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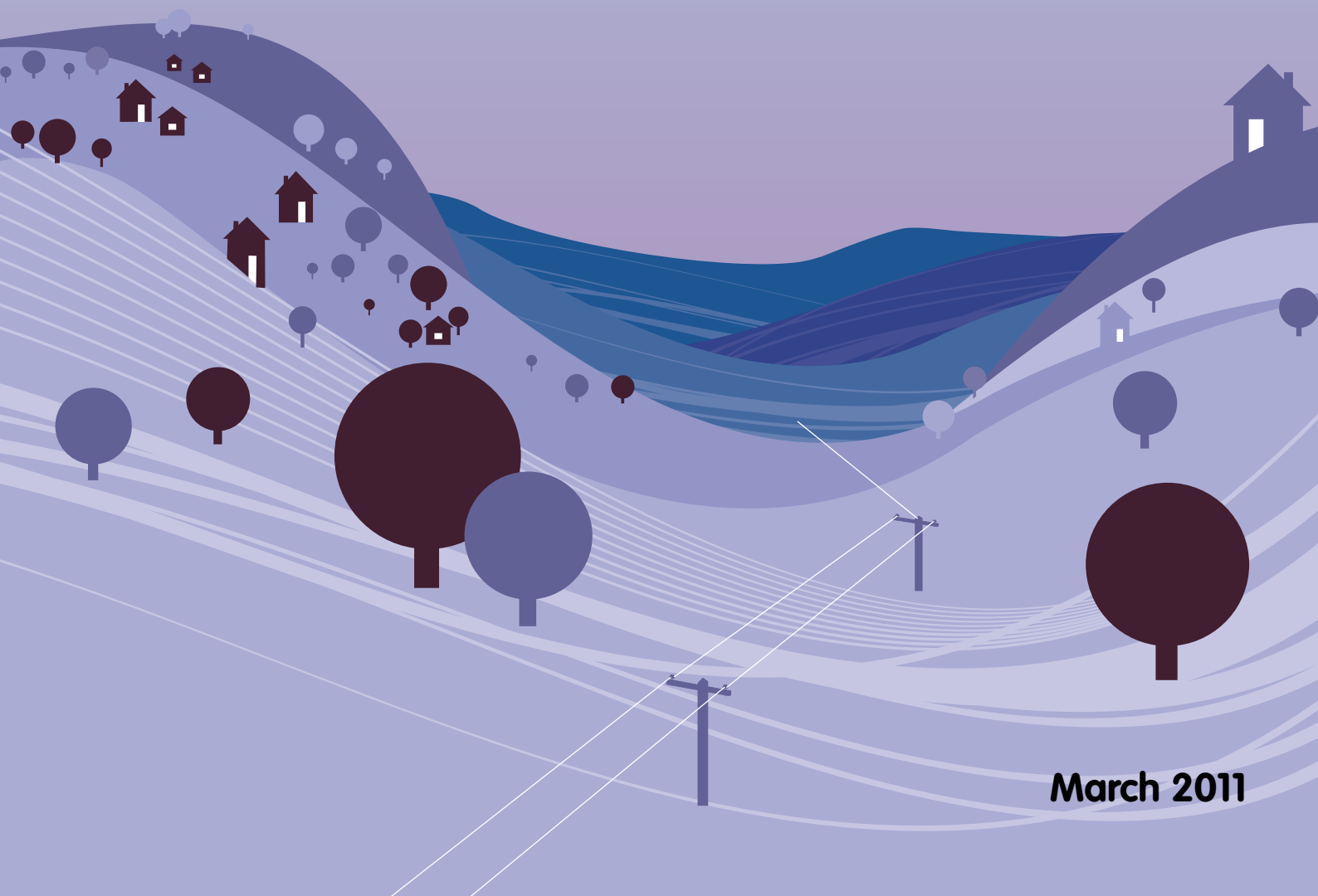
Marine Renewable Energy Strategic Framework

Approach to Sustainable Development

Report by RPS to the Welsh Assembly Government



March 2011

Executive Summary

S1. This report has been prepared by RPS on behalf of the Welsh Assembly Government (the WAG) to present the final outputs of the Marine Renewable Energy Strategic Framework (MRESF). The main aims of the MRESF project have been to investigate the potential marine renewable energy resource of Welsh Territorial Waters (TWs) and to consider potential scenarios for the sustainable development of that resource primarily as an aid to policy development and also an indicator of resource for potential developers. The project has been undertaken in three stages, starting in 2007 with Stage 1, which was focused on the initial literature reviews, data gathering, stakeholder engagement and GIS mapping. Stage 2 was conducted primarily in 2009-2010 and involved a number of discrete reports, each aimed at increasing the knowledge base for a number of key data gaps in Welsh TWs identified as part of Stage 1. Stage 3 has drawn on the findings of Stages 1 and 2 to develop the Framework. This report provides a descriptive text which, together with the GIS (that presents areas of potential wave and tidal stream resource within the context of differing levels of existing development constraint), represent the final outputs of the MRESF project. It is important that this document is read in conjunction with the MRESF Stage 1 report (RPS, 2008) and Technical Addendum (RPS, 2011a), which provide the background to the baseline information used and context for this Approach to Sustainable Development described here.

S2. The MRESF project team is comprised of RPS staff, with the project Steering Group including invited members from the following:

- The Welsh Assembly Government;
- Defence Estates – Ministry of Defence;
- The Crown Estate;
- Countryside Council for Wales;
- Department of Energy and Climate Change (formerly the Department for Business Enterprise and Regulatory Reform);
- The Marine Management Organisation (formerly the Marine and Fisheries Agency); and
- With specialist advice provided by Cefas during Stage 3.

S3. The input, discussion and advice from the Steering Group has proved highly beneficial to the project throughout. However, it should be noted that the findings of the project are intended to be applied at a strategic level and will not prejudice decisions and advice at the individual project level provided by the Steering Group members, nor do they prevent the future flexibility in approach to strategic projects, including any work undertaken by the members of the MRESF Steering Group.

S.4 The analysis and GIS mapping has been undertaken in five steps, designed to consider and apply a range of siting criteria for marine renewable energy devices within Welsh TWs. As a component of this, the GIS also provides spatial mapping of existing socio-economic uses and environmental interests and the potential constraint on consent associated with such. These steps have been termed the 'Approach to Sustainable Development' with an overall aim of enabling the potential energy resource available in areas of different levels of constraint to be assessed to provide an evidence base for determining the sustainability of different levels of wave and tidal stream power generation from Welsh TWs.

S5. It is not the intention of the MRESF project to green light or red flag areas for development, but rather to assess the implications of development in a sustainable context. To this end, the current report highlights areas where lower levels of constraint on development would be anticipated from a strategic perspective; which existing issues have the potential to represent significant hurdles to development in Welsh TWs; and for which issues there may be potential for further work to reduce or mitigate such hurdles. It is important to stress that the findings of this study do not preclude development of wave and tidal renewable energy outside of the areas identified as being least constrained.

S6. The marine renewable energy resource of Welsh TWs consists of offshore wind, wave, tidal range and tidal stream, which together with the potential for carbon capture and storage formed the subject matter of Stage 1 of the MRESF. The topics of interest have been refined during the MRESF, with work in Stage 2 focused on the wave and tidal stream industry and the current report maintains this focus on wave and tidal stream only.

S7. The potential wave and tidal stream energy resource in Welsh TWs has been identified using baseline data for the resource, from the Renewables Atlas (www.renewables-atlas.info/) together with data held by RPS. Information on the requirements of individual devices, e.g. minimum energy and water depth, has been sourced from

publicly available literature and from the stakeholder participation processes undertaken as part of the overall MRESF. It should be noted that the minimum energy requirement of tidal stream devices has been subject to considerable discussion during the study, with developers tending to state a minimum of 2-2.5m/s Mean Peak Spring Current (MPSC). The use of MPSC provides a method to characterise the overall resource, however it should be noted that other attributes of tidal energy flows (e.g. energy attenuation rates over tidal cycles etc) may also be important in determining suitable device locations at the site specific level. The potential for future devices to exploit lower levels of energy has been raised by some stakeholders, coupled with concerns about the perceived ecological sensitivity of high tidal energy areas. In response, a broad level review of the geographic location of the 1.5m/s resource and the degree of associated constraint has also been undertaken. The footprint of areas with a tidal stream energy of 1.5m/s compared to the 2m/s resource used in the MRESF show considerable similarity in the locations of these resource areas. The 1.5m/s resource does, however, have a larger footprint than the 2m/s resource (518km^2 for 1.5m/s and 200km^2 for 2m/s), albeit it within the same broad locations.

Wave and Tidal Stream Resource

S8. A key part of determining the wave and tidal stream potential of Welsh TWs is to map the geographic location of that resource. The initial steps taken in the MRESF involved identifying wave and tidal stream devices currently deployed and in development and determining, where possible, the energy and siting requirements of each. These devices have been subsequently grouped into a series of generic device types, to ensure the process is device blind.

S9. It should be noted that a key siting requirement for commercial scale deployment is access to the electricity transmission network (the grid). A lack of economical access to the grid in a practical timescale is likely to present a significant constraint on development and the importance of grid access should not be underestimated. However, it is not considered feasible to set a distance limit from the existing grid beyond which development would be uneconomical and hence the data layer has been included for informative purposes only.

S10. Given the similarity in device type requirements between some of these device groups, when resource areas are mapped there is a considerable degree of geographic overlap in some areas. As such, when considering the potential installed capacity it would be misleading to do so based on individual device type resource areas. When an overall

energy level is required, the resource areas have been amalgamated, providing a single resource area for Welsh TWs with no areas of overlap, with the device type resource taken forward in each area being selected based on the best potential energy return apart from where wave and tidal stream resource overlap. In such instances, the tidal stream resource has been selected.

S11. The MRESF is aimed at the sustainable development of wave and tidal stream energy in Welsh TWs. To enable this to be undertaken at a practical level, the project has focused on a target of 4GW installed capacity of wave and tidal stream, identified in the WAG's Energy Policy Statement, which is to be delivered in the main by 2025 (see http://wales.gov.uk/docs/desh/policy/100331energystatementen.pdf). The potential sustainability of this level of energy generation has been considered, through assessment of the potential constraints on development and the degree of potential impact for existing interests associated with such development.

S12. It is important to note that for the industry to reach such energy levels by 2025 a considerable amount of expansion in the sector would be required and that the available energy can only be translated into electrical power if such development is enabled. It is also likely that early developments will primarily be small and include demonstrator sites, with commercial scale deployments of arrays anticipated to follow later. The assessment of available energy made here does not make assumptions about the type or scale of developments that will actually be brought forward, nor does it preclude single demonstrator devices or indeed identify a cap on the maximum size of an array.

Development Constraints

S13. During the development of the MRESF, a number of potential hurdles (or constraints) to the development of marine renewables have been identified in Welsh TWs, with these summarised below

- **Practical constraints**, including financing, sourcing of materials, equipment and personnel (including regulator), moving equipment to site and access to the grid;
- **Support**, including government support, clarity in the legislative and planning requirements and initiatives such as the provision of test sites;
- **Legislative considerations**, including issues around Strategic Environmental Assessment, sustainability, climate change, the consenting process, potential for Public Inquiry and nature conservation interests, particularly Natura 2000; and

- **Data requirements**, including data ownership, licensing and availability, natural and climate induced change and uncertainty and the precautionary principle.

S14. Of the development issues and constraints identified, a number are relatively intangible or descriptive and hence difficult to display in a GIS format. However, several are more definitive and include a geographic element, and can thus be displayed in GIS and used in constraint mapping. Of the above hurdles to development, those that have been taken forward into the MRESF mapping aspect of Stage 3 as potential constraints include device specific issues (e.g. minimum energy requirements) and existing use (including environmental and socio-economic interests). A limited number of the legislative considerations also contain a geographic element and as such are included in the GIS mapping, primarily the designated sites.

S15. Where individual data layers represent a potential constraint on development, each has been graded by the RPS project team in consultation with the Steering Group on a 1-5 scale. The aim of grading the constraints is to enable a broad scale assessment of the potential degree of constraint that each data layer may represent for the consenting of marine renewable energy developments, taking into consideration factors such as the degree of legislative protection, stakeholder engagement with the issue, potential significance of impact and the importance of the receptor (e.g. military, public value etc). The definition of each constraint rank is as follows:

Grade	Description
No grade	Receptor distribution is presented for informative purposes only and no firm constraint value can be ascribed at the broad scale
1	No likely constraint/assessment required
2	Constraint assessment/study required, but low likelihood of delay
3	Constraint potentially complex and will require detailed assessment, but unlikely to stop development
4	Significant issue/constraint – probable delay and could possibly stop the project
5	Likely to preclude development

S16. It is important to note that the constraint rank approach followed is essentially precautionary, as it assumes in general a uniform constraint across each data layer (although for some data layers it has been possible to use sub-layers e.g. shipping density has sub-layers which have been grouped based on the number of vessels per

year). The constraint ranking is thus applicable at the strategic level, however at the site specific level it should be noted that there is potential for geographic variability in the constraint layers (including in the sub-layers) which, together with project mitigation, could lead to a change in the level of constraint.

S17. As noted above, the strategic approach used in assessing the sustainability of wave and tidal stream energy development in Welsh TWs has been undertaken in a series of steps. Each step, together with key outputs, are summarised below. It should be noted that the levels of installed capacity given include a 'reduction factor' of 60%, although the footprint of resource areas are given in their entirety. The installed capacity reduction factor was included for several reasons. These include the need to provide space for operation/maintenance, the need to accommodate other users even where such uses/users have a relatively low constraint rank score, the need to consider the potential for large areas of features to be affected, to include a realistic review of the potential industry capacity/interest within the period to 2025 and to take account of the potential for site specifics to bring additional constraints. In summary, the reduction factor is aimed at ensuring a realistic development scenario and is similar in approach to that taken by other strategic level projects such as the work by the Offshore Valuation Group (2010).

Step 1 – Maximum Energy Generation

S18. The original purpose behind Step 1 was to understand how much energy could be generated from Welsh TWs based on the minimum energy requirements of device types only. However, the step does have the potential to generate unrealistic areas or levels of resource as a result of significant geographic overlap between resource areas suitable for more than one device type. As such, the information presented has been limited to an overview of whether a potential resource exists in Welsh waters for each device type.

Step 2 – Maximum Achievability

S19. Step 2 builds on the outputs from Step 1, to bring in a consideration of practical development issues linked to device requirements. The project has considered a number of possible device requirements, with minimum/maximum water depth and distance from shore being used in Step 2 to re-assess the presence of the minimum energy requirements identified in Step 1. Connection to grid is always a key consideration when developers assess the commercial viability for a site. However, as listed above, it is not considered realistic to set a distance limit from the existing grid

beyond which development would be uneconomical and hence the data layer has been included for informative purposes only.

S20. Step 2 mapped potential resource areas for the following device type groups:

- Nearshore oscillating water column devices (wave);
- Nearshore single point/buoy (wave);
- Offshore single point/buoy (wave);
- Offshore multi-buoy (wave);
- Offshore attenuators (wave);
- Offshore overtopping collectors (wave);
- Tidal stream rotating turbines; and
- Tidal stream hydroplanes, hydrofoils, venture effect and sails.

S21. The main areas of commercial tidal stream energy are located around Anglesey, the Lleyn Peninsula, Pembrokeshire and the Bristol Channel, with commercial wave resource located around Pembrokeshire.

S22. As discussed above in Step 1, should the individual installed capacity levels of each device type by summed, this would present a misleading total due to extensive areas of geographic overlap between resource areas. To enable the wave and tidal stream energy potential of Welsh TWs to be assessed, an amalgamated resource area has been produced, which is constrained by device requirements only. However, a significant note of caution is attached here. In Step 2, the resource areas have not been considered within the context of existing use or environmental sensitivity and the complete development of the entire area cannot be considered as representing a sustainable development path. The implications of this are considered further in Steps 3-5.

Step 3a – Least Impacting Environmentally

S23. The purpose of Step 3a is to consider the effect of environmental constraints on the resource areas identified in Step 2. From the information presented, it is clear that all of the resource areas are subject to one or more constraints of a minimum of rank 2, with the majority of the resource areas being subject to constraints of rank 3 and 4.

Step 3b – Least Impacting for Existing Use

S24. The purpose of Step 3b is to consider the effect of socio-economic constraints on the resource areas identified in Step 2. From the information presented, it is clear that the majority of the resource areas are subject to one or more constraints of a minimum of rank 2, with the majority of the resource areas being subject to a minimum of constraint rank 3 and 4. However, there is a relatively small area of the offshore overtopping collector wave resource area that is subject to one or more data layer of constraint rank 1 only, extending some 17km^2, located along a section of the limit of territorial waters to the west of Pembrokeshire.

Step 4 - Most Sustainable for Individual Device Types

S25. The sustainable development remit within which the MRESF operates brings a need to consider marine renewable energy development in the context of existing environmental and socio-economic interests, with each issue considered separately in Steps 1-3. To ensure a sustainable approach, it is necessary to bring all the constraints together to look at the combined effect, to gain an understanding of which constraints occur in which resource areas together with the degree of constraint that these represent. To this end, the outputs from Steps 1, 2, 3a and 3b have been progressed through into Step 4, to show the combined constraint for each device type, including existing environmental and socio-economic constraints.

S26. An important part of Step 4 is to understand which constraints have geographic overlap with which areas of resource, both to understand the potential level of constraint within a given area but also to highlight which constraints are likely to affect which resource areas. This also serves to highlight any key constraints that occur across large areas of potential resource. This latter point is important in terms of understanding the potential for cumulative impacts (e.g. do certain data layers occur repeatedly across the resource) and highlighting topics that may benefit from further research. The main constraint data layers that have the potential to be affected by the Step 4 resource areas in terms of geographic overlap (10% or greater) are:

- Some shipping density data layers;
- National Parks
- Heritage coast;
- National Trust land;
- Some seascape sensitivity to wave farm areas;

- Wrecks;
- Submarine cables;
- Renewable energy interests in Welsh waters;
- Herring and sole spawning areas;
- Marine nature reserves;
- Explosive dumping sites;
- Marine military practice areas;
- Pilot boarding places;
- Protected wrecks;
- Some commercial fishing;
- Diving seabird areas;
- Some cetacean vulnerability areas;
- Some grey seal vulnerability areas;
- SAC non habitat feature and habitat features – sea caves and reefs; and
- Dredging routes.

Step 5 - Sustainable Development of Marine Renewables

S27. The aim of Step 5 is to bring together the findings from Steps 1-4, to determine the implications of different scales of development for both the potential energy return from wave and tidal stream but also for existing constraints. To enable an overall assessment of the potential resource to be undertaken, Step 5 has used the amalgamated resource area developed in Step 2 to consider the potential sustainability of **low**, **medium** and **high** levels of energy generation.

S28. It is through an understanding of how the wave and tidal stream industry may interact with existing interests that a Strategic Framework for development can be brought forward, although as previously noted the delivery of any of the development scenarios is dependant on developments being identified, consented and constructed. It is not the intention of the MRESF to identify which development scenario would be preferred, but to assess the potential level of energy that could be reached in the context of existing interests.

S29. From the previous steps, it is apparent that the minimum level of constraint across the amalgamated energy resource is rank 3, with these areas forming the starting point for the 'low energy' scenario. All areas ranked 5 are excluded from the assessment of potential resource in Step 5, as the definition for Rank 5 is 'likely to preclude development'. The 'medium' and 'high' energy scenarios therefore concentrate on resource areas affected by rank 4 constraints. The scenarios can be summarised as follows:

- **High energy yield**: which assumes development of all amalgamated resource in areas ranked up to and including constraint level 4. Such development, should it be enabled and consented, has the potential to deliver **6.4GW** installed capacity;
- **Medium energy yield**: which assumes development of all resource in areas ranked up to and including constraint level 3, together with a proportion of areas ranked 4. Such development, should it be enabled and consented, has the potential to deliver between **3.7GW** and **5.1GW** installed capacity; and
- **Low energy yield**: which assumes development of all amalgamated resource in areas ranked up to and including constraint level 3. Such development, should it be enabled and consented, has the potential to deliver **1.5GW** installed capacity.

S30. The purpose of the medium energy scenario is to explore the potential for a 'mid point' between the low energy scenario, which falls considerably short of the WAG's target of 4GW installed capacity in the main by 2025, and the high energy scenario, some of which would need to be delivered by development within in areas subject to a considerable number of highly ranked constraints. The approach taken has been firstly to determine how much of the amalgamated resource is constrained by just one data layer ranked 4, and then to determine how much is constrained by two data layers ranked 4. The potential energy when areas constrained by just one rank 4 data layer are included is **3.7GW** installed capacity (the **medium energy scenario A**) and when areas constrained by two rank 4 data layers are included is **5.1GW** installed capacity (the **medium energy scenario B**). The potential installed capacity offered by the medium energy scenarios A and B sits well between that offered by the low and high energy scenarios and for this reason, together with the appreciation of increasing levels of constraint should additional rank 4 data layers be added, the medium energy scenario was not progressed further to incorporate 3 rank 4 data layers. It should be noted that to enable development in areas constraint ranked 4 would bring considerable challenges for developers and the consenting authorities. This is perhaps not unsurprising, given

the definition of rank 4 as 'significant issue/constraint – probable delay and could possibly stop the project'.

S31. Step 5 includes a review of the data layers that have the potential to be affected most by the scenarios, both in terms of the level of constraint these represent to the development of that resource and the extent to which that resource overlaps with the constraint. The main data layers highlighted in Step 5 are as follows:

- Shipping density;
- Radar;
- Terrestrial designated sites;
- Seascape sensitivity;
- Wrecks
- Commercial fishing;
- Marine military practice areas;
- Fish spawning areas;
- Diving seabirds;
- Cetaceans;
- Grey seals;
- Marine Nature Reserves;
- Special Areas of Conservation; and
- Dredging Routes.

Key Conclusions

S32. There are a number of key points that can be drawn from the results of the GIS mapping and data processing presented in this report, which have been summarised as follows:

- There is considerable wave and tidal stream energy potential in Welsh TWs, however there are also numerous existing interests that have the potential to form significant constraints on development;
- Regardless of the level of constraint anticipated from the strategic level, all developments will require assessment and need to achieve the relevant consents;

- There is potential for the 4GW installed capacity in the main by 2025, highlighted by the WAG in the Energy Policy Statement, to be met and even exceeded, with **6.4GW** installed capacity potentially offered by the **high energy scenario**. However, to do so would require development in areas subject to significant levels of constraints (including a number of environmental and/or socio-economic constraints at constraint rank 4) and thus the acceptability of development in these areas would require careful consideration and detailed discussion with relevant parties in order to achieve a balance; realising higher installed capacity levels whilst sensibly minimising associated impacts on environmental receptors or existing sectoral use;
- For development in areas subject to a lesser degree of constraint, the potential 1.5GW installed capacity described in the **low energy scenario,** would be approximately one quarter of that in the high energy scenario. Although the 4GW level would not be achieved, this scenario is likely to be subject to fewer consenting difficulties and have fewer conflicts with existing interests. The consentability of the scenario is certainly better than the high energy scenario. The sustainability of this scenario would need to be considered in terms of the relative importance of the wave and tidal sector in context of overall sustainable development and whether the lower level of energy is deemed sufficient in the face of the alternative scenarios;
- To achieve a mid point between the low and high energy scenarios, i.e. the **medium energy scenario**, development in some areas of high constraint would be required. Although the overall level of constraint is likely to be less than in the high energy scenario, some of these constraints are likely to be significant, however a number of these constraints could potentially be mitigated or reduced in significance through additional study and discussion. This would bring a significant degree of uncertainty to a project and not least represent a potential time and financial cost to the project. An installed capacity of between **3.7GW** and **5.1GW** has been described for the medium energy scenario. The sustainability of the scenario would need to consider the implications for existing interests together with the potential benefits for the wave and tidal stream industry;
- Within the **low energy scenario**, the GIS data processing identified the maximum amount of an individual constraint that may be affected by development at this scale as being up to 11% of one of the shipping density sub-layers (at a level of vessel traffic of >50-250 per year). Again, this may bring issues for consenting multiple projects should these be developed across areas with a high proportion of

a single constraint i.e. cumulative impact of multiple projects on a single constraint (even if the single constraint is ranked at a low level);

- The report highlights data layers that were unavailable within the MRESF timeframe, being updates to fish spawning and nursery areas and the identification of MCZs in Welsh waters. It should be noted that both data layers, when they become available, have the potential to impinge on the areas of resource identified in the MRESF. However, there has been dialogue with the MCZ team, enabling information to be shared, with fish ecology included in the constraint mapping in the form of an earlier data layer;
- The level of confidence and certainty in both the baseline data layers used in constraint mapping and the level of understanding of potential impacts associated with wave and tidal stream devices is very important when assessing the potential constraints on development. It is acknowledged that limitations remain in the data used, with increased certainty only likely to be achieved as additional data is collected;
- Even within areas of lower constraint, issues such as the cumulative level of constraint (e.g. large numbers of data layers with low levels of constraint compared to areas with a few data layers of high constraint) could increase consenting risk and bring complications for sustainable development; and
- When the minimum tidal stream energy is reduced to 1.5m/s, although not generally considered a 'commercial level' of energy, the 1.5m/s resource presents a larger potential development area than the 2m/s resource (518km^2 for 1.5m/s and 200km^2 for 2m/s), albeit it within the same broad locations.

S33. To reduce the consenting risk and achieve a sustainable route, a number of approaches could be taken. At the strategic level, these could include combining an active management approach with appropriate strategic level mitigation at the site selection stage, to help reduce the potential for cumulative impact on individual constraints. For some constraints, particularly for those where there is large degree of geographic overlap with the resource area, there is potential benefit from targeted research and/or consultation with the relevant sector at the strategic level, with these constraints highlighted below. Where there may be benefit from further consultation and/or discussion with the relevant industry, this is highlighted in *italics*. Where there may need to be future research and/or monitoring at demonstrator sites, this is highlighted in **bold**. When projects are considered at the site specific level, the topics that would require consideration would be a function of the baseline environment (natural and socio-

economic) and therefore unlikely to be limited to the list below, with the use of site specific mitigation potentially reducing impact.

- *Shipping*;
- Seascape;
- ***Commercial fishing***;
- **Cetaceans**;
- **Grey seals**; and
- **Special Areas of Conservation**.

S34. It should be noted that for several of the topics highlighted in bold, there is an increasing need for monitoring of devices *in-situ* to provide field data, with further desk based work unlikely to increase the knowledge base sufficiently. Given the difficulties of achieving consent when the level of scientific certainty is not high, it is likely that a 'deploy and monitor' approach will be required. Such an approach would enable the industry to progress past the difficult stage it is currently in – essentially that a lack of certainty is hampering the consenting process and until devices are deployed and monitored, it is becoming increasingly difficult to increase the level of certainty.

Contents

Executive Summary i

Contents xv

1 Introduction 1

1.1 Background to the MRESF 1

1.2 Purpose of the Current Report 3

1.3 Format of the Current Report 4

2 Resource 6

2.1 Marine Energy Resource in the MRESF 6

2.2 The Energy and Location Requirements of Individual Device Types 7

3 Identification of Potential Generation Capacity 11

3.1 The Need to Understand the Potential Generation Capacity 11

3.2 Wave and Tidal Stream Resource 11

3.3 Device Requirements and Characteristics 12

3.4 Renewable Energy Potential of Welsh Waters 12

3.5 Overview of Process 13

4 Unmapped Hurdles to Development and Informative Data Layers 21

4.1 Unmapped Hurdles to Development 21

4.2 Informative Data Layers 23

5 Constraint Management 28

5.1 Definition of a Constraint 28

5.2 Cumulative Data Layers (Constraints) 32

5.3 Data Layers that were Unavailable within the MRESF Timeframe 34

5.4 The Importance of Mitigation and Increased Certainty 34

5.5 Combining Constraint Groups and Device Types 36

6 Approach to Sustainable Development 38

6.1 Description of Approach 38

6.2 Step 1 – Maximum Energy Generation 40

6.3 Step 2 – Maximum Achievability 42

6.4 Step 3a – Least Impacting Environmentally 49

6.5 Step 3b – Least Impacting for Existing Use 51

6.6 Step 4 – Most Sustainable for Individual Device Types 53

6.7 Step 5 –Sustainable Development of Marine Renewables 61

7 Conclusions and Recommendations 87

7.1 Introduction 87

7.2 Lessons Learnt from the Project 87

7.3 Scale and Speed of Development 89

7.4 Grid Connection 89

7.5 Potential for Sustainable Development of Wave and Tidal Stream in Welsh Waters 89

7.6 Where Next? 95

References 97

Appendices 99

Tables

Table 2.1: Summary of Device Type 9

Table 3.1: Summary of Potential Generation Capacity Data for Tidal Stream Devices 17

Table 3.2: Summary of Potential Generation Capacity Data for Wave Devices 18

Table 5.1: Definition of Constraint Rankings 30

Table 5.2: Generic Mitigation Measures Potentially Applicable for Wave and Tidal Stream..... 35

Table 5.3: Summary of Occurrence of Surface Piercing and/or Fully Submerged Devices in the Device Type Groups 37

Table 6.1: Summary of Step 1 - Maximum Energy Generation 41

Table 6.2: Summary of the Energy Potential from Step 2 'Maximum achievability'. 46

Table 6.3: Summary of the Environmental Constraints Applied During Step 3a 'Least Impacting Environmentally' 50

Table 6.4: Summary of the Socio-Economic Constraints Applied During Step 3b 'Least Impacting for Existing Use' 52

Table 6.5: Summary of All Constraints Applied During Step 4 'Most Sustainable for Individual Device Types' 59

Table 6.6: Selection of Energy Group in the Amalgamated Resource for areas constraint ranked up to and including 3 (see Figure S5-2 for geographic locations) 63

Table 6.7: Selection of Energy Group in the Amalgamated Resource for areas constraint ranked up to and including 4 (see Figure S5-3 for geographic locations) 63

Table 6.8: Summary of the Potential Level of Constraint on Wave and Tidal Stream Energy in Welsh Waters 65

Table 6.9: Summary of Planned and Proposed Wave and Tidal Stream Projects in Welsh Waters 66

Table 6.10: Rank 4 data layers potentially included in the Medium Energy Scenarios A and B 70

Figures

Baseline Data Figures

Figure B-1 Study Area and Spatial Units

Figure B-2 Renewable Energy Interests in Welsh Waters

Figure B-3i Physical Environment Bathymetry

Figure B-3ii Physical Environment Intertidal Substrata

Figure B-3iii Physical Environment Subtidal Geology

Figure B-3iv Physical Environment Seabed Landscapes

Figure B-4 Water Quality

Figure B-5i CCW LandMAP Cultural Landscape

Figure B-5ii CCW LandMAP Geological Landscape

Figure B-5iii CCW LandMAP Historic Landscape

Figure B-5iv CCW LandMAP Landscape Habitat

Figure B-5v CCW LandMAP Visual and Sensory

Figure B-5vi Seascape – Wave Energy Sensitivity

Figure B-5vii Seascape - Tidal Energy Sensitivity

Figure B-5viii Seascape – Wind Energy Sensitivity

Figure B-5ix Seascape – National Parks and National Trust Sensitivity

Figure B-6i Marine Mammals

Figure B-6ii Marine Mammals

Figure B-6iii Marine Mammals

Figure B-6iv Cetaceans Vulnerability Score

Figure B-6v Grey Seals Vulnerability Score

Figure B-7i Seabirds

Figure B-7ii Seabird Density

Figure B-7iii Seabird Density by Species

Figure B-7iv Seabird Density by Species

Figure B-7v Seabird Density by Species

Figure B-7vi Seabird Density by Species

Figure B-7vii Seabird Density by Species

Figure B-7viii Diving Seabird Vulnerability

Figure B-8i Fish Ecology

Figure B-8ii Fish Ecology

Figure B-8iii Fish Ecology

Figure B-8iv Fish Ecology

Figure B-8v Fish Ecology

Figure B-8vi Fish Ecology

Figure B-9i Benthic Ecology

Figure B-9ii Sensitivity of Benthos to Commercial Fishing

Figure B-10i Designated Sites

Figure B-10ii SAC Habitat Features

Figure B-11 Shipping

Figure B-12i Tourism and Recreation

Figure B-12ii Environment Agency Recreation Data

Figure B-12iii Tourism and Recreation Pembrokeshire Coastal Forum

Figure B-12iv Tourism and Recreation Pembrokeshire Coastal Forum

Figure B-13 Archaeology

Figure B-14i Commercial Fisheries

Figure B-14ii Commercial Fisheries

Figure B-14iii Commercial Fisheries

Figure B-15 Military Use

Figure B-16 Aviation

Figure B-17 National Grid

Figure B-18 Cables & Pipelines

Figure B-19 Aggregate Dredging Areas

Figure B-20 Oil & Gas Licence Areas

Figure B-21 Licensed Disposal Sites

Step 2 Figures

Figure S2-1 Potential Resource Areas (Constrained by Device Specific Requirements Only)

Figure R-1i Resource Area (Device Requirements Applied) Wave Shoreline (neap tide) OWC, Hydraulic Pressure, Overtopping

Figure R-2i Resource Area (Device Requirements Applied) Wave Nearshore OWC

Figure R-2ii Resource Area (Device Requirements Applied) Wave Nearshore OWC

Figure R-3i Resource Area (Device Requirements Applied) Wave Nearshore Single point/buoy

Figure R-3ii Resource Area (Device Requirements Applied) Wave Nearshore Single point/buoy

Figure R-4i Resource Area (Device Requirements Applied) Wave Offshore Multibuoy

Figure R-4ii Resource Area (Device Requirements Applied) Wave Offshore Multibuoy

Figure R-5i Resource Area (Device Requirements Applied) Wave Offshore Single point/buoy

Figure R-5ii Resource Area (Device Requirements Applied) Wave Offshore Single point/buoy

