



Seagreen Phase 1: Intertidal Survey

Seagreen

January 2012

Final Report

9V9818

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1 INTRODUCTION

Royal Haskoning was commissioned by Seagreen to undertake an intertidal walkover survey to contribute towards the Environmental Impact Assessment (EIA) process being managed by Royal Haskoning for Seagreen's Phase 1 developments. This report assesses the current morphological regime and intertidal ecology at two potential export cable route (ECR) landfall locations prior to a preliminary identification of opportunities and constraints (technical and environment), based on both an expert geomorphological assessment (EGA) and an initial ecological appraisal. The EGA is further supported by a desk based review of currently available data relating to the physical environment and physical processes at each site.

To obtain sufficient understanding for assessment a site visit was timed to coincide with low tide on the 29th and 30th of September, 2011. The site visit was undertaken by Dr Julian Carolan (coastal geomorphologist) and Dr Elizabeth Jolley (coastal ecologist) of Royal Haskoning.

1.1 Aim

The aim of the survey was to establish the baseline environment and understand the potential for natural geomorphological / sedimentological and ecological change. Such understanding will support identification of potential impacts of the proposed ECR landfall and any associated works, relative to the reported baseline. The establishment of a robust baseline also facilitates any subsequent monitoring, if required by the regulator (Marine Scotland (MS)) and statutory consultees (Scottish Natural Heritage (SNH) and Scottish Environmental Protection Agency (SEPA)).

The aims of the survey were:

- To characterise the geomorphology / sedimentology and ecology of the shore; and
- Quantify aspects of the geomorphology / sedimentology and ecology to enable possible future monitoring of change.

Each site visit involved a walkover survey to note geomorphological and ecological features. The locations of the sites surveyed are presented in **Figure 1.1**. Expert judgement was applied to the survey results and the potential for features identified to be potentially impacted by the proposed cable landfall works was appraised. This appraisal included consideration of: upper foreshore beach morphology; intertidal foreshore (including intertidal ponds); and cross shore gravel transport.

1.2 Report structure

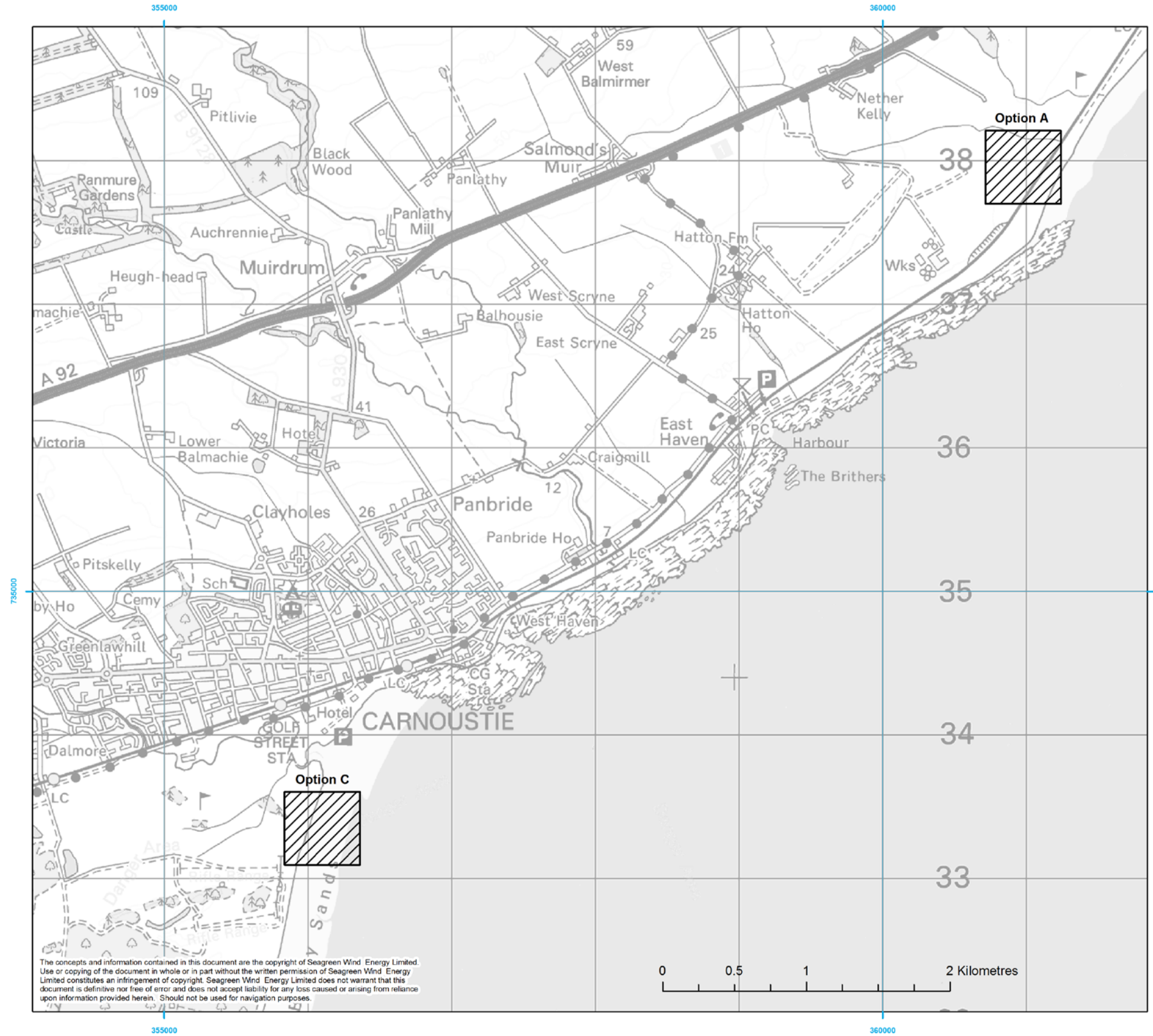
This report has five sections, this introduction being **Section 1**.


Section 2 presents a review of the physical environment, the processes active at each site and a description of the intertidal and coastal ecology, based on available data. This places the results of the survey undertaken, within a wider context.

Section 3 presents the methodology followed during the survey.

Section 4 presents results of the site visit, with sub-sections presenting the expert geomorphological assessment (EGA) and ecological observational notes, along with supporting photography for key locations within each study site.

Section 5 summarises the findings, draws conclusion, and presents recommendations with regards to Seagreen's Phase 1 ECR landfall, all within the context of coastal geomorphology and ecology.



 Export Cable Landfall Options

Coordinate System
British National Grid (OSGB36)
Projection: Transverse Mercator
Central Meridian: -2.0000
Scale Factor: 0.9996
Latitude Of Origin: 49.0000
False Easting: 400000.0000
False Northing: -100000.0000
Reference Spheroid: OSGB36



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Seagreen Phase 1: Onshore Grid Connection Works



Figure / Drawing Title:

Route Overview

Figure/Drawing Number: **Figure 1.1**

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2 BACKGROUND

2.1 Site location and development description

The proposed development will link the 1,075MW of energy generated by Seagreen Phase 1 Alpha and Bravo offshore wind farms to the National Grid. The Phase 1 development boundary lies approximately 25km offshore, east of Fife Ness and 25km north east of the Isle of May, located within the outer Firth of Forth, Scotland.

Export cable are required to connect the wind farm to the electricity distribution or transmission network system. In order to do this Seagreen will route subsea power cables from the western boundary of the Phase 1 area to landfall on the Angus coastline and then underground to the Tealing substation, approximately 20km inland.

Two cable landfall options are currently being considered, either south Arbroath beach (Option A) or at Carnoustie (Option C) (see **Figures 2.1** and **2.2** below). A wider study area, within which context the landfall options can be placed, extends from Carnoustie, in the south, to Arbroath, in the north, and comprises Buddon Ness, Carnoustie Bay and the coastal frontage up to, and including, Elliott Links. The survey area covers all areas of the intertidal foreshore from Mean High Water Springs (MHWS) to Mean Low Water Springs (MLWS) that may be directly affected by the cable installation works.

Each landfall location was surveyed along a transect following the centre line of the proposed export cable route corridor, with two further transects surveyed 250m north and 250m south of the centre line of the corridor. This approach is in line with the method used during earlier Phase 1 survey of the proposed terrestrial cable route.

