5 MARINE PROCESSES

5.1 Introduction

This chapter will discuss the two primary marine processes that relate to renewable energy production, namely Wave Climate and Tidal Flows and Levels. It will also refer briefly to secondary affects on sediment movements, which are covered in more detail in chapter 4.

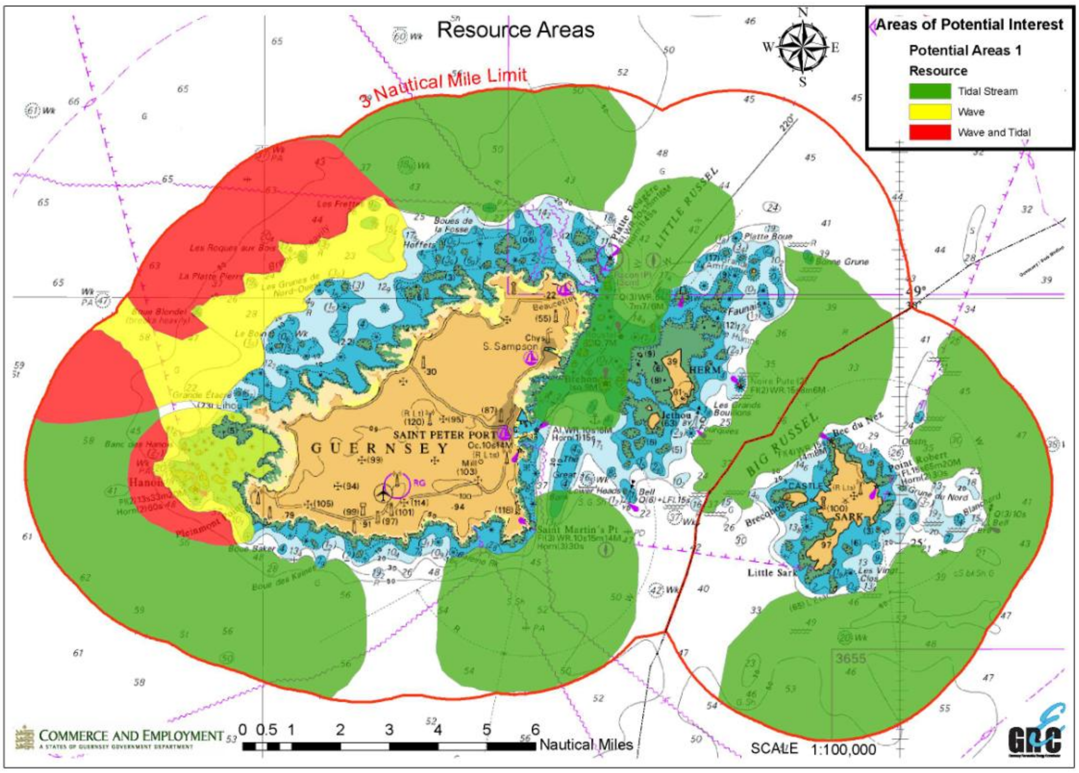
In removing either wave or tidal energy from the sea, a marine renewable energy development may influence energy levels local to its position or at remote locations. This chapter will identify the potential impacts of those changes in energy, and recommend potential mitigation measures and further investigations to allow a better understanding of risks.

5.2 Baseline Environment

5.2.1. Introduction

The REA Scoping report identified a number of potential energy resource areas as shown in the figure below.

Figure 5.2.1 – Potential Resource Areas



Whilst useful in conceptualising the potential projects that could eventually be developed, further analysis was required in order to quantify the resource and to identify likely impacts, and this is described below. Although it would be incorrect to say that wave and tidal energy devices do not affect each other's processes, their mutual affects are expected to be negligible in relation to their primary impacts. Therefore, for convenience, wave energy and tidal energy devices are considered separately.

The Atlas of UK Marine Energy Resources[1] indicates that a tidal energy resource is likely to exist that would allow extraction at a commercial scale. Local knowledge and a review of basic data provided on Admiralty charts indicate suitable tidal resources in the following key areas. These have been confirmed by tidal stream modelling work by Robert Gordon University (RGU) (Appendix C)[2].

- Big Russel
- South-east of Sark

Other areas that may be suitable after further development of energy generation technology could include the following :

- Little Russel
- South of St Martin's Point
- North of Herm
- North-west Coast of Guernsey

However, these areas are not considered as suitable for exploitation at present.

Suitable offshore wave energy deployment areas exist off the north-west coast of Guernsey, and potential near-shore or on-shore wave sites exist at Pleinmont Point.

The REA has assessed all of these areas within a wider analysis of the energy resources throughout the whole study area. For tidal energy, this has been achieved through the use of energy resource mapping tools that have been developed by the Robert Gordon University to identify flow strength and direction in relation to depth. For wave energy, additional data relating to the wave climate of the west coast of Guernsey has been obtained from the UK Met Office Channel Light-Vessel wave-buoy.

[1] BERR website - http://www.renewables-atlas.info/

[2] Tidal Resource Mapping for the Territorial Waters of Guernsey – Robert Gordon University (March 2010)

In addition to the energy resources available, the selection of specific sites as deployment areas relates to numerous other environmental aspects. Therefore key spatial constraints (eg. protected areas) that emerge from the other chapters will also be recorded here, so that any potential conflicts with the primary energy resource areas may be considered. This work will be taken forward into the Zoning exercise that will follow from the results of the REA.

5.2.2. Wave Climate

The west of Guernsey is open to the Atlantic Ocean and not shielded by islands or the European mainland, and as such provides several potentially attractive sites for wave devices. Attractiveness of a site depends on its energy resource which is affected by two key factors:

- Coastal Orientation relative to the prevailing wave direction;
- Seafloor Depth Characteristics.

The prevailing wind direction and area of greatest fetch for Guernsey is westerly and as such west facing sites will generally have the greatest energy resource.

