set 1m above the design beach profile, as recommended within the Beach Management Manual [7]. The spacing of the groynes is based upon engineering judgement and previous coastal recharge schemes within the county.

The construction material (i.e. timber or rock), groyne length, groyne spacing, and the presence of any groyne head extensions will be considered at detailed design. Additionally, terminal groynes at the frontage extents will need to be considered to prevent the net loss transport of material from the groyne system.

[End of Design Technical Note]

7 CIRIA. 2010. Beach Management Manual.

Design Risk Assessment – Stonehaven Options

Document control					
Contributing designers	Revision	Purpose of issue	Checked	Reviewed	Date
Amelia Wright	P01	For information	Johan Skanberg-Tippen	Graham Kenn	17/06/19

This Design Risk Assessment identifies any foreseeable potential hazards associated with the design, construction, operation and maintenance and decommissioning of any designed elements for each of the shortlisted options at Stonehaven, in line with Construction Design and Management (CDM) Regulations (2015). If the risk cannot be eliminated, measures will be considered to minimise the risk so far as reasonably practical.
The options covered within the Design Risk Assessment include the following:

- New reinforced concrete sea wall at N1, N2 (North Stonehaven), C1 (Central Stonehaven) and IH2 (Inner Stonehaven Harbour). Option specific risks are presented in **blue**.
- New rock armour revetment with reinforced concrete wall at N3 (North Stonehaven), NH (North Stonehaven Harbour) and SH (South Stonehaven Harbour). Option specific risks are presented in **orange**.
- Beach recharge with control structures N4 (North Stonehaven) and C2 (Central Stonehaven). Option specific risks are presented in **purple**.
- New Cowie Water training walls, including new reinforced concrete setback wall, at CW (Cowie Water). Option specific risks are presented in **green**.
- New sheet pile wall at IH1 (Inner Stonehaven Harbour). Option specific risks are presented in **burgundy**.

Health and Safety Considerations

Stage 1 **Identify**				Stage 2 **Eliminate / Reduce**	Stage 3 **Inform**		Stage 4 **Control**	
Ref. no.	Project element, material or activity	Key health and safety hazards and their possible effects	People at risk from the hazard	Design measures taken to eliminate the hazard or reduce the risk	Significant residual hazards and risks	Communication method	Risk owner(s)	Proposed control measures
Guidance	Consider all aspects involved in each stage of interface with the site, environment and structure(s).	Record the key hazards and their potential consequences.	Identify the categories of people at risk.	Include obtaining adequate data for design certainty and any further studies carried out during the risk evaluation process. Proposed measures to be taken by constructors and operators are to be included in Stage 4.	Provide details of residual hazards and risks that will need to be communicated and managed.	Record how information is provided, whether on drawings, pre-construction information, buildability statement, specification, reports or H&S File	Record the name of designers, contractors, the client or other stakeholders who are to ensure the significant residual risk is minimised and controlled.	Recommend measures to be taken by the risk owner(s) to minimise and control the significant residual risk.
Design								
DES1	Extreme water levels	Flooding to Stonehaven as a result of extreme water level inundation	Public, property, operatives, plant	Development of a design where the new structure increases the standard of protection against extreme water levels at Stonehaven, with a minimum of a 450mm freeboard, whether this be in the long- or medium- term. N4/C2 – Development of a design which utilises the existing structure maintaining the existing standard of protection against extreme water levels at Stonehaven, with a minimum of a 450mm freeboard, within medium-term adaptions only	As before - eliminated up to the 2118 0.5□ AEP design event for long-term options and up to the 2018 0.5□ AEP design event for medium-term options and adaptations. N4/C2 - As before - eliminated up to the 2018 0.5□ AEP design event for medium-term adaptations	Drawings, pre-construction information	Client	Maintain the condition and usability of the proposed design structure(s) once constructed, and consider additional mitigation measures in the future
DES2	Wave overtopping	Flooding of Stonehaven as a result of wave overtopping	Public, property	Development of a design where the new structure reduces overtopping to 1l/s/m in a 0.5□ AEP event with climate change to the year 2118	As before - eliminated up to the 2118 0.5□ AEP design event for long-term options and up to the 2018 0.5□ AEP design event for medium-term options and adaptations	Drawings, pre-construction information	Client	Maintain the condition and usability of the proposed design structure(s) once constructed, and consider additional mitigation measures in the future

Design Risk Assessment – Stonehaven Options

Health and Safety Considerations

Stage 1 **Identify**				Stage 2 **Eliminate / Reduce**	Stage 3 **Inform**		Stage 4 **Control**	
Ref. no.	Project element, material or activity	Key health and safety hazards and their possible effects	People at risk from the hazard	Design measures taken to eliminate the hazard or reduce the risk	Significant residual hazards and risks	Communication method	Risk owner(s)	Proposed control measures
DES3	Unknown foundation depth of structures	Potential destabilisation of existing structures due to future beach drawdown	Public, property	N1/CW/C1/IH1/IH2 - Development of a design where the toe of the existing structures is contained behind the proposed structure which incorporates a sheet pile toe driven into bedrock. N2 – N/A N3/N4/C2/NH/SH – Development of design where the toe of the existing structure is contained behind the proposed structure which incorporates a buried toe.	N1/CW/C1/IH1/IH2 - Eliminated N2 – Cannot eliminate N3/N4/C2/NH/SH – Cannot eliminate – risk reduced	Drawings, pre-construction information	Client, Designer(s) at detailed design	N/A
DES4	Erosion and scour of existing structures Only applicable to N2, N4 and C2	Potential undermining and destabilisation of existing structures due to scour	Public, property	N2 - Development of a design to incorporate concrete repairs to the existing structures. N4/C2 - Development of a design to incorporate concrete repairs to the existing structures and a conservative beach recharge programme to maintain beach levels.	N2 - Cannot eliminate – risk reduced N4/C1 – Cannot eliminate – risk reduced	Drawings, pre-construction information	Client	Monitor beach levels, erosion and scour, and consider additional mitigation measures in the future if required
DES5	Movement of emergency vehicles between the promenade and beach areas	Loss of emergency access to and from the beach	Public	Development of a design to maintain access points, including slipways	Eliminated	Drawings, pre-construction information	Client, designer(s) at detailed design, contractor(s)	Maintain the condition and usability of the emergency access
DES6	Movement of the public around the promenade and beach areas	Loss of access to and from the beach increasing the risk of cut-off during a rising tide	Public	Development of a design to maintain access points between the promenade and beach	Cannot eliminate – risk reduced	Drawings, pre-construction information	Client, designer(s) at detailed design, contractor(s)	Consider signage to raise awareness of hazards to the public, and maintain the condition and usability of public access
DES7	Movement of the public around exposed rock armour Only applicable to N3, NH and SH	Slips, trips, falls and entrapment	Public	Development of a design where new crown walls have a minimum height of 1.1m to prevent falls and have an angular geometry to deter climbing onto the rock. However, no design measures have been undertaken to eliminate or reduce the risk from the beach.	Cannot eliminate – risk reduced	Drawings, pre-construction information	Client, designer(s) at detailed design, contractor(s)	Consider signage, monitor the placement of rock and maintain the condition and usability of public access

www.jbagroup.co.uk
www.jbaconsulting.com
www.jbaconsulting.ie
www.jbarisk.com

Design Risk Assessment – Stonehaven Options

Health and Safety Considerations

Stage 1 **Identify**				Stage 2 **Eliminate / Reduce**	Stage 3 **Inform**		Stage 4 **Control**	
Ref. no.	Project element, material or activity	Key health and safety hazards and their possible effects	People at risk from the hazard	Design measures taken to eliminate the hazard or reduce the risk	Significant residual hazards and risks	Communication method	Risk owner(s)	Proposed control measures
Construction								
CON1	Construction in a public realm – working on an existing coastal defence	Flooding to Stonehaven during construction	Public, property	N1/N3/C1/NH/IH1/IH2/SH - Development of a design which does not include demolition of the existing structures, rather to cut down to the required level for the construction of the new structure where applicable although during construction the standard of protection will be compromised in these locations. N2/N4/CW/C2 – Development of a design which does not include the demolition of the existing structures as such that the coastline will not be less protected than at present throughout construction.	N1/N3/C1/NH/IH1/IH2/SH - Cannot eliminate – risk reduced N2/N4/CW/C2 – Eliminated	Drawings, pre-construction information	Client, designer(s) at detailed design, contractor(s)	Maintain the current design philosophy as to not demolish the existing structures where viable, otherwise consideration of phased construction, sequencing of works and temporary defences to reduce the risk in areas which will result in reduce protection during construction.
CON2	Construction in a public realm – deliveries to site	Disturbances to traffic flow, damage to property, noise and dust	Public, property, operatives	Development of a design where volumes of materials have been minimised so far as reasonably practical while achieving project aims	Cannot eliminate – risk reduced	Pre-construction information, EIA	Designer(s) at detailed design, contractor(s)	Delivery strategy and Traffic Management Plan to be developed detailing temporary diversions if appropriate and liaison with local resident groups to limit disturbance
CON3	Construction in a public realm – movement of site traffic on public rights of way	Disturbance to traffic flow and pedestrians/cyclists on the adjacent pavements/promenade	Public	N/A - Traffic Impact Assessment to be undertaken with recommendations carried forward into a Traffic Management Plan	Cannot eliminate – risk reduced	Pre-construction information, EIA	Designer(s) at detailed design, contractor(s)	Traffic Management Plan to be developed detailing temporary diversions if appropriate, and liaison with local resident groups to limit disturbance and public to be consulted early on in the programme to likely disturbances and public area closures
CON4	Construction in a public realm – public access to site	Disturbance to normal public use of pavements, the promenade and beach and public struck by plant	Public	Development of a design which allows works to be suitable for phased construction so that disturbances to the public realm can be limited to isolated areas	Cannot eliminate – risk isolated	Pre-construction information	Designer(s) at detailed design, contractor(s)	Site compound and working areas to be set up to adequately separate public from construction and public to be consulted early on in the programme to inform of likely disturbances and closures

Health and Safety Considerations

Stage 1 **Identify**				Stage 2 **Eliminate / Reduce**	Stage 3 **Inform**		Stage 4 **Control**	
Ref. no.	Project element, material or activity	Key health and safety hazards and their possible effects	People at risk from the hazard	Design measures taken to eliminate the hazard or reduce the risk	Significant residual hazards and risks	Communication method	Risk owner(s)	Proposed control measures
CON5	Construction in a public realm – public access to site adjacent to private property	Disturbance to inhabitants and property owners, and struck by plant	Public	Development of a design which allows works to be suitable for phased construction so that disturbances to the private property can be limited to isolated areas	Cannot eliminate – risk isolated	Pre-construction information	Designer(s) at detailed design, contractor(s)	Site compound and working areas to be set up to adequately separate public from construction and liaison with local resident groups to limit disturbance
CON6	Construction in a public realm – public access and egress points between the promenade and beach closed for construction	Public stranded on the beach during a rising tide	Public	N/A - Works to be planned to limit the impact on existing access and egress routes, where practicable these routes should be maintained otherwise signage will be provided to direct the public to alternative routes to the promenade from the beach	Cannot eliminate – risk reduced	Pre-construction information	Designer(s) at detailed design, contractor(s)	Traffic Management Plan to be developed detailing access and egress routes during construction and public to be consulted early on in the programme to likely disturbances and promenade closures
CON7	Construction in a public realm – mud and sand on road	Hazards to other road users	Public	Development of a design where excavation, demolition and removal of material has been minimised so far as reasonably practical	Cannot eliminate – risk reduced	Pre-construction information	Designer(s) at detailed design, contractor(s)	Impermeable surfaces to be reinstated as soon as possible to avoid churning up open ground and wheel washers at every exit of the site compound and sweepers
CON8	Construction in a public realm – movement of site traffic on the beach	Plant becoming stuck or tip over in soft beach material resulting in inundation and potential injury and loss of plant	Plant	N/A – plant access on the beach will be required.	Cannot eliminate	Pre-construction information	Designer(s) at detailed design, contractor(s)	Contractor to use appropriate vehicle routes and adaptations including trackpads and consider associated temporary works required
CON9	General construction-based risks – stability of existing structures	Destabilisation and/or collapse of existing structures due to increased loading on the structures and excavation at the toe	Public, property, operatives, plant	Development of designs which can be constructed from the beach as to reduce plant and subsequent loading onto the existing structures and where minimal (and in some options no) excavation is required at the toe has been designed.	Cannot eliminate – risk reduced	Pre-construction information	Designer(s) at detailed design, contractor(s)	Geotechnical and structural investigations to be undertaken on existing structures prior to construction to determine safe loading threshold and associated temporary works required

Health and Safety Considerations

Stage 1 **Identify**				Stage 2 **Eliminate / Reduce**	Stage 3 **Inform**		Stage 4 **Control**	
Ref. no.	Project element, material or activity	Key health and safety hazards and their possible effects	People at risk from the hazard	Design measures taken to eliminate the hazard or reduce the risk	Significant residual hazards and risks	Communication method	Risk owner(s)	Proposed control measures
CON10	General construction-based risks – manual handling of materials	Injury to personnel	Operatives	N/A – Development of the detailed design as such that all elements of works to be designed such that they can be installed with mechanical means, with elements which are to be manually lifted designed to a safe weight, for example the proposed masonry cladding to be less than the 25kg maximum lifting threshold	Cannot eliminate – risk reduced	Pre-construction information	Designer(s) at detailed design, contractor(s)	Training, including Toolbox Talks, to increase competency of operatives and suitable access routes to construction areas allowing delivery directly to working areas with lifting and handling equipment
CON11	General construction-based risks – adverse weather conditions, poor visibility (including low light), night working and soft beach	Injury to personnel with being hit by plant, personnel at risk of cold or heat exposure and increased risk of slips, trips and falls	Operatives	N/A	Cannot eliminate	Pre-construction information	Contractor(s)	Consideration of summer working, appropriate lighting and task lighting to be installed if working during low light conditions, and all personnel to wear appropriate PPE to the weather conditions
CON12	General construction-based risks – fuel or hydraulic oil spillage	Fire hazards	Public, operatives, plant	N/A	Cannot eliminate	Pre-construction information	Contractor(s)	Fuel and hydraulic oil storage remote from the water edge at pre-designated site compound, with storage areas to be bunded and containers location on drip trays, provision of spill kits, and regular maintenance of plant
CON13	General construction-based risks – dust, noise and vibration	Health implications to public and operatives as a result of dust particulates and shards, noise and vibration	Public, operatives	Development of a design where volumes of materials have been minimised so far as reasonably practical while achieving project aims	Cannot eliminate – risk reduced	Pre-construction information, EIA	Designer(s) at detailed design, contractor(s)	Dust suppression, use of clean aggregates, Safe System of Work to be developed and liaison with local resident groups to limit disturbance
CON14	General construction-based risks – stockpiling of materials	Health implications to public and operatives as a result of dust particulates and shards, noise and vibration	Public, operatives	Development of a design where volumes of materials have been minimised so far as reasonably practical while achieving project aims	Cannot eliminate – risk reduced	Pre-construction information, EIA	Designer(s) at detailed design, contractor(s)	Safe System of Work to be developed and liaison with local resident groups to limit disturbance

Health and Safety Considerations

Stage 1 Identify				Stage 2 Eliminate / Reduce	Stage 3 Inform		Stage 4 Control	
Ref. no.	Project element, material or activity	Key health and safety hazards and their possible effects	People at risk from the hazard	Design measures taken to eliminate the hazard or reduce the risk	Significant residual hazards and risks	Communication method	Risk owner(s)	Proposed control measures
CON15	General construction-based risks – UXO	Striking unexploded ordnance whether through excavation or sheet piles	Operatives, plant	N/A	Cannot eliminate	Pre-construction information	Contractor(s)	Undertake a UXO search prior to construction and follow the recommended procedures outlined within during construction
CON16	General construction-based risks – Utilities/services	Striking unknown services whether through excavation or sheet piles	Operatives, plant	Development of a design following a detailed utilities and services search. Further consideration of service spans required at detailed design	Cannot eliminate – risk reduced	Drawings, pre-construction information	Designer(s) at detailed design	Updated utilities and services search to be carried out prior to construction, with service detection and avoidance methods to be utilised during construction
CON17	Working near water – working in an exposed coastal environment	Flood of works, inundation of excavations, drowning and loss of plant	Operatives, plant	Development of design where excavation depths and widths have been minimised so far as reasonably practical while achieving project aims and which allows works to be suitable for phased construction around the tidal cycle. Development of the detailed design as such that any geotechnical variability will be assessed and localised alternative designs for where the target depths cannot be achieved due to excavation collapse and water ingress	Cannot eliminate – risk reduced	Pre-construction information	Designer(s) at detailed design, contractor(s)	Training, including Toolbox Talks, to increase competency of operatives working in tidal environments, consideration of limited open excavations, material placement schedules to ensure materials at risk are protected at the earliest opportunity
CON18	Working near water – biological hazards	Leptospirosis, Psittacosis and other bacterial diseases	Operatives	N/A	Cannot eliminate	Pre-construction information	Contractor(s)	Training, including Toolbox Talks, to increase operative awareness and knowledge to avoid contact and adopt good hygiene practices
CON19	Excavation works – excavation of beach material Not applicable to N2, N4, CW and IH1	Collapse of excavation sides as a result of high ground water and low friction angle leading to injury to personal and loss of plant	Operatives, plant	Development of design where excavation depths and widths have been minimised so far as reasonably practical while achieving project aims.	Cannot eliminate – risk reduced	Pre-construction information	Designer(s) at detailed design, contractor(s)	Geotechnical investigations to be undertaken to confirm beach parameters and analysis of capacity for temporary works required
CON20	Demolition of existing structures – removal of existing concrete elements Not applicable to N2, N4, CW and C2	Injury to personnel due to falling debris	Public, operatives	Development of a design where the existing structure is not demolished rather cut down to the required level for the construction, as to reduce the volume of potential debris	Eliminated NH/SH - Cannot eliminate – risk reduced	Drawings, pre-construction information	Designer(s) at detailed design, contractor(s)	Consideration of phased construction and use of working areas to provide safe distance between operatives and anticipated direction of falling debris

Health and Safety Considerations

Stage 1 **Identify**				Stage 2 **Eliminate / Reduce**	Stage 3 **Inform**		Stage 4 **Control**	
Ref. no.	Project element, material or activity	Key health and safety hazards and their possible effects	People at risk from the hazard	Design measures taken to eliminate the hazard or reduce the risk	Significant residual hazards and risks	Communication method	Risk owner(s)	Proposed control measures
CON21	Demolition of existing structures – removal of existing concrete elements Not applicable to N2, N4, CW and C2	Hand arm vibration syndrome and associated injuries to personnel	Operatives	Development of a design where the existing structure is not demolished rather cut down to the required level for the construction, as to reduce the volume of concrete elements to be demolished	Eliminated NH/SH - Cannot eliminate – risk reduced	Drawings, pre-construction information	Designer(s) at detailed design, contractor(s)	Consideration of alternative methods or techniques as appropriate, limiting daily exposure for operatives, and training, including Toolbox Talks, to increase operative awareness
CON22	Sheet pile works – driving sheet piles into the bedrock Only applicable to N1, CW, C1, IH1 and IH2	Early refusal of sheet piles	Operatives, plant	Development of a design which incorporates sheet piles based upon historic as-built drawings show piles to have been previously used with no issues. CW – Development of a design which incorporations a wailing beam and potential for an arrangement of ground anchors	Cannot eliminate	Drawings, pre-construction information	Contractor(s)	N/A
CON23	Concrete works – lifting and placing of precast wall units	Injuries to personnel and damage to plant during lifting operations	Operatives, plant	Development of a design which minimises the weight of the units due to minimising the depth of the wall base units and additional dimensions. Further consideration of the precast wall units is required at detailed design	Cannot eliminate – risk reduced	Drawings, pre-construction information	Designer(s) at detailed design, contractor(s)	Training, including Toolbox Talks, to increase competency of operatives and suitable access routes to construction areas allowing delivery directly to working areas with lifting equipment
CON24	Concrete works – personnel safety	Falls from height whilst working on the construction of the sea wall	Operatives	Development of a design which maximises the potential use for precast concrete as to reduce the time working at height Further consideration of pre-cast and in-situ concrete elements required at detailed design	Cannot eliminate – risk reduced	Drawings, pre-construction information	Designer(s) at detailed design, contractor(s)	Safe System of Work to be developed and consideration of phased construction and to reduce the spatial extent of the risk
CON25	Concrete works – wet concrete	Burns to personnel due to contact with wet concrete	Operatives	Development of a design where the use of in-situ concrete has been reduced due to much of the design being able to be precast concrete. N2 - Further consideration of concrete repairs required at detailed design	Cannot eliminate – risk reduced	Drawings, pre-construction information	Designer(s) at detailed design, contractor(s)	Safe System of Work to be developed, training, including Toolbox Talks, to increase competency of operatives, and all personnel to wear appropriate PPE

Design Risk Assessment – Stonehaven Options

Health and Safety Considerations

Stage 1 **Identify**				Stage 2 **Eliminate / Reduce**	Stage 3 **Inform**		Stage 4 **Control**	
Ref. no.	Project element, material or activity	Key health and safety hazards and their possible effects	People at risk from the hazard	Design measures taken to eliminate the hazard or reduce the risk	Significant residual hazards and risks	Communication method	Risk owner(s)	Proposed control measures
CON26	Geotextile works – placement of geotextile Only applicable to N3, NH and SH	Injury to personnel in deep excavations or struck by lifting equipment	Operatives	Development of a design where excavations have been minimised so far as reasonably practical while achieving project aims. Buildability to be further considered at detailed design as to specify a geotextile to be delivered on rolls that can be placed by mechanical means	Cannot eliminate – risk reduced	Drawings, pre-construction information	Designer(s) at detailed design, contractor(s)	Training, including Toolbox Talks, to increase competency of operatives
CON27	Rock armour revetment works – placement of rock Only applicable to N3, NH and SH	Health implications to operatives as a result of dust particulates and shards, noise and vibration	Operatives	Development of a design where rock armour is specified to be 'picked and placed'	Cannot eliminate – risk reduced	Pre-construction information	Designer(s) at detailed design, contractor(s)	Rocks to be mechanically picked and placed opposed to dropped at any height, with works to be undertaken within specified planning limits and noise monitoring to be undertaken throughout construction
CON28	Rock armour revetment works – placement of rock Only applicable to N3, NH and SH	Injury to personnel due to unstable excavations and working at height during levelling operations	Operatives	N/A – Buildability to be further considered at detailed design as to incorporate mechanical placement of rock for placement and levelling operations to reduce the need for any personal undertaking levelling	Cannot eliminate – risk reduced	Pre-construction information	Designer(s) at detailed design, contractor(s)	Rocks to be mechanically placed and all levelling operations to be undertaken with plant-based equipment
CON29	Embankment works – placement of reinforcement matting Only applicable to CW	Injury to personnel or struck by lifting equipment	Operatives	N/A - Buildability to be further considered at detailed design as to specify a coir matting that can be placed by mechanical means	Cannot eliminate – risk reduced	Pre-construction information	Designer(s) at detailed design, contractor(s)	Consideration to construction methodology and training, including Toolbox Talks, to increase competency of operatives
Operation & Maintenance								
O&M1	Standing water on the adjacent pavements/promenade and transport infrastructure	Slips and falls on surfaces with surface water	Public	Development of a design to include a 1 in 40 crossfall gradient seawards	Cannot eliminate – risk reduced	N/A	Client	Further consideration of drainage will be required at detailed design to determine whether additional drainage is required and consider additional drainage measures if standing water landward of the defence or on the promenade becomes a recurring issue

