9. Flood Risk and Climate Change

9.1 Uig Harbour Redevelopment Flood Risk and Climate Change Technical Note

9.2 Uig Harbour Redevelopment Culvert Extension Technical Note

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Uig Harbour Redevelopment

Flood Risk & Climate Change

The Highland Council

25 January 2019

Quality information

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1. Introduction

AECOM has been commissioned to undertake a study of flood risk, including consideration of climate change, for the proposed Uig Harbour Redevelopment. The aim of this numerical modelling study is to assess the impact of the proposed development on coastal flood risk.

The MIKE21 Spectral Wave Model (SW) developed by the Danish Hydraulics Institute (DHI) was used to simulate wind-generated waves within Uig Bay including the various harbour structures. The model was operated in hindcast mode using wind data obtained from the UK Met Office. The modelling study was used to evaluate wave conditions for the existing and redeveloped layouts (i.e. including a solid jetty structure, reclamation and two dredged pockets).

Extreme water levels were taken from SEPA's Coastal Flood Boundary (CFB) dataset which includes the coastal waters near Uig Bay. Wind statistics were derived from the Met Office data for 12 directional sectors for 30° directional intervals. Extreme winds for each sector were estimated based on the Weibull probability distribution.

The wave model was run under northern and south-westerly wind conditions for the following range of return periods: 1, 2, 10, 20, 50, 100, 200 and 1000 years. Comparisons of wave overtopping between the existing ferry terminal and the scheme layout have been made to assess flood risk under the present day and climate change scenarios.

2. Extreme Water Levels

Extreme sea levels include tides, sea level rise and surge. Present day (2018) extreme sea levels were obtained from the CFB dataset. Figure 2-1 shows available data points near the study area. The point labelled '192-8-Skye-M' has been selected for Uig Bay.

In order to consider climate change for the 100 year (2118) epoch, the present day extreme water levels were factored with the UKCP09 95th percentile medium and high emission scenarios (including surge), as shown in Figure 2-1.

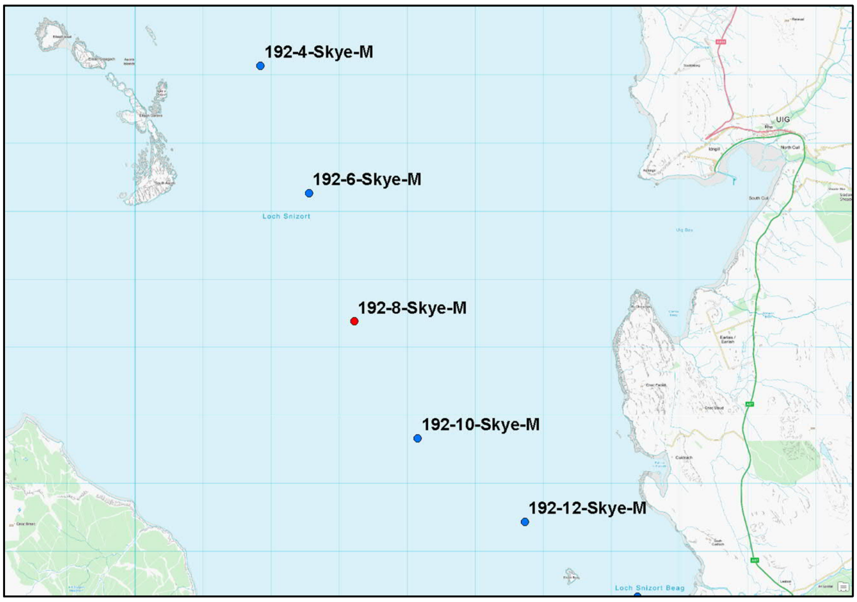

Figure 2-1. Local extreme sea level prediction points from the CFB database

Table 2-1 Extreme water levels near Uig Bay

Return Period (year)	Extreme Sea Levels (m, ODN)		
	Present Day (2018)	Future (2118) Medium Emission	Future (2118) High Emission
1	3.37	4.04	4.23
2	3.46	4.14	4.33
10	3.67	4.36	4.55
20	3.76	4.44	4.63
50	3.87	4.56	4.75
100	3.94	4.63	4.82
200	3.99	4.69	4.88
1000	4.15	4.86	5.05

3. Wave Modelling

AECOM developed a MIKE21 Spectral Wave Model (SW) for the specific requirements of the wave transformation study. The wave modelling report (UHRD-ACM-ZZ-GE-RP-MT-00001) provides further detail on the model set-up and calibration. MIKE21 SW is a state-of-the-art wave transformation model based on triangular mesh elements, which are able to provide enhanced resolution covering important features such as local variations in bathymetry.

Figure 3-1 and Figure 3-2 show the model mesh for the existing ferry terminal and the scheme layout, respectively.

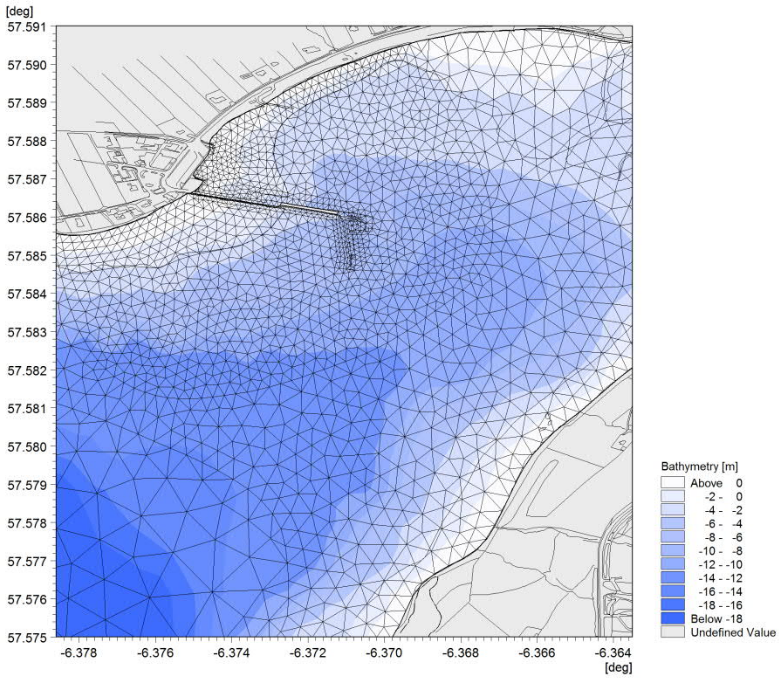

Figure 3-1. Mesh for the existing layout

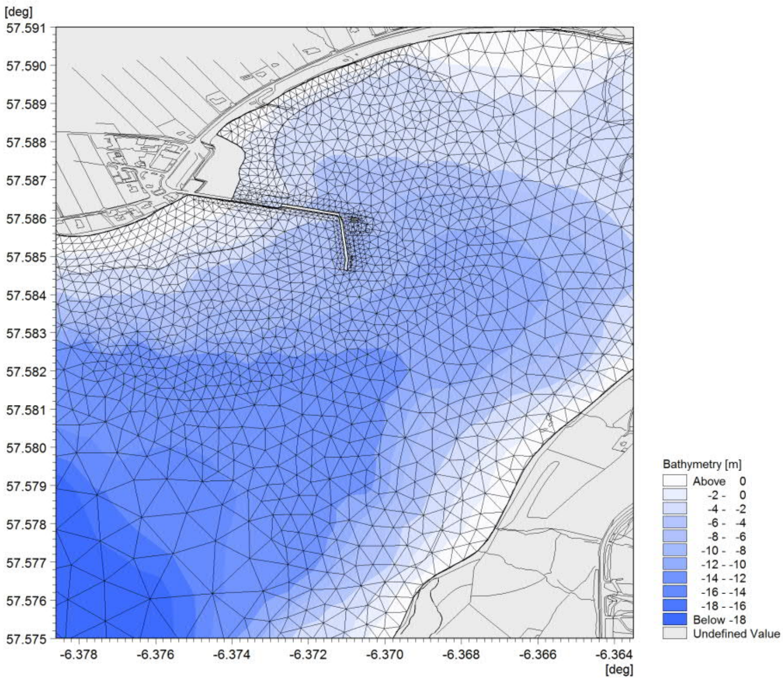

Figure 3-2. Model mesh for the scheme layout

4. Joint Probability Analysis

Joint probability refers to the chance of two or more conditions occurring at the same time. In this instance, with wave transformation modelling in mind, the coincidence of extreme waves and extreme water levels is of interest. A Joint Probability Analysis (JPA) of waves and water levels was undertaken. The simplified JPA approach, as described in the guidance (*Use of Joint Probability Methods in Flood Management: A Guide to Best Practice – R&D Technical Report FD2308/TR2, 2005*), has been used to establish combinations of waves and sea levels for the standard set of return periods previously identified. The guidance provides details of regional variations in the strength of correlation between waves and sea levels in UK waters (Figure 4-1). The correlation coefficient for Uig Bay itself is not provided therefore a 'well correlated' assumption has been assumed as a conservative approach.

The Uig Harbour ferry terminal and pier structures are exposed to wind waves propagating from the Little Minch into Uig Bay which are affected by diffraction and refraction processes and are also influenced by locally generated winds within the bay. The wave model covers a sufficiently large area to ensure that the wind generated waves can be fully developed within the model domain. The resulting significant wave heights at the toe of various structures were modelled by using combinations of extreme winds and water levels. Wave overtopping of the reclaimed area (north of the jetty) will be affected by the north-easterly (30°N sector) waves/winds, whilst south-westerly (270°N sector) winds are expected to generate the largest overtopping along the southern side of the jetty.

Directional extreme winds have been estimated based on the Weibull probability distribution involving the selection of individual storm events using the peaks over threshold method. This includes wind speeds for eight return periods of 1, 2, 10, 20, 50, 100, 200 and 1000 years. Wind extremes for the 30°N and 270°N sectors are provided in Table 4-1 and were used in the further joint probability analysis. For the climate change, high emission scenario was considered for water levels, and the allowances provided in Environment Agency Guidance 'Flood risk assessments: climate change allowances' (https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances) were applied for winds. This requires a 10% increase in wind speed up to 2115 from a 1990 baseline to investigate the range of impact.

The results of the joint probability analysis are provided in Table 4-2 to Table **4-5** and Figure 4-2 to Figure 4-5. Each table and figure present the joint exceedance return periods for a combination of extreme wind speed and sear levels.

Table 4-1 Extreme wind speeds (m/s) for present day and with future climate change

RP (yrs)	Sector 30°		Sector 270°	
	Present	Future	Present	Future
1	16.3	17.9	23.5	25.9
2	17.9	19.7	24.5	27.0
10	21.7	23.9	27.6	30.4
20	23.4	25.7	29.6	32.6
50	25.7	28.3	32.3	35.6
100	27.5	30.3	34.4	37.9
200	29.3	32.2	36.6	40.2
1000	33.6	37.0	41.7	45.9

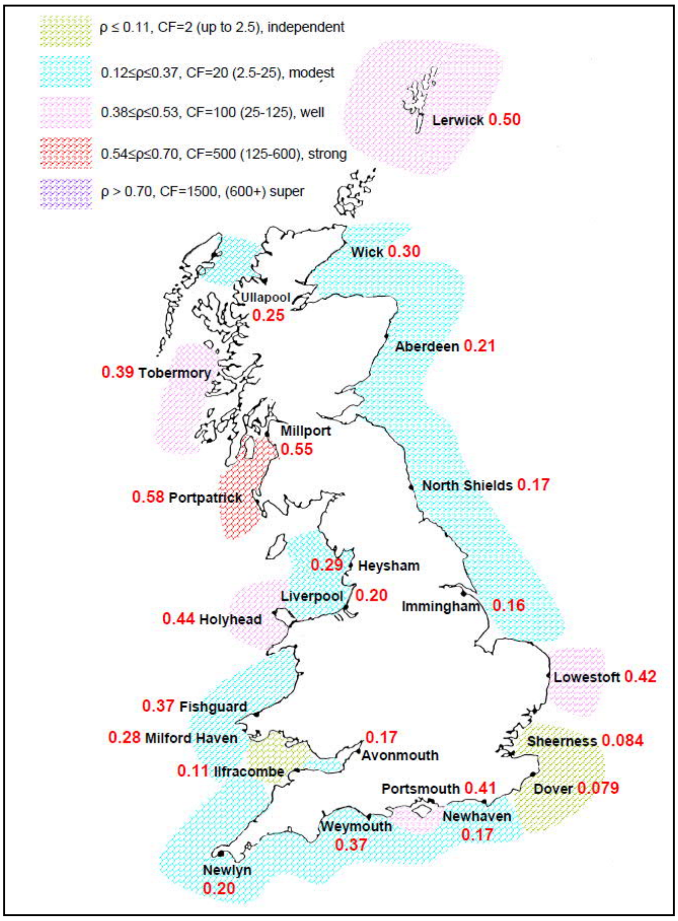

Figure 4-1. Correlation coefficient (wave height & sea levels)

Table 4-2. Joint probability for 30°N wind and water level (present day)

Wind Speed (m/s)	Joint exceedence return period (years)							
	1	2	10	20	50	100	200	1000
	Still Water Level (m, ODN)							
4.4	3.4	3.5	3.7	3.8	3.9	3.9	4.0	4.2
6.2	3.4	3.5	3.7	3.8	3.9	3.9	4.0	4.2
7.0	3.4	3.5	3.7	3.8	3.9	3.9	4.0	4.2
10.3	3.2	3.3	3.6	3.7	3.9	3.9	4.0	4.2
12.1	3.2	3.3	3.5	3.6	3.8	3.9	4.0	4.2
14.4	3.1	3.2	3.4	3.5	3.7	3.8	3.9	4.1
16.3	3.0	3.1	3.3	3.4	3.6	3.7	3.8	4.0
17.9		3.0	3.3	3.4	3.5	3.6	3.7	4.0
21.7			3.1	3.2	3.3	3.4	3.5	3.8
23.4				3.1	3.2	3.3	3.4	3.7
25.7					3.1	3.3	3.3	3.6
27.5						3.2	3.3	3.5
29.3							3.2	3.4
33.6								3.3

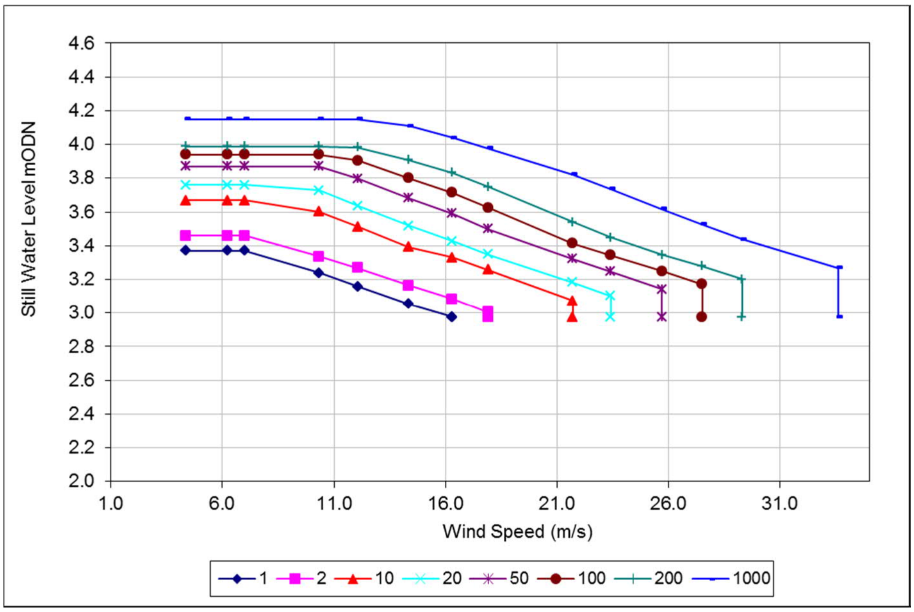

Figure 4-2. Joint probability distribution for 30°N wind and water level (present day)

Table 4-3. Joint probability for 30°N wind and water level (climate change)

Wind Speed (m/s)	Joint exceedence return period (years)							
	1	2	10	20	50	100	200	1000
	Still Water Level (m, ODN)							
4.8	4.2	4.3	4.6	4.6	4.8	4.8	4.9	5.1
6.9	4.2	4.3	4.6	4.6	4.8	4.8	4.9	5.1
7.7	4.2	4.3	4.6	4.6	4.8	4.8	4.9	5.1
11.4	4.1	4.2	4.5	4.6	4.8	4.8	4.9	5.1
13.3	4.0	4.1	4.4	4.5	4.7	4.8	4.9	5.1
15.8	3.9	4.0	4.3	4.4	4.6	4.7	4.8	5.0
17.9	3.8	3.9	4.2	4.3	4.5	4.6	4.7	4.9
19.7		3.8	4.1	4.2	4.4	4.5	4.6	4.9
23.9			3.9	4.0	4.2	4.3	4.4	4.7
25.7				4.0	4.1	4.2	4.3	4.6
28.3					4.0	4.1	4.2	4.5
30.3						4.0	4.1	4.4
32.2							4.1	4.3
37.0								4.1

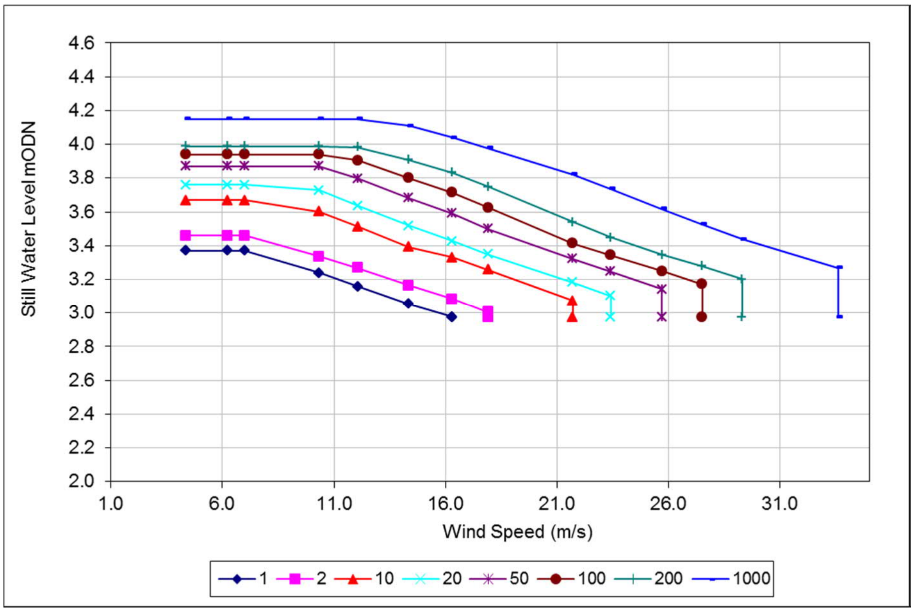

Figure 4-3. Joint probability distribution for 30°N wind and water level (climate change)

Table 4-4. Joint probability for 270°N wind and water level (present day)

Wind Speed (m/s)	Joint exceedence return period (years)							
	1	2	10	20	50	100	200	1000
	Still Water Level (m, ODN)							
9.1	3.4	3.5	3.7	3.8	3.9	3.9	4.0	4.2
11.8	3.4	3.5	3.7	3.8	3.9	3.9	4.0	4.2
13.6	3.4	3.5	3.7	3.8	3.9	3.9	4.0	4.2
16.3	3.2	3.3	3.6	3.7	3.9	3.9	4.0	4.2
18.2	3.2	3.3	3.5	3.6	3.8	3.9	4.0	4.2
20.6	3.1	3.2	3.4	3.5	3.7	3.8	3.9	4.1
23.5	3.0	3.1	3.3	3.4	3.6	3.7	3.8	4.0
24.5		3.0	3.3	3.4	3.5	3.6	3.7	4.0
27.6			3.1	3.2	3.3	3.4	3.5	3.8
29.6				3.1	3.2	3.3	3.4	3.7
32.3					3.1	3.3	3.3	3.6
34.4						3.2	3.3	3.5
36.6							3.2	3.4
41.7								3.3

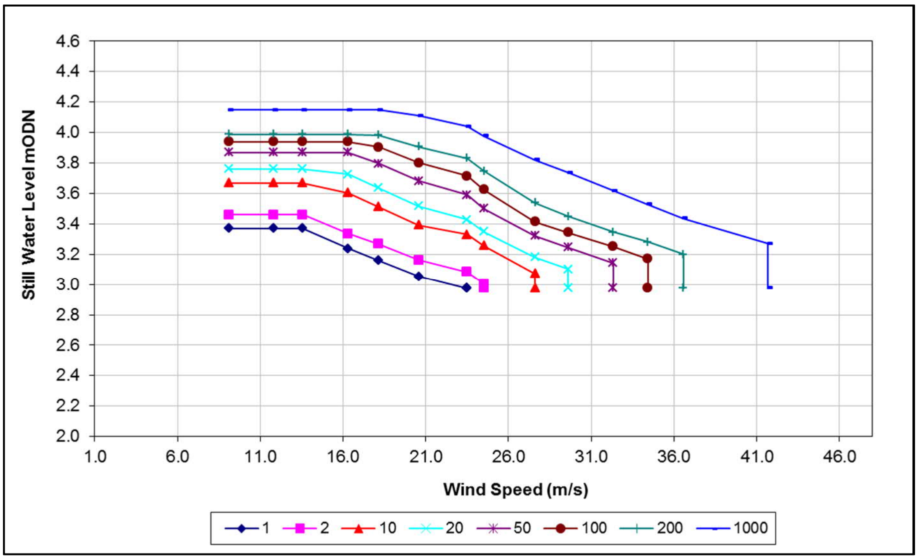

Figure 4-4. Joint probability distribution for 270°N wind and water level (present day)

Table 4-5. Joint probability for 270°N wind and water level (climate change)

Wind Speed (m/s)	Joint exceedence return period (years)							
	1	2	10	20	50	100	200	1000
	Still Water Level (m, ODN)							
10.0	4.2	4.3	4.6	4.6	4.8	4.8	4.9	5.1
13.0	4.2	4.3	4.6	4.6	4.8	4.8	4.9	5.1
14.9	4.2	4.3	4.6	4.6	4.8	4.8	4.9	5.1
17.9	4.1	4.2	4.5	4.6	4.8	4.8	4.9	5.1
20.0	4.0	4.1	4.4	4.5	4.7	4.8	4.9	5.1
22.6	3.9	4.0	4.3	4.4	4.6	4.7	4.8	5.0
25.9	3.8	3.9	4.2	4.3	4.5	4.6	4.7	4.9
27.0		3.8	4.1	4.2	4.4	4.5	4.6	4.9
30.4			3.9	4.0	4.2	4.3	4.4	4.7
32.6				4.0	4.1	4.2	4.3	4.6
35.6					4.0	4.1	4.2	4.5
37.9						4.0	4.1	4.4
40.2							4.1	4.3
45.9								4.1

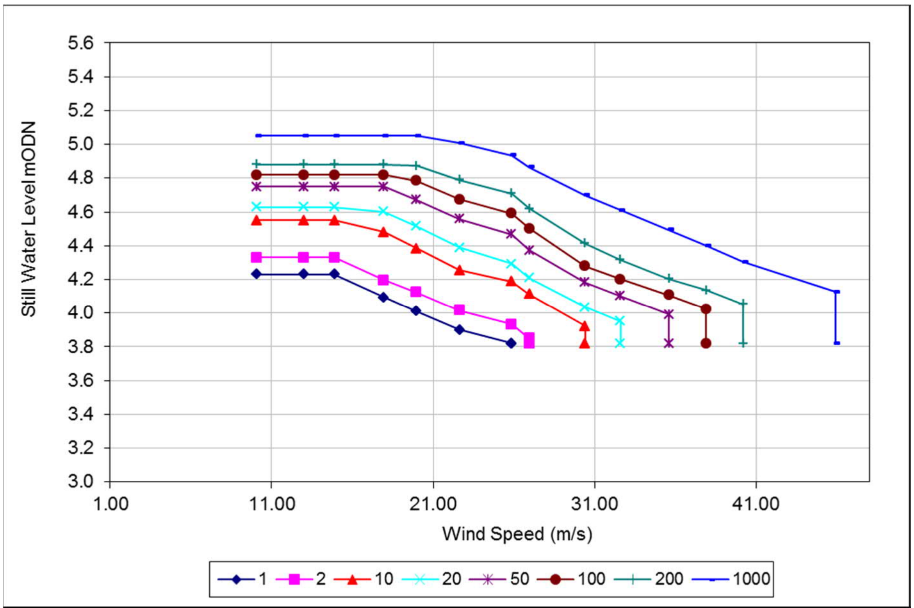

Figure 4-5. Joint probability distribution for 270°N wind and water level (climate change)

5. Overtopping Calculation

5.1 Approach

Wave overtopping is the process by which water is carried over the top of a coastal defence due to wave run-up exceeding the defence crest height. The calculations of wave overtopping discharge rate at the coastal defence structures were undertaken to identify the level of risk from coastal flooding for a range of return periods. The calculations were carried out using formulae provided in '*EurOtop – Wave Overtopping of Sea Defences and Related Structures Assessment Manua*l' (2012) to determine the mean overtopping discharge (l/s/m) for a range of structure types. At present, the EurOtop guidance is regarded as best practice within industry. The required inputs to the calculation vary according to structure type, but typically consist of:

- significant wave height (m);
- mean wave period (s);
- structure freeboard (m);
- water depth at the structure toe (m); and
- roughness coefficients and the structure slope (if applicable).

