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Scoping Study for Offshore Wind Farm Development in  
Scottish Waters

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# Scoping Study for Offshore Wind Farm Development in Scottish Waters

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## Executive Summary

The Scottish Government has set a range of challenging targets for energy and climate change. These recognise the potential to take advantage of the extensive marine energy resources (wind, wave and tidal power) available in Scottish waters and include meeting at least 30% of total energy demand from renewable sources by 2020, incorporating:

- 100% of electricity demand from renewables (31% by 2011)
- 11% of heat demand from renewables
- 10% of transport fuel from renewables

In addition, the Climate Change (Scotland) Act 2009 sets statutory targets of at least 42% emissions cuts by 2020, and at least 80% by 2050.

To assist in meeting these targets, a Sectoral Marine Plan for Offshore Wind Energy in Scottish Territorial Waters (Blue Seas - Green Energy) sets out the Government's vision for developing offshore wind energy up to 2020 and beyond and has identified short term development sites for offshore wind up to 2020, with a potential to deliver almost five Gigawatts (GW) of electricity generation capacity; and a further 25 areas for further exploration beyond 2020. Currently, up to 10GW of planned development is in progress at offshore wind sites in Scottish Waters, divided roughly equally between Round 3 sites and sites in Scottish Territorial Waters (STW).

A sensitivity analysis of the process used to develop the Plan concluded that, as additional data and monitoring information, and improved data handling procedures, become available, these should be incorporated into the emerging iterative marine planning process, as applied to the medium term options for wind farm development in STW, and to opportunities further offshore.

A process was therefore put in place by Marine Scotland to develop a Scoping Report for the potential for offshore wind development in Scottish waters out to 200 nautical miles. This report describes the process employed by Marine Scotland in collaboration with The Crown Estate to develop a series of new offshore wind plan options within STW, and presents the first discussion of development potential outside STW out to 200 nm.

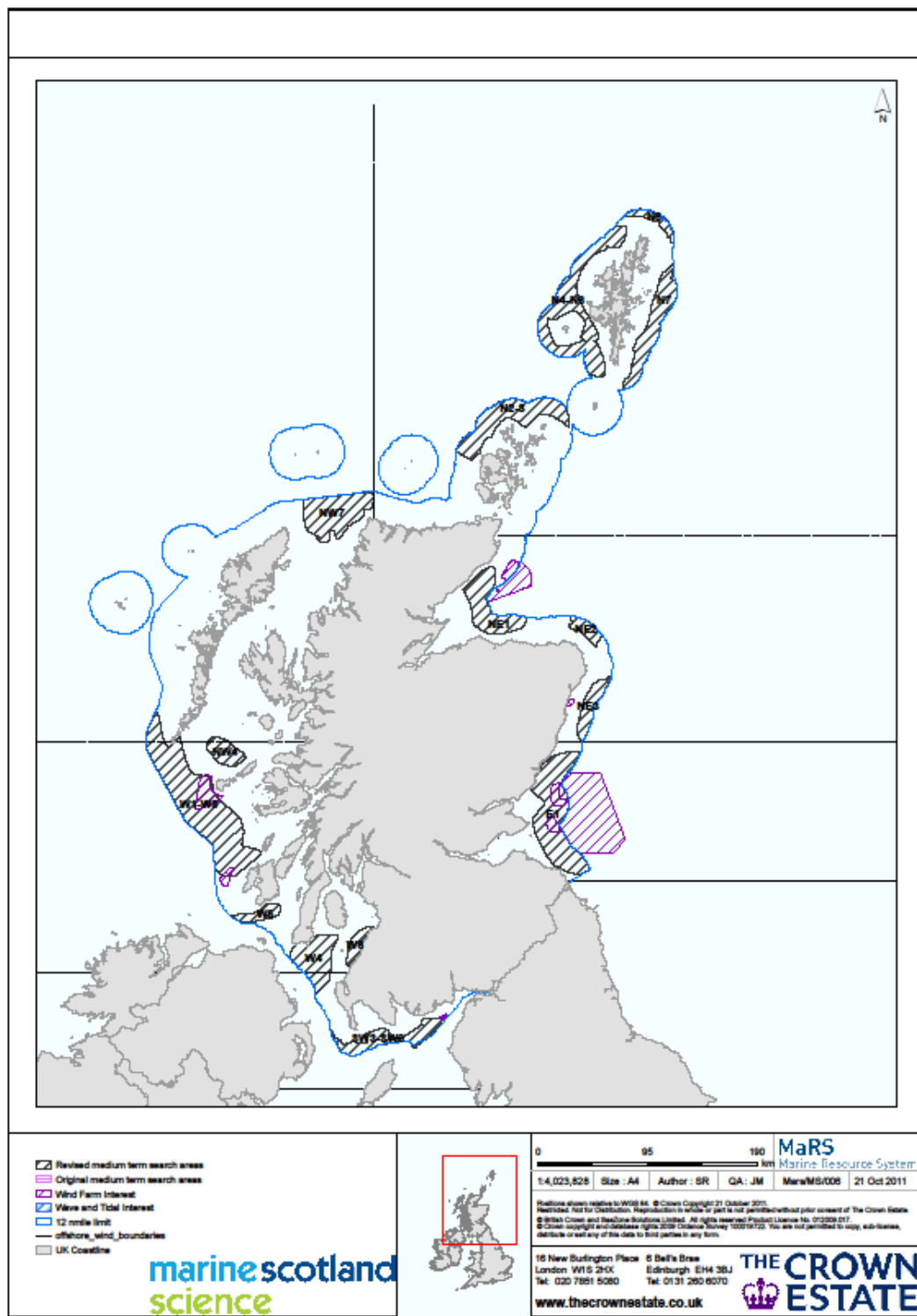
The Crown Estate spatial modelling tool MaRS was used to create multi-factorial expressions of the technical opportunities and constraints on offshore wind development in Scottish waters, and of the constraints on consenting presented by themed groups of

factors. These themes reflect current commercial (industrial) activities such as fishing, aquaculture and offshore oil and gas, environmental factors such as designated Natura sites, and a broad field of “heritage” interests including recreational uses, archaeological potential, visual and landscape factors. These models have been combined and used to develop overall expressions of the relative degrees of constraint. The sensitivity of the process was investigated through the creation of a series of combined models altering the relative influence of each the themes. Considerable similarities were found between the combined models, and the model that weights the three themes equally was taken forward and used to develop plan options for offshore wind within STW.

The options indentified are shown in Figure S1 and listed below.

Potential plan option areas within Scottish Territorial Waters identified in the scoping study:

E1	Off the Firths of Forth and Tay
NE1	In the inner Moray Firth
NE2	In the south eastern part of the Moray Firth
NE3	Off the east coast of Aberdeenshire
N2-3	North of Orkney
N4–6	West of Shetland
N7	East of Shetland
N8	North of Shetland
NW7	North Minch
NW4	South Minch
W1-3	Sea of the Hebrides
W4	South of Islay
W5	South of Islay
W6	West of Ayrshire
SW3-6	Solway region



**Figure S1** Offshore wind plan option areas identified within Scottish territorial waters, and offshore wind development areas currently within the Marine Scotland Marine Licence process.

Sea areas outside STW generally have greater depths of water, and also generally lower levels of constraint, reflecting the greater importance of coastal waters to commercial, environmental and heritage interests. A discussion of potential plan options outside STW is therefore structured around depth zones. Potential development areas with water depths less than 60m are identified in the Forth and Tay area, and in the Moray Firth, adjacent to TCE Round 3 lease areas which are currently in the process leading to application for Marine Licence and other consents. Further areas of 60 – 80 m depth are found in the same general areas, and may represent development opportunities once the technology for working in such depths of water is established. There is also a potential development area north of Orkney with 60 – 80 m depth.

There are large areas of water of 80 – 120 m depth. These areas are not currently amenable to fixed foundation turbine structures, but may be suitable for floating turbine systems. Very extensive areas in this depth range are found in the Scottish waters in the North Sea.

Areas of water of 120 – 300m depth are unlikely to be considered as priority development opportunities. The Fladen Ground in the North Sea presents the most practicable opportunities in this depth zone, while the extensive exposed area along the shelf edge west of Scotland presents very considerable technical challenges to development and may not be practicable for some years.

The outputs from this study will inform the marine planning process by leading to the development of Regional Locational Guidelines for offshore wind development, which in turn will be the basis for an SEA to cover wind farm development in Scottish waters.

## 1 Background

The Scottish Government has set a range of challenging targets for energy and climate change. These recognise the potential to take advantage of the extensive marine energy resources (wind, wave and tidal power) available in Scottish waters and include meeting at least 30% of total energy demand from renewable sources by 2020, incorporating:

- 100% of electricity demand from renewables (31% by 2011)
- 11% of heat demand from renewables
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In addition, the Climate Change (Scotland) Act 2009 sets statutory targets of at least 42% emissions cuts by 2020, and at least 80% by 2050.

To assist in meeting these targets, a Sectoral Marine Plan for Offshore Wind Energy in Scottish Territorial Waters (Blue Seas - Green Energy) sets out the Government's vision for developing offshore wind energy up to 2020 and beyond and has identified short term development sites for offshore wind up to 2020, with a potential to deliver almost five Gigawatts (GW) of electricity generation capacity; and a further 25 areas for further exploration beyond 2020. Currently, up to 10GW of planned development is in progress at offshore wind sites in Scottish Waters, divided roughly equally between Round 3 sites and sites in Scottish Territorial Waters (STW).

The Sectoral Marine Plan for Offshore Wind Energy in Scottish Territorial Waters (The Plan) was initially informed by Strategic Environmental Assessment, which allowed environmental considerations to be 'frontloaded' in the plan-making process. To further formulate The Plan, a series of options were identified, where it initially appeared that feasibility for offshore wind energy could be explored further. Firstly, the ten sites within STW holding 'exclusivity agreements' from The Crown Estate were identified as short term options. Secondly, mapping systems were used to consider where development could be technically feasible over the medium to long term. Several considerations were considered relevant at this stage – Wind Resource; Water Depth; Ports, and Grid. Thirdly, having identified the overall scope of the Plan as a whole, further analysis was undertaken to identify suitable areas for development in the medium to long term. This information was used by the consultants commissioned by The Scottish Government to develop the Plan and the associated Strategic Environmental Assessment to map zones of broad environmental sensitivity and technical issues using The Crown Estate's Marine Resource System (MaRS). The Scottish Government's consultants were granted access to use The Crown Estate MaRS software to carry out their assessments. The consultants applied a system of scoring and weighting of information held in MaRS to produce graduated maps of the least to greatest technical, and subsequently environmental, sensitivity.

The MaRS system is a powerful tool for the handling and integration of a wide range of spatial data referring to environmental and technical factors that can influence the



development of offshore wind energy (and other activities). The integrated data are presented as spatial models which map the constraints applying in potential development areas. In order to apply the MaRS tool, it is necessary for the user to make a number of decisions regarding the data to be included in the models and the way in which the data are to be handled.

It had been suggested by stakeholders that the Draft Plan gave insufficient attention to the interaction of potential windfarm developments with some existing activities, such as conservation areas and fishing grounds. Marine Scotland therefore undertook a sensitivity analysis of the spatial modelling process to explore the sensitivity of the outcome of the MaRS modelling undertaken as part of the development of the Draft Plan to the underlying decisions made during the MaRS modelling. Such a sensitivity assessment was consistent with procedures used in the MaRS modelling to identify potential development areas in the context of the Scoping Study for the Saltire Prize for wave and tidal energy projects.

The sensitivity analysis of the output from the spatial modelling that had been used to develop the proposals for medium term wind farm development in STW showed that the conclusions were sensitive to technical factors, such as the categorisation of data layers as representing complete (exclusion models) or partial (constraint models) constraints on development, the weighting applied to the layers, and the classification system used to create the scores. However, the degree of sensitivity differs between sea areas.

The sensitivity analysis noted that improvements in the available data had occurred since the Draft Plan had been prepared. For example, European Seabird at Sea (ESAS) data are now available in a compiled form suitable for inclusion in spatial modelling. Other data layers are likely to be updated and improved during 2011 and 2012. The sensitivity analysis concluded that it was likely that the data available by 2012 should allow a more robust analysis of the medium term opportunities for wind farm development. The executive devolution to Scottish Ministers of responsibility for planning (and licensing) in Scotland's seas from 12 – 200 miles in 2009 through the UK Marine and Coastal Access Act suggests that an integrated wind farm development plan covering STW and more offshore areas should be considered.

The sensitivity analysis concluded that, as additional data and monitoring information, and improved data handling procedures, become available, these should be incorporated into the emerging iterative marine planning process, as applied to the medium term options for wind farm development in STW, and to opportunities further offshore.

A process was therefore put in place by Marine Scotland to develop a Scoping Report for the potential for offshore wind development in Scottish waters out to 200 nautical miles. It is intended that that this will inform the marine planning process by leading to the development of Regional Locational Guidelines for offshore wind development, which in turn will be the basis for an SEA to cover wind farm development in Scottish waters.

## 2 Approach

As was the case in the development of the Draft Plan for Offshore Wind Energy in Scottish Territorial Waters, and the Scoping Study for the Saltire Prize programme for wave and tidal power development, Marine Scotland has worked with The Crown Estate to use MaRS for the identification of potential areas for offshore wind development .

As previously mentioned, in order to apply the MaRS tool, it is necessary for the user to make a number of decisions regarding the data to be included in the models and the way in which the data are to be handled. These decisions include factors such as:

- The factors that require consideration when locating offshore wind developments and the availability of spatial data that can be included in the models.
- Whether particular activities or uses should be considered as incompatible with wind farm development, or whether activities or uses should be considered as presenting gradations of limitation to development potential.
- The relative importance (weighting and scoring) that should be applied to the different layers of data in the final integrated model.
- The relative quality and reliability of data layers.

The Sensitivity Analysis noted that some of the sensitivity of the final outputs had probably arisen through the use of a single model of environmental constraints. This required that relative weightings are developed for very diverse types of data (e.g. the relative weighting of seabird colonies, wrecks, fish landings, and basking shark sightings). This is very difficult to apply without some clear additional frame of reference, such as consenting risk.

Alternatively, grouping the data layers into themes (e.g. industrial, environmental, heritage etc) would present fewer conceptual problems, and assessing the sensitivity of the outputs to variation in the overall weighting between themes could be achieved. This latter approach had previously been used successfully in the Scoping Study for the Saltire Prize. A similar approach has therefore been adopted in the current study, grouping constraints layers into themes representing constraints arising from industrial activity, environmental factors and heritage interests.

The purpose of the Sensitivity Analysis was explore the sensitivity of the outcome of the MaRS modelling used to identify the medium term options within The Draft Plan to the selection of data layers to use in the model, and the scoring/weighting applied to them. A number of technical improvements to the data handling processes were identified, as below, and these were implemented in the current Scoping Study.

- a) Transfer some heavily weighted data layers from the constraint models to the exclusion models. This had the effect of allowing other layers in the constraint models to have greater influence on the outcome of the modelling.

