Offshore Renewables Resource Assessment and Development (ORRAD) Project – Technical Report

South West Regional Development Agency

October 2010

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Abbreviations -

BERR	Department for Business, Enterprise and Regulatory Reform
CAA	Civil Aviation Authority
CAPEX	Capital Expenditure
cSAC	Canditate Special Area of Conservation
DECC	Department of Energy and Climate Change
DNO	Distribution Network Operator
dSAC	draft Special Area of Conservation
GIS	Geographical Information System
GW	Giga Watts
IMO	International Maritime Organtisation
LAT	Lowest Astronomical Tide
MCA	Maritime and Coastguard Agency
MCZ	Marine Conservation Zones
MEF	Marine Energy Forum
MoD	Ministry of Defence
MW	Mega Watts
NGET	National Grid Electricity Transmission
NM	Nautical Miles
NNR	National Nature Reserve
O&M	Operation and Maintenance
OFTO	Offshore Transmission Network Owner
OPEX	Operational Expenditure
OREI	Offshore Renewable Energy Installation
ORRAD	Offshore Renewable Resource Assessment and Development
PEXA	Practice and Exercise Area
PMSS	Project Management Support Services Ltd
REZ	Renewable Energy Zone
RDA	Regional Development Agency
SAC	Special Areas of Conservation
SEA	Strategic Environmental Assessment
SNH	Scottish natural Heritage
SPA	Special Protection Areas
SSSI	Special Site of Scientific Interest
STP	Severn Tidal Power Feasibility Study
TSS	Traffic Separation Scheme
O&M	Operation and Maintenance

Executive Summary

The South West Regional Development Agency (South West RDA) has commissioned the Offshore Renewables Resource Assessment and Development (ORRAD) project to deliver a broad scale, strategic assessment of the South West of England's potential to support the development of offshore renewable energy projects up to and beyond 2030 and to consider the economic benefits to the region which such projects could deliver. The project consists of two elements, a technical report presented here and an economic assessment reported separately

The ORRAD study, which has been carried out by Project Management Support Services Ltd (PMSS), in consultation with industry stakeholders, concludes that the marine renewable resource suitable for commercial utilisation in the South-West is capable of delivering 7110 Mega Watts (MW) by 2030, with a further 2110 MW consented, delivering a total of 9.22 Giga Watts (GW) in the study period.

The main baseline development scenario applied in this assessment would deliver 1.2 GW of wave capacity, 4.4 GW of intermediate wind (much of this within the existing Round 3 zones), 2.5 GW of deep water (floating) wind capacity and 1.1 GW of tidal stream capacity within 50km of the coast. Alternative development scenarios under which additional capacity may be capable of development are discussed. In particular there is excellent resource at distances greater than 50km from the coast, providing a good opportunity for significantly increasing capacity while grid and operations and maintenance challenges are resolved. The role of local institutions such as PRIMaRE and regional initiatives, such as Wave Hub, in providing solutions to these challenges is central to increasing available capacity in the South West.

Substantial capacity in addition to the base case 9.22 GW level could also be provided by tidal range technologies within the South West RDA area subject to the findings of the separate Severn Tidal Power Feasibility Study

The development study makes recommendations for an initial timely licensing round in the South West to facilitate the delivery of wave and tidal generation capacity. It also recommends a strategic approach to the provision of onshore and offshore grid infrastructure in the South West and places emphasis on the need for greater efforts to resolve potential conflicts between shipping and marine renewable energy projects.

1. Introduction

The South West Regional Development Agency (South West RDA) is committed to developing the potential of the South West of England's offshore wind, wave and tide resources for marine renewable energy generation. The early deployment of offshore renewable energy projects in the waters of the South West is considered to be important for the establishment of a successful and viable domestic marine renewable energy industry.

Project Management Support Services Ltd (PMSS) has been commissioned by South West RDA to undertake a broad scale, strategic, assessment of the South West of England's potential to support the development of offshore renewable energy projects up to and beyond 2030 and the economic benefits to the region which such projects could deliver.

PMSS is an independent consultancy, established in 1994, working solely in the field of renewable energy. PMSS has provided consultancy services to many UK offshore wind Round 1, Round 2 and Round 3 offshore wind projects as well as a wide selection of projects in the wave and tide sector. PMSS therefore has an excellent understanding of the development, commercial, regulatory and political frameworks surrounding offshore wind, wave and tidal technologies and their deployment in United Kingdom (UK) waters.

This report outlines the resource and technology assessment process, provides development scenarios, presents the results of the assessment and makes recommendations to assist in the future delivery of marine renewable energy projects in the region.

2. Scope of ORRAD Project

The purpose of the development study is to provide an estimate of the potential capacity of the South West region for wind, wave and tidal technologies. It is important at this stage to stress that this report is not a technology deployment forecast; rather, in line with the aims of the project, it aims to highlight what renewable energy capacity could be delivered in the region given a moderate level of appropriately targeted strategic support and guidance. The capacity estimates reached by this report are therefore intended to be a realistic estimate of potential rather than an attempt to set targets or to deliver overly ambitious development forecasts.

This assessment focuses on South West marine waters from the Bristol Channel to Bournemouth out to the extent of the UK Marine Renewable Energy Zone (REZ). This report incorporates the following key elements:

- Identification of broad offshore areas which have the potential for supporting the deployment of wind, wave and tidal technologies in terms of commercially available resource (i.e. energy availability combined with low levels of development and environmental constraints).
- An assessment of the generation potential for offshore renewables in the region up to and beyond 2030, taking into account probable technological developments and progress for each type of technology group.
- A discussion of potential development scenarios and challenges in predicting future potential capacity.
- Recommendations for strategic activities to assist with the successful commercial deployment marine renewables in the region.

It is also important to note that this study is not intended to pre-empt any future Strategic Environmental Assessment (SEA) of marine renewable energy in the South West and does not attempt to precisely map the suitability, or otherwise, of distinct geographical zones or sites for future development. However the ORRAD project does provide information to inform the SEA process whilst delivering the industry a robust assessment of future potential capacity.

3. ORRAD Project Methodology

3.1. Introduction

The general approach adopted in estimating the potential capacity for renewable energy development in the South West was to apply spatial mapping within a geographical information system (GIS) to define broad geographical areas suitable for development. These areas were then analysed further to deliver total capacity estimates for the region. This approach which, in keeping with the strategic nature of the work does not identify specific development sites, was agreed with South West RDA and reviewed by the various groups consulted as part of the process. This technical report should be read in conjunction with the economic assessment report which was undertaken in parallel.

The identification of development potential involved the four stage process outlined below:

- Stage 1 Mapping of realisable resource from 2010 to 2030 for each technology type
- Stage 2 Application of spatial constraints likely to exclude development from resource areas ("hard constraints")
- Stage 3 Expert analysis of other constraints, such as navigation, which may restrict the development potential of resource areas
- Stage 4 Assessment of the capacity capable of being installed in those identified potential development areas of lower constraint

3.2. Development Assumptions

It is important to acknowledge that the realistic potential generating capacity likely to be delivered in the timeframe of the next twenty years will be of a significantly lower order than the total energy potential theoretically available for commercial utilisation off the coasts of the South West. This difference arises from a number of factors including the relatively young age of the technologies, environmental constraints, and the limitations of the electricity transmission network and the demands of other sea users.

The assessment of how such factors may affect development in the future requires a degree of prediction and, therefore, some uncertainty surrounds any potential development scenarios. In order to ensure that the development scenarios are as robust as possible a suite of assumptions were initially proposed. These assumptions were then discussed with a broad number of consultees. This consultation process included a workshop in Exeter with Marine Energy Forum (MEF) members, discussions with The Crown Estate and with the Department for Energy and Climate Change (DECC) and input from Renewables UK following circulation of the assumptions list among members. The assumptions were modified accordingly and finalised in agreement with South West RDA.

It is also important to note that whilst the assumptions are based on an appraisal of current technology forecasts there is the possibility that successful commercial deployment of marine renewable energy devices in the future could occur outside of these parameters.

The relevant assumptions are set out at **Appendices 1 to 4** to this report. The key issues are discussed further in **Section 6** (Development scenarios - commentary) below.

3.3. Stage 1 – Technology and resource mapping

The available resource applicable to each technology type was mapped to provide a base layer defining the extent of resource that could potentially be exploited. In defining this area the main areas of analysis related to resource availability, distance from the shore (which affects capital expenditure related to undersea cabling) and the potential availability of grid connections.

3.3.1. Selection of technology types

The wind, wave and tide resource was assessed by broad technology types rather than by reference to specific devices. These technology groups were primarily derived from resource parameters and installation depths; the factors considered to be important in site selection. This process is outlined in greater detail in the assumptions discussion. The technology groups selected are listed below:

- Shallow water wind (installed 0 – 30m below Lowest Astronomical Tide (LAT))
- Intermediate water wind (installed 30 - 60m below LAT)
- Deep water wind (installed 60m below LAT and deeper)
- Shallow water tidal stream (installed between 5 – 35m below LAT)
- Deep water tidal stream (installed deeper than 35m below LAT)
- Offshore wave (installed between 5 – 100m below LAT)
- Shoreline wave (embedded coastal structures)
- Tidal range technology (impoundments etc.)

At the request of the South West RDA and DECC, PMSS was requested not to consider issues of tidal power technologies (both tidal range and tidal stream) within the Severn Tidal Study Area[1]. The Severn Estuary is widely recognised to hold the South West's and UK's greatest tidal resource[2] and is the subject of a comprehensive and wide-ranging study in its own right. Given the comprehensive nature of the Severn Tidal Power Feasibility Study (STP) and the acknowledged likelihood that tidal range technology is most likely to give rise to the greatest economic benefit within the STP area this report does not consider tidal range technology in detail. Any tidal range project delivered in the STP area would be in additional to the baseline 9.22 GW total which the ORRAD project concludes is available in the remaining waters around the South West, within 50 km of the coastline.

Saline gradient and thermal gradient technologies were excluded from the study.

3.3.2. Resource levels

Renewable energy devices require a minimum level of resource to be able to economically generate power. A resource parameter was applied to each of the technology types selected above. These parameters, which also allowed for improvement in technologies over the 20 year span of the study period, are listed in the table below.

5 year Interval	Minimum resource parameters by technology type					
	Shallow Tidal Stream (m/s)1	Deep tidal Stream (m/s)	Offshore wave (kW/m)2	Shallow water wind (m/s)3	Intermediate water wind (m/s)	Deep water wind (m/s)
2010 - 2015	2.0 m/s	n/a[4]	20 (kW/m)	8 m/s	n/a[5]	n/a[6]
2015 - 2020	2.0 m/s	n/a[4]	20 (kW/m)	7.5 m/s	8 m/s	n/a[6]
2020 - 2025	1.75 m/s	1.75 m/s	20 (kW/m)	7.0 m/s	7.5 m/s	n/a[6]
2025 - 2030	1.75 m/s	1.75 m/s	15 (kW/m)	7.0 m/s	7.5 m/s	7.5 m/s
2030 onwards	1.5 m/s	1.5 m/s	15 (kW/m)	7.0 m/s	7.0 m/s	7.5 m/s

1 m/s = metres per second. This is the predicted mean spring peak flow calculated across the water column.
2 kW/m = kilowatt per metre. This is the predicted full wave field power.
3 m/s = metre per second. This is the annual predicted mean wind speed at 100m.
4 No deep water tidal technology anticipated to be deployed until 2020.
5 No intermediate wind technology anticipated to be deployed until 2015.
6 No deep water wind technology is anticipated to be deployed until 2025.

Table 1: Minimum resource parameters by technology type

1 Department for Business, Enterprise and Regulatory Reform (BERR). Severn Tidal Power Feasibility Study Terms of Reference. http://www.berr.gov.uk/files/file43810.pdf
2 Sustainable Development Commission (2007) Turning the Tide - Tidal Power in the UK.

In additional to the wind, wave and tidal stream technologies, tidal range and shoreline wave technologies were also considered. Shoreline wave technologies were, for the purposes of this study, considered to be devices embedded in coastal structures such as breakwaters and sea defences. The resource parameter applied to assess shoreline wave technologies was tidal amplitude, which was assumed to remain constant throughout the 2010 – 2030 period. In general, shoreline wave technologies require a low tidal range and the maximum tidal amplitude of 2 m was therefore applied to assess the potentially suitable resource area for this technology type.

Similarly, the resource parameters for tidal range technologies are assumed to remain constant throughout the 2010 – 2030 periods. The factor used to select the area available for tidal range technologies was high tidal amplitude. For the purposes of this study tidal range technologies such as impoundments have been considered to require a tidal range of at least 6 m.

Based on the above parameters, the available wind, wave and tidal stream resources were mapped for each 5 year interval, thereby building up a picture of how resource availability might change over time for each technology.

3.3.3. Maximum distance and size of developments from shore

The envelope of available resource is also constrained by a development's distance from shore and the implications this may have on construction activities, the cost and safety risks of operations and maintenance (O&M) activities and the ability to connect devices to the onshore grid. Maximum distances from shore were broadly defined through the consideration of project economics; for example it was generally agreed at the project assumptions workshop that it would not make economic sense to locate a 10 MW demonstrator project 50 km offshore, where the high costs of offshore cable installation and O&M activities would be likely to render the project economically unviable. These economic considerations have been discussed in more detail in **Section 6**. The distance parameters applied are listed in the table below.

Technology Type	Parameter	2010 - 2015	2015 – 2020	2020 – 2025	2025 – 2030	2030 onwards
Shallow Tidal Stream	Maximum distance offshore	10 km	20 km	20 km	20 km1	20 km1
	Individual array size	Up to 10 MW	Up to 100 MW	Up to 250 MW	Up to 500 MW	Over 500 MW
Deep tidal Stream	Maximum distance offshore	n/a2	n/a2	10 km	35 km	50 km
	Individual array size	n/a	n/a	Up to 10 MW	Up to 100 MW	Over 100 MW
Offshore wave	Maximum distance offshore	10 km	20 km	20 km	35 km	50 km
	Individual array size	Up to 10 MW	Up to 50 MW	Up to 100 MW	Up to 500 MW	Over 500 MW
Shallow water wind	Maximum distance offshore	50 km	50 km	50 km	50 km	50 km
	Individual array size	No limit	No limit	No limit	No limit	No limit
Intermediate water wind	Maximum distance offshore	n/a3	50 km	50 km	50 km	50 km
	Individual array size	n/a3	Up to 500 MW	0.5 – 1 GW	No limit	No limit
Deep water wind	Maximum distance offshore	n/a4	n/a4	n/a4	50 km	50 km
	Individual array size	n/a4	n/a4	n/a4	Up to 100 MW	No maximum

1 All shallow tidal stream lies within 20 km from shore.
2 No deep water tidal technology is anticipated to be deployed until 2020
3 No intermediate wind technology will be commissioned until 2015
4 No commercial deep water wind technology will be commissioned until 2025

Table 2: Maximum development distance from shore by technology type

As discussed in **Section 6,** there are currently significant challenges in seeking to deploy marine renewable technologies at significant distance from the shore (>50km) because of issues such as high water depth, the high capital cost of underwater cabling, the commercial and safety risks associated with O&M in the offshore environment and grid constraints. This report therefore has considered that the 9.22 GW of capacity will be delivered within 50km of the coast with additional potential beyond that distance. Many of the challenges are capable of resolution by 2030 given appropriate direction and funding.

The promotion of a strategic offshore grid, either through the Offshore Transmission Network Owner (OFTO) process or otherwise, and possibly in connection with an offshore renewables licensing round, could unlock significant additional potential capacity. Detailed in-depth assessments of the grid capacity in the South West, rather than the strategic overview provided in this report, are presented in previous work carried out by Garrad Hassan[3].

3.3.4. Onshore grid connection

The ability to export electricity to either the national grid or a local distribution network is clearly of central importance to any renewable energy project. In addition to the offshore export cable constraints discussed above the proximity of onshore grid infrastructure was also considered.

In the absence of a comprehensive grid study it was agreed that availability (i.e. the potential to obtain a connection offer from either National Grid Electricity Transmission (NGET) or a Distribution Network Operator (DNO) was not able to be considered and instead a simple model based on distance from substation should be applied. In this model the size of the development is the main factor in determining how far from a grid connection point a development's offshore cable landfall can be situated.

The location of the 33 kV, 132 kV and 400 kV substations in the study area were digitised. These locations were then buffered to determine which parts of the South West coastline were not within an economic distance of a substation. The following assumptions regarding the length of viable onshore runs were made.

- For project connecting to a 33 kV substation a maximum onshore cable run of 10 km was assumed.
- For a project connecting to a 132 kV substation a maximum onshore cable run of 20 km was assumed.
- For a project connecting to a 400 kV substation a maximum onshore cable run of 50 km was assumed.

It should be noted that, in keeping with the strategic nature of this study, these values are approximations for associated development potential and relate to straight line distances without making allowance for the reality of onshore terrain or ground conditions, nor do they consider the technical or economic viability of making individual cable landfalls.

The mapping exercise revealed the sections of coastline that do not lie within the maximum distances from relevant substations set out above. These areas are highlighted in **Figure 1**.

The issue of grid connection is discussed further at **Section 6** below.

3.3.5. Results of technology and resource assessment

Figures 2 – 5 map the available areas where wind, wave and tidal resources exist.

Figure 2 shows the total available resource for shallow and deep tidal stream resource from 2010 to 2030. It can be seen that the areas available for tidal stream technology deployment are not extensive and form discrete areas in the vicinity of Lundy Island, Land's End and to the south of Portland Bill. These areas are limited by suitable tidal current resource rather than proximity to shore.

Figure 3 shows the total available resource for offshore wave resource from 2010 to 2030. Areas where offshore wave technologies could be deployed are extensive and are limited only by maximum distance from shore rather than resource availability.

Figure 4 shows the total available resource for shallow, intermediate and deep water wind resource from 2010 to 2030. Similarly to offshore wave technologies, wind technologies are not limited by the wind speed resource but by distance from the shore and, in the case of shallow and intermediate wind, by water depth.

