Stonehaven Bay Coastal Flood Protection Study

Geotechnical Desk Study Report

Final Report

September 2018

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Aberdeenshire COUNCIL

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Revision history

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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.

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Purpose

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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).

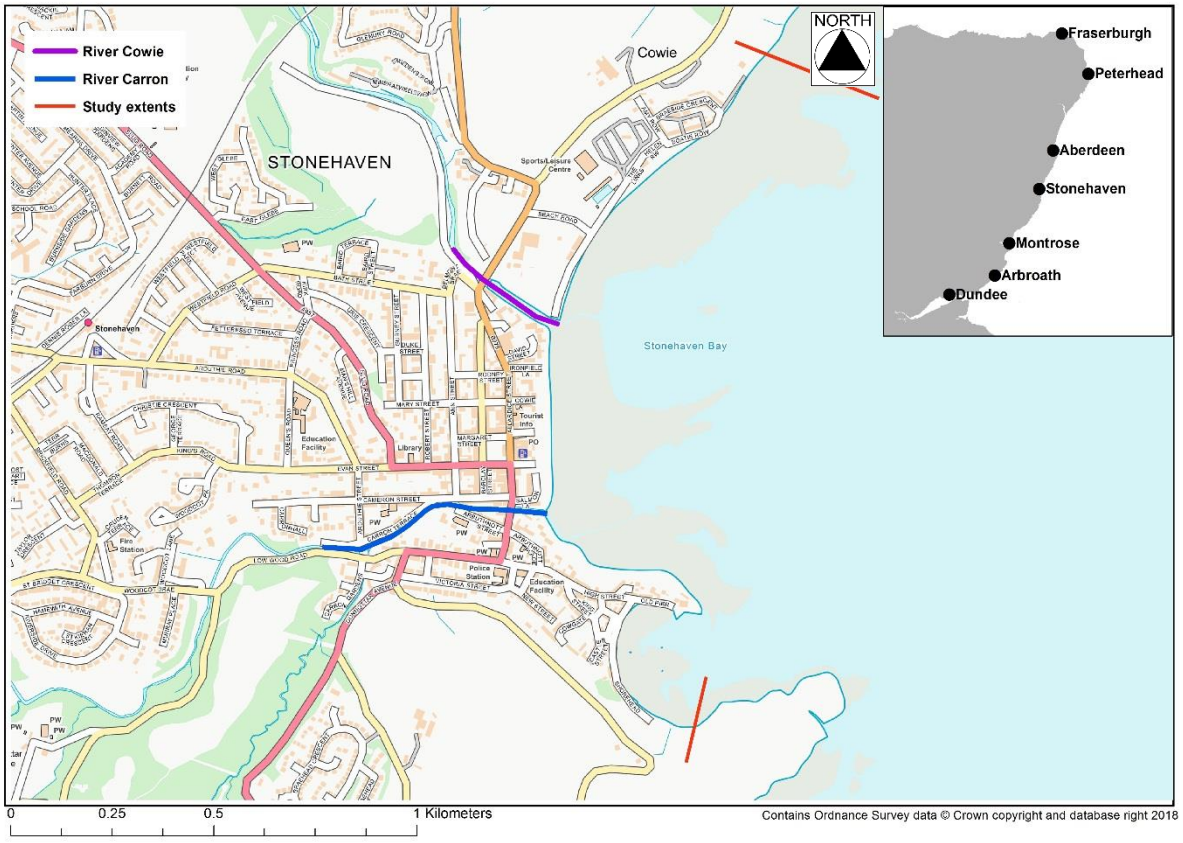


Figure 2-1: Location plan

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.