5.2 Cross Sections

Wave overtopping discharge rates have been estimated at four cross sections for the existing ferry terminal (Figure 5-1 and Figure 5-2) and five cross-sections for the developed scheme (Figure 5-3). Typical geometry of the defence structures (crest level, bed level at toe, slope etc.) are provided in Table 5-1 and Table 5-2 based on structural design parameters and topographic survey information.

Figure 5-1. Cross sections for the existing ferry terminal

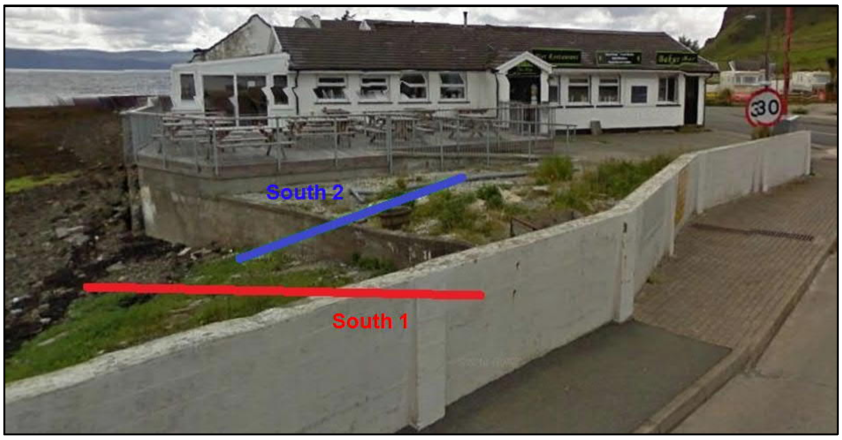

Figure 5-2. Cross sections for the existing ferry terminal (3D view)

Table 5-1. Cross-section details for the existing ferry terminal

Cross Sections	North	South 1	South 2	South 3
Crest Level (m, OD)	4.15	5.54	4.30	5.54
Crest Level (m, CD)	6.85	8.24	7.00	8.24
Bed level at toe (m, ODN)	0.80	2.20	2.20	-2.00
Slope	1/2	vertical wall	vertical wall	vertical wall

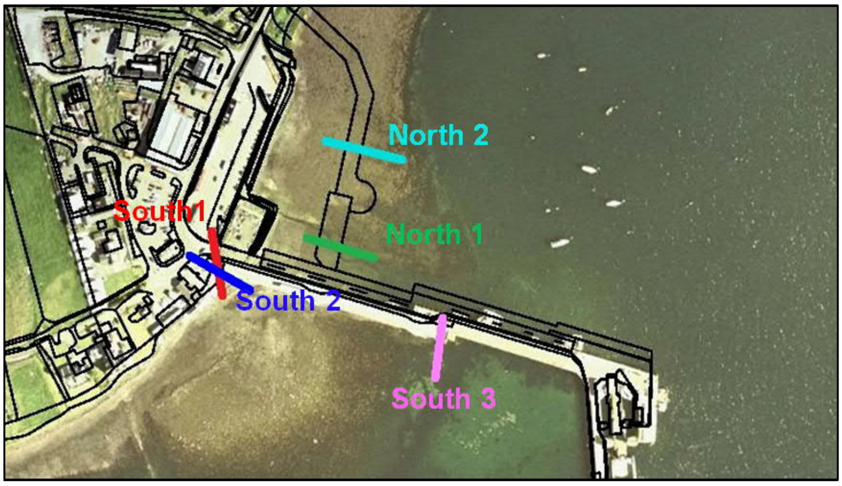

Figure 5-3. Cross-sections for the developed scheme

Table 5-2. Cross-section details for the developed scheme

Cross Sections	North 1	North 2	South 1	South 2	South 3
Crest Level (m, ODN)	4.80	4.80	5.54	4.30	5.54
Crest Level (m, CD)	7.50	7.50	8.24	7.00	8.24
Bed level at toe (m, ODN)	-1.70	-0.50	2.20	2.20	-2.00
Slope	vertical wall	1/2.5	vertical wall	vertical wall	vertical wall

5.3 Overtopping Discharge Rate

The range of sea levels and wave heights considered was based on the joint probability analysis presented in the Section 4. Wave overtopping discharge rates were calculated for combinations of wave and sea level for each cross-section. The results cover the full range of extreme events from 1 in 1 year up to a 1 in 1000 year event for both present day (2018) and a high emissions climate change scenario (2118). This resulted in a maximum wave overtopping discharge being derived for each joint probability event at each cross-section. These joint exceedance overtopping discharges are presented in Table 5-3 to Table 5-6. Figure 5-4 to Figure 5-11 shows the comparison between the existing terminal and the developed scheme. Based on these results the following conclusions can be drawn:

1. For the reclaimed area to the north of the terminal, wave overtopping discharges will be significantly reduced for the developed case due to an increase of 0.65m in the crest level of the defences.
2. For the area to the south of the terminal (Sections South 1, South 2 and South 3), wave overtopping discharges are predicted to increase due to the proposed new solid jetty structure.
3. The increase in overtopping discharge close to the coastline (Sections South 1 and South 2) is relatively small, although the proposed solid jetty has a more significant impact on overtopping near the jetty approach (Section South 3).

Further analysis suggests that the incoming waves are reflected from the proposed solid jetty structure increasing wave heights in front of the jetty approach. Figure 5-12 to Figure 5-15 show the comparison of significant wave height between the existing ferry terminal and the developed scheme. It can be seen that the proposed solid structure has a relatively small impact on wave heights (up to 9%) at the South 1 and South 2 sections. However, the increase in the incident wave height is more than 20% at the South 3 section.

Table 5-3. Overtopping rates for the existing ferry terminal 2018

Return Period (years)	Overtopping Rate (l/m/s)			
	North	South 1	South 2	South 3
1	0.0	0.7	9.0	14
2	0.2	1.2	14	19
10	2.3	3.2	47	38
20	5.0	4.9	77	47
50	12	7.9	181	57
100	21	11	397	63
200	33	16	858	72
1000	76	31	1934	111

Table 5-4. Overtopping rates for the existing ferry terminal 2118

Return Period (years)	Overtopping Rate (l/m/s)			
	North 1	South 1	South 2	South 3
1	44	23	2077	73
2	68	32	2592	89
10	149	72	3791	171
20	195	99	4448	223
50	269	183	5039	323
100	334	286	5161	421
200	402	466	5483	610
1000	571	1171	7060	1290

Table 5-5. Overtopping rates for the developed scheme 2018

Return Period (years)	Overtopping Rate (l/m/s)				
	North 1	North 2	South 1	South 2	South 3
1	0.0	0.0	1.4	11	37
2	0.0	0.0	1.9	17	46
10	0.9	0.0	4.5	58	80
20	1.2	0.0	6.2	103	90
50	1.7	0.0	10.3	282	104
100	3.6	0.0	15	727	118
200	4.6	0.0	21	1330	144
1000	9.0	0.0	41	2392	252

Table 5-6. Overtopping rate for the developed scheme 2118

Return Period (years)	Overtopping Rate (l/m/s)				
	North 1	North 2	South 1	South 2	South 3
1	1.3	0.0	30	3045	142
2	3.3	0.0	42	3276	205
10	15	0.4	96	4940	384
20	25	2.0	135	5528	493
50	43	5.3	257	6322	727
100	62	7.0	409	6455	930
200	84	13	681	6853	1351
1000	156	30	2057	8925	3651

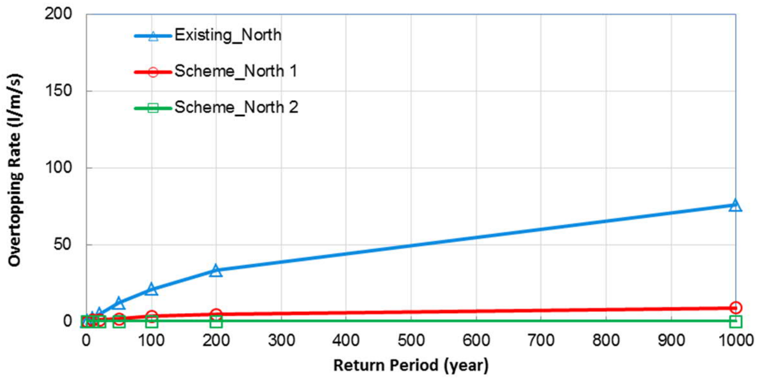

Figure 5-4. Comparison of overtopping for north sections (existing vs scheme - present day)

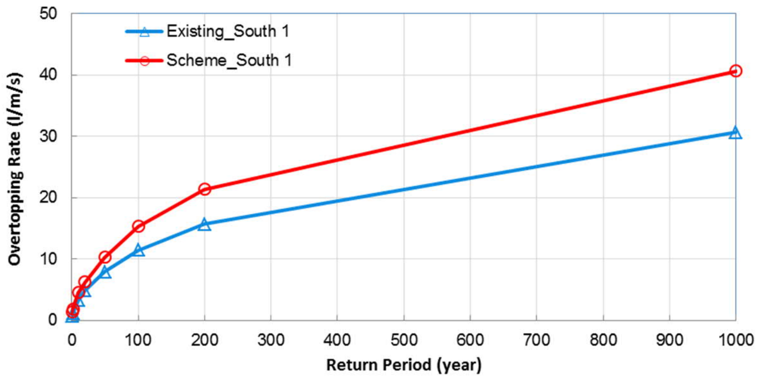

Figure 5-5. Comparison of overtopping for South 1 section (existing vs scheme - present day)

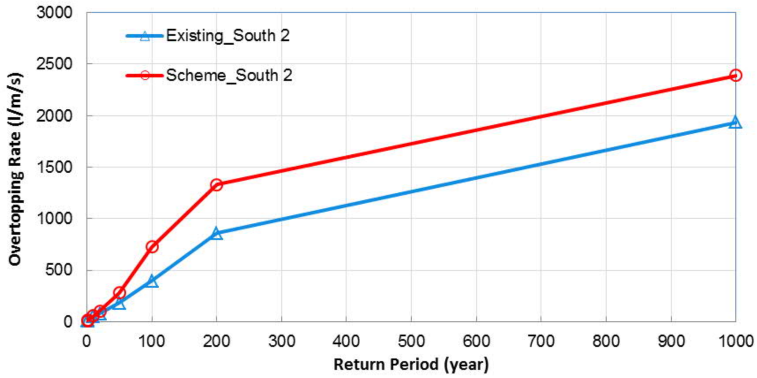

Figure 5-6. Comparison of overtopping for South 2 section (existing vs scheme - present day)

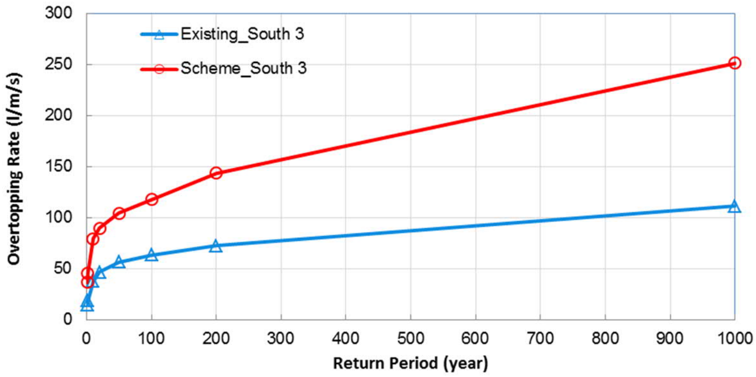

Figure 5-7. Comparison of overtopping for South 3 section (existing vs scheme - present day)

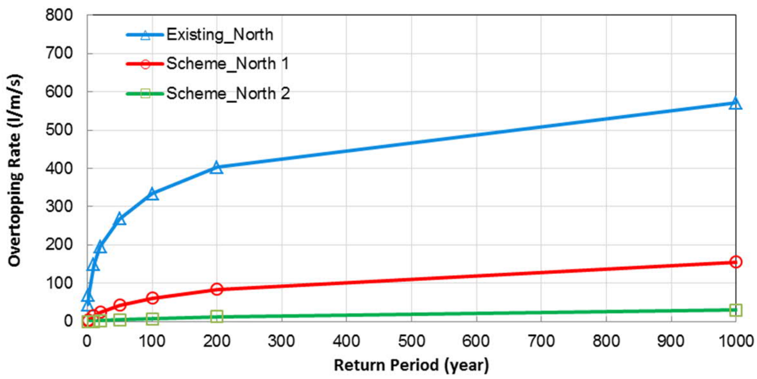

Figure 5-8. Comparison of overtopping for north sections (existing vs scheme - climate change)

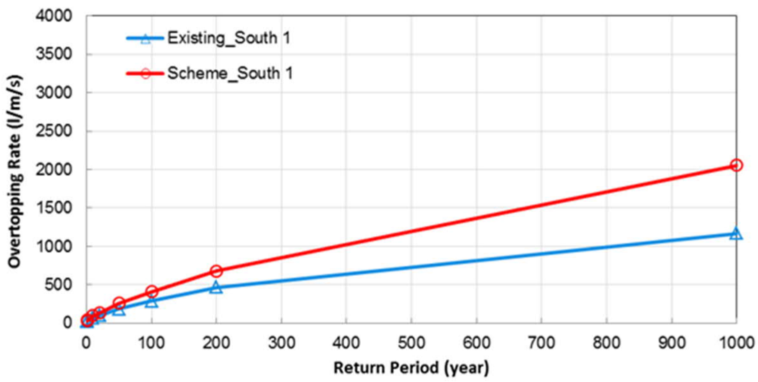

Figure 5-9. Comparison of overtopping for South 1 section (existing vs scheme - climate change)

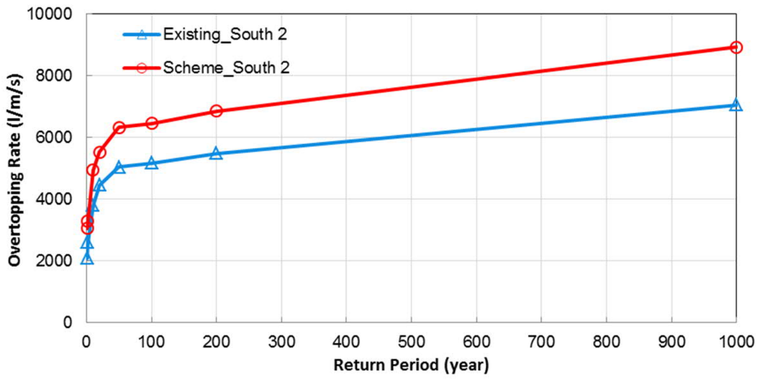

Figure 5-10. Comparison of overtopping for South 2 section (existing vs scheme - climate change)

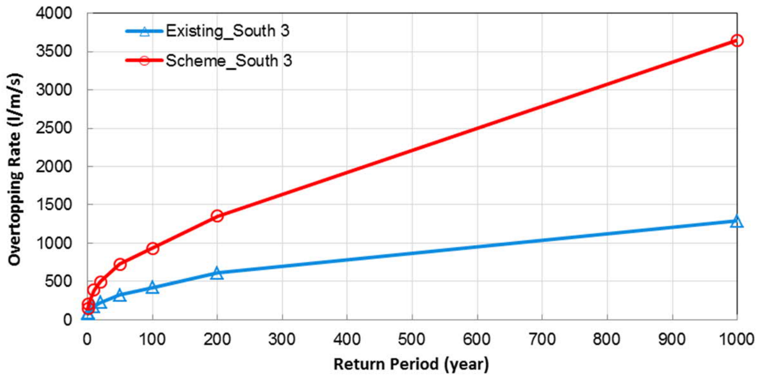

Figure 5-11. Comparison of overtopping for South 3 section (existing vs scheme - climate change)

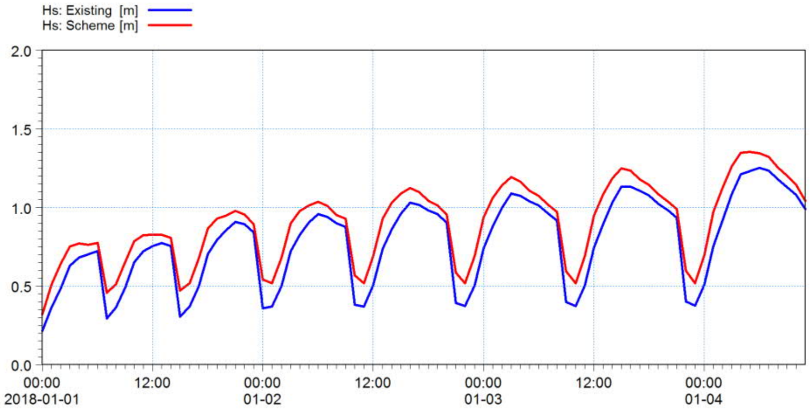

Figure 5-12. Comparison of Hs at South 1-2 sections (existing vs scheme - present day)

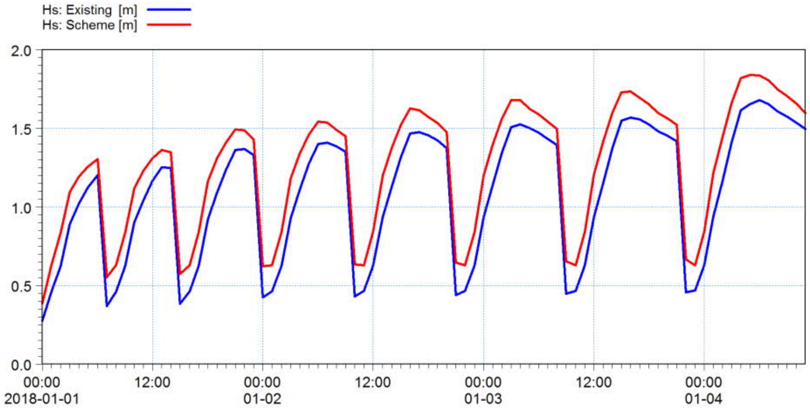

Figure 5-13. Comparison of Hs at South 1-2 (existing vs scheme - climate change)

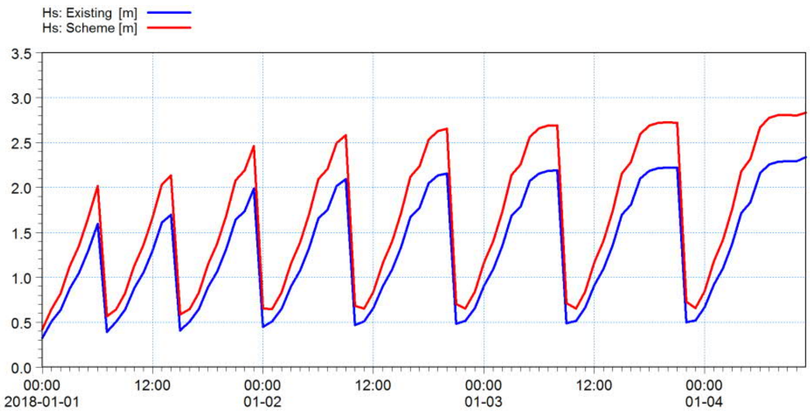

Figure 5-14. **Comparison of Hs at South 3 (existing vs scheme - present day)**

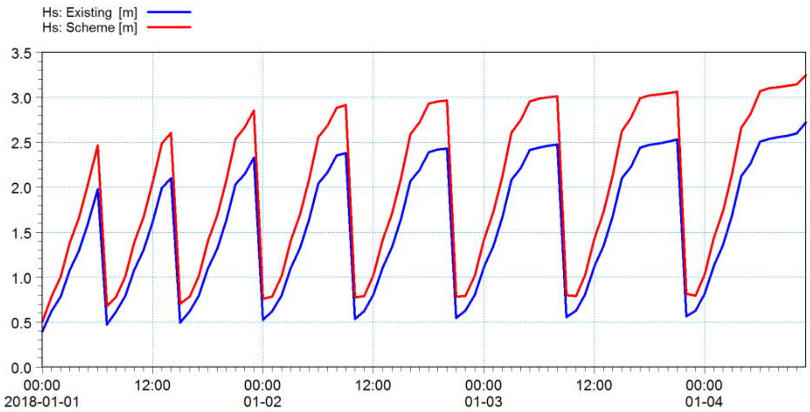

Figure 5-15. **Comparison of Hs at South3 (existing vs scheme - climate change)**

5.4 Validation

Estimations of overtopping have a large range of uncertainty. Ideally, field measurements of overtopping experienced during a storm event would be available to calibrate/validate the model setup and parameters used in the calculation. In the absence of such measurements we have collated available information on inundation close to the inland road and buildings from the port manager and local residents.