2.2 Physical environment and processes

2.2.1 Geology and geomorphology

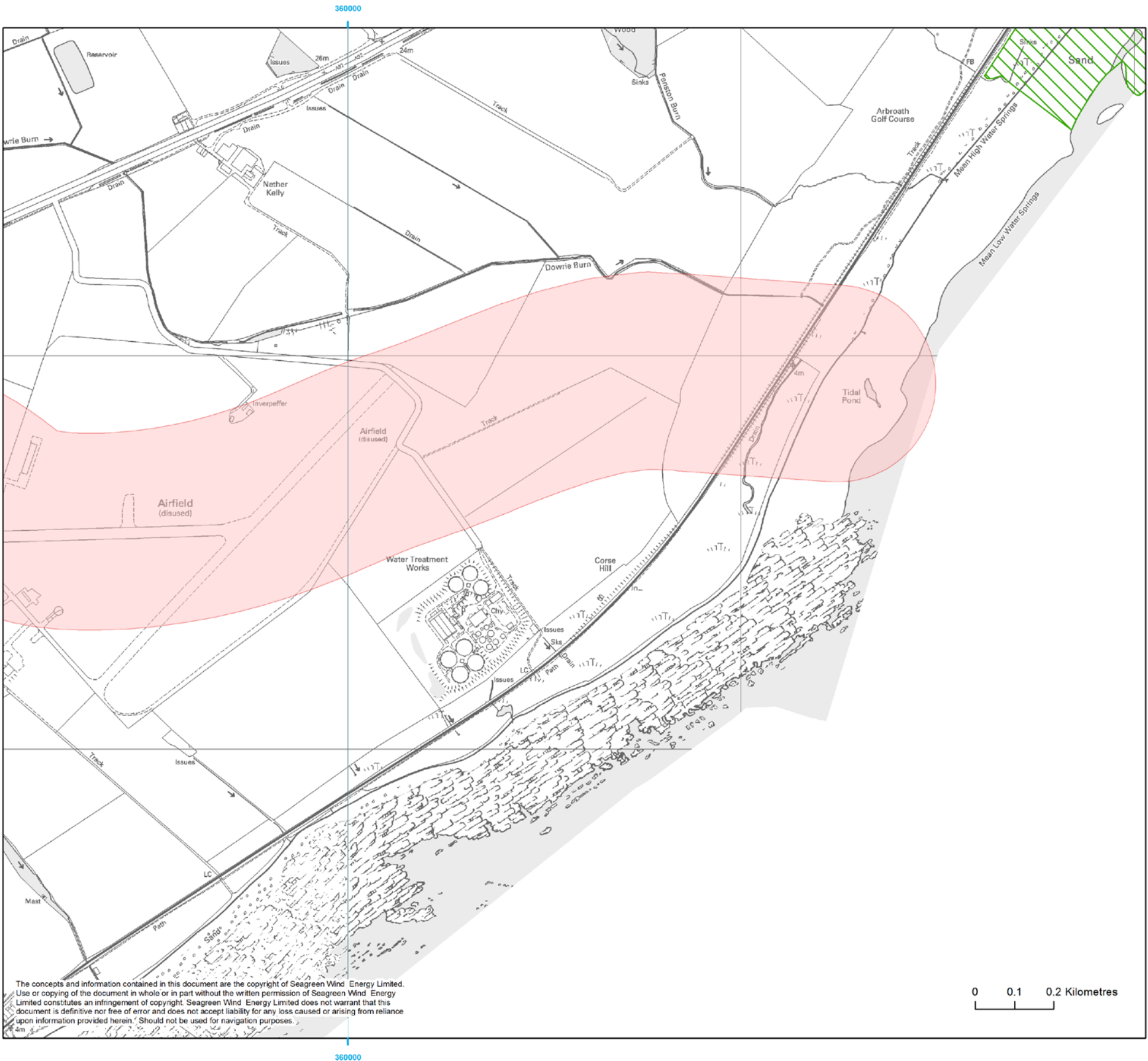
The solid geology of the larger study area is characterised by bedrock of Silurian, Devonian, Carboniferous, Permian and Triassic age. Much of the bedrock geology to the north of Fife Ness comprises mudstone, siltstone and sandstone, and in some areas marine limestone. To the south of the Ness, the geology is variable; comprising greywacke, shale, sandstone, limestone, basalt and dolerite.

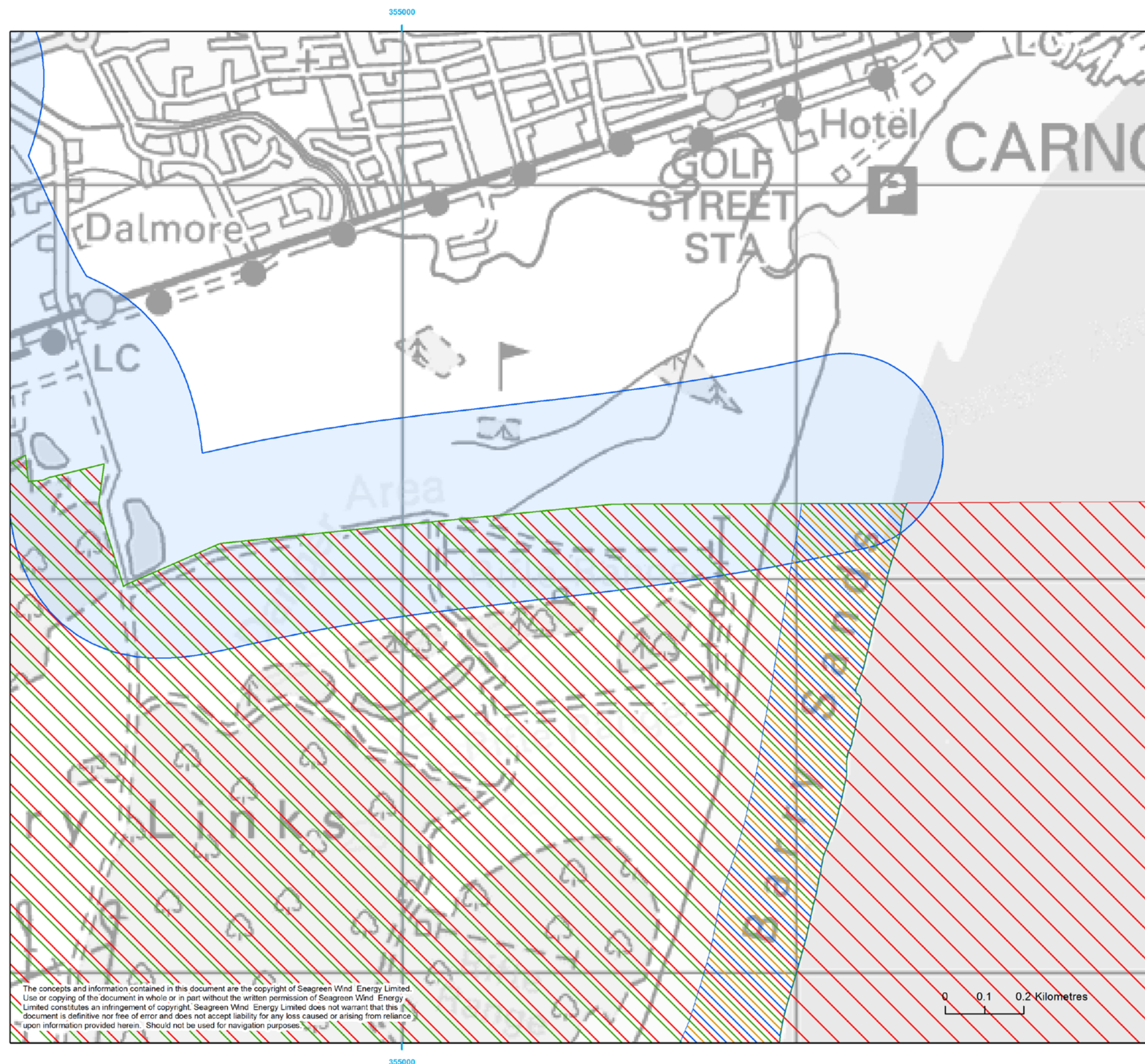
Much of the solid geology is overlain by more recent glacial and post-glacial deposits, the thickness of which varies spatially along the coastline and within the offshore. During the last glaciation, ice flow was predominantly towards the east (offshore) from the hinterland. The major effect of the glaciation, in terms of coastal geomorphology, was the widespread accumulation of glacially derived sediments (till and glaciofluvial meltwater deposits), which are currently being reworked onshore, offshore and along the contemporary shoreline, via winds, waves, tides and postglacial sea-level change.






Much of this low-lying land was inundated during the postglacial marine transgression, when relative sea-levels were higher than those of present, resulting in the formation of raised beach sequences (SNH, 2000). As relative sea-level began to drop, as a result of isostatic readjustment of the Scottish coastline, large areas of intertidal sands dried out and subsequently were reworked onshore. The coastline between Carnoustie and Arbroath consists largely of low lying land characteristic of coastal dune heath overlain

by sand dunes which are in turn fronted by sand dominated beaches interspersed with areas of rocky foreshore.

The diversity of coastal landforms and their linkages with formative agents is of particular note along the coastline of the larger study area. This variety is recognised locally, regionally, nationally and internationally in the array of geological features currently designated as Sites of Special Scientific Interest (SSSI), Special Areas of Conservation (SAC) and potential SAC.





-  Option C1 Cable Corridor
-  SPA
-  Ramsar
-  SSSI
-  SAC

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 Reference Spheroid: OSGB36



Title:
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Figure / Drawing Title:
Option C Landfall and Environmental Designations

Figure/Drawing Number: **Figure 2.2**

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2.2.2 Waves

The offshore wave climate, both total sea and significant wave height for return periods of 1-100 years, have been reported by SNH (2000) for coastal cells to the north and south of Fife Ness respectively (see **Table 2.1**). The predicted wave climates were derived from the Met Office Wave Model and considered to be representative of the general offshore wave climate i.e. they do not represent any one particular location.

Table 2.1 Total sea and significant wave height

Return Period (years)	Total sea significant wave height (m)	Significant wave height (m)
1	6.23	3.56
10	7.62	4.49
100	8.95	5.36

Source: SNH, 2000

Offshore of the Firth of Forth, wave conditions are experienced from between 340°N through to 200°N with on average approximately 35% of conditions occurring from between 20°N and 60°N (SNH 2000). Significant wave heights of over 4m can be experienced from any direction in the easterly sector (0°N - 180°N) as there tend to be more extreme wind conditions from the northeast than the southeast.

