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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, the Scottish Government has adopted an iterative approach to marine planning for the renewable energy sectors. 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. A new Scoping Study extends the potential development area out to 200 nm.

A sensitivity analysis of the process used to develop the offshore wind 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.

A process was therefore put in place by Marine Scotland to develop a Scoping Report for the potential for wave energy development in Scottish waters out to 200 nautical miles, building on the Scoping Study undertaken for the Saltire Prize (Harrald and Davies, 2010). This

report describes the process employed by Marine Scotland in collaboration with The Crown Estate to develop a series of new wave energy plan options within Scottish marine waters.

The Crown Estate spatial modelling tool MaRS was used to create multi-factorial expressions of the technical opportunities and constraints on offshore wave energy 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 the distributions of certain sensitive species, and a broad field of "socio-cultural" 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 wave energy developments within Scottish Territorial Waters (STW).

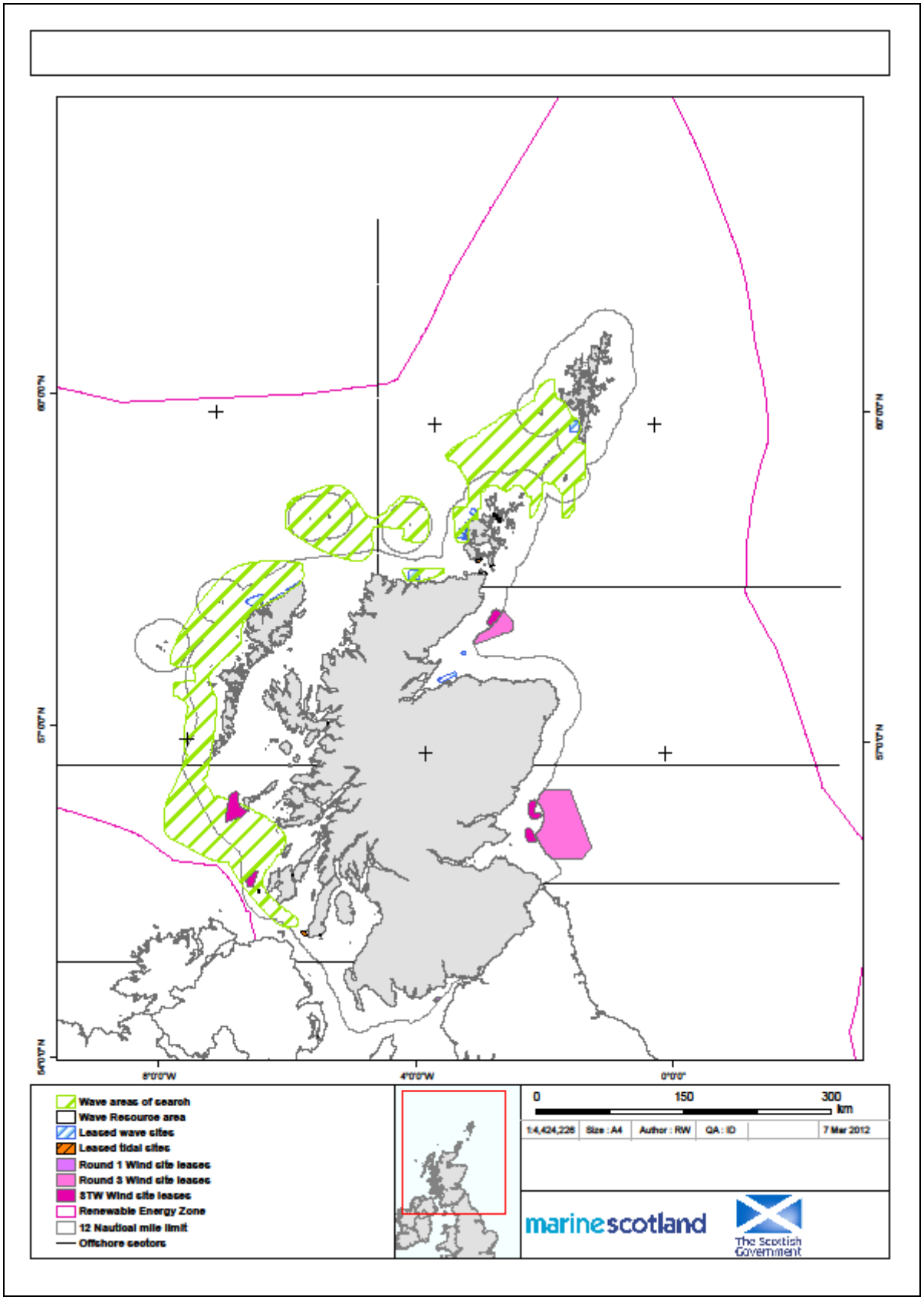

Figure S1 Areas of search for offshore wave plan option areas identified within Scottish marine waters, and marine renewable energy development areas currently within the Marine Scotland Marine Licence process.

Consideration of the resource areas, and the constraints on development arising from environmental, industry and socio-cultural factors discussed above, lead to the identification of four areas of search for wave energy development options in Scottish waters (Figure S1). The areas are limited to areas where wave energy is >20 kw/m in water depths of less than 90m, to broadly reflect the depths for which developer interest is currently being expressed. The areas are:

A. West of the Hebrides
B. North West of Cape Wrath
C. Orkney and Shetland
D. North Sutherland coast

The geographical extent of these areas A – C is large enough for there to be opportunities for fully commercial scale development of wave energy projects. Area D is relatively small and close to the boundary of the resource area. The resource areas, and areas of search, for wave energy developments occur both within and beyond Scottish Territorial Waters. In detail, there is variation between low and moderate levels of constraint within these broad areas, and more detailed assessment through Regional Locational Guidance will be required to derive plan options for wave energy.