3 Garrad Hassan, (2008). Development of Wave Energy in the South West. Report prepared for South West RDA.

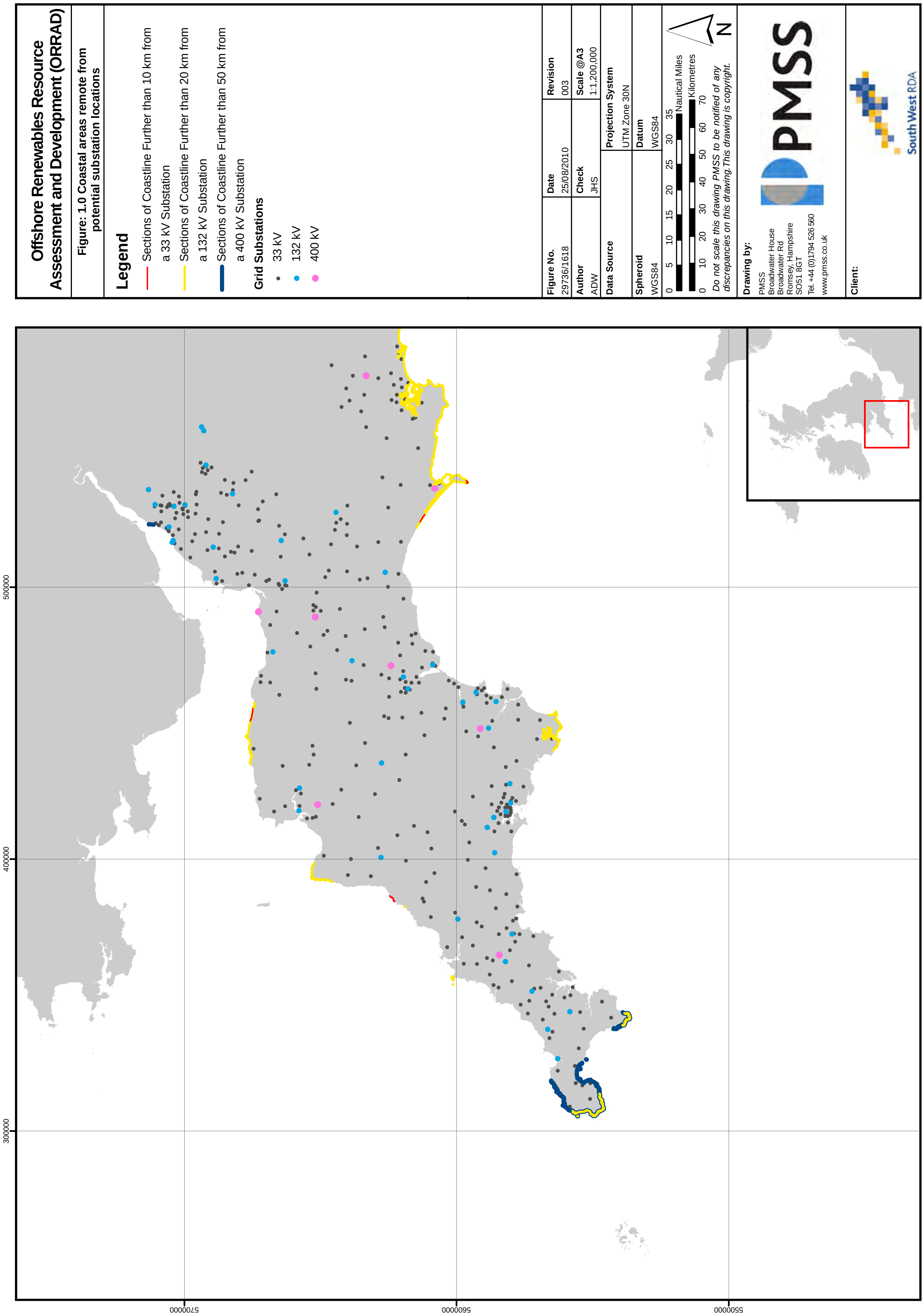

Figure 1: Coastal areas remote from potential substation locations

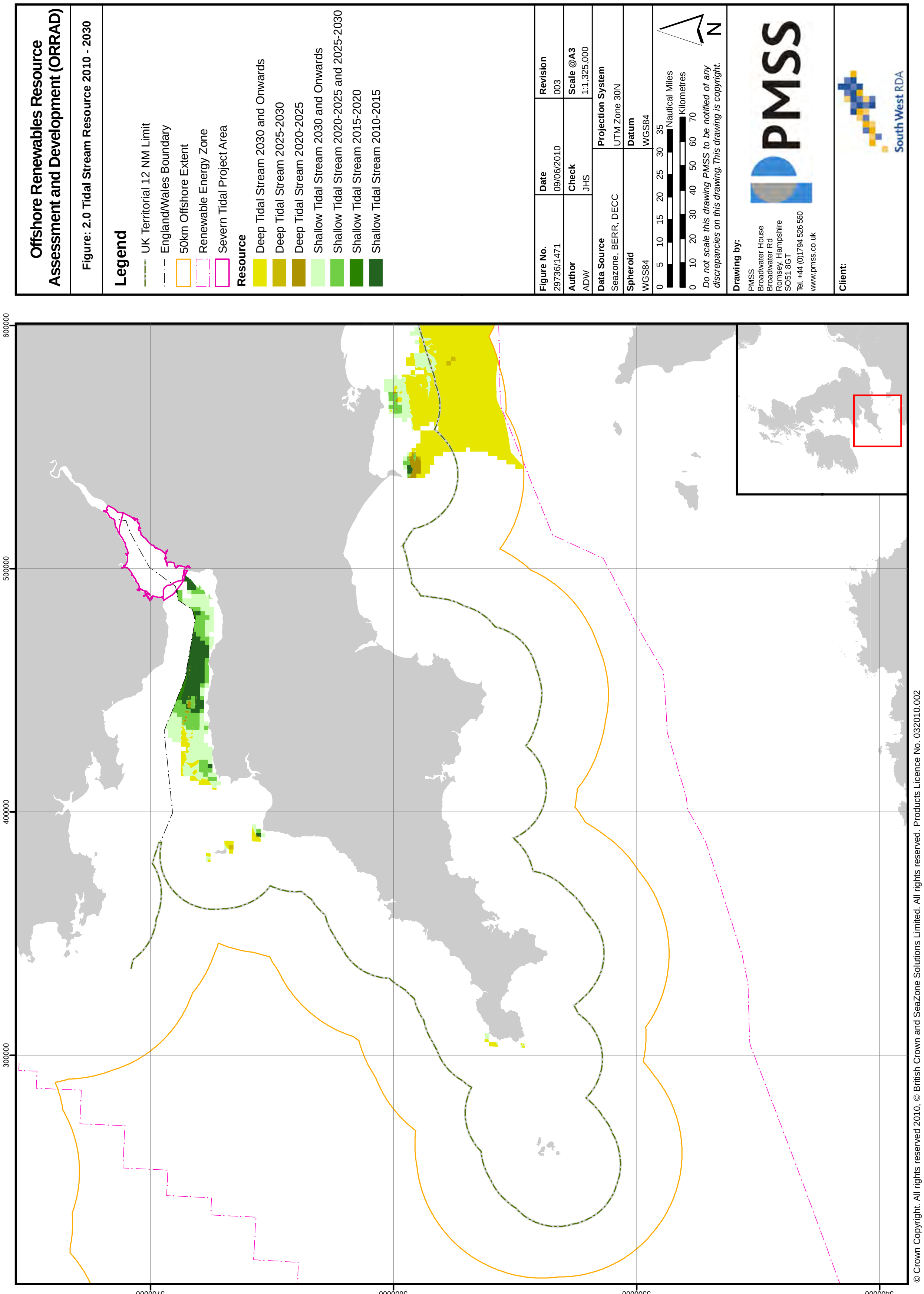

Figure 2: Tidal Stream Resource 2010 – 2030

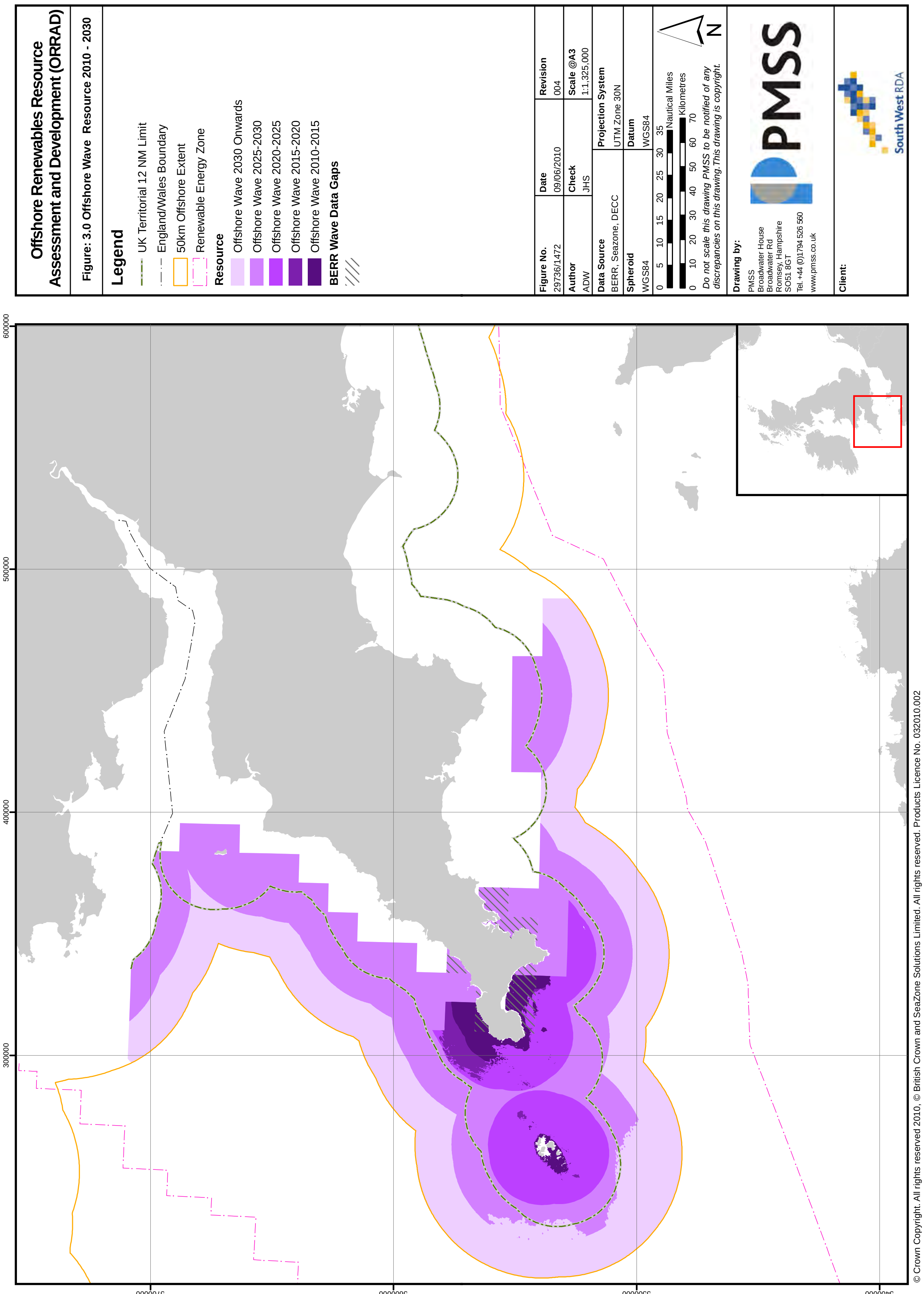

Figure 3: Offshore Wave Resource 2010 – 2030

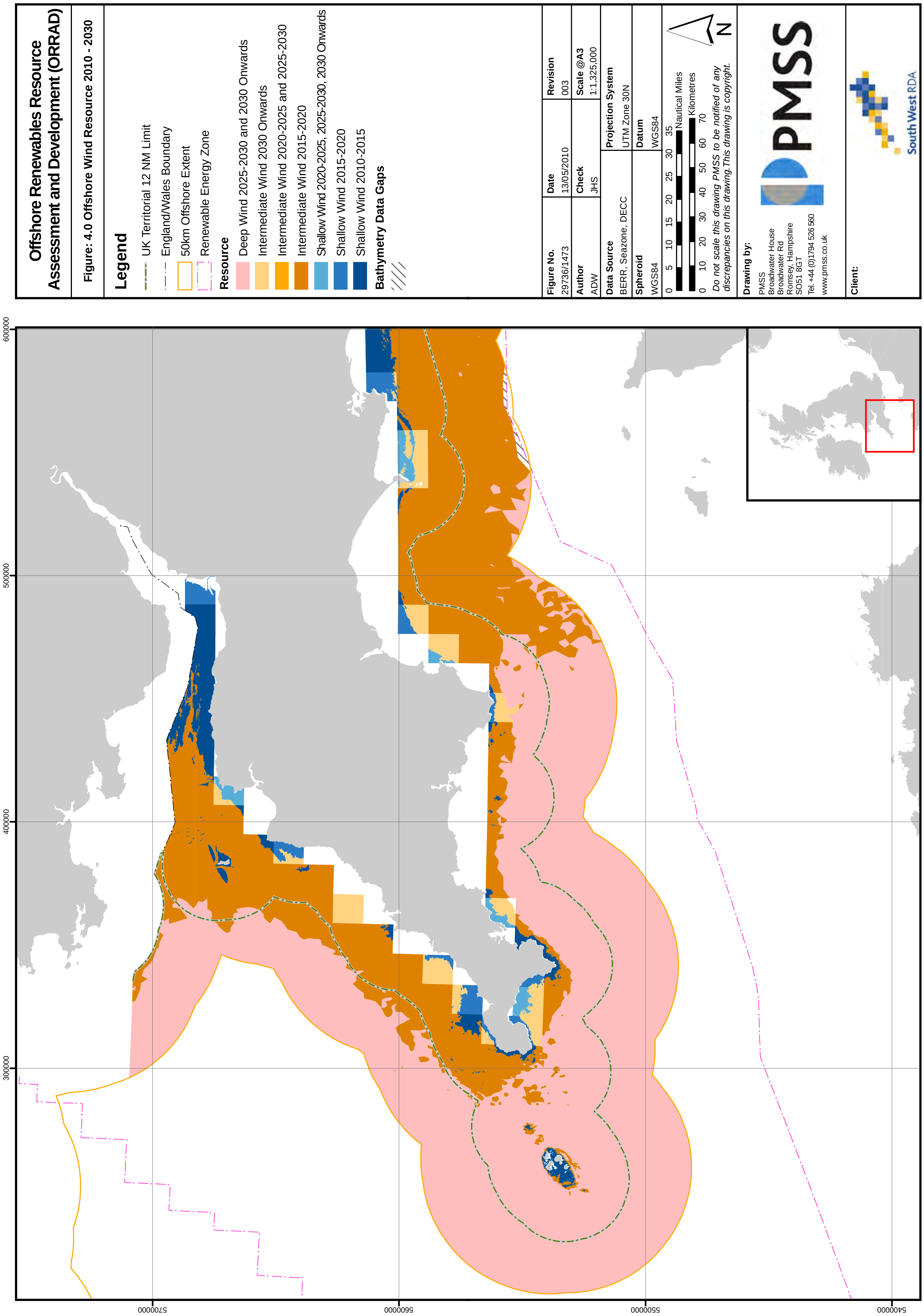

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Figure 4: Offshore Wind Resource 2010 – 2030

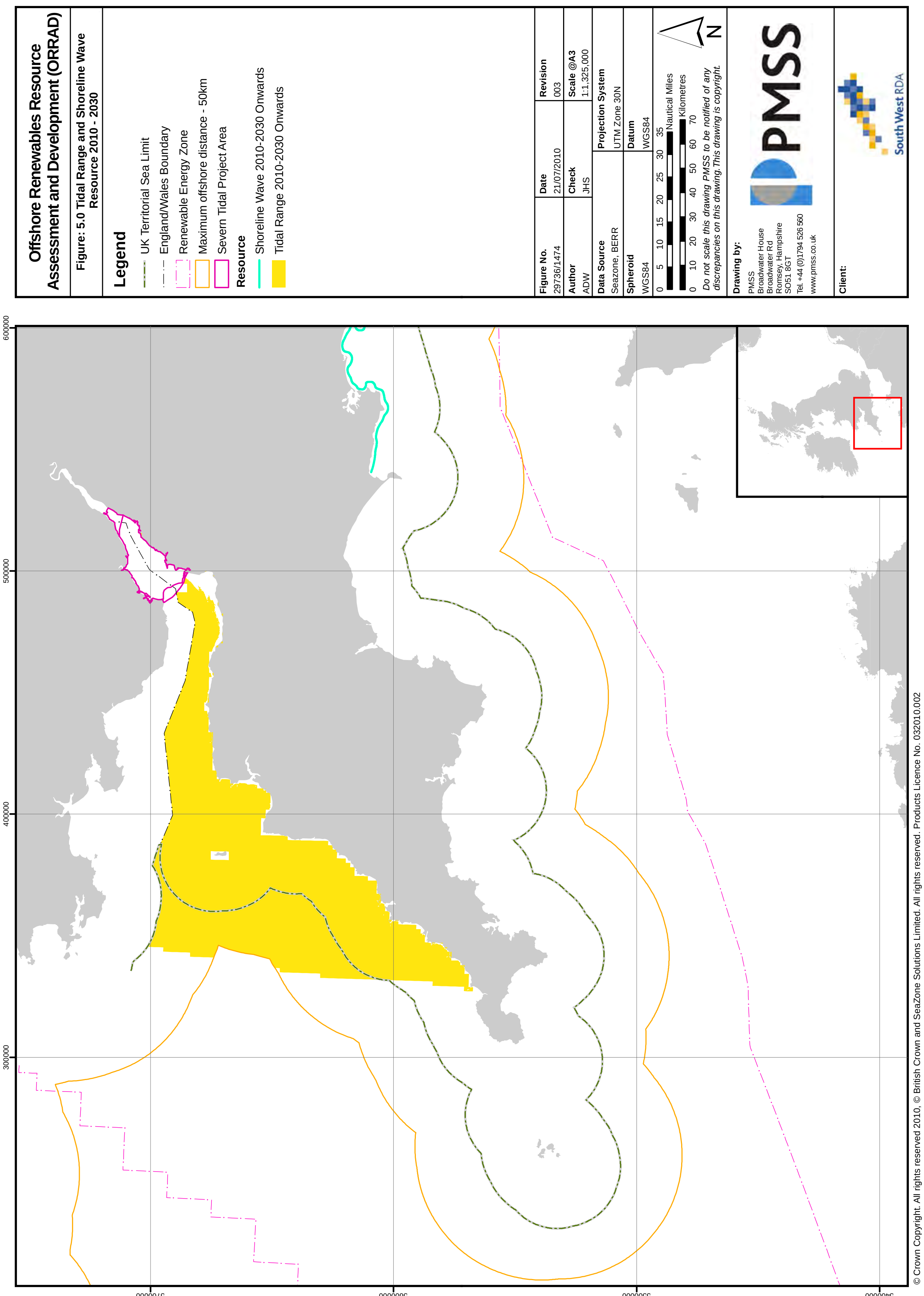

Figure 5: Tidal Range and Shoreline Wave Resource 2010 - 2030

The area available for shoreline wave technologies to be installed is east of Portland Bill and is indicated on **Figure 5**. The area available for potential tidal range technologies to be installed is largely around the Bristol Channel and coastal areas to the west, as indicated on **Figure 5**.

3.4. Stage 2 – Analysis of "hard" spatial constraints

The resource mapping exercise shows that large areas of the South West within the United Kingdom REZ have sufficient wind, wave and tidal resource to support extensive renewable technology deployment.

Much of this area, however, is not available for development due to a range of physical constraints which may preclude renewable energy device installation. To establish where these constrained areas lie, and therefore assess areas where resource is least constrained, a range of "hard" constraints were applied. These "hard" constraints, some of which are discussed in **Section 6** below include:

- International Maritime Organisation (IMO) Traffic Separation Schemes (TSS). A 5 NM Buffer was applied around the entry and exit points of each TSS to comply with the Maritime and Coastguard Agency (MCA) shipping template[4]. The shipping template addresses the high risk nature of navigational features such as a TSS and identifies minimum distances from offshore renewable energy developments to reduce navigational risk. For an entry or exit to a TSS this is minimum distance is 5 NM. It is probable that an application for consent falling within these areas may, under the current rules, be refused.
- Areas subject to zone development agreements under The Crown Estate Round 3 offshore wind farm licensing round. These are included in the study as they have already been identified for renewable energy development.
- The Wave Hub license area. This is included as it has already been consented and developed.
- Areas licensed for aggregate extraction.
- Areas which are licensed for dumping.
- Selected areas used by the Ministry of Defence (MoD).
- All areas defined on Admiralty charts as anchorages.
- A 13km landscape buffer for wind farm development.
- Areas that have the potential to be affected by civil aviation, military and meteorological radars, and airports. These constraints were only applied to offshore wind development because of the absence of significant interaction between aviation and radar interests and wave and tidal technologies.
- Areas that are constrained by the presence of a protected or historic wreck. Wreck sites form small discrete areas which have little impact on overall capacity estimates. Therefore although this constraint was considered during Stage 1, the details of all wreck sites have not been included in the mapping exercise. However it is assumed that they would be addressed during detailed site selection by developers.

The 13km landscape buffer applied to wind farm development was based on recommendations of the Round 2 Strategic Environmental Assessment report which provided for a coastal buffer of 8-13km, primarily for landscape purposes. The relevance of this buffer in the context of the natural heritage of the South West of England is discussed further in **Section 6**.

MoD Practice and Exercise Areas (PEXAs) cover wide tracts of the South West maritime area out to the limit of the REZ. Many of the offshore PEXAs cover large areas and are used for a wide range of MoD activities. However, their presence does not necessarily preclude other activities. For example neither 'Firing Danger Areas' or 'Submarine Practice Areas' place any restrictions on the right to transit through PEXA areas at any time.

Therefore, PEXA areas have not as a matter of course been excluded from calculations of potential development areas during the constraints mapping exercise. While this is appropriate for a strategic study it is acknowledged that the installation of marine renewable devices may in some cases conflict with MoD use. Developers would need to consult with the MoD on a case by case basis.

4 Maritime and Coastguard Agency, (2008). Marine Guidance Note 371 - Offshore Renewable Energy Installations (OREIs), Guidance on UK Navigational Practice, Safety and Emergency Response Issues.

Activities within PEXA areas may be dangerous or hazardous. In many cases such areas are categorised as "PEXA-D" or "danger" areas. PMSS has considered all PEXA types, including PEXA-D categories and, depending on the technology type and possible interactions, have concluded that a number are not suitable for the location of renewable energy projects.

For wind technology, those PEXA areas identified by the Civil Aviation Authority (CAA) as 'Danger' areas have been excluded. These areas are mapped on **Figure 6**. The application of these constraints is discussed further in **Section 6**.

The application of these hard constraints provides an indication of the extent of South West waters that are potentially of lower constraint for development. These lower constraint areas were then considered for further analysis (see stage 3 below).

Figure 7 illustrates the application of the above constraints to tidal stream technologies and the "lower constraint" areas that remain. **Figures 8 and 9** provide the same information for offshore wave and offshore wind technologies respectively.

3.5. Stage 3 – Consideration of "soft" spatial constraints

In addition to the "hard" constraints described above there are a significant number of other issues which are likely to further limit the deployment of renewable technologies within the lower constraint areas. These issues may be more 'flexible' in nature, albeit just as challenging, and cannot be assessed by applying broad geospatial analysis of pre-defined criteria. Indeed, in many cases, potential restrictions will be site and technology specific and will be highly dependent upon interactions with other users of the sea.