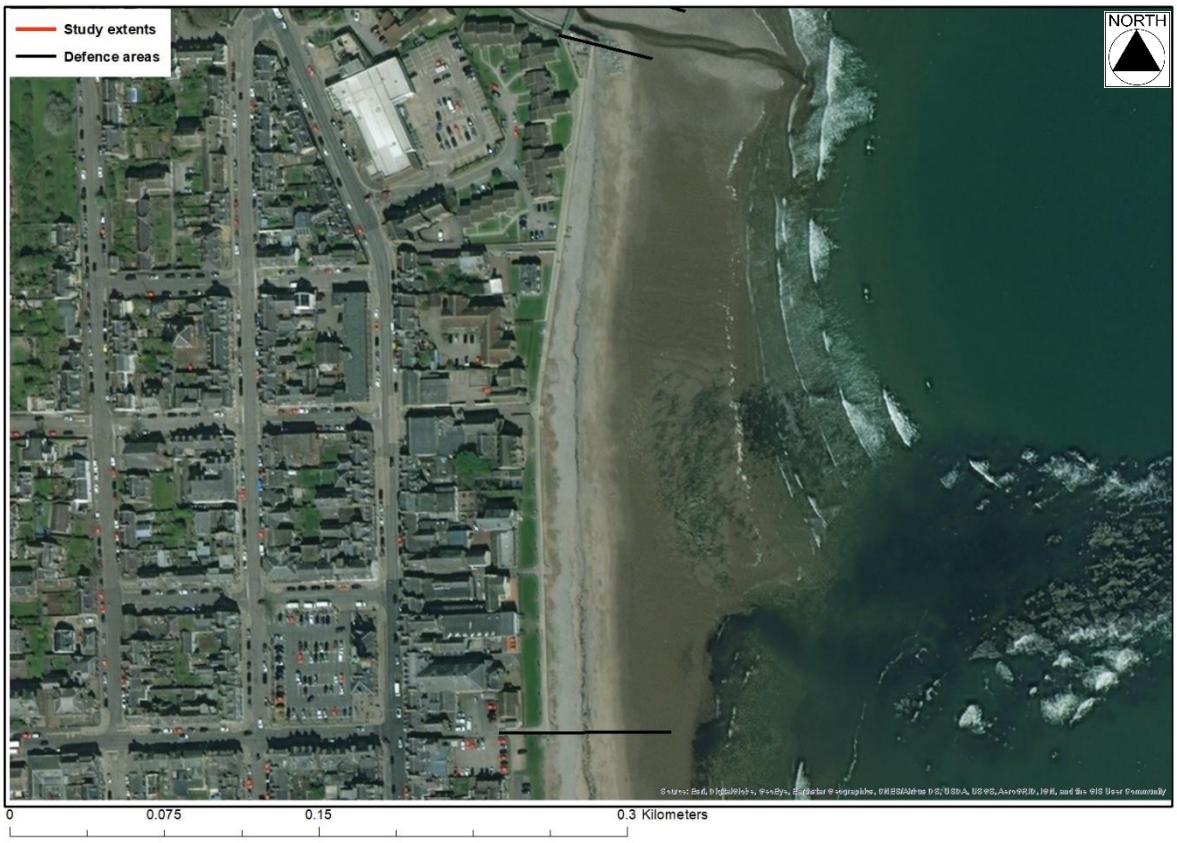


Figure 2-6: Aerial image of the central section

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.