Figure R-6i Resource Area (Device Requirements Applied) Wave Offshore Attenuators

Figure R-7i Resource Area (Device Requirements Applied) Wave Offshore Overtopping Collector

Figure R-7ii Resource Area (Device Requirements Applied) Wave Offshore Overtopping Collector

Figure R-8i Resource Area (Device Requirements Applied) Tidal Stream Rotating Turbine

Figure R-8ii Resource Area (Device Requirements Applied) Tidal Stream Rotating Turbine

Figure R-8iii Resource Area (Device Requirements Applied) Tidal Stream Rotating Turbine

Figure R-8iv Resource Area (Device Requirements Applied) Tidal Stream Rotating Turbine

Figure R-9i Resource Area (Device Requirements Applied) Tidal Stream Hydroplanes, Hydrofoils & Sails, Venturi Effect

Figure R-9ii Resource Area (Device Requirements Applied) Tidal Stream Hydroplanes, Hydrofoils & Sails, Venturi Effect

Figure R-9iii Resource Area (Device Requirements Applied) Tidal Stream Hydroplanes, Hydrofoils & Sails, Venturi Effect

Figure R-9iv Resource Area (Device Requirements Applied) Tidal Stream Hydroplanes, Hydrofoils & Sails, Venturi Effect

Figure R-10i Summary of Resource Areas

Figure R-10ii Summary of Resource Areas

Figure R-10iii Summary of Resource Areas

Figure R-10iv Summary of Resource Areas

Figure R-10v Summary of Resource Areas

Figure R-10vi Summary of Resource Areas

Step 3 Figures

Figure S3A-1 Wave (Surface Piercing) Environmental Constraints. Resource Area (Device Requirements Applied). Wave Nearshore – OWC

Figure S3A-2 Wave (Surface Piercing) Environmental Constraints. Resource Area (Device Requirements Applied). Wave Nearshore – Single Point/Buoy

Figure S3A-3 Wave (Wholly Submerged) Environmental Constraints. Resource Area (Device Requirements Applied). Wave Nearshore – Single Point/Buoy

Figure S3A-4 Wave (Surface Piercing) Environmental Constraints. Resource Area (Device Requirements Applied). Wave Offshore - Multi Buoy

Figure S3A-5 Wave (Surface Piercing) Environmental Constraints. Resource Area (Device Requirements Applied). Wave Offshore - Single Point/Buoy

Figure S3A-6 Wave (Wholly Submerged) Environmental Constraints. Resource Area (Device Requirements Applied). Wave Offshore - Single Point/Buoy

Figure S3A-7 Wave (Surface Piercing) Environmental Constraints. Resource Area (Device Requirements Applied). Wave Offshore – Overtopping Collector

Figure S3A-8 Tidal Stream (Surface Piercing) Environmental Constraints. Resource Area (Device Requirements Applied). Tidal Stream – Rotating Turbine

Figure S3A-9 Tidal Stream (Wholly Submerged) Environmental Constraints. Resource Area (Device Requirements Applied). Tidal Stream – Rotating Turbine

Figure S3B-1 Wave (Surface Piercing) Social & Economic Constraints. Resource Area (Device Requirements Applied). Wave Nearshore – OWC

Figure S3B-2 Wave (Surface Piercing) Social & Economic Constraints. Resource Area (Device Requirements Applied). Wave Nearshore – Single Point/Buoy

Figure S3B-3 Wave (Wholly Submerged) Social & Economic Constraints. Resource Area (Device Requirements Applied). Wave Nearshore – Single Point/Buoy

Figure S3B-4 Wave (Surface Piercing) Social & Economic Constraints. Resource Area (Device Requirements Applied). Wave Offshore - Multi Buoy

Figure S3B-5 Wave (Surface Piercing) Social & Economic Constraints. Resource Area (Device Requirements Applied). Wave Offshore – Single Point/Buoy

Figure S3B-6 Wave (Wholly Submerged) Social & Economic Constraints. Resource Area (Device Requirements Applied). Wave Offshore – Single Point/Buoy

Figure S3B-7 Wave (Surface Piercing) Social & Economic Constraints. Resource Area (Device Requirements Applied). Wave Offshore – Overtopping Collector

Figure S3B-8 Tidal Stream (Surface Piercing) Social & Economic Constraints. Resource Area (Device Requirements Applied). Tidal Stream – Rotating Turbine

Figure S3B-9 Tidal Stream (Wholly Submerged) Social & Economic Constraints. Resource Area (Device Requirements Applied). Tidal Stream – Rotating Turbine

Step 4 Figures

Figure S4-1 Wave (Surface Piercing) All Constraints. Resource Area (Device Requirements Applied). Wave Nearshore - OWC

Figure S4-2 Wave (Surface Piercing) All Constraints. Resource Area (Device Requirements Applied). Wave Nearshore - Single Point/Buoy

Figure S4-3 Wave (Wholly Submerged) All Constraints. Resource Area (Device Requirements Applied). Wave Nearshore - Single Point/Buoy

Figure S4-4 Wave (Surface Piercing) All Constraints. Resource Area (Device Requirements Applied). Wave Offshore – Multi Buoy

Figure S4-5 Wave (Surface Piercing) All Constraints. Resource Area (Device Requirements Applied). Wave Offshore – Single Point/Buoy

Figure S4-6 Wave (Wholly Submerged) All Constraints. Resource Area (Device Requirements Applied). Wave Offshore – Single Point/Buoy

Figure S4-7 Wave (Surface Piercing) All Constraints. Resource Area (Device Requirements Applied). Wave Offshore – Overtopping Collector

Figure S4-8 Tidal Stream (Surface Piercing) All Constraints. Resource Area (Device Requirements Applied). Tidal Stream – Rotating Turbine

Figure S4-9 Tidal Stream (Wholly Submerged) All Constraints. Resource Area (Device Requirements Applied). Tidal Stream – Rotating Turbine

Step 5 Figures

Figure S5-1 Constraint Ranking for Wave and Tidal Resource Areas

Figure S5-2 Potential Low Energy Yield Resource Areas – Constraint Ranked ≤3

Figure S5-3 Potential High Energy Yield Resource Areas – Constraint Ranked ≤4

Figure S5-4 Potential Medium Energy Yield Resource Areas – Constraint Ranked ≤3 including areas where only 1 x rank 4 is present

Figure S5-4i Potential Medium Energy Yield Resource Areas – Extent of 1 x Rank 4 Constraints - Overview

Figure S5-4ii Potential Medium Energy Yield Resource Areas – Extent of 1 x Rank 4 Constraints

Figure S5-4iii Potential Medium Energy Yield Resource Areas – Extent of 1 x Rank 4 Constraints

Figure S5-4iv Potential Medium Energy Yield Resource Areas – Extent of 1 x Rank 4 Constraints

Figure S5-5 Potential Medium Energy Yield Resource Areas – Constraint Ranked ≤3 including areas where 2 x rank 4 is present

Figure S5-5i Potential Medium Energy Yield Resource Areas – Extent of 1 x and 2x Rank 4 Constraints – Overview

Figure S5-5ii Potential Medium Energy Yield Resource Areas – Extent of 1 x and 2x Rank 4 Constraints

Figure S5-5iii Potential Medium Energy Yield Resource Areas – Extent of 1 x and 2x Rank 4 Constraints

Figure S5-5iv Potential Medium Energy Yield Resource Areas – Extent of 1 x and 2x Rank 4 Constraints

Lower Tidal Stream Energy Figures

Figure ALT-1 Resource Area (Device Requirements Applied) All Tidal Stream Devices. 1.5m/s vs 2m/s tidal velocity resource areas

Figure ALT-2 Tidal Stream (surface piercing) All Constraints Resource Area (Device Requirements Applied) Tidal Stream – All Devices

Figure ALT-3 Tidal Stream (wholly submerged) All Constraints Resource Area (Device Requirements Applied) Tidal Stream – All Devices

Cumulative Data Layer Figures

Figure C-1 Wave and Tide Resource. Constraint Rank Score. Overview Map

Figure C-1i Wave and Tide Resource. Constraint Rank Score.

Figure C-1ii Wave and Tide Resource. Constraint Rank Score.

Figure C-1iii Wave and Tide Resource. Constraint Rank Score.

Figure C-1iv Wave and Tide Resource. Constraint Rank Score.

Figure C-1v Wave and Tide Resource. Constraint Rank Score.

Figure C-1vi Wave and Tide Resource. Constraint Rank Score.

Figure C-1vii Wave and Tide Resource. Constraint Rank Score.

Figure C-1viii Wave and Tide Resource. Constraint Rank Score.

Figure C-1ix Wave and Tide Resource. Constraint Rank Score.

Appendices

Appendix A GIS Data Layers

Appendix B Percentage of Constraint Data Layers Affected by Each Device Type Resource Area in Step 4

Appendix C Percentage of Constraint Data Layers Affected by the Overall Resource Area in the Low, Medium and High Scenarios in Step 5

1 Introduction

1.1 Background to the MRESF

1.1.1 This report has been prepared by RPS on behalf of the Welsh Assembly Government (the WAG) as part of the development of the Marine Renewable Energy Strategic Framework (MRESF). The MRESF project has been undertaken in three stages, with this report presenting a summary of the findings of the final part of Stage 3. The main aim of the MRESF project has been to investigate the potential marine renewable energy resource of Welsh Territorial Waters (TWs), and to consider potential scenarios for the sustainable development of that resource.

1.1.2 The MRESF project team is comprised of RPS staff, with the project Steering Group including members from the following:

- The Welsh Assembly Government;
- Defence Estates – Ministry of Defence;
- The Crown Estate;
- Countryside Council for Wales;
- Department of Energy and Climate Change (formerly the Department for Business Enterprise and Regulatory Reform);
- Marine Management Organisation (formerly the Marine and Fisheries Agency); and
- With specialist advice provided by Cefas during Stage 3.

1.1.3 The input, discussion and advice from the Steering Group has proved highly beneficial to the project throughout. However, it should be noted that the findings of the project are intended to be applied at a strategic level and will not prejudice decisions and advice at the individual project level, nor do they prevent future flexibility in approach to future strategic projects, including those made by the MRESF Steering Group.

1.1.4 The current report provides a descriptive text to the final outputs of the MRESF, which are essentially a series of GIS maps that compare areas of potential wave and tidal stream resource with the level of existing development constraint. This report has been preceded by a number of documents, which laid the foundations for the Framework and provide the background for the overall assessment. The accompanying reports are summarised below.

Stage 1

1.1.5 The outputs from Stage 1 are presented in a single report, which includes the literature review, an overview of the status of the marine renewable industry and baseline environment of Welsh waters, information on the existing electricity transmission network (the grid), the potential for carbon capture and storage in Welsh waters and an assessment of the existing knowledge of both potential impacts of and constraints on development. The final sections of the report looked at the key data gaps that have the potential to act as hurdles to development, with a number of potential projects to address these summarised. The report reference is as follows:

- Marine Renewable Energy Strategic Framework for Wales. Stage 1 Report (RPS, 2008).

Stage 2

1.1.6 From the list of key hurdles to development in Welsh waters, the project Steering Group and the WAG identified a number of projects suitable for public funding. These projects were taken forward in Stage 2, with the resulting report references as follows:

- Assessment of Risk to Marine Mammals from Underwater Marine Renewable Devices in Welsh Waters. Phase 2 - Studies of Marine Mammals in Welsh High Tide Waters (Gordon, J, Thompson, D, Leaper, R, Gillespie, D, Pierpoint, C, Calderan, S, Macaulay, J and Gordon, T, 2011);
- Assessment of Risk to Marine Mammals from Underwater Marine Renewable Devices in Welsh Waters. Phase 1 - Desktop Review of Collision Risk to Marine Mammals from Underwater Devices in Welsh Waters (Wilson, B and Gordon, J, 2011);
- Collision Risk of Fish with Wave and Tidal Devices (ABPmer, 2010);
- The Potential for Interaction between Wave and Tidal Stream with Military Interests in Welsh Waters (RPS, 2010a);
- Positive effects of wave and tidal energy devices. Literature review and desk study (RPS, 2010b UNPUBLISHED);
- Assessment of Risk to Diving Birds from Underwater Marine Renewable Devices in Welsh Waters. Phase 1 - Desktop Review of Birds in Welsh Waters and Preliminary Risk Assessment (RPS, 2011a); and

- Assessment of Risk to Diving Birds from Underwater Marine Renewable Devices in Welsh Waters. Phase 2 - Field Methodologies and Site Assessments (RPS, 2011b).

Stage 3

1.1.7 Stage 3 has focused on the development of the Framework, drawing on the outputs from Stages 1 and 2. The work has included stakeholder engagement (with two reports, the first issued for stakeholders in advance of the stakeholder engagement process and the second issued to collate comments made during the engagement process and to highlight how this input has been used), a review of the policy context as regards sustainable development and an update to the Stage 1 work (presented as a Technical Addendum to Stage 3). The report references are as follows:

- Marine Renewable Energy Strategic Framework for Wales – Stage 3. Stakeholder Participation Process (WAG, 2010a);
- Marine Renewable Energy Strategic Framework for Wales – Stage 3. Stakeholder Participation Feedback (WAG, 2010b);
- Marine Renewable Energy Strategic Framework – Stage 3. Review of the Policy Context for Sustainable Marine Renewable Development (WAG, 2011a); and
- Marine Renewable Energy Strategic Framework – Stage 3. Technical Addendum (WAG, 2011b).

1.1.8 All of the above reports are available at http://mresf.rpsgroup.com/ and http://wales.gov.uk/topics/environmentcountryside/energy/renewable/marine/framework/?lang=en. It is important to read this document in conjunction with the MRESF Stage 1 report (RPS, 2008) and Technical Addendum (WAG, 2011b), which provide the background to the baseline information used and context for this Approach to Sustainable Development described here.

1.2 Purpose of the Current Report

1.2.1 The current report has been prepared to accompany the GIS constraint mapping undertaken as the final output of Stage 3 of the MRESF. This report is intended to provide a descriptive background to the GIS outputs, summarising the steps taken and what the results show. The GIS constraint mapping has been undertaken in 5 Steps, designed to consider and apply a range of siting criteria for marine renewable energy devices within Welsh TWs together with the spatial extent and sensitivity of existing

socio-economic uses and environmental interests. These steps, described more fully in the subsequent sections of this document, have been termed the 'Approach to Sustainable Development'. The final stage in this process, Step 5, has been developed to enable the overall potential energy resource available in areas of different levels of constraint to be assessed, to provide an evidence base for determining the sustainability of different levels of wave and tidal stream power generation from Welsh TWs.

1.2.2 It is not the intention of the MRESF project to green light or red flag areas for development, but rather to assess the implications of development in a sustainable context. To this end, the current report highlights areas where lower levels of constraint on development would be anticipated from a strategic perspective, which existing issues have the potential to represent significant hurdles to development in Welsh TWs and for which issues there may be potential for further work to reduce or mitigate such hurdles.

1.2.3 Given the above, it should be noted that as knowledge of the potential resource develops, additional areas of commercial resource may be identified, for example in nearshore areas, where broad scale data on resource is currently limited. There is no presumption against development in these areas and as such the principles of the constraint mapping presented here are equally applicable across Welsh TWs, thus representing a valuable tool in understanding the potential level of constraint to which development in any such areas may be subject.

1.3 Format of the Current Report

1.3.1 This report has been divided into sections, as follows:

- **Section 1 – Introduction.**
- **Section 2 – Resource**.
- **Section 3 – Identification of Potential Generation Capacity**.
- **Section 4 – Unmapped hurdles to development and informative data layers**.
- **Section 5 – Constraint Management**.
- **Section 6 – Approach to Sustainable Development**. Undertaken in 5 main steps, as follows:
  - **Step 1 – Maximum Energy Generation**;
  - **Step 2 – Maximum Achievability**;

  - **Step 3a – Least Impacting Environmentally**;
  - **Step 3b – Least Impacting for Existing Use**;
  - **Step 4 – Most Sustainable for Individual Device Types**; and
  - **Step 5 –Sustainable Development of Marine Renewables**.
- **Section 7 – Conclusions and Recommendations.**

2 Resource

2.1 Marine Energy Resource in the MRESF

2.1.1 The marine renewable energy resource of Welsh TWs consists of offshore wind, wave, tidal range and tidal stream. The potential for carbon capture and storage in the marine environment was also included in Stage 1, but for reasons described in the MRESF Technical Addendum (WAG, 2011b), has not been considered further in Stage 3. Tidal range was excluded at the start of the project, a reflection of the detailed work undertaken for the Department of Energy and Climate Change (DECC) in the Severn Estuary (www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/severn_tidal_power/severn_tidal_power.aspx). It should be noted, however, that additional sources of tidal range energy are found in Welsh TWs, for example there is potential interest in a tidal range project off Rhyl in north Wales. Offshore wind was considered in Stage 1, however for reasons detailed in WAG (2011b) has not been taken forward in Stage 3. As such, the potential marine energy resource considered here focuses on wave and tidal stream.

2.1.2 The main dataset for assessing the potential marine energy resource for the UK is the Renewables Atlas (www.renewables-atlas.info/). Although the dataset is in the public domain and offers the most complete example of its type for the UK, there are limitations in the detail and extent of the data, particularly for inshore areas. As a result, RPS have supplemented the inshore tidal stream data with internally held datasets, where these data have been available. It should be noted that broad scale understanding of inshore energy remains patchy, with broad scale data such as the Atlas being more limited at the scale required for site specific projects. As such, potential for additional areas of resource to be identified remains, both within inshore areas and across the wider area as the baseline data increases.

2.1.3 Importantly, although the project team recognise the risks associated with data limitations when defining potential areas of resource, it is felt that potential development areas need to represent a commercially viable level of energy within the MRESF if the framework is to achieve the requisite level of credence within the sector.

2.2 The Energy and Location Requirements of Individual Device Types

2.2.1 Stage 1 of the MRESF project identified numerous wave and tidal stream devices, together with device specific information such as commercial and/or engineering limitations on minimum energy requirements and deployment specifics such as depth and distance from shore (RPS, 2008). Such information is required by the MRESF to understand where a commercially viable resource may be found for individual device types. The information has been updated and re-assessed during Stage 3, with some 59 wave devices and 41 tidal devices now identified (WAG, 2011b). Device specific information is available from several sources, including developer websites and associated literature, with Stakeholder input during Stages 1 and 3 being key to ensuring the information held represents current knowledge (RPS, 2008 and WAG, 2010b). Given the current status of the industry, with many devices being pre-commercial but developing rapidly, the information is often patchy. However, the detailed review and stakeholder engagement has ensured that the data held represents the most complete and contemporary information available.

2.2.2 To ensure the process is 'device blind', the individual devices identified were grouped in Stage 1, following the general approach taken to previous such groupings in the wider literature, with limited changes made in Stage 3. A summary of the information collated, as relevant to the current report, is presented in Table 2.1. Text in **bold** indicates changes, additions and amendments to the original Stage 1 data made during Stage 3.

2.2.3 It should be noted that the device specific information sourced represents the project team's understanding of the current status of the marine renewables industry as of August 2010 and that as devices are developed, it is to be expected that such requirements may change. For example, commercial constraints on distance from shore (which are generally informed by a combination of device requirements and factors such as the financial cost of cable to shore) may alter, enabling devices to be deployed at greater distance from shore, a reflection of economies of scale and device development.

2.2.4 A key constraint at present as regards to where areas of potential resource exist is the minimum energy requirements of devices. Such values are driven principally by the commercial requirements of developers and consequently these criteria have been taken predominantly from developer-supplied information as summarised in Table 2.1. The information presented in Table 2.1 has been sourced from publicly available data and from information provided to RPS during the Stage 1 and Stage 3 stakeholder

engagement process (RPS, 2008 and WAG, 2010b) and reflects the available information as of August 2010. However, it should be noted that the type and amount of information available does differ significantly between devices and it is reasonable to assume that devices which have been deployed to scale at sea may have more data available than devices which are at an earlier stage in development.

2.2.5 It is notable that during the Stakeholder engagement in Stage 3, concerns were raised that strict adherence to these commercial requirements, particularly as regards to tidal stream[1], may focus potential areas of resource within areas of perceived high ecological sensitivity and that reducing the level of minimum energy could widen the areas of interest, potentially allowing some of the highest or more sensitive tidal stream areas to be completely avoided. Whilst such co-locations may not be inherently conflicting, providing opportunity for avoiding areas which may be sensitive to marine renewable energy developments fits well with the sustainable development criteria applied throughout this project. In response to the concerns, RPS have produced three additional figures. Figure ALT-1 depicts the geographic distribution of tidal stream energy in Welsh waters for both 1.5m/s and above. Figure ALT-2 indicates the level of potential constraint present across the 1.5m/s area for surface piercing and Figure ALT-3 for wholly submerged.

2.2.6 The location of the 1.5m/s areas do tend to be associated with the 2m/s resource areas, albeit with a larger footprint (approximately 518km^2 for 1.5m/s and 200km^2 for 2m/s), and as such tend to be subject to similar constraints. It should also be noted that for a development to generate a certain level of electricity in areas of lower energy it would be anticipated to require a larger footprint than for a development to generate the same amount of electricity from a higher energy area.

[1] Generally, a minimum tidal stream of 2m/s mean peak spring was identified by the majority of developers as a requirement for a viable tidal stream device deployment; however some stakeholders suggested lower levels should be included i.e. 1.5m/s as a minimum, with some developers indicating a minimum of 2.5m/s or higher.

Table 2.1: Summary of Device Type[2]

Energy Type	Device Type Group	Device Type Sub-Group	Distance from Shoreline	Water Depth	Energy Requirement
WAVE	Shoreline	Oscillating Water Column (OWC)	0m - few 100m if on breakwater	5-8m up to maximum 15m. Economic preference around 10m	Annual 15-30kw/m, significant wave height 1m and period 8-12s
		Hydraulic pressure	0m	4m	-
		Overtopping	0m	6-15m	**18 kW/m**
	Nearshore	Oscillating Water Column (OWC)	**Less than 2km**	**10-50m**	9kw/m
		Overtopping Collector	No constraints identified	**50-80m**	-
		Single point/Buoy	Between 500-800m up to 8km	30-40m ideal, up to 80-100m	20kW/m, significant wave height above 1m, wave period 5-15 seconds

[2] Please note that the information presented in Table 2.1 has been sourced from publicly available data and from information provided to RPS during the Stage 1 and Stage 3 stakeholder engagement process. The information reflects the available information as of August 2010. However, it should be noted that the type and amount of information available does differ significantly between devices and it is reasonable to assume that devices which have been deployed to scale at sea may have more data available than devices which are at an earlier stage in development

Energy Type	Device Type Group	Device Type Sub-Group	Distance from Shoreline	Water Depth	Energy Requirement
		Oscillating wave surge converter	**10m-1km**	10-50m (very variable between devices)	1-3m swell or 40kw/m^2
	Offshore	Oscillating Water Column (OWC)	10-16km	**30-100m**	60kw/m
		Single point/Buoy	2km quoted as economic presence in some cases, out to max +10km, with few to 20km	**20-100m, some needing >50m**	20kW/m
		Multi-Buoy	**3-20km**	**20km**	2m wave height or 4kw/m
		Attenuators	**5-50km**	**30-100m**	25-55kw/m
		Overtopping Collector	**5-25km**	**20->40m**	24kw/m
TIDAL	Stream	Rotating turbine	**<100m-5km**	**Generally 20-60m with some >100m**	**Min >5knots or 2-2.5m/s spring peak velocity (some potentially 1.5m/s)**
		Hydroplanes, hydrofoils and sails	Coastal (especially estuaries) with potential for some devices offshore	Shallow coast or potentially offshore	**2m/s tidal velocity**
		Single Blade	-	-	**-**
		Venturi Effect	**Often rivers, estuarine, narrow straits**	**2m (rivers) 10-60m (marine)**	**2m/s tidal velocity**

3 Identification of Potential Generation Capacity

3.1 The Need to Understand the Potential Generation Capacity

3.1.1 The identification of potential generation capacity within Welsh TWs firstly requires an assessment of the natural resource availability, coupled with deployment and operational requirements and characteristics of marine energy devices and the subsequent arrays which could be developed in suitable areas. The approach taken here has been developed by the RPS project team, drawing on the Stakeholder Participation Process (WAG 2010a and 2010b), previous examples of similar work and the expertise within the Team. It is, however, acknowledged that any such assessment includes a series of assumptions and that interpretation of the results needs to be undertaken in light of these assumptions. In addition, it should be noted that the assessment has been undertaken at a high level and does not have the detail of larger projects (see paragraph 3.5.1). Given the need for transparency and accountability, the process taken and assumptions used have been presented as fully as possible here. The results provide a technically feasible, high-level indication of the potential unconstrained energy yield within Welsh TWs. The areas involved have been re-assessed through the 'approach to sustainable development' (see Section 6), and then essentially via the application of other, non-device data in terms of environmental sensitivity or socio-economic usage, in order to provide a high level assessment of the potential installed capacity achievable from a sustainable development perspective.

3.1.2 The MRESF has been developed by the RPS project team on behalf of the WAG in order to provide a management tool for achieving low carbon energy production from marine sources in a sustainable manner. In addition to the aspects briefly noted above, it follows that a critical step in the MRESF development is the comparison of how much installed energy capacity/energy yield can be achieved sustainably against the energy potential identified by the WAG for the sector (see Section 3.4).

3.2 Wave and Tidal Stream Resource

3.2.1 The principal source of information on the potential wave and tidal resource available within Welsh TWs has been drawn from the Renewables Atlas (www.renewables-atlas.info/), supplemented, where available, by RPS modelled tidal stream data in various inshore locations. However, it should be acknowledged that the data are on a broad scale, that gaps remain in the inshore tidal stream datasets, with larger gaps in

the inshore wave data, and that site specific data would be required for developments to assess the available resource in detail. The information is, however, the most complete source of wave and tidal stream data in the public domain for Welsh waters and has allowed an appropriate level of detail on resource availability to be developed for Welsh TWs at a national strategic scale.

3.3 Device Requirements and Characteristics

3.3.1 Utilising the resource data described in Section 3.2, the areas offering potential for tidal stream and wave devices have been delimited by applying various criteria to the resource datasets which satisfy the requirements of the marine energy devices as provided by developers directly, or drawn from device literature and websites. In common with the MRESF development process employed throughout this multi-stage project, specific device requirements and characteristics have been used to ascribe a generic grouping to similar devices in order to maintain the device-blind approach necessary in a Government-led initiative. The approach employed in the MRESF, generating generic characteristics and requirements from actual device-specific data, has been taken as it is considered to produce the most accurate representation of device requirements whilst avoiding any potential issues related to anti-competitiveness in the market, which could arise through identifying a specific device over another. The requirements and characteristics of the device categories developed for the MRESF are presented in Table 2.1.

3.4 Renewable Energy Potential of Welsh Waters

3.4.1 The Welsh Assembly Government's Energy Policy Statement (http://wales.gov.uk/docs/desh/policy/100331energystatementen.pdf) includes a table in Appendix 1, which summarises Wales' sustainable renewable energy potential to 2020/2025. It should be noted here that concerns were raised during the Stakeholder engagement process that the information sets a 'benchmark' for minimum energy generation. In practice, the information provides a value which can be tested in the MRESF process, to determine the sustainability of attaining such levels of energy.

3.4.2 The value given in the WAG's Energy Policy Statement for wave and tidal stream is for a target installed capacity of 4GW in the main by 2025, which is equivalent to 9TWhrs/year. It should be noted that the table includes 8.5GW installed capacity for tidal range by 2022, which should be viewed in light of recent announcements on the Severn Barrage (see

www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/severn_tidal_power/severn_tidal_power.aspx). Should tidal range energy be generated in Welsh waters, then this would be expected to lead to a reduction in the level of tidal stream in the locality, with the issue considered for the outer Severn/inner Bristol Channel in Section 6.7.

3.4.3 Although the MRESF is looking at the sustainability of achieving the 4GW installed capacity from wave and tidal stream, it is important to note that for the industry to reach that level in the main by 2025 a considerable amount of expansion in the sector would be required and that the available energy can only be translated into electrical power if such development is enabled. It is also likely that early developments will primarily be small and include demonstrator sites, with commercial scale deployments of arrays anticipated to follow later. The assessment of available energy made here does not make assumptions about the type or scale of developments that will actually be brought forward, nor does it preclude single demonstrator devices or arrays from being developed, although a representative scale of development is required in order to assess the level of energy available.

3.5 Overview of Process

3.5.1 As noted above, in order to determine the achievability of the 4GW target in a sustainable manner, it is necessary to make an assessment of the potential generation capacity of wave and tidal stream within Welsh TWs. Essentially, this involves making a consideration of the available energy per unit area and assessing how much of that is likely to be extractable, based on practical issues such as device efficiency, device density/spacing in arrays, potential downtime (e.g. around low water/high water for tidal stream devices) etc. It is important to acknowledge that such assessments have attracted a degree of discussion in the wider literature, and that this is a potentially complex topic. The recently announced £8 million project titled 'Performance Testing of Wave and Tidal Array Systems' (PerAWaT), indicates the potential depth of the issue, and the provision of such detail is considered to be outside the scope of the current project. However, in order to assess the sustainability of energy extraction and to provide a Framework that aims towards achieving the 4GW target for marine renewable energy in Wales, it is necessary to understand at a broad level what proportion of the available energy in Welsh TWs has the potential to be converted to electricity.

3.5.2 Given the current debate on the various approaches available to do this, a high level approach to the assessment has been devised. The method has been developed by the

RPS project team and has been subject to considerable discussion and input during the Stage 3 Stakeholder Participation Process (WAG, 2010a and b). To provide a broad overview, the approach has been summarised below.

Identification of Minimum Energy Criteria for 'Resource Area'

3.5.3 For tidal stream devices, a minimum resource of 2m/s Mean Peak Spring Current (MPSC) was used. The use of MPSC provides a method to characterise the overall resource, however it should be noted that other attributes of tidal energy flows (e.g. energy attenuation rates over tidal cycles etc) may also be important in determining suitable device locations at the site specific level. For further comment on the use of 2m/s as the minimum, please see Section 2.2. The resource maps generated for this part of the process identified all areas providing flows of 2m/s MPSC and above with no maximum flow rate limiting the areas. Wave energy devices did not fit so easily to a single minimum resource requirement, with the range of device designs presenting a similarly broad range of resource criteria; ranging from 9kW/m to 40kW/m of wave crest. Again, no maxima were identified from discussions with the industry which would limit deployment in Welsh TWs. It should be noted in any case that the wave energy of Welsh waters is limited to a maximum of approximately 22.4kW/m wave crest (2008 Renewables Atlas data, see www.renewables-atlas.info).

Energy Yield Potential of Individual Device

3.5.4 The energy yield for tidal stream devices has been calculated using the following power formula:

$$P = 0.5(p\ A_0\ V^3)$$

Where P is the swept area of the device (m^2); A_0 is the density of seawater ($1025kg/m^3$); and V is the tidal stream velocity in m/s. The potential energy output is subject to additional reduction based on Betz law which delimits the theoretical maximum kinetic energy which can be extracted from the open flow system (i.e. the tidal stream current passing through and turning the turbine blades). This value under Betz law is 0.593.

3.5.5 The information presented in this current report relates to potential installed capacity, to enable a direct comparison to be made to the 4GW installed capacity contained in the WAG's Energy Policy Statement. However, to enable an assessment of the potential energy yield, additional factors would also need to be applied to the data for both wave and tidal stream where sufficient information is available, for example data such as load

factor (25%) and generator efficiencies (92%), with an additional factor for tidal stream to take account of gearbox transmission efficiency (94%) (DTI, 2005). Once these factors are applied, the data can be converted from GW to TWhrs/year.

Identification of Minimum Size of Project (in MW) to be Representative of 'Commercial Scale'

3.5.6 The MRESF is focused on providing a sustainable development 'route map' for the wave and tidal stream energy sector in Welsh TWs and thus has a clear focus on commercial scale development rather than demonstrator projects. Whilst the development of commercial scale arrays of wave and tidal devices is ambitious within the next few years, the MRESF encompasses a longer term goal of realising marine renewable development potential in the main by 2025. This does not, however, exclude demonstrator sites from being developed, with such sites likely to be a necessary precursor to commercial arrays in any case. The stakeholder engagement process (see WAG, 2010b) raised questions regarding whether the MRESF project has a focus on commercial scale arrays to the exclusion of demonstrator projects, with particular concerns voiced in relation to the exclusion of lower energy demonstration sites and the inclusion of a commercial array footprint during the assessment of potential resource.

3.5.7 It is recognised that developers may choose a lower energy site for such demonstrator sites and hence be located outside the areas of resource identified in the MRESF. However, experience from demonstrator sites chosen to date does not necessarily support this and, in any case, the MRESF is not intended to prevent development in areas not identified during the project – it is recognised that as the knowledge base increases and devices are developed further, new areas of potential resource may become available. Concerns were also raised by stakeholders (see WAG, 2010b) that the MRESF has a focus on commercial and not demonstrator size projects. The inclusion of a commercial array size project within the assessment of potential resource does not exclude smaller or larger developments, being purely a reflection of the need for a geographic footprint of a development to be factored in when calculating the potential resource within a given area i.e. the resource areas identified are open to any marine renewable development subject to required consents.

3.5.8 The current strategy development has used a commercial project size of 30MW capacity in common both with other studies undertaken for the wave and tidal stream sector and also as a reflection of the size of projects under Round 1 of the offshore wind farm leasing programme, which were limited to projects of 30 devices (rather than 30MW).

The comparison with offshore wind is pertinent to the current project, as the size of development (30 devices) was sufficient to attract companies to invest and develop at a scale where an appropriate level of return on investment could be made, but at the same time limiting the size of projects to ensure a phase of monitoring and understanding of the implications of such developments was achieved, before larger projects were taken forward. It should be noted, however, that the footprint of a 30MW array will vary between devices, based on a number of device related factors (see Paragraphs 3.5.10-3.5.15 and Table 3.1).