On 11th and 12th of January 2005 one of the worst wind storms hit Scotland and caused damage within Uig Bay. The magnitude (wind speed and direction) and the duration of the storm event are shown in Figure 5-16 which had an estimated return period of 1 in 40 years. According to the local residents, the wooden windows at the pottery were seriously damaged by the wave overtopping (Figure 5-17). The damaged windows are adjacent to Section 2 as identified in our analysis.

To simulate this event the wave model was driven with wind conditions as experienced during the January 2005 storm. The resulting significant wave heights and mean overtopping rates at South 2 are provided in Figure 5-18. EurOtop (2012) suggests that overtopping larger than 50 l/m/s may cause damage to a lightly protected structure (Table 5-7). Our calculation gave a mean overtopping rate of up to 102 l/m/s at Section 2, which would probably have been sufficient to cause damage to the wooden windows. This provides some reassurance that the results from our estimation of wave overtopping discharges are reasonable.

Moreover, the port manager suggested that the jetty approach regularly overtops, and overtopping can come close to buildings near the shore, but these are not regularly flooded. Table 5-3 provides wave overtopping rates for 8 return periods at the defined four sections. It can be seen that under the 1 in 1 year storm condition, the overtopping rates at the North, South 1, South 2 and South 3 sections (the jetty approach) are 0.0, 0.7, 9.0 and 14 l/m/s, respectively, which are consistent with the observation provided by the port manager.

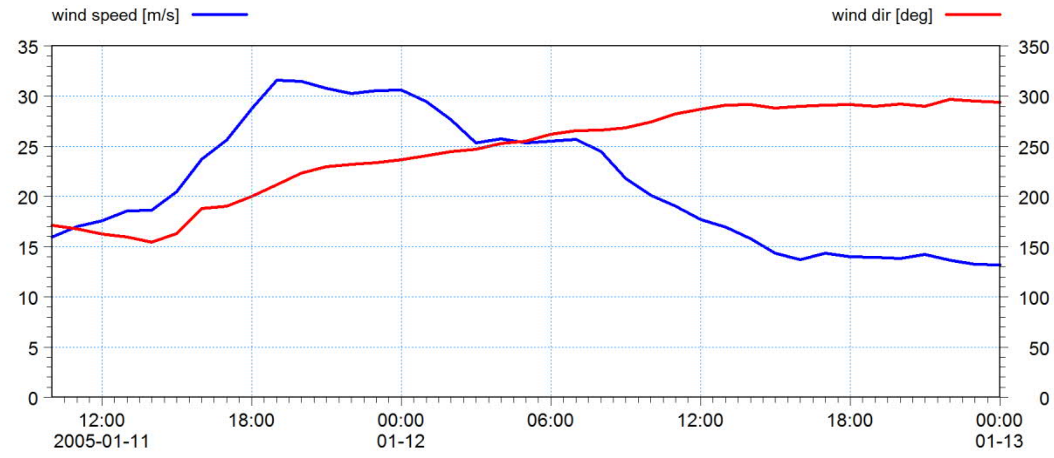

Figure 5-16. **Wind speed and directions on 11th-12th January 2005**

Figure 5-17. **Damage to properties caused by the storm on 11th-12th January 2005**

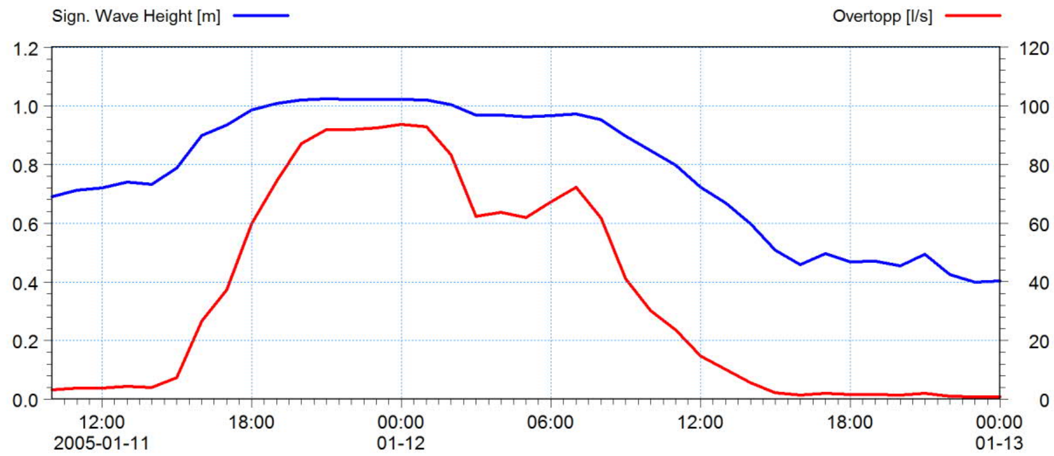

Figure 5-18. **Modelled Hs and overtopping rates for the South 2 section during the January 2005 storm**

Table 5-7 Estimated limits for overtopping damage to the defence crest or rear slope (EurOtop, 2012)

Hazard type and reason	Mean discharge q (l/s/m)
Embankment seawalls/sea dikes	
No damage if crest and rear slope are well protected	50–200
No damage to crest and rear face of grass covered embankment of clay	1–10
No damage to crest and rear face of embankment if not protected	0.1
Promenade or revetment seawalls	
Damage to paved or armoured promenade behind seawall	200
Damage to grassed or lightly protected promenade or reclamation cover	50

9.2 Uig Harbour Redevelopment Culert Extension Technical Note

Technical Note

Project:	**Uig Harbour Redevelopment**	Job No:	**60301293**
Subject:	**Hydraulic Assessment of Culvert**		
Prepared by:	**Craig Campbell**	Date:	24/05/2018
Checked by:	**Sally Homoncik**	Date:	24/05/2018
Approved by:	**Dylan Huws**	Date:	24/05/2018

Introduction

As part of the harbour redevelopment works being carried out in Uig, Skye, it is proposed to extend the existing 750 dia. concrete culvert which extends from the western edge of the harbour terminal car park and discharges into the sea at the East of the site. This technical note explains the work carried out to evaluate the impact of the extension on hydraulic performance, in particular the headwater elevation of floodwaters at the inlet and any associated increase in flooding risk.

Hydrology

A small burn drains the moorland below Creag Liath and runs off the hillside down a steep gully. There it passes through two road culverts and some rough farmland towards the end of a lane next to the Isle of Skye Brewery. At this point the burn enters the culvert and is carried to the sea.

The catchment of the burn was categorised as small (< 50 ha.) and is not included in the 2013 FEH study so a catchment shape file and descriptors are not available. The IH124 methodology developed in 1994 was instead used to calculate the catchment hydrology to estimate the peak flows in the burn under a range of return period storm events.

The IH method is recommended within the Design Manual for Roads and Bridges (DMRB) and is a valid estimation method for small catchments where catchments descriptors are absent. Descriptors are therefore based on the FSR descriptors with rainfall SARR values based on the adjacent catchment.

Maps from the Flood Studies Report (1975) were consulted to obtain values for SAAR and SOIL and the catchment area was delineated using GIS map tools. The Mean Annual Flood Q_{BAR} was calculated using these parameters for an area of 50 hectares and multiplied by the relevant growth factor for the 1 in 100 year event. This was then factored down for the measured area of 24 ha. and gave a peak flow at the culvert inlet of 0.53 cumecs.

Sea Levels

Extreme sea levels in Uig Bay were taken into account in the analysis since a high sea level would present a flow restriction at the culvert outfall.

A dataset of present day extreme sea levels are provided by SEPA and the point “192-8-Skye-M” was selected for the bay. In order to account for future climate change, the present day levels were factored by the UKCP09 95th percentile medium and high emission scenario sea level rise projections. The high emission future extreme sea level for the 1 in 100 year scenario was taken as 4.82 mAOD.

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Culvert Extension

The culvert under investigation is a 750 dia. circular concrete pipe, 142m in length, and it is proposed to extend it to approximately 220m. The arrangement of the culvert inlet is unknown but the upstream channel is assumed to have a bank overflow level of 1m. The outlet is set in a concrete headwall which is around 1m high. The dimensions and parameters used as the model input are included in Table 1:

Table 1 – Culvert dimensions

Parameter	Value	Unit
Inlet invert level	7	mAOD
Outlet invert level	2.07	mAOD
Diameter	750	mm
Length	140 or 220	m
Max. allowable headwater elevation (bank threshold level)	8	mAOD
Tailwater elevation	4.82	mAOD
Manning's n	0.013	-
Inlet (assumed)	Square edge w/headwall	-
Entry loss K_e	0.5	m

CulvertMaster Modelling

CulvertMaster culvert modelling program was used to quickly assess the flow conditions in the pipe. The software can be set to calculate discharge, headwater elevation or pipe size depending on the data available.

The analysis found that for the baseline condition with a pipe length of 140m the computed headwater is 7.72 mAOD, and flow in the culvert is outlet controlled.

Under the proposed conditions with pipe length equalling 220m the computed headwater was unchanged at 7.72 mAOD and the flow control was at the outlet as before.

Sensitivity Analysis

When measuring the catchment area there was potential for error due to a lack of reliable contour information. Some other sources of error were the presence of field drains (the functioning of which is unknown); areas of hardstanding which could be fed into the burn; or road drainage which could carry flow away from the natural catchment.

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The catchment area was increased and decreased by 50% to see what effect, if any, this might have on headwater elevations before and after the pipe extension. This is a significant variance but should encompass any error in the area estimation. For a contributing area of 12 ha. the headwater elevation was unchanged between both culvert lengths – 7.49 mAOD, and for an area of 36 ha. the headwater elevation was 7.94 mAOD in both cases.

It can be concluded that changes in contributing area do not influence the effect of extending the culvert.

Conclusion

It can be concluded therefore that the proposed extension to the harbour culvert will not change potential headwater elevations and will therefore not increase or decrease flood risk at the upstream end.

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10. Ground Conditions and Contamination

No Appendices

11. Marine Nature Conservation Areas

No Appendices

12. Benthic Ecology

12.1 Intertidal Walkover Survey

Uig Harbour Redevelopment

Intertidal Ecology Walkover Survey

The Highland Council

Document Reference: 60536743

November 2017

Quality information

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The methodology adopted and the sources of information used by AECOM in providing its services are outlined in this Report. The work described in this Report was undertaken between October and November 2017 and is based on the conditions encountered and the information available during the said period of time. The scope of this Report and the services are accordingly factually limited by these circumstances. AECOM disclaim any undertaking or obligation to advise any person of any change in any matter affecting the Report, which may come or be brought to AECOM's attention after the date of the Report.

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1. Introduction

1.1 Project Background

Uig Harbour is located in Uig Bay in the north east of the Isle of Skye. It forms part of the 'Skye Triangle' (along with Tarbert and Lochmaddy), providing lifeline ferry services for communities in the Western Isles. The Pier at Uig Harbour, named King Edward Pier, serves the CalMac ferry route to the isles of Harris and North Uist. The Pier is under the control of Highland Harbours which is run by The Highland Council (THC), whilst the ferry service operations are controlled by CalMac Ferries Ltd. (CFL).

Increasing demand and aging tonnage has led the ferry operator to commission new, larger ferry vessels for a number of its routes. The 'Skye Triangle' has been identified by the operator as a priority and the procurement of a new vessel for this route has commenced.

THC (hereafter also referred to as the 'Applicant') is required to undertake redevelopment works (hereafter referred to as the 'Proposed Development') to Uig Harbour to accommodate the new vessel which has been commissioned and is currently programmed to arrive at the harbour in October 2018.

1.2 Project Description

The Proposed Development consists of redevelopment works to Uig Harbour to accommodate a larger ferry vessel. The vessel is expected to be approximately 3 m longer and 1.2 m wider than the current ferry. The design of the Proposed Development is still being finalised and a number of alternative options are still being considered.

The Proposed Development will include a number of works that have been identified, during the scoping exercise, to result in potential impacts to intertidal habitats. These activities are described in **Table 1-1** below.

Table 1-1 Description of the Proposed Development Activities with potential impacts for intertidal habitats

Works	Description	Potential impacts in the intertidal
Dredging	Dredging of approximately 25,000 m^3 of sediment in the berth area and widened approachway.	Disturbance to intertidal benthic habitats as a result of sediment dispersion during dredging
Increased marshalling area by land reclamation	Undertaking approximately 11,000 m^2 of land reclamation in the marine intertidal area using approximately 50,000 m^3 of infilling material with rock armour revetment and sheet piles.	Intertidal benthic habitat loss

2. Site Description

2.1 Study Area

The walkover survey covered the intertidal zone in Uig Bay, from just west of the Ferry Terminal, extending approximately 1.8 km around the Bay. The survey extent was determined after examination of the prevailing wind and water movements to ensure all foreshore areas that could be affected by sediment movements from the works on site were covered.

2.2 Objectives

The objective of the walkover survey was to identify the broad habitat types in the survey area, including recording where particular habitats and species of importance were located. Samples were not taken so only conspicuous species, observed during the walkover, have been recorded.

3. Methodology

3.1 Method

The purpose of the walkover survey was to identify the broad marine intertidal habitats and assess the potential for important habitats and protected species in the vicinity of the development site. The intertidal survey was undertaken during within 2 hours either side of spring tides on 19/10/2017, 20/10/2017 and 16/11/2017 by an experienced AECOM ecologist. The ecologist is a full member of the Chartered Institute for Ecology and Environmental Management (CIEEM).

The survey methodology comprised a walkover of the northern region of Uig Bay, in accordance with the guidance for intertidal resource mapping described in the Marine Monitoring Handbook[1]. During intertidal mapping, surveyors walk along the shore in order to identify and map the extent and distribution of the broad marine habitat types present. The sampling stations are shown on the map in **Appendix A.**

A number of transects, with stations at the high, mid and low shore were determined prior to the survey, but retaining the possibility to move transects based on the nature of the habitats observed at the time of the survey to ensure all major habitat types were covered.

The classification system for marine habitats, uses standard descriptions called ‘biotopes’ which categorise habitats based on the marine zone, the physical nature of the habitat and the biological communities observed. For example, marine habitats can be divided into littoral (also known as intertidal) and subtidal zones, and then classified according to the physical nature of the substratum, either rock or sediment, and the biological community found.

These ‘biotopes’ are defined by the Marine Habitat Classification for Britain & Ireland[2] and the European Union Nature Information System (EUNIS[3]). Biotope identification is carried out in the field and, in addition, species lists are taken where necessary.

The survey was undertaken at low tide, at an appropriate time of year and in suitable weather conditions for broad scale habitats and features of interest to be visible. Photographs and a collection of target notes were taken at a number of locations at regular intervals on site and where any marine ecological features of interest were observed.

The presence of any marine algae was recorded and note was taken of the more conspicuous fauna, and any evidence of, or potential for the presence of protected and/or notable marine species. Photographs and target notes for each station are shown in **Appendix B** and the location data is provided in **Appendix C**.

3.2 Limitations

There were no significant constraints to the field survey. The tides were sufficiently low, the weather was fair with at most slight rain, and all parts of the survey area could be accessed.

The goal of the survey was to identify and record broad habitat types and conspicuous species only so the composition of the in-faunal communities has not been investigated.

[1] Davies, J., Baxter, J., Bradley, M., Connor, D., Khan, J., Murray, E., Sanderson, W., Turnbull, C. & Vincent, M. 2001. Marine Monitoring Handbook. UK Marine SACS project. Available from: http://jncc.defra.gov.uk/PDF/MMH-mmh_0601.pdf.

[2] UK Marine Habitat Classification hierarchy available at: http://jncc.defra.gov.uk/marinehabitatclassification.

[3] EUNIS classification available at https://www.eea.europa.eu/themes/biodiversity/eunis/eunis-habitat-classification.

4. Results

4.1 Survey Results

The site comprised two broad habitat types:

- *Littoral rock* (A1) – most areas of the intertidal region surveyed comprised boulders and cobbles of a size large enough to be categorised as littoral rock. There was however, very little bedrock in the intertidal area surveyed; and
- *Littoral sediment* (A2) – areas of mixed gravels, sands and muds largely found on the lower shore though there are patches of this biotope in the mid and high shore.

In reality, there is some difficulty defining boundaries between areas of mixed sediment with stable cobbles and boulders, and boulder fields which fall into the rocky shore (littoral rock) category and the difference between A1 and A2 habitat types can be relatively minor.

These habitats, with their European Nature Information System (EUNIS) and Marine Habitat Classification (MHC) biotope code and any conservation designations are summarised in **Table 4-1** below.

Table 4-1. Summary of intertidal benthic habitats (biotopes) found in Uig Bay survey area

EUNIS Biotope Code	MHC Biotope Code	Description	Priority Marine Features	Biodiversity Action Plan Habitats
A1	LR	Littoral rock		
A1.21	LR.MLR.BF	Barnacles and fucoids on moderately exposed shores	No	No
A1.31	LR.LLR.F	Fucoids on sheltered marine shores	No	No
A2	LS	Littoral sediment		
A2.24	LS.LSa.MuSa	Polychaete/bivalve-dominated muddy sand shores	No	No
A2.4	LS.LMx	Littoral mixed sediments	No	No
A2.5	LS.LMp.Sm	Coastal saltmarsh	No	No

4.2 Habitat Descriptions

4.2.1 Littoral rock habitats

A1 Littoral rock

Littoral rock includes intertidal habitats of bedrock, boulders and cobbles that are particularly common in the survey area. There are many physical variables affecting the biological communities that live on littoral rock, particularly wave exposure, salinity, temperature and the diurnal emersion and immersion of the shore. Wave exposure is most commonly used to characterise littoral rock communities from 'extremely exposed' to “extremely sheltered” shores. Exposed shores tend to support faunal-dominated communities of barnacles and mussels and some robust seaweeds. Sheltered shores are identified by a dense cover of fucoid seaweeds, with distinctive zones occurring down the shore. In between these extremes of wave exposure, on moderately exposed shores, mosaics of seaweeds and barnacles are more typical.

Just over three quarters of the stations noted were categorised as Littoral rock and in terms of extent was the most common biotope present in the intertidal zone in the survey region of Uig Bay. Of these stations most had very high algal cover as described more fully below.

A1.31 Fucoids on sheltered marine shores

This biotope comprises dense blankets of fucoid seaweeds dominating sheltered to extremely sheltered rocky shores and/or in locally sheltered patches on exposed to moderately exposed rocky shores. Typically, *Pelvetia canaliculata* occurs on the upper shore, with the wrack *Fucus spiralis* below. The middle shore is dominated by vast areas of the wrack *Ascophyllum nodosum* or the wrack *Fucus vesiculosus* or a mixture of both. The wrack *Fucus serratus* covers lower shore bedrock and boulders. Sheltered to very sheltered mixed substrata (pebbles and cobbles overlying muddy sand and gravel) shores can support fucoid communities.

This biotope was the most dominant across the survey area (recorded at 28 of the 45 stations recorded during the survey) covering substratum types comprising varying proportions of boulders, cobbles and pebbles. There is almost complete coverage of fucoid algae, including *Ascophyllum nodosum* a species indicative of sheltered conditions.

A1.21 Barnacles and fucoids on moderately exposed shores

This biotope is found on moderately exposed rocky shores and is characterised by a mosaic of fucoids and barnacles on bedrock and boulders, where the extent of the fucoid cover is typically less than the blanket cover associated with sheltered shores. Beneath a band of yellow and grey lichens at the top of the shore is a zone dominated by the wrack *Pelvetia canaliculata*, scattered barnacles and the black lichen Verrucaria maura may cover rock surfaces. Below, on the mid shore the wrack *Fucus vesiculosus* generally forms a mosaic with barnacles and limpets. The lower shore is dominated by the wrack *Fucus serratus*, while a variety of red seaweeds can be found underneath. Other species normally present and observed during the survey include winkles and red seaweeds. The presence of boulders and cobbles on the shore can increase the micro-habitat diversity, which often results in greater species richness.

This biotope was found at 6 stations across the survey area, five of which were on the upper shore, where fucoid cover was slightly reduced allowing barnacles to colonise rock surfaces.

4.2.2 Littoral sediment habitats

A2.4 Littoral mixed sediments

This biotope covers shores of mixed sediments ranging from muds with gravel and sand components to mixed sediments with pebbles, gravels, sands and mud in more even proportions. By definition, mixed sediments are poorly sorted. Stable large cobbles or boulders may be present which support epibiota such as fucoids and green seaweeds more commonly found on rocky and boulder shores. Mixed sediments which are predominantly muddy tend to support infaunal communities which are similar to those of mud and sandy mud shores.

It is probable that there are broad transition areas between areas of mudflat or sandy mudflat, and mixed sediment biotopes where the sediment consists principally of mud but has significant proportions of gravel and sand mixed in. Gravelly mud may occur in patches on mudflats. Similarly, there is unlikely to be an easily defined boundary between areas of mixed sediment with stable cobbles and boulders, and boulder fields which fall into the rocky shore category.

This biotope was found in small patches within wider areas of littoral rock habitats, mostly in the lower intertidal though patches were also observed on higher areas of the shore.

A2.24 Polychaete/bivalve-dominated muddy sand shores

Muddy sand or fine sand, often occurring as extensive intertidal flats on open coasts and in marine inlets. The sediment generally remains water-saturated during low water. The habitat may be subject to variable salinity conditions in marine inlets. An anoxic layer may be present below 5 cm of the sediment surface, sometimes seen in the worm casts on the surface. The infauna consists of a diverse range of amphipods, polychaetes, bivalves and gastropods.

A2.5 Coastal saltmarshes and saline reedbeds

A narrow strip of saltmarsh was observed along the upper intertidal edge, beginning immediately north of the rip-rap reinforcement at the ferry terminal car park and extending north-eastwards around Uig Bay. Except in the far north-east part of Uig Bay between the river mouths, this saltmarsh strip is rarely more than 2 m wide and is often fragmented. A substantial part of it close to the ferry terminal has been covered with dumped earth.

The saltmarsh is dominated by fine-leaved graminoids comprising red fescue *Festuca rubra* and/or saltmarsh rush *Juncus gerardi*, with constant and often abundant sea plantain *Plantago maritima* and sea milkwort *Glaux maritima*. There are variable amounts of scurvy-grass *Cochlearia* sp. This vegetation corresponds to the saltmarsh NVC (National Vegetation Classification) type SM16, which is a common component of mid/upper saltmarsh around much of the UK including the west coast of Scotland.

There is also a small patch of mono-specific sea club-rush *Bolboschoenus maritimus* at the base of the rip-rap reinforcement at the ferry terminal car park. This corresponds to the swamp NVC type S21, which is also common around much of the UK including the west coast of Scotland.

4.3 Incidental Grey Seal Sightings

A female grey seal was seen during ornithological surveys on two separate occasions in October and November along the coast on the opposite of Uig Bay from the ferry terminal.

Another sighting of a grey seal was made in September in the bay just north of the ferry terminal. No hauled out seals were seen during the intertidal surveys, nor during the ornithological surveys which together covered all but the outer parts of Uig Bay.