This analysis should not be taken to imply that there are no useful wave resource areas elsewhere around Scotland. The identification of resource areas has been based upon wave energy maps taken from the DECC Renewables Atlas (DECC, 2008). The wave information in that Atlas is presented as a grid of data, with cell size of 1.8 km. Resource areas smaller than this may well not be represented, and uncertainties in the boundaries of resource areas up to the scale of a few cells, or immediately adjacent to the coast, may be poorly represented. It is also likely that some smaller wave energy devices may be able to function economically in areas of less than 20 kw/m available energy. Such areas will not have been captured by this scoping study, but in favourable locations may offer considerable potential for small (and perhaps medium) scale developments for testing or commercial purposes.

The outputs from this study will inform the marine planning process by leading to the development of Regional Locational Guidelines for wave energy development, which in turn will be the basis for the Sustainability Appraisal to cover tidal stream energy development in Scottish waters. This process involves Strategic Environmental Assessment (SEA), Habitats

Regulations Appraisal, Socio-economic Assessment, as well as statutory consultation with key sectors, stakeholders and the wider public.

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
- 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.

It was recognised several years ago that Scotland was potentially uniquely placed in relation to the potential for wave energy development, with a long coastal margin (including offshore islands) exposed to the open waters of the North Atlantic. A Strategic Environmental Assessment of the potential for wave and tidal power developments in Scottish Territorial Waters to the north and west of Scotland (Scottish Government, 2007) confirmed this potential, and identified the need to ensure that environmental interactions, and interactions with other users of the sea were taken into account when creating development plans and considering individual projects in the licensing process.

Subsequently, renewable energy, including marine renewables, has become a key aspect of the Scottish Government's economic strategy. The need to encourage technological development and install early projects in the sea led to the creation of the Saltire Prize (http://www.sdi.co.uk/sectors/saltire-prize.aspx). Smooth development of potential Saltire Prize projects was assisted by the adoption of a marine planning approach to the identification of areas with the necessary wave or tidal stream resource, and in which interactions with other uses, and sensitivities, of the sea were minimised. This was achieved through a Scoping Study for wave and tidal power (Harrald and Davies, 2010), and supporting Regional Locational Guidance (RLG, Harrald *et al*., 2010). The result is that there are now more than projects with exclusivity agreements for lease for wave and tidal

power in Scottish waters, together with a further 11 commercial scale projects (a total of 1.6 GW) in the Pentland Firth and Orkney Waters Strategic Area.

The Saltire Prize Scoping Study was developed from a brief that emphasised the need to avoid sensitive areas. The report (Harrald and Davies, 2010) noted that these conditions were more restrictive than might be applied in wider development contexts. Since the Saltire Prize Scoping Study was completed, new information on interactions with the environment and other users has become available, together with new ways to handle the underlying data. Furthermore, the Scottish Government is now responsible for marine planning out to the 200 mile limit. These, and other factors, have come together to indicate a need to undertake a new Scoping Study for wave power, covering all Scottish waters, together with new Regional Locational Guidance, to form the basis for a development plan and supporting Sustainability Appraisal.

The new Scoping Study described in this report is one of a series covering offshore wind, wave and tidal stream energy. They form part of a process of regular revisions and updates of sectoral plans for offshore energy, including energy from wave power. The process to develop the Plan is being supported by using The Crown Estate's Marine Resource System (MaRS) to map zones of broad environmental sensitivity and technical opportunities and constraints.

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 wave 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. A system of scoring and weighting of information held in MaRS is used to produce graduated maps of the least to greatest technical, and subsequently environmental, and socio-cultural sensitivity. From these outputs, broad areas of technical opportunity and relatively low constraint on development can be identified and explored in more detail through Regional Locational Guidance.

The first Scoping Study for offshore wave energy in Scottish waters was undertaken in 2010. Experience of both that exercise and subsequent exercises (e.g. Davies and Watret, 2011) has shown that the conclusions are 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.

Furthermore, a sensitivity analysis of the outputs from the Draft Plan for offshore wind (Davies and Aires, 2011) noted that improvements in the available data had occurred since the Draft Plan had been prepared. For example, European Seabird at Sea (ESAS) data were now available in a compiled form suitable for inclusion in spatial modelling. Other data layers are progressively being updated and improved, demonstrating the need to keep sectoral plans under cyclical review to ensure that the outputs are as robust as possible. taking account of the best current information and data handling methods. 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 opportunities for 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 wave energy 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 Guidance for wave energy development, which in turn will be the basis for a Sectoral Marine Plan and Sustainability Appraisal to cover wave energy development in Scottish waters.

2 Approach

As was the case in the development of the Scoping Study for the Saltire Prize programme for wave and tidal power development, and parallel documents for wind energy, Marine Scotland has worked with The Crown Estate to use MaRS for the identification of potential areas for offshore wave power 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 wave energy 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 wave energy 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.

Building on experience of the Scoping Studies for the Saltire Prize, and, the data layers were grouped into themes (e.g. technical, industrial, environmental, socio-cultural). This procedure minimises the conceptual problems associated with defining appropriate relative weightings for very diverse types of data (e.g. the relative weightings of seabird colonies, fisheries landings, and basking shark sightings). The thematic grouping allows assessment of 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, and also in the Scoping Study for Offshore Wind in Scottish waters (Davies and Watret, 2011). 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 socio-cultural interests.