3.5.9 There has been a considerable amount of stakeholder input on this matter, including on the selection of an appropriate hypothetical 'commercial scale' project and the perceived consequences for demonstrator scale projects. However, the preferred scales of project recommended have been rather varied, ranging from c5MW projects through to 100MW+. With this in mind, the project has currently determined 30MW to be a reasonable size and clearly a compromise between the two extremes cited from stakeholders. To reiterate, the use of the 30MW figure does not preclude the development of smaller or larger developments, whether demonstrator or commercial.

Size of Area Required For Commercial Array

3.5.10 The size of the area required for the development of a 30MW project is a product of the number of devices required to achieve 30MW installed capacity (from the device energy yield calculated using the formula presented in paragraphs 3.5.4-3.5.5) and the spacing requirements of the devices (deployment density).

3.5.11 For tidal stream devices, the spacing of devices can be as small as 50m apart, provided the devices are not positioned within the tidal stream shadow of adjacent devices. If the layout of the site does result in devices being placed within the tidal shadow of another device, current information from developers is that they may need to be a minimum of 10 diameters apart, although there is a range of work ongoing on this subject and this may be an over or under-estimate. However, it is apparent that the separation distances of devices is likely to be closely linked to the size of the device and, assuming the target capacity of each tidal device is 1MW, the size of a device is also dependent on the tidal stream velocity at the site (see Energy Yield formula in paragraphs 3.5.4-3.5.5 above). For the purposes of the scenario development, the MRESF project is using the array size criteria given in Table 3.1 for all tidal stream turbines.

3.5.12 When the potential resource areas are mapped for each device type, the resource is generally found in discrete areas, within which several hypothetical development arrays

could fit (e.g. see Figures R-1i to R-10vi). However, given the nature of the potential resource, the GIS data processing also identified a relatively few areas of potential resource which are smaller than the array footprint required. These small areas are generally found individually or in small, patchy groups, potentially offering opportunity to demonstrator devices or strategically positioned arrays. In order to distinguish between the different sized resource areas each is clearly marked on the constraint figures, with resources areas with a footprint less than that required for a 30MW array highlighted in red.

Table 3.1: Summary of Potential Generation Capacity Data for Tidal Stream Devices

Energy Type	Mean Spring Peak Current (m/s)	Indicative installed capacity (mW/km^2) [3]	Indicative Footprint of 30MW project (km^2) [4]
TIDAL STREAM	≥2	6	5

3.5.13 For wave devices, the level of understanding in terms of device spacing criteria is less well developed for many devices, and certainly there is a much wider range of spacing requirements related to the wide range of device types, designs and sizes which would have fundamental implications for the arrangement of devices in an array. As a result, the approach adopted for the MRESF has been to take deployment density data from device developers (where available) and calculate 30MW project sizes applicable to generic device groupings. Insufficient information was available for some device types, with information on potential 30MW array footprint sizes used in the MRESF provided in Table 3.2.

[3]The indicative installed capacity and array footprint values are taken from publicly available information on individual devices together with information supplied by developers during the Stakeholder Participation Process. No error band has been applied as to do so would be highly subjective.

[4]This has been determined by calculating the power formula for a device within an area of 2m/s current flow to determine the maximum output of a single device (device sizes ranged from 10-25m rotor diameter) and therefore identifying the number of devices required for a 30MW array. The footprint of the array was then calculated by determining the spacing requirements of this number of devices based on the swept area and a separation of 10 turbine diameters.

Table 3.2: Summary of Potential Generation Capacity Data for Wave Devices

Energy Type	Device Type Group	Device Type Sub-Group	Indicative installed capacity (MW/km^2)[5]	Indicative Footprint of 30MW project (km^2)
WAVE	Shoreline	Oscillating Water Column (OWC)	Insufficient data held	-
		Hydraulic pressure	Insufficient data held	-
		Overtopping	Insufficient data held	-
	Nearshore	OWC	4.6	1.5
		Overtopping collector	-	-
		Single point/buoy	0.9	7.5
		Oscillating wave surge converter	4.6	1.5
	Offshore	OWC	1.1	9.5
		Single point/buoy	0.9	7.5
		Multi-buoy	1.6	4.3
		Attenuators	8.4	0.85
		Overtopping collector	1.8	3.75

3.5.14 Once this sequence of steps had been completed for the device type categories, it was possible to determine, within the context of commercial scale developments, what the energy yield per unit area within Welsh TWs might be.

[5] This has been determined by calculating the power formula for a device within an area of 2m/s current flow to determine the maximum output of a single device (device sizes ranged from 10-25m rotor diameter) and therefore identifying the number of devices required for a 30MW array. The footprint of the array was then calculated by determining the spacing requirements of this number of devices based on the swept area and a separation of 10 turbine diameters.

3.5.15 Two further issues merit consideration in this process. Firstly, the calculations on energy yields within Welsh TWs from wave and tidal stream devices do not include any correction to reflect maintenance or component failure at any given time. Whilst an arbitrary figure could be applied to reflect redundancy, it is difficult to do so with any degree of confidence at the current time, since there are few devices from which to draw information on such aspects. The second issue relates to the achievability of development in these areas. Whilst there is a relatively high level of detail provided in terms of other spatial constraints which follows these initial resource estimation steps, it is impractical to assume that 100% of the resource areas identified in Steps 2-5 of the Stage 3 approach to sustainable development would be developable (see Section 6). The application of a further factor in estimating developable resource area is therefore included in the energy figures presented, resulting in a 60% reduction in capacity/energy yield, which has been applied to all values of installed energy capacity given in this report. It should be noted that the reduction factor has not been applied to other values e.g. the footprint of areas of resource.

3.5.16 The reduction factor of 60% has been adopted by the RPS project team, in consultation with the Steering Group, to ensure that practicality remains at the heart of the process of deployment capacity estimation. Although the reduction factor significantly reduces the headline figure (i.e. 40% thereof), this process has been applied to accommodate a range of additional 'constraints' which arise purely from a practical perspective when considering likely device array deployments and device-farm operations. These include the following:

- A need to provide space between individual projects (e.g. for buffers for operation and maintenance access and for avoidance of resource shadowing from adjacent projects);
- A need to accommodate other users even where such uses/users have a relatively low constraint rank scoring. Clearly there is a need to recognise that even where an 'acceptable' reduction in available area for an activity occurs as a result of a renewable energy scheme development, it would not necessarily follow that the reduction in a large proportion of the total available space for this activity would be similarly acceptable. It would also be hard to argue that such an eventuality could be viewed as sustainable development;

- The anticipated need for mitigation measures to reduce wider potential impacts on environmental systems, given that the potential for energy reduction over a wide development area offers potential for far-field effects;
- A realistic view of the potential capacity (and perhaps interest) of the sector to construct over the totality of potential lower-constrained resource areas given the timeframe of present day to, in the main, 2025; and
- A recognition of the likelihood of some proportion of the areas identified within the MRESF to be subject to a greater level of constraint due to site specifics that are not apparent at the strategic scale.

4 Unmapped Hurdles to Development and Informative Data Layers

4.1 Unmapped Hurdles to Development

4.1.1 Of the potential hurdles (or constraints) to the development of marine renewables in Welsh TWs identified in Stages 1 and 3 (RPS, 2008 and WAG, 2011b), not all have a geographic element and as such these cannot be included in the constraint mapping process, which has a requirement for GIS data and is discussed in further detail in Section 5. These unmapped constraints have therefore not been directly included in the development of the GIS based 'approach to sustainable development', presented in Section 6. However, it is important that these potential constraints are not excluded from consideration and hence have been noted here. Continued interest in these factors was also highlighted during the stakeholder engagement process (WAG, 2010b).

Practical Constraints

4.1.2 Practical constraints relate to issues around financing, sourcing of materials, equipment and personnel (including regulator) together with issues such as moving equipment to site and linking the resulting power to the point of use. These are discussed in more detail in Section 7.2 of the Stage 1 report (RPS, 2008) and although they do not in general represent potential limitations on achieving consent, they do have the potential to cause issues for development.

4.1.3 Of significant importance is access to the electricity transmission network (the grid), which was subject to more detailed consideration in Section 5.5 of the Stage 1 report (RPS, 2008). Grid access is primarily limited by timescale and finance (i.e. in theory any project can be connected to the grid provided the financial cost and timescale provision required by the grid provider are met), and proximity to the grid is therefore an important consideration for any marine renewable development. The existing grid, together with the planned interconnector link to Ireland, have been included as informative data layers in the approach to sustainable development, described in Section 6. Distance from grid as a constraint on development is likely to vary depending on issues such as the scale of a development and grid capacity. In addition, grid connection is a potential constraint on development of a particular site and not a potential constraint on the consenting process of that site (constraints on consent are the basis for the constraints assigned in the MRESF, see Section 5). As such, it was not considered feasible or appropriate to

assign a degree of constraint on development based on distance from the grid, although it is recognised that lack of access to the grid is likely to have implications for delivery of projects.

Support

4.1.4 Issues linked to support extend to government support, including public funding and clarity in the legislative and planning requirements, together with other supportive measures and initiatives such as the provision of test sites. Although such issues cannot be mapped, they can be decisive both for individual projects (e.g. local opposition or difficulties in the consenting process) and for the industry (e.g. funding of projects such as the MRESF). Such support can be implemented at various levels, with the views of the Welsh Assembly Government as regards to renewable energy in Wales are clearly articulated in the Energy Policy Statement (http://wales.gov.uk/docs/desh/policy/100331energystatementen.pdf).

Legislative Considerations

4.1.5 RPS (2008) summarised the main potential constraints on marine renewable energy developments that are linked to the legislative process. Although the legislative framework for marine renewable energy developments has changed since Stage 1 ended (see WAG (2011b) for a summary), the overarching issues still apply and can be summarised as follows:

- Strategic Environmental Assessment (the Offshore Energy SEA2, which includes Welsh waters, will be available in early 2011, see www.offshore-sea.org.uk/consultations/Offshore_Energy_SEA_2/index.php);
- Sustainability and the 'bigger picture' (how to include climate change benefits into the equation);
- Achieving consent (difficulties on a project specific basis);
- Potential for changes to the consenting process (uncertainty can create difficulties and not all of the recently proposed changes have been finalised, see www.nationalpolicystatements.org.uk); and
- Public Inquiry (the potential need is a significant financial and time cost).

4.1.6 Comment was made within the Steering Group of the possibility that certain legislative and policy constraints could potentially alter should priorities shift and renewable energy becomes more important.

Data Requirements

4.1.7 Broad scale mapping projects such as the MRESF have a significant need for data, with the accuracy of and certainty in the outputs of the project being determined by the quality and quantity of that data. The key potential data constraints identified in Stage 1 were discussed in RPS (2008). Following Stage 2 and now during the completion of Stage 3, it is clear that these constraints still apply to many data types and can be summarised as follows:

- Data ownership, licensing and availability (holding a dataset does not necessarily enable the user to display it in reports as hard copy or in an interactive GIS or web based system);
- Natural and climate induced change (these issues are rarely addressed in broad scale datasets but are important for understanding the context of a dataset and for sustainability issues); and
- Uncertainty and the precautionary principle (lack of or insufficient data can lead to uncertainty and a precautionary approach may be necessitated, potentially over-constraining developments).

4.2 Informative Data Layers

4.2.1 The MRESF is built upon a series of GIS data layers that describe the existing environment of Welsh TWs, including socio-economic and environmental conditions. Considerable effort has been made during the progress of the MRESF project to ensure that the most complete baseline data for Welsh TWs are sourced, with the following summarising the approach taken:

- Detailed literature search during Stage 1, as updated during Stage 3 (RPS, 2008 and WAG, 2011b);
- Extensive stakeholder involvement during Stage 1 and Stage 3 (RPS, 2008 and WAG, 2010b);
- Engagement with organisations involved in key or parallel work (WAG, 2010b); and
- Good understanding of the limitations of the datasets and a project specific assessment of confidence.

4.2.2 A full list of the datasets sourced is presented in Appendix A. It should be noted that the information is restricted both by data availability, e.g. some potentially desirable data layers such as the distribution of OSPAR species and habitats were not available, and

by the limitations inherent in any strategic level data layer, e.g. the fish ecology data layer is restricted by number of species. Notably, subsequent to the finalisation of the MRESF constraint mapping updates to the fish ecology data layers used in the MRESF (see Figures B-8i and B-8ii) were made available, with these included as informative data layers and shown in Figures B-8iii to B-8vi.

4.2.3 The data layers held are key to the MRESF since they are central in determining the potential for geographic overlap between areas of potential wave and tidal stream resource and existing socio-economic and environmental conditions. As with any strategic (or broad scale) mapping project, it is important to ensure both that the data layers held are as complete as feasible and that a good understanding of the potential limitations of that data is attained, notably including data gaps and the quality of the base data held. For example, in a mobile species data layer it is important to consider whether the gaps in species presence are due to a genuine lack of species presence or are merely a function of the data collection effort. In addition, standardisation is rare across data from such disparate sources, since they are each generated for a specific purpose.

4.2.4 To ensure the data layers held are appropriate for use in the constraint mapping undertaken for the MRESF project, an assessment of confidence in each dataset was made, with the process followed to assess data coverage and quality described in more detail below and presented in Diagram 4-1. The assessment of data confidence resulted in some datasets been used for informative purposes only, being displayed in the baseline data figures (see Figures B-1 to B-21) and not taken forward into the subsequent constraint mapping (see Section 6). It should be noted that where datasets are excluded from the subsequent constraint mapping stages and displayed as informative only, this is not necessarily a reflection of the quality of that dataset, with the assessment of whether to include individual datasets being a function of the requirements of the project. Where data layers are identified as being 'informative' this is a combination of two factors, as described below.

Assessment of Confidence

4.2.5 The approach taken when assessing confidence has been generated by the RPS project team and draws on methods applied in previous broad scale mapping projects, for example the Crown Estate's MaRS (www.thecrownestate.co.uk/mars) and the Defra Marine Spatial Planning Pilot (www.abpmer.net/mspp), with amendments designed to focus the method on the requirements of the MRESF. The assessment method is

summarised in Diagram 4-1, with data layers that are categorised a confidence level of A-C included in the constraint mapping process (see Section 6) and those which are labelled 'informative' displayed in the baseline data maps only (Figures B-1 to B-21). The complete list of datasets presented in Appendix A includes the assessment of confidence for each individual data layer. It should be noted that the degree of confidence within data layers taken forward to the constraint mapping remains variable, with the level of variability adding to the potential level of constraint (i.e. greater uncertainty in the data has the potential to lead to greater consenting risk). However, it is considered within the project team and Steering Group that the data layers used are appropriate for the purposes of the MRESF, with increased certainty only likely to be achieved as additional data is collected.

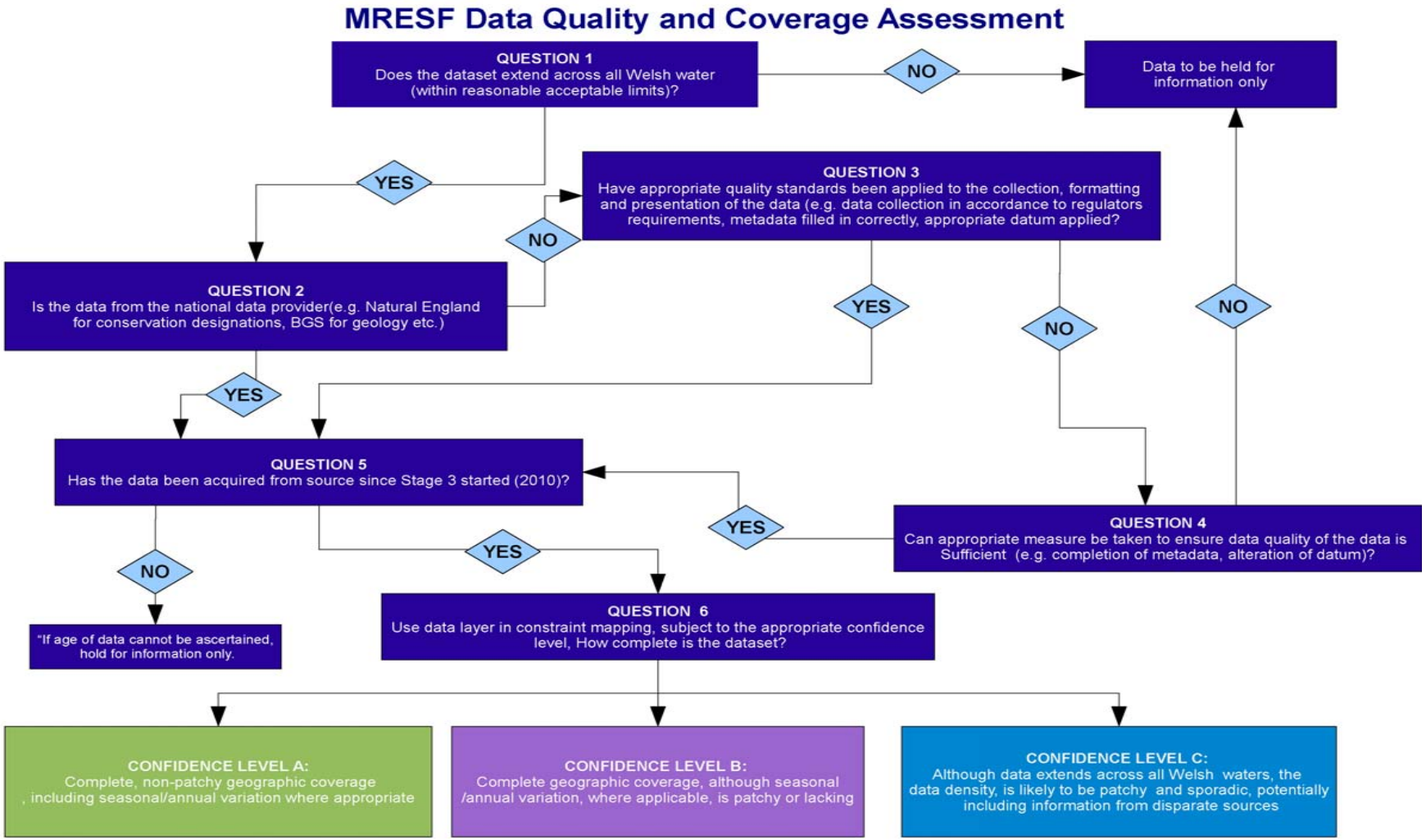


Diagram 4-1: Approach taken to assessing MRESF based confidence

GIS Datasets not Appropriate for Constraint Mapping

4.2.6 A number of datasets are held within the MRESF that would be given a confidence assessment via the process summarised in Diagram 4-1, but have not been considered appropriate for use in constraint ranking and hence have been labelled as 'informative' in Appendix A. The main type of data layer for which this applies can be summarised as follows:

- Certain onshore features e.g. location of aerodromes, for which the potential issue relates to radar (which is constraint ranked) and not physical sites;
- Careful selection of data layers when more than one data layer provides information on the same issue, both to ensure that the issue is included fully in constraint mapping but also to prevent 'double counting' should the same issue be mapped on more than one data layer;
- Some onshore land use descriptions e.g. common land; and
- Some baseline data layers for the offshore area, e.g. the HabMap data, which are highly complex data layers, with the issues more appropriately considered on a site by site basis (although known key ecological features are included through designated sites and individual species data layers e.g. marine mammals).

4.2.7 The decision to limit data layers used in the constraint mapping to strategic level datasets, i.e. those that cover Welsh TWs as a minimum, was made to ensure that the constraint mapping applied could be given equal weighting across Welsh TWs. There are a number of high quality datasets identified by the MRESF that cover local or regional areas of sea only and it was considered that to include these in the constraint mapping may give an unrealistic view of the level of constraint in areas not covered by the data layer, i.e. implying a relatively lower level of constraint that may not necessarily be the case.

5 Constraint Management

5.1 Definition of a Constraint

5.1.1 A significant aspect of Stage 1 was to identify potential constraints on the development of wind, wave, tidal stream and carbon capture and storage in Welsh TWs. Of these, it is the potential constraints on wave and tidal stream that are of particular interest to Stage 3. The various constraints identified were grouped into a number of potential 'hurdles to development', which can be summarised as follows:

- Practical limitations (e.g. financing, sourcing of materials, grid connection etc);
- Device specific issues (e.g. resource availability, water depth, distance from shore etc);
- Support (ranging from local interest to government level and including issues such as financing, research etc);
- Legislative considerations (e.g. SEA, sustainability, consenting and nature conservation legislation (the latter included in the constraint mapping through the location of existing, planned and proposed sites together with data layers provided by CCW on the known location of designated features and mobile species);
- Existing use (i.e. existing human use such as shipping, fisheries and MOD); and
- Data requirements (e.g. quantity and quality of available data, ownership issues and cost of acquisition).

5.1.2 Of the development issues/constraints identified, a number are relatively intangible or descriptive and hence difficult to define, with those that do not have a geographic element discussed in Section 4.1. However, several are more definitive and include a geographic element, and can thus be displayed in GIS and used in constraint mapping. Of the above hurdles to development, those that have been taken forward into the MRESF mapping aspect of Stage 3 as potential constraints include device specific issues and existing use. A limited number of the legislative considerations also contain a geographic element, with these included in the GIS mapping (primarily through sites designated to meet legal requirements e.g. SACs, SPAs and SSSIs). For a limited number of terrestrial features (National Parks and National Trust land), where these were not included in the seascape mapping, a Zone of Theoretical Visibility was generated to ensure full inclusion in the constraint mapping (see WAG, 2011b). For all

features where the available data is presented in either line or point form, a radii buffer has been added to enable inclusion into the constraint mapping, and the range of this included in Appendix A.

5.1.3 The data search undertaken during Stage 1 (as updated during Stage 3) has provided a large number of GIS data layers which collectively provide a strategic overview of the existing social, economic and natural environment of Welsh TWs. A full list of the data layers held by the project is provided in Appendix A. Where individual data layers represent a potential constraint on development, each has been graded by the RPS project team in consultation with the project Steering Group on a 1-5 scale. The aim of grading the constraints is to enable a broad scale assessment of the potential degree of constraint that each data layer may represent for the consenting of marine renewable energy developments. It is recognised that although the level of constraint that a given data layer represents may differ between individual device types (and hence require site specific assessment e.g. EIA), in order that a broad scale and strategic assessment of potential constraints can be made, a broader assessment is required. Therefore, the RPS project team and the Steering Group considered the potential for each GIS data layer to represent a constraint on marine renewables based on five broad groups of energy development types, namely:

- Wind;
- Tidal stream (surface piercing);
- Tidal stream (wholly submerged);
- Wave (surface piercing); and
- Wave (wholly submerged).

5.1.4 Although wind has not been considered in detail in Stage 3 (for the reasons detailed in WAG (2011b)), the constraint ranking assessment for wind has been included here for information and comparison to the wave and tidal stream.

5.1.5 The definition for each constraint rank grade is given in Table 5.1.

Table 5.1: Definition of Constraint Rankings[6]

Grade	Description
No grade	Receptor distribution is presented for informative purposes only and no firm constraint value can be ascribed at the broad scale
1	No likely constraint/assessment required
2	Constraint assessment/study required, but low likelihood of delay
3	Constraint potentially complex and will require detailed assessment, but unlikely to stop development
4	Significant issue/constraint – probable delay and could possibly stop the project
5	Likely to preclude development

5.1.6 During the stakeholder engagement process (WAG, 2010b), clarity was sought on what was considered when assigning constraint rankings together with how the existing natural environment and anthropogenic interests are prioritised within the constraint ranking process. The constraint ranks were assigned to individual data layers by the RPS project team in collaboration with the Steering Group, drawing on the varied backgrounds, interests, knowledge and expertise within both groups. The constraint ranks applied are included in the table of data layers presented in Appendix A. The various aspects taken into consideration when a constraint ranking was applied included the following (in no particular order):

- Degree of legislative protection;
- Stakeholder engagement with the issue;
- Potential significance of impact; and
- Importance of receptor (e.g. military, strategic, public value).

5.1.7 The understanding of potential significance of impact from wind, wave and tidal stream was initially investigated in Stage 1 (RPS, 2008), whereby the potential impact pathways

[6] Note: The term 'delay' takes into consideration issues such as potential sensitivity/significance, together with issues such as a requirement for additional data

for each receptor were highlighted and discussed (including references where available). The information was subsequently updated as appropriate in Stage 3 (WAG, 2011b). It is recognised that the degree of potential impact will depend on project specifics, for example construction methods, timing etc, however this level of detail will need assessment at the project level, including the application of appropriate mitigation if required, with the approach taken within the MRESF being applicable at the strategic level and being inherently precautionary.

5.1.8 It should be noted that the potential significance of impact is one of several factors and not the sole reason for the constraint rank assigned. The overriding factor for the constraint score was 'consentability' – i.e. how significant a constraint would be in terms of achieving consent rather than purely considering how significant the potential impact on the environment might be. Consideration of the constraint rankings was also made in light of any potential limitations of the data layers, any potential for variability that is not evident in the data layer (e.g. seasonal/annual/geographic) and the need to ensure no 'double counting' of constraints occurs (see Section 5.2). The issue of data limitations is likely to remain for some of the data layers, even where a confidence level A has been assigned to a data layer. Examples of this will include some natural environment baseline data layers, for example marine mammals or birds, where the data layer provides coverage across Welsh waters and originates from the key data provider but where it is likely that data patchiness still exists within the 'complete' dataset.

5.1.9 For some constraints, the data can be grouped, e.g. the shipping density has sub-layers which have been grouped based on the number of vessels per year. These sub-layers have different constraint ranks applied as appropriate. However, within a data layer that is not sub-divided, and for those which are sub-divided within individual sub-layers, the assignment of a constraint rank has been made on a broad scale and strategic basis, essentially applying the same level of constraint for individual data layers or sub-layers across Welsh TWs. The approach could therefore be considered precautionary. There is, however, potential to consider geographic variability in the level of constraint within a data layer or sub-layer.

5.2 Cumulative Data Layers (Constraints)

Handling of Cumulative Data Layers

5.2.1 Broad scale mapping projects are, in general, informed by a large number of data layers and the MRESF is no exception. Careful management and processing of the data layers used in the constraint mapping is required to ensure 'double counting' does not occur (see Section 5.1 and Appendix A). The potential for double counting was also raised during the stakeholder participation process (WAG, 2010b). Central to the approach is the careful selection of data layers used in the actual development of the constraint maps (see Section 4.2). Where more than one data layers holds information on the same constraint, or the same type of constraint, the GIS team undertook checks on those data layers to ensure that the data layers taken forward into the constraint mapping would not result in double counting (potentially removing some data layers from the constraint mapping by marking them as being for informative purposes only). Appendix A includes the full list of data layers held, with those used in constraint mapping assigned a constraint rank and those excluded labelled informative.

Display of Cumulative Data Layers

5.2.2 A number of projects completed recently have had a degree of overlap with the MRESF in that they also hold substantial numbers of data layers displayed at a broad, strategic scale. Such projects include the various renewable energy Strategic Environmental Assessments, Defra's Marine Spatial Planning Pilot and the Crown Estate's MaRS. A review of methods used to display the data layers in these and other projects and, where available, the methods used to facilitate aspects such as constraint mapping was undertaken as part of Stage 3 of the MRESF (see WAG, 2011b) prior to the finalisation of the MRESF approach, informing and developing the methodology described below.

When assessing potential constraints, there is a need to overlay several data layers, which can be difficult to interpret in flat, 2-D paper copy. While individual data layers, or groups of layers, can be displayed in separate figures, this does not enable easy comparison between such data layers. However, to simply overlay multiple data layers tends to result in a highly confusing mass of information, with much of the meaningful detail lost due to overlapping information.

In response to the problem and in order to increase the information that can be derived from a 2-D paper copy, the RPS project team has developed a method of displaying additional information that provides the viewer with information on the number of

constraint data layers for a given area and the various constraint rankings associated with those data layers. It cannot, however, provide detailed information on which layers are present. The information is presented in a numerical format, essentially summarising the number of data layers present for each of the constraint ranking groups, from those ranked number 5 (the first digit) through to those ranked number 1 (the final digit). Thus, a code of '0,0,0,0,0' would indicate that no constraint data layers are present. For an area with two data layers with constraint rank 2, three data layers with constraint rank 4 and one with constraint rank 5, the information would be presented as follows:

Data Layers Ranked				
5	4	3	2	1
1	3	0	2	0

5.2.3 To further minimise the amount of information displayed on the map, the numerical code shown reflects the maximum constraint rank presented, i.e. if the maximum constraint rank is three, then 3 digits will be shown, if the maximum constraint rank is 5, then all 5 digits will be shown. Diagram 5-1 provides an example of the numerical code and its use in the GIS mapping.

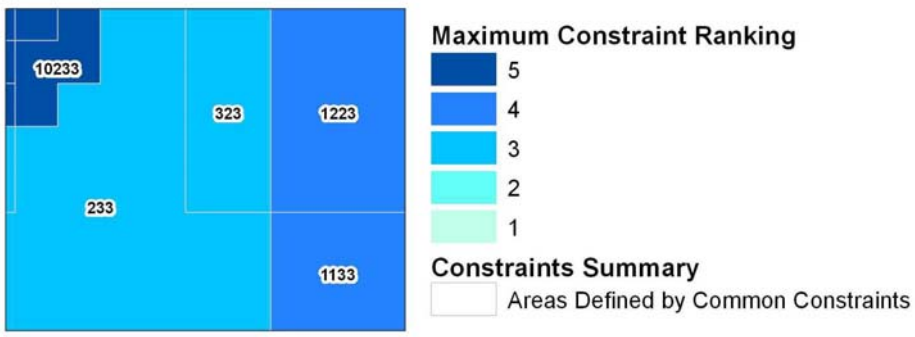


Diagram 5-1: Example of the Numerical Code used to Representative the Level of Constraint from Cumulative Data Layers

5.2.4 The cumulative display has been used in Step 5, to enable the viewer to see the overall level of constraint in the wave and tidal stream resource. Figure numbers for this are C-1 to C-1ix, with Step 5 discussed in more detail in Section 6.7.

5.3 Data Layers that were Unavailable within the MRESF Timeframe

5.3.1 A number of projects that are working on baseline data information applicable to Welsh TWs have a similar timeframe as the MRESF, with contact having been maintained with a number of these projects. However, given differences between project requirements, not all the datasets were available within the MRESF timeframe. Particular data layers of interest to the MRESF include the following:

- The existing fish spawning and nursery areas (Coull, *et al.*, 1998) are being revised by Cefas but were not available for the constraints mapping (included as informative layers only); and
- Work to identify potential Highly Protected Marine Reserves in Welsh TWs and MCZs in adjacent waters.

5.3.2 The approach taken to data storage and processing in the MRESF has been designed to facilitate the addition of new data layers, and as such these data layers could be added for subsequent revisions of the MRESF. Notably, although the revised fish ecology data layers were not available for the constraint mapping, it has been possible to include the data for informative purposes (see Figures B-8iii to B-8vi).

5.4 The Importance of Mitigation and Increased Certainty

5.4.1 As summarised in Section 5.1, the current constraint rankings applied to individual data layers are related to a number of factors including the potential significance of impact, (which is affected by the degree of uncertainty in the assessment of potential impact) and the inclusion of mitigation. The potential to reduce the level of constraint that a specific data layer represents is an important consideration, particularly when moving from a broad scale, strategic study such as the MRESF to a site specific project. It is at the site specific level that differences between devices such as construction techniques would become important.

Uncertainty

5.4.2 Where uncertainty exists, a precautionary approach to assessing the significance of an impact is often adopted, potentially resulting in elevated levels of constraint being assigned to data layers used in constraint mapping (i.e. higher uncertainty leads to greater consenting risk). Given the relatively limited number of full scale wave and tidal stream devices that have been deployed at sea, there remains a degree of uncertainty associated with sources and magnitudes of potential impact. To reduce the level of

uncertainty, an increase in the availability of empirical data would be required to enable a more scientifically robust, less precautionary assessment of the level of constraint to be made. It should be noted that an increase in scientific certainty would not automatically be followed by a reduction in constraint, although as a minimum an increase in understanding would allow for improvements in management and mitigation, which in turn may reduce the level of impact. A summary of relevant research understood to be in progress is provided in RPS (2008) and updated in WAG (2011b).

Strategic Mitigation

5.4.3 The second main method that could be applied to reduce the level of a constraint is mitigation. Essentially, on a site specific basis, certain measures can be applied to reduce the impact of a proposal on a given constraint. Such measures may include timing of construction periods, design/layout modifications etc, the specifics of which would need to be determined and assessed on a site by site basis. However, mitigation measures can also be viewed at a generic level, through the strategic consideration of mitigation, with Table 5.2 summarising examples of mitigation measures that may be of relevance to wave and tidal stream developments.

5.4.4 It should be noted that the levels of constraint assigned to individual data layers used in the constraint mapping represent the likelihood of that data layer affecting the 'consentability' of a project. The inclusion of mitigation could be applied on a site specific basis to reduce the level of constraint, if applicable, however it is considered that the constraint level assigned to individual data layers in the MRESF reflects the existing situation as regards consentability. As highlighted in Section 5.1, the assessment on constraint draws on several factors, one of which is potential significance of impact, with mitigation being an integral part of the consideration of potential significance. Therefore mitigation has not been included as a separate consideration in Section 6 'Approach to Sustainable Development'.

Table 5.2: Generic Mitigation Measures Potentially Applicable for Wave and Tidal Stream

Generic Mitigation Measures	Purpose
Best practice guidance	A number of best practice guidance notes are available for marine development, an increasing number of which are specific to marine renewables (wind, wave and tidal stream). These are summarised in WAG (2011b) and include issues such as water/sediment quality, shipping, navigational markings etc.