- b) Amend the scoring system to match the recommendations of the model owners, ie The Crown Estate. This was done for statistical reasons, which are beyond the scope of this report. However, adherence to the MaRS guidelines is likely to give greater confidence in the outputs.
- c) Amend the weightings given to different data layers to better reflect the degree of risk to consenting that experience suggests might arise from the subject covered by each layer during the licensing process.
- d) Amend the classification/scoring system for statistically skewed data sets. This had the effect of enabling these data layers to have more appropriate influence on the final integrated models and to enable improved discrimination between areas,

Furthermore, in undertaking the sensitivity analysis, it was noted that improvements could be made in some of the data layers to better reflect their significance for wind farm development. Examples include:

- a) The analyses use the JNCC seabird at sea data set. It would be better to use the more comprehensive European Seabird at Sea (ESAS) data and to distinguish between species according to their sensitivity to wind farm developments. It should be noted that these data were not available in a suitable form at the time of the original MaRS modelling work undertaken by the consultants.
- b) The fish spawning and nursery ground data are now more than 10 years old and are in the process of being revised.
- c) The fish (fisheries) value combines across all gears and all vessels. A better analysis could be developed using VMS data for >15m vessels, distinguishing between gear types (and perhaps species). There is a significant lack of detailed information on <15 m vessels, which are likely to be important in some of the proposed areas.
- d) Some of the data layers used by the SG Consultants in the MaRS models on the distribution of wildlife, such as seals, basking sharks, etc, although the best available at the time, had been derived from non-systematic survey methods and may therefore have been biased by the distribution of observer effort.
- e) All SACs and SPAs are treated equally, while the risk arising from wind farms will differ between species and habitats. A more risk-based approach could improve the targeting of the assessment.
- f) A broad range of conservation sensitivities could be taken into account by consideration of the distribution of SNH Priority Marine Features. Maps of these are in preparation.

Where possible, improved or updated data layers were used in the current Scoping Study, as indicated below.

### 3 Structures of the Models Used

As described in the documentation supporting The Draft Plan and associated Strategic Environmental Assessment (Scottish Government, 2010a, b), and as is normal in the use of MaRS, the data layers had been classified as either exclusion layers (i.e. indicating areas where development was not appropriate), or constraint layers (i.e. indicating the distribution of factors that acted as partial constraints on development). The constraint layers were each allocated a weighting. Within each constraint layer, the data had been assessed through a scoring scheme. The constraint layers were allocated either to a Technical Model or to a Constraints Models. The Constraints model was comprised of the outputs from three thematic Restriction models, covering constraints arising from industrial activity, environmental factors, and heritage interests. The heritage layer is broad in its scope, covering visual and recreational factors as well as historical heritage and archaeological potential. The outputs of these models had been normalised against the Exclusion model.

The data layers which were included in the various models were as follows:

#### 3.1 Heritage Restriction Model

Data layer	Weight	Maximum score	Potential relative influence
National scenic areas	900	90	81000
Royal Yachting Association cruising routes	300	30	9000
Royal Yachting Association racing areas	300	30	9000
Royal Yachting Association sailing areas	300	30	9000
Scheduled Ancient Monuments	800	80	64000
Bathing beaches	500	50	25000
World Heritage sites	1000	100	100000
Wrecks	700	70	49000
Protected wrecks	700	70	49000
Potential for marine archaeological remains	700	70	49000

### 3.2 Environmental Restriction Model

Data layer	Weight	Maximum score	Potential relative influence
Bird reserves	800	80	64000
Important Bird Areas	500	50	25000
Local nature reserves	800	80	64000
Special Areas of Conservation	1000	100	100000
Special Protection Areas	1000	100	100000
Sites of Special Scientific Interest	1000	100	100000
Offshore candidate SACs and SPAs	1000	100	100000
Offshore draft SACs and SPAs	1000	100	100000
Offshore possible SACs and SPAs	1000	100	100000
RAMSAR sites	1000	100	100000
Nursery areas for commercial fish species	400	73	29200
Spawning areas for commercial fish species	400	73	29200
Areas of search for potential Marine Protected areas	400	40	16000
Areas of seabird aggregation	400	80	32000
Areas of importance to vulnerable sea birds	1000	182	182000
Areas of importance to marine mammals	900	164	147600

### 3.3 Industry Restriction Model

Data layer	Weight	Maximum score	Potential relative influence
Offshore cables in UK waters (not active)	500	100	50000
Pipelines in UK waters (not active)	500	100	50000
Potential gas and CO2 storage sites	800	80	64000
Carbon capture and gas storage infrastructure	800	80	64000
Civil Aviation Aerodrome Buffers	800	80	64000
Civil Radar Interference (at 140 m above mean sea level)	600	100	60000
Royal Air Force Airfields and Stations Buffer (24 km)	800	80	64000
Current Licensed Areas for	700	70	49000

Hydrocarbons			
Oil fields	400	40	16000
Closed waste disposal sites	700	70	49000
Helicopter main routes	600	100	60000
Military low flying areas	700	70	49000
Military Practice and Exercise Areas	1000	180	180000
Shipping density	1000	182	182000
Areas identified with potential for tidal power development	800	80	64000
Areas identified with potential for wave power development	800	80	64000
Commercial fisheries landings from mobile gear in inshore waters	1000	182	182000
Commercial fisheries landings from static gear in inshore waters	600	109	65400
Commercial landings from fishing vessels >15m using mobile gears	1000	182	182000
Commercial landings from fishing vessels >15m using static gears	600	109	65400

### 3.4 Exclusion Model

The following features were treated as incompatible with wind farm development, i.e. areas covered were used to create an overall special model of areas from which wind farms should be excluded at this time.

All Offshore Cable inside UK Waters

All Pipeline in UK Waters

Anchorage Areas

Aquaculture Leases – Current

Aquaculture Leases - Pending

Waste disposal sites (open)

IMO Routeing - excluding ABTAs

Munitions Dumps

Offshore Shipping Zones

Offshore Wind Farm Demonstration Sites

Operational Anemometers in UK Waters

Protected Wreck Exclusion Buffers

Round 1 Offshore Wind Farm Sites

Areas identified under Saltire Prize process as having high potential for tidal power

Areas identified under Saltire Prize process as having high potential for wave power  
 Shipping Density - Exclusion Areas  
 Tidal Leases – Live  
 UK Deal oil and gas Safety Zones  
 UK Deal oil and gas Surface features  
 UK Deal oil and gas Subsurface features  
 UKCS Exclusion Buffer - 500 m  
 Wave Leases – Live  
 UK Detailed Coastline - not including Isle of Man (Polygon)

### 3.5 Technical Model

Data layer	Weight	Maximum score	Potential relative influence
Available wind resource	1000	182	182000 (positive)
Distance from the coast	300	100	30000 (negative)
Mean wave height	400	100	40000 (negative)

The outputs from the restriction models, after normalisation against the exclusion model, should be viewed in the context of technical opportunities and constraints of the areas under consideration. A simple Technical model, as above, was developed that combined the benefits of increased mean wind speed with the increasing difficulties in construction and operation with distance offshore and mean wave height. A further significant technical constraint is the depth of water. This is taken into account in section 5.6 of the report, primarily in relation to areas outside STW.

### 3.6 Improvements to the Previous Spatial Modelling

The Sensitivity Study noted various areas in which improvements could be made to the data layers available for use in MaRS. The main improvements made during the current exercise were:

1. Landscape and visual issues: Develop a buffering system around national scenic areas (NSA) to reflect the decreasing visibility of wind turbines with distance from the NSA boundaries.
2. Commercial fishing: To separate landings from >15m vessels (i.e. those covered by the Vessel Monitoring System) using mobile gears from those using static gears. The latter may be less vulnerable to the development of wind farms than the former.

3. Commercial fishing: To identify landings from smaller vessel operating within STW, and to partition these between internal waters, 0 – 6 miles, 6 – 12 miles, and landings from greater distances within ICES statistical rectangles that also include areas within STW. Areas. To separately identify landings from mobile and static gears.
4. Potential for archaeological heritage remains on the seabed: Maps indicating areas of the current seabed which had been exposed as land at some time since the Ice Age (and had high potential and theoretically high potential for marine archaeology) were combined with maps of seabed sediment type and structure to identify areas of seabed where potential for archaeological remains coincided with favourable seabed conditions.
5. Sensitivity of areas to seabirds: An initial approach was made to developing an index of the relative sensitivity of sea areas for vulnerable seabirds. Attention was paid to collision risk during the breeding season. Mapped data on the distribution of 17 species of sea birds at sea during the breeding season (European Seabirds at Sea survey, JNCC) were expressed in terms of the total Scottish population of each species. These distributions were scaled according to the typical proportion of birds flying at typical turbine heights, and then combined to give an overall expression of the relative sensitivity of sea areas.
6. Sensitivity of areas to marine mammals: Data from the JNCC cetacean atlas of the distribution of marine mammals at sea were scaled to the Scottish populations of each species and then summed to express the overall importance of sea areas to marine mammals.
7. Spawning and nursery areas: Maps derived from Coull et al, 1999 showing areas of spawning and nursery grounds for 14 commercial fish and shellfish species were gridded and combined to show counts of spawning species or nursery ground species within each grid cell. The resulting layers were scored and weighted.
8. Designated areas for the protection of birds: There are a number of different designations for marine or coastal areas for the protection of birds, including RAMSAR sites, SPAs, SSSIs, RSPB reserves, local reserves, IBAs etc. In many cases, areas hold more than one designation, and treating each form of designation independently (as has been done previously) resulted in potentially multiple counts of the same area for the same environmental sensitivity (birds). The data were therefore processed such that only the most important designation of any particular area was included in the final data layers, for example an area designated at European, national and local levels would be considered as designated at European level, whereas an area designated at local level only would be scored as a local designation.



Of the suggestions made in the Sensitivity Analysis report for improvements to underlying data, almost all were achieved. Exceptions were:

- a) that SACs were not filtered for sensitivity to wind farm developments. This will have little impact on the outputs, as most designated SACs are coastal, and the models took into account the current search areas for offshore SACs.
- b) the distribution of SNH Priority Marine Features was not taken into account. A significant amount of work will be necessary to convert the available information on the distributions of PMFs into a form suitable for inclusion in spatial modelling.

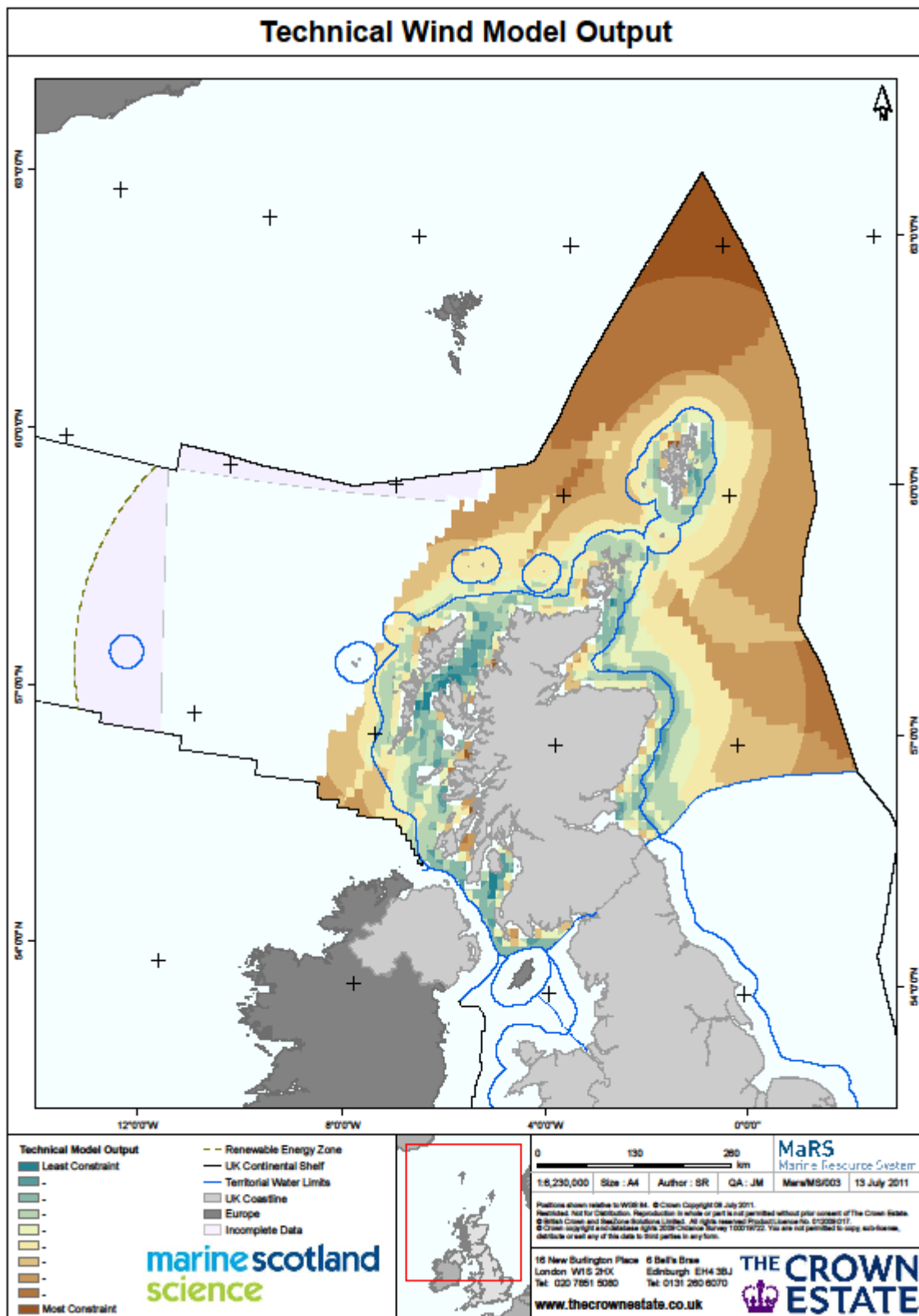
All the suggestions for alterations to the scoring and weighting systems were implemented.

## **4 Results of the MaRS Modelling**

### **4.1 Technical Constraints Model**

The output from the Technical constraints model (Figure 1) clearly demonstrate the increasing difficulty of development towards the middle of the North Sea and in areas to the north of Shetland. Areas with annual mean significant wave height of 3m or more were treated as excluded in the technical model and this, combined with lack of some data, has limited the output from the model at about 8 degrees west, but it may be assumed that these areas also are progressively more constrained further west. The apparent lack of constraint in some grid cells at the western edge of the modelled area is a spurious edge effect and is of no significance.

The least technically constrained areas are found generally within Scottish Territorial Waters to the west and north of Scotland and around the Orkney and Shetland islands, and in a strip of around 15 – 30 miles width round the eastern side of Scotland. Wind speeds immediately adjacent to the coast are generally less than those a few miles offshore, making these slightly offshore areas less technically constrained. In addition to the factors covered in this model, the depth of water acts as an important constraint through its influence on the types of foundations for turbines that are appropriate. The influence of depth on development potential is considered in more detail in section 5.6.