Health and Safety Considerations

Stage 1 **Identify**				Stage 2 **Eliminate** / **Reduce**	Stage 3 **Inform**		Stage 4 **Control**	
Ref. no.	Project element, material or activity	Key health and safety hazards and their possible effects	People at risk from the hazard	Design measures taken to eliminate the hazard or reduce the risk	Significant residual hazards and risks	Communication method	Risk owner(s)	Proposed control measures
O&M2	Use of adjacent pavements/promenade and transport infrastructure during storm event when overtopping exceeds 1l/s/m	Injury to public and damage to property	Public, property	Development of a design where the new structures reduces the overtopping to less than 1l/s/m	Cannot eliminate – risk reduced	N/A	Client	Use of flood gates and associated structures at access points, signage to raise awareness of hazards to the public and client to close adjacent pavements/promenade in events exceeding 1l/s/m
O&M3	General public safety	Slips, trips and falls (including falls from height) and risk of drowning due to cut-off from a rising tide	Public	Development of a design where new crown walls have a minimum height of 1.1m to prevent falls and access points between the promenade and beach are to be maintained	Cannot eliminate – risk reduced	H&S file	Client, designer(s) at detailed design, contractor(s)	Further consideration of safety measures including installation of lifebuoy rings, handrails and periodic signage to raise awareness of hazards to the public will be required at detailed design
O&M4	Movement of the public around the rock armour where exposed Only applicable to N1, N3, NH and SH	Slips, trips, falls and entrapment	Public	Development of a design where new crown walls have a minimum height of 1.1m to prevent falls and have an angular geometry to deter climbing onto the walls. However, no design measures have been undertaken to eliminate or reduce the risk from the beach.	Cannot eliminate – risk reduced	H&S file	Client	Consider signage, and monitor the placement of rock
O&M5	Replacement of displaced rock armour Only applicable to N1, N3, NH and SH	Injury to personnel due to picking, lifting and replacement of rock	Operatives	Development of a design where the rock armour has been designed to be stable in all but the most severe conditions	Cannot eliminate – risk reduced	H&S file	Client, contractor(s)	Safe System of Work to be developed for maintenance work to the rock armour
O&M6	Reduction of access between the adjacent pavement/promenade and the beach	Loss of access to and from the beach increasing the risk of cut-off during the tide coming in, slips, trips, falls and entrapment	Public	Development of a design to maintain access points between the promenade and beach	Cannot eliminate – risk reduced	H&S file	Client, designer(s) at detailed design, contractor(s)	Consider handrails and signage to raise awareness of hazards to the public, and maintain the condition and usability of public access
O&M7	In-situ concrete repairs	Burns to personnel due to contact with wet concrete	Operatives	N/A – further consideration of maintenance and concrete repairs required at detailed design	Cannot eliminate – risk reduced	H&S file	Client, contractor(s)	Safe System of Work to be developed, training, including Toolbox Talks, to increase competency of operatives, and all personnel to wear appropriate PPE

www.jbagroup.co.uk
www.jbaconsulting.com
www.jbaconsulting.ie
www.jbarisk.com

Health and Safety Considerations

Stage 1 **Identify**				Stage 2 **Eliminate / Reduce**	Stage 3 **Inform**		Stage 4 **Control**	
Ref. no.	Project element, material or activity	Key health and safety hazards and their possible effects	People at risk from the hazard	Design measures taken to eliminate the hazard or reduce the risk	Significant residual hazards and risks	Communication method	Risk owner(s)	Proposed control measures
O&M8	Inspection and repairs of new concrete structures	Slips, trips, fall and entrapment when inspecting section of existing structures location behind the rock armour revetment	Operatives	N/A	Cannot eliminate	H&S file	Client	Risk assessments, including Safe Systems of Work where appropriate, and appropriate surveying methods should be adopted to undertaken inspection and repairs
Demolition								
DEM1	Demolition of structures	Difficulty of demolition causing health and safety issues	Operatives	All designed elements are easily removable with standard construction techniques	Cannot eliminate – risk reduced	H&S file	Client	TBC

www.jbagroup.co.uk
www.jbaconsulting.com
www.jbaconsulting.ie
www.jbarisk.com

Design Risk Assessment – Stonehaven Options

Environmental Considerations

Stage 1 **Identify**				Stage 2 **Eliminate / Reduce**	Stage 3 **Inform**		Stage 4 **Control**	
Ref. no.	Project element, material or activity	Key environmental hazards and their possible effects	Who or what is at risk from the hazard	Design measures taken to eliminate the hazard or reduce the risk	Significant residual hazards and risks	Communication method	Risk owner(s)	Proposed control measures
Guidance	Consider all aspects involved in each stage of interface with the site, environment and structure(s).	Record the key hazards and their potential consequences.	Identify the categories of people, animals or environments at risk.	Include obtaining adequate data for design certainty and any further studies carried out during the risk evaluation process. Proposed measures to be taken by constructors and operators are to be included in Stage 4.	Provide details of residual hazards and risks that will need to be communicated and managed.	Record how information is provided, whether on drawings, pre-construction information, buildability statement, specification, reports or H&S File	Record the name of designers, contractors, the client or other stakeholders who are to ensure the significant residual risk is minimised and controlled.	Recommend measures to be taken by the risk owner(s) to minimise and control the significant residual risk.
Environment – Construction								
ENV1	General construction based risks – permanent and temporary works Not applicable to N2	Detrimentally affecting the existing foreshore marine habitat	Environment	N/A	Cannot eliminate	Pre-construction information, EIA	Client, designer(s) at detailed design, contractor(s)	Environmental Impact Assessment to be developed to include mitigation and enhancement opportunities
ENV2	General construction-based risks – permanent works	Adverse impact to the environment during and post-works	Environment	N/A – further consideration at detailed design, especially if an Environmental Impact Assessment is required with the outcome of the Screening Opinion prior to detailed design to establish impact, mitigation and enhancement where possible	Cannot eliminate – risk reduced	Pre-construction information, EIA	Client, designer(s) at detailed design	Environmental Impact Assessment to be developed to include mitigation and enhancement opportunities
ENV3	General construction-based risks – fuel or hydraulic oil spillage	Fire hazards, damage to flora and fauna and pollution to the sea	Environment	N/A	Cannot eliminate – risk reduced	Pre-construction information	Contractor(s)	Fuel and hydraulic oil storage remote from the water edge at pre-designated site compound, with storage areas to be bunded and containers located on drip trays, provision of spill kits, regular maintenance of plant and consideration of biodegradable oils
ENV4	General construction-based risks – dust, noise and vibration	Adverse impact to the environment during works and maintenance	Environment	Development of a design where volumes of materials have been minimised so far as reasonably practical while achieving project aims Further consideration at detailed design, especially if an Environmental Impact Assessment is required with the outcome of the Screening Opinion prior to detailed design to establish impact, mitigation and enhancement where possible	Cannot eliminate – risk reduced	Pre-construction information, EIA	Designer(s) at detailed design, contractor(s)	Construction methodology to comply with requirements of EIA, dust suppression, use of clean aggregates, Safe System of Work to be developed and liaison with local resident groups to limit disturbance

Environmental Considerations

Stage 1 **Identify**				Stage 2 **Eliminate / Reduce**	Stage 3 **Inform**		Stage 4 **Control**	
Ref. no.	Project element, material or activity	Key environmental hazards and their possible effects	Who or what is at risk from the hazard	Design measures taken to eliminate the hazard or reduce the risk	Significant residual hazards and risks	Communication method	Risk owner(s)	Proposed control measures
ENV5	General construction-based risks – contaminants brought onto site via imported material	Contaminants and invasive non-native species brought on site resulting in a change in localised biodiversity	Environment	Development of a design where volumes of materials have been minimised so far as reasonably practical while achieving project aims	Cannot eliminate – risk reduced	Pre-construction information	Contractor(s)	All imported material to be sourced from clean, certified sources
ENV6	Excavation works – excavation of beach material Not applicable to N2, N4, CW and IH1	Uncovering and exposing contaminated material	Environment	Development of design where excavation depths and widths have been minimised so far as reasonably practical while achieving project aims as well as undertaking a Geotechnical and Geoenvironmental Desk Study which concluded that there are no significant contamination issues at the site	Cannot eliminate – risk reduced	Pre-construction information	Designer(s) at detailed design, contractor(s)	Geotechnical Design Report, including intrusive ground investigations, to be developed to detailing any contamination issues uncovered
ENV7	Concrete works – wet concrete	Spillage or surplus concrete resulting in damage to flora and fauna and pollution to the sea	Environment	Further consideration of concrete repairs required at detailed design.	Cannot eliminate – risk reduced	Pre-construction information	Designer(s) at detailed design, contractor(s)	Safe System of Work to be developed, training, including Toolbox Talks, to increase competency of operatives, and all personnel to wear appropriate PPE
Environment - Operation & Maintenance								
ENV8	In-situ concrete repairs	Spillage or surplus concrete resulting in damage to flora and fauna and pollution to the sea	Environment	N/A – further consideration of maintenance and concrete repairs required at detailed design, and developing concrete specification to ensure sufficient curing prior to tidal inundation	Cannot eliminate – risk reduced	H&S file	Client, contractor(s)	Safe System of Work to be developed, training, including Toolbox Talks, to increase competency of operatives, and all personnel to wear appropriate PPE
Demolition								
ENV9	Demolition of structures	Hazardous materials used in permanent works causing pollution to the sea during demolition	Environment	N/A – further consideration at detailed design to ensure all materials used are considered INERT and safe for demolition and removal	Eliminated	H&S file	Client, designer(s) at detailed design, contractor(s)	Consideration of INERT construction materials which are safe for demolition

N Short-list public consultation feedback

STONEHAVEN FLOOD ACTION

Document Verification & Submission Procedure

This feedback has been prepared and written by the Stonehaven Flood Action Group (SFAG).

It has been prepared with reference to the Public Engagement Session which was held on 13th June 2019. In addition, we refer to the documents "Economic Appraisal Results", dated 29th May 2019 and the feedback which SFAG provided on 13th Feb 2019 to the public engagement session which was held on Jan 29th, 2019. All of which are part of the STONEHAVEN BAY COASTAL FLOOD PROTECTION STUDY –

Date of Response: - 24th June 2019

In addition, to this being submitted by the Stonehaven Flood Action Group, these views are shared and have been agreed by the following.

Name: -	[redacted] on behalf of Stonehaven Flood Action Group
Postal Address: - **(Inc. post code)**	[redacted] Stonehaven AB39 2HR
Contact email: -	[redacted]
Date: -	Monday 24th June 2019

Additional Comments

This is the response of Stonehaven Flood Action Group to the Consultation on Thursday 13th June 2019.

I hope that you find it helpful.

The Flood Action Group continues to be committed to working with the Coastal Flood Protection Team to achieve the most appropriate solutions to go forward to the next stage.

Stonehaven Flood Actions Group's Response to Consultation.

Executive Summary

In response to Aberdeenshire Council's (AC), request for feedback on options to reduce the risk of Coastal flooding along the Stonehaven Coastal Area, the Stonehaven Flood Action Group (SFAG), have prepared this document. It is based largely on the material shown during the "Reduction of Coastal Flood Risk Within Stonehaven Bay" Engagement poster session held between 2pm and 8pm on 13th June 2019.

This document starts by providing feedback on all 6 (or in fact 7) questions which were asked on 13th June by AC.

The main conclusion from the SFAG's feedback is that there is considerable opposition among residents to raising the height of the existing seawalls and promenade path.

The main recommendation of this feedback is that the ability of existing hard coastal defences needs to be examined and quantified together with options for beach recharge, rock armour and groynes. i.e. scenarios with no increases in the height of the seawall and promenade path.

e.g. The SFAG scenarios A-E that were provided following the earlier public engagement session in Feb 2019. Summary details are given in subsequent sections.

Further conclusions and recommendations are presented in Section 2 of this document.

Introduction

May we begin by expressing our appreciation of the opportunity to consider and comment on the short-listed options prepared by JBA Consulting and Aberdeenshire Council. These options were first shown at a public meeting on 13th June 2019. They were provided to SFAG on 13th June in email format. A set of amended posters were finally published and made available for download via the AC website on 20th June 2019. At this engagement session a request was made by Aberdeenshire Council to the attendees to provide feedback via a set of Q&A sheets.

The approach taken by the SFAG, is and always has been, one of inclusion, with involvement of residents, businesses and other stakeholders. After allowing the coastline people some time to read and consider, meetings were held on 17th June and 18th June 2019. A further meeting was held on 22nd June. In each we met as a group and collectively discussed and finalised our response.

SFAG will endeavour to continue working with Aberdeenshire Council and its consultants in a positive way.

Lastly, we welcome a flood protection study as representing progress.

Section 1: - Answers to Aberdeenshire Council's Questions

Q1: Do you have any comments on the short-term options proposed?

The options include: -

Q1.1: Property level resistance and resilience

SFAG have long supported the introduction of property level flood defence by the residents.

Q1.2: Sediment Management

The historic sediment management that was undertaken on Stonehaven beach involved material (shingle) being removed from the area around the estuary of the river Cowie. This material was subsequently transported to a part of the beach south of the river Carron. It should be remembered that the prevailing natural movement of shingle along Stonehaven beach is from north to south. Hence mechanical removal of shingle from the Cowie's estuary effectively over time reduced the volume of shingle which is in the area immediately south of the Cowie estuary. It has been shown in previous studies, that a reduction in shingle levels contributes to an increased risk of overtopping in that area. Over the last few years sediment management has not been done by Aberdeenshire Council. Residents have observed increased volumes of shingle in the area. SFAG does not support the restarting of the historic sediment management process. SFAG would welcome a more engineered approach to both maintaining and increasing the volume of shingle that is present in the area immediately south of the Cowie estuary. As an example, SFAG Option A from the prior engagement session should be investigated. (i.e. An additional training wall on the south bank of the river Cowie positioned parallel to the existing training wall on the north bank.)

Q1.3: Beach Monitoring

SFAG welcome the proposal for improved beach monitoring. The three previous studies provided useful data. However, the frequency of study could be improved; as to a more continual monitoring approach; this may be perhaps a step to far. In order to provide consructive feedback, it is something that we would welcome receiving more information about.

Q1.4: Promotion of SEPA's Flood Warning Service

SFAG feel the introduction of the SEPA warning system is a major benefit to residents. We welcome the promotion of this service.

Q1.5: Repair and Maintenance of Existing Defences.

SFAG are in favour of the continued repair and maintenance of the existing defences that are along the coastline.

Q2: Do You have any comments on the medium-term option of raising the existing defences to protect Cowie promenade and Cowie Village.

Raising the seawalls has a considerable detrimental effect to the amenities of the properties that are located behind them. A number of those residents already have resilience measures and are familiar with the area in which they live. While flooding can be quantified in terms of risk related probability terms like Standard of Protection, (SoP), the effect of heightened walls is total and irreversible to the both values of those properties and the loss of amenity to the residents.

SFAG request that the engineering analysis together with the cost analysis for the previous options that were suggested in Feb 2019 are provided and refer to SFAG option C. Offshore Rock Armour. i.e. As was applied in the north section of Aberdeen beach.

Q3: Do you have an order of preference for the long-term option for Cowie promenade and Cowie Village.

3 A New Sea wall

3 B Sea Wall with rock armour

3 C Beach Recharge.

SFAG's preferred solution is based around using the SFAG option C. In each of the three options AC has asked for feedback on, we notice that the sea walls are higher than present. This, from a resident's viewpoint, creates the most problems and we feel it should be avoided.

SFAG believe there is a need to establish the limitations of the existing hard coastal defences when beach recharge and rock armour defences are added. i.e. no sea wall height changes. It is plausible that this scenario will not provide a 200 year with climate change SoP level. – if, so what would it provide?

Note: - Q4A is the original question which feedback was requested for during the 13th of June. At a point during the day this question was replaced by Q4B.

Q4A: For the central area, it is proposed that the beach is enlarged, and control structures are installed to keep the material in place. The beach would be adapted over time to account for climate change. Please provide any comments on this below:

Following the specific wording of this question, SFAG are totally in favour of beach recharge and control structures (i.e. groynes). This we feel appears to be like SFAG options B and E. However, it should also be noted that this answer is based totally on maintaining the existing height levels for the seawall and promenade path.

It should also be noted that SFAG previously suggested extending the existing sea wall from Market Lane to the Carron Estuary. i.e. SFAG option D. For clarity the height of that extension we suggested was to be held at the same height as the existing seawall.

Q4B: For the central area, it is proposed that the wall is raised, and the beach is enlarged with control structures installed to keep the material in place. The beach would be adapted over time to account for climate change. Please provide any comments on this below:

By comparison with the drawings shown on 13th June, the proposal is for a 1 metre concrete height addition to the existing sea wall and while not mentioned in the question the level of the promenade path would also be raised by 1 metre. This would have an unacceptable impact on the properties and residents living along the sea front.

Prior to 13th June AC shared with SFAG the Economic Appraisal Results, for each of the three sections of the bay and the variety of options which were shortlisted. Unlike the North and Harbour areas, the information presented for the Central area varies between what is given in the results and what was presented in the poster session on 13th June. As examples, in the analysis option 5 (Recharge in medium term) clearly states uses the "current defences". By contrast option 5 in the posters while also titled recharge in the medium term, states the existing sea wall and promenade will be raised. The rest of the data for that specific row in the table is comparable to that shown in the Economic Appraisal Results.

If nothing else there is an inconsistency. Moreover from the addition of the work along the banks of the river Cowie, options 4 and 5 that were presented on 13th June appear to be the same. It is felt the differences between these options require a clearer explanation. It is further compounded by the fact that several members of the SFAG who read the Economic Appraisal Results all understood option 4 as using the existing seawall and promenade height levels.

SFAG would like to know what the capability of the existing seawall together with recharge, groynes and rock armour is.

Q5: In the long term, the walls along the banks of the Cowie Water will need to be raised to account for climate change. Please provide any comments on this below:

This question seems somewhat to be at odds with the data presented in Nov 2018 and included within the Interim Modelling Report published during Jan 2019. In those the flooding seen along the banks of river Cowie all directly occurred due to overtopping at the coast. i.e. not from the banks of the river. In addition, the flooding of the properties along the river's banks which occurred in Dec 2012 was due to overtopping at the seawalls.

However, we do understand that the unprotected steel piling along those banks of the river Cowie will deteriorate through time and in future there could be a need to reconstruct the section with, for example, the approach shown in the posters. Not that the capacity along that specific stretch of the Cowie river has been an issue, it follows that by narrowing the channel the wall heights have to be increased to maintain the existing capacity.

Q6: In the harbour, the options presented included property flood resistance and resilience measures, a new rock armour revetment to the north of the harbour, a new sloped revetment in the inner harbour and managed realignment to the south of the harbour. Please provide any comments on these options below: -

The variety of and locations for these different options in the harbour area makes overall comments hard to make. It is further compounded by the information presented in the posters. e.g. within the Harbour Benefit Zone, Option 7 states "construct new sea wall and raise promenade at Cowie Village and Cowie Promenade". We note that this has been amended in the posters which are presently available as an enormous 170MB file download from the AC website.

Overall it seems the only medium-term option that is short listed is property level resilience. We note this is a responsibility of the individual property owners.

<u>Section 2: SFAG Recommendations for Aberdeenshire Council.</u>

In this section of the feedback a total of six recommendation have been made.

1: - Central and North Sections - Establish and present the capability of the existing hard concrete defences with the addition of full beach recharge, groynes, rock armour. This would involve no raises to the height of the seawall and no changes to existing height of the promenade path. e.g. SFAG options A E

2: - Promenade path level. While the AC proposal to an extent allows for people to walk along the frontage and view the beach it totally ignores the consequential effects to the surrounding properties due to the raised path. The current drawings show tapering between this raised path and the existing ground level. Due to the proximity of some buildings to the path this tapering will be impossible to achieve. In addition, from a property owner's perspective there are requirements to maintain visible and practical boundaries between public land and private land. Property owners are responsible in law, for the resilience of their own property. In addition, some property owners have designed and built their boundary walls to aid in resilience. Hence by raising the path, the property owner's own boundaries and resilience measures will also have to be raised. One of the consequences is that the overall effect reduces the ability of light to enter property owner's windows. Hence SFAG would encourage AC to fully investigate alternatives to raising the heights of the seawall and path levels. For example, the items specified in the first recommendation and the use of clear/transparent barriers which could be added to the top of the existing seawall.

3: - The psychological effects. The psychological effects to residents due to wall and promenade level changes need to be factored into the decision-making process. While flooding itself can cause psychological effects to residents living next to the coast, these same psychological effects would also be caused by building a raised concrete seawall and raised promenade path right next to existing buildings. Building a wall results in a permanent structure, where as the probability of flooding occurring isn't as definite.

4: - Communication and ease of understanding. The structure of the presentation where the posters were completely full of graphics, tabularised data and text resulted in complexity. There was a considerable amount of information being conveyed on a few posters. While that approach is fine for an engineering audience, it isn't very suitable for a presentation to the general public. In places the actual drawings were small and hard to see.

The use of visuals could be improved to simplify level of technical content which is presented on each individual poster. In addition, while the public engagement session was advertised in the press ahead of the event, none of the content or agenda were included in those advertisements, and coastal residents who would be affected were not directly informed.

5: - Future technological improvements in construction methods. In many of the options, it is noted that there were portions included that were stipulated for future implementation. e.g. replacement embankment walls along banks of the Cowie River. It is thus conceivable that in future there will be alternatives to what are solid concrete walls, perhaps including specialised glazing solutions. Hence, SFAG emphasise that focus should be on using the present coastal defences and implementing the recommendations given above. Separately, but along with various other types of flood protection products, SFAG are monitoring the development, introduction and use of specialised glazing solutions as permanent coastal flood defences. SFAG would request that AC consider gathering information to assess the viability of a sea glass wall. SFAG believes that considerable data on this type of solution is readily available, but presently experimentation and approved testing procedures would be required to justify its use or not.

6: - Establish what is the practical level of SoP to base a scheme on, i.e. without affecting the scenic character or the existing beach front. e.g. Why does it have to be 1 in 200 with climate change?

END OF DOCUMENT

NOTE TO FILE

JBA Project Code	2018s0343
Contract	Stonehaven Bay Coastal Flood Protection Study
Client	Aberdeenshire Council
Day, Date and Time	4 July 2019
Author	Nicci Buckley
Subject	Public Consultation Feedback – June 2019

1 Introduction

This document collates the comments received during and following the public consultation event held at Stonehaven Town Hall on 13 June 2019.

A number of individual responses were received as well as a formal response from Stonehaven Flood Action Group (SFAG).

2 Questionnaire feedback

Reponses to the questionnaire that was available during the public consultation event are collated below. This includes the formal responses received from SFAG.

2.1 Do you have any comments on the short term options proposed?

- In general, these proposals make good sense for mitigation of sea flooding damage. I think complete and absolute protection is not obtainable because the predictions of extreme high spring tides cannot be 100% reliable.
- SFAG have long supported the introduction of property level flood defence by the residents.
- The historic sediment management that was undertaken on Stonehaven beach involved material (shingle) being removed from the area around the estuary of the river Cowie. This material was subsequently transported to a part of the beach south of the river Carron. It should be remembered that the prevailing natural movement of shingle along Stonehaven beach is from north to south. Hence mechanical removal of shingle from the Cowie's estuary effectively over time reduced the volume of shingle which is in the area immediately south of the Cowie estuary. It has been shown in previous studies, that a reduction in shingle levels contributes to an increased risk of overtopping in that area. Over the last few years sediment management has not been done by Aberdeenshire Council. Residents have observed increased volumes of shingle in the area. SFAG does not support the restarting of the historic sediment management process. SFAG would welcome a more engineered approach to both maintaining and increasing the volume of shingle that is present in the area immediately south of the Cowie estuary. As an example, SFAG Option A from the prior engagement session should be investigated. (i.e. An additional training wall on the south bank of the river Cowie positioned parallel to the existing training wall on the north bank.)
- SFAG welcome the proposal for improved beach monitoring. The three previous studies provided useful data. However, the frequency of study could be improved; as to a more continual monitoring approach; this may be perhaps a step to far. In order to provide constructive feedback, it is something that we would welcome receiving more information about.
- SFAG feel the introduction of the SEPA warning system is a major benefit to residents. We welcome the promotion of this service.
- SFAG are in favour of the continued repair and maintenance of the existing defences that are along the coastline.

2.2 Do you have any comments on the medium term option of raising the existing defences to protect Cowie promenade and Cowie village?

- No need for any heightening of promenade break water. Remove all shingle/rocks then waves will not come over. It is supposed to break the water from the sea.
- Look more at shingle management than raising the wall on the front.
- Not happy with extending wall on promenade. Shingles used to be reduced from wall.
- This sounds good sense but the sight lines for all these residents will be affected. This affect needs to be explained to the property owners by the use of 3D computer graphics.
- Important to maintain a "useable" promenade for tourists and locals. Presumably wildlife is protected and monitored?
- Raising the seawalls has a considerable detrimental effect to the amenities of the properties that are located behind them. A number of those residents already have resilience measures and are familiar with the area in which they live. While flooding can be quantified in terms of risk related probability terms like Standard of Protection, (SoP), the effect of heightened walls is total and irreversible to the both values of those properties and the loss of amenity to the residents. SFAG request that the engineering analysis together with the cost analysis for the previous options that were suggested in Feb 2019 are provided and refer to SFAG option C. Offshore Rock Armour. i.e. As was applied in the north section of Aberdeen beach.

2.3 Do you have an order of preference for the long term option for Cowie promenade and Cowie village?

New sea wall	No	2		Yes	
Sea wall with rock armour		1	1	No	
Beach recharge		3		Yes	SFAG preferred option

- Think all looks sensible - but I do not like Option 8 with the inclusion of rock armour. This section of the beach is used recreationally. Rock armour is ugly and dangerous to children/adults.
- A new sea wall would completely block our view and reduce price of all houses along the front which for the most part are occupied by elderly people.
- What does beach recharge mean? If you mean spreading or addition of new sediments to the beach for human amenity, then the Shire and the contractors need to be mindful that the rocky shore is adjacent to the habitat of birds, plants and animals. The whole ecology of the inter-tidal zone will be affected by "beach recharge".
- Beach recharge would appear to have least impact on residents/tourists? However, protection is the main consideration is weighing up the options.

- SFAG's preferred solution is based around using the SFAG option C. In each of the three options AC has asked for feedback on, we notice that the sea walls are higher than present. This, from a resident's viewpoint, creates the most problems and we feel it should be avoided.
- SFAG believe there is a need to establish the limitations of the existing hard coastal defences when beach recharge and rock armour defences are added. i.e. no sea wall height changes. It is plausible that this scenario will not provide a 200 year with climate change SoP level. – if, so what would it provide?

2.4 For the central area, it is proposed that the wall is raised and the beach is enlarged with control structures installed to keep the material in place. The beach would be adapted over time to account for climate change. Please provide any comments on this below:

- Take back the stones on beach regularly as used to be done.
- The circumspect comment above, concerning the adverse affect on living organisms, re beach enlargement applies. What does "adaptation of the beach" mean? This is vague and the relation to climate change with increasing sea temperatures needs to be explained and communicated.
- As long as the aesthetic aspects of the design were strong, this seems like a good solution. Beach access would need to be considered as this is a vital recreation area.
- By comparison with the drawings shown on 13th June, the proposal is for a 1 metre concrete height addition to the existing sea wall and while not mentioned in the question the level of the promenade path would also be raised by 1 metre. This would have an unacceptable impact on the properties and residents living along the sea front.
- Prior to 13th June AC shared with SFAG the Economic Appraisal Results, for each of the three sections of the bay and the variety of options which were shortlisted. Unlike the North and Harbour areas, the information presented for the Central area varies between what is given in the results and what was presented in the poster session on 13th June. As examples, in the analysis option 5 (Recharge in medium term) clearly states uses the "current defences". By contrast option 5 in the posters while also titled recharge in the medium term, states the existing sea wall and promenade will be raised. The rest of the data for that specific row in the table is comparable to that shown in the Economic Appraisal Results.
- If nothing else there is an inconsistency. Moreover from the addition of the work along the banks of the river Cowie, options 4 and 5 that were presented on 13th June appear to be the same. It is felt the differences between these options require a clearer explanation. It is further compounded by the fact that several members of the SFAG who read the Economic Appraisal Results all understood option 4 as using the existing seawall and promenade height levels.
- SFAG would like to know what the capability of the existing seawall together with recharge, groynes and rock armour is.

2.5 In the long term, the walls along the banks of the Cowie Water will need to be raised to account for climate change. Please provide any comments on this below:

- The view and amenity of residents in Hanover Court and the adjoining properties bordering the River Cowie will be affected and this needs to be communicated and explained with computer graphics and visual aids.
- My family have owned property at The Bridge of Cowie for 70 years. The design looks like an improvement! I have concerns about condition of iron piles in existing structure. When the river is scoured, the bottom is sometimes visible.
- This question seems somewhat to be at odds with the data presented in Nov 2018 and included within the Interim Modelling Report published during Jan 2019. In those the flooding seen along the banks of river Cowie all directly occurred due to overtopping at the coast. i.e. not from the banks of the river. In addition, the flooding of the properties along the river's banks which occurred in Dec 2012 was due to overtopping at the seawalls.
- However, we do understand that the unprotected steel piling along those banks of the river Cowie will deteriorate through time and in future there could be a need to reconstruct the section with, for example, the approach shown in the posters. Not that the capacity along that specific stretch of the Cowie river has been an issue, it follows that by narrowing the channel the wall heights have to be increased to maintain the existing capacity.

2.6 In the harbour, the options presented include property flood resistance and resillience measures, a new rock armour revetment to the north of the harbour, a new sloped revetment in the inner harbour and managed realignment to the south of the harbour. Please provide any comments on these options below:

- No options apart from purchase a gate. During storms stay at home as shorehead will be closed. Not enough homes at risk worth any investment. More interested in protecting Scottish Water plant and SCI both businesses and not homeowners.
- These proposals sound sensible and practical but all plans need to respect the conserved status of the buildings and properties in this historic harbour area.
- The variety of and locations for these different options in the harbour area makes overall comments hard to make. It is further compounded by the information presented in the posters. e.g. within the Harbour Benefit Zone, Option 7 states "construct new sea wall and raise promenade at Cowie Village and Cowie Promenade". We note that this has been amended in the posters which are presently available as an enormous 170MB file download from the AC website.