Generic Mitigation Measures	Purpose
Site selection	Use of adequate baseline data to avoid particularly sensitive sites, e.g. vulnerable species, roosting/haulout sites, areas of sensitive sediment dynamics etc.
Design of development layout (micro siting)	Layout design is a function of device requirements however the consideration of issues such as species present (e.g. benthic ecology, key feeding areas for mobile species etc), visual impact etc can reduce potential impacts. Amendments to the layout during the assessment process can provide further mitigation, if assessment/modelling/monitoring reveals potential issues.
Construction methodology	Choice of construction methodology is in part dictated by the device type and the specific environmental conditions at the development site. However, choice of construction method can reduce the potential impact, e.g. the method chosen for cable laying, scour protection, installation and type of foundations etc. The 'least impacting' option may differ between sites, depending on the site conditions.
Construction timing	Timing the construction window can avoid sensitive periods e.g. migration, breeding etc.

5.5 Combining Constraint Groups and Device Types

5.5.1 The main outputs from the MRESF project require the location of the potential energy resource for the device types identified in Section 2 to be compared to the geographic distribution of the constraints as listed in Appendix A. Constraint rankings have been undertaken for generic wave and tidal stream devices, with separate consideration for devices that are surface piercing or fully submerged. However, not all device type groups include individual devices that are fully submerged; some comprise groups of devices that are surface piercing only. Table 5.2 summarises per device type group whether the group consists of solely surface piercing devices or if it also includes fully submerged devices. GIS constraint mapping has been undertaken for each device type group, however for device type groups that only include surface piercing examples, no constraint mapping has been undertaken for the fully submerged option.

Table 5.3: Summary of Occurrence of Surface Piercing and/or Fully Submerged Devices in the Device Type Groups

Energy Type	Device Type Group	Device Type Sub-Group[7]	Surface Piercing	Fully Submerged
WAVE	Shoreline	OWC, hydraulic pressure, overtopping	Yes	No
	Nearshore	OWC	Yes	No
		Overtopping collector	No resource mapped	
		Single point/buoy	Yes	Yes
		Oscillating wave surge converter	No resource mapped	
	Offshore	OWC	No resource mapped	
		Single point/buoy	Yes	Yes
		Multi-buoy	Yes	No
		Attenuators	No resource mapped	
		Overtopping collector	Yes	No
TIDAL	Stream	Rotating turbine	Yes	Yes
		Hydroplanes, hydrofoils, venturi effect and sails	Yes	Yes
		Single blade	No resource mapped	

[7] Where a device is noted as 'no resource mapped', this does not exclude the device from development in Welsh TWs only that based on the available broadscale resource data and device characteristics, no resource has been identified at the strategic level for these devices

6 Approach to Sustainable Development

6.1 Description of Approach

6.1.1 The approach taken to assessing the sustainable development of marine renewables in Welsh TWs was initially described and discussed during the Stakeholder Participation Process (SPP) (WAG 2010a and 2010b). Generating discussion and input on the methodology was a key part of the SPP, during which it became apparent that the terminology used, namely the term 'Scenario' to describe each step, was considered confusing, since each step is required to assess sustainable development and therefore cannot be taken in isolation (WAG, 2010b). In addition, the title of Step 3a has been changed from 'least damaging ecologically' to 'least damaging environmentally', to more accurately reflect the process followed (WAG, 2010b). To address the confusion, some changes in terminology have been made, however the overall approach is very similar to that originally described, as the stakeholders engaged generally deemed it to be logical, representing a transparent method for achieving the desired objective of sustainable development (WAG, 2010b). The approach taken is summarised below:

- **Step 1 'Maximum Energy Generation'**. The maximum amount of marine renewable energy that could be developed if no constraints were in place;
- **Step 2 'Maximum Achievability'**. What is feasible from an engineering/practical constraints perspective? What effect do device type requirements such as depth/distance from shore and connection to grid have?;
- **Step 3a 'Least Impacting Environmentally'**. What are the implications for renewable energy generation of overlaying known environmental constraints on Step 2?;
- **Step 3b 'Least Impacting for Existing Use'**. What are the implications for renewable energy generation of overlaying existing use (social and economic) constraints on Step 2?;
- **Step 4 'Most Sustainable for individual device types'**. Taking consideration of the outputs from Steps 1-3, this step will explore the potential effect of different combinations of environmental and socio-economic constraints on each marine renewable device type; and
- **Step 5 'Sustainable Development of marine renewables'**. Can the 4GW target for marine renewable energy in Wales, as described in the Welsh Assembly's

Energy Policy Statement, be met, whilst balancing environmental, economic and social aspects?

6.1.2 Although such a step by step approach does inevitably lead to some repetition, it was considered necessary both by the RPS project team and during stakeholder engagement for two main reasons:

- To ensure that the approach is sustainable, by placing equal weight on the requirements of the marine renewables industry and the existing socio-economic and natural environment; and
- To ensure a transparent and auditable approach.

6.1.3 It should be noted that as discussed in Section 3.5 (paragraphs 3.5.14-3.5.15), the level of potential energy given in all the tables in Section 6 includes a 'reduction factor' of 60%, although the reduction has not been applied to the km^2 footprint of the resource areas. The reduction factor is aimed at ensuring a realistic and sustainable approach and is similar in approach to that taken by other strategic level projects such as the work by the Offshore Valuation Group (2010). It should also be noted that the levels of energy described here are for potential installed capacity of marine renewable energy and that for such levels to be achieved in the main by 2025, significant growth in the sector will be required. The values for installed capacity presented throughout the report include the reduction factor, however the area footprint in km^2 does not. As such, there is a degree of flexibility as regards the siting of developments within each resource area.

6.1.4 As discussed in Section 3.1, the data used on potential wave and tidal stream resource is from the Renewables Atlas (www.renewables-atlas.info/), supplemented, where available, by RPS modelled tidal stream data in various inshore locations. However, some gaps remain in the broad scale data layer, primarily for wave energy inshore. As such, it is not feasible to identify if these locations hold commercial levels of wave energy. For clarity, these areas are highlighted on the appropriate constraint maps as follows:

- Step 2 resource data gaps – gaps in the wave energy source data are highlighted as blue blocks, with the geographic areas meeting the step 2 requirements of depth and distance from shore highlighted within the blue blocks for information;

- Steps 3a and 3b resource data gaps – geographic areas meeting the step 3 requirements of depth and distance from shore, but where no data for wave energy resource is available, are highlighted by yellow hatching; and
- Step 4 resource data gaps – geographic areas meeting the step 4 requirements of depth and distance from shore, but where no data for wave energy resource is available, are highlighted by yellow hatching.

6.2 Step 1 – Maximum Energy Generation

6.2.1 The original purpose behind Step 1 was to understand how much energy could be generated from Welsh TWs based purely on the minimum energy requirements of device types. This step provides an understanding of whether there is a potential resource for each device type in Welsh TWs, with the intention of illustrating how the various constraints applied in the later steps reduce the level of energy that could be generated. However, the step does have the potential to generate unrealistic areas or levels of resource, notably for shoreline wave devices and as a result of significant geographic overlap between resource areas suitable for more than one device type. Shoreline devices, as the name suggests, would in practice be most likely to have a coastal distribution only, even if these meet the minimum energy criteria, and to map a potential resource that included offshore areas would therefore present a misleading impression of the potential resource for that device type. As such, the information presented has been limited to a tabular format, providing an overview of whether a potential resource exists in Welsh TWs for each device type.

6.2.2 It should be noted that the location of a potential resource based on minimum energy requirements only is not necessarily compatible with potential device constraints, particularly the onshore wave devices as noted above. These practical issues, together with the issue of geographic overlap between resource areas, are considered in Step 2 (Section 6.3).

Table 6.1: Summary of Step 1 - Maximum Energy Generation

Energy Type	Device Type Group	Device Type Sub-Group	Based on Minimum Energy Requirements only, is there a Potential Resource in Welsh Waters? [8]
WAVE	Shoreline	OWC, hydraulic pressure, overtopping	Yes but located in offshore areas unrealistic for development. Inshore areas of wave energy not covered by the resource data available. May, however, provide potential resource.
	Nearshore	OWC	Yes
		Overtopping collector	No
		Single point/Buoy	Yes
		Oscillating wave surge converter	No
	Offshore	OWC	No
		Single point/buoy	Yes
		Multi-buoy	Yes
		Attenuators	No
		Overtopping collector	Yes
TIDAL	Stream	Rotating turbine	Yes
		Hydroplanes, hydrofoils, venturi effect and sails	Yes
		Single blade	No

[8] Based on a comparison of the minimum energy requirements of the different device types, which has drawn on publicly available information (e.g. developer websites and literature) and feedback from the stakeholder participation, and the wave and tidal stream energy within Welsh waters. See Table 2.1

6.3 Step 2 – Maximum Achievability

6.3.1 Step 1 assessed the potential for a wave and tidal stream resource area in Welsh TWs for each device type, based on minimum energy requirements only. However, to enable an assessment of how much of that resource area may be achievable, there needs to be a consideration of the effect of device specific constraints on the extent of any potential resource areas. Step 2 has been designed to address this aspect. A large number of potential device constraints were considered during Stage 1 (RPS, 2008), ranging from substrate type to water depth. However, from the information sourced and feedback received during stakeholder engagement in Stage 1 and Stage 3, it is apparent that a limited number are key to mapping commercially viable sites. The device constraints included in Step 2 can be summarised as follows:

- Minimum energy requirements (defined in Table 2.1 and considered in Step 1, see Table 6.1);
- Water depth – many devices have a minimum and/or maximum water depth in which developers would look to deploy a device;
- Distance from shore – many devices have a minimum and/or maximum distance from shore that developers would look to deploy a device; and
- Connection to the electricity transmission network (the grid) – always a key consideration, access to the grid is an important factor when developers assess the commercial viability for a site. However, it is not considered feasible to set a distance limit from the existing grid beyond which development would be uneconomical and hence the data layer is included for informative purposes only.

6.3.2 Available data on these device type constraints are provided in Table 2.1.

6.3.3 The objective in Step 2 is to map the potential energy resource by device type, bringing in the practical constraints of depth and distance from shore and displaying both the existing electricity grid and planned grid links to Ireland for information (the East-West Connector). The resultant resource maps provide a more focused search area than that assessed in Step 1, highlighting areas anticipated to be of interest to developers based on current device requirements and existing strategic level wave and tidal stream resource data. It should be noted that as device development progresses and technology improves, the commercial viability of different levels of energy, deeper/shallower water and sites at greater distance from shore may increase, thus opening up additional areas to commercial interest (see Section 2.2). In addition, the

data on potential resource used (see paragraph 3.2.1) does have limitations and therefore site specific data may reveal additional areas of resource.

6.3.4 Grid connection is a significant consideration when siting potential developments, hence the inclusion of the existing grid and the planned East-West connector as an informative layer. However, as highlighted in Section 4.1.3, proximity to grid is a difficult constraint to fix in terms of distance, partly because the commercially viable distance between grid and development site is primarily a financial consideration. The financial viability of bridging the gap between grid and site, together with the availability of grid capacity, would need to be determined on a project by project basis.

6.3.5 A summary of the potential resource areas per device type is provided in Table 6.2 and Figures R-1 to R-10. The main areas of commercial tidal stream energy are located around Anglesey, the Lleyn Peninsula, Pembrokeshire and the Bristol Channel, with commercial wave resource located around Pembrokeshire.

6.3.6 The initial identification of potential areas of resource includes areas of significant geographic overlap between device types. Presenting information on the potential resource per device type alone (as presented in Table 6.2) would therefore indicate unrealistic levels of energy potential since this includes significant double counting. Therefore, a total potential resource area for wave and tidal stream has been generated by identifying all areas of geographic overlap and then selecting a single device type within each of these areas. Following discussion and agreement with the Steering Group, the main priority when determining the device type selected has depended on which device type currently offers the best potential energy return per unit area. However, in areas where wave and tidal stream resource overlap, tidal stream has been selected, for the following reasons:

- Feedback from stakeholders indicates that wave developers are likely to avoid high tidal stream areas and tidal stream developers would look to avoid unnecessarily harsh wave climates; and
- The need to safeguard the areas of tidal stream resource which, compared to the area of potential wave resource are relatively small, both to enable the industry but also in light of the more advanced state of the technology.

6.3.7 The area of overlap between wave and tidal stream resource is in any case small and limited to a small area off Pembrokeshire and with the potential to deliver an installed capacity in the order of approximately 0.05 GW. The resultant amalgamated energy resource map, constrained by device specific requirements only, is presented in Figure

S2-1. Use of an amalgamated resource map does not preclude devices being selected according to the relative degree of conflict with existing interests. However, it is considered that the level of knowledge on potential impacts is highly variable between devices (see RPS, 2008 and WAG, 2011b), which together with the need of the MRESF to remain device blind, lead to the development of constraint rankings that are split according to the source of energy (i.e. wave or tidal stream) and visibility (i.e. surface piercing or fully submerged) only.

6.3.8 During the amalgamation of overlapped resource areas into a consolidated resource area, the potential resource areas for the two types of tidal stream device groups with a resource identified in Step 2 were looked at in considerable detail (the 'rotating turbines' and 'hydroplanes, hydrofoils, venturi effect and sails'). Both device type groups use the same minimum energy level, although there are differences in the depth and distance constraints. These subtle differences made it difficult to determine, for tidal stream, which device type group to proceed with in areas of overlap, since there appeared to be little difference in potential energy return based on the device type information available to the MRESF (although the issue is discussed in the wider literature, particularly by individual developers). As such, to ensure that no bias exists between technologies, the tidal stream resource areas have been merged to form a single tidal stream device resource area for Steps 2-5. As the geographic extent of resource is similar for all types of tidal stream device, using a single resource area does not prevent selection of specific devices for a given location.

6.3.9 The potential energy within the amalgamated resource area suggests a potential wave and tidal stream resource of 7GW installed capacity (Figure S2-1). This does suggest that the 4GW installed capacity marine energy potential identified for Welsh TWs by the WAG would appear to be achievable, based on minimum energy requirements and device specific constraints only. However, as for Step 1, a significant note of caution is attached here. In Step 2, the resource areas have not been considered within the context of existing use or environmental sensitivity and development across the entire area is unlikely to be considered a sustainable development path (see Steps 3-5).

6.3.10 It should also be noted that it is considered likely by the RPS project team that the method of calculating tidal stream resource is currently very conservative, as it assumes all areas offering a minimum of 2m/s do not provide any resource in excess of this value, i.e. the entirety of the area is characterised by water flow rates of 2m/s. There are areas within the ≥2m/s flow where higher levels of tidal stream energy are found and the potential energy return per unit area, and hence the potential energy from such sites,

would be greater. This issue is explored further in Section 6.7. Conversely for wave, the method for determining potentially exploitable resource is based on far less data than the assessment for tidal stream, and as a result the potential level of energy from wave is considered to be at the higher end of what may be achievable. The information used in assessing the wave resource is, however, based on the best information currently available.

Table 6.2: Summary of the Energy Potential from Step 2 'Maximum achievability'.

Energy Type	Device Type Group	Device Type Sub-Group	Potential Resource identified in Step 2	Energy Requirement	Depth Requirement (m)	Distance from Shore (km)	Maximum Extent of Potential Resource (km^2)	Area of Exclusive Resource (km^2)	Area of Overlapping Resource (km^2)	Potential Installed Energy Capacity per device type (GW)[9]
WAVE	Shoreline	OWC, hydraulic pressure, overtopping	Figure R-1i	Annual 15-30kw/m, significant wave height 1m and period 8-12s	5-15m	0-0.1km	Depth and distance constraint not met, possibly due to limited inshore wave resource data			
	Near shore	OWC	Figure R-2i Figure R-2ii	9kw/m	10-50m	0-2km	151	144	8	1
		Overtopping collector	No	Not achieved in Welsh TWs (insufficient device type data to identify a resource)						
		Single point/buoy	Figure R-3i Figure R-	20-25kW/m, significant wave	30-100m	0.5-8km	13	0	13	<0.1

[9] Potential Installed Energy Capacity per individual device type (GW), based on the device specific information sourced, the resource data available and the assumptions and caveats detailed in this report. Values presented are pre-consideration of overlap as discussed in Sections 6.3.6 to 6.3.8.

Energy Type	Device Type Group	Device Type Sub-Group	Potential Resource identified in Step 2	Energy Requirement	Depth Requirement (m)	Distance from Shore (km)	Maximum Extent of Potential Resource (km^2)	Area of Exclusive Resource (km^2)	Area of Overlapping Resource (km^2)	Potential Installed Energy Capacity per device type (GW)[9]
			3ii	height above 1m, wave period 5-15 seconds						
		OWC	No	Not achieved in Welsh TWs (minimum energy requirements not met in available resource data)						
	Offshore	OWC	No	Not achieved in Welsh TWs (minimum energy requirements not met in available resource data)						
		Single point/buoy	Figure R-5i Figure R-5ii	20kW/m	20-100m	2-20km	789	0	789	1
		Multi-buoy	Figure R-4i Figure R-4ii	2m wave height or 4kw/m	20-100m	3-20km	789	0	789	2
		Attenuators	Figure R-6i	55kW/m	30-100m	5-50km	-	-	-	-
		Overtopping collector	Figure R-7i Figure R-7ii	24kw/m	20m	5-25km	1,760	959	802	6
TIDAL	Stream	Rotating turbine	Figure R-8i Figure R-	2m/s spring peak velocity	20m	0-5km	164	0	164	0.4

Energy Type	Device Type Group	Device Type Sub-Group	Potential Resource identified in Step 2	Energy Requirement	Depth Requirement (m)	Distance from Shore (km)	Maximum Extent of Potential Resource (km^2)	Area of Exclusive Resource (km^2)	Area of Overlapping Resource (km^2)	Potential Installed Energy Capacity per device type (GW)[9]
			8ii Figure R-8iii Figure R-8iv							
		Hydroplane, hydrofoils, venturi effect and sails	Figure R-9i Figure R-9ii Figure R-9iii Figure R-9iv	2m/s spring peak velocity	10-120m	0.5-5km	199	31	168	0.5
		Single blade	No	Not achieved in Welsh TWs (insufficient device type data to identify a resource)						

6.4 Step 3a – Least Impacting Environmentally

6.4.1 Step 2 assessed where the potential wave and tidal stream resource can be found in Welsh TWs, based on known commercial requirements for energy, water depth and distance from shore. Step 3a is focused on the known environmental constraints, essentially investigating which constraints may overlap areas of potential resource as mapped in Step 2 and how constrained these areas may be.

6.4.2 Section 5.1 described the constraints considered, together with the various rankings applied. A full list of all constraints included as 'environmental' is given in Appendix A, with all baseline data presented in Figures B-1 to B-21. GIS mapping of the level of environmental constraint applicable to the device types for which a resource has been identified in Step 2 is shown in Figures S3A-1 to S3A-9.

6.4.3 The type of information of interest within these figures includes the following:

- How much of each area of potential resource remains unconstrained by environmental factors;
- Which constraints overlay which areas of potential resource, and how much area do they cover; and
- What is the relative contribution of the different constraint ranks to the overall level of constraint – i.e. what area is affected by constraints up to and including rank 1, and then progressively up to and including 2, 3, 4 and 5.

6.4.4 Table 6.3 summarises the level of constraint that the environmental data layers represent to the areas of potential commercial wave and tidal stream resource in Welsh TWs. The information is presented to indicate the extent of the resource that is affected by the various levels of constraint rank.

Table 6.3: Summary of the Environmental Constraints Applied During Step 3a 'Least Impacting Environmentally'

Energy Type	Device Type Group	Device Type Sub-Group	Surface Piercing	Fully Submerged	Unconstrained Resource (km^2)	≤ Rank 1 (km^2)	≤ Rank 2 (km^2)	≤ Rank 3 (km^2)	≤ Rank 4 (km^2)	≤ Rank 5 (km^2)
WAVE	Shoreline	OWC, hydraulic pressure, overtopping	No resource identified in Step 2		-	-	-	-	-	-
	Nearshore	OWC	Figure S3A-1	No devices	151	0	0	7	151	0
		Overtopping Collector	No resource identified in Step 2		-	-	-	-	-	-
		Single point/Buoy	Figure S3A-2	Figure S3A-3	13	0	0	0	13	0
		Oscillating wave surge converter	No resource identified in Step 2		-	-	-	-	-	-
	Offshore	OWC	No resource identified in Step 2		-	-	-	-	-	-
		Single point/buoy	Figure S3A-5	Figure S3A-6	789	0	0	544	789	0
		Multi-Buoy	Figure S3A-4	No devices	789	0	0	544	789	0
		Attenuators	No resource identified in Step 2		-	-	-	-	-	-
		Overtopping collector	Figure S3A-7	No devices	1760	0	53	1155	1760	0
TIDAL	Stream	Rotating turbine, Hydroplanes, hydrofoils, venturi effect and sails	Figure S3A-8	Figure S3A-9	200	0	0	99	200	0
		Single blade	No resource identified in Step 2		-	-	-	-	-	-

6.5 Step 3b – Least Impacting for Existing Use

6.5.1 Step 2 assessed where the potential commercially exploitable wave and tidal stream resource can be found in Welsh TWs, based on known commercial requirements for energy, water depth and distance from shore. Step 3a investigated the environmental constraints on these areas of resource. Step 3b is similar to Step 3a in its method and approach, however the focus is on the existing socio-economic constraints, essentially investigating which constraints may overlap areas of potential resource as mapped in Step 2 and how constrained these areas may be. A full list of all constraints included as socio-economic is given in Appendix A, with all baseline data presented in Figures B-1 to B-21. GIS mapping of the level of socio-economic constraint applicable to the device types for which a resource has been identified in Step 2 is shown in Figures S3B-1 to S3B-9.

6.5.2 The type of information of interest within these figures includes the following:

- How much of each area of potential resource remains unconstrained by socio-economic factors;
- Which constraints overlay which areas of potential resource, and how much area do they cover; and
- What is the relative contribution of the different constraint ranks to the overall level of constraint – i.e. what area is affected by constraints up to and including rank 1, and then progressively up to and including 2, 3, 4 and 5.

6.5.3 Table 6.4 summarises the level of constraint that the socio-economic data layers represent to the areas of potential commercial wave and tidal stream resource in Welsh TWs. The information is presented to indicate the extent of the resource that is affected by the various levels of constraint rank.

Table 6.4: Summary of the Socio-Economic Constraints Applied During Step 3b 'Least Impacting for Existing Use'

Energy Type	Device Type Group	Device Type Sub-Group	Surface Piercing	Fully Submerged	Unconstrained Resource (km^2)	≤ Rank 1 (km^2)	≤ Rank 2 (km^2)	≤ Rank 3 (km^2)	≤ Rank 4 (km^2)	≤ Rank 5 (km^2)
WAVE	Shoreline	OWC, hydraulic pressure, overtopping	No resource identified in Step 2		-	-	-	-	-	-
	Nearshore	OWC	Figure S3B-1	No devices	151	0	0	92	125	151
		Overtopping collector	No resource identified in Step 2		-	-	-	-	-	-
		Single point/buoy	Figure S3B-2	Figure S3B-3	13	0	0	0	11	13
		Oscillating wave surge converter	No resource identified in Step 2		-	-	-	-	-	-
	Offshore	OWC	No resource identified in Step 2		-	-	-	-	-	-
		Single point/buoy	Figure S3B-5	-	789	0	0	257	735	789
			-	Figure S3B-6	789	0	48	257	735	789
		Multi-buoy	Figure S3B-4	No devices	789	0	0	257	735	789
		Attenuators	No resource identified in Step 2		-	-	-	-	-	-
		Overtopping collector	Figure S3B-7	No devices	1760	17	24	623	1598	1760
TIDAL	Stream	Rotating turbine, Hydroplanes, hydrofoils, venturi effect and sails	Figure S3B-8	-	200	0	0	73	161	200
			-	Figure S3B-9	200	0	58	101	161	200
		Single blade	No resource identified in Step 2		-	-	-	-	-	-

6.6 Step 4 – Most Sustainable for Individual Device Types

6.6.1 The sustainable development remit within which the MRESF operates brings a need to consider marine renewable energy development in the context of existing environmental and socio-economic considerations. This need was the driver behind the separate consideration of environmental and socio-economic factors in Steps 3a and 3b, to ensure that these were considered in detail and incorporated fully into the MRESF. To ensure a sustainable approach, it is necessary to bring all the constraints together to look at the combined effect, to gain an understanding of which constraints occur in which resource areas together with the degree of constraint that these represent. In order to do this, the outputs from Steps 1, 2, 3a and 3b have been progressed through into Step 4, to show the full amount of constraint for each device type, including existing environmental and socio-economic constraints. The GIS mapping for Step 4 is presented in Figures S4-1 to S4-9, with a full list of all constraint layers given in Appendix A.

Summary of Constraints Overlapping Areas of Potential Resource

6.6.2 An important part of Step 4 is to understand which constraints have geographic overlap with which areas of resource, which for the purposes of Step 4 has been limited to those with ≥10% overlap. The information is important, both to understanding the potential level of constraint within a given area and also in highlighting which constraints are likely to affect which resource areas and if there are key constraints that occur in numerous areas. The last point is a key consideration in understanding potential cumulative impacts and in highlighting topics that may benefit from further research. The information is presented for each device type for which a resource has been identified in Step 2 in full in Appendix B and is summarised below.

6.6.3 There is a small area in Cardigan Bay running approximately north/south, which occurs in all the Step 4 Figures albeit it outside any potential resource area, that is affected by constraint layers ranked to a maximum of 3 and may at first appear to be an anomaly. On closer examination, the reason for this area was revealed to be due to the presence of a number of rank 3 data layers (cetacean vulnerability, plaice and sole nursery grounds, SAC boundary and diving bird vulnerability), being bounded by constraint rank 4 data layers. The rank 4 data layers are marine military practice areas to the west and the rank 4 cetacean vulnerability data layer to the east, with the main reason for the strip being separated into 3 being the presence of the feature ‘reef’ within the SAC boundary.

Constraints within Nearshore Wave OWC Resource Areas

6.6.4 The nearshore wave OWC resource area, as defined in Step 2, covers some 151km^2. A total of 55 constraint data layers fall within this resource area, with these listed in Appendix B, including details of the constraint rank, the total area of the constraint and the percentage of the constraint data layer directly overlapping the nearshore wave OWC resource area. The data layers for which 10% or more of the total area are directly affected by the nearshore wave OWC resource area are as follows:

- Heritage Coast (constraint rank 3, covers 479km^2, 14% of which would be directly affected)
- Fish Spawning Areas - Herring (constraint rank 3, covers 101km^2, 32% of which would be directly affected);
- Marine nature reserves (constraint rank 4, covers 16km^2, 95% of which would be directly affected); and
- SAC habitat features (sea caves) (constraint rank 4, covers 52km^2, 16% of which would be directly affected).

Constraints within Nearshore Wave Single point/Buoy Resource Areas

6.6.5 The nearshore wave single point/buoy resource area, as defined in Step 2, covers some 13km^2. A total of 21 constraint data layers fall within this resource area, with these listed in Appendix B. There is no data layer for which 10% or more of the total area is directly affected by the nearshore wave single point/buoy resource area, with the maximum being 4% of the explosives dumping site (constraint rank 5).

Constraints within Offshore Wave Single point/Buoy Resource Areas

6.6.6 The offshore wave single point/buoy resource area, as defined in Step 2, covers some 789km^2. A total of 21 constraint data layers fall within this resource area, with these listed in Appendix B, There is no data layer for which 10% or more of the total area is directly affected by the offshore wave single point/buoy resource area, with the maximum being 3.7% of the Explosive Dumping Sites data layer (constraint rank 5).

Constraints within Offshore Wave Multi Buoy Resource Areas

6.6.7 The offshore wave multi buoy resource area, as defined in Step 2, covers some 789km^2. A total of 37 constraint data layers fall within this resource area, with these listed in Appendix B. The data layers for which 10% or more of the total area are directly affected by the offshore wave multi buoy resource area are as follows:

- Shipping Density - Total Ships per Year (>50 - 250) (constraint rank 3, covers 2,115km^2, 11% of which would be directly affected);
- Shipping Density - Total Ships per Year (>250 - 1000) (constraint rank 4, covers 2,160km^2, 11% of which would be directly affected);
- National Parks (constraint rank 1 for fully submerged and 3 for surface piercing, covers 7,839km^2, 10% of which would be directly affected);
- Fish Values - £5,000-£10,000 (mean landing value per cell per year) (constraint rank 2, covers 4,635km^2, 12% of which would be directly affected);
- Explosive dumping site (constraint rank 5, covers 54km^2, 46% of which would be directly affected);
- Diving Seabirds Vulnerability (combined species, constraint rank 4) (covers 843km^2, 25% of which would be directly affected); and
- Cetaceans Vulnerability (combined species, constraint rank 3) (covers 6,584km^2, 10% of which would be directly affected).

Constraints within Offshore Wave Overtopping Resource Areas

6.6.8 The offshore wave overtopping resource area, as defined in Step 2, covers some 1760km^2. A total of 55 constraint data layers fall within this resource area, with these listed in Appendix B. The data layers for which 10% or more of the total area are directly affected by the offshore wave overtopping resource area are as follows:

- Shipping Density - Total Ships per Year (>0 - 10) (constraint rank 2, covers 979km^2, 12% of which would be directly affected);
- Shipping Density - Total Ships per Year (>10 - 50) (constraint rank 2, covers 1,060km^2, 20% of which would be directly affected);
- Shipping Density - Total Ships per Year (>50 - 250) (constraint rank 3, covers 2,115km^2, 23% of which would be directly affected);
- Shipping Density - Total Ships per Year (>250 - 1000) constraint rank 4, covers 2,160km^2, 23% of which would be directly affected);
- Shipping Density - Total Ships per Year (>1000 - 5000) constraint rank 4, covers 1,829km^2, 15% of which would be directly affected);
- National Parks (constraint rank 1 for fully submerged and 3 for surface piercing, covers 7,839km^2, 21% of which would be directly affected);

- National Trust Land Ownership (constraint rank 1 for fully submerged and 3 for surface piercing, covers 12,887km^2, 11% of which would be directly affected);
- Seascape sensitivity to wave farms - medium (constraint rank 2, covers 4,597km^2, 12% of which would be directly affected);
- Seascape sensitivity to wave farms - medium/high (constraint rank 2 for fully submerged and 3 for surface piercing, covers 3,294km^2, 21% of which would be directly affected);
- Seascape sensitivity to wave farms – high (constraint rank 3, covers 2,747km^2, 14% of which would be directly affected);
- Wrecks (constraint rank 3, covers 96km^2, 11% of which would be directly affected);
- Submarine Cables - In Use (constraint rank 5, covers 199km^2, 14% of which would be directly affected);
- Renewable Energy Interests in Welsh Waters (constraint rank 5, covers 779km^2, 12% of which would be directly affected);
- Fish Values - £5,000-£10,000 (mean landing value per cell per year) (constraint rank 2, covers 4,635km^2, 24% of which would be directly affected);
- Fish Values - £10,000-£20,000 (mean landing value per cell per year) (constraint rank 2, covers 3,363km^2, 13% of which would be directly affected);
- Fish Values - £50,000-£60,000 (mean landing value per cell per year) (constraint rank 4, covers 47km^2, 50% of which would be directly affected);
- Explosives Dumping Sites (constraint rank 5, covers 54km^2, 59% of which would be directly affected);
- Marine Military Practice Areas constraint rank 4, covers 5,385km^2, 11% of which would be directly affected);
- Fish Spawning Areas - Fish Spawning - Sole constraint rank 3, covers 2,787km^2, 11% of which would be directly affected);
- Diving Seabirds Vulnerability (Combined species, constraint rank 3), covers 5,021km^2, 17% of which would be directly affected);
- Diving Seabirds Vulnerability (Combined species, constraint rank 4) (covers 843km^2, 51% of which would be directly affected);

- Cetaceans Vulnerability (combined species, constraint rank 3) (covers 6,584km^2, 21% of which would be directly affected);
- Grey Seals Vulnerability (constraint rank 2, covers 10,880km^2, 13% of which would be directly affected);
- Special Areas of Conservation (Non habitat Features) (constraint rank 3, covers 1,832km^2, 19% of which would be directly affected);
- SAC Habitat Features – Reefs (constraint rank 4, covers 1,442km^2, 12% of which would be directly affected); and
- Dredging Routes (constraint rank 4, covers 667km^2, 10% of which would be directly affected).

Constraints within Tidal Stream Resource Areas

6.6.9 The tidal stream resource area, as defined in Step 2, covers some 200km^2. A total of 50 constraint data layers fall within this resource area, with these listed in Appendix B. The data layers for which 10% or more of the total area are directly affected by the tidal stream resource area are as follows:

- Shipping Density - Total Ships per Year (>5000) (constraint rank 4, covers 95km^2, 19% of which would be directly affected);
- Pilot Boarding Places (constraint rank 5, covers 38km^2, 66% of which would be directly affected); and
- Protected Wrecks (constraint rank 5, covers 5km^2, 31% of which would be directly affected).

Relative Degree of Constraint

6.6.10 Step 4 essentially investigates which constraints overlap geographic areas of potential resource as mapped in Step 2 and how constrained these areas may be. Neither the potential installed capacity nor the sustainability of developing in these areas have been considered in Step 4, with the intention purely being to determine the degree of overlap between resource areas for each device type and the constraints.

6.6.11 Of particular interest here is the relative contribution of the different constraint ranks to the overall level of constraint – i.e. what area of potential resource, as identified in Step 2, is affected by constraints up to and including rank 1, and then progressively and

cumulatively up to and including 2, 3, 4 and 5. This information is summarised in Table 6.5.