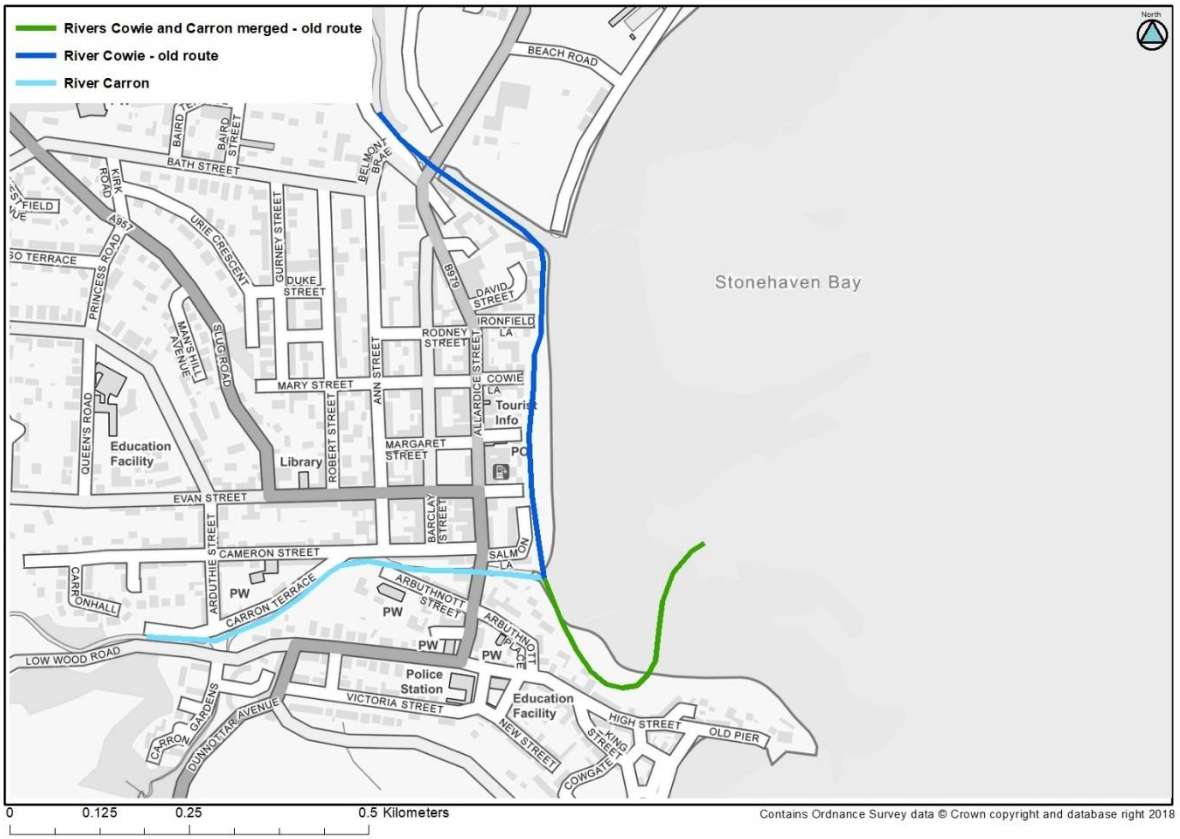


Figure 2-10: Historical configuration of the Rivers Cowie and Carron at the coast