JBA Project Code	2018s0343
Contract	Stonehaven Bay Coastal Flood Protection Study
Client	Aberdeenshire Council
Day, Date and Time	4 July 2019
Author	Nicci Buckley
Subject	Public Consultation Feedback – June 2019

3 Additional feedback

3.1 Comments

The SFAG response was submitted by the following people, with any additional comments from individuals also noted here:

1	-	We do not want the seawall raised by 1 metre. Since the flood of 2012 (7 years ago) our boundary wall was replaced by a reinforced one which we feel would make our property secure from flooding. We bought the house because of the lovely sea view. We agree wholeheartedly with the SFAG when they point out it would be detrimental to residents and the Stonehaven economy. We would not like to look out and see a brick wall which would definitely give a prison like appearance to our property.
2	[redacted]	As a resident of the sea front I am strongly opposed to the Council's scheme to make the wall and walkway higher as this would have a very detrimental effect on house prices in that area, not to mention the effect it would have to the people who would have no view whatsoever and feel like they were closed in.
3	[redacted]	I do not agree with the proposal of erecting a sea wall, this would have a detrimental effect for residents, commercial properties and tourists. Surely appropriate sea defence would be sought from the likes of rock amour prior to the destruction of Stonehaven's sea front.
4	[redacted]	We would like the sea wall to be left the way it is. If you put it higher it will spoil our sea view.
5	[redacted]	We would like the sea wall to be left the way it is. If you put it higher it will spoil our sea view.
6	[redacted]	I totally agree with the SFAG views. The raising of the sea wall and promenade by a metre would be absolutely devastating for me. I moved her 18 months ago, to enjoy my retirement by the sea. The main reason that I bought my flat was that I could sit in my living room and look out to the sea. If the wall was raised I would see nothing but a concrete wall! I could not live here with that scenario, it would affect my mental health and wellbeing, I would have to sell up. Please, please do not build the wall!
7	[redacted]	The idea of raising the sea wall and promenade in front of our flat in Turner's Court is preposterous. It will ruin the view, damage the property value and make the flat feel like a prison.

8	[redacted]	I support the flood group's proposals. I do not want a wall between me and the sea. I bought this flat a year ago so that I could enjoy looking at the sea. People did not go on holiday to see the Berlin wall, did they? A tall wall would utterly destroy the holiday atmosphere and ambience of Stonehaven – I am horrified at the suggestion. I wish to thank ?? members for all the work they do.
9	[redacted]	-
10	[redacted]	I agree raising of the wall and promenade would be a bad option for residents and tourists alike so alternatives should be considered. More time should also be allowed for considering the various options.
11	[redacted]	I feel that as long as shingle is banked up no water gets to overflow the wall as it is now.
12	[redacted]	-
13	[redacted]	If the breakwater is at the wall the flats nearest the sea will be flooded. I am opposed to wall being heightened. There was insufficient time to discuss a breakwater. The proposal still leaves the flats possible flooding.
14	[redacted]	-
15	[redacted]	I fully supportive of Stonehaven Flood Actions Group's Response to Consultation.
16	[redacted]	Do not want 1 metre concrete additional wall.
17	[redacted]	Do not want 1m concrete wall extension.
18	[redacted]	In total disagreement with the raising of the wall. This would have a disastrous effect on the Stonehaven community and have a physiological impact on the residents who live along the front.
19	[redacted]	-
20	[redacted]	As you can see from my address [redacted] I am very concerned with the idea of raising the road level near our houses and flats.
21 22	[redacted]	We do not believe that additional sea wall is required as the benefit does not outweigh costs and stress and will create an unsightly sea frontage. We believe that rock armour defence and beach recharge should be provided as control structures.
23	[redacted]	-
24	[redacted]	-
25	[redacted]	-

26 27 28 29	[redacted]	We absolutely agree strongly that the raising of the sea wall will be highly detrimental to the businesses, residents, visitors and tourists and an alternative measure must be chosen. Stonehaven's iconic bay must be preserved and not hidden from the many people who visit our town.
30	[redacted]	Do not agree to raising the sea wall.
31	[redacted]	The active management of the existing beach would be far more cost effective and much less of a physical and visual negative impact on the sea front area and its businesses and residents. I therefore support SFAG recommendations.
32	[redacted]	Since purchasing [redacted] we only had one occasion for concern when the water reached the pavement, but didn't enter the property. With this existing wall height in front of our property /car park of about 16 inches topped with grass . I feel a two meter wall would obstruct our view and be detrimental, with the view being the reason I bought the property in the first place. I would prefer to see active management of existing beach with groynes, recharge, breakwaters etc without ruining "our" beach and destroying the view for the many residents facing it, many of whom are elderly, as well as visitors.
33	[redacted]	-
34	[redacted]	-
35	[redacted]	Concrete wall seems easy straightforward solution, but ugly and undesirable. Is there a cast for a castleated solution and form coffer dam when threatened by inserting timbers or piles?
36	[redacted]	I have read and agree with the comments of SAG on the proposed flood prevention scheme. I wish to support the comments and recommendations made by SAG. I attended the recent SEPA display in the Town Hall but could not understand what is proposed in front of the houses at Salmon Lane as there is no existing wall at that area, which appears to make it more vulnerable at present??
37	[redacted]	-
38	[redacted]	-
39	[redacted]	-
40	[redacted]	-
41	[redacted]	Object 100% against any new sea wall or sea wall with rock armour. This will impede our view out to sea, also

		encourage more invasion of privacy by people looking into house, etc. Agree with beach recharge.
42 43	[redacted]	Storm drainage at the north corner of Cowie (further to the drainage which was installed a few years ago) is an effective low cost solution.
44 45	[redacted]	We consider that a 2m wall in front of the houses in Salmon Lane is completely unnecessary. During the flooding of 2012 (100yr storm) none of these houses (No. 1-21, 11 houses) were damaged by the sea. A 1m wall further out to sea would probably suffice. All other options should be vigourly re-evaluated.
46	[redacted]	My thoughts are it would be ridiculous to raise the height of the wall at the beach front bearing in mind the height harbour wall does not prevent the sea from coming over. As a child growing up in Stonehaven I clearly remember being unable to climb onto the wall as there was such a distance from the shingle to the top of the wall. Surely removal of the majority of the shingle would improve the situation but this would obviously need to be maintained.
47	[redacted]	-
48	[redacted]	-
49	[redacted]	I fully agree with the feedback and recommendations which have been made by the SFAG. I do not want the promenade path and seawall to be raised above their existing levels.
50	[redacted]	Agree with actions proposed by SFAG. With regular inspection of sea defences between harbour and Cowie.
51	[redacted]	Fully supportive of Stonehaven Flood Actions Group's Response to Consultation.
52	[redacted]	Object 100% against any new sea wall or sea wall with rock armour. This will impede our view out to sea, also encourage more invasion of privacy by people looking into house, etc. Agree with beach recharge.
53	[redacted]	I fully support SFAG's views. These are particularly relevant to Cowie. The fitting of a large scale drainage valve at the north end by AC and increased resilience by residents has significantly improved the situation. I am convinced that similarly targeted improvements based on local knowledge and professional engineering would be more cost effective in the long term.
54	[redacted]	This is the response of Stonehaven Flood Action Group to the Consultation on Thursday 13th June 2019. I hope that you find it helpful. The Flood Action Group continues to be committed to working with the Coastal Flood

		Protection Team to achieve the most appropriate solutions to go forward to the next stage.
55	[redacted]	I completely oppose to any height raising of the sea wall. Until climate change shows a significant threat to the coast of Stonehaven I don't feel the raising of the wall is the answer. I fully agree with the SFAG response. Reducing the power of the waves via beach management in a storm with high tides is the key to the present and future issues. Previous studies have been largely ignored and we now have something being submitted that the majority of people living along the coastline do not want. I also question the cost/benefit of which is vague and cannot understand why realistic considerations have not been made to the shortlisted options highlighted by SFAG.
56	[redacted]	I have been resident at [redacted] Stonehaven for 21 years. My property benefits from amazing sea views, one of the main reasons for purchasing the property. At a meeting on 22nd June, along with other local residents I was very concerned to learn from members of the Stonehaven Flood Action Group about some of the proposals being put forward by Aberdeenshire Council to reduce the risk of coastal flooding in our area. I wholly concur with the group response summarising that meeting. My more particular concerns about the impact on my property are as follows: ☐ The view from my property would be severely affected by the proposal to raise the sea wall to a height of two metres and the promenade by one metre (currently there is a 40 centimetre retaining wall rising from road level) ☐ It would affect my privacy, giving passers-by a clear view into my bedroom ☐ It would undoubtedly have a detrimental effect on the value of my property In the 21 years I have lived in [redacted] only once has there been any significant sea flooding which resulted in sea water and debris on the road in front of my house, but not encroaching on the property. I am, however, well aware of the need to address the problem of climate change and gradually increasing sea levels and agree that the problem should not be ignored. As matters progress I would like to be assured of the following: ☐ That, in addition to the possibility of a high wall being constructed, ALL other avenues of

		management be explored. In particular I wholly support the recommendation of the SFAG to actively manage the existing beach with groynes, recharge and breakwaters to reduce the risk of flooding without having to raise the sea wall ☐ Greater engagement with ALL those who will be directly affected by the proposal of a wall (currently many of us have been finding out through chance meetings and random conversations) ☐ A full explanation of what the options are, clearly presented in lay-man's terms ☐ Time to consider and respond to what is being proposed Finally, might I suggest that all the above be shared with the wider community of Stonehaven. We live in an attractive seaside town and much is being done to develop the beach front and encourage tourism to the area. I think that many other Stonehaven residents will be concerned about any development which might have a negative impact on the appearance of the beach area.
57	[redacted]	To increase the height of the sea wall appears to be a cheap option. It would however ruin the beautiful sea front for both visitors who come some distance to enjoy this (and spend money here) and residents who have selected Stonehaven above other towns because of promenade, the sea and amenities this offers. I strongly agree with this response.
58	[redacted]	-
59	[redacted]	I have tried my best to understand all the paperwork but think it is written by engineers for engineers and is of little use to any normal citizen. The idea of raising the wall and walkway seems ???. If there were bats or moles involved they would get more consideration.
60	[redacted]	I am strongly opposed to the raising of the sea wall. I have already built a defence wall at the bottom of my garden and the width of the walkway would mean this would have to be demolished and part of my garden taken away. Surely rock armour would be a better solution and leave the sea wall as it is. Raising the wall will have a detrimental effect on my property.
61	[redacted]	I object to raising the height of the sea wall.
62		-
63		-
64		-
65		-
66		-

67	[redacted]	-
68	[redacted]	Totally opposed to the raising of the sea wall but fully support the beach management and a construction of a glass sea wall.
69	[redacted]	I think the Council's proposals are perfect (what are they going to do about the slipway at Cowie?). I don't care about dog walkers or sightseers and somebody's view. There's a village on the news is going to disappear in 25 years time and they will not be compensated.
70	[redacted]	I realise that some form of flood protection is to our benefit. However, a 2m high wall, I strongly object to.
71	[redacted]	I totally support SFAG proposals. I do not support AC proposals to raise the sea wall and beach path, it would make our properties unsaleable and ruin Stonehaven's appeal to visitors and residents alike.
72	[redacted]	I strongly object to your proposals to form a 2m high wall with raised footpath, this would eliminate our view of the beach and sea, thus lowering the value of our property. The beach is one of Stonehaven's greatest assets for locals and tourists – leave it as natural as possible please.
73	[redacted]	I fully support the SFAG position, particularly for the centre section, Aberdeenshire Council must avoid any sea wall rise and investigate/pursue the beach recharge option with groynes/offshore protection to retain shingle. This should include reconsideration of the HR Wallingford report and recommendations on shingle management to realign the rock armour at the mouth of the River Carron. i.e. https://www.aberdeenshire.gov.uk/media/13789/1998-ex3731-stonehaven-seawall-feasibility-study.pdf
74	[redacted]	I strongly object to being imprisoned by a 2m high wall and revised walkway thus losing the view and the reason for purchasing my home.
75	[redacted]	Obviously oppose such myopic logic.
76	[redacted]	I am against raising the height of the sea wall and continuing it in front of Salmon Lane. I am in agreement with the attached document from SFAG.
77	[redacted]	I have lived in [redacted] for over 20 years, the primary reason being the sea view. I strongly oppose any proposals to build a sea wall in front of my property, let alone to a height greater than the existing wall and with raised promenade path. I agree with SFAG response to Aberdeenshire Council proposals and endorse the SFAG recommendations.
78	[redacted]	I disagree with the Council's proposal to raise the height of the existing sea walls and promenade path. I feel this would have a detrimental effect on not only beach front

		residents but Stonehaven as a town, not forgetting local businesses and the effect it may have on tourism which Stonehaven is heavily reliant upon. As a resident of [redacted] for over 20 years now I am angered by the proposal due to the negative impact this would have on my quality of life along with the serious devaluation to my property.
79	[redacted]	I would not like to see a sea wall and raised path in front of Salmon Lane. Neither would I like the height of the existing wall raised. I would like other measures to be investigated, such as those recommend by SFAG.
80	[redacted]	As a beachfront resident I am highly aware of the of the number of visitors we have to the promenade and boardwalk to the harbour. These visitors are vital to the economy of a small town like Stonehaven and I dread to think the impact of building a 'prison like' wall along the beachfront will have on visitor numbers – and subsequently the town's economy. I am totally against such a plan and support wholly the arguments put forward by SFAG.
81	[redacted]	Cowie now benefits from a ?? pump. The residents have barriers for the lanes between the houses and gates and we suffered little in the flood. A sea wall does not help, whereas rock armour would help. Good maintenance of all drains is also needed. The height of our wall with its splash back is effective.
82 83	[redacted]	We share the concerns of the SFAG.
84	[redacted]	I totally support the SFAG response to Aberdeenshire Council dated 24/06/2019 in connection with the Stonehaven Bay Coastal Study/flood defence scheme options as presented to the public on 13/06/2019 in the town hall.
85 86	[redacted]	The frequency, likelihood and severity of any historical flooding does not justify the addition of 1m to existing sea wall. Engineering and correct data would, in the long run develop controls/flood prevention which does not negatively affect residential and commercial property on the front.
87	[redacted]	I endorse the comments/feedback of SFAG. A balance must be struck between safety of residents, costs, ugliness of the wall proposal. I witnessed the destruction last time. I don't believe a wall of any height would not be destroyed by the sea. Measures need to reduce the force of the sea hitting the existing walls.
88	[redacted]	The Council's preferred proposal to build a "BIG WALL" is so insulting to the people of Stonehaven. To think that the Stonehaven community would contemplate such an unimaginative, infantile, badly thought out solution is

		incredulous. We are not a bunch of "morons". We are "real people" with feelings. The pathway and board walk lies at the heart of Stonehaven. People look forward to their daily walk there, young and old alike, children and dogs walking on the walls, the elderly stopping to have a chat, for many their only form of human contact that day, families pushing their prams whilst their toddlers cycle along beside them. Stonehaven Bay is a beautiful, unspoilt, scenic, picturesque environment and home to many wildlife. It attracts day trippers and visitors worldwide and unbelievably the council wants to destroy all this and build a "BIG WALL". Furthermore, they have had the most ridiculous idea that in order for the community to still see the sea they will raise the pathway. The raising of the pathway is strictly not necessary for the flood defences and is an illconceived solution to mitigate the loss of view due to the construction of a "BIG WALL". As a holiday letting business on Stonehaven Bay frontage which caters for tourists from all over the world I am 100% against this proposal. Personally, if the wall is built it will destroy my business which I have heavily invested in, as well as spending over a year renovating the apartment. I am successfully attracting visitors to Stonehaven worldwide. If Aberdeenshire Council proceed with this option the charm and beauty of one of the most important features of Stonehaven will be DESTROYED forever. One of the major tourist attractions for these worldwide visitors is the highlight of walking this route. I am quite confident that the loss of this amenity will have a significant impact on the tourism to Stonehaven whether it is day trippers or worldwide visitors. Is Aberdeenshire Council actually aware that Stonehaven is undergoing a mini boom in tourism at the moment? If they were aware of this they wouldn't be proposing and supporting such a preposterous and infantile solution which will have a significant negative economic impact on the Stonehaven economy. Below is a recent quote expressed by visitors from Oviedo, Spain who stayed in my holiday let; *"We have spent 8 unbeatable days. The house is perfect, as in the photos but better still. The views you have are spectacular. The town is very beautiful. From the house, in addition to watching endless seabirds we were lucky to see dolphins. In short impossible to improve."* On the basis of my concerns, the only viable option I am prepared to support for the defence of the Central Section, would be a full beach recharge, the introduction of groynes and rock armour. It is important that

		Aberdeenshire Council adopt imaginative solutions which inherently deal with coastal flooding and which maintains the charm of the Stonehaven Bay sea front.
89	[redacted]	Stonehaven community has been presented with, initially, 21 solutions to mitigate potential coastal flooding based on an Interim Modelling Report of January 2019 prepared for Aberdeenshire Council by JBA Consulting. It is worth noting that modelling of coastal flooding and wave over topping is an extremely complex process with a high degree of uncertainty. However, it appears that Aberdeenshire Council's preferred option is to raise the height of the existing sea defence walls along the North and Central Sections. As a home owner right on the Stonehaven Bay (Central) the option of raising the existing sea defence wall along with the raising of the existing footpath by 1 metre is totally unacceptable. This proposal is simply a crude solution which in my view has not been fully thought through by the Council nor by the appointed specialist consultants. It fundamentally fails to address the impact of raising the footpath by 1 metre on existing sea front properties in terms of, access to the properties and car parking; access to the beach front from the various lanes leading off Allardice Street and the overall impact on the public realm in general. In fact, the raising of the footpath is terms of flood defence is not strictly required and has merely been considered as an afterthought to address the loss of views with the increased height of the existing sea wall. An increase in height of the footpath by 1 metre would significantly affect access to the properties at [redacted] Cowie Lane including access to the existing garages which would render them redundant. A raised footpath would also result in my flat in effect becoming a "basement" property with no outlook other than seeing the bottom half of those who will pass by the flat. This solution will have a significant detrimental impact on the value of my property and I would be seeking the full value of my property in compensation. However, raising the existing sea wall will have a significant impact on views and general public amenity and the enjoyment of the walk from the River Cowie to the Harbour, by not only locals, but visitors as well. Stonehaven is currently going through a mini tourism boom with day trippers and also visitors from other parts of the UK and from overseas. There is significant anecdotal evidence from visitors to Stonehaven that they

		gain immense enjoyment from this walk and is in fact one of the main attractions for day visitors. The loss of this amenity will have a detrimental impact on tourism to Stonehaven and I am unclear as to whether or not this has been factored into any cost/benefit analysis. On the basis of my concerns, the only viable option I am prepared to support for the defence of the Central Section and which SFAG must continue to endorse, would be a full beach recharge, the introduction of groynes and rock armour. It is important that Aberdeenshire Council adopt imaginative solutions which inherently deal with coastal flooding and which maintains the charm of the Stonehaven Bay sea front.
90 91	[redacted]	I have read the document and agree with its comments. I am against a sea wall and in favour of more practical and flexible solutions – including speaking to residents of Cowie, especially those who have lived here for a long time and have sensible experience and ideas.
92	[redacted]	-
93	[redacted]	-
94	[redacted]	I totally agree with SFAG's views. Beach management is necessary and building a wall will only be detrimental to Stonehaven as a tourist area. Cowie residents have already put in place individual flood protection and a wall will only spoil the beauty of the village and reduce property values. Drainage is essential and that needs to be addressed.
95	[redacted]	I object to the proposals to heighten the sea wall. I agree with the proposals put forward by SFAG.
96	[redacted]	-
97	[redacted]	I am completely against raises beyond the existing height levels of the promenade path and seawall along the central section. If for no other reason any raises would have significant detrimental effects to the properties along the front. I fully support the views and answers provided by the Stonehaven Flood Action Group to the Aberdeenshire Council consultation of 13th June 2019. It is my belief that it should be possible to significantly reduce the threat of coastal flooding by periodically renourishing the existing beach with shingle/sediment. This sediment volume being maintained with the addition of rock armour, and groynes. i.e. with no changes to the height of the seawall. It is conceivable to me that in future the climate change effect could be a more quantifiable factor than it is today. However it is also fair to state, that similarly

		there will be technology advancements which will provide a more environmentally friendly solution to that of raising the heights of solid concrete walls.
98	[redacted]	-
99	[redacted]	Fully support Stonehaven Bay proposals from SFAG. In particular we need a scientific analysis of the effects of beach recharge and a glass sea wall.
100	[redacted]	Regarding Cowie village I would suggest another curve on top of the present wall but no more than 2ft (ie. Additional throw back). Also rock armour placed along the beach at a suitable distance from the present wall so as not to be buried in shingle as the present rock armour is at the promenade.
101 102	[redacted]	-
103	[redacted]	Beach recharge is the only acceptable option. A wall would be an eyesore to me and to most people along the prom. Also the proposed path etc would greatly reduce the value of our property.
104	[redacted]	Beach recharge is the only option for me, wall and raised pathway is a waste of time. We have been flooded twice and I feel if the beach was sorted out this could have been avoided.

Additional comments or questions, received separately from the SFAG response are summarised below:

1	Dear Sir/Madam I have read the options for the Central Benefits Zone and request further information on the following:- 1. The proposed height changes to the current wall and promenade – how were they calculated? 2. What drainage will be put in place to ensure that any excess water from the heightened wall/promenade simply does not flow direct into the homes of those that will be effectively 'under' the heightened wall/promenade 3. What studies have been undertaken to understand the effects on the homes that will be directly affected by the heightened wall/promenade? 4. Where a home will lose potential capital (decrease in selling price) due to the adverse building of the new heightened wall/promenade what compensation will be given e.g. flats boarding on Cowie lane will lose garages/parking spaces i.e. what are the proposed financial offers that will be made and what other provisions of new garages/parking spaces will be provided to these residents? Regards [redacted]

2	Dear Graeme Thank you for sending this information through. My apologies for not responding sooner about the consultation in the Town Hall as I had said I would submit some comments – although I understand I will get that chance via Area Committee as well. My main concerns apart, of course, from ensuring that any proposal that goes forward will be effective in delivering flood protection for residents and local businesses, is the visual impact of any scheme on the beachfront of Stonehaven and the resulting impact on the experience of visitors to and residents of the town. We know – you know as a result - that the beachfront and the walk from Cowie to the Harbour and beyond in both directions is one of the main reasons visitors come to Stonehaven and, therefore, the economy of the town needs any proposal to treat the beachfront accordingly and sensitively. I am comfortable with the idea of groynes to help stabilise the shingle and I think I am okay with a raised sea wall but only so long as the promenade behind it is also raised and the cost of that seen as an inclusive element in any proposal related to the raising of the sea wall going forward. I realise that to the northern end the sea wall could be a solid concrete wall like on the middle section which would be a change from the timber fencing we currently have which currently looks quite tired – I think this would be effective and also help with flying shingle that currently flies about and requires clearing when we have overtopping along that segment between the Cowie and the Open Air Pool. I do think, though, that there would be a visual impact and wonder whether there would be scope for half and half? Solid lower half but an open structure with a couple of railings (I am thinking of the railings at Montrose) above that – if you see what I mean. Regarding the harbour – you will remember I was present with you when there was some scepticism from local harbour residents about our proposals harbour side and the effectiveness of a sloping wall. I think you were confident this could be effectively delivered but I would want to be sure that was so. If the above raises any questions, please let me know. Kind regards [redacted]

3	Personal response to flooding issues [redacted] Stonehaven AB39 3RP I refer to the public engagement on 13 June 2019 regarding coastal flooding in Stonehaven. You may know I am involved in Stonehaven Flood Action Group but the following are my personal comments only, not theirs which have been sent seperately. I have always supported the need to install effective, and cost effective, flood defences along the sea front. My interest stems from when my late father-in-law lived at [redacted] and saw his home flooded out in December 2012. You will appreciate how traumatic this was for him and others who saw their homes awash, personal possessions destroyed and faced rehousing for several months. My wife and I still own the flat, hence our interest in the issue. On 29 January this year you and JBA presented your long list of options at a public meeting and invited feedback on these proposals. Many people responded individually and also through the Stonehaven Flood Action Group, commending some proposals, rejecting others and putting forward some additional ideas for consideration. On 29 May JBA produced a report titled Economic Appraisal Results. I realise this was an internal report, not made public, but it was given on request to the Flood Action Group. The report concluded; "North (of the Cowie) improve the existing defences immediately and adapt to a new option when the residual life is exceeded. "Central (between the Cowie and just south of the Carron) Implement an adaptive beach recharge scheme immediately and replace Cowie defences (on the banks of the river) in year 30. "Harbour, manage the medium term risk through property resilience and construct new defences when the residual life of the current defences is exceeded." I attended your engagement session on 13 June to see the options under consideration. For the north and harbour zones the options were largely as given in the May report by JBA. For the central zone the options were changed

	and all those given included raising the existing sea wall and promenade by 1 metre. My comments are as below; • There is a strong feeling that beach front residents and businesses have not been properly informed regarding options for flood defences along the sea front. I recently spoke to several residents of Salmon Lane and not one was aware of what you were considering. Indeed, many thought the engagement you held was pertaining to the Carron, not the sea front. • Consequently I feel Aberdeenshire Council has not properly consulted with residents or adequately informed them of what their own consultants have been doing and the recommendations they have made. • The short list presented did not seem to be derived from the earlier long list. Specifically, the repeated reference to raising the banks of the Cowie near it's estuary did not feature in the long list and is, I think, a seperate issue. Proposals mentioned in responses to the long list included shingle management by means of groynes, offhore breakwaters and rock armour but these appear to have been discounted • Alternative ways of tackling flood risks do not seem to have been properly considered. For example, raising the existing sea walls by glass panels, (as described in [redacted] response to you) or using removable barriers when a storm is forecast did not receive a mention in your short list. • Overall there is support for the idea of extending the beach and installing structures eg groynes or breakwaters to restrict the movement of shingle. Some rock armour just beyond the low water mark may well help to dissipate some of the power of the waves and could contribute to a low cost, unintrusive option. • The proposal to raise the sea wall and promenade by 1 metre is, I think, unacceptable. It would block sea views currently enjoyed by residents, could be psychologically harmful to those who currently enjoy their sea view and would harm property values. As shown in your own presentation the embankment supporting the raised promenade would extend to around half way up the front door of [redacted] I realise details like this could be addressed but even so, a raised promenade and sea wall would give a prison like feel to this property and probably many others. When I finally retire I hope to move into a

	flat with a sea view, not a view of people's ankles less than 4 metres from my window. • Nor does the manner of delineating the public promenade from private property appear to have been properly thought out. The current wall separating Turner's Court and Hanover Court from the promanade would be below the height of the promenade making it useless as a boundary marker and useless as a defensive measure against flooding. • Many people, including me, felt the public engagement on 13 June was misleading. Much of the information was highly technical in nature and not easily assimilated. Indeed, a lot of the print was too small to even be read. Proposals were unclear, inedequate time for response was given, no hard copies of the options were made available and it cannot be seen as proper consultation. I note that although it has been called "engagement" it appeared under the common heading of "consultation" in your posters. • I realise that proper consultation, ideally conforming to recognised standards, will be needed before any final decision is reached. However, the core option you appear to be considering for the Central Benefit Zone ie raising the promenade and sea wall, is so inappropriate I hope you wil delete it from your options and revert to proper beach management. This was, after all, a recommendation made by your own consultants. I hope you will give these commentd appropriate consideration, Yours sincerely, [redacted]

3.2 Suggestions

SFAG also put forward a series of further suggestions. These are detailed below:

1: - Central and North Sections - Establish and present the capability of the existing hard concrete defences with the addition of full beach recharge, groynes, rock armour. This would involve no raises to the height of the seawall and no changes to existing height of the promenade path. e.g. SFAG options A E

2: - Promenade path level. While the AC proposal to an extent allows for people to walk along the frontage and view the beach it totally ignores the consequential effects to the surrounding properties due to the raised path. The current drawings show tapering between this raised path and the existing ground level. Due to the proximity of some buildings to the path this tapering will be impossible to achieve. In addition, from a property owner's perspective there are requirements to maintain visible and practical boundaries between public land and private land. Property owners are responsible in law, for the resilience of their own property. In addition, some property owners have designed and built their boundary walls to aid in resilience. Hence by raising the path, the property owner's own boundaries and resilience measures will also have to be raised. One of the consequences is that the overall effect reduces the ability of light to enter property owner's windows. Hence SFAG would encourage AC to fully investigate alternatives to raising the heights of the seawall and path levels. For example, the items specified in the first recommendation and the use of clear/transparent barriers which could be added to the top of the existing seawall.