The modelling for this wave energy scoping study built upon the experience gained in the Saltire Prize modelling and subsequently in the Sensitivity Analysis (Davies and Aires, 2011) and updated Scoping Study for offshore wind (Davies and Watret, 2011). The wave study adopts a similar separation of data layers between constraint and exclusion models, to maintain a balance in the influence that different data layers have on the model outputs. Further efforts were made to ensure that the scoring systems for the various layers followed the statistical advice within the MaRS modelling guidance, and that the scoring system for statistically skewed data sets was appropriate, both in the resultant influence of the layers in the models and the degree of discrimination between areas. Where possible, improved or updated data layers were used in the current Scoping Study, as indicated in Section 3 below.

3 Structures of the Models Used

As described in the documentation supporting The Strategic Environmental Assessment for Offshore Wind (Scottish Government, 2010a), 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 technical resource assessment or to a non-Technical Model. The non-Technical Constraints Model was comprised of the outputs from three thematic Restriction models, covering constraints arising from industrial activity, environmental factors, and socio-cultural interests. The socio-cultural 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 Socio-cultural Restriction Model (MaRS ref. 2569)

Data layer	Weight	Maximum score	Potential relative influence
Landscape	1000	182	182000
Royal Yachting Association cruising routes	500	50	25000
Royal Yachting Association racing areas	500	50	25000
Royal Yachting Association sailing areas	500	50	25000
Scheduled Ancient Monuments	800	80	64000
Surfing beaches	700	100	70000
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 (MaRS ref. 2570)

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	900	100	90000
Offshore candidate SACs	1000	100	100000

and SPAs			
Offshore draft SACs and SPAs	1000	100	100000
Offshore possible SACs and SPAs	1000	100	100000
RAMSAR sites	1000	100	100000
Possible sea haul out sites	600	60	36000
Areas of importance to basking sharks	400	73	29200
Nursery areas for commercial fish species	300	55	16500
Spawning areas for commercial fish species	300	55	16500
Areas of search for potential Marine Protected areas	600	60	36000
Areas of search for seabird aggregations	400	40	16000
Areas of importance to breeding sea birds	400	73	29200
Areas of importance to sea birds in winter	400	73	29200
Areas of importance to marine mammals	800	145	116000

3.3 Industry Restriction Model (MaRS ref. 2566)

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
Current Licensed Areas for Hydrocarbons	700	70	49000
Closed waste disposal sites	700	70	49000
Military Practice and Exercise Areas	1000	180	180000
Shipping density	800	145	116000
Ferry routes	1000	100	100000
Commercial fisheries – combined layer covering inshore and offshore, mobile and static gear landings from mobile gear in inshore waters	1000	182	182000
Dredging	1000	100	100000

3.4 Non- technical Exclusion Model (MaRS ref. 2567)

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

All Offshore Cable inside UK Waters
All Pipeline in UK Waters (active)
Anchorage Areas
Aquaculture Leases – Current
Aquaculture Leases - Pending
Waste disposal sites (open)
IMO Routeing - excluding ABTAs
Munitions Dumps
Navigation aids
Offshore Shipping Zones
Offshore Wind Farm Demonstration Sites
Operational Anemometers in UK Waters
Protected Wreck Exclusion Buffers
UK offshore wind activity
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 Wave Power Resource Assessment

Wave power resource was assessed in terms of the power density (kw/m), and limited to depths of water of less than 200m. The former provides an indication of the available energy, to ensure that the necessary wave power is available at a potential development site, while the limitation to less than 200m reflects extent of the continental shell, which is anticipated to be the initial potential scope of development.

The resource assessment therefore excluded areas where there was considered to be insufficient wave energy resource (20 kw/m) for commercial scale developments, and also areas where the water depth was less than 10m or greater than 200m.

The outputs from the restriction models, after normalisation against the exclusion model, should be viewed in the context of technical (resource) opportunities and constraints of the areas under consideration.

3.6 Improvements to the Previous Spatial Modelling

The use of MaRS to develop Scoping Studies for marine renewable energy has been characterised by progressive improvements in the available data, and the data handling. Some significant differences from, and additions to, previous models have been implemented in the current exercise. The main improvements made were:

1 Landscape and visual issues: Develop a buffering system around national scenic areas (NSA), local coastal landscape designations, and other coastal areas to reflect the relative importance of landscape in different coastal areas, and the decreasing visibility of wave power devices with distance from NSA boundaries and other areas of coast.

2 Surfing beaches. There is some potential for wave energy devices close to the coast to affect the wave spectrum reaching the coast, and this in turn may affect the suitabiloity of coastal areas for surfing. The locations of surfing beaches were taken from National Marine Plan interactive (NMPi), the data underlying the development of Scotland's Marine Atlas (Scottish Government, 2011a) and buffered to a distance of 10 km.

3 Commercial fishing: A separate MaRS model was created for the commercial fishing sector. Within that model, landings from smaller vessel operating within STW, and landings from >15m vessels (i.e. those covered by the Vessel Monitoring System) were identified and distinction was made between static and mobile gears. In inshore waters, landings were partitioned between internal waters, 0 – 6 miles, 6 – 12 miles, and landings from greater distances within ICES statistical rectangles that also include areas within STW were identified. Based on current wave project design plans, is likely to be difficult to operate commercial fishing activities, using either mobile or static gear, within the footprint of wave farms. In combining the commercial

fishing data into a single layer, the four combinations of inshore and offshore vessels, mobile and static gear, were therefore given the same weight.

4 The offshore wind Scoping Study gave considerable weight to factors related to aviation. These factors are omitted from the current study, as interactions between wave farms and aviation are likely to be insignificant.

5 A additional data layer was included in the industry model to take account of the many navigational aids in both inshore and offshore areas.