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

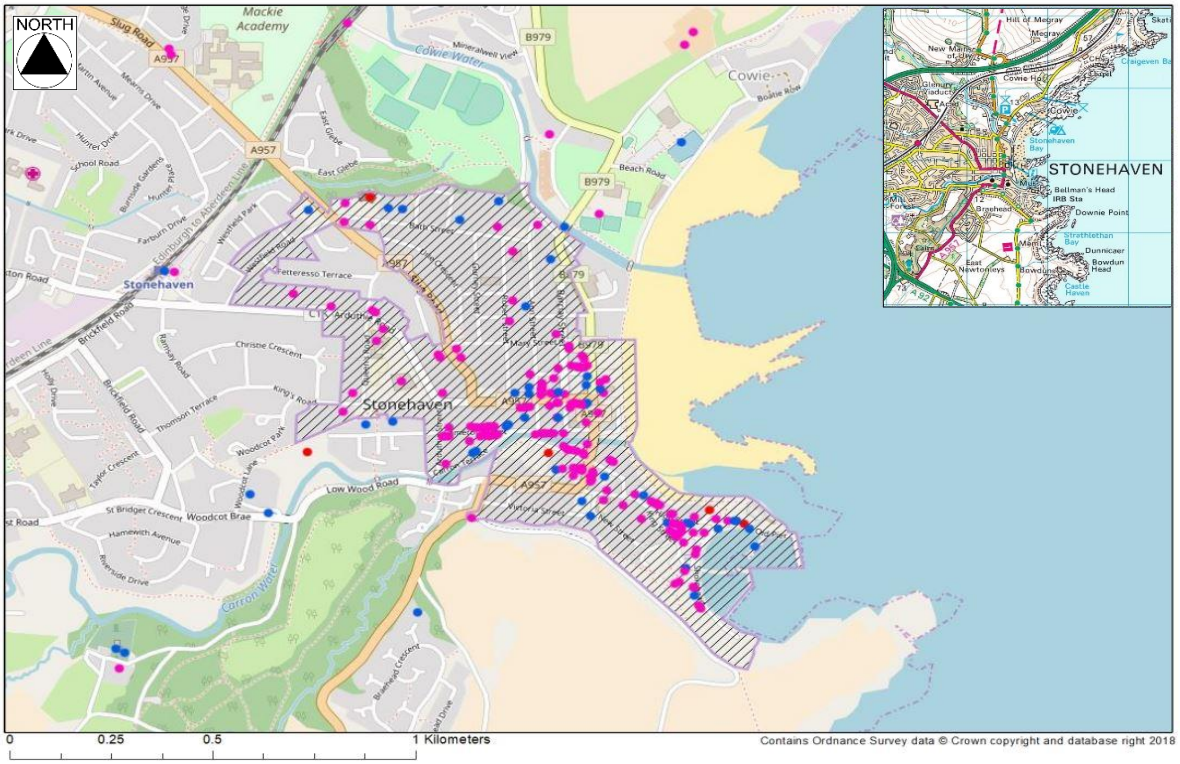


Figure 2-11: Listed building plan for Stonehaven and Cowie. (Blue - scheduled monuments; Pink - listed buildings; Hatching – Stonehaven Conservation Area).

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.

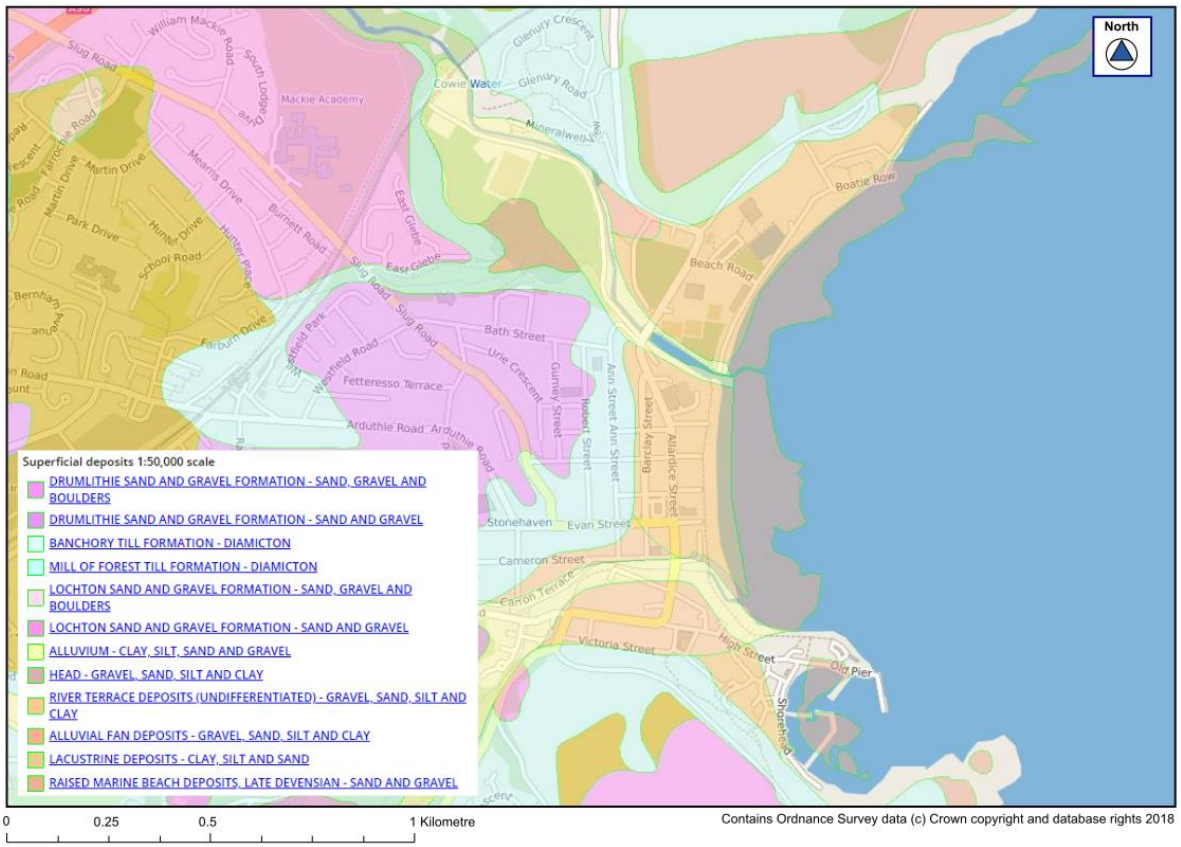


Figure 4-2: Site location with BGS superficial deposits overlay

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° to the southeast. It is expected therefore that bedrock will be at shallow levels on site with limited superficial cover.

