Adaptive Environmental Management Plan

Revision 4

25 November 2014

Contents

Adaptive Environmental Monitoring Plan – Revision 4

1 Adaptive Environmental Management Plan

1.1 Introduction

1.1.0.1 Tidal Lagoon Swansea Bay Plc (TLSB) is proposing the development of a tidal lagoon (the Project) in Swansea Bay, South Wales for the purpose of generating electricity. This Adaptive Environmental Management Plan (AEMP) Revision 4[1] represents the fourth revision of the AEMP that was produced as Appendix 23.1 of the Environmental Statement (ES), to accompany TLSB's application for a Development Consent Order (DCO) for the Project. The AEMP provides a framework for the monitoring and mitigation of effects of the Project. It is based upon:

i. the baseline surveys and monitoring already completed and reported upon in the ES (TLSB, 2014) and those following its completion; and

ii. the surveys and monitoring planned as the Project progresses through the pre-construction, construction and operational phases in respect of potential effects identified during the Environmental Impact Assessment (EIA) process, the Habitats Regulation Assessment (HRA) and the Water Framework Directive (WFD) compliance assessment.

1.1.0.2 It should be noted that this AEMP will be updated as the Project progresses as a result of discussions between TLSB and other parties, particularly in light of the data emerging from the monitoring undertaken. This is seen as an essential part of the process to validate the findings of the extensive studies that have been undertaken to determine the potential effects of this novel renewable energy development. This accords with Policy set out on page 18 of the EC Guidance Note 'The implementation of the Birds and Habitats Directives in estuaries and coastal zones with particular attention to port development and dredging' (2011) that:

"Where uncertainties or lack of knowledge on physical, morphological or biological processes still exist, these should be minimized as far as possible by additional research; where uncertainty remains adaptive monitoring programmes should be foreseen. New evidence and scientific information should be fed back into the management plan and where necessary lead to an appropriate adaptation of the management measures and monitoring schemes."

1.1.0.3 A distinction should be made between surveys (which are used to gather information) and monitoring (which is undertaken in order to validate an assumption or review an effect against a target). Due to the long lifespan of the Project (up to 120 years or more), monitoring or surveys that are required during the decommissioning and post-decommissioning phases will be developed prior to the commencement of that process. This is secured by provisions in the DCO.

1.1.0.4 Any monitoring or surveys that are programmed to take place pre-construction or during construction and that will not be continued during the operation phase are covered within the Construction Environmental Management Plan (CEMP). The exception to this is the marine mammal monitoring during piling activity, because information from this

[1] The third revision of the AEMP was issued on 28 October 2014 with changes shown in green font. Principal changes to text between the third and fourth revisions are shown in Blue font. In this document, references to the "AEMP" are to this revision, unless the context requires otherwise.

will inform future monitoring strategies. Therefore, excluding the above, a number of surveys and monitoring are not covered within the AEMP, e.g. unexploded ordnance, marine and terrestrial archaeology, land quality and hydrogeology (onshore site investigations). Note, with respect to marine archaeology, data from the bathymetric surveys immediately post-construction will be reviewed. This and other monitoring during the construction phase will be detailed in the Written Scheme of Investigation.

1.1.0.5 The AEMP will guide the monitoring of the effects of the Project at each stage of its progress. In the same way that results of the baseline surveys and monitoring carried out for the Environmental Impact Assessment (EIA) process have informed this document, so the results of pre-construction and construction-phase monitoring will provide up-to-date baseline data for operational-phase monitoring. During the lifespan of the Project, the AEMP will be updated, and it is for this reason that this is an adaptive plan (as noted previously). The document will continue to be updated and refined to give the best possible understanding of the Project's environmental effects enabling mitigation to be adjusted, where necessary.

1.2 Structure of the AEMP

1.2.0.1 The AEMP outlines the mechanism by which the monitoring will be implemented and a framework for dissemination of the findings of the studies is provided. It then describes the monitoring and surveys required for particular environmental topics following the ES chapter structure as follows:

i. Coastal processes
ii. Water quality
iii. Subtidal and intertidal benthic ecology
iv. Fish
v. Marine mammals
vi. Coastal birds
vii. Terrestrial ecology
viii. Marine noise

1.2.0.2 For each of these environmental topic areas, an overview of the baseline surveys and monitoring undertaken as part of the EIA process is presented (additional information can be found in the relevant ES chapter). Subsequently, outline methodologies for any surveys or monitoring required during the pre-construction, construction or operation phases are given. Where surveys are continuing from the baseline, the same methodologies will be followed such that there is consistency with the baseline data set. Where new surveys are proposed, the methodology will be discussed and agreed with the relevant regulatory bodies and statutory organisations prior to commencement of the construction of the Project.

1.2.0.3 As with any project, in order for monitoring to be effective the use of longer term data sets which can demonstrate natural trends is advantageous. Within the Swansea Bay area there are existing monitoring programmes that are already in place and replicating these would not necessarily provide additional benefit, whereas complementing them could provide additional synergies. As such, it is proposed that the AEMP builds on existing monitoring programmes, where appropriate, and reviews the relevant routine monitoring data sets which informed the various baseline assessments within the ES.

1.2.0.4 Areas where this would be relevant include the Swansea and Carmarthen Bay Coastal Engineering Group (SCBCEG) annual beach profile data; existing monitoring regimes which are in place to monitor siltation in the approach channels to the various ports, and routine monitoring of fish returns within rivers. These are discussed where relevant under the various subject area chapters in this AEMP.

1.2.0.5 This AEMP presents updated survey and monitoring proposals from the draft version submitted as Appendix 23.1 to the ES. The second revision of the AEMP was submitted to the Examining Authority in respect of the application for development consent on 7 October 2014, with the third revision submitted on 28 October 2014. This fourth revision has been submitted to the Examining Authority on the 25 November 2014. Subsequent to this submission, it is envisaged that further updates will be made as the Project progresses and revised documents will be submitted to the statutory authorities for approval from time to time. The Project will be required to be carried out, operated, and monitored, in accordance with the AEMP in force for the time being.

1.3 Guidance for monitoring and validation of findings of EIA and WFD processes

1.3.0.1 Guidance in respect of monitoring for construction and operation of offshore renewable energy projects is contained in the following document:

Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects. Cefas contract report: ME5403 – Module 15. May 2012.

1.3.0.2 These guidelines state the following: "*Monitoring is used for a variety of purposes. Developers invest a lot of effort to produce Environmental Statements, the conclusions of which are often based on predictions derived from numerical models, extrapolation from site-specific and historic survey data and extrapolation from other analogous activities. However, there is a paucity of published peer-reviewed articles on the environmental impacts of offshore renewable energy devices (Gill, 2005) and only limited time series data to monitor impacts (ME1117, (2010)). Monitoring conditions attached to consents and licences can therefore be used to validate predictions made in Environmental Statements. An extension of this testing of predictions is to identify unexpected outcomes or impacts and, where appropriate, trigger the development of corrective actions. Given the limited base information, monitoring can also be used to deal with uncertainties within Environmental Statements by testing hypotheses on the nature, extent and duration of potential novel impacts*."

1.3.0.3 As such, the findings of the ES have been used to develop this document.

1.3.0.4 In addition to validating the predictions of the ES, the AEMP will be used to confirm the findings of the WFD compliance assessment. The surveys and monitoring proposed consider the quality elements relevant for the WFD waterbody potentially affected by the Project. The outcome of the monitoring and surveys can be used, together with monitoring data carried out by Natural Resources Wales (NRW), under the WFD, to assess the status of the WFD waterbodies. In addition to this, the AEMP allows for the identification of effects that are outside those predicted in the ES with implementation of suitable mitigation where appropriate through the Summary Information Action Sheets (see Section 3.5.2).

1.3.0.5 The AEMP presents short, medium and long term monitoring proposals. It identifies that the findings of the monitoring will be reviewed and discussed with statutory authorities

and any changes to mitigation or ongoing monitoring will be approved by these bodies. This will ensure that the most appropriate mitigation measures are implemented to minimise any effects resulting from the Project.

1.3.0.6 This proposed review of the findings and amendment of mitigation is in keeping with the EC guidance (2011) which identifies (page 29) that "*Monitoring schemes should be designed in a way that they signal any unexpected developments at a stage where effective corrective measures can still be taken*".

1.4 Collaborations

1.4.0.1 In order to inform the AEMP, such that the monitoring identified within the ES can be developed for the construction and operational phase of the Project, TLSB is working in conjunction with the SEACAMS (Sustainable Expansion of the Applied Coastal and Marine Sectors in Wales) project at Swansea University, as well as Trinity St David's University School of Built and Natural Environment. TLSB is also looking to work with other departments of Swansea University, where opportunities present themselves.

1.4.0.2 TLSB has also developed further collaborations linked to delivery of some of the Project enhancement measures. Plans are underway to develop aquaculture facilities within the proposed Swansea Bay Tidal Lagoon Scheme. Tidal Lagoon Swansea Bay (TLSB) is currently working with Alex Keay from the Shellfish Company, Professor Kam Tang and Dr Ruth Callaway from Swansea University's SEACAMS project, Alex Mulholz from Jellagen Ltd, Ashley Jones from Selwyn's Seafood Ltd and Gary Hunt from Cenin Cement to develop a range of facilities that will support the introduction of native oysters, lobsters and edible seaweed to the proposed lagoon area. Plans are also underway to develop and trial "bioblocks" that will enrich biodiversity within the lagoon, whilst making use of waste products from local manufacturing processes. Each of these is described further below.

Native Oyster Scheme

1.4.0.3 There are two main species of oysters grown in the coastal waters of the UK. The native or European flat oyster (*Ostrea edulis*) and the Pacific oyster (*Crassostrea gigas*). The native oyster was once an abundant and geographically widespread fishery. However, it is now severely depleted. It is thought that over-exploitation, disease and pollution have all impacted on native oyster numbers to such an extent that the 100 tonne annual harvest in the UK represents as little as 1% of the oyster fishery production in the 18th and 19th centuries. Swansea Bay was an important part of that fishery, employing many hundreds of people in the area.

1.4.0.4 The importance of the native oyster is recognised in the UK by its inclusion as a UK Biodiversity Action Plan (BAP) Priority Species. The conservation importance of this species is also reflected in its inclusion on the OSPAR list of Threatened and/or Declining Species and Habitats (2003) in the North Sea, the Celtic Sea and the English Channel. The BAP aims to maintain and expand, where possible, its distribution in UK waters.

1.4.0.5 As a result of disease concerns associated with Pacific oyster production on the continent and of a greater consumer interest in environmental sustainability of native species, there is an increasing desire to try and re-establish native oyster fisheries in the UK.

1.4.0.6 TLSB would like to re-introduce native oysters by working with SEACAMS to develop an oyster hatchery and spatting ponds. The oyster hatchery would hold and condition

broodstock that would be induced to spawn in a controlled environment providing optimal conditions for high levels of maturation, fertilisation, growth and survival. The developing larvae would be reared in high densities in the hatchery facilities and fed on a variety of microalgal species cultivated on site. Spatting ponds within the lagoon would be used to complement the hatchery.

Lobster Hive Scheme (Partner: Jellagen Ltd)

1.4.0.7 TLSB is working with Jellagen Ltd to explore the use of lobster hives within the proposed area of impoundment. Lobster hives provide suitable habitats to support commercial scale lobster mariculture. Jellagen has successfully trialled the hives in West Wales and is seeking to expand its operation in the Swansea area.

Seaweed Scheme (Partner: Selwyn's Seafood Ltd)

1.4.0.8 TLSB is working with Selwyn's Seafood Ltd to explore the use of the lagoon area to grow edible seaweed. Selwyn's is a well-established local business that has recently invested in new machinery that supports the production and packaging of dried seaweed food products. The development of a joint programme between the two organisations will support local industry and secure sustainable jobs in the Swansea area.

Bioblock Scheme (Partners: SEACAMS and Cenin Cement)

1.4.0.9 TLSB is working with the SEACAMS project at Swansea University on a number of MSc projects, including translocation of *Saballeria alveolata* reefs and a Mumbles Head Recipe Book (species recording). In addition, TLSB is working with SEACAMS and a local business, Cenin Cement Ltd, to develop bioblocks that could be used to attract a broad range of marine species to the lagoon structure. These make use of waste material from Tata Steel, and are cement structures, approximately a metre in diameter, that are moulded into blocks and incorporate a variety of pits and crevices. Such bioblocks have been trialled by SEACAMS staff from Bangor University[2], and were shown to attract a broad range of marine wildlife within a relatively short period of time. Funding proposals are currently being developed with SEACAMS and Cenin Cement for the Horizon 2020 EU Funding Programme under the 'Innovation in small and medium-sized enterprises' theme[3].

[2] http://www.seacams.ac.uk/case-study/9/

[3] European Commission Decision C (2013)8631 of 10 December 2013

2 The Project

2.1 Introduction

2.1.0.1 This section of the AEMP describes the Project to provide context for the monitoring proposals that are described below. The Project is described more fully in the ES and is constrained by the DCO, which imposes limitations upon it as well as requirements that operate in the same way as planning conditions. Subsequent revisions to the AEMP will be prepared under the provisions of the DCO.

2.1.0.2 TLSB is proposing to construct and operate a tidal energy lagoon, located in Swansea Bay, South Wales (Figure 2.1). The tidal lagoon will generate renewable energy in the form of electricity using the large tidal range (the difference between high and low water) which is a distinguishing feature of the Bay. The lagoon will have an installed capacity of 320MW and a rated capacity of 240 Megawatts (MW), generating 495GWh net annual output. This is enough electricity for approximately 155,000 homes: more than Swansea's annual domestic electricity use (109k households); c.90% of Swansea Bay's annual domestic electricity use (Swansea, Neath & Port Talbot, 173k households); or c.11% of Wales' annual domestic electricity use (based on 1,381k households).

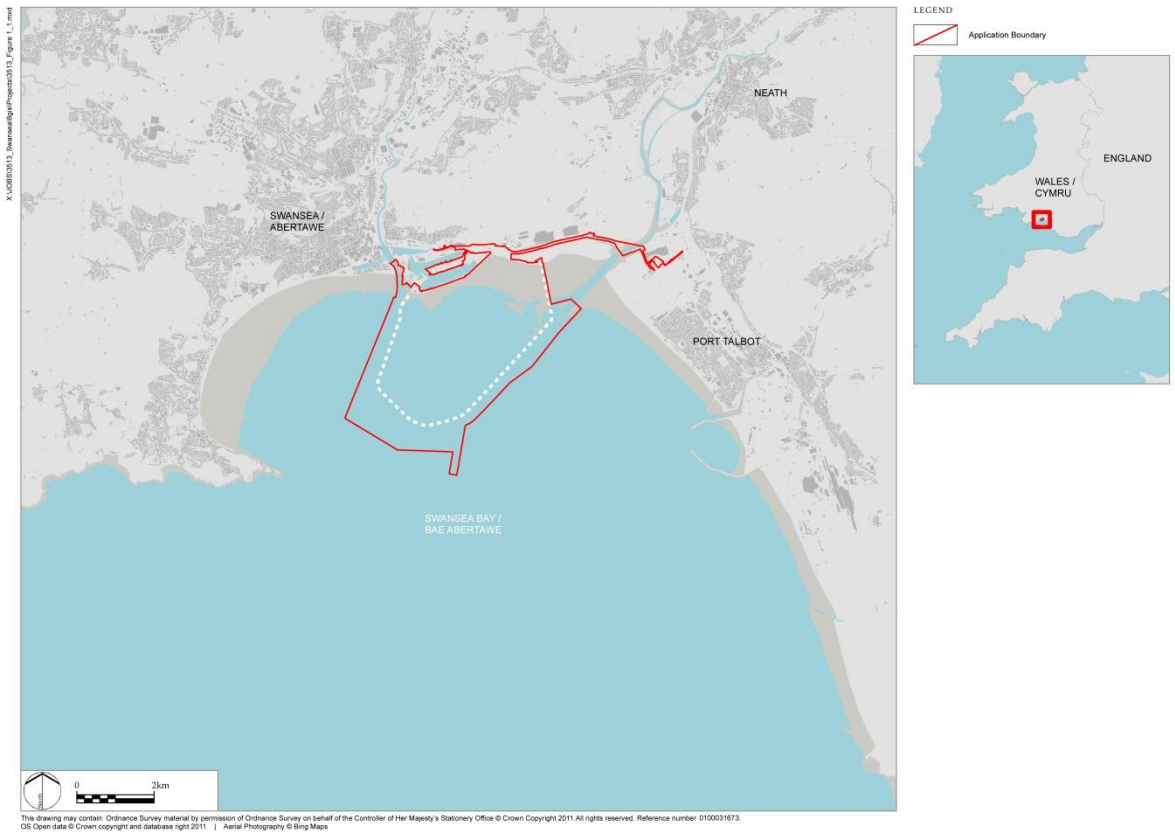


Figure 2.1 Location of the Project

2.1.0.3 In addition to generating electricity, the Project also aims to provide visitor facilities and other amenities including art, education, mariculture and sporting/recreational facilities. The seawall is expected to be open to the public during daylight hours for walking, running, cycling etc, though access will be controlled in extreme weather.

2.2 Consenting Process

2.2.0.1 As the Project is an offshore electricity generating station of more than 100MW, it is a Nationally Significant Infrastructure Project (NSIP) under the Planning Act 2008 (PA 2008). Construction of such a project requires that a DCO is first granted by the Secretary of State for Energy and Climate under the PA 2008.

2.2.0.2 The DCO for the Project will embrace a number of separate consents formerly required for a project of this type. Section 33 of the PA 2008 dispenses with the need for separate planning permission or deemed planning permission under the Town and Country Planning Act 1990 (TCPA 1990) and consents under Section 36 of the Electricity Act 1989. Any permissions required under TCPA 1990 will be sought after the grant of DCO, as these elements will not be integral to the construction or operation of the elements of the Project as defined by the DCO.

2.2.0.3 The DCO will authorise construction and operation of the generating station itself, and its component parts. These include both offshore and onshore elements of the Project, including the integral electrical grid connection works.

2.2.0.4 As the Project lies within Welsh waters, an application for a Marine Licence will be made to the Marine Licensing Team within Natural Resources Wales (NRW). The process for granting a Marine Licence (ML) is regulated by the Marine and Coastal Access Act 2009 which gives the appropriate licensing authority (NRW in this case) powers to grant or not grant a marine licence to an applicant who wishes to carry out licensable activities in territorial waters.

2.2.0.5 An application for a Marine Licence has been submitted concurrently with the application for the DCO. The requirement for a ML is broadly defined by works taking place in the offshore environment that affect the seabed or the movement of materials related to it. In this sense, elements of the offshore Project that are subject to the DCO application are also subject to a separate ML application.

2.3 Overview of the Project

2.3.0.1 The Project is situated in Swansea Bay, near to the Port of Swansea, approximately 2.2 km southeast of Swansea City Centre. The Project contains elements within the administrative areas of the City and County of Swansea Council (CCSC) and Neath Port Talbot County Borough Council (NPTCBC). The main onshore development lies within the Port of Swansea, immediately south of Fabian Way (A483) which is the main road from Junction 42 of the M4 into Swansea.

2.3.0.2 Figure 2.2 provides an indication of the Project and the wider extent to the mouth of the River Neath related to the national grid connection at Baglan.

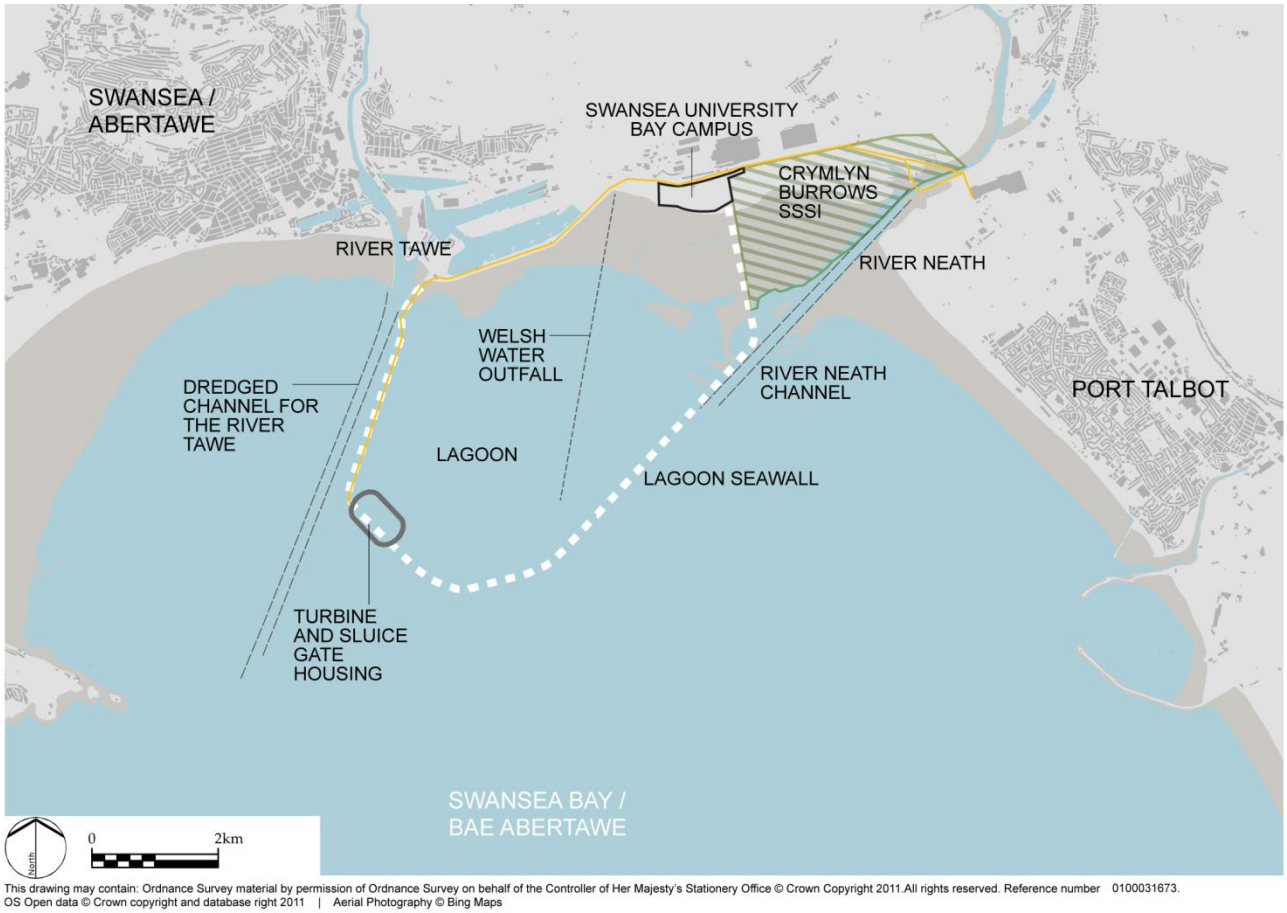


Figure 2.2: The Project

2.3.0.3 The lagoon will enclose part of Swansea Bay, from the eastern side of the River Tawe (western landfall) to the eastern edge of the new Swansea University Bay Campus (SUBC) (eastern landfall). The new seawalls that impound the lagoon will extend approximately 1.5km directly offshore from the campus, adjacent to Crymlyn Burrows SSSI. The seawalls will then extend in a southwest direction along the western boundary of the training wall of the River Neath Channel. The turbine and sluice gate housing will be located in the south west of the lagoon, at an angle to the dredged channel of the river Tawe. The seawall will then extend north towards Swansea Port, close to the mouth of the River Tawe parallel but offset by 100m to the dredged channel for the River Tawe. In total, this will form an approximately 9.5km-long, U-shaped, seawall which will encompass approximately 11.5km^2 of the seabed, foreshore and intertidal area of Swansea Bay.

2.3.0.4 The seawall will have a sediment core either held in place by a casing of sediment-filled geotextile tubes, known as Geotubes® or by a conventional sea wall construction method. The outside of the structure will be covered in rock armour of various sizes, depending on its level of exposure (Figure 2.3). The sand used to form the seawalls will be taken from within the Lagoon footprint. Rock armour will then be brought in by sea to provide protection. The top of the seawall will have an access road which will be used for operation and maintenance of the lagoon as well as for visitors.

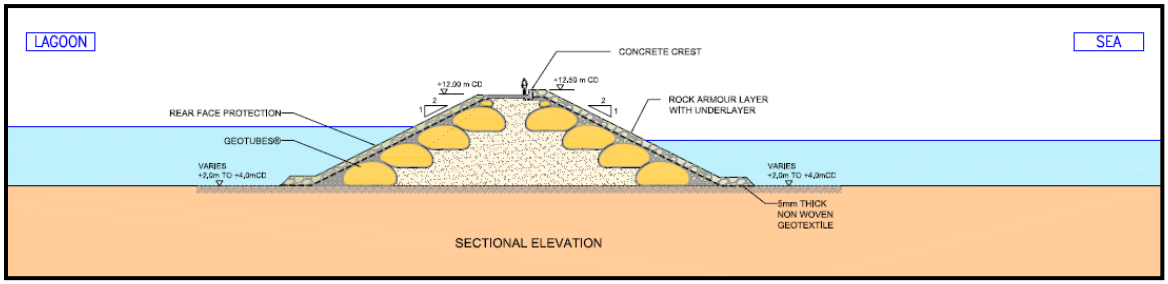


Figure 2.3: Example cross-section through lagoon seawall

2.3.0.5 An alternative design of the seawall may be used which does not incorporate Geotubes® and uses a more conventional construction for a seawall structure An illustration of this is shown below in Figure 2.4. The seawall would still have a sediment core which would be held in position by large piles of gravel dredged from within the lagoon or quarry run material. The quarry run material would be material remaining after the blasting for the larger grade rock used for rock armour. The footprint and angle of the slopes would remain largely unchanged from the design incorporating Geotubes®.

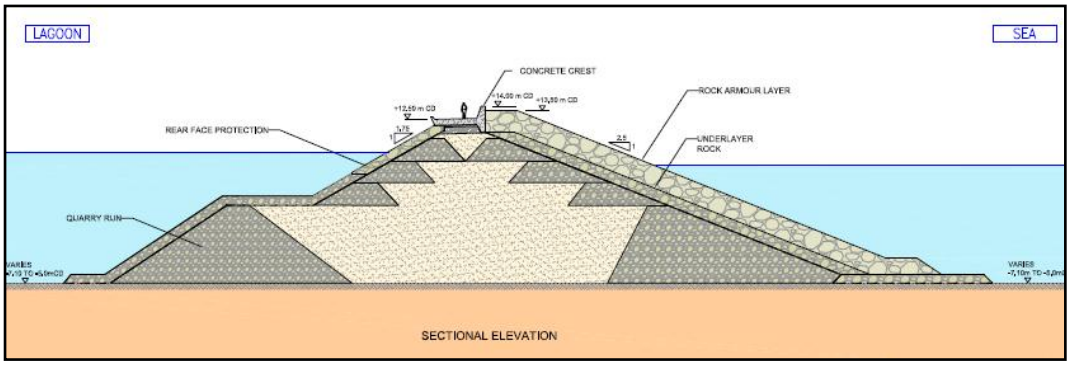


Figure 2.4 Section of the lagoon seawall using conventional construction

2.3.0.6 The 16 variable speed hydro (water) turbines, located within the turbine and sluice gate housing, will be bi-directional, i.e. able to generate power with flows of water in both directions (i.e. on both incoming and outgoing tides). The turbines, which will be up to 7m in diameter, will be permanently underwater (Figure 2.5). There will also be eight sluice gates – these are large gates which will be underwater and able to let seawater in and out of the lagoon without going through the turbines, as required.

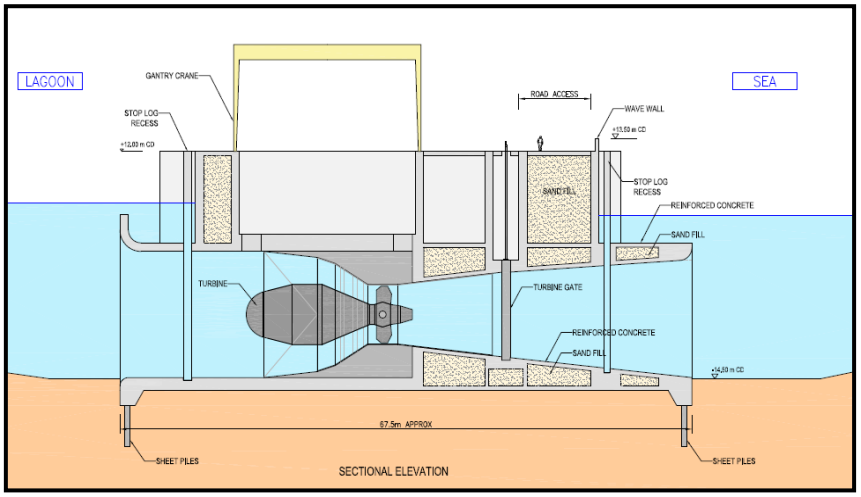


Figure 2.5: Cross-section of turbine housing structure

2.3.0.7 To generate electricity, as the sea starts to rise (flood tide) from low tide level, water is prevented from entering the lagoon for an average of 2.5 hours, and this creates a difference in water levels known as 'head'. Once sufficient head has been reached, the water is allowed to flow into the lagoon through the turbines, turning the runner (like a propeller) and generating electricity. This process is repeated on the ebb tide, where the water is prevented from leaving the lagoon until there is sufficient head to start the process again (Figure 2.6).

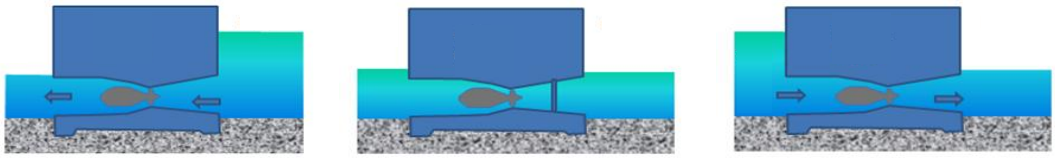


Figure 2.6: Illustration of water flow between the sea and the lagoon

2.3.0.8 Towards the end of the ebb or flood tide the sluice gates will be opened. This is to empty or fill the lagoon as quickly as possible before low or high tide level. By doing this, it ensures that the lagoon water level is as close to the outside sea level as possible, before the tide starts to rise or fall again. With variable speed turbines, pumping can be undertaken at the end of the operating sequence. This would maximise electricity generation whilst returning the intertidal area to that occurring naturally outside the lagoon. This generation sequence will happen on both the flood and ebb tides, four times a day in total. Figure 2.7 illustrates the generating cycle.

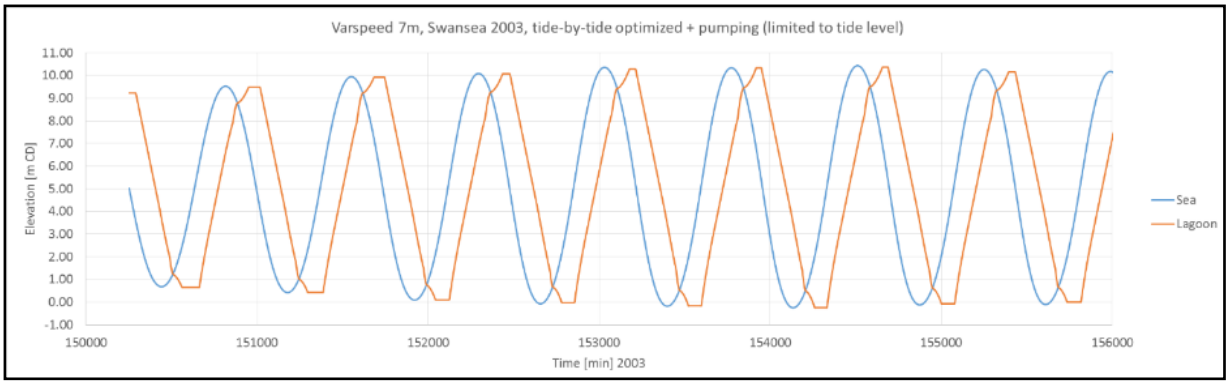


Figure 2.7: Indicative spring tide operating cycle for the lagoon

2.3.0.9 The electricity generated from the lagoon will be transported to the nearest National Grid substation at Baglan Bay by underground cables. The cable landfall is located at the Western Landfall and runs eastwards along the coastline before either running alongside the A483 Fabian Way and then beside the tarmac path through Crymlyn Burrows Site of Scientific Interest (SSSI). The route then turns southeast, crossing the River Neath either by directional drill, before continuing across Baglan Burrows to connect with a sub-station at Baglan Power Station.

2.3.0.10 In 120 years' time there are two potential options for decommissioning: namely to replace equipment, to upgrade and extend the life of the power generating station; or to remove the turbines and sluice gates so as to allow continued leisure use of the impounded lagoon area. It is proposed that from the fiftieth year of operation a sinking fund will be established. The fund would be derived from revenues generated by the

Project and would make provision for future maintenance of the retained structures of the Project following completion of operation.

2.4 Project updates

2.4.0.1 Since submission of the DCO application, a number of refinements to the Project identified within the ES have been confirmed and the monitoring proposed within this AEMP Revision 2 reflects the current situation. The variations particularly relevant to this AEMP Revision 2 compromise:

- Following discussions with Dwr Cymru Welsh Water (DCWW), it has been confirmed that the existing Swansea Bay WWTW long sea outfall will be extended by approximately 1.5km to discharge outside the lagoon.
- The temporary cofferdam required for the construction of the turbine and sluice gate housing structure comprised in the Project will be in the form of a sediment cofferdam with Geotubes® or quarry run, and rock armour. This means that the engineering alternative comprising a double sheet-piled wall will not be deployed.
- The micrositing of the turbine and sluice gate housing structure will be constrained considerably, to focus on "Location A" as shown in the ES and not Location B. The turbine and sluice gate housing structure will be positioned in the area of Location A (as presented in the ES) in the southwest of the lagoon seawall (as indicated in Figure 2.2).
- Variable speed turbines will be used, with pumping at the end of the tidal cycle (see Figure 2.7 above).
- The grid connection will be laid within the highway verge alongside Fabian Way and not along a parallel route through the Crymlyn Burrows SSSI, and it will be directionally drilled beneath the River Neath.

3 Plan Implementation and Dissemination of Findings

3.1 Introduction

3.1.0.1 This document is intended to be capable of being read on its own, even though it is supported by other documents. The AEMP also interacts with the Construction Environmental Management Plan (CEMP) and the Operational Environmental Management Plan (OEMP), as well as drawing on a number of assessment documents. All of the plans (AEMP, OEMP and CEMP) will be imposed upon the relevant phases of the Project, being secured by requirements under the DCO or conditions under the Marine Licence. The measures that are secured by these plans will be delivered via the construction contract or via the day-to-day running of the operational Lagoon, including generation. The requirement to produce final versions of these documents is secured by requirements attached to the DCO. With regard to the AEMP, as discussed above, where necessary individual proposals will be developed for survey methodologies and agreed as appropriate with the relevant statutory organisations.

3.2 Pre-construction Plan Implementation

3.2.0.1 A number of pre-construction studies are already taking place, such as quarterly fish baseline surveys, through the tide bird surveys, marine mammal monitoring and high resolution aerial survey with sediment and biotope mapping. Any other surveys required (as detailed in Sections 5 – 12) will be commissioned, undertaken and reported prior to construction commencing. As discussed in Section 1.2.0.2 is intended that the methodologies for these pre-construction surveys will either follow methods used in the ES, where sufficient detail has been given, will be as set out in the body of this AEMP r3 or will be contained in the final pre-construction version of the AEMP submitted in accordance with the requirements contained in the DCO. The results of the studies will be reported prior to construction and disseminated to statutory and non-statutory consultees as appropriate and used to progress the detailed design phase where appropriate.

3.3 Construction – Plan Implementation

3.3.0.1 An Environmental Liaison Officer (ELO) will be identified for the construction phase of the Project. The ELO will be responsible for working with statutory and non-statutory organisations and managing the environmental aspects of the construction phase of the Project. Further details of the roles and responsibilities of the ELO are detailed within the CEMP produced for the Project.

3.3.0.2 During the operational phase of the Project, Lagoon Wardens will be employed, whose responsibilities will include securing the delivery of elements of this AEMP. Other elements may be the responsibility of independent consultants or contractors. In any event, ultimate responsibility will lie with TLSB, which will be a statutory undertaker.

3.3.0.3 As discussed in Section 3.2.0.1, survey or monitoring methodologies will be agreed with statutory and non-statutory consultees as DCO requirements, marine licence conditions and the AEMP itself provide. The findings from the surveys and monitoring will be reported annually and the documents disseminated to relevant statutory bodies and other stakeholders. The results of the studies will be used to inform mitigation, construction methods or strategies as appropriate.

3.3.0.4 Note: Monitoring will be continuously reviewed, both in terms of the monitoring effort and techniques, and the data collected. If, during a monitoring period, significant change outside that predicted or anticipated is recorded, a Summary Information Action Sheet (SIAS) (see section 3.5.2) will be prepared for immediate circulation to NRW, CCSC and NPTCBC.

3.4 Operation – Plan Implementation

3.4.0.1 The operation phase monitoring will take place following completion of construction and commencement of operation. Prior to the commencement of operation of the lagoon trigger level will be established for each relevant Objective identified in the AEMP, so far as appropriate since trigger levels may not be capable of being established at that stage in each case. The establishment of trigger levels will be based on review of information from the ES, additional site specific data collected prior to operation and current understanding of the receptor, its natural variation and objectives for its ongoing presence. Where trigger levels can only be identified as a result of evolution of a dynamic resource, the trigger levels will be identified through the ATR review process under each of the Topic headings. The acceptance of trigger levels will be agreed at the AEMP Core Review Group. At this stage the potential mitigation measures identified in the AEMP will also be reviewed in terms of current practices and understanding.

3.4.0.2 The monitoring will be adapted over the lifetime of the Project in order that it can identify effects both short and long term. Initially, this AEMP covers a 15 year operational timescale, but the AEMP is capable of constant review and extension. Within and beyond this period, ongoing monitoring, trigger thresholds and mitigation will be reviewed, discussed and agreed through the reporting system (see Section 3.5) with statutory consultees and the AEMP updated accordingly. The findings of the surveys and monitoring will generally be reported annually to relevant statutory bodies and other stakeholders within three months of the anniversary of operation commencing in each case. In the same way as will take place during construction, if during a monitoring period significant change outside that predicted or anticipated is recorded, a SIAS will be prepared for immediate circulation.

3.4.0.3 The period over which monitoring will take place, and the intervals for survey or reporting, will be established prior to operation, and will be reviewed in each annual report along with the anticipated duration of monitoring, in the light of the results of the report. The relevant local planning authorities will be requested in each case (under the DCO) and NRW (under the ML) to approve the monitoring duration for the existing period.

3.4.0.4 As in the construction phase, methodologies will be agreed/reviewed with statutory organisations and the results reported annually and disseminated as appropriate. The findings will be used to inform mitigation and operation strategies as appropriate.

3.5 AEMP Review Process and Reporting

3.5.0.1 The flow chart below provides an illustration of the AEMP review process during construction and operation, with further explanation provided in the subsequent sections.

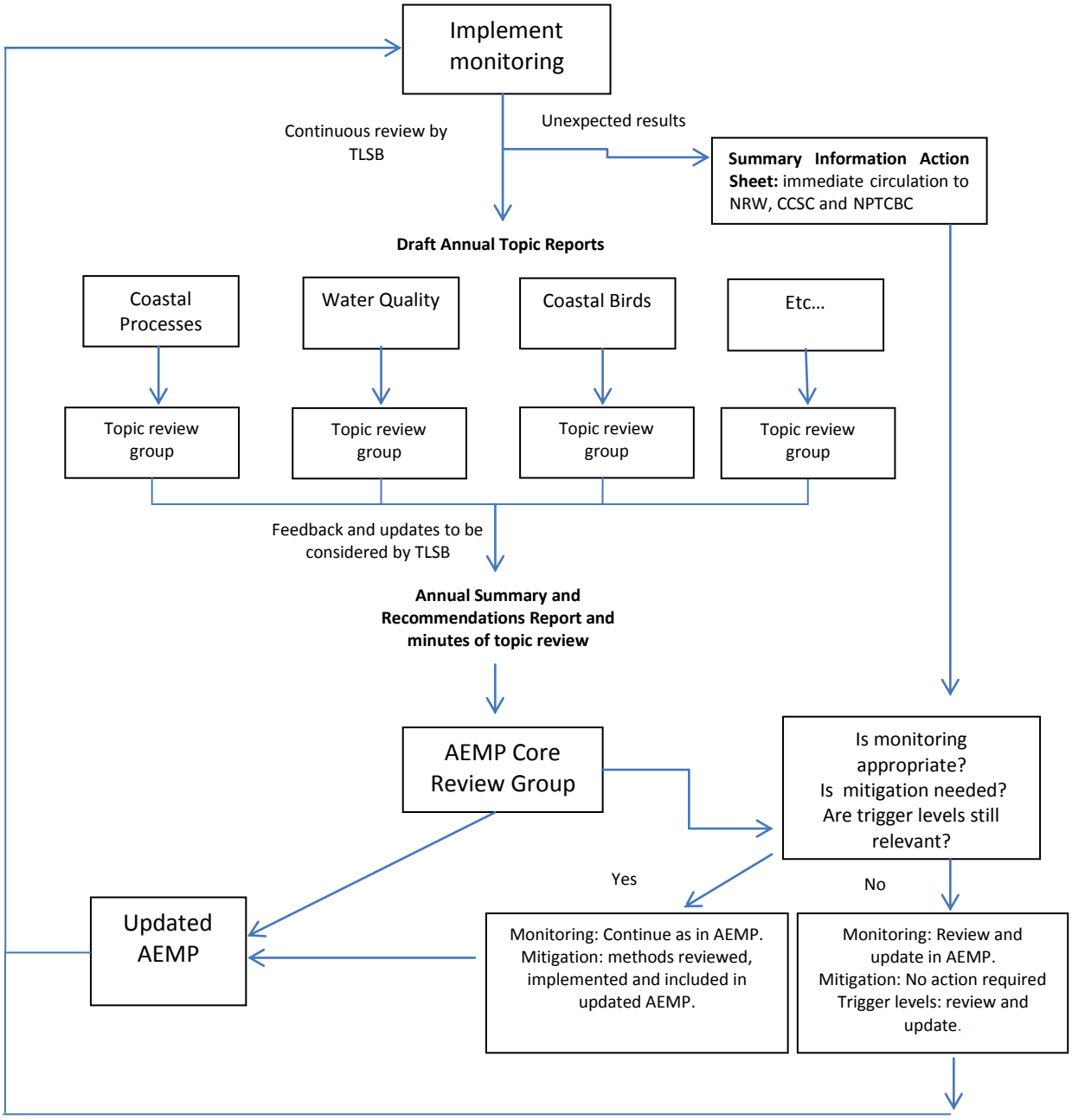


Figure 3.1 Flow diagram illustrating monitoring reporting process

3.5.1 Annual Topic Reports

3.5.1.1 Annual Topic Reports (ATR) will be prepared presenting the findings of the surveys and monitoring completed in that year. This will include the findings of the surveys and monitoring completed pre-construction. An ATR will be prepared for each environmental subject heading identified in this AEMP. Where specialist surveys have been undertaken by consultants or survey specialists, the main body of the ATR will provide an overview and discussion of the findings of the surveys, whilst the specialist report will be provided as an Appendix or as a supporting document.

3.5.1.2 As the Project progresses and during operation the main body of the ATRs will be updated and the data gathered evaluated against the previous years' data sets. The reports will examine the findings of the surveys and monitoring against the relevant trigger levels and also compliance with the WFD. Where necessary the ATR will make recommendations for modification to the monitoring proposals and mitigation that is being or might be implemented as a result of trigger levels being exceeded. The AEMP ATRs will be provided to NRW, CCSC and NPTCBC and other relevant stakeholders. Feedback on the ATRs and any suggested modification to the AEMP and its content, if appropriate, will be discussed at the relevant Topic Review Group meeting (see Section 3.6). This will include discussions on proposals for any mitigation required as a result of exceedances of trigger levels.

3.5.1.3 As identified in section 3.4.0.1 trigger level will be established based on review of information from the ES, additional site specific data collected prior to operation and current understanding of the receptor, its natural variation and objectives for its ongoing presence. The trigger level will be identified through the ATR review process under each of the Topic headings. The acceptance of trigger values will be agreed at the AEMP Core Review Group.

3.5.2 Summary Information Action Sheet

3.5.2.1 If, during a monitoring period, significant changes outside those predicted or anticipated are recorded including an exceedance of any established trigger level, a Summary Information Action Sheet (SIAS) will be prepared for immediate circulation to NRW, CCSC and NPTCBC. This is important because it means that if change is detected, action to consider and - if need be manage - such change need not await the ATR. The SIAS will outline the survey work undertaken and provide an overview assessment of the preliminary results against the specific targets. It will then identify mitigation measures or remedial measures to be implemented, where appropriate. For example, if change is apparent as a result of a naturally occurring phenomenon, such as a storm, then mitigation will not necessarily be recommended. Following circulation, in accordance with the requirements contained in the DCO, TLSB would request responses to the SIAS in order that any mitigation can be agreed and implemented within an appropriate timescale, which would be specified in the SIAS.

3.5.3 Annual Summary and Recommendations Report

3.5.3.1 The Annual Summary and Recommendations Report (ASRR) will be prepared and provided to an AEMP review group. It will summarise the findings from all topic areas and present recommendations made from the Topic Review Group, which would include, where necessary, modification to the monitoring proposals or mitigation.

3.6 Stakeholder Engagement Reporting

3.6.0 Introduction

3.6.0.1 TLSB considers that it is important to review monitoring findings regularly with the relevant statutory authorities as well as with relevant stakeholder groups. It is proposed that Topic Review Groups and an AEMP Review Group are established. The overall purpose of the group would be to ensure the AEMP remains fit for purpose, takes into account and shares the latest developments in knowledge, technology and best practice, and responds promptly to emerging issues. The AEMP will be a key tool used to inform mitigation and adaptation measures associated with the development and operation of the Project.

3.6.0.2 Involvement of stakeholders in reviewing the AEMP reinforces the European Commission on Maritime Spatial Planning and Integrated Coastal Management initiative proposed in March 2013[4]. It particularly supports the implementation of the Marine Strategy Framework Directive, the Water Framework Directive, the Natura and Habitats Directives and the Biodiversity Strategy.

3.6.0.3 It is notable that although the Cardiff Bay Environmental Monitoring Scheme[5] does make data publicly available, it does not provide opportunities for feedback or for any active engagement to resolve emerging issues. Multi-stakeholder review has been a key element of a number of successful coastal management initiatives in recent years, including the Association of Severn Estuary Relevant Authorities[6] and the Pembrokeshire Coastal Forum[7]. It is the opinion of TLSB that such initiatives provide effective opportunities for thorough review and adaptation to emerging issues.

3.6.1 AEMP Topic Review (ATR) Group

3.6.1.1 Topic review groups would be established for coastal processes, water quality, benthic ecology, fish, marine mammals, coastal birds and terrestrial ecology. The topic review groups would be set up during the pre-construction phase of the Project to examine the findings of ongoing data collection, consider the methodologies of surveys or monitoring in the light of these findings and to confirm trigger levels for relevant specialist topics prior to operation of the Project. The groups would meet at least once a year in advance of the main AEMP Core Review Group meeting. These groups would be formed of technical specialists relevant to each subject area. Each specialist group would be provided with the ATR, would be given advance access to raw data monitoring results and relevant specialist reports. A representative from TLSB (e.g. the Warden) would act as secretariat for the groups. TLSB would provide minutes of the meeting and incorporate any feedback appropriate into the ASRR in preparation for the AEMP Core Review Group.

3.6.1.2 The Topic Review Group could include technical specialists from the following organisations:

[4] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a framework for maritime spatial planning and integrated coastal management. COM(2013) 133 final.
[5] http://www.cardiffharbour.com/content.asp?nav=3,40&parent_directory_id=1
[6] http://www.severnestuary.net/asera/index.html
[7] http://www.pembrokeshirecoastalforum.org.uk/

1. Statutory agencies (Natural Resources Wales, City and County of Swansea Council and Neath Port Talbot County Borough Council);
2. Representatives from Non-Government Organisations as appropriate by invitation of TLSB (e.g. RSPB, local ecology groups, Swansea Environmental Forum); and
3. TLSB (the Warden to act as secretariat, to co-ordinate release of ATRs and to liaise between relevant individuals to ensure action points are followed up) and its appointed technical specialists.

3.6.2 AEMP Core Review Group

3.6.2.1 It is proposed that the AEMP Core Review Group is chaired by or on behalf of TLSB. Secretariat and report access support could be provided TLSB. A group of up to 12 representatives it proposed to meet on an annual basis to review the findings of the Topic Review Group and Annual Summary and Recommendations Report (ASRR) which would consider the multi-disciplinary issues that had emerged over the previous 12 months. The group would include statutory agencies (NRW, CCSC, NPTCBC).

3.6.2.2 The AEMP Core Review Group would be expected either to confirm its agreement with the ASRR report, make recommendations for adapting the AEMP in light of the ASRR and ATR, or make recommendations for implementing mitigation measures. TLSB would be asked to consider recommendations and include the findings of the AEMP Review Group. TLSB would then propose to the relevant planning authorities and NRW such measures in respect of the ASRR as it considered appropriate in light of the ASRR and the recommendations of the AEMP Review Group. TLSB would then implement any changes to the AEMP and such measures as were agreed or approved by the relevant planning authorities and NRW.

3.6.2.3 Where the AEMP Core Review Group and/or any members do not agree with the course of action proposed by TLSB in the light of the findings of the AEMP Review Group, any dispute would be settled by arbitration pursuant to the DCO. TLSB shall then seek to implement the settled outcome of the arbitration subject to securing any statutory approvals necessary, which TLSB will diligently pursue.

3.6.2.4 An overview of the reporting documents associated with the AEMP is provided in Table 3.1.

Table 3.1 Overview of documents and roles associated with the AEMP.

Document	Purpose
Summary information Action Sheet (SIAS)	If during a monitoring period, significant change outside that predicted or anticipated, including an exceedance of any trigger levels, are recorded, a SIAS will be prepared for immediate circulation to NRW, CCSC and NPTCBC. This will outline the survey work undertaken and provide an overview assessment of the preliminary results against any specific targets. It will then identify mitigation measures or remedial measures to be implemented, so far as appropriate.
Annual Topic Report (ATR)	Annual Topic Reports (ATR) will be prepared presenting the findings of the surveys and monitoring completed in that year. An ATR will be prepared for each environmental subject heading identified in this AEMP. Where specialist surveys have been undertaken by consultants

	or survey specialists, the main body of the ATR will provide an overview and discussion of the findings of the survey, whilst the specialist report will be provided as an Appendix or as a supporting document. The ATRs will be updated, if appropriate, based on feedback from Annual Topic Review meeting.
Annual Summary and Recommendations Report (ASRR)	The annual summary and recommendations report will summarise the findings from all topic areas. It will present the recommendations which have been put forward from the Topic Review Group, where necessary, which would include modification to the monitoring proposals or mitigation recommendations. This report will be considered by the AEMP review group.
Updated AEMP	The AEMP document will be updated in agreement with NRW, CCSC and NPTCBC.
Role	**Responsibility**
Environmental Liaison Office (ELO)	An Environmental Liaison Officer (ELO) will be appointed for the duration of the construction period. The post of the ELO is intended to provide a focus for environmental issues related to works carried out on behalf of TLSB as part of construction of the Project. Further details of the roles and responsibilities of the ELO are detailed within the CEMP produced for the Project. The ELO will also be responsible for assisting with the risk assessment implemented within the CEMP. This will encompass aspects such as the Biosecurity Risk Assessment for invasive species both terrestrial associated with the cable route and marine.
Lagoon Warden	The Lagoon Warden will be responsible for ensuring that surveys monitoring and mitigation is implemented as agreed during operation. The Lagoon Warden will ensure that all survey results are provided to the appropriate TLSB specialist consultant for review, and will continually report to the TLSB EIA team. Further details of the roles and responsibilities of the warden are detailed within the OEMP, which will be prepared for the Project and approved by the relevant local planning authorities. The Warden will also be responsible for assisting with the risk assessment implemented within the OEMP. This will encompass aspects such as the Biosecurity Risk Assessment proposed for marine invasive species.
TLSB specialist consultants	Specialist consultants will be used by TLSB to review the results of the monitoring and prepare the ATR's, discussing findings and make recommendations for future monitoring where necessary.
TLSB EIA team	The EIA team will overview and manage the AEMP and process of review.
AEMP topic review group	This will comprise technical specialist from statutory consultees; NRW, CCSC, NPTCBC and selected stakeholder groups, who will meet annually to discuss the ATR's. Feedback will be considered and will inform the Annual summary and recommendations report where appropriate.
AEMP review group	This will be a higher level group, with nominated representatives from NRW, CCSC and NPTCBC, who will discuss the findings as a whole, and agree where, if necessary, recommendations of changes to monitoring should be implemented. They will also decide, based on the findings if mitigation is needed.

4 Structure of Specialist Topic Sections

4.1 Introduction

4.1.0.1 As identified in Section 1, the AEMP has been divided into specialist topics considered within the ES as listed below:

i. Coastal processes
ii. Marine water quality
iii. Subtidal and intertidal benthic ecology
iv. Fish
v. Marine mammals
vi. Coastal birds
vii. Terrestrial ecology
viii. Marine noise

4.1.0.2 For each of these specialist topic areas, an overview of the baseline surveys and monitoring undertaken as part of the EIA process is presented (additional information can be found in the relevant ES chapter).

4.1.0.3 Subsequently, the objectives of any further monitoring or surveys are outlined. The objectives relate to potential effects on environmental receptors that have been identified, either within the ES or the WFD compliance process as discussed below. In addition, the AEMP will be used to validate the findings of the EIA and WFD compliance process, and will become a tool for research appropriate for the future development of other tidal lagoons. Objectives have been set to achieve these aims.

4.1.0.4 As outlined in Section 3.2.0.1, prior to undertaking the surveys and monitoring, methodologies will be discussed and agreed with NRW, CCSC and NPTCBC.

4.2 EIA Process

4.2.0.1 Within each environmental Chapter of the ES, which reports on the findings of the EIA process, significant effects are identified that remain after mitigation measures have been identified - i.e. the residual effects of the Project. The residual effects are considered and weighed by the Examining Authority and the Secretary of State as part of the decision-making process of the application for a DCO. Therefore, assessment of the significance of the residual effects after mitigation is a key outcome of the EIA process. For ease of reference, the significant effects which require mitigation (to reduce the residual effects) and monitoring, as identified in the ES, are given in Table 4.1 of this AEMP. The AEMP is implemented to help ensure that impacts are no greater than the residual effect predicted in the ES. In addition to this, areas where monitoring is proposed to validate the findings of the EIA process are also given. Within this AEMP, objectives have been identified within each specialist topic area based on these residual effects, in order to validate the findings of the EIA and the success of any mitigation measures.

4.3 WFD process

4.3.0.1 Similarly for the WFD process, objectives have been based on the findings of the WFD compliance assessment. The WFD creates a mechanism through which each signatory has to aim to bring its water resources to an accepted biological and chemical standard (good ecological/chemical status for natural waterbodies; and good ecological potential/good chemical status for artificial/heavily modified waterbodies) by 2015; this is based on a series of parameters (quality elements) dependent on the type of waterbody considered (i.e. rivers; lakes; transitional waters and coastal waters) and its hydromorphological designation (i.e. natural; artificial or heavily modified). In cases where good status/potential cannot be achieved by 2015 a provision is given under Article 4.4 of the WFD extending the deadline to 2021 or 2027. The date has been extended to 2027 in respect of a large number of waterbodies. The WFD (Articles 4.7 and 4.8) provides that, in the event of a project resulting in an adverse impact on a waterbody which could cause a deterioration in its WFD status, or could prevent actions (i.e. mitigation) which are required to raise the WFD status of the waterbody, then the project must be assessed and justified in the context of the actions proposed to mitigate the adverse impact on the status of the waterbody.

4.3.0.2 The revised WFD report produced for the Project (submitted 5 August 2014) confirms that in the case of Swansea Bay Coastal waterbody it has been identified that there is a potential risk of deterioration of the benthic invertebrate quality element and the biological quality element supporting hydromorphological conditions. The Project also has a potential effect on the mitigation measures proposed for the "heavily modified waterbody" and thus this may affect the potential of the waterbody to achieve 'good ecological potential' by 2027. The Swansea Bay Coastal waterbody therefore requires assessment under Article 4.7 of the WFD.

4.3.0.3 In the case of the Neath and Tawe Estuary waterbodies, since submission of the revised WFD report on the 5th August, it has been identified that based on guidance provided by NRW in September 2014, that the Project will not cause deterioration in the status of the Neath or Tawe waterbody, nor will it compromise the future achievement or maintenance of "Good" chemical or ecological status in terms of the dissolved inorganic nitrogen quality element.

4.3.0.4 For the WFD compliance process, any potential effects on quality elements that may cause a change in WFD status or achievement of future objectives, are presented in Table 4.1. Objectives have been based on the quality elements outlined above for the Swansea Bay Coastal waterbody. Prior to commencing any surveys or monitoring associated with WFD compliance, methodologies would be reviewed in line with any available UKTAG guidance as further discussed below. The final methodologies to be deployed would be approved under the final pre-construction iteration of the AEMP in accordance with the requirements contained in the DCO.

Validation of the findings of the EIA and WFD compliance process and tidal lagoon research

4.3.0.5 As noted above, the AEMP will also be used as a tool to validate the findings of the EIA (both adverse and beneficial) and WFD compliance assessment. In addition, the findings of the surveys and monitoring will be used to identify any effects of the Project that arise that were not foreseen as part of the EIA or WFD assessment process. If identified, and

where appropriate, monitoring or surveys will be further developed to further examine these effects and / or appropriate mitigation will be identified. The AEMP will also establish research opportunities that will inform the future development of tidal lagoon projects. An overview is provided in Table 4.1, with the detail incorporated into the following environmental topic sections.

4.3.0.6 Once objectives have been identified, details of proposed surveys and monitoring are provided for the relevant phases of the Project i.e. pre-construction, construction and operation.

4.3.0.7 A summary table is then produced for each objective. This identifies the relevant potential environmental effect that is being examined and, where appropriate, the WFD parameter. An overview of the surveys and monitoring is provided. The person or organisation responsible for organising and carrying out the surveys is then noted. A limit of change to an environmental receptor that is considered acceptable is then identified. Where this limit is exceeded, the summary table details what further action/mitigation is required. This could include additional mitigation or ongoing monitoring.

4.3.0.8 Further details of the surveys are then provided. Recent guidance (April and July 2014) has been produced by UKTAG in relation to surveys and assessment for the WFD. Prior to the commencement of surveys, the scope of works within this AEMP will be reviewed in relation to this and any more recent guidance. To date, UKTAG updates that will be considered include:

a. UKTAG (2013) Method statement for the classification of surface waterbodies v3 (2012 classification release): Monitoring Strategy
b. UKTAG (2014a) UKTAG Transitional and Coastal Water Assessment Method: Macroalgae: Opportunistic Macroalgal Blooming Tool.
c. UKTAG (2014b) UKTAG Transitional and Coastal Water Assessment Method: Benthic Invertebrate Fauna: Infaunal Quality Index
d. UKTAG (2014c) UKTAG Coastal Water Assessment Method, Phytoplankton Coastal Water Phytoplankton Tool
e. UKTAG (2014d) UKTAG Coastal Water Assessment Method Macroalgae, Intertidal Rocky Shore Macroalgal Index
f. UKTAG (2014e) UKTAG Transitional and Coastal Water Assessment Method, Angiosperms, Saltmarsh Tool

4.3.0.9 As discussed previously, where different from the baseline, the final survey methodologies proposed within this and any subsequent revisions to the AEMP will require approval prior to the relevant phase of the Project.

4.3.0.10 A summary of the individual objectives and the supporting survey is provided in table 13.1. A summary of the surveys and their frequency of occurrence up to 2028 is provided in table 13.2.

4.3.0.11 Monitoring, especially marine monitoring, can in some cases (e.g. fish) yield varied results due to natural seasonal and annual fluctuations. As such, a balance has to be struck on a number of levels;

a. between the specific effects of the Project versus what would be “nice to know” about the wider area;

b. what data should be collected to validate an impact, versus what would be interesting to know about the species in terms of numbers or behaviour; and

c. what existing monitoring programmes are already in place so that these are not replicated but complemented.

4.3.0.12 As such, the monitoring proposed in this AEMP has been considered in proportion to the impacts identified through the EIA process but are also sufficient for validating the findings of the ES.