**Figure 1** Output from the technical constraints model for offshore wind development in Scottish waters.

## **4.2 Industry Restriction Model**

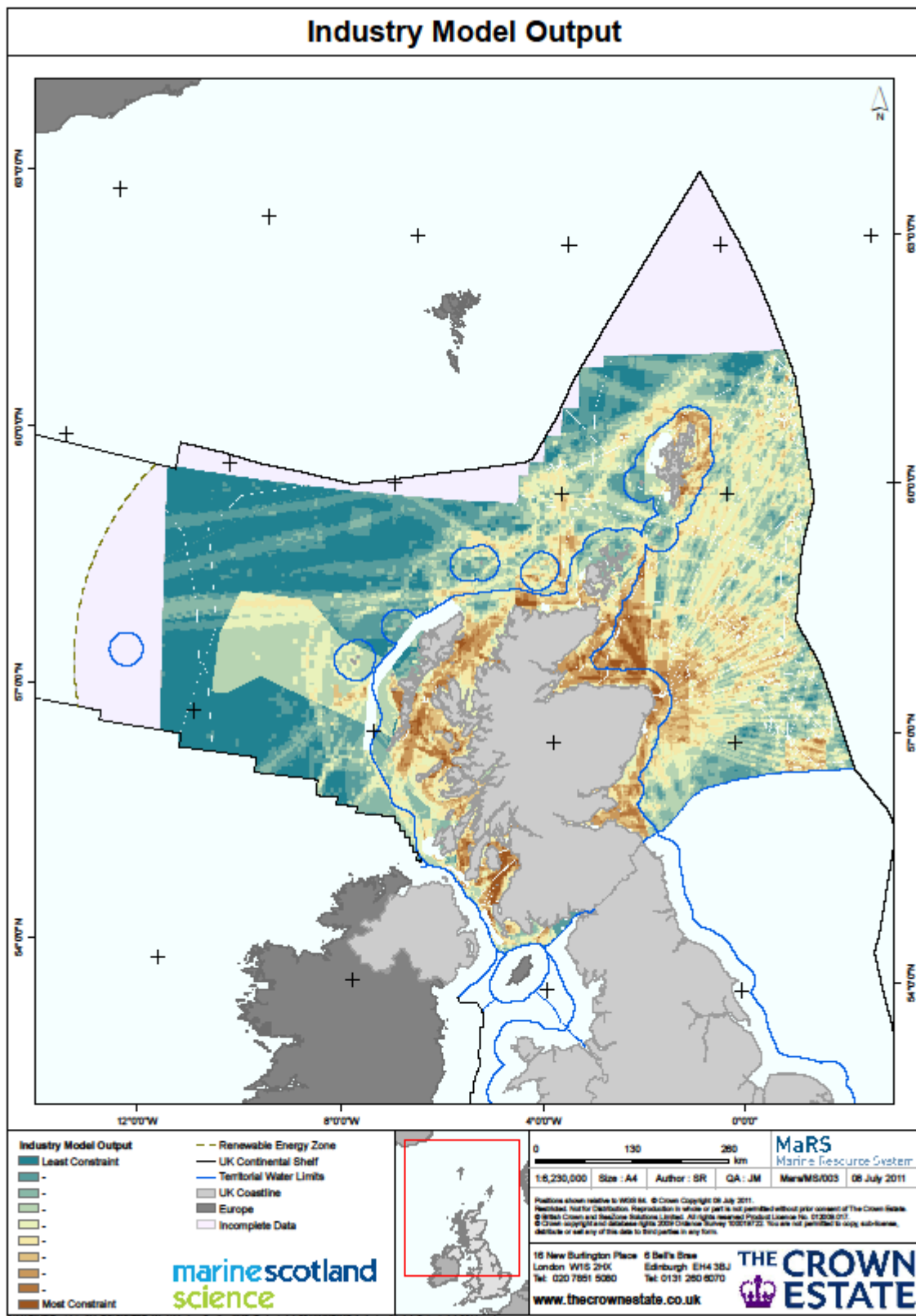
The output from the Industry restriction model (Figure 2) is dominated by the predominance of current “industrial” activity in the coastal zone. For example, aquaculture is currently entirely limited to waters within a short distance of the shoreline, as is much of the shipping activity (ferries, vessels on passage around Scotland). Some of our most valuable fishing grounds are in the sheltered waters of the Minch and aviation routes to oil and gas installations in the North Sea are a clear feature of the east coast off the Grampian region.

## **4.3 Environmental Restriction Model**

The output from the Environment restriction model (Figure 3) again indicates greater levels of constraint in inshore waters. Relatively high levels of constraint in the North and South Minches will be influenced by their importance to seabirds and marine mammals. The designated areas around Rhum and St Kilda, and in the inner Moray Firth are prominent, as is the general importance of waters off the east coast between Peterhead and Berwick to seabirds.

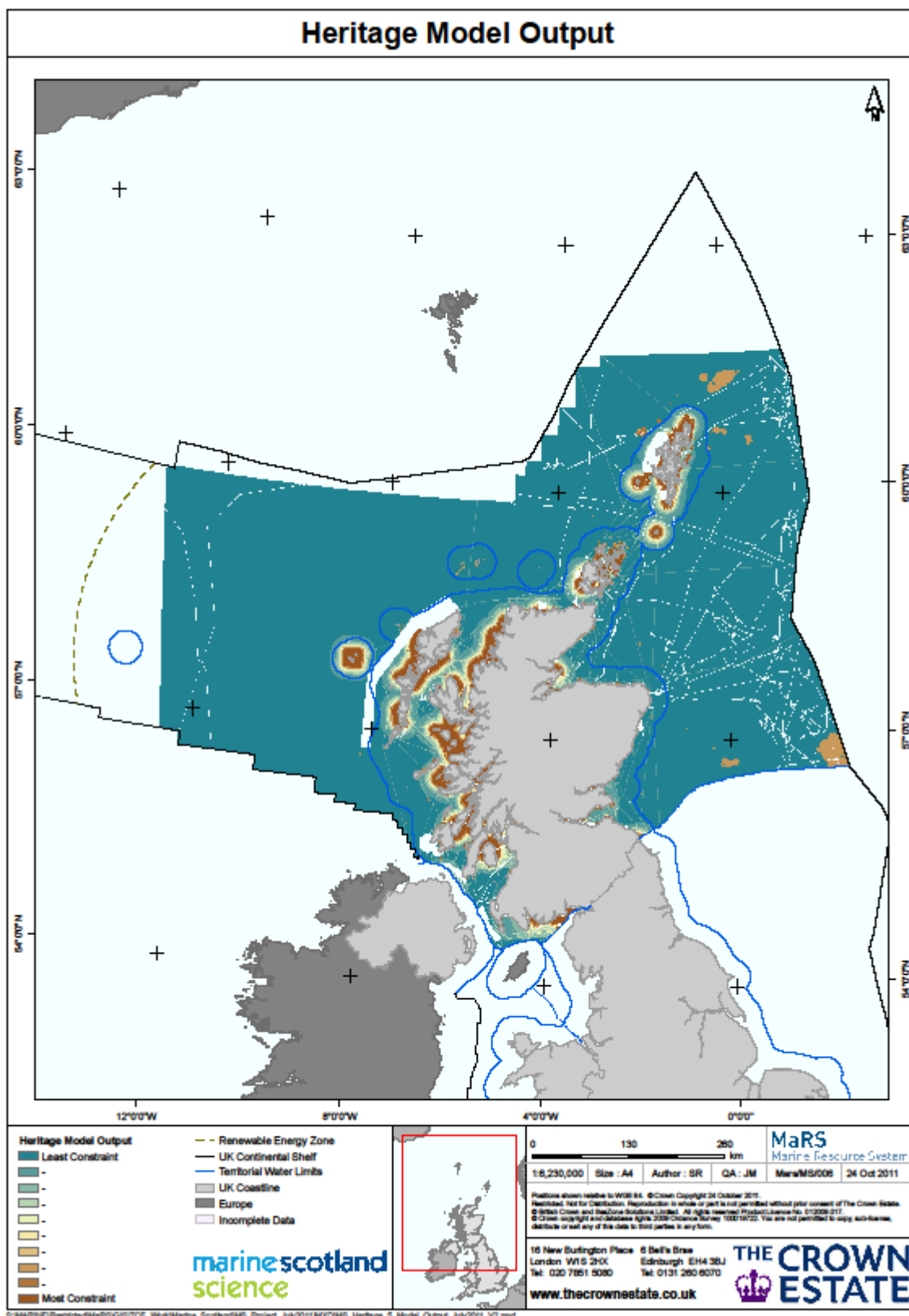
## **4.4 Heritage Restriction Model**

The output from the Heritage restriction model (Figure 4) generally indicates low levels of constraint in most areas of Scottish waters. The areas where constraint is encountered are dominated by areas in and adjacent to National Scenic Areas, where particular sensitivity to offshore wind farms may be anticipated. It may be noted that the model does not capture seascape and visual impact issues in areas that are not designated, and it may be anticipated that such matters will be significant aspects of consenting in many other areas not presently designated. Further contributions to heritage restrictions arise from yachting and sailing activity and the potential for sub-sea archaeological remains.



**Figure 2** Output from the industry restriction model for offshore wind development in Scottish waters.





**Figure 4** Output from the heritage restriction model for offshore wind development in Scottish waters.

## 4.5 Combined Models

An expression of the overall level of constraint on wind farm developments in Scottish waters needs to take account of environmental, industry and heritage restrictions. The Sensitivity Analysis noted that the presentation of the information by theme reduced the difficulties inherent in developing relative weightings for very diverse types of data (e.g. the relative weighting of seabird colonies, wrecks, fish landings, and basking shark sightings). The current Scoping Study has been carried out with the minimisation of consenting risk in mind. Having grouped the data and developed thematic restriction models, it is now possible to combine the models within MaRS and assess the sensitivity of the outputs to variation in the overall weighting between themes. This approach had previously been used successfully in the Scoping Study for the Saltire Prize

Four Combined models were created, in which the relative weightings of the themes were changed. In an Equal Weighting model, the three themes were weighted equally. Three further models were developed, in which each of the themes was assigned a weighting equal to the sum of the weightings for the other two themes, as in Table 1.

**Table 1**

	<b>Environmental theme</b>	<b>Industry theme</b>	<b>Heritage theme</b>	<b>Figure</b>
Equal weighting constraints model	100	100	100	Figure 5
Environmental focused constraints model	200	100	100	Figure 6
Industry focused constraints model	100	200	100	Figure 7
Heritage focused constraints model	100	100	200	Figure 8

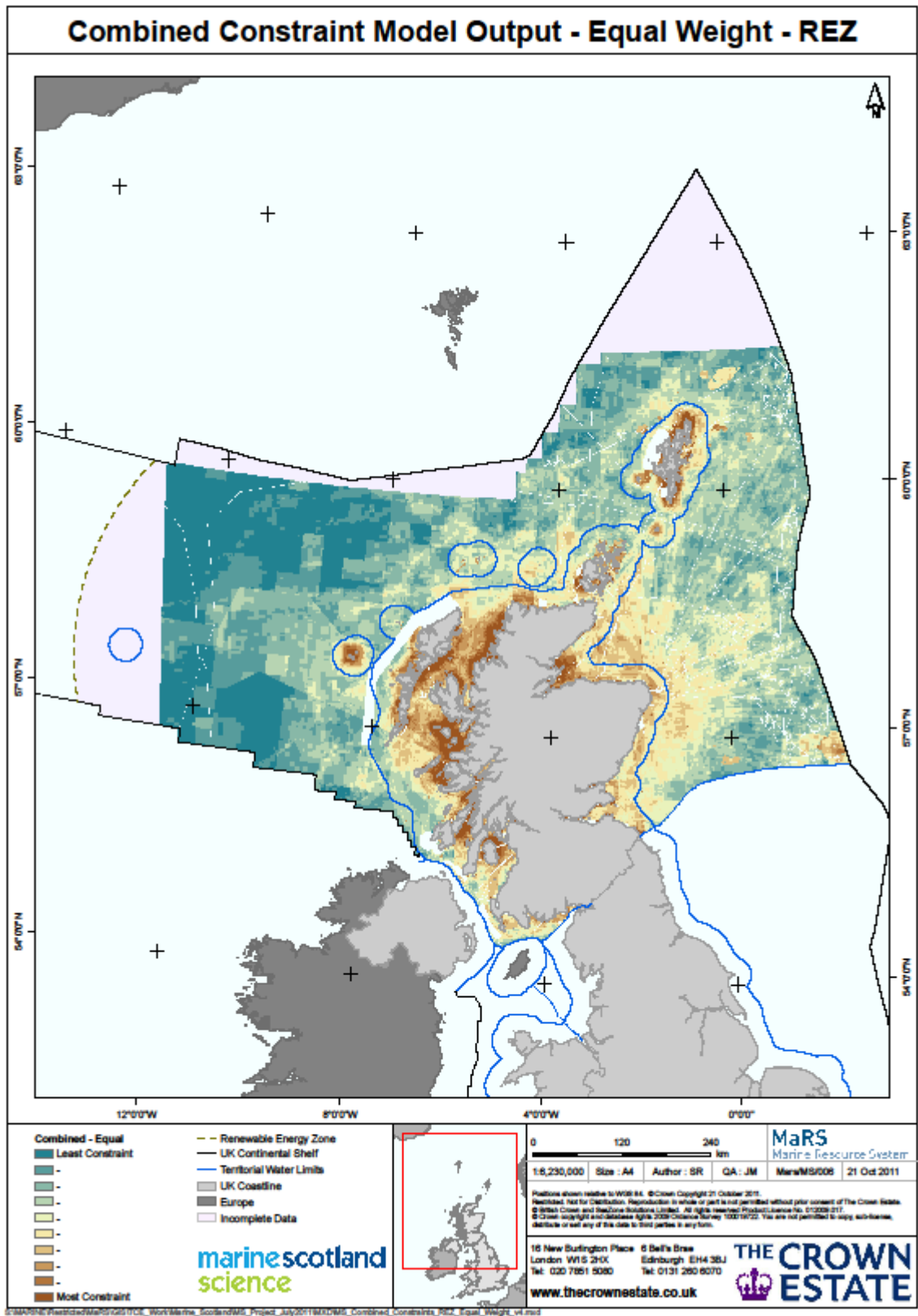
The resultant models are shown in Figures 5, 6, 7 and 8.

There are some broad similarities between the outputs, i.e. features that are not very sensitive to the relative weightings of the three themes:

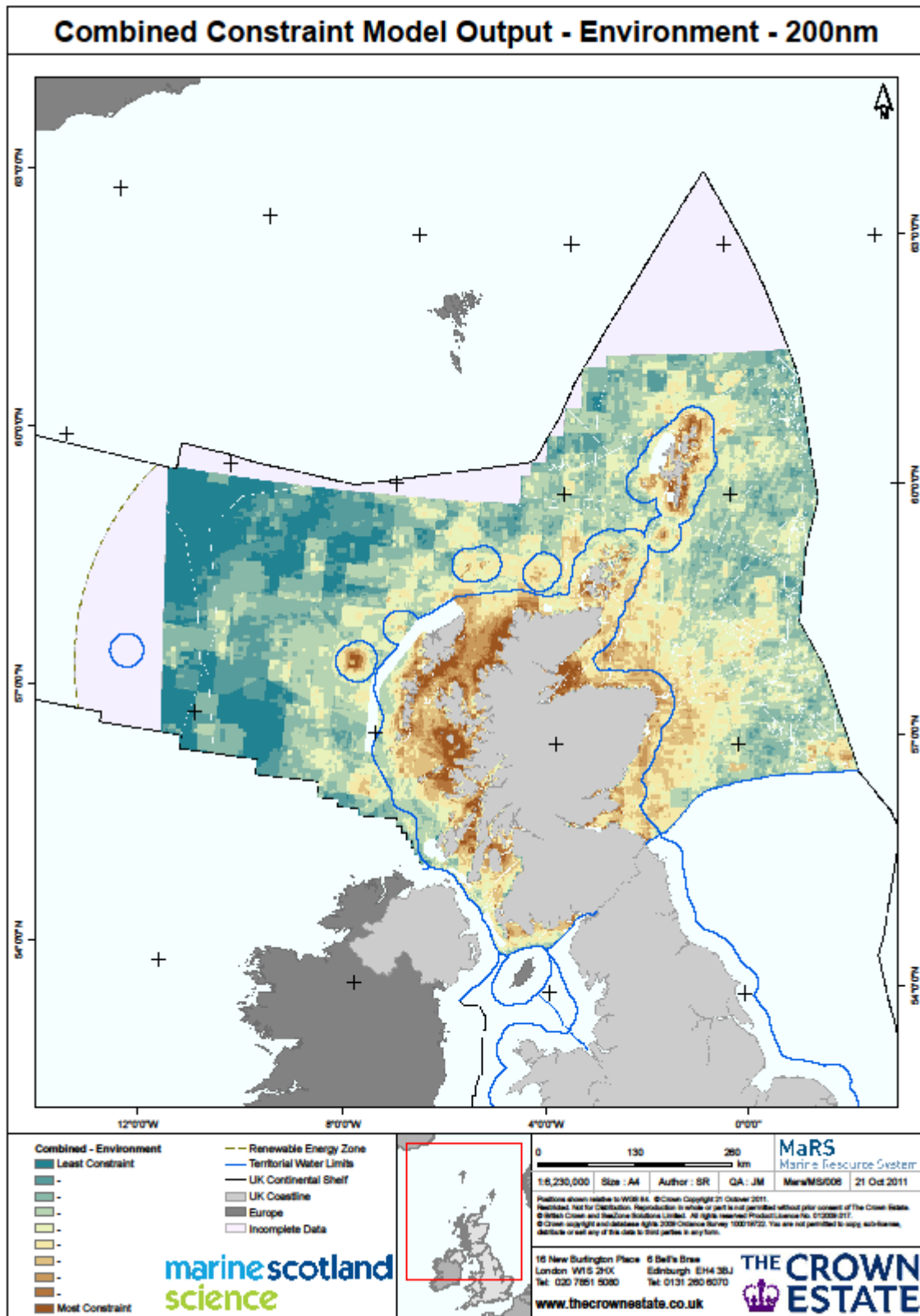
1. Constraint is generally a coastal phenomenon. Most of the activities in the sea, from all three themes, are concentrated in coastal waters. The degree of constraint decreases with distance from the coast. This is particularly clear in the North Minch area, where waters east of the Western isles are generally highly constrained, while those to the west of the Western Isles show much lower levels of constraint.
2. On the east coast, the most constrained areas are in the inner parts of the major firths, the Moray Firth and the Firths of Forth and Tay. The degree of constraint decreases seawards.