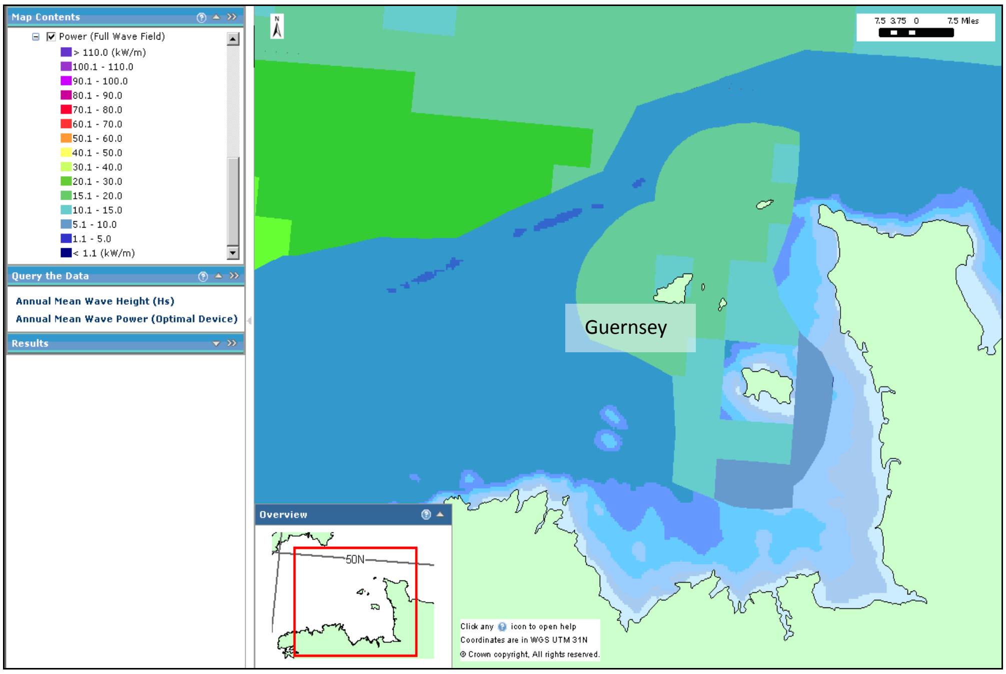
Friction from the seabed removes energy from waves when they encounter seafloor depths of approximately 100 meters or shallower. The resource decreases steadily shoreward with decreasing depth and so the most attractive sites are those that have deep waters close to the shore. Depths of 50m are often considered to be ideal for offshore devices, and these exist within the 3 nm study area.

Using data taken from the BERR Atlas of UK Marine Renewable Energy Resources[3], there is evidence of a 10-15kW/m total power resource around Guernsey. A commercial wave device developer, Pelamis[4], states that for its devices any area of a yearly average resource with a 15kW/m resource there is a commercial possibility to generate wave energy at competitive prices. The significant wave height that the BERR Atlas suggests is of the order of 1.51-1.75m (excluding the region east of Sark). Suitability of Wave Energy Resource also depends on the wave frequency, which is not covered by the BERR Atlas. Furthermore, it should be noted that this is just an average, power will not be constant and is also subject to the same potential inaccuracies as the current tidal power model data.

[3] BERR website - http://www.renewables-atlas.info/

[4] (http://www.pelamiswave.com/content.php?id=155)

Figure 5.2.2 – Potential Wave Energy Resource



Taking data from the nearest wave buoy, the Channel Light Vessel[5], it is possible to give examples of when power would be extractable from a Pelamis device (the Pelamis devices are considered because they are the only company to publish sufficient information to make calculations). There is a power matrix available from the Pelamis website that has been used to assess the available power. The Channel Light Vessel records data on average wave height and average wave frequency which makes it possible to identify when the resource is extractable, as at different wave heights the wave frequency affects how much power is extractable.

The resource is not extractable below 1m wave height, so all wave amplitudes below this can be discounted. As such, all of the area below the green line (see Figure 5.2.3 below) represents an unusable part of the resource. Where the red line indicating average wave height is above the green line this indicates potentially usable resource, depending on wave frequency. The highest wave height was just over 5.5m, which would need a wave frequency of every 6.5 seconds or longer, in order for power to be extractable. As can be seen from the graphs below, there is also a peak in frequency at this time of a wave every 13 seconds. This pattern appears to correspond to all the peaks, with increasing wave height occurring at the same time as increasing frequency, which means that so long as the height is available the frequency should be too.

The graph also shows the sporadic and unpredictable nature of wave power, with periods of time where the wave heights are not great enough for electricity

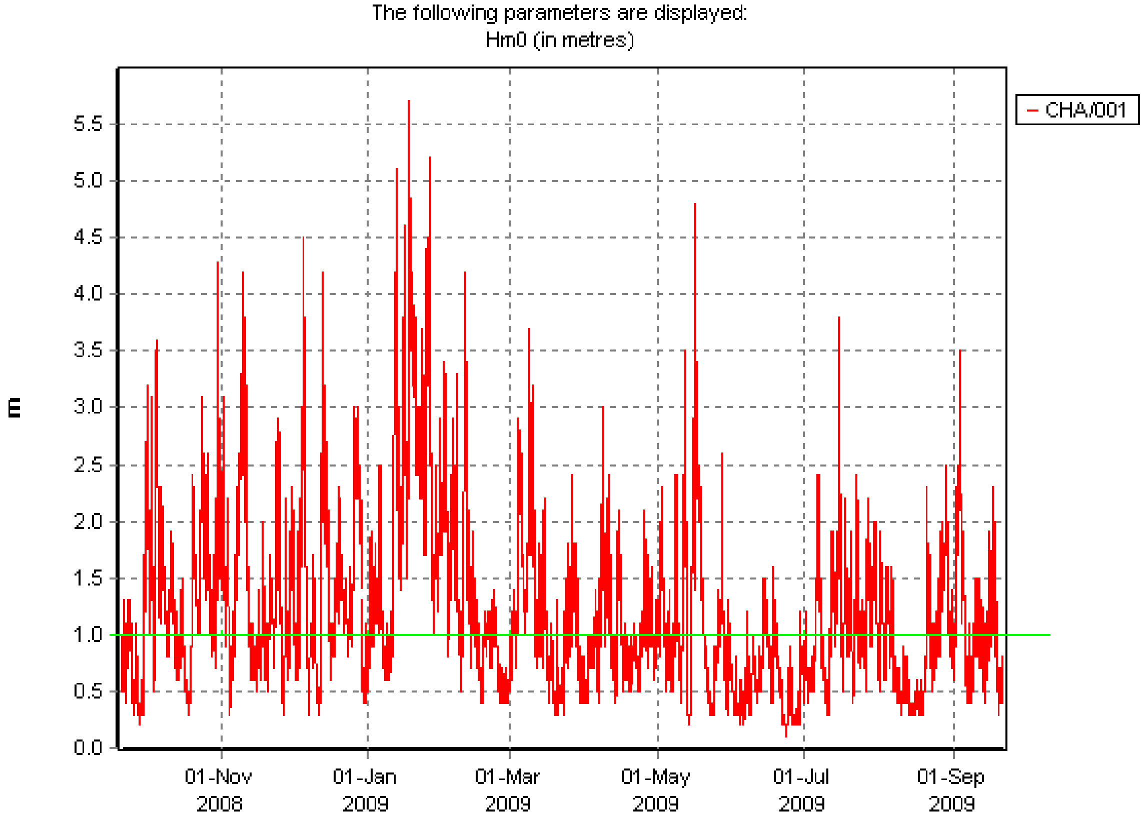
[5] http://www.cefas.co.uk/data/wavenet.aspx