Table 4.1 Potential effects requiring mitigation and monitoring following the EIA and WFD compliance processes within the AEMP

Environmental topic	ES Residual Effect	WFD
Coastal processes	***Flows*** - **Minor adverse** / **neutral** across the intertidal in the vicinity of both the Blackpill and Crymlyn Burrows SSSIs. **Minor adverse** within the Lagoon itself, and **neutral** within the 'jetting' flows from the turbines/ sluice gates within the subtidal outside of the Lagoon. ***Waves*** - Largely **neutral** within the subtidal region of Swansea Bay. **Minor adverse** in localised areas where wave reflection (from the seawalls) increase wave heights. ***Sediment*** - Predominantly **neutral** within the western region (subtidal and intertidal) of Swansea Bay, with localised **moderate/ minor adverse** impacts across the sandy beaches in the Blackpill SSSI (where there may be a potential reduction in sand supply) and within the Swansea Channel (due to possible sedimentation). Within the Lagoon, impact significant is assessed as **minor adverse**, whilst immediately outside within the 'jetting' flows significance is **neutral**. Changes to the east of the Lagoon, i.e. at the entrance to the Neath and along the Crymlyn Burrows frontage, are considered **minor adverse / neutral**, as are changes within the Port Talbot Channel. Elsewhere across the wider bay, impact significance is assessed as **neutral**. (Table 6.21 of ES). The coastal processes effects within Chapter 6, are assessed with respect to specific receptors in the other chapters of the ES. Mitigation measures, where relevant, are assigned therein to reduce effects to acceptable levels. To save duplication the assessment of these effects are covered under that subject area. AEMP Objective: Validation of coastal processes predictions: intertidal areas, subtidal areas, siltation, waves and currents.	The WFD compliance assessment identified that there is a potential risk of deterioration of the benthic invertebrate quality element and hydromorphological conditions supporting the biological quality elements within Swansea Bay Coastal waterbody. The Project also has a potential effect on the mitigation measures proposed for the "Heavily Modified Waterbody" and thus may affect the potential of the waterbody to achieve 'good ecological potential' by 2027. AEMP Objective: Validation of coastal processes predictions for hydromorphological conditions: intertidal areas, subtidal areas, siltation, waves and currents (note: benthic invertebrates are addressed later on in this table).
Marine water quality	Generally no significant effects predicted to wider area; although a small net improvement at Swansea Designated Bathing Water is predicted. Significant improvement from "sufficient" to "excellent" status within the Lagoon as a result of extension of the long sea outfall (Table 7.28 of ES). Short term impacts were determined	The WFD compliance assessment identified that the Project will not cause deterioration in the status of any the Neath or Tawe waterbody, nor will it compromise the future achievement or maintenance of "Good" chemical or ecological status in terms of the dissolved inorganic

	during construction and a further understanding of these to inform future projects is considered advantageous. AEMP Objective: Further understanding of construction effects. Bacteriological assessment within lagoon following extension of outfall. Water quality in wider bay.	nitrogen quality element. The WFD compliance assessment has considered the potential for changes in phytoplankton within the lagoon following construction of the Project. Overall the risk of significantly increased phytoplankton production within the Lagoon is considered low and it is concluded that the Project will not result in deterioration of the status of the Swansea Bay coastal waterbody in relation to the phytoplankton quality element, or that the Project will compromise the future achievement of the WFD objectives. However, monitoring will be undertaken in the shallow areas at the shoreward margins within the lagoon. AEMP Objective: Validation of WFD compliance assessment for physico-chemical quality element (dissolved inorganic nitrogen) and phytoplankton quality element through monitoring of dissolved inorganic nitrogen within the Neath and Tawe Estuaries transitional waterbodies and for Chlorophyll within the lagoon.
Intertidal and Subtidal Benthic Ecology	Significant effects identified for changes in habitat suitability and habitat extent. Insignificant to minor adverse residual effect on INNS (Table 8.10 of ES) AEMP Objective: Intertidal and subtidal studies both within the lagoon and within the wider Bay. Species/habitats protected under national legislation. Monitoring of *Sabellaria* mitigation and reef enhancement.	The WFD compliance assessment identified that there is a potential risk of deterioration of the benthic invertebrate quality element and hydromorphological conditions supporting the biological quality elements within Swansea Bay Coastal waterbody. The Project also has a potential effect on the mitigation measures proposed for the HMWB and thus may affect the potential of the waterbody to achieve 'good ecological potential' by 2027. AEMP Objective: Intertidal and subtidal studies both within the lagoon and within the wider Bay. Species/habitats protected under national legislation. *Sabellaria* mitigations Validation of WFD compliance assessment for the benthic invertebrate and opportunistic macroalgae quality elements.
Fish, including Recreational and Commercial	Minor effect on adult Sea Trout (table 9.34) due to "entrainment and injury from turbines" post mitigation and moderate effect predicted for herring based on precautionary principal (Table 9.35). (Other Valued Ecological Receptors in Tables 9.28 to 9.68 of ES).	No significant effect predicted.

	Minor effects from "habitat modification". AEMP Objective: Monitoring of turbine encounter. Monitoring of herring spawning habitat mitigation. Monitoring of habitat around Lagoon.	AEMP Objective: Validation of WFD compliance assessment for the Fish quality element (transitional waters) and Fish (migratory fish only) river waterbodies hydrologically connected to Swansea Bay Coastal waterbody
Marine mammals	With mitigation no significant residual effects predicted (table 10.12 of ES). AEMP Objective: Validation of findings of ES and proposed mitigation. In particular monitoring of piling activities under JNCC protocol (during construction), effectiveness of acoustic deterrents; barrier to movement.	Not applicable
Coastal birds	No significant effects predicted, some minor beneficial effects (table 11.12 of ES). AEMP Objective: Validation of findings of ES. Monitoring of mitigation.	Not applicable
Terrestrial ecology	Minor adverse effects predicted (Blackpill SSSI; Crymlyn Burrows SSSI and Sand dunes) related to coastal processes and minor adverse to reptiles; all which are reduced to insignificant residual effects with mitigation; minor beneficial to various habitats including Crymlyn Burrows and formation of new dune, saltmarsh and maritime grassland (table 12.8). AEMP Objective: Validation of findings of ES including enhancement measures. Mitigation to minimise effects on protected species during construction.	No significant effect predicted. AEMP Objective: Validation of WFD compliance assessment for the angiosperm (saltmarsh) quality element.
Marine noise	Assessment of effects on marine receptors within relevant chapters of ES. No significant effects predicted with mitigation during construction. AEMP Objective: Validation of findings of ES in terms of marine noise during construction and operation.	Not applicable

5 Coastal Processes

5.1 Introduction

5.1.0.1 Chapter 6, Coastal Processes, Sediment Transport and Contamination, of the ES provides full details of the data review and site-specific survey work carried out to collect baseline information to develop the conceptual understanding of Swansea Bay and to input into the coastal processes model.

5.1.0.2 EIA studies, which are informed by modelling, are able to demonstrate a high level of confidence in relation to baseline conditions, as these can be validated against suitable baseline evidence. In contrast, the description of equivalent conditions with the introduction of a scheme can only be proven in a similar way once the scheme has been constructed. The EIA helps to manage the issue of confidence, in part, by opting for a conservative consideration of issues through the application of a realistic worst case, with a premise that any scale of affects is described as an upper value. What would actually be built thereafter will be similar to what was assessed in the EIA but will be more likely to have a lesser effect. As such, monitoring can validate the assumptions made in the EIA, taking into consideration the difference between the assessment of a realistic worst case and the actual case.

5.1.0.3 This section outlines the monitoring and surveys which are proposed during the pre-construction, construction and operational phases of the Project, in order to review and confirm the findings of the EIA and WFD compliance assessment. A distinction should be made between surveys (which are used to gather information) and monitoring (which is undertaken in order to validate an assumption/achieve a target). Where there is only a survey requirement, it is not applicable to set limits of acceptable change. However, it is relevant to identify any further actions that may result from the surveys.

5.1.0.4 Additional data will be collected to support the validation of the coastal process assessment of impacts, and as discussed above, noting the key differences between the predicted realistic worst case and the actual case following implementation. This is a validation of method and outcomes, and it will help add confidence to the approach used. As such, it has direct value to developers and regulators, especially if a similar approach is required on future projects.

5.1.0.5 As discussed in Table 4.1, the coastal processes effects within Chapter 6 are assessed with respect to specific environmental receptors within other chapters of the ES. Where significant effects are identified, mitigation measures are assigned to reduce effects to acceptable levels. Monitoring with respect to these, and monitoring in its own right, is discussed within the relevant section of this AEMP. This section of the AEMP therefore primarily focuses on validating the wider findings of the coastal process assessment and the following topics will be monitored:

i. Intertidal – monitoring of beach profiles to ascertain any changes in erosion and accretion patterns (linked into substrate, habitats, intertidal ecology and coastal birds);

ii. Subtidal – changes to wider bathymetry (linked into subtidal ecology and fish).

iii. Siltation within the lagoon – resulting from operation of the Project used to determine maintenance dredging frequency.

iv. Siltation in approach channels – Port of Neath, Port of Swansea and Swansea Marina, and Port Talbot, potentially affecting navigation.

v. Waves and currents – changes in wave reflection off the lagoon wall and currents in the wider bay affecting navigation and validating FCA; and

vi. Currents – localised flows through the turbines and sluice gates affecting navigation.

5.1.0.6 The surveys and monitoring presented within this Section are also relevant for the requirements of the WFD. Under the provisions of the WFD, hydromorphological conditions play a role in the status of biological quality elements such as phytoplankton, fish and benthic invertebrates. The annual topic report will consider the results of the coastal processes studies and examine how any changes to the hydromorphological quality elements may affect the biological quality elements within a WFD waterbody.

5.2 Baseline

5.2.0.1 The baseline is the reference point for determining changes to the physical environment which may be brought about by the Project. The baseline is defined here as the environmental conditions that are likely to occur over the same period as the Project lifecycle but without any development in place. Necessarily, long-term variability of the baseline over periods of up to 120 years, or more, draws on climate change related effects. The baseline includes the measured data for the current environmental conditions and the modelled future development of those conditions.

5.2.0.2 To provide the basis to enhance the initial conceptual understanding of the baseline, the following surveys were undertaken as part of the EIA process:

i. A metocean survey (Titan, 2012b) to measure currents, waves and turbidity at two locations within the bay over a period of 3 months between February and May, 2012;

ii. A geophysical survey (Titan, 2012a) to collect detailed swathe bathymetry, side scan sonar, sub-bottom profiler and magnetometer data within the immediate vicinity of the Project;

iii. A geotechnical survey (Atkins, 2013) to investigate sediment characteristics at surface and at depth for specific locations within the lagoon footprint where capital dredging is expected to occur; and

iv. A subtidal benthic survey (Titan, 2013) to collect sediment samples for Particle Size Analysis (PSA) and sediment contamination analysis from both within the lagoon footprint and across the Bay.

5.2.0.3 In addition, further clarification of the baseline evidence underpinning the assessment was provided with a specific focus on sensitive sites at Kenfig, Crymlyn Burrows and Blackpill. A greater level of confidence can therefore be assigned to the assessment outcomes described in the Project ES.

5.2.0.4 The methodologies and results of the surveys are discussed in detail in Chapter 6 and also within the survey reports as referenced above.

5.3 Coastal Processes Objectives

5.3.0 Introduction

5.3.0.1 The following objectives have been identified for coastal processes (CP) based on the findings of the ES:

- CP1 – Intertidal – to monitor potential change to intertidal areas through beach profiles (no change or more stable beach profiles across wider area; accretion at Crymlyn Burrows adjacent to Lagoon wall).
- CP2 – Subtidal – monitor broad scale changes in bathymetry and intermittent increase localised subtidal siltation.
- CP3 – To examine the levels of sediments (accretion and erosion) within the lagoon and navigation channels.
- CP4 – To examine changes in wave reflection, suspended sediments and currents outside the lagoon.
- CP5 – To examine changes in currents as a result of the turbine and sluice gate operation.

5.3.0.2 The objectives are outlined below and details of surveys are given in Section 5.4.

5.3.1 CP1: To monitor potential changes to intertidal area

5.3.1.1 This section describes a number of studies that will be used to examine any potential changes in intertidal areas. The following methods are proposed:

Survey 1 - Beach transect monitoring;

Survey 2 - Intertidal sediment sampling;

Survey 3 - Fixed point photography; and

Survey 4 - High resolution aerial surveys.

5.3.1.2 In addition, the bathymetry data collected as described further on within this section will also be reviewed in conjunction with the beach profile data.

5.3.1.3 The monitoring as set out above is summarised in Table 5.3 below.

Table 5.1 Objective summary – intertidal areas

Target	To provide a record of potential changes in intertidal area as a result of construction of the lagoon. No significant erosion or accretion outside natural variation at key locations (including Blackpill SSSI, Kenfig SAC, Swansea beach, Aberavon Sands). Monitor accretion at Crymlyn Burrows SSSI adjacent to lagoon wall.
WFD	Hydromorphological conditions quality element (coastal and transitional waters)
Management/operation	Construction of lagoon may cause temporary changes to sediment deposition in intertidal area. Maintenance dredging and the physical presence of the lagoon will

	result in change to coastal processes thereby having potential varying degrees of effect on intertidal areas.
Monitoring	***Monitoring of beach profiles and RGA (Survey 1)*** Historical and ongoing review of SCBCEG routine beach profile data (see Figure 5.1 for transects). SCBCEG transects are monitored once a year, usually in the spring. At eleven of the routine profiles sites more detailed monitoring will be undertaken by TLSB. These Key Transect sites are 202, 205, 206, 209, 210, 214, 215, 218, 220, 228 and 230 (Figure 5.1). At these Key Transect sites the routine SCBCEG transect will be supplemented with two further transects 100m either side of the SCBCEG transect (giving 33 detailed transects). Surveys will be undertaken using the following methodology guidance, http://www.walescoast.org/publication/national-beach-monitoring-specification/. Where appropriate, on the additional transects, a Rapid Geomorphological Assessment (RGA) would be undertaken on upper beach/dune interface for a distance 100m either side of the transect (except at Crymlyn Burrows SSSI where RGA will be undertaken along the section running from the Lagoon eastern wall to the Neath Estuary - further details are given below under Survey 1) . RGA is a largely field-based method used to characterise the 'condition' of geomorphological systems and can be applied to quantify the dynamism and stability of frontal dune and beach systems. These attributes may be recorded in parallel with surveys of features of ecological interest to provide an overall assessment of habitat / feature 'condition'. ***Sediment samples (Survey 2)*** Sediment samples will be collected along the 33 Key Transects and analysed for Particle Size Analysis (PSA)[8]. For each of the 33 Key Transects, three samples will be collected: one at Mean High Water Spring tide, Mean tide, and Mean Low Water Spring tide level i.e. in total 99 sediment samples. A photographic record of each transect will also be taken. ***Frequency Survey 1 and 2 -*** Monitoring of all transects including the detailed Key Transects (and sediment sampling) will be undertaken prior to construction. Monitoring of Key detailed transects twice a year (spring and autumn) through construction until five years post construction; monitoring of remaining SCBCEG transect once a year to complement existing SBCECG monitoring strategy for 5 years post-construction. Subsequently, the transects will be monitored on an annual basis for the next five years. The frequency of the monitoring and the need for the additional sites 100m either side of the Key Transect will then be reviewed. Ongoing SCBCEG monitoring data from the wider area will also be reviewed. ***Fixed Point Photography (Survey 3)*** Fixed point photography along the beach profile transects as noted above. Fixed point photographic records to be taken outside of the eastern seawall adjacent to Crymlyn Burrows and along the western seawall. Photographs taken on a monthly basis over the construction period at Low Water Springs. The need for ongoing specific profiles or recording at these locations will be determined based on review of the photographic records. Pending the results of the survey the

[8] Subtidal sediment samples have been collected during surveys carried out as part of the EIA process in 2013 and a further baseline survey in 2014 (see Section 5.4.6 for more details).

	construction photographic monitoring will cease six months after completion of construction. Findings reported in the annual reporting system. ***High Resolution Aerial Surveys (Survey 4)*** High-resolution aerial surveys of the coastal area from Mumbles to Kenfig using a photogrammetric-grade, multispectral camera. Data from the aerial surveys to be linked in with beach transect data (Survey 1) and will be used to monitor potential change in the beach levels in the intertidal areas. Accuracy of aerial survey would be sufficient to detect change (as it is comparable to LiDAR) and as such the use of LiDAR to monitor height change is not anticipated to be required. Notwithstanding this, if sufficient accuracy is not achieved in the future (by end of Yr 1 operation) the use of LiDAR will be reconsidered. In addition to this the aerial images will be used to produce maps showing broad classifications of sediment which will also act as a base map for biotope mapping (see Table 7.3 and subsequent sections). Initial aerial survey undertaken in autumn 2014 and subsequent aerial surveys will be undertaken in either autumn or spring of the relevant year to tie in with the larger astronomical tide and the beach profile surveys. ***Frequency*** **-** Surveys will be undertaken once pre-construction (completed August 2014), at year 2 of construction; at years 1, 3 and 5 operation and then every 5 years. The frequency of the aerial surveys will be reviewed at year 10 of operation. ***Bathymetry data*** Bathymetric survey (See bathymetry, Table 5.2) data collected within the wider Bay will also be analysed.
Responsibility	TLSB
Objective	To validate findings of ES and if necessary identify change outside that already predicted, including exceedance of agreed trigger levels, such that mitigation measures can be implemented.
Limits of acceptable change	Beach systems are inherently dynamic and subject to periods of deposition and erosion. By analysis of historical data as described above, broader scale sediment changes/trends may be discernible and this would supplement the understanding of the Bay's "behaviour". Data from the studies will be interpreted by expert analysis. As discussed in Section 3.4.0.1, during this analysis process, trigger levels will be established in order to evaluate if changes as a result of the Project require mitigation. Ongoing review of data obtained from the monitoring against historic changes/trends will then be used to determine if a trigger level is exceeded.
Further / remedial action	The following is proposed for potential scenarios which have been raised by interested parties but are not predicted in the ES: **<u>Blackpill SSSI</u>** • If beach erosion is considered to be in excess of natural variation, in particular at the upper tidal area of Blackpill, beach replenishment will be undertaken. Note the upper area of Blackpill is used for bird roosting as such appropriate sand from an agreed source would be used. The timing of beach replenishment would be agreed with NRW(A) and CCSC. • Although not predicted in the ES, if erosion as a result of the Project was recorded and considered to be in excess of natural variation on the main intertidal areas of Blackpill SSSI, beach replenishment would be discussed with NRW(A). The sand source, method and timings of beach replenishment would be discussed and agreed

	including consideration of minimising the potential for sterilisation of habitats, such as those used as bird feeding habitats, where appropriate. • Discussion would be held with NRW and CCSC concerning the undertaking of the beach replenishment activity and a marine licence would be obtained from NRW(MLT). If, as potentially predicted, the area affected is upper shore which is used for roosting, it is proposed that works would be undertaken in one phase. If the area potentially affected is identified as a bird foraging area, a phased beach replenishment strategy would be proposed to reduce any impacts. This would potentially entail the application of sand in agreed areas, with a suitable timescale (eg 7 months) between each application. For instance the timing of the application could be at the end of the overwintering period, such that the in-fauna could re-colonises over the summer period before overwintering birds return to the area. As discussed above an appropriate source of sand would be identified in agreement with NRW/CCSC and the relevant landowner. • The intertidal area is a mosaic of naturally changing muds especially in the lower intertidal areas, where the depth of mud varies from a few centimetres to tens of centimetres. Mudflats are important in their own right and are of value to birds. Of particular note in the wider area are the mudflats of the Severn and adjacent estuaries. The coastal process modelling undertaken for TLSB is predicting no significant change to intertidal areas and as such the habitats that are currently present are predicted to remain, but their distribution will continue to change naturally as it is a dynamic system. If a significant increase in mud distribution outside natural variation is detected, which is deemed to have an unacceptable adverse effect on ecology of the area, mitigation measures could be considered. This could include dredging/scraping the intertidal areas to remove any deposited muds. The scraping would also result in the loss of benthic ecology within the mud and therefore the need for mitigation and the appropriateness of scraping as a mitigation measure would need to be considered carefully through the AEMP review process. <u>Swansea Designated Beach</u> • If there is increased sand on the upper Swansea Beach which results in increased windblown sand to adjacent roads, particularly Oystermouth Road, management strategies would be discussed with City and Council of Swansea. These could include short term assistance for road cleaning and longer term measures to reduce windblown sand, through measures such as beach shaping or sand fences. These measures would be implemented in agreement with CCSC and appropriate licences (if needed would be obtained). • If there is a reduction in sand on Swansea designated bathing beach (outside natural variation) beach replenishment will be undertaken in consultation with NRW and CCSC. Sand from an agreed appropriate source would be used and the timing of works agreed. <u>Crymlyn Burrow SSSI</u> • As identified in the ES sand (Chapter 6, table 6.22) it is predicted that sand will accrete in the region fronting Crymlyn Burrows,

	against the eastern arm of the lagoon wall. The amount and extent of deposition is largely dependent on the prevailing SW storm conditions, with more severe storms potentially carrying more sand into this part of the bay, therefore increasing the potential accretion. Crymlyn Burrows SSSI frontage is not sheltered by the lagoon from south-easterly gales and as such sand would be reworked during these events. If significant sand accretion, particularly after south-westerly storms, is observed, the need for redistribution of sand or introduction of sand back into the wider bay, for instance as a beach replenishment source, will be discussed with NRW(A) and the appropriate landowner. Measures to be employed could include those which have been used in past management campaigns with regard to redistribution of sand adjacent to the Neath Channel. Practices also employed on other sand dunes systems would also be considered and theses would be discussed and reviewed with key stakeholders. As such appropriate measures would be identified at the time in agreement with NRW and NPTCBC, based on currently accepted practices. • Aeolian processes also transfer sand into the main Crymlyn SSSI from the intertidal area. The presence of the landscaped beach within the lagoon adjacent to the eastern lagoon wall is designed to facilitate this process. The beach area within the lagoon will be maintained at an appropriate level to maintain this process. Any appropriate measures would be identified at the time in agreement with NRW, CCSC and NPTCBC, where relevant, based on currently accepted practices. <u>Kenfig SAC</u> • The proposed maintenance dredging of the Lagoon is expected to begin some 10 – 15 years after completion of construction and commencement of operation. A licence for maintenance dredging and disposal will be obtained at that time and NRW(MLT). This will identify an appropriate spoil ground for disposal of maintenance dredging material. As such, no negative impacts are predicted to Kenfig SAC as a result of the operation of the Project since licensing will be subject to assessment demonstrating its acceptability in relation to potential effects upon Kenfig SAC or the use of an alternative disposal grounds would be required. • Notwithstanding this, to enable anticipated use of the Swansea Outer Ground, monitoring as identified above will form part of the main AEMP. If Swansea Outer Ground is to be used in the future, the need for additional monitoring commencing 2 years in advance of disposal at the outer grounds will be secured by requirement attached to the DCO and agreed with NRW(A). At that stage, appropriate triggers which may require cessation of use of the Swansea Outer Ground or remedial action will be reviewed via the AEMP review process. The triggers will be defined so as to indicate a potential effect from the use of the offshore disposal site. Triggers would be based on long term trends in beach and dune sediment supply as identified from the review of historic data described above and could include i) volumes of sand in the area from mean low water to dune toe; and ii) erosion rate of the sand dune toe. • The selection of appropriate SAC features to be monitored would take into consideration the influence of other natural and anthropogenic pressures not related to the Project (including other

	users of Swansea Outer Grounds), whilst the triggers would take into consideration any management practices or other activities which maybe on-going at that time which may influence the results. Trigger levels would be proposed and then discussed and agreed with NRW near the time of when deposition at the offshore disposal grounds is proposed to confirm that they are reasonable and fit for purpose. <u>Aberafan Sands</u> • There is no predicted effect on Aberafan Sands. Notwithstanding this, if erosion outside natural variation is recorded, which is attributed to the Lagoon, the need for beach replenishment would be discussed with NRW(A) and NPTCBC. Appropriate sand sources would be identified, timings confirmed and a marine licence obtained.

5.3.2 CP2 Subtidal – monitor broad scale changes in bathymetry and intermittent increase localised subtidal siltation.

5.3.2.1 This section describes a number of studies that will be used to examine any potential changes in subtidal areas. The following methods are proposed:

Survey 5 – Subtidal transect monitoring; and

Survey 6 – Subtidal sediment sampling

5.3.2.2 Bathymetric surveys and data review will be undertaken to examine the area adjacent to the lagoon and the wider Bay area in relation to broad changes in erosion or accretion (note more detailed surveys with respect to the navigational channels and the lagoon are discussed below). These surveys will validate the findings of the coastal processes assessment in Chapter 6 of the ES and will also feed into wider monitoring with respect to beach profiles. In addition, this information can be used to further analyse changes to ecological receptors.

Table 5.2 Objective summary – Wider bathymetry

Target	To understand potential broad scale changes in bathymetry and to investigate changes to the seabed morphology and sediment transport.
WFD	Hydromorphological conditions quality element (coastal and transitional waters)
Management/operation	Presence of lagoon walls
Surveys	***Subtidal transect monitoring (Survey 5)*** As discussed previously the proposed maintenance dredging of the Lagoon will be commenced some 10 – 15 years after completion of construction. Any licence for maintenance dredging will be obtained at that time and NRW(MLT) will identify an appropriate spoil ground for disposal of maintenance dredging material, or suitable monitoring/triggers relating to effects upon Kenfig SAC. As such, no negative impacts are anticipated on Kenfig SAC as a result of the operation of the Project. Notwithstanding this Single Beam Echosounder (SBES) bathymetry data would be collected over the wider Bay area from Mumbles Head to Port Talbot and for an area off Kenfig SAC for the baseline. SBES data at 100m line spacings

	which would provide a similar data set to traditional beach topographical monitoring (as per beach profiles) with set lines run each time. Side scan sonar data would be simultaneously collected on all lines, to provide mapping of surface sediment types. ***Subtidal sediment sampling (Survey 6)*** 50 small grab samples would be collected on any SBES survey for PSA analysis. It is proposed that the bathymetry transects in the wider Bay will be carried out pre-construction (in either the autumn or spring to tie in with beach profiles), and once every five years from operation. If at the time that a licence is sought for disposal and an alternative site to LU 130 is allocated, subtidal monitoring will be restricted to between Mumbles Head and Port Talbot Port.
Responsibility	TLSB
Objective	To validate findings of ES and if appropriate to use the data to identify change outside that already predicted, including exceedance of any relevant trigger levels such that mitigation measures identified for CP1 can be implemented if need be.
Limits of acceptable change	Not applicable
Further / remedial action	The bathymetry data collected for the wider Bay area will be used together with beach profile data (see CP1 and CP2) to assess the changes to the intertidal and subtidal environment and to inform any potential requirements for beach replenishment or accretion management as referred to in objective CP1.

5.3.3 CP3: To examine the levels of sediments (accretion and erosion) within the lagoon and navigation channels

5.3.3.1 Bathymetric surveys and data review will be undertaken to examine the area within the lagoon and navigational channels in relation to the accretion and erosion of sediments. This will validate the findings of the coastal processes assessment in Chapter 6 of the ES and also provide information as to the requirement for ongoing maintenance dredging and assistance in maintenance dredging of navigational approach channels.

Table 5.3 Objective summary – local operational bathymetry

Target	To assess levels of siltation and erosion within the lagoon and within navigation channels.
WFD	Hydromorphological conditions quality element (coastal and transitional waters)
Management/operation	Presence of lagoon walls and maintenance dredging
Surveys	***Survey 7*** **-** Multi-beam bathymetric and side scan sonar surveys within the lagoon footprint and a 250m wide corridor around the outside of the lagoon boundary. With permission from ABP and CCSC surveys would also extend up the Tawe estuary to the Tawe Barrage. Information will be requested from CCSC concerning current and future accretion patterns upstream of the Tawe Barrage. Pre construction survey within the dredged channels to be undertaken prior to works commencing. Frequency of surveys during construction would be discussed and agreed with the Ports of

	Swansea, Port Talbot and Neath, and CCSC, and would be dependent on the location of construction works. Post-construction survey would take place as soon as feasible following project completion. Data will be passed to ABP, NPA and CCSC for review, where appropriate. Frequency of future surveys would be discussed and agreed with ABP, CCSC and NPA and would be designed to tie in with existing surveys. Surveys within the lagoon would be annually for the first 5 years and the frequency reviewed thereafter to tie in with anticipated maintenance regime.
Responsibility	TLSB
Objective	To validate findings of ES and if necessary identify change outside that already predicted such that mitigation measures can be implemented.
Limits of acceptable change	Not applicable
Further / remedial action	It is proposed that in relation to Swansea, Port Talbot and Neath navigational channels, data collected by the Port authorities and CCSC will be reviewed in conjunction with the stakeholder taking into consideration the additional data collected through surveys. Although no change is predicted, data for the Tawe between Kings Lock and Tawe Barrage will also be reviewed with CCSC/Swansea Marina. The data will be used to identify additional dredging requirements outside natural variation as a result of the Project (taking into consideration weather conditions). Any additional maintenance dredging will be discussed and agreed with the relevant Port or CCSC. Data from within the lagoon will be used to develop and refine the maintenance dredging strategy. When needed a licence for dredging/disposal will be sought from the relevant statutory authority (currently NRW Marine Licence Team).

5.3.4 CP4: To examine changes in wave reflection, suspended sediments and currents outside the Lagoon

5.3.4.1 A fixed point temporal analysis of wave reflection, suspended sediment and currents will be undertaken at two locations within Swansea Bay. This will validate the findings of the coastal processes modelling presented in Chapter 6 of the ES and provide information in relation to waves, currents and suspended sediments which can be used further to analyse changes to ecological receptors.

Table 5.4 Objective summary – operational waves and currents

Target	To collect data on waves, water levels, current profiles and suspended sediment (acoustic backscatter), combined with Optical Back Scatter (OBS) for suspended sediment (turbidity).
WFD	Hydromorphological conditions quality element
Management/operation	Presence and operation of the lagoon
Surveys	Deployment of two Nortek Acoustic Wave and Current Profiler (AWAC) instruments in seabed frames, at two locations in the first year of operation (See **Survey 8**, section 5.4.8). Site 2 is in the same location as the original survey undertaken as part of the EIA. Site 1

	has been re-positioned in the west of Swansea Bay to examine residual flows in this area (see Figures 6.40 and 6.41 of the ES, Volume 2). Measurement of current speed and direction throughout the water column, together with directional wave data. Measurement of water levels (m above CD) using the AWAC pressure sensors. Deployment of Optical Backscatter Sensors (OBS) to measure near bed turbidity in Formazine Turbidity Units (FTU). Collection of water samples at the time of initial deployment and final recovery to assist calibration of recorded turbidity data into Suspended Particulate Material (SPM) in mg/l. Grab sampling on initial deployment and final recovery for Particle Size Analysis (PSA). Meteorological data will be obtained from the existing CCSC monitoring station. The monitoring devices will be installed immediately post construction and will be deployed over the subsequent autumn and winter period to gather storm event data. If no storm data has been obtained, the deployment time period will be reviewed. Likewise if the results from the deployment are outside the predicted effects of the ES, the need for extending the data collection period would be considered through the AEMP review process.
Responsibility	TLSB
Objective	To validate findings of ES and if necessary identify change outside that already predicted.
Limits of acceptable change	Not applicable
Further / remedial action	The information collected will be set out and analysed in an annual report. The data will be reviewed against the predictions of the ES and the need for additional data collection will be discussed through the AEMP review process. Data on waves and current flows in the wider bay will be made available to the Ports and Swansea Marina to inform other users of the area should that be necessary.

5.3.5 CP5: To examine changes in currents as a result of the turbine and sluice gate operation

5.3.5.1 A spatial analysis of currents and suspended sediment will be undertaken around the Lagoon. This will validate the flow data presented in Chapter 4 of the ES and provide information in relation to currents around the turbine sluice gate structure for navigational purposes.

Table 5.5 Objective summary – operational currents and suspended sediments

Target	To collect data on flows through turbines and sluices to provide spatial current data (as opposed to fixed point temporal data which is collected by the AWAC deployments). The survey data could also be used to provide more detailed information on flow patterns within the lagoon as a whole, as well as to measure backscatter intensity, which would provide an indication of turbidity in the water column.

WFD	Hydromorphological conditions quality element (coastal and transitional waters)
Management/operation	Presence and operation of the lagoon
Surveys	Three survey areas using a vessel mounted Acoustic Doppler Current Profiler (ADCP) (see Survey 9 Section 5.4.9): • Inside Lagoon survey focussed on inlet • Inside Lagoon General Flow Pattern Survey • Outside Lagoon flows Moving Vessel ADCP surveys would be undertaken across several transects over the flood and ebb phase of a spring and a neap tide on a single occasion on each of a spring and neap tide. The transect surveys above would also provide information on suspended sediment within the water column. An Argus Silt Meter, which measures deposition/turbidity profiles near-bed (approx. 1m high) to be deployed in a suitable intertidal location within the lagoon on one occasion post construction (informed by modelling output and bathymetric surveys).
Responsibility	TLSB
Objective	To validate findings of ES and if necessary identify change outside that already predicted.
Limits of acceptable change	Not applicable
Further / remedial action	The information collected will be set out and analysed in the first annual topic report , in year 1 operation. Data on current flows around the turbine sluice gate structure will be made available to the Ports and Swansea Marina to further inform other users of the area. Data on currents within the Lagoon will be made available to users of the lagoon at the boating centre. Information from Argus silt meter will be used to further inform future maintenance dredging schedule.

5.4 Survey Methodology

5.4.0 Survey 1 - Monitoring of Beach Profiles and Rapid Geomorphological Assessment

5.4.0.1 An existing long term data set of beach profiles for Swansea Bay has been collected by Swansea and Carmarthen Bay Coastal Engineering Group (SCBCEG). Up to thirty sets of data have been collected from locations between Mumbles Head and Kenfig dating from 1998-2013. To date, no real analysis of data sets has been undertaken and consequently trends and short/long term beach responses are not well understood.

5.4.0.2 Currently, Trinity St David's University is analysing all relevant beach profiles to establish temporal trends and storm response. In addition to the data analysis review, it is proposed to review historic aerial images for the area for the same time period. In this way, broader scale sediment changes/trends may be discernible and this would supplement the understanding of the "behaviour" of the Bay.

5.4.0.3 Recently Trinity St David's University has also undertaken an analysis of Swansea Point dunes for CCSC. Consequently, they have extensive expertise on such analyses informed by research on various Welsh and global coastlines. Once these analyses of Swansea Bay

profiles are completed, they will be used to identify potentially vulnerable locations as well as trigger points which indicate change outside natural variation.

5.4.0.4 In addition to historic data analysis of the SCBCEG historical beach profiles, any future data gathered annually by the SCBCEG will also be reviewed. SCBCEG transects are usually monitored once a year, currently in the spring.

5.4.0.5 This ongoing review of monitoring data will be supplemented by additional monitoring data gathered on behalf of TLSB. The data would be collected from two additional transects positioned approximately 100m either side of eleven Key routine SCBCEG transects. The additional Key Transects would be at sites 202, 205, 206, 209, 210, 214, 215, 218, 220, 228 and 230 (Figure 5.1). The surveys will be undertaken using the following methodology, http://www.walescoast.org/publication/national-beach-monitoring-specification/.

5.4.0.6 Photographic records at key sediment transition points along each of the 33 transects will also be taken.

5.4.0.7 Monitoring of the all transects and sediment sampling at 33 detailed Key beach transects (see Survey 2 below) will be undertaken prior to construction. Monitoring of 33 detailed transects twice a year (spring and autumn) through construction until five years post construction. Monitoring of remaining SCBCEG within bay annually to compliment wider SCBCEG surveys. Subsequently the transects will be monitored on an annual basis for the next five years. The frequency of monitoring and the need for the additional sites 100m either side of the main transect will be reviewed at end of year 5 operation. Ongoing SCBCEG monitoring data from the wider area will also be reviewed.

5.4.0.8 The beach transect data will be used to assess, amongst other things, changes to beach profiles and the net change in sediment volume at the transect sites. This data will be linked into the aerial survey data (Survey 4). The aerial survey data will provide coverage of the upper sections of the beaches, which will include the dune interface.

5.4.0.9 In addition to this where appropriate, on the additional transects, a Rapid Geomorphological Assessment (RGA) would be undertaken on upper beach/dune interface for a distance 100m either side of the transect, except at Crymlyn Burrows SSSI where RGA will initially be undertaken along the dune frontage running from the eastern lagoon wall to the Neath Estuary. RGA is a largely field-based method used to characterise the 'condition' of geomorphological systems and can be applied to quantify the dynamism and stability of frontal dune and beach systems. These attributes may be recorded in parallel with surveys of features of ecological interest to provide an overall assessment of habitat / feature 'condition'. A summary of the RGA process as provided by NRW at Deadline III, is given in Appendix 1.

5.4.0.10 As identified in 5.4.0.7 TLSB will monitor all transect sites once a year up to 5 years operation, targeted to compliment (and irrespective of/in addition to) the routine SCBCEG monitoring. If at some time in the future SCBCEG does not continue to monitor the wider transects annually, the need for monitoring all sites twice a year will be reviewed to provide an optimum set and frequency of transect monitoring. The review will determine whether the additional transects provide valuable data, or whether data from the wider spread of sites is more advantageous. Should SCBCEG monitoring cease,

and the information available be insufficient for the purposes of this AEMP, the responsibility for data gathering will be assumed by TLSB.

5.4.0.11 This beach profile data will be used to further examine the potential effects of the Project on other environmental topics e.g. terrestrial ecology in terms of the dune system and coastal birds in relation to intertidal foraging areas.

Figure 5.1 Locations of SCBCEG Beach Profiles

5.4.1 Survey 2 Intertidal sediment sampling

5.4.1.1 Sediment samples will be collected along the beach profile transects and analysed for Particle Size Analysis (PSA). For each transect, three samples will be collected over the tidal range: one at Mean High Water Springs, one at Mean Tide and one at Mean Low Water Springs i.e. in total 99 sediment samples. The exact locations of the transects will be recorded so that samples can be collected from the same location on the subsequent sampling occasion.

5.4.1.2 Particle size analysis would be undertaken using traditional sieve analysis – with laser diffraction of fines where these are present in significant amounts (the <63 micron fraction only analysed if <10% present in the sample). Samples are analysed at ½ phi intervals and results reported together with all traditional statistical parameters (median diameter, sorting coefficient, skewness and kurtosis).

5.4.2 Survey 3 Fixed Point Photography

5.4.2.1 Construction photographic records will be taken at the position of the outside of the eastern seawall adjacent to Crymlyn Burrows and along the western seawall. The

photography is not meant to be a quantitative assessment but more a qualitative record of changes as the construction proceeds. Photographs will be taken from fixed points on a monthly basis over the construction period generally at Low Water Springs. If notable adverse weather occurs, additional photographic records will be taken. The need for specific beach profiles to record changes at these locations will be determined based on review of the photographic records. The construction phase photographic record will be analysed and reported. Pending the results of the survey the construction monitoring will cease six months after completion of construction and findings reported in the annual reporting system.

5.4.3 Survey 4 High Resolution Aerial Surveys

5.4.3.1 It is also proposed to undertake high-resolution aerial surveys of the coastal area from Mumbles to Kenfig once pre-construction (completed August 2014), at year 2 of construction; at years 1, 3 and 5 post construction and then every 5 years. The frequency of the aerial surveys will be reviewed at 10 years operation.

Aerial Survey and Image Rectification

5.4.3.2 High-resolution surveys of the coastal area from Mumbles to Kenfig will be completed using a photogrammetric-grade, multispectral camera. The coast will be surveyed in blocks of overlapping parallel flight lines as this is the most efficient way to capture the area and to facilitate potential extraction of terrain height data.

5.4.3.3 Upon completion of the aerial survey, the data will be geo-referenced. The rectified image data will be provided on a suitably sized external hard drive for use in GIS. Imagery can be collected at any resolution required, but for this type of survey it is recommended surveying at 10cm resolution.

5.4.3.4 Surveys will be undertaken in the spring prior to construction (completed August 2014), year 2 of construction and then year 1, 3 and 5 operation and every 5 years thereafter. The frequency of the aerial surveys will be reviewed after 10 years of operation.

Digital Elevation Model Extraction

5.4.3.5 Post-processing and photogrammetric software can also generate a Digital Elevation Model (DEM) of the area from the imagery. The DEM models the elevation of the earth surface and can be used to describe the slope of the ground and calculate the heights and volumes of the objects upon it. The DEMs provide millions of height measurements of the survey area (approximately 20 height measurements per square metre) and can be merged with the aerial imagery to produce powerful 3D visualizations of the landscape from any given view point (see Figures 5.2 and 5.3). This is extremely useful for visually assessing the environment particularly in remote or hostile areas. The 3D model accuracy would be approximately 10cm vertical accuracy (which is similar to LiDAR[9]). Data from the aerial surveys will be reviewed and if sufficient accuracy is not achieved by end of Year 1 operation the use of LiDAR will be reconsidered and reported.

5.4.3.6 The results of the aerial mapping exercise would be verified against the beach profiles for that year. This would pick up highly accurate spot heights that will assist in the model creation. The surveys will be repeated as discussed above and this qualitative method will be used to detect changes in accumulation/erosion of material.

[9] http://www.centremapslive.co.uk/page/accuracy

5.4.3.7 In addition to this, the results of the high resolution aerial mapping will be used to identify habitats across the Bay, both in terms of sediments and silts. Further information on the intertidal mapping process is provided in section 7.3.3.

5.4.3.8 If possible, historic aerial Google maps will be compared to the historic beach profiles and the aerial survey data, and this will used to assess potential trends in beach deposition and erosion. If available broad scale habitat mapping will be undertaken as well such that a longer term baseline is formed for ongoing monitoring.

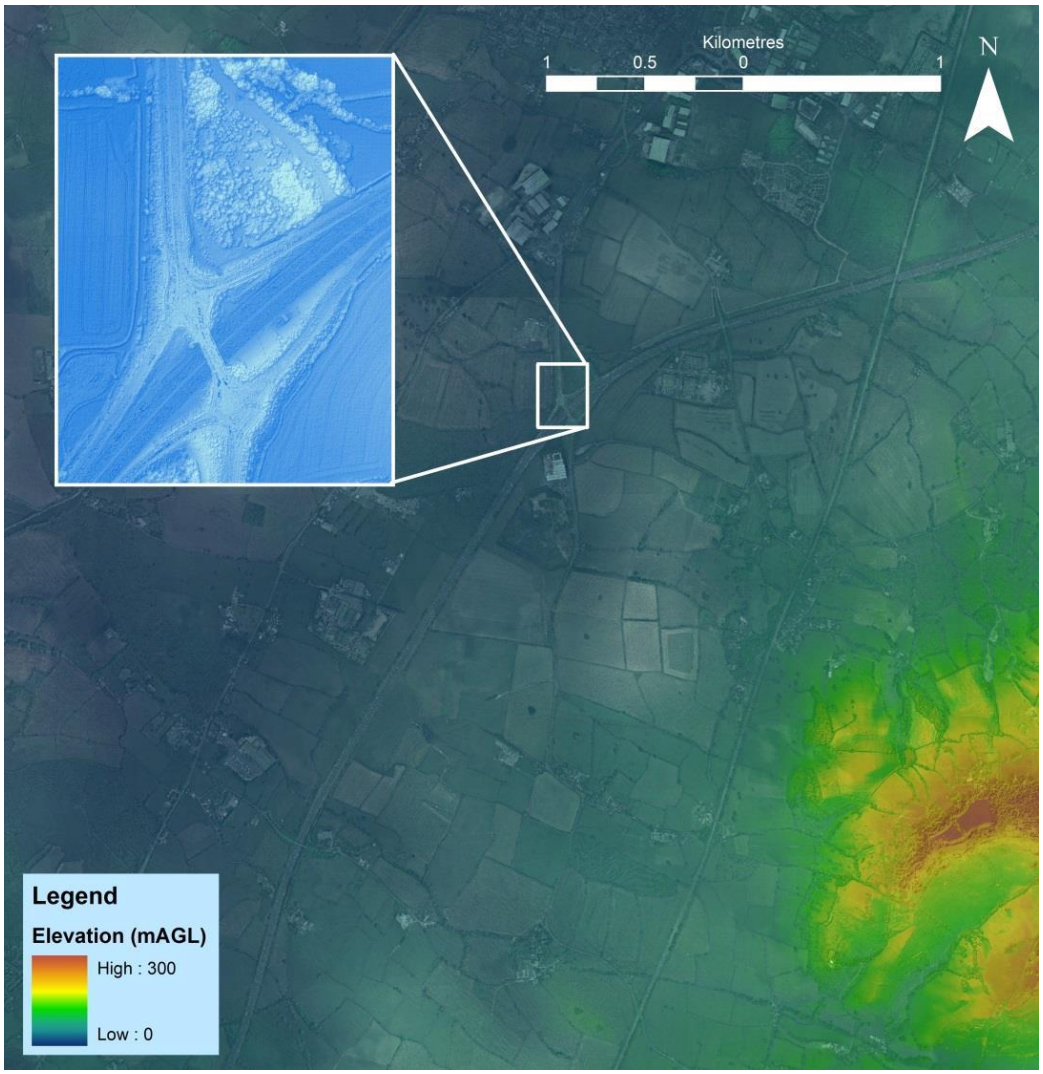


Figure 5.2 High-density DSM extracted from 10cm imagery.

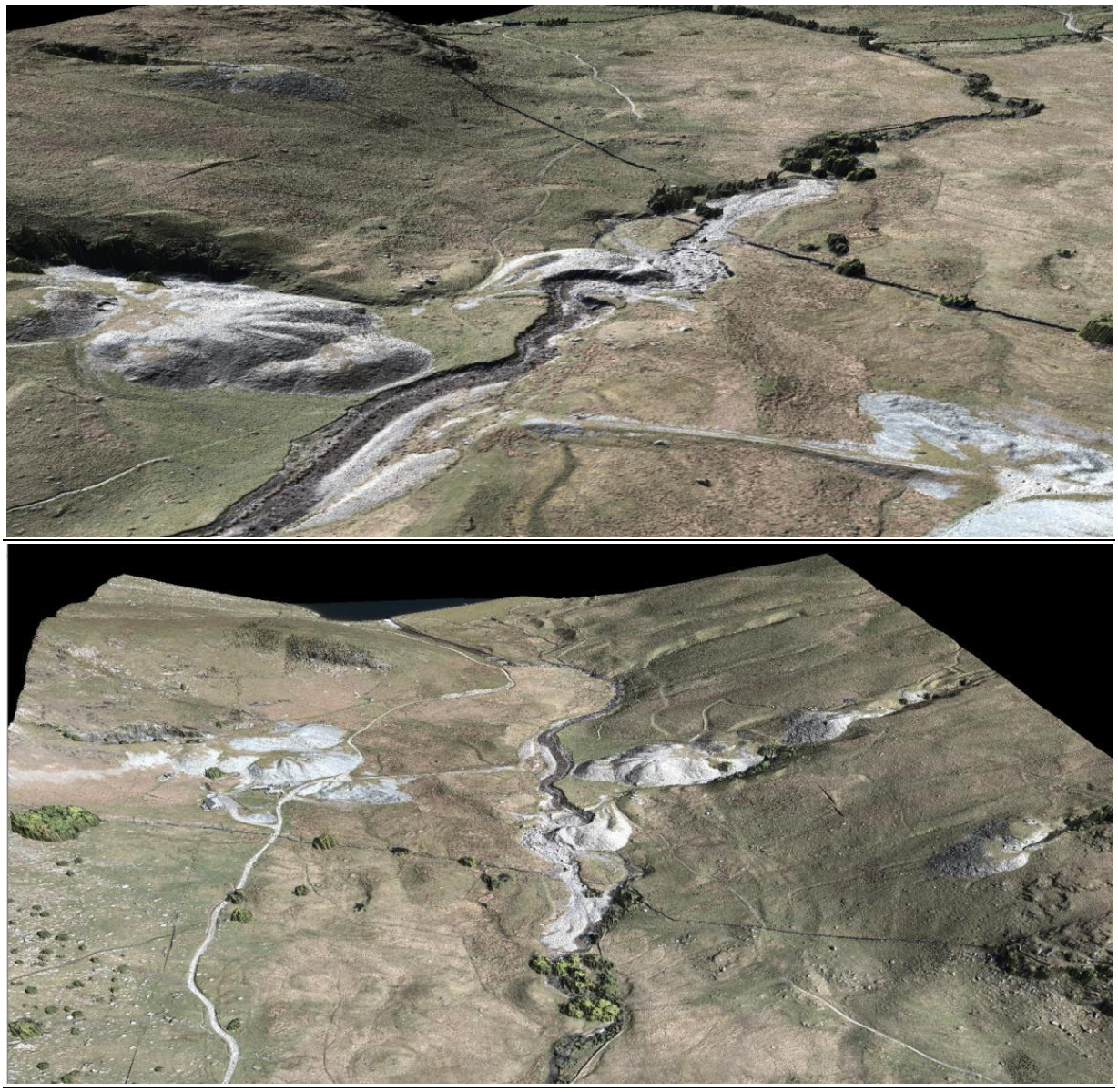


Figure 5.3 Image drapes provide 3D visualisation perspective views of the environment from any given location.

Use of aerial survey information

5.4.3.9 As identified above, the high resolution imagery can be used for the following:

- Produce a classified map showing broad classifications of sediment. Repeat surveys would allow any change in coverage to be quantified;
- Provide the imagery that will act as a base map for biotope mapping. The standard technique for biotope mapping is greatly improved by using up-to-date aerial imagery as a base for delineating the various zones;
- Map extent and change over time of vegetation. The imagery can be used to map the extent of vegetation such as sea grass and algal mats.

5.4.3.10 This approach has successfully previously been used on a number of Projects including:

- **Mersey Tidal Power Feasibility Study. Client: Peel Holdings Ltd –** an aerial survey classification of the broad sediment types across the estuary based on a supervised image classification was undertaken and used as a basis for a marine ecology assessment.
- **Roosecote intertidal eelgrass and ephemeral algae survey. United Utilities. 2007-2010.** Aerial survey captured high resolution imagery to assess eelgrass extent which supported a monitoring programme and mapping exercise to examine the distribution of eelgrass at Roosecote Sands within South Walney and Piel Flats SSSI in the Morecambe Bay SAC/SPA and to assess the potential impacts of a waste water discharge.
- **Aerial survey for Sea Grass in Studland Bay**. R&D project to assess the value of using high resolution aerial imagery for mapping subtidal seagrass at Studland Bay including identifying areas of mooring scour.
- **Aerial survey of Poole Harbour, Dorset. Bournemouth University. 2013** ultra-high resolution aerial survey of Poole Harbour in order to map algal cover over the intertidal zone.

5.4.3.11 The use of aerial imagery has also been used by other organisations, such as in the study 'A multi-century record of linked nearshore and coastal change' (Thomas et al, 2011).

5.4.3.12 In addition to this it is understood, from meeting of 24 July 2014, that Swansea University has recently completed an aerial survey of Crymlyn Burrows SSSI. It would be proposed to liaise with Swansea University concerning their localised survey such that, if they wish, their data can be tied back into the wider scale survey.

Data Analysis

5.4.3.13 All of the above proposed methods, together with bathymetry data (see Survey 5), will be used to assess the potential effects of the Project on coastal processes and the resultant impacts on beach profiles and sediment distribution.

5.4.3.14 As identified above, the data will also be used to inform the studies into intertidal ecology (Section 7) and terrestrial habitats (Section 9). This information can be used to further review the potential changes that could affect coastal birds (that are a feature of Blackpill SSSI) (see Section 10).

5.4.3.15 Particular attention will be paid to: accretion at Crymlyn Burrows SSSI and the need for redistribution of sand or introduction of sand back into the wider bay system (as well as linking into the SUBC management of the SSSI); potential erosion in the upper beach sandy areas of Blackpill SSSI (see ES Chapter 6, 6.5.1.60, Coastal Processes, Sediment Transport and Contamination) and the need for any mitigation, such as beach replenishment. Although not anticipated, increased windblown sand, particularly on Oystermouth Road and loss of sand to the designated bathing beaches (outside natural variation) will also be considered. The nature of sand required at the receptor site, suitable sand sources, method and timings of beach replenishment work would be considered and discussed with NRW, CCSC, NPTCBC as well as relevant land owners (see table 5.1).

5.4.4 Survey 5 Subtidal – monitor broad scale changes in bathymetry

5.4.4.1 Single Beam Echosounder (SBES) bathymetry data would be collected over the wider Bay area from Mumbles Head to Port Talbot and for an area off Kenfig SAC. SBES data would be collected at 100m line spacings across the area 0m CD to -10m CD between Mumbles Head and Port Talbot and 0m CD to -5m CD off Kenfig SAC. This information would provide a similar data set to traditional beach topographical monitoring (as per beach profiles) with set lines run each time.

5.4.4.2 Side scan sonar data would be simultaneously collected on all lines, to provide mapping of surface sediment types, thereby providing a robust dataset similar to multibeam survey. It is also proposed to collect grab samples (50 in total) at the transects for Particle Size Analysis. This would assist in assessing suspended solids and sediment structure.

5.4.4.3 Surveys to be undertaken once pre-construction (spring 2015), in year 1 operation and every 5 years thereafter. Survey frequency will be reviewed after year 10 of operation.

5.4.5 Survey 6 – subtidal sediments

5.4.5.1 Sediment samples have been collected across the Bay and other than the sampling identified above no further baseline sampling is proposed. A summary of the baseline sampling is provided below:

5.4.5.2 Subtidal sediment samples were collected during the benthic baseline survey. This survey included sampling and particle size analysis (PSA) of 59 sediment samples from across Swansea Bay, 27 of which were taken from within the proposed footprint of the Lagoon.

5.4.5.3 In addition to this, additional samples were collected during the preliminary geotechnical investigation for the Project (Atkins, 2013), which included a number of exploratory boreholes, vibrocores and cone penetration tests which provide additional sediment data within the vicinity of the lagoon.

5.4.5.4 Finally 102 additional subtidal sediment samples have been collected across the wider Bay as part of additional benthic sampling completed by SEACAMS on behalf of TLSB. These will be analysed and the results will be used to inform the monitoring programme as a whole. The location of the sites was based on a simple grid network which can be seen in Figure 7.2, Section 7.

5.4.5.5 Sampling of subtidal sediments in the future will be tied in with the subtidal transects, as discussed elsewhere in Section 5.4, and the benthic sampling programme as discussed in Section 7 of this AEMP.

5.4.6 Survey 7 – To examine the levels of sediments (accretion and erosion) within the lagoon and navigation channels.

5.4.6.1 Multi-beam bathymetric and side scan sonar surveys will be undertaken within the lagoon footprint and within a 250m wide corridor around the outside of the lagoon boundary. The proposed line spacing would be 40m, with multi-beam echo sounders used to infill at 10-20m line spacing for shallower areas. With permission from ABP and CCSC, surveys would also extend up the Tawe estuary to the Barrage.

5.4.6.2 A pre-construction survey will be undertaken prior to any works commencing. Frequency of surveys during construction would be discussed and agreed with the Ports, and would be dependent on the location of construction works. For example, more frequent surveys would be undertaken within the Tawe Channel in year 1 when the western lagoon wall is being constructed. Likewise surveys would be focused on the Neath Channel in Year 2, when marine works are being used to construct sections of the eastern lagoon wall.

5.4.6.3 A post-construction survey would take place as soon as feasible following project completion. Data will be passed to ABP, CCSC and NPA for review. Frequency of future surveys would be discussed and agreed with ABP, CCSC and NPA and would be designed to tie in with existing surveys.

5.4.6.4 Surveys within the lagoon would be annually for the first 5 years of operation and the frequency reviewed thereafter to tie in with anticipated maintenance regime. Data from other surveys discussed above would also be evaluated.

5.4.7 Survey 8 – wave reflection, suspended sediments and currents outside the lagoon

5.4.7.1 Deployment of two Nortek Acoustic Wave and Current Profiler (AWAC) instruments in seabed frames, at two locations in the first year of operation (see Figure 5.4 below). Site 2 is in the same location as the original survey undertaken as part of the EIA. Site 1 has been re-positioned in the west of Swansea Bay to examine residual flows in this area (see Figures 6.40 and 6.41 of the ES, Volume 2).

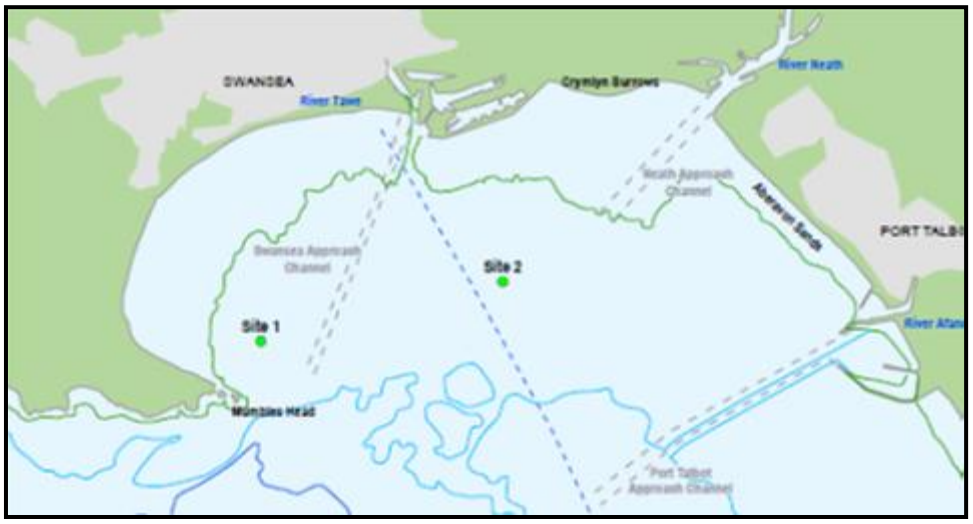


Figure 5.4 Proposed locations of AWAC device deployment

5.4.7.2 The survey method employed for the EIA baseline would be followed. Measurement of current speed and direction would be undertaken throughout the water column at 0.5m intervals, together with directional wave data including: significant wave height (Hs), mean wave direction (Mdir) and the peak wave period (Tp). Measurement of water levels (m above CD) would be obtained using the AWAC pressure sensors.

5.4.7.3 In addition to this, Optical Backscatter Sensors (OBS) would be deployed to measure near bed turbidity in Formazine Turbidity Units (FTU). Collection of water samples at the time

of initial deployment and final recovery to assist calibration of recorded turbidity data into Suspended Particulate Material (SPM) in mg/l.

5.4.7.4 It is proposed that up to forty two suspended sediment samples (as per baseline survey) will be taken at the time of initial deployment for calibration purposes, while three samples will be collected per site at bottom, mid-depth and surface. The samples collected would be used for suspended sediment concentration of acoustic backscatter and calibration of the turbidity sensors. Grab sampling on initial deployment and final recovery using a hand operated 0.045m^2 stainless steel mini Van-Veen grab, for Particle Size Analysis (PSA). Meteorological data will be obtained from the existing CCSC monitoring stations. CCSC have confirmed that they are happy to share their data. CCSC have 2 met stations logging the following parameters at 1 minute intervals:-

- Blackpill - Wind speed and direction at 8m;Global Radiation, UVA, UVB and UV index at 2.5 m; Temperature and humidity at 2.5m; Rainfall.
- Cwm Level Park, Morriston - Wind speed and direction at 30m; Global radiation at 30m; Wind speed and direction at 10m; Differential temperature at 2 and 8m; Absolute temp and humidity at 2m Rainfall.

5.4.7.5 The AWAC monitoring devices will be installed immediately post construction and deployed over the following autumn and winter period to gather storm event data. If no storm data has been obtained, the deployment time period will be reviewed.

5.4.7.6 The information collected will be processed and set out and analysed in an annual report. After analysis of the data, if it is considered appropriate to further examine the effects of the Project, additional wave data could be obtained. Data on waves and current flows in the wider Bay will be made available to the Ports and Swansea Marina to further inform other users of the area.

5.4.8 Survey 9 – Change in currents as a result of the turbine and sluice gate operation

5.4.8.1 Monitoring the change in currents will be undertaken using the deployment of Acoustic Doppler Current Profiler (ADCP) instruments at three main locations around the lagoon. This will validate the flow data presented in Chapter 4 of the ES with respect to currents and output in Chapter 6 on scour. The data will also provide information in relation to currents for navigational users of the Bay.

5.4.8.2 The following three survey types will be undertaken using a vessel-mounted ADCP as follows and illustrated in Figure 5.5:

- Inside lagoon survey focussed on inlet (red)
- Inside lagoon General Flow Pattern Survey (green)
- Outside lagoon flows (purple)

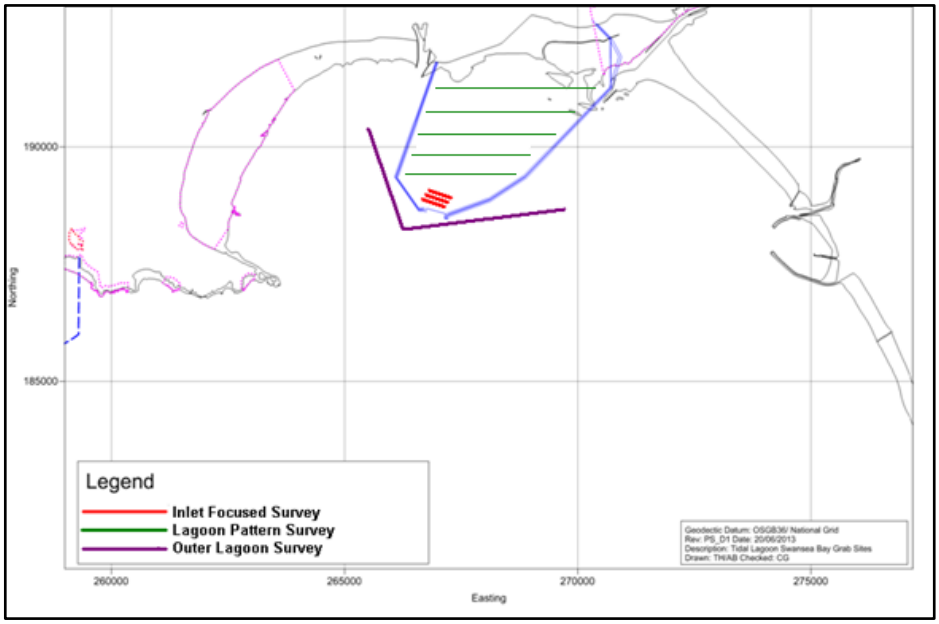


Figure 5.5 Potential ADCP survey areas

5.4.8.3 Moving vessel ADCP surveys would be undertaken across several transects over a flood and ebb tide tidal cycle. This would provide current profile data through the water column over the transect lines. This would be carried out on a single occasion on each of a spring and neap tide.