These so-called "soft constraint" issues include navigational constraints posed by shipping outside of a TSS, potential impacts on commercial fisheries and leisure users of the sea and the restrictions presented by areas of nature conservation interest. Defining precisely how, and to what extent, such potential limitations on development may arise from these issues will require detailed consultation with relevant stakeholders on a case by case basis once specific sites have been identified. Because the purpose of this report is to identify capacities based on broad areas with the potential for renewables deployment at a strategic level, rather than potential development sites, it is not possible to fully map the various "soft" constraints.

However, it is important to strategically consider what potential limits and risks may apply to deployment and what impact this may have on the overall capacity of potential development areas.

3.5.1. Shipping and navigation review

The waters of the South West are of strategic importance for UK and international shipping, being the entry and exit point for much trans-Atlantic shipping entering and leaving the English Channel. Many of the vessels transiting through the area are large ships with limited manoeuvrability and many carry hazardous cargoes. The area is also important for smaller commercial vessels such as ferries and coastal and offshore fishing vessels.

A shipping and navigation review of South West English waters was carried out with major shipping routes being determined from a variety of data sources including relevant chapters from the DECC SEA navigational technical appendices. A precautionary 1 NM buffer was then applied to these indicative shipping routes in conformance with the MCA shipping template. Development within these buffer areas was considered to be of high risk to shipping interests and therefore unsuitable for the purposes of a strategic study.

Maritime traffic levels will vary with the general economic cycle. Although it is likely that over the period of time this study relates to (to 2030) that traffic volumes will increase it is assumed that preferred routes will remain broadly consistent with those taken today, including recent variations to the Land's End TSS.

The above assumptions, and alternative navigation scenarios, are discussed in more detail in **Section 6**.

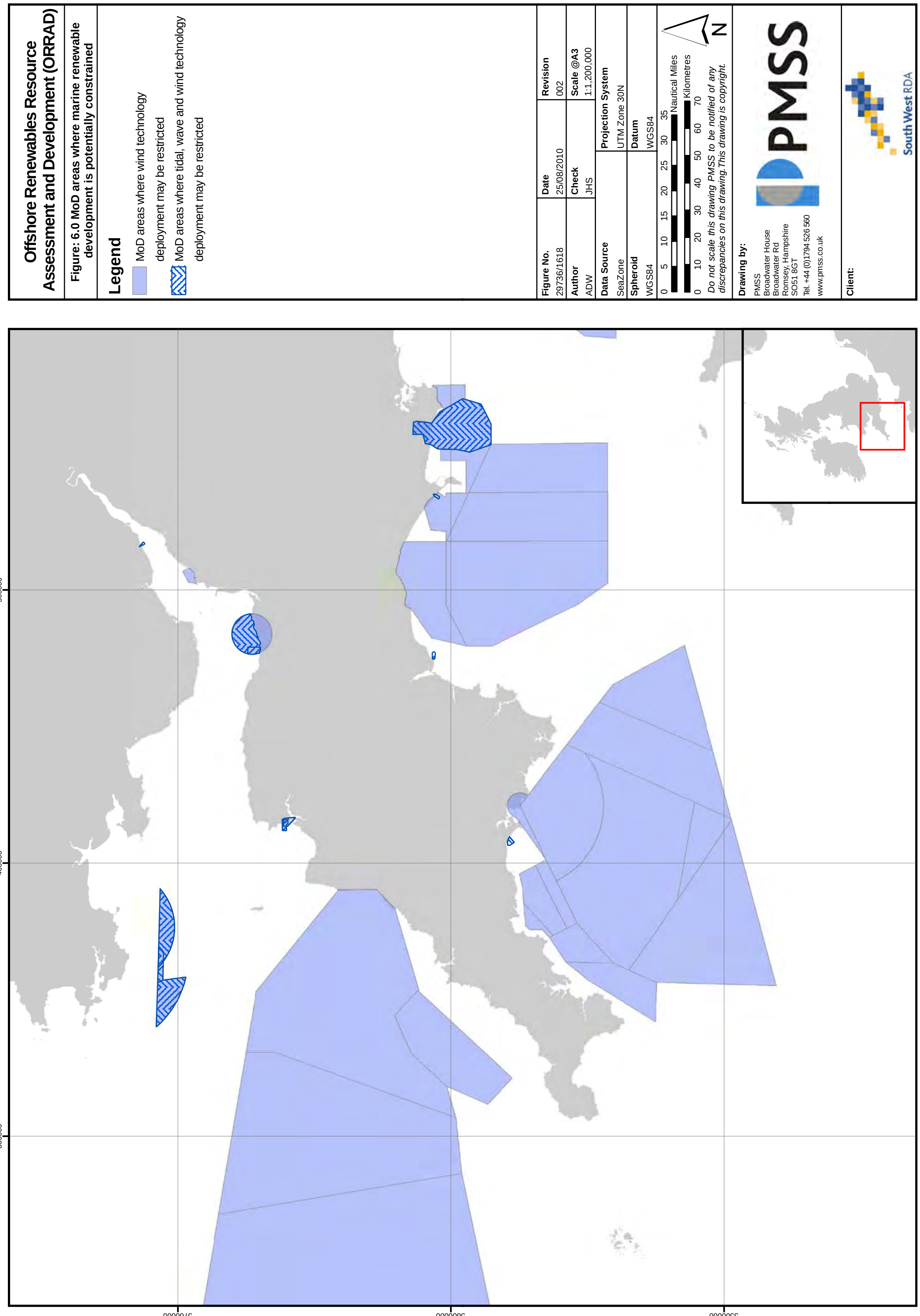

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Figure 6: MoD areas where marine renewable development is potentially constrained

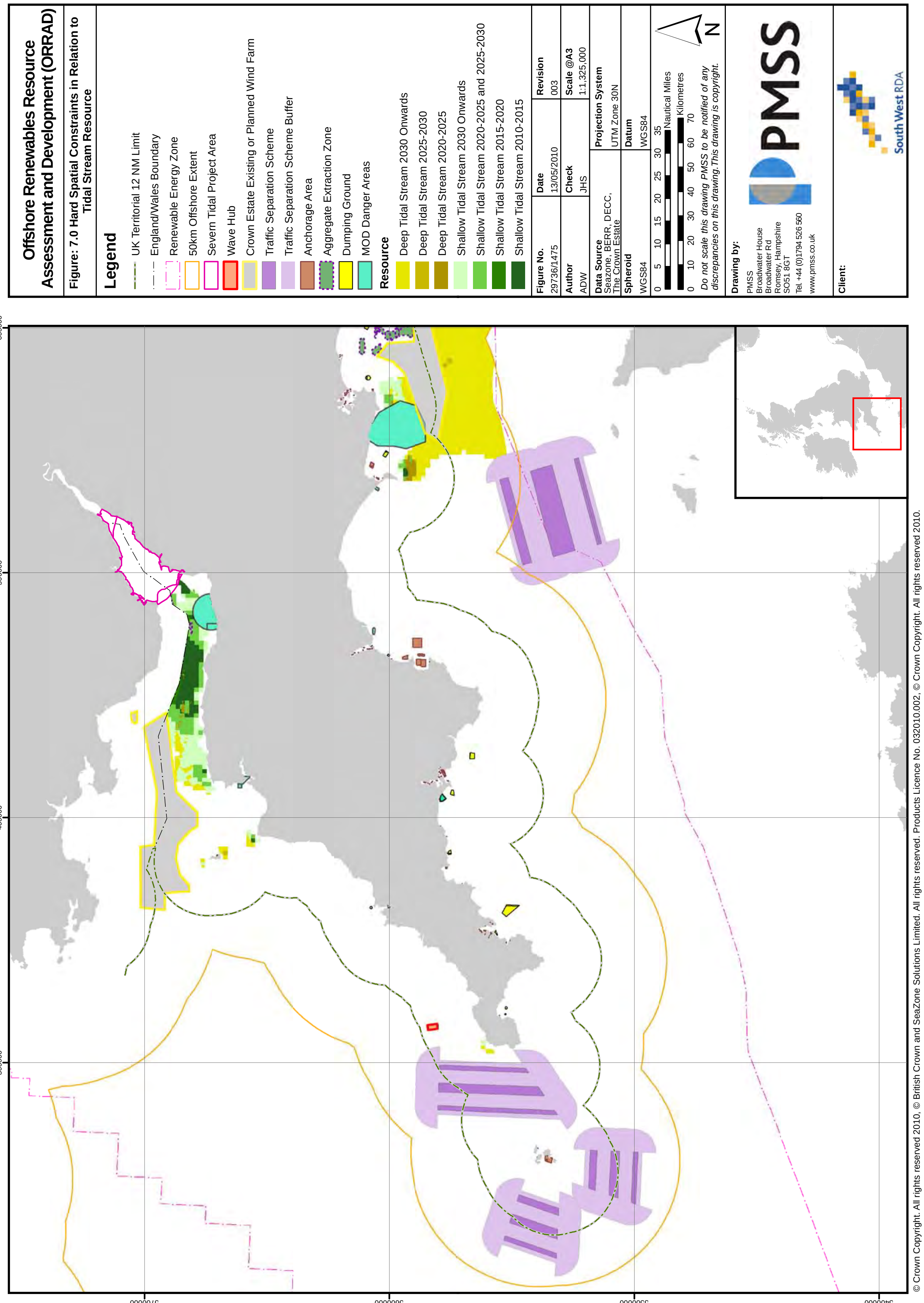

Figure 7: Hard Spatial Constraints in Relation to Tidal Stream Resource

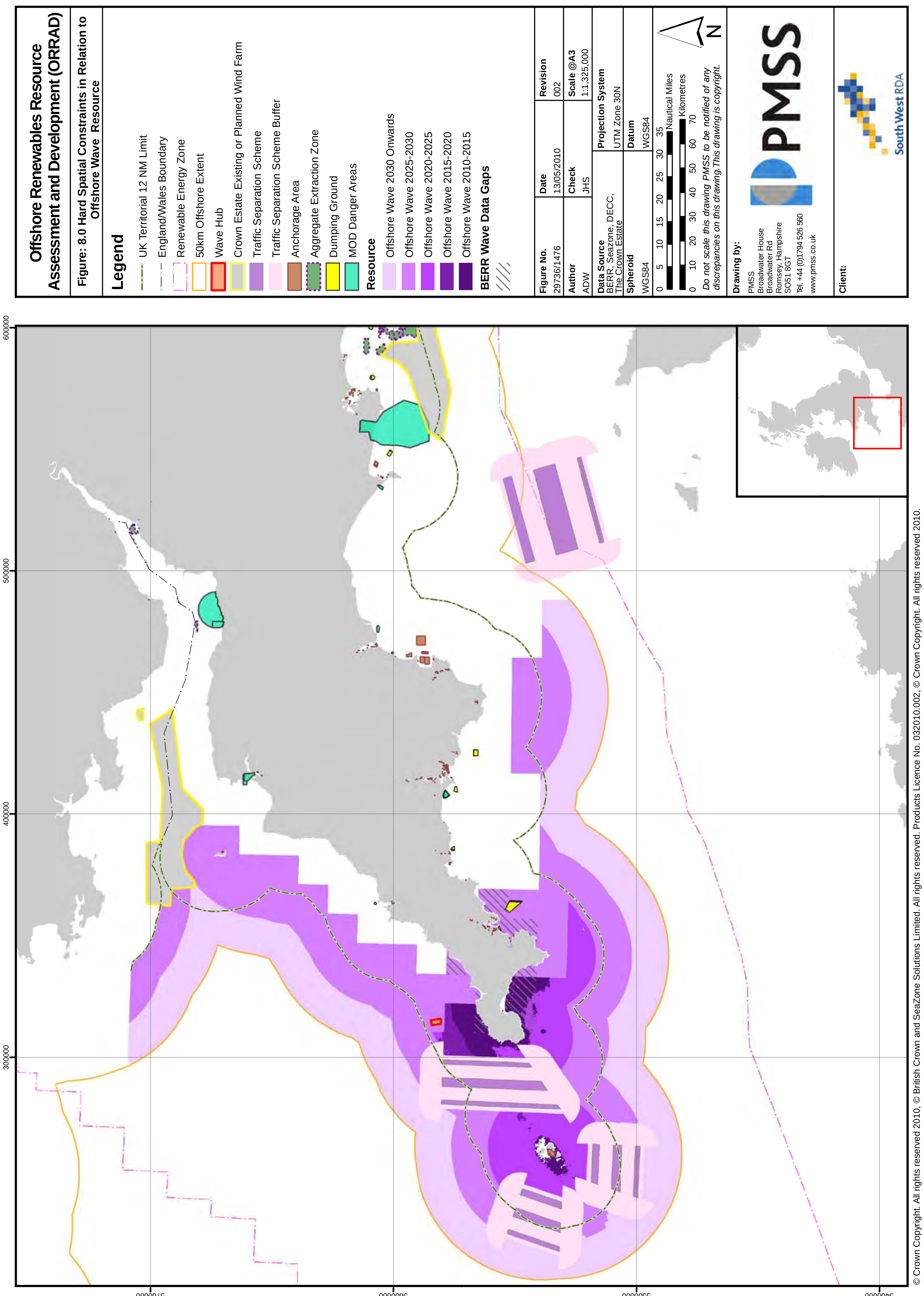

Figure 8: Hard Spatial Constraints in Relation to Offshore Wave Resource

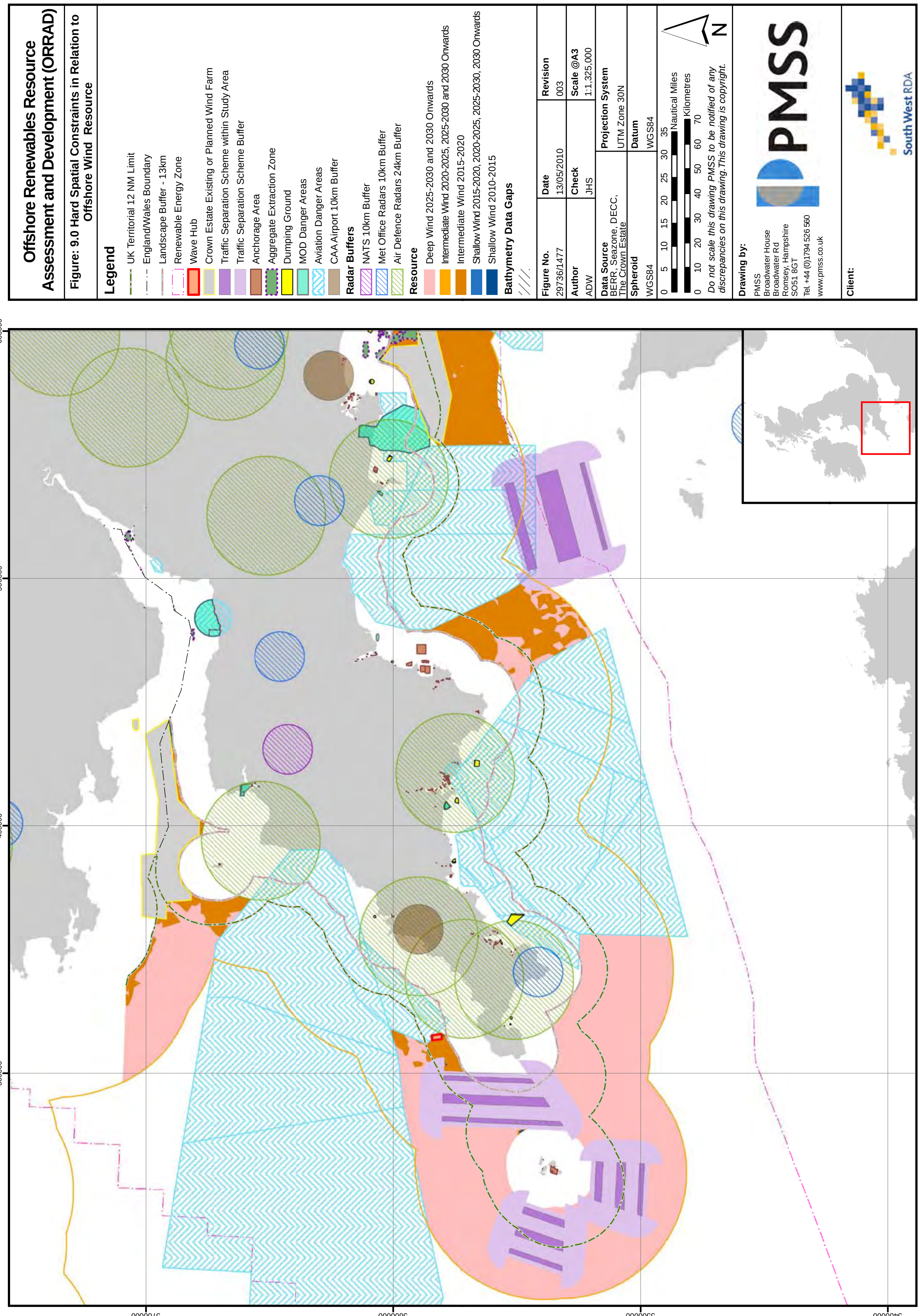

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Figure 9: Hard Spatial Constraints in Relation to Offshore Wind Resource

3.5.2. Interactions with commercial fisheries

The South West is an important commercial fishing region with a rich maritime heritage. Marine renewable technologies will interact with fishing activities to a greater or lesser extent depending on the nature of the devices and the restrictions placed on activities within a development's footprint.

In many cases most fishing activities may be largely unaffected. For example in the case of offshore wind farm development potting activities and static netting may be able to take place within a wind farm footprint while turbine bases and the potential exclusion of more intensive activities such as heavy bottom trawling may provide opportunities for stock enhancement through the reef effect.

In other cases, particularly where underwater moving components are involved (as would be the case with many tidal turbines), areas of seabed may have the potential to be closed to fisheries.

Renewable energy deployment is just one of a number of other significant challenges facing the fishing industry and it is incumbent upon the developers of renewable energy projects to engage with all potentially affected members of the industry at the earliest opportunity to assess to potential for interactions and to seek to minimise potential impacts. It is anticipated that any SEA of marine renewable deployment in the South-West would provide appropriate opportunities for detailed assessment and consultation on the potential impacts of marine renewables on fisheries in the region.

3.5.3. Interactions with other marine users

The seas around the South West coast are also heavily used by people during their leisure time, supporting an economically significant leisure craft industry as well as tourism. Potential visual impacts on onshore tourist areas have been considered by the application of a 13 km landscape buffer for offshore wind projects. It is thought that potential visual impacts from tidal stream and wave devices, if they arise at all, are likely to be less significant and more manageable because of the relatively small size of surface piercing features.

Yachts and other leisure craft are less likely to be affected by offshore wind development than their commercial counterparts and representative bodies, such as the Royal Yachting Association, acknowledge that these vessels can safely transit through a wind farm which may, in some cases, act as an aid to navigation.

More densely packed tidal turbine arrays, particularly those with surface piercing features, and wave turbines are more likely to create navigational challenges for leisure users. Therefore, and array location and layout will need to be discussed with relevant stakeholders as part of any development process as well as during any future SEA.

Other leisure uses, such as surfing, will also need to be taken into account during development proposals, particularly where there are concerns about wave devices adversely affecting wave formation on the coast. Early engagement with representative bodies, such as Surfers Against Sewage which has published Environmental Impact Assessment (EIA) guidance for marine renewable projects, is recommended.

3.5.4. Interactions with the natural environment

The South West has a rich natural environment with a defined network of designated sites which have been established to protect these rich habitats and species. Those habitats and species are vulnerable to the effects of climate change and therefore the successful commercial deployment of low carbon marine renewable technologies has the potential to provide a positive environmental effect on nature conservation interests. Most marine renewable technologies, if appropriately sited, will have limited or little effect on sensitive environmental receptors. Nature conservation bodies such as Natural England and Scottish Natural Heritage (SNH), while stressing the need to reduce overall electricity demand, are strongly supportive of the deployment of marine renewables[5]. SNH has concluded that wave and tidal stream technologies are likely to have the lowest impact on the natural heritage of any method of electricity generation[6].

5 http://www.naturalengland.org.uk/ourwork/climateandenergy/default.aspx and http://www.snh.gov.uk/planning-and-development/renewable-energy/our-approach-to-renewables/our-approach/

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This section reviews the possible interactions between offshore renewable energy projects and designated conservation areas. This high level review has focused on the Natura 2000 network of sites; the Special Areas of Conservation (SAC) and Special Protection Areas (SPA) designated under the Habitats and Birds Directives. These are the areas most heavily protected by legislation and are recognised as being of particular conservation importance. Many other designated areas such as National Nature Reserves (NNRs) and Special Sites of Scientific Interest (SSSI) could also have the potential to be adversely affected by inappropriately sited renewable energy development. Such features as well as species and habitats of conservation importance not benefiting from statutory designations (for example Biodiversity Action Plan species) would need to be considered as part of any future Strategic Environmental Assessment (SEA) for marine renewables in the South West and during the EIA process required in respect of any development project.