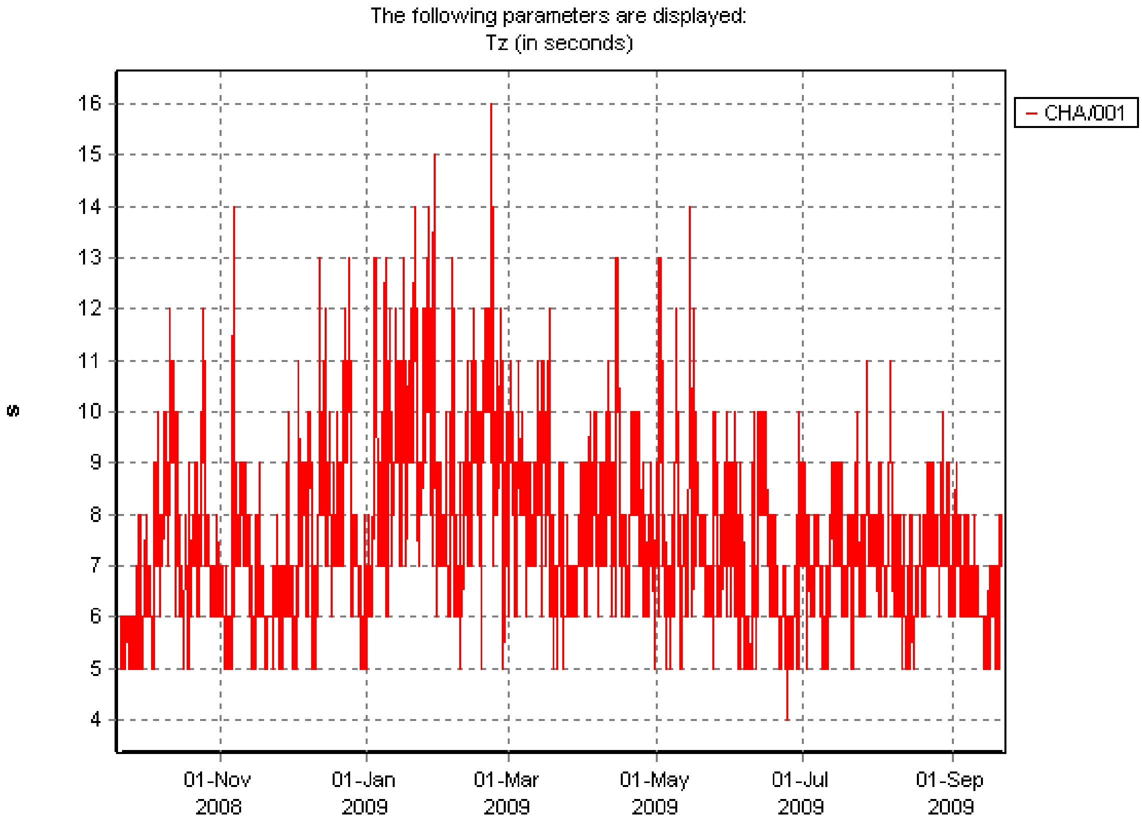
generation. This is evident from the graph for the second half of May and June having few peaks above the 1m required energy. But this does outline that there is a potentially exploitable resource in the waters surrounding Guernsey, although it does have to be taken into consideration that the Channel Light Vessel buoy is more in the middle of the channel than Guernsey, Herm and Sark and so the wave profile may differ around the coast of Guernsey.

With further information it may be possible to identify a number of specific areas of interest off the west coast of Guernsey. However due to the significant visual and environmental impact that would result from deploying throughout the length of the west coast, the total generating capacity would be a small fraction of the overall resource. A typical 20MW array would take the form of a 4km long 2km wide deployment area.

It is also important to point out that once again the data taken is from the BERR Atlas of UK Marine Renewable Energy Resources and from the Channel Light Vessel Buoy in the middle of the English Channel. While this is the closest wave buoy to Guernsey the resource would be better assessed by deploying a wave-measurement buoy, or multiple buoys, in the waters around Guernsey. This would then allow a detailed assessment of the wave resource within the area of study. As well as this, different wave devices will have different efficiencies, both in extraction of resource and in the ability to extract waves of different frequency. Pelamis was used as an example as the information was readily available.