East of the mouth of the river Tay, the dominant wave conditions approach from between 20°N and 60°N. However, extreme wave conditions (>4m) can be experienced from the entire eastern sector (0° to 180°). Numerical modelling of the offshore wave climate (HR Wallingford, 1989) has shown that storm wave conditions can occur from any direction where fetch length extends into the North Sea.

Little information exists on the nearshore wave climate within the larger study area. HR Wallingford (1989) state that the largest wave heights are incident from the ENE sector (45°N – 90°N) with inshore wave height varying due to complex nearshore bathymetry and planform.

2.2.3 Tides and tidal currents

The tidal regime at both landfall locations is complex being of a semi-diurnal nature though characterised by a variable mean spring tidal range. Tidal range varies spatially along the coast in response to the interaction of incident tidal energy, bathymetry and coastal planform, and orientation. Tidal range along the eastern Scottish shoreline, to the west of the Phase 1 area, is 4.6m at Dundee, 4.8m at Anstruther and 4.5m at Dunbar (SNH 2000).

North of the Tay Estuary the flood and ebb tides are rectilinear, flowing parallel with the coast. Offshore of the Tay estuary the flood current flows in a southerly direction across the mouth. The tide rotates in a clockwise direction with a maximum spring tidal velocity of 0.6m/s (SNH, 2000). The same tidal current processes are observed within the Firth of Forth with tidal flow moving south along the coastline via Fife Ness (SNH, 2000). Between St Abbs Head and Barns Ness tidal streams run east-southeast and west-northwest on the flood and ebb tide with a peak tidal velocity of 0.5m/s off the coast.

2.2.4 Coastal (littoral) processes

Within the coastal and nearshore environment, physical processes are driven by complex processes of wind and wave, tides and tidal currents and, to varying degrees, estuarine / fluvial forcing with the latter dependant upon the coastal / estuarine setting.

HR Wallingford (1989) noted in a detailed study of littoral processes that erosion dominated the northern part of Carnoustie Bay between 1969 and 1988 with the transport of material subsequently towards the south. On the intertidal beach, historical map analysis (Mitchell, 1997) at Barry Links illustrated the substantial seaward movement of the MHWS tide line over the period 1865 to 1959, with erosion and retreat since 1959. The recent erosion and coastal retreat being attributed to the formation of a large anti-clockwise eddy on the ebb tide to the east of Barry Links, which tended to re-circulate material towards the shoreline at Buddon Ness.

The net longshore drift of beach material within Carnoustie Bay is north to south, with the rate of coastal retreat slowing notably to the north of Carnoustie, due to the geological character of the coastline being dominated by the presence of an extensive inter- to subtidal bedrock platform. The interaction of the bedrock platform ensures that coastal erosion is limited to episodic (storm) events due to the ability of the bedrock to induce breaking of the incident waves.

Along the coastal frontage from Elliott to East Haven there is a southerly net movement of beach sediment along the entire frontage, but the rate is low, particularly along the section fronted by the rock platform. However, there is a potential input of beach material into the active coastal system through reworking (erosion), though this is spatially limited (SNH 2000). Fluvial input from the River Tay is unlikely to be significant with much of the material being deposited on the intertidal sand banks found within the Tay Estuary, or being deposited further offshore. Outside of the Tay estuary, i.e. on the open coast, longshore sediment transport is wave dominated and therefore tends to be northward.

2.3 Nature conservation designations

At the Arbroath landfall site, there are no nature conservation designations within the intertidal area of the ECR corridor itself, but to the north is the Elliot Links SSSI, a national conservation designation (see **Figure 2.1**). At Carnoustie, the southern edge of the ECR corridor overlaps part of the Barry Links SAC and SSSI, and the Firth of Tay and Eden Estuary SAC, Special Protection Area (SPA) and Ramsar sites. The boundaries of all these designations are illustrated in **Figure 2.2**.

Table 2.1 Nature conservation designations at Carnoustie ECR corridor

Site Name	Designation	Feature
Barry Links	SAC	Dunes
	SSSI	Bryophyte assemblage, coastal geomorphology, invertebrate assemblages, sand dunes
Firth of Tay and Eden	SAC	Subtidal sandbanks, estuaries, intertidal mudflats and sandflats, common seal
	SPA	Includes: Little tern, marsh harrier, oystercatcher, shelduck, velvet scooter, grey plover, greylag goose,
	Ramsar	Greylag goose, waterfowl assemblage, bar-tailed godwit, pink-footed goose, redshank

3 SURVEY METHODOLOGIES

3.1 Survey area

Two potential landfall locations (A and C) were surveyed (see **Figures 1.1, 2.1 and 2.2** above). The survey area covers all areas of the intertidal foreshore from MHWS to MLWS that may be directly affected by the cable installation works.

Each potential landfall location was defined by a transect along the centre line of the proposed onshore electrical connection cable with two further transects 250m to the north and south. This approach was consistent with the earlier terrestrial Phase 1 survey of the proposed cable route. Six shore normal transects (three for each landfall location), each extending from the upper foreshore to low water, were surveyed. The transects provided a spatial reference for fixed point photography as well as representative survey of ecology within the intertidal.

3.2 Sedimentology and geomorphology

The presence or absence of geomorphological and sedimentological features was noted in the field and their presence or absence used to inform judgments on likely constraints upon ECR landfall locations.

The establishment of a geomorphological and sedimentological baseline the ability to anticipate subsequent changes relative to the reported baseline and facilitates assessment of the potential for those landfall works to cause change.

3.3 Intertidal biotope survey

A walkover survey of the intertidal zone was conducted at the two landfall sites in order to gain an understanding of the intertidal biotopes present and their distribution.

The survey enabled the characterisation of the intertidal biotopes¹ within the study area in accordance with the Marine Habitat Classification system for Britain and Ireland (Connor *et al.*, 2004), as well as noting the conspicuous infaunal, epifaunal and floral species within each identified biotope. It should be noted that due to this being only a walkover survey and not a quantitative survey, the data are not suitable for ecological monitoring in the future if this is required.

A photographic record was made along three transects at each of the landfall locations.

These surveys aim to establish baseline data for intertidal floral and faunal communities and allow predictions of the potential impact of the proposed scheme upon them.

A qualitative assessment of the abundance of dominant benthic species was performed in sedimentary areas; where areas of high species abundance were encountered; the assessment was carried out by counting visible indicators such as siphon holes, burrows or casts. Target notes were also be made on the presence of vegetation, benthic green algae and sediment characteristics. Any notable features had positions recorded using a handheld GPS.

¹ Biotope: a complex of a habitat and its associated species / community

As part of the walkover survey, the intertidal biotopes on any bedrock / artificial hard substrata were identified and photographically recorded. An estimate of the abundance and species richness within each of the identified biotopes was made by surveying a 1m² area, and noting conspicuous species and their abundance (in terms of percentage cover within the 1m² area). Target notes were made for any notable features, a photographic record made and the extent of each biotope identified recorded.

4 SURVEY RESULTS

A brief overview of the regional and local processes driving the evolution of the larger study area has been detailed in the preceding section (**see Section 2.2**). The purpose of the site visit was to ascertain to what degree the various external forces controlling change within each section of coastline and to note any evidence present within the field indicating the forces and processes in play.

The following sections on the two study sites present observational notes and supporting photography for key locations within each of the study sites. Both intertidal geomorphology and ecology are considered.

4.1 Arbroath landfall site

4.1.1 Intertidal geomorphology

In planform (see **Figure 2.1**) this section of coastline is distinctly curved, controlled by the rock revetment to the north and area of outcropping intertidal bedrock to the south (see **Plate 4.1**).

Plate 4.1 Looking landward from low water; centre transect Arbroath

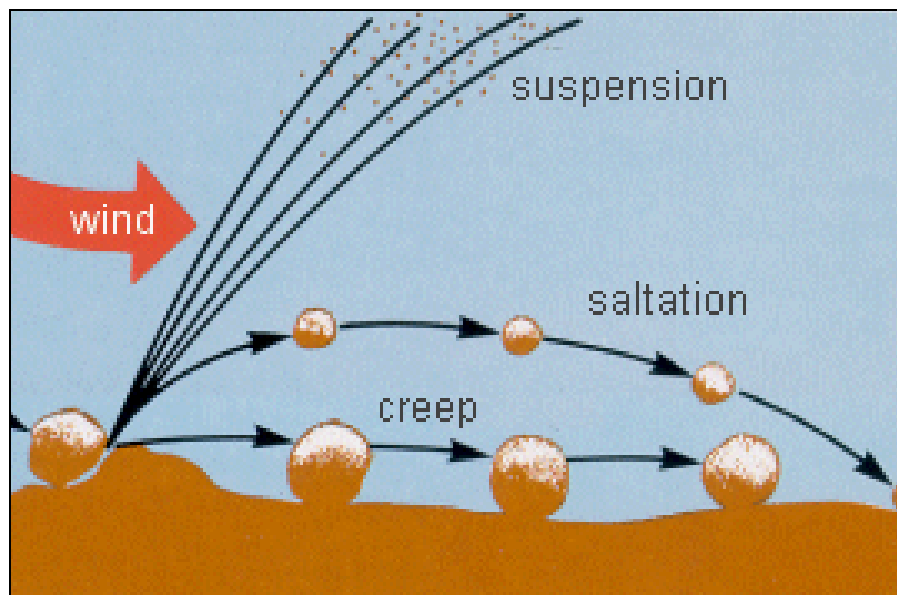


Plate 4.1 illustrates, looking from sea towards land, the processes in play at the central transect of the Arbroath site.