5.4.8.4 The transect surveys above would also provide information on suspended sediment within the water column during the surveys.

5.4.8.5 Additional data on bed level turbidity values will be obtained during operation (as completed in the baseline ADCP survey by Titan). An Argus Silt Meter, which measures deposition/turbidity profiles near-bed (approx. 1m high) will be deployed in a suitable intertidal location within the lagoon post construction (informed by modelling output and bathymetric surveys).

5.4.8.6 The data collected from the surveys would be used to review the data provided in the ES.

6 Water Quality

6.1 Introduction

6.1.0.1 Chapter 7 Marine Water Quality of the ES provides full details of the data review carried out to collect baseline information for Swansea Bay.

6.1.0.2 Since submission of the DCO, it has been confirmed that the Waste Water Treatment Works (WWTW) long sea outfall which is situated within the lagoon will be approximately extended 1.5km to discharge outside the lagoon seawalls. The use of the lagoon for water sports, particularly swimming and bathing, will be dependent upon water quality within the lagoon. The extension of the existing long sea outfall by 1.5km to discharge outside the lagoon will optimise water quality within the lagoon and "excellent" status is predicted.

6.1.0.3 The review of water quality will examine bacteriological water quality and also physico-chemical elements under the WFD.

6.2 Baseline

6.2.0.1 Data collected by Natural Resources Wales (NRW) under the Water Framework Directive (EC 2000/60/EC) (WFD), the Bathing Water Directive (EC 76/160/EEC) (BWD), and the Shellfish Water Directive (EC 2006/113/EC) (SWD), which are the principal legislative drivers for water quality assessments in coastal waters around the UK were reviewed. In addition, data gathered under the European Commission (EC) regulations pertaining to bacterial sampling of shellfish flesh, which is a key water quality indicator, were also reviewed.

6.3 Water Quality Objectives

6.3.0 Introduction

6.3.0.1 The following section has been divided into 'bacteriological water quality' and 'other water quality' aspects. Surveys relating to the objectives are provided within the relevant subsection.

6.3.0.2 The following objectives have been identified for water quality (WQ) based on the findings of the ES:

- WQ1: To investigate water quality and re-suspension of sediments.
- WQ2: To examine bacteriological water quality within the lagoon.
- WQ3: Further understanding of bacterial water quality influence outside lagoon.
- WQ4: To examine water quality (nutrients) within the Neath Estuary, Tawe Estuary and Swansea Bay

6.3.1 Objective WQ1: To investigate water quality and re-suspension of sediments

6.3.1.1 It is proposed to undertake surveys to further understand the potential effect from sediments released during marine construction and dredging activities on water quality. The surveys would be focused on metals and faecal indicator organisms. An outline framework is provided but it would be proposed to develop this further in conjunction with Professor Kay at the Centre for Research into Environment and Health, Aberystwyth University.

Table 6.1 WQ1 objective summary – monitoring of water quality due to suspended sediments

Target	To gain further understanding of the potential releases of bacteria and metals from re-suspended sediments during construction.
WFD	Temporary impacts – not applicable
Management/operation	The construction of the lagoon.
Survey	**Survey 10** - Pre-construction samples (approx 20) collected of sediment within key areas to be disturbed by construction activities. (see Figure 6.1). Data would be analysed for Faecal Indicator Organisms (FOI) and metals (note all metal analysis to date has confirmed that levels detected are below CEFAS action level 2 and therefore are fit for disposal). Five samples would be collected from the wider bay to act as controls. The results of the analysis will determine any areas of higher bacteria levels. During construction, water quality sampling undertaken when area of sediment identified with higher FOI is disturbed. The samples would be analysed for FOI and dissolved metals. This sampling is anticipated to be in Year 2 or 3 of construction when works near the existing outfall are undertaken. Sampling of the water quality would be undertaken at distances along the plume.
Responsibility	TLSB
Objective	To further understand some effects of suspended sediments from marine construction on the environment.
Limits of acceptable change	No limits are applicable.
Further / remedial action	Information from the survey would be reported in the annual report and the information would be used to further understand effects of marine construction activities.

Survey 10 – monitoring of water quality due to suspended sediments

6.3.1.2 Samples of sediment would be collected prior to construction within key areas which are going to be disturbed by construction activities. Approximately 20 samples would be collected based on a simple sampling grid which covers the outfall area as a whole, extending across an approach channel (see Figure 6.1). Five samples would be collected from the wider bay to act as controls.

6.3.1.3 Data would be analysed for Faecal Indicator Organisms (FOI) and the following metals. The results of the analysis will determine any areas of higher bacteria levels and the associated metal level.

Cd – Cadmium	Hg – Mercury	Sn - Tin
Cr – Chromium	Ni - Nickel	Zn - Zinc
Fe – Iron	Pb - Lead	

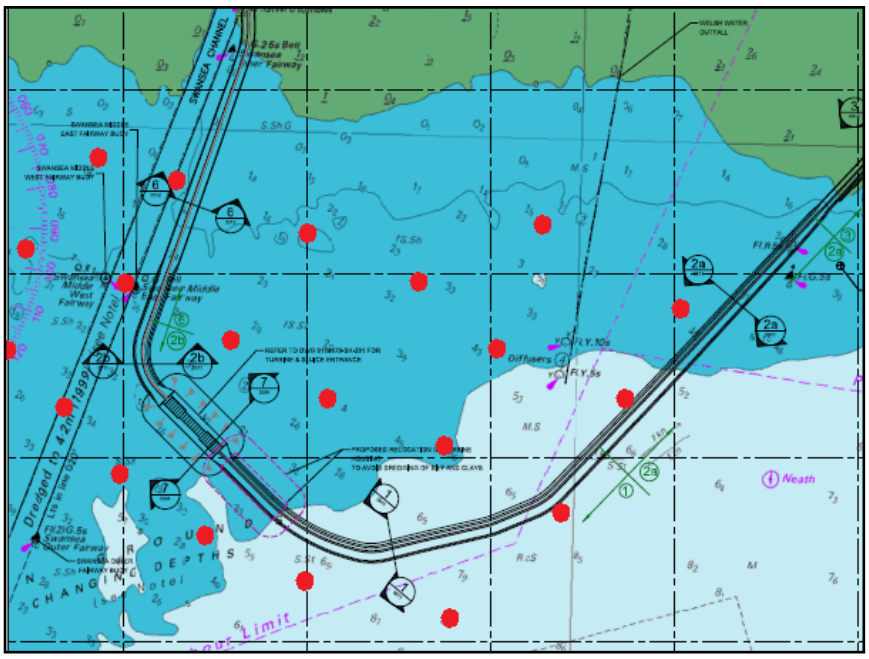


Figure 6.1 Indicative lagoon sediment sampling grid

6.3.1.4 During construction, water quality sampling would be undertaken when the area of sediment identified with higher FOI are disturbed. Samples would be collected of the water at distances along the plume. The samples would be analysed for FOI and dissolved metals.

6.3.1.5 This sampling is anticipated to be in Year 2 or 3 of construction when works near the existing outfall are undertaken.

6.3.2 Objective WQ2: To examine bacteriological water quality within the lagoon

6.3.2.1 As identified in Chapter 7 Marine Water Quality, with the extension of the outfall outside the lagoon, "excellent" water quality status (under the revised Bathing Waters Directive) is predicted within the Lagoon.

Table 6.2 WQ2 objective summary – monitoring of lagoon bacteriological water quality

Target	To confirm water quality within the Lagoon in terms of suitability for water contact sports, bathing and shellfish (wet and dry weather).
WFD	Applicable for potential effect on Community Legislation – Bathing Water Directive, Shellfish Waters Directive, Urban Waste Water Treatment Directive.
Management/operation	The physical presence and operation of the lagoon.
Survey	**Survey 11** - Faecal Indicator Organism would be surveyed at 5 points within the lagoon (see Figure 6.1). The survey would take place at hourly intervals over a full tidal

	cycle (13 hours). The survey would be repeated for dry weather and wet weather conditions and over spring and neap tides (four surveys). **Survey 12-** Routine sampling would be taken from four points within the lagoon at fortnightly intervals between October and April and then weekly in the bathing season, from 15 May to 30 September, for the first year of operation. Samples will also be collected for the analysis of Chlorophyll.
Responsibility	TLSB
Objective	To validate findings of ES and determine the future use of the lagoon as a shellfish harvesting area.
Limits of acceptable change	Compliance under revised Bathing Water standards (excellent) Class B shellfish (potentially Class A)
Further / remedial action	Review the requirement for any further monitoring based on the findings of the studies. Following extension of the outfall, it is not expected that levels of FIO will exceed acceptable trigger limits for bathing within the lagoon and Excellent status is predicted. The Excellent standard should also meet Shellfish requirements for Class A. These will be reviewed once the lagoon is built and if it is proposed to use areas of the lagoon for shellfish harvesting a monitoring programme would be developed in order to inform the production of a sanitary plan. Remedial action would include implementation of water quality management plan, if need be. Information on intertidal exposure in relation to lagoon operation will also be made available to SUBC and at the Lagoon visitors centres, such that users of the beach are aware of health and safety risk with regard to bathing at low water where there large intertidal expanses.

Survey 11 – Lagoon tidal cycle bacterial monitoring

6.3.2.2 Once the Project is operational, it is proposed that bacterial water quality monitoring for Faecal Indicator Organism (FIO) would be undertaken. Sampling at 5 locations as shown on Figure 6.1, within the lagoon.

6.3.2.3 The samples have been identified as follows (see Figure 6.1):

Site no.	Location and reason for inclusion
1	Open-water swim area – contact sport - swimming
2	Boating beach – contact sport - recreational paddling
3	University beach – contact sport – recreational swimming/ paddling
4	Potential future shellfish area
5	Sailing area – potential contact sport - sailing

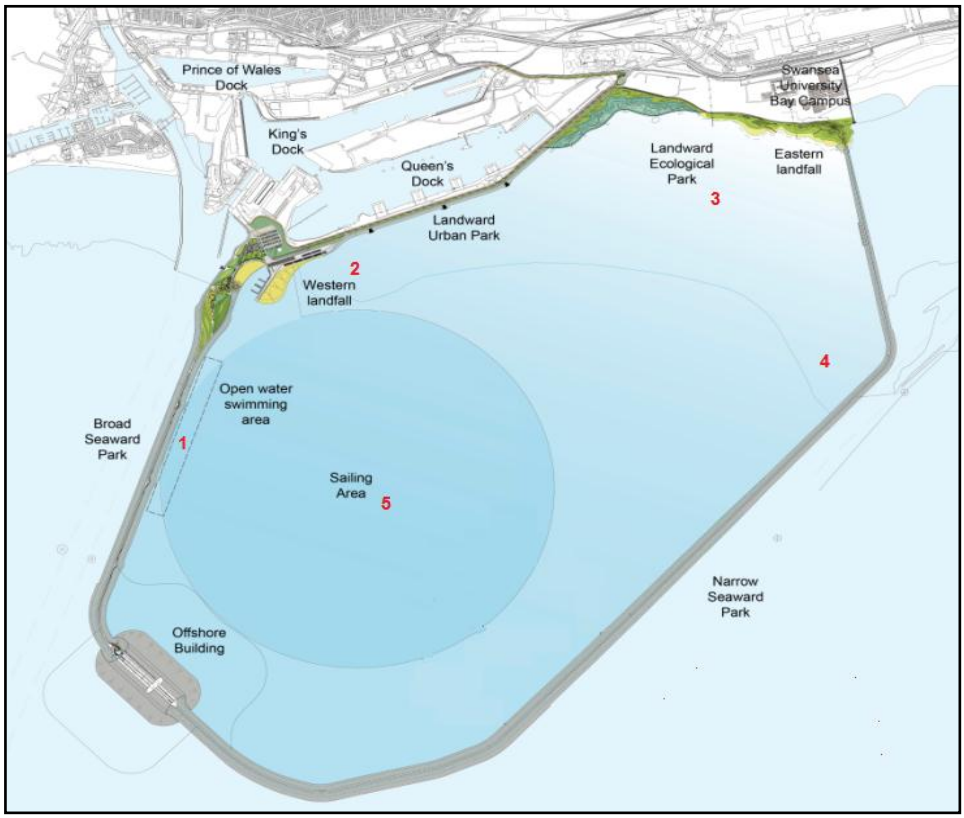


Figure 6.1 Proposed bacteriological water quality sampling points

6.3.2.4 Samples would be taken hourly for a full tidal cycle (13 hours). The survey would be repeated for dry weather and storm conditions and over spring and neap tides. Concurrent sampling of the WWTW final treated effluent and storm water discharges would also be undertaken (if permission from DCWW is granted), to determine input loads. Samples would be collected and analysed using current industry methods and best practise.

6.3.2.5 The primary aim of this sampling would be to provide a comprehensive picture of how the lagoon is performing in terms of FIO concentrations in the lagoon, under wet and dry weather conditions. It will also provide an indication of water quality during wet weather with respect to the outfall extension with pumping at the end of the tidal cycle. This information would be used to confirm the results of model predictions in the ES and aid in confirming the location of water activity areas.

6.3.2.6 The data will be analysed and provided to NRW and the CCSC. The requirement for any further monitoring will then be discussed and agreed with NRW and CCSC.

6.3.2.7 Classification of shellfish harvesting areas is required under EC Regulation No. 854/2004. The management and co-ordination of the shellfish harvesting area classification monitoring programme in Wales is carried out by CEFAS, on behalf of the Food Standards Agency. If it is proposed to establish a shellfish area, under Regulation 854/2004, a sanitary plan must be completed and submitted to the Food Standards Agency in order

that the waters within the lagoon can be classified. The sanitary plan must include the following:

a) Make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production area;

b) Examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, waste-water treatment etc.;

c) Determine the characteristics of the circulation of pollutants by virtue of current patterns, bathymetry and the tidal cycle in the production area; and

d) Establish a sampling programme of bivalve molluscs in the production area which is based on the examination of established data, and with a number of samples, a geographical distribution of the sampling points and a sampling frequency which must ensure that the results of the analysis are as representative as possible for the area considered.

6.3.2.8 Based on the findings of the bacteriological surveys detailed below, and future proposals for use of the lagoon, proposals for ongoing monitoring in order to inform a sanitary plan would be developed.

Survey 12 – Routine water quality sampling

6.3.2.9 Routine sampling would be undertaken from four points within the lagoon, as shown below.

Site no.	Location and reason for inclusion
1	Open-water swim area – contact sport - swimming
2	Boating beach – contact sport - recreational paddling
3	University beach – contact sport – recreational swimming/ paddling
4	Potential future shellfish area

6.3.2.10 Samples would be collected at fortnightly intervals between October and April and then weekly in the bathing season, from 15 May to 30 September, for the first year of operation. Samples will also be collected for the analysis of Chlorophyll. The samples would be analysed for FOI namely Escherichia coli and Intestinal enterococci. The frequency of sampling would be reviewed based on the results of survey 11 and after year one operation. If "excellent" water quality status is confirmed under dry and wet weather conditions, sampling would be undertaken during the bathing season only at weekly intervals.

6.3.3 Objective WQ3: Further understanding of bacterial water quality influence outside lagoon

6.3.3.1 The current designated sampling point in Swansea Bay is reliant upon a prediction model to protect public health and for directive compliance. There has been considerable uncertainty over the effect of the lagoon on the predictions produced by the existing Black Box predictive water quality model, given that it is a statistical model identifying suitable predictors and weightings identified before the lagoon was built.

6.3.3.2 To address the uncertainty, it is proposed that TLSB will provide an agreed contribution to the original 'smart-coast' partners, enabling recalibration of this model upon completion of the lagoon. This recalibration will be administered by and the responsibility of CCSC and will commence at the earliest opportunity upon completion of the physical impoundment (the construction of the lagoon walls and the turbine / sluice gate structure), and following operation of the turbines/sluice gate house (anticipated to be mid bathing season 2018 at the earliest). Field work could be split over two bathing seasons depending on the timing of construction. The agreed financial contribution will be secured by an agreement under s106 Town and Country Planning Act 1990.

6.3.3.3 TLSB will make the relevant financial contribution prior to commencement of the recalibration exercise to CCSC to hold for the smart-coast partners to undertake the re-calibration of the Swansea designated sample point prediction model. The smart-coast partners will carry out all necessary field work, laboratory analysis and statistical analysis to select the most appropriate model, predictors and weightings to satisfy the partnership that the selected model has an explained variance at least as good as the existing model. The smart-coast partners will use their best endeavours to complete the field work in the first full bathing season after this point in the construction programme and the full report will be public information.

6.3.3.4 It is intended that the final selected DSP predictive model will be agreed by CCSC and NRW (or their successor bodies) and will be owned by NRW for Directive compliance purposes. Should NRW as 'compliance regulator' decide that the Swansea DSP cannot achieve Directive compliance by the use of any program or other measures, funding will cease and any remaining funds will be returned for reinvestment into the lagoon.

6.3.3.5 It is noted that DCWW will be undertaking significant survey, monitoring and hydrodynamic modelling work in AMP6. They are also one of the smart-coast partners and there is expected to be full collaboration between all partners throughout this project to share data, including the hydrodynamic data and microbial data collected by TLSB.

Table 6.3 WQ3 objective summary – Bacterial water quality outside the lagoon

Target	To work in collaboration with CCSC, DCWW and NRW to investigate the potential effects of changes from the Project and from sewerage improvements on the model predictions of the existing black box model, and to provide funding up to an agreed amount for the recalibration of the Black Box Model so as to enable compliance with the rBWD.
WFD	Applicable for potential effect on Community Legislation – Bathing Water Directive, Urban Waste Water Treatment Directive.
Management/operation	The physical presence and operation of the lagoon.
Survey	Provision of funding up to an agreed ceiling (See S106) and any relevant field data undertaken as part of the AEMP eg from Survey 8 (AWAC deployment for currents/waves).
Responsibility	TLSB
Objective	To validate findings of ES.
Limits of acceptable change	None applicable to Project
Further / remedial action	Not applicable

6.3.4 Objective WQ4: To examine water quality (nutrients) within the Neath Estuary, Tawe Estuary and Swansea Bay

6.3.4.1 The WFD compliance assessment and Chapter 7 Marine Water Quality (Section 7.7.7) assessments identify that overall the lagoon serves to reduce nitrogen concentrations within Swansea Bay, by modifying the trajectories of the river plumes and generating additional mixing with offshore waters. Extending the WWTW long sea outfall causes further changes in offshore nitrogen concentrations, as moving the discharge further offshore displaces the nitrogen load from the WWTW into deeper, more dynamic waters, with greater available dispersion. The net change is a general reduction of nitrogen concentrations in Swansea Bay. This reduction is, however, partly offset by localised increases in nitrogen concentrations (<100 µg/l) in the transitional waters in the downstream reaches of the Tawe and Neath estuaries. This change is due to the river plumes being constrained at the estuary mouth as the lagoon wall restricts lateral dispersion. However, the assessment of the nutrient levels within the transitional waterbodies against NRW guidance for the WFD provided in September 2014 has predicted that the Project will not cause deterioration in the status of any the Neath or Tawe waterbody, nor will it compromise the future achievement or maintenance of "Good" chemical or ecological status in terms of the dissolved inorganic nitrogen quality element. Mitigation of this local effect is not possible without moving the lagoon walls further away from the estuaries combined with removal of nutrient loadings from the upstream water bodies, neither of which would be feasible. The location of the lagoon seawalls has been the result of an iterative process detailed in Chapter 3 Site Selection and Option Appraisal of the ES involving coastal processes modelling and consultation with Port and Harbour Authorities. Measures to reduce nutrient loadings to upstream water bodies are outside of the remit of the Project.

Table 6.4 WQ4 objective summary – dissolved inorganic nitrogen

Target	To examine nutrient levels within the Tawe and Neath Estuaries and Swansea Bay To examine phytoplankton within the lagoon
WFD	Physico-chemical quality element (transitional and coastal waters) Phytoplankton quality element
Management/operation	The physical presence and operation of the lagoon
Survey	**Survey 13** - dissolved inorganic nitrogen (DIN) on the Tawe Estuary, Neath Estuary and offshore site. Tawe Estuary - 5 monitoring sites and Neath Estuary -2 monitoring sites. Samples would be collected for DIN, salinity and temperature. Sampling at these locations would commence monthly pre-construction, during construction and then for two years post construction. Sampling would then be reduced to two monthly for the following three years. The requirement for continued sampling would then be reviewed. Offshore sample point – 1 monitoring site - sample collected at the western extent of the lagoon, off the seawall once the Project was operational. Sampling would be undertaken monthly for two years for dissolved inorganic nitrogen and then sampling would be reduced to two monthly for the following three years. The requirement for continued sampling would then be reviewed. Phytoplankton (chlorophyll) would be sampled within the lagoon

	as part of **Survey 12**.
Responsibility	TLSB
Objective	To validate findings of ES and if necessary identify change outside that already predicted.
Limits of acceptable change	Change in dissolved inorganic nitrogen concentrations outside of natural variability. Change in chlorophyll outside of natural variability.
Further / remedial action	Review the requirement for any further monitoring based on the findings of the study. No intervention is appropriate.

Survey 13 – Dissolved Inorganic Nitrogen Sampling

6.3.4.2 For the WFD compliance assessment revised report (submitted to the Planning Inspectorate on the 5 August 2014 and updated 7 October 2014), water quality data for dissolved inorganic nitrogen available on the Water Information Management System (WIMS) database gathered by NRW between 1990 to 2013 was reviewed. Data were reviewed at the following sampling locations on the Neath and Tawe.

Table 6.4 NRW WIMS Sample Points reviewed on the Tawe and the Neath

Location	Sample point	NGR
River Tawe		
River Tawe @ Morriston Road Bridge	30001	SS6736797989
Tawe, Glais Road Bridge	30009	SN7013200837
TAWE EST. @ WHITE ROCK RD.BR.	72138	SS6632694993
Tawe Est. @ New Cut Rd.Bridge	30008	SS6614693230
River Neath		
R.Clydach At Dyffryn Arms R.B	71618	SN7412001000
Neath 500m Below Aberdulais Gs	10004	SS7730299209
R.Neath @ A474 Neath Rb	71660	SS7460097200
River Neath At Briton Ferry	71586	SS7340094500

6.3.4.3 In relation to ongoing assessment, for the Tawe Estuary, two NRW sample points upstream of the Tawe Barrage: New Cut Rd Bridge (30008) and White Rock Rd Bridge (72138) would be appropriate for use as sample points for future surveys. The Morriston Road Bridge (30001) sample site would be appropriate as a control site in relation to river inputs. Presently these sites are sampled regularly by the NRW in summer and winter. The WIMS data suggest that there are no sample sites downstream of the Tawe Barrage where nutrient data have been recently collected. Ongoing data gathered at these sample points would be reviewed.

6.3.4.4 The WIMS data for the Neath suggests that there are no sample sites on the Neath where nutrients are regularly sampled in the summer and winter.

6.3.4.5 It is therefore proposed to survey for dissolved inorganic nitrogen, temperature and salinity at the following locations on the Tawe Estuary:

- Site 1 – mouth of the Tawe along the Eastern Breakwater;
- Site 2 – downstream of Barrage on the west shore (to avoid storm water discharge)
- Site 3 – upstream of Barrage at New Cut Rd. Bridge (existing NRW sampling site)
- Site 4 – upstream of Barrage at White Rock Rd. Bridge (existing NRW sampling site)
- Site 5 – upstream of Barrage at Morriston Rd. Bridge (existing NRW sampling site) – control site for river inputs.

6.3.4.6 For the Neath Estuary, two sample points have been identified:

- Site 1 – near the mouth of the Neath, along the BP jetty;
- Site 2 – upstream near Britton Ferry (upstream limit of impact on dissolved inorganic nitrogen predicted by the modelling – see Chapter 7 Marine Water Quality).

6.3.4.7 Sampling at these locations within the Tawe and Neath would commence monthly pre-construction and during construction and then for two years post construction. Sampling would then be reduced to once every two months for the following three years. The requirement for continued sampling would then be reviewed.

6.3.4.8 A further sample point would be used offshore within the wider Bay, with the sample collected at the western extent of the lagoon, off the seawall once the Project was operational. Sampling would be undertaken monthly for two years for dissolved inorganic nitrogen and then sampling would be reduced to once every two months for the following three years. The requirement for continued sampling would then be reviewed.

6.3.4.9 The findings of the sampling, would, together with the ongoing NRW monitoring, be reviewed to examine the potential effects of the lagoon and extension of the outfall on nutrient levels within the wider Bay and the Neath and Tawe Estuaries. This work would assist in the assessment of the classification of the Neath and Tawe Estuaries in relation to the dissolved inorganic nitrogen WFD physico-chemical quality element. The findings would also be used to further consider the effects of the Project on biological quality elements of the WFD, including phytoplankton and opportunistic macroalgae.

Phytoplankton

6.3.4.10 Within Swansea Bay coastal waterbody, the presence of the lagoon increases mixing within the Bay, leading to greater dispersion of the discharge from the outfall (which will be re-positioned outside of the lagoon) and the nutrient loads from rivers such as the Neath, Tawe and the Afan. There are therefore unlikely to be any effects on phytoplankton resulting from the Project. It follows that these predicted changes are not expected to significantly alter the distribution of phytoplankton in the Swansea Bay coastal waterbody, or lead to significant changes in primary production.

6.3.4.11 Overall the risk of significantly increased phytoplankton production within the Lagoon is considered low, given the relatively small changes predicted over the bulk of the Lagoon area and the relatively limited supply of phytoplankton and nutrients. However monitoring of nutrient and phytoplankton (chlorophyll) concentrations in the most at-risk areas (shallow areas at the shoreward margins) will be undertaken.

6.3.4.12 The chlorophyll-a 90th percentile metric utilises the monthly data from the growing season only (March to October, inclusive) but the elevated count and seasonal succession indices require monthly data from the whole year (i.e. 12 months). Note: a minimum of nine months data across a single year is required to run the seasonal succession and elevated counts indices.

6.3.4.13 Sampling for chlorophyll will be undertaken in conjunction with Survey 12. In the two years samples will be collected at sites 2, 3 and 4, as identified in Figure 6.1 at monthly intervals. After year 2 the data will be reviewed and the need for additional sampling will be determined.

7 Intertidal and Subtidal Benthic Ecology

7.1 Introduction

7.1.0.1 It is recognised that the construction of the Project will result in loss and changes to intertidal and subtidal habitats and the species that they support. Mitigation for effects on many of these habitats is not technically feasible, as they cannot be replaced on a like-for-like basis. The Project has incorporated enhancements to maximise ecological diversity. Monitoring of the lagoon seawalls and the enhancements is seen as key to confirming the approach taken to maximise ecological opportunities while recognising losses that cannot be replaced. This will then support the evidence base for any future tidal lagoon projects and also support the principles that formed many of the conclusions of the ES (for example, ecological diversification of the reef encouraging increased fish species which would have beneficial effects on recreational fishing).

7.1.0.2 Chapter 8 Intertidal and Subtidal Benthic Ecology of the ES provides full details of the data review and site-specific survey work carried out to collect baseline information for Swansea Bay. This section outlines the further monitoring and surveys which will be undertaken during the pre-construction, construction and operational phases, in order to review and confirm the findings of the EIA. In addition, the findings of the surveys will assist in the understanding of the effects of the Project on the biological quality elements (macroalgae and benthic invertebrate) of the WFD.

7.1.0.3 The monitoring programme in intertidal and subtidal ecology aims to assess, among other things, the colonisation rate of the lagoon seawall and its potential to develop into an artificial reef. Monitoring will therefore assess the biodiversity of the seawall and the presence/absence of non-native marine species.

7.1.0.4 At a wider level, benthic sampling and substrate sampling carried out from baseline through to operation will allow for a better understanding of the marine ecology of the Bay and the potential changes as a result of the Project.

7.1.0.5 The results of mitigation and enhancement implemented as part of the Project will also be investigated, including the *Sabellaria* translocation, colonisation of the seawalls and the re-introduction of the native oyster.

7.2 Baseline

7.2.0 Intertidal

7.2.0.1 An intertidal phase 1 walkover survey was undertaken for the area between the River Tawe and River Neath. In particular, the survey looked to confirm the presence, distribution and condition of *Sabellaria* reefs adjacent to the existing eastern Port breakwater, and confirm the presence and distribution of any nationally important biotopes or rare species. In addition, the area west of the River Tawe extending to Mumbles Head was surveyed specifically for protected habitats and species. The landward boundary of the survey was Mean High Water Springs (MHWS) with the seaward boundary following Mean Low Water Springs (MLWS) (or as near as possible depending on surf and surge conditions). The surveys were undertaken on 14-15 January 2013 and 28-29 May 2013, at low water during spring tides.

7.2.1 Benthic and sediment sampling

7.2.1.1 A benthic survey consisting of sediment sampling, epifaunal trawls and CTD profiling within Swansea Bay as part of the subtidal benthic characterisation for the Project was undertaken on 4-8 May and 18 June 2013. The survey comprised:

i. 59 sites for sediment sampling;

ii. 49 sites for benthic samples;

iii. 10 CTD (Conductor, Temperature and Depth) salinity profiles; and

iv. 7 epifaunal trawls.

7.2.1.2 The 59 sediment sampling sites were located both in the lagoon and in the surrounding area. The sites comprised 49 sites for benthic analysis (27 samples from within Project footprint and 22 samples from the surrounding area), 59 sites for particle size analysis (PSA) and 17 sites for metal analysis.

7.2.1.3 As identified above, benthic sampling was undertaken at 49 sites as shown in Figure 7.1. In selecting these sites out of the total 59 sites sampled, the following factors were considered:

i. faunal classification during Characterisation Survey (see Figure 7.1 and Appendix 2).

ii. extent of effect of the Project

iii. sites of a similar substrate outside the tidal influence of the lagoon.

iv. sites within the lagoon footprint.

v. sites outside of the lagoon but within its zone of tidal influence.

vi. geographic distribution.

7.2.1.4 At each of the 49 sites, three replicates were collected, but only one was processed to "characterise" the benthic ecology in the area. The remaining two samples from each site have been stored. Details of the survey findings are presented in Chapter 8 Intertidal and Subtidal Benthic Ecology and also contained within the Swansea Bay Tidal Lagoon Benthic Data Report (Titan, 2013).

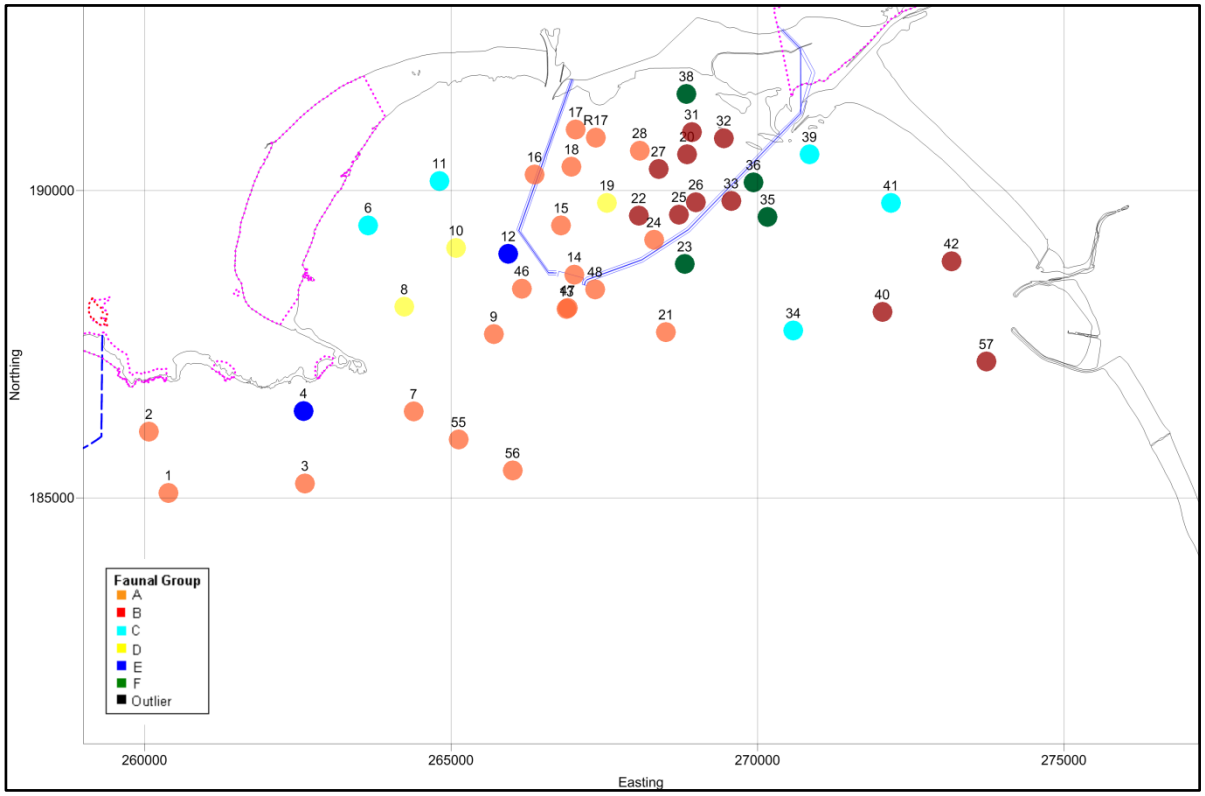


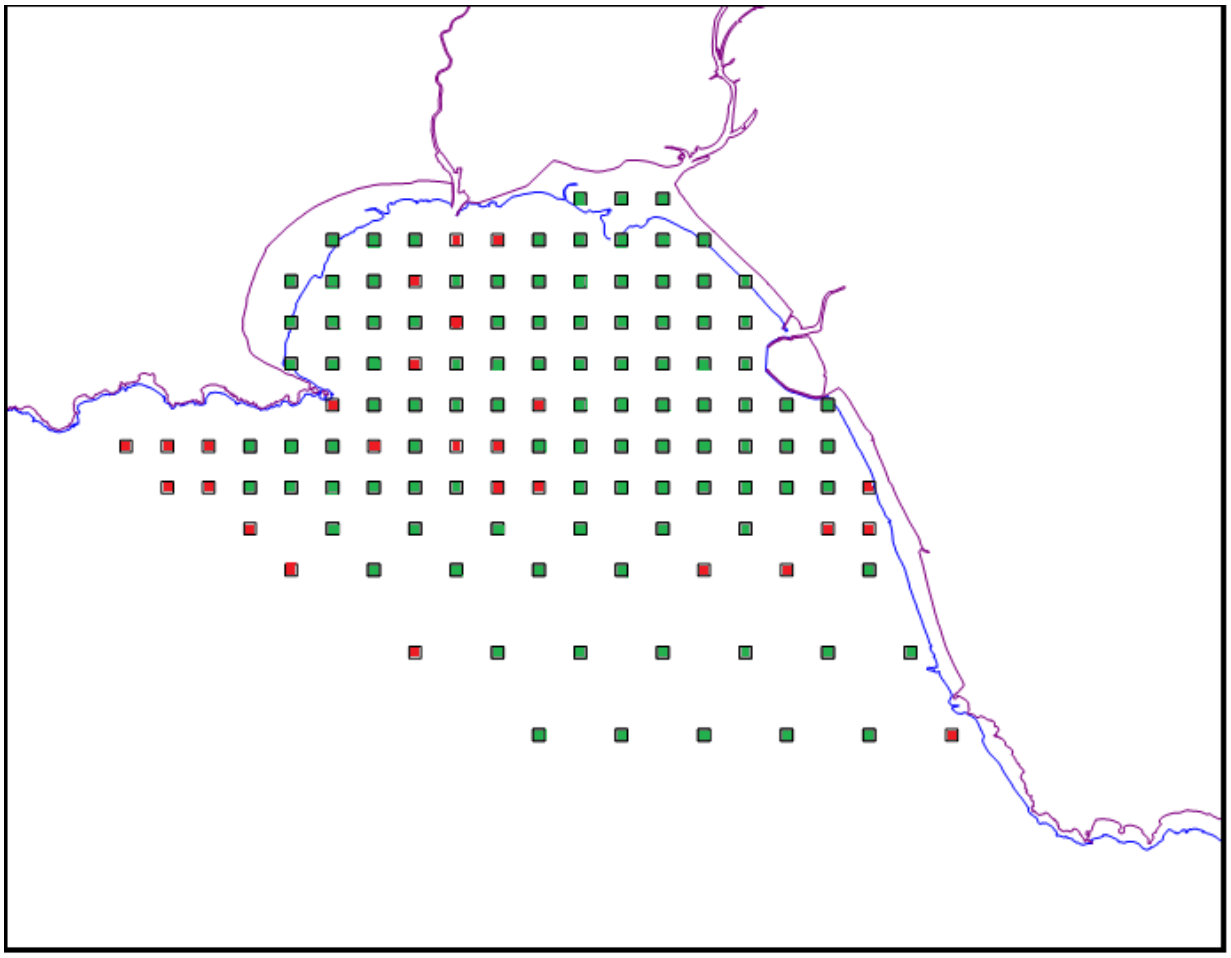
Figure 7.1 Location of the Benthic Sampling Sites and Faunal Groupings (see Appendix 2)

7.2.1.5 Further characterisation benthic sampling was undertaken by SEACAMS in collaboration with TLSB in May 2014. The sampling design was a 1km grid, where a single sample was taken at each position. There were two main reasons for this design.

- Currently there is a lack of data characterising the subtidal benthic community in Swansea Bay because few benthos studies have been undertaken over the past decade. The comprehensive grid will allow to identify spatial community patterns, without emphasis on any particular sampling point and without prioritising any particular area in Swansea Bay (although the area further off-shore was sampled more sparsely);

- The sampling design replicates a study by Welsh Water reported in 1988 (Conneely 1998). This will allow conclusions to be drawn on long-term changes in the benthos of Swansea Bay.

7.2.1.6 Around 128 sites were visited on a 1km grid layout across the bay as a whole and from these 102 single samples were successfully collected. A plan showing the survey locations is provided in Figure 7.2.



Swansea Bay, SEACAMS Day-Grab sampling, May 2014. Benthos and sediment samples; ■ grab sample taken, ■ sampling unsuccessful due to rocky substratum.

Figure 7.2 Location of SEACAMS benthic sampling locations (May 2014)

7.2.1.7 A 0.1m^2 Day-grab was used to collect one sample at each of the positions marked on the Figure 7.2. The ISO 16665:2014 "Water quality- Guidelines for quantitative sampling and sample processing of marine soft-bottom macrofauna" methodology was followed. This provides guidance on the quantitative collection and processing of subtidal soft-bottom macrofauna samples in marine waters. A sub-sample was taken, from each grab sample, for sediment analyses. The remaining grab sample was then washed through a 1mm sieve onboard the research vessel. The sieve remains were preserved in 4% formalin and transferred to 70% ethanol after two days.

7.2.1.8 The sediment samples have yet to be examined, but they will be analysed for grain size distribution and benthic fauna. The data will be analysed with the software package 'PRIMER' for community patterns, and links with abiotic parameters such as sediment properties and depth will be analysed with PERMANOVA. This will allow assessment as to the degree to which community patterns are driven and determined by abiotic parameters.

7.2.1.9 In addition to this benthic survey identified above, 2m beam trawl surveys, 200m across samples sites, has been undertaken at a 34 sites across the Bay. Again a simple grid system has been used as shown on Figure 7.3 below.

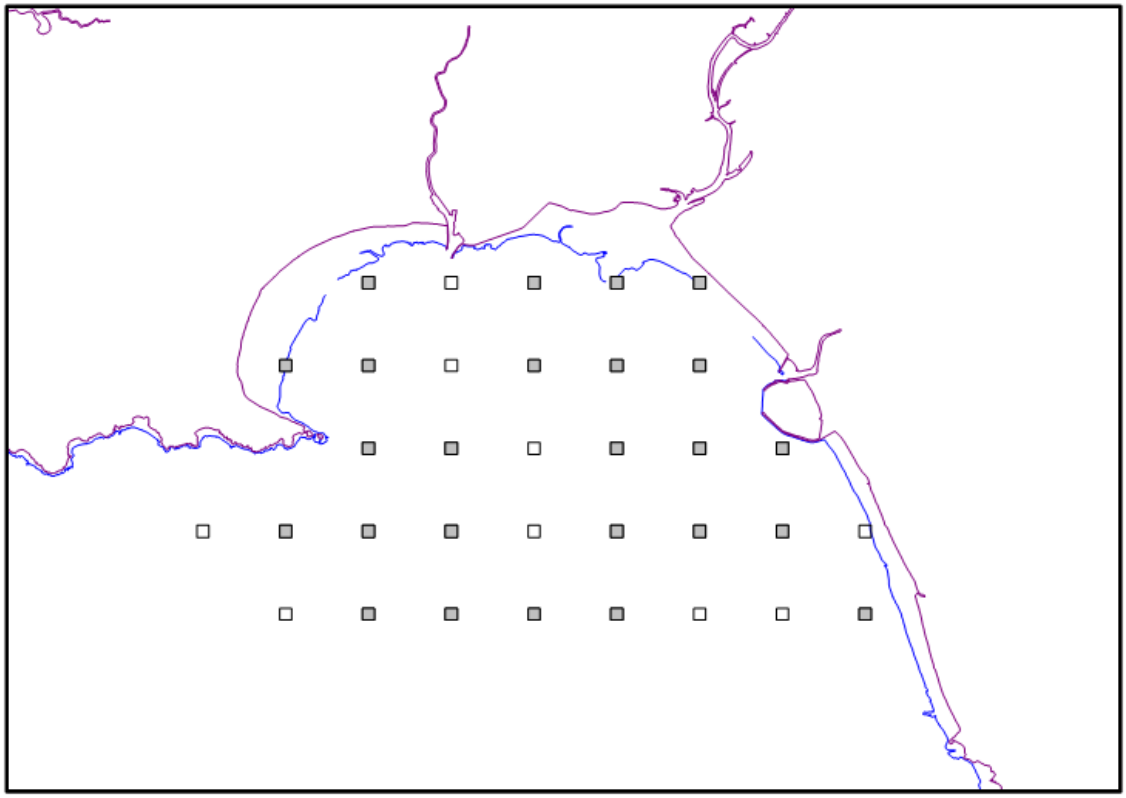


Figure 7.3 Location of SEACAMS beam trawl sampling locations (July 2014)

7.3 Marine Ecology Objectives

7.3.0 Introduction

7.3.0.1 This section examines the objectives in relation to the following aspects:

- ME1 - to maximise the colonisation opportunities associated with the lagoon seawalls.
- ME2 - to minimise the potential for colonisation of the seawall by invasive species.
- ME3 - to study to examine intertidal habitat extents and any changes in habitats in the lagoon and wider Bay.
- ME4 - to examine the changes in subtidal benthic ecology resulting from the Project.
- ME5 - To monitor the effect of the project on Sabellaria species within Swansea Bay and to monitor colonisation of the seawall by Sabellaria species
- ME6 - to maximise the potential for the reintroduction of the native oyster.

7.3.0.2 As identified in Chapter 23, Point 8.8 "Investigation of opportunities for encouragement of seagrass within lagoon, once lagoon operational," studies may be progressed once the lagoon is operational to determine the feasibility of introducing seagrass beds. Details of any studies would be included within the AEMP at an appropriate time once the lagoon

is operational, and it such consents as were necessary to deliver the seagrass beds would be sought from NRW and the relevant local planning authority.

7.3.1 Objective ME1 : To maximise the colonisation opportunities associated with the lagoon seawalls

7.3.1.1 The diversity of intertidal habitat within Swansea Bay is variable although habitat associated with Mumbles Pier is particularly species-rich. Oakley (2011) recorded 91 species in the intertidal area since 2004. Rocky habitat at Mumbles Pier has the potential to be replicated in the design of the lagoon walls. In addition to exposed rocky habitat on the exterior of the lagoon, the potential exists to replicate the natural mixture of rocky and soft shore habitat elements within the interior.

Table 7.1 ME1 objective summary – colonisation of the lagoon seawalls

Target	Maximise the value of intertidal habitat, particularly rocky shore habitat, for intertidal ecology. Monitor colonisation to help inform future schemes. Identification of design changes that would benefit intertidal biodiversity interest with most appropriate value.
WFD	Benthic invertebrate and macroalgae quality elements (coastal and transitional waterbodies).
Management/operation	Construction and physical presence of the operational lagoon.
Survey	*Potential to enhance the lagoon seawalls* **Survey 14** - intertidal ecology survey around Mumbles Head in order to differentiate habitat features, determine their contribution to biodiversity and identify potential for habitat replication on Lagoon walls. Findings of surveys will be assessed to determine where the seawall or other features within the lagoon could be enhanced to promote biodiversity. **Survey 15** -*Lagoon colonisation* Survey of completed sections of Lagoon wall (in spring and autumn) to be undertaken to assess initial colonisation. Representative transects (see figure 7.4) around the Lagoon wall with differing levels of exposure will be fixed as permanent monitoring sites. Species will be recorded within a 0.5m^2 quadrat at approximately 1m in intervals from the upper intertidal to lower tidal area. Transects will be monitored twice per year through construction (where H&S permit), then every two months for the first year of operation, once every three months for the second year and twice a year thereafter for the following 3 years. The need for and the frequency of continued monitoring will be reviewed through the AEMP process. In addition to transect species recording, a fixed point photographic record will be taken to provide a visual element to operational monitoring. It would be proposed that a transect would also be located in an area where a Bioblock has been located in order to examine the colonisation of these structures. Intertidal Bioblocks elsewhere will also be examined at the same time that the transect surveys are undertaken. Photographic recording of the intertidal Bioblocks will also be undertaken. In addition, some of the transects will also be positioned to assess the other enhancements measures including rockpools. (note the

	study to examine mitigation proposed for *Sabellaria spp* is covered under Objective ME5.)
Responsibility	TLSB
Objective	To assess enhancement measures and to use the data for as baseline research e.g. the use of Bioblocks and the colonisation of the artificial reef (seawalls) for future lagoon projects.
Limits of acceptable change	Not applicable - objectives are enhancement-related.
Further/ remedial action	Re-evaluate features of the lagoon wall design (based on findings of Survey 14) to accommodate changes benefiting biodiversity interest. Review any further opportunities to enhance ecological diversity post construction of the lagoon seawalls.

Survey 14 – Intertidal survey of Mumbles Head

7.3.1.2 Marine ecology surveys are currently ongoing (summer 2014) around Mumbles Head in order to differentiate habitat features, determine their contribution to biodiversity and identify potential for habitat replication on lagoon walls. Intertidal flora and fauna has been recorded by field survey or where necessary through laboratory analysis. Findings of the field surveys will be assessed to determine where the seawall or other features within the lagoon could be enhanced to promote biodiversity.

7.3.1.3 This study will also review existing literature available for the area. Although relevant for the subtidal area, the desk study review will include the Mumbles Pier Lifeboat Station Subtidal Survey report (Moore, J.J. (2003) Mumbles Lifeboat Station Subtidal Survey, May 2003). A report to Posford Haskoning Ltd from Coastal Assessment, Liaison and Monitoring. Cosheston, Pembs.

Survey 15 – Colonisation of Seawalls

7.3.1.4 Bi-annual walkover surveys of completed sections of lagoon walls will be undertaken in the spring and autumn to assess initial colonisation.

7.3.1.5 Twelve representative transects (see Figure 7.4) around the lagoon wall with differing levels of exposure will be fixed as permanent monitoring sites. The sites have been selected as pairs one inside and one outside the lagoon, with the ones outside the lagoon having varying levels of exposure. The transects will be used to examine the colonisation of the lagoon seawalls.

7.3.1.6 Species will be recorded at 1 metre intervals within a 0.5m^2 quadrat from the upper intertidal to lower tidal area. The presence and abundance of any invasive non native species (INNS) will also be recorded. Transects will be monitored twice per year through construction, where health and safety permits, then every two months for the first year of operation and every three months for the second year and twice a year thereafter for the following 3 years. The need for continued and the frequency of future monitoring will be reviewed through the AEMP process.

7.3.1.7 In addition to transect species data, a fixed point photographic record will be taken to provide a visual element to operational monitoring.

7.3.1.8 As an additional feature it is proposed to use Bioblocks to further enhance the ecological diversity of the lagoon seawall. Studies are ongoing in relation to the optimum size and location of the Bioblocks in conjunction with Cenin Cement. Details of the current proposals are provided in Appendix 2.

7.3.1.9 Additional monitoring of key features such as rockpools will also be undertaken during operation. In this way the surveys will be used to assess the success of methods used to enhance opportunities for ecological diversification, such as any findings of the above study at Mumbles.

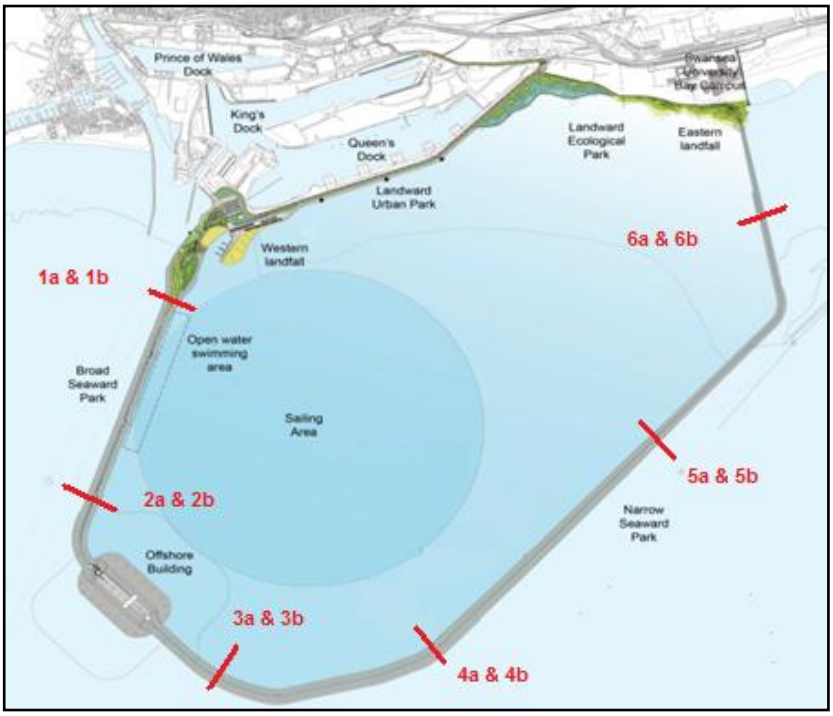


Figure 7.4 Intertidal fixed monitoring transect sites (site locations will be finalised following confirmation location of enhancement features including Bioblocks and rockpools)

7.3.2 Objective ME2 – Minimising the potential for colonisation of the seawall by invasive species

7.3.2.1 Chapter 8 Intertidal and Subtidal Benthic Ecology describes the baseline situation in relation to invasive species within Swansea Bay and assesses the potential effects of the Project. A biosecurity risk assessment is also being prepared and will be incorporated into the CEMP and OEMP which will be implemented. As identified in Table 3.1, the ELO and Lagoon Warden will assist with environmental risk assessments required as part of the CEMP and OEMP. Surveys to check for the presence of invasive species will be undertaken on the lagoon seawalls and a reporting system established in order that any species found to be present can be managed appropriately. The wardens will keep up-to-date with invasive species alerts from GBINNS. They will record and report any such occrrence of species such as carpet sea squirt *Didemnum vexillum*, and Quagga Mussel - Dreissena *rostriformis bugensis* also zebra mussel, wireweed, etc.

7.3.2.2 The potential for invasive species in the subtidal environment will also be considered (see below).

Table 7.2 ME2 objective summary – presence of invasive species

Target	Minimise the potential for colonisation and spread of invasive species.
WFD	Presence of invasive species affecting biological status of transitional and coastal waters
Management/operation	Construction and physical presence of the operational lagoon.
Survey	The establishment of invasive species will be monitored as part of the seawall survey (See Survey 15 above), the aerial biotope mapping (see ME3 below) and will be the focus of a more general annual walkover survey. Specific attention will be given to species such as Pacific Oyster or invasive seaweeds and horizon scanning for other species not currently recorded in Swansea Bay will be undertaken. This methodology will be updated and co-ordinated with the bio-security risk assessment that is being prepared for the construction and operational phases of the Project.
Responsibility	TLSB, contractor (invasive species)
Objective	To validate findings of ES, to assess effectiveness of INNS strategy and to reduce the risk of spread of INNS as a result of the Lagoon.
Limits of acceptable change	The establishment of a diverse ecological environment. To assess the extent of any opportunistic species e.g. opportunistic macro-algae.
Further/ remedial action	To review the requirement for any further monitoring of opportunistic species e.g. the presence of opportunistic algal mats. To review/updated INNS strategy, including relevant mitigation, in OEMP.

7.3.3 Objective ME3 – Study to examine intertidal habitat extents and any changes in habitats in the lagoon and wider Bay

7.3.3.1 Chapter 8 Intertidal and Subtidal Benthic Ecology and the revised WFD report examine the potential effects of the Project on intertidal habitats. Surveys will be undertaken to validate the predictions of the assessments.

Table 7.3 ME3 objective summary – mapping of habitat extents and changes in habitats

Target	Examine any intertidal habitat extents and any changes in habitats in the lagoon and wider Bay, including opportunistic macroalage.
WFD	Benthic invertebrate and macroalgae quality elements (coastal and transitional waterbodies)
Management/operation	Construction and physical presence of the operational lagoon.
Survey	The output from the high resolution aerial surveys (see Survey 4, Section 5) will be used to further examine intertidal habitats and substrates. This data will be used to update Phase 1 habitat maps and look for the presence of opportunistic macroalgae. Inter-tidal ground truthing surveys will be undertaken in areas of particular interest, with particular attention focused on protected habitats or species. The Phase 1 maps will updated in line with the aerial surveys namely once pre-construction (August 2014), at year 2 of construction; at years 1, 3 and 5 operation and then every 5 years.

	The frequency of the aerial surveys will be reviewed after 10 years. Additional intertidal walkover surveys will be undertaken associated with Sabellaria study (see ME5).
Responsibility	TLSB
Objective	To validate findings of ES and if necessary identify change outside that already predicted such that mitigation measures can be implemented (see CP1).
Limits of acceptable change	Beach systems are inherently dynamic and subject to periods of deposition and erosion and thus the supported habitats will also be subject to change. By analysis of historical data, both beach profile and habitat data, broader scale sediment changes/trends and habitat changes may be discernible. The findings of this study, will be assessed together with the results of the coastal bird studies (see Section 10), particularly sanderling and ringed plover which forage on intertidal habitats. Data from the studies will be made available for expert peer review and if a consensus of opinion suggests the lagoon has brought about adverse change this will trigger remedial action.
Further/ remedial action	Management strategies could include beach nourishment where erosion persists or measures to manage accretion (see Section 5, Table 5.1, where potential scenarios, some not predicted by the ES, are presented). Further intertidal monitoring may be required in areas where deterioration or loss of habitats are noted.

7.3.3.2 The output from the high resolution aerial surveys (see Survey 4, Section 5) will be used to further examine intertidal habitats (including sediments types, biotope mapping, habitat change and extent e.g. macroalgal coverage). This would include protected habitats and species within the intertidal areas. The *Sabellaria* monitoring data (ME5) will feed into the broader mapping of the Bay. The data gathered will be used to update Phase 1 habitat maps. More detail of the four stage mapping process is given below. This information will be compared to historical data and beach transects, and will be used to examine any changes in habitat types or extents.

Stage 1. Aerial survey (survey 4, section 5)

7.3.3.3 The initial visualisation and assessment of sub-features (or biotopes) will use aerial imagery of the entire area (100% coverage) as described for survey 4, section 5. Preliminary biotope boundaries will be assigned to visually distinct features on the georeferenced photographs. This phase will provide location of broad scale soft (mainly sand and muds) and hard (rock and artificial structures) substratum types, together with many of the biotope complexes and biological communities. Previous biotope maps will be compared with this initial map and potential biotope identity annotated on the newly created maps. These maps will be amended following the biotope field verification survey.

Stage 2. Biotope verification planning

7.3.3.4 A stratified survey approach for the biotope verification work will be undertaken. In this method, the preliminary biotope maps are used to assist with the location of search areas that contain the greatest diversity of biotopes. Given the size of the area, considering the range of biotopes identified in previous surveys undertaken for the ES,

three, 4km-long[10], search areas will effectively provide the level of field verification required to inform the 100% coverage maps produced through aerial imagery. This approach requires some level of interpretation for areas outside the verified locations which will have comparatively lower biotope resolution. However, during survey planning, coverage and resolution will be optimised to provide a robust mapping output.

7.3.3.5 Biotope boundaries apparent on the images will be digitised and printed on waterproof paper to produce wire frame maps for use in the field.

Stage 3. Phase I biotope survey

7.3.3.6 The Phase I biotope verification and mapping survey will be conducted at each of the three pre-identified areas. The Phase I survey will be undertaken by moving along the shore, using vertical and horizontal transects as appropriate, so as to establish boundaries of all biotopes present using a handheld dGPS. New wireframe maps (derived from the aerial imagery), and previous biotope maps (from ES chapter 8), will be taken into the field to identify biotope similarities/differences when compared to the current biotope distributions.

7.3.3.7 For the identification of biotopes and biotope complexes within littoral rock habitat, macroalgae and invertebrates will be identified *in situ*, and biotopes allocated to EUNIS level 5 (or 6, where possible). Where not coincident with the wireframe map, the boundary of each biotope will be recorded using GPS and its distribution sketched. A parallel approach will be undertaken for areas of soft sediment. In these areas visual inspection of sediments will be undertaken along transects. Any noticeable changes in sediment type or surface features will be recorded, and a GPS reading for each boundary taken. At selected locations, sediment will be dug and sieved to assess the biota present. Classifications will be to the highest possible level. Target notes will be made to record small-scale features and anthropogenic impacts. Photographs will be taken of all target noted features and of all biotopes and conspicuous biota recorded.

Stage 4. Biotope map production

7.3.3.8 The biotope boundaries produced following aerial imagery will then be amended within ArcGIS, using the GPS readings and hand drawn maps produced during the Stage 3 survey, to make use of all available data to produce the biotope map. The maps will also be reproduced as 4km^2 maps for the report.

7.3.3.9 A review of the Phase 1 mapping will be linked into the aerial surveys. These will be undertaken in late summer/autumn once pre-construction, at year 2 of construction; at years 1, 3 and 5 during operation and then every 5 years. The frequency of the aerial surveys will be reviewed after 10 years.

7.3.4 Objective ME4: To examine changes in subtidal ecology resulting from the Project

7.3.4.1 The construction and operation of the Project will result in changes to the subtidal benthic environment, particularly within the lagoon. Ongoing subtidal benthic surveys are proposed and the findings will be analysed together with the results of the coastal processes studies (including the aerial surveys) to examine the effects of the Project.

[10] 4km is the standard shore length covered by a team of two field surveyors conducting a Phase I survey in one day (usually one low tide period).

Surveys are proposed in the wider Bay and also in the subtidal environment in the vicinity of the seawalls.

Table 7.4 ME4 objective summary – Subtidal environment

Target	To clarify and describe pre-construction conditions and monitor any changes brought about by the Project.
WFD	Benthic invertebrate quality element (coastal and transitional waters) Fish quality element (transitional waters)
Management/operation	Construction and physical presence of the operational lagoon.
Survey	Analysis of the 2014 SEACAMS survey data for benthic fauna and PSA. Subject to discussions with NRW(A), and based on the findings from the surveys undertaken by SEACAMS, further analysis of replicates collected by Titan in 2013 at up to 20 sample locations may also be undertaken to inform the subsequent monitoring of the Project. **Survey 17** – Subtidal benthic monitoring of the wider Bay area and lagoon area will be undertaken at approximately 20 sites (3 replicates). Surveys will be repeated in year one and year five operation. At year 10 operation the 2014 SEACAMS survey would be repeated. The need for further surveys will be considered in the relevant annual report. **Survey 18 –** Epifauna trawls will be undertaken to compliment the benthic sampling programme. Trawls will be undertaken at six sites, two within the lagoon and four outside the lagoon. The surveys will be repeated at Yr1, 5 and 10 operation. **Survey 19** – Targeted survey using divers/drop down underwater cameras (either stationary or via a boat) will be used to monitor submerged sections of completed Lagoon walls. The aim will be to identify motile fauna particularly, *crustacea* and fish. The effectiveness of this methodology will be evaluated and if successful will be repeated in years 3 and 5 of the operational scheme.
Responsibility	TLSB
Objective	To validate findings of ES and if necessary identify change outside that already predicted.
Limits of acceptable change	The establishment of invasive species would trigger remedial action.
Further / remedial action	Any records of invasive species and particularly those not already present in Swansea Bay will be immediately reported to the statutory authorities and where necessary control mechanisms instigated or potential control mechanisms investigated further.

Survey 17 Subtidal Benthic Survey wider bay and Lagoon

7.3.4.2 As identified above, additional sub-tidal benthic sampling has been undertaken within Swansea Bay in 2014. As yet, the samples have yet to be analysed for benthic fauna and sediment particle size. The findings of this additional survey, together with the results of the characterisation survey completed in 2013 and the predicted extent of potential effect resulting from changes in tidal flows modelled as part of the coastal processes assessment (predicted difference in mean spring tidal flow (relative change) shown in Figure 7.5) will be used to refine the ongoing survey methodology. Note, in addition to the benthic surveys commissioned by TLSB and SEACAMS, as described in section 7.2,

NRW(A) undertook benthic sampling in summer 2014 to assess Swansea Bay Waterbody with respect to the WFD assessment. Where possible, the extent and methodology of the following surveys will be reviewed and discussed with NRW(A) taking into consideration the sampling sites and methods used by NRW in 2014, such that appropriate benthic survey programme is developed.