Table 6.5: Summary of All Constraints Applied During Step 4 'Most Sustainable for Individual Device Types'

Energy Type	Device Type Group	Device Type Sub-Group	Surface Piercing	Fully Submerged	Unconstrained Resource (km^2)	≤ Rank 1 (km^2)	≤ Rank 2 (km^2)	≤ Rank 3 (km^2)	≤ Rank 4 (km^2)	≤ Rank 5 (km^2)
WAVE	Shoreline	OWC, hydraulic pressure, overtopping	No resource identified in Step 2		-	-	-	-	-	-
	Nearshore	OWC	Figure S4-1	No devices	151	0	0	0	125	151
		Overtopping collector	No resource identified in Step 2		-	-	-	-	-	-
		Single point/buoy	Figure S4-2	Figure S4-3	13	0	0	0	11	13
		Oscillating wave surge converter	No resource identified in Step 2		-	-	-	-	-	-
	Offshore	OWC	No resource identified in Step 2		-	-	-	-	-	-
		Single point/buoy	Figure S4-5	Figure S4-6	789	0	0	187	735	789
		Multi-buoy	Figure S4-4	No devices	789	0	0	197	735	789
		Attenuators	No resource identified in Step 2		-	-	-	-	-	-
		Overtopping collector	Figure S4-7	No devices	1760	0	0	465	1598	1760

Energy Type	Device Type Group	Device Type Sub-Group	Surface Piercing	Fully Submerged	Unconstrained Resource (km^2)	≤ Rank 1 (km^2)	≤ Rank 2 (km^2)	≤ Rank 3 (km^2)	≤ Rank 4 (km^2)	≤ Rank 5 (km^2)
TIDAL	Stream	Rotating turbine, Hydroplanes, hydrofoils, venturi effect and sails	Figure S4-8	Figure S4-9	200	0	0	23	161	200
		Single blade	No resource identified in Step 2		-	-	-	-	-	-

6.7 Step 5 –Sustainable Development of Marine Renewables

The Aim of Step 5

6.7.1 The aim of Step 5 is to bring together the findings from Steps 1-4, to determine the implications of different scales of development for both the potential energy return and for existing constraints. Essentially, Step 5 is aimed at the following:

- Determination of the potential installed capacity – to provide an indication of the potential geographic location and extent of development required to reach and potentially exceed a 4GW level of energy, together with an understanding of the implications for existing constraints – **the high energy yield scenario**;
- Determination of the potential energy return should development be restricted to the resource in areas of lesser constraint – **the low energy yield scenario**; and
- Determination of the implications for wave, tidal stream and existing constraints from a balance between high energy yield and existing constraints – **the medium energy yield scenario**.

6.7.2 It is through an understanding of how the wave and tidal stream industry may interact with existing interests that a Framework for development can be brought forward, although as previously noted the delivery of any of the scenarios is obviously dependant on developments being progressed, consented and constructed. It is not the intention of the MRESF to identify which scenario would be preferred, but to assess the potential level of energy that could be reached in the context of existing interests. The process highlights what the implications of such development may be for existing interests (environmental and socio-economic), providing an opportunity at an early stage to start to address key concerns or issues that may arise, ideally both benefiting existing receptors and enabling development. For example, are some interests at greater 'risk' from wave and tidal stream development than others? Is there a need for additional research to further understand what the impacts may be? Could mitigation be designed at the strategic level to enable development without significantly compromising existing interests?

Within Areas of Device Resource Areas Overlap, which Device Resource Offers the Most Sustainable Option?

6.7.3 As described in Step 2 (see Section 6.3), to enable an overall assessment of potential resource to be made in Step 5 it is necessary to use an amalgamated resource area. The amalgamation of resource areas is not intended to remove the potential to select alternative device types for specific locations, rather, the intention is to provide an indication of the potential maximum energy yield from a given area. The amalgamated resource is given in Figure S5-1. In addition, as discussed in Section 5.2, a number of additional figures have been prepared to accompany Figure S5-1. These essentially show, in numerical digits, the overall cumulative constraints present within the wave and tidal stream resource, both in terms of the different constraint ranks but also how many layers of each constraint rank are present. These are presented in Figures C-1 to C-1ix.

6.7.4 The information presented in Step 5 is referred to as 'wave' or 'tidal stream' only, to avoid any impression of bias towards particular device types. Within the amalgamated resource area, the minimum level of constraint is rank 3 (i.e. no resource has been identified in Step 5 with only constraint rank 1 or 2). Areas ranked 5 are considered 'likely to preclude development' and therefore are not included here. The information used for constraint ranks up to and including 3 is summarised in and depicted in Figure S5-2, with the information for areas constraint ranked up to and including 4 in Table 6.7 and Figure S5-3. The wave energy resource area is found to the west of Pembrokeshire, with a larger area in the more offshore waters and smaller areas closer inshore. The tidal stream resource tends to be more discrete in area and with a smaller footprint overall, occurring around Anglesey, off the Lleyn Peninsula, around Pembrokeshire and the outer Severn/inner Bristol Channel.

Table 6.6: Selection of Energy Group in the Amalgamated Resource for areas constraint ranked up to and including 3 (see Figure S5-2 for geographic locations)

Area ID (Figure S5-1)	Energy Group Selected for Step 5	Area (km^2) ≤ constraint rank 3	Potential Installed Capacity (GW) for device type selected [10]
1	Wave	125	0.4
2	Wave	123	0.4
3	Wave	116	0.4
4	Wave	35	0.1
5	Wave	23	0.1
6	Tidal stream	23	0.1
7	Wave	16	0.1
8	Wave	15	0.1
9	Wave	7	<0.1
10	Wave	6	<0.1

Table 6.7: Selection of Energy Group in the Amalgamated Resource for areas constraint ranked up to and including 4 (see Figure S5-3 for geographic locations)

Area ID (Figure S5-3)	Energy Group Selected for Step 5	Area (km^2) ≤ constraint rank 4	Potential Installed Capacity (GW) for device type selected [11]
1	Wave	1596	5.1
2	Wave	61	0.5
3	Tidal stream	46	0.1

[10] The figures for potential installed capacity should be taken in the context of the previous sections of this report. Although the information from which the figures have been generated has been informed by the best available data, it does include a number of assumptions and hence is subject to a degree of uncertainty.

[11] The figures for potential installed capacity should be taken in the context of the previous sections of this report. Although the information from which the figures have been generated has been informed by the best available data, it does include a number of assumptions and hence is subject to a degree of uncertainty.

Area ID (Figure S5-3)	Energy Group Selected for Step 5	Area (km^2) ≤ constraint rank 4	Potential Installed Capacity (GW) for device type selected [11]
4	Tidal stream	27	0.1
5	Wave	23	0.2
6	Tidal stream	23	0.1
7	Tidal stream	22	0.1
8	Tidal stream	19	0.1
9	Wave	15	0.1
10	Tidal stream	15	<0.1
11	Wave	10	0.1
12	Tidal stream	9	<0.1
13	Wave	5	<0.1
14	Wave	3	<0.1

Development of Step 5

6.7.5 As summarised above, the aim of Step 5 is to bring together the information generated in Steps 1-4 to develop a Framework for the sustainable development of wave and tidal stream in Welsh TWs. It is not the intention of the MRESF to green light or red flag areas for development, rather to assess where the areas of resource are; how much energy can potential be generated from these areas; and what the implications may be for the existing environmental and socio-economic constraints. It should be noted that it is recognised by the MRESF that as understanding of the marine environment increases, both in terms of where the commercial resource is but also the baseline environment and its sensitivity to development, that there is potential for additional areas of potential resource to be identified and for the level of constraint in some areas of resource to be altered. As such, the MRESF is not creating 'no go' areas, however it is equally important to note that based on current knowledge, development outside the areas highlighted in Step 5 is likely to be subject to greater levels of constraint (and hence greater consenting difficulty).

6.7.6 Drawing on the results from Steps 1-4, three development scenarios have been identified for consideration within Step 5, which have the potential to offer a high,

medium or low energy yield. The aim is to understand what the implications of achieving 4GW installed capacity for wave and tidal stream may be for existing constraints[12], while understanding which constraints feature most frequently and which constraints may need particular consideration in order to facilitate the development of the industry in a sustainable manner. Although it is not the intention to simply have a 'trade off' between renewable energy and existing interests, it should be noted that to enable sustainable development of the wave and tidal stream industry a degree of interaction is inevitable.

6.7.7 The first part of Step 5 was to generate a single map of potential resource, removing areas of device type resource overlap as described above and summarised in Tables 6.6 and 6.7 and Figures S5-2 and S5-3. The next part of Step 5 was, in a similar manner to that undertaken in Steps 3 and 4, to calculate the area (in km^2) of potential resource with differing levels of constraint, essentially for areas unconstrained and those constrained up to and including areas ranked 1, 2, 3, 4 and then 5. This information is summarised in Table 6.8, which shows that the minimum level of constraint within areas of resource is 3, with a significant increase in the amount of available energy when areas ranked 4 are included.

Table 6.8: Summary of the Potential Level of Constraint on Wave and Tidal Stream Energy in Welsh Waters

Maximum Level of Constraint within Step 5 Area of Resource	Area of Potential Resource (km^2)	Potential Installed Capacity in Area of Resource (GW)[13]
Unconstrained	0	0
Up to and including constraint rank 1	0	0
Up to and including constraint rank 2	0	0
Up to and including constraint rank 3	487	1.5
Up to and including constraint rank 4	1875	6.4
Up to and including constraint rank 5	Not calculated	Not calculated

[12] see the Welsh Assembly's Energy Policy Statement http://wales.gov.uk/docs/desh/policy/100331energystatementen.pdf

[13]The figures for potential installed capacity should be taken in the context of the previous sections of this report. Although the information from which the figures have been generated has been informed by the best available data, it does include a number of assumptions and hence is subject to a degree of uncertainty.

6.7.8 All areas ranked 5 are excluded from the assessment of potential resource in Step 5, as the definition for Rank 5 is 'likely to preclude development'. It should, however, be noted that all existing renewable energy proposals and applications are included in the constraint mapping, with the data layer ranked '5', as the presence of an existing interest, licence, consent or planning application (or similar) is considered 'likely to preclude development' of all new projects within that area (see Section 5.1). The same assessment is applied to other applications, e.g. marine aggregate dredging licence application or prospecting areas are similarly ranked 5. This does not mean that these sites cannot be developed by wave or tidal stream, merely that an expression of interest in the site has already been made and hence the area is effectively removed from further consideration. However, these areas do, unsurprisingly, hold commercial levels of wave or tidal stream resource which, subject to appropriate consents, could contribute to the overall levels of energy generated in Welsh waters. Given the existing interest in these areas and the commercial levels of resource, it is considered that to completely exclude the available energy within these areas from the calculations of resource in Step 5 would be misleading. As such, the anticipated energy generation from each of these areas has been summarised in Table 6.9. However, as these sites are currently subject to commercial interest, the underlying level of constraint has not been determined nor has the potential energy been added to the overall total.

Table 6.9: Summary of Planned and Proposed Wave and Tidal Stream Projects in Welsh Waters

Planned/Proposed Wave and Tidal Stream Development in Welsh Waters	Location	Installed Capacity (MW)
Wave Dragon	Pembrokeshire	7
Lunar Energy	Pembrokeshire	12
Tidal Energy Ltd DeltaStream Technology	Pembrokeshire	1.2
Marine Energy Ltd	Pembrokeshire	10
Marine Current Turbines	Skerries, Anglesey	10.5

6.7.9 The potential for tidal stream energy (maximum achievable) in the Bristol Channel covers some 70km^2, representing a potential unconstrained installed capacity of 0.14GW (see Diagram 6-1). However, the Welsh Assembly's Energy Policy Statement, which gives the target for renewable energy from wave and tidal stream energy in Welsh

TWs as 4GW installed capacity, also identifies a separate 8.5GW of installed capacity by 2022 delivered by tidal range, the majority of which would be expected to come from the Severn. Should the tidal range energy be realised from the Severn at some future date, it would be expected that the potential for tidal stream energy in the Bristol Channel would be reduced, although by how much is uncertain. The current status of tidal range interest in the Severn is summarised in Section 2.1, in light of which and following a discussion with the WAG and the Steering Group, the tidal stream energy potential within the Bristol Channel has been included in the overall total.

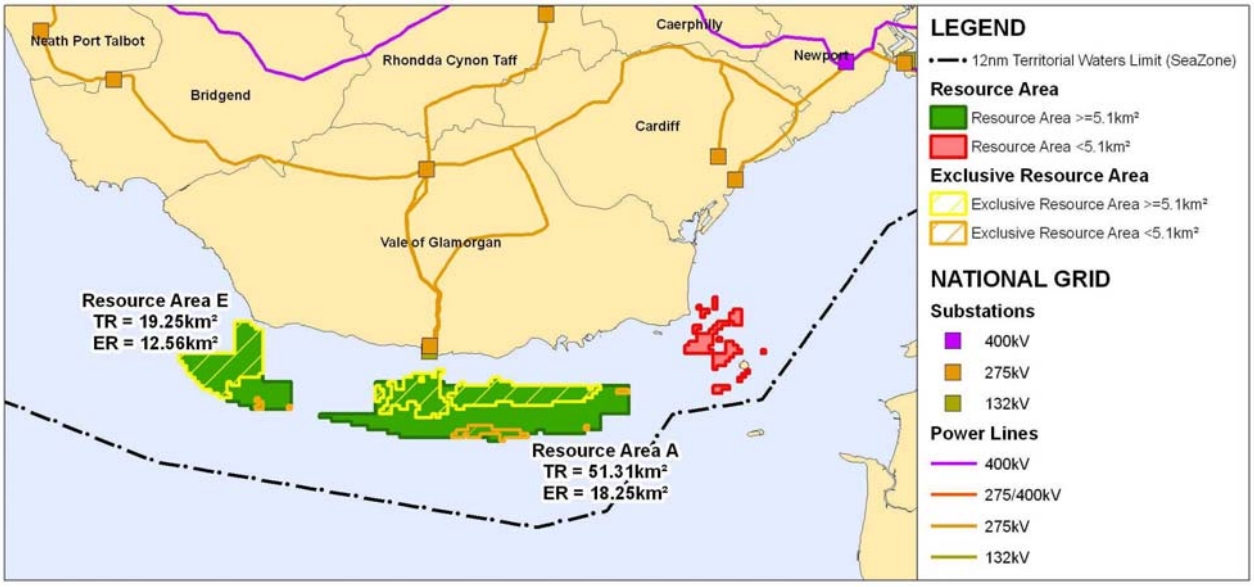


Diagram 6-1: Tidal Stream Resource Area in the Bristol Channel (inset from Step 2 Resource Figures)

6.7.10 The calculations of tidal stream energy resource are based on a conservative assumption that the entire area of potential resource has a tidal flow level of 2m/s. However, within the potential resource it is not unrealistic to assume that there will be areas with a greater flow rate and hence offer the potential for a greater energy return per unit area. The issue is of interest for various reasons, not least to maximise the potential energy return, but also as a possible route to minimising the footprint of development to mitigate any impacts that may result from the need to develop over a greater area. In order to determine how significant this may be, calculations were made using the GIS data on the extent of tidal stream resource identified in Step 2. The results indicate that the increase in available energy, when the tidal flow rates within the resource data are used and not a blanket value of 2m/s, is in the order of 160MW for areas constrained by device requirements only (i.e. minimum energy, depth and distance from shore). By assuming the resource to be 2m/s, this therefore brings a

degree of caution to the values of installed capacity presented within this report, however the approach may not necessarily be appropriate at the site specific level. This additional energy has not been included in the subsequent high/medium/low energy scenario calculations.

6.7.11 The potential need to consider geographic variability in the degree of constraint that individual data layers represent was mentioned in Section 5 and discussed during the Stage 3 stakeholder workshops (WAG, 2010b). Essentially, the broad scale and strategic nature of the project means that individual constraint layers are generally considered to have the same degree of constraint across Welsh TWs, which could be viewed as a precautionary approach and hence lead to areas being 'over constrained'. In practice, a degree of variability is likely in the level of constraint across a data layer, which has been included in the constraint ranking to a certain extent where the data lends itself to the process of sub-layers (e.g. differences in shipping density layers or fish values – see Appendix A). The potential for geographic variability across designated sites was discussed between RPS and the Steering Group, with the following solution for Natura 2000 sites:

- To rank the boundary of SAC and SPA sites as 3;
- To rank the mapped habitat features as 4 (including data processing to ensure no double counting with the boundary of the site); and
- Use of separate data layers for mobile species, ranked from 2 to 4 depending on the vulnerability score assigned by CCW (data layers for marine mammals and birds processed and provided by CCW).

6.7.12 As discussed in Section 3.5 (paragraphs 3.5.14-3.5.15), it should be noted that the level of potential energy given in all the tables in Section 6 includes a 'reduction factor' of 60% for the installed capacity only (values for the footprint of resource areas are presented in their entirety). The installed capacity reduction factor was included for several reasons. These include the need to provide space for operation/maintenance, the potential for energy 'shadows' to be created following the extraction of energy, the need to consider the potential for large areas of features to be affected, the need to accommodate other users even where such uses/users have a relatively low constraint rank score, to include a realistic review of the potential industry capacity/interest within the period to 2025 and to take account of the potential for site specifics to bring additional constraints. In summary, the reduction factor is aimed at ensuring a realistic development scenario and is similar in approach to that taken by other strategic level projects such as the work by the Offshore Valuation Group (2010). It should also be noted that the levels of energy

described here are for potential marine renewable energy development and that for such levels to be generated in the main by 2025, significant growth in the sector will be required.

Scenarios for Marine Renewable Energy Development

6.7.13 The final output from Step 5 is the development of three scenarios, all of which draw on the amalgamated energy resource maps shown in Figure S2-1. It should be noted that assumptions do exist in the baseline data and methodology used to arrive at the figures for energy potential, however the results have been generated using the most robust available information and hence represent the best estimate on current knowledge. The scenarios are summarised as follows:

- **Low energy yield**: which assumes development of all amalgamated resource in areas ranked up to and including constraint level 3. Such development, should it be enabled and consented, has the potential to deliver 1.5GW installed capacity. These areas are highlighted in Figure S5-2.
- **High energy yield**: which assumes development of all amalgamated resource in areas ranked up to and including constraint level 4. Such development, should it be enabled and consented, has the potential to deliver 6.4GW installed capacity. These areas are highlighted in Figure S5-3;
- **Medium energy yield**: which assumes development of all resource in areas ranked up to and including constraint level 3, together with a proportion of areas ranked 4. These areas are highlighted in Figures S5-4 and S5-5;

6.7.14 The purpose of the medium energy scenario is to explore the potential for a 'mid point' between the low energy scenario, which falls considerably short of the WAG's 4GW installed capacity figure, and the high energy scenario, some of which is subject to a considerable number of highly constrained areas. The approach taken has been firstly to determine how much of the amalgamated resource is constrained by a single data layer ranked 4 (regardless of which constraint), and then to determine how much is constrained by up to two overlapping data layers ranked 4. The potential energy when areas constrained by a single rank 4 data layer is included is 3.7GW installed capacity (the medium energy scenario A) and when areas constrained by up to two rank 4 data layers are included is 5.1GW installed capacity (the medium energy scenario B). The potential installed capacity offered by the medium energy scenarios A and B sits well between that offered by the low and high energy scenarios and for this reason, together with the appreciation of increasing levels of constraint should additional rank 4 data

layers be added, the medium energy scenario was not progressed further to incorporate 3 rank 4 data layers. The data layers ranked 4 that have the potential to be directly affected in the medium energy scenarios A and B are summarised in Table 6.10.

Table 6.10: Rank 4 data layers potentially included in the Medium Energy Scenarios A and B

Rank 4 Data Layer	Medium Energy Scenario	Extent of the Medium Resource Area (km^2)	Potential Installed Capacity (GW)
Shipping density - total ships per Year (>250 -1000)	A	201	0.6
	B	361	1.1
Shipping density - total ships per Year (>1000 – 5000)	A	122	0.4
	B	192	0.7
Shipping density - total ships per Year (>5000)	A	-	-
	B	11	<0.1
Fish values - £40,000-£50,000 (mean landing value per cell per year)	A	-	-
	B	16	0.1
Fish values - £50,000-£60,000 (mean landing value per cell per year)	A	-	-
	B	9	<0.1
Marine Military Practice Areas	A	148	0.5
	B	256	1.2
Diving seabirds vulnerability (Combined species, constraint rank 4)	A	111	0.4
	B	238	0.8
Cetaceans vulnerability (Combined species, constraint rank 4)	A	44	0.2
	B	71	0.3
Grey Seals vulnerability (constraint rank 4)	A	0.6	<0.1
	B	41.6	0.2
SAC habitat features – reefs	A	9.3	<0.1
	B	121	0.4
SAC habitat features - sea caves	A	-	-
	B	0.4	<0.1
SAC habitat features - sandbanks	A	-	-

Rank 4 Data Layer	Medium Energy Scenario	Extent of the Medium Resource Area (km^2)	Potential Installed Capacity (GW)
	B	3	<0.1
SAC habitat features - shallow inlets & bays	A	-	-
	B	4	<0.1
Dredging routes	A	6	<0.1
	B	31	0.1

6.7.15 From the information presented in Table 6.10, specifically with reference to what comprises the constraint within these layers, it is clear that enabling development in areas constraint ranked 4 would bring considerable challenges for both developers and consenting authorities. This is perhaps not unsurprising, given the definition of rank 4 as the following:

Significant issue/constraint – probable delay and could possibly stop the project'

6.7.16 In order to appreciate how the rank 4 data layers identified in the medium energy scenarios A and B may affect the resource area, a series of additional figures have been prepared. Figures S5-4i to S5-4iv illustrate which rank 4 data layers occur in the medium energy scenario A and across which section of the resource area. Similarly, Figures S5-5i to S5-5iv illustrate which rank 4 data layers occur in the medium energy scenario B and across which section of the resource area, including the combination of rank 4 data layers where 2 such layers overlap. The information has been generated as an addition to the process, to provide additional information on the key constraint(s) that developers may need to consider should the medium energy scenario be taken forward.

6.7.17 There are several factors to take into account when considering the potential for development in areas with a constraint rank of 4, which as an overview can be summarised as follows:

- Sustainability – at which point does the level of existing constraint make development in an area unsustainable?;

- Need for energy – the inclusion of areas constrained to rank 4 brings the installed capacity closer to or can exceed the 4GW level identified by the WAG[14]. Given the importance of renewable energy to the 'green economy' and overall sustainability of energy supply, to what extent can/should such high level needs affect the consentability of individual projects;
- Do some of the areas subject to constraint rank 4 data layers offer greater amounts of energy than others, and if so is it more sustainable to develop in these areas?;
- At which stage do site specifics need to play a part – there is likely to be geographic variability in most of the data layers which is not evident or feasible to map at the strategic level (although such variability has been mapped where feasible), potentially enabling a lower level of constraint to be identified at the site specific stage; and
- Need to consider cumulative constraint in areas ranked up to and including 3 (e.g. is the area affected by 1 rank 3 data layer of 12?) and the potential for a significant percentage of a data layer to be affected by an identified resource area (e.g. does the low energy scenario include most or all of the geographic extent of individual data layers, or just small percentages?).

6.7.18 Given the types and level of constraint presented in the high energy scenario in Figure S5-3, and the importance of the interests potentially affected, it is difficult to put forward an argument for the consenting of sustainable development across the entire high energy scenario resource area, as to do so would essentially prioritise wave and tidal stream energy above the existing interests. In a similar fashion, the medium energy scenario also includes areas with a constraint rank of 4, which would bring challenges both for the practicalities of development and for the consenting process. If wave and tidal stream development in Welsh waters is to progress beyond the low energy scenario, it is necessary to consider potential approaches to development in areas subject to a rank 4 constraint. To provide the most information on which a decision can be made as regards both the sustainability and practical potential of development within these rank 4 areas, the medium energy scenario has been presented in the form of A and B, with discussion on the issues associated with each of the data layers involved presented below.

[14] see the Welsh Assembly's Energy Policy Statement http://wales.gov.uk/docs/desh/policy/100331energystatementen.pdf

Shipping Density

6.7.19 The shipping density data layers were sourced from Anatec in 2008 to provide information on current shipping movements within a calendar year. It should be noted that the data provided do not include the movements of 'non-routine traffic' such as fishing vessels, military vessels, tugs, dredgers and recreational craft, however the majority of these are included separately in the MRESF in the appropriate data layers. The movements and routeing information is combined in the ShipRoutes database and used to calculate the number of ships per year passing through each cell. The data is sourced from a number of places, including the following:

- Offshore installation, standby vessel and shore-based survey data (radar and AIS);
- Satellite tracking of ships;
- Passage plans obtained from Ship Operators;
- Consultation with ports and pilots; and
- Admiralty charts and publications.

6.7.20 The potential for development of marine renewables in areas with significant levels of shipping depends on a number of factors, which would need to be addressed at the site specific level, and include issues such as the following:

- Vessel traffic tends to follow certain routes, the centre line generally having the highest density of traffic with levels reducing towards the edges. The relative position of the resource area to the shipping lanes would be important, as the areas closer to the edges may be constrained less than areas towards the centre;
- There may be potential for fully submerged devices to be deployed in areas with higher levels of vessel traffic, depending on issues such as clearance at low water and provision for access during construction, maintenance and decommissioning;
- There are legal provisions for applications to be made to amend navigation routes. However, these are associated with time constraints and bring a further uncertainty regarding the potential for agreement with the relevant authorities; and
- Potential cost implications for shipping should the existing route be affected – e.g. increased travel times, fuel use etc.

Fish Values

6.7.21 The fish values data layer has been sourced from the COWRIE report 'Development of spatial information layers for commercial fishing and shellfishing in UK waters to support strategic siting of offshore wind farms' (see www.offshorewindfarms.co.uk). The information is held in a series of GIS data layers that display the mean fish value for the period 2004-2007, which for the purposes of the MRESF provides GIS data on the value and intensity of fishing within Welsh TWs. The grid resolution is based on a cell size of 0.05 degrees longitude by 0.05 degrees latitude (approximately 3km by 5.5km). The data layer is useful in highlighting areas of importance and value to the fishing industry.

6.7.22 The data do however have limitations, for example information on certain types of vessels has not been included, including those under 15m in length, foreign vessels and those without the Vessel Monitoring System on board. Given that the 2008 Wales Fisheries Strategy (http://wales.gov.uk/strategy/strategies/walesfisheriesstrategy/walesfisheriesstratjuly08.pdf?lang=en) identified the offshore fleet in Welsh waters (beyond 6nm) to be vessels over 10m, most of which are Spanish, and the inshore (within 6nm) to be vessels less than 10m, there is potential for commercial fishing activity to be under represented by the dataset used. The data is, however, the most complete dataset available at a strategic scale. The WAG's Fisheries Unit (which now includes the Welsh Sea Fisheries Committees) may be able to proved additional information on inshore fleets.

6.7.23 The UK database used in the COWRIE report gives a range of fish landing values per grid cell per year from £0-£364,579 (with the note that a 0 value does not necessarily mean no fishing). The fish value ranges of relevance to the medium energy B scenario being between £40,000 and £60,000. These do therefore represent relatively high values of fish landings and hence importance for the fishing industry. However, given the uncertainties inherent in such a strategic level data layer and the annual variation in fishing patterns, there is potential that site specific assessment, potentially involving survey and/or fisheries liaison, could result in a variation to the level of constraint. In addition, the potential for wave and tidal stream developments to affect commercial fishing activity is partly dependant on the type of fishing activity. For example, restrictions on potting activity are generally less than restrictions on trawling. In addition, the type of fishing is important, e.g. large vessels may have greater flexibility in the distance travelled to fishing grounds, whereas small scale, artisan fisheries tend to be more restricted in area and are in any case are likely to be poorly reflected in the data layer.

Marine Military Practice Areas

6.7.24 The Stage 2 report 'The Potential for Interaction between Wave and Tidal Stream with Military Interests in Welsh Waters' (RPS, 2010a) includes information on the likely views of the MoD as regards renewable energy applications within designated practice areas. The views of the MoD as regards the practice areas that overlap areas of potential resource are as follows (see Figure B-15 for the distribution of these areas):

- Valley and Mona Airfields (located on and around Anglesey). MoD may consider deployment of all device types possible, including cabling/pipelines;
- Aberporth D201C (skirts the edge of the Lleyn Peninsula). The MoD are unlikely to consider deployment of wave and tidal stream devices possible. However, the Aberporth area only directly affects the edge of the resource area;
- Castlemartin D113A (south west Pembrokeshire). Available time for survey is likely to be limited, with device deployment unlikely to be considered possible however cabling and pipelines deployment may be considered;
- Castlemartin D113B (south west Pembrokeshire). Available time for survey is likely to be limited, with device deployment unlikely to be considered possible however cabling and pipelines deployment may be considered; and
- Manorbier D115B (southern Pembrokeshire/eastern Carmarthen Bay). MoD may consider deployment of cabling/pipelines and/or inshore devices only.

6.7.25 From the information available, it is clear that the potential for development within most of the marine practice areas is highly constrained, with some areas having the potential for limited types of devices or for cabling/pipelines only. For developers interested in these areas, early discussions with the MoD are recommended to clarify site specific options for development together with potential restrictions e.g. on type of device, location of deployment, access to site etc. The RPS 2010a report, a component of the MRESF project, provides advice on how to proceed with such consultation.

Diving Seabirds Vulnerability

6.7.26 The diving seabirds vulnerability data layer (see Figure B-7vii) has been compiled and provided by CCW (2011, in prep), with the aim of generating data layers that can be used to present the vulnerability, or the relative risk of potential negative interactions, between tidal stream devices and diving seabirds. CCW have confirmed that the data layer can equally be applied to wave energy devices for the MRESF project as a strategic level assessment, however it should be noted that the data have been

produced in reference to vulnerability to tidal stream devices and therefore may be precautionary for wave devices. The data layer draws on information such as life history traits, population and conservation status combined with factors such as bathymetry and the available species distribution data and numerical abundance. The information was used to calculate relative vulnerability scores for Welsh TWs and for diving seabirds has been undertaken on a grid of 3km by 3km.

6.7.27 The data layer presents the best available information for assessing the degree of constraint that diving birds may represent to the deployment of wave and tidal stream devices. However, given the nature of the data layer (in that it contains a degree of extrapolation; has been prepared on a grid basis of 3km by 3km; that data density and quality is likely to be variable across Welsh TWs, with species density within cells similarly variable; and that the data layer has perhaps a greater applicability to tidal stream than to wave devices), there may be potential at the site specific level to reassess the level of constraint. To do so is likely to require additional data collection and it does not automatically follow that additional data would reduce the level of constraint. Such assessments would greatly benefit from *in-situ* monitoring of devices, for example in a 'deploy and monitor' type approach to consent.

Cetacean Vulnerability

6.7.28 The cetacean vulnerability data layer (see Figure B-6iv) has similarly been compiled and provided by CCW (2011, in prep), with the aim of generating data layers that can be used to present the vulnerability, or the relative risk of potential negative interactions, between tidal stream devices and cetaceans. CCW have confirmed that the data layer can equally be applied to wave energy devices for the MRESF project as a strategic level assessment, however it should be noted that the data have been produced in reference to vulnerability to tidal stream devices and therefore may be precautionary for wave devices. The data layer draws on species attribute information such as seasonal use of sea areas, juvenile presence in sea areas, length of breeding cycle, female age at sexual maturity, average longevity, biogeographical population size, proportional importance of the Welsh population and protected species status. These values were combined with available data on species distribution (based on mean standardised sightings rates) and bathymetry. The information was used to calculate relative vulnerability scores for Welsh TWs and for cetaceans has been undertaken on a grid measuring 10' latitude by 10' longitude (approximately 11x19km^2).

6.7.29 The data layer presents the best available information for assessing the degree of constraint that cetaceans may represent to the deployment of wave and tidal stream

devices. However, it should be noted that the interpretations within the data layer makes no assumptions about the behaviour of animals in the vicinity of devices. In a similar manner to the seabird data described above, the nature of the data layer (in that it contains a degree of extrapolation; has been prepared on a grid basis of 10' latitude by 10' longitude; that data density and quality is likely to be variable across Welsh TWs, with species density within cells similarly variable; and that the data layer has perhaps a greater applicability to tidal stream than to wave devices), there may be potential at the site specific level to reassess the level of constraint. To do so is likely to require additional data collection and it does not automatically follow that additional data would reduce the level of constraint. Again, such assessments would greatly benefit from *in-situ* monitoring of devices, for example in a 'deploy and monitor' type approach to consent.

6.7.30 In addition, all species of cetacean are classified as European Protected Species (EPS) and as such there may be a requirement to apply for an EPS licence for certain aspects of work, which in some cases may trigger the need for conducting some baseline data surveys.

Grey Seal Vulnerability

6.7.31 The grey seal vulnerability data layer (see Figure B6-v) has similarly been compiled and provided by CCW (2011, in prep), with the aim of generating data layers that can be used to present the vulnerability, or the relative risk of potential negative interactions, between tidal stream devices and grey seals. CCW have confirmed that the data layer can equally be applied to wave energy devices for the MRESF project as a strategic level assessment, however it should be noted that the data have been produced in reference to vulnerability to tidal stream devices and therefore may be precautionary for wave devices. The data layer draws on species attribute information such as length of breeding cycle, female age at sexual maturity, average longevity, biogeographical population size, proportional importance of the Welsh population and an additional factor accounting for protected sites for which grey seal are a feature. These values were combined with available data on species distribution (based on mean counts from summer and winter haul outs and mean pup counts) and bathymetry. The information was used to calculate relative vulnerability scores for Welsh TWs and for grey seals has been undertaken on a grid measuring 10' latitude by 10' longitude (approximately 11x19km^2).

6.7.32 The data layer presents the best available information for assessing the degree of constraint that grey seals may represent to the deployment of wave and tidal stream

devices. However, it should be noted that the interpretations within the data layer makes no assumptions about the behaviour of animals in the vicinity of devices. In a similar manner to the seabird and cetacean data described above, given the nature of the data layer (in that it contains a degree of extrapolation; has been prepared on a grid basis of 10' latitude by 10' longitude; that data density and quality is likely to be variable across Welsh TWs, with species density within cells similarly variable; and that the data layer has perhaps a greater applicability to tidal stream than to wave devices), there may be potential at the site specific level to reassess the level of constraint. To do so is likely to require additional data collection and it does not automatically follow that additional data would reduce the level of constraint. As above, such assessments would greatly benefit from *in-situ* monitoring of devices, for example in a 'deploy and monitor' type approach to consent.