The centre transect was orientated 110° from north, from the active dune toe (actively eroding dune system $<5.0\text{m}$) which backs the beach across $\sim 150\text{m}$ of intertidal sands, which are occasionally reworked by wave processes into a series of bedforms. At mid-foreshore the survey area is characterised by the presence of a persistent shingle band to a featureless sand dominated lower foreshore.

The upper foreshore area immediately fronting the dune toe is characterised by an area of sand with a relatively high proportion (15-25%) of shingle clasts. This area serves as a sediment source for dune accretion under predominant onshore incident wind. This is evidenced by the exposure of the shingle clasts at this elevation relative to the tidal frame (i.e. above MHW), which indicate an active sand transport zone via creep, saltation and suspension (see **Figure 4.1**).

Figure 4.1 Schematic representation of sand transport on upper foreshore



Source: http://en.wikipedia.org/wiki/Saltation_%28geology%29

The upper sandy foreshore is characterised by the presence of a detritus strandline at 18m and a sand dominated berm crest which occurs at 27m from the dune toe (see **Plates 4.2** and **4.3**). Seaward of the berm crest the beach adopts a relatively steeper foreshore angle of between $8-10^\circ$. Landward of the crest the upper beachface displays a marked concave curvature which gradually dissipates both to the north and south, where it adopts a more shore parallel orientation.

Plate 4.2 Upper foreshore looking north toward revetment at Dowrie Bitumen works



Plate 4.3 Upper foreshore looking south toward headland



The area of active sand transport on the upper foreshore can be identified as the grey patch to the upper centre of **Plate 4.4**.

Plate 4.4 **Detail of upper foreshore looking south toward headland**



From the low water (LW) mark the degree of coastal erosion and exposed dune toe decreases towards the north where the active dune face decreases in vertical extent and displays a marked increase in the degree of vegetation cover. Corresponding with the marked change in dune morphology there is a marked increase of shingle, which takes the morphological form of a band/berm plastered against the lower dune toe. The height of the shingle crest elevation increases towards the north.

At 60-76m seaward of the dune toe the foreshore is characterised by the presence of a shingle band which displays a sharp transition with the upper foreshore sands. The shingle tends to be well-rounded and approximately 10-50cm in size (see **Plate 4.5**) Within the shingle band were noted occasional well-rounded and abraded red bricks. Seaward of the shingle band the foreshore is dominated by the presence of outcropping concrete clasts which is densely colonized with macro-algae growth.

At 76m seaward from the dune toe, the transect traverses a small (~2m wide) intertidal pool which runs parallel to the dune system, prior to turning south to merge with the larger lower-foreshore intertidal pool to the south (**Plate 4.6**).

From approximately 78-138m seaward the foreshore is characterised by the presence of a distinct zone of wave worked ripple marks. The ripples attain elevations of approximately 2-5cm with wavelengths of 10-15cm and are scattered with small (~2-4cm) shingle clasts. The presence of ripples gradually dissipates towards the north where they progress to a featureless intertidal sandy foreshore.

Plate 4.5 **View north across mid- to lower foreshore shingle band**



Plate 4.6 **View south across mid- to lower foreshore**



The lower foreshore bedrock platform to the south is characterised by an irregular surface expression with topographic depressions and intertidal pools (see **Plate 4.7**). The bedrock is colonised with macroalgae. Where the bedrock platform provides a

degree of topographic variation, crevices are partially to totally infilled with coarse-grained sands.

Plate 4.7 **View to the west from low water toward headland across intertidal bedrock platform**



The lower foreshore on the central transect is devoid of any morphological features. This featureless lower foreshore extends to the north (see **Plate 4.8**). To the south the featureless sandy foreshore is built into a small sand wave feature which occurs on the seaward side of the tidal pool on the northern boundary of the outcropping intertidal bedrock platform.

Plate 4.8 **View to the east from low water towards Arbroath**



On the mid-foreshore to the north of the central transect, a line of irregular large clasts (>1m) form a line to the north. The line of clasts parallels the coastline. It was not possible to determine whether these were naturally occurring or anthropogenic features.

The beach planform is controlled by the general absence of outcropping intertidal bedrock, with the exception of the presence of a distinct area of intertidal concrete blocks, in various states of degradation (see **Plates 4.5** and **4.6**). The presence of the concrete marks a transition on the foreshore profile, landward of which there is a marked increase in the beach profile angle.

The exposed nature of the beach means that incident waves are competent to move large clasts (<10cm). Despite the wave strength, however, some large (>5-10cm) shingle clasts litter the shore. These clasts are not being actively transported within the intertidal, and probably represent a storm lag deposit.

The beach is characterised by detritus on the upper foreshore which is reworked by wave and tidal process to form a distinct low level (~5-10cm) detritus berm crest. From this point landwards the proportion of shingle increases.

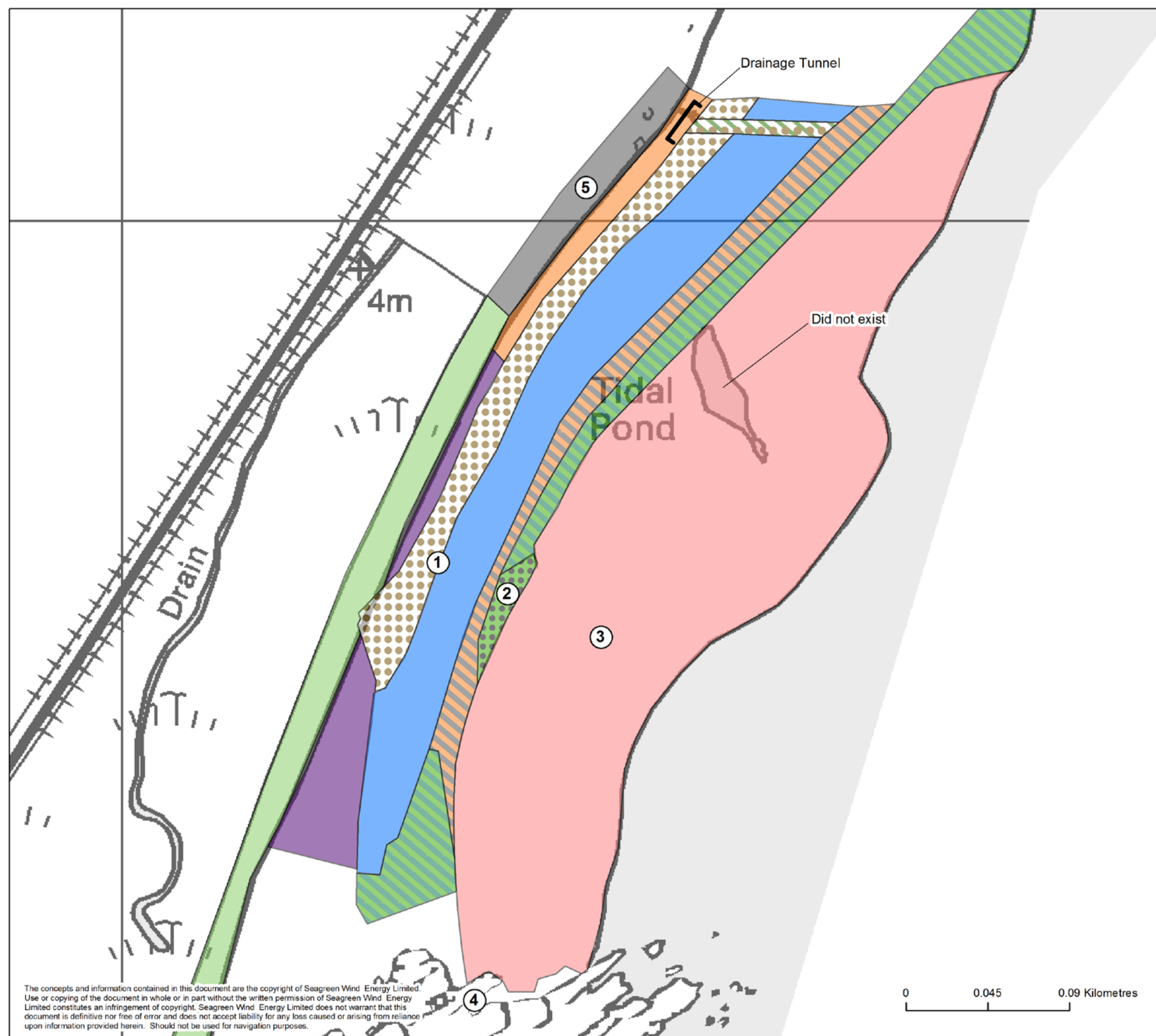
Plate 4.9 **View to the north from low water; southern extent of survey, Arbroath**



Active marine erosion of the dune toe (approx 2-5m) is evidenced along much of the coastline, with the degree of erosion decreasing toward the east corresponding to a decrease in dune and dune toe erosion zone height.