Figure 5.2.3 – Wave Energy Resource Assessment





5.2.3. Tidal Currents

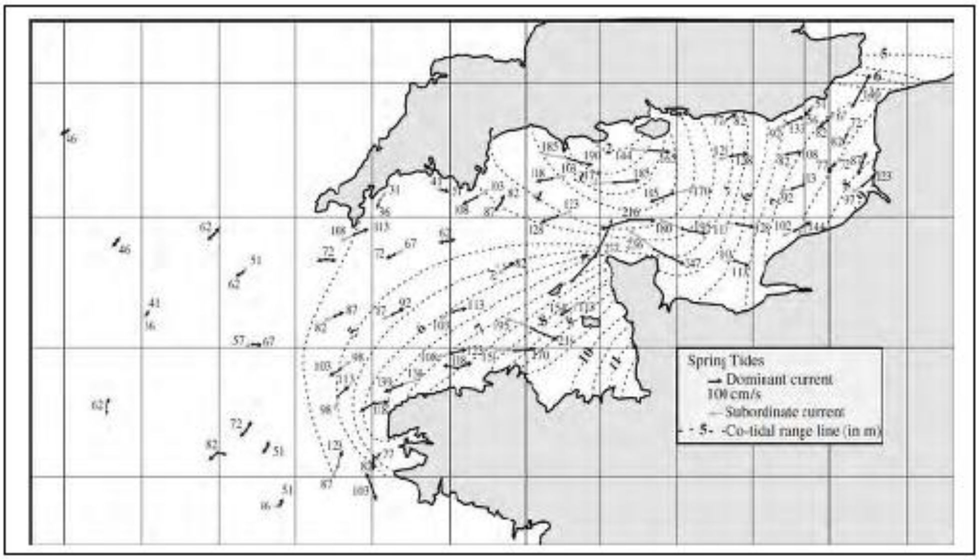
Bathymetry and Tidal Current Processes

Located on the western margin of the Normandy-Brittany Gulf the REA area lies on the boundary with the western English Channel. The Islands within the study area generally have a low topography, and are bounded by rugged coastlines and shallow offshore shoals. Only Herm has an appreciable accumulation of sand on its norththern margin. Water depths are up to 60-65m. Around the islands the water depth increases rapidly to 20 m and then more gradually to 40 m. To the west of Guernsey water depths offshore increase fairly rapidly to 60 m.

There are two major controls on sedimentation: wind driven waves, that mainly affect the shoreline and are dominated by westerly swells, and offshore tidal currents that are dominant.

Tides in the English Channel are derived from a tidal wave generated in the Atlantic Ocean, the range of which does not exceed 0.5 m. When this tidal wave passes over the continental slope and reaches the shelf it is amplified, with the amplification becoming greater as the wave progresses eastwards in the Channel. The wave is then reflected along the western coast of the Cotentin Peninsula, in such a way that a standing wave is created causing very large tidal ranges in the area of the Brittany-Normandy Gulf (Figure. 2.4). Another standing wave system is generated further east by reflection of the incident wave along the north-eastern coast of France. This creates a second area of maximum tidal range in the eastern English Channel.

Figure 5.2.4 day surface currents in the English Channel. Spring maximum current vectors using data of the (1968) (From Reynaud et al, 2003)[6]



[6] Reynaud, J.-Y. et al., 2003. The offshore Quaternary sediment bodies of the English Channel and its Western Approaches. Journal of Quaternary Science, 18(3-4): 361-371.

Superimposed on this standing wave system, another wave (lower in range) is propagated from the North Sea. This wave also generates a standing wave by reflection along the eastern coast of the Bay of Seine and the Cotentin Peninsula. The node, where tidal ranges are relatively low but tidal current velocities are at their maximum, is located in the central English Channel at about the longitude of Cherbourg in this complex multiple standing wave system. The antinode, marked by high tidal ranges and low velocities of tidal currents, is located east of the Eastern Channel. From this point, towards the North Sea, the narrowing of the basin causes the tidal current velocities to increase reaching a maximum in the Dover Strait.

This pattern of the tidal waves controls the general tidal circulation in the English Channel, resulting in very high current velocities near the central part associated with macrotidal ranges up to 10–15 m in the Brittany–Normandy Gulf, and a little less in the Eastern Channel. The currents in the Gulf are locally influenced by the complex pattern islands and shoals present. Because of the large amplitude of the tidal range the Gulf fills and empties rapidly in all directions. Within the Gulf, the tidal currents operate as an anticlockwise gyre. But there are localised differences and maximum current speeds within narrow passages or in the proximity of islands or shoals that transform the gyre into an alternating tidal current. This focussing is particularly severe in the Grand and Petit Russel to the east of Guernsey.

Tidal Resources

Potential tidal stream sites are confined to specific locations. The most abundant resource in the study area appears to be the Big Russel as this area has been highlighted by the RGU Report (Appendix X) [7] and by the BERR Atlas of UK Marine Renewable Energy Resources[8], as a potentially utilisable resource. This area, together with the Little Russel, are examples of tidal constriction by land masses, a constriction of the flow causing higher tidal speeds thereby providing a large amount of energy potential. Despite its apparent high current velocities, the Little Russel is discounted at this stage from the REA because its small size and its depth (<20m) is considered to be insufficient for use with contemporary energy devices.

Other potential sites are located around the ‘corners’ of the islands, for example off St Martin’s Point and around the south and east coasts of Sark. Of these, the South-east of Sark is indicated by the RGU report to have the most suitable tidal flow.

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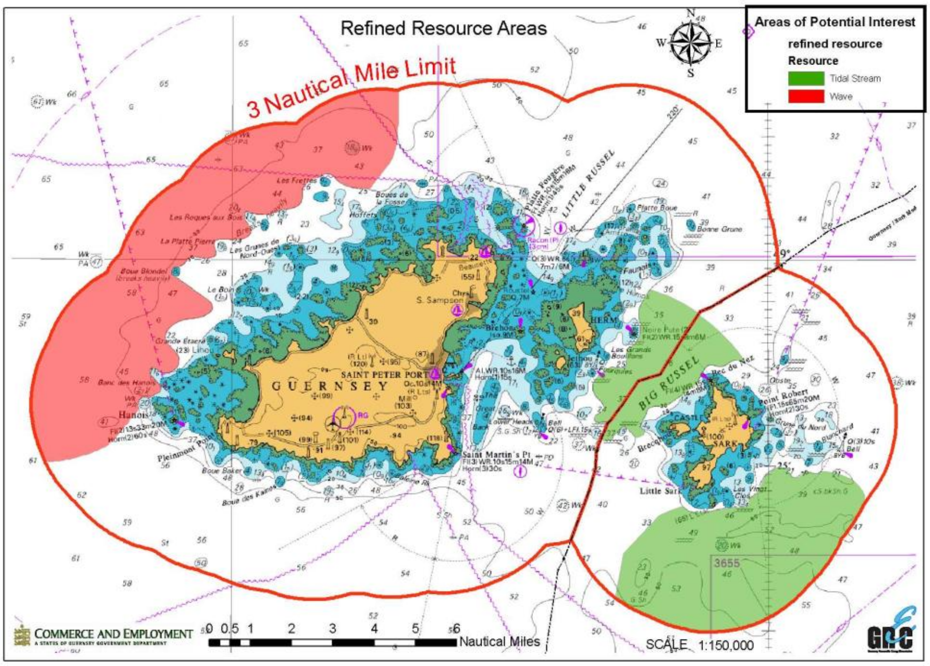
[7] Tidal Resource Mapping for the Territorial Waters of Guernsey – Robert Gordon University (March 2010)