6 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. This layer had initially been used in the wind Scoping Study (Davies and Watret, 2011), and was carried forward into the current study.

7 Sensitivity of areas to seabirds: An initial approach was made to developing indices of the relative sensitivity of sea areas for vulnerable seabirds. Collision with wave energy devices is likely to be minor risk to seabirds, but disturbance during construction and operation may be of greater concern. Mapped data on the distribution of 17 SPA species of sea birds at sea during the breeding and winter seasons (European Seabirds at Sea survey, JNCC) were expressed in terms of the total Scottish population of each species. These distributions were combined to give an overall expression of the relative sensitivity of sea areas in the winter and in the breeding season.

8 Disturbance of seals at sensitive periods in their life cycle may arise from the construction and operation of wave farms in coastal waters. Following from the Marine (Scotland) Act 2010, preliminary work has been carried out to identify important seal haul out and breeding sites around Scotland. A data layer was created showing haul out sites for both grey and harbour seals, and buffers created out to 30 km.

9 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.

10 Spawning and nursery areas: Maps derived from Coull et al. (1998) 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.

11 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 was done in the Saltire Prize Scoping Study) 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 previous reports, for improvements to underlying data, almost all were achieved and further additions made. Exceptions were:

a) that SACs were not filtered for sensitivity to wave energy developments.

b) the distribution of SNH Priority Marine Features (PMF) 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.

4 Results of the MaRS Modelling

4.1 Wave Resource Assessment

The wave resource assessment provides the necessary background against which the range of environmental, socio-cultural and industry factors must be assessed. Unlike tidal stream power, the areas with potential for wave energy developments in Scottish waters are not strongly limited by the availability of the power resource. The resource assessment output

(Figure 1) clearly indicates that the resource area covers large areas of the sea to the west, north and east of Scotland. The least technically constrained areas are to the west and north of Scotland, while the resource area in the North Sea is progressively more constrained to the south by decreasing wave power.

The resource assessment is dominated by the distribution of wave energy. Offshore waters to the west of the Outer Hebrides are fully exposed to the open North Atlantic and contain the most powerful wave resources in Scotland. Current development interest is mainly in waters closer to shore (for example, west of Orkney, Shetland and Lewis) where although the wave resource is rather less, other technical aspects combine to make the areas potentially attractive for development at this time. The powerful resources further offshore indicate that there is considerable scope for expansion into new areas as technical capabilities improve.

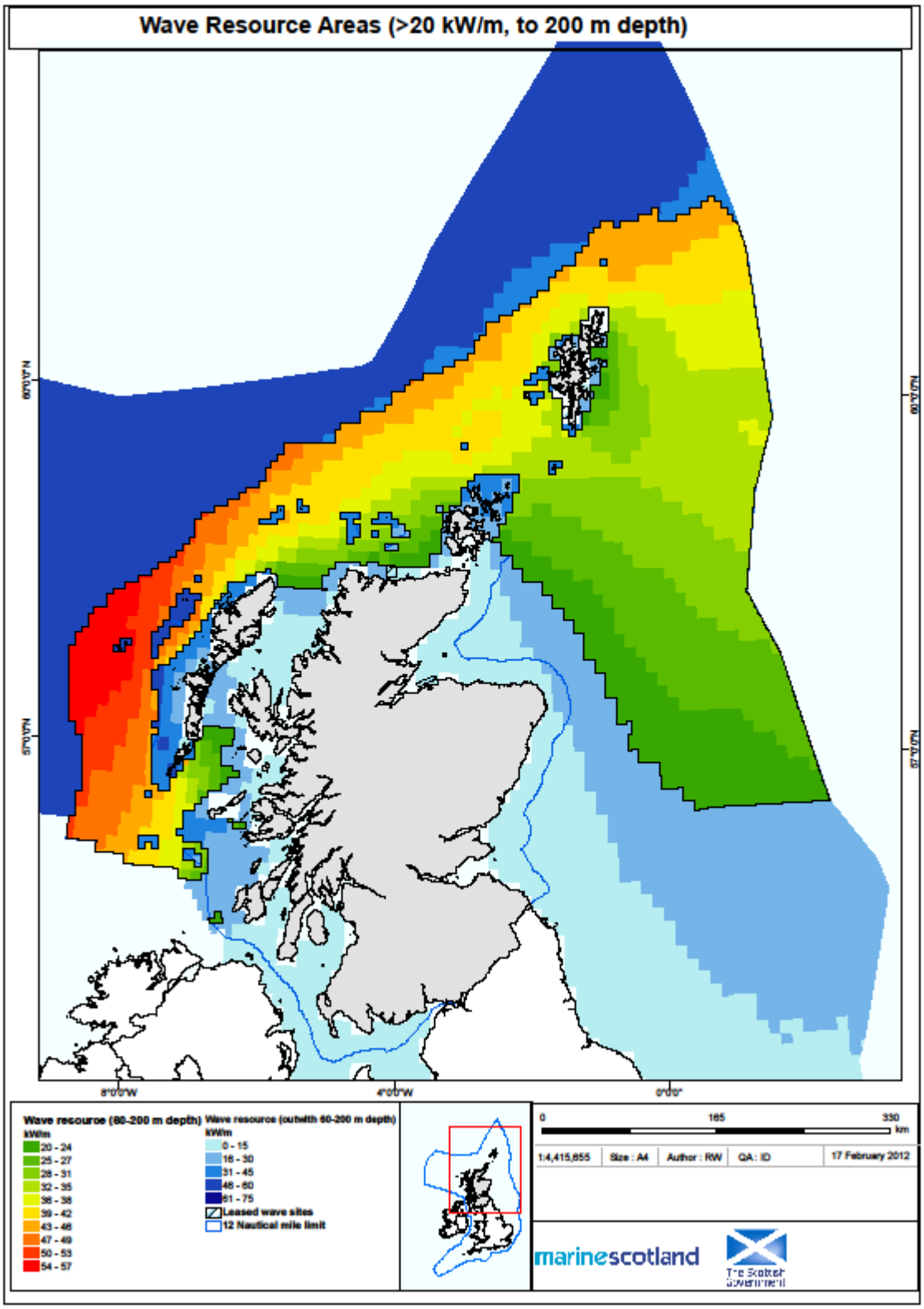

Figure 1 Resource assessment for offshore wave energy development in Scottish waters.