The table below lists all relevant coastal SACs and SPAs in the South West including those on the South Welsh coast, and indicates where there is the potential for interaction between the technologies and the features in these designated areas. It is important to note in this context that potential impacts will vary considerably between sites and technologies. As the Natural England and SNH policies make clear, there is the potential to deploy these technologies without the risk of adverse environmental effect and therefore Natura 2000 sites may be capable of hosting significant levels of development, subject to adherence to the Appropriate Assessment process outlined in the relevant legislation. Similarly, future Marine Conservation Zones (MCZs) need not be regarded as "no go" areas for marine renewables, particularly given the positive environmental effects which these technologies can deliver.

Conservation designations which overlap or may be affected by renewable energy installations.	Shallow Tidal Stream	Deep Tidal Stream	Offshore Wave	Shallow Water Wind	Intermediate Water Wind	Deep Water Wind	Shoreline Wave	Tidal Range
Poole Harbour SPA				✓	✓	✓	✓	
Isle of Portland to Studland Cliffs SAC								
Poole Bay to Lyme Regis dSAC	✓						✓	
Exe Estuary SPA				✓	✓	✓		
Dawlish Warren SAC								
Prawle Point to Plymouth Sound and Eddystone dSAC								
Fal and Helford SAC								
Lizard point dSAC			✓					
Lands End and Cape Bank dSAC	✓	✓	✓		✓			
Isles of Scilly Complex SAC			✓					
Isles of Scilly SPA	✓	✓	✓		✓	✓		
Lundy SAC	✓		✓					
Severn Estuary SAC	✓							✓
Severn Estuary SPA	✓							✓
Haig Fras cSAC			✓			✓		
Carmarthen Bay and Estuaries SAC[7]								✓
Carmarthen Bay SPA[8]				✓	✓	✓		✓
Pembrokeshire Marine SAC[9]								

Table 3: Interaction of technology types with conservation designations

7 A number of designated sites outside of the South West study area have been considered in respect of the potential for impact on mobiles species such as birds and marine mammals

8 See footnote above

9 See footnote above

3.5.4.1. Wind Farm Development

The locations where possible development areas for offshore wind technologies directly (i.e. spatially) interact with designated conservation sites are limited. The only conservation designations with which potential wind development areas may directly overlap is the Haig Fras candidate SAC (cSAC) and the Lands End and Cape Bank draft SAC (dSAC).

The Haig Fras cSAC is an underwater rock outcrop and is relatively well defined. It is designated for the diverse bedrock reef community found there. This site is approximately 100km from the Isles of Scilly and due to its distance offshore is therefore not considered by this report to be a priority site for offshore wind development from 2010 to 2030. Wind farm development is likely to be further precluded from this area due to the steep bathymetry gradients and the installation challenges this presents.

The Lands End and Cape Bank dSAC extends up to 22km from the coast and has been designated for its upstanding reef structure which supports high biodiversity tide-swept communities such as sponges, faunal and algal turfs. Although good wind resource exists in this area, much of the dSAC lies within an area which has been excluded from the development scenarios in this report due to the presence of the extended north - south TSS and associated buffers that have been applied to prioritise safe navigation. Some small areas of the dSAC lie outside this TSS area; however navigational assessment suggested that wind development in this area was of potentially high risk to navigation and therefore development in this area is considered to be unlikely.

Many other designated areas lie inside the 13km landscape buffer adopted in this study and therefore do not overlap with possible development areas for offshore wind. Some areas of the Prawle Point to Plymouth Sound and Eddystone dSAC fall outside of 13km, however this area has been excluded due to the presence of a MoD PEXA and therefore development is probably not thought to be likely in proximity to this dSAC.

Cable routing may impact upon seabed habitats in coastal SACs within the 12 NM limit from wind development areas which lie offshore. If routeing around sensitive areas is required, this may incur a significant additional project cost. Due to the strategic nature of this study such issues have not been considered in detail but will need to be considered as part of any SEA or, at the project level, through EIA.

The potential wind farm development areas assessed in this report do not overlap with any SPAs directly. However wind farm development has the potential to adversely affect birds transiting to and from SPAs for migration or foraging. Wind farm impacts on bird species may occur through displacement (birds using the wind farm area), collision (impact with blades) or through a barrier effect (where birds may be forced to deviate from usual foraging or migratory routes by reason of the presence of a wind farm). The SPAs found in the South West and along the South Welsh coast are designated for a wide range of species. Species of specific concern in regard to offshore wind farms include Bewicks' Swan, Common Tern, Mediterranean Gull, Storm Petrel and Common Scoter along with the assemblages of waterfowl and seabirds protected by SPA designation.

3.5.4.2. Offshore Wave Technology

There is a potential for conflict between the deployment of offshore wave technologies with designated conservation sites. The most notable of these possible impacts is likely to be the potential disturbance to seabed habitats caused by the mooring structures of wave devices. Types of wave devices vary considerably, as do their mooring systems and, as such, the type and magnitude of potential impacts is likely to vary significantly. Direct impacts would include the loss and/or disturbance of seabed habitats from the mooring of devices. Those devices tethered by a taut mooring system are anticipated to have less direct impact on the seabed than those which employ a catenary mooring system and may drag chains or tethers across the seabed.

In addition to the potential impacts associated with mooring, the impact of the installation of export cables also presents a potential risk to sensitive habitats. Much of the offshore wave resource lies offshore of any conservation designations and as such the most direct export cable route to shore may pass through areas of potential nature conservation sensitivity. If routeing around sensitive areas is required, this may incur a significant additional project cost. Due to the strategic nature of this study such issues have not been considered in detail but would need to be considered as part of any SEA or, at the project level, through EIA.

Stakeholders have also historically raised the concern that indirect impacts on features of nature conservation importance may arise from reduced wave power or wave height, particularly in respect of subtidal and intertidal communities. Below is a summary of potential locations for significant adverse interactions between potential wave development and features of nature conservation importance.

The Lizard Point dSAC has been designated for both coastal and offshore upstanding and bedrock reef areas up to approximately 9km offshore. This area overlaps with an area identified as having the potential for offshore wave technology deployment, in particular small scale nearshore developments. These have the potential to affect reef habitats although the extent and magnitude of such an impact would be dependent on detailed project design and therefore outside of the scope of this report.

The Lands End and Cape Bank dSAC extends up to 22km from the coast and has been designated for its upstanding reef structure which supports high biodiversity tide-swept communities such as sponges, faunal and algal turfs. Although good wave resource exists in this area, much of the dSAC lies within an area which has been excluded from the development scenarios in this report due to the presence of the extended north - south Traffic Separation Scheme (TSS) and associated buffers that have been applied to prioritise safe navigation. Some small areas of the dSAC lie outside this TSS area; however navigational assessment suggested that wave development in this area was of potentially high risk to navigation and therefore development in this area is considered to be unlikely.

The Isles of Scilly Complex SAC is designated for its hard bedrock reef, to a depth of greater than 50m, sandbanks covered by seawater at all times and mudflat and sandflat habitats. Although the TSSs around the Isles of Scilly present a significant barrier to development there is scope for offshore wave technology deployment inside of the three TSSs, and, as such, development could potentially affect SAC features. However, this can only be assessed at project level through EIA.

Lundy SAC is designated for its granite and slate reef system. The range of physical conditions experienced at Lundy gives rise to the presence of a diverse complex of marine habitats and associated communities within a small area. The reefs of Lundy extend well over 1 km offshore and drop steeply into deep water in some areas. Good wave resource exists around Lundy Island and it may be possible to develop some areas to the south west of Lundy, these however are unlikely to be within 1km of the island, and has such the potential direct impacts may be reduced. The possible effects of reduced wave resource on sensitive habitats arising from the installation of devices would need to be considered as part of any SEA or EIA.

The development of offshore wave technology is unlikely to have a significant adverse affect on SPAs situated at distance from development sites or cable routes. Some nature conservation bodies have suggested that birds may be attracted by fish populations that are benefitting from the shelter provided by devices although the operation of current designs would seem unlikely to give rise to significant risk of collision mortality.

3.5.4.3. Shoreline Wave Technology

The area of coast suitable for the development of shoreline wave devices is limited to the east of Portland Bill. There are number of SACs and SPAs which have coastal features and species which may have the potential to be affected by such development. These include Poole Bay and Lyme Bay Reef dSAC, the Isle of Portland to Studland Cliffs SAC and Poole Harbour SAC.

3.5.4.4. Tidal stream technology

Possible development areas for offshore tidal technologies overlap with a number of areas designated for nature conservation reasons. In such areas the most significant potential risk is likely to arise from direct disturbance to habitats arising from the construction and installation of devices. Foundation and device designs are likely to vary considerably, as will the probability, extent and magnitude of such impacts.

In addition to impacts associated with installation, the impact of laying export cables may also present a potential risk. Much of the offshore tidal stream resource lies offshore of any conservation designations and as such the most direct export cable route to shore may pass through areas of potential nature conservation sensitivity. If routeing around sensitive features is required, this may incur a significant additional project cost. Due to the strategic nature of this study, such issues have not been considered in detail but will need to be considered as part of any SEA or, at the project level, through EIA.

Below is a summary of possible direct interactions between potential tidal stream development areas and conservation designations. There may also be indirect impacts to consider such as scour effects and reduction in tidal current and the effects that these factors may have on subtidal and intertidal communities.

The Poole Bay to Lyme Bay Reefs dSAC has been designated for its complex of reef and sea cave systems. Potential tidal stream development areas overlap with some portions of this SAC. The Portland Reefs area lies off the south, east and north-east coasts of Portland Bill and is characterised by flat bedrock and limestone ledges with high densities of mussel beds. Installation of tidal stream devices in this area could potentially impact on this SAC although the extent and magnitude of such impacts would be dependent on detailed project design and are therefore outside of the scope of this report.

The Lands End and Cape Bank dSAC has been designated for its offshore and coastal upstanding reef structure. Small areas of tidal stream development areas overlap with the coastal element of this SAC. The installation of tidal stream devices in this area could potentially impact on this SAC although the extent and magnitude of such impacts would be dependent on detailed project design and are therefore outside of the scope of this report. It is also likely that, due to the linear nature of the SAC parallel with the coast, potential impacts could arise from the installation of export cables.

The Lundy SAC is designated for its granite and slate reef system. The range of physical conditions experienced at Lundy gives rise to the presence of a diverse complex of marine habitats and associated communities within a small area. The reefs of Lundy extend well over 1 km offshore and drop steeply into deep water in some areas. Tidal resource exists in the vicinity of the northward boundary of the SAC and in the south eastern corner of the SAC. Installation of tidal stream devices in these areas could therefore potentially impact on this SAC although the extent and magnitude of such impacts would be dependent on detailed project design and are therefore outside of the scope of this report.

The Severn Estuary SAC has been designated for a range of habitats including estuarine, sandbanks and mudflats and also a number of Annex II species. This SAC directly overlaps the easternmost area of potential tidal stream resource. Installation of tidal stream devices could potentially impact on this SAC in these areas although the extent and magnitude of such impacts would be dependent on detailed project design and are therefore outside of the scope of this report.

The development of offshore tidal stream technology is unlikely to have a large impact on SPAs, apart from the Isles of Scilly SPA where there is the potential for interaction between the devices and diving birds, particularly those species, such as gannet, known to dive to significant depth. Such potential would need to be explored as part of any SEA and EIA process.

3.5.4.5. Tidal Range Technologies

As discussed at **section 4.3.1** above, consideration of the environmental impacts of tidal range technologies (i.e. barrages or lagoons) is outside of the scope of this report. There are a number of Natura 2000 sites from the Severn Estuary westward along the Somerset and Devon coasts which could potentially affected by tidal range development. The concern that tidal range technologies (both barrages and lagoons) can give rise to large scale impacts on sensitive habitats has been a significant challenge to the deployment of these technologies.

3.6. Stage 4 - Identification of indicative potential development areas

The output of the three-stage spatial analysis outlined above provided the size and location of potential development areas of lower constraint for the different technology types. The potential development areas of lower constraint for tidal stream, offshore wave and offshore wind technologies from 2010 to 2030, out to 50 km, are presented in **Figures 10, 11 and 12**. As discussed above, in keeping with the strategic aims of the ORRAD project, no attempt has been made to precisely map the suitability, or otherwise, of distinct geographical zones or sites for future development.

These areas were subsequently used as a basis for calculating total capacity forecasts for each technology from 2010 to 2030.

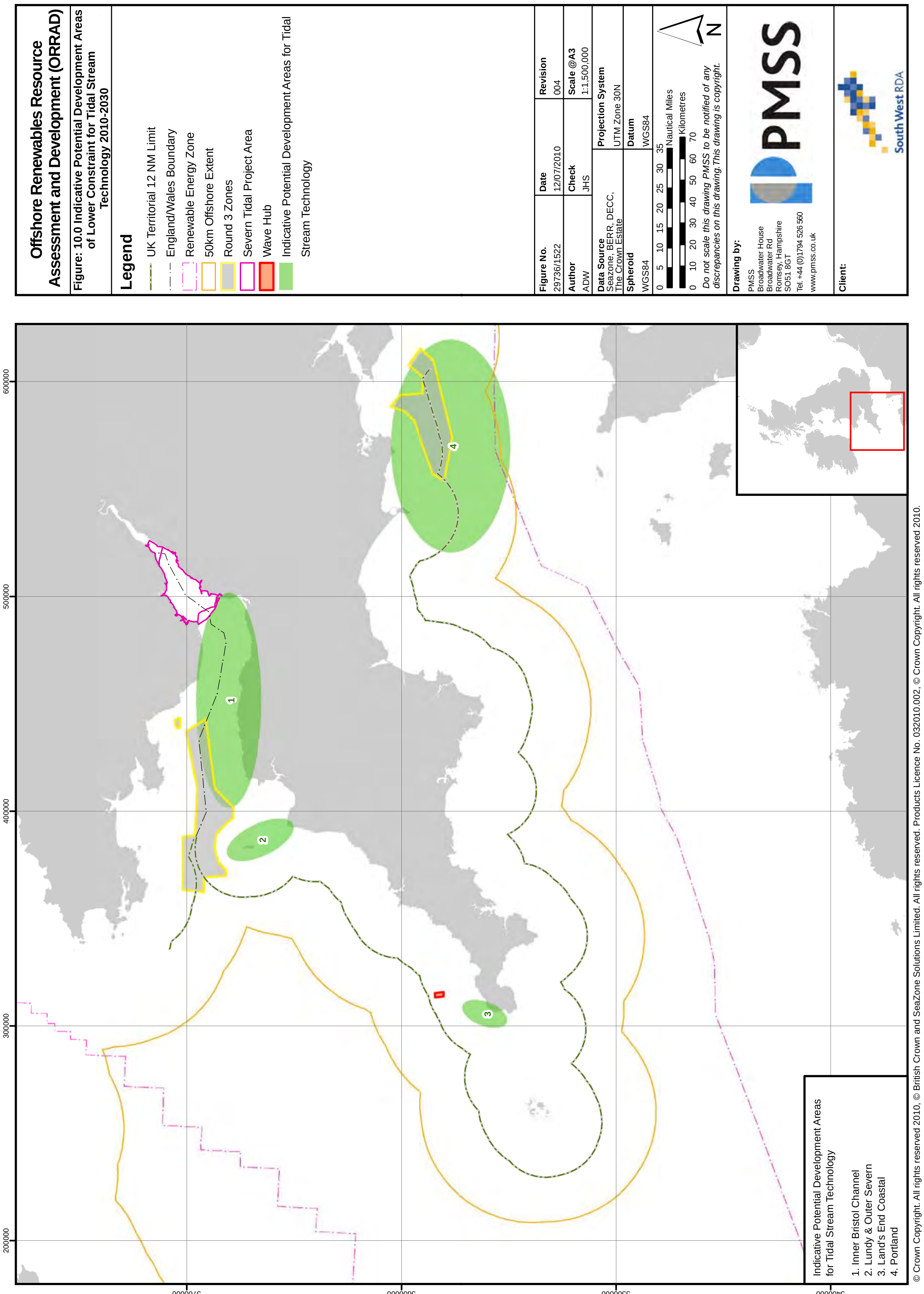

Figure 10: Indicative Potential Development Areas of Lower Constraint for Tidal Stream Technology 2010-2030

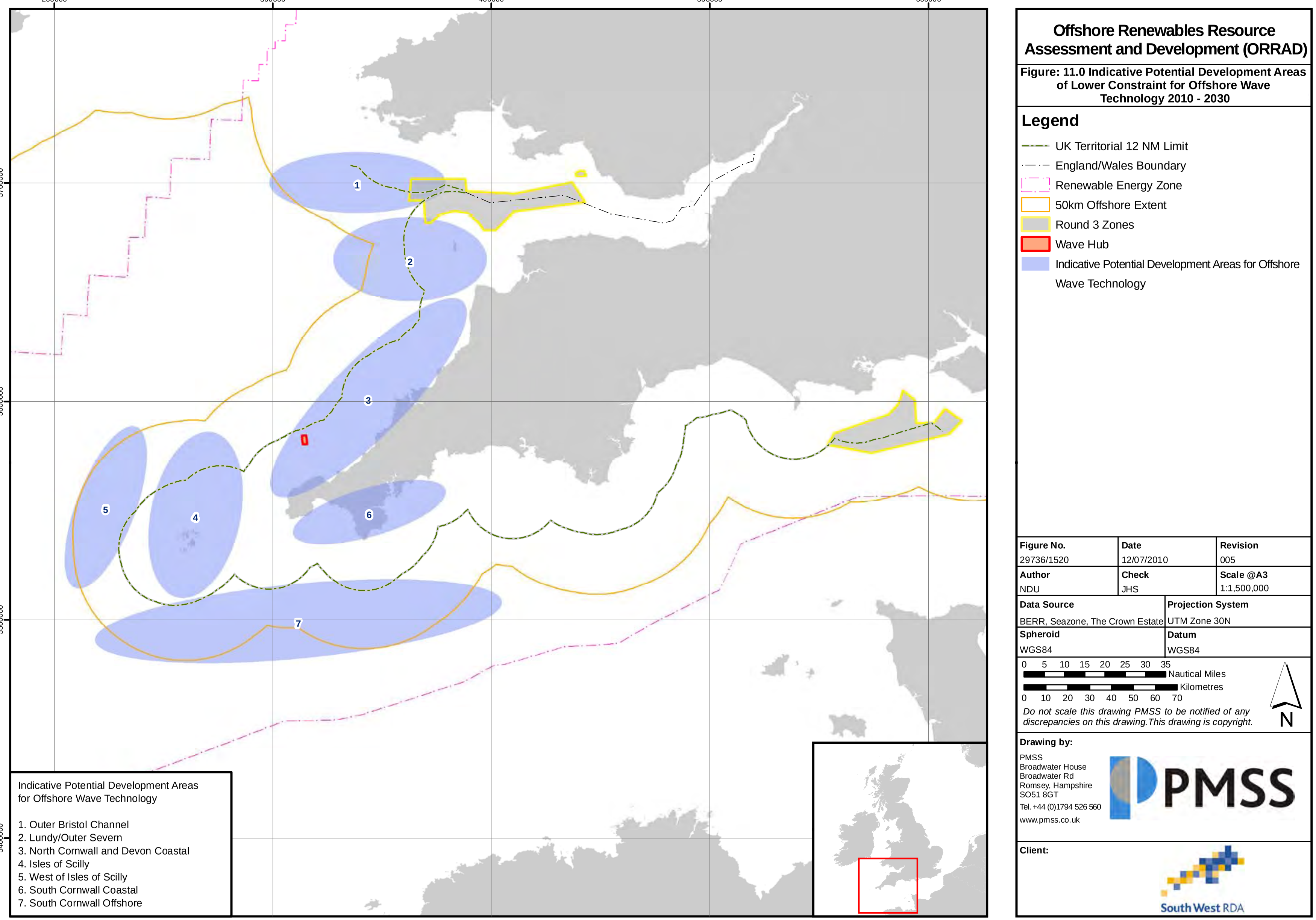

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Figure 11: Indicative Potential Development Areas of Lower Constraint for Offshore Wave Technology 2010-2030