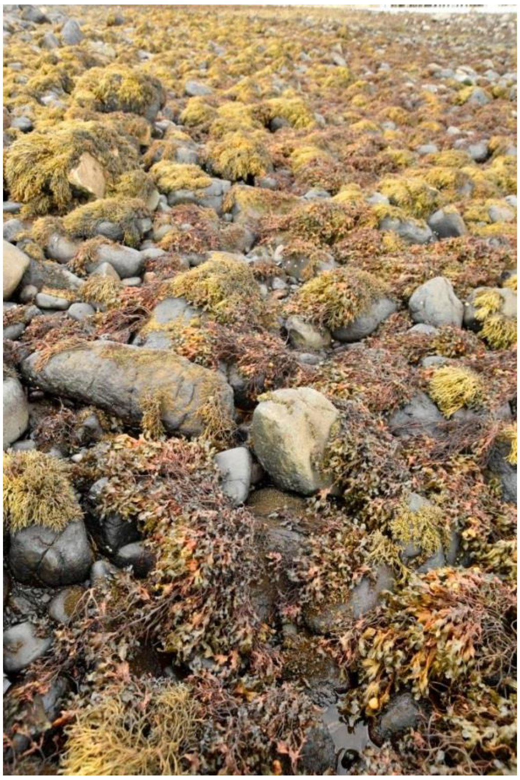
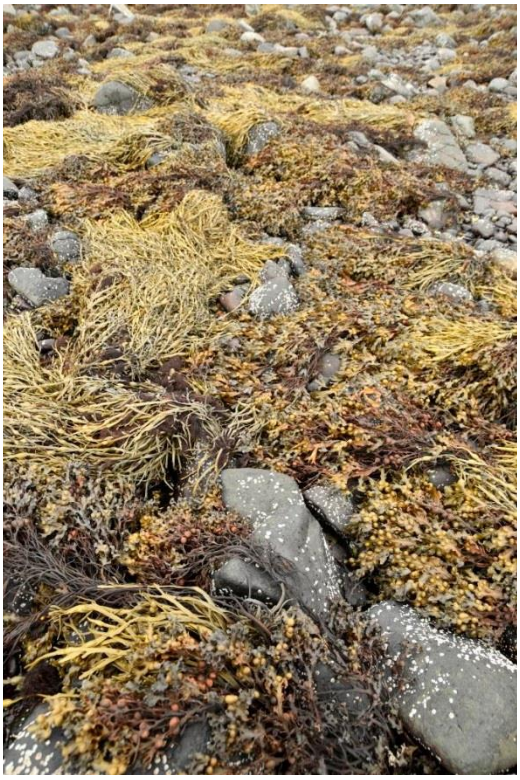
5. Conclusion

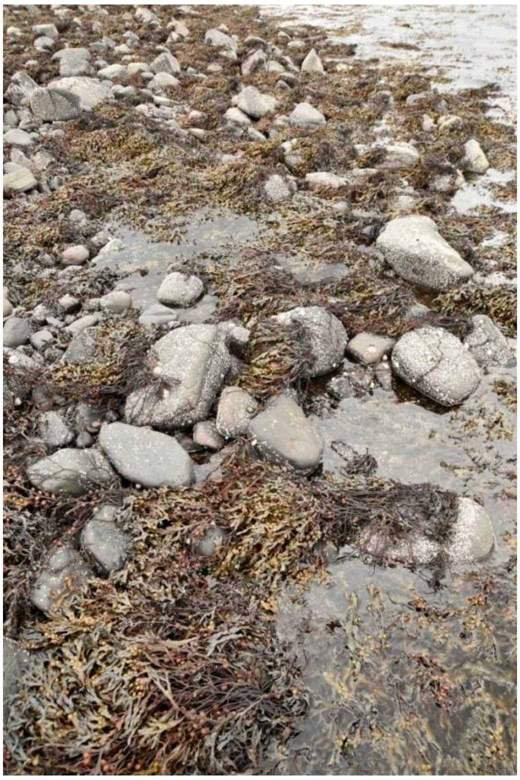
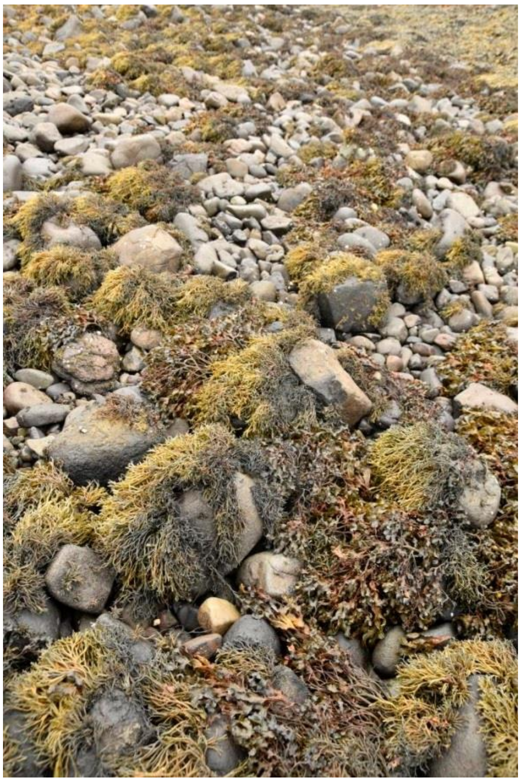
The intertidal walkover survey established the habitats in the survey area of Uig Bay were primarily habitats dominated by large boulders and cobbles with coverage of fucoid algae interspersed with occasional smaller patches of muddy, sandy or gravelly sediments. In general, the muddy areas were observed on the lower shore where polychaete worms and other infauna were in evidence.

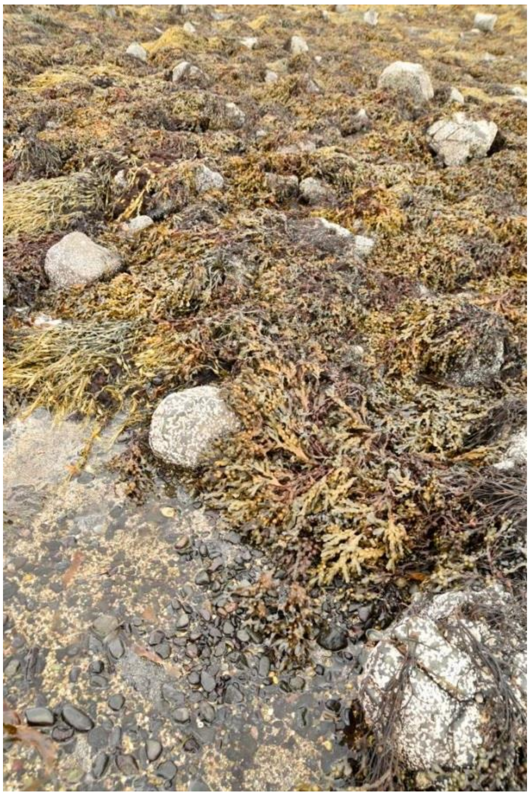
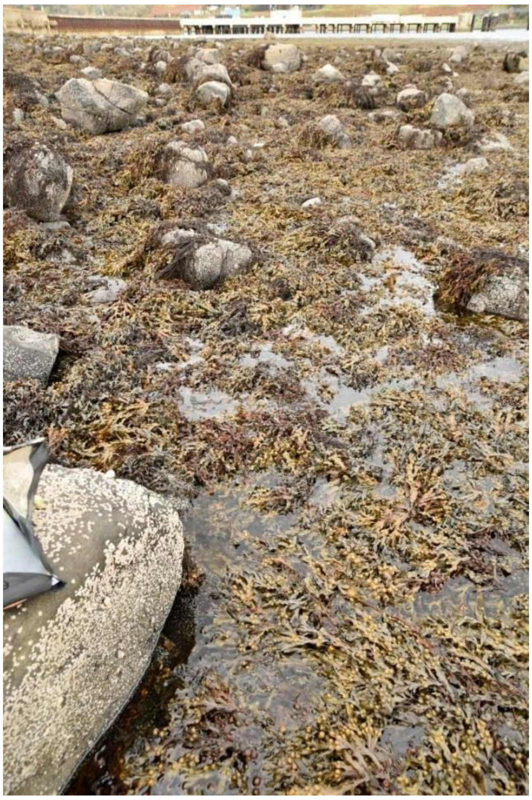
The marine habitats and species seen in Uig Bay are considered to be typical and representative of intertidal habitats that are widespread in Scottish coastal waters. There were no habitats or species of conservation concern, such as Priority Marine Features, observed. The patches of saltmarsh present were very small and limited in extent and of generally low diversity.

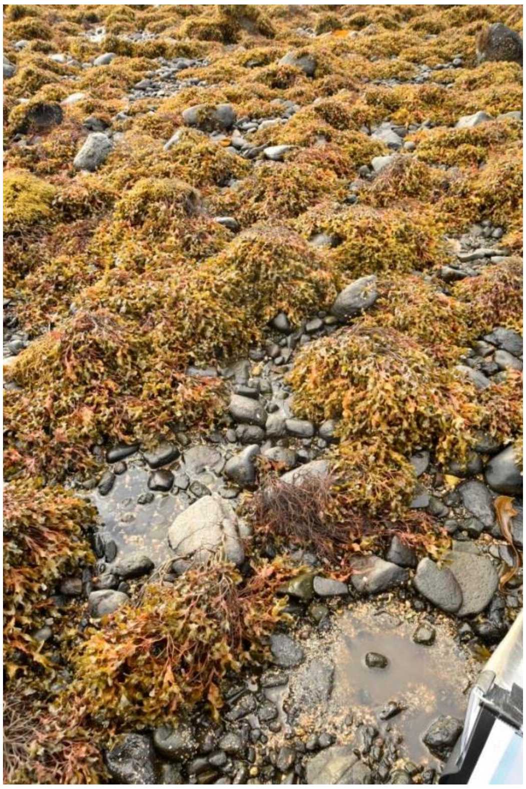
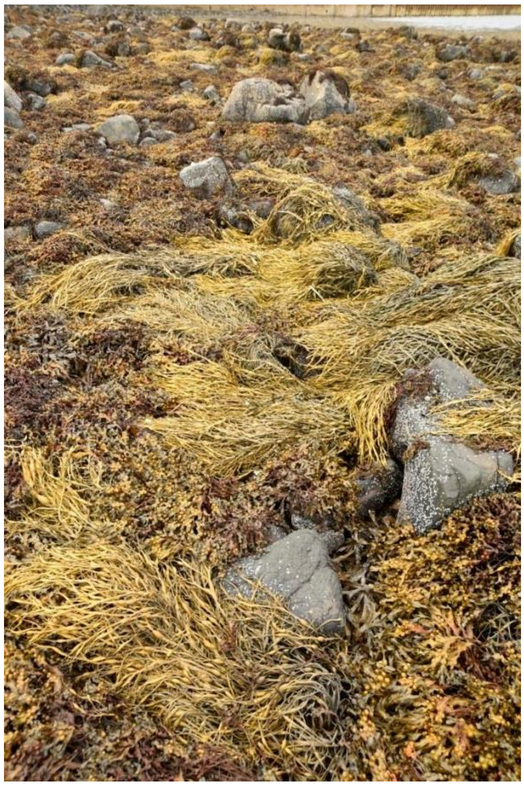
Appendix A – Sample stations map

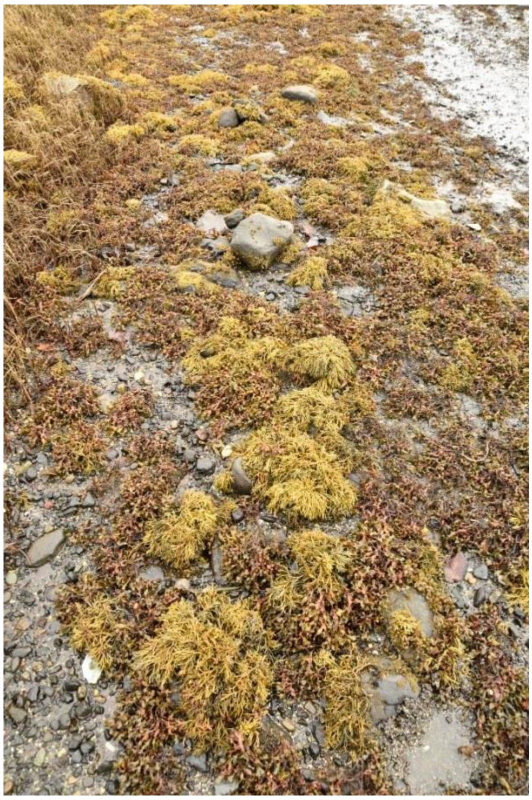
Appendix B – Survey log and photographs

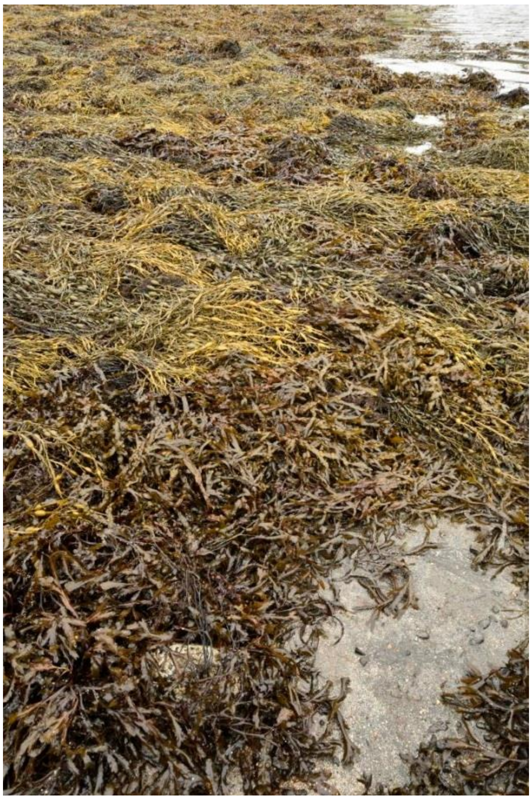
Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
1 – High shore	Boulders, cobbles and pebbles 75% algal cover: *Pelvetia canaliculata* and *Fucus spiralis* **A1.31 - Fucoids on sheltered marine shores**	
1 – Mid shore	Boulders, cobbles and pebbles 75% algal cover with *Ascophyllum nodosum* and *Fucus vesiculosus*. Barnacles, whelks (*Nucella lapillus*) and periwinkles (*Littorina* spp.). **A1.31 - Fucoids on sheltered marine shores**	

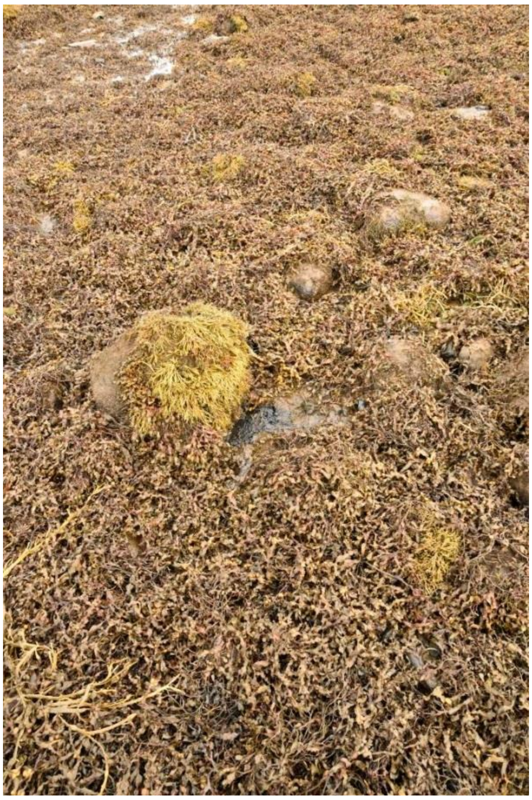
Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
1 – Low shore	Boulders, cobbles and pebbles 75% algal cover with *Fucus vesiculosus* and *Ascophyllum nodosum* Barnacles, limpets, periwinkles (*Littorina* spp.), *Calliostoma* spp. **A1.21 – Barnacles and fucoids on moderately exposed shores**	
2 – High shore	Boulders and pebbles 50% algal cover with *Pelvetia canaliculata* and *Fucus spiralis.* Barnacles and periwinkles (*Littorina* spp.). **A1.21 – Barnacles and fucoids on moderately exposed shores**	

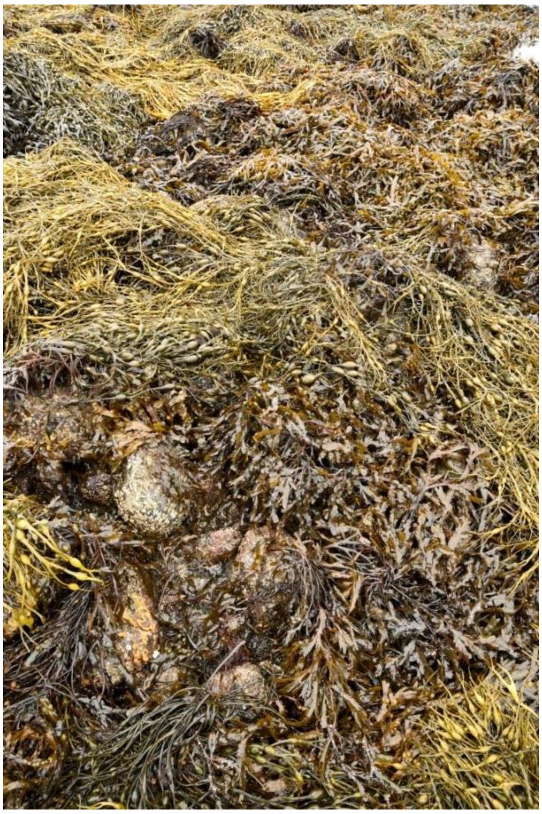
Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
2 – Mid shore	Boulders, cobbles, some areas of pebbles and local shell deposits amongst the rocks. 90% algal cover with *Ascophyllum nodosum* and *Fucus vesiculosus. Polysiphonia spp.* found on *Ascophyllum nodosum* Barnacles, limpets, and periwinkles (*Littorina* spp.). **A1.31 - Fucoids on sheltered marine shores**	
2 – Low shore	Boulders and cobbles with shell deposits between. 99% algal cover with *Ascophyllum nodosum, Fucus vesiculosus, Fucus serratus* and encrusting calcareous red algae. Barnacles, periwinkles (*Littorina* spp.), whelks (*Nucella lapillus),* beadlet anemone. **A1.31 - Fucoids on sheltered marine shores**	

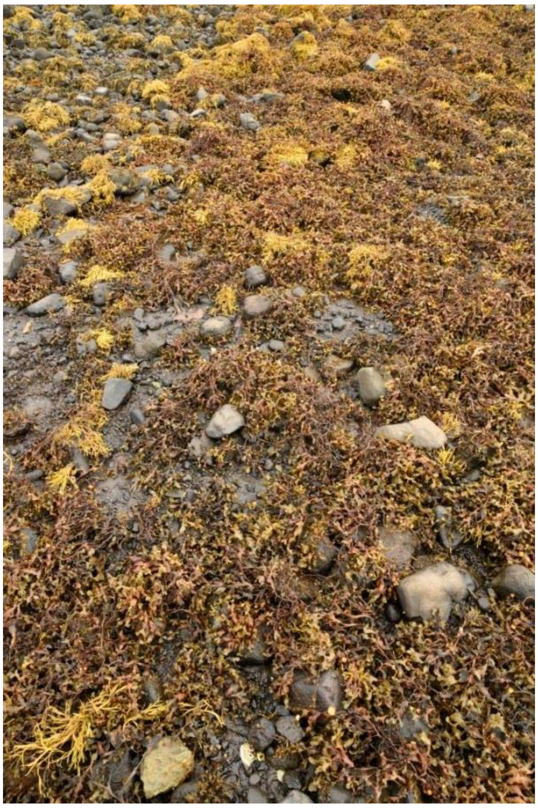
Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
3 – High shore	Cobbles and pebbles with sand and shell patches 75% algal cover with *Pelvetia canaliculata* and *Fucus spiralis* Occasional barnacles on larger stones **A1.31 - Fucoids on sheltered marine shores**	
3 – Mid shore	Boulders and cobbles, with shell deposits 95% algal cover with *Ascophyllum nodosum* and *Fucus vesiculosus. Polysiphonia spp.* found on *Ascophyllum nodosum* Barnacles, limpets, and periwinkles (*Littorina* spp.). **A1.31 - Fucoids on sheltered marine shores**	

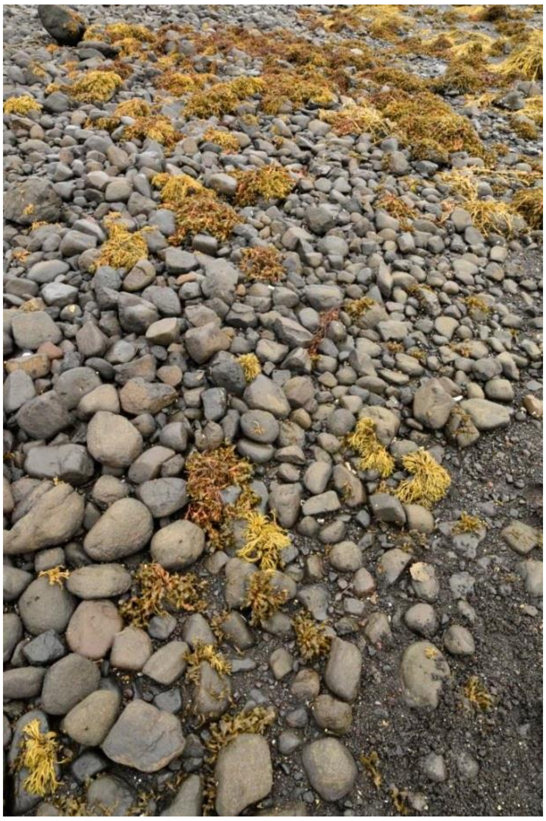
Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
3 – Low shore	Boulders and cobbles with shell deposits amongst them. 99% algal cover mainly comprising *Ascophyllum nodosum, Fucus vesiculosus* and *Fucus serratus. Polysiphonia spp.* and *Ulva spp.* found on *Ascophyllum nodosum*. Encrusting red algae also present, and occasional *Chondrus crispus* and other foliose red algae. Barnacles, periwinkles (*Littorina* spp.), limpets and beadlet anemone. **A1.31 - Fucoids on sheltered marine shores**	
4 – High shore	Sand with mud, gravel and occasional cobbles. 75% algal cover with *Pelvetia canaliculata* and *Fucus spiralis.* **Additional observations** Small stand of sea club-rush *Bolboschoenus maritimus* present at upper limit of intertidal, adjacent to rip-rap reinforcement of terrestrial edge. Vehicular disturbance from adjacent track, which runs close to the rip-rap reinforcement along the terrestrial edge **A1.31 - Fucoids on sheltered marine shores**	

Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
4 – Mid shore	Mud with mixed pebbles, scattered boulders. 80% algal cover with *Ascophyllum nodosum* and *Fucus vesiculosus. Polysiphonia spp.* found on *Ascophyllum nodosum* Barnacles on boulders, periwinkles (*Littorina* spp.) and cockles **A1.31 - Fucoids on sheltered marine shores**	
4 – Low shore	Sandy mud with pebbles, occasional cobbles 99% algal cover with *Ascophyllum nodosum, Fucus vesiculosus* and *Fucus serratus. Polysiphonia spp.* found on *Ascophyllum nodosum*. Occasional patches of the green alga *Ulva spp.* Barnacles on cobbles, periwinkles on macroalgae (*Littorina* spp.) **A1.31 - Fucoids on sheltered marine shores**	