3: - The psychological effects. The psychological effects to residents due to wall and promenade level changes need to be factored into the decision-making process. While flooding itself can cause psychological effects to residents living next to the coast, these same psychological effects would also be caused by building a raised concrete seawall and raised promenade path right next to existing buildings. Building a wall results in a permanent structure, where as the probability of flooding occurring isn't as definite.

4: - Communication and ease of understanding. The structure of the presentation where the posters were completely full of graphics, tabularised data and text resulted in complexity. There was a considerable amount of information being conveyed on a few posters. While that approach is fine for an engineering audience, it isn't very suitable for a presentation to the general public. In places the actual drawings were small and hard to see.

The use of visuals could be improved to simplify level of technical content which is presented on each individual poster. In addition, while the public engagement session was advertised in the press ahead of the event, none of the content or agenda were included in those advertisements, and coastal residents who would be affected were not directly informed.

5: - Future technological improvements in construction methods. In many of the options, it is noted that there were portions included that were stipulated for future implementation. e.g. replacement embankment walls along banks of the Cowie River. It is thus conceivable that in future there will be alternatives to what are solid concrete walls, perhaps including specialised glazing solutions. Hence, SFAG emphasise that focus should be on using the present coastal defences and implementing the recommendations given above. Separately, but along with various other types of flood protection products, SFAG are monitoring the development, introduction and use of specialised glazing solutions as permanent coastal flood defences. SFAG would request that AC consider gathering information to assess the viability of a sea glass wall. SFAG believes that considerable data on this type of solution is readily available, but presently experimentation and approved testing procedures would be required to justify its use or not.

6: - Establish what is the practical level of SoP to base a scheme on, i.e. without affecting the scenic character or the existing beach front. e.g. Why does it have to be 1 in 200 with climate change?

O Additional wave overtopping and beach recharge analysis

DESIGN TECHNICAL NOTE

JBA Project Code	2018s0343
Contract	Stonehaven Bay Coastal Flood Protection Study
Client	Dougall Baillie Associates / Aberdeenshire Council
Day, Date and Time	15th August 2019
Author	Johan Skanberg-Tippen, Amelia Wright, Hannah Otton
Reviewer / Sign-off	Douglas Pender / Nicola Buckley
Subject	Wave overtopping beach design technical note

1 Introduction

This technical note has been developed to present the performance of the existing beach profile and proposed beach recharge (option C2) at Stonehaven. This is in response to the Stonehaven Flood Action Group (SFAG) comments on the design process following the public consultation event held at Stonehaven Town Hall on 13 July 2019.

Option C2 has been designed to include both a medium- and long-term design life, as shown in Appendix A. The medium-term design incorporates a 10m wide beach with a 1m wall raise, whereas the long-term design consists of a 20m wide beach with a 1m wall raise. However, for the purpose of this report the medium- and long- term options are relating to the beach width only, and any inclusion of a wall raise will be additionally stated.

For full details on the design process and information relating to other design options, please refer to the Design Technical Note (AKI-JBAU-00-00-TN-C-0001-S3-P01-Options_Design_Technical_Note.pdf) and the beach specific design technical note (AKI-JBAU-00-00-TN-C-0002-S3-P01-Beach_wave_overtopping_design_note.pdf).

The main challenge to the design was whether a larger beach (e.g. the long-term profile) could provide an appropriate level of protection in the present day without having to raise the existing wall at the rear. Considering these comments, additional wave overtopping analysis has been undertaken with a view of better understanding the wave overtopping risk for the beach recharge options.

These additional calculations employ a range of methods (empirical overtopping formula, wave run-up estimates and numerical modelling), and aim to support the design process and establish whether an acceptable performance standard can be offered by a beach recharge option without raising the existing sea wall.

1.1 Key terminology

Several concepts are referred to in this technical note and are important to understand in the context of wave overtopping design:

- **Performance standard** - The prescribed acceptable wave overtopping rate limits for public safety, damage to infrastructure, properties and flooding. In the context of the Stonehaven study this has been set to 1l/s/m given the exposure and risk of flooding the coastline.
- **Standard of Protection** – The return period for which the performance standard is met. This is usually set to a 1 in 200-year likelihood of occurrence, or higher for safety-critical locations. Where flood risk is of less concern the Standard of Protection can be relaxed.
- **Design life** – The duration for which the coastal structure is designed last. This is set at 100 years for this study.

1.2 Wave overtopping risk

Stonehaven is at risk of flooding caused by wave overtopping. This has been demonstrated by recent historical events, particularly since 2005, and is evidenced by the frequent flooding of residential properties.

The 15 December 2012 storm event was the most significant in regard to the resulting flooding, structural damage and risk to life. During this event a total of 69 properties, both residential and commercial, flooded internally. Figure 1-1 (a-d) shows some examples of the impacts caused by historical flood events.

(a) Cowie promenade

(b) Central wall

(c) Cowie promenade

(d) Central wall

Figure 1-1 Observed overtopping and subsequent damage during historical flood events (photographs provided by Aberdeenshire Council)

The 2012 event was used for the calibration and verification of the tidal inundation model developed by JBA Consulting. The calibration compared the modelled flood extents and depths to records from the 2012 event, which by extension also provided validation of the overtopping rates and nearshore wave heights.

This model shows that the overtopping rate of the 2012 was in the order of **3.8l/s/m**, nearly four times the 1l/s/m performance target adopted within the proposed concept designs.

The 2012 event forms the baseline risk comparison within this report.

It should also be noted that the wave overtopping rates presented within this report are predictions and considered accurate within an order of magnitude, as opposed to an absolute value. Precise estimations of wave overtopping rates are typically only achieved through physical modelling, as is often recommended during detailed phases of design.

1.3 Wave climate conditions

Wave data for the 1 in 200-year event has been used to develop the proposed beach recharge design at Stonehaven, and thus has been the focus of the calculations behind this technical note.

All calculations have been based upon present day conditions at central Stonehaven. It should be noted that an allowance for climate change has **not** been considered in this technical note, and the reader should be aware that this would significantly increase the wave overtopping and flood damages to Stonehaven.

Table 1-1 Hydraulic input paraments for the 1 in 200-year 2018 event

Parameter	Value
Epoch	2018
Return period	1 in 200-year
Hm0,deep (significant wave height in deep water)	5.08m
Hm0,t (significant wave height at the toe)	1.83m
Tm-1,0,deep (mean wave period in deep water)	9.95s
Tm-1,0,t (mean wave period at the toe)	8.73s
Tp (peak period in deep water)	10.94s
Lm-1,0 (wavelength in deep water)	119m
Extreme sea level	3.02mAOD
Toe level	-0.60mAOD
Local water depth	3.62m

1.4 Report structure

This report seeks to undertake additional analysis to provide better confidence in the wave overtopping predictions determined by the Artificial Neural Network (ANN)[1], from which the proposed medium- and long- term beach recharge option have been designed. Table 1-2 shows how this has been achieved.

Table 1-2 Wave overtopping analysis undertaken for the beach design at Stonehaven

Report section	Description	Purpose of analysis
2	Beach performance	To show the standard of protection of the existing beach and long-term beach profile without a wall raise. The analysis is also used to provide context to the standard of protection and wave overtopping rates if the performance standard were to be relaxed.
3	Empirical methods	Provides an alternative means of calculating wave overtopping rates with the long-term beach. Results used to support the ANN predictions.
4	Spatial distribution	Alternative means of calculating the spatial distribution of wave overtopping across the beach and past the existing wall. Results provide a comparison of overtopping spread vs. the predictions of the ANN and empirical methods.
5	Run-up	Used to gauge whether predicted overtopping rates are plausible based upon the wave run-up equations designed specifically for beaches. Run-up heights provide a visual representation of the broken wave momentum and run-up height relative in scale to the design beach profile.
6	XBeach-G modelling	Numerical modelling approach for calculating wave overtopping rates while considering the morphodynamic response of beach. Used to determine the response of the shingle beach during the design storm event, establishing where beach material is eroded and deposited.

[1] Artificial Neural Network. 2016. http://overtopping.ing.unibo.it/overtopping/

2 Wave overtopping beach performance and standard of protection

2.1 Methodology

The proposed beach recharge options with a 1m wall raise were designed in accordance with the European Wave Overtopping Manual (EurOtop II; 2018)[2] guidance on wave overtopping. Schematisations for the typical sections for each frontage at Stonehaven have been assessed within the latest release of the wave overtopping ANN (2016)[1], with wave climate data based upon latest modelling results. This is the industry best practice for the design of complex coastal structures.

The additional wave overtopping results presented herein were also obtained through this methodology, for the following schematisations:

- Existing beach profile (as surveyed in May 2018);
- Long-term design beach (i.e. 20m wide) without a wall raise;
- Medium-term design beach (i.e. 10m wide) with a 0.5m wall raise; and
- Medium-term design beach (i.e. 10m wide) with a 1m wall raise.

2.2 Existing beach and wall overtopping performance

Figure 2-1 and Table 2-1 present the wave overtopping of the existing beach profile during present day wave conditions. These calculations show that the 2012 event resulted in wave overtopping rates of 3.8l/s/m, comparable to a 1 in 50-year event.

At present, the 200-year event would result in overtopping rates of 7.5l/s/m, roughly twice that of the 2012 event.

The design performance standard for the proposed schemes is 1l/s/m, which, with the existing beach, is exceeded approximately every 2 to 3 years.

[2] EurOtop. 2018. Manual on wave overtopping of sea defences and related structures.

JBA Project Code	2018s0343
Contract	Stonehaven Bay Coastal Flood Protection Study
Client	Dougall Baillie Associates / Aberdeenshire Council
Day, Date and Time	15th August 2019
Author	Johan Skanberg-Tippen, Amelia Wright, Hannah Otton
Reviewer / Sign-off	Douglas Pender / Nicola Buckley
Subject	Wave overtopping beach design technical note

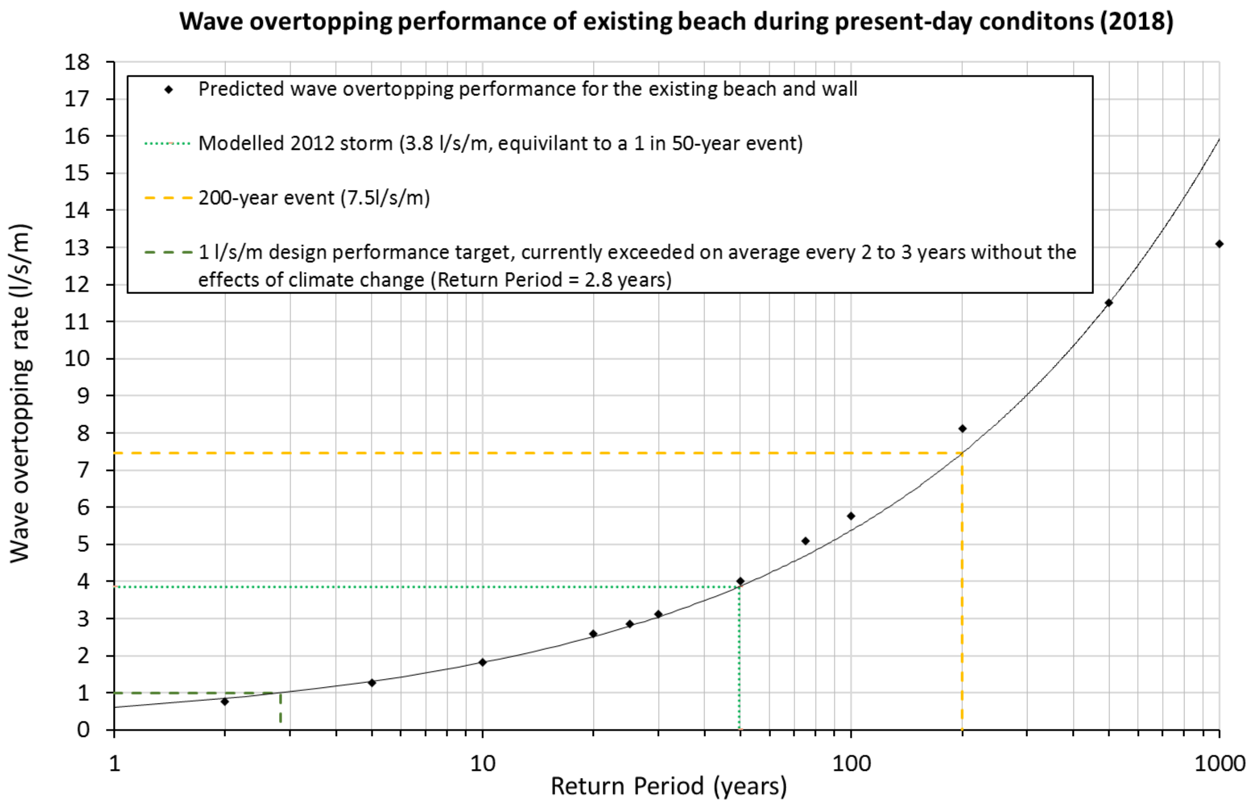


Figure 2-1 Wave overtopping performance of the existing beach and wall profile at central Stonehaven

Table 2-1 Summary of key wave overtopping performance of the existing beach profile at central Stonehaven

Description	Overtopping rate (l/s/m)	Return period (likelihood of occurrence)
Standard of Protection for wave overtopping design performance target (1l/s/m)	1	1 in 2-year
Wave overtopping in 200-year event	7.5	1 in 200-year
Modelled 2012 event storm conditions	3.8	1 in 50-year

2.3 Long-term beach without a wall raise overtopping performance

The second set of calculations were based upon the long-term beach design (i.e. beach width of 20m) without a wall raise. The results are presented in Figure 2-2 and summarised in Table 2-2.

This design beach profile would decrease the frequency of a 3.8l/s/m overtopping event (2012 equivalent flood damages) from a 1 in 50-year to a 1 in 134-year event, thus improving the standard of protection.

The 2012 event wave conditions – not wave overtopping rate – would result in a lower overtopping rate than that experienced in 2012. This is because the wider design beach would provide more protection than the current beach profile reducing the 3.8l/s/m to 2.6l/s/m, or approximately two thirds (2/3) of the overtopping experienced in 2012. This is likely to result in a reduction in flooding also.

The frequency at which the design performance target of 1l/s/m would be reached would increase by ~6.4 years, increasing from every 2 to 3 years to once every 8 to 9 years on average. Therefore, **the standard of protection for the 20m wide long-term beach without a wall extension is therefore approximately 1 in 8-years**, using modelling and overtopping calculations in line with the concept stage of the design.

This, therefore, suggests that without any inclusion of a wall raise, reasonable design life and standard of protection cannot be achieved.

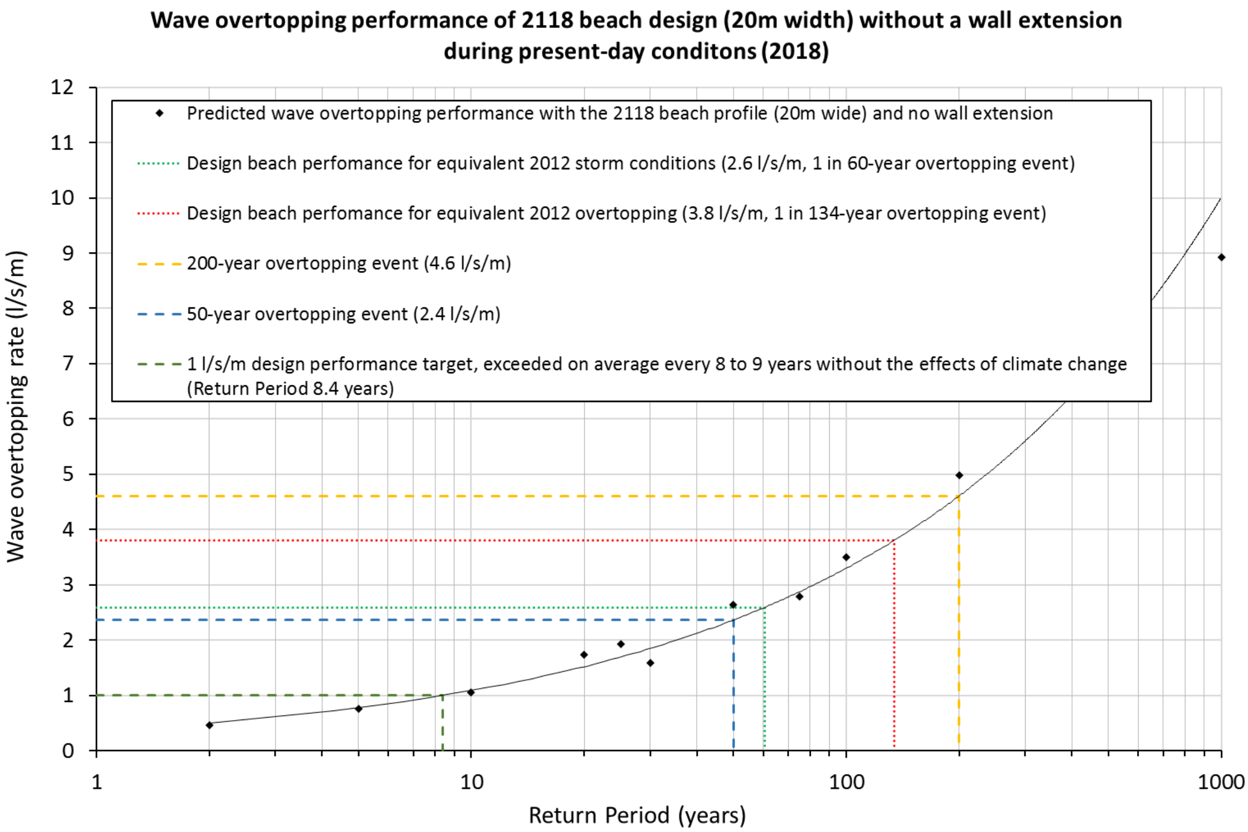


Figure 2-2 Wave overtopping performance of the long-term beach profile without a wall raise at central Stonehaven

Table 2-2 Summary of key wave overtopping performance of the long-term beach profile without a wall raise at central Stonehaven

Description	Overtopping rate (l/s/m)	Return period (likelihood of occurrence)	Change relative to current beach
Standard of Protection for wave overtopping design performance target (1l/s/m)	1	1 in 8.4-year	0l/s/m +6.4 years
Wave overtopping in 200-year event	4.6	1 in 200-year	-2.9l/s/m +0 years
Modelled 2012 event storm conditions	2.6	1 in 60-year	-1.2l/s/m +10 years
2012 equivalent flood damages	3.8	1 in 134-year	0l/s/m +84 years

2.4 Medium-term beach with wall raising overtopping performance

The medium-term design beach (i.e. 10m wide) with a 0.5m and a 1m wall raise have also been considered for comparison to the previous results. As shown in Figure 2-3, the impacts of the 2012 event would increase the return period from a 1 in 50 year event to a 1 in 750 year and >1 in 1,000 year events with a 0.5m and 1m wall raise, respectively.

The 1l/s/m performance target will also be exceeded much less frequency than the current 1 in 2 to 3-year event. For the 0.5m wall raise the 1l/s/m performance target has a return period of a 1 in 70-years, while a 1m wall raise achieves the required 200-year standard of protection.

This analysis shows that **the 1m wall raise has a 1 in 500-year standard of protection in the present day.**

A summary of the key wave overtopping performances for the medium-term design beach are presented within Table 2-3.

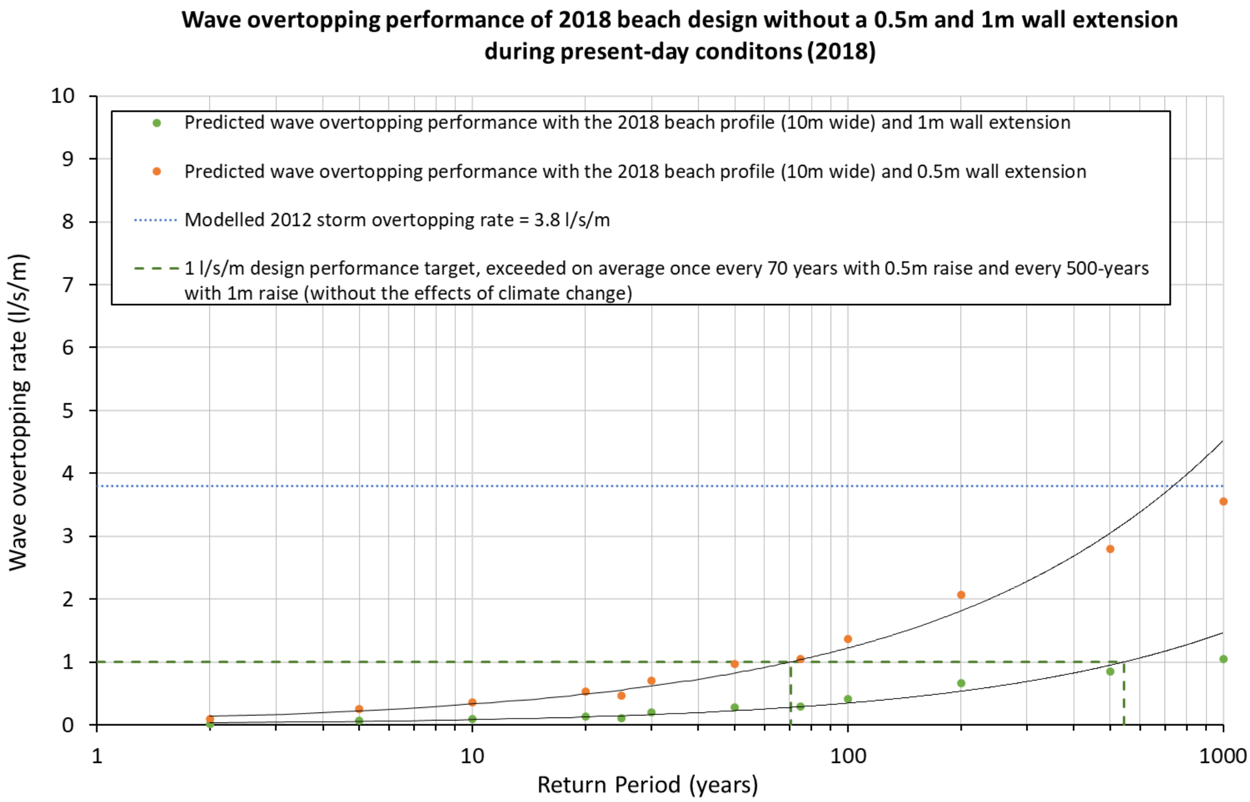


Figure 2-3 Wave overtopping performance of the medium-term beach profile with a 0.5m and 1m wall raise at central Stonehaven

Table 2-3 Summary of key wave overtopping performance of the medium-term beach profile with a 0.5m and 1m wall raise at central Stonehaven

Description	Wall raise (m)	Overtopping rate (l/s/m)	Return period (likelihood of occurrence)	Change relative to current beach
Standard of Protection for wave overtopping design performance target (1l/s/m)	0.5	1	1 in 70-year	0l/s/m +68 years
	1	1	1 in 500-year	0l/s/m +498 years
Wave overtopping in 200-year event	0.5	1.8	1 in 200-year	-5.7l/s/m +0 years
	1	0.6	1 in 200-year	-6.9l/s/m

				+0 years
Modelled 2012 event storm conditions	0.5	0.75	1 in 50-year	-3l/s/m +0 years
	1	0.22	1 in 50-year	-3.5l/s/m +0 years
2012 equivalent flood damages	0.5	3.8	1 in 750-year	0l/s/m +700 years
	1	3.8	> 1 in 1,000-year	0l/s/m +1,000 years

2.5 Summary

Figure 2-4 and Table 2-4 below presents the key data contained within in Section 2. The summary of this assessment is as follows:

- With the existing beach and wall, the 2012 storm was the equivalent of a 1 in 50-year event, experiencing overtopping rates of about 3.8l/s/m.
- The implementation of the long-term beach (i.e. 20m wide) without raising the wall would increase the return period to a 1 in 60-year event for the 2012 wave conditions, resulting in lower overtopping rates of 2.6l/s/m.
- The same overtopping rate as experienced in 2012 (3.8l/s/m) would correlate to a 1 in 134-year event with the long-term beach design, offering an increase in performance over the current 50-year return standard of protection.
- If the existing long-term beach design is implemented at central Stonehaven without a wall extension, the overtopping performance standard of 1l/s/m would result in a standard of protection of 1 in 8 or 9-years in the present day (i.e. without an allowance for climate change). The 200-year standard of protection would not be achieved.
- The implementation of the medium-term beach (i.e. 10m wide) with a 1m wall raise would achieve the wave overtopping standard of protection for return periods in excess of a 1 in 200-year event in the present day.
- The results presented demonstrate that the freeboard – vertical height of the defence - is much more efficient at reducing wave overtopping rates than increasing the defence width.