3. The North and South Minch are generally strongly constrained. However, there are areas on the west coast further south, west and south west of the Inner Hebrides, where the degree of constraint is much less. The level of constraint in inshore waters between the Inner Hebrides and the mainland is generally similar to that in the Minch.
4. The degree of constraint off the east coast of Scotland is less than in the Minch, but constraint if present over much of the Moray Forth persists for 30 miles or more offshore of most of the east coast. This feature is less prominent in the model which emphasises heritage interests, possibly because of the greater importance of designated scenic areas on the west coast.
5. The degree of constraint in Scottish waters in the Solway Firth is generally intermediate between that in the Minches and off the east coast. However, there is a narrow strip of water with lesser constraint along the boundary with Isle of Man waters.
6. In all areas, the levels of constraint outside STW is much less than that within STW. It also decreases with distance offshore outside STW, such that at 30-40 miles offshore the levels of constraint are generally very low. There will be some sensitive areas, such as those associated with the oil and gas industry, where development may not be appropriate.
7. Relatively large areas within STW where the level of constraint is low occur off the west of Scotland between Barra and Islay, west/northwest of Cape Wrath, north and north west of Orkney. Smaller areas can be noted south of Islay, south of the Mull of Kintyre, and on the southern edge of Scottish waters in the Solway.

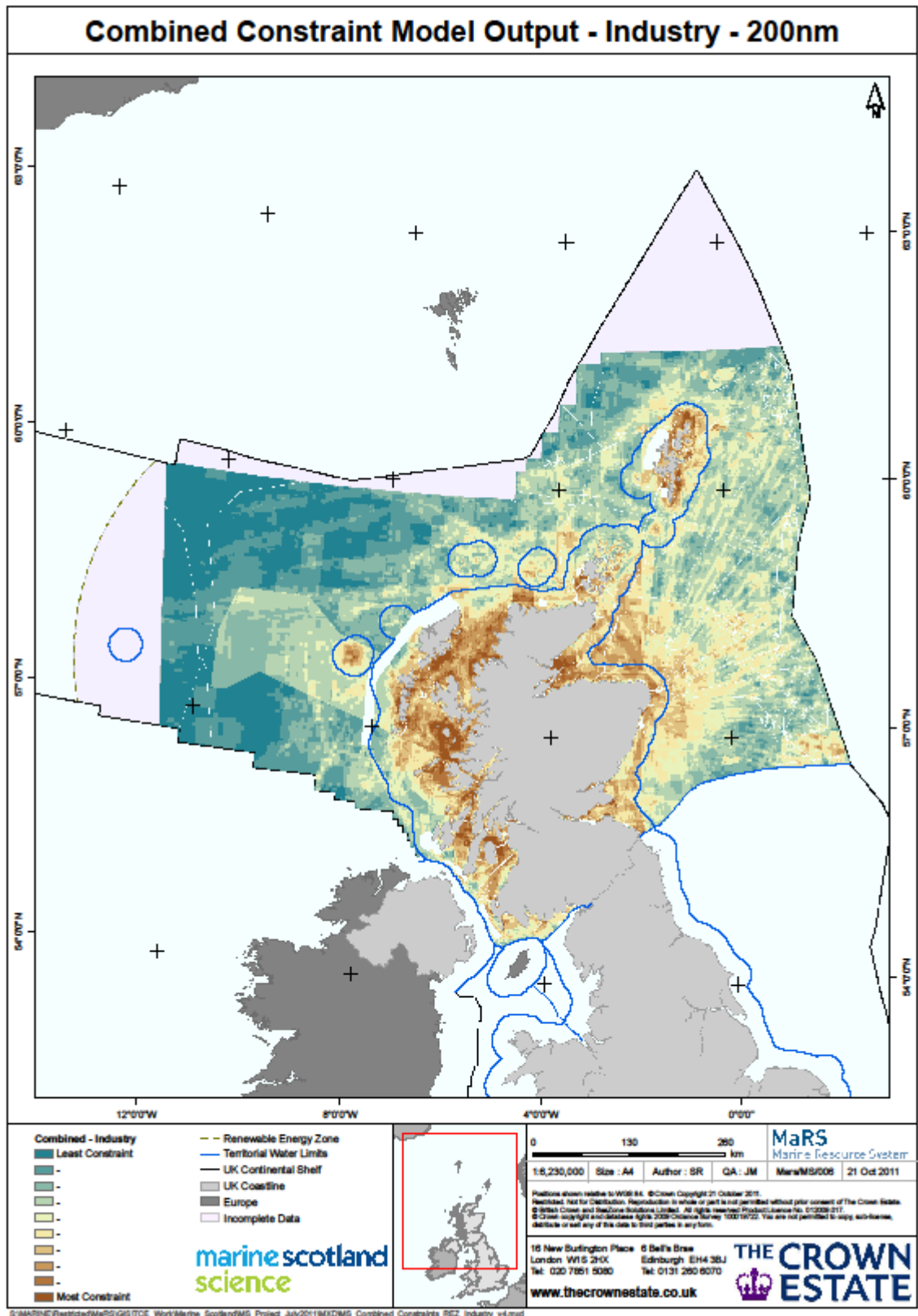




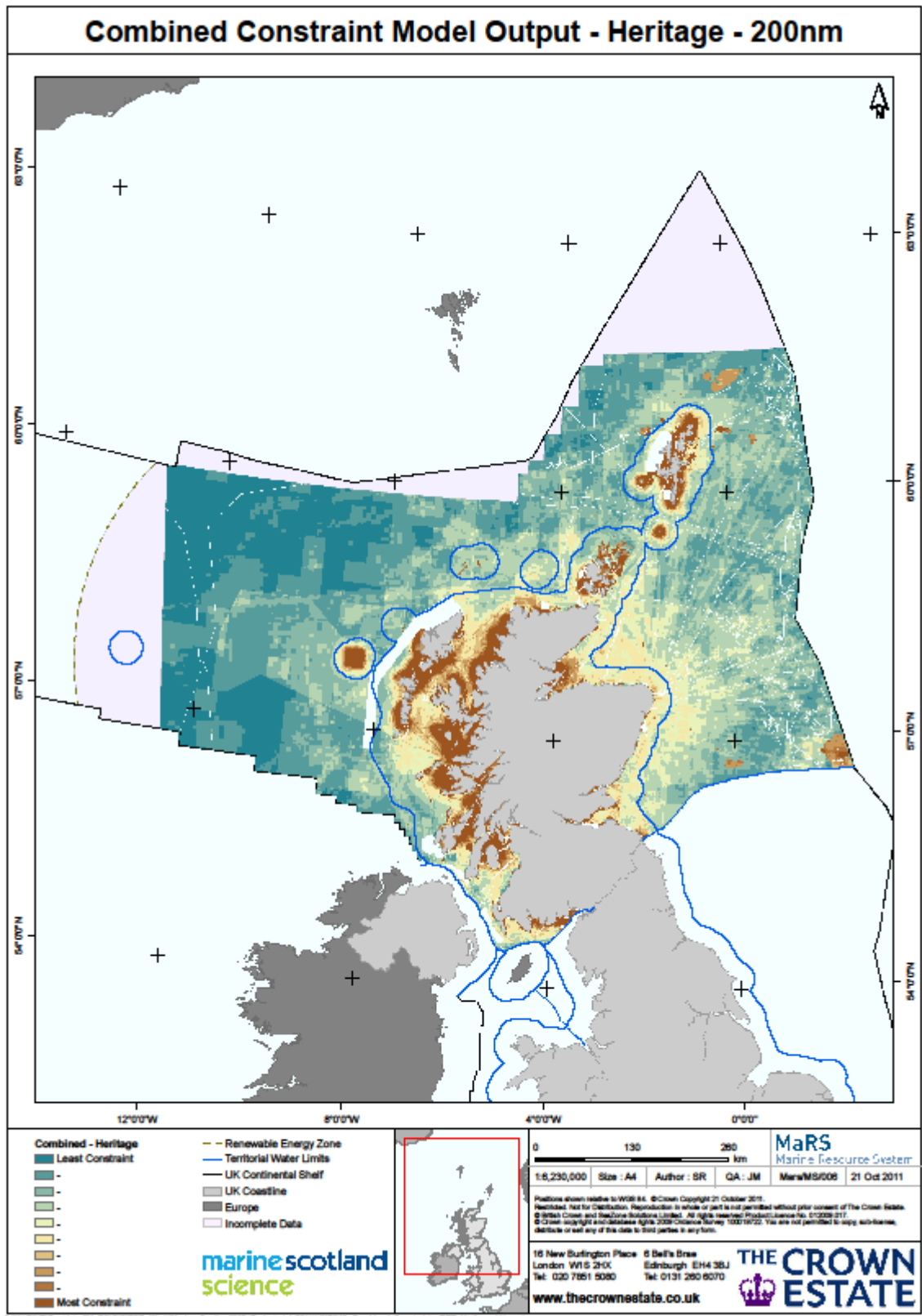
**Figure 5** Combined restriction model, giving equal weight to the environmental, industry and heritage themes.



**Figure 6** Combined restriction model, emphasising the environmental theme.



**Figure 7** Combined restriction model, emphasising the industry theme.



**Figure 8** Combined restriction model, emphasising the heritage theme.

## **5 Congruence of the Scoping Study with the Plan of Offshore Wind Energy in Scottish Territorial Waters**

The Plan of Offshore Wind Energy in Scottish Territorial Waters incorporated six short term options for offshore wind development, and also a larger number of areas of search with potential for development as medium term options. The short term options have been included in TCE's Scottish Territorial Waters leasing round. Most of these are currently progressing through the licensing system, and five of these sites have recently been awarded agreements for lease. Areas within the medium term option search areas have not yet been offered for lease. The distribution of the STW sites and the medium term areas of search are shown in Annex 1, Figure A1.

In view of the conclusions of the sensitivity analysis of the modelling undertaken for the Plan of Offshore Wind Energy in Scottish Territorial Waters, and the improvements to the modelling undertaken in the current Scoping Study, comparisons have been made between the distributions of the level of constraint, as indicated by the Combined Equal Weighting Model, and the locations of the short and medium term options (Annex 1, Figures A2).

### **5.1 East Coast**

The short term options on the east coast of Scotland (and the Round 3 lease areas) are concentrated off the Forth and Tay estuaries, and in the north western part of the Moray Firth.

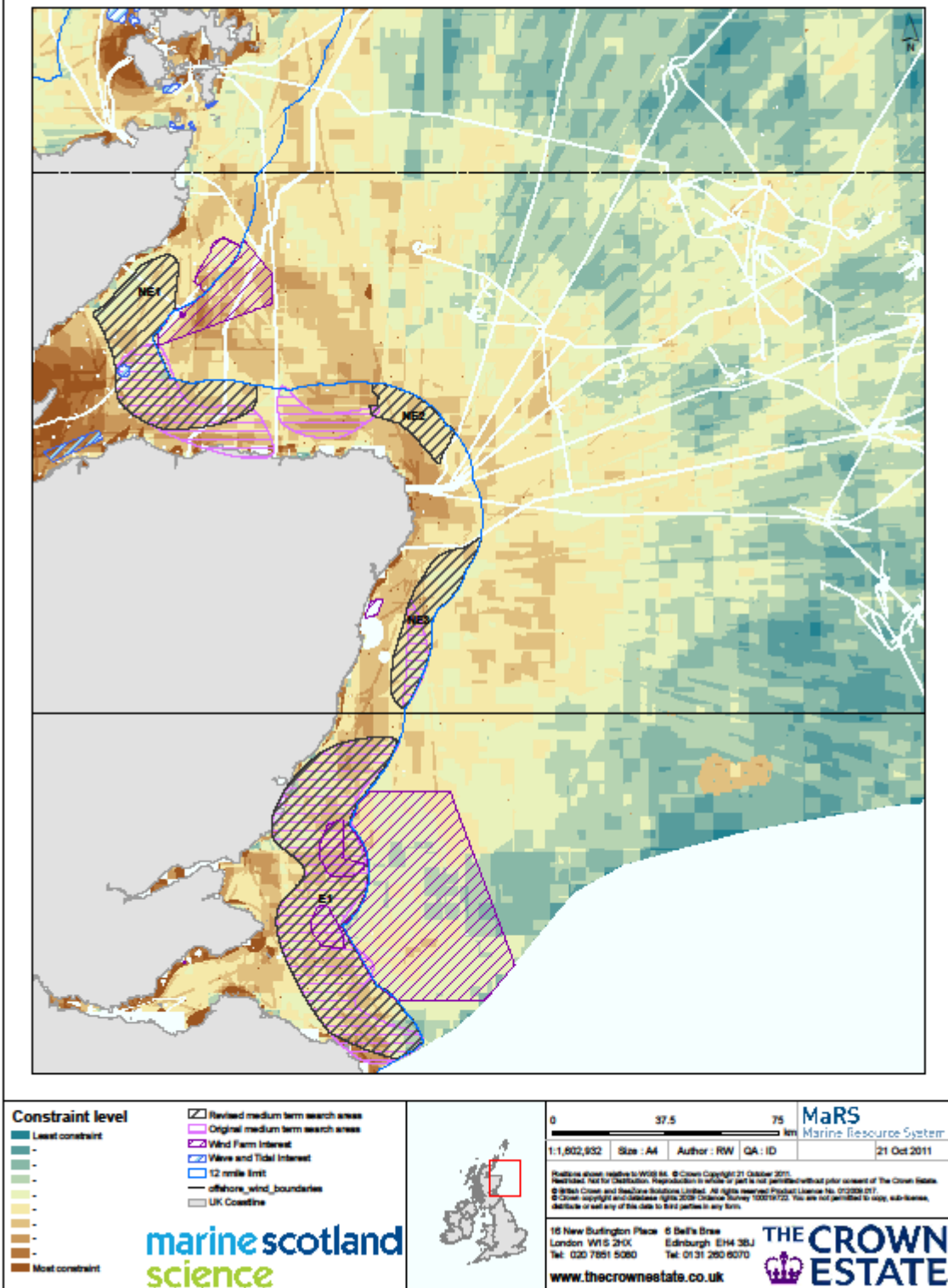
Those off the Forth/Tay are located within medium term site E1, and generally in areas of moderate to low levels of constraint. Higher level of constraint are found in the extreme north and south of E1. The current study is therefore broadly supportive of short and medium term options in the area, and also suggests that additional areas of relatively low constraint may be present immediately inshore of NE3, and also NNE of NE3 off the Aberdeenshire coast.