SAC Habitat Feature – Reefs, Sea Caves, Sandbanks and Shallow Inlets and Bays

6.7.33 The distribution of all Annex I habitats, including reefs, sea caves, sandbanks and shallow inlets and bays, is shown in Figure B-10ii. The data on Annex I habitats used in the MRESF project has been provided by CCW and covers the known location of Annex I habitats within SACs in Welsh TWs. Such sites and the associated habitat and species are designated under the Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora (the 'Habitats Directive'), as transposed into UK law by the Conservation (Natural Habitats &.c) Regulations 1994 (the 'Habitats Regulations') (as amended) and the Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (as amended) (collectively known as the 'Habitat and Offshore Marine Regulations').

6.7.34 For developers applying for consent within or in proximity to a SAC or SPA, the requirements of the Habitats Regulations will need to be met, which in practice may include the provision of sufficient information for the Competent Authority to undertake a Habitats Regulations Assessment, to ensure that the proposal will not have a significant impact on a site of European Interest. The potential for significant effect would need to be determined on a site specific basis, but would be dependant on a number of aspects including the type and location of the Annex I habitat and the type and scale of planned development.

Dredging Routes

6.7.35 The dredging route data layer, which has been provided by BMAPA, refers to routes used by all aggregate dredgers on transit typically between licensed dredging grounds

and the aggregate wharves. Although there are differences between the type and purpose of traffic, there are similarities between the type of constraint for wave and tidal stream devices represented by dredging routes and the shipping density constraint discussed in paragraph 6.7.19. The main difference is that the width of the dredge routes tends to be narrower, with the route chosen often being an important factor in the economics of a dredge area due to the financial and time costs of transport.

6.7.36 The potential for development of marine renewables within the dredge routes would need to be addressed at the site specific level, with the following issues being of potential significance:

- The degree to which dredge traffic would need to be diverted to accommodate a wave or tidal stream development and any implications of this e.g. financial, navigational etc; and
- There may be potential for fully submerged devices to be deployed along dredge routes, depending on issues such as clearance at low water and provision for access during construction, maintenance and decommissioning.

The Extent of Geographic Overlap between Resource Area and Constraint Data Layers

6.7.37 The preceding paragraphs of Section 6.7 are primarily concerned with understanding which constraint data layers overlap the Step 5 resource areas and the degree to which the resource areas may be affected by individual data layers. However, to ensure that sustainability is central to the development of the Step 5 Scenarios, it is also important to consider how the resource areas may affect the constraint data layers.

6.7.38 Section 6.6 assessed the percentage of individual constraint data layers affected by the device type resource areas in Step 4. A similar process has been followed here, with the focus being on understanding how individual constraint data layers may be directly affected by the high, medium and low energy yield scenarios of Step 5. The information is presented in Appendix C and summarised below. The potential for the resource areas to overlap with all constraints has been considered (i.e. not just the maximum constraint rank present), hence the data layers listed include ranks between 1 and 4.

Constraints within the High Energy Yield Scenario

6.7.39 The high energy scenario has the potential to deliver 6.4GW installed capacity, within an overall area extending to some 1,875km^2 (Figure S5-3). The maximum amount of an individual constraint that may be affected by development at this scale is 94% (Marine

Nature Reserves), with such development having potential implications for sustainability. The main issues for a high energy scenario are likely to be related to shipping, radar, designated sites, seascape, wrecks, commercial fishing, marine military practice areas, fish spawning areas, diving seabirds, marine mammals, marine nature reserves, SACs and marine dredging routes. Although the amount of potential energy within this scenario exceeds the 4GW level, it is considered that the consenting risk for developers is likely to be higher than in the low energy and medium energy scenarios due to the higher levels of constraint. As regards to the potential implications for other interests, from the GIS data it is apparent that as the potential installed capacity increases, both the number and extent of constraint data layers potentially affected are also significantly increased. Both the consenting risk and sustainability of the high energy scenario would require significant consideration should the scenario be adopted.

6.7.40 The data layers that may present the greatest consenting risk are summarised below, together with the potential energy levels and proportion of the overall area affected:

- Shipping density (ships per year from 0->5000, constraint ranks 2-4). The constraint is represented in six data layers, with between 11-24% of each data layer overlapping with the high energy resource area with the potential to deliver from <0.1-1.7GW installed capacity of wave and tidal stream;
- Terrestrial designated sites and protected land (heritage coasts, National Parks and National Trust land, constraint ranks 1 and 3). The constraint is represented in three data layers, with between 11-21% of each data layer overlapping with the high energy resource area with the potential to deliver from 0.5-5.8GW installed capacity of wave and tidal stream;
- Seascape sensitivity (wave farm data layers high, high/medium and medium, constraint ranks 2-3). The constraint is represented in three data layers, with between 11-20% of each data layer overlapping with the high energy resource area with the potential to deliver from 1.3-2.4GW installed capacity from wave energy;
- Wrecks, constraint rank 3. The constraint data layer extends to some 96km^2 in Welsh waters, of which 15% overlaps with the high energy resource area with the potential to deliver 0.1GW installed capacity from wave and tidal stream energy.
- Fish values (£5,000-£10,000, £10,000-£20,000, £20,000-£30,000 and £50,000-£60,000, mean landing value per cell per year, constraint ranks 2-4). The constraint is represented in four data layers, with between 9-50% of each data layer

overlapping with the high energy resource area with the potential to deliver from 0.1-4GW installed capacity from wave and tidal stream energy;

- Marine military practice areas, constraint rank 4. The constraint data layer extends to some 5,385km^2 in Welsh waters, of which 10% overlaps with the high energy resource area with the potential to deliver 1.8GW installed capacity from wave energy;
- Fish spawning areas (herring and sole, constraint rank 3). The constraint is represented in two data layers, with between 8-14% of each data layer overlapping with the high energy resource area with the potential to deliver from 0.1-0.7GW installed capacity from wave energy;
- Diving Seabirds vulnerability (combined species, constraint rank 3-4). The constraint is represented in two data layers, with between 17-45% of each data layer overlapping with the high energy resource area with the potential to deliver 1.3-2.9GW installed capacity from wave and tidal stream energy;
- Cetacean vulnerability (combined species, constraint rank 2-3). The constraint is represented in two data layers, with between 7-20% of each data layer overlapping with the high energy resource area with the potential to deliver 1.3-4.3GW installed capacity from wave and tidal stream energy;
- Grey seals vulnerability (constraint rank 2-4). The constraint is represented in three data layers, with between 11-12% of each data layer overlapping with the high energy resource area with the potential to deliver 0.8-4GW installed capacity from wave and tidal stream energy;
- Marine Nature Reserves, constraint rank 4. The constraint data layer extends to some 16km^2 in Welsh waters, of which 94% overlaps with the high energy resource area with the potential to deliver 0.1GW installed capacity from wave energy;
- Special Area of Conservation (non-habitat features, habitat feature reefs and habitat feature sea caves, constraint rank 3-4). The constraint is represented in three data layers, with between 16-20% of each data layer overlapping with the high energy resource area with the potential to deliver 0.1-1.2GW installed capacity from wave and tidal stream energy; and
- Marine dredging routes, constraint rank 4. The constraint data layer extends to some 667km^2 in Welsh waters, of which 13% overlaps with the high energy resource area with the potential to deliver 0.3GW installed capacity from wave and tidal stream energy.

Constraints within the Medium Energy Yield A Scenario

6.7.41 The medium energy scenario A has the potential to deliver 3.7GW installed capacity, within an overall area extending to some 1,139km^2 (Figure S5-4). The maximum amount of an individual constraint that may be affected by development at this scale is 18% (shipping density ships per year >50-250), with the main issues likely to be related to shipping, seascape, commercial fishing, diving seabirds, marine mammals and sites designated as SACs. Although the amount of potential energy within this scenario is approaching the 4GW level, it is considered that the consenting risk for developers is likely to be higher than in the low energy scenario due to the higher levels of constraint. As regards the potential implications for other interests, from the GIS data it appears that the relative proportion of the different data layers that may be directly affected by any development is greater than that for the low energy scenario, with up to 18% of an individual constraint potentially directly affected.

6.7.42 The data layers that may present the greatest consenting risk are summarised below, together with the potential energy levels and proportion of the overall area affected:

- Shipping density (ships per year from 0-5000, constraint rank 2-4). The constraint is represented in five data layers, with between 7-18% of each data layer overlapping with the medium energy A resource area with the potential to deliver from 0.3-1.2GW installed capacity of wave and tidal stream;
- Seascape sensitivity (wave farm data layers high and high/medium, constraint rank 2-3). The constraint is represented in two data layers, with 12% of each data layer overlapping with the medium energy A resource area with the potential to deliver from 1.1-1.3GW installed capacity from wave energy;
- Fish values (£5,000-£10,000 and £10,000-£20,000, mean landing value per cell per year, constraint rank 2). The constraint is represented in two data layers, with between 8-16% of each data layer overlapping with the medium energy A resource area with the potential to deliver from 0.8-2.5GW installed capacity from wave and tidal stream energy;
- Diving seabirds vulnerability (combined species, constraint rank 3-4). The constraint is represented in two data layers, with between 11-13% of each data layer overlapping with the medium energy A resource area with the potential to deliver from 0.4-1.8GW installed capacity from wave and tidal stream energy;
- Cetacean vulnerability (combined species, constraint rank 3). The constraint data layer extends to some 6,584km^2 in Welsh waters, of which 14% overlaps with the

medium energy A resource area with the potential to deliver 3GW installed capacity from wave and tidal stream energy;

- Grey seals vulnerability (constraint rank 2). The constraint data layer extends to some 10,880km^2 in Welsh waters, of which 9% overlaps with the medium energy A resource area with the potential to deliver 3GW installed capacity from wave and tidal stream energy; and
- Special Area of Conservation (non-habitat features, constraint rank 3). The constraint data layer extends to some 1,832km^2 in Welsh waters, of which 15% overlaps with the medium energy A resource area with the potential to deliver 1GW installed capacity from wave energy.

Constraints within the Medium Energy Yield B Scenario

6.7.43 The medium energy scenario B has the potential to deliver 5.1GW installed capacity, within an overall area extending to some 1,563km^2 (Figure S5-5). The maximum amount of an individual constraint that may be affected by development at this scale is 28% (diving seabirds vulnerability combined, constraint rank 4), with the main issues likely to be related to shipping, designated sites, seascape, wrecks, commercial fishing, marine military practice areas, fish spawning areas, diving seabirds, marine mammals and SACs. Although the amount of potential energy within this scenario exceeds the 4GW level, it is considered that the consenting risk for developers is likely to be higher than in both the low energy and medium energy A scenarios due to the higher levels of constraint. As regards the potential implications for other interests, from the GIS data it is apparent that with the increase in potential installed capacity, both the number and extent of constraint data layers potentially affected have significantly increased.

6.7.44 The data layers that may present the greatest consenting risk are summarised below, together with the potential energy levels and proportion of the overall area affected:

- Shipping density (total ships per year from 0->5000, constraint rank 2-4). The constraint is represented in six data layers, with between 11-23% of each data layer overlapping with the medium energy B resource area an with d the potential to deliver from <0.1-1.5GW installed capacity of wave and tidal stream.
- Terrestrial designated sites and protected land (heritage coasts, National Parks and National Trust land, constraint rank 1-3). The constraint is represented in three data layers, with between 9-17% of each data layer overlapping with the medium energy B resource area with the potential to deliver from 0.2-4.6GW installed capacity of wave and tidal stream.

- Seascape sensitivity (wave farm data layers high, high/medium and medium, constraint rank 2-3). The constraint is represented in three data layers, with between 8-17% of each data layer overlapping with the medium energy B resource area with the potential to deliver from 1.2-1.9GW installed capacity from wave energy.
- Wrecks, constraint rank 3. The constraint data layer extends to some 96km^2 in Welsh waters, of which 12% overlaps with the medium energy B resource area with the potential to deliver <0.1GW installed capacity from wave energy.
- Fish values (£5,000-£10,000, £10,000-£20,000 and £50,000-£60,000, mean landing value per cell per year, constraint rank 2 and 4). The constraint is represented in three data layers, with between 11-21% of each data layer overlapping with the medium energy B resource area with the potential to deliver from <0.1-3.2GW installed capacity from wave and tidal stream energy.
- Marine military practice areas, constraint rank 4. The constraint data layer extends to some 5,385km^2 in Welsh waters, of which 7% overlap with the medium energy B resource area with the potential to deliver 1.2GW installed capacity from wave energy.
- Fish spawning areas (herring and sole, constraint rank 3). The constraint is represented in two data layers, with between 7-13% of each data layer overlapping with the medium energy B resource area with the potential to deliver from 0.1-0.6GW installed capacity from wave energy.
- Diving Seabirds vulnerability (combined species, constraint rank 3-4). The constraint is represented in two data layers, with between 15-28% of each data layer overlapping with the medium energy B resource area with the potential to deliver 0.8-2.4GW installed capacity from wave and tidal stream energy.
- Cetacean vulnerability (combined species, constraint rank 3). The constraint data layer extends to some 6,584km^2 in Welsh waters, of which 18% overlaps with the medium energy B resource area with the potential to deliver 3.8GW installed capacity from wave and tidal stream energy.
- Grey seals vulnerability (constraint rank 2-3). The constraint is represented in two data layers, with between 10-11% of each data layer overlapping with the medium energy B resource area with the potential to deliver 1.3-3.6GW installed capacity from wave and tidal stream energy.

- Special Area of Conservation (non-habitat features and habitat feature reefs, constraint rank 3-4). The constraint is represented in two data layers, with between 8-19% of each data layer overlapping with the medium energy B resource area with the potential to deliver 0.4-1.2GW installed capacity from wave and tidal stream energy.

Constraints within the Low Energy Yield Scenario

6.7.45 The low energy scenario has the potential to deliver 1.5GW installed capacity, within an overall area extending to some 487km^2 (Figure S5-2). The maximum amount of an individual constraint that may be affected by development at this scale is 11% (shipping density ships per year >50-250), with the main issues likely to be related to shipping, seascape, commercial fishing, marine mammals and SACs. Although the amount of potential energy within this scenario is considerably less than 4GW, it is considered that the consenting risk for developers is likely to be less than in areas subject to higher levels of constraint. As regards the potential implications for other interests, from the GIS data it appears that the proportion of the different data layers that may be directly affected by any development is relatively low, with up to 11% of an individual constraint potentially directly affected.

6.7.46 The data layers that may present the greatest consenting risk to the low energy scenario are summarised below, together with the potential energy levels and proportion of the overall area affected:

- Shipping density (ships per year >50-250, constraint rank 3). The constraint data layer extends to some 2,115km^2 in Welsh waters, of which 11% overlaps with the low energy scenario wave resource area with the potential to deliver 0.8GW installed capacity from wave energy;
- Seascape sensitivity to wave farms (high, constraint rank 3). The constraint data layer extends to some 2,747km^2 in Welsh waters, of which 7% overlaps with the low energy scenario wave resource area with the potential to deliver 0.6GW installed capacity from wave energy;
- Fish values (£5,000-£10,000, mean landing value per cell per year, constraint rank 2). The constraint data layer extends to some 4,635km^2 in Welsh waters, of which 7% overlaps with the low energy scenario wave resource area with the potential to deliver 1.1GW installed capacity from wave energy;
- Cetacean vulnerability (combined species, constraint rank 3). The constraint data layer extends to some 6,584km^2 in Welsh waters, of which 7% overlaps with the

low energy scenario wave resource area with the potential to deliver 1.4GW installed capacity from wave and tidal stream energy; and

- Special Area of Conservation (non-habitat features, constraint rank 3). The constraint data layer extends to some 1,832km^2 in Welsh waters, of which 6% overlaps with the low energy scenario wave resource area with the potential to deliver 0.4GW installed capacity from wave energy.

7 Conclusions and Recommendations

7.1 Introduction

7.1.1 The work presented within this report has been prepared to provide a commentary to the GIS data processing and mapping, which form the central part of the final outputs of the MRESF project. The aim is to provide a description of the maps and an overview on how they should be interpreted. The main lessons learnt from the data processing and GIS mapping are summarised below.

7.2 Lessons Learnt from the Project

7.2.1 There are a number of key points that can be drawn from the results of the GIS mapping and data processing presented in this report, which have been summarised as follows:

- There is considerable wave and tidal stream energy potential in Welsh TWs, however there are also numerous existing interests that have the potential to represent significant constraints on development;
- Regardless of the level of constraint anticipated from the strategic level, all developments will require assessment and need to achieve the relevant consents;
- There is potential for the 4GW installed capacity, highlighted by the WAG in the Energy Policy Statement, to be met and even exceeded. However, to do so would require development in areas subject to potentially significant levels of constraint (the 6.4GW installed capacity described in the **high energy scenario** and the 5.1GW described in the **medium energy scenario B**);
- For development in areas subject to a lesser degree of constraint, the 1.5GW installed capacity described in the **low energy scenario,** would be approximately one quarter of that in the high energy scenario and therefore would fall considerably short of the 4GW identified in the WAG's Energy Policy Statement;
- To achieve a mid point between the low and high energy scenarios, i.e. the **medium energy scenario**, development in some areas of high constraint would be required. Although the overall level of constraint is likely to be less than in the high energy scenario, some of these constraints are likely to be significant and although some could potentially be mitigated or reduced in significance through additional study and discussion, it is likely to bring a significant degree of uncertainty to a

project and not least represent a potential time and financial cost to the project. An installed capacity of between 3.7GW and 5.1GW has been described for the medium energy scenario;

- Within the **low energy scenario**, the GIS data processing identified the maximum amount of an individual constraint that may be affected by development at this scale as being up to 11% of one of the shipping density sub-layers (at a level of vessel traffic of >50-250 per year). Again, this may bring issues for consenting multiple projects should these be developed across areas with a high proportion of a single constraint i.e. cumulative impact of multiple protects on a single constraint;
- Section 5.3 highlights data layers that were unavailable within the MRESF timeframe, being updates to fish spawning and nursery areas and the identification of MCZs in Welsh waters. It should be noted that both data layers, when they become available, have the potential to impinge on the areas of resource identified in the MRESF. However, there has been dialogue with the MCZ team, enabling information to be shared, with fish ecology included in the constraint mapping in the form of an earlier data layer (additional data on fish ecology has subsequently become available and shown in Figures B8-iii to B8-vi for information);
- The level of confidence and certainty in both the baseline data layers used in constraint mapping and the level of understanding of potential impacts associated with wave and tidal stream devices is very important when assessing the potential constraints on development. It is acknowledged in the report (and accompanying reports e.g. RPS (2008) and WAG (2011b)) that limitations remain in the data used, with increased certainty only likely to be achieved as additional data is collected;
- Even within areas of lower constraint, issues such as the cumulative level of constraint (e.g. large numbers of data layers with low levels of constraint compared to areas with a few data layers of high constraint) could increase consenting risk and bring complications for sustainable development; and
- When the minimum tidal stream energy is reduced to 1.5m/s, although not generally considered a 'commercial level' of energy, the 1.5m/s resource presents a larger potential development area than the 2m/s resource (518km^2 for 1.5m/s and 200km^2 for 2m/s), albeit it within the same broad locations.

7.3 Scale and Speed of Development

7.3.1 The potential figures for installed capacity given in the various energy scenarios relate to the available resource, the manner in which devices are anticipated to be deployed (e.g. device density within and between arrays) and potential constraints on exploitation of that resource. In practice, it is likely that in the short term, applications and developments will continue to be for demonstrator devices and small arrays prior to larger arrays being brought forward. It should be noted that for the industry to reach the potential installed capacity identified here, considerable expansion would be required involving both an increase in applications and the granting of consents. Of particular note is the 2025 date highlighted in the Energy Policy Statement, by which point the 4GW installed capacity is expected in the main.

7.4 Grid Connection

7.4.1 Access to grid is frequently raised as being a significant constraint on the development of wave and tidal stream, both in Wales and more widely. As discussed in Section 4.1, grid access is primarily limited by timescale and finance, which are both a function of project and site specifics. As such, grid has been included here for informative purposes only and has not been applied in the constraint mapping. It is important to note, however, that provision of an adequate grid, with available access at a cost and timescale compatible with project needs, has been raised by developers throughout the MRESF project. As such, it is considered that lack of sufficient access to the grid as a potential constraint on development should not be underestimated as it is likely to be a significant limiting factor on the industry and its ability to move towards the commercial generation of wave and tidal stream energy in Welsh waters. It has been noted by the Steering Group that grid connection has been the deciding factor in some cases with regard to the placement of projects.

7.4.2 Any future expansion to the existing grid will need to meet the appropriate legislative requirements, and are likely to require assessments of potential impacts upon the terrestrial, coastal and subtidal environment (as relevant to the geographic location).

7.5 Potential for Sustainable Development of Wave and Tidal Stream in Welsh Waters

7.5.1 The MRESF has investigated the potential wave and tidal stream energy in Welsh TWs, to consider the sustainability of reaching an installed capacity of 4GW. The assessment

has been achieved through the use of GIS data processing to investigate the potential issues associated with the attainment of low, medium and high levels of energy. The low energy scenario considers the potential installed capacity in areas ranked to a maximum of 3 ('Constraint potentially complex and will require detailed assessment, but unlikely to stop development'), with the high energy scenario considering the potential for development in areas ranked to a maximum of 4 ('significant issue/constraint – probable delay and could possibly stop the project') without regard to the cumulative number of rank 4 data layers. The medium energy scenario is presented in two forms, to take consideration of the cumulative nature of rank 4 data layers. The medium energy scenario A considers areas affected by a single rank 4 data layer, with medium energy scenario B considering areas with up to and including two rank 4 data layers, with the constraint data layers potentially affected being a function of the overlap with the resource areas. The main constraints that may be affected in each scenario are highlighted below.

Low Energy Scenario

7.5.2 The low energy yield Scenario resource area, as defined in Step 5, covers some 487km^2. A total of 35 constraint data layers fall within this resource area, up to and including those ranked 3, with these listed in Appendix C. The maximum area of an individual data layer which could fall within the footprint of the low energy yield Scenario resource area is 11% of the shipping density ships per year (>50-250) data layer (constraint rank 3). The total potential installed capacity that could be achieved in this area is approximately 0.8GW. The area affected falls within the wave energy resource area.

Medium Energy Scenario A

7.5.3 The medium energy yield A Scenario resource area, as defined in Step 5, covers some 1,139km^2. A total of 52 constraint data layers up to and including an individual rank 4 data layer fall within this resource area, with these listed in Appendix C. The maximum area of an individual data layer which could fall within the footprint of the medium energy yield A Scenario resource area is 18% of the shipping density – total ships per year (>50-250) data layer (constraint rank 3). The total potential installed capacity that could be achieved in this area is approximately 0.6GW. Less than 1% of the area is affected by the tidal stream resource, the majority being within the wave energy resource area.

Medium Energy Scenario B

7.5.4 The medium energy yield B Scenario resource area, as defined in Step 5, covers some 1,563km^2. A total of 59 constraint data layers up to and including two rank 4 data layers fall within this resource area, with these listed in Appendix C. The maximum area of an individual data layer which could fall within the footprint of the medium energy yield B Scenario resource area is 28% of the diving seabirds vulnerability constraint rank 4 data layer. The total potential installed capacity that could be achieved in this area is approximately 0.8GW. The area affected falls within the wave energy resource area.

High Energy Scenario

7.5.5 The high energy yield Scenario resource area, as defined in Step 5, covers some 1875km^2. A total of 63 constraint data layers ranked up to and including 4 fall within this resource area, with these listed in Appendix C, including the constraint rank, the total area of the constraint and the percentage of that constraint data layer directly overlapping the high energy yield resource area. The data layers that may present the greatest consenting risk to the high energy scenario are summarised below (including those of constraint rank 3 and above that have a minimum of 10% overlap with the resource area), together with the potential energy levels and proportion of the overall area affected:

- Shipping density (ships per year from 50->5000, constraint ranks 3-4). The constraint is represented in four data layers, with between 11-24% of each data layer overlapping with the high energy resource area with the potential to deliver from <0.1-1.7GW installed capacity of wave and tidal stream;
- Terrestrial designated sites and protected land (heritage coasts, National Parks and National Trust land, constraint ranks 1 and 3). The constraint is represented in three data layers, with between 11-21% of each data layer overlapping with the high energy resource area with the potential to deliver from 0.5-5.8GW installed capacity of wave and tidal stream;
- Seascape sensitivity (wave farm data layers high and high/medium constraint ranks 2-3). The constraint is represented in two data layers, with between 14-20% of each data layer overlapping with the high energy resource area with the potential to deliver from 1.3-2.4GW installed capacity from wave energy;
- Wrecks (constraint rank 3). The constraint data layer extends to some 96km^2 in Welsh waters, of which 15% overlaps with the high energy resource area with the potential to deliver 0.1GW installed capacity from wave and tidal stream energy.

- Fish values (£20,000-£30,000 and £50,000-£60,000, mean landing value per cell per year, constraint ranks 3-4). The constraint is represented in two data layers, with between 8-50% of each data layer overlapping with the high energy resource area with the potential to deliver 0.1GW installed capacity from wave and tidal stream energy;
- Marine military practice areas (constraint rank 4). The constraint data layer extends to some 5,385km^2 in Welsh waters, of which 10% overlaps with the high energy resource area with the potential to deliver 1.8GW installed capacity from wave energy;
- Fish spawning areas (herring and sole, constraint rank 3). The constraint is represented in two data layers, with between 8-14% of each data layer overlapping with the high energy resource area with the potential to deliver from 0.1-0.7GW installed capacity from wave energy;
- Diving seabirds (vulnerability, constraint rank 4). The constraint data layer extends to some 843km^2, of which 54% overlaps with the high energy resource area with the potential to deliver 1.3GW installed capacity from wave stream energy;
- Cetacean vulnerability (combined species, constraint rank 3). The constraint data layer extends to some 3,573km^2, of which 20% overlaps with the high energy resource area with the potential to deliver 4.3GW installed capacity from wave and tidal stream energy;
- Grey seals vulnerability (constraint rank 3-4). The constraint is represented in two data layers, with between 11-12% of each data layer overlapping with the high energy resource area with the potential to deliver 0.8-1.6GW installed capacity from wave and tidal stream energy;
- Marine Nature Reserves (constraint rank 4, covers 16km^2, 94% of which would be directly affected by the wave energy resource area). The total potential installed capacity that could be achieved in this area is approximately 0.1GW;
- Special Area of Conservation (non-habitat features, habitat feature reefs and habitat feature sea caves, constraint rank 3-4). The constraint is represented in three data layers, with between 16-20% of each data layer overlapping with the high energy resource area with the potential to deliver 0.1-1.2GW installed capacity from wave and tidal stream energy; and
- Marine dredging routes (constraint rank 4). The constraint data layer extends to some 667km^2 in Welsh waters, of which 13% overlaps with the high energy

resource area with the potential to deliver 0.3GW installed capacity from wave and tidal stream energy.

Potential to Reduce Consenting Risk and to Promote Sustainable Development

7.5.6 To reduce the consenting risk and achieve a sustainable route, a number of approaches could be taken. Underlying the constraint mapping are the baseline data layers and the level of constraint these present for wave and tidal stream development. Although both the data layers and constraint rankings represent the best strategic level information available for Welsh TWs at present, greater certainty would be beneficial in terms of understanding and potentially refining the potential constraints. To do so would require additional baseline data (to build on the existing baseline data layers) and additional data on potential device related impacts, preferably from monitoring of devices *in-situ* (to increase certainty of the potential constraint).

7.5.7 Although the majority of the main potential consenting risks appear to relate to wave energy (e.g. the highest percentage of potential overlap between resource area and constraint data layers generally relate to the wave resource area only – see Section 6.7), it should be noted that this is primarily a reflection of the larger footprint of the potential wave resource and that proportionally similar risks apply to tidal stream.

7.5.8 Based purely on geographic footprint, wave energy does appear to offer greater scope for development sites than tidal stream in Welsh TWs. It should, however, be noted, as highlighted in paragraph 6.3.10, that the relative proportion of the overall installed capacity that relates to tidal stream is likely to be conservative, with the relative proportion from wave energy more likely to be at the higher end of what would be considered achievable, albeit it both being based on the best available information. In addition, the energy return per unit area from tidal stream is generally greater than for wave devices (with the exception of offshore attenuators), with the location of areas of resource (particularly proximity to landfall and potential grid connection sites) potentially favouring some areas of energy resource, at least for early stage developments.

7.5.9 Combining an active management approach with appropriate strategic level mitigation would be beneficial at the site selection stage, to help reduce the potential for cumulative impact on individual constraints. Of particular relevance here is the reduction factor applied to the potential installed capacity figures, which essentially reduces the energy levels by 60%. The reduction factor has been applied to provide a more realistic and sustainable view of the potential level of resource. The use of the reduction factor also enables more flexibility when considering site selection within the resource area, as the

reduction factor presumes that a percentage of the resource area will be developed and not the entire area.

7.5.10 The constraints that are highlighted in the low energy scenario tend to reappear throughout all the energy scenarios, generally becoming affected to a greater extent as the potential energy level increases. These constraints are joined by others in the medium and high energy scenarios. It is also apparent that some constraints have the potential to be affected more than others, with potential issues for sustainability and cumulative impacts if site selection is not managed appropriately. In addition, some constraints are associated with higher levels of energy. There may, therefore, be benefit in targeting any future research or consultation at constraints that have the potential to be disproportionately affected and on constraints associated with areas containing a potential greater higher energy yield.

7.5.11 Constraints that appear throughout the energy scenarios are listed below. Where there may be benefit from further consultation and/or discussion with the relevant sector at the strategic level, this is highlighted in *italics*. Where there may need to be future research and/or monitoring at demonstrator sites, this is highlighted in **bold**. When projects are considered at the site specific level, the topics that would require consideration would be a function of the baseline environment (natural and socio-economic) and therefore unlikely to be limited to the list below, with the use of site specific mitigation potentially reducing impact.

- *Shipping;*
- Seascape;
- ***Commercial fishing****;*
- **Cetaceans**; and
- **Special Areas of Conservation**.

7.5.12 Constraints that are associated with higher levels of energy in the low and medium energy A scenarios are summarised below. Where there may be benefit from further consultation and/or discussion with the relevant sector at the strategic level, this is highlighted in *italics*. Where there may need to be future research and/or monitoring at demonstrator sites, this is highlighted in **bold**. As above, when projects are considered at the site specific level, the topics that would require consideration would be a function of the baseline environment (natural and socio-economic) and therefore unlikely to be

limited to the list below, with the use of site specific mitigation potentially reducing impact.

- *Shipping* (low energy scenario, medium energy scenario A);
- Seascape (medium energy scenario A);
- ***Commercial fishing*** (low energy scenario, medium energy scenario A);
- **Cetaceans** (low energy scenario, medium energy scenario A);
- **Grey seals** (medium energy scenario A); and
- **Special Area of Conservation** (medium energy scenario A).

7.5.13 It should be noted that for several of the topics highlighted in bold, there is an increasing need for monitoring of devices *in-situ* to provide field data, with further desk based work unlikely to increase the knowledge base sufficiently. Given the difficulties of achieving consent when the level of scientific certainty is not high, it is likely that a deploy and monitor approach may be required at least for early stage demonstrator devices, a situation acknowledged by some members of the Steering Group. Such an approach would enable the industry to progress past the difficult stage it is currently in – essentially that a lack of certainty is hampering the consenting process and until devices are deployed and monitored, it is becoming increasingly difficult to increase the level of certainty.

7.6 Where Next?

7.6.1 The MRESF project has been undertaken by RPS for the WAG to provide a management tool, which can be used to encourage and enable development of wave and tidal stream development in Welsh waters for particular sites. It also represents a useful source of information for developers as regards the baseline data currently available (with strategic level data used in the GIS mapping and a considerable amount of site specific work listed in the bibliography in WAG (2011b)) together with current understanding of the potential impacts of such developments.

7.6.2 The MRESF project has investigated the sustainability of reaching the 4GW installed capacity target, with three potential development scenarios being put forward as part of the process. Of the scenarios, the high energy and medium energy B have the potential to exceed the 4GW level, with the medium energy A and the low energy scenario likely to deliver lower levels of energy. The level of constraint, and hence the potential difficulty in achieving consent for a project, increases as the installed capacity goes up

between the scenarios. Regardless of which scenario is chosen, there remains considerable progress to be made if the 4GW target is to be considered attainable in the main by 2025.

7.6.3 It is frequently highlighted in the wider literature that the wave and tidal stream industry is in its 'infancy', which is undoubtedly true. However, there have been considerable developments in the past 5-10 years, with understanding of devices and how they interact with the environment increasing (see RPS, 2008 and WAG, 2011b). It is to be expected that such developments will continue, and as such it is considered that there is likely to be benefit in updating the MRESF in 5 years time to ensure the scenarios developed within this report remain relevant and appropriate towards 2025. Particular advances in the knowledge base that would be of interest are:

- Improved resource data, e.g. filling in the gaps in the current broad scale data, increasing the resolution of the data and potentially incorporating more site specific information;
- Improved and/or additional broad scale and strategic data layers for the existing environment; and
- Increases in the knowledge base of the potential impacts of wave and tidal stream devices, with the potential to alter the level of constraint associated with different data layers. There is significant potential for a 'deploy and monitor' approach to bring considerable benefit to the industry in Welsh waters here. It should, however, be noted that an increase in understanding would not necessarily lead to a reduction in the constraint, although it should increase the scientific certainty on which such an assessment can be made and hence decrease consenting risk, with potential for improvement in investor confidence.