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, shipping routes and military exercise areas. 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), and some of our most valuable fishing grounds are in the sheltered waters of the Minch.

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 are 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 Socio-Cultural Restriction Model

The output from the Socio-cultural 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 close to the coast, and particularly areas in and adjacent to National Scenic Areas, where particular importance of landscape considerations may be anticipated. Further contributions to socio-cultural restrictions arise from yachting and sailing activity, surfing beaches and the potential for sub-sea archaeological remains.

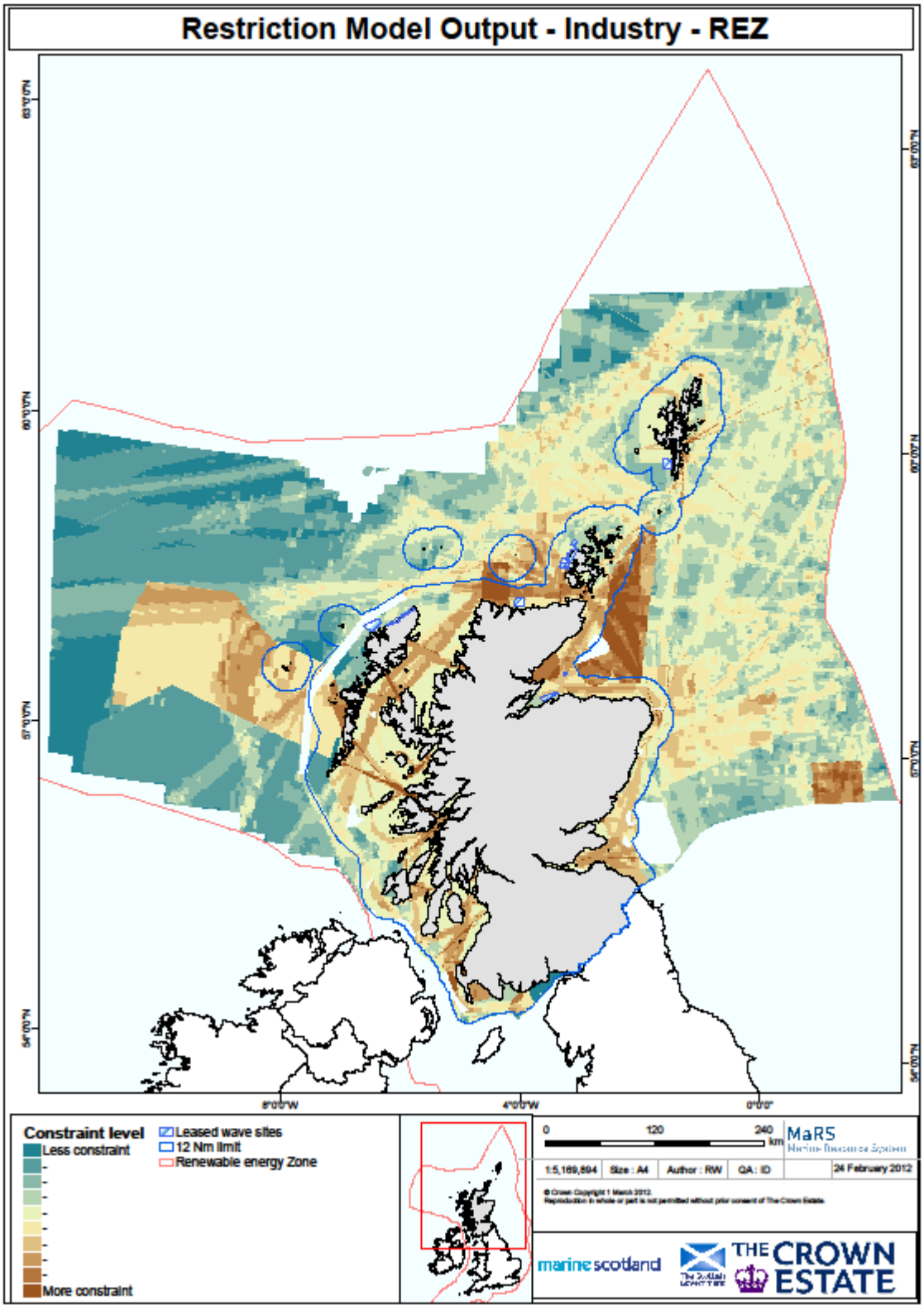

Figure 2 Output from the Industry Restriction model for offshore wave energy development in Scottish waters.