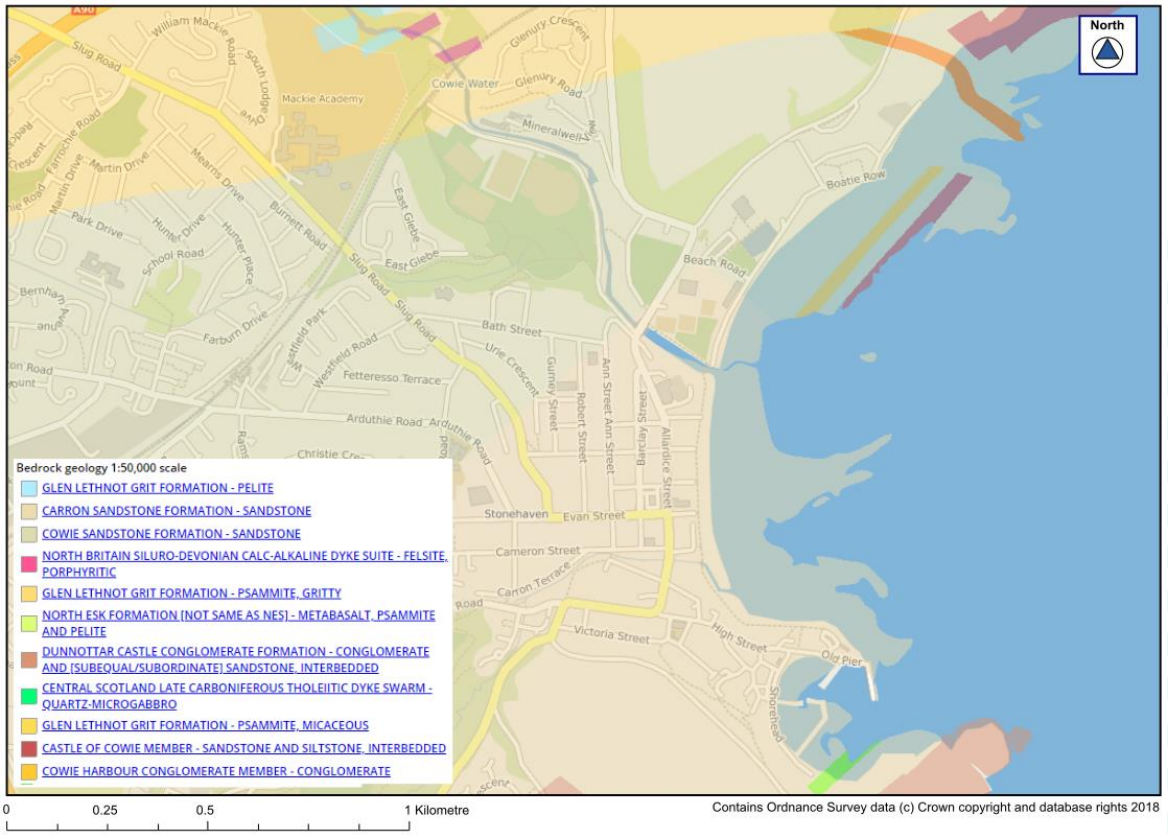


Figure 4-3: Site location with BGS bedrock geology indicated

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 (mbgl)	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