The short term options in the Moray Firth have similar levels of constraint to those off the Forth and Tay. Two areas of medium term search (NE1 and NE2) have been identified in the Plan. The Scoping Study suggests moderate to high levels of constraint in NE2, and in the southern part of NE1. However, areas of lower constraint exist between the north of NE1 and the Sutherland/Caithness coast.

In the light of this discussion, the boundaries of the search areas on the east coast of Scotland have been revised, and new strategic search areas are shown in Figure 9.

- E1 Off the Firths of Forth and Tay
- NE1 In the inner Moray Firth
- NE2 In the south eastern part of the Moray Firth
- NE3 Off the east coast of Aberdeenshire

## Combined Constraint Model Output - Equal Weight - REZ



**Figure 9** Proposed strategic search areas for offshore wind farms in Scottish Territorial Waters on the east coast of Scotland. The proposed areas are outlined in red, the medium term sites from the 2010 Plan in black, and the 12 mile limit in blue.

## 5.2 Northern Isles

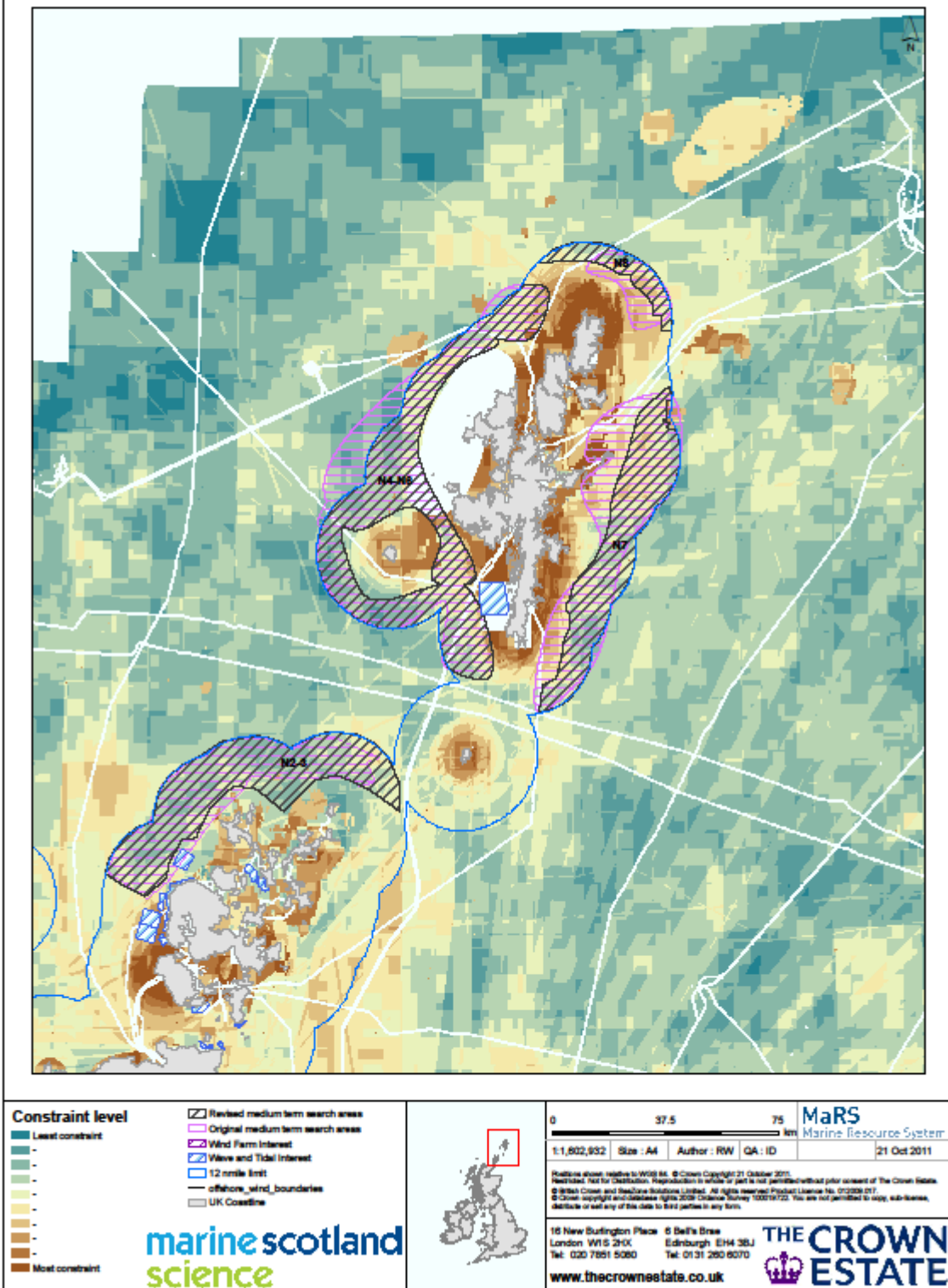
The Draft Plan identified a potential large area of search (N2 and N3) north and north west of Orkney. This is supported by the low to moderate level of constraint in this area, and also in other areas with STW around the northern part of Orkney.

The Plan identified several areas of search in the waters around Shetland (N4, N5, N6, N7, N8). The Scoping Study broadly supports this suggestion. While high to moderate levels of constraint have been identified in near shore waters, the level of constraint is much less (low to moderate) in the outer part of STW (approximately 6 – 12 miles offshore) except in the far north (medium term option N8) where moderate to high constraint is identified.

The proposed strategic search areas in the Northern Isles are shown in Figure 10.

N2-3	North of Orkney
N4 – 6	West of Shetland
N7	East of Shetland
N8	North of Shetland

## Combined Constraint Model Output - Equal Weight - REZ



**Figure 10** Proposed strategic search areas for offshore wind farms in Scottish Territorial Waters round the Northern Isles of Scotland. The proposed areas are outlined in red, the medium term sites from the 2010 Plan in black, and the 12 mile limit in blue.



### 5.3 North and North West of Scotland

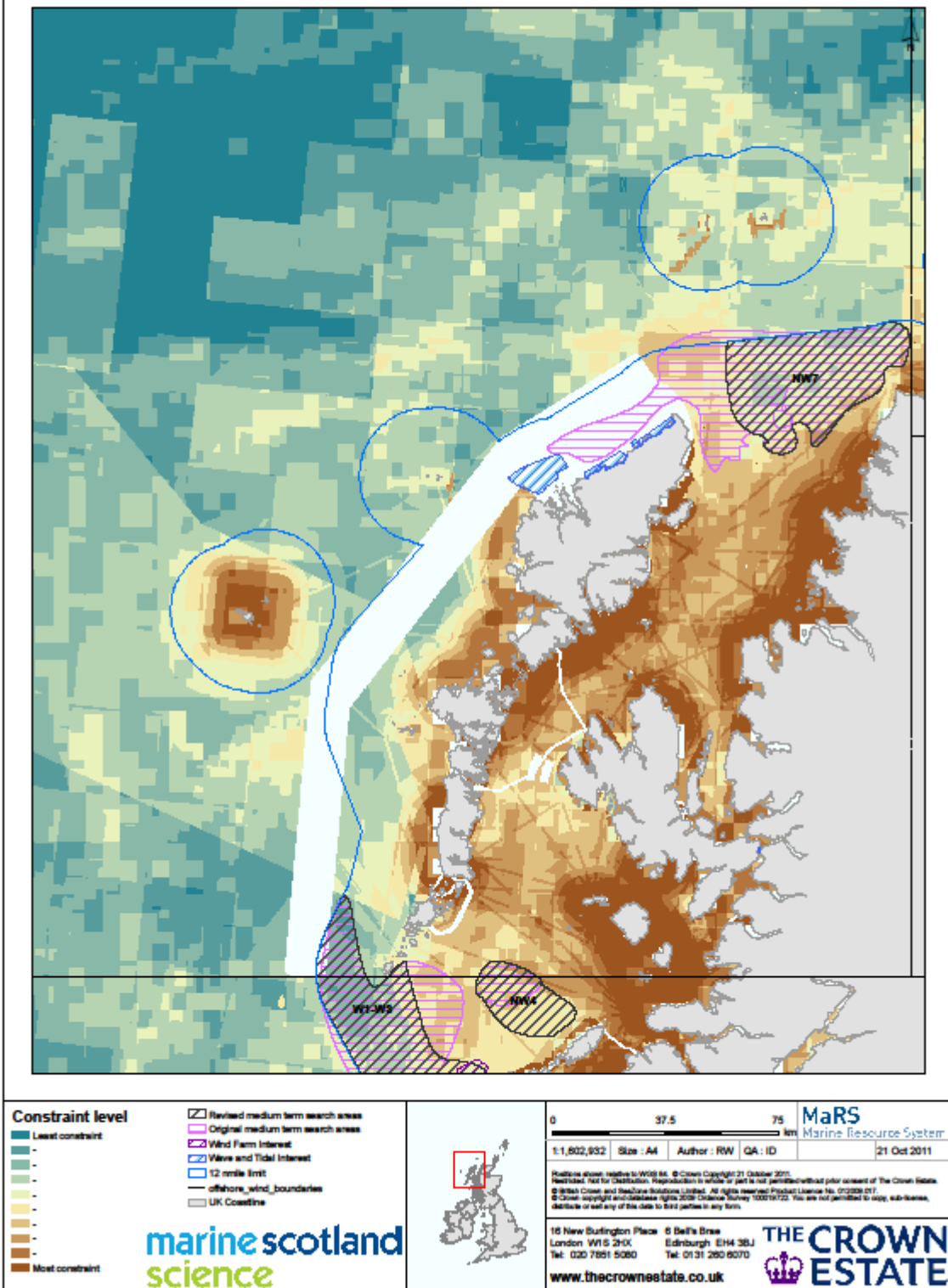
The Plan identified medium term options around several small island groups off the north and north west of Scotland (Flannan Islands, North Rona, Sule Skerry etc). The level of constraint in these remote locations is generally low. However, the boundaries of these areas are strongly influenced by the boundaries of the disconnected areas of STW centred on the islands. The medium term options NW8, NW2 and N1 are better viewed as elements of the very extensive area of waters off the west and north west of Scotland, outside the 12 mile limit drawn around the mainland baseline, where environmental, industry and heritage constraints on development are low. Development in these areas currently presents significant technical difficulties. Obviously, there is no grid connection to these islands, and the degree of exposure and depth of water are currently challenging. However, there is very great potential for development of both wind and wave energy in these areas.

The Plan identified three further medium term search areas in and north of the Minch (NW5, NW6 and NW7). The current Scoping Study indicates that the levels of constraint in the Minches (NW5 and NW6) are high to moderate, and that development might therefore be more difficult than in some areas with lower levels of constraint. The large area NW7 at the north of the Minch contains some areas of low to moderate constraint, but also areas of higher constraint north of Lewis and adjacent to the mainland coast. It also includes waters identified in the Saltire Prize Scoping Report as appropriate for wave power development. Regional Locational Guidance will be particularly valuable in this area in refining the boundaries of the areas of search and clarifying the relative suitability of the area for wave and wind power projects.

The proposed strategic search areas to the north and north west of Scotland are shown in Figure 11.

NW7 North Minch

## Combined Constraint Model Output - Equal Weight - REZ



**Figure 11** Proposed strategic search areas for offshore wind farms in Scottish Territorial Waters in the north west of Scotland. The proposed areas are outlined in red, the medium term sites from the 2010 Plan in black, and the 12 mile limit in blue.

## 5.4 West of Scotland

The boundary of Scottish Territorial Waters to the west of Scotland between Barra and Kintyre is rather further from the mainland coast than in some other parts of the country, and therefore encompass a large sea area. The Scoping Study identifies a low to moderate levels of constraint in the outer parts of STW between Barra and Islay. This is reflected in the medium term options W1, W2 and W3, and in the STW sites off Tiree and Islay. More detailed analysis of the area through Regional Locational Guidance may be used to develop a regional approach in this area.

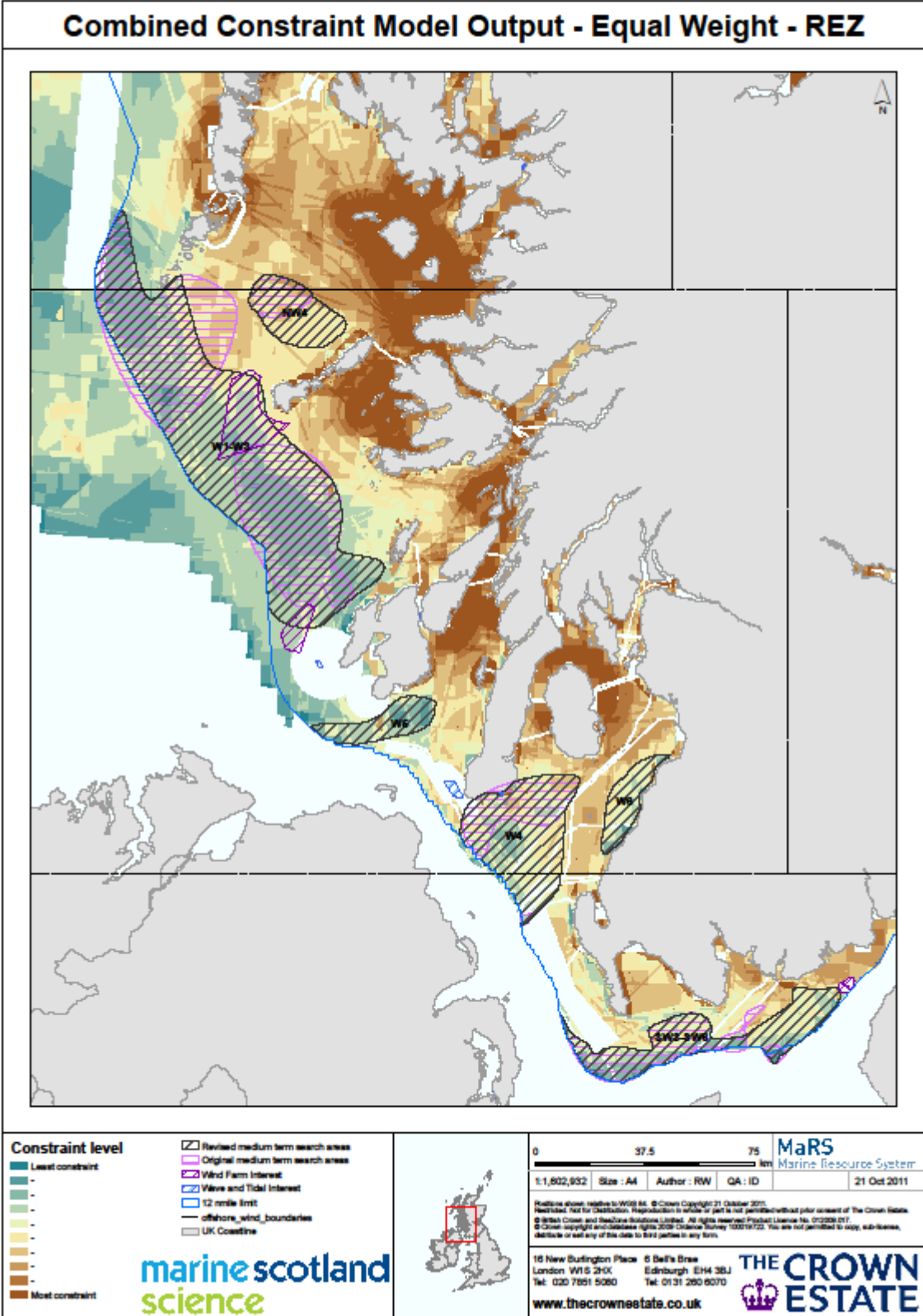
The small medium term option area NW4 is located in the north western part of an area of moderate to low constraint west and north west of Coll and Tiree. This area is contiguous with the STW area of low constraint SW of Tiree and may offer opportunities for integrated offshore wind development. Similarly, it may be possible to consider waters of moderate to low constraint west of Colonsay together with the adjacent areas of lower constraint further offshore.