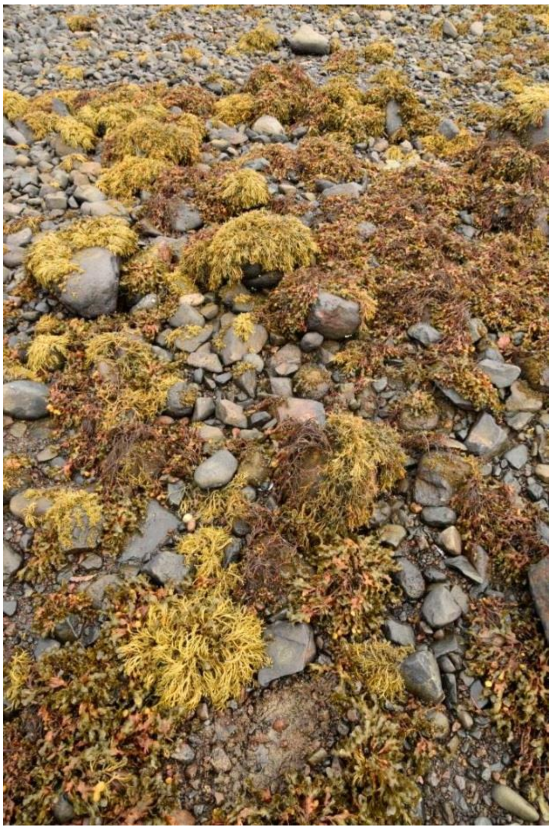
Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
5 – High shore	Mud with mixed pebbles, cobbles and scattered boulders. 90% algal cover with *Pelvetia canaliculata*, *Ascophyllum nodosum* and *Fucus spiralis.* Scattered filamentous green algae. **Additional observations** Dumped earth on adjacent land, with material washed onto intertidal giving rise to patches of deep mud **A1.31 - Fucoids on sheltered marine shores**	
5 – High shore	On very high shore a narrow strip of saltmarsh was present though covered by dumped earth in a large section. **A2.5 - Coastal saltmarshes and saline reedbeds**	

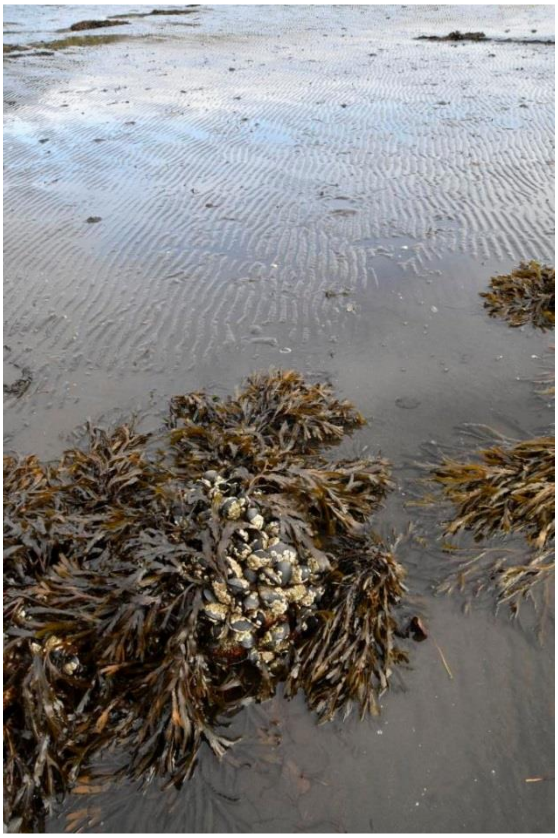
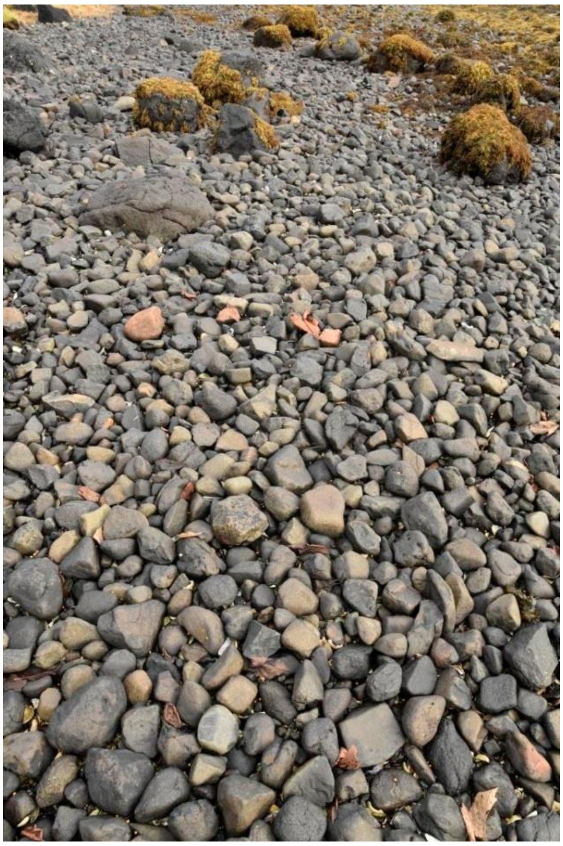
Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
5 – Mid shore	Sandy mud, scattered pebbles, cobbles and boulders. 99% algal cover with *Ascophyllum nodosum. Polysiphonia spp.* found on *Ascophyllum nodosum* Washed up periwinkles (*Littorina* spp.) and cockles **A1.31 - Fucoids on sheltered marine shores**	
5 – Low shore	Cobbles and boulders with muddy sand and shell deposits between. 100% algal cover with *Ascophyllum nodosum, Fucus vesiculosus, Fucus serratus.* Also present encrusting calcareous red algae and occasional *Chondrus crispus.* Barnacles on cobbles, periwinkles (*Littorina* spp.) and breadcrumb sponge. Sand mason worms present in muddy sand. **A1.31 - Fucoids on sheltered marine shores**	

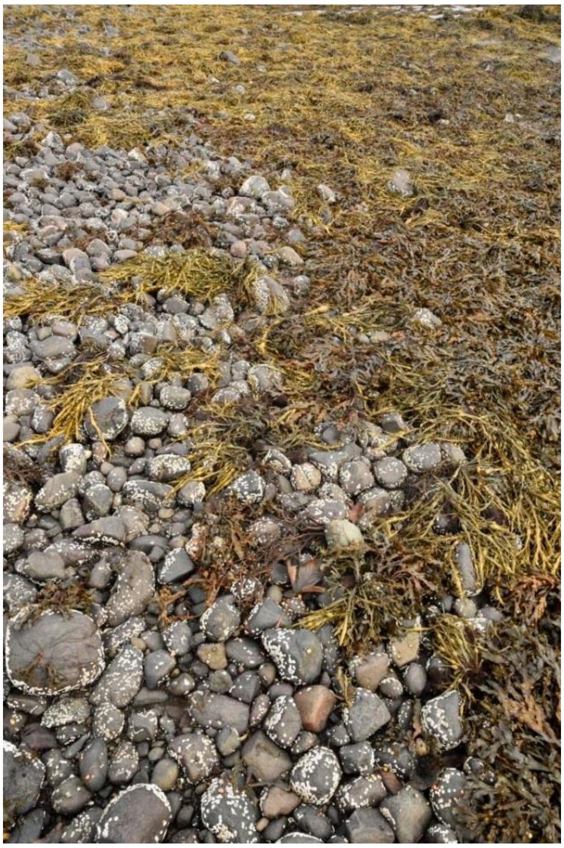
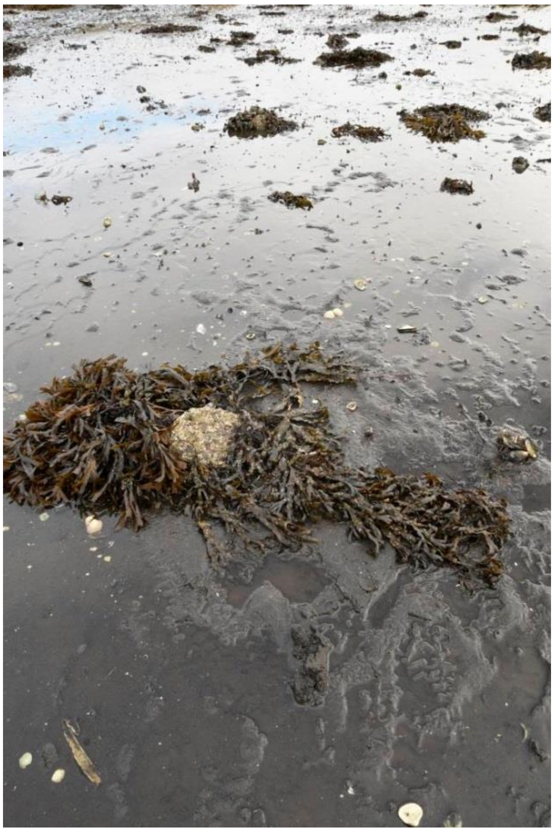
Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
6 – High shore	Muddy sand with abundant surface pebbles and cobbles 75% algal cover with *Pelvetia canaliculata* and *Fucus spiralis.* Periwinkles (*Littorina* spp.) **A1.31 - Fucoids on sheltered marine shores**	
6 – Mid shore	Muddy sand with pebbles, scattered cobbles and boulders 99% algal cover with *Ascophyllum nodosum* and *Fucus serratus. Polysiphonia spp.* found on *Ascophyllum nodosum* **A1.31 - Fucoids on sheltered marine shores**	

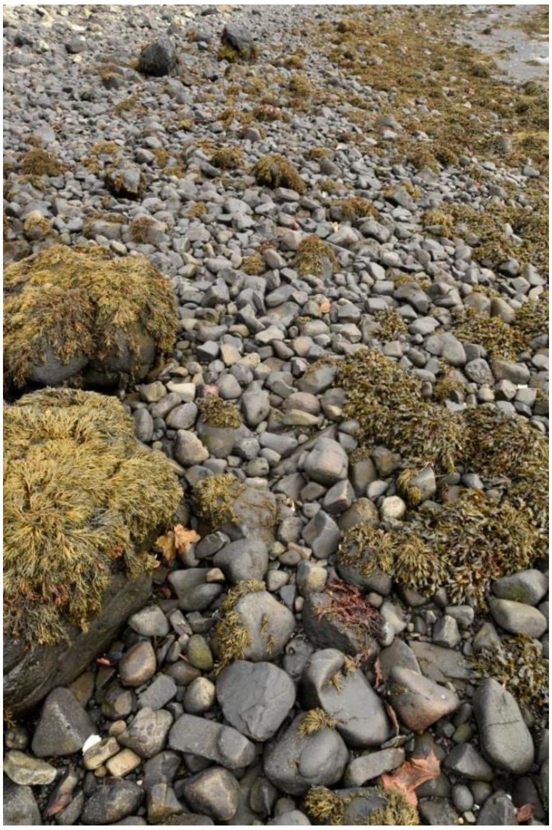
Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
6 – Low shore	Muddy sand with scattered cobbles, pebbles and boulders. 99% algal cover with *Fucus vesiculosus and Fucus serratus* Flat periwinkle, limpet, barnacles, breadcrumb sponge, periwinkles (*Littorina* spp.). Sand mason worm present in muddy sand. **A1.31 - Fucoids on sheltered marine shores**	
7 – High shore	Cobbles, pebbles and gravel 10% algal cover with *Pelvetia canaliculata* and *Fucus spiralis.* Occasional barnacles **A1.21 – Barnacles and fucoids on moderately exposed shores**	

Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
7 – Mid shore	Muddy sand with pebbles, scattered cobbles and boulders 99% algal cover with *Ascophyllum nodosum* and *Fucus vesciculosus. Polysiphonia spp.* found on *Ascophyllum nodosum.* Mussels and periwinkles (*Littorina* spp.). Scattered barnacles. **A1.31 - Fucoids on sheltered marine shores**	
7 – Low shore	Mud with pebbles, scattered cobbles and bolders 95% algal cover with *Fucus vesiculosus, Fucus serratus* and occasional *Ascophyllum nodosum* Barnacles, mussels and breadcrumb sponge on rocks, sand mason worm present in mud **A1.31 - Fucoids on sheltered marine shores**	

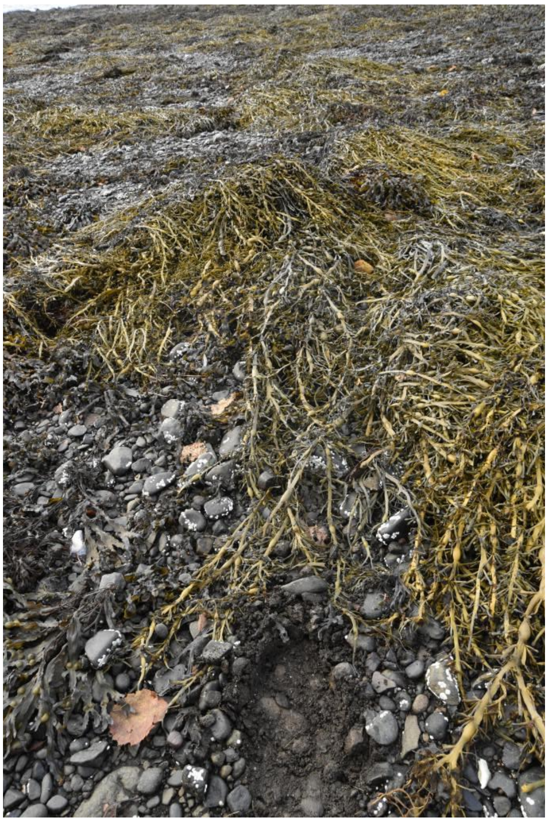
Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
8 – High shore	Gravel andpebbles with sand under, and scattered cobbles/boulders 60% algal cover with *Pelvetia canaliculata* and *Fucus spiralis. Fucus ceranoides locally present in very small stream.* Occasional barnacles and whelks. **A1.31 - Fucoids on sheltered marine shores**	
8 – Mid shore	Sand and gravel with pebbles, and scattered cobbles and boulders 90% algal cover with *Ascophyllum nodosum* and *Fucus vesiculosus. Polysiphonia spp.* found on *Ascophyllum nodosum. Ulva spp.* scattered in percolating water from stream. **A1.31 - Fucoids on sheltered marine shores**	

Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
8 – Low shore	Muddy sand, rippled <1% algal cover with *Fucus serratus* Barnacles and mussels on very occasional rocks, sand mason worm common in sand **A2.24 – Polychaete/bivalve-dominated muddy sand shores**	
9 – High shore	Cobbles with scattered boulders 5% algal cover with *Pelvetia canaliculata* and *Fucus spiralis.* Saltmarsh present at upper edge of intertidal in thin strip **A1.21 – Barnacles and fucoids on moderately exposed shores**	

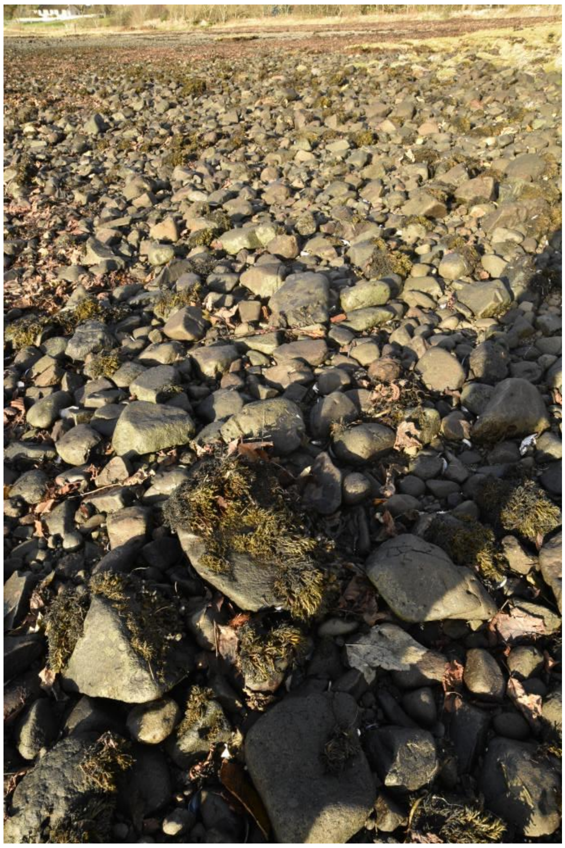
Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
9 – Mid shore	Cobbles with occasional boulders 50% algal cover with *Ascophyllum nodosum* and *Fucus vesiculosus.* Periwinkles, barnacles **A1.31 - Fucoids on sheltered marine shores**	
9 – Low shore	Muddy sand, rare cobbles <1% algal cover with *Fucus serratus* and encrusting calcareous red algae. Barnacles and mussels on rare cobbles, occasional razor shell. **A2.24 – Polychaete/bivalve-dominated muddy sand shores**	

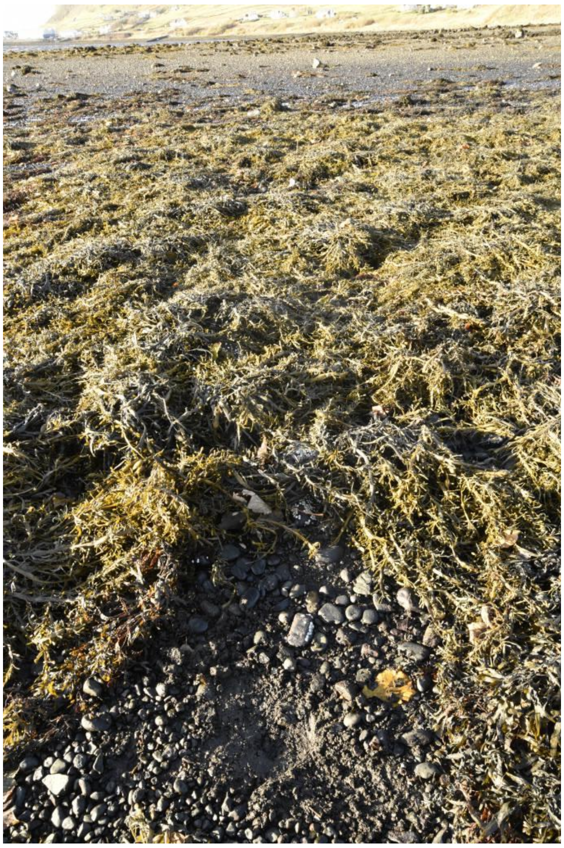
Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
10 – High shore	Cobbles and pebbles with scattered boulders 25% algal cover with *Pelvetia canaliculata* and *Fucus spiralis. Ulva spp.* in nearby small stream. **A1.21 – Barnacles and fucoids on moderately exposed shores**	
10 – Mid shore	Muddy sand with intermixed gravel and occasional cobbles/boulders 1% algal cover with *Ascophyllum nodosum* and *Fucus vesiculosus.* Sand mason worm, mussels **A2.24 – Polychaete/bivalve-dominated muddy sand shores**	

Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
10 – Low shore	Muddy sand with intermixed gravel/pebbles and occasional cobbles <1% algal cover with *Fucus serratus* and *Fucus vesiculosus* Sand mason worms, periwinkles, barnacles and mussels on cobbles **A2.24 – Polychaete/bivalve-dominated muddy sand shores**	
11- High shore	Sand with pebbles and scattered cobbles 25% algal cover with *Pelvetia canaliculata* and *Fucus spiralis* **A2.4 – Littoral mixed sediments**	

Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
11- Mid shore	Pebbles with sand underneath 50% algal cover, mainly *Ascophyllum nodosum, with Fucus vesiculosus* **A1.31 - Fucoids on sheltered marine shores**	
11- Low shore	Pebbles and gravel with sand underneath 80% algal cover with *Fucus vesiculosus.* Mussels and barnacles on larger rocks **A1.31 - Fucoids on sheltered marine shores**	

Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
12- High shore	Combination of sand, gravel and pebbles 2% algal cover with *Pelvetia canaliculata.* Small saltmarsh patches present, increasing towards upper intertidal edge. **A2.4 – Littoral mixed sediments**	
12- Mid shore	Pebbles with sand underneath 30% algal cover consisting of *Ascophyllum nodosum* and *Fucus vesiculosus* Barnacles present on larger stones **A2.4 – Littoral mixed sediments**	

Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
12- Low shore	Pebbles and gravel with sand underneath. Scattered boulders 50% algal cover consisting of *Ascophyllum nodosum* and *Fucus vesiculosus*, occasional *Chondrus crispus.* Mussels and barnacles on larger rocks **A1.31 - Fucoids on sheltered marine shores**	
13- High shore	Cobbles and pebbles 2% algal cover consisting of *Pelvetia canaliculata* and *Fucus spiralis*. The adjacent river outflow contains abundant *Fucus ceranoides* **A1.21 – Barnacles and fucoids on moderately exposed shores**	

Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
13- Mid shore	Pebbles and gravel over sand 25% algal cover consisting primarily of *Ascophyllum nodosum* as well as *Fucus spiralis* and *Fucus vesiculosus*. *Fucus ceranoides* abundant in adjacent river. **A1.31 - Fucoids on sheltered marine shores**	
13- Low shore	Sand with pebbles 30% algal cover, mainly *Fucus vesiculosus*, some *Fucus ceranoides* near the river Barnacles on larger scattered boulders. **A2.4 – Littoral mixed sediments**	

Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
14- High shore	Sand with pebbles and scattered cobbles 5% algal cover consisting of *Pelvetia canaliculata*, *Fucus spiralis*, *Ascophyllum nodosum* with *Polysiphonia spp*. attached. Barnacles on cobbles. Patchy saltmarsh nearby becoming denser at upper intertidal limit. **A2.4 – Littoral mixed sediments**	
14- Mid shore	Sand with pebbles 20% algal cover mainly *Ascophyllum nodosum* and *Fucus vesiculosus* Barnacles on larger stones **A1.31 - Fucoids on sheltered marine shores**	

Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
14- Low shore	Sand with pebbles, gravel and occasional cobbles/boulders <1% algal cover consisting of *Fucus vesiculosus* Barnacles and occasional live mussels on occasional larger rocks **A2.24 – Polychaete/bivalve-dominated muddy sand shores**	
15- High shore	Sand with cobbles and pebbles 30% algal cover consisting of *Pelvetia canaliculata* and *Fucus spiralis* Washed up mussel shells **A1.31 - Fucoids on sheltered marine shores**	

Station No.	Target Notes and EUNIS Biotope code	Supporting photograph
15- Mid shore	Sand with small pebbles and occasional cobbles 30% algal cover consisting of *Ascophyllum nodosum* and *Fucus vesiculosus* Barnacles present on cobbles and some washed up mussel shells present **A1.31 - Fucoids on sheltered marine shores**	
15- Low shore	Muddy sand with pebbles and cobbles 5-10% algal cover consisting of *Fucus vesiculosus*. Encrusting red algae is present on pebbles and shells. Live mussels present on occasional larger rocks. **A2.24 – Polychaete/bivalve-dominated muddy sand shores**	

Station No.	Target Notes and EUNIS Biotope code	Supporting photograph

Appendix C – Sample station location data and assigned biotope

Station No.	Shore position	Coordinate	EUNIS biotope code
1	H	NG 38434 63462	A1.31
1	M	NG 38436 63454	A1.31
1	L	NG 38441 63437	A1.21
2	H	NG 38485 63502	A1.21
2	M	NG 38493 63476	A1.31
2	L	NG 38505 63460	A1.31
3	H	NG 38544 63541	A1.31
3	M	NG 38569 63486	A1.31
3	L	NG 38577 63476	A1.31
4	H	NG 38588 63653	A1.31
4	M	NG 38616 63641	A1.31
4	L	NG 38680 63625	A1.31
5	H	NG 38632 63765	A1.31 & A2.5
5	M	NG 38658 63748	A1.31
5	L	NG 38685 63725	A1.31
6	H	NG 38710 63833	A1.31
6	M	NG 38717 63826	A1.31
6	L	NG 38739 63817	A1.31
7	H	NG 38792 63904	A1.21
7	M	NG 38800 63893	A1.31
7	L	NG 38821 63877	A1.31
8	H	NG 38854 63837	A1.31
8	M	NG 38854 63928	A1.31
8	L	NG 38877 63890	A2.24
9	H	NG 38991 63997	A1.21
9	M	NG 38996 63981	A1.31
9	L	NG 38998 63933	A2.24
10	H	NG 39108 64011	A1.21
10	M	NG 39105 63984	A2.24
10	L	NG 39086 63922	A2.24
11	H	NG 39240 63947	A2.4
11	M	NG 39212 63923	A1.31
11	L	NG 39150 63878	A1.31
12	H	NG 39351 63916	A2.4
12	M	NG 39306 63881	A2.4
12	L	NG 39256 63838	A1.31
13	H	NG 39465 63845	A1.21
13	M	NG 39416 63852	A1.31
13	L	NG 39283 63791	A2.4
14	H	NG 39514 63754	A2.4

Station No.	Shore position	Coordinate	EUNIS biotope code
14	M	NG 39467 63750	A1.31
14	L	NG 39354 63692	A2.24
15	H	NG 39540 63693	A1.31
15	M	NG 39496 63682	A1.31
15	L	NG 39417 63635	A2.24

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13. Fish and Shellfish Ecology

13.1 Underwater Sound Propagation Modelling and Results

Underwater Sound Calculations for Uig Harbour (21/11/2018)

Introduction

This Technical Note presents the results of calculations of sound levels and the preliminary determination of noise impact zones for proposed marine piling activities at Uig. For the purposes of this assessment, sound propagation has been calculated using a simplified spreading model which accounts for source sound levels and propagation of sound over distance.