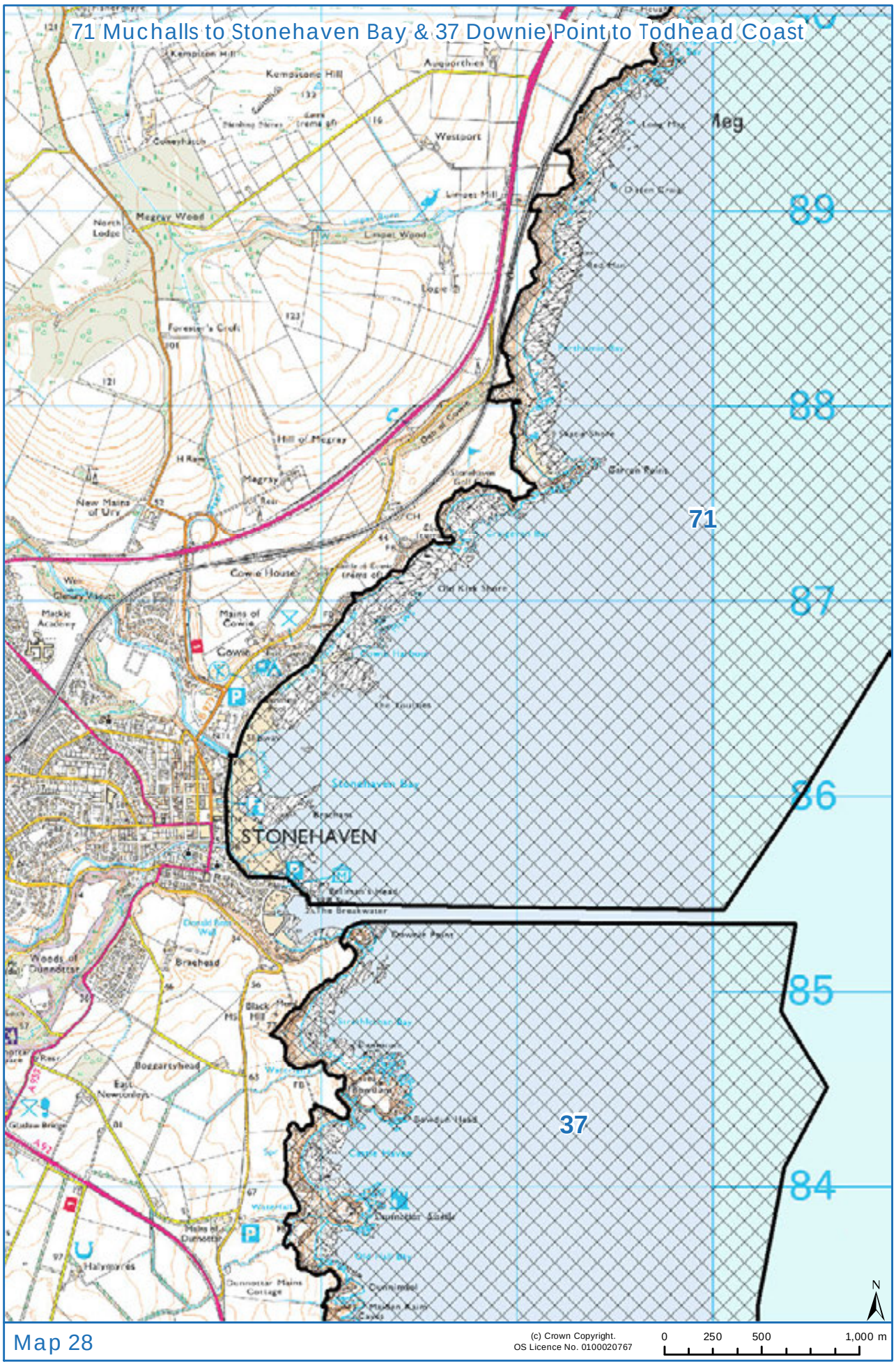
In order to inform design of the proposed improvements to flood defences along the Stonehaven frontage, a GI is recommended to determine shallow ground conditions and quantify geotechnical risk. As near surface deposits of granular material are anticipated, the extent of seepage into excavation works 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
Kempstone Hill
Auquorthies
Westport