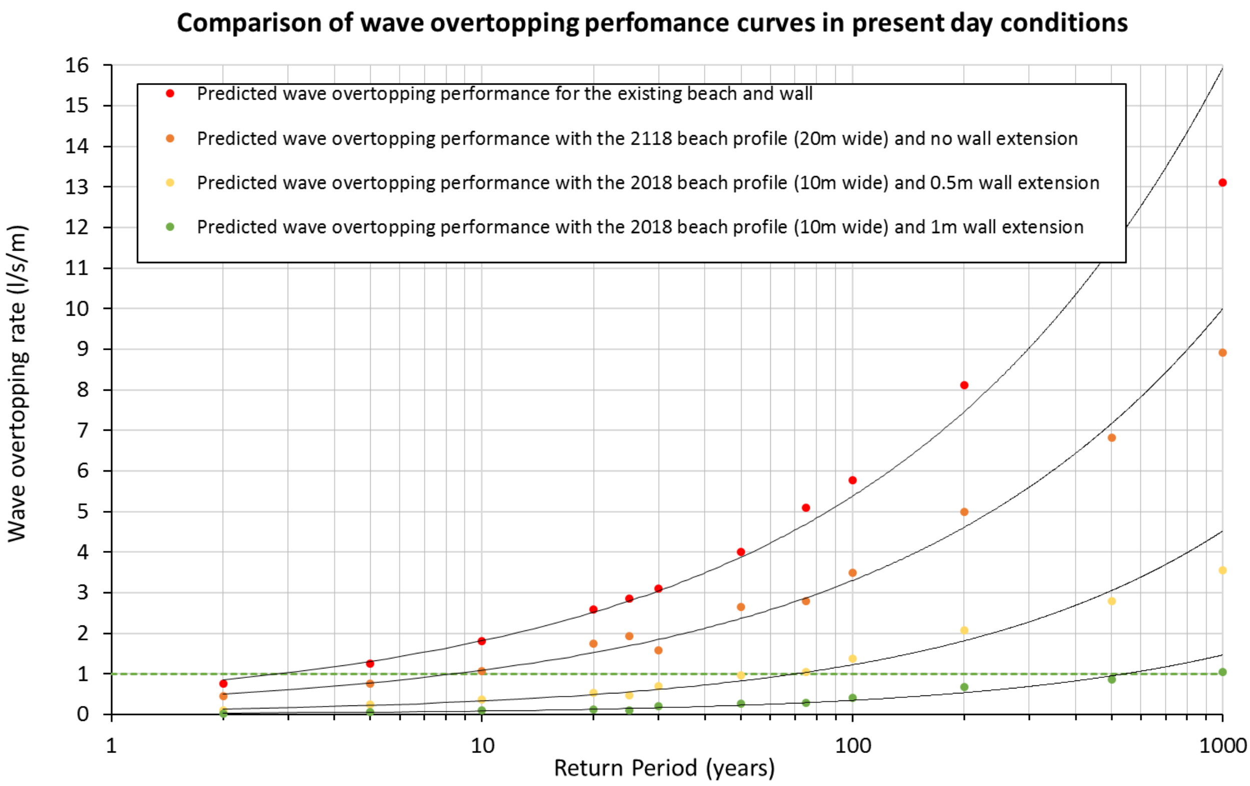


Figure 2-4 Summary of wave overtopping performances for a range of beach recharge options at central Stonehaven

Table 2-4 Summary of the 1l/s/m overtopping target threshold for a range of beach recharge options at central Stonehaven

	Existing beach and wall	2118 beach (20m wide) and no wall	2018 beach (10m wide) and 0.5m wall raise	2018 beach (10m wide) and 1m wall raise
Standard of Protection for wave overtopping design performance target (1l/s/m)	2-3 year	8-9 year	70-year	500-year

3 Wave overtopping using empirical methods

3.1 Methodology

As part of the Stonehaven Bay Coastal Flood Protection Study all wave overtopping calculations have been assessed using the ANN[1], in accordance with EurOtop II[2] as is standard industry practice. Empirical formulae provide an alternative means of estimating wave overtopping rates and have been used as a comparison to the ANN.

Several empirical formulae are presented within EurOtop II for the use in design, each intended for coastal structures with specific characteristics, such as: vertical walls, rock armour slopes, etc. The following sets of equations are the most applicable to the Stonehaven beach assessment:

- Sloped structures with relatively gentle slopes; and
- Sloped structures with very shallow foreshores.

These two empirical methods have been applied to the long-term design beach (i.e. 20m wide) without the wall raise, as a comparison to the ANN results presented in Figure 2-2.

For each of the empirical formulae, the wave overtopping rates have been calculated at the top of the beach slope, as shown in Figure 3-1 (1). Wave overtopping influence factors have then been applied in accordance with EurOtop II guidance to account for the beach crest width (2), and existing wall height (3).

These empirical methods are based upon physical model tests and are therefore only applicable for design assessment when conditions are similar. In the case of the beach study at Stonehaven, the promenade and wall influence factors are not applicable for slopes >1 in 3. Therefore, the results presented herein assume that the beach with a slope of 1 in 10 have similar reduction factors to those a 1 in 3 slope which may result in an over or underestimation of actual overtopping rates.

Following our analysis, the results for the very shallow foreshores has been excluded from this report due to unrealistic overpredictions of wave overtopping. As a result, the results only contain a comparison between the ANN and relatively gentle slopes wave overtopping results.

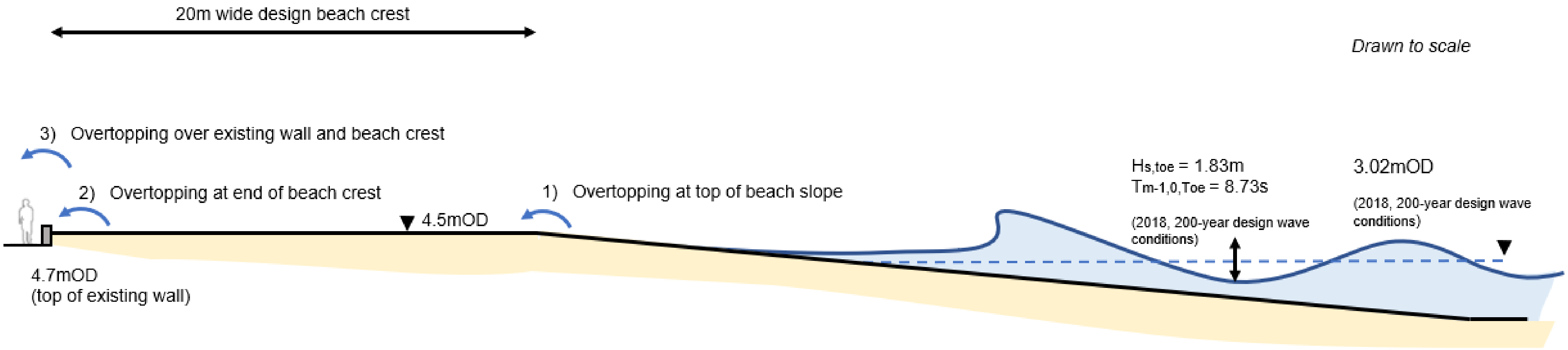


Figure 3-1 Long-term design beach profile with existing sea wall, as the base for the empirical wave overtopping calculations, with the three overtopping locations specified

3.2 Results

Table 3-1 summarises the wave overtopping rates for each of the three locations along the existing beach profile for the relatively gentle slopes EurOtop II empirical methods described in Section 3.1. Table 3-2 presents the ANN wave overtopping results for the same three locations. When compared to the wave overtopping rate of 4.6l/s/m at the top of the existing sea wall determined for the 1 in 200 year event by the ANN, the relatively gentle slopes empirical method result in a wave overtopping rate greater than this value, at 11.5l/s/m.

The EurOtop II manual suggests that the relatively gentle slopes formulae may be an underestimation of the wave overtopping, compared to the formulae at very shallow foreshores. However, given the divergence of these predictions from the ANN and XBeach-G results (see Section 6) it is believed the method for 'relatively gentle slopes' provides a better match for the site.

The comparison between the ANN and empirical formulae provides additional confidence in the order of magnitude of the mean wave overtopping results determined via the ANN, and thus the requirement that a wall raise is necessary.

Table 3-1 Wave overtopping performance of the long-term beach profile without a wall raise at central Stonehaven, as calculated by empirical formulae

Method	Location of wave overtopping calculation	Overtopping rate (l/s/m)
EurOtop II - Relatively gentle slopes	1) Top of beach slope	33.04
	2) End of beach crest	23.94
	3) Top of existing sea wall	11.48

Table 3-2 Wave overtopping performance of the long-term beach profile without a wall raise at central Stonehaven, as calculated by the Artificial Neural Network

Method	Location of wave overtopping calculation	Overtopping rate (l/s/m)
Artificial Neural Network	1) Top of beach slope	25
	2) End of beach crest	5.5
	3) Top of existing sea wall	4.6

4 Spatial distribution of wave overtopping volumes

4.1 Methodology

As an alternative to using influence factors to account for the beach width and wall height as previously discussed, a more generalised method of determining the spatial distribution of overtopped water can be assessed. The spatial distribution of overtopped water volumes is useful in determining what volumes of water are likely to remain seaward of the sea wall and what will overtop onto the promenade and could therefore affect adjacent properties. This also provides an alternative means to confirming and supporting the ANN results.

In order to calculate the spatial distribution, the following rules from EurOtop II[2] (pg. 223) can be applied:

- 50% of the violently-overtopped discharge will land with a distance of $0.06 \times L_{m-1,0}$
- 90% of the violently-overtopped discharge will land with a distance of $0.20 \times L_{m-1,0}$
- 95% of the violently-overtopped discharge will land with a distance of $0.25 \times L_{m-1,0}$

Where $L_{m-1,0}$ is the deep water wavelength.

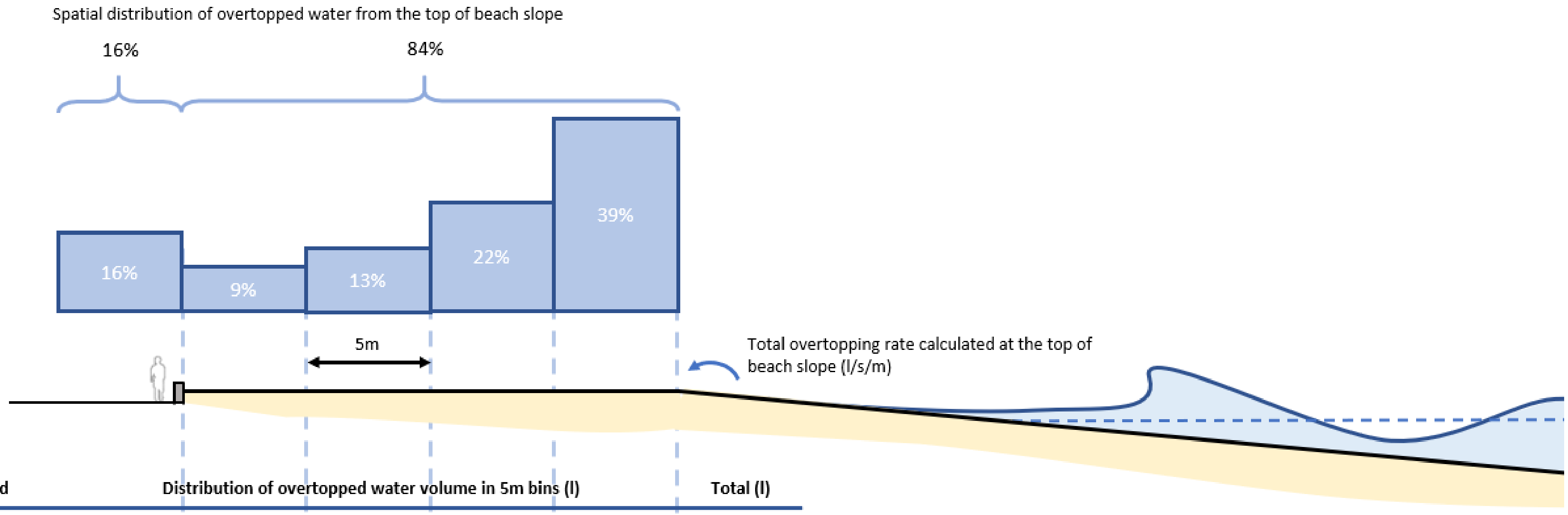
These rules have been applied to the long-term design beach (i.e. 20m wide) without the wall raise, for the overtopping values determined through the ANN and empirical formulae within Section 3.

4.2 Results

The spatial distribution at Stonehaven is presented in Figure 4-1. Each 5m 'bin' has been assigned a percentage of wave overtopping water volume that will land within that bin. As such, approximately 16% of the total wave overtopping volume passes over the existing defence line and has the potential to cause damage to the promenade and adjacent properties.

The overtopping predictions from this method provide rates between 4 and 5.3l/s/m to the rear of the existing wall; these values are directly comparable to those from the ANN, which estimates overtopping rates of 4.6l/s/m (as shown in Table 3-2).

It should be noted that this spatial distribution calculation has been developed for wave overtopping at vertical structures and is not strictly applicable to beach structures. However, given the good correlation between calculated overtopping rates and the distribution patterns, the results are useful for illustrating the spreading effect of violently overtopped water.



Method	Distribution of overtopped water volume in 5m bins (l)					Total (l)
Neural Network	4.0	2.3	3.3	5.5	9.8	25
EurOtop 2 - 'Relatively gentle slopes'	5.3	3.1	4.3	7.4	12.8	33

Figure 4-1 Long-term design beach profile with existing sea wall and the resulting spatial distribution of wave overtopping volumes

5 Run-up

5.1 Methodology

Run-up is defined as the vertical height reached by waves breaking on a sloping structure measured in meters from the extreme still water level (3.03mAOD) to the point which is exceeded by only 2% of incoming waves. This calculation provides an alternative means to confirm and support the order of magnitude of the wave overtopping results predicted through the ANN, as high run-up would support wave overtopping at the landward end of the crest, whereas low run-up heights would indicate lower rates.

A visual representation of run-up is shown in Figure 5-1.

A total of six methodologies from the latest research and prediction methods within literature have been used to calculate the run-up at the shingle beach at Stonehaven.

5.2 Results

The minimum, maximum and average values from the run-up calculations are presented in Figure 5-1. The run-up ranges from 2.3m-7.6m, as also presented in Table 5-1.

Table 5-1 Wave run-up of the long-term beach profile at central Stonehaven, as calculated by a range of methodologies

Method	Application	Run up, Ru2% (m)
EurOtop (2007)	Beaches	4.43
EurOtop II (2018)[2]	General slopes	2.32 to 4.10
Poate, T., McCall, R. and Masselink, G. (2016)[3]	Gravel beaches	5.29 to 7.68
Polidoro, A., Dornbusch, U. and Pullen, T. (2013)[4]	Mixed beaches	4.37
Stockdon, H. F., Holman, R. A., Howd, P. A. and Sallenger, A. H. (2006)[5]	Mixed	3.3
Shingle B (2019)[6] – online tool	Gravel beach	6.51
Average of all calculations	**-**	**4.84**

[3] Poate, T., McCall, R. and Masselink, G. (2016) A new parameterisation for runup on gravel beaches

[4] Polidoro, A., Dornbusch, U. and Pullen, T. (2013) Improved Maximum Run-Up Formula for Mixed Beaches Based on Field Data

[5] Stockdon, H. F., Holman, R. A., Howd, P. A. and Sallenger, A. H. (2006) Empirical parameterization of setup, swash, and runup.

In reality, the calculated run-height may not necessarily be reached by the projected broken wave as the calculations assumed that the beach slope has an infinite length, and so represents a theoretical reach of the run-up height. The run-up value is, however, useful for demonstrating the momentum contained within the waves.

Historically, wave run-up has been used to define the maximum design crest height of an embankment so that waves do not run-up and overtop the defence crest. This could be true of beach design also, although if run-up exceeds the beach crest, overtopping and overwashing processes occur causing erosion and deposition of sediments landward of the beach slope.

Nonetheless, the run-up values calculated are relatively high, which would indicate that wave overtopping in the order of magnitude predicted by the ANN is likely. Furthermore, as run-up heights exceed the beach crest level by several meters, it is also highly likely that the shingle beach will respond accordingly through the processes of erosion and accretion. The shingle entrained within broken waves would be carried violently toward the landward extent of the beach crest, posing a severe hazard to pedestrians and properties; this is as has been experienced during historical events in Stonehaven. Further analysis on the morphological response of the design beach profile is provided in Section 6.

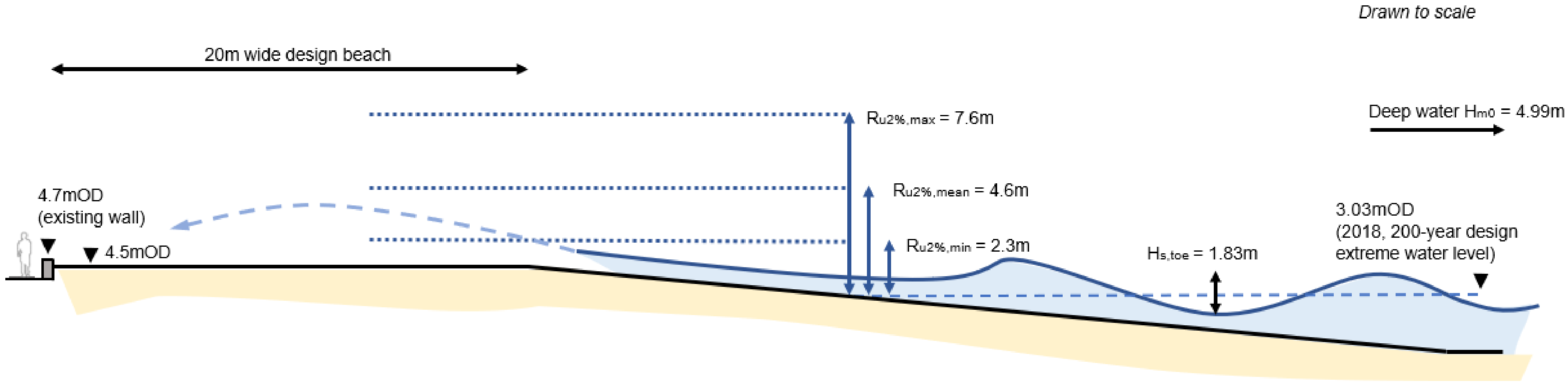


Figure 5-1 Long-term beach profile with statistical measures of wave run-up

6 XBeach-G modelling

During extreme events, the design beach will respond dynamically to the wave conditions, changing in cross-section profile. Depending on these changes the overtopping rate at the wall may increase or decrease.

The overtopping calculations undertaken previously are based on fixed profile structures and therefore do not account for such a response. While beach response is implicitly included in some of the wave runup height estimates, these cannot be translated to overtopping rate.

To better assess the potential changes in overtopping rate while accounting the response of the profile, XBeach-G numerical models were set up. These allow for the modelling of the individual waves within the design conditions and provide estimates of the overtopping rate at the wall based on wave breaking and runup along the crest.

The following scenarios have been modelling in XBeach-G to support this further design process:

1. Modelling of the 200-year design event with a fixed profile;
2. Modelling of the 200-year design event with a dynamic profile;

To provide context to the results, additional simulations based on the 2012 event conditions have also been conducted.

6.1 Methodology

6.1.1 Model Build

The model geometry was set up based on the long-term recharge design profile (Appendix 0) and extended offshore (to -12mAOD) using the available bathymetry data. The ground beyond the wall was set to slope downwards to make sure sediment and water movement would not affect the storm response of the profile near the wall/area of interest (Figure 6-1).

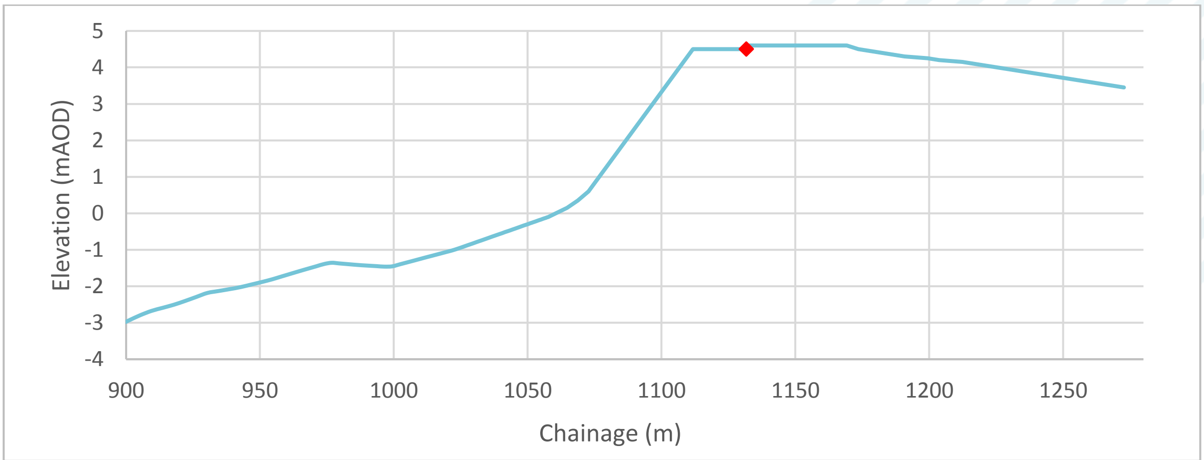


Figure 6-1: Profile schematisation including location of sea wall in red

At this stage in the process the grain size distribution of the design beach has yet to be determined. The working assumption for the XBeach-G models is that sediment would have a D_{50} of 20mm; similar to the top of the existing beach.

Figure 6-2: Beach sediment at XS17

Given the lack of detailed information about how the beach responds during extreme events there is no way that the model can be calibrated. To provide an initial estimate, Shingle-B[6] was used to estimate the predicted response of the profile to the defined input wave and water level conditions.

Shingle-B is a parametric model for estimating the morphodynamic response of shingle beaches. It is web-based, and the input parameters can be altered, along with the initial beach profile, to simulate the beach response. The profile response to the input wave conditions (deepwater from Table 6-1) and the concept design profile estimates the following response:

- Creation of a large berm landward of the crest
- Erosion of the upper beach and deposition in the surfzone
- Accretion of the beach below the surf zone
- Change in beach slope around the 2mAOD contour

A summary of the response can be seen in Figure 6-3, with the full report provided in Appendix B. It should be noted that this estimates that almost all of the design beach crest will be lost.

This response mechanism is used to sense check the validity of the XBeach-G modelling.

6 Shingle-B Online Predicted Shingle Beach Profile. Accessed 1/8/19 https://www.channelcoast.org/shingle/

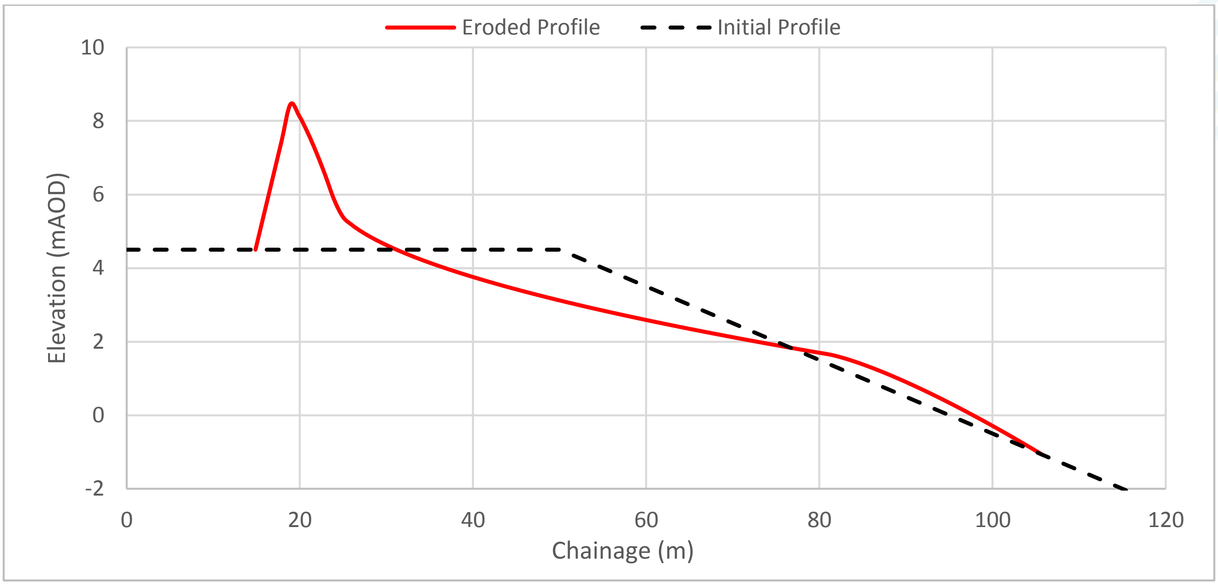


Figure 6-3: Shingle-B estimated profile response

6.1.2 Boundary conditions

For the overtopping estimates, the design conditions have been estimated from a 2D SWAN wave transformation model that represents the entire bay and extends out into very deep water. For the XBeach modelling, conditions for the same event have been used, but at the location of the historic wave buoy (located at -12mAOD).

As the model used here is 1D, these wave conditions will be propagated shoreward in a "flume" like manner. Given the complex bathymetry and 2D processes that occur in the bay (e.g. interaction with the rock platforms, refraction, etc.), such an approach will likely overestimate the wave conditions reaching the beach.

To avoid this and provide comparable results between XBeach-G and EurOtop, a check was done on the transformation of wave heights within the model.

The variance in water surface elevation (zs) at the -0.6mAOD contour was extracted and used to calculate H_s of the nearshore waves using the following equation:

$$H_{m0} = 4\sqrt{var_{zs}}$$

The offshore waves at the boundary were then reduced to provide results that matched the conditions at the base of the beach ($H_{m0,t}$ = 1.83m). It was found that a 45% reduction in the offshore wave heights were required (Table 6-1).

Table 6-1: Offshore wave conditions – 200-year design conditions

Parameter	Conditions at buoy	Model inputs
Hs (m)	4.99	2.99
Tp (s)	10.94	8.47
Peak Water Level (mAOD)	3.02	3.02

A 12-hour tidal series was created, peaking at the peak 200-year design condition water level of 3.02mAOD. The wave conditions were input as a constant level throughout the storm event.