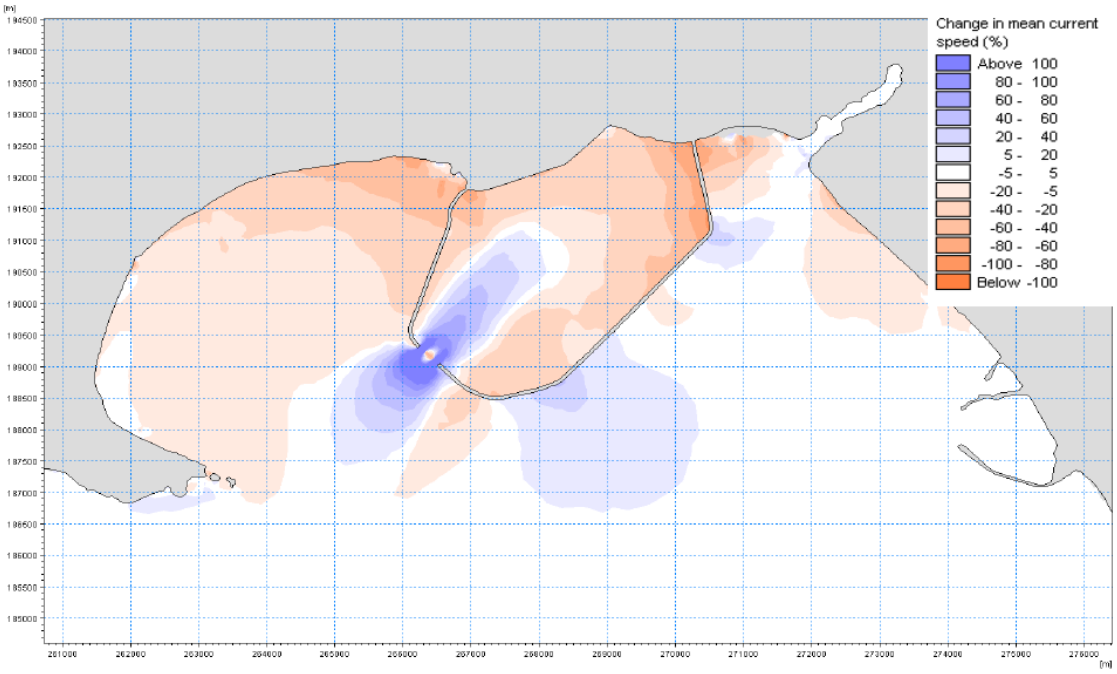


Figure 7.5 Predicted difference in mean spring tidal flow (relative change)

7.3.4.3 Following construction of the Project, the impacts of the development on the benthic habitats and species. Data collection at this phase of monitoring should contribute to an assessment of the accuracy of predictions made in the EIA and WFD. The key questions to be answered by this benthic monitoring programme (Impact monitoring (IM)) are presented below. This table also presents the questions answered by the characterisation surveys undertaken to date for the EIA and WFD processes.

Stage of Project	Key Question
EIA	Are there any benthic habitats or species of note present (i.e. priority, rare, protected, invasive, etc.)
EIA	What is the spatial distribution of these species or habitats?
EIA/WFD	How will these habitats or species likely to be affected by the Project?
EIA	What would be the significance or implications of any damage or loss incurred?
WFD	Will this damage or loss result in a deterioration in status or the non-achievement in achieving future objectives in relation to the benthic invertebrate quality element of the WFD?
IM	Is there a significant change in the broad benthic community structure that can be attributed to the Project?
IM	Is there a significant change in abundance of dominant or characterising benthic species that can be attributed to the Project?

IM	Has the Project significantly modified the flow dynamics, scour patterns or turbulence character of the area in such a way to have caused a change in benthic community structure?
IM	Where appropriate, e.g. within the lagoon footprint, what is the nature and rate of recolonisation by benthic invertebrates post construction dredging and subsequently, between maintenance dredging events.

7.3.4.4 An initial survey protocol (impact monitoring (IM)) has been provided below but this will be confirmed on the basis of this further baseline characterisation study, relevant guidance including the UKTAG (2014b), ISO 16665:2014, the CEFAS (2011) Guidelines for the Conduct of Benthic Studies at Marine Aggregate Extraction Sites: 2nd Edition, and discussions with NRW and CEFAS. The IM will be designed considering the following:

- to examine the localised effects of the positions of the components of the Project;
- the total predicted area of impact based on the findings presented in the EIA, Figure 7.5 above and Figures 6.50 – 6.52 of the ES illustrating potential sediment deposition;
- The location of any special interest features identified during the characterisation surveys; and
- Other factors such as predominant tidal flow, substrate types, and cumulative effects of other projects in the area (such as ongoing dredging within the navigation channels).

7.3.4.5 The IM will also include reference sites (out of the influence of the Project), with similar substrates, communities and depths to sites affected by the Project.

7.3.4.6 It is proposed to re-sample for subtidal benthic ecology at 20 sites (3 replicates) within the lagoon and wider bay at year 1 and year 5 post operation.

7.3.4.7 Based on the results of the EIA, twenty sites have been selected where replicate analysis will be undertaken and these are shown in Table 7.5. Site 1, 42 and 57 are proposed as a control sites and are located outside the influence of the Project. As such they will therefore fulfil the 'control' requirement in the Before After Control Impact (BACI) approach.

Table 7.5 Benthic Sampling locations

Proposed Sites for Ongoing Monitoring Site	Selection	Sediment Type observed	Faunal Group (identified during Benthic Survey 2012)	Infauna	PSA	Metals
1	Outside Tidal Influence	Gravelly Sand	A	Y	Y	
4	Within Tidal Influence	Sand	E	Y	Y	Y
6	Within Tidal Influence		C	Y	Y	
10	Within Tidal Influence	Sand	D	Y	Y	Y
11	Within Tidal Influence	Sand	C	Y	Y	Y
12	Within Tidal Influence	Sand and Gravel	E	Y	Y	Y
15	Inside Lagoon	Gravelly Sand	A	Y	Y	Y
16	Within Tidal Influence	Gravelly Sand	A	Y	Y	
18	Inside Lagoon	Gravelly Sand	A	Y	Y	
19	Inside Lagoon	Gravelly Sand	A	Y	Y	
21	Within Tidal Influence	Gravelly Sand	A	Y	Y	
22	Inside Lagoon	Muddy sand	B	Y	Y	
27	Inside Lagoon	Muddy Sand	B	Y	Y	Y
32	Inside Lagoon	Muddy Sand	B	Y	Y	Y
35	Within Tidal Influence	Sand	F	Y	Y	Y
38	Inside Lagoon	Sand	C	Y	Y	
41	Within Tidal Influence	Sand	B	Y	Y	
42	Outside Tidal Influence	Sand	B	Y	Y	Y
55	Within Tidal Influence	Sand	A	Y	Y	
57	Outside Tidal Influence	Sand	B	Y	Y	Y

7.3.4.8 Benthic sampling will be undertaken using the following survey methodology:

Sampling Procedures

7.3.4.9 It is proposed that a single benthic grab sample would be collected from each site using a refined compact 0.1m^2 Hamon grab with stainless steel head (Figure 7.6). Using a stainless steel head, the grab will be suitable for collecting samples for metal and chemical analysis.

7.3.4.10 In terms of the mini Hamon, Titan has refined the standard mini Hamon grab design to provide a compact 0.1m² sampler unit. Its single shovel action makes this unit the ideal sampler for coarse sediments and is routinely used in areas where the standard Day grab is deemed unsuitable. The mini-Hamon grab consists of a rectangular frame forming a stable support for a sampling bucket attached to a pivoted arm. On reaching the seabed, tension in the wire is released which activates the grab; the pivoted arm is rotated through 90°, driving the stainless-steel sample bucket through the sediment. At the end of its movement, the sample locates onto an inclined rubber-covered steel plate, sealing it completely and preventing the sample washing out during recovery.

Figure 7.6 Mini Hamon grab

7.3.4.11 There replicate samples for infaunal analysis will be collected from each site listed in table 7.5. The minimum acceptance volume for hard-packed sand will be 2.5L and for muddy sands /muds 5L. Samples will be rejected where jaws are not completely closed, as this would result in a loss of material when it is brought to site. Once the sample is brought to the surface, the grab will be opened and the sample photographed. Comprehensive notes will be taken on the nature of sediment and any obvious larger epifauna recovered within the grab together with detailed logs of sampling coordinates, times and all onboard activities/observations.

7.3.4.12 A 3cm Perspex corer will be used to collect a sub sample from one of the grabs which would be analysed for Particle Size Analysis (PSA). A metal subsample will also be removed from one of the grab samples where appropriate. The remainder of the three samples will be sieved though a 1mm mesh and the residue stored in separate containers in buffer formalin. The samples will be transported to the labs for benthic analysis.

7.3.4.13 A salinity sample will also be taken at each sampling location at the same time as the grab samples.

Analytical Methodology

Macro-invertebrate analysis of benthic samples

7.3.4.14 Samples will be rinsed with freshwater prior to sorting and identification. Sieve residues are initially elutriated with fresh water to extract the majority of "light" organisms, notably amphipods and small polychaetes (care being taken to retain all specimens adhering to the surface film). Subsequent sample examination of the residue is under x10 magnification (binocular microscope) where necessary. Routine procedures require the resorting of at least 10% of samples, with the aim of extraction of ≥95% of individuals and 100% of species in each sample.

7.3.4.15 All animal specimens are identified to species where possible using experience, the latest identification keys (in litt. or otherwise if more recent) and with reference to existing voucher material held at the laboratory, attributing names as in accord with the most recent publications available (e.g. Howson & Picton, 1997 for the British Marine Fauna and Flora) except where such publications have been superseded. Relevant experts in certain taxonomic groups are consulted for any difficult specimens. Specimens are counted as "heads", or as oral disks for ophiuroids/asteroids. Voucher material is retained if required.

7.3.4.16 Animal specimens and sample residues (as required) are retained in formaldehyde or alcohol. Should staining (for example with Rose Bengal to enhance specimen extraction efficiency), or sub-sampling be considered efficacious, such practices would be discussed in the first instance with the client and only undertaken with their agreement.

Sediment Particle Size Analysis

7.3.4.17 A sub-sample would be taken from the mini Hamon sample for particle size and organic content analysis (loss on ignition). In coarse or heterogeneous sediment areas with large pebbles or shell material, where small volumes of material will not adequately reflect the sediment composition, sub-samples for PSA will be taken from the grab sample. Samples for PSA will be stored chilled, but not frozen, as this would break down any clay mineral lattice bonds present altering the natural particle size distribution. Samples will then be delivered to a specialist laboratory with proven expertise in such analysis on marine sediment samples.

7.3.4.18 Particle size analysis is undertaken using traditional sieve analysis – with pipette analysis of fines where these are present in significant amounts (the <63 micron fraction only analysed if <10% present in the sample). Samples are analysed at ½ phi intervals and results reported together with all traditional statistical parameters (median diameter, sorting coefficient, skewness and kurtosis).

Metals analysis

7.3.4.19 It is proposed to undertake the following analysis at sites listed in Table 7.5.

- Al – Aluminium
- B – Barium
- Cd – Cadmium
- Cr – Chromium
- Fe – Iron
- Hg – Mercury
- Ni – Nickel
- Pb – Lead
- Sn – Tin
- V – Vanadium
- Zn – Zinc
- TPH – Total Petroleum Hydrocarbons
- PSA – particle size analysis
- LoI – loss of ignition
- TBT – Tributyl Tin

7.3.4.20 At year 10 post construction, a full survey based on the 2014 sample points (see Figure 7.2) would be undertaken, with analysis for benthic fauna and PSA at all sites, with metal analysis at 30 sites. The requirement for ongoing subtidal benthic surveys would be reviewed at this time.

7.3.4.21 It is proposed that the samples will be based on the grid system surveyed in 2014 (see above), although a number of samples may be focused around areas of particular interest and re-positioned once the lagoon construction has been completed.

Statistical Analysis

7.3.4.22 As detailed in the Titan (2013) benthic ecology survey report, statistical analysis was carried out on the data collected. This involved the use of community level analyses, incorporating the whole assemblage present in a habitat, which is widely considered to provide a more statistically credible measure of an ecosystem response to an anthropogenic impact when compared to simple species abundance counts (Scottish Natural Heritage, 2011). The method used to analyse data from ongoing studies will be based on the requirements of UKTAG (2014b) and the characterisation data sets and the need to provide a statistically credible evaluation of the effects of the Project.

Survey 18 – Epifauna Trawls

7.3.4.23 In addition to the benthic sampling survey, six epifauna/fish trawls will be used to obtain qualitative samples of the epibenthos from across the area. Two trawls are planned to be taken within the lagoon with a further four in the wider area of Swansea Bay. The epifauna trawls will comprise approximately 200m trawls using a 2m beam trawl with 5mm cod end mesh. The material collected in the trawl to be fixed in a 10% buffered formalin and seawater solution.

7.3.4.24 Each trawl will be chosen to represent the major sediments and therefore biotypes within the development area. They have initially been positioned adjacent to a benthic sampling site such that more detailed information is obtained at each location. In addition, it is proposed to undertake three trawls in the wider area of the development area. Again these trawls have been positioned next to a benthic sampling site. The sites where the epifauna trawls have provisionally been placed are: Sites 1, 4, 12, 21, 27, 32 and 42.

7.3.4.25 The locations of the beam trawls will be confirmed after the benthic grab survey has been undertaken. The initial inspection of the benthic samples onboard will be used to confirm that there are no-protected species present at the sites.

Survey 19 – Colonisation of the subtidal environment of the lagoon seawalls

7.3.4.26 Targeted survey using divers and/or drop down underwater cameras (either stationary or via a boat, where possible using a freshwater lens) will be used to monitor submerged sections of completed lagoon walls. The aim will be to identify the presence of *Sabellaria alveolata* and *Sabellaria spinulosa* and also motile fauna particularly, crustacea and fish. The effectiveness of this methodology will be evaluated and if successful will be repeated in years 3 and 5 of the operational Project. Further surveys focusing on fish are outlined in Section 8.

7.3.5 Objective ME5: To monitor the effect of the project on Sabellaria species within the Bay and to monitor colonisation of the seawall by Sabellaria species

7.3.5.1 One of the key issues for the lagoon in terms of intertidal and subtidal ecology is the direct loss of biogenic reefs that are built by tube-worms of the genus *Sabellaria*. Further information about the presence of *Sabellaria alveolata* and *Sabellaria spinulosa* is contained within the Swansea Lagoon Benthic Data Report (Titan, 2013). The sampling methodology for the benthic survey undertaken in May 2014 is described in Section 7.2.2 (benthic sediment sampling).

7.3.5.2 Figure 7.7 (taken from the Titan Report) illustrates the location of *Sabellaria alveolata* within the intertidal environment in the vicinity of the Project based on the Phase 1 habitat mapping undertaken for the ES, and the number of individual worms found in the benthic samples collected during the May boat survey. Figure 7.8 illustrates the location of *Sabellaria spinulosa* found during the same surveys. The results of the analysis of the May 2014 subtidal sampling undertaken by SEACAMS will also provide information as to the location of *Sabellaria spinulosa* within the Bay (See Section 7.2.2).

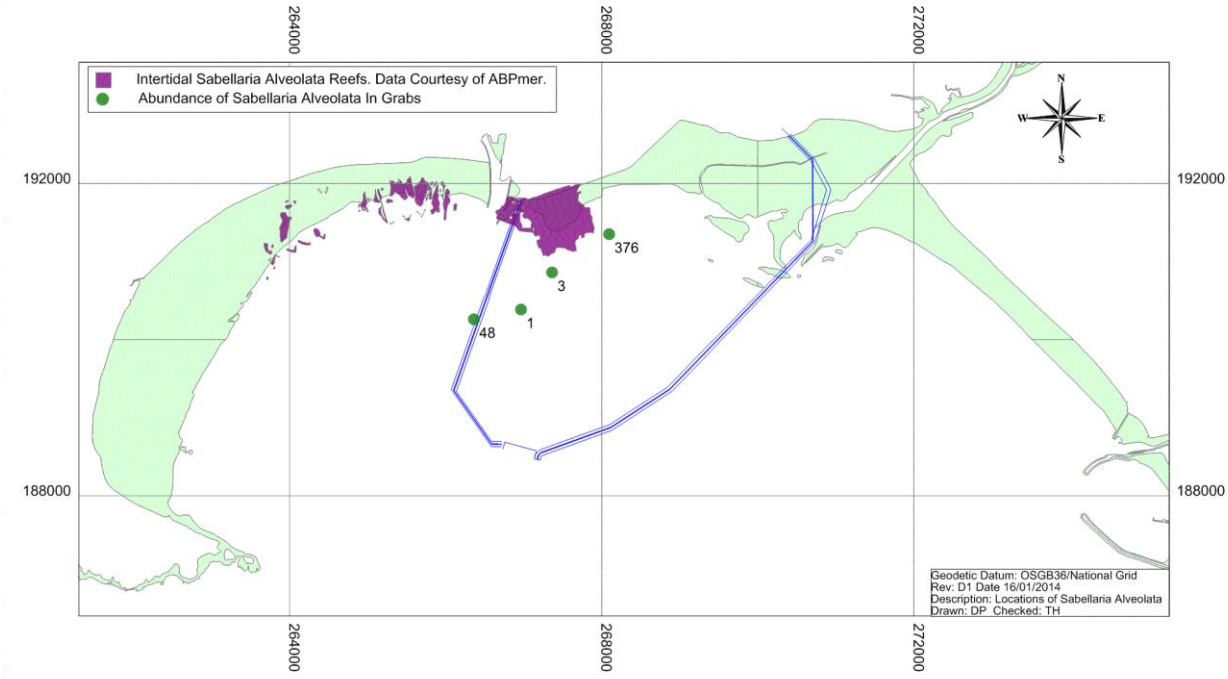


Figure 7.7 Location of *Sabellaria alveolata* found at both the subtidal and intertidal surveys (Titan Environmental Surveys Ltd, 2013)

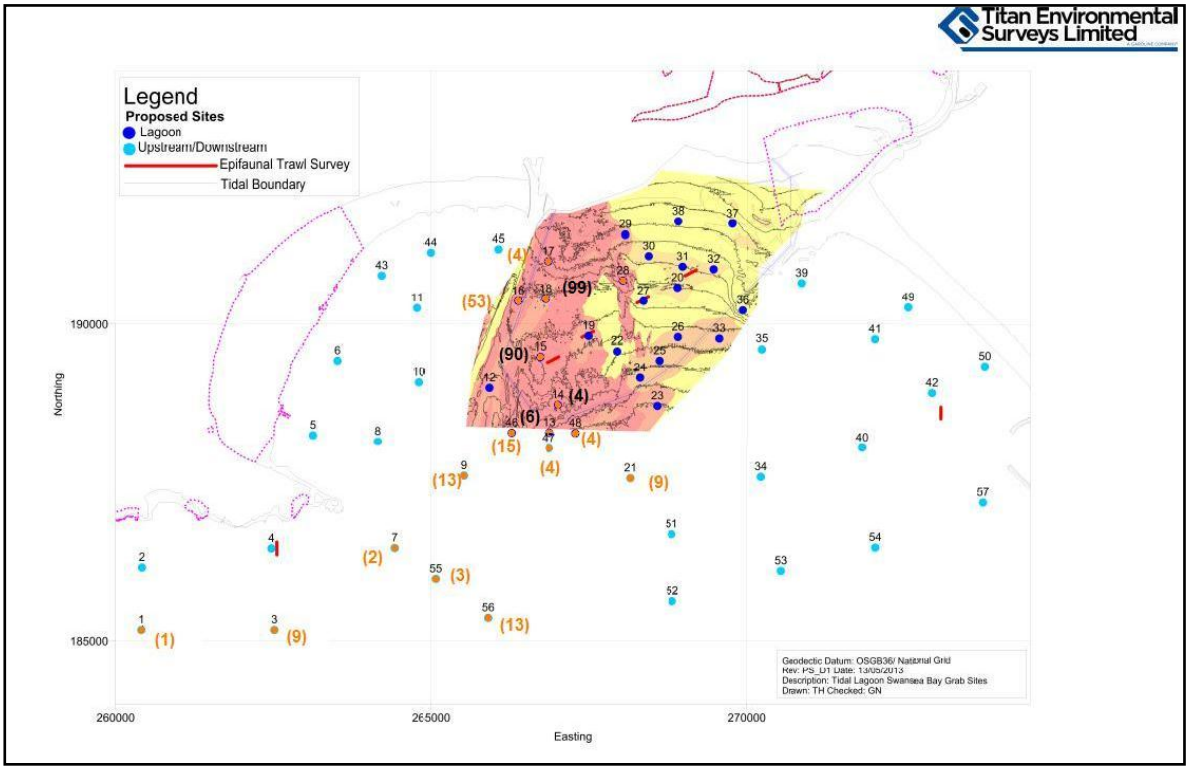


Figure 7.8 Location of *Sabellaria spinosa* found at the subtidal (data taken from Titan Environmental Surveys Ltd, 2013) (Sample numbers are annotated in heavy black (within the lagoon footprint) and orange (outside the lagoon footprint) text

Sabellaria alveolata

7.3.5.3 As identified in the ES Chapter 8, Sections 8.5.8 and 8.5.9 the construction of the Western landfall will have a direct impact on a *Sabellaria alveolata* population which is located at the Port beach at the east of the mouth of the River Tawe. Translocation of Sabellaria is proposed to reduce the impact (see Section 8.7 of the ES). Translocation of Sabellaria alveolata is not a mitigation technique previously used or trailed. As such, on a precautionary basis, residual effects would be assessed as major adverse.

7.3.5.4 Environmental conditions in which *Sabellaria* are found, and plausibility for translocation, is discussed in a report undertaken by SEACAMs, "Artificial Structures in Coastal Habitats: Optimising the value for biodiversity by creating an artificial reef", included as Appendix 8.3. Paragraph 6.2.3.2 states "*The tube worm is generally found in lower intertidal and shallow subtidal areas with relatively strong water movement. Initially larvae of S.alveolata settle on firm substrate such as rock, pebbles or bivalve shells. They construct firm tubes by cementing sand grains together, and the first step to a reef is generally a veneer of tube aggregations covering the settlement substrate. The firm worm-tubes then provide settlement substrate themselves for future generations, creating a self-promoting, sustainable system, which can result in substantial reefs.*"

7.3.5.5 Paragraph 6.2.3.4 goes on to say *"Like other coastal invertebrates Sabellaria alveolata has specific habitat requirements such as food supply and a preferred current regime, and subtle changes may render a location unsuitable. However, if substantial blocks of reef could be moved to areas in Swansea Bay which are already colonised, and which are in*

the vicinity of the original location, then successful re-location is plausible. Further, if the worms themselves would not survive the move, the rigid tube structures are generally robust and would survive at least for some weeks or even months, depending on the exposure to hydrodynamic forces. The worm-free tube aggregations would still allow colonisation by other invertebrates, and they would promote biodiversity. The tubes would also enable juvenile Sabellaria larvae to settle and rejuvenate the reef."

7.3.5.6 The success of translocating *Sabellaria alveolata* is currently being investigated by a MSc project supervised by staff of the SEACAMS project (Swansea University) in a partnership with TLSB. A trial translocation was undertaken on the 6 June 2014 to help identify a suitable receptor site and locations for placement, and to gain a preliminary understanding of the potential success of any proposed translocation programme.

7.3.5.7 An outline of the trial study and the key findings of the results are provided below. The results have shown the translocation to be successful. The detailed findings of the pilot study now form part of a MSc project which will be reported in October 2014, and pre-construction translocation on a larger scale will be refined based on these findings.

Table 7.6 ME5 objective Summary of *Sabellaria alveolata* translocation

Target	To identify areas of healthy reef within the Lagoon footprint and to implement a translocation programme.
WFD	Benthic invertebrate quality element (coastal and transitional waterbodies)
Management/operation	Construction and physical presence of the operational lagoon.
Survey	• Preconstruction - Detailed review of trial translocation study undertaken between June and September 2014. • An assessment of the formations and health of the Port reef prior to construction of the Lagoon and identification reef suitable for translocation. • Identification of potential locations of receptor sites for a sub-sample of Sabellaria reef affected by the Project footprint using updated biotope maps (Objective ME3). These will be agreed in discussion with NRW and the relevant Local Planning Authorities. • Translocation of a selection of healthy reef blocks prior to the start of construction. • Areas of Sabellaria not identified for translocation to be stored (within the red line area, but in an appropriate location so that it does not interfere with the works) and relocated onto the foot of the Lagoon wall, to help re-colonisation within that area. • Construction - Monitoring and assessment of the health of receptor reefs and translocated samples following guidelines by Cumbrian Wildlife trust. Surveys will be carried out bi-annually during the construction phase (**Survey 20**). • Once operational general monitoring of Sabellaria reefs will be undertaken as part of the intertidal survey mapping linked with the high resolution aerial surveys (**Survey 4 and Survey 16**). In addition to this in year one operation and again year 5 the health of the intertidal reef will be assessed (**Survey 20**). • The objective of operation monitoring will be to assess the extent and quality of Sabellaria reef within Swansea Bay,

	within the Lagoon, on Lagoon walls, and at translocation sites.
Responsibility	TLSB and SEACAMS
Objective	To validate findings of ES and to provide a research basis for future projects.
Limits of acceptable change	Not applicable for pre-construction translocation trial. If a deterioration in the monitored reefs is noted from analysis, the findings will be discussed with NRW and an appropriate remedial strategy implemented if feasible.
Further / remedial action	The findings of the pre-construction translocation trial will be used to inform the likelihood of any success of future translocation programmes. If deterioration of reefs at the translocation site is identified, the frequency of the surveys will be increased to quarterly during the construction phase. The findings of the surveys will be discussed with NRW and any feasible mitigation measures will be identified and implemented in the form of a 'Sabellaria Impact Mitigation Protocol'. Through this monitoring the success of the translocation of Sabellaria to receptor sites will be determined. The results of the monitoring will be discussed with NRW and through the adaptive nature of the plan, the need for further action, or not, will be agreed. Four potential outline management actions are indentified below pending discussion of the results of the monitoring. 1) If the translocation of Sabellaria is successful (as with pilot study) then it would be more beneficial to the species to leave it in situ at its new location. In this was disturbance is minimised and the extended colony is preserved. 2) If the translocation was unsuccessful, but the adjacent reef remained in its previous state, the rocks with remnant translocated Sabellaria would be left in place, to allow potential recolonisation in the future. 3) If the translocation was successful but the adjacent receptor reef showed detrimental effect from the presence of the donor material then translocation back to the lagoon area would be discussed with NRW. 4) If the translocation was unsuccessful and the adjacent receptor reef showed detrimental effect from the presence of the donor material then the translocation material would be removed. In terms of the remaining rocky material directly impact by the Lagoon footprint, which is not translocated prior to construction, this will be used to provide additional range/diversity of habitat at the foot of the lagoon wall (this will also act as additional herring spawning material above that of the lagoon wall itself).

7.3.5.8 The main objectives of the pilot study were:

a) to develop a method of relocating Sabellaria alveolata reef blocks;

b) to assess whether relocation has a detrimental effect on the survival of the tube worms; and
c) to assess whether the handling of reef blocks itself (without relocation) has a detrimental effect on the reef and its populations.

7.3.5.9 *Sabellaria alveolata* reef blocks were selected from a donor site within the proposed Lagoon footprint adjacent to the existing eastern breakwater of the Port of Swansea (shown by a red star on Figure 7.9). These blocks were identified for relocation to a receptor site Sabellaria *alveolata* reef located west of the River Tawe opposite Swansea City Civic Centre (shown by a yellow star on Figure 7.9).

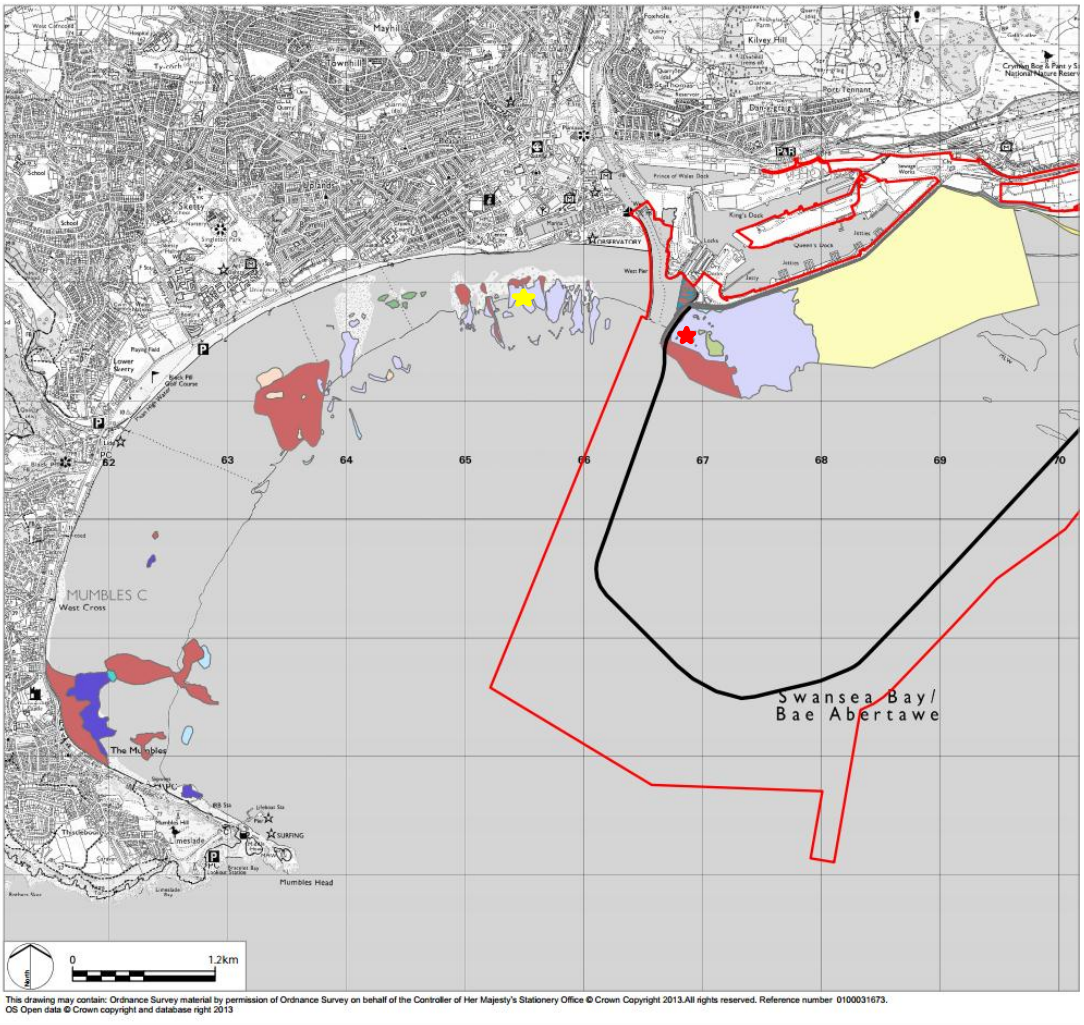


Figure 7.9: Areas of S. *alveolata* are marked in lilac. Red star marks the area of selection for translocation samples. Yellow star marks the area S. *alveolata* samples were translocated to.

7.3.5.10 For the pilot translocation study, 20 block samples were selected at random at the east of the River Tawe, which lies within the footprint of the Project. The block sample selection was based on the following criteria:

1. The samples were on approximately 30cm square sized boulders to represent the type of environment at the yellow star receptor site in Swansea Bay.

2. The samples were easily moved and transportable.
3. The *Sabellaria alveolata* tube colony on the boulders was large enough (approx 20cm-30cm square) in order to take 10x10cm corer samples.

7.3.5.11 A method was developed that allowed relocation of the *Sabellaria alveolata* reef blocks by boat within a 24 hour period. Nine of the samples were moved from the donor site east of the River Tawe (adjacent to the existing eastern breakwater) to the receptor site west of the River Tawe. A further 10 samples were used as controls to assess the effect of handling of reef blocks. These blocks were treated in the same manner as those which were moved so as to mimic the relocation process. However, the control samples remained at the donor site. The samples were visited 5 weeks after relocation or handling.

7.3.5.12 The study also looked at the formations and health of the reefs at the donor site and the receptor site, to provide a baseline of the existing reef condition. This provides a snap shot of each of the reefs at each site, but allows an understanding of the differences of the reefs at the donor and receptor sites.

7.3.5.13 The assessment of existing reefs was carried out in accordance to guidelines by the Cumbrian Wildlife Trust (Egerton 2014). Quadrats measuring 50cm^2 were placed randomly on top of reef blocks. The percentage cover of *Sabellaria alveolata* and formation of the reef was recorded within the quadrat area. Reef formation was recorded according to the descriptions set out by Gruet (1984) cited in Egerton 2014, shown below.

Formation	**Description**
Patchy	Small crusts or mounds which are less than 30cm^2
Hummock	Raised mound which are greater than 30cm^2
Sheet	Flat crust which are greater than 30cm^2
Reef	Large mounds which are greater than 1m^2

7.3.5.14 The percentage of the type of cover was also recorded. A photographic guide used by Edgerton (2014), was used to standardise and increase accuracy of the assessment (see following page). Categories included ‘crisp apertures’, ‘worn apertures’, ‘dead’ and newly settled’.

Formation Type

Patchy	Sheet	Hummock	Reef
			
Small crusts or mounds which are less than 30 cm^2	Flat crust which are greater than 30 cm^2	Raised mound which are greater than 30 cm^2	Large mounds which are greater than 1 m^2

Health Categories

Dead	Worn Apertures	Crisp Apertures	Newly Settled
			
Tubes have merged into a block of sediment. If a piece of reef is detached from the substratum.	There has been no clear new growth/ tube building. The apertures can still be seen. The tubes are still attached to the substratum.	New growth of tubes can be seen, the apertures are crisp and will have a fine wall. Tend to be a lighter sandy colour compared with worn reef.	Very small apertures between 1 mm and 4 mm. Usually found around the larger, older apertures as shown above.

Results

7.3.5.15 The results of the study are presented in Figure 7.10 below. The results show:

a) *Sabellaria alveolata* density prior to translocation ranged widely between the two sites and within groups of samples from 1100 worms/m^2 up to 20,000 worms/m^2.

b) The mean density of *Sabellaria alveolata* in untreated, non-relocated samples was 5000 worms/m^2.

c) The mean density of *Sabellaria alveolata* in the controls, which were treated to mimic the relocation process but were not relocated, was 2500 worms/m^2.

d) The mean density of *Sabellaria alveolata* in the relocated samples was 6700 worms/m^2.

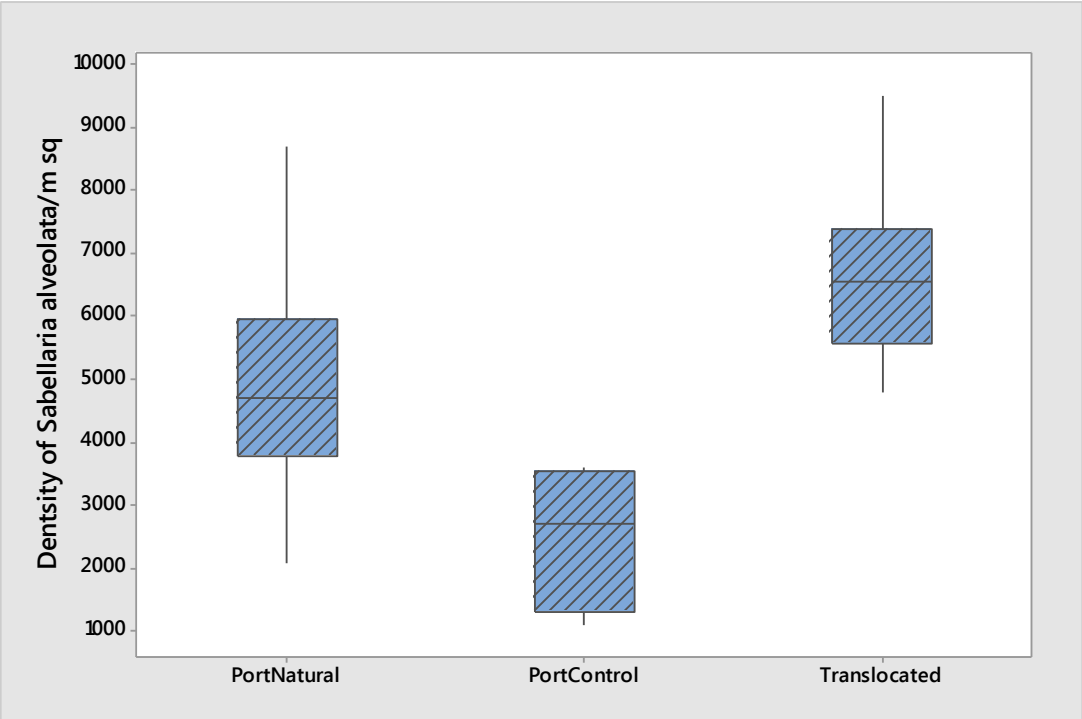


Figure 7.10. Boxplot showing the mean densities of *Sabellaria aveolata* per m^2 at Swansea Port (PN), control samples (PC) and translocated samples (TR).

7.3.5.16 Generally, the *Sabellaria alveolata* reef at the receptor site (west of the River Tawe) was noted as a healthier reef, showing a higher frequency of crisp apertures than prior to translocation. A greater percentage of 'sheet' reef was found at the donor site. Both sites contained 'dead' areas of *Sabellaria alveolata*, but a higher proportion was recorded at the donor site and a lower proportion of newly settled *Sabellaria alveolata* was seen compared to the receptor site west of the River Tawe.

7.3.5.17 The results of the pilot study show that translocation of *Sabellaria alveolata* from the port donor site to the receptor site west of the River Tawe was successful, with all translocated specimens surviving. However, densities in control samples, i.e. samples that were handled in the same way as the relocated ones but not actually placed at the

receptor site, had lower densities of the tube worms. This is not unexpected and it suggests that the handling of the reef blocks and the physical process of relocation (disturbance) has a potentially negative effect on the reef handled.

7.3.5.18 The difference in recovery could be attributable to the conditions present at the Port donor site and the receptor site west of the River Tawe, which affect the quality of the reef. A preliminary assessment of reef formations and health indicated the receptor site at the west of the River Tawe was healthier than the donor site reef at the Port. As such, it is plausible that the translocated worms to the west of the River Tawe recovered faster and to a greater degree as the conditions at the translocation receptor site were more favourable than at the port donor site.

Photo 1 - Example of Port *Sabellaria alveolata*

Photo 2 - Example of *Sabellaria alveolata* west of the River Tawe

7.3.5.19 Although control samples did show lower densities of worms, it may be that due to conditions of the donor site it may take longer for the handled reef to recover. An experiment by Tyler Walter (2005) investigating effects of trampling on *Sabellaria alveolata* reef, showed that *Sabellaria alveolata* reefs could recover quickly after disturbance, but it was noted that a full recovery could take several years. *Sabellaria alveolata* reefs are also known to go through higher and lower periods of recruitment, which may have contributed to the difference in density.

7.3.5.20 More detailed comparison between the health of reefs at the port donor site and the receptor site west of the River Tawe is proposed to be provided in the MSc thesis to be submitted in October. Preliminary results confirm that recruitment of young *Sabellaria alveolata* was greater at the receptor site than at the donor site, with a greater proportion of newly settled reef formation seen.

7.3.5.21 Overall the results of the study have shown, as would be expected, that temporary disturbance to the reef blocks does occur through handling, but translocation of *Sabellaria alveolata* is feasible, with the survival of all samples (controls and translocated specimens). The results also demonstrate that a receptor site to the west of the River Tawe would be a suitable receiver site, although further consideration will be given to this for future translocation. Any receptor site for a large-scale translocation would be discussed with relevant regulators.

Pre-construction translocation

7.3.5.22 The pre-construction translocation will be on a much larger scale than that undertaken for the trial. The effectiveness of translocation at this larger scale is not known, however it will be implemented to attempt to reduce impacts where possible, optimise the potential for colonisation of the habitat created as a result of the Project, as well as for the benefit of enhancing scientific knowledge.

7.3.5.23 It will not be possible to move the entire reef due to its size and in some cases the substrate it is attached too. Therefore certain areas will need to be targeted for translocation. A snapshot assessment of the health and formations of the Port reef show that much of the reef is patchy and sheet reef, with less defined reef formations. TLSB therefore propose to target moveable, crisp aperture reef and hummock reef formations, as these are the most healthy category reef.

7.3.5.24 An assessment of the health and formations of reef at the Port will be undertaken prior to construction to identify that suitable for translocation. This survey will be based on the method used in the trial study to assess the health of the reefs, namely the Cumbrian Wildlife Trust guidelines (Egerton 2014). As discussed below a random grid sampling method will be employed due to the extent of potential reef area and the limited duration of tidal exposure.

7.3.5.25 The reef area will be segmented grid of waypoints, and at each way point quadrats measuring 0.5m^2 will be randomly placed. Photographs will be taken for post-survey assessment due to tidal time constraints. Within each quadrat the percentage cover and formations of *Sabellaria alveolata* reef will be recorded, and it will be recorded whether the blocks appear to be suitable for translocation.

7.3.5.26 Detailed mapping of intertidal habitat across Swansea Bay, as identified in the AEMP Table 7.3, Objective ME3, will be used to identify a range of potential receptor sites and suitable locations that can be considered for translocation. These will be discussed with NRW, the relevant local authority and landowner.

7.3.5.27 An assessment of the health and formations of potential receptor sites will also be undertaken prior to construction. This will help inform the types of formation and reef that would be suitable to be translocated to this site, and the potential to accommodate the reef translocated. It is suggested that the amount translocated reef will not exceed an agreed percentage of the already existing reef, to prevent any smothering or major disturbance.

7.3.5.28 Where possible areas of reef not deemed suitable for translocation and other loose rock will be stored (within the red line area) at an appropriate location so that it does not interfere with the construction works. This material will be positioned at the foot of the western Lagoon wall, to help re-colonisation within that area.

7.3.5.29 A translocation method statement will be developed prior to construction of the Lagoon, using the results of the trail study and the assessment discussed above. The method statement will be discussed and agreed with NRW(A) and CCSC ecologist prior to implementing.

Survey 20 – Sabellaria alveolata Health Check

7.3.5.30 High resolution aerial surveys (Survey 4 and 5) can be used to monitor the area and extent of the reefs in Swansea Bay. In addition, as identified in Table 7.6, walkover surveys will be undertaken bi-annually during the construction phase and then at 1 and 5 years post construction which can be used to monitor the extent of the reefs and general condition. As such, the high resolution aerial surveys and the subsequent biotope verification will monitor the extent of the Sabellaria reefs, whilst Survey 20 will focus on the extent and health of Sabellaria species within the donor and receptor reefs and translocation sites on the lagoon seawalls.

7.3.5.31 The assessment of the formations and health of *Sabellaria alveolata* reef, following guidelines by the Cumbrian wildlife Trust (Edgerton 2014), will be undertaken at the locations of any reef remaining within the lagoon footprint and at the receptor sites.

7.3.5.32 If a deterioration in the monitored reefs is noted from analysis of the reefs and the site walkovers, the frequency of the surveys will be increased to quarterly during the construction phase. However, it should be noted that many biogenic reef biotopes undergo natural fluctuations in populations which are either remarkably wide, so that even almost complete loss of reefs could be regarded as 'normal' (Department of Environment Northern Ireland (DOENI), 2005). The abundance and diversity of the associated fauna and flora will inevitably have their own sources of variation in recruitment, growth and survival superimposed upon the variations in the 'supporting' reef populations. The findings of the surveys will be discussed with NRW, and if it is considered that the changes are as a result of the Project and not natural variation, feasible mitigation measures will be identified and a 'Sabellaria Impact Mitigation Protocol' would be developed. Mitigation could include the following methods to promote the viability of the reef:

1. Notices advising the public not to walkover areas of reef habitat, as it is known that trampling can physically damage reef habitats (DOENI, 2005);
2. Reduction of interspecific competition – heavy settlement of common mussels *Mytilus edulis* has been suspected of causing short-term destabilisation and loss of habitat (DOENI, 2005);

7.3.5.33 A PhD to further research the success of larger translocation and effects on the reefs in Swansea Bay is also being progressed. This has been approved by the College of Science. The project could include:

1. Assessment of success of larger scale Sabellaria alveolata translocation works at a number of receptor sites within the Bay;
2. Potential changes to existing Sabellaria alveolata as a result of changes in environmental condition or use as receptor site;
3. Potential colonisation of new structures/areas within/on the lagoon;
4. Recruitment patterns within the Bay and potential changes linked to hydrodynamics and larvae dispersal, making use of hydrodynamic model.

Sabellaria spinulosa

7.3.5.34 No mitigation is possible for the potential effects of the Project on *Saballaria spinulosa*. As identified in Section 7.2.2, the subtidal lagoon seawalls may provide a suitable habitat for colonisation and this will be monitored during the subtidal surveys (see Table 7.4, **Surveys 17, 18** and **19**).

7.3.5.35 The Natural England document[11] 'Best Methods for Identifying and Evaluating Sabellaria Spinulosa and cobble reef' (2010) identifies that "as a general guidance, sidescan is likely to remain the system of choice for the detection of *S. spinulosa* reef, although the way the system is deployed (low altitude, low speed, small swath range) is critical for reef detection". As identified under CP2, subtidal survey transects will be undertaken to monitor seabed change. Side scan sonar data would be simultaneously undertaken on all lines, and this would provide mapping of surface sediment types which would be used to check for the presence of reef (**Survey 5**).

7.3.5.36 The Natural England report then notes that visual observation of reef structures remains the only certain way of confirming their presence. Video and stills may however, not be able to detect lower agglomerations of *S. spinulosa*, such as appears to be the case in Swansea Bay based on the results of the sampling carried out for the Project. In areas of lower agglomerations, the report identifies that other sampling techniques must be used of which grab sampling remains the most effective. This may also be needed if poor visibility rules out the use of visual observation, which is likely to be the case in Swansea Bay, where there are high baseline levels of suspended sediment. On-board examination of the grab samples for worm tubes that will be collected as part of the on-going subtidal benthic surveys (see Section 7.3.5) will be undertaken.

7.3.6 Objective ME6: To maximise the potential for the re-introduction of Native Oysters

7.3.6.1 Oysters are native to Swansea Bay and found in low numbers within lower intertidal and subtidal habitat. As discussed in Section 1.4.1, TLSB are working in collaboration with SEACAMS to re-introduce the native oyster. An opportunity therefore exists to implement an oyster restoration programme in addition to using the lagoon as a "living laboratory".

7.3.6.2 The development of a method that utilises a tidal lagoon for the enhancement of oysters will depend on a series of optimisation stages. Each stage may have to be adapted to site-specific conditions, technical feasibility and nature conservation requirements. However, the longevity of the tidal lagoon allows a step-by-step adaptive process and TLSB aspires to develop a procedure that can be transferred to other lagoons or similar structural developments. If successful the method could be rolled out to assist oyster restoration programs in other areas. Further details are provided below Table 7.7.

11 http://www.cefas.co.uk/media/463842/mal0008_best%20methods%20for%20identifying%20and%20evaluating%20sabellaria%20spinulosa%20and%20cobble%20reef_final%20with%20cover.pdf

Table 7.7 ME6 Objective summary – maximise re-introduction of Native Oysters

Target	Restoration of the Swansea Bay native oyster population through a captive rearing programme. Research to address current knowledge gaps.
WFD	Swansea Bay Coastal Waterbody – mitigation measure - preserve and, where possible, restore historic aquatic habitats.
Management/operation	Construction and physical presence of the operational lagoon.
Survey	Oyster dredge trawls of construction impact areas associated with the lagoon footprint to be undertaken and any oysters recovered to be relocated to the Centre for Sustainable Aquatic Research (CSAR) at Swansea University where their spawning behaviour and spat development will be monitored. The oyster hatchery would hold and condition broodstock that would be induced to spawn in a controlled environment providing optimal conditions for high levels of maturation, fertilisation, growth and survival. The developing larvae would be reared in high densities in the hatchery facilities and feed on a variety of microalgal species cultivated on site. Spatting ponds within the lagoon would be used to compliment the hatchery. The growth and survival of oysters in and outside the lagoon will be monitored by boat sampling.
Responsibility	TLSB and SEACAMS
Objective	To provide a research baseline for use in future Projects.
Limits of acceptable change	N/A
Further / remedial action	Research will be reported to inform future developments.

7.3.6.3 The development of aquaculture facilities within Tidal Lagoon Swansea Bay meets aquaculture development priorities as set out in the Wales Fisheries strategy paper (November 2013) and also as set out in the Marine Spatial Planning documentation (September 2014).

Overview of **the 10 Year Plan**

7.3.6.4 The aquaculture scheme at TLSB has been planned over a period of 10 years, involving 3 phases. Phase 1 (Year 1) focuses on detailed planning and preparation, Phase 2 (years 2-4) focus on facility and business development and Phase 3 (years 5 - 10) focus on further developing the research and commercial aspects of the scheme. TLSB will fully fund phases 1 to 3 and it is intended that the commercial development officer will ensure operations are economically self-sustaining by the end of Phase 3.

Key Objectives

7.3.6.5 Key Objectives for the aquaculture scheme are as follows:

1) To safeguard native oysters within the footprint of the tidal lagoon, store them in an aquaculture facility and develop a local brood stock for future oyster production.
2) To develop methods of rearing native oysters in the tidal lagoon using spatting ponds, a hatchery and the lagoon area.

3) To create oyster reefs inside the lagoon and restore or supplement stocks in the wider Swansea Bay area in order to promote biodiversity.
4) To develop an oyster aquaculture inside the lagoon as part of an integrated, multitrophic aquaculture system (IMTS).
5) To participate in national and international research projects that explore opportunities to modify coastal and marine infrastructure in order to improve their ecological value and to produce marketable seafood.
6) To develop a commercial oyster business that trades lagoon oysters for human consumption, restoration projects and oyster spat.
7) To develop community engagement platforms.
8) To develop education and training opportunities.

7.3.6.6 Table 1 below summarises the key tasks and objectives within each of these phases.

Table 1 Key Tasks and Objectives through Phases

Phase 1: Pre- lagoon construction period (Year 1)		
Objectives addressed	Task	Description of work
1,2	Removing oysters from within the footprint of the tidal lagoon by dredging key areas with an oyster dredge.	The location of oyster grounds in Swansea Bay are broadly known and it is feasible to dredge them prior to construction of the Lagoon in order to preserve them as brood stock. There is uncertainty regarding the exact numbers of oysters in the area, but stocks are generally rudimentary and consist of relatively old individuals (10yrs +).
1,2	Place oysters in hatchery or relocate within Swansea Bay	Trials in SEACAMS have shown that Swansea Bay oysters survive well under hatchery conditions within the Centre for Sustainable Aquaculture Research. The facility could be used to temporarily house the oysters from the Lagoon. The oysters will be monitored in terms of health and condition.
2,3	Development of brood stock	The oysters will be kept in experimental spatting ponds and conditioned to spawn. Research into food and temperature requirements will be carried out, and fecundity will be assessed.
6	Development of commercial business plan	Two products could be commercialised: oyster spat (for restoration projects and market size oysters (for human consumption). The commercial business plan would target local, national and international markets and would ensure the scheme is economically viable by Year 10. This will include clear business aims, descriptions of products, unique selling point(s), target customers and overview of customer needs, test trading plan, operations and logistics plan and costings (including cost per unit and price per unit as well as % profit

		margins), risk assessment, sales and profits forecasts over 1, 3 and 5 years. This would also include details of marketing activities. The facility could also be used on a commercial basis by becoming involved in EU funded research projects.
Phase 2: Lagoon construction period (Years 2-4)		
Objectives addressed	Task	Description of work
2,4,5,6,7,8	Construction of ponds inside the tidal lagoon.	Spatting ponds shelter oysters from severe environmental conditions and can stimulate spawning. Closed pond systems will restrict the dispersal of larvae and promote larval settlement. It is proposed that 7+ ponds, each 100-400m^2 (i.e. 10x10m to 20x20m) would be constructed.
2,3,4,5,6,7,8	Constructing a hatchery and laboratory at the tidal lagoon	The hatchery facility will allow producing oyster spat in a controlled environment. Factors such as temperature and algal food supply can be optimised. The laboratory will also be used for research and monitoring of environmental factors as well as the condition of oysters.
6	Build up market links and develop marketing strategy	The commercial development officer would build up a robust network of local, national and international market contacts and would develop unique selling points and a marketing strategy for the TLSB products.
Phase 3: Post-lagoon construction period (Years 5-10)		
Objectives addressed	**Task**	**Description of work**
1,2,6	Stocking spatting ponds with oysters that were translocated from within the footprint of the tidal lagoon prior to construction	Oysters housed in CSAR will be relocated to the spatting ponds.
2,4,5,6	Optimising the spatting conditions in ponds	The successful production of offspring from oysters in spatting ponds underlies many variables. It is site specific and depends on the condition of the oysters. The process within the Lagoon will be trialled and optimised. For example, the duration of time oysters stay in the spatting ponds needs to be trialled as well as different cutch material for the oyster larvae to settle on.
2,4,5,6	Optimising the spatting conditions in hatchery	The production of spat in hatcheries is a well-documented process. However, the physiological condition of oysters differs and the process has to be trialled and optimised.
2,3,4,5,6	Monitoring of habitat conditions	Assessment of quantity and quality of plankton and toxic algal blooms; we assumption that other parameters such as oxygen and nutrient levels are monitored as part of ongoing water quality monitoring requirements.
2,3,4,5,6	Monitoring of oyster condition and health	Assessment of oyster maturation, spawning, larvae development and spat settlement. One of the greatest threats to oyster cultivation is

		the infection with *Bonamia ostreae*. The stock would have to be regularly tested for Bonamia.
3,4,5	Creating oyster reefs from offspring generated in spatting ponds or hatchery	The aim is to stock 3-5 discrete areas inside the lagoon with oysters from the spatting ponds and/or hatchery. The exact location depends on sediment and hydrodynamic conditions within the lagoon. It is anticipated that there will be suitable subtidal areas, but possibly also intertidal areas; in Swansea Bay native oysters are naturally found in lower intertidal areas, although in low numbers. In order to create control areas, it is aimed to stock a similar number of sites outside the lagoon.
3,4,5,6,7,8	Monitoring of created oyster reefs	The growth and survival of oysters inside and outside the lagoon will be monitored.
6,8	Commercialisation	Implementation of the business plan to secure commercial viability. By the end of Phase 3 the facility should be self-funding and profitable.
3,4,5,7,8	Assessment of biodiversity of created reefs	The extent to which the created oyster reefs support biodiversity compared with other habitats will be assessed. Invertebrate fauna, algae and fish will be monitored.
5	Research	TLSB seeks to expand the network of research collaborations, particularly in terms of applied research. The company will strengthen the collaboration with Swansea University and other academic partners to address current knowledge gaps. The aim is to integrate and develop the concept of oyster production and other mariculture in tidal lagoons through international research projects. Fundamental research questions could be addressed related the role of water quality and algal composition, effects of harmful algal blooms (HABs) or climate change related issues such as ocean acidification (OA) and the calcification of shells.
2,3,5,6,8	Development of strategy to contribute to oyster restoration programs	The development of a method that utilises a tidal lagoon for the creation of oyster reefs will depend on a series of experiments and optimisation stages. Each stage may have to be adapted to site-specific conditions, technical feasibility and nature conservation requirements. However, the longevity of the tidal lagoon allows a step-by-step adaptive process and TLSB aspires to develop a procedure that can be transferred to other lagoons or similar structural developments. If successful the method could be rolled out to assist oyster restoration programs in other areas.
7	Community engagement	Development of an outreach program for schools and community groups. Active engagement with the TLSB visitor centre. This would cover displays, events and work experience placements.
8	Education and training	Development of education and training courses for students and professionals in collaboration with the lagoon hatchery.

Facilities

Staff	1 FTE commercial development officer; 2 FTE aquaculture technicians; 1 FTE researcher (aquaculture/ecology/marine biology)
Commercial Infrastructure	Hatchery 1000m^2 with areas for algal growth, tanks and dry labs. Construction of 7-10 spatting ponds, 10-20m^2 each. Pond inflow and outflow (with pumps) pipes, Pond lining Biofoul removal facilities 3-5 oyster reefs Artificial cultch Broodstock storage facilities Oyster sorting equipment Oyster packaging equipment Oyster cold storage facilities Intertidal transport (tractor/ quad bike plus trailer) Land based transport (commercial van)
Laboratory	Microscopes, balances, drying oven, freeze dryer, consumables.

Business Planning

7.3.6.7 A business development officer will be recruited in Year 1 of the scheme to develop and implement a detailed business plan. This will include:

a. clear business aims (eg. to be the most profitable welsh shellfish supplier)

b. description of products (eg. native oyster spat and mature native oysters for human consumption)

c. unique selling point (eg. only lagoon shellfish supplier)

d. overview of customer needs and how to reach target market (eg. high quality products, competitively priced, marketed through food fayres and direct sales contacts)

e. test trading plan (eg. 5 customers over 6 months at reduced price)

f. operations and logistics plan (eg. process of algae growth, larvae development, maturation, offspring, sale)

g. costings (eg. including cost per unit and price per unit as well as % profit margins),

h. sales and profits forecasts over 1, 3 and 5 years

i. risk assessment (including how will meet FSA standards).

7.3.6.8 Opportunities to use the facilities on a commercial basis by becoming involved in EU funded research projects would also be considered.

7.3.6.9 The business development officer would also be responsible for ensuring the facility is developed in a robust and sustainable way.

Biosecurity

7.3.6.10 Biosecurity is a major issue for aquaculture developments. One of the greatest threats to oyster cultivation is infection of *Bonamia ostreae*. The stock would have to be regularly tested for Bonamia and other common infections. In addition, monitoring of plankton levels and toxic algal blooms as well as oxygen and nutrient levels would be required. This should be applied across all stages of oyster maturation, spawning and larvae development.

7.3.6.11 In addition to ongoing monitoring, options for safeguarding biosecurity within the hatched will be considered. This could include using deploying physical meshes, UV systems, and heating water to kill off bacteria. FSA standards (Ref http://www.food.gov.uk/business-industry/fish-shellfish) will be adhered to where applicable.

8 Fish, Recreational and Commercial Fisheries

8.1 Introduction

8.1.0.1 Chapter 9 Fish, including Recreational and Commercial Fisheries in the ES provides details of the data review and site specific survey work carried out to collect baseline information for Swansea Bay. This section outlines the further monitoring and surveys proposed for the various phases of the Project.

8.1.0.2 In relation to the WFD, the fish quality element is relevant only for transitional and river waterbodies. However, the main effects of the Project in relation to the potential effects on migratory fish will occur within the Swansea Bay Coastal waterbody as this is where the construction will occur and the operational turbines. Migratory fish will pass through Swansea Bay Coastal waterbody to reach the river waterbodies within the vicinity of the Project, principally the Tawe and the Neath. Monitoring and surveys proposed within Swansea Bay Coastal waterbody are therefore relevant to assess the potential effects of the Project on both the transitional waterbodies and hydrologically connected river waterbodies.

8.2 Baseline

8.2.0 Quarterly fish surveys – characterisation

8.2.0.1 For a detailed account of survey methodologies, please refer to Appendix 9.2 Quarterly survey reports of the Environmental Statement. An overview of the methods used in site-specific surveys is provided below.

8.2.0.2 Four surveys involving intertidal and subtidal techniques were conducted at 6 intertidal sites and 6 subtidal sites. Surveys were: Quarter one (winter 2012); Quarter two (spring 2013); Quarter three (summer 2013) and Quarter four (autumn 2013).

i. Intertidal surveys involved two surveying methods: a beach seine net (43m long by 4m deep, with 6.5mm knotless mesh) set from a small rigid vessel; and a Riley push-net (1.5m wide push-net with a 6.5mm mesh trouser legs lined with 1mm fry mesh) used from the shore.

ii. The subtidal surveys were carried out from a 12.1m mono-hull trawler using both otter and beam trawls.

iii. For each survey the catch was identified to species level and measured to the nearest millimetre; fish were sub-sampled when > 50 specimens of the same species were captured.

8.2.0.3 The fish community of Swansea Bay is characterised by a broad range of demersal, pelagic and bentho-pelagic species. The subtidal and intertidal surveys described above recorded a total of 55 species. The fish assemblage was dominated by pelagic species; sprat (42.6%), herring (12.2%) and sand smelt (4%). Benthic species (goby sp., plaice, grey gurnard, common sole, thornback ray, lesser sandeel, dab, sand goby, hooknose, solenette, turbot and flounder) made up a further 24% of the species recorded over the course of the year with five demersal species (whiting, bass, pouting, lesser spotted dogfish and poor cod) accounting for a further 14% of the stock.

8.2.0.4 The remaining 3% of the annual fish population in Swansea Bay is composed of 37 species, each with an abundance of less than 0.1%.

8.2.0.5 Further surveys have been undertaken in 2014: Quarter one (spring 2014); Quarter two (summer 2014) and Quarter three (autumn 2014), with a further survey planned for Quarter four (winter 2014).

8.2.0.6 Fish abundance is seasonal and composition of the recorded catch fluctuates significantly between both years and seasons.