Megray Wood
North Lodge
Hill of Megray
Megray
New Mains of Ury
Cowie House
Mains of Cowie
Cowie
Mackie Academy
STONEHAVEN
Stonehaven Bay
Breakwater
Woods of Dunnottar
Brackhead
Boggarsyhead
East Newtonleys
Dunnottar Castle
Dunnottar Mains Cottage
Garron Point
Meg
89
88
87
86
85
84
71
37
N
Map 28
(c) Crown Copyright.
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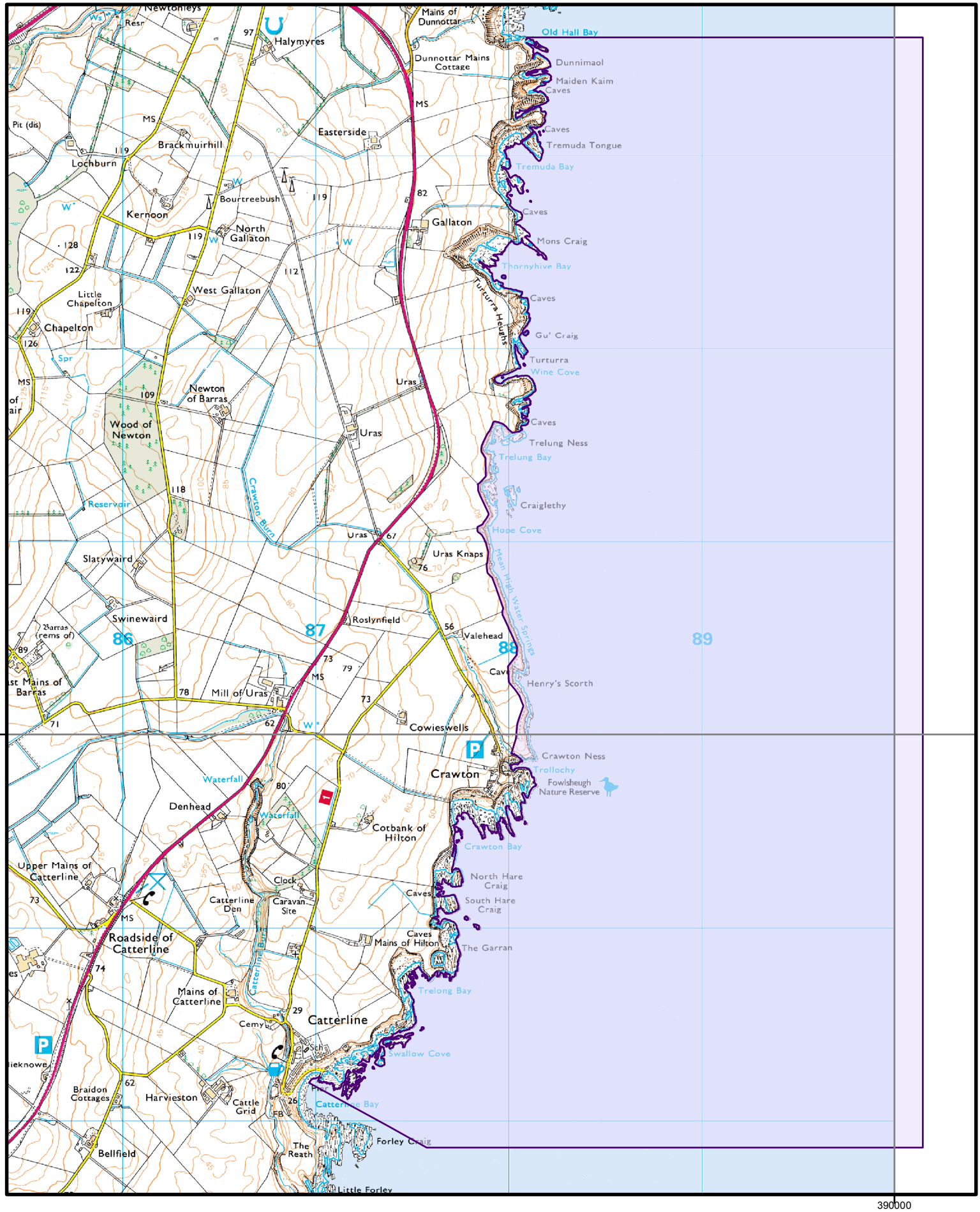
0
250
500
1,000 m