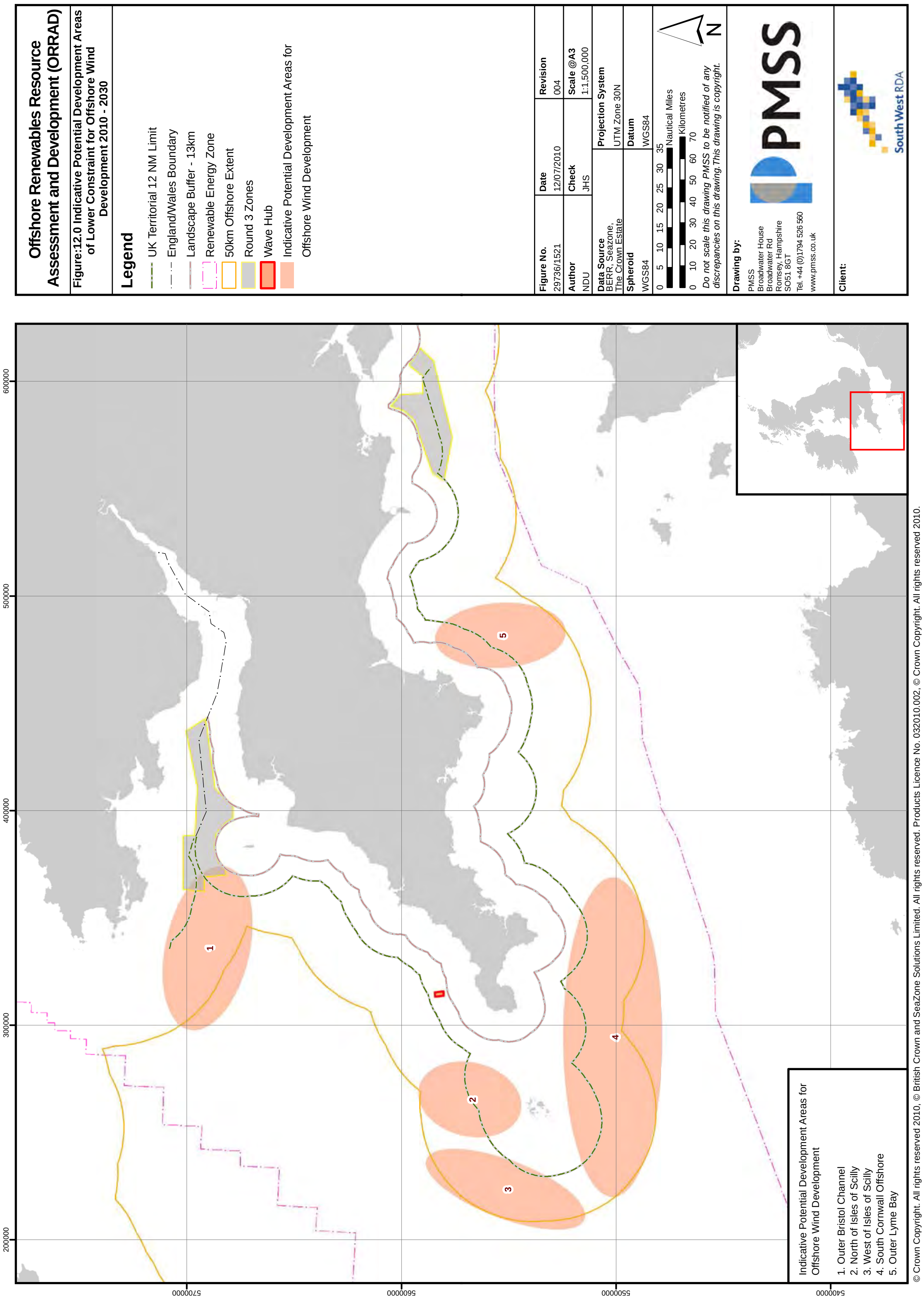

Figure 12: Indicative Potential Development Areas of Lower Constraint for Offshore Wind Development 2010-2030

3.7. Capacity estimate methodology

Baseline capacity estimates for each technology were derived by GIS analysis. Under this process generic arrays with the dimensions set out in the assumptions tables at appendices 1-4 were placed within each potential development areas of lower constraint. Additional arrays were added until, on the basis of the spatial constraints outlined in the assumptions register, and expert opinion, each development area for each 5 year time period was considered to be "saturated" with development. In most cases this "saturation" occurred because of shipping and navigation constraints rather than the maximum theoretical capacity of each area having been achieved.

Indeed it appears from the basis of this analysis that the single most significant constraint on marine renewable energy deployment relates to the risk posed by navigation and shipping. For this reason further detail is provided on the outline navigational risk assessment carried out for this study.

3.7.1. Navigational risk assessment

The navigational risks presented by the deployment of renewable energy arrays were reviewed for each offshore technology type. The technology types considered were:

- Shallow tidal stream. All shallow tidal stream arrays were assumed, for the purposes of navigational assessment, to be surface piercing.
- Deep tidal stream. All deep tidal stream arrays were assumed, for the purposes of navigational assessment, to be seabed mounted and submerged.
- Offshore wave.
- Intermediate wind.
- Deep water wind.

Generic array sizes were assumed for each of these technologies to serve as a basis for the navigational risk assessment. The generic array sizes assumed were 0.5 km2 for tidal stream arrays, 1x4 km for wave arrays and 83 km2 for wind arrays. Buffers around the arrays were also applied to take account of inter-array losses in efficiencies or any large array effect.

The degree of the navigational risk is influenced by a wide range of different factors. To assess the potential level of risk that the development of renewable energy within each of the potential development areas could present the following issues were considered as part of the navigation risk assessment.

- Proximity of potential arrays to any TSS and associated buffers.
- Proximity of potential arrays to areas of existing heavy shipping use.
- Proximity of potential arrays to converging shipping lanes.
- Potential for development to create pinch points.
- The potential influence of wind turbines on ships radar, especially in areas of high navigation risk.
- Consideration of emergency/loss of power incidents within a TSS and maintenance of clear exits for shipping.
- Maintenance of access to ports.
- Consideration of coastal routes and inshore vessel activity.
- Consideration of the likely impacts that proposed development of The Crown Estate Round 3 zones may have on existing shipping lanes.
- Consideration of the likely impact on shipping due to the future development of Portland as a commercial port.
- The potential for combinations of multiple arrays to create significant linear barriers
- The potential for wind and surface piercing tidal devices to act as navigational aids in some areas.
- The potential for increased levels of risk to shipping traffic during the construction phases of development.
- The feasibility of safe and efficient operation and maintenance activities in proximity to shipping.
- Consideration of the potential for displacement of smaller coastal vessels away from coast into heavier trafficked shipping lanes.

- Consideration of ferry routes, which due to the presence of passenger numbers represent a high risk.
- Identification of areas of low shipping use and natural barriers which may create a lee from business shipping activity, such as Lundy Island.
- Identification of areas of existing high navigation risk such as the approaches to Western Solent and the waters around the Isles of Scilly.

Having undertaken the detailed navigation risk assessment based on generic array areas, generic outputs in MW for each array were then applied to produce a baseline capacity estimate. The output for the generic arrays was assumed to be 30 MW for tidal stream arrays, 50 MW for wave arrays and 500 MW for wind arrays.

4. Baseline Capacity Estimates

The process of estimating capacity from the application of notional arrays within a geospatial model provides a robust assessment of the feasibility of developing a significant number of commercial marine renewable energy arrays in the coastal waters of South West England in the period up to and including 2030.

As set out in greater detail below this geospatial approach estimates that there is marine renewable capacity available in the South-West capable of delivering some 7600 MW of developed generation projects by 2030, with a further 1500 MW in planning by 2030, delivering a total of 9.2 GW in the study period.

The tables below show the delivery period for this capacity and the total predicted capacity for each technology type.

	Total Capacity (MW) per 5 yr interval
2010 - 2015	20
2015 - 2020	4030
2020 - 2025	1800
2025 - 2030	1840
2030 in planning	1530
Total capacity (MW)	9220

Table 4: Total predicted capacity (MW) by 5 year delivery period.

	Offshore Wave Capacity (MW)	Intermediate Wind Capacity (MW)	Deep Wind Capacity (MW)	Shallow Tidal Capacity (MW)	Deep Tidal Capacity (MW)	Total Capacity (MW)
Total capacity (MW) by technology	1240	4400	2500	780	300	9220

Table 5: Total predicted capacity (MW) by technology type.

As discussed further below the 9.22 GW capacity estimate excludes shoreline wave development and potential tidal range projects.

As discussed in **Section 3** above it is important to remember that the purpose of this development study is to provide an estimate of the potential capacity of the South West region for wind, wave and tidal technologies. This report is not a technology deployment forecast but rather, in line with the aims of the project, it aims to highlight what renewable energy capacity could be delivered in the region given a moderate level of appropriately targeted strategic support and guidance. In this context the 20 MW figure for the period 2010-2015 represents the Wave Hub project. This assessment estimates that given current technology there is potential to develop 230 MW of shallow tidal generation capacity and 140 MW of wave generation capacity in the 2010-2015 period. However, in this context given the challenges of the consenting process and the need to await the outcome of the current SEA, it is more likely that the 230 MW of shallow tidal generation capacity and 140 MW of wave generation will negotiate the consenting process in the next 5 years with construction taking place shortly thereafter. This would not affect the overall 2030 capacity estimate but suggests an emphasis on development and consenting in the period to 2015 with a greater amount of construction activity taking place in the 2015-20 period.

4.1. Tidal Stream Technologies

Tidal stream technologies contribute 1080 MW of the 9.22 GW capacity estimate. This contribution is split between shallow tidal stream technologies (with over half in the period 2015 – 2020 reflecting current consenting constraints noted above) and deeper water technologies (240 MW, all at the end of the study period).

	Shallow Tidal Capacity (MW)	Deep Tidal Capacity (MW)
2010 - 2015	0	0
2015 - 2020	390	0
2020 - 2025	100	0
2025 - 2030	100	60
2030 in planning	190	240
Total capacity (MW)	780	300

Table 6: Total predicted capacities (MW) for shallow and deep tidal stream technology.

As might be expected this tidal generation capacity does not have an even geographical spread. In the table below the tidal generation capacity is broken down further by reference to the broad geographical areas shown in **Figure 10**.

Potential Development Area	2010-2015 estimate (MW)	2015-2020 estimate (MW)	2020–2025 estimate (MW)	2025–2030 estimate (MW)	Consent in 2030 (MW)	Capacity Totals
Tidal Stream Technology						
1 - Inner Bristol Channel *	0	300	100	100	100	600
2 - Lundy and Outer Severn	0	60	0	30	120	210
3 – Land's End Coastal	0	0	0	0	150	150
4 - Portland	0	30	0	30	60	120
Total Tidal	0	390	100	160	430	1080

* excludes Severn tidal project area

Table 7: Total tidal generation capacity for each broad development area 2010 – 2030.

As would be expected much of this development potential is in the Bristol Channel, an area recognised for its excellent resource; even when, for the reasons outlined at **Section 4.3.1** above, the Severn Tidal Project area is excluded. It should be noted that the potential for barrage and other tidal range (i.e. lagoon) proposals in the Inner Severn area has created a level of uncertainty surrounding the viability of tidal stream projects in the wider area. It is possible, therefore, that should such large-scale schemes proceed, a large proportion of the Inner Bristol Channel capacity outlined above might not be developed. Conversely the Severn Tidal Study may conclude that a large number of tidal stream devices could be deployed within the study area, significantly increasing the available capacity above the 600 MW outlined above.

On this basis of the estimates in the above table, and the density assumption TS4 in **Appendix 1**, the total area utilised by these arrays would be only 18km^2, which, as discussed below is a small proportion of the total notionally available resource outlined in **table 13**.

4.2. Offshore Wave Technologies

Offshore wave technologies contribute 1240 MW of the 9.22 GW capacity estimate, with 20 MW already consented at Wave Hub. Around half of this capacity (680 MW) is only capable of delivery towards the end of the study period (2025 - 2030) as, with improving reliability, larger arrays are capable of delivery further offshore. This capacity is also further enhanced by improvements in technology allow more near-shore resource to be utilised.

	Offshore Wave Capacity (MW)
2010 - 2015	20
2015 - 2020	240
2020 - 2025	200
2025 - 2030	680
2030 in planning	100
Total capacity (MW)	1240

Table 8: Total predicted capacities (MW) for offshore wave technology.

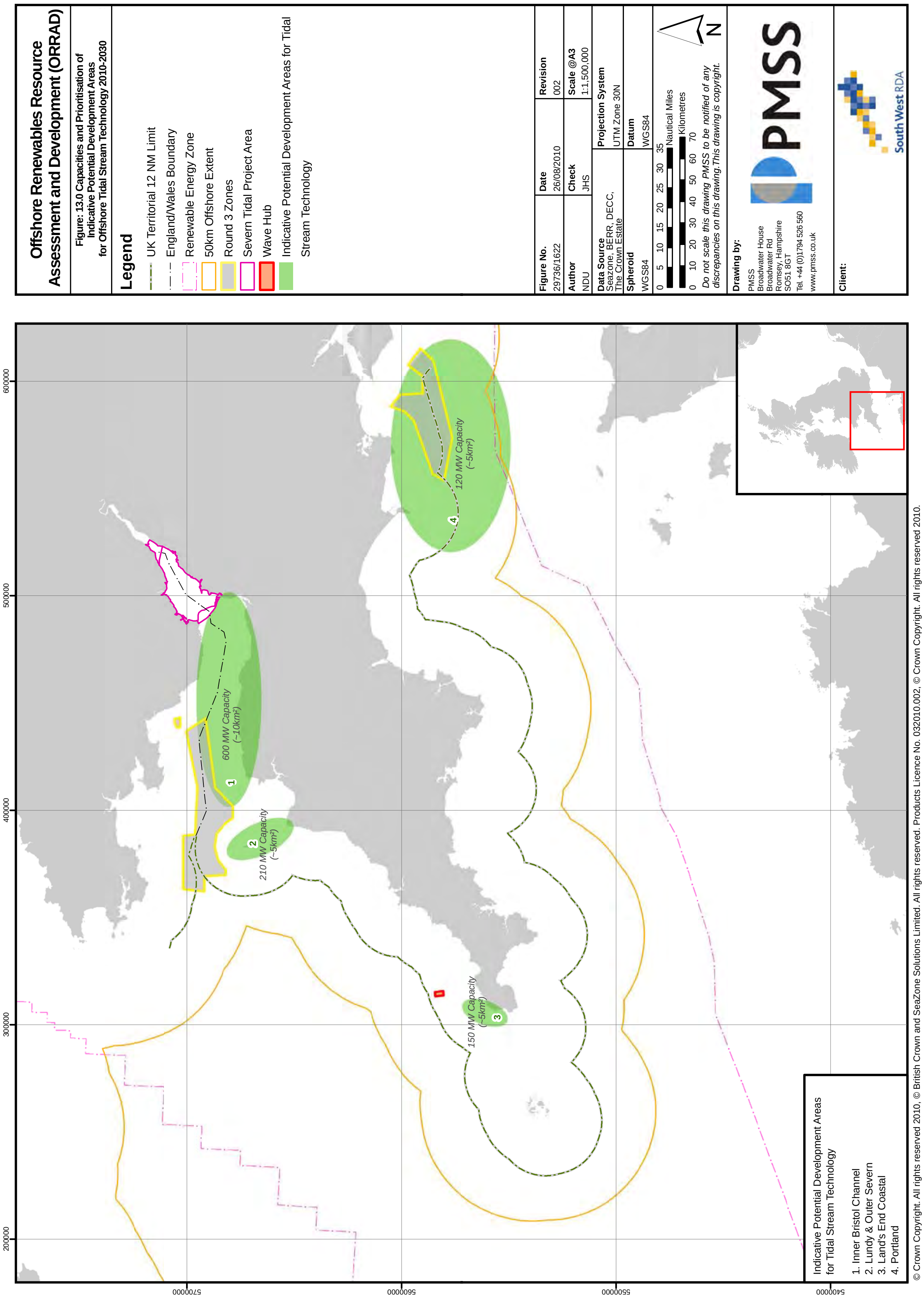

Figure 13: Capacities and Prioritisation of Indicative Potential Development Areas for Offshore Tidal Stream Technology 2010-2030

In the table below the wave generation capacity estimates are broken down further by reference to the broad geographical areas shown in **Figure 11**. This table does not include the contribution of Wave Hub which adds an additional 20 MW of capacity to the 1220 MW total.

Potential Development Area	2010-2015 estimate (MW)	2015-2020 estimate (MW)	2020–2025 estimate (MW)	2025–2030 estimate (MW)	Consent in 2030 (MW)	Capacity Totals
Wave Technology						
1 - Outer Bristol Channel	Area has been prioritised for wind technology deployment in the baseline scenario					
2 – Lundy and Outer Severn	0	0	0	0	100	100
3 - North Cornwall and Devon Coastal	0	90	0	430	0	520
4 - Isles of Scilly	0	100	200	100	0	400
5 - West of Isles of Scilly	Area has been excluded due to navigational constraints in the baseline scenario					
6 – South Cornwall Coastal	0	50	0	150	0	200
7 - South Cornwall Offshore	Area has been prioritised for wind technology deployment in the baseline scenario					
Total Wave	0	240	200	680	100	1220

Table 9: Total offshore wave generation capacity for each broad development area 2010 – 2030.

Given the large amount of wave resource in the west of the study area the importance of Cornwall and the Isles of Scilly is apparent. However towards the end of the study period North Devon and Lundy also become significant as marine traffic constraints (and economic limits arising from distance offshore) start to limit the overall capacity of the early development areas further west. By 2030 around a quarter of the total capacity arising in the twenty year study period will come from these more northerly and easterly areas. On this basis of these estimates, and the density assumption W5 in **Appendix 3**, the total area utilised by these arrays would be approximately 100km^2, which, as discussed below is a small proportion of the total notionally available resource outlined in **table 13**.

4.3. Offshore Wind Farm Development

There is potential for over two-thirds of the marine renewable capacity in the South West over the study period to be delivered from offshore wind farm development (6.9 GW of the 9.22 GW total); either through current technologies, albeit in deeper water than developed to date (4.4 GW), or through deeper water floating technologies (2.5 GW).

	Intermediate Wind Capacity (MW)	Deep Wind Capacity (MW)
2010 – 2015	0	0
2015 – 2020	3400	0
2020 – 2025	1000	500
2025 – 2030	0	1000
2030 in planning	0	1000
Total capacity (MW)	4400	2500

Table 10: Total predicted capacities (MW) for offshore wind technology

In the table below the wind generation capacity estimates are broken down further by reference to the broad geographical areas shown in **Figure 12**. This table does not include the contribution of the existing Round 3 projects in the South West; Eneco's Zone 7 West of Isle of Wight project (900 MW) and RWE nPower's Zone 8 Atlantic Array project (1500 MW). It is also assumed for the purposes of this report that notwithstanding The Crown Estate's target zone capacity of 900 MW the size of Round 3 Zone 7 provides the potential for a further 500 MW of capacity from that area, resulting in a total Round 3 capacity of 2900 MW.

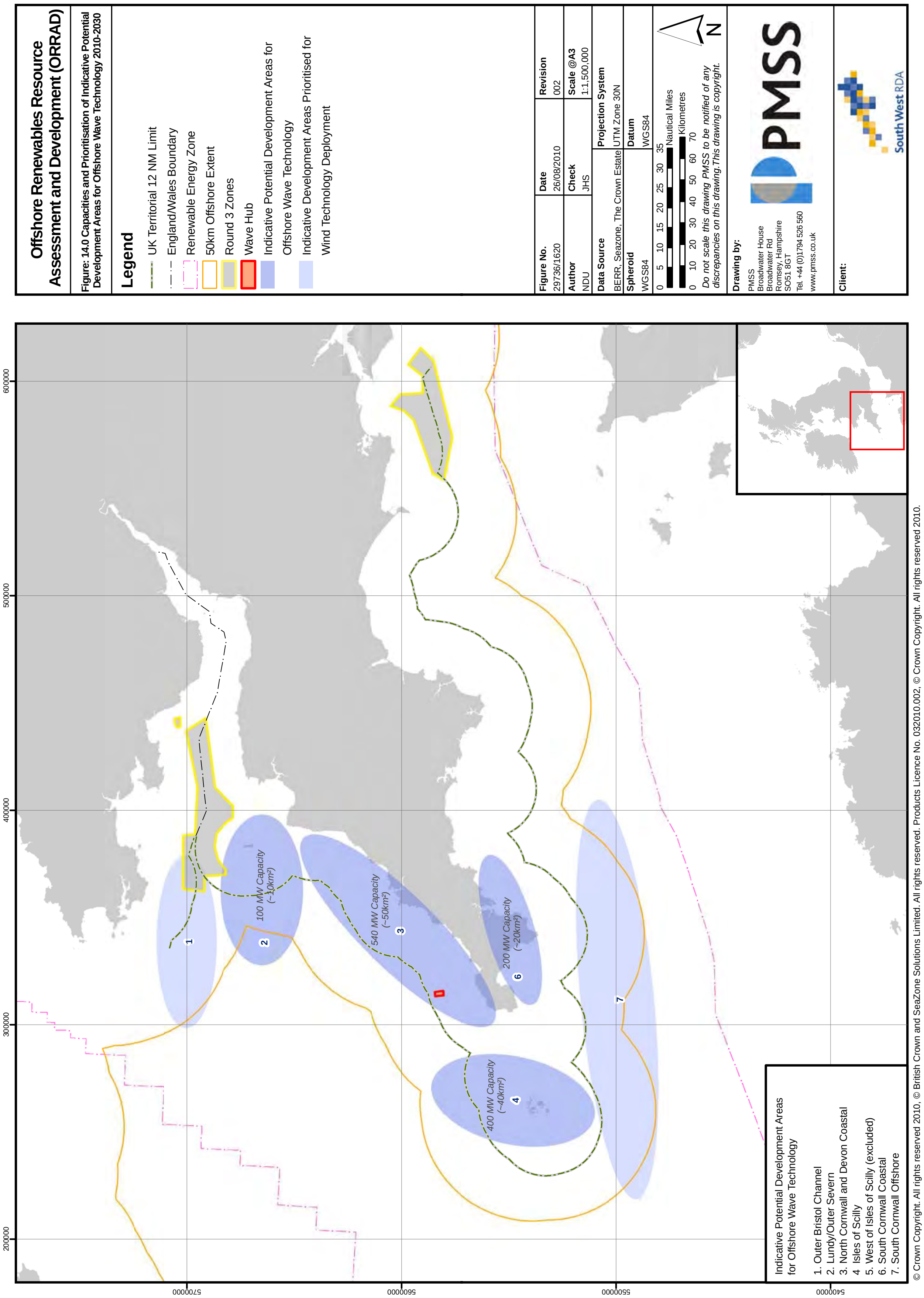

Figure 14: Capacities and Prioritisation of Indicative Potential Development Areas for Offshore Wave Technology 2010-2030

Potential Development Area	2010-2015 estimate (MW)	2015-2020 estimate (MW)	2020–2025 estimate (MW)	2025–2030 estimate (MW)	Consent in 2030 (MW)	Capacity Totals
Wind Technology						
1 - Outer Bristol Channel	0	500	500	500	0	1500
2 - North of Isles of Scilly	0	0	0	500	0	500
3 - West of Isles of Scilly	This area has been excluded due to navigational constraints in the baseline scenario					
4 - South Cornwall Offshore	0	0	0	0	1000	1000
5 - Outer Lyme Bay	0	0	1000	0	0	1000
Total Wind	0	500	1500	1000	1000	4000

Table 11: Total offshore wind generation capacity for each broad development area 2010 – 2030.