4.1.2 Intertidal ecology

The biotopes within the ECR corridor for landfall at Arbroath are illustrated in **Figure 4.2**. In general, the intertidal area was typical of a sandy beach fronting a dune system, with limited number of biotopes, mostly associated with sediment habitats.



- ① Target Note
- Rock revetment
 - Tidal pool and exposed concrete rocks (EntPor)
 - Shingle (Sh)
 - Fine mobile sediments with amphipods (MoSa.AmSoo)
 - Mobile rippled sediments with polychaetes (FiSa.Po)
 - Shingle/detritus (Sh / St.Tal)
 - Fine sediments over coarse barren mobile sediments (MoSa.BarSa)
 - Vegetated sand dunes
 - Water logged sediments / surface water (FiSa.Po / feature)
 - Fine mobile sediments with sandhoppers (MoSa / St.Tal)
 - River discharge and mobile coarse sediments (MoSa.BarSa / feature)

Coordinate System

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Figure / Drawing Title:

Biotope Map for Arbroath Landfall Site

Figure/Drawing Number: **Figure 4.2**

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There was an elongated tidal pool within the mid-eulittoral surrounding a number of exposed artificial substrata (mimicking natural bedrock). Yet even within this tidal pool and on these concrete clast rocks the diversity of species was limited. The interest locations within the ECR corridor have been marked with a target note number on **Figure 4.2** and discussed in more detail below.

Target note [1]: Upper shore sediments

Figure 4.2 illustrates the biotopes in the upper to mid shore, all of which are sediments, with a low diversity of macrofaunal communities. The dunes were fronted by fine dry sediments, with the occasional strandline debris and evidence of strandline fauna being present, in particular sandhoppers (talitrid amphipods) (see **Plate 4.10**; Biotope: **LS.LSa.St.Tal**). Seaward of this, on the sloping shore the sediments were of fine mobile sediments on the surface, covered with larger cobbles, and below surface coarse mixed sediments lacking of any significant macrofaunal community (Biotope: **LS.LSa.MoSa.BarSa**). The exception were occasional talitrid amphipods, found where there were remains of strandline; particularly around 18m from the toe of the sand dune (see **Plate 4.11**). Landward of these coarser sediments, was a band of finer, well drained mobile sediments, with little apparent organic matter or anoxic layer, though still covered in shingle and cobbles (see **Plate 4.12**).

Plate 4.10 **Fine dry sediments populated by talitrid amphipods**

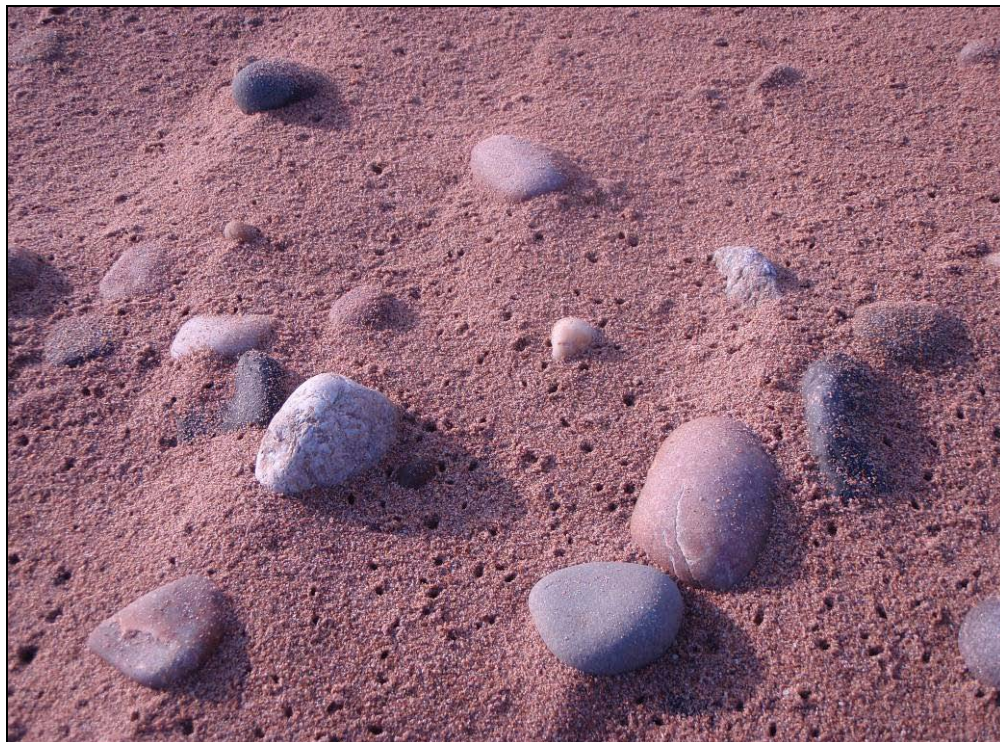


Plate 4.11 View landward over coarse sediments of mid to upper shore²



Plate 4.12 View north-eastwards along beach toward rock revetment¹



This biotope is typical on clean sandy beaches and has a species-poor community, dominated by amphipods (e.g. *Bathyporeia* spp., *Pontocrates arenarius* and *Haustorius arenarius*), isopods (e.g. *Eurydice pulchra*) and occasionally polychaetes such as *Scoelepsis* spp. that can tolerate well-drained conditions (Biotope: **LS.LS.MoSa.AmSco**). The lack of polychaetes along the upper beach is due to the large degree of drainage during low tides as the majority of polychaetes are not tolerant of well-drained sediments. To the east, near to the rock revetment (**Plate 4.12**), the sediments were finer with less overlain shingle (see **Plate 4.13**).

² Taken on a recently fallen tide, so sediments have not drained (refer to **Plate 4.13** for drained sediments)

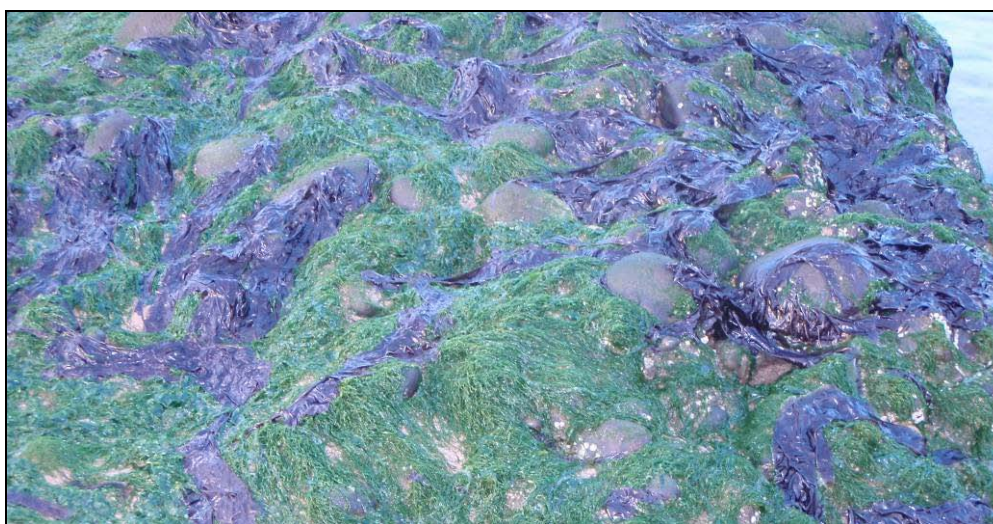
Plate 4.13 **View westwards along beach towards the rocky intertidal bedrock**



Target note [2]: Artificial rocks and tidal pool

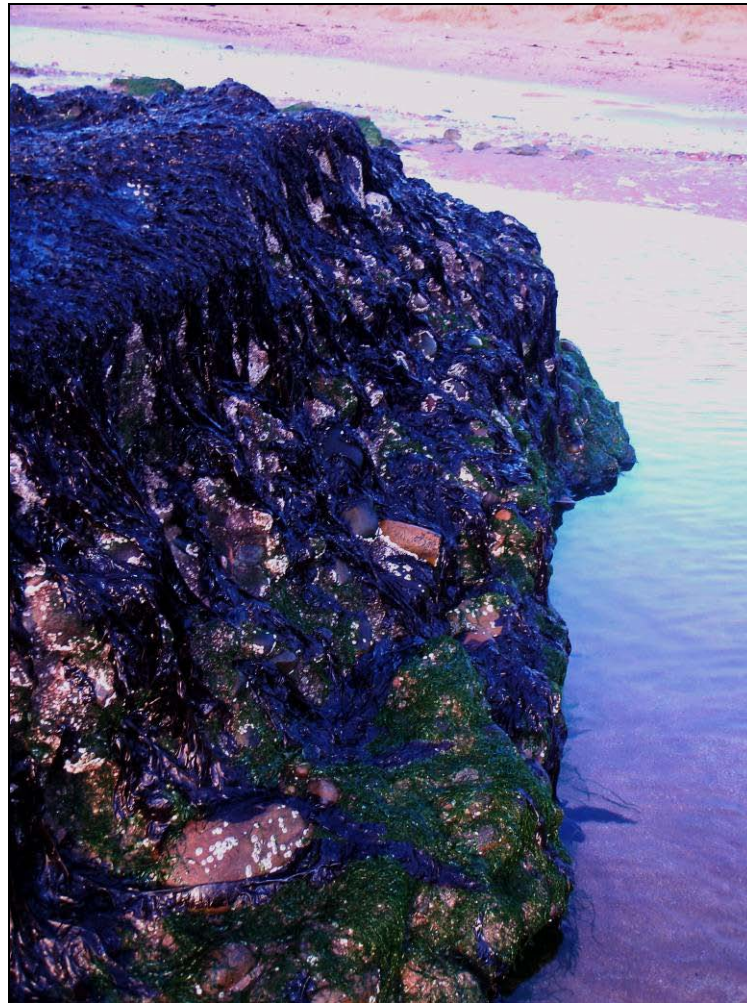
Plates 4.5 and **4.6** illustrate the area of pooled water surrounding exposed concrete rocks in the midshore, which were dominated by the colonisation of ephemeral green (*Ulva intestinalis*) and red (*Porphyra purpurea*) algae typical of sand-scoured areas (see **Plate 4.14**); this impoverished biotope, **LR.FLR.Eph.EntPor** is shown in **Figure 4.2**.