Glossary

Ambient sound	Background environmental sound
dB	Decibel, unit used in the logarithmic measure of sound strength
dB_{peak}	Peak sound pressure over the measurement period, expressed in dB re 1 μPa
$dB_{peak\text{-}peak}$	Minimum to maximum peak sound pressure over the measurement period, expressed in dB re 1 μPa
dB_{rms}	Root mean square sound pressure over the measurement period, expressed in dB re 1 μPa.
Hz	Hertz. The number of cycles per second and refers to the frequency of the particular sound
L_p	Sound Pressure Level. The sound pressure averaged over the measurement period, expressed in dB re 1 μPa; applicable to peak, peak-peak and rms sound pressure levels.
M-weighting	Frequency weightings designed to best reflect the hearing sensitivity of marine mammals, similar to the use of the A-weighting for measuring sound impacts on humans.
PTS	Permanent Threshold Shift. Irreversible and permanent reduction in auditory sensitivity.
SEL	Sound Exposure Level. Sound energy over the measurement period expressed in dB re 1 μPa^2s. SEL is commonly used for impulsive underwater sound sources because it allows a comparison of the energy contained in impulsive signals of different duration and peak levels. The measurement period for impulsive signals is usually defined as the time period containing 90% of the sound energy.
SEL_{cum}	Cumulative Sound Exposure Level. Summation of the sound energy of multiple impulsive or transient signals over a defined assessment period expressed in dB re 1 μPa^2s i.e. SEL_{cum} = SEL + 10 log (*number of events*).
SL	Source Level. The intensity of underwater sound sources is compared by their source level, expressed in dB re 1 μPa for peak, peak-peak and rms sound pressure levels, and dB re 1 μPa^2s for SEL. The source level is defined as the sound pressure (or energy) level that would be measured at 1 metre from an ideal point source radiating the same amount of sound as the actual source being measured.
TTS	Temporary Threshold Shift. Short-term reversible reduction in auditory sensitivity. TTS will be gradually reversed upon removing exposure to the high sound levels that cause the change in hearing sensitivity.

Adopted Sound Metrics and Source Levels

It is understood that the piling will utilise a 100T crane using a 10T Drop Hammer or Vibro Hammer to drive the piles to the required depth. Source levels for the various proposed marine pile types are based on measured data[1] and are summarised below.

For the SEL_{cum} calculations, this has assumed impact piling every 15 seconds over a 15 minute accumulation period for a single pile, and vibratory piling occurring continuously over a 15-minute accumulative period for a single pile. The predictions are based on a stationary receiver and a stationary source assumption, and do not take into account any movement of the source or receiver, the frequency spectrum of the sound source or the hearing sensitivity weightings of the receptor species. As such it is considered that the SEL_{cum} predictions are representative of a worst-case scenario.

Combined scenarios have also been considered, whereby both impact and vibratory piling take place at the same time. In order to assess the range of effects, the highest and lowest source levels have been considered i.e.

- Combined scenario #1: Sheet piles = PU32 Arcelor mittal, impact and vibratory piling (highest level)
- Combined scenario #2: H piles = 204 mm x 207 mm, impact and vibratory piling (lowest)

Given the difference in source levels between impact and vibratory piling for sheet piles, the dominant sound source will be impact piling, and the combined source level would be equal to that of impact piling alone. As such any predicted noise impact zones for sheet piling would be the same as combined scenario #1.

Given the difference in source levels between impact and vibratory piling for H piles, the dominant sound source will be impact piling, and the combined Peak, RMS and SEL source level would be equal to that of impact piling alone. As such any predicted noise impact zones for H pile piling for Peak, RMS and SEL would be the same as combined scenario #2. However, the combined source level for the SELcum metric would be 182 dB.

Table 1. Pile Type Source Level

Pile Type and Dimensions	Impact Hammer Near-Source Level at 10 metres, dB				Vibratory Driver/Extractor Near-Source Level at 10 metres, dB			
	Peak	RMS	SEL	SELcum (15minutes)	Peak	RMS	SEL	SELcum (15minutes)
Sheet piles = PU32 Arcelor mittal	205	190	180	198	175	160	160	190
H piles = 204 mm x 207 mm	190	175	160	178	165	150	150	180
H piles = 465 mm x 460 mm	195	183	170	188	165	150	150	180
Tubular steel piles = 559 mm diameter with 25 mm steel casing	200	184	174	192	171	155	155	185
Fender piles (tubular steel piles) = 762 mm diameter with 25 mm steel casing	203	190	177	195	180	170	170	200
Straight web sheet piles AS500-12.7	205	190	180	198	175	160	160	190

[1] The California Department of Transportation. (2007).Compendium of Pile Driving Sound Data.

Sound Level Threshold Criteria

The following table presents thresholds for key receptors (cetaceans, seals and fish) in the vicinity of the project area, for which the distance to onset for the thresholds has been assessed.

Table 2. Assessment Thresholds – Marine Mammals

Sensitivity	PTS (multiple pulse)	TTS/behaviour (single pulse)	Threshold source
Impulsive sound (impact piling)			
All cetaceans	230 dB$_{peak}$ 198 dB SEL	224 dB$_{peak}$ 183 dB SEL	Southall et al., 2007
Pinnipeds in water	218 dB$_{peak}$ 186 dB SEL	212 dB$_{peak}$ 171 dB SEL	
Low Frequency Cetaceans	219 dB$_{peak}$ 183 dB SEL$_{cum}$	213 dB$_{peak}$ 168 dB SEL$_{cum}$	NOAA, 2016 incorporating weighting functions
Mid Frequency Cetaceans	230 dB$_{peak}$ 185 dB SEL$_{cum}$	224 dB$_{peak}$ 170 dB SEL$_{cum}$	
High Frequency Cetaceans	202 dB$_{peak}$ 155 dB SEL$_{cum}$	196 dB$_{peak}$ 140 dB SEL$_{cum}$	
Phocid Porpoise	218 dB$_{peak}$ 185 dB SEL$_{cum}$	212 dB$_{peak}$ 170 dB SEL$_{cum}$	
Continuous sound (vibratory piling)*			
All cetaceans	230 dB$_{peak}$ 215 dB SEL	n/a	Southall et al., 2007
Pinnipeds in water	218 dB$_{peak}$ 203 dB SEL	n/a	
Low Frequency Cetaceans	199 dB SEL$_{cum}$	179 dB SEL$_{cum}$	NMFS, 2018
Mid Frequency Cetaceans	198 dB SEL$_{cum}$	178 dB SEL$_{cum}$	
High Frequency Cetaceans	173 dB SEL$_{cum}$	153 dB SEL$_{cum}$	
Phocid Porpoise	201 dB SEL$_{cum}$	181 dB SEL$_{cum}$	

Table 3. Assessment Thresholds – Fish (thresholds from Popper et al., 2014)

Sensitivity	Mortality/mortal injury	Recoverable injury	TTS	Low level disturbance
Impulsive sound (impact piling)				
Low sensitivity fish	213 dB$_{peak}$ 219 dB SEL$_{cum}$	213 dB$_{peak}$ 216 dB SEL$_{cum}$	186 dB SEL$_{cum}$	150 dB$_{rms}$
Medium sensitivity fish	207 dB$_{peak}$ 210 dB SEL$_{cum}$	207 dB$_{peak}$ 203 dB SEL$_{cum}$	186 dB SEL$_{cum}$	150 dB$_{rms}$
High sensitivity fish	207 dB$_{peak}$ 207 dB SEL$_{cum}$	207 dB$_{peak}$ 203 dB SEL$_{cum}$	186 dB SEL$_{cum}$	150 dB$_{rms}$
Eggs & larvae	207 dB$_{peak}$ 210 dB SEL$_{cum}$	-	-	-
Continuous sound (vibratory piling)*				
Low & Medium sensitivity fish	(N/I/F) Low	(N/I/F) Low	(N) Moderate; (I/F) Low	(N/I) Moderate (F) Low
High Sensitivity fish	(N/I/F) Low	170 dB$_{rms}$ for 48 hours	150 dB$_{rms}$ for 12 hours	(N) High (I) Moderate (F) Low

Calculation Methodology

The standard formula[2] used for estimating the transmission loss from underwater sound sources is:

TL = A log (r) + B r + C

Where:

TL is the transmission loss at a distance r from the source.

A is the wave mode coefficient. For spherical waves (e.g. low frequency sound) A = 20, and cylindrical waves (e.g. high frequency sound) A = 10.

B is an attenuation factor that is dependent on water depth and sea bottom conditions.

C is a fixed attenuation due to acoustic screening. In open water this will be 0.

For the purposes of this assessment and to provide a reasonable estimate of sound propagation, an empirical wave mode coefficient A = 20 has been used. Transmission losses due to absorption, scattering and diffraction have been excluded from these predictions. Additionally, the effect of the ambient underwater sound environment has not been considered in this assessment.

For receptor locations without a direct line of sight to the sound source (such as due to physical obstructions) the received level would be substantially lower in comparison to a receptor location with direct line of sight. The actual level of attenuation is dependent on a number of factors (e.g. separation distance between receptor and source, frequency content of the sound source, and angle of view from the diffracting edge of the obstruction). For the purposes of this project however, in order to account for physical screening of the sound propagation path by land massing between piling locations into open water, an estimated attenuation factor of 30 dB has been applied.

Although the use of spherical and cylindrical formulae for predicting the sound propagation loss is widely used as a simple way of evaluation, this methodology does not entirely take into account the influence of both environmental characteristics (bathymetry, seafloor geo-acoustic properties, water salinity and temperature profiles etc.) and of signal frequency on the propagation of sound and hence the propagation loss may be under- or over-estimated. However for the purposes of undertaking a preliminary assessment of the effects of piling sound sources and the identification of noise impact zones, it is considered that the above calculation methodology is robust and provides a conservative yet reasonably realistic estimate of sound propagation.

[2] Lurton, Xavier. (2002). An introduction to underwater acoustics: principles and applications. Springer Science & Business Media.

Results and Conclusions

The following tables present preliminary recommendations for noise impact zones for each of the receptors and associ ated threshold criteria (as shown in Tables 2 and 3). The noise impact zones have been provided for receptor locations and propagation paths within the following scenarios:

- Scenario 1 – within Uig Harbour and/or in open water with direct line of sight to piling works (line of sight, “LoS”)
- Scenario 2 – in open water with no direct line of sight to piling works (no line of sight, “No LoS”)

It is considered that due to the impulsive nature of the sound emissions and the limitations of a simplified spreading model, the use of the Peak and RMS sound pressure level metrics provide the most realistic representation of potential effects on the various receptors considered in this assessment. Note that the use of the SEL_{cum} metric for a stationary source and stationary receptor may be overestimated, since the hearing sensitivities of a receiver have not been accounted for, together with the possibility of the receiver attempting to move away from a disturbing sound source.

As discussed above, sound propagation has been calculated using a simplified spreading model which accounts for source sound levels and propagation of sound over distance, and an estimated attenuation factor for physical screening by land massing. This methodology does not entirely take into account the influence of both environmental characteristics (bathymetry, seafloor geo-acoustic properties, water salinity and temperature profiles etc.) and of signal frequency on the propagation of sound. In addition, the far-field received sound signature would be also affected by the directivity of the selected sound source and the propagation path (including any reflections and physical screening interactions), which can be complex.

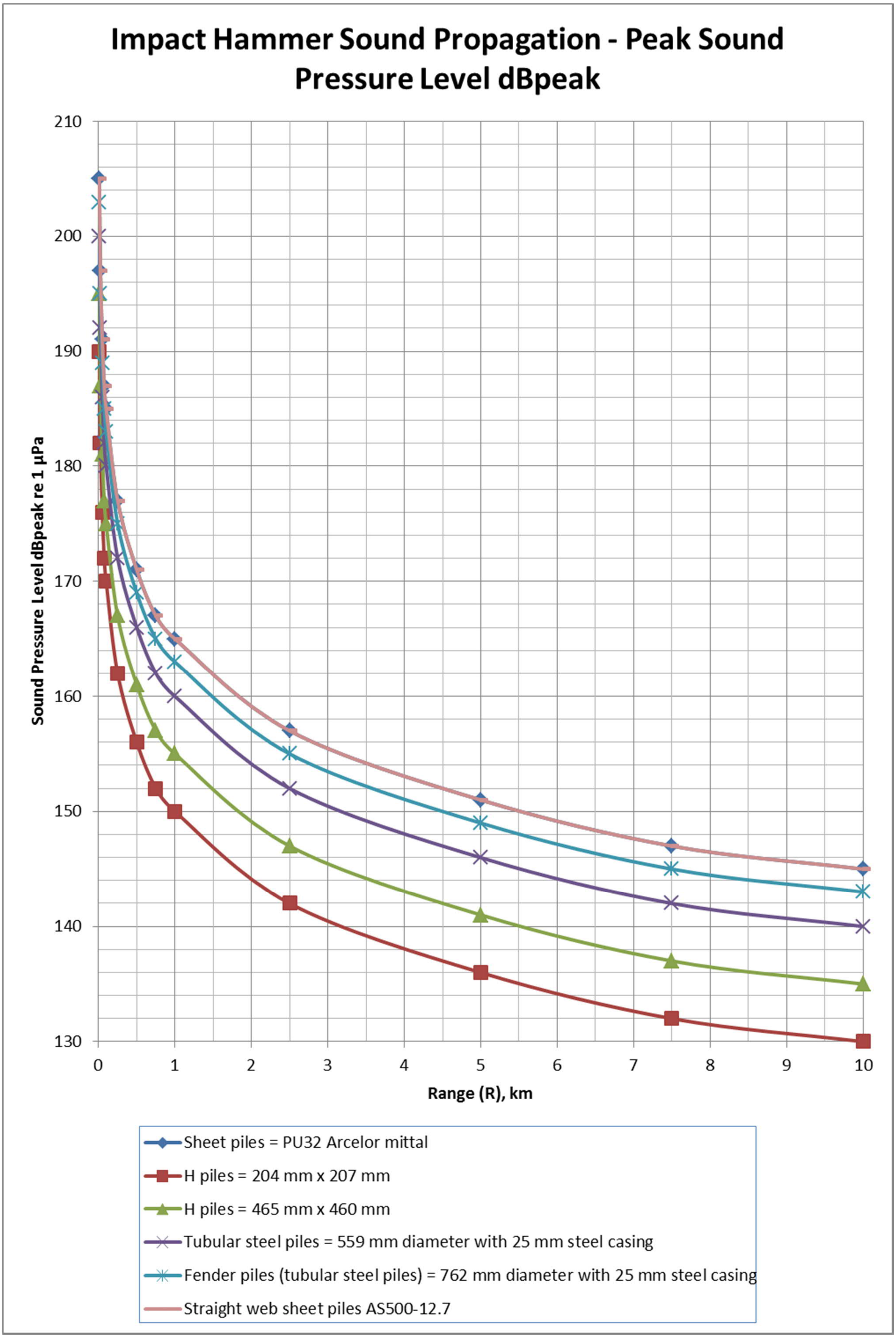
Table 4. Preliminary Recommendations for Noise Impact Zones – Marine Mammals

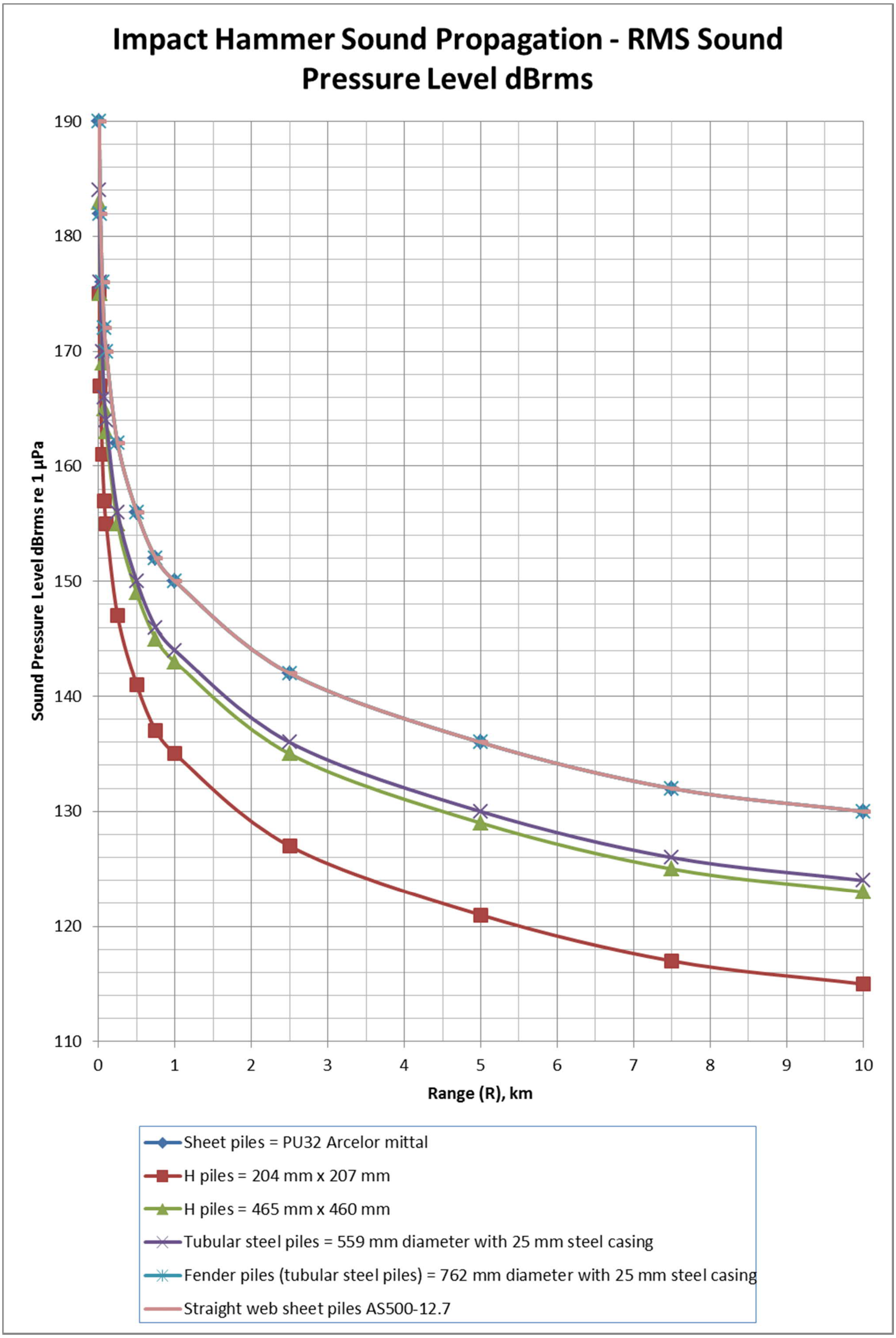
Sensitivity	Threshold source	Effect	Threshold	Sheet piles = PU32 Arcelor mittal		H piles = 204 mm x 207 mm		H piles = 204 mm x 207 mm (combined SELcum)		H piles = 465 mm x 460 mm		Tubular steel piles = 559 mm diameter with 25 mm steel casing		Fender piles (tubular steel piles) = 762 mm diameter with 25 mm steel casing		Straight web sheet piles AS500-12.7	
				Impact zone, metres		Impact zone, metres		Impact zone, metres		Impact zone, metres		Impact zone, metres		Impact zone, metres		Impact zone, metres	
				LoS	No LoS	LoS	No LoS	LoS	No LoS	LoS	No LoS	LoS	No LoS	LoS	No LoS	LoS	No LoS
Impulsive sound (impact piling)																	
All cetaceans	Southall et al., 2007	PTS	230 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			198 dB SEL	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
		TTS	224 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			183 dB SEL	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
Pinnipeds in water		PTS	218 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			186 dB SEL	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
		TTS	212 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			171 dB SEL	28	<10	<10	<10	n/a	n/a	<10	<10	14	<10	20	<10	28	<10
Low Frequency Cetaceans	NOAA, 2016 incorporating weighting functions	PTS	219 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			183 dB SEL$_{cum}$	56	<10	<10	<10	<10	<10	18	<10	28	<10	40	<10	56	<10
		TTS	213 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			168 dB SEL$_{cum}$	316	10	32	<10	50	<10	100	<10	158	<10	224	<10	316	10
Mid Frequency Cetaceans		PTS	230 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			185 dB SEL$_{cum}$	45	<10	<10	<10	<10	<10	14	<10	22	<10	32	<10	45	<10
		TTS	224 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			170 dB SEL$_{cum}$	251	<10	25	<10	40	<10	79	<10	126	<10	178	<10	251	<10
High Frequency Cetaceans		PTS	202 dB$_{peak}$	14	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	11	<10	14	<10
			155 dB SEL$_{cum}$	1413	45	141	<10	224	<10	447	14	708	22	1000	32	1413	45
		TTS	196 dB$_{peak}$	28	<10	<10	<10	n/a	n/a	<10	<10	16	<10	22	<10	28	<10
			140 dB SEL$_{cum}$	7943	251	794	25	1259	40	2512	79	3981	126	5623	178	7943	251
Phocid Porpoise		PTS	218 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			185 dB SEL$_{cum}$	45	<10	<10	<10	<10	<10	14	<10	22	<10	32	<10	45	<10
		TTS	212 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			170 dB SEL$_{cum}$	251	<10	25	<10	40	<10	79	<10	126	<10	178	<10	251	<10
Continuous sound (vibratory piling)																	
All cetaceans	Southall et al., 2007	PTS	230 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			215 dB SEL	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
Pinnipeds in water		PTS	218 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			203 dB SEL	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
Low Frequency Cetaceans	NMFS, 2018	PTS	199 dB SEL$_{cum}$	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	11	<10	<10	<10
		TTS	179 dB SEL$_{cum}$	35	<10	11	<10	14	<10	11	<10	20	<10	112	<10	35	<10
Mid Frequency Cetaceans		PTS	198 dB SEL$_{cum}$	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	13	<10	<10	<10
		TTS	178 dB SEL$_{cum}$	40	<10	13	<10	16	<10	13	<10	22	<10	126	<10	40	<10
High Frequency Cetaceans		PTS	173 dB SEL$_{cum}$	71	<10	22	<10	28	<10	22	<10	40	<10	224	<10	71	<10
		TTS	153 dB SEL$_{cum}$	708	22	224	<10	282	<10	224	<10	398	13	2239	71	708	22
Phocid Porpoise		PTS	201 dB SEL$_{cum}$	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		TTS	181 dB SEL$_{cum}$	28	<10	<10	<10	11	<10	<10	<10	16	<10	89	<10	28	<10