An area of low constraint is identified immediately south of Islay. This area has not been included in either the short or medium options in the current Plan, and may present an opportunity for development, and for integration with other potential development sites west of Scotland.

There is an area of low to moderate constraint in the outer part of the Clyde Sea area. To a degree, this was recognised through the identification of the medium term option area W4. However, the current scoping study suggests that the boundaries of this area could be reviewed to incorporate areas of low and low to moderate constraint south and southwest of W4. There may also be an area of low constraint close inshore on the eastern side of the Clyde Sea north of Ballantrae.

The proposed strategic areas in the west of Scotland are shown in Figure 12.

- NW4 South Minch
- W1-3 Sea of the Hebrides
- W4 South of Islay
- W5 South of Islay
- W6 West of Ayrshire



**Figure 12** Proposed strategic search areas for offshore wind farms in Scottish Territorial Waters in the west of Scotland. The proposed areas are outlined in red, the medium term sites from the 2010 Plan in black, and the 12 mile limit in blue.

## 5.5 The Solway Area

The Solway area generally shows moderate to high levels of constraint. However, within the medium term search area SW3, SW4 and SW5 there is a strip of water of low to moderate constraint along the boundary between Scottish and Isle of Man waters. This area may therefore present opportunities for development in areas that are less sensitive than areas closer to the Galloway coast. Waters in the northern part of the search region (SW5) have higher levels of constraint.

SW3-6            Solway region

## 5.6 Waters Between 12 and 200 miles Beyond Baseline

The Technical Model (Figure 1) emphasises the increasing technical difficulty of developing wind energy projects further offshore. The main difficulties are associated with distance from opportunities for terrestrial grid connections, difficulties of construction in deeper water, and the generally more adverse wave climate in these areas. Gaps in data have curtailed the technical Model west of the Hebrides, but it may be anticipated that high levels of technical difficulty will be found in more westerly areas, as in the far north of Scottish waters. In general, the technically least constrained areas off the east of Scotland lie between about 5 and 20 miles offshore. The current progress with the STW and Round 3 sites off the east coast suggest that additional large areas of sea can be considered as technically feasible areas of search for development sites without significant new technical developments. To the west of Scotland, the least technically constrained areas are within STW, and include areas around NW7 and W1 – W3, where other constraints are also not high.

The combined environment, heritage and industry constraint maps indicate that there are large areas of relatively low constraint both east and west of Scotland, and that therefore there may be very considerable opportunity for development in deeper water further offshore. The technical constraints on projects in these areas are likely to decrease as other developments occur. For example, the construction of offshore transmission grid networks to the east and west of Scotland may remove the necessity to bring power to the shore from the point of generation to obtain grid connection.

At the present time, the offshore wind industry is planning to develop projects in water up to about 60m deep. This is considerably deeper than was the case in early projects in Rounds 1 and 2, and reflects continuing engineering development. While seabed-mounted foundation become more difficult in deeper water, the current engineering and developer interest in floating wind turbine structures holds the prospect of removal of the constraint arising from depth of water, and may lead to the recognition of very large areas of remote Scottish offshore waters as having potential for offshore wind energy projects.

The depth of water is clearly an important aspect of the feasibility of development of offshore wind farms at the current time. The initial Round 1 and Round 2 sites were generally located in rather shallow water, while the deeper water found in Round 3 and STW sites reflects the progressive improvements in the technical ability to construct projects in deeper water. However, depth of water remains a very important consideration in project design and development opportunity.

In order to further explore the opportunities for development outside Scottish Territorial Waters, a series of maps have been prepared (Figures 13 – 16) which illustrate the levels of constraint on development in waters of 0 – 60m depth, 60 – 80m, 80 – 120m, and 120 – 300 m depth. 60m corresponds approximately to the maximum depth of water encountered in areas (Round 3 and STW) where projects are currently being developed. 60 – 80m approximates to the possible limits to the applicability of current designs of rigid foundations. Some developers are beginning to express interest in water depths of 80 – 120m, primarily as potential areas for the deployment of floating (moored) wind turbines, while depths of 120 – 300 m are less likely to be considered as potential development areas in the near future. There have been no clear expressions of interest in development in water of greater than 300m depth.

#### **5.6 1 Potential development areas in water 0 – 60 m depth outside Scottish Territorial waters (STW)**

Figure 13 shows the output from the Combined Restriction model, giving equal emphasis to the environmental, industry and heritage themes, showing proposed strategic areas in STW, existing STW and Round 3 offshore wind sites, the 12 mile limit (boundary to STW) and the relative levels of constraint in waters of 0 – 60 metres depth.

The main areas of low to moderate levels of combined constraint, with water depth less than 60m, are in the east of Scotland:

- North east of the Round 3 site off the Forth and Tay
- East and south of the Round 3 site in the Moray Firth

#### **5.6.2 Potential development areas in water 60 - 80 m depth outside Scottish Territorial waters (STW)**

Figure 14 shows the output from the Combined Restriction model, giving equal emphasis to the environmental, industry and heritage themes, showing proposed strategic areas in STW, existing STW and Round 3 offshore wind sites, the 12 mile limit (boundary to STW) and the relative levels of constraint in waters of 60 - 80 metres depth.

The main areas of low to moderate levels of combined constraint, with water depth of 60 – 80m, outside STW are:

- An extensive area east of Scotland between Peterhead and the Tay estuary
- In the outer part of the Moray Firth from Fraserburgh to Orkney
- An area north of Orkney
- Areas off the north coast of the Scottish mainland
- Smaller scattered areas west of the Outer Hebrides and south west of Tiree

### **5.6.3 Potential development areas in water 80 – 120 m depth outside Scottish Territorial waters (STW)**

Figure 15 shows the output from the Combined Restriction model, giving equal emphasis to the environmental, industry and heritage themes, showing proposed strategic areas in STW, existing STW and Round 3 offshore wind sites, the 12 mile limit (boundary to STW) and the relative levels of constraint in waters of 80 - 120 metres depth. At this time, the emphasis for this depth of water will be to identify potential sites for demonstration projects to establish the technical viability of development in depths that exceed those currently being used in Round 3 or STW sites.

There are very extensive areas of water of 80 – 120 m depth all round Scotland, out to the median line in the North Sea, towards the shelf edge in the north west, and around the southwest, south and east of Shetland. The area within 80 -120m depth zone exceeds that of all waters shallower than 80m. The generally lower levels of constraint in the deeper, offshore waters emphasises the potential opportunities that could arise from the development of engineering solutions appropriate to offshore wind farms in these remote areas.

The requirements for demonstration sites differ from those for fully commercial sites, with greater emphasis on the ease of access, and reduced exposure that can be found in areas closer to the shore. Figure 15 suggests that test sites in 80 – 120 m depth of water may be found in areas of low to moderate levels of combined constraint, such as:

- Off the coast of east Scotland from Fraserburgh south to the northern boundary of the Round 3 site off the Tay
- In the strategic search areas identified round Shetland
- In an area between Orkney and the Farr Point wave power area
- In the STW strategic area at the northern end of the Minch (NW7)
- In the STW strategic area at the mouth of the Clyde Sea area (W4), and in scattered areas north and south of this between Islay and the Mull of Galloway

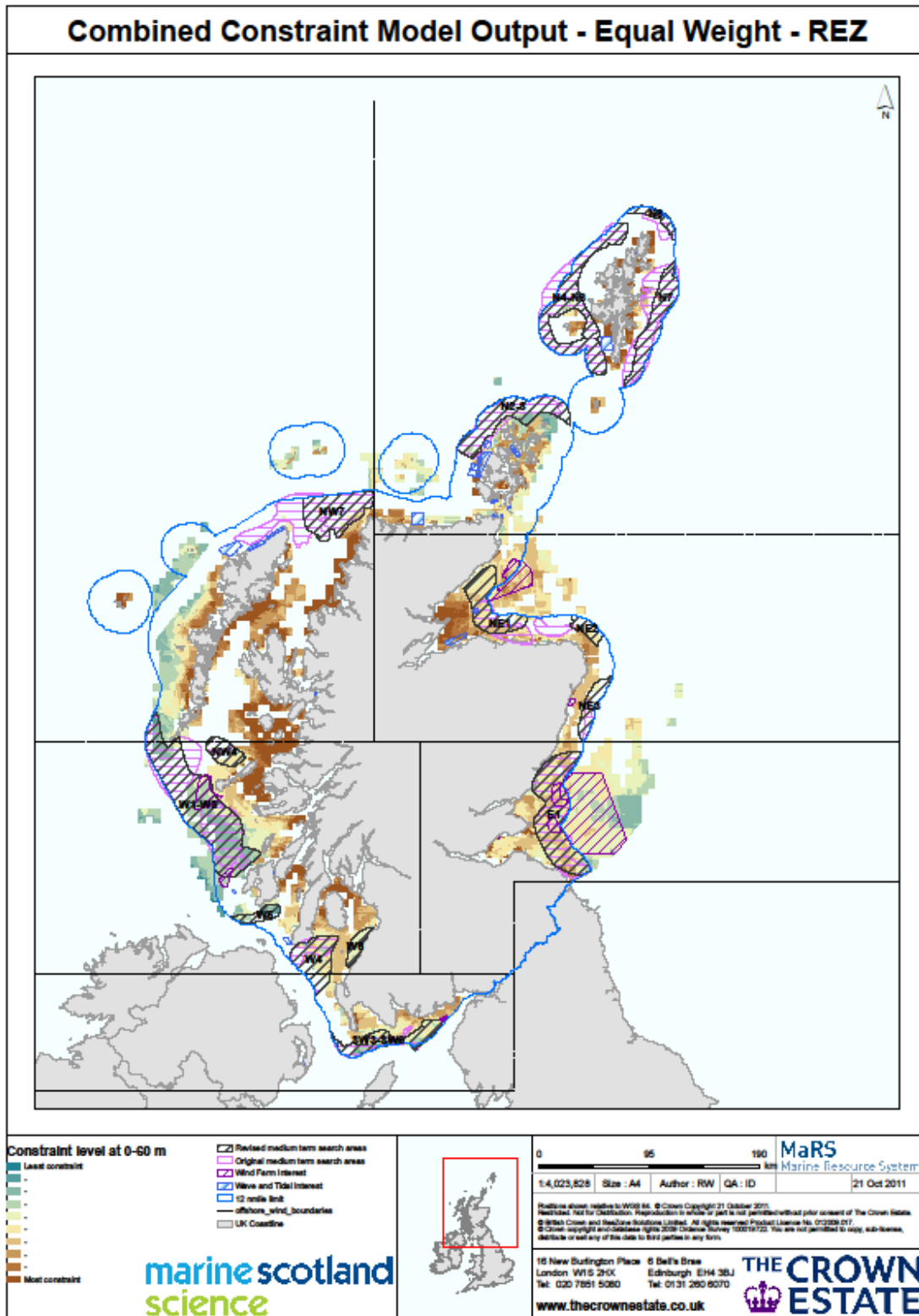
### **5.6.4 Potential development areas in water 120 - 300m depth outside Scottish Territorial waters (STW)**

Figure 16 shows the output from the Combined Restriction model, giving equal emphasis to the environmental, industry and heritage themes, showing proposed strategic areas in STW, existing STW and Round 3 offshore wind sites, the 12 mile limit (boundary to STW) and the relative levels of constraint in waters of 120 - 300 metres depth.

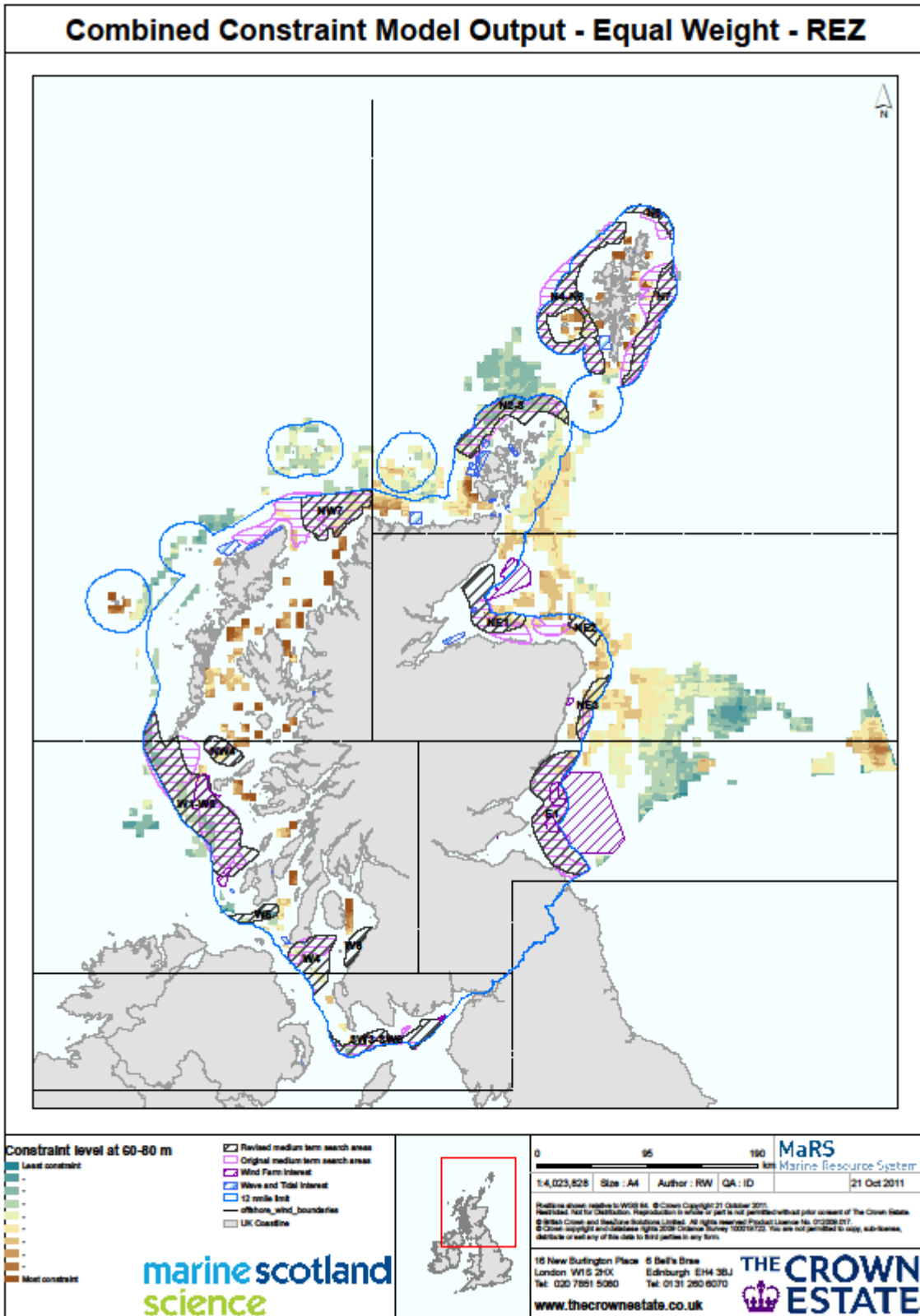
There is currently very limited commercial interest in water of greater than 120m depth. There are extensive areas of Scottish waters of 120 – 300m depth in the extreme north around Shetland, and to the north west of Scotland along the edge of the continental shelf possibly with long term development potential. There is probably greater development potential in the medium term in the Fladen area east of Scotland from Orkney to Peterhead.