Plate 4.14 **Colonisation of concrete clast rock in mid-eulittoral**



There were also a small number of barnacles (*Semibalanus balanoides*) on the exposed shingle clasts in the concrete (see **Plate 4.15**), though no limpets or winkles were observed under the algae or within crevices, nor was there any observations of fucoid species, which would not tolerate the sand-scoured environment. The pool surrounding the rocks was barren of any mobile species, even under the crevices of the rocks (e.g. fish and crustaceans). The sediments within the pool were however dominated by polychaetes, similar to that lower down this shore (see target note [3] below).

Plate 4.15 **Colonisation of concrete clast in mid-eulittoral**



Target note [3]: Fine polychaete dominated mid – lower shore sediments

The sediments landward of the pool and concrete rocks were rippled on the surface and marked with numerous worm casts, indicating the presence of *Arenicola marina*, the common lugworm (see Plate 4.16). The sediments were fine, waterlogged and the anoxic layer was deeper than 20cm. There was a reasonable abundance of polychaetes, with few amphipods. The biotope is classified as polychaetes in fine littoral sand (**L.LSa.FiSa.Po**), which could be either dominated by *Nephtys cirrosa* (Ncir) or *Paraonis fulgens* (Pful). This biotope stretched from the tidal pool down to the low water mark. The presence of the lugworms is a temporary phenomenon and usually occurs during the summer months, and when detritus is abundant. The worm casts were greater around the rocky bedrock outcrop to the west, where the detritus builds up and is trapped during a falling tide (see **Plate 4.17**).

Plate 4.16 **View landward over rippled sediments on lower shore with common abundance of *Arenicola marina***



Plate 4.17 **View eastward over rippled sediments on lower shore towards the exposed bedrock**



Target note [4]: Intertidal bedrock

To the east of the ECR corridor is a stretch of exposed intertidal bedrock between low water and the foot of the dunes (see **Plate 4.18**). Although this was not included in the walkover survey, it was noted that it was colonised by a diverse algal community and harboured a variety of algal species, anemones, mobile fish and crustacean within the abundant rockpools.

Plate 4.18 The exposed bedrock ledges to the east of the ECR corridor



Target note [5]: Rock revetment

To the west, but still within the ECR corridor, was a rock revetment that was protecting a low-lying area landward, including the land either side of Dowrie Burn, which discharged via a concrete tunnel through the revetment (**Plate 4.19** and **Plate 4.20**).

Plate 4.19 Rock revetment within the ECR corridor fronting the low-lying land behind



The rock revetment was devoid of any fauna or flora, due to being above the littoral zone. Landward of the rock revetment, was a band of dense shingle, that was not present fronting the dunes, and again was barren of any fauna (e.g. sandhoppers), due to the lack of significant strandline debris. The discharge of Dowrie Burn can be seen in **Plate 4.20** below.

Plate 4.20 **Rock revetment within the ECR corridor fronting the low-lying land behind**



4.2 Carnoustie landfall site

4.2.1 Intertidal geomorphology

In planform (see **Figure 2.2**) this section of coastline is remarkably straight owing to the coastal defence structure (see **Plate 4.21**) which backs the intertidal to the north and south. The coastal defence varies in height (5-10m) along the frontage but attains an average elevation of approximately 5-7.5m. The structure consists of approximately 1-1.5tonne rocks placed in an interlocking network. The coastal defence varies in width according to its elevation and degree to which it protrudes into the intertidal, but is typically 10-15m. **Plate 4.21** shows the landward view from low water, centre transect Carnoustie. The beach extended approximately 22m to the low water mark at the time of survey. The centre transect was orientated 90° from north, from the revetment toe which fronts the sand dune system to the rear. The transect runs from the revetment toe across the upper foreshore across ~20m of intertidal featureless sand which slopes at 6-8°.

The width of the intertidal to the north and south of the centre transect increases in both directions (see **Plate 4.22** and **Plate 4.23**), though the pattern of featureless upper foreshore sand repeats, indicating that in the immediate area high energy conditions prevail.

To the northern extent of the survey area, when viewing to the southwest across the intertidal (see **Plate 4.24**), waves were seen to break slightly (~150m) offshore indicating an area of otherwise raised seafloor.

Plate 4.21 **View south from Point 13 looking south across intertidal platform**



Plate 4.22 **View to the south from mid-foreshore towards apex of Buddon Ness**

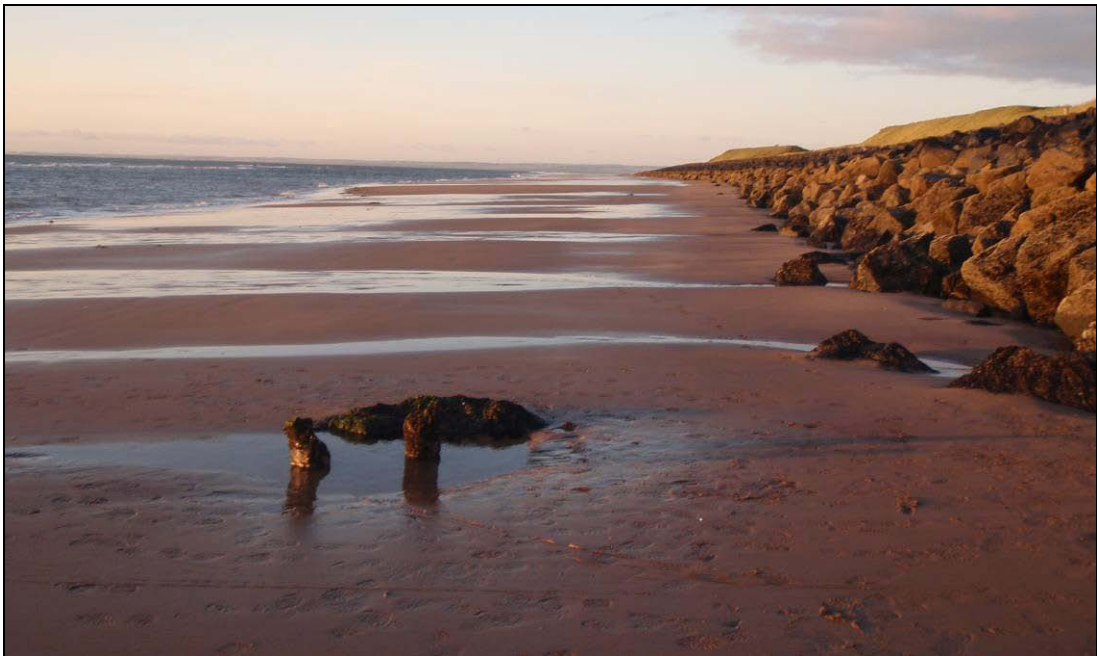


Plate 4.23 **View to the north from mid-foreshore towards Carnoustie**



To the north of the proposed landfall location the intertidal area is relatively wide (200-400m) and gently sloping ($2-3^{\circ}$). The intertidal area has a variety of wave and tidal induced bedforms (see **Plate 4.25**), indicating a much lower mixed energy regime at this location in comparison to the area immediately fronting the coastal defence.

Plate 4.24 **View to the southwest from lower-foreshore towards apex of Buddon Ness**



Plate 4.25 View to the northeast from lower-foreshore towards Carnoustie



4.2.2 Intertidal ecology

The biotopes within the ECR corridor for landfall at Carnoustie are illustrated in **Figure 4.3**. In general, the intertidal area was not particularly diverse, with the greatest diversity of species and habitats on the artificial substrata of the rock revetment protecting the sand dunes from wave action, as well as the occasional exposed bedrock or ship-wrecked timber within the sandy sediments of the beach. The sandy beach itself was typical of a beach exposed to high currents and wave action, with mobile sediments, devoid of benthic fauna. The lower eulittoral sediments were dominated by polychaetes and by the sediment tidal pools observed in **Figure 4.3**, present as a result of a raised bank of sediment either side, which was exposed on a spring low tide. These pools were sediment lined, and therefore did not result in diverse lower tidal pools, only the presence of fish and mobile species caught by the falling tide, although the sediments along the lower shore of these tide pools did have occasional occurrence of the sand mason polychaete *Lanice conchilega*. Further north, at the entrance to the discharge of Barry Burn, the sediments were densely populated by this polychaete and were observed to support large numbers of feeding birds at low tide, however, this was not observed for the long stretch of beach fronting the revetment and dunes.