The Round 3 timetable requires that target zone capacities be in place by 2020 and it is assumed that only a further 500 MW of intermediate depth offshore wind would come forward in that time period (in the Outer Bristol Channel Area). 1 GW of intermediate depth offshore wind could be delivered in the Outer Lyme Bay area from 2020 onwards with the remaining 2.5 GW of offshore wind capacity being delivered by deep water (floating) technologies, primarily in the West of the study area, particularly towards the Western Approaches.

On the basis of these estimates, and the density assumption OW8 in **Appendix 4**, the total area above and beyond the existing Round 3 zones utilised by intermediate and deep water wind arrays would be approximately 670 km^2, which, as discussed below is a small proportion of the total notionally available resource outlined in **table 13**.

4.4. Shoreline Wave Technology

Areas suitable for the deployment of shoreline wave technologies are shown in **Figure 5**. The section of coastline that was identified as potentially being suitable for shoreline wave device deployment was from near Overcombe to the north of Weymouth to the eastern edge of the study area. This limited area is where the tidal range falls below 2 m and is therefore potentially suitable for the deployment of shoreline wave devices. This is a total of approximately 58 km of shoreline, excluding Poole Harbour inside of the Sandbanks ferry route.

Not all of this area will be available for deployment due to existing coastal constraints that already exist. A review of the area indicates that the following significant constraints exist along this coastline:

- MoD land around Lulworth and the Isle of Purbeck, including the active Lulworth firing range.
- Coastal conservations designations including Poole Bay and Lyme Bay Reef dSAC.
- The coast also forms part of the Jurassic Coast World Heritage Site which is protected for its geological features which would potentially be impacted by the deployment of shoreline wave devices.

To accurately estimate the contribution that shoreline wave technologies can contribute to total renewable energy production figures, identification of suitable development sites would be required. At this scale, this would entail a site selection exercise which is lies outside the scope of this strategic study. However at a power density of 2.5 MW/per 100m the following estimates, based on length of shoreline developed, are presented.

Length of shore developed	500m	1 km	2km	3km	4km	5km	10km
Total MW	12.5 MW	25 MW	50 MW	75 MW	100 MW	125 MW	250 MW

Table 12: Estimated shoreline wave capacity based on length of development.

For the purposes of this study such relatively small contributions to the overall 2030 capacity are not considered further.

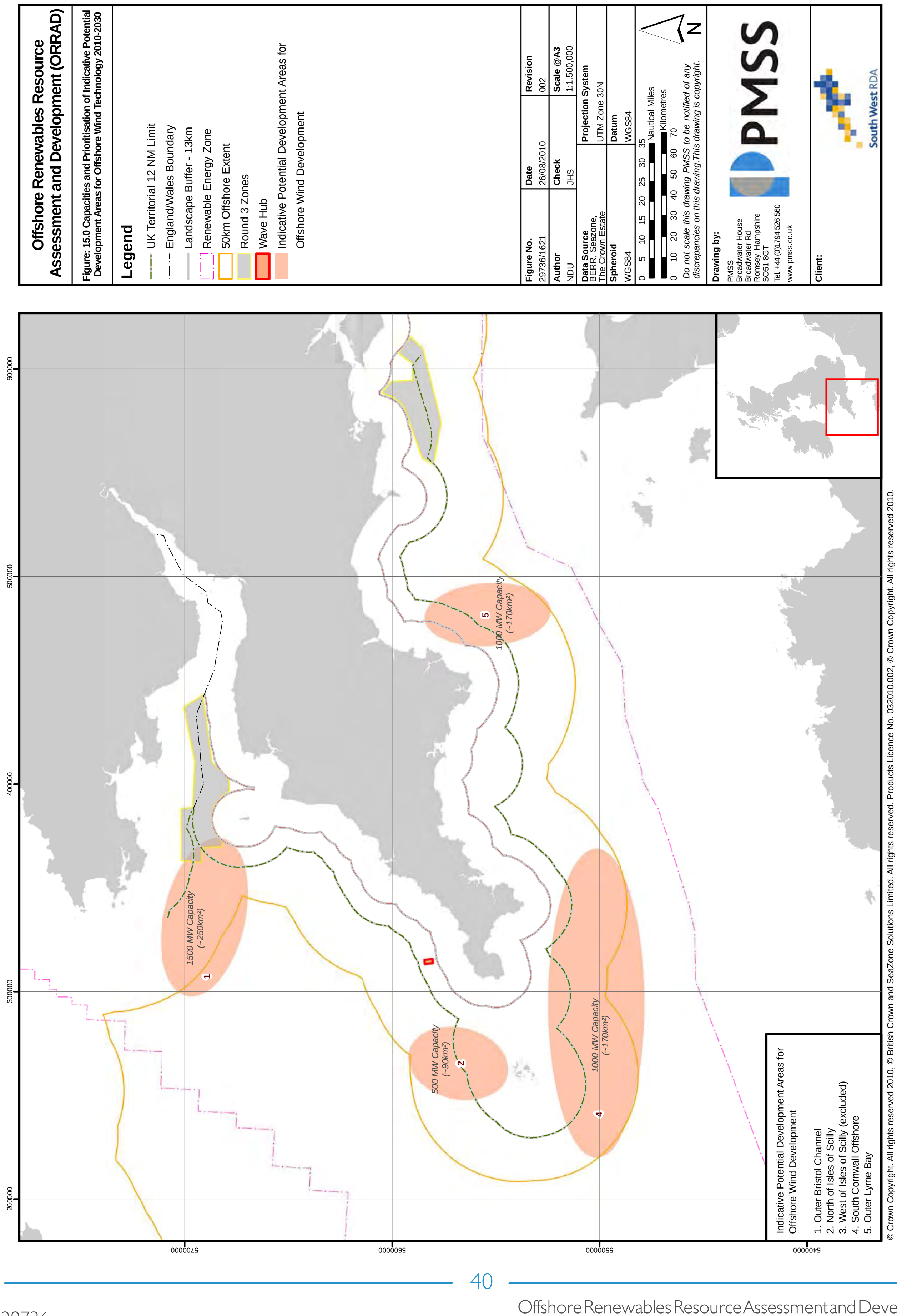

Figure 15: Capacities and Prioritisation of Indicative Potential Development Areas for Offshore Wind Technology 2010-2030

4.5. Tidal Range Technology

As shown in **Figure 5** the tidal range resource in the study area is significant. Once the stage 2 ("hard constraint") geospatial analyses were applied this total area shown yellow in the figure was reduced to 6417 km^2, a significant area of available resource although this would be likely to be substantially reduced further by around 2700 km^2 due to shipping constraints.

As discussed in **Section 4.3.1** this study has not considered tidal power technologies (both tidal range and tidal stream) within the Severn Tidal Study Area. The Severn Estuary is widely recognised to hold the South West and UK's greatest tidal resource and is the subject of a comprehensive and wide-ranging study in its own right. Tidal range technology is most likely to give rise to the greatest economic benefit within this DECC study area and it is considered that tidal range technologies have the greatest potential to be deployed there. For this reason tidal range technologies have not been included in the 9.22 GW total capacity estimate. Tidal range technologies could, subject to the resolution of significant environmental concerns surrounding their deployment, significantly increase the potential marine renewable energy capacity in the South West.

5. Development Scenarios - Commentary

The geospatial approach used to deliver the development study provides a robust assessment of the potential capacity for marine renewables in the study area from 2010 to 2030. The baseline development scenario, which is discussed further below, is both realistic and deliverable, and provides a firm baseline figure on which the economic study builds.

It is worth re-iterating that the estimates of capacity contained in the baseline development scenario are not development forecasts. Similarly, none of the technology capacity estimates represents a cap on development potential. The capacity estimates represent a realistic assessment of what could be built in the study period timetable, based on current knowledge. The alternative scenarios provided below explore how these capacity estimates might be extended.

5.1. Baseline development scenario

The baseline development scenario is defined by the assumptions set out at appendices 1-4 of this report. This scenario delivers 1.2 GW of wave capacity, 4.4 GW of intermediate wind (much of it within the existing Round 3 zones), 2.5 GW of deep water (floating) wind capacity and 1.8 GW of tidal stream capacity (excluding the DECC Severn study area).

It is notable that the study's findings of 9.22 GW of wind, wave and tidal power within 50km of shore are significantly lower than the excellent, theoretically available, resource might imply. This is most clearly illustrated by the reduction in available area for each technology type at each of the stages set out in **Section 4** above. Although the initial useable resource areas shown in **Figures 2-5** are significant, a large proportion of these are not capable of being developed because of the hard constraints shown in **Figures 7-9** such as traffic separation zones, potential visual impacts and conflicts with existing defence uses. This potential developable area is reduced further by the "soft" constraints, such as shipping, culminating in only limited areas with the potential for relatively unconstrained development, as highlighted in **Figures 10 -12**.

There are four main factors which act to limit the potentially available resource. Two of these, MoD and landscape issues, primarily limit the available capacity for offshore wind deployment. The other two factors, distance from available offshore and onshore grid connections and shipping constraints, limit the potential for all technology types. Each of these factors is considered in further detail below.

5.1.1. Shipping and navigational constraints

The baseline development scenario applies a navigational risk assessment exercise to individual notional array locations to ensure that the potential capacity calculations are compliant with MCA guidance and, in particular Marine Guidance Note 371 - Offshore Renewable Energy Installations (OREIs), Guidance on UK Navigational Practice, Safety and Emergency Response Issues, referenced at **Section 4.4** above.

The scenario therefore assumes that shipping will continue to be a major constraint to marine renewable deployment (due to the importance of the shipping sector to the UK economy).

The table below highlights the extent to which shipping and marine renewable generation interests overlap.

	A	B	C	D	E
Technology Type	Total Available Resource (km2)	Total area taken up by hard constraints (km2)	Total resource area minus hard constraints (km2)	Area taken up by shipping routes plus 1 NM buffer (km2)	Unconstrained resource (A-B-D)
Shallow Wind	2064	2045	19	10	9
Intermediate Wind	13194	10483	2711	2053	658
Deep wind	20307	11665	8642	5077	3565
Offshore Wave	23869	3795	20074	12188	7886
Shallow tidal Stream	1215	341	874	535	339
Deep Tidal Stream	2172	554	1618	1502	116
Tidal Range	7225	807	6418	2710	3708

*Note: These figures have been rounded to the nearest whole number

Table 13: Total area counts taken up by available resource, hard constraints and shipping.

Column D indicates the total area taken up in the waters of the South West by the major shipping routes, buffered by one nautical mile after the stage 2 constraints had been considered. For many technology types over half of the notional available resource is directly affected major shipping routes. Even in the unconstrained resource area (column E) it will not be possible to build in all locations; pinch points, the risk of creating converging traffic routes and the need to provide safe exit from shipping lanes will restrict development in these areas further.

Although previous experience with Wave Hub, and other renewable energy projects elsewhere in the UK, has illustrated that it is possible to move or relocate shipping lanes this will become increasingly challenging as the number of developments increases and the cumulative impact on shipping lanes becomes more difficult to manage. It should also be noted that the primary development scenario based on the assumption that shipping lanes and vessel traffic will remain at present day levels; it is possible, however, that traffic levels will increase significantly over the study period.

As discussed at **sections 5.1 – 5.3** above the capacity estimates contained in this report give rise to areas capable of development which are relatively small compared to either the total available or to the utilisable resource. For example under the development scenario wave arrays would only utilise around 100km^2 (less than 2%) of the 7886km^2 unconstrained resource in column E above. Similarly the predicted tidal stream capacity of 18km^2 would utilise less than 4% of the total available combined shallow and deep water tidal resource. Intermediate and deep water wind projects outside of the Round 3 zones would amount for a larger proportion, albeit still less than 16% of the unconstrained resource and less than 2% of the total available wind resource in the South West area in column A above.

5.1.2. Distance from available grid connection

The importance, and challenges, to marine renewable energy projects of connecting to the grid is extremely significant with grid issues frequently identified as the greatest challenge to the successful deployment of these technologies. A detailed grid analysis is outside of the scope of this study and instead the various assumptions set out in the appendices to this report have been applied.

Those assumptions general provide that:

- Capacity for connection is available at the closest appropriately sized sub-station – either on the local distribution network or the national grid.
- That onshore cabling will run directly from the substation to the nearest point on the coast to the project site, regardless of the physical or environment constraints on that route or the feasibility of the landfall
- That offshore cabling will run directly from the project to the landfall location closest to the nearest appropriately sized substation

Further assumptions have been made in respect of the areas to the west and south of the Isles of Scilly. The baseline study area incorporates a 50km range around the Isles of Scilly, not just the mainland of Cornwall. The capacity of the 33 kV cable and associated infrastructure connecting the islands to the mainland is not sufficient to export significant amounts of capacity and therefore some form of cable upgrade (or an offshore grid project bypassing the islands altogether) would be needed to deliver the larger projects in the area to the south and west of the islands.

A further assumption has been made in respect of onshore grid; namely that the 400 kV network will be extended from Indian Queens to Hayle by 2020 in order to facilitate large developments.

Because the above assumptions are relatively simplistic and, in some cases, dependent on activities outside the direct control of developers it is likely that the potential 9.22 GW capacity considered in the baseline development scenario can only be delivered by significant strategic intervention from government or regulators in respect of the provision of onshore and offshore grid availability.

Perhaps the most significant assumption relating to grid involves the maximum distance from shore at which projects can be constructed without the level of capital expenditure (reflected in any offshore transmission operator's use of system charges) adversely affecting the economics of the development. For the purposes of the baseline development scenario it has been assumed that, even with a licensing round in place, individual projects would probably seek individual offshore transmission solutions and, therefore, that beyond 50 km the project economics on long offshore cable runs are likely to become unviable. **Section 6.2.1** below discusses a development scenario incorporating an enhanced offshore network.

The upper limit on capacity is also partly affected by the potential pace of development. While the image of large offshore wave farms producing many GW of power has captured the imagination of many in the industry the steering group endorsed the assumption used in this report that the maximum size of wave arrays likely to arise during the study period would be around 500 MW.

5.1.3. Ministry of Defence

As discussed at **Section 4.4** above the waters of the South West area are important to defence operations. The offshore area is used for aerial and seaborne exercises as well as much of it being in sufficient proximity to air defence and air traffic control radars for wind farm development to give rise to concerns from the MoD about the potential risks associated with national security or aviation safety. **Figure 6** clearly illustrates the extent to which these defence interests may directly conflict with the marine renewable energy industry. The baseline development scenario assumes that development will take place in areas where these potential conflicts are least likely.

1.1.1. Landscape issues

Marine renewable energy devices have the potential to give rise to seascape and landscape impacts. This is particularly the case with wind turbines but is also relevant to the surface piercing elements of tidal flow devices and, to a lesser extent, those parts of wave generating equipment visible above the surface. Opposition to potential visual impacts has led to significant delay, although to date not the refusal, in the consenting of offshore wind farm projects, most notably Gwynt-y-Mor in North Wales. Potential visual impacts are of particular significance in the South West which is associated with undeveloped coastline and which benefits from the tourism income associated with the natural environment.

The UK government's Round 3 SEA concluded that the "bulk" of new offshore wind farm development should be beyond 12 NM from the coast. Notwithstanding that view the two Round 3 zones in the study area are both partly further inshore than 12 NM, being 13 km (or around 8 NM) from the coast at their nearest points. This 13 km landscape buffer was applied by the Round 2 SEA in the Irish Sea to minimise potential impacts. The baseline development scenario has also adopted this 13 km coastal buffer.

Much of the shallow and intermediate wind resource in the South West is within this 13 km buffer. Indeed the application of this constraint removes nearly all of the available shallow wind capacity and, in combination with MoD constraints, the vast majority of the intermediate wind capacity (see columns A, B and C of **table 13** above).

5.2. Alternative Development Scenarios

The baseline development scenario discussed above is relatively conservative in approach rather than aspirational, providing a realistic estimate of potential capacity. Under alternative development scenarios it would be possible to increase this potential capacity. Under such scenarios, which are listed below, the 9.22 GW of estimated capacity could be regarded as an initial tranche of development with additional future capacity capable of being unlocked as technical solutions to various challenges are delivered, as the industry advances and as the understanding of the possible conflicts between technologies and other sea users improves.

It should be noted, however, that the evidence base for these scenarios is more limited than that applying to the baseline development scenario, particularly in respect of how the treatment of maritime safety and vessel interactions with marine renewable energy structures may evolve in the future.

5.2.1. Alternative Scenario 1 – Enhanced Grid/OFTO provision

This scenario assumes that centralised / strategic development of offshore grid delivers the ability to build beyond 50 km from the coast out to 75 km. A strategic approach to grid (as opposed to project-by-project OFTO led tenders) would be similar to that envisaged by the Scottish Government and NGET in respect of the Scottish East and West coast offshore network proposals. An offshore "loop" running from Plymouth out around the Isles of Scilly at or around the 50 km limit and returning into, for example, Hayle or even Hinkley Point (or the ability to tie into a proposed Brittany / Cork interconnector) would mean that the costs of connecting to the grid would be shared among projects. Such an approach could also negate the future need for onshore upgrades by directly accessing grid nodes with spare capacity.

Earlier studies have confirmed that extensive wave and wind resource occurs in the environment further offshore[10]. As is shown in the table below the additional area available by extending the potential area of development from within 50 km to within 75 km is 16,486 km^2. Around half of this is potentially affected by shipping traffic.

	0-50 km	50-75 km
Area bounded by coast and limit (km2)	40253	16487
Shipping lanes (AIS 90th percentile)	16757	6025
Shipping lanes plus 1nm buffer	24805	8993

Table 14: Additional areas available out to 75km

As the table shows, shipping remains a significant constraint in this area and there are, additionally, higher risks associated with operation and maintenance activities this far offshore. Notwithstanding these challenges an initial analysis of the 50-75km area suggests that there is potential for around 4GW of capacity for deep water (floating) wind projects and wave generation devices in this wider area. It should be noted, however, that in addition to grid challenges, device reliability would need to be extremely high to offset the increased operation and maintenance cost of deploying so far from port.

The challenges of deploying in the broader renewable energy zone are significant, not least in respect of health and safety and operation and maintenance issues, but longer term (2030 onwards) these areas, too, may be capable of utilisation delivering significant additional capacity.

5.2.2. Alternative Scenario 2 – Resolution of shipping and MoD conflicts

This scenario assumes that part of central government's action during a licensing round would be to reassess constraints posed by shipping and MoD areas. This could release wider areas for renewable development.

In respect of shipping, such an approach might necessitate the re-positioning of TSS's to regulate displaced traffic. Of particular relevance is the TSS's around the Isles of Scilly which if displaced further offshore would allow extended development inside of the TSS's, releasing a further 200-400 MW in that area.

However, it should be noted that politically acceptable as well as technical solutions to ensure safe vessel traffic movement would be required to deliver this scenario. Maritime safety could not be compromised and a significant redrafting of current guidance (and probably greater expenditure on technical solutions) would be required. In addition to safety the shipping industry is likely to baulk at any proposals with the potential to increase journey times or fuel costs.