[8] BERR website - http://www.renewables-atlas.info/

According to BERR and the RGU report there is a potential resource to the north of Guernsey. However, this is unlikely to be suitable for exploitation using contemporary equipment due to the depth of water (up to 60m) and slow velocities. Also, this large resource area falls partly outside the 3nm territorial limit. The currently predicted areas of interest and resources are illustrated in figure 2.4.

Figure 5.2.5 – Tidal Energy Resource – Key Target Areas



The BERR Atlas of Marine Renewable Energy Resources (2008) indicates an Annual Average Tidal Power of up to 1.5 kW/m2 of the water column, and Mean Peak Spring Tidal Velocities of 2.5m/s. This is broadly supported by the RGU report, which estimates a raw resource in the Big Russel of 700GWh/yr and a similar resource south-east of Sark. However, only a proportion of this may be available, and this will depend on numerous technical and environmental constraints.

Generally, potential tidal stream sites do not overlap with the sites of high potential wave development due to their geographical locations. However exceptions to this can be seen on the west coast of Guernsey.

It is important to reaffirm that the data presented thus far is taken from the BERR Atlas of UK Marine Renewable Energy Resources and the tidal resource modelling work undertaken by RGU. Further work is being undertaken to allow the calibration and verification of the model against real tidal measurements to ensure an accurate portrayal of the resource available in the waters around Guernsey, Herm and Sark and this will be available to future updates to the REA.

5.2.4. Water Levels

Table 6.2 summarises the typical mean water levels, excluding sea level rise (estimated at 5mm/year) and excluding surge conditions.

Table 5.2.1: Typical Water Levels

Typical Water Levels at St Peter Port	Water Level (mAOD local)
Mean Low Water Springs (MLWS)	-3.66
Mean High Water Springs (MLWS)	4.24

5.2.5. Sediments

There are a variety of sea-bed conditions within the study area, ranging from exposed areas of bedrock of different topography, including flat areas, gullies and rocky pinnacles, through to highly mobile shoals of sediment of varying size particles. The geology of the seabed is described in detail in Chapter 4. The strong tidal flows that occur in the study area act to mobilise sediments and to create patterns of scour and deposition. Key historic deposition areas are the Grand Bank (in the Little Russel, south-east of St Peter Port), Northern Herm, and a large bank outside of the study area between Guernsey and Alderney.

There are numerous beaches along the north-west coast of Guernsey. The profile of these beaches is maintained to some extent by the action of waves in the intertidal zone. However, typical seasonal changes may be expected with lowering of beach levels and the creation of intertidal bars during winter. It is typical for beach levels to reduce by up to 2m following storms.

It is speculated that no significant change has occurred to the seabed over the past 100 years since no major features, in response to either construction or destructive forces, have been recorded. This may be with the exception of the dunes and beaches at the northern end of Herm, which are showing signs of recent erosion through the formation of a cliff feature at the back of the beach.

5.2.6. Key Spatial Constraints to Resource Areas

The following are environmental protection areas, and should if possible be avoided in the selection of deployment sites.

Table 5.2.2: Environmental Protection Areas and other Constraints

Area	Subject	Constraint
Lihou Island and L'Erée Headland Ramsar Site	Ecology (Benthic, Pelagic, Birds)	Environmental protection area
The Humps, north of Herm	Ecology (Benthic, Pelagic, Birds)	Possible future environmental protection area
The Little Russel (off Beaucette Marina)	Benthic Ecology	Maerl Beds
The Little Russel	Navigation	High intensity of marine traffic
St Martin's Point	Navigation	Pinch point for marine traffic
Guilliot caves RAMSAR site, Sark	Ecology (Benthic, Pelagic, Birds)	Environmental protection area
Potential Marine Reserves in Sark waters; L'Etacs to the south, Guillaumesse off the west coast and Guilliot Caves.	Ecology (Benthic, Pelagic, Birds)	Environmental protection area
Coastlines	Landscape	All coastal areas are designated. This may present significant constraints to the deployment of on-shore or near-shore wave-energy devices. Similarly, offshore energy devices (wave and tidal) that are dominantly visible from the shore may not be acceptable.
UNKNOWN	Benthic Ecology	Unknown benthic ecology. Further classification surveys will be required to establish a habitats map prior to zoning

5.3 Potential Effects

5.3.1. Wave Climate

General

Wave Energy Converter (WEC) devices generate electricity by taking and converting energy derived from passing waves. Therefore, WECs have the potential to change the general wave conditions in the vicinity of an array. The degree by which wave energy is impacted by a device or an array will depend on:

- The wave climate at the deployment site
- The size of device
- Its mechanism for the capture of energy, and efficiency of conversion
- The size of the array
- The alignment of the device to the waves

It is clear that the size and nature of potential impacts are very project specific. Therefore, this REA will describe the further studies and analysis that will be required to be undertaken by Wave Energy developers in the assessment of project and device specific impacts.

Previous studies undertaken for the Environmental Statement for the Wave Hub Project[9] in the south-west of England have indicated that a 5% reduction in average wave height may occur at specific beaches in the lee of an array. However, this analysis was based on an array at least 10nm from the affected coast. Therefore, at this stage, and without further analysis and data, a reduction in wave height in the region of 10% may be expected from an array only 3nm from the Guernsey coast.

For the Wave Hub project, wave modelling studies indicated that wave heights are reduced in the sheltered sea areas immediately behind the WEC devices. As wave energies can propagate through the (semi-) floating WEC devices, waves can then re-build after a distance of about 5km (2.5nm), depending upon the width and nature of the WEC devices.