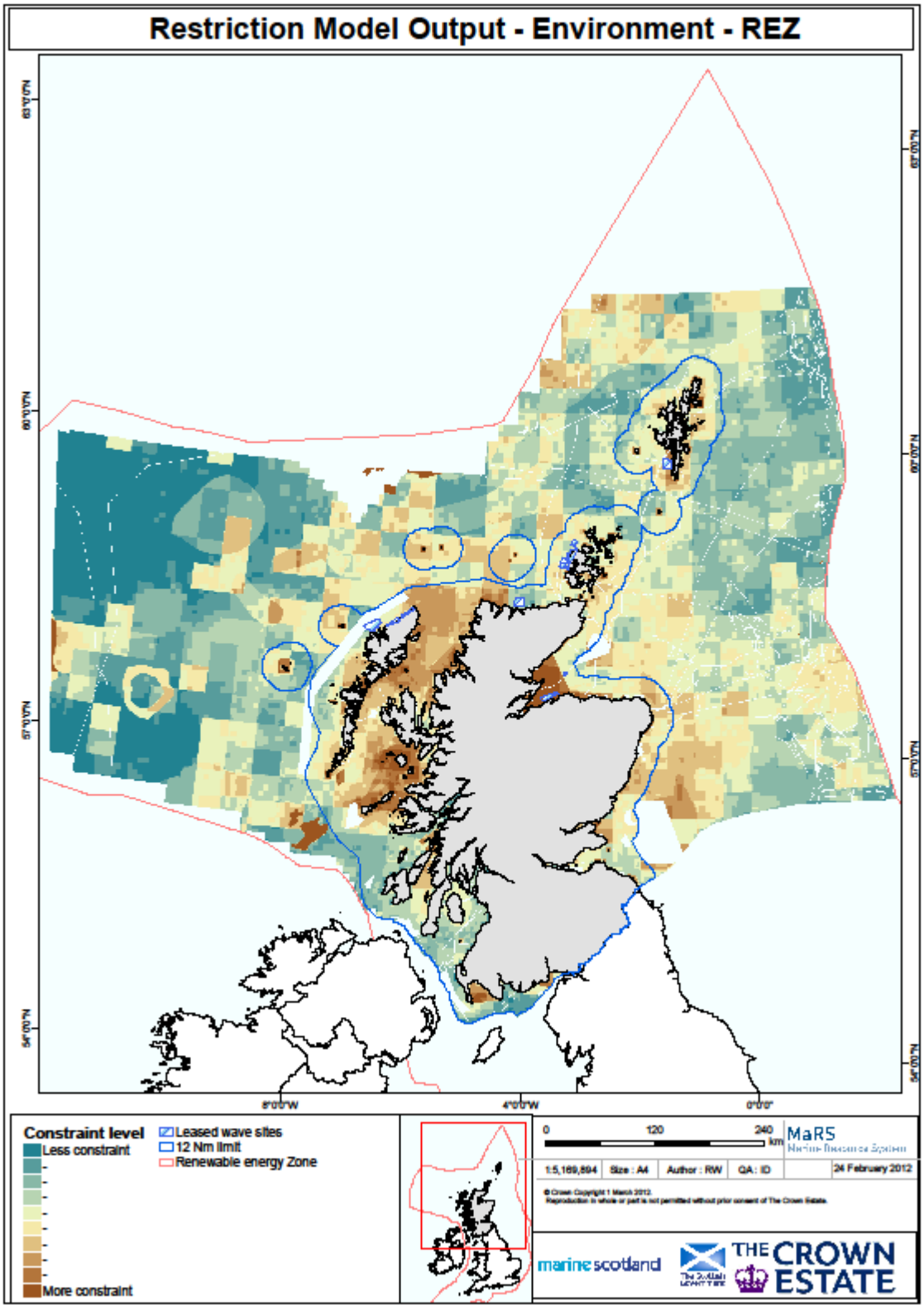

Figure 3 Output from the Environmental Restriction model for offshore wave energy development in Scottish waters.