8.2.0.7 In addition to the general assemblage of marine species that frequent or reside within the Bay, the waters provide a pathway for a number of migratory species migrating to or emigrating from freshwater systems that either discharge to the Bay or to adjacent coastal areas. These species include Atlantic salmon, sea trout, European eel and river lamprey. Sea lamprey and twaite shad, whilst uncommon, have also been recorded in the bay or within freshwater systems that feed into the Bay.

8.3 Fish Objectives

8.3.0 Introduction

8.3.0.1 A key issue of the tidal lagoon project is the potential impact during operation through entrainment of fish through the turbines. Within the ES (chapter 9) the STRIKER™ v.4 model was used to determine the impact on fish as they pass through the turbines. Fixed speed turbines were modelled in the ES as they are considered worst case in comparison with variable speed. This is described further in 9.5.3.97 of the ES where it states "*This use of fixed speed turbines has two potential effects with regard to the safety of fish passage. First, as the water flow through the turbine reduces at the same time as operating head decreases, the axial velocity of water through the turbine becomes slower but the blade speed remains the same. This means that the water-length (described above) reduces and therefore that the probability that a fish will be struck by the blade increases towards lower flows. Second, as the blade angles change, the turbine moves away from its most efficient operating point, hence efficiency reduces and more turbulence, hydrodynamic pressure change and shear stress is generated, potentially creating more harmful conditions for fish*."

8.3.0.2 In terms of rotational speeds, fixed speed or 'synchronous' turbines would operate at approx 60rpm (+/- 2.5rpm); whereas variable speed turbines would operate between 30 to 67rpm, average 50rpm (4.3.2.2). For the purpose of the EIA a precautionary approach was undertaken (section 4.3.2.7) and an assessment of fixed speed turbines with a rotational speed of 67rpm was provided (tables 9.20 and 9.21). The predicted impacts on fish presented in the ES for fixed speed turbine are therefore a worst case, as in reality if variable speed turbines had been used they would be at a slower rpm and they would therefore have lesser impact.

8.3.0.3 Since the submission of the DCO application in February 2014, the turbine tendering process for the lagoon has been progressed and variable speed turbines are proposed. In comparison to fixed speed turbines (9.5.3.98 of ES) "*Variable speed turbines are matched to distribution grid frequency either by using variable speed gearboxes or using electronic inverters. In a variable-speed turbine the converse of the above with regard to fish is true. First, as the water flow reduces, the blades slow proportionately so that the water-length remains constant. Secondly, the water-to-blade angle remains constant so that efficiency*

is maintained". Modelling within the ES at 67rpm (table 9.23) demonstrated that on average there would be around a 25% reduction in mortality through the turbines for salmonid species.

8.3.0.4 As identified in Chapter 4, Project Description, Section 4.3.2.6 and Table 4.1, "*variable speed turbines have the ability to be used in a pumping mode. As such, if variable speed turbines are chosen, this would be utilised at the end of each tidal cycle to equalise the water levels inside and outside the lagoon before the turn of the tide*." In this way, intertidal losses would be minimised which would be of benefit across a number of environmental areas (including subtidal ecology, birds and fish).

8.3.0.5 In the pumping mode, generally as the head difference of water increases between inside and outside the lagoon, the rotational speed of the turbine needs to increase. The rotational speed would generally have a range in pumping of between 39rpm for a 1m pumping head up to 90rpm for 5.5m pumping head. For the Swansea Bay Tidal Lagoon, a maximum head of 3.5m is anticipated. At this head the maximum turbine speed would be 73rpm. Notwithstanding this a precautionary approach was applied and a variable turbine speed of 90rpm was run through the STRIKER™ v.4 model. The results of the model output are presented in Table 8.1.

Table 8.1. Predicted injury rates during turbine passage for 'worst case' of 67 rpm Fixed Speed Turbines versus 90 rpm Variable Speed Turbines.

Species /Lifestage	Predicted Mortality Rate		
	Variable Speed 90rpm	Fixed Speed 67rpm	% reduction with Variable Speed
Atlantic salmon & sea trout smolt	2.62%	2.83%	-7.2%
Atlantic salmon adult[12]	8.16%	9.23%	-11.3%
Sea trout adult	7.68%	8.70%	-11.7%
Shad adult	50.08%	50.45%	-0.5%
Herring	49.22%	49.44%	-0.4%
Glass eel/elver	0.55%	0.60%	-7.6%
Silver eel	4.71%	5.50%	-14.0%
Gadoids	8.37%	8.94%	-6.1%
Bass	4.41%	4.74%	-6.9%
Flatfish	1.60%	1.82%	-11.8%
Lamprey	4.88%	5.70%	-14.0%

8.3.0.6 As can be seen from Table 8.1 above, the predicted fish injury rates during pumping (at 90rpm) would still result in a reduction in mortality over the fixed speed turbines modelled in the ES. For adult salmon and sea trout this would be around an 11% reduction compared to fixed speed turbines.

8.3.0.7 Once again, this assessment is precautionary as the modelling has been undertaken using a maximum of 90rpm, when a peak of 73rpm is anticipated. In addition, the modelling has been based on the internal design of a fixed speed turbine which would potentially create more harmful conditions for fish. This is because as the blade angles change, the turbine moves away from its most efficient operating point, efficiency reduces and more turbulence occurs, hydrodynamic pressure changes and shear stress is generated.

[12] Including Panteg trap data

8.3.0.8 Since the submission of the DCO in February 2014, the turbine tendering process has progressed and variable speed turbines will be chosen for the Project. Internal flow characteristics (CFD) will become available as the tender and design process progresses. Once available the STRIKER™ v.4 model will be set up to represent the chosen turbine and the encounter modelling will be re-run.

8.3.0.9 The following objectives have been identified in relation to fish, including recreational and commercial fisheries, taking into consideration the availability of turbine encounter data in the near future:

- F1 - To assess fish passage through the turbines
- F2 - To examine the effects of the Project on herring;
- F3 - To examine broad scale changes in fish fauna assemblage within Swansea Bay pre and post construction;
- F4 - To examine the diversity and abundance of fish associated with the artificial reef;
- F5 - To review migratory fish stocks on the Afan and Tawe;
- F6 - Analyse rod catch data to understand any effects of the Lagoon
- F7 - To review NRW WFD Compliance Data to assess any changes in ecological status.
- F8: To monitor fish movements across the Bay and into/out of the Lagoon by acoustic telemetry

8.3.1 Objective F1 - To assess fish pass through the turbines

Table 8.1 F1 Objective Summary – turbine encounter predictions

Target	Evaluation of turbine encounter performance
WFD	Fish quality element (transitional waters) Fish (migratory fish only) quality element (river waterbodies)
Management/operation	Operation of lagoon.
Survey	**Before turbine installation -** Smolt and eel fish tagging studies (**Survey 27c** under Objective F8) to be undertaken in 2015. Results from tracking study used to review IBM modelling undertaken for ES. Re-run STRIKER™ v.4 model with selected variable speed turbines. Assess results against ES trigger values and discuss findings with NRW and CEFAS. **During manufacture -** Undertake preliminary modelling of AFD systems design for vulnerable species namely herring and sea trout. Review system in conjunction with requirements for marine mammals. **Operation**: Monitoring of turbine encounter performance using Hydro-acoustic monitoring systems (eg Didson Cameras) and ground truthing surveys (**Survey 21**). On-going Didson camera data to be collected. If AFD's have been installed as a precautionary measure, undertake studies to confirm effectiveness (survey methodology will be developed if needed). Review based on findings of assessment.

	Mobile hydroacoustic survey (**Survey 22a**) to be undertaken once per month (Feb to April) across outside of turbines with particular focus on salmon, sea trout and herring entrainment (yr1, yr2, yr3 and yr5 operation). Opportunities to utilise the mobile cameras on the Tawe Barrage at an appropriate time of year, would be considered through the AEMP review process. Smolt tracking and eel tracking (**Survey 27c**) would be repeated yr 1 and 2 operation. Turbine passage (**Survey 22b**) – netting downstream of flows. Data to be cross calibrated with hydroacoustic data. Yr 1 of operation.
Responsibility	TLSB
Objective	To validate findings of ES and if necessary identify change outside that predicted, including need for mitigation measures such as AFD.
Limits of acceptable change	Modelling pre-DCO decision - targets set within ES Chapter 9 for VERs Monitoring – operation – assessed impact same or greater than in ES
Further / remedial action	**Before turbine installation – STRIKER v4 Results** Depending on scale of results, if predictions are an improvement on ES findings, report findings to NRW and CEFAS and defer installation of AFD system until validated by field monitoring of effect on VERs once operational (Yr1/Yr2 operation). If NRW/CFEAS consider STRIKERv4 modelling results require mitigation – install AFD prior to operation (Yr 3 construction) **Monitoring once operational (Yr1 and Y2 operation)** If no AFD present and results of monitoring show increased impact, then install AFD system. If AFD present and results of monitoring show impacts above ES findings, refine AFD deployment in consultation with NRW/CEFAS

Survey 21 - Turbine Monitoring

8.3.1.1 Hydro-acoustic monitoring systems are now a commonly used tool for monitoring and evaluating fish entrainment in hydropower schemes and power station intakes as well as being used to for fisheries based monitoring and research.

Fish Monitoring - Proposed Methodology

8.3.1.2 Operation of hydroelectric projects such as a tidal lagoon can result in the sporadic entrainment of fish into the project turbines which can result in some degree of mortality. TLSB would like to understand the relationship of project operation and the potential impacts of entrainment and turbine mortality on fish in Swansea Bay through field based monitoring and a comparison with the estimated entrainment and mortality rates from the modelling discussed in the EA.

8.3.1.3 The proposed monitoring programmes are based on generally accepted practices for evaluating fish entrainment and turbine mortality at hydroelectric projects. The proposed study methodology is consistent with generally accepted fishery sampling principles and practices.

Technology

8.3.1.4 The technology uses high resolution imaging sonar cameras which can give near video quality images even in turbid waters. Specialist fisheries software supplied with the units (see figure 8.1 below) can be used for:

i. Quantification of fish entrainment,
ii. Conducting fish counts,
iii. Monitoring fish behaviour,
iv. Monitoring temporal and special distribution of fish, and
v. Identifying fish species/types.

8.3.1.5 The software is user friendly and can allow remote 24hr data collection and data analysis tools. There are also a number of specialist software packages available such as HTI Echoshape and Sonarpro.

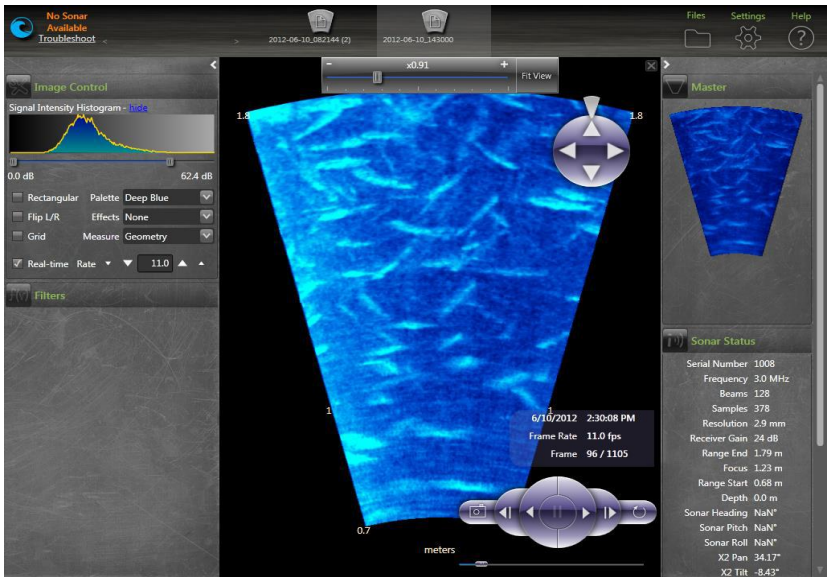


Figure 8.1 ARIS software

8.3.1.6 There are two main types of device commonly used (including by the Environment Agency and Natural Resources Wales): High definition sonar DIDSON (Dual Frequency Identification Sonar) 1.8MHz and the more recent ARIS (Adaptive Resolution Imaging Sonar) Explorer 1800 1.8MHz (see Figure 8.2 below).

Figure 8.2 High resolution sonar cameras

8.3.1.7 The ARIS 1800 has an effective range of 35m and can be mounted to the external wall of the turbine housing (see Figure 8.3), on a frame. Alternatively, a specially designed slot for the cameras could be incorporated into the turbine housing design for each turbine (or sluice gate) to minimise blind spots. Incorporating slots in the design would mean cameras could be easily moved between turbine or sluice gate units and would minimise interference in the water passage.

Figure 8.3 Mounting at Arzal dam, France

Methodology

8.3.1.8 TLSB proposes to assess entrainment effects both quantitatively and qualitatively, through the use of two separate types of hydroacoustic surveys. Many studies have used hydroacoustics to estimate fish abundance or density, fish length distribution and to evaluate entrainment rates at hydropower facilities. In addition, hydroacoustics can

provide a high degree of sampling power encompassing seasonal and daily variations. TLSB propose to use DIDSON and ARIS hydroacoustic equipment, as appropriate, and associated post processing software for fixed position and mobile surveys. The fixed position survey will be centred on the turbine and sluice gate housing structure and turbine hydraulic passage and the mobile survey will be within the lagoon impoundment, in the area of Swansea Bay immediately before the turbines on the sea side of the lagoon and potentially in the mouth of the River Tawe, to investigate migratory behaviour of salmon and sea trout.

8.3.1.9 This study will focus monitoring on turbine units 1 and 16 with fixed position ARIS or DIDSON cameras at either end of the turbine hydraulic passage (inlet & exit). All 16 turbine units will be fitted with fixing brackets for the DIDSON and ARIS units in the optimum position to maximise coverage of the intake and exit areas so these can easily be transferred between units for long term monitoring following the initial monitoring period.

8.3.1.10 The hydroacoustic cameras (transducers) will be positioned below the water surface to maximise sampling volumes covering the intake and draft tube exit of the turbine. These will be used to estimate the fish numbers, sizes, species types as well as fish behaviour. An additional pair of transducers will be used to undertake mobile fish surveys.

8.3.1.11 Hydroacoustic sampling from the transducers will be collected over an entire year collecting and recording sufficient data to provide fish counts, entrainment rates including fish size and species. Hydroacoustic data files from the units will be processed with specialist fisheries based post-processing software to determine fish densities and size distribution. Additional catch and release monitoring could be used to calibrate and/or validate likely injury rates post entrainment. Following the initial fixed monitoring of the turbines the equipment could then be moved to assess movement through the sluice gates, though injury from entrainment is likely to be significantly lower through sluice gates.

Survey 22a - Mobile Hydroacousitc Surveys

8.3.1.12 Mobile surveys using boat mounted hydroacoustic transducers will be performed in the spring (once per month Feb - April) in conjunction with the fixed surveys performed at or near the intake. These surveys will target the areas around the turbine housing on both the lagoon side and the sea side. The sampling will use the same DIDSON & ARIS system used for the fixed deployment study and will be processed with the same specialist software. Each mobile survey will be used to obtain fish density, including vertical and longitudinal distributions in the inlet and exit areas around the turbine power house and sluice gate structure.

8.3.1.13 Mobile survey equipment will include pole mounted DIDSON or ARIS transducers attached to the starboard side of the boat and positioned facing downward at a depth of 0.5m below the water surface. A global positioning system (GPS) will be used to track and record the transect tracks.

8.3.1.14 Mobile surveys will be performed during the day and repeated at night within a 24 hour period each month to incorporate diurnal variability. Each survey will consist of 15 continuous zigzag transects beginning at approximately 2km from the turbine housing, crossing the main channel with each pass. Transects will be spaced approximately 100m apart and boat speeds maintained at approximately 3 knots. The night survey would be

conducted one hour after dusk on the same day by following the same GPS ship track, effectively re-sampling the same area as the day survey. Every survey event (2 surveys (1 day + 1 night) X 3 months = 6 total) would follow the same approximate GPS ship track.

8.3.1.15 Based on the modelled entrainment estimates along with the field study, TLSB would develop a report that includes a recommendation regarding the level of impact that entrainment and turbine mortality potentially has on the local fisheries, with specific emphasis on the salmon, sea trout and herring. Surveys repeated year 1, year 2, year 3 and year 5 of operation.

Survey 22b – Turbine Passage

8.3.1.16 Surveys are proposed to assess fish pass through the turbines. Methods are currently being refined due to the complexity of sampling in areas of high flow. It is considered feasible to position a small fishing vessel with a bass trawl downstream of a turbine and collect a number of trawls over a defined period. Flow from one turbine would be monitored. The fishing boat would be repositioned to monitor fish passage through the different turbines. It may not be feasible to deploy a boat of sufficient size within the lagoon, in which case this work would be confined to areas outside the lagoon wall during the ebb generation phase.

8.3.1.17 Direct capture of specimens and assessment of condition following turbine passage may be validated by short term deployment of high-frequency imaging sonar, which may allow for subsequent extrapolation of data to all turbines.

8.3.2 Objective F2: To examine the effects of the Project on herring

8.3.2.1 The fish community of Swansea Bay is characterised by a broad range of demersal, pelagic and bentho-pelagic species. Subtidal and intertidal surveys throughout 2013 recorded a total of 55 species. The fish assemblage was dominated by pelagic species; sprat (42.6 %), herring (12.2 %) and sand smelt (4 %). Herring in particular are a potential sensitive receptor to the development of a tidal lagoon due to potential spawning locations within Swansea Bay. The ES has recognised the need to assess the potential impact to herring spawning grounds within the zone of influence of the proposed scheme.

8.3.2.2 Herring are seasonally abundant within Swansea Bay where they have been observed to spawn within three areas of the Bay, namely at Mumbles, the Swansea Roughs by the Swansea Port eastern breakwater and Port Talbot Harbour wall. They spawn in spring (February/March) and autumn (Sept/Oct) of each year. Loss of seabed during the construction of the lagoon may temporally reduce the total area of spawning habitat within the Bay. Mitigation which included timings of the western landfall works around the known spawning period (commencing April at the earliest), and the design of the newly introduced seawall which it is considered will provide additional/alternative spawning substrate, should ameliorate these potential impacts.

8.3.2.3 The modelling undertaken to support the ES was a worst case assessment based on fixed speed turbines. In addition to this, the results of entrainment was based on only those herring using the Port beach area, and it did not consider the fact that multiple sites within the Bay are used. Based on the single site, the results demonstrated that a significant impact would occur, namely 26.69% potential losses, however this would only be for those using the Swansea Port area.

8.3.2.4 As with the Port Talbot Port breakwater, the lagoon seawall will be covered by rock armour, and, as such, it is entirely reasonable to anticipate that herring will use the lagoon seawall for spawning. This is further corroborated by studies undertaken in the Netherlands (Groot, S. J. 1980 and U.S. Army Corps of Engineers. 2013). These have demonstrated that where historic spawning areas have been obstructed by manmade seawalls, herring spawn on the first available spawning material which in the case subject to study was the seawall.

8.3.2.5 In addition, anecdotal evidence (Thornton et al. 2010) suggests that older spawning male herring scout along the coast and mark suitable sites for spawning with milt, several days before leading the majority of the spawning population into the coast. Also, Aneer et al, (1983) and Nøttestad et al, (1996) describe various behaviour patterns in spawning shoals, including searching for suitable spawning sites. This adaptive behavioural strategy could provide a mechanism whereby most herring avoid any dangerous or unsuitable sites for spawning even if they may have been used extensively in the past.

8.3.2.6 It is therefore considered probable that herring may spawn on the outside of the western arm of the lagoon wall without heading offshore close to the turbines. Consequently, potential impacts from the operational lagoon would be considerably less than predicted. If this were the case, the need for AFD would be negated, which would remove a potential underwater noise source from the area.

8.3.2.7 As such, central to this objective is the determination of the effectiveness of the mitigation. A suite of surveys have therefore been identified to monitor herring around the lagoon seawalls, such that the success of the mitigation can be assessed prior to completion of the lagoon and installation of the AFD.

Table 8.2 F2 - Objective summary - monitoring viability of Herring mitigation

Target	Determination of effectiveness of mitigation to safeguard herring which used Swansea Roughs by Swansea Port.
WFD	Fish quality element (transitional waters)
Management/operation	Construction and physical presence of the operational lagoon.
Survey	<u>Preconstruction</u> Ichthyoplankton surveys (**Survey 23a)** will be undertaken to assess spawning activity within Swansea Bay during 2015. Modelling using a Lagrangian particle backtracking model will be used to track simulated larvae back to their hatching sites enabling the development of a spawning map for herring within Swansea Bay to be prepared. <u>Operation</u> A selection of surveys (TBC in summary table 13.2) would be undertaken between February and March, during construction and years 1, 3 and 5 post construction. The survey suite would be reviewed each year pending success and results. *Mobile Hydroacoustic survey and trawling (**Survey 23b**)* Scientific acoustic surveys using small mid-water (pelagic) trawl for validation – abundance and distribution. *Artificial spawning media (**Survey 24**)* Installation of anchored and buoyed steel frames covered in mesh

	media in a grid pattern over known spawning sites. *Grab survey and Video capture (**Survey 25**)* Grab surveys (using e.g. a 0.1m^2 Day grab or a van Veen grab) in order to identify any eggs deposited within the vicinity of the known spawning areas. Use of video capture technology for three elements: confirming herring spawning around artificial spawning media, assessing the presence of eggs on rocky ground (if applicable) and investigating the use of sea walls and defences as a spawning media by herring. This method would form a particularly useful component of a suite of herring-specific surveys but it may be impractical in Swansea Bay due to high background turbidity levels. Further investigation into the practicality of the method is required given the constraints. ***AFD system*** Preliminary design of Herring AFD system, taking into consideration requirements of other species such as sea trout and marine mammals.
Responsibility	TLSB
Objective	To validate findings of ES and if necessary identify and implement appropriate mitigation measures such as AFD.
Limits of acceptable change	Monitoring of artificial spawning media prior to operation will guide any remedial action required. If artificial spawning media is ignored by herring and they are found to still access the Lagoon footprint then this will trigger further action.
Remedial action	Installation of AFD system upon operation.

Survey 23a - Ichthyoplankton Monitoring

8.3.2.8 It is proposed to undertake a programme of ichthyoplankton monitoring throughout Swansea Bay in order to investigate the presence and distribution of larval herring from which the location of spawning grounds may be predicted.

8.3.2.9 A suite of ichthyoplankton trawls will be undertaken across Swansea Bay from late January to mid-March 201 giving a total of 8 sampling occasions. Surveys would be undertaken once a week for 6-8 weeks. On each sampling occasion ten oblique, ten minute trawls sampling the full depth of the water column would be undertaken on transects covering the Bay from Port Talbot in the east to Blackpill to the west.

8.3.2.10 Trawls would comprise of an ichthyoplankton sampler such as a bongo net fitted with a 500 µm net. The trawl would be fitted with a flow meter to allow accurate estimations of volume sampled and subsequent determination of larval density. A CDT (conductivity, depth and temperature) probe will provide additional environmental data and a depressor hung beneath the frame of the net will ensure net stability.

8.3.2.11 For each transect the start and end location, tow speed and bearing would be recorded along with tidal state enabling accurate repetition.

8.3.2.12 Samples would be preserved in labelled sample containers and brought back to the laboratory for processing. All fish larvae will be sorted and herring larvae identified and standard lengths measured. All other fish larvae will be preserved unidentified.

8.3.2.13 Distribution of herring larvae of size classes <6–10 mm will be used to track simulated larvae back to their hatching sites using an offline Lagrangian particle tracking model based on existing hydraulic models. This methodology has been successfully used by Bauer *et al.* (2013) and Christensen *et al*. (2007) to identify the location of spawning sites of Western Baltic herring and North Sea lesser sandeel.

8.3.2.14 Herring larvae distribution and density within Swansea Bay throughout the sampling period will be provided. In addition the methodology, data analysis, and a summary of the findings and provide geospatial mapping of larval density within the Bay. If larvae <10mm are recorded a Lagrangian particle tracking model will be used to track simulated larvae back to their hatching sites that will enable mapping of likely herring spawning grounds for 2015.

Survey 23b – Mobile hydroacoustic survey and trawling

8.3.2.15 Scientific acoustic surveys using small mid-water (pelagic) trawl for validation – abundance and distribution. Scientific split-beam echo-sounder deployed from survey vessel or chartered commercial vessel. Sub-sampling of stock with a small mid-water (pelagic) trawl. In samples collected fish would be measured to the nearest mm (total length) and their spawning condition would be ascertained using established CEFAS maturity keys.

Survey 24 - Artificial spawning media

8.3.2.16 Installation of anchored and buoyed steel frames covered in mesh media in a grid pattern over known spawning sites. These would be monitored and retrieved utilising spawning timing data from local fishermen and the hydroacoustic survey. Upon retrieval the media would be visually inspected for herring eggs and presence/absence recorded. This would provide information on spawning locations and timings.

Survey 25- Video capture technology and/or sediment grabs

Grab survey

8.3.2.17 Grab surveys (using e.g. a 0.1m^2 Day grab or a van Veen grab) in order to identify any eggs deposited within the vicinity of the known spawning areas. This method is limited to finer substrates and could not be used on rock. Grabs deployed from chartered commercial or survey vessel.

Video capture

8.3.2.18 This method would form a particularly useful component of a suite of herring-specific surveys but it may be impractical in Swansea Bay due to high background turbidity levels. Further investigation into the practicality of the method is required given the constraints.

8.3.2.19 It would be proposed to use video capture technology for three elements: confirming herring spawning around artificial spawning media, assessing the presence of eggs on rocky ground (if applicable) and investigating the use of sea walls and defences as a spawning media by herring.

8.3.2.20 Video capture technology would be used after the retrieval of artificial spawning media in order to investigate the bed surrounding confirmed spawning sites to confirm that a wider area than the artificial media itself was utilised for spawning. Similarly to the grab

surveys, a survey vessel would be used to lower underwater camera equipment to the sea bed.

8.3.2.21 Where the artificial spawning media show presence of herring eggs on rocky sea bed, it is proposed that underwater camera equipment be used as a surrogate for grab survey to confirm egg deposition.

8.3.2.22 It is also proposed to use video capture technology to monitor the seawalls in order to investigate their use as spawning media. However, in addition to potential problems associated with turbidity, this element has the potential to involve further constraints linked to the potential health and safety implications of vessel navigation in proximity to rocks etc. The success of this particular element would be reliant on the distance at which the survey vessel would need to keep to allow safe working conditions.

8.3.2.23 It is anticipated that the video capture surveys would serve to identify the location and spatial extent of the current spawning grounds used by the herring population of Swansea Bay, with particular relevance to the lagoon seawalls.

8.3.3 Objective F3: To examine broad scale changes in fish fauna assemblage within Swansea Bay pre and post construction

8.3.3.1 The large inter-annual variability in fish stocks within the Bay means that long-term monitoring of stocks pre- and post-development would be required to measure relatively small changes in stocks or to distinguish changes brought about by natural ecosystem processes (such as climate variability) or other anthropogenic (principally industrial) impacts to the Bay, and those brought about specifically by the Project.

8.3.3.2 Surveys would be completed to build upon the characterisation surveys undertaken for the baseline (winter 2012 to autumn 2013), by utilising selected sampling sites and methods as described previously. Extension of the characterisation survey is intended to provide a more robust characterisation of the fish fauna assemblage within the Bay allowing for an assessment of diversity both pre- and post-development using the Shannon Diversity Index. Pre and post- construction surveys will then be used to analyse potential larger scale changes to the seasonal and annual community diversity that may result from the development of a lagoon. To deal with the possible long stabilisation period, such assessments should be carried out at geometric intervals, e.g. 1,2, 4, 8, 16, 32 years.

8.3.3.3 The data will be used to test the following hypotheses:

a) Diversity Index of samples collected within the lagoon (intertidal and sub-tidal combined) is the same as for those collected inside Swansea Bay but outside the lagoon.

b) Diversity Index of samples collected within the lagoon (intertidal and sub-tidal combined) prior to construction is the same as for those collected within the lagoon (intertidal and sub-tidal combined) during the operational phase.

c) Diversity Index of samples collected within Swansea Bay but outside the lagoon (intertidal and sub-tidal combined) prior to construction is the same as for those collected within Swansea Bay but outside the lagoon (intertidal and sub-tidal combined) during the operational phase.

8.3.3.4 In this second set of hypotheses the sample unit is the combined fish community described by intertidal sampling location(s).

a) Diversity Index of samples collected within lagoon is the same as those collected within Swansea Bay but outside the lagoon.

b) Diversity Index of samples collected within Swansea Bay intertidal region is the same as those collected outside the lagoon.

c) Diversity Index of intertidal sample(s) collected within lagoon prior to construction is (are) the same as that collected within lagoon during the operational phase

d) Diversity Index of intertidal samples collected within Swansea Bay intertidal region prior to construction is the same as those intertidal samples collected within Swansea Bay intertidal region during the operational phase

e) Diversity Index of samples collected outside Swansea Bay prior to construction is the same as those intertidal samples collected outside Swansea Bay intertidal region during the operational phase

8.3.3.5 It is also proposed that surveys would also look into targeting particular species of interest (e.g. herring) whilst taking into consideration long term data sets and other routine and non-routine sampling undertaken in the Bay.

8.3.3.6 Characterisation surveys would be undertaken pre- and post- construction to examine the diversity of fish species within the Bay.

Table 8.3 F3 Objective Summary: To monitor fish fauna assemblage change

Target	Continued characterisation of the Swansea Bay fishery and monitoring of changes brought about by Project construction and operation.
WFD	Fish quality element (transitional waters) Fish (migratory fish only) quality element (river waterbodies)
Management/operation	Construction and physical presence of the operational lagoon.
Survey	Four further pre-construction surveys (**Survey 26**) using intertidal and subtidal techniques are proposed: Quarter one (spring 2014); Quarter two (summer 2014), Quarter three (autumn 2014) and Quarter four (winter 2014). Survey methodology will follow that used during baseline surveys to enable comparisons to be made. An additional survey will be undertaken in autumn 2015, as per WFD survey protocol. Statistical analysis of the three year autumn data set will be undertaken and need to focus future surveys on quarterly or autumn only will be determined. Surveys will be undertaken in year 2 of construction surveys outside the lagoon (for health and safety reasons). Further surveys will be carried after Project completion and will include monitoring using intertidal and subtidal techniques. To deal with the possible long stabilisation period, such assessments should be carried out at geometric intervals, e.g. 1,2, 4, 8, 16, 32 years.
Responsibility	TLSB
Objective	To validate findings of ES and provide a research baseline.
Limits of acceptable change	Not applicable
Further / remedial action	Findings will be reported.

Survey 26 – Fish intertidal and subtidal surveys

8.3.3.7 For a detailed account of survey methodologies, please refer to Appendix 9.2 Quarterly survey reports of the Environmental Statement. An overview of the methods used in site-specific surveys is provided below:

8.3.3.8 Four quarterly surveys (spring, summer, autumn and winter 2014) using intertidal and subtidal techniques to be conducted at 6 sites intertidal (table 8.4) and 6 subtidal sites (tables 8.5a and 8.5b). Surveys to be repeated year two construction, and year one, year three, year five and year ten of operation.

i. Intertidal surveys using two surveying methods:
- a beach seine net (43m long by 4m deep, with 14mm wings and 6.5mm knotless mesh) set from a boat in accordance with JNCC procedural guidelines. The net will be set and hauled twice at each sampling station; and
- a Riley push-net (1.5m wide push-net with a 6.5mm mesh trouser legs lined with 1mm fry mesh) will be fished along a 100m transect in knee deep water used from the shore. Two replicates will be undertaken at each sampling station.

ii. The subtidal surveys using;
- otter trawl with a 15m head line, the depth from head line to foot line is 3.6m. The net will be trawled for 15 minutes at each station at an average speed of between 1 and 2 knots; and
- beam trawls single 1.5m beam trawl carried out along a parallel transect for a period of 15 minutes at an average speed of between 1 and 2 knots.

iii. For each survey the catch is to be identified to species level and measured to the nearest millimetre; fish to be sub-sampled when > 50 specimens of the same species were captured.

Table 8.4 Intertidal sites sampled during the surveys

Site Code	Site Name	Co-ordinates
I1	Caswell Bay	51:34.13312N 4:1.94620W
I2	Blackpill	51:36.27098N 3:58.87818W
I3	Abertawe	51:36.77037N 3:56.14407W
I4	Port Talbot West	51:35.86105N 3:49.59318W
I5	Pwlldu Bay	51:33.88237N 4:3.48465W
I6	Crymlyn Burrows	51:36.96590N 3:52.44125W

Table 8.5a Subtidal otter trawl sites sampled during the survey

Site code	Start	End
O1	51:32.084N 3:50.019W	51:33.066 3:51.006W
O2	51:34.099N 3:49.096W	51:35.041N 3:51.014W
O3	51:35.098N 3:53.064W	51:35.013N 3:53.025W
O4	51:34.035N 3:58.003W	51:34.095N 3:57.026W
O5	51:34.044N 3:55.057W	51:34.090N 3:54.040W
O6	51:35.030N 3:57.016W	51:35.086N 3:56.030W

Table 8.5b Subtidal beam trawl sites sampled during the survey

Site code	Start	End
B1	51:32.098N 3:50.044W	51:33.038N 3:50.089W
B2	51:35.039N 3:50.024W	51:35.015 N 3:50.049W
B3	51:35.065 N 3:53.045W	51:36.027N 3:53.054W
B4	51:35.071N 3:57.074W	51:34.039N 3:58.003W
B5	51:34.058N 3:54.095W	51:34.040N 3:55.051W
B6	51:36.041N 3:55.076W	51:35.015N 3:57.014W

8.3.4 Objective F4: To examine the diversity and abundance of fish associated with the artificial reef

8.3.4.1 The construction of the lagoon wall is predicted to afford increased spawning, juvenile, foraging and refuge habitat to a variety of species of fish and invertebrates. A suite of surveys designed to assess the colonisation and development of the lagoon wall (reef) and the diversity and abundance of associated fish fauna will inform the post impact assessment of the lagoon and inform impact assessments and designs of future developments. The assessment in the ES considers that the artificial reef is likely to create a diverse ecological environment and provide increased opportunities for both commercial and recreational fishing. The findings of the characterisation surveys (see **Survey 21** above) and the surveys of the artificial reef will provide the basis of evidence to validate the findings of the ES.

Table 8.6 F4 Objective Summary: Fish abundance and diversity associated with artificial reef

Target	Characterisation of the Swansea Bay fishery and monitoring of changes brought about by Project construction and operation.
WFD	Fish quality element (transitional waters)
Management/operation	Construction and physical presence of the operational lagoon.
Survey	Surveys to examine the diversity and abundance of fish associated with the artificial reef. The surveys will be agreed with NRW but are likely to include: • *Fine sediment environments*: potential use of juvenile beach seining, push nets, small beam trawls; • *Subtidal Rocky Habitats*: potential use of fyke netting, trapping, underwater transects and baited remote underwater video (depending on turbidity of water and spatial scale of surveys required); and • *Intertidal rockpools*: sampling by anaesthetisation, hand netting and visual assessment. ***Angling data*** Data will be collected from anglers using the seawall on both an *ad hoc* basis as well as during organised angling competitions. Angling opportunity and desirability to fish from the lagoon wall to be assessed.
Responsibility	TLSB
Objective	To validate findings of ES and to provide a research baseline for future projects.
Limits of acceptable change	Not applicable

Further / remedial action	Findings will be reported. Review any further opportunities to enhance ecological diversity post construction of the lagoon seawalls.

8.3.4.2 It is proposed to undertake a suite of surveys within the range of habitats created by the development, to include fine sediment environments of the inner lagoon, sub-tidal rocky habitats and inter-tidal rock pools. Surveys may include, but not be limited to:

- Fine sediment environments: juvenile beach seining, push netting, small beam trawls (**Survey 26**), drop tapping and fyke netting (**Survey 27a** – methods to be confirmed).
- Sub-tidal Rocky Habitats: fyke netting, trapping, scuba diving transects/underwater camera (**Survey 19**), baited remote underwater video (this technique may not be effective in turbid waters or for large spatial scale);
- Intertidal rock pools (**Survey 15**): sampling by anaesthetisation, hand netting and visual assessment.

8.3.4.3 In addition, data will be collected from anglers using the seawall on both an *ad hoc* basis as well as during organised angling competitions. Data collected would include species, weight and length as well as stomach content, where possible. This would provide an indication of predation on smaller species or young from larger predators that may be associated with the subtidal rocky habitat of the lagoon seawall.

8.3.4.4 Angling opportunity and desirability to fish from the lagoon wall may be assessed by angler surveys (creel census) or by multiple fixed CCTV. Time lapse CCTV images could be analysed to determine the density of anglers, tide or time of day preference, type of angling experience afforded i.e. static fishing on the bed, float fishing or spinning (method of angling helping to determine target species).

8.3.5 Objective F5: To review migratory fish stocks along the Afan and Tawe

Afan Green Park Weir Fishpass Data Review

8.3.5.1 A compound super-active bottom baffle fish pass was installed in 2012 at the tidal limit of the River Afan at Green Park Weir, Port Talbot. A video camera was fitted in to the upstream exit of the pass to enable the effectiveness of the pass to be assessed. NRW has operated the camera since the pass was installed. NRW has advised that it is currently (July 2014) working to analyse the data collected by the Afan fish counter for research into environmental factors affecting salmonid passage. The camera is known to have recorded numerous fish passing through the facility. Analysis of the existing and future data set would provide data on stocks of returning migratory fish on the Afan pre- and post-development of the Project. Data may be used to provide minimum estimates of returning spawners that would enable Conservation Limits to be determined as described above.

Panteg Fish Trap Refurbishment

8.3.5.2 Annual compliance with salmon conservation limits (a level below which further reductions in spawner numbers are likely to result in significant reductions in the number of juvenile fish produced in the next generation) is estimated using egg deposition

figures. The procedure for estimating egg deposition requires derivation of run size and within the Rivers Tawe and Afan these are derived from rod catch using estimates of exploitation (and an appropriate adjustment for under-reporting). However, these procedures may not fully take into account annual changes in fishing effort.

8.3.5.3 The Panteg fish trap is operated by NRW, who have confirmed that juvenile survey data demonstrate that salmon pass the weir every year to spawn upstream. Nevertheless the water level below the weir has dropped making entry to the fish pass difficult. NRW are currently undertaking works to raise the water level in the weir pool and address these issues. As such this refurbishment would allow the free passage of salmonids under all flow conditions.

8.3.5.4 NRW have confirmed that they would welcome the installation of a remote fish counter at the upstream exit[13] and further discussion would be undertaken. It would be proposed to provide a Vaki Riverwatcher counter, or similar. The fish counter could consist of an infrared, resistivity or video counter. Data collected would include species, length (biomass estimate), date, time and direction of fish passage. Annual data would be collated and the results would be reviewed.

Table 8.7 F5 Objective summary: review migratory fish stocks along the Afan and Tawe

Target	Analysis to provide data on the stocks of returning migratory fish.
WFD	Fish (migratory fish only) quality element on river waterbodies
Management/operation	Construction and physical presence of the operational lagoon.
Survey	Provision of fish counter and potential refurbishment of Panteg fish trap. Data (both historical and ongoing) review and analysis, where appropriate, to clarify historical data and provide ongoing information up until 15 years post construction on stocks of returning migratory fish. The frequency and need for ongoing data analysis and review would be considered based on a comprehensive, holistic review of the findings of studies undertaken for the Project, compliance with the WFD and discussions with NRW.
Responsibility	TLSB
Objective	To validate findings of ES and if necessary identify change outside that already predicted.
Limits of acceptable change	Data will be used as part of the study into WFD compliance for the potential effects of the Project on 'good ecological status' (see Table 8.3 above).
Further action	Findings will be reported. If consistent decline in fish stocks are observed further a review of the status of stocks in adjacent catchments would be undertaken to establish whether the condition is local or more wide spread and driven by external factors. If appropriate mitigation measures at the turbine and sluice gate structure will be reviewed. If no AFD present and results of monitoring show increased impact, then install AFD system. If AFD present and results of monitoring show impacts above ES findings, refine AFD deployment in consultation with NRW/CEFAS.

[13] There is currently no electrical power to the site; however it is believed that an existing conduit from a local water utility facility could potentially feed the site with power sufficient to operate a fish counter.

8.3.6 Objective F6 - Analyse rod catch data to determine effect of the Lagoon

8.3.6.1 Rod catch reports are the only direct measure available of adult salmonids in local rivers incorporating long-term data sets. These rod catch reports can be used to evaluate the influence of the lagoon's construction and operation on adult salmonid numbers.

8.3.6.2 It is therefore proposed to undertake further analysis of the available data to provide:

1. The quantitative comparison of adult salmonid numbers before, during and after construction of the Swansea Bay Tidal Lagoon. This comparison will be made in each of three rivers, the Afan, Neath (to the extent not already collected) and Tawe which are local to the construction and operation of the Swansea Bay Tidal Lagoon.

2. The quantitative comparison of adult salmonid numbers in a reference (control) river compared to the rivers identified above. This comparison will be made between the reference river and each of three rivers, the Afan, Neath and Tawe which are local to the construction and operation of the Swansea Bay Tidal Lagoon.

Methodology

8.3.6.3 Rod catch data for Atlantic salmon adults will be obtained for the Afan, Neath, and Tawe for the years 2001 to present. Rod catch data for Atlantic salmon adults will also be obtained for the Afan, Neath, and Tawe for the years prior to construction, during construction and three years post-construction.

8.3.6.4 The rod catch data will also be obtained for a reference river in south Wales that does not drain to Swansea Bay for the years 2001 to present, during construction, and three years post-construction.

8.3.6.5 The amount of variability in rod catch data was estimated using reported rod catches from 2001 through 2011 for three rivers: Afan, Neath and Tawe. Using this estimate of variability, the number of years estimated to be necessary to detect a change in rod catch was determined. Three years of data post-construction will allow a 90% chance of detecting a 15% change (with a 0.05 Type I Error Rate) in the contribution of a particular year to overall production in the period of record.

Hypotheses

8.3.6.6 Below are a range of hypotheses which will be tested.

8.3.6.7 H01 = There is no difference in the rod catch rate in the River Afan before, during, or after construction.

8.3.6.8 Hypothesis H01 will also be evaluated for the Rivers Neath (Hypothesis H02) and Tawe (Hypothesis H03).

8.3.6.9 H04 = Before construction, there is no difference in the rod catch rate in the River Afan compared to the reference river.

8.3.6.10 Hypothesis H04 will also be evaluated for the Rivers Neath (Hypothesis H05) and Tawe (Hypothesis H06).

8.3.6.11 H07 = During construction, there is no difference in the rod catch rate in the River Afan compared to the reference river.

8.3.6.12 Hypothesis H07 will also be evaluated for the Rivers Neath (Hypothesis H08) and Tawe (Hypothesis H09).

8.3.6.13 H010 = After construction, there is no difference in the rod catch rate in the River Afan compared to the reference river.

8.3.6.14 Hypothesis H010 will also be evaluated for the Rivers Neath (Hypothesis H011) and Tawe (Hypothesis H012).

8.3.6.15 Annual survey reports will be produced reflecting the yearly returns. Statistical analysis as well as geospatial maps will be provided. The final report will include the results of the statistical comparisons that lead to the acceptance or rejection of each of the 12 null hypotheses listed above. After the 12 null hypotheses are tested, a written description of the interpretation of each hypothesis will be included. Then, the interpretation of the pattern in the hypothesis testing will be conducted and reported.

8.3.6.16 Power analysis for Sampling Rod Catch Data is presented below to determine the number of years data requiring analysis to detect potential change as a result of the Project. The analysis is presented for both Atlantic salmon and sea trout catch for the three rivers that flow into Swansea Bay or nearby.

Atlantic Salmon

8.3.6.17 Presented below are the data for the period of record (2001-2011) available at the time of the analysis.

Table 8.7a. Atlantic salmon rod catch data, counts and proportional representation.

Year	Afan	Neath	Tawe	Afan	Neath	Tawe
2001	8	70	113	0.0833	0.0925	0.0682
2002	7	90	148	0.0729	0.1189	0.0894
2003	5	35	61	0.0521	0.0462	0.0368
2004	10	73	155	0.1042	0.0964	0.0936
2005	6	37	164	0.0625	0.0489	0.0990
2006	5	85	184	0.0521	0.1123	0.1111
2007	3	53	183	0.0313	0.0700	0.1105
2008	9	99	195	0.0938	0.1308	0.1178
2009	15	62	114	0.1563	0.0819	0.0688
2010	18	76	230	0.1875	0.1004	0.1389
2011	10	77	109	0.1042	0.1017	0.0658
Sum	96	757	1656	1.0000	1.0000	1.0000
Mean	8.7273	68.8182	150.5455	0.0909	0.0909	0.0909
sd	4.4742	20.5223	48.1235	0.0466	0.0271	0.0291

Note: Highlighted are the standard deviations (sd) for count data for the three rivers, the maximum of these is 48.1235.

8.3.6.18 The first power analysis (Table 8.7b) completed shows that a minimum of 76 years of sampling would be required to have a 90% chance of detecting a 15% reduction in rod catch-count. And, 33 years of sampling would be required to have an 80% chance of detecting a 20% reduction in rod catch-count.

Table 8.7b Power analysis and sample size (n) required of the number of years of sampling required to detect a difference of 15 or 20% (d%) in the actual count data using the maximum sd from Table 8.7a.

Power	d%	d	Alpha	Tails of Test	Rounded(n)
0.9	15	23	0.05	2	94
0.8	20	30	0.05	2	42
0.9	15	23	0.05	1	76
0.8	20	30	0.05	1	33

Note: The value of d is the smallest difference in rod catch count it is desired to detect. Alpha is the maximum Type I Error rate that is acceptable.

8.3.6.19 In the next power analysis (Table 8.7c), proportions of total catch were analysed. These proportions can be inspected in Table 8.7a. The maximum observed sd for the proportional data was 0.0466. Using this value, it was determined that a minimum of three years of sampling would be required to have a 90% chance of detecting a 15% reduction in rod catch-proportion. And, two years of sampling would be required to have an 80% chance of detecting a 20% reduction in rod catch-proportion.

Table 8.7c. Power analysis and sample size (n) required of the number of years of sampling required to detect a difference of 15 or 20% (d%) in the actual proportional representation data using the maximum sd (0.0466) from Table 8.7a.

Power	d%	d	Alpha	Tails of Test	Rounded(n)
0.9	15	0.15	0.05	2	4
0.8	20	0.2	0.05	2	2
0.9	15	0.15	0.05	1	3
0.8	20	0.2	0.05	1	2

Note: The value of d is the smallest difference in rod catch proportion change it is desired to detect. Alpha is the maximum Type I Error rate that is acceptable.

8.3.6.20 In the light if the bio-statistical analysis salmon rod catch data will be monitored for at least three years from when the Project is in operation. This will provide a 90% chance of detection at 15% reduction in the proportional representation of catch in the years after the Lagoon begins operation.

8.3.6.21 There are two reasons that the proportional representation produces such smaller numbers of years needed. First, the raw counts are extremely variable due to natural environmental variation. Second, the relative proportion of catch compared between sampling periods is much more stable, i.e. reliable.

Power Analysis for Sampling Rod Catch Data Sea trout

8.3.6.22 Table 8.7d presents the rod catch data for sea trout over the period of record (2001-2011) available at the time of the analysis.

Table 8.7d Sea trout rod catch data, counts and proportional representation

Year	Afan	Neath	Tawe	Afan	Neath	Tawe
2001	166	673	373	0.1101	0.1267	0.1236
2002	103	782	424	0.0683	0.1472	0.1405
2003	162	400	272	0.1074	0.0753	0.0901
2004	168	532	173	0.1114	0.1002	0.0573

2005	153	393	372	0.1015	0.0740	0.1233
2006	63	298	153	0.0418	0.0561	0.0507
2007	158	487	243	0.1048	0.0917	0.0805
2008	161	317	144	0.1068	0.0597	0.0477
2009	120	492	242	0.0796	0.0926	0.0802
2010	112	493	426	0.0743	0.0928	0.1412
2011	142	444	196	0.0942	0.0836	0.0649
Sum	1508	5311	3018.000	1.0000	1.0000	1.0000
Mean	137.0909	482.8182	274.3636	0.0909	0.0909	0.0909
sd	33.5722	143.6627	107.1553	0.0223	0.0271	0.0355

Note: Highlighted are the standard deviations (sd) for count data for the three rivers, the maximum of these is 143.6627.

8.3.6.23 The first power analysis (Table 8.7e) completed shows that a minimum of 69 years of sampling would be required to have a 90% chance of detecting a 15% reduction in rod catch-count. And, 28 years of sampling would be required to have an 80% chance of detecting a 20% reduction in rod catch-count.

Table 8.7e Power analysis and sample size (n) required of the number of years of sampling required to detect a difference of 15 or 20% (d%) in the actual count data using the maximum sd from Table 8.7d.

Power	d%	d	Alpha	Tails of Test	Rounded(n)
0.9	15	72.423	0.05	2	84
0.8	20	96.564	0.05	2	36
0.9	15	72.423	0.05	1	69
0.8	20	96.564	0.05	1	28

Note: The value of d is the smallest difference in rod catch count it is desired to detect. Alpha is the maximum Type I Error rate that is acceptable.

8.3.6.24 In the next power analysis (Table 8.7f), proportions of total catch were analysed. These proportions can be inspected in Table 8.7e. The maximum observed sd for the proportional data was 0.0355. Using this value, it was determined that a minimum of two years of sampling would be required to have a 90% chance of detecting a 15% reduction in rod catch-proportion. And, two years of sampling would be required to have an 80% chance of detecting a 20% reduction in rod catch-proportion.

Table 8.7f Power analysis and sample size (n) required of the number of years of sampling required to detect a difference of 15 or 20% (d%) in the actual proportional representation data using the maximum sd (0.0355) from Table 8.7e.

Power	d%	d	Alpha	Tails of Test	Rounded(n)
0.9	15	0.15	0.05	2	3
0.8	20	0.2	0.05	2	2
0.9	15	0.15	0.05	1	2
0.8	20	0.2	0.05	1	2

Note: The value of d is the smallest difference in rod catch proportion change it is desired to detect. Alpha is the maximum Type I Error rate that is acceptable.

8.3.6.25 In the light if the bio-statistical analysis sea trout rod catch data will be monitored for at least two years from when the Project is in operation. This will provide a 90% chance of detection of a 15%, or greater, reduction in the proportional representation of catch in the years after the Lagoon begins operation.

8.3.6.26 There are two reasons that the proportional representation produces a smaller numbers of years needed. First, the raw counts are extremely variable due to natural environmental variation. Second, the relative proportion of catch compared between sampling periods is much more stable, i.e. reliable.

8.3.6.27 Note, for either species any change detected may not necessarily be attributed to the Project and this would be considered through the wider AEMP results.

8.3.7 Objective F7: To review NRW WFD compliance data to assess any changes in ecological status

8.3.7.1 NRW undertakes routine monitoring of fish fauna in the freshwater catchments that feed into Swansea Bay. NRW has advised that it carries out electro-fishing at a network of sites to assess compliance against Good Ecological Status, required by the WFD. The surveys are primarily aimed at juvenile salmonids but also record eels, and a range of minor species, and follow a pre-defined protocol for data collection and analysis. Local angling clubs do not routinely undertake surveys and the results cannot be incorporated into the compliance sampling.

8.3.7.2 Local angling clubs carry out *ad hoc* monitoring and the data can provide an indication of fish species present but the results cannot be incorporated into the NRW compliance sampling.

8.3.7.3 An ongoing review of compliance data collected by NRW would be undertaken to examine any changes in status in the fish (Neath and Tawe transitional waterbodies) and the fish (migratory fish only) quality element of any waterbodies hydrologically linked to Swansea Bay Coastal waterbody. Information from the data review in F6 above would also be taken into consideration.

Table 8.8a F7 Objective Summary: WFD Compliance review

Target	Review of status of WFD waterbodies fish quality element and further data collection, where appropriate, to provide increased resolution and statistical robustness to assess compliance with 'Good Ecological Status'
WFD	Fish quality element (transitional waters) Fish (migratory fish only) quality element (river waterbodies)
Management/operation	Operation of the lagoon.
Survey	Survey 27b - quantitative electro-fishing.
Responsibility	TLSB
Objective	To validate findings of ES and if necessary identify change outside that already predicted.
Limits of acceptable change	Change in status of fish quality element (transitional) waters and fish (migratory fish only) quality element of waterbodies hydrologically linked to Swansea Bay Coastal waterbody. Data from any additional studies will be made available for expert peer review and if a consensus of opinion suggests the lagoon has brought about adverse change this will trigger remedial action.
Further / remedial action	Findings will be reported. TLSB will work with NRW to develop appropriate mitigation strategies. It should be noted that NRW are undertaking works at the Panteg fish trap to promote migratory fish passage within waterbodies connected to Swansea Bay Coastal waterbody. TLSB will make provision for the installation of a fish counter.

8.3.7.4 Since submission of AEMPr2 in October 2014, NRW has confirmed that no WFD compliance monitoring is currently being carried out in the Neath or Swansea Transitional waters. As such quantitative electro-fishing surveys are proposed as discussed below.

Survey 27b - quantitative electro-fishing

Objective

8.3.7.5 The objective is to analyse changes in salmon and trout fry and parr density (i.e. a measure of production). This is assessed alongside the other salmonid monitoring elements to establish whether the operation of the Lagoon impacts migratory salmonids migrating into the rivers discharging into Swansea Bay.

Methodology

8.3.7.6 The monitoring programme would consist of quantitative electric fishing surveys at historic survey stations within identified catchments (and a reference site). Surveys would be undertaken once per year and would need to include a pre-construction survey along with consecutive years thereafter. The number of survey years post-construction is discussed below. Surveys would record species, length and abundance of fish fauna, the area of river sampled and environmental variables including DO, temperature, pH and conductivity. This would enable the calculation of fry and parr densities for trout and salmon.

8.3.7.7 The number of survey sites is limited by the availability of suitable historic data to two sites on the rivers Tawe, Afan and Neath. These are (EA codes) TW03, TW05, AF07, AF11AX, NE07i and NE19. However, the exact positions of these surveys have changed slightly over time (see Limitations below).

8.3.7.8 Two reference sites with the same historic data set (2003-2007) from a geographically separate river (e.g. the Loughor, Towy or Taf which discharge into Carmarthen Bay) would also be surveyed in order to put any potential change over time into context.

8.3.7.9 The selection of methodology and reference sites for this element would require involvement from (and the local expertise of) NRW Fisheries.

Hypothesis

8.3.7.10 The certainty of detecting a change is improved by increasing the number of years monitoring post-construction. For example, with 3 years post-monitoring it is estimated that there is an 80% probability of detecting a 20% difference in salmon fry density pre-, during and post construction assuming a significance (α) of 0.05. However, with 5 years post-monitoring it is estimated that there is a 90% probability of detecting a 15% difference in salmon fry density pre-, during and post construction assuming a significance (α) of 0.05. The number of year's post-monitoring required for these levels of certainty changes for fry and parr stages of salmon and trout.

8.3.7.11 The following are examples (specific to salmon fry) of the hypotheses that would be tested:

8.3.7.12 H01. There is no difference in the salmon fry density prior to, during and after Lagoon construction.

8.3.7.13 H02. There is no difference in the salmon fry density prior to, during and after Lagoon construction in the reference sites and rivers subject to alteration by the Lagoon.

8.3.7.14 Statistical tests to be used will be dependent on the results but it is expected that ANOVAs will be used. Alternatively non-parametric equivalents (e.g. Kruskal-Wallis) will be used.

8.3.7.15 The hypotheses allow analysis of change pre-, during and post Lagoon construction and, if a change is detected, it can be analysed against a reference site to establish whether the primary contributor is the Lagoon or another factor.

8.3.7.16 The number of years post-monitoring required for fry and parr stages of salmon and trout at an 80% probability of detecting a 20% difference and 90% probability of detecting a 15% difference assuming a significance of 0.05 are outlined in Table 8.8b

Table 8.8b Post-monitoring requirements in years for fry and parr stages of salmon and trout

Species/Lifestage	Number of years post-monitoring required to achieve:	
	80% prob. of detecting 20% change	90% prob. of detecting 15% change
Salmon fry	3	5
Salmon parr	2	3
Trout fry	5	9
Trout parr	4	8

8.3.7.17 It is therefore recommended that post-monitoring continues for at least 5 years after Lagoon operation has commenced in order to describe differences in salmon juveniles at a high level of certainty.

8.3.7.18 Annual survey reports will be produced for inclusion in the ATR reflecting the sampling season and. Statistical analysis as well as geospatial maps will be provided. The final report would present statistical analysis of the combined data.

Limitations

8.3.7.19 The exact positions of the survey sites have changed slightly over time (see Figure 8.1) resulting in potential issues of comparability. However, it is considered that the variation is limited enough not to adversely affect results.

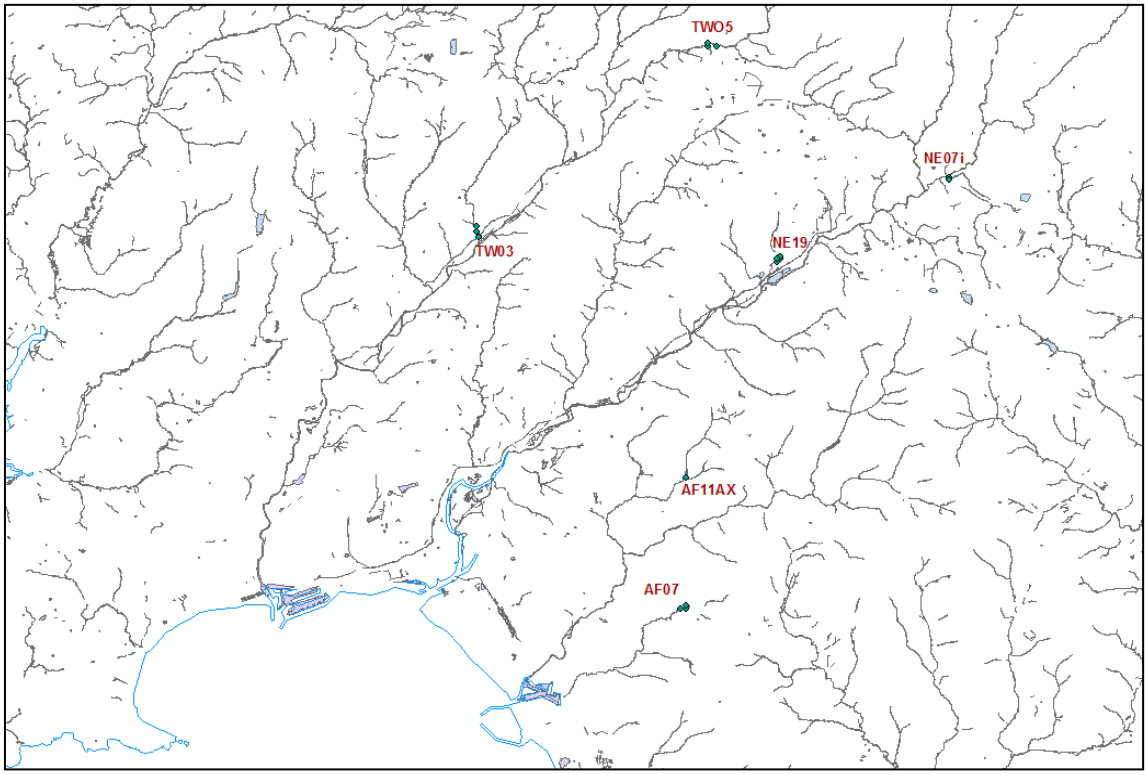


Figure 8.1 GIS layer showing the slight variation in site locations over time

8.3.8 Objective F8: To monitor fish movements across the Bay and into/out of the Lagoon by acoustic telemetry

8.3.8.1 The impacts of lagoon operation on migratory fish, including salmon, sea trout and eels, and marine fish species, are partly dependent on their patterns of movement across Swansea Bay as they move into and out of local rivers. This has been assessed using Individual Based Models (IBMs) of fish behaviour models to predict turbine encounter rates for different species, with parameters for the IBM models being derived from laboratory data and fish tracking studies carried out elsewhere. Only very limited useable data were available from tracking studies previously carried out in Swansea Bay specifically. NRW and other stakeholders have proposed that fish baseline and operational phase fish telemetry studies should be carried out to consolidate information on local migratory fish behaviour and to validate model inputs to provide more confidence in related assessments.

8.3.8.2 A question specific to sea trout concerns their behaviour following outmigration to sea at the smolt stage. It is widely believed that sea trout post-smolts will remain in coastal waters for much or all of their marine phase life, which could increase their vulnerability to turbines. The fish characterisation surveys found little evidence of sea trout remaining in the Bay but at low densities they are difficult to detect. The ES identified this aspect as an area of uncertainty and telemetry studies can be used to provide better information.

8.3.8.3 NRW also proposed that the Project should monitor impacts on European eel. Since densities of eel within the Bay are known from fish characterisation surveys to be low, further monitoring based on survey techniques is considered likely to yield little useful information and the use of telemetry on adult eels to assess their likelihood of encountering the turbines will be more informative.