Table 5. Preliminary Recommendations for Exclusion Zones – Fish

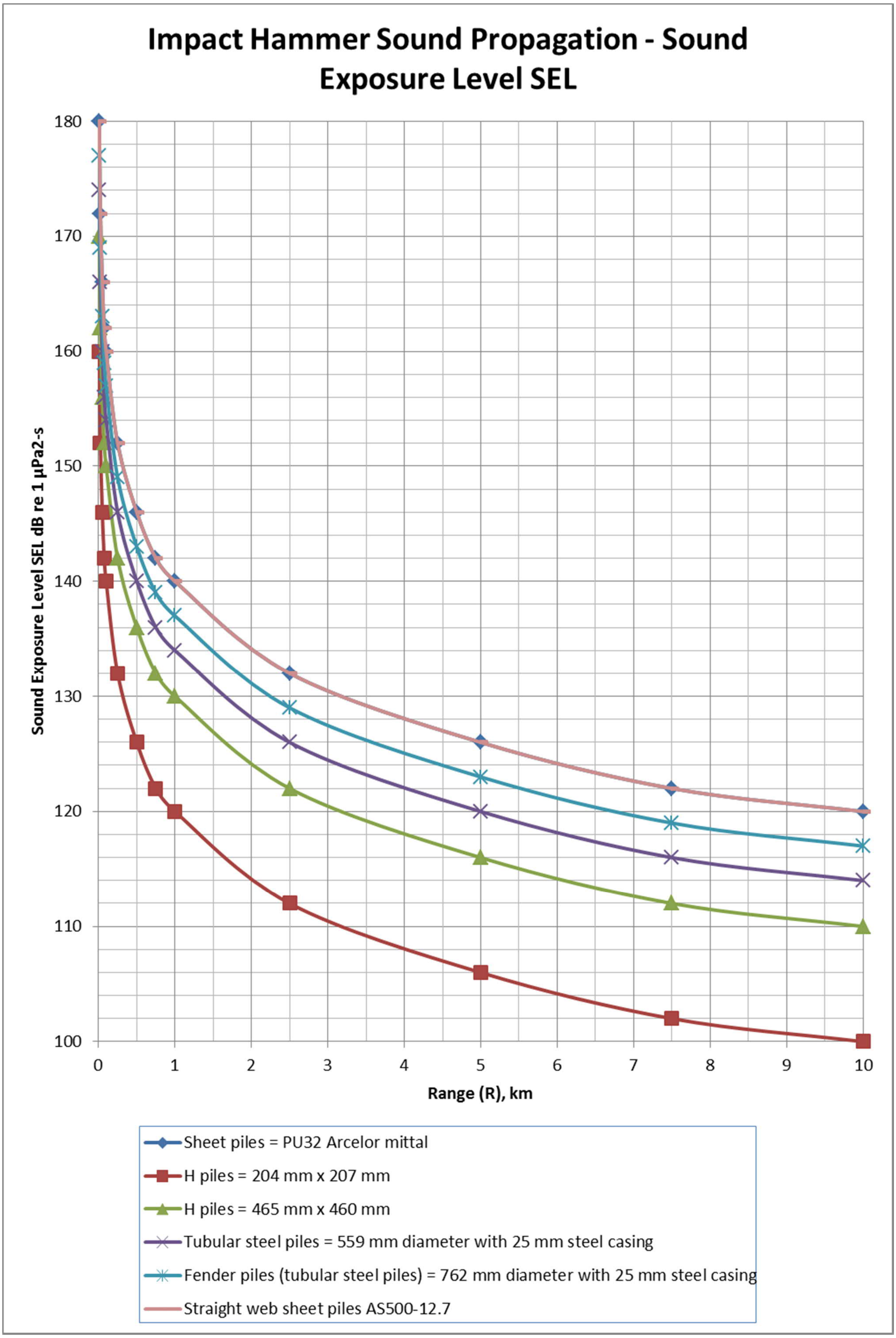
Sensitivity	Threshold source	Effect	Threshold	Sheet piles = PU32 Arcelor mittal		H piles = 204 mm x 207 mm		H piles = 204 mm x 207 mm (combined SELcum)		H piles = 465 mm x 460 mm		Tubular steel piles = 559 mm diameter with 25 mm steel casing		Fender piles (tubular steel piles) = 762 mm diameter with 25 mm steel casing		Straight web sheet piles AS500-12.7	
				Impact zone, metres		Impact zone, metres		Impact zone, metres		Impact zone, metres		Impact zone, metres		Impact zone, metres		Impact zone, metres	
				LoS	No LoS	LoS	No LoS	LoS	No LoS	LoS	No LoS	LoS	No LoS	LoS	No LoS	LoS	No LoS
Impulsive sound (impact piling)																	
Low sensitivity fish	Popper et al., 2014	Mortality/mortal injury	213 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			219 dB SEL$_{cum}$	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		Recoverable injury	213 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			216 dB SEL$_{cum}$	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		TTS	186 dB SEL$_{cum}$	40	<10	<10	<10	<10	<10	13	<10	20	<10	28	<10	40	<10
		Low level disturbance	150 dB$_{rms}$	1000	32	178	<10	n/a	n/a	447	14	501	16	1000	32	1000	32
Medium sensitivity fish		Mortality/mortal injury	207 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			210 dB SEL$_{cum}$	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		Recoverable injury	207 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			203 dB SEL$_{cum}$	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		TTS	186 dB SEL$_{cum}$	40	<10	<10	<10	<10	<10	13	<10	20	<10	28	<10	40	<10
		Low level disturbance	150 dB$_{rms}$	1000	32	178	<10	n/a	n/a	447	14	501	16	1000	32	1000	32
High sensitivity fish		Mortality/mortal injury	207 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			207 dB SEL$_{cum}$	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		Recoverable injury	207 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			203 dB SEL$_{cum}$	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		TTS	186 dB SEL$_{cum}$	40	<10	<10	<10	<10	<10	13	<10	20	<10	28	<10	40	<10
		Low level disturbance	150 dB$_{rms}$	1000	32	178	<10	n/a	n/a	447	14	501	16	1000	32	1000	32
Eggs & larvae		Mortality/mortal injury	207 dB$_{peak}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	<10	<10	<10	<10
			210 dB SEL$_{cum}$	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Continuous sound (vibratory piling)																	
High Sensitivity fish	Popper et al., 2014	Recoverable injury	170 dB$_{rms}$	<10	<10	<10	<10	n/a	n/a	<10	<10	<10	<10	10	<10	<10	<10
		TTS	150 dB$_{rms}$	32	<10	10	<10	n/a	n/a	10	<10	18	<10	100	<10	32	<10

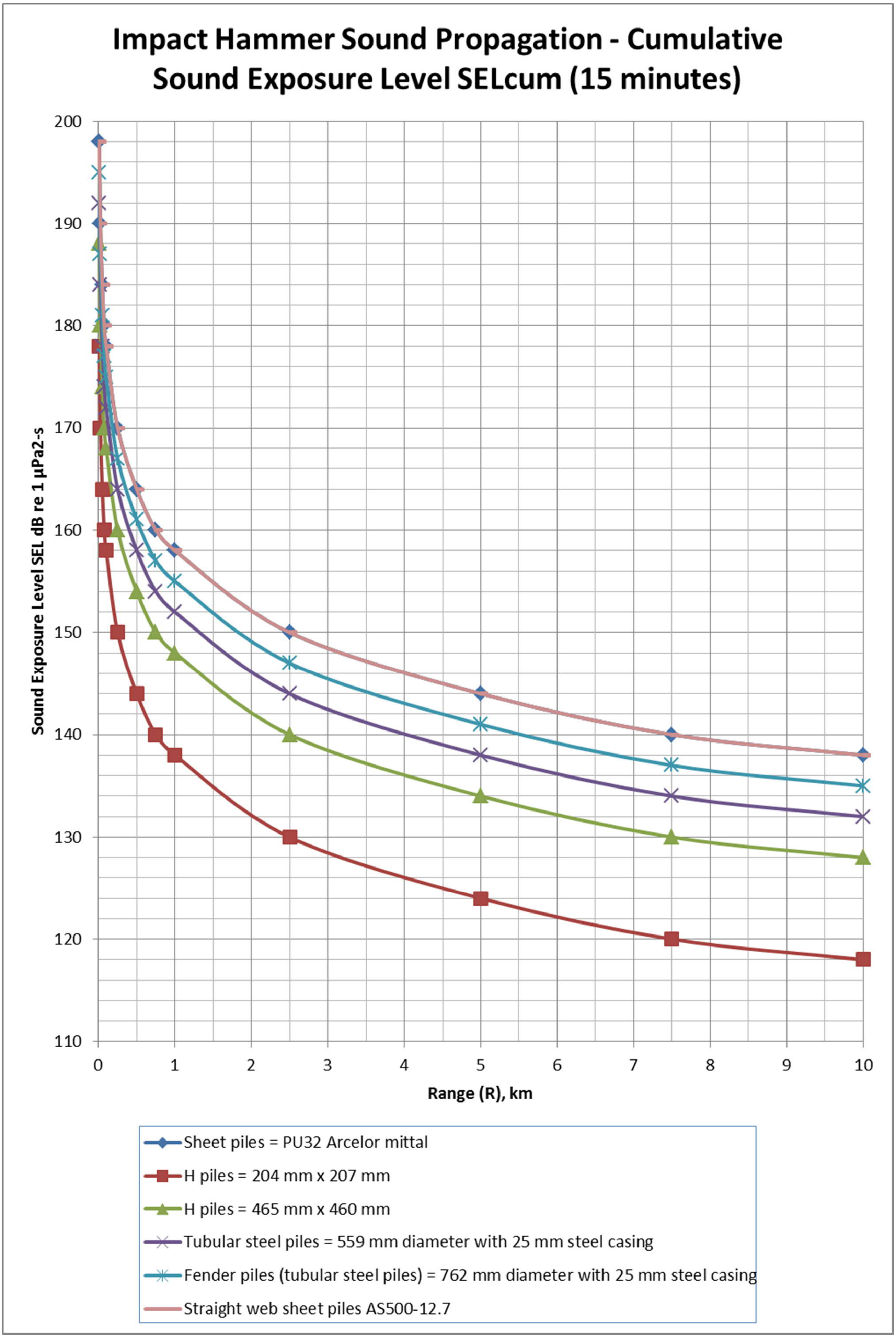
Sound Propagation Charts – Scenario 1 – within Uig Harbour and/or in open water with direct line of sight to piling works


Impact Hammer Sound Propagation - Peak Sound Pressure Level dBpeak
Sound Pressure Level dBpeak re 1 µPa
210
200
190
180
170
160
150
140
130
0
1
2
3
4
5
6
7
8
9
10
Range (R), km
Sheet piles = PU32 Arcelor mittal
H piles = 204 mm x 207 mm
H piles = 465 mm x 460 mm
Tubular steel piles = 559 mm diameter with 25 mm steel casing
Fender piles (tubular steel piles) = 762 mm diameter with 25 mm steel casing
Straight web sheet piles AS500-12.7

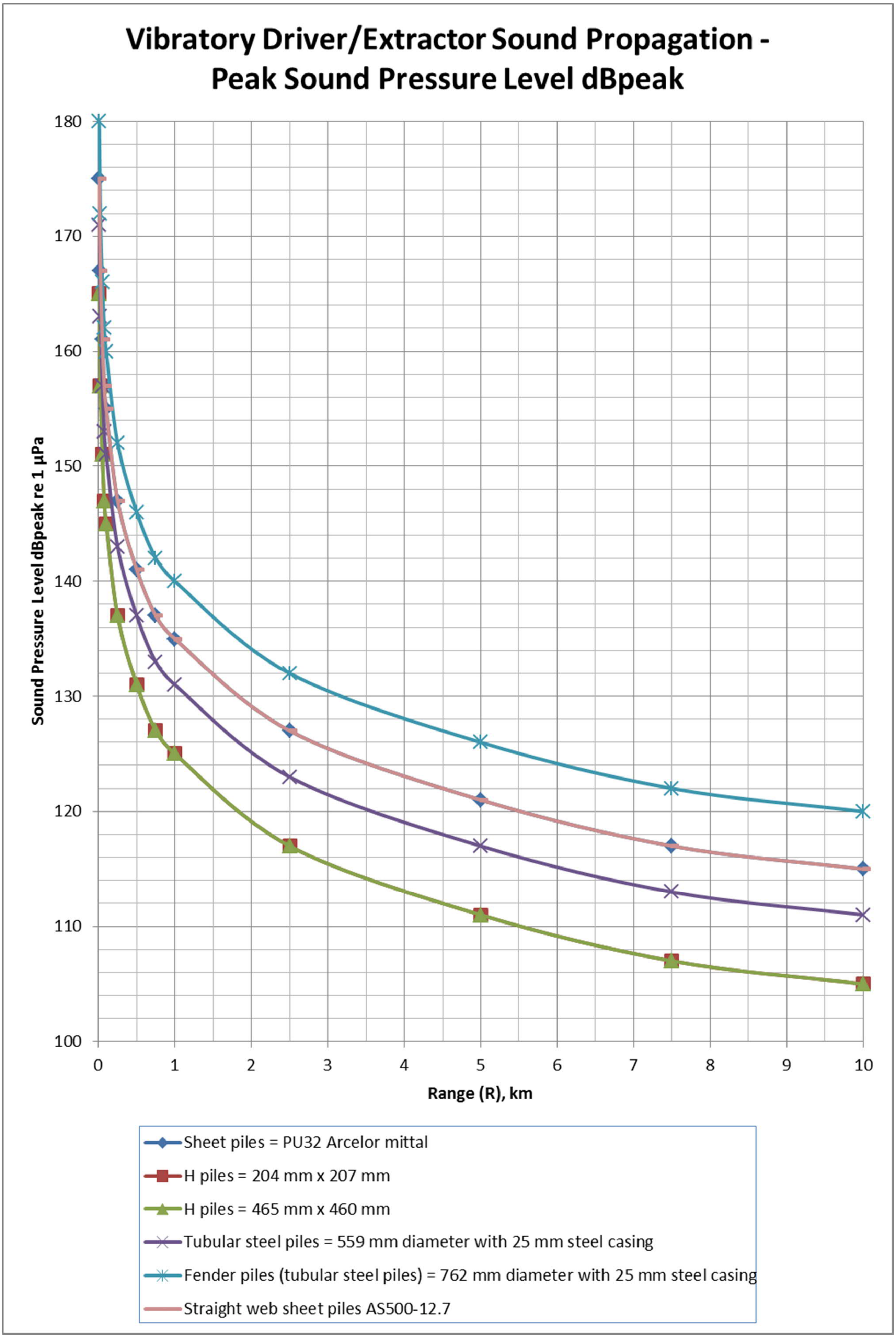


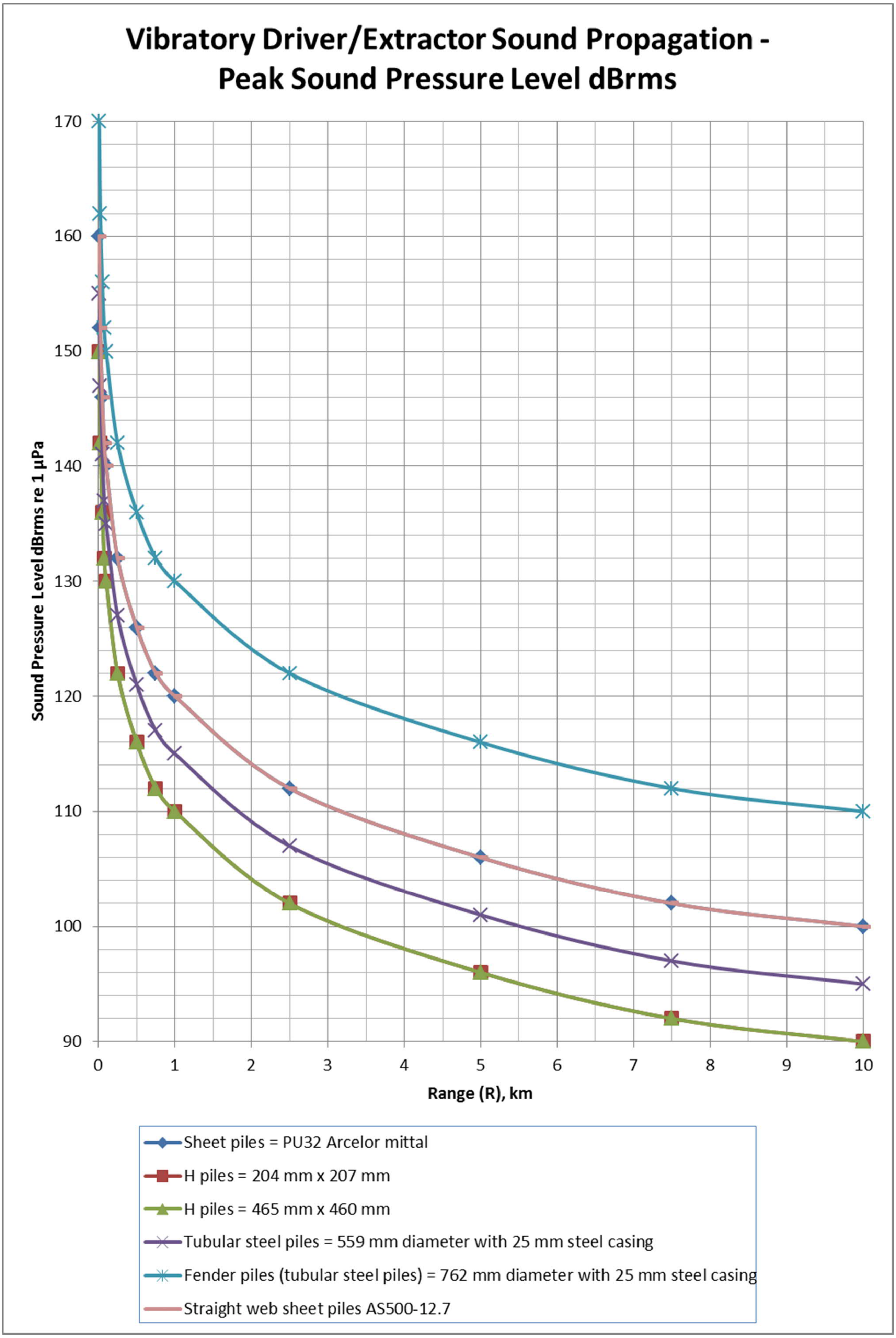
Impact Hammer Sound Propagation - RMS Sound Pressure Level dBrms
Sound Pressure Level dBrms re 1 µPa
190
180
170
160
150
140
130
120
110
0
1
2
3
4
5
6
7
8
9
10
Range (R), km
Sheet piles = PU32 Arcelor mittal
H piles = 204 mm x 207 mm
H piles = 465 mm x 460 mm
Tubular steel piles = 559 mm diameter with 25 mm steel casing
Fender piles (tubular steel piles) = 762 mm diameter with 25 mm steel casing
Straight web sheet piles AS500-12.7