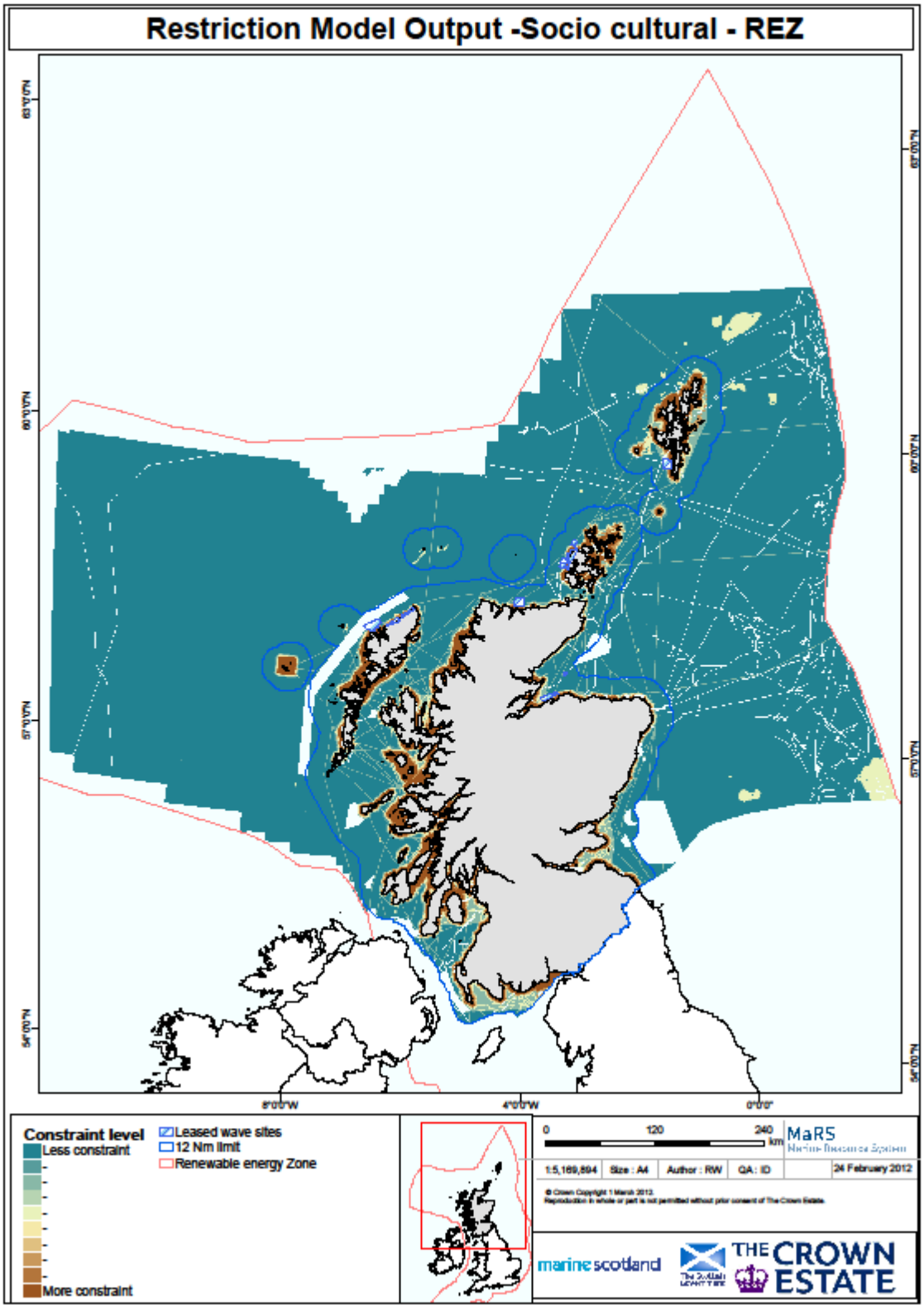

Figure 4 Output from the Socio-cultural Restriction model for offshore wave energy development in Scottish waters.

4.5 Combined Models

An expression of the overall level of constraint on wave energy developments in Scottish waters needs to take account of environmental, industry and socio-cultural restrictions. The presentation of the information by theme has been shown to reduce 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

	Environment theme	**Industry theme**	**Socio-cultural theme**	**MaRS model ref.**	**Figure**
Equal weighting constraints model	100	100	100	2592	Figure 5
Environmental focused constraints model	200	100	100	2590	Figure 6
Industry focused constraints model	100	200	100	2591	Figure 7
Socio-cultural focused constraints model	100	100	200	2589	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 moderately to 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 moderate constraint is present over much of the Moray Forth and persists and for 30 miles or more offshore of most of the east coast. This feature is much less prominent in the model which emphasises socio-cultural interests, possibly because of the greater importance of designated scenic areas on the west coast.

5 The model emphasising socio-cultural interests is dominated by landscape issues in the inshore waters west of Scotland in Orkney and Shetland. Landscape is generally considered to be a less significant issue for wave energy projects than for wind power projects, and this is reflected in the confining of the high levels of constraint to the area of sea immediately adjacent to the coast. The underlying landscape layer was based upon floating devices, or devices which emerge from the sea by a few metres. It may be anticipated that wholly submerged devices, or those which emerge to a lesser degree, would be considered to have less interaction with the landscape.

5 The degree of constraint in offshore waters in the Solway Firth is generally low to moderate. However, issues of conservation designation and landscape clearly increase the sensitivity in waters immediately adjacent to the coast.

6 Generally, the levels of constraint outside STW is much less than that within STW. It is 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.