Finally, it is also worth considering the economic importance of shipping to the South West and potential damage to tourism and other industries that can arise from shipping accidents such as that which occurred to the MV Napoli in 2007. Given the nascent nature of the industry it is not yet proven that renewable energy development can coexist safely with shipping and therefore the precautionary approach adopted by the primary development scenario, in compliance with MCA guidance, is appropriate.

It is likely that displaced traffic could adversely affect future development areas further offshore. For this reason it is thought likely that this scenario (alternative development scenario 2) is not fully compatible with alternative development scenario 1, particularly if more marine traffic is pushed beyond 50 km.

As suggested in the baseline development scenario discussion there may be the capacity for increased sharing of areas currently used by the MoD. This could be particularly beneficial to the deployment of deep water wind turbines in areas currently used for low flying practice. The impacts of this on defence planning and national security have not been considered by this report.

10 e.g. BERR (2008) Atlas of UK Marine Renewable Energy Resources: Technical Report. Report prepared by ABPmer

5.2.3. Alternative Scenario 3 – Improved economics

As outlined in the economic assessment report, the underlying assumptions for the relative capital costs of Offshore Renewable Energy Installations (OREIs) and their profile over the period 2010-2030 intrinsically reflects a cost effective scenario for these technologies to deliver a growing and ever more significant proportion of UK energy supply. This is anticipated to be delivered in the context of offshore wind by assumed enhancements to the existing supply chain and by effective improvements in economies of scale for the deployment of existing fixed wind turbine technology at ever larger scale in ever deeper waters, and by the development and effective demonstration of floating wind turbine technology. In the case of wave and tidal technologies, it is assumed that existing prototype devices will move through the stage of demonstration into deployment within the next 5 years and that thereafter such deployment, at ever larger scale, will mirror that seen for offshore wind as the capital costs for these technologies continue to fall.

Without this underlying assumption of a consistent and prolonged reduction in the levelised cost of generation (£/MWh) of electricity from all offshore renewable technologies, but in particular those of tidal and wave, the deployment of OREIs to the capacities outlined in the baseline scenario are likely to require far greater levels of strategic and economic intervention to be achievable.

Conversely, the attractiveness to developers of marginal (lower resource) areas indentified in this technical assessment would be achieved if the overall economics of marine renewable energy were improved (i.e. greater reductions in capital costs were achieved) or if the climate in which such investments were considered was influenced by wider economic or political factors. Such changes might arise from increases in oil prices and new international support mechanisms such as the taxation of carbon. Areas in the study which have been considered to be of marginal commercial interest could be opened up under this scenario. Similarly, changes in economics or new sources of funding could facilitate the resolution of stakeholder concerns by providing additional funding for the introduction of innovative methods of managing interactions (for example by provision of active aids to navigation or solutions to radar conflicts). This process is not considered further, however, as it is primarily a national, economic, argument concerning the deployment of renewables generally.

5.2.4. Alternative Scenario 4 – Project prioritisation and mixed technology projects

The navigation review currently prioritises offshore wind over wave in a number of the development areas, primarily because of the greater visibility of wind turbines to marine traffic. Overall wave capacity could be increased by assuming, as part of the alternative scenario 2 above, that wave devices in close proximity to areas such as TSS become more acceptable. This is, however, unlikely to significantly increase the overall renewable energy capacity of the region; it merely changes the mix of technologies.

Hybrid devices or developments incorporating wave or tidal features with offshore wind structures could further increase output. If it were to be assumed that wave devices could efficiently operate within a wind farm array, an effective doubling of deep water wind and wave resource could be delivered in certain development areas providing around a further 1 – 1.5 GW of capacity. This estimate is based on the possibility of wave development being integrated with deep water wind at 2-3 array locations. This report has not considered whether such an approach is currently technically feasible. More detailed consideration would need to involve modelling to assess the effect of the interaction between different types of devices on resource utilisation.

5.2.5. Alternative Scenario 5 – Bristol Channel

As discussed in **Section 5.1** above the proposals for tidal range development in the Severn give rise to a significant level of uncertainty in respect of the excellent tidal stream resource which the area also provides.

The final alternative development scenario considers a position where, due to environmental or economic constraints, the barrage proposals (or other large scale impoundment schemes) currently being considered by the Severn Tidal Study are not progressed, thereby opening the Inner Severn area up to tidal stream device developers. This scenario would doubtlessly unlock further capacity while removing the uncertainty surrounding the 600MW or so of capacity in the Inner Bristol Channel discussed further in **Section 5.1** above.

5.3. Increasing understanding of interactions

The development study has been based on the current understanding of the interaction between marine renewable energy devices and the physical, human and biological environment. Our knowledge of these interactions, and our ability to deploy large scale commercial technologies in the marine environment, is currently limited. Even in respect of the most advanced offshore wind technology, there are significant challenges relating to stakeholder conflicts, foundation design, grid connection and project economics.

In this context the role of regional research facilities, including most notably Wave Hub and PRIMaRE, is central to ensuring that the potential capacity detailed in this report can be successfully and commercially utilised. Projects such as Wave Hub will increase our understanding of wave technology/interactions and facilitate industry growth.

6. Development Study Conclusions and Recommendations

The development study concludes that 9.22 GW of marine renewable energy capacity is available in the study area up to 2030. This potential capacity is broken down by technology as follows:

	Offshore Wave Capacity (MW)	Intermediate Wind Capacity (MW)	Deep Wind Capacity (MW)	Shallow Tidal Capacity (MW)	Deep Tidal Capacity (MW)	Total Capacity (MW)
Total capacity (MW) by technology	1240	4400	2500	780	300	9220

Table 15: Total predicted capacity (MW) by technology type.

In order to assist with the delivery of this capacity a number of recommendations are listed below. By implementing such recommendations it may be possible to view the 9.22 GW capacity as merely an initial tranche of development with future capacity capable of being unlocked as the industry advances and the understanding of the interaction between technologies and other uses of the sea improves.

The recommendations, based on the requirements for the delivery of the baseline development scenario are as follows:

- Licensing Round to deliver wave projects

  It is recommended that an initial well structured licensing round, supported by fully resourced SEA, is commenced as soon as possible to provide the momentum necessary to deliver commercial projects. The evidence in this report provides a robust baseline figure to support calls for a licensing round in the South West in a similar manner to which the Scottish Government's SEA for marine renewables paved the way for the Pentland Firth licensing round.

  Learning from early technology deployment in the UK, should be used to maximise the potential of a South West licensing round or rounds. Consideration should be given to whether a future round or rounds could be geographically defined; they might incorporate the entire South West area and be based on releases of capacity, rather than more tightly defined areas. Conversely, focused and appropriately sized licensing rounds may deliver more immediate benefits than a single broad, large scale capacity round, particularly if developers are subject to the discipline of tendering.

- Improvements to onshore grid

  A number of grid reinforcements or upgrades will be required in order to deliver electricity to the National Grid or local distribution networks and it is recommended that a grid study be commissioned to provide more detail than the limited, strategy, grid discussion contained in this report. In particular the study should consider the potential for upgrading the national grid from Indian Queens westward and the issues associated with connecting resource to the South and West of the Isles of Scilly to the National Grid.

- Offshore grid

  Economies of scale provided by a strategic approach to offshore transmission are more likely to increase the level of successful deployment than ad-hoc connection requests from stand-alone projects. An offshore grid could also provide direct access to 400 kV grid connections further east, thereby negating the need for onshore upgrades. The OFTO process is more likely to deliver such a strategic grid if deployment is facilitated by licensing round following which likely future demand for offshore grid infrastructure can be more readily assessed.

- Resolution of potential conflicts with shipping

  Greater efforts are required to resolve conflicts between shipping and marine renewables in the South West

- Continued need for research and knowledge transfer in respect of marine renewable technologies

  There is the need to promote research which can improve the understanding of interactions between devices and other sea users; thereby enabling the release of additional resource area.

Appendix 1: Tidal Stream Technology Assumptions

Item	Technology type	Subtopic	Assumption	Reference	Justification
Tidal Stream Resource					
TS1	Tidal Stream	Depth	Deep water tidal stream technologies require more than 35m water depth	PMSS/MEF Workshop 15th April 2010	
TS2	Tidal Stream	Depth	Shallow water Tidal Stream operates in 5m - 35m	PMSS/MEF Workshop 15th April 2010	
TS3	Tidal Stream	Resource	Tidal Stream requires a minimum speed of 2.0 m/s	METOC/Scottish SEA	2.0m/s is used as links with BERR Atlas categories
TS4	Tidal Stream	Array	Array density = 0.5 km2 = 30MW	PMSS/MEF Workshop 15th April 2010	Supported by Mackay estimate of 60W/m2 at 2m/s = 30MW, 200W/m2 at 3m/s = 100MW
TS5	Tidal Stream	Commerciality	First commercial tidal arrays will have a capacity of 10MW up to 50MW	Scottish SEA/BERR guidance	
TS6	Tidal Stream	Commerciality	Pre commercial tidal arrays considered to be up to 10 MW	BERR guidance	
Spatial Constraints					
TS7	Spatial Constraints	Aggregates	Active aggregate extraction areas are unsuitable for development	PMSS	Licence holder has exclusive rights to area for activities
TS8	Spatial Constraints	Aggregates	100m buffer area applied to aggregate extraction areas	PMSS	Safety zone applied due to vessel activity within area
TS9	Spatial Constraints	Disposal Areas	All active and inactive disposal areas are unsuitable for development	PMSS	Due to potentially contaminated nature of sediments
TS10	Spatial Constraints	Wrecks	100m applied to all wrecks	PMSS	Working area to include anchor handling etc, scour issues possible
TS11	Spatial Constraints	Wrecks	250m applied to all protected wrecks and military sites	PMSS	Precautionary due to legal requirement to avoid disturbance to protected wrecks
TS12	Spatial Constraints	Cables and Pipelines	500m applied to all active cables and all pipelines	PMSS	Due to proximity to assets, existing operators require access, safety zones around oil and gas structures
TS13	Spatial Constraints	Oil and gas	500m applied to all oil and gas installations	PMSS	Statutory requirement - safety zones
TS14	Spatial Constraints	Oil and gas	100m applied to all oil and gas wells, including capped / dormant	PMSS	Precautionary due to proximity to asset. Potential interference with construction
TS15	Spatial Constraints	Shipping	A minimum 1 nm buffer was applied to all charted routes. A 5nm buffer was applied to entry and exit points of TSS	MCA	The MCA requires a buffer zone to be applied around all charted shipping routes, e.g. TSS, due to high vessel density. Buffers are defined in MCA shipping template in terms of 'tolerance'. A standard 1nm has been applied to all routes in this case
TS16	Spatial Constraints	Shipping	1 nm applied to all other major shipping lanes	PMSS	Shipping lane defined as area of sea with regular vessel traffic. Information acquired from combination of SEA, unpublished data (including MCA clearways) and historical AIS information
TS17	Spatial Constraints	Ministry of Defence	The following PEXAs were included in hard constraint analysis. Tregantile Rifle ranges, Lulworth, Chickerell, Lympstone, Lilstocl, St Thomas Head, Braunton Burrows, Rogiet Morr, Castlemartin, and Manorbier.	PMSS	Other PEXA areas defined as 'Firing Danger Area' and/or 'Submarine Exercise Area' have not been included as consultation would be required over any fixed installation.
TS18	Spatial Constraints	Onshore cable distances	Onshore cable run for areas under 10 MW will be a maximum distance of 10km and connect to a 33kV substation	PMSS / MEF workshop	Routes will be constrained by economics to a maximum distance.
TS19	Spatial Constraints	Onshore cable distances	Onshore cable run for areas from 10-100 MW will be a maximum distance of 20km and connect to a 132kV substation	PMSS / MEF workshop	Routes will be constrained by economics to a maximum distance.
TS20	Spatial Constraints	Onshore cable distances	Onshore cable run for areas from 100-500 MW will be a maximum distance of 35km and connect to a 400kV substation	PMSS / MEF workshop	Routes will be constrained by economics to a maximum distance.
TS21	Spatial Constraints	Onshore cable distances	Onshore cable run for areas over 500 MW will be a maximum distance of 50km and connect to a 400kV substation	PMSS / MEF workshop	Routes will be constrained by economics to a maximum distance.

Item	Technology type	Subtopic	Assumption	Reference	Justification
TS22	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 10km for areas under 10 MW	PMSS / MEF workshop	Routes will be constrained by economics to a maximum distance.
TS23	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 20km for areas from 10-100 MW	PMSS / MEF workshop	Routes will be constrained by economics to a maximum distance.
TS24	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 35km for areas 100-500 MW	PMSS / MEF workshop	Routes will be constrained by economics to a maximum distance.
TS25	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 50km for areas over 500 MW	PMSS / MEF workshop	Routes will be constrained by economics to a maximum distance.
TS26	Spatial Constraints	Cable landfall	All coast is accessible for cable landfall	PMSS / MEF workshop	Detailed coastal survey not within the scope of this strategic study
Grid Infrastructure					
TS27	Grid Infrastructure	Connection	Isles of Scilly 33kV cable may not have the capacity to export electricity	PMSS	
TS28	Grid Infrastructure	Connection	400kV network will be extended from Indian Queens to Hayle by 2020.	PMSS	Based on South West RDA guidance that grid should not be considered a limiting factor
TS29	Grid Infrastructure	Connection	1-20 MW developments can connect to 33kV, 20-100 MW can connect to 132KV, developments over 100MW can connect to 400KV	Garrad Hassan	
Consenting					
TS30	Consenting	SEA	Strategic Environmental Assessment for England will not identify discrete areas to be excluded for development	PMSS	This approach was adopted in the Scottish SEA
TS31	Consenting	Consents	All consents applied for are granted	PMSS	Therefore resource decreases over time
TS32	Consenting	Consenting period	Consenting period for all devices is 4 years. Construction period for tidal developments is 3 years.	PMSS	
Technology Assumptions					
TS33	Technology	Cumulative impacts	Up to 2015 potential cumulative impacts will not lead to refusal of consent for developments	PMSS	Due to small size of developments up to 2015
TS34	Technology	Commerciality	Lifespan of demonstration devices - 5 years, Commercial tidal development 20 years,	SDC2	
TS35	Technology	Commerciality	Demonstration technology only considered “proven” (and therefore capable of commercial exploitation) after 5 years	METOC	
TS36	Technology	Commerciality	A commercial project is defined as 10 MW or over.	BERR guidance	
TS37	Technology	Commerciality	For the purposes of this study commercial projects will be commissioned from 2015 onwards for tidal projects	Marine Action Plan/ PMSS	
TS38	Technology	Ports	Maximum distance to operations and maintenance port for pre commercial arrays = 20nm	PMSS	Project economics

Short name in above table	Full Reference
SDC2	Sustainable Development Commission (2007) Tidal Power in the UK. Research Report 2 - Tidal Technologies Overview.
Metoc	South West RDA (2004) Seapower South West Review - Resource, constraints and development scenarios for wave and tidal stream power in the South West of England. Report prepared by METOC.
Carbon Trust (2005)	The Carbon Trust (2005). Marine Energy Challenge - Oscillating Water Column Wave Energy Convertor Evaluation Report.
Garrad Hassan	Garrad Hassan (2008) Development of Wave Energy in the South West.
Wave Hub	South West RDA (2006) Wave Hub Environmental Statement. Prepared by Halcrow.
Scottish SEA	Scottish Executive (2007) Scottish Marine Renewables Strategic Environmental Assessment. Environmental Report Section B: Marine Renewables - Resource and Technology. Report prepared by METOC, Faber Maunsell, AECOM.
Energy Act 2004	Energy Act 2004.
BERR guidance	DTI (2005) Guidance on consenting arrangements in England and Wales for pre-commercial demonstration phase for wave and tidal stream energy devices (marine renewables).
Mackay	Mackay (2009) Sustainable Energy Without the Hot Air. UIT Cambridge press Ltd. ISBN 978-0-9544529-3-3
Marine Action Plan	DECC (2010) Marine Energy Action Plan
MCA	Maritime and Coastguard Agency, (2008). Marine Guidance Note 371 - Offshore Renewable Energy Installations (OREIs), Guidance on UK Navigational Practice, Safety and Emergency Response Issues.

Appendix 2: Tidal Range Technology Assumptions

Item	Technology type	Subtopic	Assumption	Reference	Justification
Tidal Range					
TR1	Tidal Range	Depth	Tidal Range technology requires a minimum of 5m water depth (if dredged) and 8m (without dredging).	SDC2	Assumed to be dredged for this exercise
TR2	Tidal Range	Range	Tidal Range requires a minimum of 6m tidal range to be economic	PMSS/SDC2	SDC2 - 5.2 - 7m
TR3	Tidal Range	Resource	Potential power density for tidal lagoons is 7 W/m2 at 6m range	MacKay	
TR4	Tidal Range	Size	Tidal Range projects are assumed to be over 100 MW	PMSS	Small scale projects will not be commercially viable.
Spatial Constraints					
TR5	Spatial Constraints	Aggregates	Active aggregate extraction areas are unsuitable for development	PMSS	Licence holder has exclusive rights to area for activities
TR6	Spatial Constraints	Aggregates	100m buffer area applied to aggregate extraction areas	PMSS	Safety zone applied due to vessel activity within area
TR7	Spatial Constraints	Disposal Areas	All active and inactive disposal areas are unsuitable for development	PMSS	Due to potentially contaminated nature of sediments
TR8	Spatial Constraints	Wrecks	100m applied to all wrecks	PMSS	Working Area to include anchor handling etc, scour issues possible
TR9	Spatial Constraints	Wrecks	250m applied to all protected wrecks and military sites	PMSS	Precautionary due to legal requirement to avoid disturbance to protected wrecks
TR10	Spatial Constraints	Cables and Pipelines	500m applied to all active cables and all pipelines	PMSS	Due to proximity to assets, existing operators require access, safety zones around oil and gas structures
TR11	Spatial Constraints	Oil and gas	500m applied to all oil and gas installations	PMSS	Statutory requirement - safety zones
TR12	Spatial Constraints	Oil and gas	100m applied to all oil and gas wells, including capped / dormant	PMSS	Precautionary due to proximity to asset. Potential interference with construction
TR13	Spatial Constraints	Shipping	A minimum 1 nm buffer was applied to all charted routes. A 5nm buffer was applied to entry and exit points of TSS	MCA	The MCA requires a buffer zone to be applied around all charted shipping routes e.g. TSS due to high vessel density. Buffers are defined in MCA shipping template in terms of 'tolerance'. A standard 1nm has been applied to all routes in this case
TR14	Spatial Constraints	Shipping	1 nm applied to all other major shipping lanes.	PMSS	Shipping lane defined as area of sea with regular vessel traffic. Information acquired from combination of SEA, unpublished data (including MCA clearways) and historical AIS information
TR15	Spatial Constraints	Ministry of Defence	The following PEXAs were included in hard constraint analysis.. Tregantile Rifle ranges, Lulworth, Chickerell, Lympstone, Lilstocl, St Thomas Head, Braunton Burrows, Rogiet Morr, Castlemartin, and Manorbier.	PMSS	Other PEXA areas defined as 'Firing Danger Area' and/or 'Submarine Exercise Area' have not been included as no restrictions on right to transit exist and these are operated on a clear range procedure. Consultation would be required over any fixed installation.
TR16	Spatial Constraints	Onshore cable distances	Onshore cable run for areas under 10 MW will be a maximum distance of 10km and connect to a 33kV substation	PMSS/MEF workshop	Routes will be constrained by economics to a maximum distance.
TR17	Spatial Constraints	Onshore cable distances	Onshore cable run for areas from 10-100 MW will be a maximum distance of 20km and connect to a 132kV substation	PMSS/MEF workshop	Routes will be constrained by economics to a maximum distance.
TR18	Spatial Constraints	Onshore cable distances	Onshore cable run for areas from 100-500 MW will be a maximum distance of 35km and connect to a 400kV substation	PMSS/MEF workshop	Routes will be constrained by economics to a maximum distance.
TR19	Spatial Constraints	Onshore cable distances	Onshore cable run for areas over 500 MW will be a maximum distance of 50km and connect to a 400kV substation	PMSS/MEF workshop	Routes will be constrained by economics to a maximum distance.
TR20	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 10km for areas under 10 MW	PMSS/MEF workshop	Routes will be constrained by economics to a maximum distance.
TR21	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 20km for areas from 10-100 MW	PMSS/MEF workshop	Routes will be constrained by economics to a maximum distance.