Table 8.9 F8 To monitor fish movements across the Bay and into/out of the Lagoon by acoustic telemetry

Target	Migratory and marine fish movements across the Bay
WFD	Fish quality element (transitional waters) Fish (migratory fish only) quality element (river waterbodies) Eel Regulations
Management/operation	Operation of lagoon.
Survey	**Survey 27c- Fish tagging studies** **Before construction**: Capture, tag and release specimens of salmon/sea trout smolts (April/May) and silver eel (autumn). Monitor movements through active boat tracking only. Analyse data and assess whether contained within limits. Duration: 1 year 2015, target no. of tags/boat days: 50. **During construction:** No tracking proposed: not appropriate to undertake tracking work during this period as construction activities may disturb equipment and findings. **Operation:** Repeat active tracking for smolts and eel. Establish a network of listening stations from Tawe barrage to Tawe training wall, close to proposed turbine inlet and out to Mumbles Head; including stations to either side (W-E) of turbine house on outside of lagoon and one on inside of the lagoon to detect fish entering or leaving the lagoon. Release, according to season and receiver capacity, tagged salmon and sea trout smolts and silver eel; salmon and sea trout adults. Other fish species may be added if AEMP (e.g. turbine passage monitoring, Objective F1) identifies a need, provided that tagging is viable for the species/lifestage. Duration: 2 years from commencement of operation year; target no. of fish/tags to be released over 2 year period: 50 salmon smolts, 50 large sea trout smolts; 50 silver eels; 30 adult salmon; 30 adult sea trout .
Responsibility	TLSB
Limits of acceptable change	Modelling pre-DCO decision - targets set within ES Chapter 9 for VERs Monitoring – operation – assessed impact greater than in ES.
Further / remedial action	To validate IBM model for future lagoon applications.

Survey 27c - Fish tagging studies

8.3.8.4 Acoustic telemetry would be used in all fish tracking studies as radio telemetry is not effective in salt water. To carry out the studies, trial fish would be captured locally and fitted with acoustic transmitting tags and released at river or marine locations as appropriate. Tracking of movements would by two methods: (1) via a network of passive underwater listening stations positioned at strategic points (e.g. on existing data buoys or fixed structures), which would require the fish to pass within ~500 m to be detected, and (2) by active tracking using a boat mounted receiver to either follow the migration paths of individual fish or to carry out sweep survey transects across the Bay to identify any tagged fish present in the Bay. Baseline studies will be limited to active tracking methods and will be confined to smolts and eels.

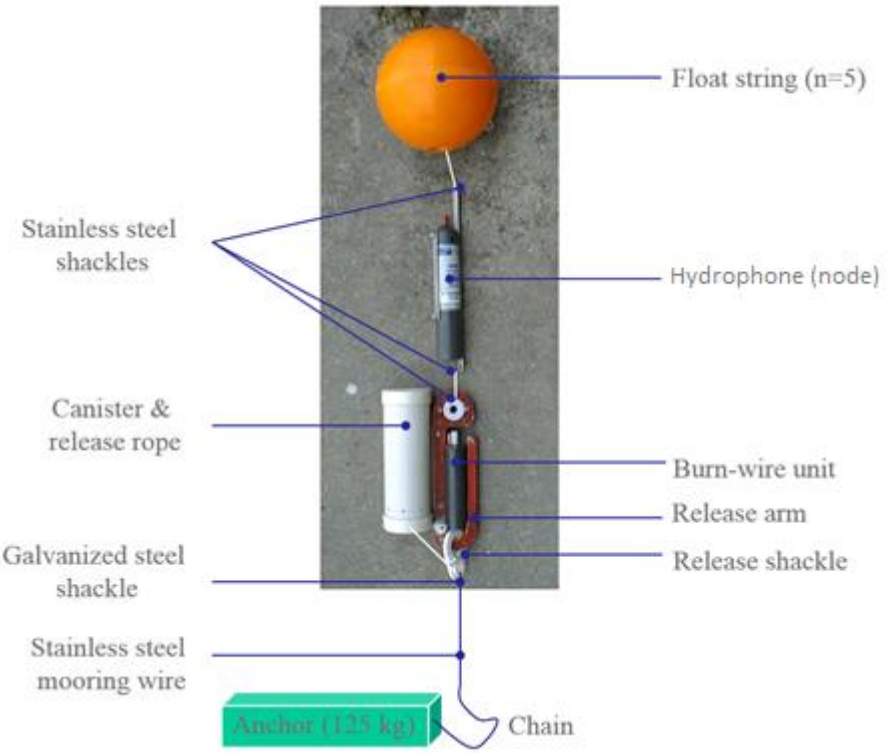


Figure 8.2 Fixed submerged listening station with automatic release mechanism

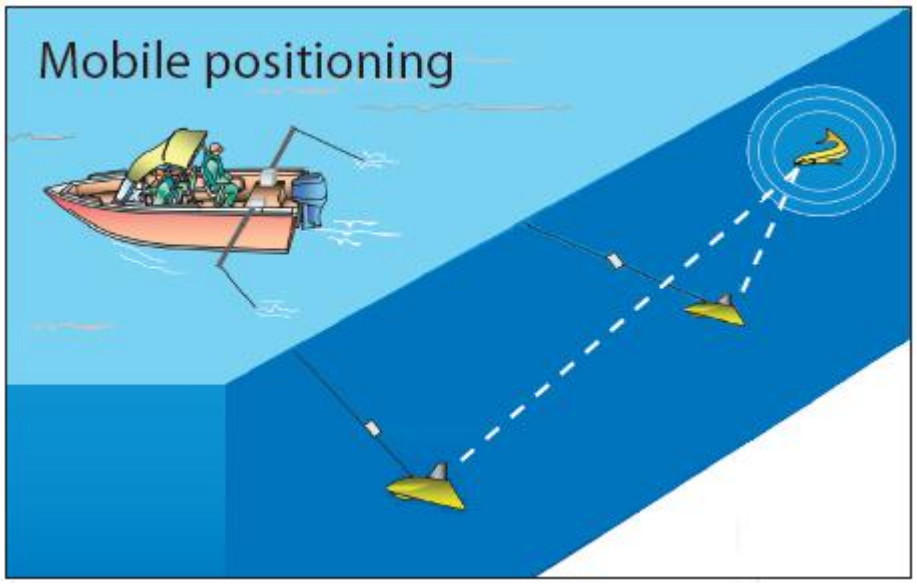


Figure 8.3 Active Tracking sussing dual hydrophones for position-fixing

8.3.8.5 Tracking of adult salmon or sea trout is desirable in the longer-term but is not planned during the baseline phase. However, once a monitoring network has been established, potentially these and other species could be tagged and monitored subject to limitations on receiver tag capacity, and depending on a need being identified through the AEMP.

8.3.8.6 In the cases of tracking the rapid seaward outmigration of salmon and sea trout smolts and silver eels, lightweight tags with short battery life (e.g. 4-5 days) will be required to avoid over-burdening the fish. For investigating longer-term coastal behaviour of sea

trout post-smolts a longer tag life would be needed, and this would require selection of larger smolts (>20 cm) in order to accommodate the larger tag mass.

8.3.8.7 Capture of fish for tagging is invariably problematical where there are not routine capture facilities (e.g. eel racks, smolt traps) as is the cases for the local rivers. It will be desirable to source local fish as far as possible and for this purpose discussions with NRW have suggested that rotary screw trapping would be best for smolt capture and fyke-netting for silver eels, both carried out within the freshwater reaches. A number of screw traps are owned by the Environment Agency. Capture of adult salmon and sea trout may need to be e.g. at Swansea Barrage.

8.3.8.8 Analysis of active tracking position-time data will be carried out within the framework of the ABPmer Coastal Processes hydraulic model so that real fish swimming data can be separated from tidal and fluvial movements.

8.3.8.9 All fish tagging work is subject to permitting by the Home Office under the Animals (Scientific Procedures) Act 1986. Captures of smolts and silver eel will be under licence from NRW.

8.3.8.10 Initial surveys will be undertaken in 2015 with capture, tag and release of specimens of salmon/sea trout smolts in April/May and silver eel in autumn. Monitoring of movements will be undertaken through active boat tracking only. Further monitoring will be undertaken during year 1 and 2 from commencement of operation of the Lagoon.

9 Marine Mammals

9.1 Introduction

9.1.0.1 Chapter 10 Marine Mammals and Turtles of the ES provides details of the data review and site specific survey work carried out to collect baseline information for Swansea Bay. This section outlines the further monitoring and surveys which will be undertaken during the pre-construction, construction and operational phases, in order to review and confirm the findings of the EIA.

9.1.0.2 With mitigation, impacts on harbour porpoise are predicted to be minor, as such the need for a European Protected Species (EPS) Licence during construction will be discussed and agreed with NRW (MLT) before the Project commences. An application will be made to NRW (MLT) to obtain a licence for the operation of the Project and the mitigation and monitoring proposed herein will be used to support this application. Further discussions will be held with NRW (MLT) and NRW(A) to ensure an appropriate package of monitoring for this process and any additional measures will be incorporated within subsequently updated iterations of this AEMP.

9.1.0.3 The grey seal population of Swansea Bay has been assessed as very small and, similarly to harbour porpoise, with mitigation there is anticipated to be no significant effects on grey seal as a result of the Project.

9.2 Baseline

9.2.0.1 The scope of works for the assessment of the potential effects of the Project on marine mammals and turtles was presented in the Proposed Tidal Lagoon Development in Swansea Bay, South Wales, Environmental Impact Assessment Scoping Document (October 2012). Numerous sources of information were reviewed to inform the marine mammal baseline description, and it was determined that site specific surveys were not necessary. These include a number of national and regional studies to provide information on marine mammal distribution and ecology. These data were used to inform the understanding of the relative importance and functionality of the Bristol Channel and Swansea Bay in the context of the wider Celtic Sea area.

9.2.0.2 Mitigation measures to offset potential impacts during construction and operation are detailed in Chapter 23 of the ES and further outlined in the relevant objective sections below.

9.3 Marine Mammal Objectives

9.3.0 Introduction

9.3.0.1 This section sets out the objectives for marine mammals. The following objectives are examined:

- MM1 - Marine mammal monitoring to understand effects of Project;
- MM2 - To minimise and further understand the potential effects of construction;
- MM3 - To examine the potential for interaction with the project during operation;

The objectives and monitoring are discussed further in the following sections.

9.3.1 Objective MM1: Marine mammal monitoring to understand effects of Project

9.3.1.1 Numerous sources of information were reviewed to inform the marine mammal baseline description. These included a number of national and regional studies to provide information on marine mammal distribution and ecology. These data were used to inform the understanding of the relative importance and functionality of the Bristol Channel and Swansea Bay in the context of the wider Celtic Sea area. In addition to this data from recent studies within the bay were also reviewed.

9.3.1.2 As such, the assessment undertaken within the ES, Chapter 10, was robust and it adopted a worst case assessment. As stated at paragraph 10.5.1.3 "*Throughout the impact assessment all marine mammal species are considered to be of high importance given the high level of protection they are afforded under a range of UK and European Legislation*"; and at 10.5.1.2 "*in the absence of dedicated effort based survey data for the inner part of Swansea Bay and using a precautionary approach, the assumption has been made that harbour porpoise occur at similar frequencies to other parts of Swansea Bay such as Port Talbot.*"

9.3.1.3 Notwithstanding this, more detailed localised data is required for a more definitive understanding of the usage of the inner Bay by marine mammals and to detect any changes as a result of the Project. As such a long-term acoustic monitoring programme for harbour porpoises is being established in the proposed lagoon footprint and the wider Swansea Bay area as part of a Before After Control Impact (BACI) study. This monitoring will be undertaken pre-construction, during construction and then when the lagoon is operational. This section examines the objectives and outline monitoring proposed during pre-construction and construction.

Table 9.1 MM1 Objective Summary: Marine mammal monitoring to understand effects of Project

Target	To investigate and further understand marine mammals usage within inner Swansea Bay.
WFD	Not applicable
Management/operation	Construction and operation of the lagoon.
Survey	Pre-construction survey - deployment C-PODs during 2014 at 2 sites. Data to inform Before After Control Impact (BACI) study. Existing C-PODS to be re-deployed in 2014. Additional C-PODS to be deployed at 2 new sites. Data will be analysed to determine daily and seasonal patterns. The results of the surveys will inform the subsequent monitoring strategies. Due to the low presence of seals within the bay and distance to known haulout sites, dedicated boat seal surveys are not proposed. An on-going review of new seal data for the Swansea Bay area will be undertake through consultation with local groups and interested parties. In addition site visits will be undertaken, initially, once a month to key known haul out site at Worms Head Rhossili to check for presence/abundance (Survey 28b). Baseline data will be collected at monthly intervals and the need to increase the survey frequency to once every two week during construction and operation will be reviewed through the AEMP

	process. Incidental observations on seals recorded during monthly through 2014 – 2015 bird surveys and during any site or boat work will be recorded.
Responsibility	TLSB and SEACAMS
Objective	To validate findings of ES and to supplement the existing data for the Bay.
Limits of acceptable change	Not applicable
Further / remedial action	If seals are recorded more frequently than anticipated dedicated surveys will be implemented. Data will be reviewed prior to construction commencing to reaffirm appropriate mitigation is in place. The data will be used to understand the true potential collision risk of the Lagoon once operational as a function of site specific density/encounter rate for commonly occurring species. Data will also be used to understand temporal variability of site usage and risk to individual species due to factors including differing seasons, tide state or time of day.

Survey 28a – Static Acoustic Monitoring

9.3.1.4 Static acoustic monitoring (SAM) of cetaceans encompasses a wide variety of fixed, mainly passive, acoustic methods. One type of automated click logger is the C-POD (Chelonia Ltd.). The C-POD, and its predecessor, T-POD, were developed to detect small odontocetes such as the harbour porpoise which produces a stereotypical narrowband high frequency (NBHF) signal and is particularly well suited for automated detection (Dudzinski *et al.* 2011).

9.3.1.5 Continuous acoustic monitoring using C-PODs is suggested instead of visual boat surveys as the amount of data collected is much larger using C-PODs than that typically achieved using visual observations from boat surveys. The power to detect statistically significant change to baseline from continuous acoustic monitoring data is therefore much greater (see SMRU/Royal Haskoning report on SeaGen Environmental Monitoring Programme, 2011).

9.3.1.6 In order to achieve large amounts of visual sightings across the lagoon footprint, extended boat surveys would be required (Dawson et al, 2008), which are restricted to daylight hours and calm weather. Static acoustic monitoring allows data collected throughout the day and tidal cycle, but also during sea states which would not allow visual data collection from a vessel. As the Project will be constructed at some distance from the cliffs at Mumbles, it is not feasible to conduct visual observations from a land-based vantage point that would allow field of view over the lagoon footprint.

9.3.1.7 Appropriate C-POD placement is important and should be selected to ensure best passive acoustic coverage of the area, and where porpoises are known to visit – and where the impact is likely to be felt. The choice of C-POD placement is constrained by a number of factors, including the need to stay away from the navigation channel between Swansea and Port Talbot, mainly to minimise the risk of a boat becoming accidentally entangled in the C-POD mooring ropes and also to ensure risk free deployment and pick up. Additionally it will be important to place C-PODs relatively close to the expected turbine housing area, which spans 450m of the lagoon wall structure.

9.3.1.8 Four C-PODs have been deployed (initially in February 2014) by SEACAMS in collaboration with TLSB as a pilot and calibration exercise. Two C-PODS were deployed within the lagoon footprint adjacent to the existing long sea outfall and two near Mumbles as shown in Figure 9.1 and detailed in Table 9.1.

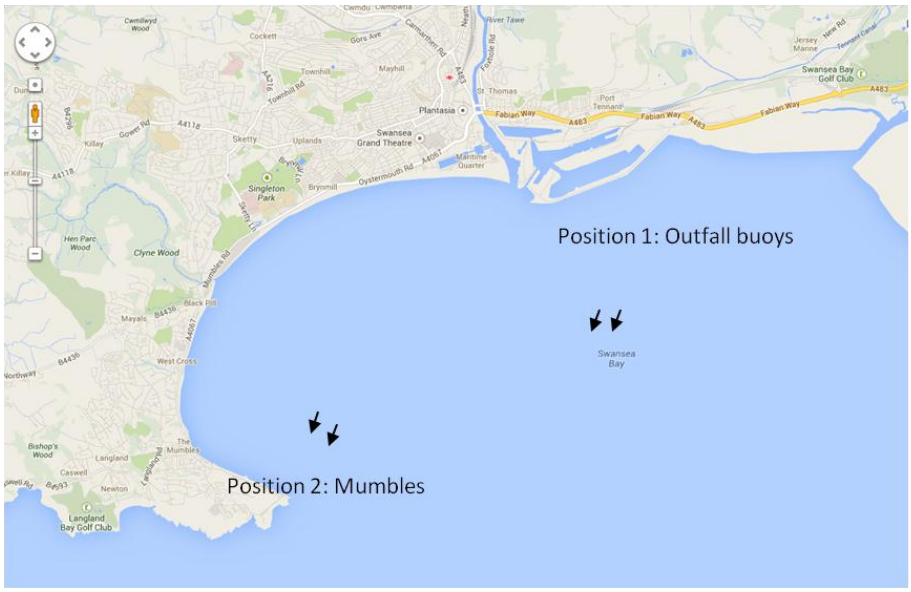


Figure 9.1 C-POD deployment locations

Table 9.1 C-POD deployment locations.

Date	C-POD ID	Lat (N)	Long (W)	Site
10-Feb	2382	51 35.087	3 54.249	Outfall East
10-Feb	2383	51 35.014	3 54.757	Outfall West
19-Feb	2384	51 34.555	3 57.104	Mumbles East
19-Feb	2391	51 34.589	3 57.427	Mumbles West

9.3.1.9 The four C-PODs were moored using a tested set-up, of two sets of weights used in similar projects in Cardigan Bay (Figure 9.2). An exemption for a Marine Licence was sought from NRW Marine Licensing Team and the mooring set up was approved by MCA and Trinity House. The C-PODS were retrieved in March 2014 and the data is currently being analysed before further deployment of the C-PODS.

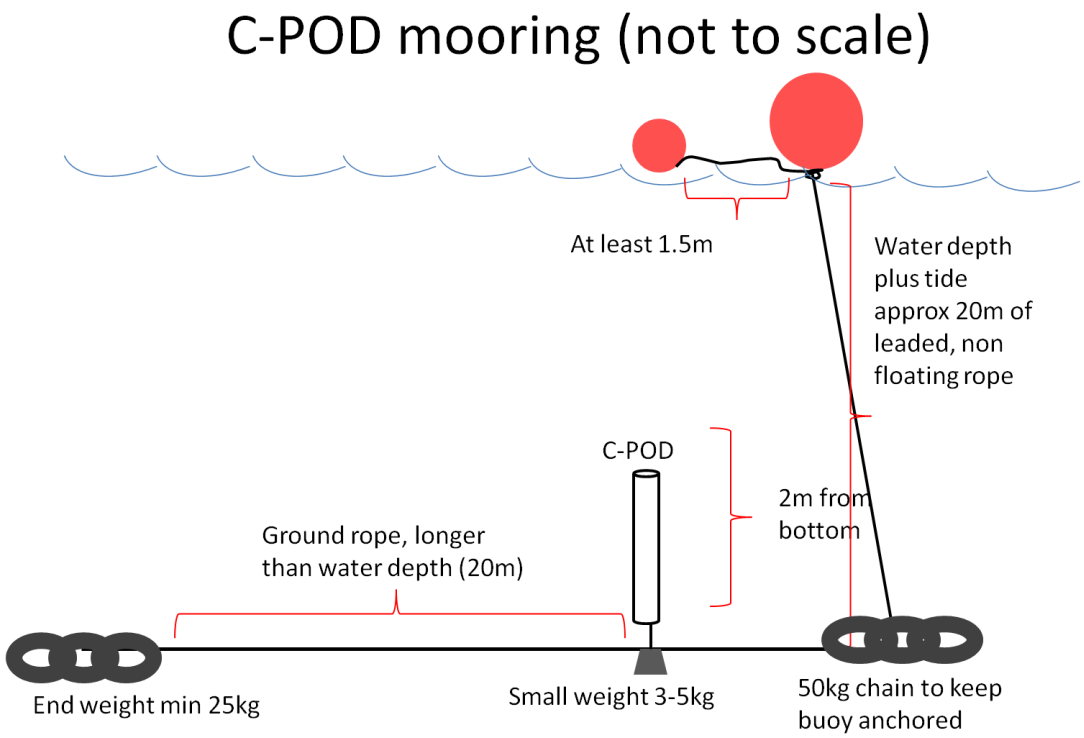


Figure 9.2 C-POD mooring

9.3.1.10 The initial data collection will be used to develop a Before-After-Control-Impact (BACI) study in consultation with NRW. The initial data has been downloaded from the C-PODs and this has been used to check the appropriateness of the C-POD sites. Unfortunately one C-POD has since been lost through shipping activity and, as such, further consideration of appropriate sites for an effective BACI study for all stages of the Project, as well as final choice of moorings, needs to be undertaken.

9.3.1.11 As an initial stage in this further assessment, such that additional suitable monitoring sites within Swansea Bay can be determined, data from a wider Low Carbon Research Institute (LCRI) study was evaluated. The data from this wider study area was extracted and reported for the local area. "*The survey area covers coastal and inshore waters of both central and outer Swansea Bay, extending from Whiteshell Point in the west to Port Talbot docks in the east. This study area includes the proposed Tidal Lagoon 'footprint' which is located adjacent to Swansea Port and between the dredged channels of the Tawe and Neath estuary. These areas are subjected to diverse anthropogenic pressures, with tourism and maritime traffic featuring heavily.*" However it is important to note that *"There were no dedicated vessel transects undertaken specifically within Swansea Bay for this research. However, casual sightings made across Swansea Bay, while en route to the North Gower coast, (an area between Whiteshell Point and Port Talbot Docks) were noted (Figure 3.3).*" Although the study did not cover the Lagoon area in detail, with the main focus of interest at the 10 to 20m contour between Gower and Port Talbot Port, it does provide useful information upon which to base a BACI study.

9.3.1.12 Below are the study areas for which the data was extracted and a summary of the data for the three study areas. Although the Inner Bay which includes the lagoon is twice the area of the two other study areas (Figure 3.3 below) the numbers of marine mammals recorded is significantly lower (Figure 4.5 extracted below).

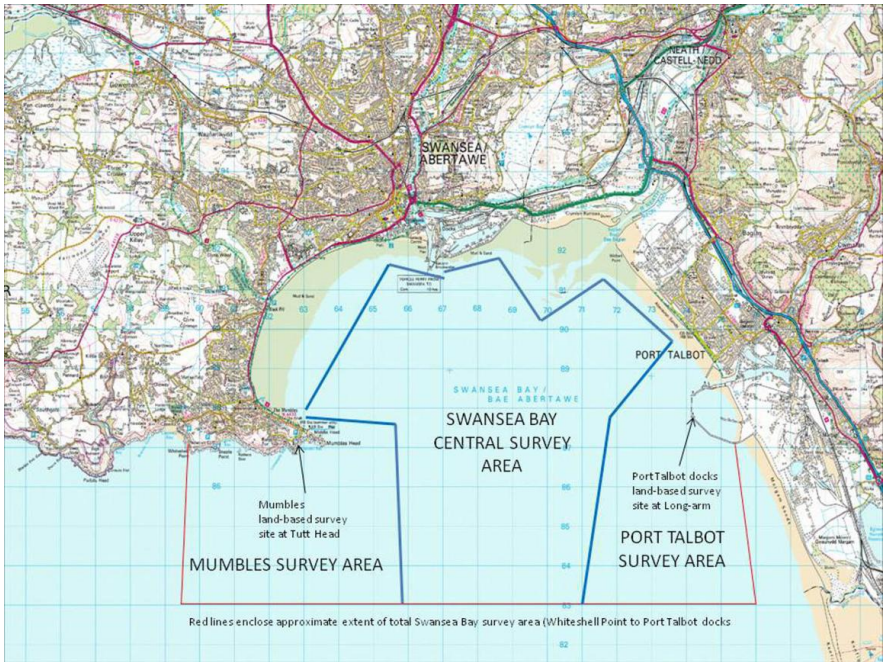


Figure 3.3 Map of Swansea Bay highlighting areas referred to in the report

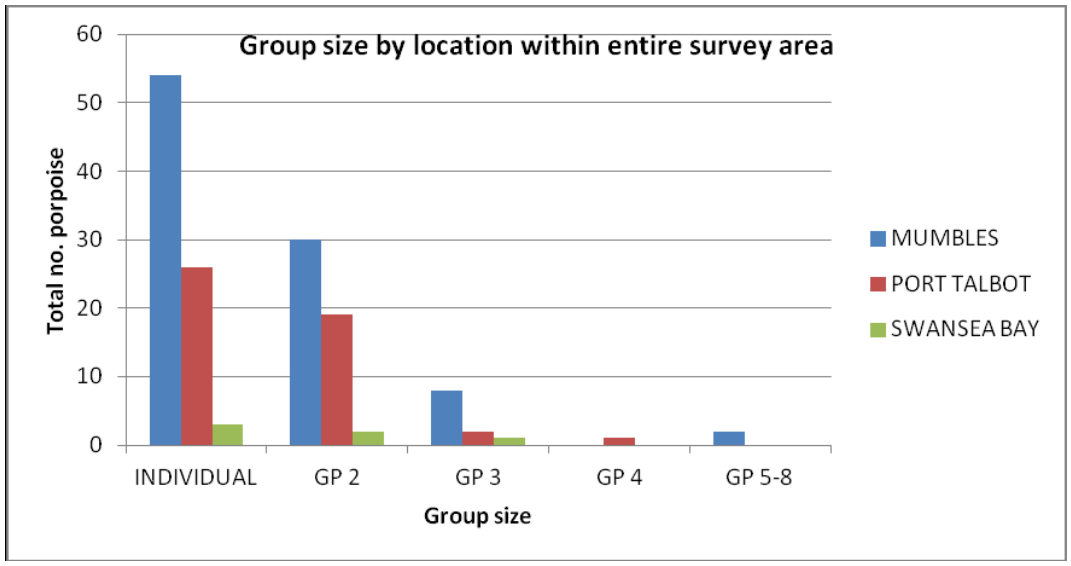


Figure 4.5: Group size according to location within survey area (2011-13)

9.3.1.13 Based on the information above, it is proposed to purchase one replacement C-POD and a further four C-PODs. It would be proposed to retain two on the outfall location within the lagoon, retain two at Mumbles Head (although an alternative further offshore point linked into the LCRI study will be considered), two near Port Talbot Harbour and potentially two further offshore, possibly near the Scarweather Buoy. Note, for all of these sites, a secure location will have to be found such that the C-POD does not interfere with fishing or shipping activities. As identified in Section 6, Marine Water Quality, the long sea outfall will be extended as part of the lagoon Project. When this occurs, the C-PODs will be relocated at the new outfall location.

9.3.1.14 The chosen C-POD locations, namely at the lagoon within the inner bay, at known areas of marine mammal usage at the edge of Swansea Bay and at a control site (namely Scarweather Buoy) will provide a good data set from which to determine the impacts of the Project through its various life stages.

9.3.1.15 The methodology for data analysis is currently being confirmed from the pilot deployment of the C-PODS to ensure reliability of the data. For the pilot study, it is proposed that the click data will be analysed using C-POD.exe v.2.043. GENENC classifier in order to reduce the number of false positives of possible dolphin detections. Only "High" and "Mod" quality click trains will be used for analysis. Preliminary analysis will be undertaken using Detection Positive Days across the deployment period, and the average Detection Positive Minutes per hour for each site and C-POD.

9.3.1.16 The C-PODS will continue to be deployed for up to 5 years after operation at the four monitoring sites. The data will be used in the BACI study to understand the true effect of the project as a function of site specific density/encounter rate for commonly occurring species. It will also help understand temporal variability of site usage and risk to individual species due to factors including differing seasons, tide state or time of day.

9.3.1.17 The data collected will be analysed together with data for any collisions that have occurred with the operational Project and any sightings from the vantage point surveys.

9.3.1.18 It is proposed that results of this ongoing study would be reported annually as described in Section 3, but half yearly updates would be provided to NRW. The results from the BACI study would be used to review the findings of the ES in respect of impacts on marine mammals and to amend and update any mitigation and monitoring. The findings of other studies within the AEMP, which are monitoring potential changes in marine ecology, will also be reviewed.

Survey 28b – Vantage point surveys of known seal haul out site

9.3.1.19 Individual seals are occasionally observed in Swansea Bay, but no regular sightings are recorded. Although seals are known to occasionally use other bays between Mumbles and Worms Head, the closest frequently used haul out site to Swansea Bay is Worms Head, Rhossili on the Gower peninsular. Here two sites are reported to be used by seals in this area. Although no potential impact is predicted by the ES, if significant effects were to occur then this should be perceptible at the nearest haul out site, namely Worms Head.

9.3.1.20 In order to ascertain the feasibility of a land-based site survey to monitor the potential effects of the lagoon, an initial site visit was undertaken to Worms Head, on 4 November 2014. The preliminary site visit was to determine access restrictions and to get an indication of the numbers of seals present at the two haul out sites.

9.3.1.21 The initial site visit was undertaken around low water and, on that day, the usage of one haul out site was confirmed. Here approximately 12 seals were recorded and photographs were taken of each seal.

9.3.1.22 For health and safety reasons it is proposed to repeat the land based seal surveys once per month at around low water on a spring tide, (note access to Worms Head is around 2.5 hours either side of low water). Survey methodology will be based on Grey Seal

Monitoring Handbook, Skomer Island[14] and other available relevant guidance. Baseline data will be collected at monthly intervals and the need to increase the survey frequency during construction and operation to once every two week will be reviewed.

9.3.2 Objective MM2 - To minimise and further understand the potential effects of construction

9.3.2.1 Data reviewed for the ES indicates that marine mammal (harbour porpoise) numbers within inner Swansea Bay are lower than that further offshore between Whiteshell Point, Mumbles Head and Port Talbot Harbour. Even with this distance, noise from construction activities, for instance piling, will travel through water and will therefore have the potential to impact on the wider area.

9.3.2.2 The Swansea Bay grey seal population was assessed as very small, with occasional visits of single animals to the area who feed within the Bay, and sometimes the Tawe and Neath river mouths. There are no known haul-out locations or pupping beaches within the Bay, leading to the conclusion that grey seal are assumed to occur relatively frequently in Swansea Bay but only in small numbers.

9.3.2.3 Since the submission of the ES, the option for 24/7 pilling for 6 months has been removed and, as such, impacts on marine mammals will be significantly reduced. Notwithstanding this, marine piling (vibro and impact) is still required for the installation of navigation safety piles and therefore measures need to be put in place to ensure minimal effects on marine mammals. JNCC protocol will be followed for this activity, and this also provides an opportunity to further understand marine mammals in the inner bay and their behaviour.

Table 9.3 MM2 Objective Summary: to minimise and further understand the potential effects of construction

Target	To minimise the potential for disturbance to marine mammals during construction. To gather data during construction to further understand marine mammal behaviour with respect to piling and other activities.
WFD	Not applicable
Management/operation	Construction of the lagoon.
Survey	The JNCC piling protocol will be followed for the installation of the dolphin piles (expected 15 days duration, day time and good visibility/less than sea state 4 only). MMO and use of PAM for piling operations. Noise monitoring during piling and other activities (**Survey 42**). Analysis of C-POD, MMO and PAM data linked to key construction activities (**Survey 28a**).
Responsibility	TLSB
Objective	To validate findings of ES and supplement existing data on the effects of construction on marine mammals for use in future projects.
Limits of acceptable change	Not applicable. The requirements of the JNCC piling protocol will be followed.
Further action	The data will be used to examine the effects of construction on

[14] Poole, J (1996a) *Grey Seal Monitoring Handbook, Skomer Island.* Countryside Council for Wales. Unpublished report.

	marine mammals. Data from C-PODs, the noise surveys and information from the construction programme will be analysed to determine any changes in daily and tidal patterns of marine mammals. The results of the surveys will inform the subsequent monitoring strategies.

Survey 29 – Marine mammal mitigation and monitoring

9.3.2.4 Monitoring and mitigation would be undertaken during vibro-piling or impact piling associated with the installation of the navigation safety dolphin piles following the guidelines highlighted in the JNCC "Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals during piling" (JNCC, 2010). The majority of the installation would be using vibro-piling, but impact piling may be required to drive the piles into their end depth. The following procedure would be observed:

i. Installation of the dolphin piles would be during daylight hours, with good visibility and sea state <4 only. It is anticipated that the installation of the dolphin piles would last approximately 15 days.

ii. For vibro and percussive piling for dolphin piles, a 'mitigation zone' of radius 500m around the piling site would be established, prior to any piling.

iii. Within this mitigation zone, detection would be undertaken visually by two Marine Mammal Observers (MMO) and acoustically using appropriate Passive Acoustic Monitoring (PAM) equipment.

iv. Both the observers and equipment will be deployed at least 30 minutes before any piling is due to commence.

v. Any piling will not commence if marine mammals are detected within the mitigation zone or until 30 minutes after the last visual or acoustic detection. Piling will not commence if marine mammals are within mitigation zone or until 30 minutes after the last visual or acoustic detection.

vi. The MMO/PAM operative will track any marine mammals detected and ensure that they are satisfied that the animals have left the mitigation zone before they advise the crew to commence percussive piling activities.

vii. Piling will commence using an agreed soft start procedure for at least 30 minutes (the gradual increase of piling power, incrementally, until full operational power is achieved). The soft-start procedure will vary according to hammer and pile design and other factors.

9.3.2.5 The data collected can provide information on relative abundance, distribution and behaviour. Any additional data on marine mammal sightings and behaviour will be recorded for other activities which will be on-going in the surrounding area.

9.3.2.6 Surveys will also be undertaken to monitor noise levels in the vicinity of the different types of construction works as detailed in Section 12. If impact piling is required, and there is sufficient advance notice available, additional marine mammal observers would be based on survey vessels in the vicinity of the site, as well on strategic locations in the bay. This would allow the extent of behavioural change and relative abundance to be assessed before and during noise generating activities. JNCC protocols for observation will be followed.

9.3.2.7 Data from the on-going C-POD monitoring (Survey 28) will be reviewed and assessed taking into consideration the key construction activities taking place at the time. This will further inform understanding of marine mammal behaviour during construction of marine projects.

9.3.3 Objective: MM3 - To monitor and manage the potential for interaction of marine mammals with the Project during operation

9.3.3.1 The operation of the Project needs to be monitored and managed adaptively throughout its lifetime, as the Project becomes "accepted" into its environment. This is particularly relevant as information about marine mammals and how they will react to operational turbines is only recently becoming available. Further information on this can be found in a review of marine renewables which was published by WGMME in 2012. Amongst other items, the report reviews the findings of the monitoring of marine mammals at the first active marine turbine, which is located in Strangford Lough SAC. The area is designated for harbour seals, and harbour porpoise also move up and down the Narrows past the turbine. The study concluded, amongst other things, that:

A. *"there was no evidence of a change in seal haul-out behaviour, transit rates through the Narrows, time spent within the Narrows and time spent in the immediate vicinity of the device;*

B. *Post-mortems of marine mammal carcasses have shown no link between mortality and the operating SeaGen turbine;*

C. *No significant difference between porpoise detections during baseline and post-installation were observed in the inner Lough;*

D. *Shore based observation of seals showed no evidence of disturbance during installation phase, and there was no evidence of a change in underlying relative seal abundance in the area;*

E. *Active sonar monitoring showed that both marine mammals and 'other' targets moved past the turbine in close proximity. However, due to the requirement for "precautionary turbine shutdowns" it was not possible to determine how marine mammals would interact with the turbine during operation*."

9.3.3.2 Further conclusions drawn from the Environmental Monitoring Programme were that "*no major impacts have been detected from any of the monitoring programmes*"; and that "*there have been no changes in abundance of either seals or porpoises detected which can be attributed to SeaGen; seals and porpoises are continuing to swim past SeaGen, demonstrating a lack of any concern or hindrance*"[15]

9.3.3.3 Further studies by Scottish Marine Research Unit (SMRU) identifies "*The ranges that 'marine mammals' were detected at Strangford Lough suggest that marine mammals do move in close proximity to the tidal turbine both when it was operational (minimum range = 9.9m) and non-operational (minimum = 8.4m)."*

9.3.3.4 The results of these studies are promising in that the turbine, located in a SAC with notable numbers of marine mammals moving through the Loughs Narrows past the

[15] http://www.marineturbines.com/3/news/article/56/seagen_tidal_turbine_gets_all_clear_from_environmental___scientific_studies

turbine, appears to cause no significant effect on behaviour and marine mammals appear to avoid both the operational and non-operational turbine.

9.3.3.5 Whilst appropriate deterrents will be put in place at the lagoon to reduce the potential impact on harbour porpoise to "insignificant to minor", in order to meet the requirements of any EPS licence (if required), opportunities exist to further understand marine mammal behaviour around marine turbines. Any studies would only be undertaken, in agreement with NRW, and once behaviour patterns of marine mammals have been established during operation.

9.3.3.6 During operation it is proposed to manage and further understand marine mammal interaction with the tidal lagoon through monitoring. The results of the monitoring will be regularly reviewed and reported on an annual basis to ensure that any EPS licence requirements are met. The content and duration of the monitoring programme will be agreed with NRW (MLT) and NRW(A) based on further discussion as part of the EPS licensing conditions. A marine mammal rescue programme will also be put in place in the event that a marine mammal enters the lagoon via the sluices.

Table 9.4 MM3 Objective Summary: Monitor and manage potential Lagoon interactions

Target	To monitor and manage the potential of interaction of marine mammals with the Project.
WFD	Not applicable
Management/operation	Operation of the lagoon.
Survey	Use of an acoustic deterrent device to be used as a mitigation measure for the potential turbine collision. The development of an appropriate Acoustic Deterrent System will be undertaken pre-construction and it will be reviewed based on monitoring data prior to installation. Consideration of requirements of other species will also be included in the design. • Adaptive monitoring of operational turbines and acoustic deterrents system (this will be developed as part of the EPS licence). • Surface detection surveys and use of a passive acoustic monitoring device both from the lagoon seawalls and off a boat. • Monitoring of noise from turbines and acoustic deterrents during operation. • Recording and reporting of collision events or near misses (including post mortem investigations). • Management of any marine mammals that enter the lagoon. • Controlled studies of marine mammal behaviour with Project.
Responsibility	TLSB
Objective	To validate findings of ES and to trigger further action in the event of any collision of a harbour porpoise.
Limits of acceptable change	Any collision of a harbour porpoise will trigger further actions, which are expected to be secured by the EPS licence and DCO. Any collision of a seal will trigger further action.
Future / Remedial action	Review of techniques and consultation with statutory authorities to improve effectiveness of deterrents.

Survey 30 - Acoustic Deterrent Devices (ADD) modelling and monitoring

9.3.3.7 During operation, it is proposed that an acoustic deterrent system would be positioned on the turbine and sluice gate structure to minimise the potential for marine mammals to come into contact with the turbines. The use of acoustic warning equipment if appropriately designed and implemented, has the potential to be a valuable mitigation tool for reducing collision risk. The design of any acoustic deterrent array is dependent on a range of factors including:

- The source noise levels and noise frequency of an acoustic deterrent;
- The noise sensitivity of the target marine mammal receptors;
- Site specific factors such as ambient noise levels; and
- The number and spacing of acoustic deterrents in an array.

9.3.3.8 An initial study has been undertaken to review the suitability of a range of different acoustic deterrent devices currently on the market based on the above factors. The results of this study is presented in Appendix 4. In addition to this noise monitoring data from the turbine manufacturer for the operational turbines will also be reviewed. Data will be used together with research previously undertaken (e.g. Dawson *et al*, 2013), to determine the suitability and design for using acoustic deterrent devices.

9.3.3.9 Subsequent to this broad review, the devices considered most appropriate will be taken forward and incorporated into noise modelling to understand the potential effective spatial ranges of avoidance. Different spatial configurations will be modelled as part of this review to identify the most effective array designs. The assessment will also take into consideration the acoustic deterrent devices that are being considered in relation to fish.

9.3.3.10 Acoustic modelling will be used to assess the likelihood of deterrent noise interfering with movement of for instance marine mammals. Sound projector source levels are typically 160 dB re 1µPa@1m, with frequencies covering a maximum range of 20-3000 Hertz. Normally effective ranges are limited to a few tens of metres. The actual acoustic field would be measured during the commissioning phase to allow adjustment of sound levels to the desired values.

9.3.3.11 As discussed above, any active acoustic warning system in the marine environment also represents a new source of sound and has the potential to cause a temporary barrier, as such a balance needs to be achieved. Exclusion effects will also be considered using the results of the noise surveys (both baseline and operational – See Section 12).

9.3.3.12 Once appropriate equipment has been identified, it will be appropriately positioned. Regular maintenance will be undertaken during the operational phase.

Survey 31 - Turbine collision monitoring

9.3.3.13 In terms of monitoring potential encounters, the turbine shaft bearings will be equipped with vibration monitoring equipment. Such vibration monitoring equipment is used for condition monitoring (trending of shaft vibrations for various operating conditions and changes with time) and for unit protection purposes (emergency shut-down in case of excessive vibration). Radial shaft vibration is typically measured via two radially mounted proximity probes located at 90°. In addition, axial shaft vibration can be measured via an axially oriented vibration probe on the shaft thrust collar. Should a marine mammal strike a turbine runner blade, this would be recorded as a one-off event in the vibration

recordings and would be recorded. If this did occur, the Project Warden would be notified and the search protocol implemented.

9.3.3.14 The methodology to be deployed in relation to collision, near misses and strandings will be confirmed in the iterations of the AEMP approved prior to commencement of operation. Any collision events or near misses will be recorded and an appropriate reporting mechanism (including post mortem investigations) will be set up to report such events to the appropriate authorities and to inform the mitigation and monitoring protocols. Surveillance data will be shared with the UK Cetacean Strandings Investigation Programme (CSIP).

Survey 32 - Surface detection and use of PAM

9.3.3.15 Surface detection surveys and an acoustic device (PAM) will be used to monitor marine mammals during the operational phase. In order to inform and target these surveys, data from the C-PODs and MMO construction surveys will be reviewed. The data will be looked at in terms of diurnal and tidal patterns, such that any "high risk" periods can be identified and survey effort focussed accordingly.

9.3.3.16 The data gathered during these surveys, along with C-POD data and potential collision data, would be subject to on-going review and the operation surveys would be adapted accordingly. Final details of the monitoring are anticipated to be secured as part of the EPS licence to be obtained through NRW (MLT) and an outline scope is provided below.

9.3.3.17 Post-construction, the lagoon structure itself provides a useful vantage point to observe the presence, distribution and behaviour of any marine mammals around the lagoon wall. In addition, surface detection surveys will also be undertaken from a boat.

9.3.3.18 For the first year post construction, regular marine mammal visual observations on harbour porpoise and grey seal relative abundance, distribution and behaviour will be undertaken involving:

- standardised scans using binoculars;
- high definition photography/videography or alternatively theodolite tracking.

9.3.3.19 A minimum of two observers will undertake visual observations using theodolite or photographic systems. This will be used to locate animals in reference to the lagoon wall, track their travel paths and observe their behaviour around the turbine areas. As discussed above, the duration and timing of these observations would be determined based on the review of monitoring data for the inner bay collected pre-construction and construction.

9.3.3.20 In this first year, it would be proposed that training would be provided to the Project Wardens and other members of staff or volunteers. This would include the production of a training manual and species identification sheets. Training would be provided to the observers in the use of range finder binoculars, filling survey data sheets and handling data. Ongoing monitoring would then be continued by TLSB staff and volunteers, supported by a marine mammal consultant or SEACAMS.

9.3.3.21 It is recognised that during hours of darkness or poor visibility, the surface detection surveys will not provide an appropriate method to detect the presence of marine

mammals. An alternative acoustic device would be appropriate for vocalising animals at these times, but would not be suitable for non-vocalising animals, e.g. seals.

9.3.3.22 As such, the surface detection will be combined with use of an appropriate active sonar system. This combination was used successfully to monitor collision risk at Strangford Lough SAC (Royal Haskoning, 2011). Strangford Lough active sonar relied on 24-hour a day manual monitoring which reflected its location in a SAC with notable numbers of seals and harbour porpoise. However, SMRU (2013) have recently been developing software for the detection and classification of marine mammals using active sonar which could be developed as part of an automated system. The study concludes that "*results of the analysis of the software 'detection efficiency' suggest that there is a significant negative relationship between range and probability of detection; the probability of the software automatically detecting a seal was greater than 0.9 for ranges up to around 37 metres and dropped to below 0.1 at ranges greater than 56 metres. In the context of using this sonar as a behavioural monitoring tool, this appears to limit analysis of small marine mammal behaviour to ranges of approximately 40-50m*". As can be seen above, there are limitations to this, as with all, systems. The choice of an appropriate system will therefore be developed in discussion with NRW (MLT) and NRW(A), with respect to harbour porpoise (EPS). The likely risk to seals (non EPS) would also be considered. Appropriate measures would be incorporated in the further revisions to the AEMP.

Survey 33 - Management of marine mammals found within the lagoon

9.3.3.23 A protocol will be developed in discussion with NRW in relation to the management of any marine mammals which become trapped within the lagoon or are found as a result of the above search procedure. Live stranded animals would be reported to the appropriate organisation eg The British Divers Marine Life Rescue (TBDMLR), while dead animals would be reported to the Cetacean Strandings Investigation Programme. If an incident does occur in the future and a functioning contact is not available for Wales, contact would be made to the English or Scottish contact points and guidance sought. Removal of live animals could involve a humane method of capture and release under the supervision of relevant organisations, for instance TBDMLR, and a veterinary surgeon. The Project Warden will be aware of the protocol to be followed and appropriately trained, for example, by attendance on TBDMLR's Marine Mammal Medic Course[16]. The provisions of Annex G, Supplement to the Secretary of State's Standards of Modern Zoo Practice Additional Standards for Cetacean Keeping in relation to cetacean strandings (1) Strandings-S (a-e) would be followed for any animal found, together with guidance from TBDMLR or veterinary surgeon. These standards relate to the immediate care and then the subsequent release, emergency accommodation or transportation to an establishment that fully complies with the Secretary of State's Standards of Modern Zoo Practice.

9.3.3.24 The Project Warden would also closely liaise with other marine mammal groups in the area such that any information on stranded or injured animals within the wider area is fed back into the monitoring system. The Warden will liaise with Cornwall Seal group regarding seals.

[16] http://www.bdmlr.org.uk/index.php?page=training-course

10 Coastal Birds

10.1 Introduction

10.1.0.1 Swansea Bay is important for over-wintering birds with Blackpill SSSI in the west of the Bay being notified for its importance as an over-wintering and passage site for waders, particularly Ringed Plover (*Charadrius hiaticula*) and Sanderling (*Calidris alba*). The site is considered of local importance for Oystercatcher (*Haematopus ostralegus*), Grey Plover (*Pluvialis squatarola*), Bar-tailed Godwit (*Limosa lapponica*), Knot (*Calidris canutus*) and Dunlin (*Calidris alpina*).

10.1.0.2 Chapter 11 Coastal Birds of the ES provides full details of the data review and site specific survey work carried out to collect baseline information for Swansea Bay. The findings of the assessment concluded that there will be insignificant or neutral impact on most features with a minor impact on a limited number of species such as Sanderling, Ringed Plover and Great Crested Grebe. Potential beneficial impacts are also identified during the operation of the Project through offset foraging times and additional roosts.

10.1.0.3 As such, the key objective for coastal birds would be further monitoring and surveys in order to review and confirm the findings of the EIA. This will be undertaken during the pre-construction, construction and operational phases.

10.2 Baseline

10.2.0.1 To inform the EIA and to supplement the more extensive longer term Wetland Bird Survey (WeBS) data. Coastal bird surveys were undertaken within a study area, divided into 23 sectors, that extended from just east of the River Neath to Mumbles Head.

10.2.0.2 Wintering bird surveys were completed on a monthly basis (October 2011 – March 2012 and September 2012 – March 2013). Additional surveys were carried out in the east of the survey area (between the River Tawe and River Neath) in the summer of 2013 (April-August 2013).

10.2.0.3 Survey methodology was based on that used by the British Trust for Ornithology in their Wetland Bird Survey (WeBS), consisting of both Core Count and Low Tide Count methods (Gilbert *et al*, 1998). Generally, Low Tide Counts are used to determine the spatial distribution of birds across a site whilst Core Counts (carried out at high tide) can give accurate counts of the number of birds using a site.

10.2.0.4 Data were also collected on bird movement around the Bay and the presence of any water birds (sea-duck, grebe and diver species present). Full details of the survey areas and methodology can be found in Chapter 11 Coastal Birds of the ES and its supporting Appendices.

10.3 Coastal Birds Objectives

10.3.0 Introduction

- CB1 - To monitor change in bird usage in the lagoon and wider Bay;
- CB2 – To monitor usage of lagoon and enhancement measures;

10.3.1 Objective CB1: To monitor changes in bird usage in the Lagoon and wider Bay

10.3.1.1 During construction minor impacts were identified through disturbance from construction work particularly at a local roost site; or disturbance of foraging in the lagoon intertidal area. Impacts to the wider area, including Blackpill SSSI, are not predicted.

10.3.1.2 Once operational the minor impacts on these species are primarily related to their food source, namely potential changes in intertidal feeding habitat (for waders) or herring (for great crested grebe). As discussed in table 5.1 (Objective CP1), monitoring objectives have been identified and mitigation measures have been linked to potential changes in the environment such that mitigation can be implemented where necessary. Likewise, as identified in Objective F1 (Table 8.2), phased monitoring of the herring spawning mitigation will be undertaken prior to operation of the turbines to assess its success. If unsuccessful, alternative measures would be put in place to minimise impact on herring, namely acoustic deterrents.

10.3.1.3 The monitoring will therefore look at potential changes to bird distribution in the lagoon area and wider Bay. It will also assess the potential effects of the herring mitigation on great crested grebe. Results from other monitoring discussed previously will be reviewed and assessed with respect to birds, where necessary.

Table 10.1 CB1 Objective Summary: To monitor changes in bird usage in the Lagoon and wider Bay

Target	Monitor numbers and distribution of waders and wildfowl during construction and operation of the Project. Review results in terms of construction programme. Once operational review results in relation to findings of coastal process and marine ecology monitoring. Monitor numbers and distribution of divers and grebe species during construction and operation of Project. Consider effects of herring mitigation and any increases in numbers on fish population of the Bay.
WFD	Not applicable
Management/operation	Pre-construction, construction and operation
Monitoring	**Pre-construction (Survey 34)**: Additional monitoring of numbers and distribution of coastal bird to further inform the baseline data. WeBS surveys over study area between August 2014 – May 2015 throughout the tidal cycle. The baseline data will be reviewed in the context of the results of a study which is currently being undertaken (due for completion August 2015). The study is looking to see if there is any association between foraging behaviour and biotope's in Blackpill for sanderling, oystercatcher and a other bird species. **Construction (Survey 35)** - Annual WeBS surveys over study area (east of the river Neath to Mumbles Head) between August – May as per ES methodology over the construction period. Where possible surveys would be targeted to occur with any land based construction activities over winter that could coincide with the presence of birds. Surveys would take place over 2015/16 and 2016/17. Additional observations around lagoon area during construction

	period by Lagoon Warden. **Operation (Survey 35)**: WeBS surveys over study area between August – May using ES methodology. Operational birds monitoring surveys to commence following completion of offshore work namely years 1 (winter 2017/18), Yr2, Yr 3, yr5, yr7 and yr10. The frequency of surveys will be reviewed thereafter based on the results of the bird, coastal processes and biotope survey results. **Operation (Survey 36)** Additional observations around lagoon area during operation period by Lagoon Warden will include behaviour of birds with respect to other lagoon uses (eg water sports) and bird usage of the quiet area. In addition records will be maintained of numbers and distribution of great crested grebe in the lagoon and the area outside the lagoon. Ad-hoc vantage point surveys will be undertaken when birds are present to monitor their behaviour in the vicinity of the turbines and along the western lagoon wall when herring maybe spawning. Surveys will also be undertaken for two years following maintenance dredging (10-15 years from operation). The results of the bird surveys will be reviewed in the light of the coastal process monitoring results, the and the intertidal biotope mapping.
Responsibility	TLSB
Objective	To validate findings of ES and if necessary identify change outside that already predicted such that mitigation measures can be implemented.
Limits of acceptable change	Persistent decline in the numbers, or significant changes in the distribution of waders and wildfowl leading to a persistent decline in numbers across the lagoon and Swansea Bay area in particular Blackpill SSSI. The definition of "persistent decline" or "significant change" will be reviewed in consultation with statutory consultees taking into consideration natural variation or longer term changes as a result of other influences, not associated with the Project. Surveys will be linked with the intertidal benthic surveys, the beach profile surveys and aerial surveys (to be undertaken as part of coastal process modelling) in order to establish any causal link between the Project and any impact on birds. The results of the surveys will be expertly reviewed every year and the need for any increase in survey effort or remedial action considered. Persistent decline in the numbers of great crested grebe recorded across the Bay.
Future / Remedial action	The results of the surveys will be reviewed annually and the need for any remedial action, such as beach nourishment at Blackpill will be considered. **Blackpill SSSI** • If beach erosion is considered to be in excess of natural variation, in particular at the upper tidal area of Blackpill, beach replenishment will be undertaken. Note the upper area of Blackpill is used for bird roosting and as such appropriate sand from an agreed source would be used. The timing of beach replenishment would be agreed with NRW(A) and CCSC. • Although not predicted in the ES, if erosion as a result of the

	Project was recorded and considered to be in excess of natural variation on the main intertidal areas of Blackpill SSSI, beach replenishment would be discussed with NRW(A). The sand source, method and timings of beach replenishment would be discussed and agreed including consideration of minimising the potential for sterilisation of habitats, such as those used as bird feeding habitats, where appropriate. • Discussion would be held with NRW and CCSC concerning the undertaking of the beach replenishment activity and a marine licence would be obtained from NRW(MLT). If, as potentially predicted, the area affected is upper shore which is used for roosting, it is proposed that works would be undertaken in one phase. If the area potentially affected is identified as a bird foraging area, a phased beach replenishment strategy would be proposed to reduce any impacts. This would potentially entail the application of sand in agreed areas, with a suitable timescale (eg 7 months) between each application. For instance, the timing of the application could be at the end of the overwintering period, such that the in-fauna could re-colonises over the summer period before overwintering birds return to the area. As discussed above an appropriate source of sand would be identified in agreement with NRW/CCSC and the relevant landowner. • The intertidal area is a mosaic of naturally changing muds especially in the lower intertidal areas, where the depth of mud varies from a few centimetres to tens of centimetres. Mudflats are important in their own right and are of value to birds. Of particular note in the wider area are the mudflats of the Severn and adjacent estuaries. The coastal process modelling is predicting no significant change to intertidal areas and as such the habitats that are currently present are predicted to remain, but their distribution will continue to change naturally as it is a dynamic system. If a significant increase in mud distribution outside natural variation is detected, which is deemed to have an unacceptable adverse effect on ecology of the area, mitigation measures could be considered. This could include dredging/scraping the intertidal areas to remove any deposited muds. The scraping would also result in the loss of benthic ecology within the mud and therefore the need for mitigation and the appropriateness of scraping as a mitigation measure would need to be considered carefully through the AEMP review process.

Survey 34 – Tidal cycle WeBS survey

10.3.1.4 Pre-construction, the Wetland Bird Survey (WeBS) counts will be continued during the pre-construction phase over the winter and passage period (August 2014 – May 2015). This survey will provide sufficient data for robust comparison and assessment of potential impacts against construction and operational monitoring works. The surveys would be extended compared to the existing baseline surveys and three visits will be undertaken per month be completed (August 2014 – May 2015). The surveys would aim to record the numbers and spatial distribution of birds within the survey area around High Tide, Mid tide and Low tide.

Survey 35 – High tide/Low Tide WeBS survey

10.3.1.5 During construction and operation, the same survey methodology as employed for the ES data collection would be used. It would be based on the methodologies developed by the BTO for the WeBS and consist of both Core Count and Low Tide Count methods (Gilbert et al, 1998). The methodology for surveying and recording non-breeding waterfowl using the generic WeBS Core and Low Tide Count methodology was assessed as sufficient and appropriate for the purposes of assessment on the basis of professional judgment. WeBS Low Tide Counts are used to determine the spatial distribution of birds across a site and the relative importance of different areas, while WeBS Core Counts are carried out at high tide when wading birds gather into roost sites and are more easily counted. Together, these counts give an as accurate assessment as possible of the number of birds using a site.

Warden Bird Surveys (Survey 36)

10.3.1.6 Additional observations and *ad hoc* surveys will be undertaken by the Lagoon Warden during operation period. Particular areas of focus will be:

a. Behaviour of birds with respect to other lagoon uses (e.g. water sports)
b. Bird usage of quiet area.
c. Routine checks of usage in Roost 2 (August – May)
d. Numbers and distribution of great crested grebe in the lagoon and the area outside the lagoon.
e. *Ad hoc* vantage point surveys to monitor behaviour of great crested grebe in the vicinity of the turbines. Records will be kept of the birds' behaviour and if fish are caught by grebe within the lagoon.
f. *Ad hoc* vantage point surveys to monitor behaviour of great crested grebe in the vicinity along the western lagoon wall when herring maybe spawning (Feb – March).
g. Visitors to the lagoon will be encouraged to report records of birds within the lagoon.

10.3.1.7 Surveys would be undertaken annually throughout the construction period and following completion of offshore work namely years 1 (winter 2017/18), yr2, yr3, yr5, yr7 and yr10. Surveys will also be undertaken for two years following first maintenance dredging (10-15 years from operation). The need for additional surveys would be reviewed based on the results.

10.3.1.8 This data from the surveys will be used to provide a comparison between baseline data and birds using intertidal habitats during the construction and operation phase.

10.3.1.9 This data will be used to:

a. Examine the effects of temporary disturbance during construction works within the lagoon footprint and wider Bay;
b. Examine the effects of operation activities, within the lagoon footprint and wider Bay;
c. To validate the coastal process modelling results that predict there will be no adverse effect on the distribution of sediments and therefore the availability of benthic invertebrates, for birds using Blackpill SSSI in particular. This study will utilise data collected as outlined in Section 5. This will principally compromise the high resolution aerial survey data which will provide information on changes to sediments and habitat extents, which could affect foraging areas. Intertidal surveys

will be carried out on areas of interest identified during the high resolution aerial surveys to further inform the potential effects on foraging areas. The study will particularly examine the potential effects of the Project on Ringed Plover and Sanderling.

d. To confirm continued use of Roost 2 adjacent at western end of Crymlyn Burrows (this will be tied into the enhancement measures assessment CP2).
e. To assess numbers and behaviour of great crested grebe in relation to the turbines, herring spawning mitigation and general feeding behaviour. Results from other relevant surveys will be reviewed including the intertidal and subtidal benthic ecology surveys, monitoring colonisation of the lagoon walls, herring spawning monitoring and dropdown camera surveys of lagoon wall.

10.3.2 CB2 – to monitor usage of lagoon and enhancement measures

10.3.2.1 Within the Project, opportunities for enhancement have also been provided, which have been assessed as having a beneficial effect. These include the potential utilisation of new habitat for instance rocky shores of the lagoon wall for roosting, nesting ledges for kittiwakes and displaced tides providing extending intertidal feeding habitat for birds at some states of the tide.

10.3.2.2 A potential roosting island was also identified in the ES, and the opportunity to construct this would be reviewed once the lagoon is operational, such that siltation patterns can be confirmed and any issues concerning other users of the area can be taken into consideration.

Table 10.2 CB2 Objective Summary: to monitor usage of lagoon and enhancement measures

Target	Monitor numbers and distribution of coastal birds within and adjacent to Lagoon during operation of Project. Monitor and assess success of enhancement measures.
WFD	Not applicable
Management/operation	Physical presence of the operational lagoon.
Monitoring	**Operation (Survey 35)**: WeBS surveys over study area between August – May using ES methodology. Operational birds monitoring surveys to commence following completion of offshore work namely years 1 (winter 2017/18), Yr 3, yr5, yr7 and yr10. The areas to be surveyed include those within the lagoon and the data will provide information on the potential effects of a slightly displaced tidal cycle. The data will also be able to inform the usage by birds of the Lagoon quiet area. The monthly over-wintering surveys will also look for great crested grebes both within the lagoon and outside the lagoon. **Operation (Survey 36)** Additional observations around lagoon area during operation period by Lagoon Warden which will include; routine checks of potential roost opportunities on eastern seawall; additional observations of Roost 2 (Crymlyn Burrows); assessment of kittiwake ledges; intertidal foraging and effects of offset tide. Records of numbers and distribution of Great Crested Grebe in the lagoon and the area outside the lagoon. Routine checks of kittiwake roosts. The findings of the coastal processes, marine ecology and fisheries monitoring surveys from within and around the lagoon will be used

	in order to fully evaluate the effects of the operation of the Project on birds within and adjacent to the Lagoon.
Responsibility	TLSB
Objective	To validate findings of ES and assess effectiveness of enhancement measures.
Limits of acceptable change	Persistent reduced number of birds feeding in intertidal area. Reduced numbers roosting at Crymlyn Site 2 which is not compensated by changes in distribution e.g. roosting opportunities offered by the lagoon wall. Persistent decline in the numbers of great crested grebe recorded in vicinity of Lagoon. Adverse impacts from turbines.
Future / Remedial action	The results of the surveys will be reviewed every year and the need for remedial action considered. Remedial action for great crest grebe could include acoustic deterrents to keep fish away from turbines. Potential provision of additional roost such as island or raft.

10.3.2.3 Chapter 11 of the ES identified the installation of an island in order to provide an alternative high tide roost. It is proposed that the final location of this island will be determined post construction of the lagoon, when the results of the coastal processes (see Section 5) studies are available. This will inform the optimum location of the roost in relation to erosion and sedimentation patterns within the operational lagoon.

Additional operation (Survey 36)

10.3.2.4 In addition to observations and *ad hoc* surveys identified above, the Lagoon Warden will undertake:

a. Routine checks of lagoon wall for roosts (August – May)
b. Comparison of bird usage within the lagoon through the tide to assess whether any advantage from offset tide;
c. winter surveys to see if low level lagoon lighting provides advantage to intertidal feeding;
d. Surveillance monitoring will also be undertaken in respect of uptake of the proposed kittiwake nesting ledges (on turbine housing) on an annual basis.