Key receptors to a reduction in wave energy, and the mechanisms by which they are affected, are described in the following sub-sections.

[9] http://www.southwestrda.org.uk/working_for_the_region/areas/cornwall__the_isles_of_scilly/wave_hub/documents.aspx

Other Energy Resource Users

It is acknowledged that if an array were to be aligned to face the prevailing wave direction (west or south-west), then any similar array that were to be deployed in the lee of the first would experience a reduced energy resource. Therefore, it is likely that energy developers would consider such sites to be unsuitable. This aspect has been accounted for in the overall resource assessment, and has been used to arrive at the development scenarios that act as the basis of the REA. Therefore, the impact of the change in wave energy on other resource users will not be considered further.

Surfing

A key receptor is the surfing activities that take place on the north-west coast of Guernsey, and the associates industries that benefit from the good surfing conditions that prevail from the Atlantic Ocean. Previous studies associated with the Wave Hub project have identified that impacts vary over a range of wave heights, wave periods and direction, and the reduction in energy that occurs to classic surfing waves may be larger than that occurring to the overall wave energy resource. Modelling was targeted at monochromatic waves to demonstrate the impact of WEC devices on surfing waves at the coast. Monochromatic waves were used to consider the impact of a single wave condition approaching from a single direction (i.e. to simulate a long period swell wave approaching from the North Atlantic) because surfers are primarily concerned with long period swell waves. These studies indicated that wave energy in classic surfing waves could be reduced at beaches directly in the lee of an array by as much as 15%. However, if wave energy development were to be restricted to a discrete area of the overall resource, then if one beach were found on a particular day to be immediately in the lee of an array (with an associated reduction in wave height) then other beaches could remain unaffected.

Whilst it is understood that surfers do not often travel to Guernsey with the sole intention of surfing, it is likely that it will form part of the overall attraction of a holiday in Guernsey. Furthermore, as for fishing, there are a large number of residents who participate in the sport and it may be considered to be an integral part of the healthy sporting lifestyle. See also the related chapter on Tourism and Recreation (Chapter 16).

Sediment movement / beach profile

A strong ground-swell can be observed to mobilise sea-bed sediment in water depths of up to approximately 50m, but the majority of sediment movement occurs at reduced depths, particularly depths less than 10m. As the potential wave-energy deployment areas are in depths up to 40m, and the wave energy in the lee of arrays (at depths 0 to 40m) is likely to reduce, then it is clear that the development of wave energy systems will have an effect of reducing sediment movements. However, this is unlikely to obstruct or change the overall patterns of sediment movements within the vicinity of a deployment site, due to the additional influence of tidal currents and the fact that the coastline will be exposed to waves from a range of directions. This should be confirmed by project-specific investigations to be undertaken by developers.

In addition to the direct reduction in wave energy through the operation of the WECs, other impacts related to scour and deposition may be caused by the interaction of moorings, sub-sea electrical infrastructure and cables, with a mobile sedimentary sea-bed. These are described in section 5.3.2.

Landfall arrangements will include the installation of a large electrical cable (of up to 300mm diameter) across the intertidal zone. Unless routed by drilling under a cliff or surface-laid across a rocky foreshore, the cable will be buried in sands and gravels below a beach. As beach levels may vary during the operational life of a project, there is a risk that if not laid sufficiently deep during installation, the movement of beach material during significant storms could expose the cable. Whilst not representing an immediate danger to the public who may use the beach, an exposed cable can cause alarm and be considered to be unsightly.

Habitat

A reduction in wave energy along coasts in the lee of an array would present a minor benefit to many species, as this will lead to a reduction in disturbance to habitat through wave damage. However, predatory species may benefit from disturbance of the seabed, as this will act to expose, disorientate and injure their prey.

5.3.2. Tidal Currents

General

Tidal Energy devices generate electricity by taking and converting energy derived from the tidal current in which they are deployed. By removing energy from the water, the devices have the potential to change the flow conditions in the vicinity of an array, or further afield. The degree by energy is removed from the water by a device or an array will depend on:

- The tidal flow conditions (depth, velocity, direction, turbulence, variation) at the deployment site
- The size of device, number and size of blades or foils, and height off the seabed
- Its mechanism for the capture of energy, and efficiency of conversion
- The size of the array
- The alignment of the device to the flow

It is clear that the size and nature of potential impacts are very project specific. Therefore, this REA will describe the further studies and analysis that will be required to be undertaken by Tidal Energy developers in the assessment of project and device specific impacts.

The studies undertaken for Black & Veatch by the Robert Gordon have indicated that up to 10% of the energy may be taken from the water column at a particular site without a significant environmental impact occurring remotely from the site. However, this work is extremely theoretical at this time, and based predominantly on mathematical modelling, and until multi-device arrays are constructed and tested, there will remain a significant uncertainty in this field.

Key receptors to a reduction in tidal energy, and the mechanisms by which they are affected, are described in the following sub-sections.

Other resource users

As for wave energy devices, the removal of energy from a particular location will have the potential to reduce energy at downstream sites. This will be particularly the case if two or more arrays are located within the same narrow channel (eg. The Little Russel). Conversely, if a tidal array is installed in one channel, this may act to divert tidal flows into, and increase the available energy within an adjacent channel. Without project and device specific modelling it will not be possible to quantify the impact on tidal flows presented by an array. However, through consideration of the energy resource mapping that has been undertaken by RGU[10] , it is possible to speculate on the location of potential impacted areas, so that mutually impacting energy resource development zones may be avoided. This will be taken forward to the Zoning exercise that will follow the production of this REA.

Sediment movement / beach profile

The macroscopic effects of changes in tidal flow patterns cannot be adequately described without further study, including use of hydrodynamic and sediment modelling software. At this stage, it is only possible to speculate on potential impacts. For example, it is possible to envisage a deployment site within one of the channels between the Islands of Guernsey, Herm and Sark. In the event that only one of these channels were to be exploited, the deployment of devices would form a partial obstruction to tidal flows in that channel. A potential affect of such an obstruction could be to force more tidal flow into the other, unobstructed channel. This could in turn change the direction or strengths of tidal flows around the islands. This could then lead to modifications in the patterns of erosion and deposition of sediments around the islands. Such changes in patterns could be presented in the form of beach erosion similar to that already observed at Shell Beach on the northern end of Herm.