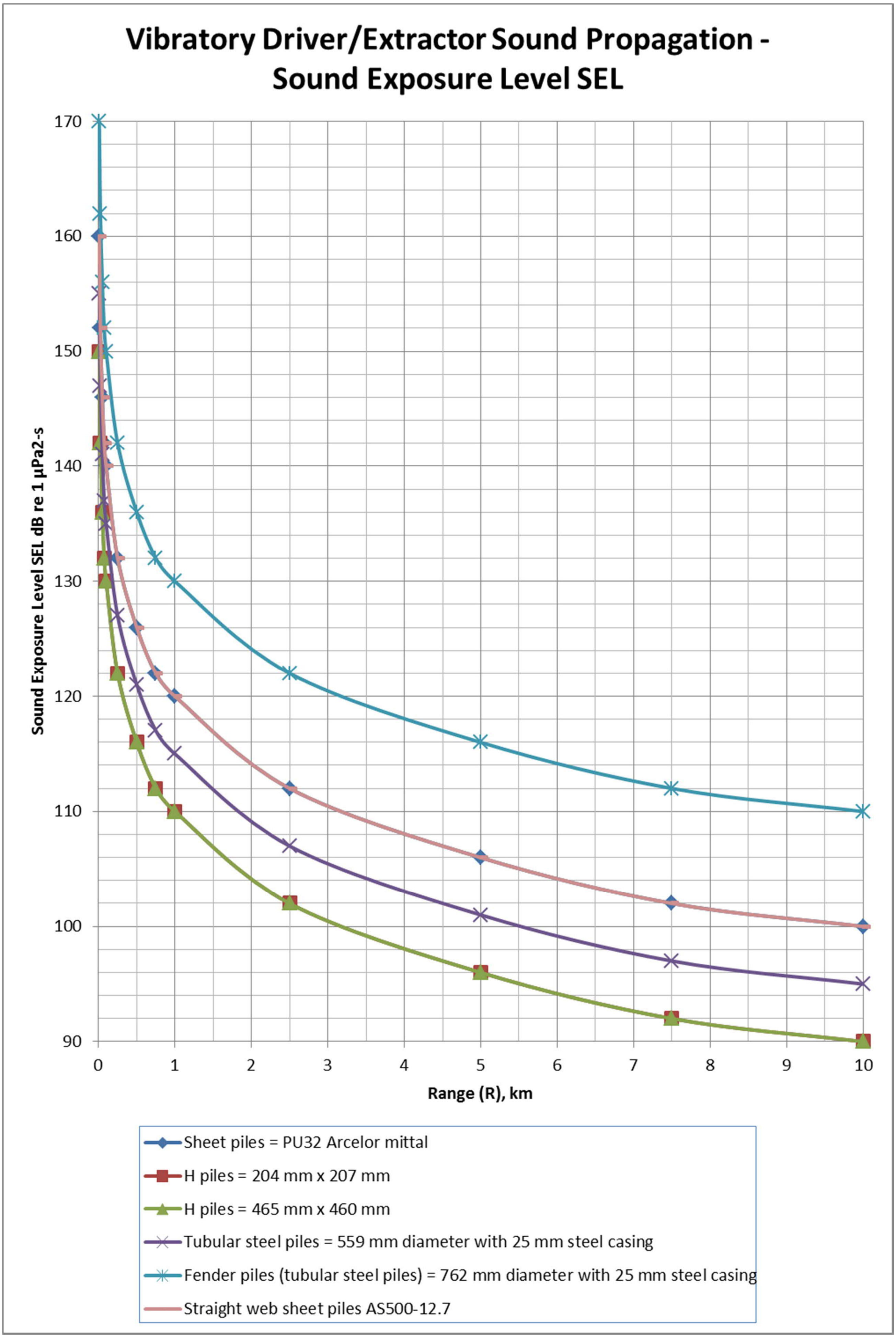

Impact Hammer Sound Propagation - Sound Exposure Level SEL
180
170
160
150
140
130
120
110
100
Sound Exposure Level SEL dB re 1 µPa2-s
0
1
2
3
4
5
6
7
8
9
10
Range (R), km
Sheet piles = PU32 Arcelor mittal
H piles = 204 mm x 207 mm
H piles = 465 mm x 460 mm
Tubular steel piles = 559 mm diameter with 25 mm steel casing
Fender piles (tubular steel piles) = 762 mm diameter with 25 mm steel casing
Straight web sheet piles AS500-12.7



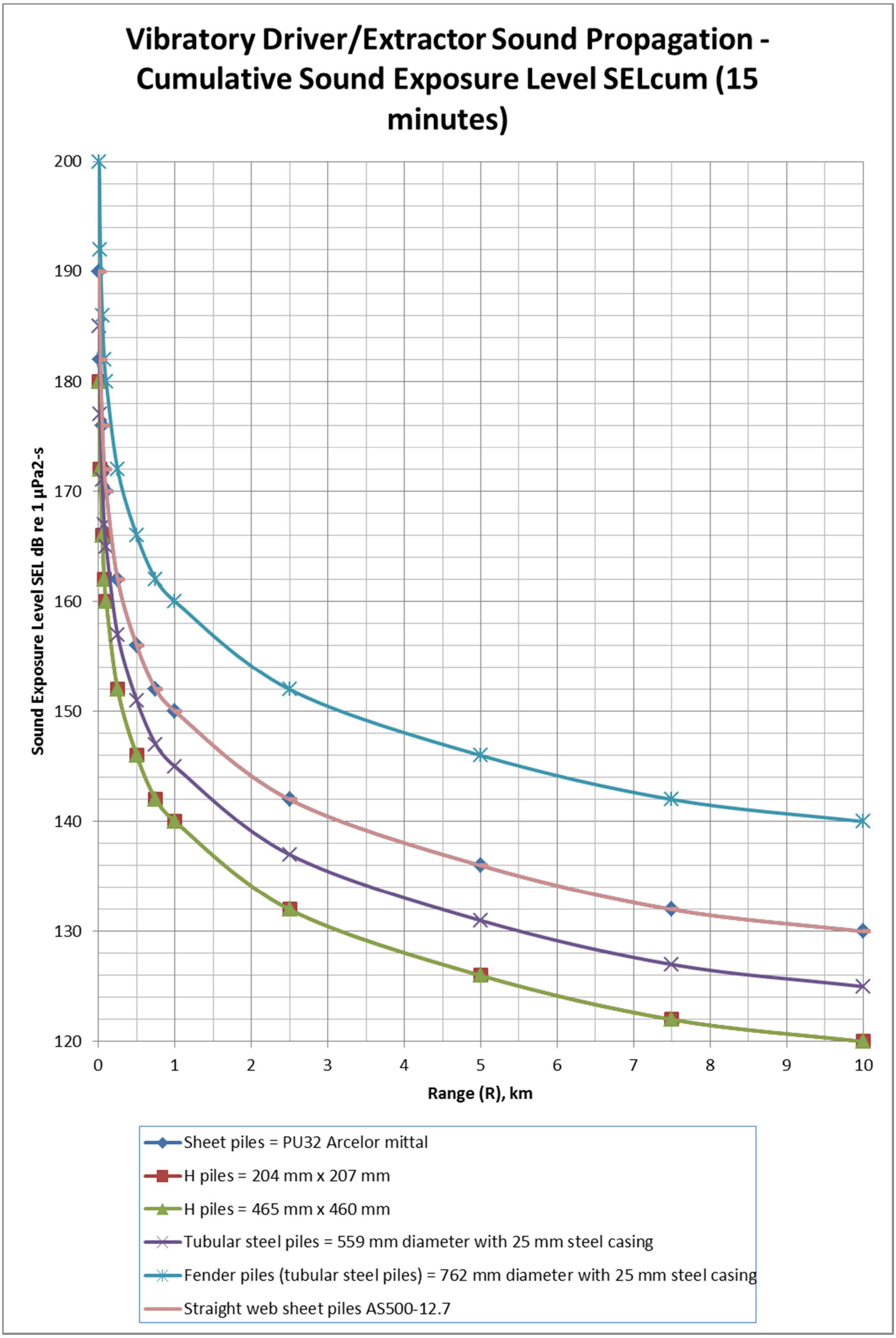
Impact Hammer Sound Propagation - Cumulative Sound Exposure Level SELcum (15 minutes)
Sound Exposure Level SEL dB re 1 µPa2-s
200
190
180
170
160
150
140
130
120
110
0
1
2
3
4
5
6
7
8
9
10
Range (R), km
Sheet piles = PU32 Arcelor mittal
H piles = 204 mm x 207 mm
H piles = 465 mm x 460 mm
Tubular steel piles = 559 mm diameter with 25 mm steel casing
Fender piles (tubular steel piles) = 762 mm diameter with 25 mm steel casing
Straight web sheet piles AS500-12.7


Vibratory Driver/Extractor Sound Propagation - Peak Sound Pressure Level dBpeak
Sound Pressure Level dBpeak re 1 µPa
180
170
160
150
140
130
120
110
100
0
1
2
3
4
5
6
7
8
9
10
Range (R), km
Sheet piles = PU32 Arcelor mittal
H piles = 204 mm x 207 mm
H piles = 465 mm x 460 mm
Tubular steel piles = 559 mm diameter with 25 mm steel casing
Fender piles (tubular steel piles) = 762 mm diameter with 25 mm steel casing
Straight web sheet piles AS500-12.7


Vibratory Driver/Extractor Sound Propagation - Peak Sound Pressure Level dBrms
Sound Pressure Level dBrms re 1 µPa
170
160
150
140
130
120
110
100
90
0
1
2
3
4
5
6
7
8
9
10
Range (R), km
Sheet piles = PU32 Arcelor mittal
H piles = 204 mm x 207 mm
H piles = 465 mm x 460 mm
Tubular steel piles = 559 mm diameter with 25 mm steel casing
Fender piles (tubular steel piles) = 762 mm diameter with 25 mm steel casing
Straight web sheet piles AS500-12.7



Vibratory Driver/Extractor Sound Propagation - Sound Exposure Level SEL
Sound Exposure Level SEL dB re 1 µPa2-s
170
160
150
140
130
120
110
100
90
0
1
2
3
4
5
6
7
8
9
10
Range (R), km
Sheet piles = PU32 Arcelor mittal
H piles = 204 mm x 207 mm
H piles = 465 mm x 460 mm
Tubular steel piles = 559 mm diameter with 25 mm steel casing
Fender piles (tubular steel piles) = 762 mm diameter with 25 mm steel casing
Straight web sheet piles AS500-12.7



Vibratory Driver/Extractor Sound Propagation - Cumulative Sound Exposure Level SELcum (15 minutes)
Sound Exposure Level SEL dB re 1 µPa2-s
200
190
180
170
160
150
140
130
120
0
1
2
3
4
5
6
7
8
9
10
Range (R), km
Sheet piles = PU32 Arcelor mittal
H piles = 204 mm x 207 mm
H piles = 465 mm x 460 mm
Tubular steel piles = 559 mm diameter with 25 mm steel casing
Fender piles (tubular steel piles) = 762 mm diameter with 25 mm steel casing
Straight web sheet piles AS500-12.7

14. Marine Mammals

No Appendices

15. Ornithology

15.1 Breeding Bird Survey Report

Uig Ferry Terminal

Ornithological Survey

June 2017

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Summary

A desktop study was carried out to identify potential breeding and wintering bird species that may utilise the site.

A breeding birds survey was carried out of the area of Uig Ferry Terminal, Skye, in May 2017. Very few breeding birds were found in the vicinity of the ferry terminal, and no breeding Schedule 1 birds were found.

1 Introduction

1.1 Site Description

The area of the survey was the ferry terminal at Uig, Isle of Skye and all suitable breeding bird habitat within 250m of the terminal.

1.2 Aims of Survey

A desktop study was carried out to identify potential breeding and wintering bird species that may utilise the site.

A field survey was also carried out, which aimed to locate all breeding birds within the survey area and asses the requirement for further breeding bird survey visits to the area.

2 Methodology

Desktop Survey

The following were consulted for data on breeding and wintering birds in the vicinity of Uig ferry terminal:

BTO Wetland Bird Survey
BTO Breeding bird atlas
JNCC's Seabirds at Sea and European Seabirds at Sea database
Data collated for the Shiant Isles Seabird Recovery Project
Surveys carried out for the Inner Hebrides and the Minches candidate Special Area of Conservation

Field Survey
A standard walkover survey of the site, including the existing pier structure and a 250m buffer zone, was carried out by Alison Tyler on 24 and 25 May 2017. The survey was undertaken in good weather conditions. The area was surveyed between 0900 and 1800, and suitable long vegetation for corncrakes was surveyed again between 0015 and 0045.

The survey was undertaken by Alison Tyler, an experienced ornithologist.

3 Results

Desktop Survey
There are no designated sites for breeding birds within 20km of the Uig Ferry Terminal. Uig Bay is within the candidate (submitted to EC) Special Area of Conservation Inner Hebrides and the Minches, which has harbour porpoise as its qualifying feature. The Trotternish Ridge SAC is also within 20km of the site.

Very little information on breeding birds of the Uig area was available. RSPB have records of breeding corncrake in the area, so the field survey included surveying following standard RSPB methodology.

No data on the seabirds of Uig bay was available from either the surveys carried out for the Shiant Isles Seabirds Recovery Project or the Inner Hebrides and the Minches candidate SAC. A single count was carried out for the Wetland Bird Survey in winter 2005/2006.

Field Survey
The existing pier is an open mental construction at the seaward end and a solid concrete wall and rock armour at the shore end. As detailed in the Phase 1 Habitats and Otter Survey Report[1], the intertidal area is brown algal beds with a small area of saltmarch at the upper llimits of the area below the rock armoured sea wall. The shingle area above high tide has sparse vegetation (Figure 1). There is a grass verge between the seawall and the roads and car park area.   The adjacent crofts land is herb-rich semi-improved grassland.

Figure 1: Pier and Intertidal Area

<u>Species found breeding in the survey area</u>

House sparrow *Passer Domesticus*
Two breeding pairs under the eaves of the filling station adjacent to the ferry terminal

Starling *Sturnus vulgaris*

At least 4 pairs nesting in the roof area of the CalMac ferry terminal building.

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[1] A Tyler, Uig Ferry Terminal Phase 1 Habitats and Otter Survey, June 2017

Sedge Warbler *Acrocephalus schoenobaenus*

One pair nesting in the shrub vegetation between the road and the shore west of the ferry terminal.

Wren *Troglodytes troglodytes*

One pair nesting in the shrubs near the ferry car park.

<u>Other birds recorded during the survey</u>

Pied Wagtail *Motacilla alba*

Seen flying near the ferry car park.

Swallow *Hirundo rustica*

Flying over shore near pier – probably nesting in croft buildings near survey area

Herring Gull *Larus argentatus*

7 birds recorded in the vicinity of the pier

Eider *Somateria mollissima*

Flock of 5 birds on sea loch within 200m of pier.

4 Assessment

There are no designated sites for breeding or wintering birds within 20km of the Uig Ferry Terminal. There are records for breeding corncrake within the township of Uig, and there is suitable long vegetation within the survey area, but no calling corncrakes were recorded during the survey. The breeding birds found during the survey are all common species found throughout Skye and the Highlands and Islands. The survey timing was sub-optimal for Black Guillemot *Cepphus grylle* however the habitat present did not provide suitable nesting sites, for that species.

The desktop study did not identify any published data on wintering birds in Uig Bay, other than the single WeBS count. Uig Bay was not included on the Areas of Search for inshore aggregations of waterbirds outside the breeding season by the JNCC Seabirds at Sea team surveys. Eider were recorded during the breeding bird survey and it is known that they are also present as a wintering species.

5 Further Survey Recommendations

As the breeding birds in the vicinity of the ferry terminal are relatively common in Skye, and there were no Schedule 1 breeding birds, there is no immediate requirement for further breeding bird survey work.

There is a lack of information on wintering seabirds in the vicinity of the ferry terminal. There is no published data to suggest that Uig Bay is a nationally important area for seaduck. Eider are present throughout the year, and, although eider can feed in the intertidal areas, the proposed development is unlikely to have an adverse effect on the eider population in Uig Bay.

Appendix 1 Uig Ferry Terminal
Breeding Birds

Legend
House sparrow
Starling
Sedge warbler
Wren

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16. Socio-economics and Public Access

No Appendices

17. Terrestrial Noise and Vibration

17.1 Acoustic Terminology

17.2 Noise Model Input Data

17.1 Acoustic Terminology

Appendix 17.1 – Acoustic Terminology

Between the quietest audible sound and the loudest tolerable sound there is a million to one ratio in sound pressure (measured in pascals, Pa). Because of this wide range a noise level scale based on logarithms is used in noise measurement called the decibel (dB) scale.

The human ear system does not respond uniformly to sound across the detectable frequency range and consequently instrumentation used to measure noise is weighted to represent the performance of the ear. This is known as the 'A weighting' and annotated as dB (A) or LpA dB. The table below lists the sound pressure level in dB (A) for common situations.

Sound Pressure Levels for a Range of Situations

Typical Noise Levels dB(A)	Example
0	Threshold of hearing
30	Rural area at night, still air
40	Public library Refrigerator humming at 2m
50	Quiet office, no machinery Boiling kettle at 0.5m
60	Normal conversation
70	Telephone ringing at 2m Vacuum cleaner at 3m
80	General factory noise level
100	Pneumatic drill at 5m
120	Discotheque - 1m in front of loudspeaker
140	Threshold of pain

The noise level at a measurement point is rarely steady, even in rural areas, and varies over a range dependent upon the effects of local noise sources. Close to a busy road, the noise level may vary over a range of 5 dB(A), whereas in a suburban area this may increase up to 40 dB(A) and more due to the multitude of noise sources in such areas (cars, dogs, aircraft etc.) and their variable operation. Furthermore, the range of night time noise levels will often be smaller and the levels significantly reduced compared to daytime levels.

The equivalent continuous A-weighted sound pressure level, LAeq dB (or Leq dBA), is the single number that represents the average sound energy measured over that period. The LAeq is the sound level of a notionally steady sound having the same energy as a fluctuating sound over a specified measurement period.

Human subjects are generally only capable of noticing changes in steady levels of no less than 3 dB(A). It is generally accepted that a change of 10 dB(A) in an overall, steady noise level is perceived to the human ear as a doubling (or halving) of the noise level. (These findings do not necessarily apply to transient or non-steady noise sources such as changes in noise due to changes in road traffic flow, or intermittent noise sources).

A parameter that is widely accepted as reflecting human perception of the ambient noise is the background noise level, L_{A90}. This is the noise level exceeded for 90% of the measurement period and generally reflects the noise level in the lulls between individual noise events. Over a 1-hour period the L_{A90} will be the noise level exceeded for 54 minutes.

The $L_{Amax,slow}$ and $L_{Amax,fast}$ measurement parameters are the maximum instantaneous sound pressure level attained during the measurement period (30 seconds, 5 minutes etc.), measured on the ‘slow’ or ‘fast’ response setting of the sound level meter. This is sometimes expressed as L_{Amax} dB or L_{max}

dB(A). Even though sounds appear fairly steady to the human ear they are seldom if ever steady in level. To accommodate this factor, sound level meters (SLMs) are generally provided with at least two meter responses or exponential averaging circuits. Fast meter response has a time constant of 1/8th of a second (125ms) and approximates the integration time of human hearing. The slow time response (time constant = 1 second) is intended to obtain an approximate average value of rapidly fluctuating levels from simple meter readings.

17.2 Noise Model Input Data

Appendix 17.2 – Noise Model Input Information

Assumed Construction Activities

List of Assumed Construction Activities and Construction Plant

Construction Activity	Plant	Sound Power Level L_w dB(A)	No. of plant	Overall L_w dB(A)	On-time (%hrs per 1hr)	Reference
PERIOD 1						
Formation of temporary compound	Road roller	108	1	108	83	BS5228 Table C.5 no 19
	Excavator (tracked)	110	1	110	83	BS5228 Table D.3 ave no.s 34-40
	Dumper	101	1	101	83	BS5228 Table C.5 ave no.s 81-92
PERIOD 2						
Diesel generator at temporary compound	Diesel Generator 150KVA	93	1	93	100	BS5228 Table C.6 no 39
Berthing structure demolition works	Breaker mounted on excavator	118	1	118	75	BS5228 Table C.1 no 9
	Loading lorry	107	1	107	50	BS5228 Table C.2 ave no.s 26-28
	Lorry	105	3	110	50	BS5228 Table D.7 ave no.s 121-122
Circular cell piling	Vibratory piling rig for steel sheet piling	116	2	119	50	BS5228 Table C.3 no 8
Berthing structure construction works	Concrete pump + cement mixer truck (discharging)	95	1	95	50	BS5228 Table C.4 no 24
	Telescopic handler	98	1	98	100	BS5228 Table C.4 no 55
	Mobile telescopic crane	95	1	95	100	BS5228 Table C.4 no 46
	Hand-held circular bench saw	107	1	107	50	BS5228 Table C.4 no 72
	Diesel Generator	89	1	89	100	BS5228 Table C.4 no 76
	Water pump (diesel)	96	1	96	100	BS5228 Table C.4 no 88
Formation of marshalling area	40T excavator	107	2	110	83	BS5228 Table C.2 no 14
	40T Load Dumpers	104	4	110	83	BS5228 Table C.4 no 4
	Backhoe Loader 30T	95	2	98	83	BS5228 Table C.4 no 14
	Road roller	108	1	108	83	BS5228 Table C.5 no 19
Dredging and disposal	Cutter suction dredger (CSD)	103	1	103	100	GW-TM* no CNP 070
	Hopper barge	104	2	107	50	GW-TM* no CNP 061
PERIOD 3						
Diesel generator at temporary compound	Diesel Generator 150KVA	93	1	93	100	BS5228 Table C.6 no 39
Dredging and disposal	Cutter suction dredger (CSD)	103	1	103	100	GW-TM* no CNP 070

	Hopper barge	104	2	107	50	GW-TM* no CNP 061
Approachway steel tubular piling	Vibratory piling rig for steel sheet piling	116	2	119	50	BS5228 Table C.3 no 8
Approachway deck construction	Concrete pump + cement mixer truck (discharging)	95	1	95	50	BS5228 Table C.4 no 24
	Telescopic handler	98	1	98	100	BS5228 Table C.4 no 55
	Mobile telescopic crane	95	1	95	100	BS5228 Table C.4 no 46
	Hand-held circular bench saw	107	1	107	50	BS5228 Table C.4 no 72
	Diesel Generator	89	1	89	100	BS5228 Table C.4 no 76
	Water pump (diesel)	96	1	96	100	BS5228 Table C.4 no 88
Removing the steel superstructure	Tracked excavator	111	1	111	75	BS5228 Table C.1 ave no.s 16-17
	Gas cutter	107	1	107	50	BS5228 Table C.4 no 18
	Tracked crane	100	1	100	30	BS5228 Table C.4 ave no.s 50-52
	Loading lorry	107	1	107	30	BS5228 Table C.2 ave no.s 26-28
	Lorry	105	2	108	50	BS5228 Table C.2 ave no.s 121-122
Cutting existing piles	Welding / cutting steel piles	101	1	101	100	BS5228 Table C.3 no 31
Lifting heavy cons. material	Craneage for piling	98	1	98	100	BS5228 Table C.3 no 30
Driving linkspan piles	Vibratory piling rig for steel sheet piling	116	2	119	50	BS5228 Table C.3 no 8
Construction of ticket office, fishermans compound and new dry berth	Concrete pump + cement mixer truck (discharging)	95	1	95	50	BS5228 Table C.4 no 24
	Telescopic handler	98	1	98	100	BS5228 Table C.4 no 55
	Mobile telescopic crane	95	1	95	100	BS5228 Table C.4 no 46
	Hand-held circular bench saw	107	1	107	50	BS5228 Table C.4 no 72
	Diesel Generator	89	1	89	100	BS5228 Table C.4 no 76
	Water pump (diesel)	96	1	96	100	BS5228 Table C.4 no 88
PERIOD 4						
Diesel generator at temporary compound	Diesel Generator 150KVA	93	1	93	100	BS5228 Table C.6 no 39
Dredging and disposal	Cutter suction dredger (CSD)	103	1	103	100	GW-TM* no CNP 070
	Hopper barge	104	2	107	50	GW-TM* no CNP 061
Demolition of existing ticket office	Breaker mounted on excavator	118	1	118	75	BS5228 Table C.1 no 9
	Loading lorry	107	1	107	50	BS5228 Table C.2 ave no.s 26-28
	Lorry	105	3	110	50	BS5228 Table D.7 ave no.s 121-122

PERIO 5 (MAINTENANCE)

Maintenance dredging	Grab hopper dredging ship	110	1	110	100	BS5228 Table C.7 no 2

* The Government of the Hong Knog, Environmental Protection Department (1996). 'Technical Memorandum on Noise From Construction Work Other Than Percussive Piling'.

18. Commercial and Recreational Fisheries

No Appendices

19. Commercial Fisheries

No Appendices

20. Marine Archaeology and Cultural Heritage

No Appendices

21. Summary of Mitigation

No Appendices

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