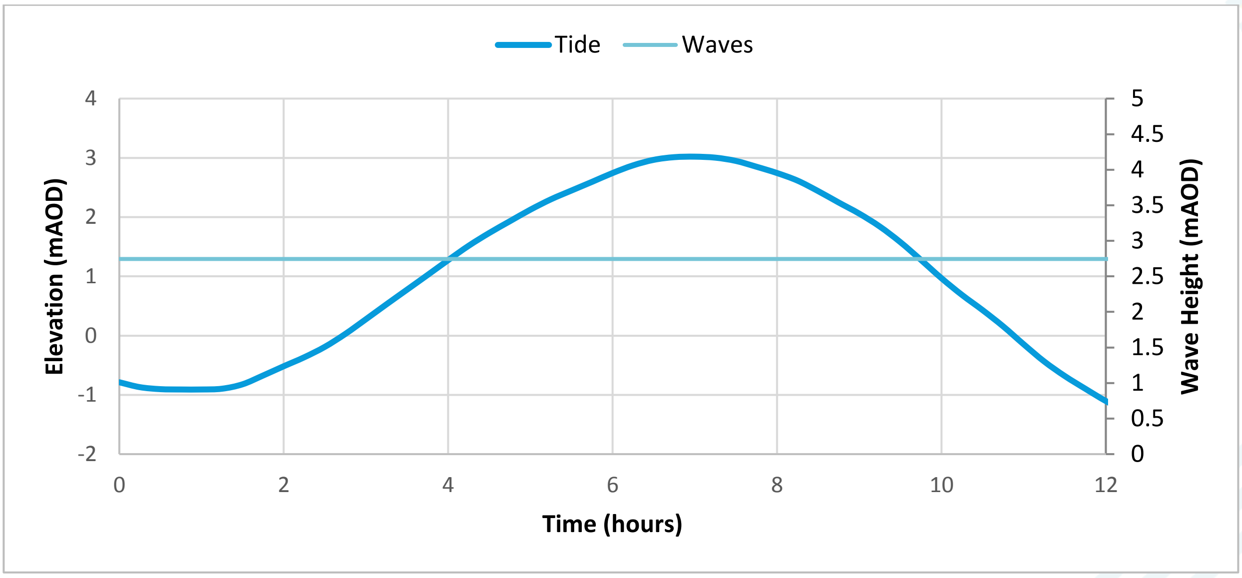


Figure 6-4: 200-year design event boundary conditions

6.2 Results

6.2.1 200-year design conditions

Two models were set up and run with the present day 200-year design conditions; one allowed for dynamic profile response, and one did not. This allows the impact of sediment movement on profile response and flow rates to be analysed.

Profile response

The first stage in the analysis is to assess the morphodynamic response of the profile and compare with that estimated using Shingle-B. Technically, as XBeach explicitly solves the processes for the given beach conditions, it should be a more accurate model than Shingle-B. In this case, given the uncertainty of the profile response, the response mechanism of Shingle-B will provide a good comparison with the XBeach results.

The XBeach results show that beach experiences significant erosion at the crest, with the 4.5m contour retreating 7m, and a build-up of 0.2m of sediment in front of the location of the wall (Figure 6-5). The upper beach slope becomes steeper and the lower beach becomes less steep, as the eroded sediment from the upper beach is transported to the lower beach.

Approximately 0.33m^3/m of sediment is transported landward onto the path and lost from the beach.

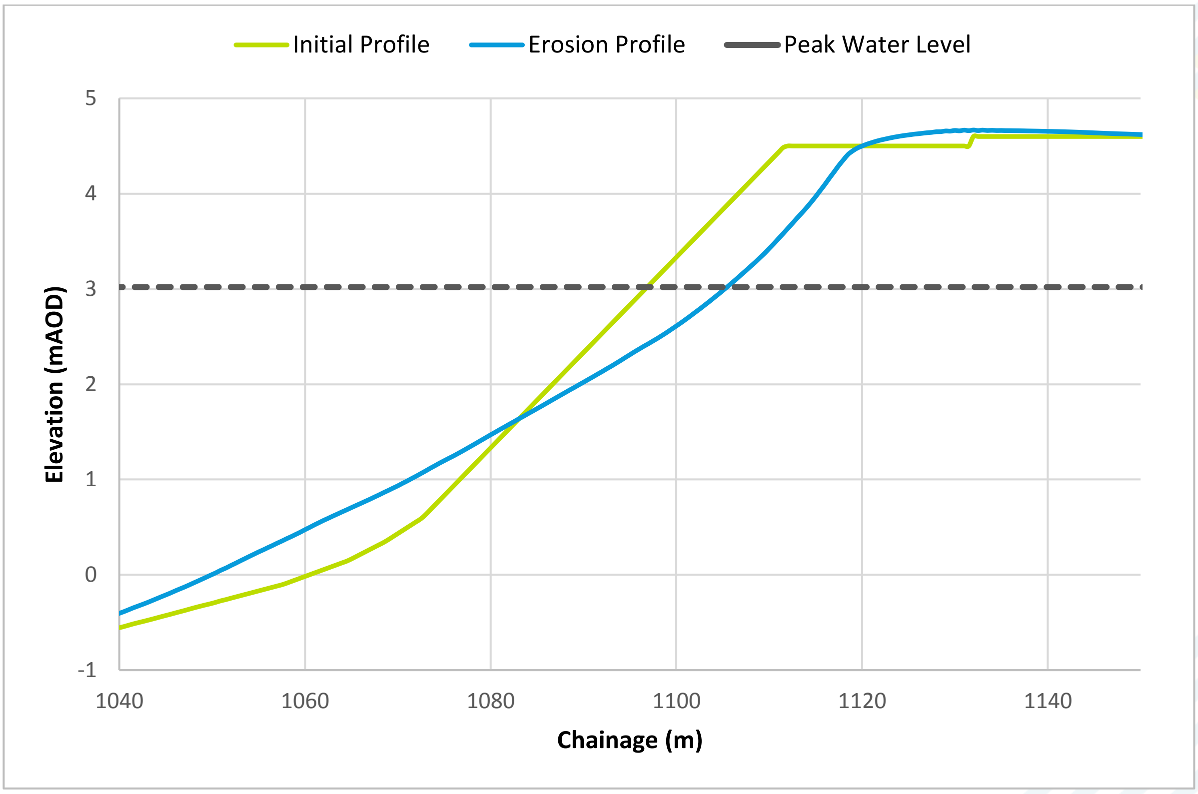


Figure 6-5: Eroded beach profile using 200-year design conditions

While overall this is comparable to Shingle-B, both the erosion of the crest and the building of a berm are significantly less. It is likely that this is due to flatter foreshore that exists in Stonehaven Bay (typical of mixed beaches), which are less prevalent on the steep gravel beaches in England upon which the Shingle-B responses have been developed.

Average overtopping rates

To estimate the potential overtopping rates during the 200-year design event, estimates of flow rate at the point of the existing wall (e.g. 20m along the crest) were taken from the model (Figure 6-1)**Error! Reference source not found.**.

This was done in two ways:

1. Average flow rate over 15-minute periods
2. Instantaneous flow rates at one second intervals during the peak of the event

The results for the 15-minute averaged flow are provided in (Figure 6-6) and show the following:

- The highest flow rate for the model with a fixed profile is **17.9l/s/m**,
- The highest flow rate for the model with a dynamic profile is **4.2l/s/m**.

During the storm event, the flow rate is above the design threshold of 1l/s/m for 1.5 hours for the dynamic profile, and for 2 hours for the fixed profile model.

This shows that by allowing the profile to respond to the wave conditions, the estimated flows at the wall reduce significantly, compared to the fixed profile. This is due to the steepening of the top section of the beach (from a 1 in 10 slope, to a 1 in 9 slope), the shallowing of the lower section of beach (from a 1 in 10 slope to a 1 in 19 slope) along with building of the berm. However, even with this reduction, the rate is still four times greater than the target design rate of 1l/s/m.

It is clear that sediment movement is a key factor in reducing overtopping rates at the wall, however there is an uncertainty as to how long the beach will protect the community for, if numerous storm events occur and cause continuous sediment erosion to a beach profile that has not fully recovered from the previous storm event. It should also be noted that this is only considering losses to the system in cross shore. It would be anticipated that longshore movement would further increase the losses to the system and therefore further increase overtopping.

It should be noted that the peak rate with the fixed profile is similar to the empirically estimated overtopping rates from the EurOtop equations (Table 3-1).

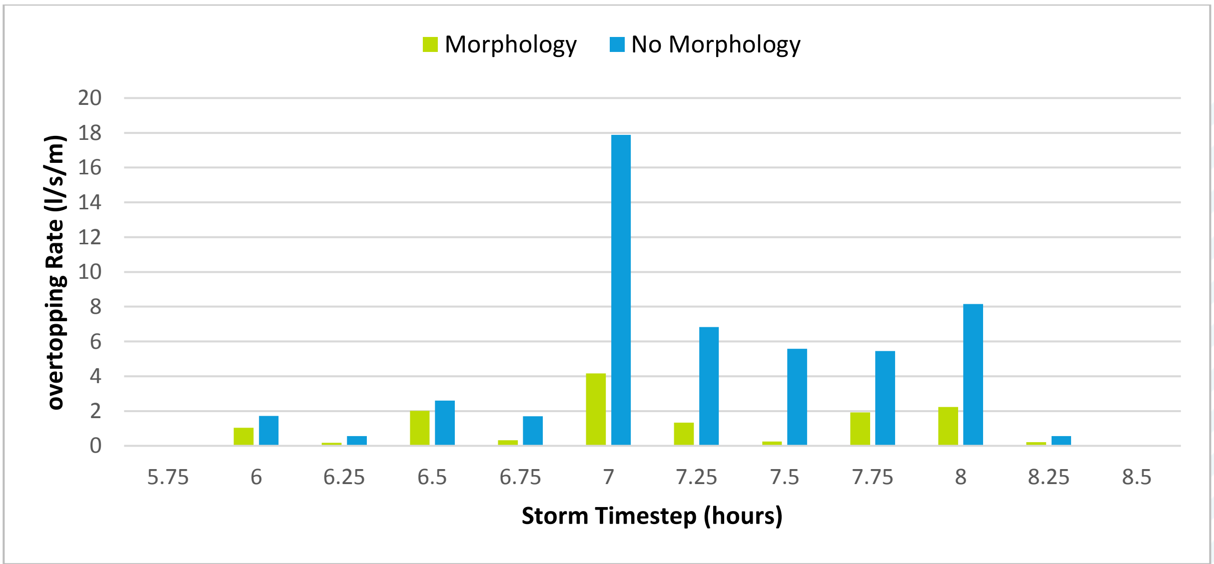


Figure 6-6: Average overtopping rates over peak of the storm event (l/s/m)

Cumulative volume

The instantaneous flow rates at the wall over the peak three hours of the event were analysed to estimate the potential volume of water that will accumulate behind the defences.

This cumulative overtopping volume is provided in Figure 6-7**Error! Reference source not found.** and shows that there is a reduction from 47m^3/m to 12m^3/m associated with the fixed and dynamic profile respectively, equating to a reduction of 75%.

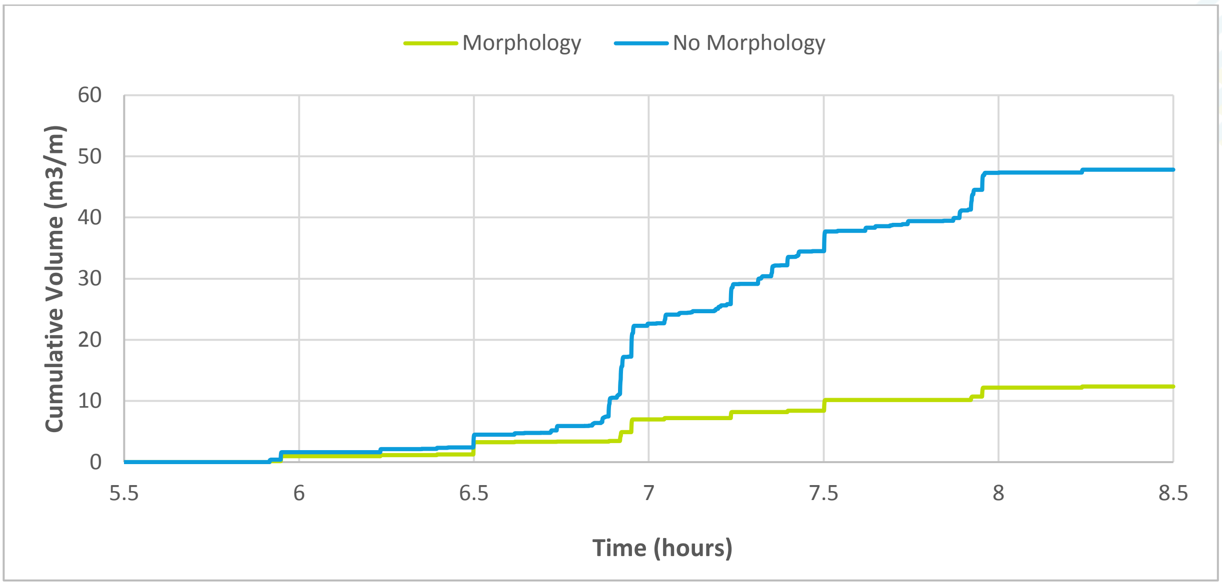


Figure 6-7: Cumulative volume at the location of the wall over the peak of the storm event

6.3 2012 event

To provide context to the protection offered by the design beach, the same steps were undertaken to analyse the profile response and overtopping rates for the December 2012 storm event.

An identical input profile was used along with conditions from the wave buoy (Table 6-2). These were reduced by 50% to provide results that matched the conditions at the base of the beach ($H_{m0,t}$ = 1.67m).

Table 6-2: Offshore wave Conditions – 2012 event

Parameter	Conditions at buoy	Model inputs
Hs (m)	8.56	4.28
Tp (s)	10.52	7.44
Peak Water Level (mAOD)	2.74	2.74

A tidal graph was created, peaking at the peak water level for the event of 2.74mAOD (Figure 6-8). Two models were run as above; one with and one without the morphology module. Data was available on the main wave direction for this event, and this was inputted into the model, ranging between 257° and 271° (default is 270° where waves approach the shore perpendicularly).

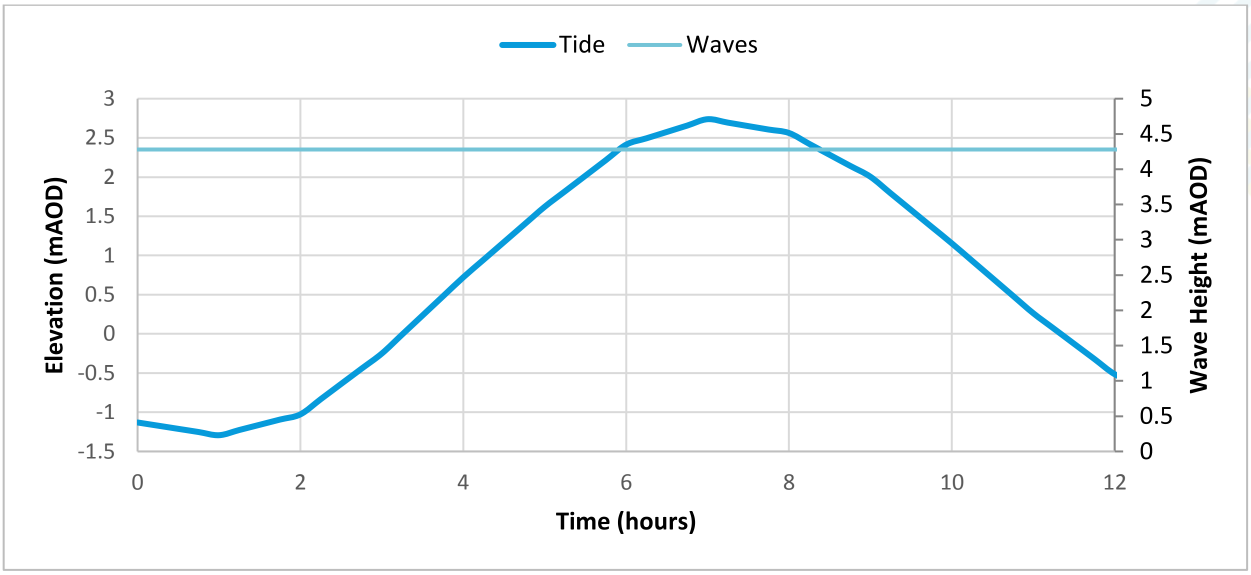


Figure 6-8: 2012 boundary conditions

Profile response

The model shows that the beach responds in a similar manner to the 200-year event, experiencing erosion of the crest, with the 4.5m contour retreating 4m, and the building of a small berm on the crest (Figure 6-9). The upper beach steepens and much of the eroded sediment from the upper beach accumulates in the lower beach, below the MHWS location.

Generally, the erosion from this event is of a smaller magnitude than that estimated for the 200-year design conditions model, which is as expected as the water levels and wave conditions are significantly larger in the 200-year event.

Approximately 0.2m^3/m of sediment is transported landward onto the path and lost from the beach.

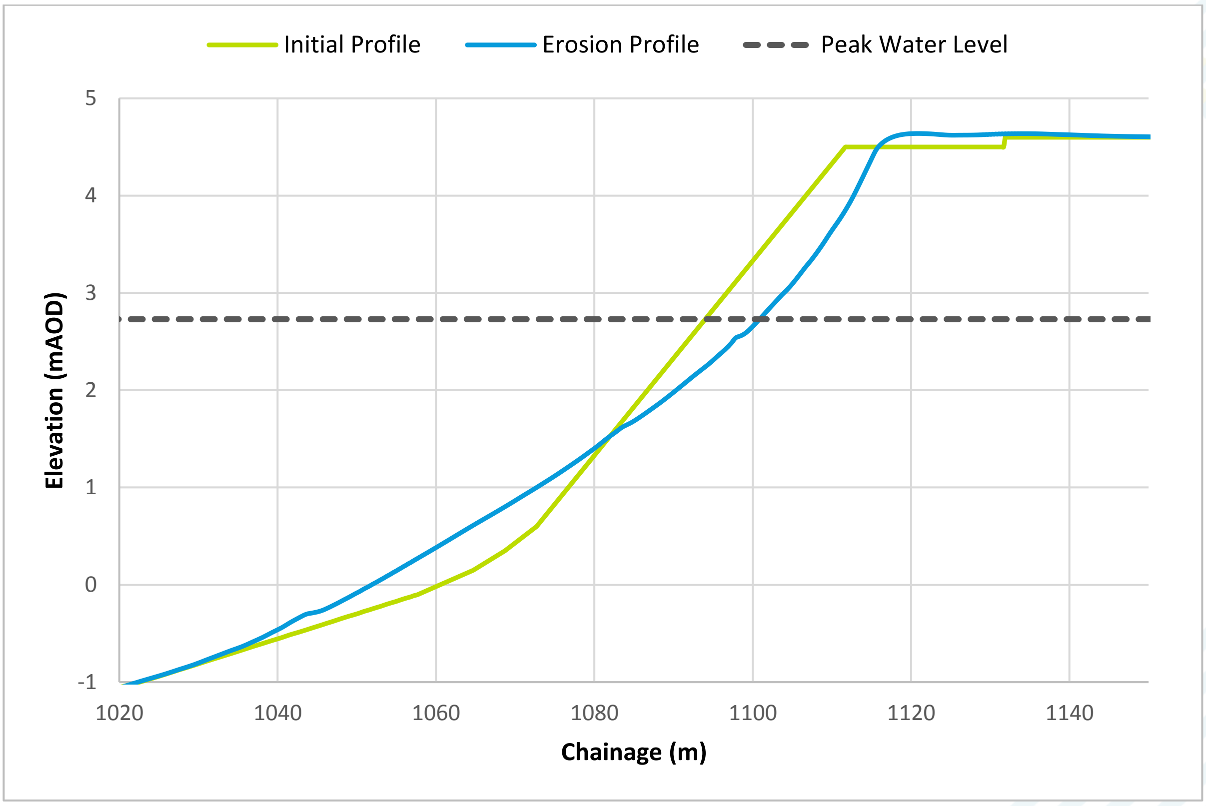


Figure 6-9: Eroded beach profile using 2012 storm event conditions

Average overtopping rates

The average flow rates over 15-minute intervals were again analysed over the peak of the event (Figure 6-10). This shows that the highest estimated overtopping rate for the model with a fixed profile was 3.8l/s/m, and 3.0l/s/m for the model with a dynamic profile.

While these rates are smaller than those experienced during the 200-year design conditions (particularly for the fixed profile) it is shown that the response of the profile under these conditions is not as effective in reducing the flow rates. It is likely due to the lower sea level resulting in a smaller berm being built, proving less effective at reducing overtopping rates at the wall.

This shows that the design standard overtopping rate of 1l/s/m is still exceeded for the 2012 event conditions.

JBA Project Code	2018s0343
Contract	Stonehaven Bay Coastal Flood Protection Study
Client	Dougall Baillie Associates / Aberdeenshire Council
Day, Date and Time	15th August 2019
Author	Johan Skanberg-Tippen, Amelia Wright, Hannah Otton
Reviewer / Sign-off	Douglas Pender / Nicola Buckley
Subject	Wave overtopping beach design technical note

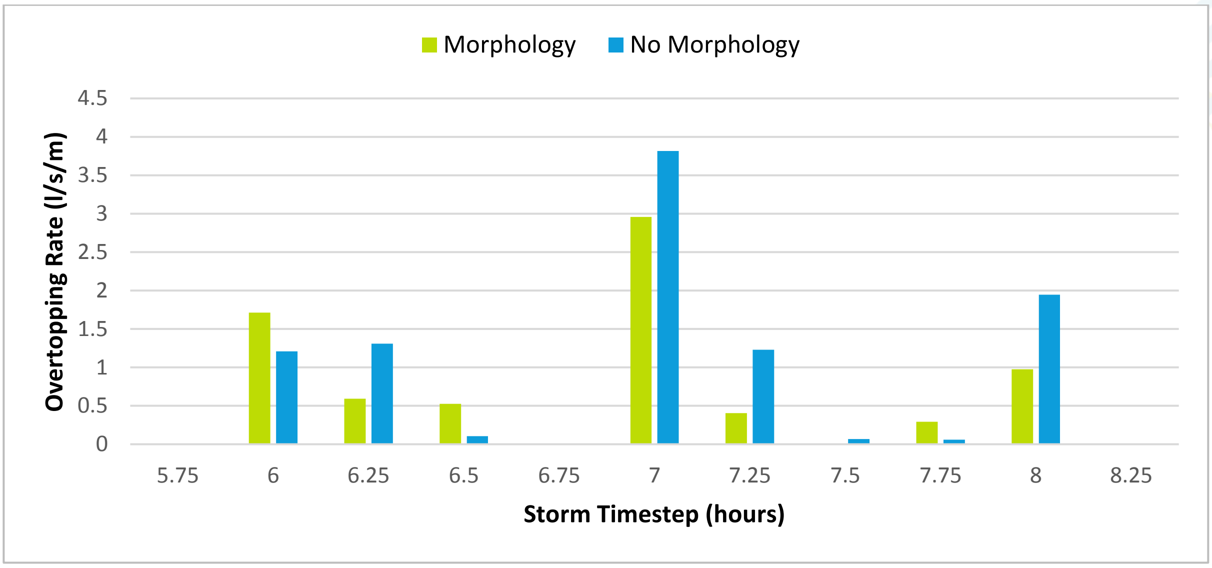


Figure 6-10: Average overtopping rates over peak of storm event (l/s/m)

Cumulative volume

The cumulative volume graph shows a significantly smaller volume of overtopping compared to the 200-year event, as would be expected with lower water levels. The total volume at the location of the wall is 9.2m³/m for the fixed profile model, and 6.5 m³/m for the dynamic profile model.

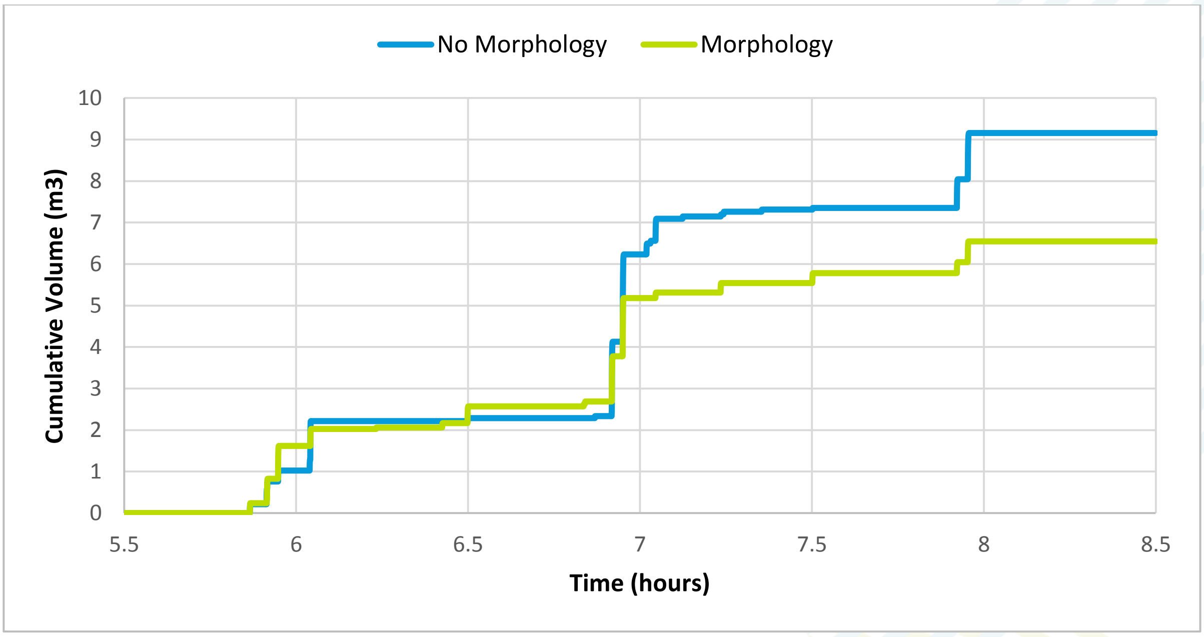


Figure 6-11: Cumulative discharge at the location of the wall over the peak 3 hours of the storm event

6.4 Sensitivity testing

A high degree of confidence in the XBeach model results is only possible if the model can be calibrated and validated against observed conditions. To demonstrate the implications of some of the key assumptions made here, some sensitivity testing was undertaken for the 200-year design model (dynamic profile). These were:

1. Making no modification to the wave conditions at the boundary;
2. Increasing the hydraulic conductivity of the beach (kx) to 0.02m/s (default = 0.01m/s);
3. Combination of 1 and 2

The results of these tests are provided in Figure 6-12, Figure 6-13 and Table 6-3.