The scope for inshore test sites is limited, but opportunities may exist north west of Orkney, south of Barra, and in scattered locations west of the Mull of Galloway.

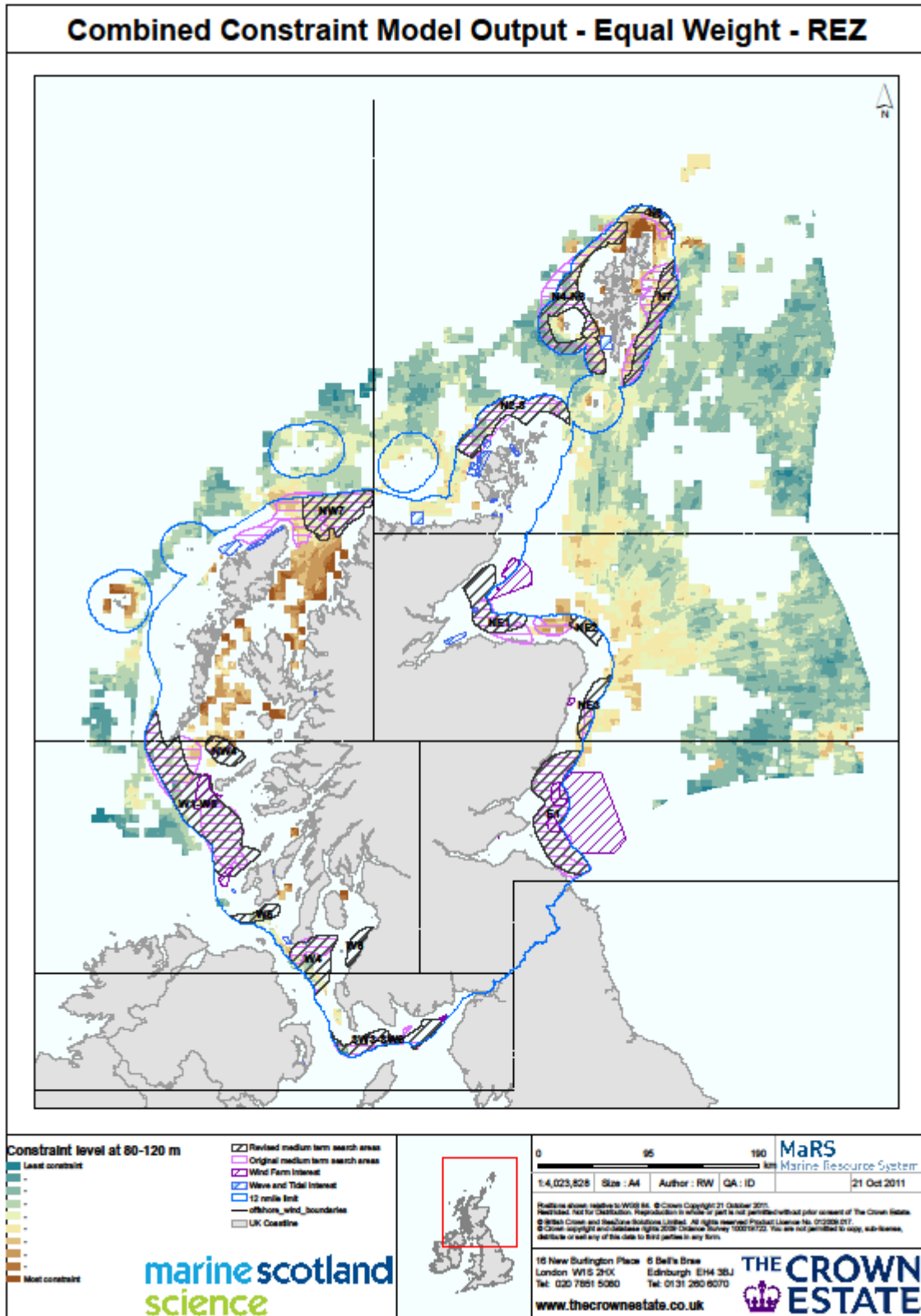




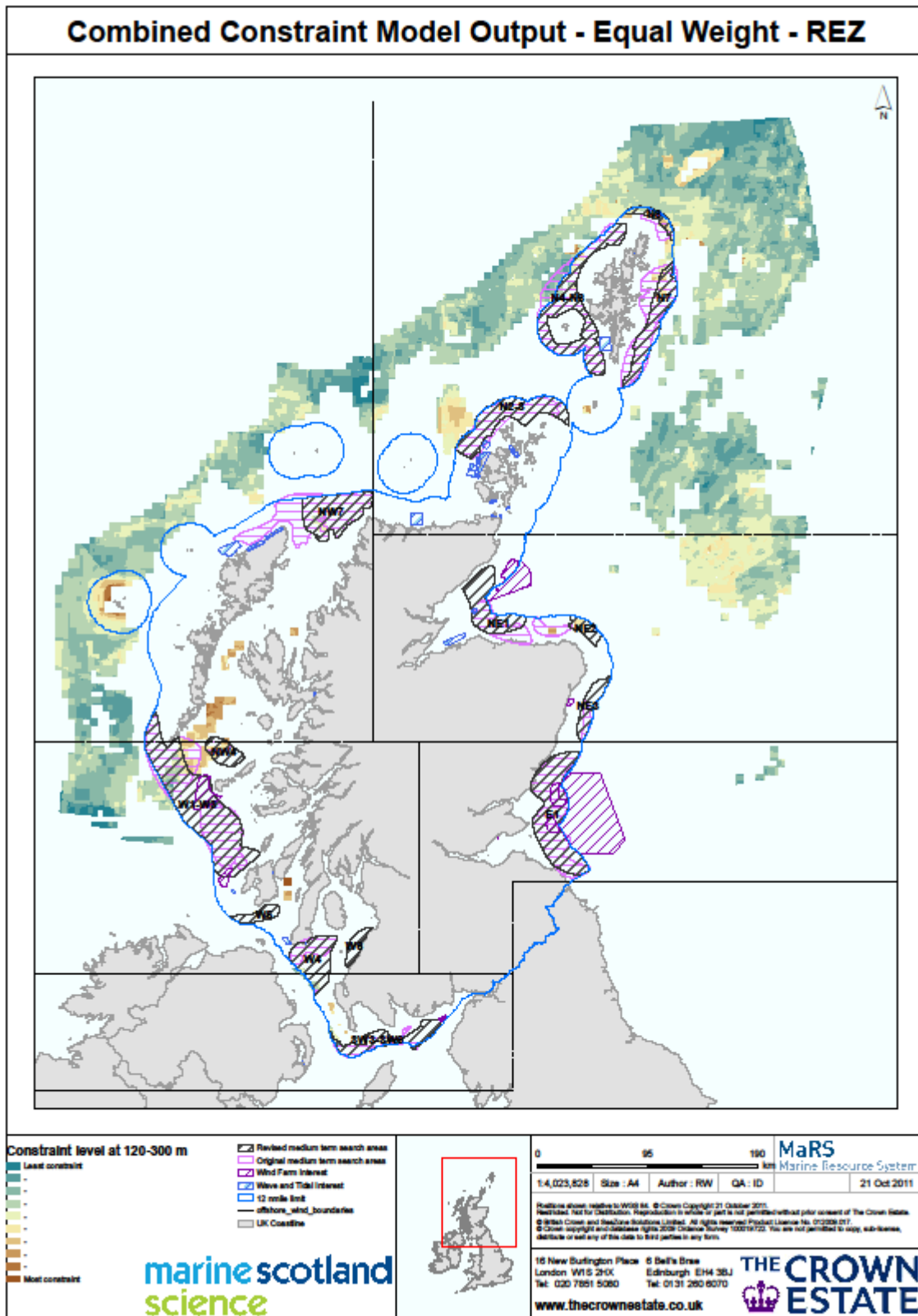
**Figure 13** The Combined Restriction model, giving equal emphasis to the environmental, industry and heritage themes, showing proposed strategic areas in STW, existing STW and Round 3 offshore wind sites, the 12 mile limit (boundary to STW) and the relative levels of constraint in waters of 0 – 60 metres depth.



**Figure 14** The Combined Restriction model, giving equal emphasis to the environmental, industry and heritage themes, showing proposed strategic areas in STW, existing STW and Round 3 offshore wind sites, the 12 mile limit (boundary to STW) and the relative levels of constraint in waters of 60 - 80 metres depth.



**Figure 15** The Combined Restriction model, giving equal emphasis to the environmental, industry and heritage themes, showing proposed strategic areas in STW, existing STW and Round 3 offshore wind sites, the 12 mile limit (boundary to STW) and the relative levels of constraint in waters of 80 - 120 metres depth.



**Figure 16** The Combined Restriction model, giving equal emphasis to the environmental, industry and heritage themes, showing proposed strategic areas in STW, existing STW and Round 3 offshore wind sites, the 12 mile limit (boundary to STW) and the relative levels of constraint in waters of 120 - 300 metres depth.

## 6 The Next Steps

The current Scoping Study has used new data and improved data handling methods to develop a new view of the potential of Scottish offshore waters for wind energy projects. The Scoping Study did not use the existing Plan for Offshore Wind Energy in Scottish Territorial Waters as a starting point, but has built upon the Sensitivity Analysis of the spatial modelling that lies behind that Plan to develop a new and more robust approach, comparable to that used for the Scoping Study for wave and tidal power (Saltire Prize).

The use of a themed approach to the spatial modelling has allowed the sensitivity of the models to the relative importance given to different spatial factors to be explored, and the general comparability of the outputs from the four Combined Models gives confidence that the outputs from the current exercise are robust.

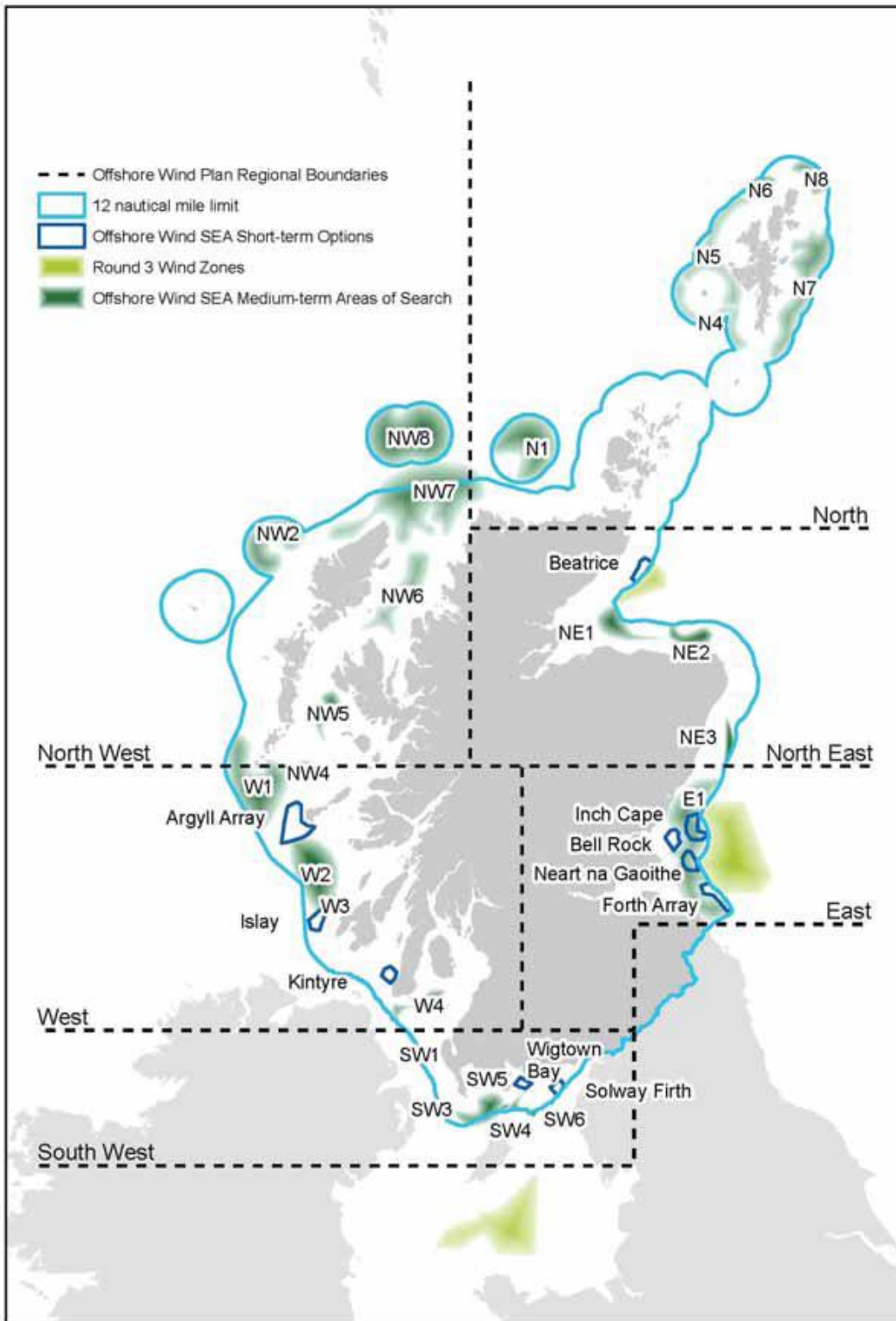
There are considerable similarities (and some differences) between the areas identified in the existing Plan as short or medium term search options, and those identified in this Scoping Study as strategic search areas of relatively low constraint on development. In view of the updating of data used, and the modifications to the data handling process between the two modelling exercises, this gives further confidence that the outputs are robust and can form the basis for further work.

As the potential for expansion of offshore wind energy in Scottish waters is becoming more clear, it will be necessary to take greater account of cumulative effects arising from interactions with other developments, or potential developments. For example, existing Round 3 and STW proposals in the Moray Firth, and off the Firths of Forth and Tay will be the background against which cumulative impacts of developments further offshore or in adjacent areas of STW will have to be considered. Similarly, proposals that emerge from the Northern Ireland leasing round may interact with proposals in the south and south west of Scotland.