10.3.2.5 This data from the surveys will be used to assess the effectiveness of the mitigation and enhancement measures proposed.

11 Terrestrial Ecology

11.1 Introduction

11.1.0.1 Chapter 12 Terrestrial Ecology of the ES provides full details of the data review and site specific survey work carried out to collect baseline information for Swansea Bay. The key issues associated with the Project include its impact on existing and created habitats as well as the presence of protected or otherwise notable species including invasive species. With mitigation impacts during construction are either minor or insignificant (Table 12.7). During operation, impacts are predicted to be insignificant or minor to moderate beneficial (Table 12.8).

11.1.0.2 This section outlines the further monitoring and surveys which will be undertaken during the pre-construction, construction and operational phases, in order to review and confirm the findings of the EIA.

11.2 Baseline

11.2.0.1 The following site specific surveys were undertaken between 2012 and 2013 to understand the terrestrial ecology baseline environment within the Project study area and along the cable route to Baglan power station:

i. Phase 1 habitat survey;
ii. Botanical survey;
iii. Bat survey;
iv. Breeding/overwintering bird survey (terrestrial birds);
v. Otter survey;
vi. Reptile survey; and
vii. Invertebrate survey.

11.3 Terrestrial Ecology Objectives

11.3.0 Introduction

11.3.0.1 The following objectives have been identified for terrestrial ecology:

TE1 - To minimise potential effects on Crymlyn Burrows (SSSI) and other dune systems within Swansea Bay;

TE2 - To minimise the deterioration or loss of existing coastal grasslands and to optimise the potential of the introduced coastal grassland;

TE3 - To maximise the potential for creation of saltmarsh within the designated area of the lagoon;

TE4 - To optimise the creation of sand dunes within designated area of the lagoon;

TE5 - To minimise the potential for colonisation by invasive species;

TE6 - To minimise the loss or deterioration of extent of notable plants;

TE7 - To minimise the potential effects of lighting of the Project on Bats;

TE8 - To minimise the potential effects of the Project on Otters – access and lighting; and

TE9 - To minimise the potential effects of construction of the Project on Reptiles

TE10 - To minimise the potential effects of the Project on Invertebrates

Any surveys to monitor the effects on ecology would follow the survey methods undertaken within the ES and also agreed methods for SSSI condition monitoring.

11.3.1 Objective TE 1: To minimise potential effects on Crymlyn Burrows (SSSI) and other dune systems in Swansea Bay

11.3.1.1 Crymlyn Burrows is located immediately east of the eastern landfall. Key issues comprise:

- effects on the SSSI during construction of the grid connection (the potential for this has been limited by the chosen route along Fabian Way) – the potential effects on the Project on species and habitats within the SSSI are discussed in the relevant sections below;
- sheltering of Crymlyn Burrows from prevailing westerly conditions due to the presence of the lagoon leading to:
- a reduction in the supply of windblown sand to the dune system;
- a reduction in wave action from sheltering causing changes to coastal processes including accretion or erosion of the dune system and effects on botanical composition and structure;
- increased recreational use resulting from the presence of Swansea University Bay Campus and the tidal lagoon.

11.3.1.2 Dune systems outside the SSSI are located to the west of the lagoon in Swansea Bay SINC and Blackpill SSSI and immediately east at Baglan. Key issues (none of which are predicted to occur) comprise:

- Increase in erosion of Swansea Bay SINC (which ranges from Spontex Dunes at SA1 round to Mumbles);
- Localised mud deposition, sediment stability and potential increased likelihood of saltmarsh creation in the area of Blackpill SSSI.

Table 11.1A TE 1 Objective Summary: To minimise potential effects on Crymlyn Burrows SSSI

Target	No decline in habitat extent or in condition of the strandline, embryo dune and young shifting dune SSSI features from the baseline due to the presence of the lagoon.
WFD	Angiosperms (saltmarsh) quality element (transitional waters)
Management/operation	Maintenance of artificial sand dune habitat at the north-eastern corner of the lagoon. Presence of lagoon.
Monitoring	***Monitoring of the cable route:*** A baseline map will be produced showing the habitats to be effected by the proposed works (as the cable runs alongside an existing tarmac track, these are expected to be able to be

	minimised). A pre-construction survey will be undertaken to identify any areas that may be suitable for turf translocation. In addition, suitable turf storage areas will also be identified within the easement. During construction a watching brief will be kept on the condition of any turves (should turf translocation be required). Works on the cable route will also fall under the remit of the Environmental Liaison Officer (ELO) to ensure that works are carried out in accordance with method statements and no long-term damage to the SSSI occurs. Post-construction surveillance monitoring will be undertaken on a quarterly basis for the first two years to ensure: • Re-instated areas are not becoming colonised by ruderal species; • Any translocated turves are re-establishing. ***Dune system*** The presence of the lagoon walls would lead to a sheltering effect on Crymlyn Burrows SSSI and the following scenarios require monitoring: Scenario 1: a reduction in the supply of wind-blown sand to the frontal dunes; Scenario 2: a reduction in wave action resulting in accumulation of sediment, particularly muddy sand in the intertidal zone; formation of one more sand bars with windblown sand cappings and areas of muddy sand behind, attached to the eastern Lagoon wall. Scenario 3: less frequent/intense erosion of the frontal dunes and lower mobility of intertidal sand bar features due to the reduction in wave action; Scenario 4: a reduced influence of salt spray on dune vegetation . See Chapter 5 above for details of coastal processes studies. Relevant to the assessment of the effects of the Project on the sediment supply to the SSSI, its morphology and sedimentary character: • To examine the levels of sediments (accretion and erosion) within the lagoon, (through beach transect monitoring - table 5.1), navigation channels (table 5.3Error! Bookmark not defined.) and the wider Bay area (Table 5.2);); • To monitor changes to annual intertidal beach profiles **as** specified in table 5.1 including sediment sampling (particularly profile 214 and 215 Crymlyn Burrows with additional profiles established either side). The aerial survey data to be used together with the beach profile data to examine any changes in extent of saltmarsh on the SSSI. • To undertake a Rapid Geomorphological Assessment (RGA) of the Crymlyn Burrows frontage between the Eastern lagoon wall and the River Neath will be undertaken annually at the same time as routine beach profile monitoring or with the annual habitat extent and condition surveys (Table 5.1). • NRW advise that monitoring is also undertaken to determine the effectiveness (or otherwise) of the landscaped beach within the lagoon to transfer sand to Crymlyn Burrows SSSI (Table 5.1). Pre-construction, a detailed baseline habitat extent map and habitat condition map and map of Crymlyn frontage features presented below will be produced with methodologies to be agreed

	with NRW, and an RGA will be undertaken. SUBC will also be contacted to obtain any baseline data they hold for the whole of the SSSI. It is proposed that an annual survey of habitat extent and condition of the following SSSI features is undertaken: • Strandline (including the presence of the strandline beetle (*Eurynebria complanata*); • Sea stock (Matthiola sinuata); • Embryo dunes; • Shifting dunes; • Saltmarsh. The monitoring will initially be undertaken by a suitably qualified ecologist who will be able to train the Warden (should this be required) and will follow agreed methods for SSSI condition monitoring of dune habitats and saltmarsh. Monitoring will also include interpretation of fixed point photography associated with beach transect and aerial survey/LIDAR (Surveys 1 and 4, AEMPr3) *Management of recreational pressure* • The warden appointed for the tidal lagoon will work with the management organisation responsible for the SSSI under the provisions of the planning permission for the SUBC in order to monitor and manage visitors and access to the SSSI. These measures are likely to include visitor surveys, monitoring numbers of visitors/cars through observations, in line with the requirements of the management organisation responsible. • In addition, data from other surveys identified in the AEMP, including fixed point photography, fixed point vegetation surveys, aerial imagery and ad hoc checks by the Lagoon warden will be used to monitor potential effect of visitors.
Responsibility	TLSB, Environmental Liaison Officer and Project warden
Objective	To validate findings of ES and if necessary identify change outside that already predicted such that mitigation measures can be implemented, if appropriate.
Limits of acceptable change	*Monitoring of the cable route* • Coverage of ruderal/weed species (e.g. Common nettle (*Urtica dioica)*, Willowherb sp. (*Epilobium sp*.) of no more than 10% per transect; • No invasive species present e.g. Japanese knotweed (*Fallopia japonica)*; • 60% of any translocated turves will successfully re-establish within two years; • Recolonisation of bare sand areas by native dune species. *Scenarios 1-4 brought about by the sheltering effect of the lagoon walls* Beach systems are inherently dynamic and subject to periods of deposition and erosion. By analysis of historical data as described above, broader scale sediment changes/trends may be discernible and this would supplement the understanding of the Bay's "behaviour" and change to the Crymlyn Burrows frontal dune

	system. Results of the annual condition monitoring will be assessed in line with the Performance Indicators to ensure that no adverse change from the baseline is taking place. Data from the studies will be made available for expert peer review and if a consensus of opinion suggests the lagoon has brought about adverse change this will trigger remedial action. *Management of recreational pressure*: The absence of vehicle or visitor damage throughout the strandline, foreshore and shifting dune habitats.
Future / Remedial action	*Monitoring of cable route* Infestations of ruderal weed or invasive plant species will be subject to spot-treatment using herbicide; It is considered likely that the dry conditions on-site and the friable nature of the substrate will result in a high failure rate of any translocated turves (should they be considered necessary). Where failure does occur, other options will be considered, such as re-colonisation from bare sand or the collection and spread of seed from species-rich areas in the SSSI. *Scenarios 1-4 brought about by the sheltering effect of the lagoon walls* If excessive beach erosion occurs at the landscaped beach inside the lagoon adjacent to the eastern lagoon wall, beach replenishment will be undertaken. Sand from an appropriate source would be identified and agreed for use with NRW(A) and NPTCBC. A marine licence would be south from NRW(MLT). Should any of the scenarios presented above become apparent on the Crymlyn Burrows intertidal zone, strandline, embryo or shifting/mobile dune features of the SSSI due to the presence of the lagoon, then a range of management measures to address the impacts would be considered, subject to peer review (chapter 3) and any interventions agreed with NRW. These could include (but not be limited to) beach replenishment with sand, sand nourishment on the frontal dunes, redistribution of sand, manipulation of habitats to arrest stabilisation (vegetation stripping or other interventions to encourage bare sand/mobility, introduction of grazing, treatment of invasive species and scrub control) and the propagation and management of rare or notable species. <u>Management of recreational pressure from the Lagoon</u> Management measure could include fencing, creation of signed walks, litter patrols, restricted access to SSSI from lagoon, habitat recreation, site security, community liaison. Any management strategies would be carried out in agreement with the with the SSSI landowner and management organisation responsible for the conservation objectives of the SSSI.

Table 11.1B TE 1 Objective Summary: To minimise potential effects on sand dune systems outside Crymlyn Burrows i.e. Swansea Bay SINC, Blackpill SSSI, Baglan Burrows and Aberavon Sands

Target	No decline in habitat extent or in condition of the strandline, embryo dune and young shifting dunes from the baseline due to the presence of the lagoon. Note
WFD	Angiosperms (saltmarsh) quality element (transitional waters)
Management/operation	Presence of lagoon.
Monitoring	*Although not predicted by the ES, the presence of the lagoon walls leading to an increase in erosion of sand dunes of Swansea Bay SINC and an increase in mud deposition, sediment stability and increased likelihood of saltmarsh creation in the intertidal area of Blackpill SSSI* See Chapter 5 above for details of coastal processes studies. Relevant to the assessment of the effects of the Project on the sediment supply to the site: • To examine the levels of sediments (accretion and erosion) within the lagoon, navigation channels and the wider Bay area (Table 5.1 and Table 5.2); • To monitor changes to annual intertidal beach profiles (particularly profile 201, 202, 203, 204, 205, 206, 208, 209, 209A, 210 Swansea Beach). • Additional beach profiles at 217/218 Baglan Burrows will also be monitored to provide a wider picture of coastal processes throughout Swansea Bay. However; no significant concerns have been raised about potential impacts on Baglan Burrows or Aberavon Sands. • The high resolution aerial survey data to be used together with the beach profile data to examine any changes in extent of habitats such as saltmarsh. • To undertake a Rapid Geomorphological Assessment (RGA) on the upper beach transect interface with any dune system (where appropriate) for 100m either side of the transect, and for a 400m section where there is a grouping of transects. Monitoring for the bird features of Blackpill SSSI (in particular sanderling and ringed plover) are detailed in Chapter 10.
Responsibility	TLSB, Environmental Liaison Officer and Project warden
Objective	To validate findings of ES and if necessary identify change outside that already predicted such that mitigation measures can be implemented.
Limits of acceptable change	*Although not predicted by the ES, the presence of the lagoon walls leading to an increase in erosion of sand dunes of Swansea Bay SINC and an increase in mud deposition, sediment stability and increased likelihood of saltmarsh creation in the intertidal area of Blackpill SSSI* Beach systems are inherently dynamic and subject to periods of deposition and erosion. By analysis of historical data as described above broader scale sediment changes/trends may be discernible and this would supplement the understanding of the Bay's "behaviour" and change to the Swansea Bay dune system. Undertaking annual beach profile monitoring and RGA will enable a finer scale analysis. Data from the studies will be made available for expert peer review and if a consensus of opinion suggests the lagoon has brought about an unacceptable adverse change (for

	example a defined increase in cover of saltmarsh, or extensive erosion) this will trigger remedial action.
Future / Remedial action	*The presence of the lagoon walls leading to an increase in erosion of sand dunes of Swansea Bay SINC and an increase in mud deposition, sediment stability and increased likelihood of saltmarsh creation in the intertidal area of Blackpill SSSI* If excessive beach erosion occurs along the fragmented dune frontage of Swansea Bay SINC, beach replenishment will be considered. Sand from an appropriate source would be identified and agreed for use with NRW(A) and CCS. The method and timings of beach replenishment would consider the areas use, such as those used as bird roosting, where appropriate. The intertidal area is a mosaic of naturally changing muds especially in the lower intertidal areas, where the depth of mud varies from a few centimetres to tens of centimetres. Mudflats are important in their own right and are of value to birds. Of particular note in the wider area are the mudflats of the Severn and adjacent estuaries. The coastal process modelling is predicting no significant change to intertidal areas and as such the habitats that are currently present are predicted to remain, but their distribution will continue to change naturally as it is a dynamic system. If a significant increase in mud distribution outside natural variation is detected, which is deemed to have an unacceptable adverse effect on ecology of the area, mitigation measures could be considered. This could include dredging/scraping the intertidal areas to remove any deposited muds. The scraping would also result in the loss of benthic ecology within the mud and therefore the need for mitigation and the appropriateness of scraping as a mitigation measure would need to be considered carefully through the AEMP review process. It has been postulated that an increase in mud deposition on the intertidal area at Blackpill could lead to sediment stability and the formation of more saltmarsh. Should an increase in saltmarsh at Blackpill become apparent due to the presence of the lagoon, then removal of the saltmarsh would be undertaken, should it be considered necessary. Any impacts of the changes in sediment characteristics on the bird features of the SSSI is covered in Chapter 5.

11.3.2 Objective TE2: To minimise the deterioration or loss of existing coastal grasslands and to optimise the potential of the introduced coastal grassland

11.3.2.1 Baseline surveys identified the presence of coastal grassland habitat within areas likely to be disturbed during Project construction. In particular, habitat that has established on made-ground within the docks estate includes localised stands of relatively diverse grassland. These communities have developed naturally with very little management and support self-seeded native species of local provenance.

11.3.2.2 Extensive landscaping works will take place during Project construction resulting in areas of bare ground. Natural colonisation provides the preferred mechanism for re-vegetation of disturbed ground. However, prolonged exposure of un-vegetated substrates could lead to loss of material through erosion. It is proposed to use existing plant communities to provide a source of seed and turf to facilitate the vegetation of bare ground following completion of the construction of the Project.

Table 11.2 Objective Summary TE2: To minimise the deterioration or loss of existing coastal grasslands and to optimise the potential of the introduced coastal grassland

Target	• Retain existing grassland habitat where possible. • Allow the establishment of species-rich grassland habitat in newly landscaped areas through natural colonisation facilitated by seed and turf recovered from grassland resources disturbed during construction. • Desirable species include Restharrow, Common Bird's-foot-trefoil, Yellow Rattle, Kidney Vetch, Wild Parsnip and Wild Carrot. • Ensure no net loss of coastal grassland habitat.
WFD	Not applicable
Management/operation	• Pre-construction brush harvesting of suitable grassland resources (July-August 2014) and preparation to enable storage until use in 2015. • Pre-construction identification and demarcation of habitat for retention / removal (Spring 2015). • Take and store species-rich turf and topsoil resources at a secure location. • Manage to discourage deterioration (such as watering if required). • Landscaping of Seaward Ecological Park using nutrient-poor materials (sandy / aggregate substrate). • No fertilisers to be used. • Translocate species-rich turf and top-soil resources for use within coastal grassland habitat plots of the Seaward Ecological Park. • Use brush-harvested seed at locations within the Seaward Ecological Park. • Spot-treat invasive weed species with herbicide or locally manage (such as by periodic mowing) to encourage development of a species-rich sward.
Monitoring	• Supervise pre-construction brush-harvesting of seed as well as demarcation of grassland resources and eventual turf / top-soil resource recovery. • Monitor condition of stored materials. • Supervise translocation/planting of stored materials. • Survey newly created as well as retained grassland resources to determine condition in years 1, 2, 3, 5, 7 and 10 post-construction(**Survey 37** as per ES). • Monitoring to include fixed point quadrats and fixed point photography.
Responsibility	TLSB, Environmental Liaison Officer and Project warden
Objective	To validate findings of ES and if necessary identify if management intervention is required.
Limits of acceptable change	The objective is to allow natural regeneration to create habitat of local provenance that will develop in time. The establishment of opportunistic 'weed' species (identified by a suitably qualified ecologist) will be discouraged through management intervention.
Further / Remedial action	• Safeguarding intervention of stored materials may include weed control and watering. • Herbicide spot-treatment of problem weeds. • Localised mowing. • Additional collection / planting of seed.

11.3.3 Objective TE3: To maximise the potential for creation of saltmarsh within the designated area of the lagoon

11.3.3.1 The plan for the Seaward Ecological Park includes an area designed to form saltmarsh habitat. Monitoring the condition of the saltmarsh once established will be linked to both the Common Standards Monitoring Guidance for Saltmarsh (English Nature, 2004) and the Water Framework Directive UKTAG Guide to the Saltmarsh Tool (WFD-UKTAG, 2014).

11.3.3.2 The potential changes to saltmarsh on the Crymlyn Burrows SSSI have been considered above.

Table 11.3 Objective Summary TE3: To maximise the potential for creation of saltmarsh within the designated area of the lagoon

Target	• Allow the natural establishment of saltmarsh habitat in the dedicated habitat creation area. • Encourage desirable species including Sea-purslane, Sea-milkwort, Glasswort, Sea-arrowgrass, Sea-aster, Sea-plantain, Saltmarsh Rush and Saltmarsh-grass.
WFD	Swansea Bay Coastal Waterbody – mitigation measures: - preserve and, where possible, restore historic aquatic habitats - preserve and where possible enhance ecological value of marginal aquatic habitat, banks and riparian zone
Management/operation	Landscaping of target area of Seaward Ecological Park to create a sheltered area subject to varying degrees of tidal inundation.
Monitoring	Ecological input to be provided during construction and operation phases. Survey of new habitat to determine condition in years 1, 2, 3, 5, 7 and 10 post-construction. Monitoring to include fixed point quadrats and fixed point photography. Monitoring will focus on: • the extent of saltmarsh; • saltmarsh zones; • saltmarsh diversity in order that it is compliant with WFD requirements.
Responsibility	TLSB, Environmental Liaison Officer and Project warden
Objective	To validate findings of ES.
Limits of acceptable change	The objective is to allow the natural establishment of saltmarsh habitat. The creation of saltmarsh does not form mitigation for loss of habitat elsewhere and if natural processes such as input of windblown sand result in the gradual creation of sand dune / dune slack habitat this will not be impeded by management intervention.
Future / Remedial action	Localised re-landscaping if early monitoring reveals ineffective tidal flooding.

11.3.4 Objective TE4: To optimise the creation of sand dunes within designated area of the lagoon

11.3.4.1 Sand dune habitat creation is proposed at the north-eastern end of the lagoon.

Table 11.4 Objective Summary TE4: To optimise the creation of sand dunes within designated area of the lagoon

Target	• Allow the natural establishment of artificial dune habitat in newly landscaped areas. • Encouragement of desirable species including Sand Couch, Marram, Prickly Sandwort, Sea-rocket, Sea Stock, Sea Bindweed and species of Orache.
WFD	Swansea Bay Coastal Waterbody – mitigation measures: - preserve and, where possible, restore historic aquatic habitats - preserve and where possible enhance ecological value of marginal aquatic habitat, banks and riparian zone
Management/operation	• Landscaping of target area of Seaward Ecological Park to create dune habitat. • Localised planting of Marram to limit erosion of key landscape features.
Monitoring	Ecological input to be provided during construction and operational phases. Survey of new habitat to determine condition in years 1, 2, 3, 5, 7 and 10 post-construction. Monitoring to include fixed point quadrats and fixed point photography.
Responsibility	TLSB
Objective	To validate findings of ES and if necessary identify change outside that already predicted such that mitigation measures can be implemented.
Limits of acceptable change	The objective is to allow the natural establishment of dune habitat. Sand loss equating to 30% of created area will require remedial action.
Remedial action	Beach replenishment will be undertaken if required. Sand from an approved source would be used. The method and timings of beach replenishment would consider the potential for sterilisation of habitats, such as those used as bird feeding habitats, if relevant.

11.3.5 Objective TE5: To minimise the potential for colonisation by invasive species

11.3.5.1 Invasive plant species including Japanese Knotweed were identified during baseline surveys (see Chapter 12 Terrestrial Ecology of the ES). The locations of these invasive species will require demarcation at pre-construction stage prior to *in-situ* treatment or controlled removal.

11.3.5.2 In addition, the presence of Cord-grass (*Spartina* species) was controlled within the intertidal environment within Swansea Bay in the 1970's and 1980's (*pers comm* CCSC, 22 July 2014). The potential for the re-colonisation of this species will be examined.

Table 11.5 Objective Summary TE5: To minimise the potential for colonisation by invasive species

Target	Eradication of invasive plant species listed under Schedule 9 of the Wildlife and Countryside Act 1981 (as amended) from the footprint of the scheme (Japanese Knotweed in particular). To minimise the spread of Spartina within the wider Bay
WFD	Not applicable
Management/operation	In situ herbicide treatment or other recommended methods (such as prescribed by The Knotweed Code of Practice (Environment Agency 2013, version 3)
Monitoring	• Register containing accurate location and description of infestations to be held by TLSB project team. • All on-site treatment locations to be monitored annually until eradication achieved. • To monitor changes to intertidal beach profiles (Table 5.3). The aerial survey data to be used together with the beach profile data to examine any changes in extent of Spartina growth in the wider Bay.
Responsibility	TLSB, Contractor, Environmental Liaison Officer and Project warden
Objective	To validate findings of ES and if necessary identify change outside that already predicted such that mitigation measures can be implemented.
Limits of acceptable change	Increase in number and size of infestations.
Remedial action	New infestations to be added to register and treatment initiated. Where infestations are non-responsive, review and where necessary change treatment regime. Management of any re-colonisation by Spartina in discussion with CCSC.

11.3.6 Objective TE6: To minimise the loss or deterioration of extent of notable plants

11.3.6.1 Baseline surveys identified the presence of notable plant species, including Golden-samphire, within construction impact zones. Mitigation measures including the translocation of robust species or substrates containing target species have been proposed within the ES although these species are not formally protected in law. The location of target plants or substrates and areas suitable to act as temporary receptor sites will be demarcated during pre-construction.

Table 11.6 Objective Summary TE6: To minimise the loss or deterioration of extent of notable plants

Target	Salvage of notable plant species from construction impact areas.
WFD	Not applicable
Management/operation	• Collection of seed (late Summer / Autumn 2014). • Pre-construction identification and demarcation of species for retention / removal (Spring 2015). • Take and transfer of individual plants (or recovery of topsoil resources) to a growing medium at a dedicated transit site (Spring 2015). • Manage to discourage deterioration (water/weed if required). • Create suitable niches at locations within lagoon wall or within Seaward Ecological Park (construction phase).

	• Translocate plants and/or top-soil resources for use at habitat creation plots (as soon as these become available).
Monitoring	• Register containing accurate location and description of receptor sites to be held by TLSB project team. • Regular visual inspection of receptor sites (at least monthly but more frequently during adverse weather conditions such as hot weather) to be undertaken during first year. • Longer-tern monitoring is to comprise visits at an appropriate season in years 1, 2, 3, 5, 7 and 10 post-construction. • Monitoring to include fixed point photography.
Responsibility	TLSB, Environmental Liaison Officer and Project warden
Objective	To validate findings of ES and if necessary identify change outside that already predicted.
Limits of acceptable change	Failure of 25% or more of translocated plants to trigger remedial action.
Remedial action	Review and modification (where possible) of receptor sites or other management intervention to increase potential for survival.

11.3.7 Objective: To minimise the potential effects of lighting of the Project on Bats

11.3.7.1 Surveys focused on the docks estate identified the presence of foraging bats (see Chapter 12 Terrestrial Ecology), particularly Common and Soprano Pipistrelle. The ES sets out a commitment to limit the impact of light spill on foraging bats.

Table 11.7 Objective Summary TE7: To minimise the potential effects of lighting of the Project on Bats

Target	To ensure foraging habitat unaffected by light spill is available to bats through implementation of a sympathetic construction and operational lighting strategy.
WFD	Not applicable
Management/operation	Ecological input into the placement, direction and intensity of construction and operational lighting requirements.
Monitoring	Check position and illumination levels of lighting infrastructure deployed for construction as well as that set out for the operational scheme. Undertake remote detector surveys (for at least one week duration), bi-annually between May and September, for three years post-construction (**Survey 38, method as per ES**). Investigate use of lagoon habitat by foraging bats using hand-held detectors bi-annually for three years post-construction.
Responsibility	TLSB, Contractor, Environmental Liaison Officer, Project warden
Objective	To validate findings of ES.
Limits of acceptable change	Corridors of habitat unaffected by light spill must be available to bats during construction. Continued use of habitat by bats.
Future / Remedial action	Review and modification of lighting infrastructure to limit light spill and ensure unlit foraging habitat remains within the scheme.

11.3.8 Objective TE8: To minimise the potential effects of the Project on Otters – access and lighting

11.3.8.1 Otters are known to be present locally and surveys (see Chapter 12 Terrestrial Ecology) have identified use of the docks estate.

Table 11.8 Objective Summary TE8: To minimise the potential effects of the Project on Otters – access and lighting

Target	• To ensure foraging habitat unaffected by light spill is available to otters through implementation of a sympathetic construction and operational lighting strategy. • Ensure access for otters is maintained between the docks estate, scheme and coastline.
WFD	Not applicable
Management/operation	Ecological input into the placement, direction and intensity of construction and operational lighting requirements. Ensure barriers to movement are not created that block all access for otters between the docks estate and coastline.
Monitoring	• Check position and illumination levels of lighting infrastructure deployed for construction as well as that set out for the operational scheme. • Undertake trail camera surveys (remote cameras triggered by movement or passive infra-red sensors) to be employed in the three years post-construction to confirm / identify the continued use of the area by otters (**Survey 40, method as per ES**). • Undertake searches for spraint within the project area in the three years post-construction to identify use of habitat by otters.
Responsibility	TLSB, Contractor, Environmental Liaison Officer/Project Warden
Objective	To validate findings of ES.
Limits of acceptable change	Potential access points must be maintained between the docks estate and coastline. Any cause of otter mortality must be reviewed.
Future / Remedial action	Re-positioning of lighting to reduce light spill. Any cause of otter mortality to be reviewed and intervention undertaken to reduce risk to an acceptable level.

11.3.9 Objective TE9: To minimise the potential effects of construction of the Project on Reptiles

11.3.9.1 Common Lizard were recorded from the docks estate during surveys in 2013 (see Chapter 12 Terrestrial Ecology). Measures will be required in order to minimise the risk of injury or mortality to reptiles during construction.

Table 11.9 Objective Summary TE9: To minimise the potential effects of construction of the Project on Reptiles

Target	• Retention of habitat supporting reptiles within the scheme. • Implementation of a strategy to safeguard reptiles during construction. • Creation and maintenance of habitat with potential for reptiles that allows dispersal locally.

WFD	Not applicable
Management/operation	• Pre-construction identification and demarcation of habitat for retention / removal (Spring prior to construction). • Habitat manipulation to discourage reptiles from habitat subject to construction losses (Spring prior to construction). • Deployment of artificial refugia and fencing to facilitate a reptile translocation operation (Spring prior to construction). • Supervised destructive search of habitat affected by construction activities. • Creation of suitable refuges for reptiles at locations within the Seaward Ecological Park (construction phase). • Vegetation management sympathetic to reptiles within suitable parts of the Seaward Ecological Park (retention of rough grassland habitat and basking sites).
Monitoring	Visual searches and where possible use of artificial refugia to be undertaken annually, five years post-construction, to identify presence of reptiles within retained or recreated habitats. Habitat assessment to determine potential for reptiles and barriers to movement annually five years post-construction then on an ad hoc basis.
Responsibility	TLSB, Environmental Liaison Officer, Project warden
Objective	To validate findings of ES and if necessary identify change outside that already predicted such that mitigation measures can be implemented.
Limits of acceptable change	Disappearance of reptiles from habitat associated with the construction of the Project to trigger remedial action.
Future / Remedial action	Any cause of reptile mortality to be reviewed and intervention undertaken to reduce risk to an acceptable level. Significant barriers to dispersal to be investigated for potential sympathetic modification.

11.3.10 Objective TE10: To minimise the potential effects of the Project on Invertebrates

11.3.10.1 A number of section 42 NERC 2006 invertebrate species were identified from the docks estate during baseline surveys. Additionally, Crymlyn Burrows is notified for invertebrate assemblages as well as presence of the strandline beetle (*Eurynebria complanata*).

11.3.10.2 Post-construction survey of habitats within the Project will be undertaken by the Lagoon Warden on an *ad hoc* basis but specific surveys will also be commissioned to determine the colonisation of intertidal habitat as well as coastal grassland habitat in years 1, 2, 3, 5, 7 and 10.

Table 11.10 Objective Summary TE10: To minimise the potential effects of the Project on Invertebrates

Target	Retention or recreation of habitats with potential to support a diverse native invertebrate assemblage.
WFD	Not applicable
Management/operation	Tied with habitat management objectives, in particular those set out to encourage diverse coastal grassland.
Monitoring	To be undertaken by the Environmental Liaison Officer and Project warden on an *ad hoc* basis (survey 41) but specific surveys will also be commissioned to determine the colonisation of intertidal habitat and coastal grassland habitat in years 1, 2, 3, 5, 7 and 10.
Responsibility	TLSB, Environmental Liaison Officer and Project warden

Objective	To validate findings of ES and if necessary identify change outside that already predicted such that mitigation measures can be implemented.
Limits of acceptable change	25% reduction in number of section 42 NERC 2006 invertebrate species identified during baseline surveys three years after construction to trigger further investigation.
Remedial action	Any significant reduction in invertebrate diversity to be reviewed and where feasible remedial action taken to reverse trend.

Survey 41

Surveys to be undertaken on an *ad hoc* basis by ELO and Project Warden. Additional specific surveys will also be commissioned to determine the colonisation of intertidal habitat and coastal grassland habitat. These surveys would link into the high resolution aerial surveys (survey 4) and the quadrat surveys (Survey 37). The more detailed surveys would be undertaken in years 1, 2, 3, 5, 7 and 10 of operation.

12 Marine Noise

12.1 Introduction

12.1.0.1 Chapter 19 Noise and Vibration of the ES provides full details of the data review and site specific survey work carried out to collect baseline information for the Project area. The results of the noise assessment within the ES concluded that during construction, with mitigation for marine piling, there will be no impact to minor impact on receptors. Once operational, it can be seen that the Project is not anticipated to increase underwater sound levels apart from in very close proximity to the turbines. Chapters 9 and 10 of the ES provide an assessment of the potential effects of the Project on fish and marine mammals respectively.

12.1.0.1

12.1.0.2 This section outlines noise monitoring that will be undertaken in the marine environment to gain a better understanding of marine noise levels during construction and operation in terms of verifying the findings of the ES in relation to potential impacts on fish and marine mammals.

12.2 Baseline

12.2.0.1 Baseline underwater noise measurements were undertaken in April 2013 at five locations around the proposed Project area. The Centre for Environment, Fisheries and Aquaculture Science (CEFAS) was consulted on the proposed underwater noise measurement methodology prior to the survey, and all measurements were undertaken in accordance with this methodology.

12.3 Noise Objectives

12.3.0 Objective N1: To further characterise the baseline noise environment within the Bay and the effects of construction and operation of the Project on fish and marine mammals

12.3.0.1 Additional noise surveys will be undertaken to further characterise baseline noise levels within the Bay, particularly in the vicinity of the Tawe Estuary. In addition, surveys will be undertaken during the construction phase to examine the potential effects on marine mammals and fish. Piling will now be limited to the construction of dolphin piles over a period of 15 days. It is expected that the majority of piling will be using vibro piling, with the end range of the dolphin pile requiring impact piling.

12.3.0.2 It is proposed to use acoustic deterrents to minimise the potential for fish and marine mammals to encounter the turbines. Prior to their installation, surveys will be undertaken to understand any potential effects on migratory fish routes or marine mammal use within the wider Bay. Surveys of the operational turbines will also be undertaken.

Table 12.1 Objective N1: To further characterise the baseline noise environment within the Bay and the effects of construction and operation of the Project on fish and marine mammals

Target	• To further characterise the noise environment prior to Project commencement • Monitoring of noise from key marine plant during construction and • Monitoring of turbines during operation to verify predictions made in the EIA.
WFD	Fish quality element in transitional waters and Fish (migratory only) quality element in rivers
Management/operation	Construction and physical presence of the operational lagoon.
Monitoring	• Pre-construction baseline noise surveys – repeat of ES baseline mobile noise surveys on two additional occasions at different locations within the bay. • Construction related noise monitoring to be undertaken to understand underwater noise generated from marine construction activities. Data to be collected during differing activities including piling, dredging works and rock armour placement. • Monitoring associated with the operation of the Project will include an investigation of proposed acoustic deterrents as well as monitoring of turbines: i. Noise monitoring of the operational turbines. ii. Monitoring of acoustic field from ADD during commissioning phase to allow adjustment of sound levels to the desired values.
Responsibility	TLSB
Objective	To validate findings of ES and to supplement existing data. Data will also be used for future projects.
Limits of acceptable change	No limit; JNCC guidelines to be followed for marine piling with soft start procedures.
Future / Remedial action	Review /modify ADD to reduce noise levels.

Survey 42 – Mobile noise survey (as per ES methodology)

12.3.0.3 Pre-construction - mobile noise surveys (following ES methodology) on two additional occasions at different locations within the Bay. Locations to include:

a. Mouth of the River Tawe

b. Proposed turbine and sluice gate housing site

c. 500m of the turbine and sluice gate infrastructure

d. 1000m westwards towards Mumbles.

12.3.0.4 Construction - mobile noise surveys (following ES methodology) to be undertaken to understand underwater noise generated from marine construction activities. Data to be collected during differing activities including but not limited to:

a. installation of dolphin piles (impact and percussive)

b. dredging works,

c. rock armour placement.

12.3.0.5 Operation - mobile noise surveys (following ES methodology).

12.3.0.6 Locations to include:

a. Mouth of the River Tawe.

b. Proposed turbine and sluice gate housing site (with and without turbines operating to obtain noise data from ADD system if installed)

c. 500m of the turbine and sluice gate infrastructure

d. 1000m westwards towards Mumbles

12.3.0.7 It would be proposed that the recording of un-weighted received noise levels and the analysis of data through SEL and peak SPL metrics, will be reported.

12.3.0.8 All equipment to be used for the noise recordings will be calibrated, traceable to the UK national measurement standard. Certificates will be available on request.

12.3.0.9 In order to ensure scientific integrity of the work, internationally established methods, i.e. those approved through a peer-review process or through a consensus of an expert committee, would be used in reporting the impact zones and potential impact on marine life (Urick 1983).

~~**Summary**~~

13 Summary

13.0.0.1 Monitoring measures, and in many areas, mitigation measures have been proposed for coastal processes, water quality, intertidal and subtidal benthic ecology, fish, marine mammals, coastal birds, terrestrial ecology, water framework directive indicators and noise in this third revision to the AEMP since submission of the DCO application. However, further details and individual proposals for monitoring will be developed within the framework of this Plan throughout the duration of the Project. Survey methodologies will be agreed as appropriate with the relevant statutory authorities. It is intended that the methodologies will be provided to relevant statutory consultees for review with a response required within twenty eight days, in order to agree proposals and to avoid delays in implementation. The findings of the surveys will be analysed and disseminated to relevant organisations. Further work or remedial action will be taken following analysis of the findings of the surveys against identified acceptable limits of change, and discussions with relevant organisations.

13.0.0.2 It is proposed that the final AEMP will serve not only as a guide for this Project but also a template for future tidal energy schemes. Collaborations between TLSB and various consultancies and academic institutions may well lead to the publication of peer-reviewed scientific articles, thereby increasing the collective knowledge of Swansea Bay's environment.

13.0.0.3 A summary of the Monitoring Objectives and surveys associated with them is provided in Table 13.1. A summary of the survey and frequency of occurrence over pre-construction, construction and operation to year 10 is provided in Table 13.2. Abbreviations and survey frequency coding is provided below.

PC = Pre-construction
C1, C2, C3 = construction year
Op1, etc = Operation year
2/1 = Survey 1, Key transects twice a year, SCBCEG transects once a year.
1 = annual survey
2 = biannual
6 = every 2 months
12 = monthly
24 = twice per month
6/R = 6 monthly survey and then review
x3 = on three occasions
C = Complete
R = Review
TBC = to be confirmed
M = Modelling
1H = Herring survey
OG = Ongoing
OW = Overwinter bird survey (August to May)
W = Warden surveys

Table 13.1 Summary of Monitoring objectives and surveys

	S1- Beach transects and RGA	S2 - Intertidal sediments	S3 - Fixed point photos	S4 - High res aerial surveys	S5 – SBES transects	S 6 – Subtidal sediments	S7 - Survey lagoon and approach channels	S8 – Currents by AWAC and Sediments	S9 - Currents by ADCP and sediments	S10- WQ and suspended sediments	S11 – Tidal bacterial WQ monitoring	S12–Routine bacterial monitoring	S13 –DIN sampling	S14 – Ecology Mumble Head	S15 – Colonisation of sea walls	S16 – intertidal ecology	S17 – Benthic ecology	S18 – Epifauna trawls	S19 – drop down camera/diver survey	S20 –Sabellaria health monitoring	S21 –Fish turbine monitoring	S22a/S22b-Mobile Hydroacousitc/turbine encounter	S23a Ichthyoplankton trawls	S23b Mobile hydroacoustic + trawls	S24 –Artificial spawning media	S25 – video and grabs	S26 –Fish surveys (intertidal and subtidal)	S27a - drop tapping and fyke netting	S27b - Electro-fishing surveys	S27c - Fish tagging study	S28 a– Static Acoustic monitoring	S28b - Seal survey	S29 – marine mammal mitigation	S30- ADD modelling and monitoring	S31 – turbine collision monitoring	S32 – surface detection and PAMs	S33 – management MM in lagoon	S34 – Tidal cycle WeBS Survey	S35 – HT/LT WeBS survey	S36 – Warden Bird Surveys	S37 – Quadrat surveys	S38 – Bat surveys	S39 – Otter checks	S40 – reptile survey	S41 –Warden Invertebrate surveys	S42 – Mobile Noise monitoring
Coastal Processes																																														
CP 1 intertidal – changes to area	X	X	X	X			X	X	X						X	X																															
CP2 Subtidal - changes to wider bathymetry					X	X	X	X									X																													
CP3 Siltation within the lagoon and in approach channels					X	X	X	X	X																																					
CP4 Changes in waves and currents in wider Bay								X	X																																					
CP5 Currents – localised flows through turbines and sluice gates							X	X	X																																					
Marine Water Quality																																														
WQ1- investigate water quality and re-suspension of sediments										X																																				
WQ2: Bacteriological water quality in the lagoon											X	X																																	
WQ3: Bacteriological water quality outside the lagoon								X																																					
WQ4: Nutrients in Neath Estuary, Tawe Estuary and Swansea Bay													X																																
Intertidal and subtidal benthic ecology																																													
ME1 - colonisation associated with the lagoon seawalls														X	X												X	X	X																
ME2 - To minimise colonisation of the seawall by invasive species															X													X																
ME3 - To study to examine intertidal habitat extents and any changes in habitats in the lagoon and wider Bay	x	x		x										X	x	X											X	X	X																
ME4 - to examine the changes in subtidal benthic ecology resulting from the Project	x	x		x	x	x	x	x					x				x										X	X	X			X												
ME5: monitor the effect on Sabellaria spp and colonisation of Sabellaria spp	x	x	x	x	x	x	x	x	X						x	x	x		x	x																									
ME6 - to maximise the potential for the reintroduction of the native oyster							X		X								x	x	x	x																									
Fish, recreational and commercial																																														
F1- to assess fish passage through turbines									X												X	X					X																	X
F2 - To examine herring mitigation effectiveness																					X	X	X	X	X	X																	X
F3 - Broad scale changes in fish fauna assemblage within Swansea Bay																X	X	X			X	X								X													X
F4 – To monitor diversity and abundance of fish associated with the artificial reef																X	X	X	X		X	X																						
F5 – To review migratory fish stocks along the Afan and Tawe.																														X													
F6 – To analyse rod catch data to determine effect of the Lagoon.																														X													

	S1- Beach transects and RGA	S2 - Intertidal sediments	S3 - Fixed point photos	S4 - High res aerial surveys	S5 – SBES transects	S 6 – Subtidal sediments	S7 - Survey lagoon and approach channels	S8 – Currents by AWAC and Sediments	S9 - Currents by ADCP and sediments	S10- WQ and suspended sediments	S11 – Tidal bacterial WQ monitoring	S12–Routine bacterial monitoring	S13 –DIN sampling	S14 – Ecology Mumble Head	S15 – Colonisation of sea walls	S16 – intertidal ecology	S17 – Benthic ecology	S18 – Epfauna trawls	S19 – drop down camera/diver survey	S20 –Sabellaria health	S21 –Fish turbine monitoring	S22a/S22b-Mobile Hydroacousitc/turbine encounter	S23a Ichthyoplankton trawls	S23b Mobile hydroacoustic + trawls	S24 –Artificial spawning media	S25 – video and grabs	S26 –Fish surveys (intertidal and subtidal)	S27a - drop tapping and fyke netting	S27b - Electro-fishing surveys	S27c - Fish tagging study	S28 a– Static Acoustic monitoring	S28b - Seal survey	S29 – marine mammal mitigation	S30- ADD modelling and monitoring	S31 – turbine collision monitoring	S32 – surface detection and PAMs	S33 – management MM in lagoon	S34 – Tidal cycle WeBS Survey	S35 – HT/LT WeBS survey	S36 – Warden Bird Surveys	S37 – Quadrat surveys	S38 – Bat surveys	S39 – Otter checks	S40 – reptile survey	S41 –Warden Invertebrate surveys	S42 – Mobile Noise monitoring
F7 – Review NRW WFD Compliance Data to assess any changes in ecological status																												x	X																
F8 - Monitor fish movements by acoustic telemetry																	X			X	X	X	X						X															
MM1 - marine mammals monitoring to understand effects of Project on					X	X	X	X						X	X		X	x	x		x		X	x	x	x	x	x			x	X	x	X	X	X	X							X
MM2 - To minimise and further understand the potential effects of construction.																																X	X	X											X
MM3 - To examine the potential for interaction with the project during operation.																																X	X	X	X	X	X	X							X
CB1 - To monitor changes in bird usage in the Lagoon and wider Bay	x	x	x	x				x	x					x	x	x	x	x	x	x	x		x	x	x	x	x	x										x	x	X						
CB2 – To monitor usage of lagoon and enhancement measures	x	x	x	x			x	x	x					x	x	x	x	x	x	x	x		x	x	x	x	x	x										x	x	x						
TE1 To minimise potential effects on Crymlyn Burrows (SSSI) and other dune systems within Swansea Bay	x	x	x	x											x	x																														
TE2 – To minimise deterioration /loss of existing coastal grasslands / optimise potential of introduced coastal grassland				X																																								x				
TE3 - To maximise the potential for creation of saltmarsh within the designated area of the lagoon				X																																								x				
TE4 – To optimise creation of sand dunes within designated area of lagoon	x	x	x	X												x																												x				
TE5 – To minimise the potential for colonisation by invasive species	x	x	x	X												x																																
TE6 – To minimise loss / deterioration of extent of notable plants				X																																								x				
TE7 – To minimise the potential effects of lighting on Bats																																													x				
TE8 – To minimise potential effects of the Project on Otters.																																													X				
TE9 – To minimise potential effects of construction of on Reptiles																																														X			
TE10: To minimise the potential effects of the Project on Invertebrates																																														x		
N1: To further characterise the baseline noise environment within the Bay and the effects of construction and operation of the Project on fish and marine mammals																																																X

Table 13.2 Summary of surveys timetable (Abbreviations provided in 13.0.0.3)

	2014/ 2015	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Survey/ Project year	PC	C1	C2	C3	Op1	Op2	Op3	Op4	0p5	0p6	Op7	Op8	Op9	Op10
S1- Beach transects and RGA	1	1/1	2/1	2/1	2/1	2/1	2/1	2/1	1	1	1	1	1	1
S2 - Intertidal sediments	1	1	2	2	2	2	1	1	1	1	1	1	1	1
S3 - Fixed point photos (ELO)		12	12	12	6/R									
S4 - High resolution aerial surveys	C		1		1		1		1					1
S5 – SBES transects	1				1				1					1
S 6 – Subtidal sediments	C				1				1					1
S7 - Lagoon/approach channels	1	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC
S8 – Currents 2 x AWAC and SS					1									
S9 - Currents ADCP and SS					1									
S10 - WQ and SS	1		1											
S11 – Lagoon bacterial WQ					4									
S12–Routine bacterial lagoon					36	18	18	18	18	18	18	18	18	18
S13 –DIN sampling	TBC	12	12	12	12	12	6	6	6	R				
S14 – Ecology Mumble Head	C													
S15 – Colonisation of sea walls		2	2	2	6	4	2	2	2	R				
S16 – intertidal ecology	1		1		1		1		1					1
S17 – Benthic ecology	C				1				1					1
S18 – Epifauna trawls	C				1				1					1
S19 – drop down camera/diver					1				1					1
S20 –Sabellaria health		2	2	2	1				1					1
S21 – Fish turbine monitoring		M			1	1	1	1	1	1	1	1	1	1
S22a-Mobile Hydroacousitc Survey	1				x3	x3	x3		x3	R				
S22b - Turbine passage					1									
S23a – Icthyoplankton trawls	1				TBC		TBC		TBC					
S23b Mobile hydroacoustic/trawls		1H	1H	R	TBC		TBC		TBC					
S24 –Artificial spawning media		1	1	R	TBC		TBC		TBC					
S25 – Herring video and grabs		1	1	R	TBC		TBC		TBC					
S26 –Fish (intertidal + subtidal)	4		4		4	4		4				4		
S27a-drop tapping /fyke netting					TBC	TBC	TBC	TBC	TBC					
S27b - Electro-fishing surveys	1				1	1	1	1	1/R					
S27c - Fish Tagging studies	1				1	1								
S28a – Static Acoustic monitoring	OG	OG	OG	OG	OG	OG	OG	OG	OG	OG	OG	OG	OG	OG
S28b- Seal vantage survey	6	6	12	12	12	12	12	12	12	R				
S29 – marine mammal mitigation		1												
S30- ADD modelling/monitoring		1			OG	OG	OG	OG	OG	OG	OG	OG	OG	OG
S31 – turbine collision monitoring					OG	OG	OG	OG	OG	OG	OG	OG	OG	OG
S32 – surface detection and PAMs					OG	OG	OG	OG	OG	OG	OG	OG	OG	OG
S33 – management MM in lagoon					OG	OG	OG	OG	OG	OG	OG	OG	OG	OG
S34 – through tide bird count	10				10				10					10
S35 – HT/LT Core WeBS bird count		OW	OW	OW	OW	OW			OW		OW			OW
S36 – Warden Bird Surveys		OG	OG	OG	OG	OG	OG	OG	OG	OG	OG	OG	OG	OG
S37 – Quadrat surveys					1	1	1		1		1			1
S38 – Bat surveys					2	2	2							
S39 – Otter checks		W	W	W	2	2	2							
S40 – reptile survey		W	W	W	W	W	W	W	W					
S41 –Warden Invertebrate surveys		W	W	W	W	W	W	W	W					
S42 – Mobile Noise monitoring	1	TBC	TBC	TBC	1									

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Appendix 1
Note on Rapid Geomorphological Assessment Provided in NRW Response to ExA 7 Oct 2014.

Professor Ken Pye
Kenneth Pye Associates Ltd
2nd October 2014

Rapid Geomorphological Assessment (RGA) is a largely field-based method used to characterise the 'condition' of geomorphological systems. To date it has been used principally in the context of fluvial systems, notably to quantify the degree of stability / instability of river channels (e.g. Heeren *et al*., 2012), but potentially it can be applied in any geomorphological context including quantification of the dynamism of stability of frontal dune and beach systems. The method is particularly useful in reconnaissance surveys of areas for which no background information or recent aerial photographs are available, as a method of quantifying the erosion / accretion status, and of monitoring temporal change by serial surveys.

In the context of frontal dune and beach systems the aim of a synoptic RGA survey is to characterise alongshore variations in frontal dune and beach morphology, the nature and extent of active geomorphological processes, and surface sedimentary characteristics. These attributes may be recorded in parallel with surveys of features of ecological interest to provide an overall assessment of habitat / feature 'condition' (e.g. potential changes to the degree of geomorphological and ecological dynamism of the Crymlyn Burrows frontage following construction of the proposed Swansea Bay Tidal Lagoon).

The methodology for RGA of coastal frontal dune systems was initially explored by Saye (2003) and Pye *et al.* (2007) and has subsequently been refined by KPAL (Pye

& Blott, in preparation). Essentially the procedure involves ground walkover survey of a length of coastal frontage with observations relating to the nature of beach and frontal dune features made at specified intervals (typically 50 m spacings, with positions determined either using hand-held GPS or RTK-GPS survey equipment). At each location observations are made of the frontal dune form, degree of vegetation cover, presence of any human impacts, and evident accretion / erosion status. Observations are also made of the nature of the beach at each location, notably the width and sedimentary character of the backshore (approximately above mean high water spring tide level) and foreshore (defined here as the area between mean high water spring tide level and mean low water spring tide level), the presence and nature of sedimentary bedforms on the beach (including windblown sand features), the presence and nature of any beach control structures, and the possible presence of vegetation including saltmarsh. To facilitate rapid survey and recording of information the presence or absence of specified features is recorded on a check-sheet, a blank example of which is provided at Annex I and a completed example for part of the Kenfig Burrows shore is presented at Annex II.

The list of features on the check-sheet can be modified to suit the circumstances of particular areas. At each data recording point digital photographs are taken from the upper beach in four directions - landward towards the dune front, seawards and each direction along the beach. Where required, sediment samples may also be taken along a transect normal to the dune front.

A photographic and diagrammatic reference guide to the range of dune and beach forms which may be encountered, and their interpretation in terms of geomorphological processes, is currently under development by KPAL. An example of a diagrammatic guide sheet, reproduced from Pye *et al.*, 2007) is provided at Annex III. An updated series of reference sheets will be made available in due course.

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ANNEX I

Rapid Geomorphological Assessment Form

LOCATION	DATE	WEATHER

DUNE AND BEACH MORPHOLOGICAL FEATURES		LOCATION / POSITION / GRID REFERENCE									
Frontal dune form	Ridge										
	Hummocks										
	Platform										
	Sand sheet										
	Blowout										
	Manmade dune ridge / heaps										
Dune erosion / accretion Status	Stable										
	Eroding										
	Recovering										
	Accreting										
Frontal dune features	Frontal dune | % veg										
	Sand ramp | % veg										
	Attached embryo dunes | % veg										
	Detached embryo dunes | % veg										
	Climbing dunes | % veg										
	Cliffing | % veg										
	Fallen/slumped material | % veg										
	Stabilisation measures - state type										
Beach features	Backshore width in metres										
	Backshore - gravel | sand | mud										
	Foreshore - gravel | sand | mud										
	Stabilisation measures - state type										
	Dunes on beach - state type										
	Saltmarsh - state type										
Notes											

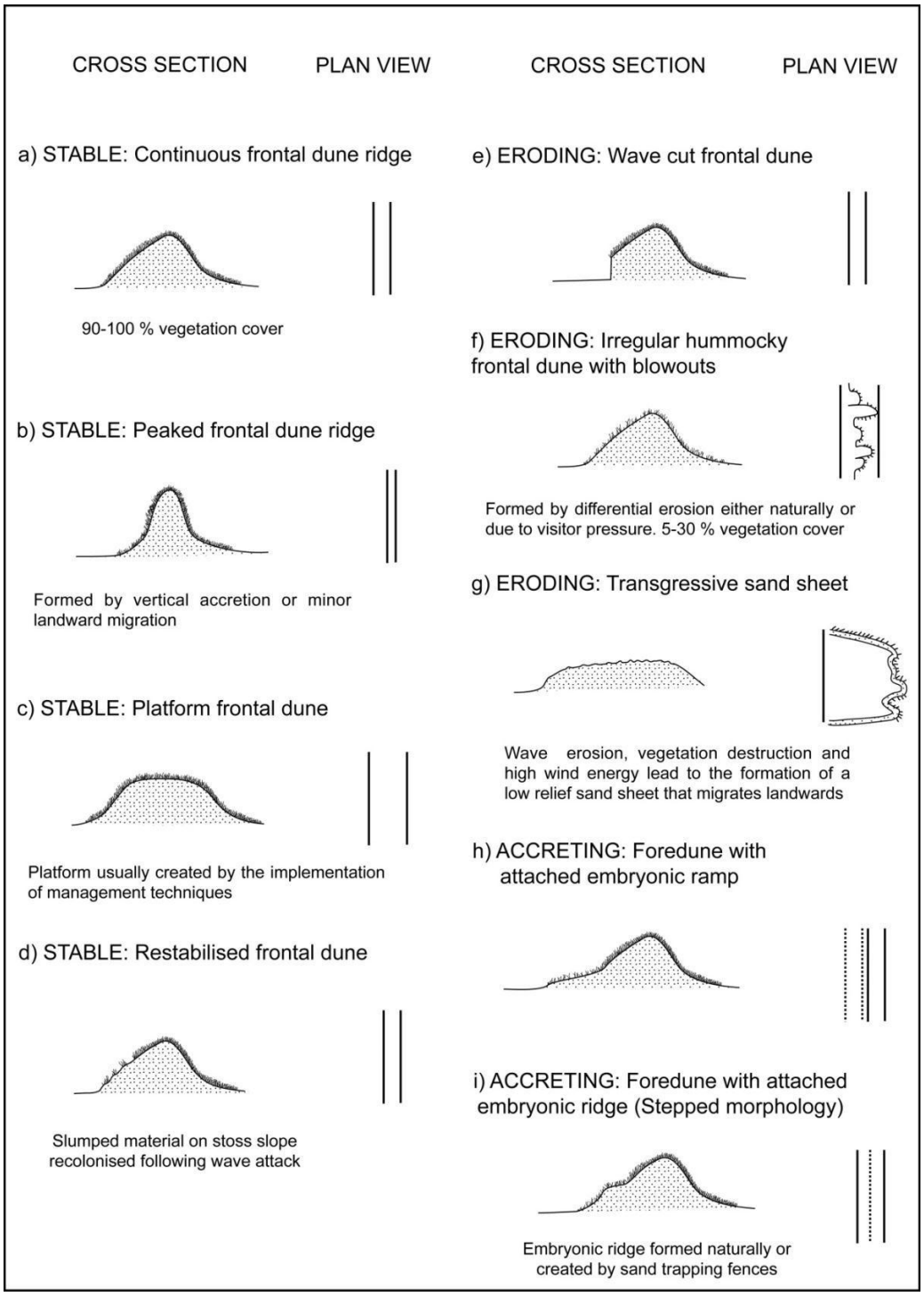
Rapid Geomorphological Assessment Form

LOCATION Kenfig Burrows Phase I reactivation site | **DATE** 09/10/2012 | **WEATHER** Overcast, dry

DUNE AND BEACH MORPHOLOGICAL FEATURES		LOCATION / POSITION / GRID REFERENCE									
		278117E 182380N	278133N 182328E	278148E 182280N	278168E 182223N	278185E 182175N	278203E 182123N	278220E 182075N	278243E 182017N	278256E 181972N	278280E 181918N
Frontal dune form	Ridge	X	X					X	X	X	X
	Hummocks			X	X						
	Platform					X	X				
	Sand sheet										
	Blowout			X					X		X
	Manmade dune ridge / heaps										
Dune erosion / accretion Status	Stable	X	X								
	Eroding			X	X	X	X	X	X	X	X
	Recovering										
	Accreting										
Frontal dune features	Frontal dune | % veg	X 100	X 100	X 20	X 10	X 10	X 30	X 100	X 60	X 100	X 50
	Sand ramp | % veg			X 0	X 0	X 0	X 0	X 0			
	Attached embryo dunes | % veg										
	Detached embryo dunes | % veg										
	Climbing dunes | % veg										
	Cliffing | % veg				X 0	X 0	X 0	X 0		X 10	
	Fallen/slumped material | % veg				X 80					X 80	
	Stabilisation measures - state type										
Beach features	Backshore width in metres	10	12	12	12	14	14	16	16	18	20
	Backshore - gravel | sand | mud	80 20 0	70 30 0	50 50 0	40 60 0	20 80 0	20 80 0	10 90 0	10 90 0	10 90 0	10 90 0
	Foreshore - gravel | sand | mud	10 90 0	10 90 0	5 95 0	5 95 0	5 95 0	5 95 0	5 95 0	5 95 0	5 95 0	5 95 0
	Stabilisation measures - state type										
	Dunes on beach - state type										
	Saltmarsh - state type										
Notes		well vegetated fordune ridge	well vegetated fordune ridge	dune reactivation area - vegetation stripped	dune reactivation area - vegetation stripped	dune reactivation area - vegetation stripped	dune reactivation area - vegetation stripped	steep eroded dune cliff	old blowout - vegetated	cliffing and slumping of frontal dune onto the beach	recently active blowout

ANNEX II

ANNEX III


CROSS SECTION
PLAN VIEW
CROSS SECTION
PLAN VIEW
a) STABLE: Continuous frontal dune ridge
90-100 % vegetation cover
b) STABLE: Peaked frontal dune ridge
Formed by vertical accretion or minor landward migration
c) STABLE: Platform frontal dune
Platform usually created by the implementation of management techniques
d) STABLE: Restabilised frontal dune
Slumped material on stoss slope recolonised following wave attack
e) ERODING: Wave cut frontal dune
f) ERODING: Irregular hummocky frontal dune with blowouts
Formed by differential erosion either naturally or due to visitor pressure. 5-30 % vegetation cover
g) ERODING: Transgressive sand sheet
Wave erosion, vegetation destruction and high wind energy lead to the formation of a low relief sand sheet that migrates landwards
h) ACCRETING: Foredune with attached embryonic ramp
i) ACCRETING: Foredune with attached embryonic ridge (Stepped morphology)
Embryonic ridge formed naturally or created by sand trapping fences

Appendix 2

Bioblock Proposals

Bioblocks - numbers, dimension, design, where they will be placed and more details on their colonisation (from past trials).

Introduction:

TLSB are working with Cenin Cement to optimise the construction of Bioblocks to be used to enhance ecological diversity within the lagoon seawalls. The following provides an overview of the current proposals in relation to the numbers, dimension, design and locations. This appendix will be updated to provide the confirmed details so that it can be used as a basis for ongoing monitoring within this AEMP (see Table

Numbers:

The final number of Bioblocks has not yet been confirmed but a maximum number of 20 is expected (between 10 – 20).

Dimension:

The Bioblock is a cuboid construction with dimensions 1.5 x 1.5 x 1 m and modifications on 5 sides.

Design:

The purpose of the Bioblock is to provide additional suitable habitats within the lagoon seawall to provide a diverse range of habitats suitable for colonisation in order to increase the potential ecological biodiversity. The Bioblock is designed to contain rock-pool type environments, sheltered shelves and pockets providing a stable habitat for colonisation. The Bioblock includes pools of variable depths on the upper surface, multiple depth holes on 2 opposing vertical surfaces and horizontal grooves on the remaining two exposed surfaces.

Placement locations:

Various locations are arrangements are currently under consideration. Options both on the inner and outer rock armour of the lagoon seawalls within the intertidal area. Research (Borsje et al. 2011) suggests that their biodiversity increases if they are placed in the lower intertidal zone. It is considered that to minimise erosion and stripping of species, the Bioblocks should be placed in areas where water flow rates are low. The Bioblocks could be grouped together to develop a pocket of high biodiversity or spread around the lagoon structure to act as reference points for scientific study.