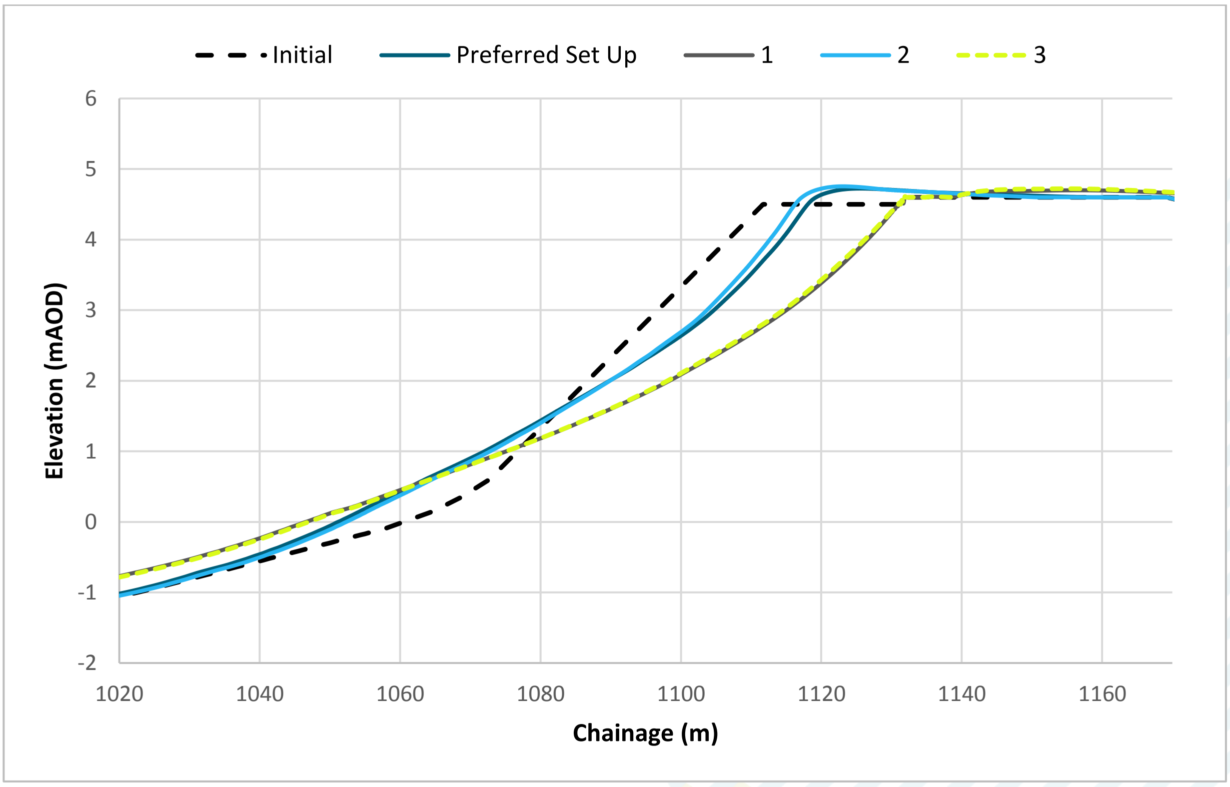


Figure 6-12: Sensitivity tests erosion profiles

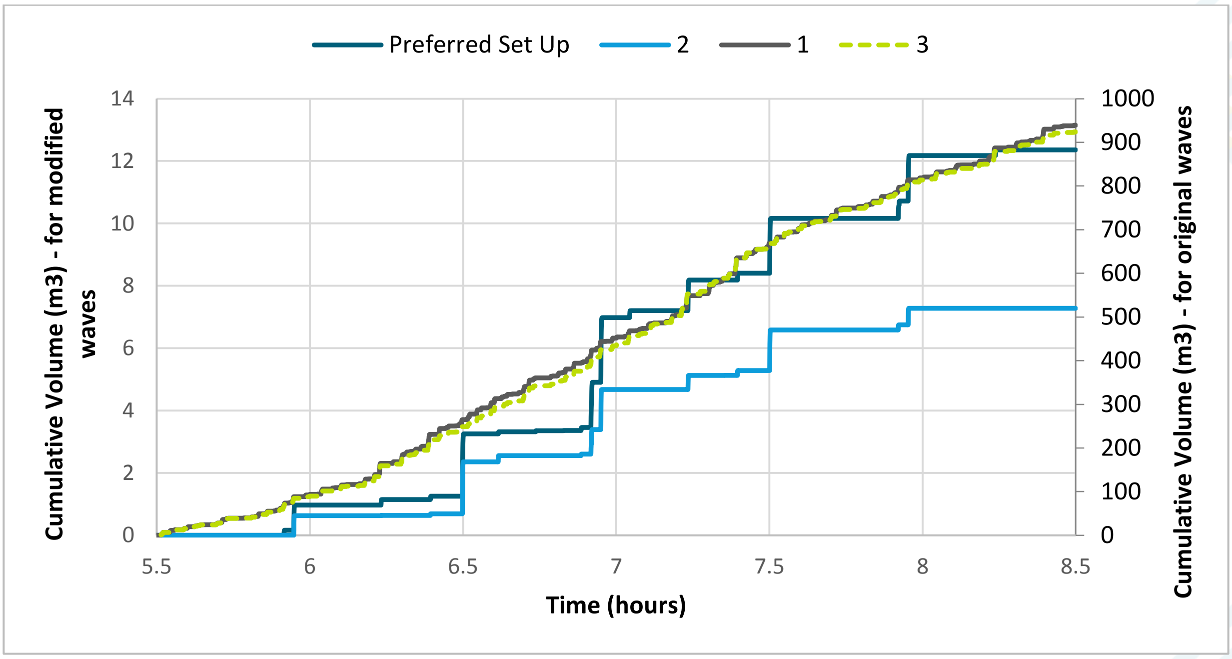


Figure 6-13: Sensitivity Tests cumulative volume

Table 6-3: Sensitivity tests – maximum 15-minute average flow rates and cumulative volume

Model Scenario	Max Average Flow Rate (l/s/m)	Cumulative Volume (m³)
Preferred Set Up	4.3	12.36
1. Non-modified waves	172.6	939.22
2. Increased hydraulic conductivity	2.4	7.28
3. Both non-modified waves and increased hydraulic conductivity	177.2	923.95

6.5 Conclusions

Morphodynamic modelling of the beach has shown that during a storm event the crest will erode to some degree, sediment will accumulate across the lower beach and a berm may form landward of the location of the wall, leading to an overall steeper upper beach slope and a shallower lower beach slope.

The main conclusions following the modelling include:

- For the fixed profile model, flow rates are high and comparable to the EurOtop II ANN wave overtopping rates. The dynamic profile model helps to reduce the overtopping rates but still results in flow rates that exceed the desirable limit of 1l/s/m.

- Approximately 7m of the crest width (30%) is likely to be lost during a 200-year storm event. This will potentially significantly reduce the performance of the beach should multiple events occur in quick succession.
- While it is likely that sediment transported offshore will return to the upper beach under calm conditions, longshore-gradients may temporarily move this around the bay, however the profile and topographic surveys don't indicate any long-term loss in volume. There is not sufficient information to understand how quickly the profiles can recover after extreme conditions.

7 Previous study recommendations

JBA Consulting's proposal to incorporate a 1m wall raise with the long-term beach profile (i.e. 20m wide) is not a new idea, with many previous studies concluding that in addition to a larger beach profile, a wall raise is required. This section summarises the recommendations of those reports.

- Stonehaven Coastal Frontage Assessment – JBA Consulting, 2014
  - Beach crest width of 15-31m, at 3.0mAOD, with a 0.5m wall raise to achieve present day 5l/s/m wave overtopping thresholds
  - Beach crest width of 12m, at 4.5mAOD, with a 0.5m wall raise to achieve present day 5l/s/m wave overtopping thresholds
  - A wall raise of up to 2m would be required to achieve 5l/s/m thresholds in the future
- Inverbervie and Rosehearty Beach Management (TN DDM6256-02) – HR Wallingford, 2009
  - "Minimum beach widths" would be required
  - In North Stonehaven, despite the placement of rock armour in 2006, a wall raise is recommended to reduce wave overtopping further
- Wave Overtopping, Crovis, Whitehills and Stonehaven Assessment and Mitigation Study (Report EX 5310) – HR Wallingford, 2006
  - A minimum 0.5m wall raise is required, and up to 2m would be required to achieve 5l/s/m thresholds but HR Wallingford deems this is still not tolerable
  - Beach crest at 4mAOD with a 1.2m wall raise to achieve 1l/s/m as deemed acceptable by HR Wallingford
- Stonehaven Seawall, Aberdeenshire, Feasibility Study of Improvements (Report EX 3731) – HR Wallingford 1998
  - Beach nourishment would help reduce overtopping, although no specific dimensions of the beach are provided
  - A wall raise of 0.5-1m would not achieve acceptable wave overtopping rates
  - A 3.6m wall raise (up to 8.3mOD) is required to achieve tolerable overtopping thresholds

8 Conclusions and recommendations

8.1 Overtopping design

Based upon the results of the ANN, if the 20m wide (long-term) beach design is built in present-day conditions, without the effect of climate change, the 1l/s/m wave overtopping performance standard would be exceeded on average every 8 to 9 years. Typically, for high-risk coastal sites where public safety and infrastructure are critical, the return period for this threshold is recommended to be set at 1 in 200-years.

Alternative means of calculating wave overtopping rates - empirical methods, spatial distributions, run-up - all estimate that the 20m wide long-term beach without raising the sea wall will result in overtopping in the order of 4-10l/s/m for the 200-year design conditions. These alternative estimates are higher than the ANN and provide more onerous design predictions, though not necessarily more accurate.

Relaxation of the design standard could be considered by either allowing a greater overtopping rate or designing to a lower return period storm. In doing this, reflection upon the damages caused by the 2012 event with 3.8l/s/m should be balanced against what could instead be accepted. For example, should 2l/s/m instead of 1l/s/m be accepted for the 200-year event, this would still equate to approximately half the overtopping rate of the 2012 event. This relaxed design standard would be achieved with a 0.5m wall raise and the 10m wide beach, without the effects of climate change.

8.2 Final recommendation

It is concluded that the initial predictions used to develop the concept design are still valid for this stage of design, with further wave overtopping calculation methods demonstrating similar orders of magnitude to, although potentially higher rates than, the ANN predictions.

While the numerical modelling undertaken with XBeach-G shows the response of the design profile under extreme conditions will help to reduce flow rates at the base of the wall, these still exceed the target design standard. Additionally, the sensitivity of the model to input assumptions has demonstrated the level of uncertainty in the estimates at this stage in the design process.

These results, combined with the very real risk to life along the frontage, mean that we are strongly recommending that the medium-term design of the beach recharge scheme includes the raising of the existing wall, as provided in the concept design drawings.

The large overtopping rates presented are the result of the low freeboard – the measure between the extreme water level and the top of the defence. For this reason, raising the wall provides a much larger efficiency in reducing overtopping than is achieved by widening the beach. As sea levels rise due to climate change, this efficiency becomes even more apparent.

If the beach recharge option (C2) is taken forward, optimisation of the beach and wall profiles should be further investigated during outline and detailed design stages, meaning that a wall raise of less than 1m may be adopted. Regular topographic surveys of the beach will allow for a better understanding of the existing morphodynamic response at Stonehaven, which can be incorporated into the design. This process may also show that sheltered areas of the bay will be sufficiently defended with a smaller new wall relative to the 'hot spots' in the centre and north of the bay, where the concept design is based.

A C2 concept design

AKI-JBAU-00-00-DR-C-3002_Section_C2

B Shingle-B report

AKI-JBAU-00-00-TN-C-0004-S3-P01-ShingleB_report

C XBeach-G animations

AKI-JBAU-00-00-AM-HM-0001-S1-P01-XBeach_animation

AKI-JBAU-00-00-AM-HM-0002-S1-P01-XBeach_animation_full_profile

P Additional beach recharge design considerations

DESIGN TECHNICAL NOTE

JBA Project Code	2018s0343
Contract	Stonehaven Bay Coastal Flood Protection Study
Client	Dougall Baillie Associates / Aberdeenshire Council
Day, Date and Time	6 September 2019
Author	Johan Skanberg-Tippen, Douglas Pender
Reviewer / Sign-off	Douglas Pender
Subject	Further Design Considerations

1 Introduction

This technical note has been developed in response to the meeting with the Stonehaven Flood Action Group (SFAG) on 27 August 2018.

The intention is to demonstrate how the feedback and comments have been incorporated into the current design process; and propose further design considerations that may be required for satisfactory completion of the project.

The note is structured as follows:

- Technical response to SFAG concerns.
- Further design considerations and decisions.
- Additional considerations for project completion.

1.1 Key terminology

Several concepts are referred to in this technical note and are important to understand in the context of wave overtopping design:

- **Performance standard** - The prescribed acceptable wave overtopping rate limits for public safety, damage to infrastructure, properties and flooding. In the context of the Stonehaven study this has been set to 1l/s/m given the exposure and risk of flooding the coastline.
- **Standard of Protection** – The return period for which the performance standard is met. This is usually set to a 1 in 200-year likelihood of occurrence, or higher for safety-critical locations. Where flood risk is of less concern the Standard of Protection can be relaxed.
- **Design life** – The duration for which the coastal structure is designed last. This is set at 100 years for this study.

1.1.1 SFAG Concerns

From the meeting with SFAG the following primary concerns relating to proposed design information provided to date were:

- The raising of the promenade behind the defences will have significant impact on the seafront residents, with users being able to look directly into properties.
- There were concerns the that promenade raising would exacerbate surface water flood risk, allowing ponding against boundary walls. The design drawings showed no detail of drainage arrangements.
- The design for the new defences is based on the most exposed conditions (XS17) with no consideration given to the area sheltered by the Brachans potentially requiring a lower rear wall.
- No consideration has been given to the offshore attenuation of wave energy with the aim of reducing defence heights.
- The design drawings showed that the proposed defences would extend across the entire Central zone and there was no separate consideration for the area south of the Carron, where the wall is potentially not required.

1.2 Technical response to SFAG concerns

1.2.1 Update of design drawings

In response to the above concerns we have updated the design drawing for the Central zone (Option C2). This is provided in Appendix A and better reflects:

- The potential variation in geometry of the design at different sections along the front. This includes a note on the potential variation in wall crest and different promenade arrangements for locations with and without property boundary walls.
- Indicative detail of the crossfall to demonstrate the management of surface water and overtopping volume.
- Updating of the plan to better reflect the variation in the option that will be required to the south of the Carron. This assumption is also included in the costs developed for the economics.

1.2.2 Promenade raising

The below provides details on the technical considerations surrounding the request that the promenade not be raised in conjunction with the wall.

Engineering issues:

- Without a raised promenade, a larger wall base would be required for stability. This is because there are no favourable restoring forces from the promenade acting against the shingle beach and wave impacts. Additional measures to make the wall stable may also be required; including the use of a shear key and dowels.
- Construction becomes more complex as the promenade will need to be demolished and excavated to allow for the new wall base installation.
- Excavation for the wall base may encroach onto private property and pose a risk to property boundary walls and other structures.
- The raised promenade would have a fall toward the sea for drainage purposes. Normally, drainage points would be built into the wall at promenade level to allow overtopped water to drain back out to sea. In the current concept designs these drainage points are 0.2m above the design beach level. However, if the promenade is not raised above the design beach level, these drainage points would be constantly blocked and unmaintainable. An alternative and more costly drainage system would then need to be designed into the footpath area.
- Re-routing of services (mainly the sewer main) may be required to prevent the increased risk of clashes with a lower construction level than with a raised promenade.
- Wave overtopping design guidance states that tolerable wave overtopping rates (1 l/s/m) are based upon public having a clear view of the sea and see approaching breaking waves. If the wall is too tall, and promenade users have no clear view of incoming waves, the tolerable threshold becomes more stringent by several magnitudes - 0.03 l/s/m to 0.01 l/s/m. This performance standard could only be achieved by further increasing the height of the wall.

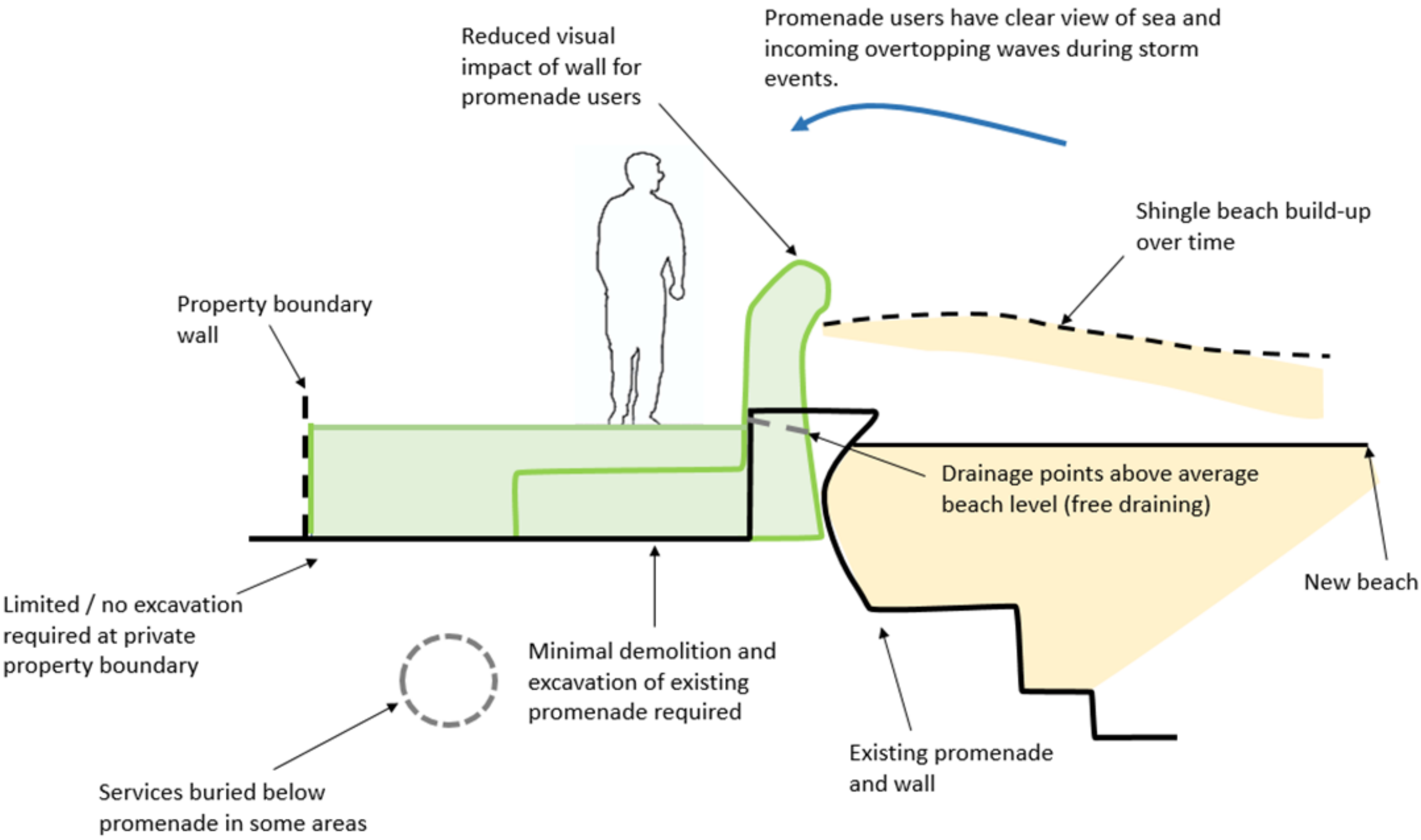
Operational issues:

- There is an increased risk of falls from height for beach users due to beach build-up against the wall. The fall distance will be almost 2m. To manage this, it would be recommended that, Aberdeenshire Council adopt a stringent maintenance programme that will effectively redistribute beach material from the wall face to discourage climbing and risk of falls.

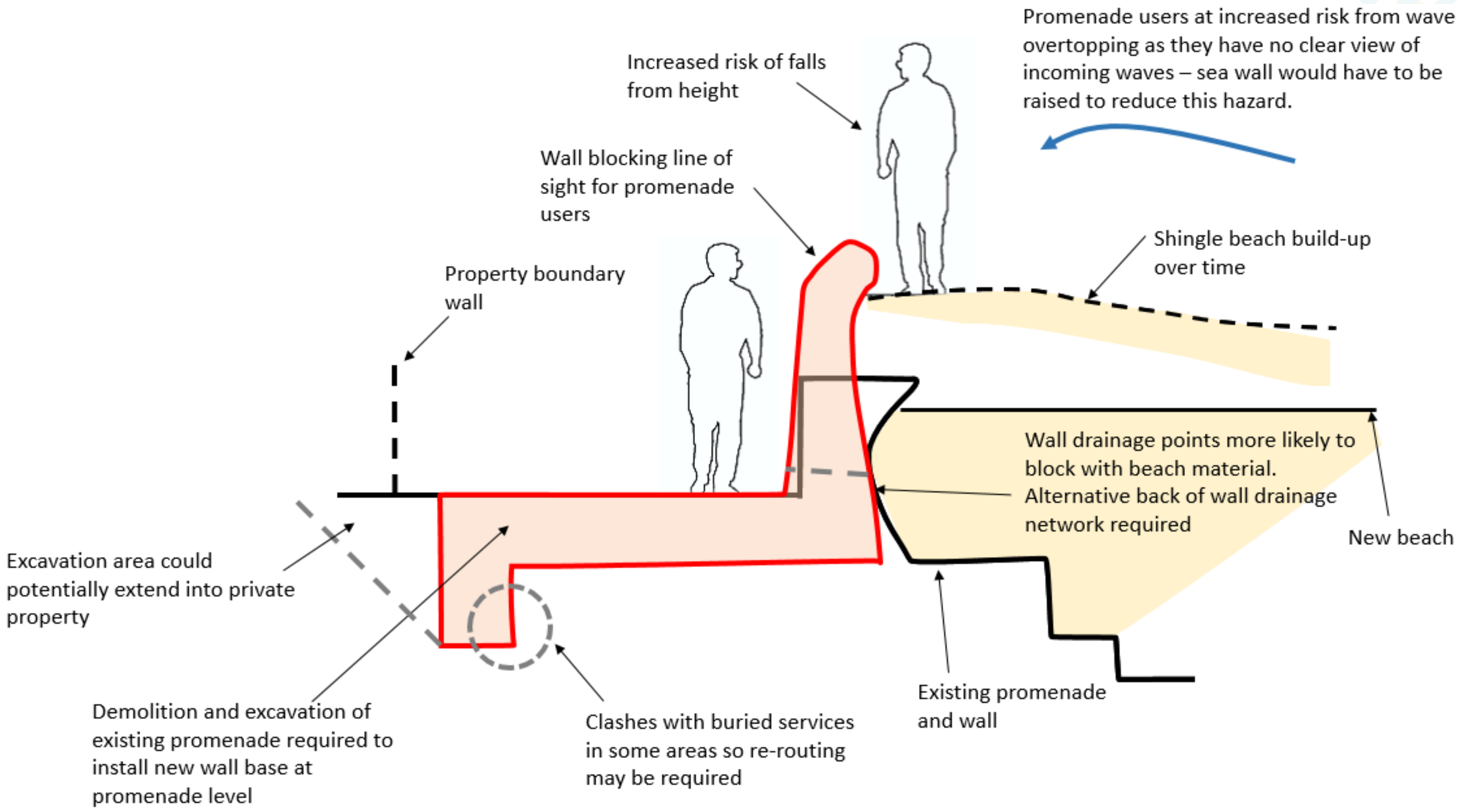
Aesthetic issues:

- Line-of-sight impacts for promenade users as the wall will be taller than most members of the public.

Existing Configuration



Configuration with no raised promenade

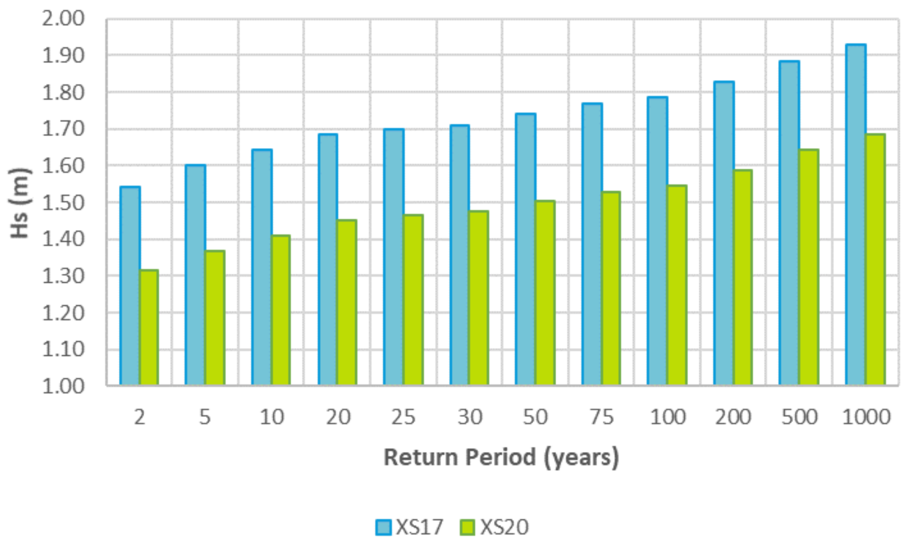


1.2.1 Offshore attenuation of wave energy

Further analysis has been conducted to investigate the potential effects of including an additional wave attenuation structure (e.g. offshore reef) to optimise the wall height in the Central zonea.

This has been implemented using the existing modelling results and the assumption that the new structure will provide a similar level of protection as currently offered by the Brachans.

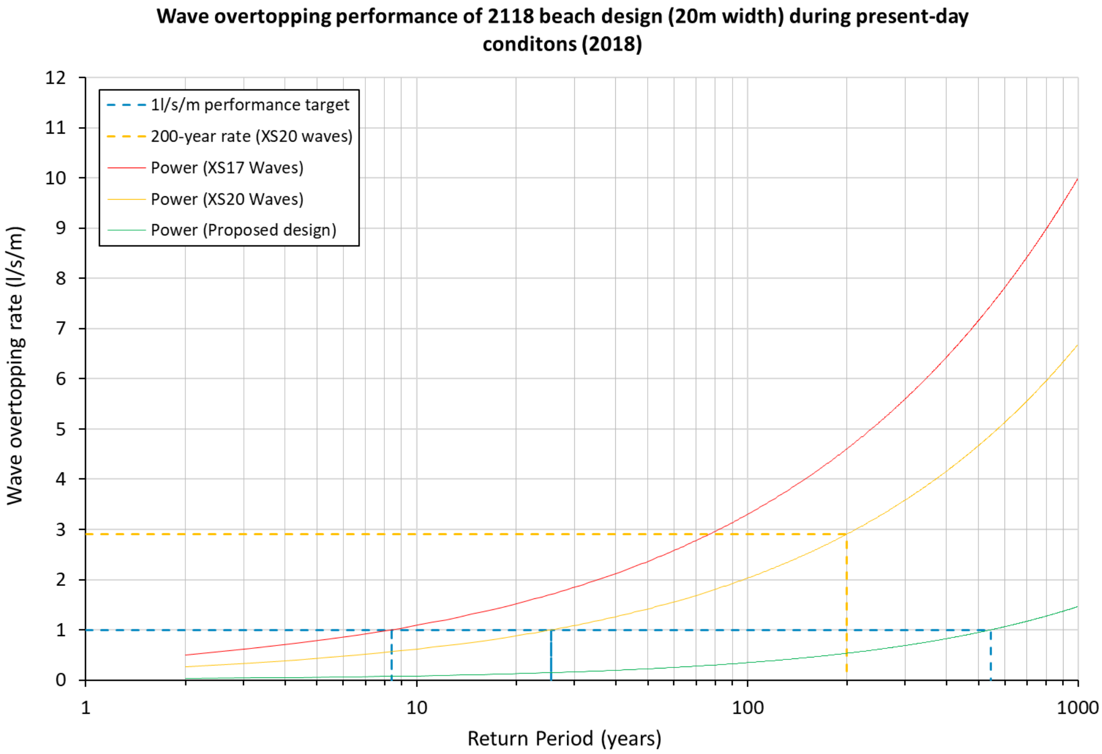
The figure below shows the variation in extreme wave height distribution at XS17 and XS20 (Brachans). This shows that the wave transformation modelling estimates the Brachans reduce wave heights by approximately 15%.