In addition, to the summary above, a number of interest locations have been marked on **Figure 4.3** with target note location which are discussed below.

Target note [1]: rock revetment

The rock revetment comprised of granite rock approximately 75 x 75 cm in size (see **Plate 4.21** above), and illustrated typical colonisation by species within habitats exposed to high wave attack. The supralittoral (i.e. within the splash zone above high water) was typically characterised by a maritime community of lichens, with the upper lichen zone of

yellow/orange and grey lichens (e.g. *Xanthoria parietina* and *Caloplaca marina*; Biotope LR.FLR.Lic.YG³), and the lower lichen zone of black lichen (e.g. *Verrucaria maura*; LR.FLR.Ver.Ver⁴); see **Plate 4.26**. Since this stretch of the coast is highly exposed to wave action the distinction between these two bands is distinct; the layer covered in black lichens can be seen clearly in **Plate 4.26** between the bare rock at the top of the rock and the barnacle covered rocks at the bottom. The depth of this layer indicates the high wave and tidal exposure of the shore.

Plate 4.26 Lichen covered boulders of the rock revetment (left photo: grey and yellow lichens, right photo: black band of lichens)



Between the band that is dominated by black lichen and the dense colonisation of barnacles (see below), was a band around the littoral fringe of black lichen (*Verrucaria maura*) and sparse barnacles (Biotope: **LR.FLR.Lic.Ver.B**). There was also an occasional presence of the winkles (*Littorina saxatilis* and *Littorina (Melarhapha) neritoides*) and limpets (*Patella vulgata*).

Seaward of the band on the littoral fringe, but within the littoral was a large band of dense barnacles (*Semibalanus balanoides*) interspersed by small mussels (*Mytilus edulis*); see **Plate 4.27**. Within the crevices and sheltered sides of the rock faces, there were large abundances of littorinid molluscs and dog whelks *Nucella lapillus*, and presence of limpets (mainly *Patella ulyssiponensis*), as well as the occasional beadlet anemone (*Actinia equina*) in damp crevices. The colonisation of the lower revetment was **LR.HLR.MusB.MytB**⁵.

Target note [2]: sandy beach sediments

The sediments of the beach were species poor overall, with the majority of the beach comprising of barren compacted sediments, which were mobile due to the hydrodynamic regime resulting in the redistribution of these sediments by the tide and currents (Biotope: **LS.Lsa.MoSa.BarSa**). Excavations during the walkover showed a lack of macrofauna, of either amphipods or polychaetes (see **Plate 4.28**). Towards the mid to lower shore, the sediment became more rippled in appearance with a presence of polychaetes, and was similar to that found at Arbroath (Biotope: **LS.LSa.FiSa.Po**); see **Plate 4.17** above.

³ **Biotope LR.FLR.Lic.YG**: Yellow and grey lichens on supralittoral rock (Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b)

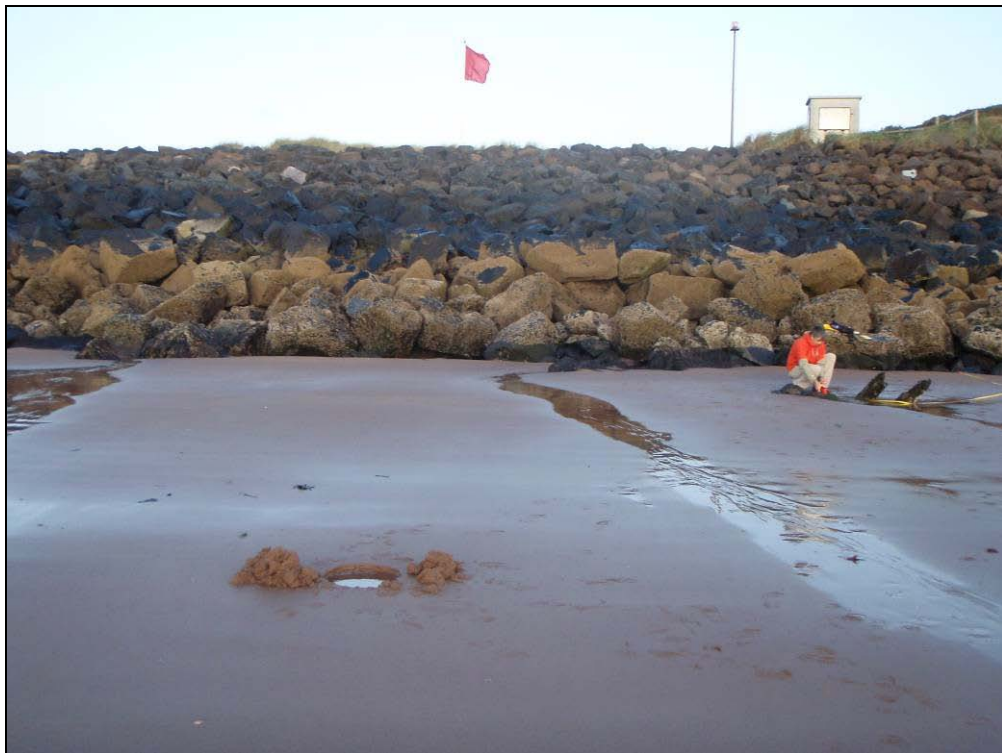
⁴ **Biotope LR.FLR.Ver.Ver**: Black lichens on supralittoral rock (Version 97.06: Connor *et al.*, 1997a, b)

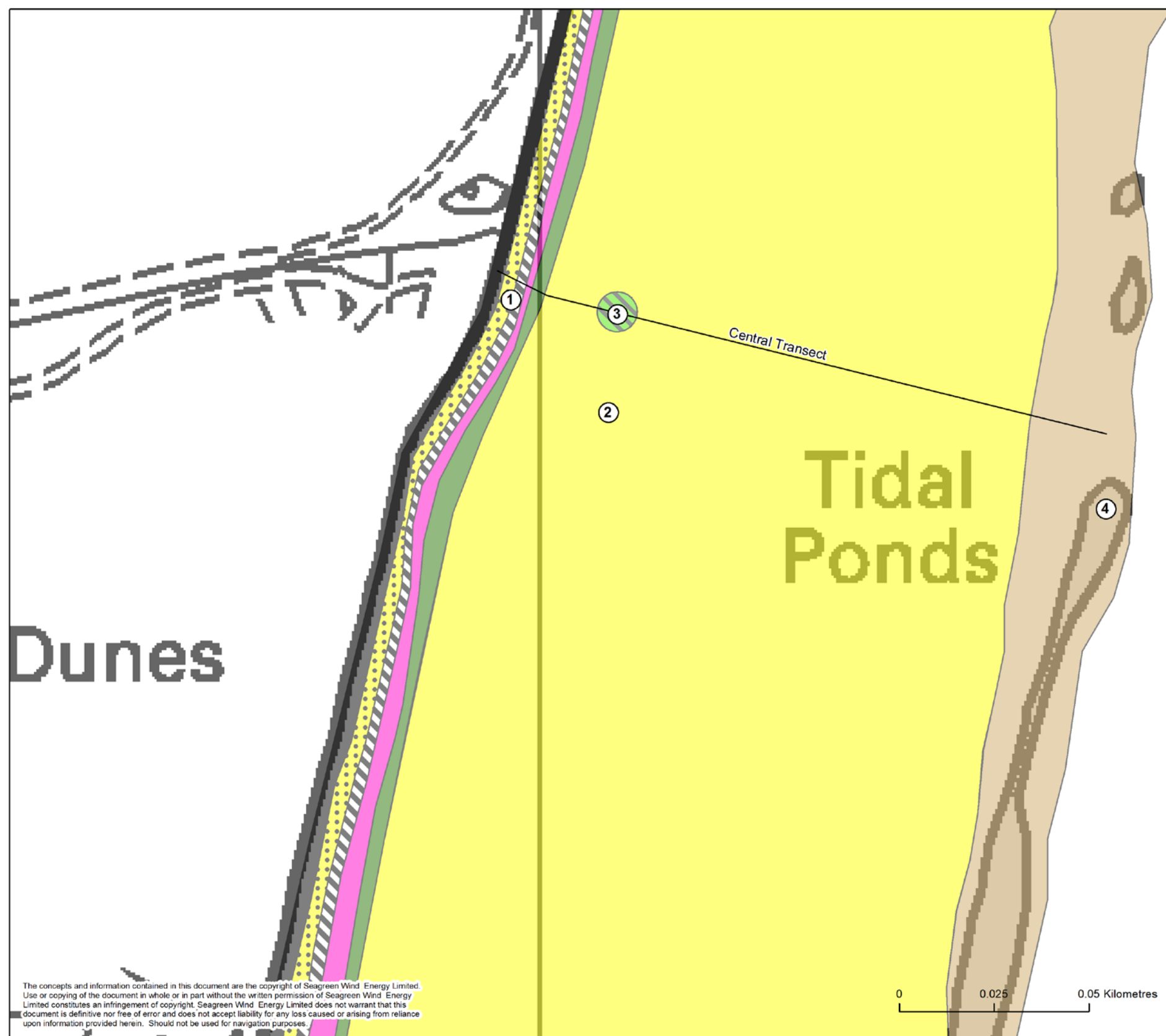
⁵ **Biotope LR.HLR.MusB.MytB**: *Mytilus edulis* and barnacles on very exposed eulittoral rock