Item	Technology type	Subtopic	Assumption	Reference	Justification
TR22	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 35km for areas 100-500 MW	PMSS/MEF workshop	Routes will be constrained by economics to a maximum distance.
TR23	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 50km for areas over 500 MW	PMSS/MEF workshop	Routes will be constrained by economics to a maximum distance.
TR24	Spatial Constraints	Cable landfall	All coast is accessible for cable landfall	PMSS/MEF workshop	Detailed coastal survey not within the scope of this strategic study
Grid Infrastructure					
TR25	Grid Infrastructure	Connection	Isles of Scilly 33kV cable may not have the capacity to export electricity	PMSS	
TR26	Grid Infrastructure	Connection	400kV network will be extended from Indian Queens to Hayle by 2020.	PMSS	Based on South West RDA guidance that grid should not be considered a limiting factor
TR27	Grid Infrastructure	Connection	1-20 MW developments can connect to 33kV, 20-100 MW can connect to 132KV, developments over 100MW can connect to 400KV	Garrad Hassan	
Consenting					
TR28	Consenting	SEA	Strategic Environmental Assessment for England will not identify discrete areas to be excluded for development	PMSS	This approach was adopted in the Scottish SEA
TR29	Consenting	Consents	All consents applied for are granted	PMSS	Therefore resource decreases over time
TR30	Consenting	Consenting period	Consenting period for all devices is 4 years. Construction period for tidal lagoons is 5 years	PMSS	

Short name in above table	Full Reference
SDC2	Sustainable Development Commission (2007) Tidal Power in the UK. Research Report 2 - Tidal Technologies Overview.
Metoc	South West RDA (2004) Seapower South West Review - Resource, constraints and development scenarios for wave and tidal stream power in the South West of England. Report prepared by METOC.
Carbon Trust (2005)	The Carbon Trust (2005). Marine Energy Challenge - Oscillating Water Column Wave Energy Convertor Evaluation Report.
Garrad Hassan	Garrad Hassan (2008) Development of Wave Energy in the South West.
Wave Hub	South West RDA (2006) WaveHub Environmental Statement. Prepared by Halcrow.
Scottish SEA	Scottish Executive (2007) Scottish Marine Renewables Strategic Environmental Assessment. Environmental Report Section B: Marine Renewables - Resource and Technology. Report prepared by METOC, Faber Maunsell, AECOM.
Energy Act 2004	Energy Act 2004.
BERR guidance	DTI (2005) Guidance on consenting arrangements in England and Wales for pre-commercial demonstration phase for wave and tidal stream energy devices (marine renewables).
Mackay	Mackay (2009) Sustainable Energy without the hot air. UIT Cambridge press Ltd. ISBN 978-0-9544529-3-3
Marine Action Plan	DECC (2010) Marine Energy Action Plan
MCA	Maritime and Coastguard Agency, (2008). Marine Guidance Note 371 - Offshore Renewable Energy Installations (OREIs), Guidance on UK Navigational Practice, Safety and Emergency Response Issues.

Appendix 3: Offshore Wave Technology Assumptions

Item	Technology type	Subtopic	Assumption	Reference	Justification
Offshore Wave					
W1	Offshore Wave	Array	Assume a 500m buffer around any commercial sized wave array for shipping.	Energy Act 2004 / WaveHub	Where low profile devices such as those used in wave arrays are deployed, a buoyed exclusion zone may be required (as at Wave Hub). Although there is no standard MCA requirement, 500m has been selected as to be applied in addition to the "shipping lane" buffers
W3	Offshore Wave	Resource	Wave devices require a minimum wave power of 20 kW/m (defined as full wave field as per BERR Renewable Energy Atlas definition)	RDA workshop 19th March 2010	
W4	Offshore Wave	Depth	Offshore wave technologies can be operated in depths ranging from 5m to 100m at the current time	Scottish SEA	Wide range of depths is due to range of technologies with different depths requirements
W5	Offshore Wave	Power	Array footprint - first commercial wave - 1x4km = 50MW	Scottish SEA	Supported by Mackay estimate of 10kW/m for wave technology (10kW x 4000m - 40000 kW - 40 MW)
W6	Offshore Wave	Development	First commercial wave arrays will have a capacity of 10MW up to 50 MW	Scottish SEA/BERR guidance	
W7	Offshore Wave	Development	Pre commercial wave arrays will have a capacity of up to 10MW	BERR guidance	
Shoreline wave					
W8	Shoreline Wave	Depth	Shoreline wave technologies are assumed to land based, fixed or embedded into structures such as breakwaters	PMSS	
W9	Shoreline Wave	Physical environment	Low tidal range – less than 2m	Carbon Trust (2005) /PMSS	
W10	Shoreline Wave	Power	Device will deliver 2.5 MW per 100m (minimum of 20m)	WaveGen 2002	
W11	Shoreline Wave	Resource	Any offshore wave array within 15 km of the coast may 'shadow' the shoreline wave resource.	PMSS	Precautionary distance. Models to assess maximum change in wave height were undertaken as part of the Wavehub EIA. Research into potential shadowing issues is being carried out
Spatial Constraints					
W12	Spatial Constraints	Aggregates	Active aggregate extraction areas are unsuitable for development	PMSS	Licence holder has exclusive rights to area for activities
W13	Spatial Constraints	Aggregates	100m buffer area applied to aggregate extraction areas	PMSS	Safety zone applied due to vessel activity within area
W14	Spatial Constraints	Disposal Areas	All active and inactive disposal areas are unsuitable for development	PMSS	Due to potentially contaminated nature of sediments
W15	Spatial Constraints	Wrecks	100m applied to all wrecks	PMSS	Working area to include anchor handling etc, scour issues possible
W16	Spatial Constraints	Wrecks	250m applied to all protected wrecks and military sites	PMSS	Precautionary due to legal requirement to avoid disturbance to protected wrecks
W17	Spatial Constraints	Cables and Pipelines	500m applied to all active cables and all pipelines	PMSS	Due to proximity to assets, existing operators require access, safety zones around oil and gas structures
W18	Spatial Constraints	Oil and gas	500m applied to all oil and gas installations	PMSS	Statutory requirement - safety zones
W19	Spatial Constraints	Oil and gas	100m applied to all oil and gas wells, including capped / dormant	PMSS	Precautionary due to proximity to asset. Potential interference with construction
W20	Spatial Constraints	Shipping	A minimum 1 nm buffer was applied to all charted routes. A 5nm buffer was applied to entry and exit points of TSS	MCA	The MCA requires a buffer zone is applied around all charted shipping routes e.g. TSS due to high vessel density. Buffers are defined in MCA shipping template in terms of 'tolerance'. A standard 1nm has been applied to all routes in this case

Item	Technology type	Subtopic	Assumption	Reference	Justification
W21	Spatial Constraints	Shipping	1 nm applied to all other major shipping lanes	PMSS	Shipping lane defined as area of sea with regular vessel traffic. Information acquired from combination of SEA, unpublished data (including MCA clearways) and historical AIS information
W22	Spatial Constraints	Ministry of Defence	The following PEXAs were included in hard constraint analysis.. Tregantile Rifle ranges, Lulworth, Chickerell, Lympstone, Lilstocl, St Thomas Head, Braunton Burrows, Rogiet Morr, Castlemartin, and Manorbier.	PMSS/MEF Workshop	Other PEXA areas defined as 'Firing Danger Area' and/or 'Submarine Exercise Area' have not been included as no restrictions on right to transit exist and these are operated on a clear range procedure. Consultation would be required over any fixed installation.
W23	Spatial Constraints	Onshore cable distances	Onshore cable run for areas under 10 MW will be a maximum distance of 10km and connect to a 33kV substation	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
W24	Spatial Constraints	Onshore cable distances	Onshore cable run for areas from 10-100 MW will be a maximum distance of 20km and connect to a 132kV substation	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
W25	Spatial Constraints	Onshore cable distances	Onshore cable run for areas from 100-500 MW will be a maximum distance of 35km and connect to a 400kV substation	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
W26	Spatial Constraints	Onshore cable distances	Onshore cable run for areas over 500 MW will be a maximum distance of 50km and connect to a 400kV substation	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
W27	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 10km for areas under 10 MW	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
W28	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 20km for areas from 10-100 MW	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
W29	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 35km for areas 100-500 MW	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
W30	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 50km for areas over 500 MW	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
W31	Spatial Constraints	Cable landfall	All coast is accessible for cable landfall	PMSS	Detailed coastal survey not within the scope of this strategic study
Grid Infrastructure					
W32	Grid Infrastructure		Isles of Scilly 33kV cable may not have the capacity to export electricity	PMSS	
W33	Grid Infrastructure		400kV network will be extended from Indian Queens to Hayle by 2020.	PMSS	Based on South West RDA guidance that grid should not be considered a limiting factor
W34	Grid Infrastructure		1-20 MW developments can connect to 33kV, 20-100 MW can connect to 132KV, developments over 100MW can connect to 400KV	Garrad Hassan	
Consenting					
W35	Consenting		Strategic Environmental Assessment for England will not identify discrete areas to be excluded for development	PMSS	This approach was adopted in the Scottish SEA
W36	Consenting		All consents applied for are granted	PMSS	Therefore resource decreases over time
W37	Consenting		Consenting period for all devices is 4 years. Construction period for wave developments is 3 years.	PMSS	
Technology Assumptions					
W38	Technology	Cumulative impacts	Up to 2015 no cumulative impact restrictions on development of resource	PMSS	Due to small size of developments up to 2015
W39	Technology	Commerciality	Lifespan of demonstration devices - 5 years, Commercial wave development 20 years	SDC2	
W40	Technology	Commerciality	Demonstration technology only considered "proven" (and therefore capable of commercial exploitation) after 5 years	METOC	
W41	Technology	Commerciality	A commercial project is considered to be 10 MW or over (see tables for array sizes).	BERR guidance	

Item	Technology type	Subtopic	Assumption	Reference	Justification
W42	Technology	Commerciality	Assuming commercial projects from 2012 (Path to Power). For the purposes of this study 2015 will be assumed for wave projects	Marine Action Plan/ PMSS	
W43	Technology	Ports	Maximum distance to O&M port for pre commercial arrays = 20nm	PMSS	Project economics

Short name in above table	Full Reference
SDC2	Sustainable Development Commission (2007) Tidal Power in the UK. Research Report 2 - Tidal Technologies Overview.
Metoc	South West RDA (2004) Seapower South West Review - Resource, constraints and development scenarios for wave and tidal stream power in the South West of England. Report prepared by METOC.
Carbon Trust (2005)	The Carbon Trust (2005). Marine Energy Challenge - Oscillating Water Column Wave Energy Convertor Evaluation Report.
Garrad Hassan	Garrad Hassan (2008) Development of Wave Energy in the South West.
Wave Hub	South West RDA (2006) WaveHub Environmental Statement. Prepared by Halcrow.
Scottish SEA	Scottish Executive (2007) Scottish Marine Renewables Strategic Environmental Assessment. Environmental Report Section B: Marine Renewables - Resource and Technology. Report prepared by METOC, Faber Maunsell, AECOM.
Energy Act 2004	Energy Act 2004.
BERR guidance	DTI (2005) Guidance on consenting arrangements in England and Wales for pre-commercial demonstration phase for wave and tidal stream energy devices (marine renewables).
Mackay	Mackay (2009) Sustainable Energy without the hot air. UIT Cambridge press Ltd. ISBN 978-0-9544529-3-3
MCA	Maritime and Coastguard Agency, (2008). Marine Guidance Note 371 - Offshore Renewable Energy Installations (OREIs), Guidance on UK Navigational Practice, Safety and Emergency Response Issues.
Marine Action Plan	DECC (2010) Marine Energy Action Plan
Wavegen 2002	Wavegen (2002) Islay LIMPET Project Monitoring Final Report.

Appendix 4: Offshore Wind Technology Assumptions

Item	Technology type	Subtopic	Assumption	Reference	Justification
Offshore Wind					
OW1	Offshore Wind	Depth	Deep water wind can only be installed in water deeper than 60m	RDA workshop 19th March 2010	Applicable to floating technology only. Deep water fixed technology is unlikely due to project economics
OW2	Offshore Wind	Depth	Intermediate wind technologies (jackets etc) can be installed in depths of between 30 - 60m	PMSS	
OW3	Offshore Wind	Depth	Shallow water wind technologies (driven piles) are economic up to 30m	PMSS	Based on current industry position
OW4	Offshore Wind	Resource	8 m/s threshold chosen as viable threshold for offshore wind	PMSS	Based on current industry position
OW5	Offshore Wind	Radar	24 km buffer applied to all air defence radar	Scottish Wind SEA (Halcrow)	This is a precautionary minimum buffer. Radar effects can exist at distance, however this can only be assessed on a site by site basis
OW6	Offshore Wind	Radar	10 km buffer applied to civil aviation and meteorological radar	PMSS	This is a precautionary minimum buffer. Radar effects can exist at distance, however this can only be assessed on a site by site basis
OW7	Offshore Wind	Landscape	A landscape buffer of 13km will be applied for wind only	Round 2 SEA for offshore wind	SEA imposed a coastal buffer of 8-13km. 13km has been applied due to the generally sensitive nature of SW coast
OW8	Offshore Wind	Power	Power density of 6MW/km2 (7MW MW/ km2, Royal Haskoning, 2008)	PMSS	Confirmed at MEF workshop 15th April 2010
Spatial Constraints					
OW9	Spatial Constraints	Aggregates	Active aggregate extraction areas are unsuitable for development	PMSS	Licence holder has exclusive rights to area for activities
OW10	Spatial Constraints	Aggregates	100m buffer area applied to aggregate extraction areas	PMSS	Safety zone applied due to vessel activity within area
OW11	Spatial Constraints	Disposal Areas	All active and inactive disposal areas are unsuitable for development	PMSS	Due to potentially contaminated nature of sediments
OW12	Spatial Constraints	Wrecks	100m applied to all wrecks	PMSS	Working area to include anchor handling etc, scour issues possible
OW13	Spatial Constraints	Wrecks	250m applied to all protected wrecks and military sites	PMSS	Precautionary due to legal requirement to avoid disturbance to protected wrecks
OW14	Spatial Constraints	Cables and Pipelines	500m applied to all active cables and all pipelines	PMSS	Due to proximity to assets, existing operators require access, safety zones around oil and gas structures
OW15	Spatial Constraints	Oil and gas	500m applied to all oil and gas installations	PMSS	Statutory requirement - safety zones
OW16	Spatial Constraints	Oil and gas	100m applied to all oil and gas wells, including capped / dormant	PMSS	Precautionary due to proximity to asset. Potential interference with construction
OW17	Spatial Constraints	Shipping	A minimum 1 nm buffer was applied to all charted routes. A 5nm buffer was applied to entry and exit points of TSS	MCA	The MCA requires a buffer zone is applied around all charted shipping routes e.g. TSS due to high vessel density. Buffers are defined in MCA shipping template in terms of 'tolerance'. A standard 1nm has been applied to all routes in this case
OW18	Spatial Constraints	Shipping	1 nm applied to all other major shipping lanes	PMSS	Shipping lane defined as area of sea with regular vessel traffic. Information acquired from combination of SEA, unpublished data (including MCA clearways) and historical AIS information
OW19	Spatial Constraints	Ministry of Defence	The following PEXAs were included in hard constraint analysis. Tregantile Rifle ranges, Lulworth, Chickerell, Lympstone, Lilstocl, St Thomas Head, Braunton Burrows, Rogiet Morr, Castlemartin, and Manorbier.	PMSS	Other PEXA areas defined as 'Firing Danger Area' and/or 'Submarine Exercise Area' have not been included as no restrictions on right to transit exist and these are operated on a clear range procedure. Consultation would be required over any fixed installation

Item	Technology type	Subtopic	Assumption	Reference	Justification
OW20	Spatial Constraints	Ministry of Defence	PEXAs defined by the CAA (Civil Aviation Authority) as being a Danger to aircraft have been included in hard constraint analysis. (for wind only)	PMSS/MEF Workshop	Consultation would be required over any fixed installation.
OW21	Spatial Constraints	Onshore cable distances	Onshore cable run for areas under 10 MW will be a maximum distance of 10km and connect to a 33kV substation	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
OW22	Spatial Constraints	Onshore cable distances	Onshore cable run for areas from 10-100 MW will be a maximum distance of 20km and connect to a 132kV substation	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
OW23	Spatial Constraints	Onshore cable distances	Onshore cable run for areas from 100-500 MW will be a maximum distance of 35km and connect to a 400kV substation	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
OW24	Spatial Constraints	Onshore cable distances	Onshore cable run for areas over 500 MW will be a maximum distance of 50km and connect to a 400kV substation	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
OW25	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 10km for areas under 10 MW	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
OW26	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 20km for areas from 10-100 MW	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
OW27	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 35km for areas 100-500 MW	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
OW28	Spatial Constraints	Offshore cable Distances	Maximum offshore cable distances are 50km for areas over 500 MW	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
OW29	Spatial Constraints	Cable landfall	All coast is accessible for cable landfall	PMSS/MEF Workshop	Routes will be constrained by economics to a maximum distance.
Grid Infrastructure					
OW30	Grid Infrastructure	Connection	Isles of Scilly 33kV cable may not have the capacity to export electricity	PMSS	
OW31	Grid Infrastructure	Connection	400kV network will be extended from Indian Queens to Hayle by 2020.	PMSS	Based on South West RDA guidance that grid should not be considered a limiting factor
OW32	Grid Infrastructure	Connection	1-20 MW developments can connect to 33kV, 20-100 MW can connect to 132KV, developments over 100MW can connect to 400KV	Garrad Hassan	
Consenting					
OW33	Consenting	Consents	All consents applied for are granted	PMSS	Therefore resource decreases over time
OW34	Consenting	Consenting period	Consenting period is 4 years. Construction period for wind farms is 3 years.	PMSS	
Technology Assumptions					
OW35	Technology	Commerciality	Demonstration technology only considered "proven" (and therefore capable of commercial exploitation) after 5 years	METOC	

Short name in above table	Full Reference
SDC2	Sustainable Development Commission (2007) Tidal Power in the UK. Research Report 2 - Tidal Technologies Overview.
Metoc	South West RDA (2004) Seapower South West Review - Resource, constraints and development scenarios for wave and tidal stream power in the South West of England. Report prepared by METOC.
Carbon Trust (2005)	The Carbon Trust (2005). Marine Energy Challenge - Oscillating Water Column Wave Energy Convertor Evaluation Report.
Garrad Hassan	Garrad Hassan (2008) Development of Wave Energy in the South West.
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Scottish SEA	Scottish Executive (2007) Scottish Marine Renewables Strategic Environmental Assessment. Environmental Report Section B: Marine Renewables - Resource and Technology. Report prepared by METOC, Faber Maunsell, AECOM.
Energy Act 2004	Energy Act 2004.
BERR guidance	DTI (2005) Guidance on consenting arrangements in England and Wales for pre-commercial demonstration phase for wave and tidal stream energy devices (marine renewables).
Mackay	Mackay (2009) Sustainable Energy without the hot air. UIT Cambridge press Ltd. ISBN 978-0-9544529-3-3
Round 2 SEA for wind	BMT Cordah Ltd (2003) Offshore Wind Energy Generation: Phase 1 Proposals and Environmental Report. Report prepared for the DTI F
MCA	Maritime and Coastguard Agency, (2008). Marine Guidance Note 371 - Offshore Renewable Energy Installations (OREIs), Guidance on UK Navigational Practice, Safety and Emergency Response Issues.
Marine Action Plan	DECC (2010) Marine Energy Action Plan
Scottish Wind SEA (Halcrow)	Halcrow Group Ltd (2010) Strategic Environmental Assessment (SEA) of Draft Plan for Offshore Wind Energy in Scottish Territorial Waters: Volume 1: Environmental Report. Report prepared for the Scottish Executive

Appendix 5: Data Sources

Datasets Used in Analysis	Dataset Source
Wave Resource Data	BERR (2008) Atlas of UK Marine Renewable Energy Resources. Annual Mean Wave Power dataset from http://www.renewables-atlas.info/ - accessed March 2010
Wind resource Data	BERR (2008) Atlas of UK Marine Renewable Energy Resources. Annual wind speed at 100m dataset from http://www.renewables-atlas.info/ - accessed March 2010
Tidal Resource Data	BERR (2008) Atlas of UK Marine Renewable Energy Resources. Spring peak Flow and Tidal Range datasets from http://www.renewables-atlas.info/ - accessed March 2010
Conservation Designations (including SPA, pSAC, SAC, dSAC, cSAC)	NE/JNCC
Existing R1,2 and 3 wind farm lease areas	SeaZone/CE
Wave Hub lease area	WaveHub Environmental Statement
Mod Areas	SeaZone
Anchorage areas	SeaZone
Traffic separation schemes	SeaZone/Maritime Data
Aggregate areas	SeaZone
Dumping grounds	SeaZone
Severn Tidal Project area	DECC
UK territorial 12 NM limit	SeaZone
England/Wales water boundary	SeaZone
REZ limit	SeaZone
Wrecks	SeaZone
MoD Radar	PMSS
Meterological radar	Meteorological Office
Civilian radar and airports	PMSS
Shipping and Navigation	Data drawn from a combination of DECC (2009) UK Offshore Energy Strategic Environmental Assessment. Unpublished data (including MCA Clearways) and historical AIS data.

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