This 15% reduction was applied to the design wave conditions at X17 to demonstrate the potential improvement in overtopping performance. This is presented in the figure below and shows that, even if a similarly efficient structure were constructed offshore of XS17, the 1l/s/m performance target would not be met without raising the wall.

Further analysis showed that a design Hs of 1.23m would be required to meet this standard. This would require an offshore structure capable of reducing the 200-year wave conditions to below those that occur on average twice a year (0.5-year RP).

With this 15% reduction it is, however, possible that the wall may only require raising by 0.5m to meet the design standard. This combination is shown to result in a rate of 0.63 l/s/m for the 200-year conditions.



Wave overtopping performance of 2118 beach design (20m width) during present-day conditons (2018)
1l/s/m performance target
200-year rate (XS20 waves)
Power (XS17 Waves)
Power (XS20 Waves)
Power (Proposed design)
Wave overtopping rate (l/s/m)
Return Period (years)
0
1
2
3
4
5
6
7
8
9
10
11
12
1
10
100
1000

JBA Project Code	2018s0343
Contract	Stonehaven Bay Coastal Flood Protection Study
Client	Dougall Baillie Associates / Aberdeenshire Council
Day, Date and Time	6 September 2019
Author	Johan Skanberg-Tippen, Douglas Pender
Reviewer / Sign-off	Douglas Pender
Subject	Further Design Considerations

A Revised C2 Option Drawing

Q Economic analysis calculation sheets

Project Summary Sheet

Client/Authority				Prepared (date)	23/05/2019
Aberdeenshire Council				Printed	19/12/2019
Project name				Prepared by	DP
Stonehaven Coastal FPS				Checked by	AEP
Project reference	2018s0343			Checked date	28/05/2019
Base date for estimates (year 0)	Nov-2018				
Scaling factor (e.g. £m, £k, £)	£k	(used for all costs, losses and benefits)			
Year	0	30	75		
Discount Rate	3.5%	3.00%	2.50%		
Optimism bias adjustment factor	60%				

Costs and benefits of options

	Costs and benefits £k									
Option number	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**	**Option 7**	**Option 8**	**Option 9**	**Option 10**
Option name	Do Minimum	Wall Adaptive	Rock Adaptive	Recharge Adaptive	Wall Precautionary	Rock Precautionary	Wall Delayed	Rock Delayed	Recharge Delayed	Wall Raise
AEP or SoP (where relevant)	< 2-year	200-year + CC	200-year + CC	200-year + CC	200-year + CC	200-year + CC	200-year + CC	200-year + CC	200-year + CC	200-year
COSTS:										
PV Costs	500	7,514	8,425	21,491	8,458	9,009	4,311	4,508	10,707	1,298
Optimism bias adjustment	300	4,508	5,055	12,895	5,075	5,405	2,587	2,705	6,424	779
Total PV Costs £k	800	12,022	13,479	34,386	13,533	14,414	6,898	7,212	17,131	2,076
BENEFITS:										
PV monetised flood damages	11,360	534	534	534	378	378	534	534	534	
PV monetised flood damages (30-year)	5,599									320
PV monetised flood damages avoided		10,826	10,826	10,826	10,982	10,982	10,826	10,826	10,826	5,278
PV monetised recreational damages	841	84	168	0	84	168	84	168	0	
PV monetised recreational damages (30-year)	354									35
PV monetised recreational damages avoided (protected)		757	672	841	757	672	757	672	841	319
Total monetised PV damages £k	12,201	618	703	534	462	546	618	703	534	
Total monetised PV damages £k (30-year)	5,953									356
Total monetised PV benefits £k		11,583	11,498	11,667	11,739	11,655	11,583	11,498	11,667	5,597
PV damages (from scoring and weighting)										
PV damages avoided/benefits (from scoring and weighting)										
PV benefits from ecosystem services										
Total PV damages £k	12,201	618	703	534	462	546	618	703	534	
Total PV damages £k (30-year)	5,953									356
Total PV benefits £k		11,583	11,498	11,667	11,739	11,655	11,583	11,498	11,667	5,597
DECISION-MAKING CRITERIA:										
Based on total PV benefits (includes benefits from scoring and weighting and ecosystem services)										
Net Present Value **NPV**		-440	-1,981	-22,719	-1,795	-2,759	4,684	4,286	-5,464	3,521
Average benefit/cost ratio **BCR**		0.96	0.85	0.34	0.87	0.81	1.68	1.59	0.68	2.70
Incremental benefit/cost ratio **IBCR**		0.0	0.0	0.0	0.1	0.2	0.0	-0.3	0.0	0.4
										Highest bcr

Brief description of options:	**Name**	**Description**
Option 1	Do Minimum	Continue with current maintenance and reactive repairs of defences
Option 2	Wall Adaptive	New sea wall constructed present day and adapted (year 30) in response to climate change
Option 3	Rock Adaptive	New rock revetment constructed present day and adapted (year 30) in response to climate change
Option 4	Recharge Adaptive	New recharge scheme constructed present day and adapted (year 30) in response to climate change
Option 5	Wall Precautionary	New sea wall constructed present day that includes 2118 climate change allowance
Option 6	Rock Precautionary	New rock revetment constructed present day and adapted (year 30) in response to climate change
Option 7	Wall Delayed	Existing walls raised and new sea wall constructed (with climate change allowance) constructed year 30
Option 8	Rock Delayed	Existing walls raised and new rock revetment constructed (with climate change allowance) constructed year 30
Option 9	Recharge Delayed	Existing walls raised and new recharge scheme constructed (with climate change allowance) constructed year 30
Option 10	Wall Raise	Existing walls raised until design lfe is exceeded - 30 year appraisal only

Project Summary Sheet

Client/Authority				
Aberdeenshire Council			Prepared (date)	23/05/2019
Project name			Printed	19/12/2019
Stonehaven Coastal FPS			Prepared by	DP
Project reference	2018s0343		Checked by	AEP
Base date for estimates (year 0)	Nov-2018		Checked date	28/05/2019
Scaling factor (e.g. £m, £k, £)	£k	(used for all costs, losses and benefits)		
Year	0	30	75	
Discount Rate	3.5%	3.00%	2.50%	
Optimism bias adjustment factor	60%			

Costs and benefits of options

	Costs and benefits £k				
Option number	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**
Option name	Do Minimum	Wall Adaptive + Cowie Walls	Wall Precautionary + Cowie Walls	Recharge Adaptive + Cowie Walls	Recharge Short-term
AEP or SoP (where relevant)	< 2-year	200-year + CC	200-year + CC	200-year + CC	200-year
COSTS:					
PV Costs	500	7,963	8,977	7,793	4,751
Optimism bias adjustment	300	4,778	5,386	4,676	2,850
Total PV Costs £k	800	12,740	14,362	12,468	7,601
BENEFITS:					
PV monetised flood damages	12,595	677	375	677	
PV monetised flood damages (30-year)	6,039				338
PV monetised flood damages avoided		11,918	12,220	11,918	5,702
PV monetised recreational damages	841	84	84	0	
PV monetised recreational damages (30-year)	354				0
PV monetised recreational damages avoided (protected)		757	757	841	354
Total monetised PV damages £k	13,436	761	459	677	
Total monetised PV damages £k (30-year)	6,394				338
Total monetised PV benefits £k		12,675	12,976	12,759	6,056
PV damages (from scoring and weighting)					
PV damages avoided/benefits (from scoring and weighting)					
PV benefits from ecosystem services					
Total PV damages £k	13,436	761	459	677	
Total PV damages £k (30-year)	6,394				338
Total PV benefits £k		12,675	12,976	12,759	6,056
DECISION-MAKING CRITERIA:					
Based on total PV benefits (includes benefits from scoring and weighting and ecosystem services)					
Net Present Value **NPV**		-65	-1,386	290	-1,545
Average benefit/cost ratio **BCR**		0.99	0.90	1.02	0.80
Incremental benefit/cost ratio **IBCR**			0.2	0.1	1.4
				Highest bcr	

Brief description of options:	**Name**	**Description**
Option 1	Do Minimum	Continue with current maintenance and reactive repair of defences
Option 2	Wall Adaptive + Cowie Walls	New sea wall constructed present day and adapted (year 30) in response to climate change. New walls along River Cowie in year 30.
Option 3	Wall Precautionary + Cowie Walls	New sea wall constructed present day that includes 2118 climate change allowance. New walls along River Cowie in year 30
Option 4	Recharge Adaptive + Cowie Walls	New recharge scheme constructed present day and adapted (year 30) in response to climate change. New walls along River Cowie year 30.
Option 5	Recharge Short-term	New recharge scheme implemented until the life of structures in the north is exceeded - 30 year appraisal only

Project Summary Sheet

Client/Authority				Prepared (date)	23/05/2019
Aberdeenshire Council				Printed	19/12/2019
Project name				Prepared by	DP
Stonehaven Coastal FPS				Checked by	AEP
Project reference	2018s0343			Checked date	28/05/2019
Base date for estimates (year 0)	Nov-2018				
Scaling factor (e.g. £m, £k, £)	£k	(used for all costs, losses and benefits)			
Year	0	30	75		
Discount Rate	3.5%	3.00%	2.50%		
Optimism bias adjustment factor	60%				

Costs and benefits of options

	Costs and benefits £k							
Option number	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**	**Option 7**	**Option 8**
Option name	Do Minimum	North Rock + Inner Revetment + South Rock	North Rock + Inner Wall + South Rock	North Rock + Inner Revetment + South MRL	North Rock + Inner Wall + South MRL	PFR + North Rock + Delayed Inner Revetment + South MRL	PFR + Delayed North Rock + Inner Revetment + South MRL	PFR - 30 years
AEP or SoP (where relevant)	< 2-year	200-year + CC	200-year + CC	200-year + CC	200-year + CC	200-year + CC	200-year + CC	NA
COSTS:								
PV Costs	500	6,566	8,604	5,126	7,164	3,584	2,113	277
Optimism bias adjustment	300	3,940	5,162	3,076	4,298	2,150	1,268	166
Total PV Costs £k	800	10,506	13,766	8,202	11,462	5,734	3,381	442
BENEFITS:								
PV monetised flood damages	1,836	27	27	27	27	27	375	
PV monetised flood damages (30-year)	1,049							320
PV monetised flood damages avoided		1,809	1,809	1,809	1,809	1,809	1,461	729
PV monetised recreational damages	841	0	84	0	84	0	0	
PV monetised recreational damages (30-year)	354							0
PV monetised recreational damages avoided (protected)		840.62	756.56	840.62	756.56	840.62	840.62	0
Total monetised PV damages £k	2,677	27	111	27	111	27	375	
Total monetised PV damages £k (30-year)	1,404							320
Total monetised PV benefits £k		2,650	2,565	2,650	2,565	2,650	2,301	1,084
PV damages (from scoring and weighting)								
PV damages avoided/benefits (from scoring and weighting)								
PV benefits from ecosystem services								
Total PV damages £k	2,677	27	111	27	111	27	375	
Total PV damages £k (30-year)	1,404							320
Total PV benefits £k		2,650	2,565	2,650	2,565	2,650	2,301	1,084
DECISION-MAKING CRITERIA:								
Based on total PV benefits (** *in* ***cludes benefits from scoring and weighting and ecosystem services)								
Net Present Value **NPV**		-3,917	-6,038	-2,477	-4,598	-934	188	807
Average benefit/cost ratio **BCR**		0.25	0.19	0.32	0.22	0.46	0.68	2.45
Incremental benefit/cost ratio **IBCR**			0.0	0.0	0.0	0.0	0.0	0.3
								Highest bcr

Brief description of options:	**Name**	**Description**
Option 1	Do Minimum	Continue with current maintenance and reactive repairs of defences
Option 2	North Rock + Inner Revetment + South Rock	New rock revetments (north and south) and stepped revetment (inner) constructed present day that includes 2118 climate change allowance
Option 3	North Rock + Inner Wall + South Rock	New rock revetments (north and south) and wall (inner) constructed present day that includes 2118 climate change allowance
Option 4	North Rock + Inner Revetment + South MRL	New rock revetment (north), stepped revetment (inner), and managed realignment (south) constructed present day that includes 2118 climate change allowance
Option 5	North Rock + Inner Wall + South MRL	New rock revetment (north), wall (inner), and managed realignment (south) constructed present day that includes 2118 climate change allowance
Option 6	PFR + North Rock + Delayed Inner Revetment + South MRL	PFR and rock revetment (north) implemented present day with new new stepped revetment (inner), and managed realignment (south) constructed in year 30 with a climate change allowance
Option 7	PFR + Delayed North Rock + Inner Revetment + South MRL	PFR implemented present day with new rock revetment (north), stepped revetment (inner), and managed realignment (south) constructed in year 30 with a climate change allowance
Option 8	PFR - 30 years	PFR resilience implemented present day - 30 year appraisal period only

Project Summary Sheet

Client/Authority		Prepared (date)	23/05/2019
Aberdeenshire Council		Printed	04/10/2019
Project name		Prepared by	DP
Stonehaven Coastal FPS		Checked by	AEP
Project reference	2018s0343	Checked date	28/05/2019
Base date for estimates (year 0)	Nov-2018		
Scaling factor (e.g. £m, £k, £)	£k	(used for all costs, losses and benefits)	

Year	0	30	75
Discount Rate	3.5%	3.00%	2.50%
Optimism bias adjustment factor	60%		

Costs and benefits of options

	Costs and benefits £k								
Option number	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**	**Option 7**	**Option 8**	**Option 9**
Option name	Do Minimum	North 7 + Central 4 + Harbour 7	North 8 + Central 4 + Harbour 7	North 9 + Central 4 + Harbour 7	North 7 + Central 4 + Harbour 6	North 8 + Central 4 + Harbour 6	North 9 + Central 4 + Harbour 6	North 10 + Central 5 + Harbour 8 (30-years)	North 7 + Central 4
AEP or SoP (where relevant)	< 2-year	200-year + CC	200-year + CC	200-year + CC	200-year + CC	200-year + CC	200-year + CC	200-year + CC	200-year + CC
COSTS:									
PV Costs	1,500	14,217	14,413	20,613	15,688	15,884	22,083	6,325	12,104
Optimism bias adjustment	900	8,530	8,648	12,368	9,413	9,531	13,250	3,795	7,263
Total PV Costs £k	2,400	22,748	23,062	32,980	25,101	25,415	35,334	10,120	19,367
BENEFITS:									
PV monetised flood damages	25,791	1,587	1,587	1,587	1,238	1,238	1,238		1,211
PV monetised flood damages (30-year)	12,687							978	0
PV monetised flood damages avoided		24,205	24,205	24,205	24,553	24,553	24,553	11,709	24,580
PV monetised recreational damages	2,522	84	168	0	84	168	0		84
PV monetised recreational damages (30-year)	1,063							35	
PV monetised recreational damages avoided (protected)		2,438	2,354	2,522	2,438	2,354	2,522	1,028	2,438
Total monetised PV damages £k	28,313	1,671	1,755	1,587	1,322	1,407	1,238		1,295
Total monetised PV damages £k (30-year)	13,751							1,013	
Total monetised PV benefits £k		26,643	26,559	26,727	26,991	26,907	27,075	12,737	27,018
PV damages (from scoring and weighting)									
PV damages avoided/benefits (from scoring and weighting)									
PV benefits from ecosystem services									
Total PV damages £k	28,313	1,671	1,755	1,587	1,322	1,407	1,238		1,295
Total PV damages £k (30-year)	13,751							1,013	
Total PV benefits £k		26,643	26,559	26,727	26,991	26,907	27,075	12,737	27,018
DECISION-MAKING CRITERIA:									
Based on total PV benefits (*in*cludes benefits from scoring and weighting and ecosystem services)									
Net Present Value **NPV**		12,425	12,145	6,114	11,303	11,023	4,991	6,412	7,651
Average benefit/cost ratio **BCR**		1.17	1.15	0.81	1.08	1.06	0.77	1.26	1.40
Incremental benefit/cost ratio **IBCR**									
									Highest bcr

Brief description of options:

Option 1	Do Minimum	Continue with current maintenance and reactive repairs of defences
Option 2	North 7 + Central 4 + Harbour 7	Wall raise and new wall in year 30 - North Adaptive recharge - Central PFR and new rock revetment (north), stepped revetment (inner) and MRL (south) in year 30 - Harbour
Option 3	North 8 + Central 4 + Harbour 7	Wall raise and new rock revetment in year 30 - North Adaptive recharge - Central PFR and new rock revetment (north), stepped revetment (inner) and MRL (south) in year 30 - Harbour
Option 4	North 9 + Central 4 + Harbour 7	Wall raise and new recharge in year 30 - North Adaptive recharge - Central PFR and new rock revetment (north), stepped revetment (inner) and MRL (south) in year 30 - Harbour
Option 5	North 7 + Central 4 + Harbour 6	Wall raise and new wall in year 30 - North Adaptive recharge - Central Rock revetment (north) year 0; stepped revetment (inner) and MRL (south) in year 30 - Harbour
Option 6	North 8 + Central 4 + Harbour 6	Wall raise and new rock revetment in year 30 - North Adaptive recharge - Central Rock revetment (north) year 0; stepped revetment (inner) and MRL (south) in year 30 - Harbour
Option 7	North 9 + Central 4 + Harbour 6	Wall raise and new recharge in year 30 - North Adaptive recharge - Central Rock revetment (north) year 0; stepped revetment (inner) and MRL (south) in year 30 - Harbour
Option 8	North 10 + Central 5 + Harbour 8 (30-years)	Wall raise - North Recharge - Central PFR - Harbour
Option 9	North 7 + Central 4	Wall raise and new wall in year 30 - North Adaptive recharge - Central

R SEPA comments on economic analysis

Scottish Environment Protection Agency
Buidheann Dìon Àrainneachd na h-Alba

Our ref: PCS/165744
Your ref:

If telephoning ask for:
Simon Watt

20 June 2019

Graeme McCallum
Aberdeenshire Council
Infrastructure Services
Carlton House
Arduthie Road
Stonehaven
AB39 2QP

By email only to: graeme.mccallum@aberdeenshire.gov.uk

Dear Sir

Flood Risk Management (Scotland) Act 2009
Stonehaven Bay Coastal Flood Protection Study – Economic Appraisal Results
Stonehaven, Aberdeenshire

Thank you for consulting SEPA on the Stonehaven Bay Coastal Flood Protection Study – Economic Appraisal Results (dated 29 May 2019). Following review of the submitted report, we can offer the flood risk advice enclosed in Appendix 1.

Please note that we are reliant on the accuracy and completeness of any information supplied in undertaking our review and can take no responsibility for incorrect data or interpretation made by the authors.

If you have any queries relating to this letter please contact me by telephone on 01738 448 155 or by e-mail to planningaberdeen@sepa.org.uk.

Yours faithfully

Simon Watt
Senior Planning Officer
Planning Service

ECopy to: lee.watson@aberdeenshire.gov.uk

Appendix 1 – Economic Appraisal Results

1.1 As there is a known flood risk in Stonehaven, ideally long term, precautionary flood alleviation measures with an allowance for climate change should be applied. However, we understand that this may not be economically feasible and as such any improvement to the existing defences is welcomed.

1.2 We note from the Interim Modelling Report (Nov 2018) that the UKCP18 medium emissions 95th percentile climate change scenario has been adopted which results in an uplift of 0.73m above the extreme sea level and astronomical tide. Whilst this is an acceptable approach, for information, we have recently published new Climate Change Allowances Guidance (April 2019) which would recommend an uplift of 0.87m in North East Scotland.

1.3 We have provided comment on the three benefit zones below.

North: Improve existing defences immediately and adapt to a new option when the residual life is exceeded.

1.4 We note that the residual life of the existing defences is thought to be a 30 years. With regards to the future adaption of the defences, in year 30, no detail has been provided to demonstrate what adaption is likely to be required. For example, how much additional height is likely to be required? Will extra length be required? What works will need to be undertaken at this stage to ensure that the existing defences will be able to structurally support adaption works in year 30? Will there be a need to move any existing utilities which would make adaption economically unfeasible?

1.5 We note that conceptual design drawings have been submitted however robust justification of the current and adapted levels of protection should be provided with regards to finalised designs.

Central: Implement an adaptive beach recharge scheme immediately and replace Cowie defences in year 30.

1.6 At present there is limited information regarding the sediment dynamics and beach profile in the Central Benefit Zone. Whilst beach recharge seems like a reasonable approach to managing flood risk, further monitoring of the beach regime would be required to justify the baseline level and gradient to which the beach will be recharged.

1.7 Given the continual fluctuations to the beach profile, the recharge scheme would require to be actively managed on a regular basis to ensure that the beach profile remains appropriate for supporting the alleviation of flood risk.

1.8 With regards to the defences on the Cowie, we would expect a detailed Flood Risk Assessment, including a hydraulic model of the Cowie and a joint probability analysis of the combined fluvial and coastal flood risk, to be submitted in support of the proposed design.

Harbour: Manage the medium-term risk through PFR and construct new defences when the residual life of the current defences is exceed (year 30).

1.9 It is not clear how the Property Flood Resilience will be implemented and if the onus for this will be on the property owners or if measures will be put in place by the Planning Authority. If the onus is on the property owners, it is possible that PFR won't or can't be implemented and as a result there would be no improvement to flood risk in the harbour area.

Engineering Design Drawings

1.10 We note that conceptual design drawings have been submitted which indicate that all new defences would be at least 1 metre above the 2118 1 in 200 year extreme water level. When submitting final designs, robust justification of the defence heights with regards to overtopping and still water level should be provided and it should be demonstrated that the current infrastructure is suitable for adaption in the future.

1.11 Where possible, we would expect that any overtopping that may occur, would have a flow route back to the seaward side of the defences to prevent extended periods of ponding after the event has passed.

SEPA
Scottish Environment Protection Agency
Buidheann Dìon Àrainneachd na h-Alba

Our ref: PCS/168662
Your ref: 2018s0343

If telephoning ask for:
Simon Watt

03 December 2019

Dr Douglas Pender
JBA Consulting
Unit 2.1, Quantum Court
Research Avenue South
Heriot Watt Research Park
Edinburgh
EH14 4AP

By email only to: Douglas.Pender@jbaconsulting.com

Dear Sir

Flood Risk Management (Scotland) Act 2009
Stonehaven Bay Coastal Flood Protection Study – Economic Appraisal Results
Stonehaven, Aberdeenshire

Thank you for consulting SEPA on the Stonehaven Bay Coastal Flood Protection Study – Economic Appraisal Results (dated 07 October 2019). We have previously offered advice on the appraisal (letter dated 20 June 2019 under PCS/165744). Our comments enclosed in Appendix 1 should therefore be read in conjunction with that previous response.

Please note that we are reliant on the accuracy and completeness of any information supplied in undertaking our review and can take no responsibility for incorrect data or interpretation made by the authors. Once the defence designs are finalised we can provide further advice if consulted.

If you have any queries relating to this letter please contact me by telephone on 01738 448 155 or by e-mail to planningaberdeen@sepa.org.uk.

Yours faithfully

Simon Watt
Senior Planning Officer
Planning Service

ECopy to: Nicola.Buckley@jbaconsulting.com lee.watson@aberdeenshire.gov.uk graeme.mccallum@aberdeenshire.gov.uk

Appendix 1 – Economic Appraisal Results

1.1 We note that the updated appraisal states an additional benefit of the scheme would be '*Support of shorefront development and re-development opportunities through the provision of a 200-year standard of protection*'. In line with our Planning Information Note 4 (PIN4) on Development Protected by a Flood Protection Scheme and Scottish Planning Policy (SPP), certain developments may be acceptable behind an existing or planned scheme in a built up area.

1.2 We would highlight however that although a Flood Protection Scheme can reduce the probability of flooding, the risk cannot be entirely eliminated. All built defences carry a residual risk and development located behind such defences could be vulnerable due to the potential for structural failure and/or overtopping in the event of a flood larger than the design standard of protection.

1.3 We have a shared duty with Scottish Ministers and other responsible authorities under the Flood Risk Management (Scotland) Act 2009 to reduce overall flood risk and promote sustainable flood risk management. The cornerstone of sustainable flood risk management is the avoidance of flood risk in the first instance. As such, the building of new defences against coastal erosion or coastal flooding should not be undertaken with the sole purpose of creating new development.

1.4 For defences with a standard or protection of equal to or greater than 200 years (0.5□ AEP), water compatible uses□essential infrastructure□least vulnerable land uses□and redevelopment with no increase in land use vulnerability□may be acceptable. Highly vulnerable land uses would only be considered if a suitable allowance for climate change is included in the standard of protection of the defences and most vulnerable land uses would not be acceptable. PIN4 and our Flood Risk and Land Use Vulnerability Guidance should be read in conjunction with this response.

1.5 We would also expect that any development protected by a formal scheme would have a water resilient design and adequate evacuation procedures in place that are appropriate to the level of risk and use.

1.6 In line with our climate change allowances for flood risk assessment in land use planning guidance, the expected sea level rise for the North East is 0.87m by 2100 based on the latest UK climate change predictions reported in 2018.

1.7 As sea level rise is predicted to continue, over time the standard of protection the defences offer will decrease. As such, in the future, development behind defences would be at risk from lower return period floods than when the defences were initially built unless adaptive works are continually carried out to ensure that the minimum required standard of protection is achieved.

1.8 We therefore consider lower vulnerability land uses to be a more sustainable approach to development behind defences and in the long term, as redevelopment opportunities arise for existing buildings, redeveloping to a lower vulnerability land use should be considered to ensure the longevity of such development.

JBA consulting

Offices at

Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Glasgow
Haywards Heath
Isle of Man
Limerick
Newcastle upon Tyne
Newport
Peterborough
Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

Registered Office
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE
United Kingdom

+44(0)1756 799919
info@jbaconsulting.com
www.jbaconsulting.com
Follow us:

Jeremy Benn Associates Limited

Registered in England 3246693

JBA Group Ltd is certified to:
ISO 9001:2015
ISO 14001:2015
OHSAS 18001:2007

New Civil Engineer TechFest. Awards FESTIVAL OF INNOVATION AND TECHNOLOGY 2017 WINNER
New Civil Engineer 100 COMPANIES OF THE YEAR 2016 WINNER
New Civil Engineer 100 COMPANIES OF THE YEAR 2017 RANKED COMPANY
CHAS Accredited Contractor CHAS.co.uk