Plate 4.27 Barnacles, mussels, winkles and limpets on lower band of revetment



Plate 4.28 Barren upper shore sediments



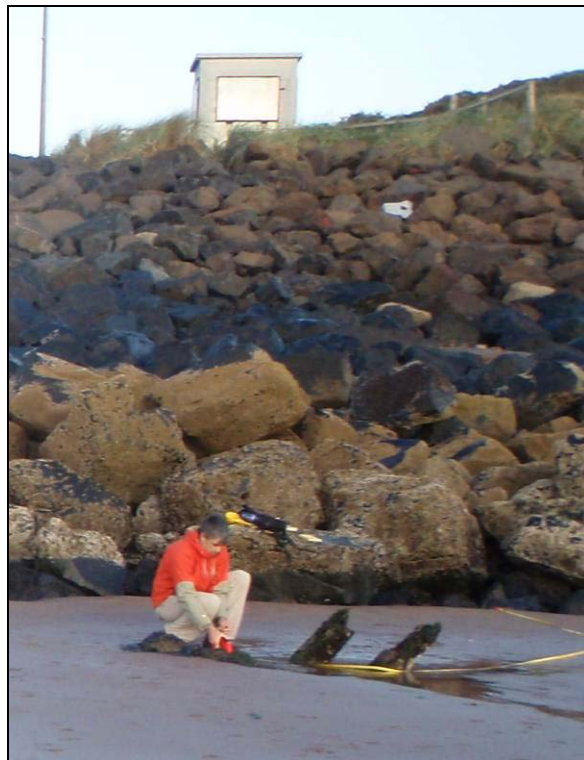


The sediments around the discharge point of Barry Burn were more species-rich, with the presence of *Lanice conchilega* (Biotope: **LS.LSa.MuSa.Lan**), where it is tide-swept yet sheltered. In addition, bivalves were present (potentially *Cerastoderma edule* rather than *Macoma balthica*). These polychaete rich sediments were attracting significant numbers of feeding birds, which were not observed elsewhere along the frontage of the rock revetment within the ECR corridor, potentially due to the lack of macrofaunal communities as a food source.

Target note [3]: exposed bedrock and rockpools

In the area of the ECR corridor was a small exposure of bedrock and wood (potentially remnants of a wreck) surrounded by a sediment tidal pool (see **Plate 4.29**). The wood was colonised by ephemeral green and red algae (*U. intestinalis* and *P. purpurea*) typical of sand-scoured mixed substrata in the eulittoral (**LR.FLR.Eph.EntPor**). In addition, there were occasional barnacles and winkles (*Littorina littorea*) and abundant dog whelks (*Nucella lapillus*; **LR.HLR.MusB.Sem.LitX**).

Plate 4.29 **Exposed wood and rock landward of rock revetment**



5 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

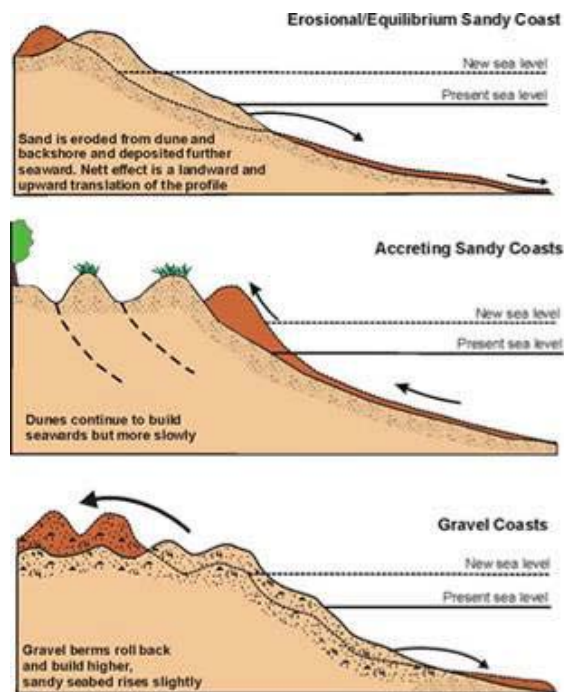
5.1 Summary

5.1.1 Arbroath landfall site

Geomorphology

Where dunes occur along the Arbroath coastline they are typically eroded at their toe. Actively eroding dunes extend from the headland to the south to the rock revetment fronting the Dowrie Bitumen Works, to the north. Vegetated dune slumps are present along much of the eroding dune, with their presence increasing in relation to the active dune face (i.e. greater proportion of active slumps where there is an increase in dune height).

Figure 5.1 Generalised models of dune morphology



Source: <http://www.mfe.govt.nz/publications/climate/coastal-hazards-climate-change-guidance-manual/page4.html>

As illustrated in **Figure 5.1**, the dune system at Arbroath displays elements of erosional/equilibrium and accreting sand coasts. However, it should be noted that on most northern hemisphere coasts, particularly those that are isostatically adjusting such as the Scottish coastline, most dune systems are superimposed on former gravel deposition systems. Such systems may pose a technical issue with regards to their crossing during the construction phase of any proposed works.

Intertidal ecology

The intertidal area within the Arbroath ECR landfall was typical of a moderately exposed sandy beach fronting a dune system, with a limited number of different biotopes, mostly associated with sediment habitats with macrofaunal communities mainly being amphipod (upper to mid shore) and polychaete (mid to lower shore) dominated. The

only exception was the concrete blocks within the mid-eulittoral, which were surrounded by a tidal pool with limited diversity of species.

5.1.2 Carnoustie Landfall Site

Geomorphology

The entire coastline is characterised as very high energy with the intertidal sandy foreshore being devoid of any wave of tidally induced morphological features. The beach at Carnoustie is extremely constrained, in terms of the potential for intertidal working, even at mean low water on a spring tide.

To the north of the proposed landfall location the intertidal area is relatively wide and gently sloping. Furthermore, the intertidal area is exposed for a much a longer duration during the tidal cycle and therefore may provide an alternative landfall option at Carnoustie.

Intertidal ecology

The intertidal area was generally species-poor, with the communities on the rock revetment being most diverse within the ECR corridor. The sandy beach itself was typical of that exposed to high currents and wave action, with mobile sediments, almost devoid of benthic fauna until the lower shore, where it was dominated by polychaetes and sediment tidal pools. These sediment tide pools were a result of a raised bank of sediment either side, which was exposed on a low spring tide, and harboured trapped fish and crustacean on the falling tide. The nature conservation designations associated with the shore, are unlikely to result in a significant constraint, since many of the features either do not exist or are not in exceptional condition, given that the designation is related to features either further inland, or further south in the 'Firth of Tay'.

5.2 Conclusion

The landfall option at Arbroath seems favourable and does not provide any technical constraints, apart from the dune on gravel system which backs most of the beach. However, due consideration to the dune system will be required and works will be required to be sympathetic to the natural environment.

The main ecological consideration for the intertidal would be to ensure that any works would not have an effect on the rocky intertidal exposures to the south, although these are not designated. Any temporary cable routing works will result in a relatively quick recovery of the macrofaunal communities within the sediments, providing there are no significant changes to the surrounding hydrodynamics, since the species present are quick to colonise and have a short reproductive cycle.

Landfall at Carnoustie is significantly constrained by the presence of the rock revetment coastal defence, the relatively small intertidal area, the limited amount of intertidal area exposed (other than during the lowest spring tides) and the relatively high energy experienced along this section of coastline.

The ecological recovery of the sediments will be relatively quick, though much slower on the rock revetment. However, the rock revetment is not a designated feature.

5.3 Recommendations

At Arbroath there is clear evidence that shingle and gravel can remain on the upper foreshore, and provide a protective benefit to the dune systems. The shingle in **Plate 4.13** provides a clear demonstration of this. Depending on the source of this material it can provide a sustainable solution, in some circumstances, to the management of dune erosion, with the behavior of coarse material, once deposited, being more predictable than sand. This should be viewed as an opportunity for Seagreen to mitigate any perceived adverse effects upon the environment at Arbroath via the provision of erosion control features along the coastline.

The coastal frontage at Carnoustie is located within the Firth of Tay and Eden Estuaries SAC. The site is geologically and ecologically important due to the sandflats and mudflats, which are either exposed or not exposed by seawater immediately fronting the coastal defence (refer to **Section 2.3**).

The intertidal foreshore at the proposed landfall location is extremely constrained in terms of access to the intertidal foreshore for working. Furthermore, the coastal system at Carnoustie is sand dominated and therefore the technical feasibility of installing cable works through the intertidal foreshore and across the dune systems will require further investigative works to determine the feasibility of this approach.

Where beaches are constrained by a fixed landward boundary, such as the steep and wide coastal protection at Carnoustie, the natural process of landward migration under conditions of rising sea-level is halted. As a consequence of the upper limit of the beach being constrained by the presence of the coastal defence, the gradual disappearance of the beach is likely to result. This process, known as coastal squeeze has been occurring and continues to do so at this location.

Finally, the propagation of sea waves into the area and resultant energy at the toe of the coastal defence is likely to result in significantly higher wave energy via wave reflection from the static structure. Such increases in energy may result in the partial removal of foreshore sands to considerable depths, especially in response to storm events. The high energies encountered along the coastal defence at Carnoustie would therefore require burial of the cables to a substantial depth and their possible protection from subsequent scour.

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