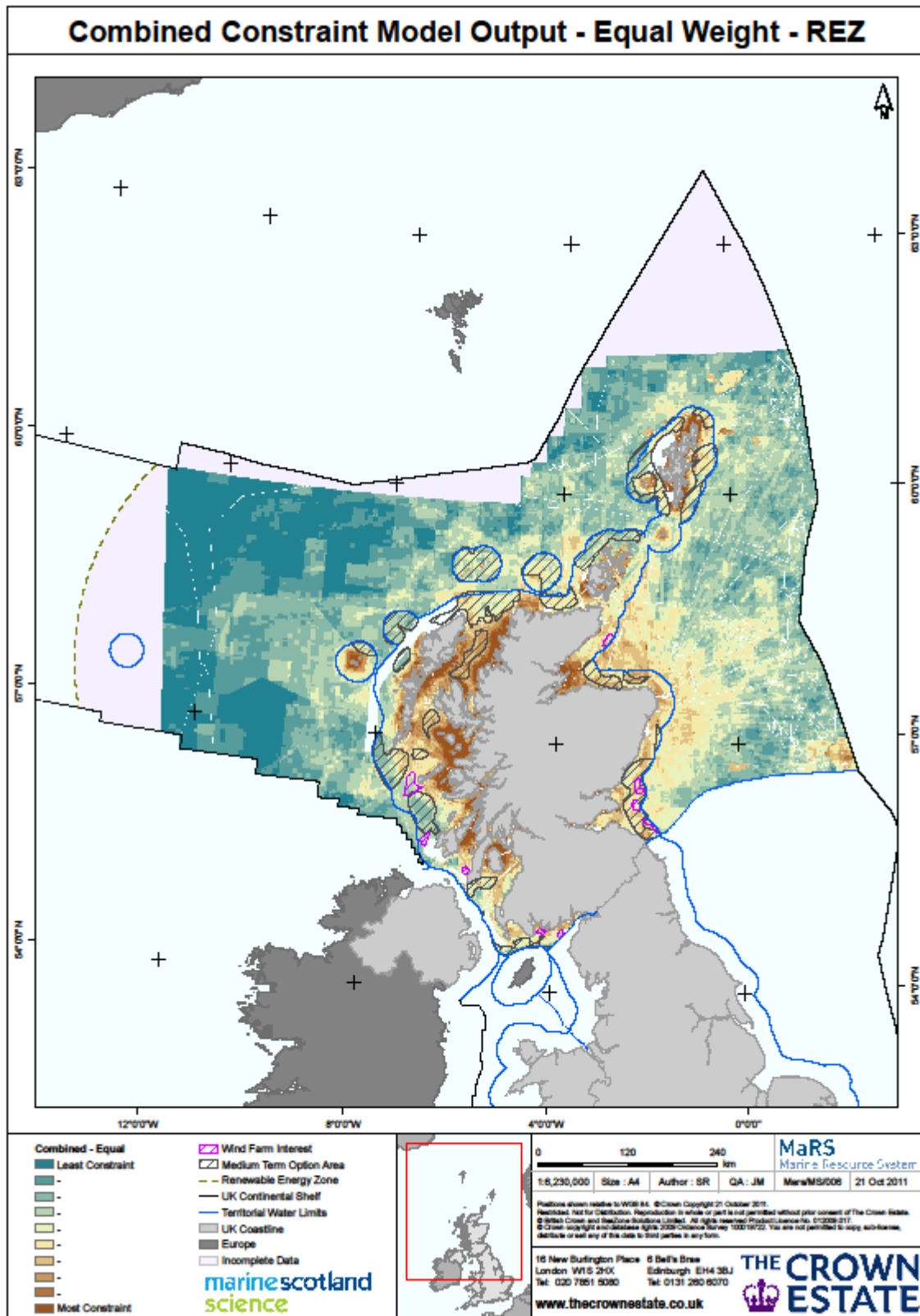
The current report has extended the scoping study to cover all of Scottish waters, i.e. including the 12 – 200 mile zone. The study shows that there is potential to expand wind farms in Scottish waters well outside the limits of Scottish Territorial Waters. While there are large potential opportunities available using current technologies (up to about 60m depth), the development of new and improved technologies to operate in water of greater depth could release very extensive additional areas for potential development.

The output maps presented in this report cover the whole of Scottish waters. Inevitably, the scale of the maps result in some local detail being difficult to discern, as are details of technical constraints. The next stage in the extension of the Plan for Offshore Wind Energy out from territorial waters to cover all Scottish marine waters is therefore to address each of the potential development areas in more detail through a Regional Locational Guidance process.

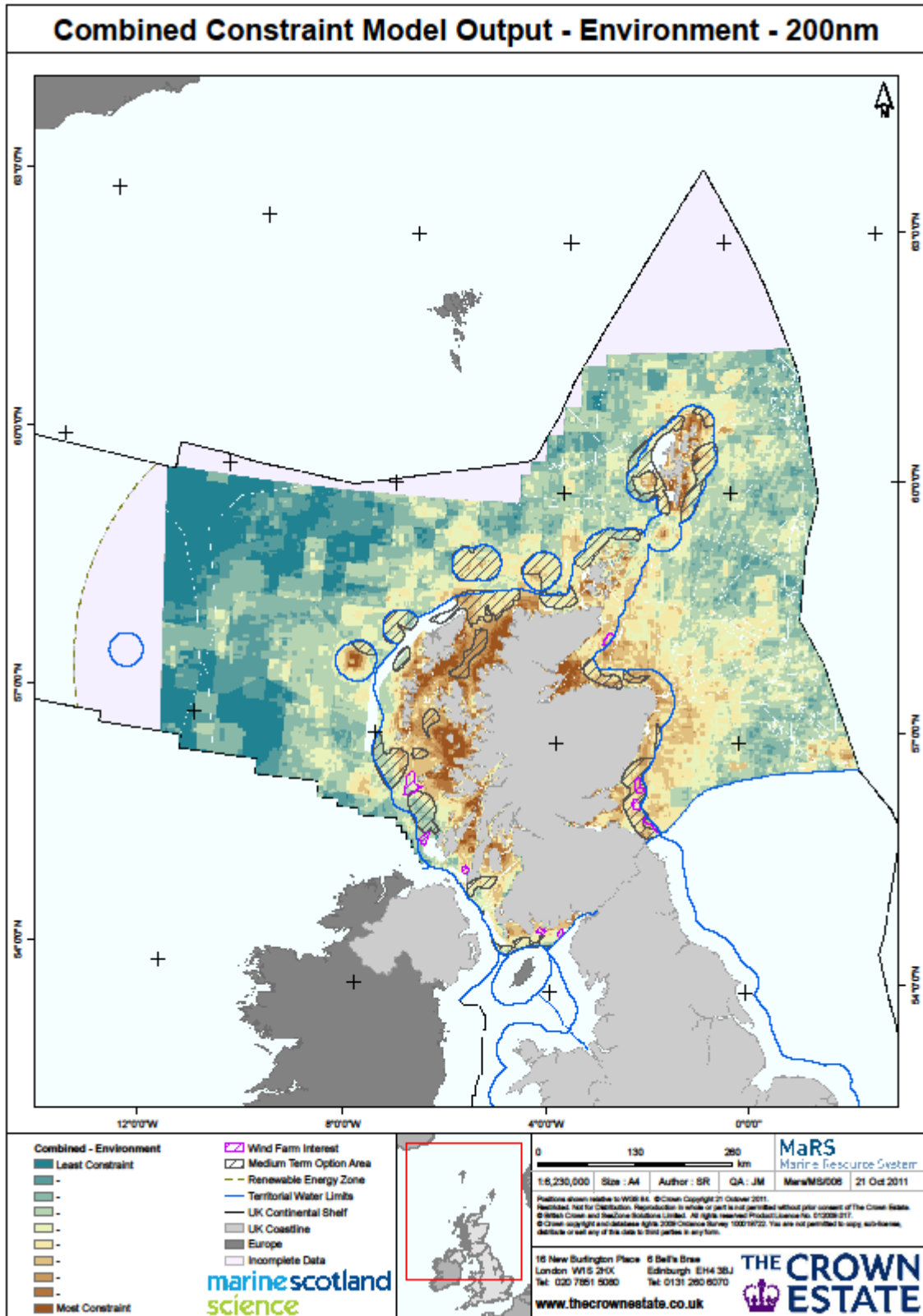
Annex 1



**Figure A1** Short and medium term options included in the Draft Plan for Offshore wind energy in Scottish territorial waters.

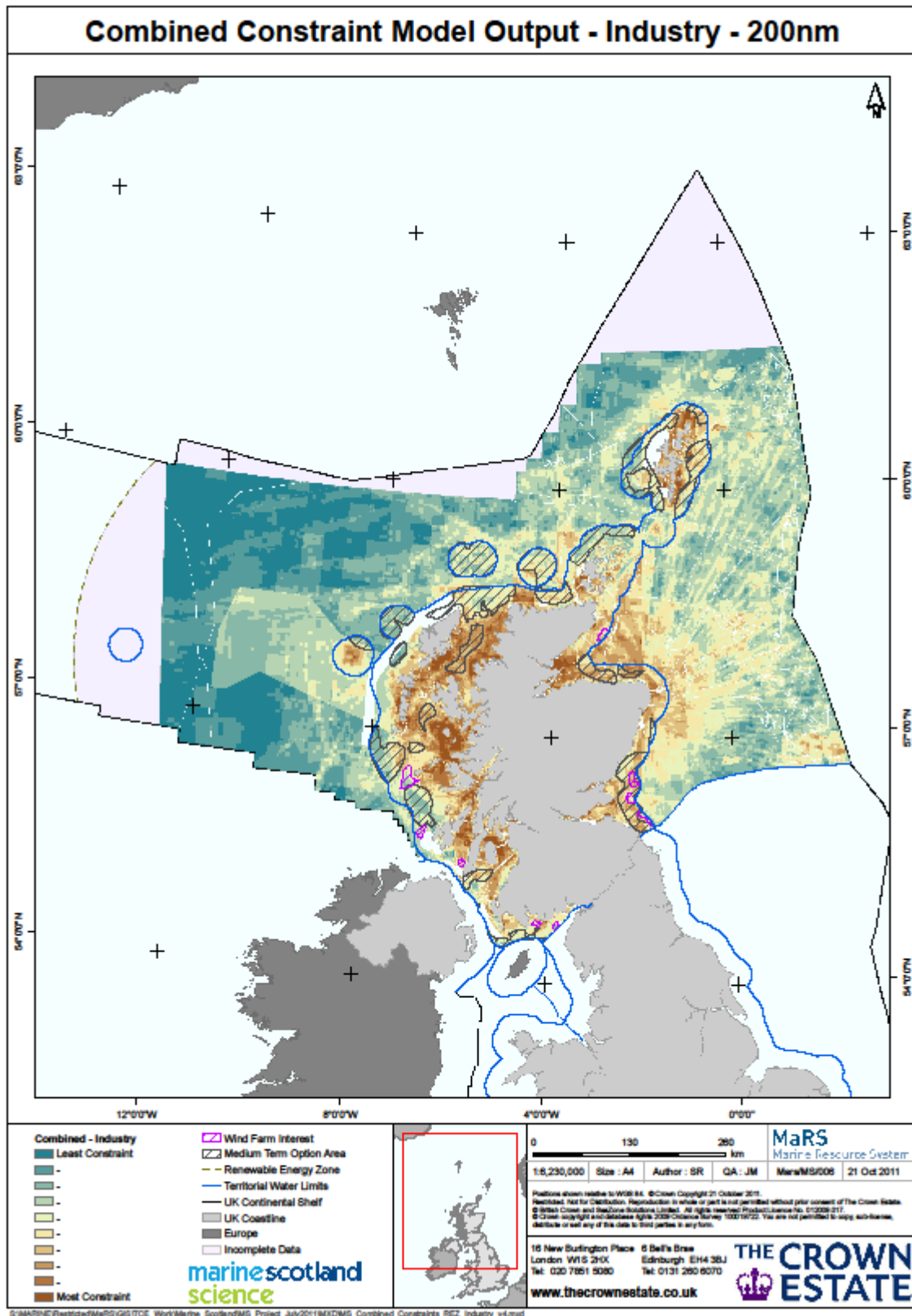


**Figure A2** Distribution of short and medium term offshore wind energy options (Draft Plan) and the Combined Restriction model, giving equal emphasis to the environmental, industry and heritage themes.

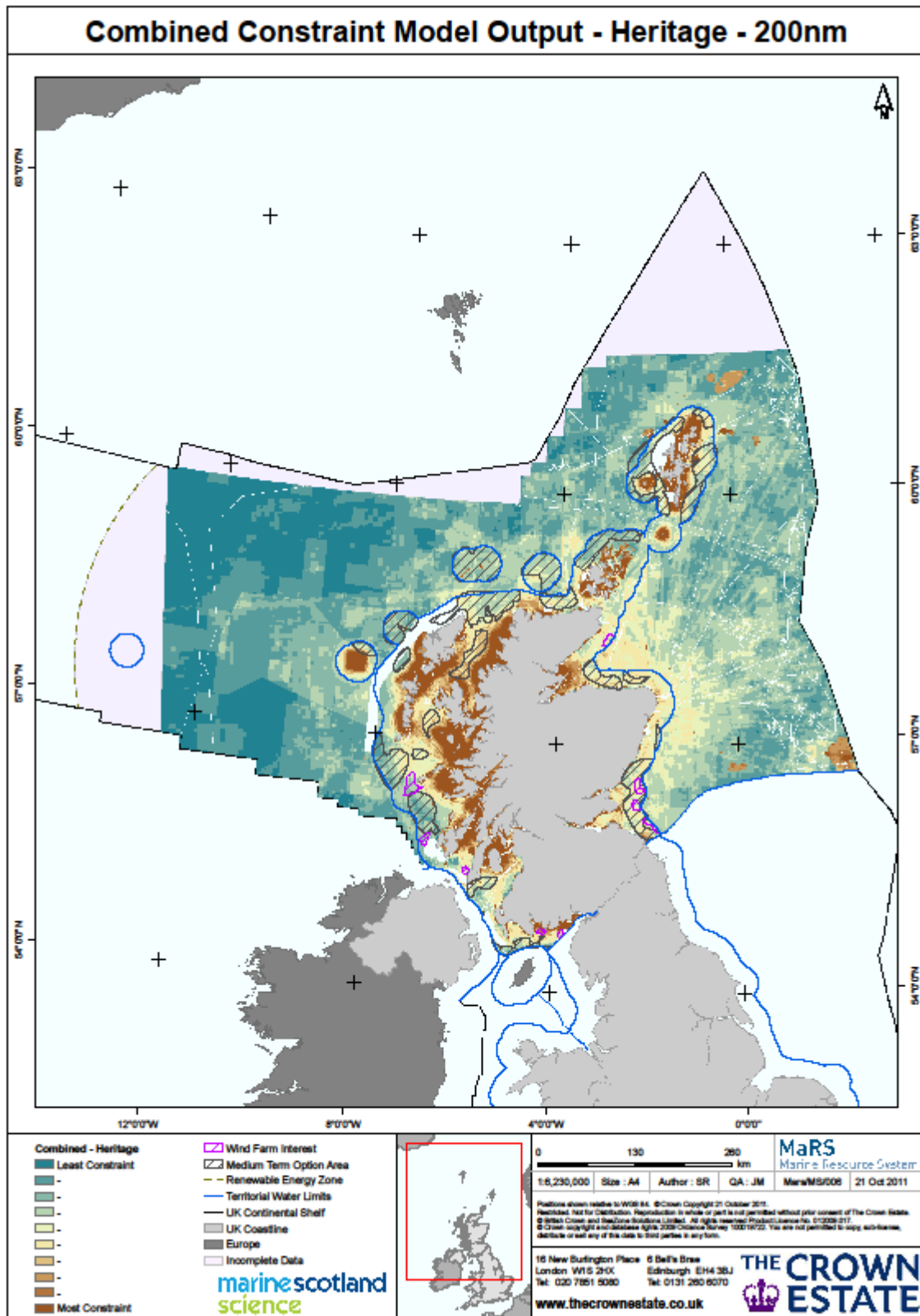


**Figure A3** Distribution of short and medium term offshore wind energy options (Draft Plan) and the Combined Restriction model, emphasising the environmental theme.





**Figure A4** Distribution of short and medium term offshore wind energy options (Draft Plan) and the Combined Restriction model, emphasising the industry theme.



**Figure A5** Distribution of short and medium term offshore wind energy options (Draft Plan) and the Combined Restriction model, emphasising the heritage theme.



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