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

Fowlsheugh

Site of Special Scientific Interest

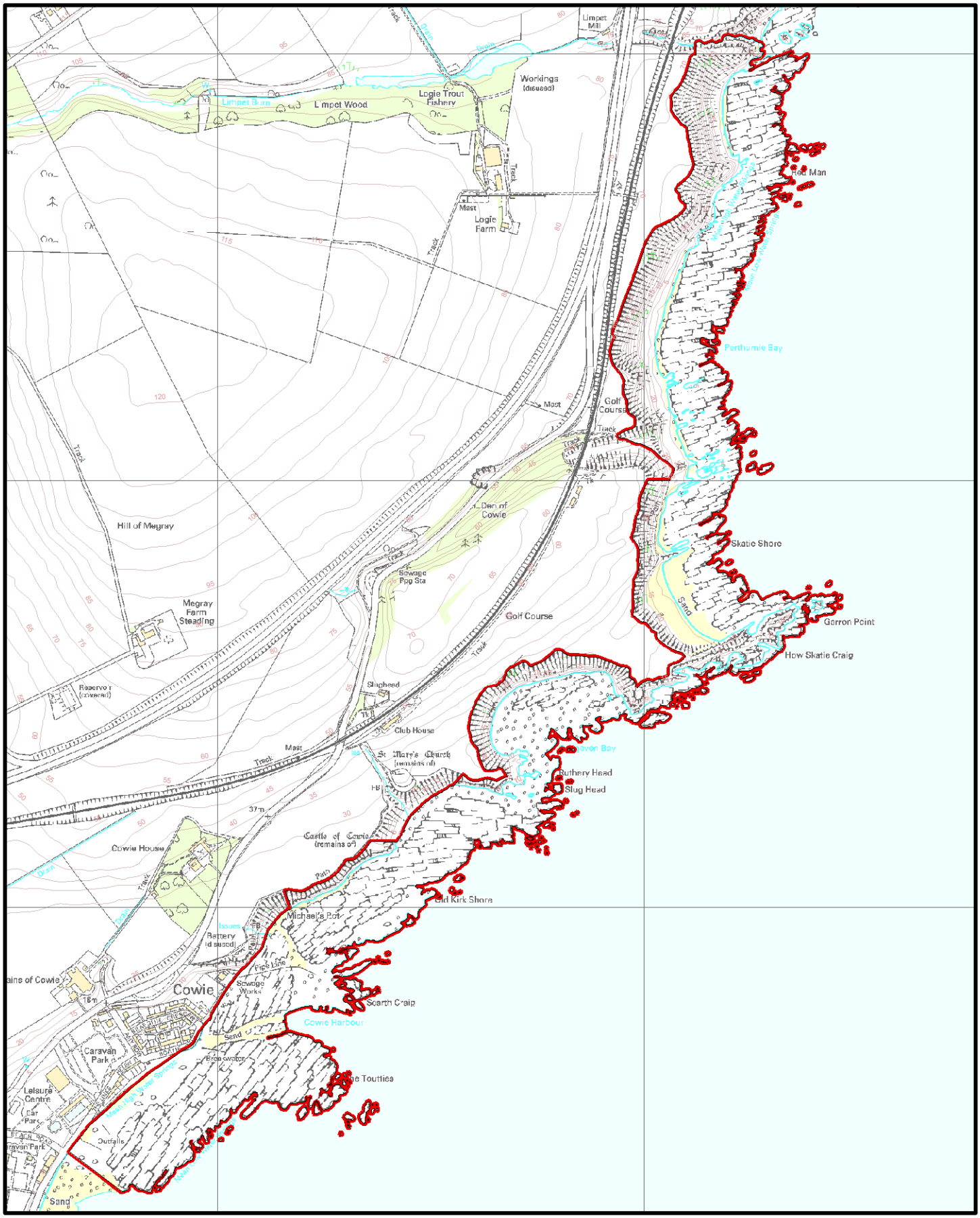
Site Code: 660

Site boundary

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

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

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[7] JBA Consulting. 2013. Stonehaven River Carron and Burn of Glaslaw Flood Protection Scheme. Site Investigation – Desk Study. Final Report for Aberdeenshire Council.
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[15] https://maps.nls.uk/townplans/background/stonehaven.html.

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