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Appendices

Appendix A

GIS Data Layers

LAYER	SUBLAYER	BUFFER RADIUS (m)	UNITS	DISTRIBUTOR	ORIGINATOR	GEOGRAPHIC EXTENT	LAST UPDATE / DOWNLOADED	Social & Economic / Environmental / Base Data	Wind	Tide (Surface Piercing)	Tide (Wholly Submerged)	Wave (Surface Piercing)	Wave (Wholly Submerged)
Shipping and Navigation													
Shipping Density	*Total Ships per Year (>0 - 10)*		Count	Anatec UK Ltd	Anatec UK Ltd	Wales	03/04/2008	Social and Economic	2	2	2	2	2
	Total Ships per Year (>10 - 50)		Count	Anatec UK Ltd	Anatec UK Ltd	Wales	03/04/2008	Social and Economic	2	2	2	2	2
	Total Ships per Year (>50 - 250)		Count	Anatec UK Ltd	Anatec UK Ltd	Wales	03/04/2008	Social and Economic	3	3	3	3	3
	Total Ships per Year (>250 - 1000)		Count	Anatec UK Ltd	Anatec UK Ltd	Wales	03/04/2008	Social and Economic	4	4	4	4	4
	Total Ships per Year (>1000 - 5000)		Count	Anatec UK Ltd	Anatec UK Ltd	Wales	03/04/2008	Social and Economic	4	4	4	4	4
	Total Ships per Year (>5000)		Count	Anatec UK Ltd	Anatec UK Ltd	Wales	03/04/2008	Social and Economic	4	4	4	4	4
Shipping Routes				Anatec UK Ltd	Anatec UK Ltd	Wales	03/04/2008	Social and Economic	Informative	Informative	Informative	Informative	Informative
IMO Routeing	*IMO Routeing: Traffic Lane Extents*	500m		Maritime Data	International Maritime Organisation (IMO); Maritime Data	United Kingdom	02/03/2010	Social and Economic	5	5	5	5	5
	IMO Routeing: Area to be Avoided (ATBA)			Maritime Data	International Maritime Organisation (IMO); Maritime Data	United Kingdom	02/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	IMO Routeing: Separation Zones	500m		Maritime Data	International Maritime Organisation (IMO); Maritime Data	United Kingdom	02/03/2010	Social and Economic	5	5	5	5	5
Ports		250m		Maritime Data	Anatec UK Ltd; Maritime Data	United Kingdom	02/03/2010	Social and Economic	5	5	5	5	5
Harbour Facilities		250m		SeaZone Solutions Limited	Seazone Hydrospatial	Wales	04/03/2010	Social and Economic	5	5	5	5	5
Small Craft Facilities		250m		SeaZone Solutions Limited	Seazone Hydrospatial	Wales	05/03/2010	Social and Economic	5	5	5	5	5
Anchor, Berth, Dock Areas				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	06/03/2010	Social and Economic	5	5	5	5	5
Fairways				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	07/03/2010	Social and Economic	4	4	4	4	4
Pilot Boarding Places				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	08/03/2010	Social and Economic	5	5	5	5	5
Free Port Areas				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	09/03/2010	Social and Economic	4	4	4	4	4
Harbour Areas				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	10/03/2010	Social and Economic	5	5	5	5	5
Navigational Aids				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	04/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Aviation and Radar													
Radar (20m - 200m)				BWEA Avaition	NATS En Route Plc ("NERL")	United Kingdom	07/04/2010	Social and Economic	3	2	1	2	1
Air-Ground-Air (AGA) Consultation Zones				BWEA Avaition	NATS En Route Plc ("NERL")	United Kingdom	07/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Navigation Aids Consultation Zones				BWEA Avaition	NATS En Route Plc ("NERL")	United Kingdom	07/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Secondary Surveillance Radar (SSR) Consultation Zones				BWEA Avaition	NATS En Route Plc ("NERL")	United Kingdom	07/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Suggested Consultation Zones				RESTATS	Civil Avaition Authority	United Kingdom	07/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Aerodromes				Civil Avaition Authority	Civil Avaition Authority	United Kingdom	31/08/2007	Social and Economic	Informative	Informative	Informative	Informative	Informative
Civil Air Traffic Zones (CATZ)				Civil Avaition Authority	Civil Avaition Authority	United Kingdom	31/08/2007	Social and Economic	Informative	Informative	Informative	Informative	Informative
Landscape and Social Designations													
Historic Landscapes				CADW, Welsh Assembly Government	CADW, Welsh Assembly Government	Wales	02/03/2010	Social and Economic	4	3	1	3	1
Registered Parks and Gardens	*Park Boundary; Gardens & Kitchen Gardens; Essential Setting*			CADW, Welsh Assembly Government	CADW, Welsh Assembly Government	Wales	02/03/2010	Social and Economic	2	2	1	2	1
World Heritage Sites	*World Heritage Sites; Essential Setting*			CADW, Welsh Assembly Government	CADW, Welsh Assembly Government	Wales	02/03/2010	Social and Economic	4	4	2	4	2
Areas of Outstanding Natural Beauty				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	17/03/2010	Social and Economic	4	3	1	3	1
Country Parks				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	17/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Heritage Coast		Extent to Coastline		Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	17/03/2010	Social and Economic	3	3	3	3	3
Access Land				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	01/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Open Country				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	01/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative

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Public Forests				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	01/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Registered Common Land				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	01/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
National Parks*				National Parks Authorities	National Parks Authorities	Wales	14/04/2010	Social and Economic	4	3	1	3	1
Landscape and Seascape													
Landmap	*Cultural Landscape overall evaluation outstanding*			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Cultural Landscape overall evaluation high			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Cultural Landscape overall evaluation moderate			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Cultural Landscape overall evaluation low			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Geological Landscape overall evaluation outstanding			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Geological Landscape overall evaluation high			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Geological Landscape overall evaluation moderate			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Geological Landscape overall evaluation low			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Historic Landscape overall evaluation outstanding			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Historic Landscape overall evaluation high			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Historic Landscape overall evaluation moderate			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Historic Landscape overall evaluation low			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Landscape Habitats overall evaluation outstanding			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Landscape Habitats overall evaluation high			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Landscape Habitats overall evaluation moderate			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Landscape Habitats overall evaluation low			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Visual and Sensory overall evaluation outstanding			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Visual and Sensory overall evaluation high			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Visual and Sensory overall evaluation moderate			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
	Visual and Sensory overall evaluation low			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Seascape	*Seascape sensitivity to offshore wind - low*			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	02/02/2010	Social and Economic	1	N/A	N/A	N/A	N/A
	Seascape sensitivity to offshore wind - low/medium			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	03/02/2010	Social and Economic	1	N/A	N/A	N/A	N/A
	Seascape sensitivity to offshore wind - medium			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	04/02/2010	Social and Economic	2	N/A	N/A	N/A	N/A
	Seascape sensitivity to offshore wind - medium/high			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	05/02/2010	Social and Economic	3	N/A	N/A	N/A	N/A
	Seascape sensitivity to offshore wind - high			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	06/02/2010	Social and Economic	4	N/A	N/A	N/A	N/A
	Seascape sensitivity to wave farms - low			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	07/02/2010	Social and Economic	N/A	N/A	N/A	1	1
	Seascape sensitivity to wave farms - low/medium			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	08/02/2010	Social and Economic	N/A	N/A	N/A	1	1
	Seascape sensitivity to wave farms - medium			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	09/02/2010	Social and Economic	N/A	N/A	N/A	2	2
	Seascape sensitivity to wave farms - medium/high			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	10/02/2010	Social and Economic	N/A	N/A	N/A	3	2
	Seascape sensitivity to wave farms - high			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	11/02/2010	Social and Economic	N/A	N/A	N/A	3	3
	Seascape sensitivity to tidal stream developments - low			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	12/02/2010	Social and Economic	N/A	1	1	N/A	N/A
	Seascape sensitivity to tidal stream developments - low/medium			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	13/02/2010	Social and Economic	N/A	1	1	N/A	N/A
	Seascape sensitivity to tidal stream developments - medium			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	14/02/2010	Social and Economic	N/A	2	2	N/A	N/A

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	Seascape sensitivity to tidal stream developments - medium/high			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	15/02/2010	Social and Economic	N/A	3	2	N/A	N/A
	Seascape sensitivity to tidal stream developments - high			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	04/03/2010	Social and Economic	N/A	4	3	N/A	N/A
Archaeology													
Wrecks		50m		SeaZone Solutions Limited	Seazone Hydrospatial	Wales	07/03/2010	Social and Economic	3	3	3	3	3
Protected Wrecks	-	Various		MCGA	MCGA	Wales	14/07/2010	Social and Economic	5	5	5	5	5
Scheduled Ancient Monuments				CADW, Welsh Assembly Government	CADW, Welsh Assembly Government	Wales	02/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Oil and Gas													
25th Round of Offshore Licensing				Department of Energy and Climate Change (DECC)	UK Deal	United Kingdom	28/02/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Blocks on Offer (Round 26)				UK Deal	UK Deal	United Kingdom	28/02/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
License History				UK Deal	UK Deal	United Kingdom	28/02/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Installation Safety Zones				UK Deal	UK Deal	United Kingdom	28/02/2010	Social and Economic	5	5	5	5	5
Subsurface Installations		500m		UK Deal	UK Deal	United Kingdom	28/02/2010	Social and Economic	5	5	5	5	5
Surface Installations		500m		UK Deal	UK Deal	United Kingdom	28/02/2010	Social and Economic	5	5	5	5	5
Wells		500m		UK Deal	UK Deal	United Kingdom	28/02/2010	Social and Economic	5	5	5	5	5
Offshore Installations				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	04/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Cables and Pipelines													
Pipelines	*In Use*	500m		Seazone / Department of Energy and Climate Change (DECC)	UK Deal	United Kingdom	31/02/2010	Social and Economic	5	5	5	5	5
	Not In Use	500m		Seazone / Department of Energy and Climate Change (DECC)	UK Deal	United Kingdom	31/02/2010	Social and Economic	3	3	3	3	3
Submarine Cables (Kisca)	*In Use*	500m		Sea Fish Industry Authority	Kisca Kingfisher	Wales	13/04/2010	Social and Economic	5	5	5	5	5
	Not In Use	500m		Sea Fish Industry Authority	Kisca Kingfisher	Wales	13/04/2010	Social and Economic	3	3	3	3	3
East West Interconnector		500m		EIRGIRD Environmental Report	EIRGIRD Environmental Report	United Kingdom	13/07/2010	Social and Economic	5	5	5	5	5
Renewable Energy													
Renewable Energy Interests in Welsh Waters		250m		Project Specific Sources	Project Specific Sources	Wales	16/04/2010	Social and Economic	5	5	5	5	5
Electricity Substation Sites				National Grid	National Grid	United Kingdom	12/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Overhead Power Cables				National Grid	National Grid	United Kingdom	12/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Recreation													
Water-Related Recreational Activity Areas	*Angling (Sea)*			Environment Agency - Wales	Environment Agency - Wales	Wales	01/04/2010	Social and Economic	2	2	2	2	2
	Canoeing			Environment Agency - Wales	Environment Agency - Wales	Wales	01/04/2010	Social and Economic	2	2	2	2	2
	Dragon Boating			Environment Agency - Wales	Environment Agency - Wales	Wales	01/04/2010	Social and Economic	2	2	2	2	2
	Rowing			Environment Agency - Wales	Environment Agency - Wales	Wales	01/04/2010	Social and Economic	2	2	2	2	2
	Sailing			Environment Agency - Wales	Environment Agency - Wales	Wales	01/04/2010	Social and Economic	2	2	2	2	2
	Sea Bathing			Environment Agency - Wales	Environment Agency - Wales	Wales	01/04/2010	Social and Economic	2	2	2	2	2
	Kite Surfing			Environment Agency - Wales	Environment Agency - Wales	Wales	01/04/2010	Social and Economic	2	2	2	2	2
	Surfing			Environment Agency - Wales	Environment Agency - Wales	Wales	01/04/2010	Social and Economic	2	2	2	2	2
	Wind Surfing			Environment Agency - Wales	Environment Agency - Wales	Wales	01/04/2010	Social and Economic	2	2	2	2	2
	Motor Cruising (Coastal)			Environment Agency - Wales	Environment Agency - Wales	Wales	01/04/2010	Social and Economic	2	2	2	2	2
	Personal Water Crafting			Environment Agency - Wales	Environment Agency - Wales	Wales	01/04/2010	Social and Economic	2	2	2	2	2

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	Power Boating & Water Ski-ing			Environment Agency - Wales	Environment Agency - Wales	Wales	01/04/2010	Social and Economic	2	2	2	2	2
	Power Boating Only			Environment Agency - Wales	Environment Agency - Wales	Wales	01/04/2010	Social and Economic	2	2	2	2	2
Marine Pollution Control Zone				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	30/01/2008	Social and Economic	Informative	Informative	Informative	Informative	Informative
Bathing Waters - Designated Sensitive Areas				Environment Agency - Wales	Environment Agency - Wales	Wales	23/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
EC Bathing Waters				Environment Agency - Wales	Environment Agency - Wales	Wales	23/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Non EC Bathing Waters				Environment Agency - Wales	Environment Agency - Wales	Wales	23/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
South West Wales Recreational Activities				Pembrokeshire Coastal Forum	Pembrokeshire Coastal Forum	South West Wales	29/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Boat Cruising Routes		50m		Royal Yachting Association (RYA)	Royal Yachting Association (RYA)	United Kingdom	27/04/2010	Social and Economic	2	2	2	2	2
Boat Racing Areas				Royal Yachting Association (RYA)	Royal Yachting Association (RYA)	United Kingdom	27/04/2010	Social and Economic	2	2	2	2	2
Marinas		250m		Royal Yachting Association (RYA)	Royal Yachting Association (RYA)	United Kingdom	27/04/2010	Social and Economic	4	4	4	4	4
Sailing Areas				Royal Yachting Association (RYA)	Royal Yachting Association (RYA)	United Kingdom	27/04/2010	Social and Economic	2	2	2	2	2
Yachting Clubs				Royal Yachting Association (RYA)	Royal Yachting Association (RYA)	United Kingdom	27/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Yachting Training Centres				Royal Yachting Association (RYA)	Royal Yachting Association (RYA)	United Kingdom	27/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
National Cycle Network and Other Routes				Sustrans	Sustrans	Wales	13/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
National Trust Land Ownership*				National Trust	National Trust	Wales	15/06/2010	Social and Economic	4	3	1	3	1
Visit Wales Attractions		100m		Visit Wales	Visit Wales	Wales	08/06/2010	Social and Economic	2	2	1	2	1
Fisheries and Shellfisheries													
Designated Sensitive Areas (Eutrophic)				Environment Agency - Wales	Environment Agency - Wales	Wales	23/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Shellfish Waters - Designated Sensitive Areas				Environment Agency - Wales	Environment Agency - Wales	Wales	23/04/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Fishing - Days Fished				Maritime Data	DECC SEA; Hartley Anderson Limited; Maritime Data; Scottish Government Marine Directorate	United Kingdom	02/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Fishing - Landings Density				Maritime Data	DECC SEA; Hartley Anderson Limited; Maritime Data; Scottish Government Marine Directorate	United Kingdom	02/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Fishing - Port Landings				Maritime Data	Marine Fisheries Agency (MFA); Maritime Data	United Kingdom	02/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Fishing - Ports and Vessels				Maritime Data	DECC SEA; Hartley Anderson Limited; Marine Fisheries Agency (MFA); Maritime Data	United Kingdom	02/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Fishing - Satellite				Maritime Data	Marine Fisheries Agency (MFA); Maritime Data	United Kingdom	02/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
Fish Values	*1430-2000*		£	COWRIE	ABPmer Ltd	United Kingdom	02/03/2010	Environmental	1	1	1	1	1
	2000-5000		£	COWRIE	ABPmer Ltd	United Kingdom	02/03/2010	Environmental	1	1	1	1	1
	5000-10000		£	COWRIE	ABPmer Ltd	United Kingdom	02/03/2010	Environmental	2	2	2	2	2
	10000-20000		£	COWRIE	ABPmer Ltd	United Kingdom	02/03/2010	Environmental	2	2	2	2	2
	20000-30000		£	COWRIE	ABPmer Ltd	United Kingdom	02/03/2010	Environmental	3	3	3	3	3
	30000-40000		£	COWRIE	ABPmer Ltd	United Kingdom	02/03/2010	Environmental	3	3	3	3	3
	40000-50000		£	COWRIE	ABPmer Ltd	United Kingdom	02/03/2010	Environmental	4	4	4	4	4
	50000-60000		£	COWRIE	ABPmer Ltd	United Kingdom	02/03/2010	Environmental	4	4	4	4	4
Sensitivity of Benthos to Commercial Fishing				Countryside Council for Wales (CCW)	ABPmer Ltd	Wales	06/08/2010	Environmental	Informative	Informative	Informative	Informative	Informative
Classified Bivalve Mollusc Harvesting Areas				MAGIC	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	England and Wales	31/03/2010	Environmental	4	4	4	4	4
Marine Obstructions				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	04/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
MoD interests													
MoD Establishments*				Ministry of Defence	Ministry of Defence	Wales	13/03/2008	Social and Economic	Informative	Informative	Informative	Informative	Informative

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Military Air Traffic Zones (MATZ)				RPS Planning & Devlopment	Civil Avaition Authority	United Kingdom	31/08/2007	Social and Economic	Informative	Informative	Informative	Informative	Informative
Explosives Dumping Sites				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	04/03/2010	Social and Economic	5	5	5	5	5
Marine Military Practice Areas				SeaZone Solutions Limited	SeaZone Hydrospatial	Wales	04/03/2010	Social and Economic	4	4	4	4	4
Disposal at Sea													
Spoil Grounds				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	04/03/2010	Social and Economic	5	5	5	5	5
Fish Ecology													
Fisheries Sensitivity Maps in British Waters	*Nursery Area - Cod*			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Nursery Area - Haddock			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Nursery Area - Herring			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Nursery Area - Lemon Sole			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Nursery Area - Nephrops			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Nursery Area - Plaice			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Nursery Area - Sole			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Nursery Area - Whiting			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Fish Spawning - Cod			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Fish Spawning - Haddock			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Fish Spawning - Herring			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Fish Spawning - Lemon Sole			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Fish Spawning - Nephrops			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Fish Spawning - Plaice			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Fish Spawning - Sole			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
	Fish Spawning - Whiting			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	15/10/2007	Environmental	3	3	3	3	3
Spawning and Nursery Areas of Fish of Commercial and Conservation Importance	*Spawning - Cod*			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Spawning - Ling			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Spawning - Mackerel			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Spawning - Plaice			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Spawning - Sandeel			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Spawning - Sole			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Spawning - Whiting			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Nursery - Anglerfish			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Nursery - Blue whiting			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Nursery - Cod			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Nursery - European hake			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Nursery - Herring			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Nursery - Ling			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Nursery - Mackerel			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Nursery - Plaice			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative

LAYER	SUBLAYER	BUFFER RADIUS (m)	UNITS	DISTRIBUTOR	ORIGINATOR	GEOGRAPHIC EXTENT	LAST UPDATE / DOWNLOADED	Social & Economic / Environmental / Base Data	Wind	Tide (Surface Piercing)	Tide (Wholly Submerged)	Wave (Surface Piercing)	Wave (Wholly Submerged)
	Nursery - Sandeel			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Nursery - Sole			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Nursery - Spotted ray			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Nursery - Spurdog			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Nursery - Thornback ray			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Nursery - Tope shark			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
	Nursery - Whiting			Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Centre for Environment, Fisheries & Aquaculture Science (CEFAS)	Great Britain	10/02/2011	Environmental	Informative	Informative	Informative	Informative	Informative
Bird Ecology													
Common Scoter Concentrations				CCW / Coastal Assesment, Liason & Monitoring (CALM)	Countryside Council for Wales (CCW)	Wales	16/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
Seabird 2000				CCW / Coastal Assesment, Liason & Monitoring (CALM)	Joint Nature Conservation Committee (JNCC)	Wales	16/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
Seabirds at Sea: Vulnerability to Oil				CCW / Coastal Assesment, Liason & Monitoring (CALM)	Countryside Council for Wales (CCW)	Wales	16/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
Seabird Colonies				CCW / Coastal Assesment, Liason & Monitoring (CALM)	Coastal Assesment, Liason & Monitoring (CALM)	Wales	16/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
Wetland Birds				CCW / Coastal Assesment, Liason & Monitoring (CALM)	WeBS Partnership	Wales	16/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
Diving Seabirds Vulnerability (Combined)	*0-10*		Score	CCW	Countryside Council for Wales (CCW)	Wales	10/11/2010	Environmental	N/A	2	2	2	2
	10-25		Score	CCW	Countryside Council for Wales (CCW)	Wales	10/11/2010	Environmental	N/A	3	3	3	3
	25-1300		Score	CCW	Countryside Council for Wales (CCW)	Wales	10/11/2010	Environmental	N/A	4	4	4	4
Marine Mammals													
Grey Seals Pupping & Haul Out Sites				CCW / Coastal Assesment, Liason & Monitoring (CALM)	Countryside Council for Wales (CCW)	Wales	16/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
Cetaceans Vulnerability	*0-3*		Score	Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	10/11/2010	Environmental	Informative	2	2	2	2
	3-15		Score	Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	10/11/2010	Environmental	Informative	3	3	3	3
	15-216		Score	Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	10/11/2010	Environmental	Informative	4	4	4	4
Grey Seals Vulnerability	*0-20*		Score	Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	10/11/2010	Environmental	Informative	2	2	2	2
	20-890		Score	Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	10/11/2010	Environmental	Informative	3	3	3	3
	890-5410		Score	Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	10/11/2010	Environmental	Informative	4	4	4	4
JNCC Cetacean Atlas	*White Beaked Dolphin*			Joint Nature Conservation Committee (JNCC)	Joint Nature Conservation Committee (JNCC)	United Kingdom	12/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
	Short Beaked Common Dolphin			Joint Nature Conservation Committee (JNCC)	Joint Nature Conservation Committee (JNCC)	United Kingdom	12/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
	Common Bottlenose Dolphin			Joint Nature Conservation Committee (JNCC)	Joint Nature Conservation Committee (JNCC)	United Kingdom	12/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
	Atlantic White Dolphin			Joint Nature Conservation Committee (JNCC)	Joint Nature Conservation Committee (JNCC)	United Kingdom	12/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
	Long Finned Pilot Whale			Joint Nature Conservation Committee (JNCC)	Joint Nature Conservation Committee (JNCC)	United Kingdom	12/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
	Risso's Dolphin			Joint Nature Conservation Committee (JNCC)	Joint Nature Conservation Committee (JNCC)	United Kingdom	12/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
	Harbour Porpoise			Joint Nature Conservation Committee (JNCC)	Joint Nature Conservation Committee (JNCC)	United Kingdom	12/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
	Killer Whale			Joint Nature Conservation Committee (JNCC)	Joint Nature Conservation Committee (JNCC)	United Kingdom	12/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
	Sei Whale			Joint Nature Conservation Committee (JNCC)	Joint Nature Conservation Committee (JNCC)	United Kingdom	12/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
	Fin Whale			Joint Nature Conservation Committee (JNCC)	Joint Nature Conservation Committee (JNCC)	United Kingdom	12/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
	Minke Whale			Joint Nature Conservation Committee (JNCC)	Joint Nature Conservation Committee (JNCC)	United Kingdom	12/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
Intertidal Ecology													
Phase 1 Intertidal Biotopes				CCW / Coastal Assesment, Liason & Monitoring (CALM)	Countryside Council for Wales (CCW)	Wales	16/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative

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Conservation Designations													
Biogenetic Reserves				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	17/03/2010	Environmental	3	3	3	3	3
Biospheric Reserves				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	17/03/2010	Environmental	3	3	3	3	3
Local Nature Reserves				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	17/03/2010	Environmental	3	3	3	3	3
Marine Nature Reserves				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	17/03/2010	Environmental	4	4	4	4	4
National Nature Reserves				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	17/03/2010	Environmental	3	3	3	3	3
RAMSAR Sites				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	17/03/2010	Environmental	3	3	3	3	3
Sites of Special Scientific Interest				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	17/03/2010	Environmental	3	3	3	3	3
Special Areas of Conservation (Non Habitat Features)				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	17/03/2010	Environmental	3	3	3	3	3
SAC Habitat Features	*Reefs*			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	16/08/2010	Environmental	4	4	4	4	4
	Dunes			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	16/08/2010	Environmental	4	4	4	4	4
	Salicornia			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	16/08/2010	Environmental	4	4	4	4	4
	Sea Caves	50m		Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	16/08/2010	Environmental	4	4	4	4	4
	Lagoons			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	16/08/2010	Environmental	4	4	4	4	4
	Vegetated Sea Cliffs			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	16/08/2010	Environmental	4	4	4	4	4
	Mud & Sandflats			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	16/08/2010	Environmental	4	4	4	4	4
	Sandbanks			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	16/08/2010	Environmental	4	4	4	4	4
	Drift Lines			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	16/08/2010	Environmental	4	4	4	4	4
	Atlantic Salt Meadows			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	16/08/2010	Environmental	4	4	4	4	4
	Estuaries			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	16/08/2010	Environmental	4	4	4	4	4
	Shallow Inlets & Bays			Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	16/08/2010	Environmental	4	4	4	4	4
Offshore Areas of Search for SACs				Joint Nature Conservation Committee (JNCC)	Joint Nature Conservation Committee (JNCC)	Wales	16/08/2010	Environmental	Informative	Informative	Informative	Informative	Informative
Special Protection Areas				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	16/08/2010	Environmental	3	3	3	3	3
Potential Special Protection Areas				Countryside Council for Wales (CCW)	Countryside Council for Wales (CCW)	Wales	17/03/2010	Environmental	3	3	3	3	3
Important Bird Areas				Royal Society for the Protection of Birds (RSPB)	Royal Society for the Protection of Birds (RSPB)	Great Britain	07/04/2010	Environmental	3	3	3	3	3
Bird Reserves				Royal Society for the Protection of Birds (RSPB)	Royal Society for the Protection of Birds (RSPB)	United Kingdom	07/04/2010	Environmental	3	3	3	3	3
Pembroke Island Marine Environmental High Risk Areas				RPS Planning & Development	Department for Transport (DfT)	Pembroke Island	-	Environmental	Informative	Informative	Informative	Informative	Informative
Subtidal Ecology													
Subtidal Biotopes (HabMap)				Habitat Mapping For Conservation and Management of the Southern Irish Sea (HabMap)	Habitat Mapping For Conservation and Management of the Southern Irish Sea (HabMap)	Irish Sea	14/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
Seabed Landscapes				Joint Nature Conservation Committee (JNCC)	Joint Nature Conservation Committee (JNCC)	United Kingdom	16/10/2007	Environmental	Informative	Informative	Informative	Informative	Informative
Offshore Flora & Fauna				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	04/03/2010	Environmental	Informative	Informative	Informative	Informative	Informative
Physical Processes and Geology													
Hydrological Features				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	04/03/2010	Environmental	Informative	Informative	Informative	Informative	Informative
Phase 1 Intertidal Substrata				CCW / Coastal Assesment, Liason & Monitoring (CALM)	Countryside Council for Wales (CCW)	Wales	16/04/2010	Environmental	Informative	Informative	Informative	Informative	Informative
Subtidal Geology				SeaZone Solutions Limited	British Geological Society (BGS)	Wales	04/03/2010	Environmental	Informative	Informative	Informative	Informative	Informative
Tides & Tidal Currents				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	04/03/2010	Environmental	Base Data	Base Data	Base Data	Base Data	Base Data

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Resource													
Atlas of UK Marine Renewable Energy Resources - Wave				Department of Trade & Industry	ABPmer Ltd	United Kingdom	15/01/2010	Social and Economic	Base Data	Base Data	Base Data	Base Data	Base Data
Atlas of UK Marine Renewable Energy Resources - Wind				Met Office	ABPmer Ltd	United Kingdom	15/01/2010	Social and Economic	Base Data	Base Data	Base Data	Base Data	Base Data
Atlas of UK Marine Renewable Energy Resources - Tide				Proudman Oceanographic Laboratory (POL)	ABPmer Ltd	United Kingdom	15/01/2010	Social and Economic	Base Data	Base Data	Base Data	Base Data	Base Data
Aggregate Dredging													
Dredging Areas				The Crown Estate	The Crown Estate	United Kingdom	03/10/2010	Social and Economic	5	5	5	5	5
Dredging Routes		250m		British Marine Aggregate Producers Association	British Marine Aggregate Producers Association	United Kingdom	30/07/2010	Social and Economic	4	4	4	4	4
General													
Spatial Units				RPS Planning & Development	RPS Planning & Development	Wales	-	Base Data	Base Data	Base Data	Base Data	Base Data	Base Data
Study Area				RPS Planning & Development	RPS Planning & Development	Wales	-	Base Data	Base Data	Base Data	Base Data	Base Data	Base Data
Land & Sea Cover				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	04/03/2010	Base Data	Base Data	Base Data	Base Data	Base Data	Base Data
National Limits				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	04/03/2010	Base Data	Base Data	Base Data	Base Data	Base Data	Base Data
Bathymetry				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	04/03/2010	Base Data	Base Data	Base Data	Base Data	Base Data	Base Data
Other													
Sites under IPC (Intergrated Pollution Control)				Environment Agency - Wales	Environment Agency - Wales	Wales	14/03/2005	Environmental	Informative	Informative	Informative	Informative	Informative
Sites under IPPC (Intergrated Pollution Provention Control)				Environment Agency - Wales	Environment Agency - Wales	Wales	14/03/2005	Environmental	Informative	Informative	Informative	Informative	Informative
Shoreline Constructions				SeaZone Solutions Limited	Seazone Hydrospatial	Wales	04/03/2010	Social and Economic	Informative	Informative	Informative	Informative	Informative
*** Data processed to generate a Zone of Theoretical Visibility (ZTV) and a viewshed created including Earth Curvature and refractivity in the calculation, with the maximum visible distance set at 24km. A combined ZTV was created and used in the constraints mapping with the constraint ranks in this table used.**													

Appendix B

Percentage of Constraint Data Layers Affected by Each Device Type Resource Area in Step 4