Details of colonisation from past trials:

Ecological engineering is a relatively new concept which integrates ecological, economic and social needs into the design of man-made ecosystems. The creation of novel habitats can have a positive effect on biodiversity on artificial coastal defence structures. Borsje et al. (2011) incorporated modifications (surface roughness, grooves and pits) to concrete blocks at different tidal heights (low, mid, high) on the breakwaters at the entrance to the North Sea Channel at IJmuiden, the Netherlands. All sections of the slabs in the mid and low tidal zone were rapidly colonised by invasive non-native barnacles (*Austrominius modestus*). Mussels (*Mytilus edulis*) were only found in the sections with grooves and holes, and developed best within the grooves (Borsje et al. 2011). Both grooves and holes were used as refugia from adverse environmental conditions by periwinkles (*Littorina littorea*) during low tide. Also, slabs which were mounted low in the intertidal area showed a more rapid and diverse colonisation, compared to the slabs which were mounted higher in the intertidal zone. Thompson et al. (unpublished, cited in Witt et al. 2010) attached tiles (which had been drilled with holes of differing diameters) to a coastal defence structure in SW England. The addition of habitat complexity to

concrete surfaces resulted in significantly increased diversity of intertidal organisms within five months.

Chapman and Blockley (2009) demonstrated that creating artificial “rock-pools” into a vertical seawall significantly increased the diversity of species colonising the wall. This was achieved very simply by omitting a large block every now and then. This was replaced with a sandstone lip, which created a pool that retained water during low tide. Diversity was increased both by the pool environment and the creation of shaded surfaces. Modifications like this one are very effective when they can be incorporated at the construction stage, but Chapman and colleagues came up with a novel solution to enable the incorporation of artificial rock pools into existing seawalls. Browne & Chapman (2011) affixed specially designed flowerpots that were affixed to seawalls in Sydney Harbour. The pots were cast in such a way that they retained water during low tide, thus creating an artificial rock pool. The addition of these novel habitats increased species richness by 110%. Importantly, the increased number of mobile species was particularly pronounced with many species that were not normally able to survive on the vertical faces of seawalls.

In addition, research as part of the THESEUS project (Innovative technologies for safer European coasts in a changing climate), where Dr Louise Firth from Bangor University (now National University of Ireland, Galway) designed an experimental block that could be incorporated into coastal engineering projects either as part of a wall design, or as part of a revetment structure is ongoing.

A Bioblock prototype was placed in the Colwyn Bay Waterfront Project development in 2012 and is being monitored for plant and animal colonisation by Dr Firth and the SEACAMS team. Results were published in May 2014 (Firth et al. 2014) and concluded that simple enhancement methods can be cost-effective measures to manage local biodiversity

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Appendix 3

Benthic Faunal Groupings

Faunal Group A (average group similarity of 28.89%) was the most commonly occurring and most diverse group identified from benthic samples collected across the area, occurring at 19 stations. Characterising fauna of this group included the polychaete worms *Pomatoceros lamarcki, Sabellaria spinulosa, Cirriformia tentaculata, Jasmineira elegans* the bivalve *Sphenia binghami* and the amphipod Ampelisca diadema.

Faunal Group B (average group similarity of 29.77%) comprised 11 stations across the Swansea Bay area and constituted 10 taxa (at the 90% cut-off for low species) contribution). Characterising taxa for fauna of this group included the polychaete worms *Spiophanes bombyx, Owenia fusiformis, Nephtys hombergii,* the bivalve *Nucula nitidosa* and individuals belonging to the Phylum *Nemertea*.

Faunal Group C (average group similarity of 30.19%) comprised 5 stations across the study area and consisted of 6 taxa (at the 90% cut-off for low species contribution). The polychaete worms *Magelona johnstoni*, *Nephtys, Glycera tridactyla, Magelona filiformis*, *Magelona mirabilis* and the bivalve *Nucula nitidosa* were key characterising fauna of this group.

Faunal Group D (average group similarity of 25.14%) occurred at 3 stations across the study area. This group was characterised by the presence of one individual, the polychaete worm *Travisia forbesii.*

Faunal Group E (average group similarity of 29.29%) was the least commonly occurring group, being found at only two locations across the study area. This was not a diverse group with the amphipod Urothoe brevicornis accounting for 100% of this group's similarity.

Faunal Group F (average group similarity of 29.90%) comprised 4 stations across the Swansea Bay area. Characterising fauna of this group included the polychaete worms *Nephtys cirrosa, Nephtys (juv), Chaetozone christiei and Owenia fusiformis.*

The geographical distribution of these faunal groups is likely to reflect differences in sediment composition across the survey area.

Appendix 4

Marine Mammal Acoustic Deterrent Device Review

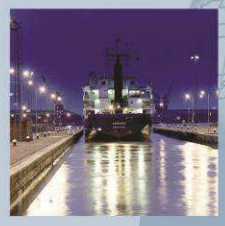
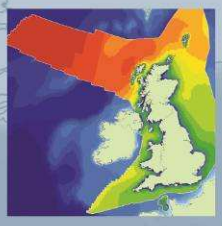
Tidal Lagoon (Swansea Bay) plc

Marine Mammal Acoustic Deterrent Device Review

Report R.2318

September 2014

Creating sustainable solutions for the marine environment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Tidal Lagoon (Swansea Bay) plc

Marine Mammal Acoustic Deterrent Device Review

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Marine Mammal Acoustic Deterrent Device Review

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Appendix

Tables

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1. Introduction

ABP Marine Environmental Research Ltd (ABPmer) was commissioned to undertake an investigation into the design of an acoustic deterrent device (ADD) mitigation system to be used as mitigation in respect of marine mammals during the operation of the Swansea Bay Tidal Lagoon Project.

The marine mammal which occurs most frequently and in the highest abundances within the Swansea Bay area is the harbour porpoise. The study has therefore focused primarily on developing an ADD mitigation system for this species. Grey seal are also recorded relatively frequently, and so the study has also considered this species. Harbour porpoise are afforded a higher level of statutory protection than grey seal. Although a number of other species, such as common dolphin, are recorded elsewhere in the Bristol Channel, these are rarely sighted inshore around Swansea Bay and are not considered specifically in this report (TLSB, 2014).

The principle behind the use of ADDs is that they produce an aversive signal that causes a marine mammal to move away from a target area (Xodus and SMRU, 2013; Carter & Wilson, 2013; Dawson *et al*. 2013). Therefore, the use of acoustic warning equipment, if appropriately designed, is capable of providing a valuable mitigation tool to reduce the risk of collision with tidal turbines or entrapment in the lagoon following passage through sluices (Carter & Wilson, 2013). However, any active acoustic warning system in the marine environment represents a new source of sound and has the potential to cause temporary barrier and exclusion effects which need to be considered when developing such a system (Olesiuk *et al.* 2002).

The study has evaluated the suitability of a range of different ADDs currently on the market. Noise modelling has then been undertaken for the devices considered most appropriate based on the criteria developed by Southall *et al.* (2007) and Nedwell *et* al. (2007). Further information on these criteria is presented in Appendix A. For the purposes of this review and in order to apply some objective criteria, predicted strong behavioural avoidance reactions in a zone around an ADD of less than 300 m are only considered to cause minor habitat displacement effects.

It is understood that a staged approach to mitigation is being proposed as part of the Adaptive Environmental Monitoring Plan, with any impact triggering increased mitigation. In order to help with this a 'low range' and 'high range' ADD array design scenario will be recommended.

2. Acoustic Deterrent Device Review

Acoustic deterrent devices (ADD) broadly fit into three categories:

- **Commercial Aquaculture Acoustic Devices (CADDs):** Also known as Acoustic Harassment Devices (AHDs). These 'seal scarers/scrammers' produce intense sounds (generally above 185 dB re 1 µPa). These work primarily by emitting sound levels so powerful that they are painful or unpleasant for a receptor (typically targeted at seals) at close range. These devices can be triggered by a motion or sonar sensor near an aquaculture facility;
- **Pingers:** These devices operate at lower sound pressure levels (usually <150 dB re 1 µPa) and are primarily used to reduce bycatch of cetaceans in a wide variety of fisheries and also reduce predation (marine mammals taking fish from fishing gear). These devices are unlikely to cause discomfort but instead promote local avoidance behaviour; and
- **Mitigation Devices:** Devices typically in the source level range of 160-195 dB re 1 µPa that are designed to be primarily used on a temporary basis as part of mitigation for various projects, e.g. to cause avoidance of an area when piling is being undertaken. Some devices can be triggered by a sonar system.

The majority of devices currently on the market are either CADDs or Pingers. In the UK, CADDs are used widely in Atlantic salmon farms to reduce seal predation around pens. Pingers used in the UK are used in midwater pair trawl fisheries and gillnet fisheries to reduce bycatch (since June 2013 pingers have been mandatory on all vessels over 12 m operating in certain waters around the UK[1]). Devices used for mitigation is a more recent application of ADDs and are generally less well tested in the field than CADDs or Pingers.

After a preliminary broad review of a wide range of ADDs, five devices have been taken forward for more detailed consideration. These devices were chosen based on their suitability in relation to the Project in respect of the following factors:

- They are manufactured by well established companies with devices on the market which are already widely used;
- Devices are specifically focused on or have been tested with harbour porpoise and grey seal; and
- Companies have offices in the UK, making the set up and maintenance of devices easier and more cost effective.

Information on the five devices taken forward are summarised in Table 1.

[1] European regulation No 812/2004 applies all year round in ICES Area IV to all EU vessels of 12 m or over, using bottom set gill or entangling nets, with a mesh size of 220 mm or more. It also applies in Area IV between 1 August and 31 October for 12 m and over vessels using nets of 400 m in length or less, of any mesh size.

Table 1. ADD's Investigated as Part of the Review

Type	Manufacturer	Device Name	Frequency (kHz)	Source Level (dB re 1µPa@1m)	Manufacturer Information
CADD	Ace Aquatec	Universal Scrammer 3	8-20	195	The standard US3 transducer offers a high volume, randomized dual tone sound pattern that is highly effective at deterring marine predators. Can be used as a continuous or triggered noisemaker. Compatible with fish motion detector triggers and seal sonar triggers.
Mitigation	Ace Aquatec	MMD	10-20	195	Paired with Tritech's Gemini multi beam sonar system allows the MMD to be installed for example in a river system or near an underwater turbine and to make excluding noise only when a marine mammal is detected approaching the zone of danger. In this way the device reduces unnecessary underwater noise pollution.
Pinger	Aquatec Sub-Sea	AQUAmark 100	Harmonic energy in the 5 to 160 band	145	The AQUAmark series are acoustic pingers which help prevent marine mammal (porpoise and dolphin) bycatch. The device transmits a variety of complex ultrasonic signals and has been in commercial use since 2000 with several thousand devices in service. It is targeted specifically at the Harbour Porpoise.
Mitigation	Aquatec Sub-Sea	AQUAmark 848	Primary bandwidth 5 to 30. Harmonic energy to 120	Typically 165	The AQUAmark 848 is a programmable acoustic pinger designed to deter marine mammals from fishing gear and man-made hazards. Its programmable nature allows research scientists to evaluate different acoustic signal types to determine the optimum deterrent solution for a given marine mammal interaction. The instrument is available to qualified research institutions for discounted purchase on a data sharing basis. It is also available for commercial rental in a pre-configured form for marine mammal mitigation applications.
Pinger	Fishtek	Banana Pinger	50 to 120 kHz	145	The ping production has been intensively optimised to prolong battery life without using long gaps between pings. Pings produced with intervals randomised between 4 and 10 seconds. Each ping itself has a randomised structure including dominant frequencies between 40 and 110 kHz plus harmonics. This makes it difficult for seals to hear, but unpleasant for porpoise and dolphins.

3. Results

The predicted behavioural responses and injury risk for harbour porpoise and grey seal based on criteria developed by Southall *et al*. (2007) and Nedwell *et al*. (2007) are presented in Tables 2 and 3. These tables include a summary of the research findings for these ADDs from other modelling or field trials. Based on using the Southall *et al. (*2007) and Nedwell *et al*. (2007) criteria it is apparent that the Universal Scrammer 3 and MMD have the potential to cause exclusion over a very large area for harbour porpoise (up to 6 km) (Figure 1). These devices also have the potential to cause physiological injury and even mortality in harbour porpoise at very close range. Strong avoidance reactions in grey seal up to approximately 800m is also predicted for these devices (Figure 2).

It is possible for these devices to be triggered as part of an automated sonar system if a marine mammal is detected approaching near the turbines/sluices comprised in the Project. The active sonar uses software algorithms to identify potential marine mammal targets. This would ensure that any exclusion impacts are temporary. However, the use of these devices combined with the sonar triggering device is a more costly option. A visual proximity alarm can also be set to alert a human observer to the presence of a target that has a high probability of being a marine mammal and then the ADD can be manually activated. This would however require a dedicated full time technician.

The AQUAmark 848 is likely to deter harbour porpoise over a much smaller area than the Universal Scrammer 3 and MMD (up to 200 m). Based on this avoidance zone it is suggested that an array using two ADD's attached to the turbine and sluice housing could be used (Figure 3). The device is only predicted to cause very minor and localised avoidance in grey seals (Figures 3 and 4). The signal type can also be programmed and it has a sophisticated noise repertoire (that can mask echolocation clicks). However, it is currently only available on a rental basis for commercial applications, as it is primarily designed as an experimental tool for research due to its programmable nature.

The AQUAmark 100 and Banana Pinger have the potential to act as a deterrent to harbour porpoise over a relatively small distance (up to 100 m) and can therefore be used on a more permanent basis without causing wide-scale harbour porpoise exclusion effects. Based on this avoidance zone it is suggested that an array using four ADD's attached to the turbine and sluice housing could be used (Figures 5 and 6). Field trials have also indicated that the AQUAmark 100 and Banana Pinger are effective in deterring harbour porpoise (Crosby & Williams, 2013; Hardy & Tregenza, 2010 and Hardy *el al.* 2012). However, the AQUAmark 100 is only predicted to deter seals from a very small area near the turbine and sluice housing (Figure 7) with the Banana Pinger predicted to cause no response in grey seal. Field trials also recorded no response of grey seals to the Banana Pinger which is considered to be out of the audible frequency range of grey seal (Crosby & Williams 2013).

Aquatec Sub-Sea, the manufactures of the AQUAmark 100 and 848 stated that it is possible to create modified, custom versions of these models to a source noise level/frequency which best suits client requirements. However, Aquatec Sub-Sea also stressed these should be considered as research tools instead of commercially proven devices and would also be more expensive than 'off the shelf' models.

Table 2. Potential Response of Harbour Porpoise to ADD

ADD	Range (m)						Other Scientific Evidence
	Southall Criteria		Nedwell (dBht)				
	PTS (Permanent Threshold Shift)	TTS (Temporary Threshold Shift)	75-90 dBht (Strong Reaction by Majority of Individuals)	90-130 dBht (Strong Avoidance Reaction by All Individuals and Increasing Risk of Physiological Injury)	Above 130 dBht (Possibility of Traumatic Hearing Damage from Single Event)	Above 140 (Risk of Lethal Injury)	
Universal Scrammer 3	-	4	1100-6300	11-1100	3-11	1-3	Kastelein *et al.* (2010) concluded that the Aquatec device would be likely to deter porpoises at ranges between 0.2 and 1.2 km.
MMD	-	4	1100-6300	11-1100	3-11	1-3	-
AQUAmark 100	-	-	18-100	1-18	-	-	In 650 days of acoustic data from pingered and non-pingered nets, there was a highly significant reduction in the number of porpoise clicks recorded at nets with pingers to 48% of the number predicted from the number recorded at control nets. To assess habituation, single, modified pingers that were active for alternate seven hour periods were moored below a click detector. There was evidence of a period of exclusion of porpoises following pinger use that could exceed seven hours, and no evidence of habituation. (Hardy & Tregenza, 2010; Hardy *et al.* 2012). Field experiments suggested that AQUAmark 100 may exclude porpoises to 400 m, though it should be noted that exclusion is not complete but rather decreases with increasing distance from the sound source (Northridge *et al* 2011)
AQUAmark 848	-	-	35-200	1-35	-	-	-
Banana Pinger	-	-	18-100	1-18	-	-	Detection rate of porpoises around nets with pingers was reduced by 82% (Crosby & Williams 2013)

Table 3. Potential Response of Grey Seal to ADD

ADD	Range (m)						Other Scientific Evidence (Where Available)
	Southall Criteria		Nedwell (dBht)				
	PTS (Permanent Threshold Shift)	TTS (Temporary Threshold Shift)	75-90 dBht (Strong Reaction by Majority of Individuals)	90-130 dBht (Strong Avoidance Reaction by All Individuals and Increasing Risk of Physiological Injury)	Above 130 dBht (Possibility of Traumatic Hearing Damage from Single Event)	Above 140 (Risk of Lethal Injury)	
Universal Scrammer 3	3	15	140-790	1-140	-	-	Previous version of seal scrammer with similar noise levels was found to cause a deterrence range in seals of approximately 60 m, although deterrence was not complete, with 50% of animals remaining within 60m (Gotz & Janik, 2010).
MMD	3	15	140-790	1-140	-	-	-
AQUAmark 100	-	-	1-3	-	-	-	-
AQUAmark 848	-	-	5-28	1-5	-	-	-
Banana Pinger	-	-	-	-	-	-	Banana Pinger was tested on grey seals in an outdoor pool. In over 140 tests the investigation demonstrated no significant movement towards or away from the pinger which is thought to be outside of the audible frequency range of grey seals (Crosby & Williams 2013).

4. Conclusion and Recommendations

Based on the results of this study and previous research it is apparent that harbour porpoise and other small cetaceans are considered to be more sensitive to noise than grey seal over the broad frequency range typically used in ADDs (Brandt *et al*. 2013; Nedwell *et al*. 2007). The effective range of an ADD is therefore generally less for a grey seal than a harbour porpoise. ADDs at the louder end of the spectrum therefore might potentially only cause exclusion to grey seals over a small range (tens of metres) but harbour porpoise over several kilometres. However, quieter devices which are tailored towards small cetaceans could be ineffective in deterring seals near to a turbine.

The noise criteria used in this study are considered useful tools to help better understand effective spatial ranges of avoidance and potential injury with different devices. However, some caution should be used when considering the findings of this study as the response and effectiveness of an ADD used specifically in Swansea Bay could be different to those predicted as part of theoretical modelling and previous field studies at different geographical locations. This is because species' responses to the same ADD can vary between different local populations and also for individuals within a local population (e.g. due to age, sex, prior experience, ambient noise) (Brandt *et al*. 2013; Dawson *et al*. 2013). Furthermore, the models are a simplistic characterisation of the propagation of underwater noise and do not take account of physical parameters (e.g. bathymetry, substrate type, temperature).

Based on the results of the noise calculations and other available information, the following devices are suggested for further consideration as part of a deterrent mitigation system:

- **Low Range Scenario:** The use of AQUAmark 100 is considered a viable mitigation option to trial during initial turbine operation given that the device is unlikely to cause wide-scale displacement and has had proven effectiveness in harbour porpoise field trials. Given the predicted relatively small area of avoidance this could be used on a permanent basis without the need for a triggering system. The main concern with using this device is that it is only predicted to cause avoidance in seals within a localised area (several metres) of the turbine and sluice gate housing structure which is unlikely to be sufficient to enable evasion. Using a custom version of the AQUAmark 100 at a higher source level could increase the potential avoidance zone for grey seal. Based on the Nedwell *et al*. (2007) criteria it is suggested that a source level of 168 dB re 1 µPa is the optimum noise level to cause some avoidance reaction in seals but at levels which avoid excluding harbour porpoise over an area more than 300 m. At this source level a strong behavioural response is predicted in the majority of individuals in seals from 7-40 m and harbour porpoise 50-280 m. Based on these avoidance zones it is suggested that an array using two ADD's attached to the turbine and sluice gate housing structure could be used (Figure 8 and 9).
- **High Range Scenario:** The AceAquatec MMD is recommended as an option should increased mitigation be needed. Given the potential for wide-scale exclusion impacts on harbour porpoise, this should only be used for short periods of time when a marine mammal is recorded in a defined area in the vicinity of turbines. The use of an automated sonar system to trigger the device is a potentially useful (albeit more costly) tool.

Overall, solutions are available which are capable of mitigating effects of the operation of the Project on harbour porpoise, as well (in certain cases) as for grey seal. It is proposed that the final selection and design of such mitigation should be approved by regulators prior to installation.

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6. Abbreviations

List to be updated once all edits received

ABPmer	ABP Marine Environmental Research
ADD	Acoustic Deterrent Device
AHD	Acoustic Harassment Devices
AMD	Acoustic Mitigation Devices
CADD	Commercial Aquaculture Acoustic Devices
EU	European Union
ICES	International Council for the Exploration of the Sea
MMD	Mammal Mitigation Device
OS	Ordnance Survey
PTS	Permanent Threshold Shift
SEL	Sound Exposure Level
SMRU	Sea Mammal Research Unit
TLSB	Tidal Lagoon (Swansea Bay)
TTS	Temporary Threshold Shift
UK	United Kingdom
Xodus	Xodus Group, Energy Consultant

Cardinal points/directions are used unless otherwise stated.

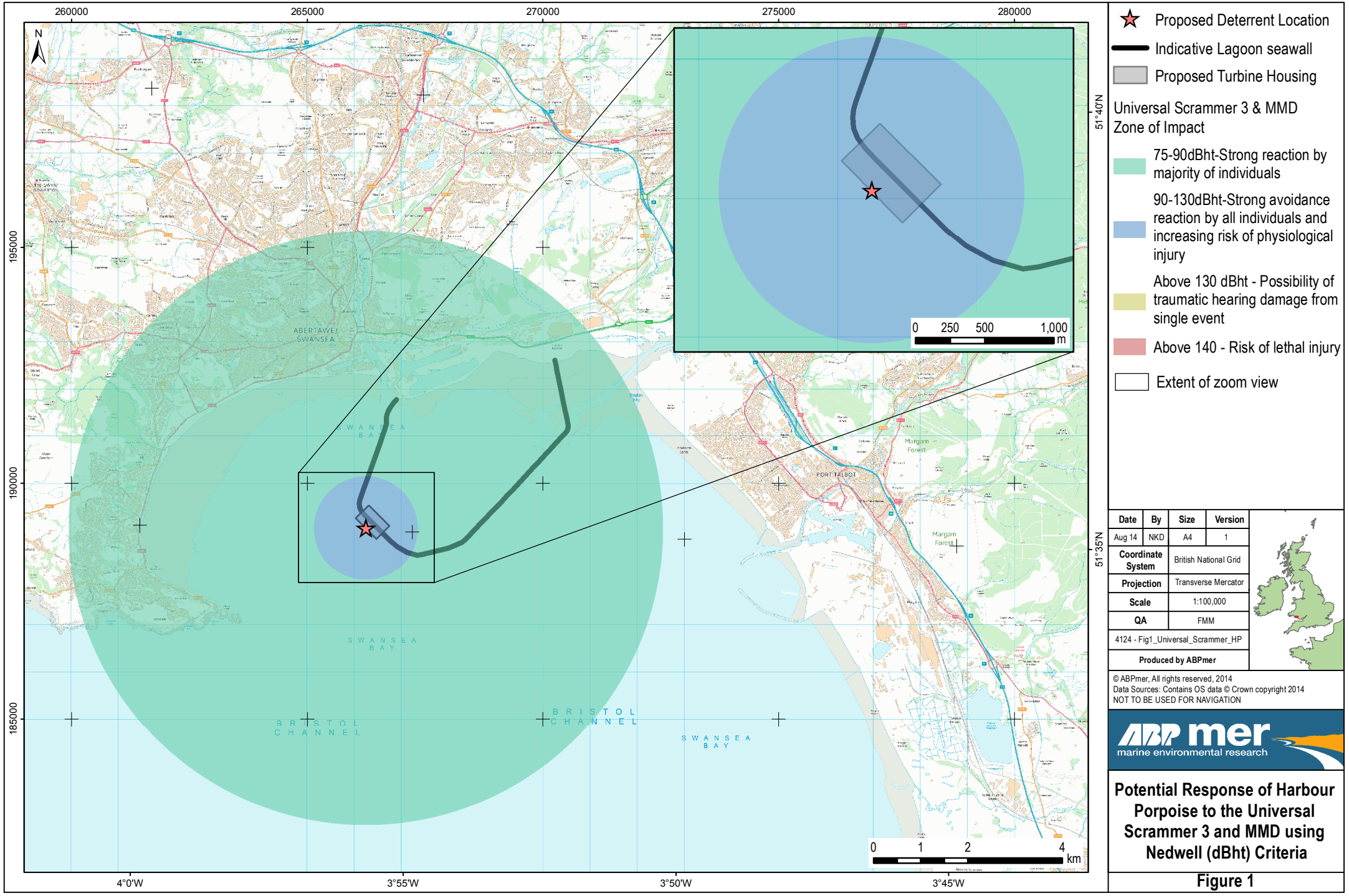
SI units are used unless otherwise stated.

7. Glossary

List to be updated once all edits received

AQUAmark	Acoustic pingers which help prevent marine mammal (porpoise and dolphin) bycatch by Aquatec Group
Banana Pinger	Acoustic pingers which help prevent marine mammal (porpoise and dolphin) bycatch by Fishtek Ltd
Universal Scrammer 3	Flexible seal deterrent / scarer which can be deployed in all situations when there is a need to modify the behaviour of marine mammals in general and seals in particular by Ace Aquatec Ltd

Figures



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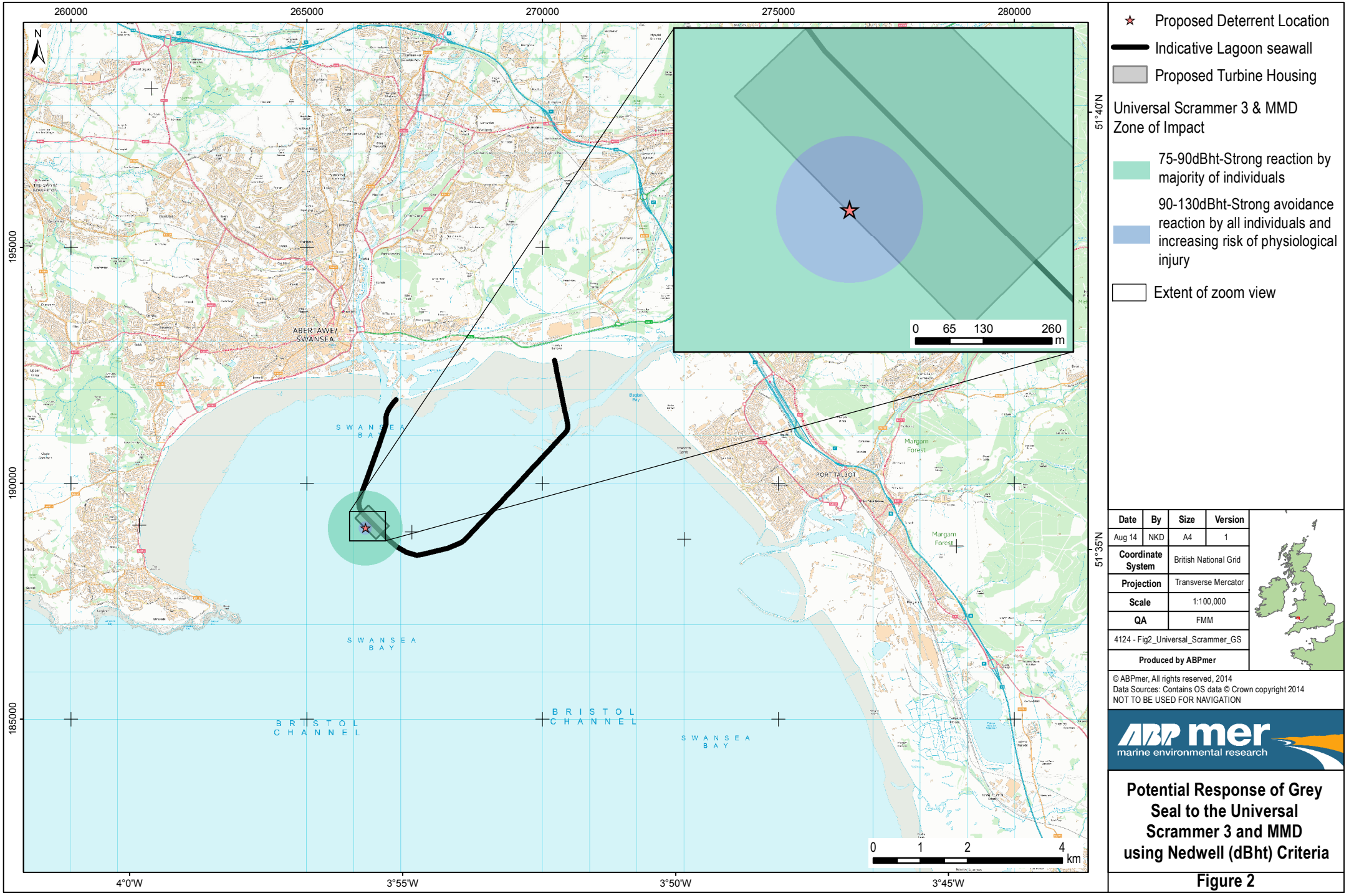
Potential Response of Harbour Porpoise to the Universal Scrammer 3 and MMD using Nedwell (dBht) Criteria

Figure 1



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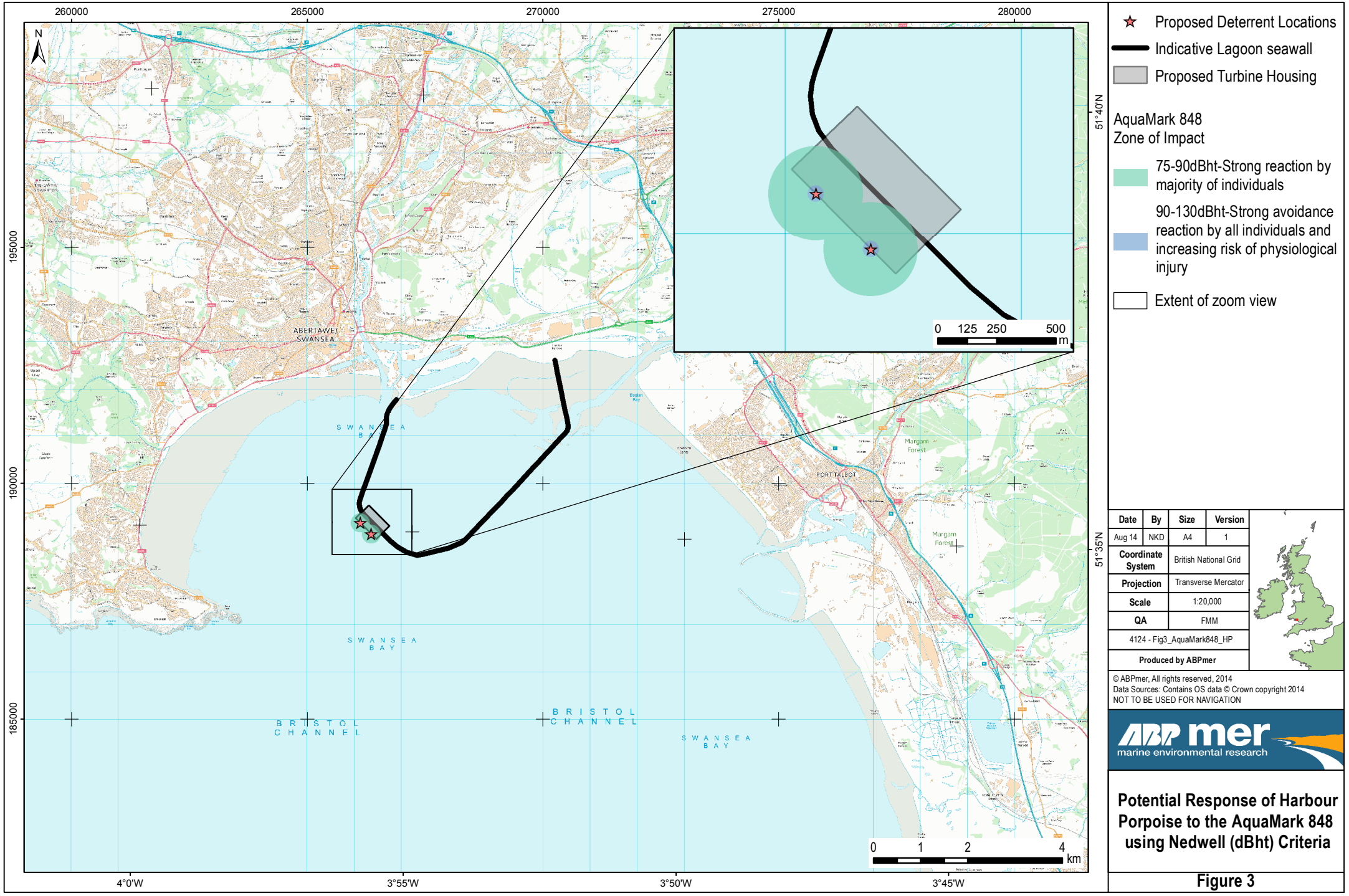
Potential Response of Grey Seal to the Universal Scrammer 3 and MMD using Nedwell (dBht) Criteria

Figure 2



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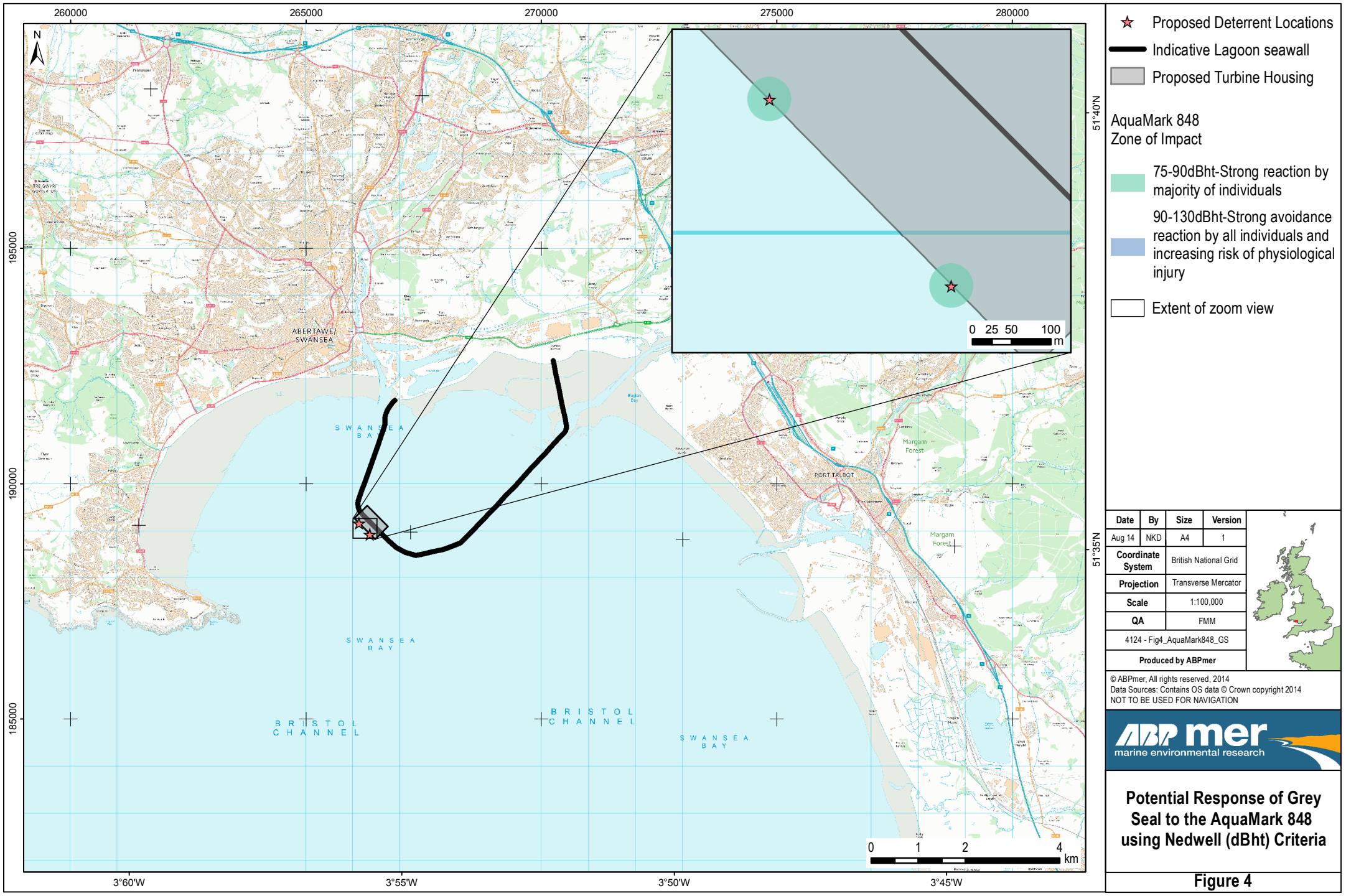
Potential Response of Harbour Porpoise to the AquaMark 848 using Nedwell (dBht) Criteria

Figure 3



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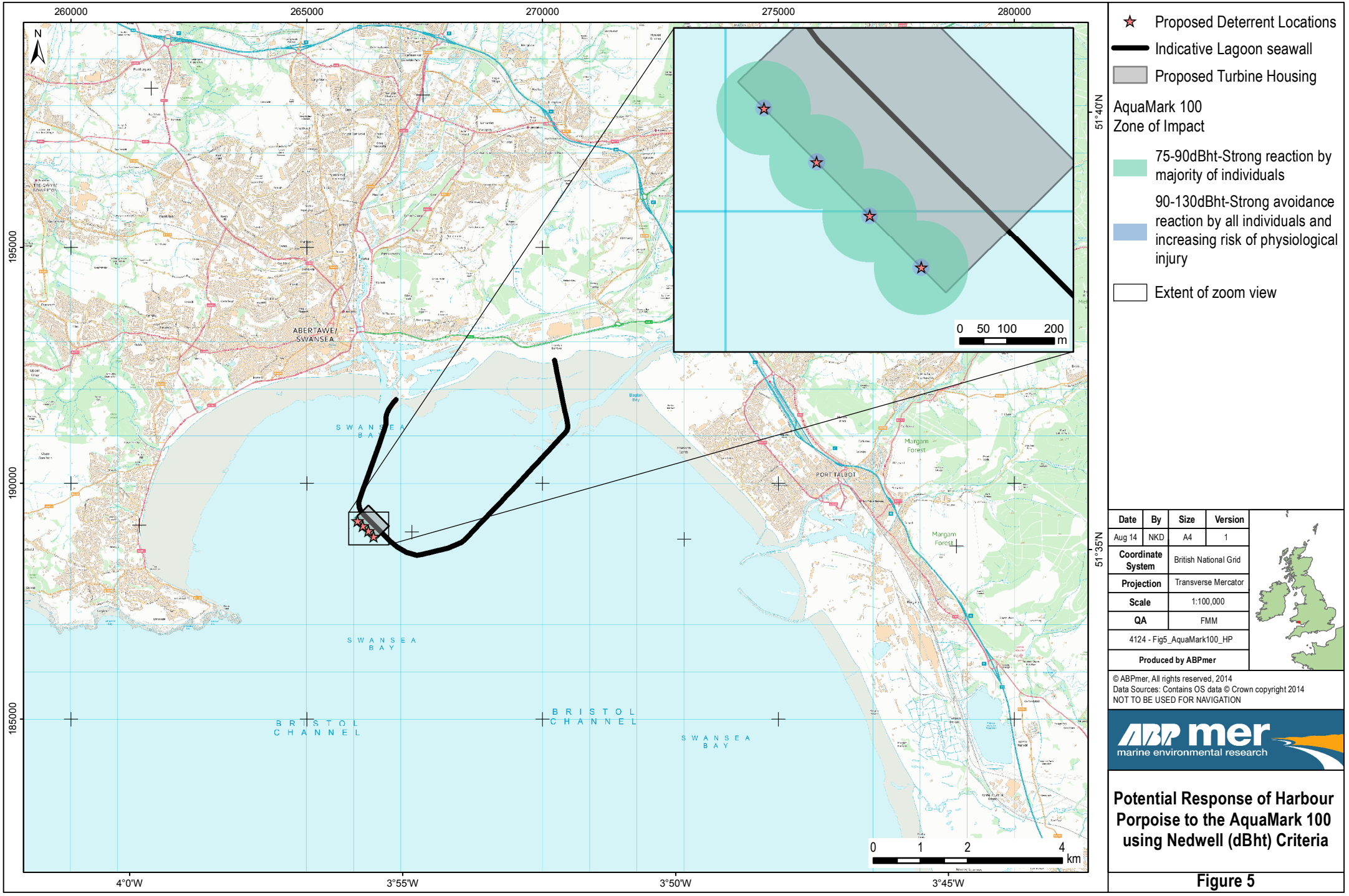
Potential Response of Grey Seal to the AquaMark 848 using Nedwell (dBht) Criteria

Figure 4



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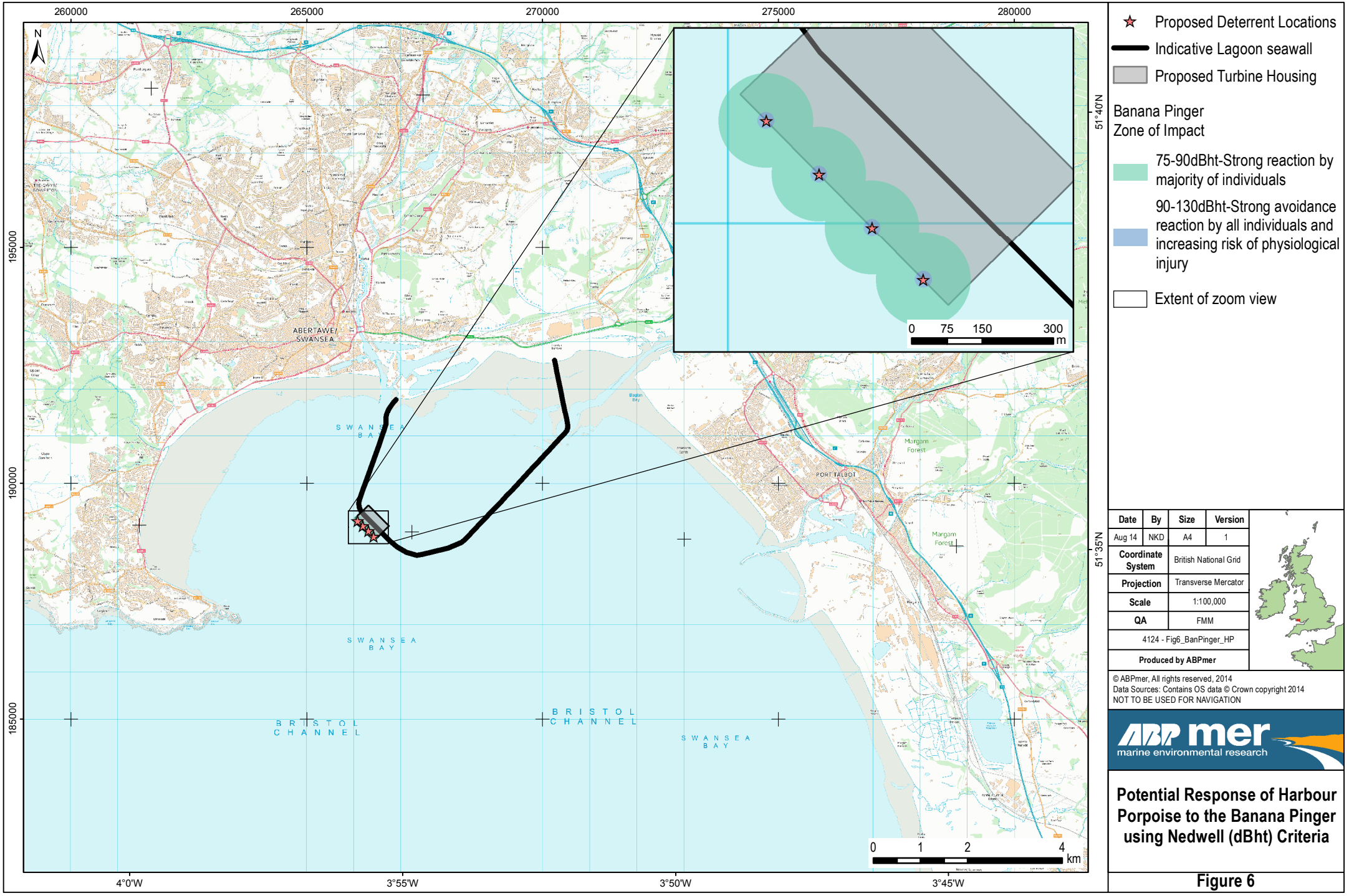
Potential Response of Harbour Porpoise to the AquaMark 100 using Nedwell (dBht) Criteria

Figure 5



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Scale		1:100,000	
QA		FMM	
4124 - Fig6_BanPinger_HP			
Produced by ABPmer			

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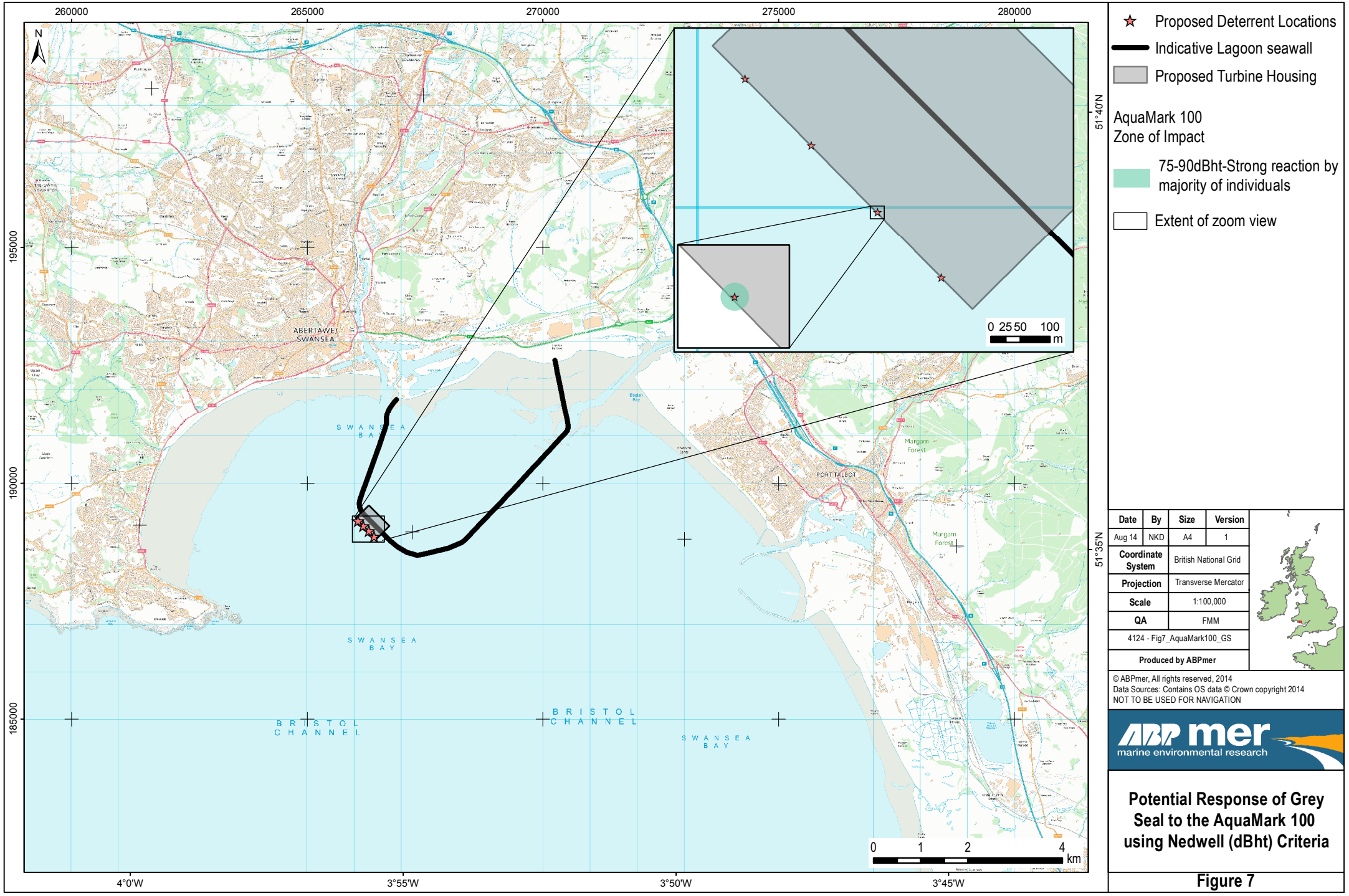
Potential Response of Harbour Porpoise to the Banana Pinger using Nedwell (dBht) Criteria

Figure 6



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QA		FMM	
4124 - Fig7_AquaMark100_GS			
Produced by ABPmer			

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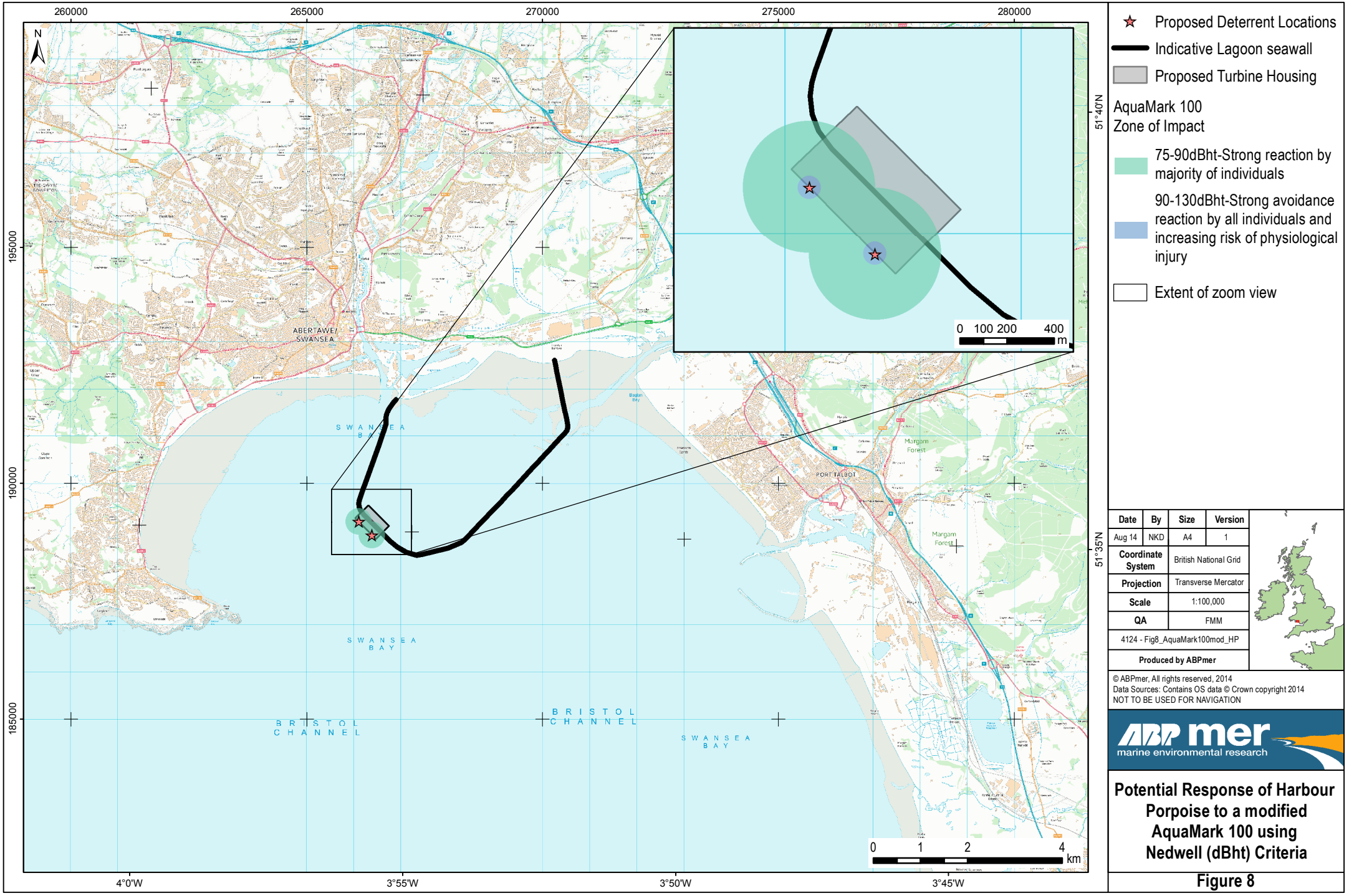
Potential Response of Grey Seal to the AquaMark 100 using Nedwell (dBht) Criteria

Figure 7



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QA		FMM	
4124 - Fig8_AquaMark100mod_HP			
Produced by ABPmer			

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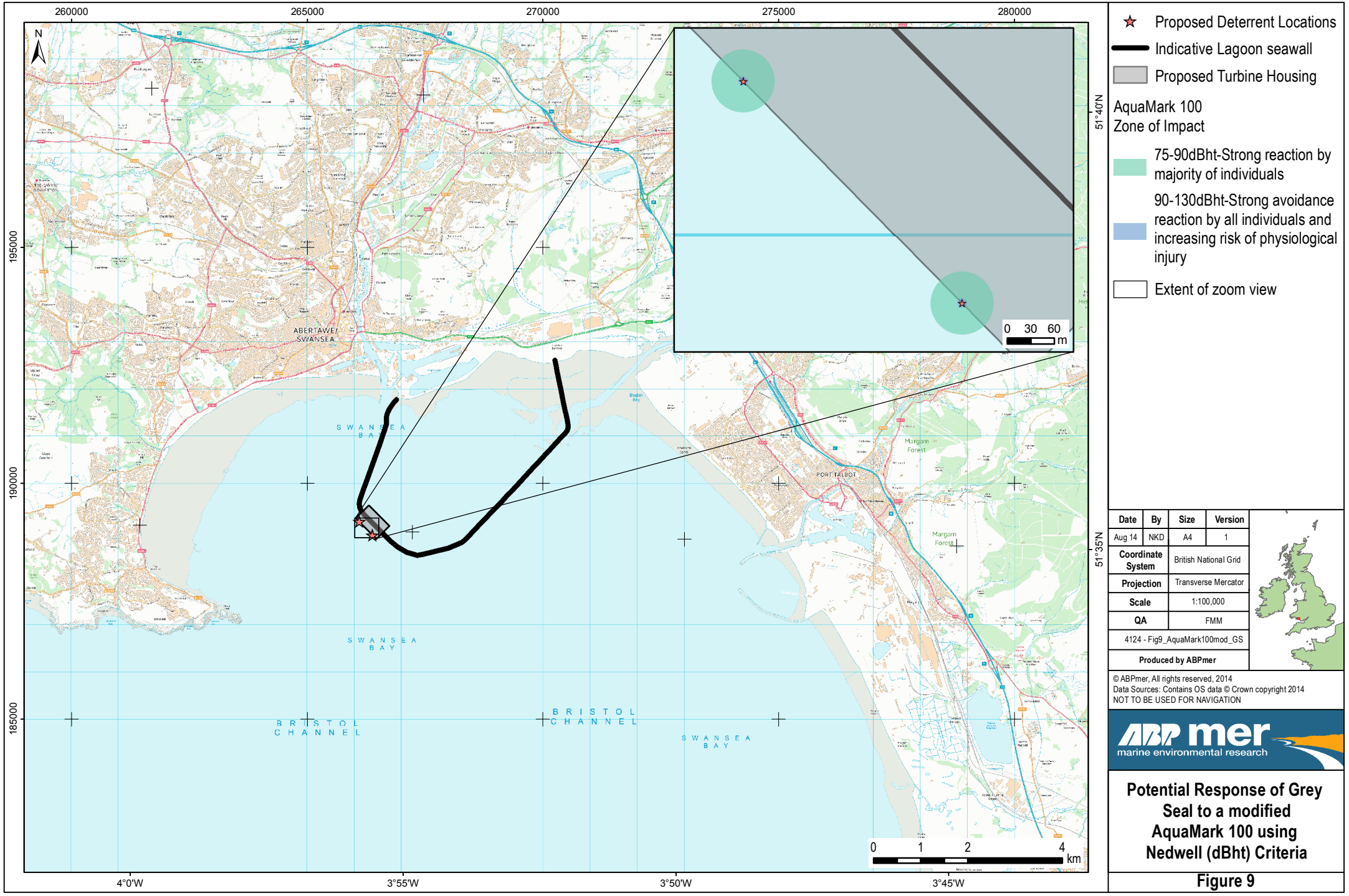
Potential Response of Harbour Porpoise to a modified AquaMark 100 using Nedwell (dBht) Criteria

Figure 8



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4124 - Fig9_AquaMark100mod_GS			
Produced by ABPmer			

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Potential Response of Grey Seal to a modified AquaMark 100 using Nedwell (dBht) Criteria

Figure 9

Appendix A

Noise Criteria Developed by Southall *et al*. (2007) and Nedwell *et al*. (2007)

A. Noise Criteria Developed by Southall *et al.* (2007) and Nedwell *et al.* (2007)

A.1 Introduction

Impacts of noise on marine mammals can broadly be split into lethal and physical injury, auditory injury and behavioural response. The possibility exists that lethality and physical damage can occur at very high exposure levels, such as those typically close to underwater explosive operations or offshore impact piling operations. A permanent threshold shift (PTS) is permanent hearing damage caused by very intensive noise or by prolonged exposure to noise. A temporary threshold shift (TTS) involves a temporary reduction of hearing capability caused by exposure to noise. An intense short exposure can produce the same scale of TTS as a long-term, repeated exposure to lower sound levels. The significance of the TTS varies among species depending on their dependence on sound as a sensory cue for ecologically relevant functions. Both PTS and TTS are considered to be auditory/physiological injuries. At lower Sound Pressure Levels it is more likely that behavioural responses to underwater sound will be observed. These reactions may include the animals leaving the area for a period of time, or a brief startle reaction. While a range of potential responses is recognised, the received noise levels around which lethality, physical damage or disturbance can occur are not well understood.

Southall *et al.* (2007) proposed a set of criteria for preventing auditory/physiological injuries to marine mammals. These criteria are based on both peak sound levels and SEL (Sound Exposure Level). The SEL criteria can be applied either to a single transient pulse or the cumulative energy from multiple pulses. The study by Southall *et al.* (2007) recommended a peak noise criterion of 230 dB re.1 µPa for cetaceans (whales, porpoises and dolphins) and 218 dB re.1 µPa for pinnipeds (seals), to prevent physiological auditory injury and the onset of PTS. This corresponds to a Sound Exposure Level of 198 dB re.1 µPa^2s M-Weighted for whales and dolphins and 186 dB re.1 µPa^2s M-Weighted for pinnipeds. Behavioural response criteria and the onset of TTS are defined at a peak noise criterion of 224 dB re.1 µPa for cetaceans and 212 dB re.1 µPa for seals; and a corresponding Sound Exposure Level of 183 dB re.1 µPa2s M-Weighted for cetaceans and 171 dB re.1 µPa^2s M-Weighted for pinnipeds.

Another way to evaluate the responses of marine mammals and the likelihood of behavioural responses is by comparing the received sound level against species specific hearing threshold levels[2]. The hearing sensitivity and frequency range of marine mammals varies between different species and is dependent on their physiology. For example, odontocete cetaceans (toothed whales, porpoises and dolphins) are particularly sensitive to high frequencies.

Nedwell &Edwards (2004) developed a generic dB scale to enable better estimates of the effects of sound on marine species. Although this approach is not internationally recognised and has not been validated by experimental study, it has been recommended by other UK government agencies, particularly in relation to fish, and is the only method available that provides an indication of the behavioural reaction of marine mammals to underwater noise.

[2] The minimum level of sound at which a species can detect noise.

In their dB_{ht} (Species) scale, Nedwell *et al.(*2004) use a frequency dependent filter to weight the sound. The suffix 'ht' relates to the fact that the sound is weighted by the hearing threshold of the species. The effects of sound that may prospectively be addressed by the dB_{ht} metric include behavioural effects such as an avoidance reaction, the limit of tolerance, the onset of hearing damage presenting as a temporary threshold shift, and traumatic hearing loss. A set of criteria based on the use of the dB_{ht} (Species) was proposed by Nedwell *et al.* (2007) that allow the likelihood of behavioural effects and damage to hearing to be assessed for a wide range of species. These criteria are shown in Table A1. Although these threshold ranges provide a useful summary, it is important to note that the relationship between noise and effect is a continuous sliding scale.

Table A1 Criteria for the Effects of Underwater Noise on Marine Mammals and Fish

Level in dBht (Species)	Effect
Less than 50	Mild reaction by minority of individuals
50 to 75	Mild reaction by majority of individuals
75 to 90	Stronger reaction by majority of individuals
90 to 130	Strong avoidance reaction by all individuals and increasing risk of physiological injury
Above 130	Possibility of traumatic hearing damage from single event
Above 140	Risk of lethal injury

A.2 References

Nedwell, J.R., Edwards, B., Turnpenny, A.W.H., Gordon, J. 2004. Fish and Marine Mammal Audiograms: A summary of available information. Subacoustech Report ref: 534R0214.

Nedwell, J.R., Turnpenny, A.W.H. Lovell, J., Parvin, S.J., Workman, R., Spinks, J.A.L. & Howell, D., 2007. A validation of the dBht as a measure of the behavioural and auditory effects of underwater noise. Subacoustech Report No. 534 R1231.

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene Jr, C. R., Kastak, D., Miller, J.H., Nachigall, P.E., Richardson, W,.J., Thomas, J.A., & Tyack, P.L., 2007. Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals 33:411–521.

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