It is easy to speculate upon such 'disaster scenarios' without recourse to proper evidence-based analysis, and it is not the intention of this REA to cause undue alarm. However, it is appropriate, at this stage, to record this receptor as having the potential to be severely and permanently impacted. It is also appropriate for the REA to clearly describe the need for robust surveys and analysis to be undertaken by tidal energy developers in the presentation of their project specific environmental impact assessments.

The deployment of equipment on the seabed, including energy devices, subsea connection and transformation arrangements and cabling, has be potential to have a localised impact on the movement of sediments during the operational phase as follows:

- Disruption of existing sediment movement due to the presence of the offshore infrastructure and cables
- Localised scour or undermining of devices, moorings, offshore infrastructure and cable
- Potential unforeseen abrasion of cables where they pass over jagged outcrops of rock after scouring of previous sediments
- The exposed cables could then be damaged by trawling or anchoring
- Exposed cables could cause a secondary effect on certain species of fish and mammals due to EMF

[10] Tidal Resource Mapping for the Territorial Waters of Guernsey – Robert Gordon University (March 2010)

Habitat

The secondary impacts on benthic habitat relate to changes in tidal flow strength and direction and associated changes to sediment movement patterns.

- Changes in direction, strength and location of tidal flows could influence the filter-feeding of benthic organisms
- These changes could also influence the ability of some mobile organisms to move around, or to hold themselves in position
- If new deposition areas form as a result of changing sediment movement patterns, then any existing habitat could be inundated
- Existing shoals or banks that form habitat may be destroyed or relocated by changes in sediment patterns

Changes in sediment patterns have the potential to be dramatic immediately after the causal event has occurred, but will then diminish over time as the environment settles to the new regime. It is likely that new habitats will establish once this has occurred.

Sea Levels

As described in the section above regarding the influence of tidal energy devices on tidal flows, the deployment of an array can form an obstruction to flows within a channel. This will have a corresponding affect on adjacent water levels. By the introduction of an obstruction to a channel, it is clear that there will be a corresponding rise in water levels upstream of the obstruction and a reduction in levels downstream. The changes in water level will depend on the size of the array, the type, size and blade area of a device, and the speed of the current. Such changes can only be assessed by use of a hydrodynamic model that is calibrated with water level recordings at key locations such as ports. This impact is unlikely to significantly affect operations at ports within the study area, but it may influence the maximum flood level experienced during a high tide that coincides with a surge, so there may be a minor increase in coastal flood risk.

5.4 Sensitivity of receptors

The following table identifies the perceived sensitivity of the receptors. These refer to the three designations of importance :

- International (UK, France and Channel Islands)
- Regional (Channel Islands)
- Local (Single island)

Table 5.4.1: Sensitivity of Receptors

Receptor	Sensitivity	Comments
Surfing	Local	Local beaches in the lee of a wave energy deployment may experience a reduced wave height
Sediment Movement / Beach Profile	Regional	Some shoals, banks and beaches are of regional significance in terms of the habitat that they provide, fishing or their landscape value (in reference to beaches). There are also risks that devices and associated infrastructure may be impacted by scour or burial during operation
Habitat (in reference to wave climate)	Local	Wave climate in bays that may be affected by changes in wave climate is not remarkable or rare
Habitat (in reference to changes in tidal flow patterns and sediment transport)	Local	Tidal flow climate may be altered locally by installation of devices
Sea Levels	Regional	Changes in sea level could be experienced in Jersey, although this is unlikely to affect port operations.

5.5 Potential Significance of Effects

The following table records the severity of the impacts and, through reference to the sensitivity recorded above, shows the Significance of the affects.

Table 5.5.1: Sensitivity of Receptors

Receptor	Sensitivity (from Table 5.4.1 above)	Effect	Magnitude of Impact	Significance of Effect
Surfing	Local	Reduction in wave height due to wave energy devices	Medium	Unknown
Sediment Movement / Beach Profile	Local	Changes to erosion and deposition patterns	High	Unknown
Habitat (in reference to wave climate)	Local	Change in wave climate	Low	None
Habitat (in reference to changes in tidal flow patterns and sediment transport)	Local	Changes to erosion and deposition patterns	Moderate	Minor
Sea Levels	Regional	Changes to times and heights of low and high water	Low	Minor

5.6 Likelihood of Occurrence

The following table identifies the perceived probability of the receptors being affected by the potential effects based on currently available information. For the purpose of this assessment, these impacts are considered, at this stage, as unmitigated.

Table 5.6.1: Table outlining the probability of effect on receptors

Receptor	Effect	Likelihood of Occurrence
Surfing	Reduction in wave height due to wave energy devices	Moderate
Sediment Movement / Beach Profile	Changes to erosion and deposition patterns	Moderate
Habitat (in reference to wave climate)	Change in wave climate	Low
Habitat (in reference to changes in tidal flow patterns and sediment transport)	Changes to erosion and deposition patterns	Moderate
Sea Levels	Changes to times and heights of low and high water	High

5.7 Mitigation Measures

The following mitigation measures are envisaged.

5.7.1 Surfing

The primary purpose of installing a wave energy array off the coast of Guernsey would be to exploit, and hence reduce, the energy in the waves. This would have an unavoidable affect of reducing the height of surfing wave, even if by only a small amount. Mitigation for this could be the creation of an artificial reef that would locally focus the energy of incoming waves to form locally higher or better formed surfing waves. An example of such a feature exists at Bournemouth on the south coast of England.

5.7.2 Sediment Movement / Beach Profile

Prior to the deployment of any devices a good scientific understanding should be developed of the existing regime of sediment movement, including scour and deposition areas on the seabed and foreshores. This work could include physical measurements of seabed and beach topography in combination with mathematical computer modelling. If it is foreseen that a proposed development could lead to undesirable outcomes, such as the significant alteration of the existing regime, then mitigation measures could include the following:

- Relocation of a deployment site to a less sensitive location
- Subsea engineering works to trap sediment
- Coastal defence works such as groynes
- Careful design of cable-routes and depth where they cross beaches to ensure that there is a minimal risk of exposure

5.7.3 Habitat (in reference to wave climate)

The main foreseeable mitigation to the impacts of wave climate change on habitats is careful site selection. Although it is unlikely to be the case, if a particular target species is found to vulnerable to a reduction in wave energy, then locating deployment sites away from the habitat would reduce the significance of the potential impact.