CONSTRAINT	Tide (Surface Piercing)	Tide (Wholly Submerged)	Wave (Surface Piercing)	Wave (Wholly Submerged)	Percentage of Constraint within Welsh Waters Affected (%)					
					Nearshore OWC	Nearshore SPB	Offshore Multi-Buoy	Offshore SPB	Offshore Overtopping Collector	Tidal Stream
Shipping Density - Total Ships per Year (>0 - 10)	2	2	2	2	1.50	0.00	5.05	5.05	12.37	3.10
Shipping Density - Total Ships per Year (>10 - 50)	2	2	2	2	1.99	0.00	7.99	7.99	20.24	2.41
Shipping Density - Total Ships per Year (>50 - 250)	3	3	3	3	1.32	0.01	10.98	10.98	22.81	0.97
Shipping Density - Total Ships per Year (>250 - 1000)	4	4	4	4	0.33	0.32	10.72	10.72	22.53	0.67
Shipping Density - Total Ships per Year (>1000 - 5000)	4	4	4	4	0.80	0.33	5.44	5.44	14.83	2.20
Shipping Density - Total Ships per Year (>5000)	4	4	4	4	4.92	0.00	0.00	0.00	0.00	18.65
Small Craft Facilities	5	5	5	5	1.45	0.00	0.00	0.00	0.00	0.00
Anchor, Berth, Dock Areas	5	5	5	5	0.00	0.00	0.00	0.00	0.00	0.10
Fairways	4	4	4	4	8.14	0.00	0.00	0.00	0.00	0.00
Pilot Boarding Places	5	5	5	5	0.00	0.00	0.00	0.00	0.00	65.78
Harbour Areas	5	5	5	5	4.71	0.00	0.00	0.00	8.49	1.40
Radar (20m - 200m)	2	1	2	1	1.78	0.00	1.49	1.49	9.97	0.00
Historic Landscapes	3	1	3	1	3.56	0.00	0.00	0.00	0.00	0.26
Areas of Outstanding Natural Beauty	3	1	3	1	0.00	0.00	0.00	0.00	0.00	0.73
Heritage Coast	3	3	3	3	13.87	0.00	0.00	0.00	0.21	8.03
National Parks	3	1	3	1	1.93	0.17	10.07	10.07	21.28	0.35
National Trust Land Ownership	3	1	3	1	1.15	0.10	5.91	5.91	10.86	0.95
Seascape sensitivity to wave farms - medium	-	-	2	2	1.58	0.14	6.42	6.42	11.66	0.00
Seascape sensitivity to wave farms - medium/high	-	-	3	2	1.92	0.21	8.27	8.27	20.52	0.00
Seascape sensitivity to wave farms - high	-	-	3	3	0.56	0.00	8.08	8.08	14.21	0.00
Seascape sensitivity to tidal stream developments - low/medium	1	1	-	-	0.00	0.00	0.00	0.00	0.00	3.24
Seascape sensitivity to tidal stream developments - medium	2	2	-	-	0.00	0.00	0.00	0.00	0.00	1.74
Seascape sensitivity to tidal stream developments - medium/high	3	2	-	-	0.00	0.00	0.00	0.00	0.00	1.90
Seascape sensitivity to tidal stream developments - high	4	3	-	-	0.00	0.00	0.00	0.00	0.00	0.45
Wrecks	3	3	3	3	2.84	0.00	4.69	4.69	11.38	3.67
Protected Wrecks	5	5	5	5	0.00	0.00	0.00	0.00	8.70	30.52
Wells	5	5	5	5	0.00	0.00	0.00	0.00	6.75	0.00
Submarine Cables (Kisca) - In Use	5	5	5	5	0.00	0.00	2.39	2.39	14.24	0.00
Submarine Cables (Kisca) - Not In Use	3	3	3	3	0.00	0.00	0.00	0.00	0.68	0.08
Renewable Energy Interests in Welsh Waters	5	5	5	5	0.92	0.00	3.84	3.84	11.86	1.22
Boat Cruising Routes	2	2	2	2	1.87	0.12	2.15	2.15	6.14	2.46
Boat Racing Areas	2	2	2	2	0.33	0.00	0.00	0.00	0.00	2.09
Sailing Areas	2	2	2	2	0.09	0.00	0.00	0.00	0.00	2.62
Fish Values - 1430-2000	1	1	1	1	0.54	0.00	0.00	0.00	1.00	2.31
Fish Values - 2000-5000	1	1	1	1	0.29	0.00	1.00	1.00	2.30	0.61
Fish Values - 5000-10000	2	2	2	2	2.34	0.29	11.60	11.60	24.20	0.59
Fish Values - 10000-20000	2	2	2	2	0.22	0.00	6.77	6.77	13.13	2.01
Fish Values - 20000-30000	3	3	3	3	0.00	0.00	0.00	0.00	6.28	3.73
Fish Values - 40000-50000	4	4	4	4	0.42	0.00	0.00	0.00	4.45	0.00
Fish Values - 50000-60000	4	4	4	4	0.00	0.00	0.00	0.00	50.00	0.00
Explosives Dumping Sites	5	5	5	5	0.00	3.73	45.80	45.80	59.32	0.00
Marine Military Practice Areas	4	4	4	4	0.45	0.04	5.36	5.36	10.71	0.00
Spoil Grounds	5	5	5	5	1.81	0.00	0.00	0.00	0.00	0.00
Fish Nursery Areas - Nursery Area - Lemon Sole	3	3	3	3	0.00	0.00	0.23	0.23	3.11	0.00
Fish Nursery Areas - Nursery Area - Plaice	3	3	3	3	0.64	0.00	0.00	0.00	0.00	0.00
Fish Nursery Areas - Nursery Area - Sole	3	3	3	3	0.67	0.00	0.00	0.00	0.00	0.07
Fish Nursery Areas - Nursery Area - Whiting	3	3	3	3	0.75	0.00	0.05	0.05	1.35	1.68
Fish Spawning Areas - Fish Spawning - Herring	3	3	3	3	31.74	0.00	0.00	0.00	6.14	0.00
Fish Spawning Areas - Fish Spawning - Lemon Sole	3	3	3	3	0.00	0.00	0.23	0.23	3.10	0.00
Fish Spawning Areas - Fish Spawning - Plaice	3	3	3	3	0.00	0.00	1.43	1.43	3.76	0.00
Fish Spawning Areas - Fish Spawning - Sole	3	3	3	3	0.00	0.00	4.59	4.59	11.11	0.00
Diving Seabirds Vulnerability (Combined) - 0-10	2	2	2	2	0.80	0.00	1.73	1.73	4.70	1.69
Diving Seabirds Vulnerability (Combined) - 10-25	3	3	3	3	0.91	0.15	8.09	8.09	17.10	0.60
Diving Seabirds Vulnerability (Combined) - 25-1300	4	4	4	4	2.98	0.72	24.75	24.75	50.79	0.00
Cetaceans Vulnerability - 0-3	2	2	2	2	0.53	0.00	2.12	2.12	6.58	1.19
Cetaceans Vulnerability - 3-15	3	3	3	3	0.30	0.20	10.09	10.09	20.81	0.88
Cetaceans Vulnerability - 15-216	4	4	4	4	2.80	0.00	0.00	0.00	0.02	2.00
Grey Seals Vulnerability - 0-20	2	2	2	2	0.01	0.12	6.53	6.53	12.62	0.86
Grey Seals Vulnerability - 20-890	3	3	3	3	1.46	0.00	2.02	2.02	9.18	1.71

CONSTRAINT	Tide (Surface Piercing)	Tide (Wholly Submerged)	Wave (Surface Piercing)	Wave (Wholly Submerged)	Percentage of Constraint within Welsh Waters Affected (%)					
					Nearshore OWC	Nearshore SPB	Offshore Multi-Buoy	Offshore SPB	Offshore Overtopping Collector	Tidal Stream
Grey Seals Vulnerability - 890-5410	4	4	4	4	6.84	0.00	0.20	0.20	2.78	3.03
Marine Nature Reserves	4	4	4	4	95.48	0.00	0.00	0.00	0.00	0.00
National Nature Reserves	3	3	3	3	5.72	0.00	0.00	0.00	0.58	0.11
Sites of Special Scientific Interest	3	3	3	3	1.55	0.00	0.00	0.00	0.08	0.36
Special Areas of Conservation (Non habitat Features)	3	3	3	3	0.65	0.02	6.86	6.86	19.49	0.00
SAC Habitat Features - Reefs	4	4	4	4	6.81	0.70	4.37	4.37	11.64	2.72
SAC Habitat Features - Sea Caves	4	4	4	4	15.59	0.00	0.00	0.00	0.89	0.12
SAC Habitat Features - Mud & Sandflats	4	4	4	4	0.00	0.00	0.00	0.00	0.00	0.00
SAC Habitat Features - Sandbanks	4	4	4	4	0.52	0.00	0.00	0.00	0.84	0.95
SAC Habitat Features - Shallow Inlets & Bays	4	4	4	4	2.52	0.00	0.00	0.00	0.02	0.00
Special Protection Areas	3	3	3	3	0.34	0.00	0.00	0.00	0.03	0.04
Important Bird Areas	3	3	3	3	1.27	0.00	0.00	0.00	0.04	0.07
Bird Reserves	3	3	3	3	1.22	0.00	0.00	0.00	0.56	2.55
Dredging Routes	4	4	4	4	0.61	0.13	2.28	2.28	10.23	3.40

Appendix C

Percentage of Constraint Data Layers Affected by the Overall Resource Area in the Low, Medium and High Scenarios in Step 5

Low Energy Scenario

CONSTRAINT	Tide (Surface Piercing)	Tide (Wholly Submerged)	Wave (Surface Piercing)	Wave (Wholly Submerged)	Percentage of Constraint within Welsh Waters Affected by Resource Area (%)		Potential Energy (GW) x0.4 Reduction		
					Wave	Tidal Stream	Wave	Tidal Stream	TOTAL Potential Energy
Shipping Density - Total Ships per Year (>0 - 10)	2	2	2	2	4.97	1.49	0.16	0.04	0.19
Shipping Density - Total Ships per Year (>10 - 50)	2	2	2	2	5.04	0.71	0.17	0.02	0.19
Shipping Density - Total Ships per Year (>50 - 250)	3	3	3	3	11.22	0.00	0.76	0.00	0.76
Radar (20m - 200m)	2	1	2	1	0.29	0.00	0.02	0.00	0.02
Areas of Outstanding Natural Beauty	3	1	3	1	0.00	0.32	0.00	0.00	0.00
Heritage Coast	3	3	3	3	0.00	0.96	0.00	0.01	0.01
National Parks	3	1	3	1	5.34	0.00	1.34	0.00	1.34
National Trust Land Ownership	3	1	3	1	2.11	0.18	0.87	0.05	0.93
Seascape sensitivity to wave farms - medium	-	-	2	2	0.78	0.00	0.11	0.00	0.11
Seascape sensitivity to wave farms - medium/high	-	-	3	2	4.20	0.00	0.44	0.00	0.44
Seascape sensitivity to wave farms - high	-	-	3	3	7.22	0.00	0.63	0.00	0.63
Seascape sensitivity to tidal stream developments - low/medium	1	1	-	-	0.00	1.95	0.00	0.05	0.05
Wrecks	3	3	3	3	3.06	0.42	0.01	0.00	0.01
Submarine Cables (Kisca) - Not In Use	3	3	3	3	0.45	0.00	0.00	0.00	0.00
Boat Cruising Routes	2	2	2	2	1.83	0.33	0.09	0.01	0.10
Boat Racing Areas	2	2	2	2	0.00	0.20	0.00	0.01	0.01
Sailing Areas	2	2	2	2	0.00	0.45	0.00	0.05	0.05
Fish Values - 1430-2000	1	1	1	1	0.36	0.00	0.04	0.00	0.04
Fish Values - 2000-5000	1	1	1	1	0.42	0.00	0.03	0.00	0.03
Fish Values - 5000-10000	2	2	2	2	7.26	0.00	1.08	0.00	1.08
Fish Values - 10000-20000	2	2	2	2	3.17	0.67	0.34	0.05	0.40
Fish Values - 20000-30000	3	3	3	3	0.06	0.00	0.00	0.00	0.00
Fish Spawning Areas - Fish Spawning - Plaice	3	3	3	3	0.38	0.00	0.04	0.00	0.04
Fish Spawning Areas - Fish Spawning - Sole	3	3	3	3	0.80	0.00	0.07	0.00	0.07
Diving Seabirds Vulnerability (Combined) - 0-10	2	2	2	2	2.28	0.22	0.73	0.05	0.79
Diving Seabirds Vulnerability (Combined) - 10-25	3	3	3	3	4.68	0.00	0.75	0.00	0.75
Cetaceans Vulnerability - 0-3	2	2	2	2	0.85	0.00	0.16	0.00	0.16
Cetaceans Vulnerability - 3-15	3	3	3	3	6.30	0.34	1.33	0.05	1.38
Grey Seals Vulnerability - 0-20	2	2	2	2	3.90	0.00	1.36	0.00	1.36
Grey Seals Vulnerability - 20-890	3	3	3	3	1.06	0.60	0.13	0.05	0.18
Sites of Special Scientific Interest	3	3	3	3	0.00	0.03	0.00	0.00	0.00
Special Areas of Conservation (Non habitat Features)	3	3	3	3	6.33	0.00	0.37	0.00	0.37
Special Protection Areas	3	3	3	3	0.00	0.01	0.00	0.00	0.00
Important Bird Areas	3	3	3	3	0.00	0.01	0.00	0.00	0.00
Bird Reserves	3	3	3	3	0.00	0.20	0.00	0.00	0.00

Medium Energy Scenario A

CONSTRAINT	Tide (Surface Piercing)	Tide (Wholly Submerged)	Wave (Surface Piercing)	Wave (Wholly Submerged)	Percentage of Constraint within Welsh Waters Affected by Resource Area (%)			Potential Energy (GW) x0.4 Reduction			
					Nearshore Wave	Offshore Wave	Tidal Stream	Nearshore Wave	Offshore Wave	Tidal Stream	TOTAL Potential Energy
Shipping Density - Total Ships per Year (>0 - 10)	2	2	2	2	0.31	8.02	1.74	0.02	0.25	0.04	0.32
Shipping Density - Total Ships per Year (>10 - 50)	2	2	2	2	0.05	12.99	1.58	0.00	0.44	0.04	0.49
Shipping Density - Total Ships per Year (>50 - 250)	3	3	3	3	0.15	17.10	0.74	0.03	1.16	0.04	1.22
Shipping Density - Total Ships per Year (>250 - 1000)	4	4	4	4	0.00	8.92	0.38	0.00	0.62	0.02	0.64
Shipping Density - Total Ships per Year (>1000 - 5000)	4	4	4	4	0.00	6.21	0.46	0.00	0.36	0.02	0.38
Radar (20m - 200m)	2	1	2	1	0.30	0.98	0.00	0.05	0.06	0.00	0.10
Historic Landscapes	3	1	3	1	1.24	0.00	0.00	0.03	0.00	0.00	0.03
Areas of Outstanding Natural Beauty	3	1	3	1	0.00	0.00	0.32	0.00	0.00	0.00	0.00
Heritage Coast	3	3	3	3	1.40	0.00	1.15	0.05	0.00	0.01	0.07
National Parks	3	1	3	1	0.20	12.13	0.00	0.13	3.04	0.00	3.17
National Trust Land Ownership	3	1	3	1	0.12	5.50	0.40	0.12	2.27	0.12	2.52
Seascape sensitivity to wave farms - medium	-	-	2	2	0.12	3.84	0.00	0.05	0.56	0.00	0.61
Seascape sensitivity to wave farms - medium/high	-	-	3	2	0.31	11.20	0.00	0.08	1.18	0.00	1.26
Seascape sensitivity to wave farms - high	-	-	3	3	0.00	12.35	0.00	0.00	1.09	0.00	1.09
Seascape sensitivity to tidal stream developments - low/medium	1	1	-	-	0.00	0.00	2.76	0.00	0.00	0.08	0.08
Seascape sensitivity to tidal stream developments - medium	2	2	-	-	0.00	0.00	0.31	0.00	0.00	0.02	0.02
Seascape sensitivity to tidal stream developments - medium/high	3	2	-	-	0.00	0.00	1.04	0.00	0.00	0.11	0.11
Wrecks	3	3	3	3	0.19	6.45	1.46	0.00	0.02	0.00	0.02
Submarine Cables (Kisca) - Not In Use	3	3	3	3	0.00	0.68	0.08	0.00	0.00	0.00	0.00
Boat Cruising Routes	2	2	2	2	0.12	2.75	1.21	0.01	0.13	0.04	0.19
Boat Racing Areas	2	2	2	2	0.00	0.00	1.57	0.00	0.00	0.06	0.06
Sailing Areas	2	2	2	2	0.00	0.00	1.23	0.00	0.00	0.15	0.15
Fish Values - 1430-2000	1	1	1	1	0.22	0.97	0.92	0.05	0.09	0.07	0.22
Fish Values - 2000-5000	1	1	1	1	0.07	1.23	0.00	0.01	0.10	0.00	0.11
Fish Values - 5000-10000	2	2	2	2	0.05	16.43	0.00	0.02	2.44	0.00	2.45
Fish Values - 10000-20000	2	2	2	2	0.13	6.19	1.43	0.03	0.67	0.12	0.82
Fish Values - 20000-30000	3	3	3	3	0.00	1.37	1.99	0.00	0.02	0.03	0.05
Marine Military Practice Areas	4	4	4	4	0.10	2.65	0.00	0.04	0.46	0.00	0.50
Fish Nursery Areas - Nursery Area - Lemon Sole	3	3	3	3	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Fish Nursery Areas - Nursery Area - Plaice	3	3	3	3	0.28	0.00	0.00	0.08	0.00	0.00	0.08
Fish Nursery Areas - Nursery Area - Sole	3	3	3	3	0.26	0.00	0.07	0.03	0.00	0.00	0.03
Fish Nursery Areas - Nursery Area - Whiting	3	3	3	3	0.14	0.00	0.67	0.05	0.00	0.07	0.11
Fish Spawning Areas - Fish Spawning - Herring	3	3	3	3	4.96	0.00	0.00	0.04	0.00	0.00	0.04
Fish Spawning Areas - Fish Spawning - Lemon Sole	3	3	3	3	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Fish Spawning Areas - Fish Spawning - Plaice	3	3	3	3	0.00	1.55	0.00	0.00	0.18	0.00	0.18
Fish Spawning Areas - Fish Spawning - Sole	3	3	3	3	0.00	5.22	0.00	0.00	0.47	0.00	0.47
Diving Seabirds Vulnerability (Combined) - 0-10	2	2	2	2	0.11	3.87	0.83	0.09	1.25	0.20	1.54
Diving Seabirds Vulnerability (Combined) - 10-25	3	3	3	3	0.10	10.66	0.06	0.04	1.71	0.01	1.76
Diving Seabirds Vulnerability (Combined) - 25-1300	4	4	4	4	0.00	13.11	0.00	0.00	0.35	0.00	0.35
Cetaceans Vulnerability - 0-3	2	2	2	2	0.10	2.16	0.48	0.05	0.41	0.07	0.52
Cetaceans Vulnerability - 3-15	3	3	3	3	0.00	13.79	0.39	0.00	2.91	0.06	2.97
Cetaceans Vulnerability - 15-216	4	4	4	4	0.29	0.00	0.93	0.08	0.00	0.08	0.16
Grey Seals Vulnerability - 0-20	2	2	2	2	0.00	8.19	0.31	0.00	2.85	0.08	2.93
Grey Seals Vulnerability - 20-890	3	3	3	3	0.42	3.81	1.39	0.13	0.46	0.13	0.72
Grey Seals Vulnerability - 890-5410	4	4	4	4	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Sites of Special Scientific Interest	3	3	3	3	0.26	0.00	0.03	0.01	0.00	0.00	0.01
Special Areas of Conservation (Non habitat Features)	3	3	3	3	0.37	14.79	0.00	0.05	0.87	0.00	0.92
SAC Habitat Features - Reefs	4	4	4	4	0.03	0.62	0.00	0.00	0.03	0.00	0.03
Special Protection Areas	3	3	3	3	0.00	0.00	0.01	0.00	0.00	0.00	0.00

CONSTRAINT	Tide (Surface Piercing)	Tide (Wholly Submerged)	Wave (Surface Piercing)	Wave (Wholly Submerged)	Percentage of Constraint within Welsh Waters Affected by Resource Area (%)			Potential Energy (GW) x0.4 Reduction			
					Nearshore Wave	Offshore Wave	Tidal Stream	Nearshore Wave	Offshore Wave	Tidal Stream	TOTAL Potential Energy
Dredging Routes	4	4	4	4	0.00	0.00	0.84	0.00	0.00	0.01	0.01

Medium Energy Scenario B

CONSTRAINT	Tide (Surface Piercing)	Tide (Wholly Submerged)	Wave (Surface Piercing)	Wave (Wholly Submerged)	Percentage of Constraint within Welsh Waters Affected by Resource Area (%)			Potential Energy (GW) x0.4 Reduction			
					Nearshore Wave	Offshore Wave	Tidal Stream	Nearshore Wave	Offshore Wave	Tidal Stream	TOTAL Potential Energy
Shipping Density - Total Ships per Year (>0 - 10)	2	2	2	2	0.62	8.94	2.62	0.05	0.28	0.06	0.39
Shipping Density - Total Ships per Year (>10 - 50)	2	2	2	2	0.35	14.29	2.41	0.03	0.48	0.06	0.58
Shipping Density - Total Ships per Year (>50 - 250)	3	3	3	3	0.25	21.38	0.94	0.04	1.45	0.05	1.54
Shipping Density - Total Ships per Year (>250 - 1000)	4	4	4	4	0.16	15.97	0.60	0.03	1.10	0.03	1.16
Shipping Density - Total Ships per Year (>1000 - 5000)	4	4	4	4	0.36	9.14	1.06	0.05	0.54	0.05	0.63
Shipping Density - Total Ships per Year (>5000)	4	4	4	4	0.00	0.00	11.27	0.00	0.00	0.03	0.03
Radar (20m - 200m)	2	1	2	1	0.75	3.53	0.00	0.11	0.21	0.00	0.33
Historic Landscapes	3	1	3	1	1.67	0.00	0.22	0.04	0.00	0.00	0.05
Areas of Outstanding Natural Beauty	3	1	3	1	0.00	0.00	0.32	0.00	0.00	0.00	0.00
Heritage Coast	3	3	3	3	4.25	0.00	6.46	0.16	0.00	0.07	0.24
National Parks	3	1	3	1	0.62	16.32	0.35	0.39	4.09	0.07	4.55
National Trust Land Ownership	3	1	3	1	0.35	7.96	0.75	0.36	3.28	0.23	3.88
Seascape sensitivity to wave farms - medium	-	-	2	2	0.31	7.26	0.00	0.11	1.07	0.00	1.18
Seascape sensitivity to wave farms - medium/high	-	-	3	2	0.86	15.84	0.00	0.23	1.67	0.00	1.90
Seascape sensitivity to wave farms - high	-	-	3	3	0.23	13.02	0.00	0.05	1.14	0.00	1.19
Seascape sensitivity to tidal stream developments - low/medium	1	1	-	-	0.00	0.00	2.76	0.00	0.00	0.08	0.08
Seascape sensitivity to tidal stream developments - medium	2	2	-	-	0.00	0.00	0.75	0.00	0.00	0.05	0.05
Seascape sensitivity to tidal stream developments - medium/high	3	2	-	-	0.00	0.00	1.47	0.00	0.00	0.16	0.16
Seascape sensitivity to tidal stream developments - high	4	3	-	-	0.00	0.00	0.44	0.00	0.00	0.07	0.07
Wrecks	3	3	3	3	0.71	8.47	2.36	0.01	0.03	0.01	0.04
Submarine Cables (Kisca) - Not In Use	3	3	3	3	0.00	0.68	0.08	0.00	0.00	0.00	0.00
Boat Cruising Routes	2	2	2	2	0.49	4.25	1.62	0.06	0.20	0.06	0.32
Boat Racing Areas	2	2	2	2	0.33	0.00	1.88	0.04	0.00	0.07	0.11
Sailing Areas	2	2	2	2	0.09	0.00	1.84	0.04	0.00	0.23	0.26
Fish Values - 1430-2000	1	1	1	1	0.49	0.97	1.35	0.12	0.09	0.10	0.31
Fish Values - 2000-5000	1	1	1	1	0.28	1.99	0.00	0.06	0.15	0.00	0.21
Fish Values - 5000-10000	2	2	2	2	0.28	20.44	0.58	0.10	3.03	0.07	3.20
Fish Values - 10000-20000	2	2	2	2	0.22	9.09	1.76	0.06	0.98	0.14	1.18
Fish Values - 20000-30000	3	3	3	3	0.00	3.07	3.45	0.00	0.05	0.04	0.10
Fish Values - 40000-50000	4	4	4	4	0.42	0.98	0.00	0.04	0.04	0.00	0.08
Fish Values - 50000-60000	4	4	4	4	0.00	18.70	0.00	0.00	0.03	0.00	0.03
Marine Military Practice Areas	4	4	4	4	0.25	6.52	0.00	0.11	1.12	0.00	1.23
Fish Nursery Areas - Nursery Area - Lemon Sole	3	3	3	3	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Fish Nursery Areas - Nursery Area - Plaice	3	3	3	3	0.60	0.00	0.00	0.18	0.00	0.00	0.18
Fish Nursery Areas - Nursery Area - Sole	3	3	3	3	0.41	0.00	0.07	0.05	0.00	0.00	0.05
Fish Nursery Areas - Nursery Area - Whiting	3	3	3	3	0.46	0.55	0.98	0.15	0.07	0.10	0.33
Fish Spawning Areas - Fish Spawning - Herring	3	3	3	3	12.96	0.00	0.00	0.10	0.00	0.00	0.10
Fish Spawning Areas - Fish Spawning - Lemon Sole	3	3	3	3	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Fish Spawning Areas - Fish Spawning - Plaice	3	3	3	3	0.00	1.55	0.00	0.00	0.18	0.00	0.18
Fish Spawning Areas - Fish Spawning - Sole	3	3	3	3	0.00	7.08	0.00	0.00	0.63	0.00	0.63
Diving Seabirds Vulnerability (Combined) - 0-10	2	2	2	2	0.35	4.13	1.32	0.28	1.33	0.32	1.94
Diving Seabirds Vulnerability (Combined) - 10-25	3	3	3	3	0.23	14.25	0.26	0.09	2.29	0.03	2.41
Diving Seabirds Vulnerability (Combined) - 25-1300	4	4	4	4	0.19	27.99	0.00	0.01	0.75	0.00	0.77
Cetaceans Vulnerability - 0-3	2	2	2	2	0.33	3.93	0.70	0.15	0.74	0.10	1.00
Cetaceans Vulnerability - 3-15	3	3	3	3	0.12	17.23	0.80	0.06	3.63	0.13	3.82
Cetaceans Vulnerability - 15-216	4	4	4	4	0.62	0.01	1.46	0.18	0.00	0.13	0.30
Grey Seals Vulnerability - 0-20	2	2	2	2	0.00	10.01	0.59	0.00	3.48	0.15	3.64
Grey Seals Vulnerability - 20-890	3	3	3	3	1.08	7.15	1.45	0.33	0.87	0.13	1.33
Grey Seals Vulnerability - 890-5410	4	4	4	4	0.56	0.53	1.95	0.06	0.02	0.07	0.15

CONSTRAINT	Tide (Surface Piercing)	Tide (Wholly Submerged)	Wave (Surface Piercing)	Wave (Wholly Submerged)	Percentage of Constraint within Welsh Waters Affected by Resource Area (%)			Potential Energy (GW) x0.4 Reduction			
					Nearshore Wave	Offshore Wave	Tidal Stream	Nearshore Wave	Offshore Wave	Tidal Stream	TOTAL Potential Energy
Sites of Special Scientific Interest	3	3	3	3	0.33	0.00	0.26	0.02	0.00	0.00	0.02
Special Areas of Conservation (Non habitat Features)	3	3	3	3	0.47	18.52	0.00	0.07	1.09	0.00	1.15
SAC Habitat Features - Reefs	4	4	4	4	1.11	5.41	1.87	0.13	0.25	0.07	0.44
SAC Habitat Features - Sea Caves	4	4	4	4	0.66	0.00	0.00	0.00	0.00	0.00	0.00
SAC Habitat Features - Sandbanks	4	4	4	4	0.00	0.43	0.03	0.00	0.01	0.00	0.01
SAC Habitat Features - Shallow Inlets & Bays	4	4	4	4	0.32	0.00	0.00	0.03	0.00	0.00	0.03
Special Protection Areas	3	3	3	3	0.05	0.00	0.01	0.01	0.00	0.00	0.01
Important Bird Areas	3	3	3	3	0.78	0.00	0.01	0.05	0.00	0.00	0.05
Bird Reserves	3	3	3	3	0.00	0.00	1.64	0.00	0.00	0.00	0.00
Dredging Routes	4	4	4	4	0.02	2.24	2.56	0.00	0.05	0.04	0.09

High Energy Scenario

CONSTRAINT	Tide (Surface Piercing)	Tide (Wholly Submerged)	Wave (Surface Piercing)	Wave (Wholly Submerged)	Percentage of Constraint within Welsh Waters Affected by Resource Area (%)			Potential Energy (GW) x0.4 Reduction			
					Nearshore Wave	Offshore Wave	Tidal Stream	Nearshore Wave	Offshore Wave	Tidal Stream	TOTAL Potential Energy
Shipping Density - Total Ships per Year (>0 - 10)	2	2	2	2	1.19	9.20	2.63	0.09	0.29	0.06	0.44
Shipping Density - Total Ships per Year (>10 - 50)	2	2	2	2	1.84	15.17	2.41	0.16	0.51	0.06	0.73
Shipping Density - Total Ships per Year (>50 - 250)	3	3	3	3	0.95	21.77	0.94	0.16	1.47	0.05	1.68
Shipping Density - Total Ships per Year (>250 - 1000)	4	4	4	4	0.33	21.52	0.60	0.06	1.49	0.03	1.58
Shipping Density - Total Ships per Year (>1000 - 5000)	4	4	4	4	0.59	13.98	1.06	0.09	0.82	0.05	0.95
Shipping Density - Total Ships per Year (>5000)	4	4	4	4	0.13	0.00	11.27	0.00	0.00	0.03	0.03
Radar (20m - 200m)	2	1	2	1	0.90	7.09	0.00	0.14	0.43	0.00	0.57
Historic Landscapes	3	1	3	1	3.17	0.00	0.26	0.08	0.00	0.00	0.09
Areas of Outstanding Natural Beauty	3	1	3	1	0.00	0.00	0.32	0.00	0.00	0.00	0.00
Heritage Coast	3	3	3	3	11.50	0.00	6.87	0.44	0.00	0.08	0.52
National Parks	3	1	3	1	1.50	19.23	0.35	0.94	4.82	0.07	5.83
National Trust Land Ownership	3	1	3	1	0.88	9.72	0.87	0.91	4.01	0.27	5.19
Seascape sensitivity to wave farms - medium	-	-	2	2	1.02	9.87	0.00	0.38	1.45	0.00	1.83
Seascape sensitivity to wave farms - medium/high	-	-	3	2	1.91	18.22	0.00	0.50	1.92	0.00	2.42
Seascape sensitivity to wave farms - high	-	-	3	3	0.28	14.11	0.00	0.06	1.24	0.00	1.30
Seascape sensitivity to tidal stream developments - low/medium	1	1	-	-	0.00	0.00	2.76	0.00	0.00	0.08	0.08
Seascape sensitivity to tidal stream developments - medium	2	2	-	-	0.00	0.00	0.75	0.00	0.00	0.05	0.05
Seascape sensitivity to tidal stream developments - medium/high	3	2	-	-	0.00	0.00	1.79	0.00	0.00	0.19	0.19
Seascape sensitivity to tidal stream developments - high	4	3	-	-	0.00	0.00	0.45	0.00	0.00	0.07	0.07
Wrecks	3	3	3	3	1.90	10.27	2.36	0.01	0.03	0.01	0.05
Submarine Cables (Kisca) - Not In Use	3	3	3	3	0.00	0.68	0.08	0.00	0.00	0.00	0.00
Boat Cruising Routes	2	2	2	2	1.38	5.35	1.63	0.16	0.25	0.06	0.48
Boat Racing Areas	2	2	2	2	0.33	0.00	1.88	0.04	0.00	0.07	0.11
Sailing Areas	2	2	2	2	0.09	0.00	1.84	0.04	0.00	0.23	0.26
Fish Values - 1430-2000	1	1	1	1	0.52	0.97	1.35	0.13	0.09	0.10	0.32
Fish Values - 2000-5000	1	1	1	1	0.29	2.25	0.61	0.06	0.17	0.04	0.27
Fish Values - 5000-10000	2	2	2	2	1.68	22.73	0.59	0.62	3.37	0.07	4.06
Fish Values - 10000-20000	2	2	2	2	0.22	10.63	1.76	0.06	1.14	0.14	1.35
Fish Values - 20000-30000	3	3	3	3	0.00	4.39	3.45	0.00	0.08	0.04	0.12
Fish Values - 40000-50000	4	4	4	4	0.42	4.45	0.00	0.04	0.17	0.00	0.21
Fish Values - 50000-60000	4	4	4	4	0.00	50.00	0.00	0.00	0.08	0.00	0.08
Marine Military Practice Areas	4	4	4	4	0.26	10.02	0.00	0.11	1.73	0.00	1.84
Fish Nursery Areas - Nursery Area - Lemon Sole	3	3	3	3	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Fish Nursery Areas - Nursery Area - Plaice	3	3	3	3	0.64	0.00	0.00	0.19	0.00	0.00	0.19
Fish Nursery Areas - Nursery Area - Sole	3	3	3	3	0.41	0.00	0.07	0.05	0.00	0.00	0.05
Fish Nursery Areas - Nursery Area - Whiting	3	3	3	3	0.47	1.35	0.98	0.16	0.18	0.10	0.44
Fish Spawning Areas - Fish Spawning - Herring	3	3	3	3	14.01	0.00	0.00	0.11	0.00	0.00	0.11
Fish Spawning Areas - Fish Spawning - Lemon Sole	3	3	3	3	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Fish Spawning Areas - Fish Spawning - Plaice	3	3	3	3	0.00	1.55	0.00	0.00	0.18	0.00	0.18
Fish Spawning Areas - Fish Spawning - Sole	3	3	3	3	0.00	7.71	0.00	0.00	0.69	0.00	0.69
Diving Seabirds Vulnerability (Combined) - 0-10	2	2	2	2	0.54	4.59	1.34	0.43	1.48	0.33	2.24
Diving Seabirds Vulnerability (Combined) - 10-25	3	3	3	3	0.81	15.55	0.52	0.32	2.50	0.06	2.89
Diving Seabirds Vulnerability (Combined) - 25-1300	4	4	4	4	2.74	41.91	0.00	0.18	1.13	0.00	1.32
Cetaceans Vulnerability - 0-3	2	2	2	2	0.33	5.53	0.70	0.16	1.05	0.10	1.30
Cetaceans Vulnerability - 3-15	3	3	3	3	0.17	19.26	0.80	0.09	4.06	0.13	4.28
Cetaceans Vulnerability - 15-216	4	4	4	4	2.43	0.02	1.88	0.69	0.00	0.16	0.86
Grey Seals Vulnerability - 0-20	2	2	2	2	0.00	11.14	0.59	0.00	3.88	0.15	4.03
Grey Seals Vulnerability - 20-890	3	3	3	3	1.15	9.16	1.45	0.35	1.11	0.13	1.60
Grey Seals Vulnerability - 890-5410	4	4	4	4	5.33	2.64	3.03	0.59	0.12	0.10	0.81

CONSTRAINT	Tide (Surface Piercing)	Tide (Wholly Submerged)	Wave (Surface Piercing)	Wave (Wholly Submerged)	Percentage of Constraint within Welsh Waters Affected by Resource Area (%)			Potential Energy (GW) x0.4 Reduction			
					Nearshore Wave	Offshore Wave	Tidal Stream	Nearshore Wave	Offshore Wave	Tidal Stream	TOTAL Potential Energy
Sites of Special Scientific Interest	3	3	3	3	1.42	0.07	0.28	0.07	0.00	0.00	0.07
Special Areas of Conservation (Non habitat Features)	3	3	3	3	0.56	19.08	0.00	0.08	1.12	0.00	1.20
SAC Habitat Features - Reefs	4	4	4	4	4.58	9.66	2.72	0.53	0.45	0.10	1.07
SAC Habitat Features - Sea Caves	4	4	4	4	14.59	0.89	0.12	0.06	0.00	0.00	0.06
SAC Habitat Features - Mud & Sandflats	4	4	4	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SAC Habitat Features - Sandbanks	4	4	4	4	0.52	0.79	0.95	0.02	0.02	0.01	0.05
SAC Habitat Features - Shallow Inlets & Bays	4	4	4	4	2.48	0.02	0.00	0.25	0.00	0.00	0.25
Special Protection Areas	3	3	3	3	0.33	0.03	0.01	0.04	0.00	0.00	0.04
Important Bird Areas	3	3	3	3	1.24	0.04	0.02	0.08	0.00	0.00	0.08
Bird Reserves	3	3	3	3	0.98	0.56	1.76	0.00	0.00	0.00	0.01
Dredging Routes	4	4	4	4	0.05	10.23	2.56	0.00	0.22	0.04	0.26