A secondary, technical solution could be to encourage wave energy technologies that could be tuned or switched to a safe mode during certain wave conditions or at certain times of year to reduce impact on the wave climate. However, this would appear to contradict the purpose of the device.

5.7.4 Habitat (in reference to changes in tidal flow patterns and sediment transport)

The benthic habitat close to a deployment site could be vulnerable to scour or deposition of sediment (smothering). This has the potential to disrupt communities over a wide area. The key mitigation measure to address this risk is for comprehensive hydraulic and sediment modelling work to be undertaken prior to consenting. It is likely that this work would be undertaken by developers who are seeking to obtain consent to deploy. The accuracy and usefulness of any modelling work should be verified against actual flow and sediment data prior to submission with the consent application.

5.7.5 *Sea Levels*

The detailed hydraulic modelling identified above should incorporate an assessment of the likely changes in sea-level that may result from the deployment of a large array of devices. This should be undertaken with reference to the numbers and types of vessels using nearby ports, to ensure that a full understanding is obtained on the risks posed to navigation.

5.7.6 *Zoning*

Although not specifically applicable to any one potential impact, the application of this as a mitigation measure will provide benefits across many topic areas.

As described in section 6.3 of the REA Scoping Documents[11], areas of potential resource can be identified by enhanced tidal resource and wave energy modelling. The environmental data that has been analysed and assessed in this REA will be overlaid using GIS software onto the potential resource areas to allow selection, or 'zoning' of the best deployment areas. In this way, the sites that carry the least environmental risk can be promoted.

It is acknowledged that selection of deployment areas based on resource data that is not supported by site-specific tidal flow or wave energy monitoring data carries some risk. Furthermore, other detailed environmental classification surveys may be required to fill any data gaps that are identified by the REA.

[11] Regional Environmental Assessment of Marine Renewable Energy – Scoping Report (October 2009)

5.8 Confidence and Knowledge Gaps

5.8.1 Wave Energy

The wave energy resource assessment shown in this chapter is based on the BERR Atlas of Marine Renewable Energy Resources (2008) and WaveNet data from the Channel Light Vessel Wave Bouy. Whilst this is enough to identify that there may be a suitable resource, this will not be sufficient to identify the suitability of a specific site or project. For this, a WaveRider type measurement buoy should be deployed for up to 1 year at or close to a potential site to establish the wave resource.

The effects of wave energy devices on surfing waves are not well understood, and current analysis is theoretical and based on computer-based analysis. Therefore, further research is required into this aspect.

5.8.2 Tidal Energy

The REA has included the production of a tidal energy model by the Robert Gordon University. At the time of publishing of the REA, this modelling has not been verified against recent tidal current survey measurements. As such, the modelling can only be used to broadly identify the resource that may be available. The modelling cannot be used to identify turbulence that may occur in the actual flows, and cannot accurately predict the occurrence of eddying currents.

5.9 Residual Effects

The suitability and effectiveness of the mitigation measures listed in Section 5.6 will be very dependent on the specific characteristics and sensitivities of individual deployment sites. It is not possible to estimate the reduction in potential impacts at this strategic level. Therefore, pending further investigation of the wave and tidal energy resources at specific sites, and the development of a better understanding of benthic habitats, the significance of residual effects is recorded as Unknown.

An exception to this is the need to undertake a zoning exercise to direct future site selection activities. A well defined description of the zones that are deemed suitable for renewable energy development would act to deter development of more environmentally sensitive sites.

5.10 Recommendations for Survey and Monitoring

5.10.1 Wave Energy

The REA has included the production of a tidal energy model by the Robert Gordon University. As described in Section 5.8 above, a WaveRider type measurement buoy should be deployed for up to 1 year at or close to potential wave energy deployment sites to establish the wave resource. The deployment would provide key wave data (in terms of height and wave frequency), at 15 minute intervals. This work could be undertaken by GREC, if they wished to promote wave energy deployment quickly, or alternatively by a potential developer who may be interested in a particular site.

Figure 5.10.1 – Waverider Buoy

The effects of wave energy devices on surfing waves are not well understood, and current analysis is theoretical and based on computer-based analysis. The Universities of Exeter and Plymouth, through the establishment of their joint research group PRIMaRE, are undertaking a study into the affects of the Wave Hub project on the surfing waves at the nearby north-Cornish beaches of Gwithian, Porthtowen and Perranporth. This study will involve the deployment of multiple wave measurement buoys, together with the use of other photographic and video evidence. It is anticipated that the results of this study will be useful in informing any such project on Guernsey.

5.10.2 *Tidal Energy*

In order to prove the suitability of a particular deployment site, prospective developers will wish to procure detailed flow survey information. This is commonly provided by Acoustic Doppler Current Profiler (ADCP) devices that are deployed on the seabed to record velocities at a range of depths for a period of up to 3 weeks.

GREC are currently investigating the procurement of ADCP data for a number of sites around Guernsey. It is anticipated that this data would allow proper verification of the tidal model. However, it is likely that developers would wish to undertake their own site proving surveys prior to deployment.

Even after zoning of deployment sites based on available environmental data, there would remain a significant lack of knowledge relating to the impact of an array of tidal devices on sediment movement. There would be potential for scour and deposition areas to be formed on the sea-bed in the vicinity of the array, or between devices. Such impacts should be properly understood prior to deployment through the development of a hydraulic and sediment movement model. This will by device and site specific, and should be undertaken by prospective developers.

References

BERR website - http://www.renewables-atlas.info/

Robert Gordon University (March 2010) - Tidal Resource Mapping for the Territorial Waters of Guernsey

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BERR website - http://www.renewables-atlas.info/

SWRDA Wave Hub Website http://www.southwestrda.org.uk/working_for_the_region/areas/cornwall__the_isles_of_scilly/wave_hub/documents.aspx

Regional Environmental Assessment of Marine Renewable Energy – Scoping Report (October 2009)