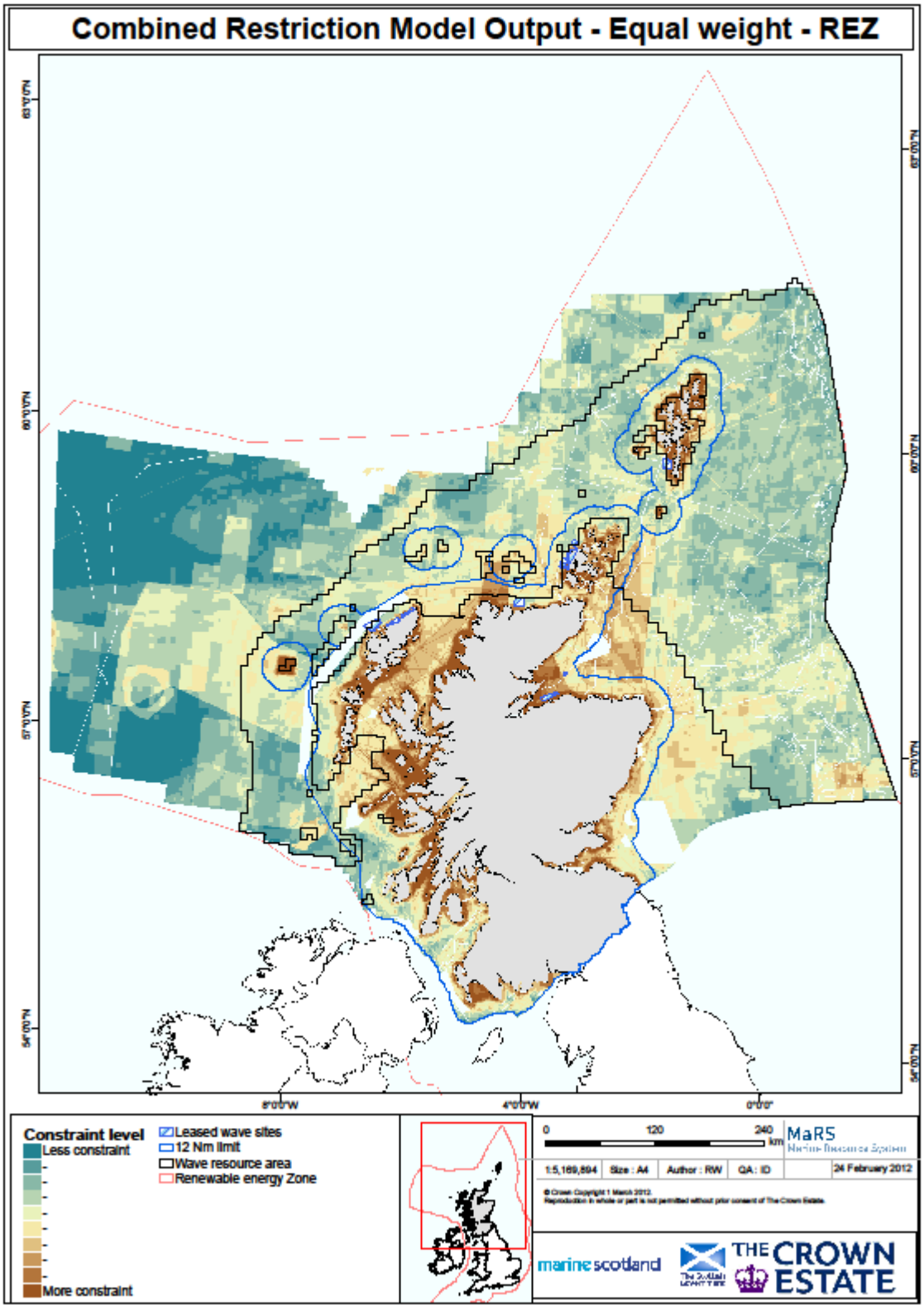

Figure 5 Combined restriction model, giving equal weight to the environment, industry and socio-cultural themes.

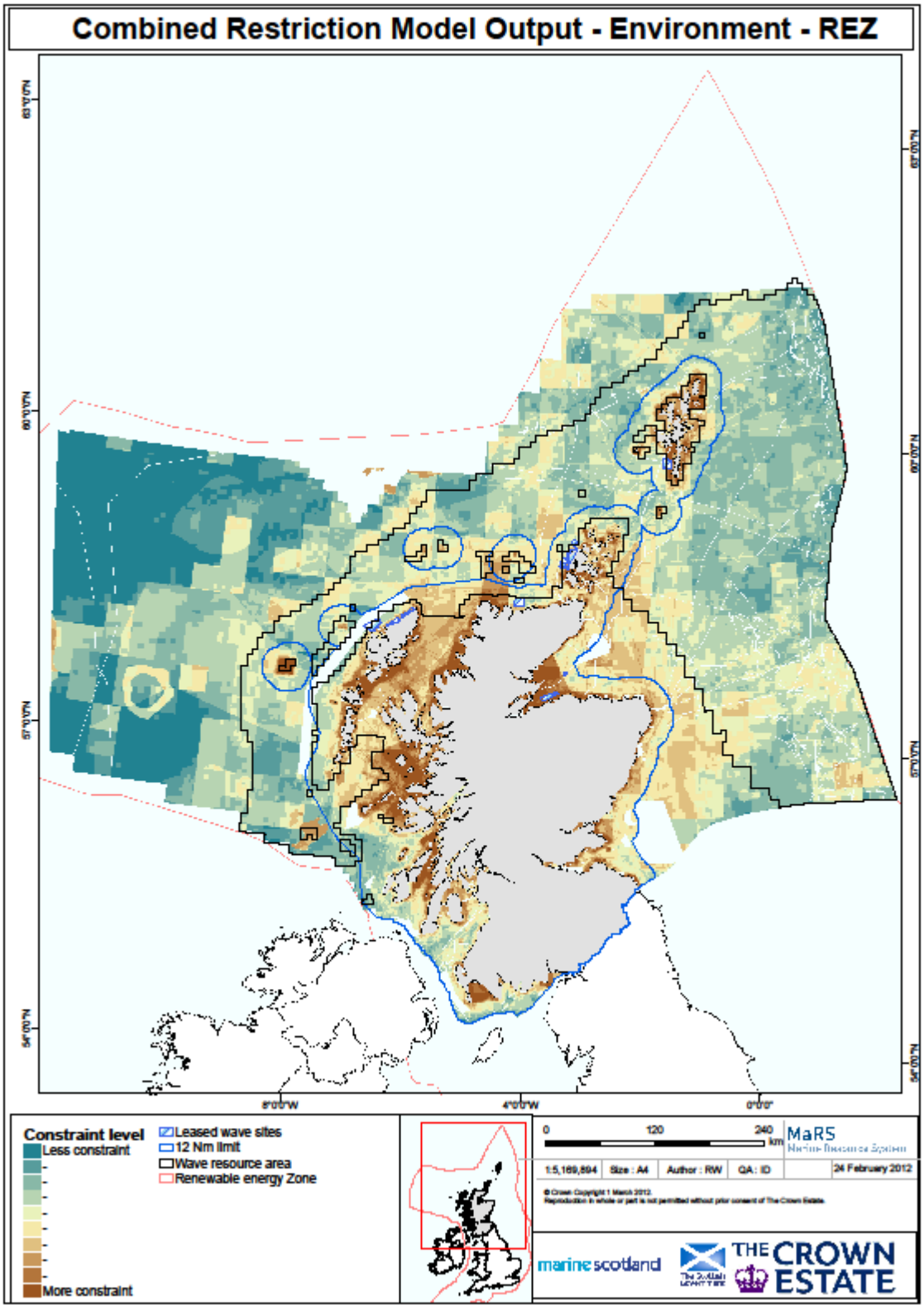

Figure 6 Combined restriction model, emphasising the environment theme.

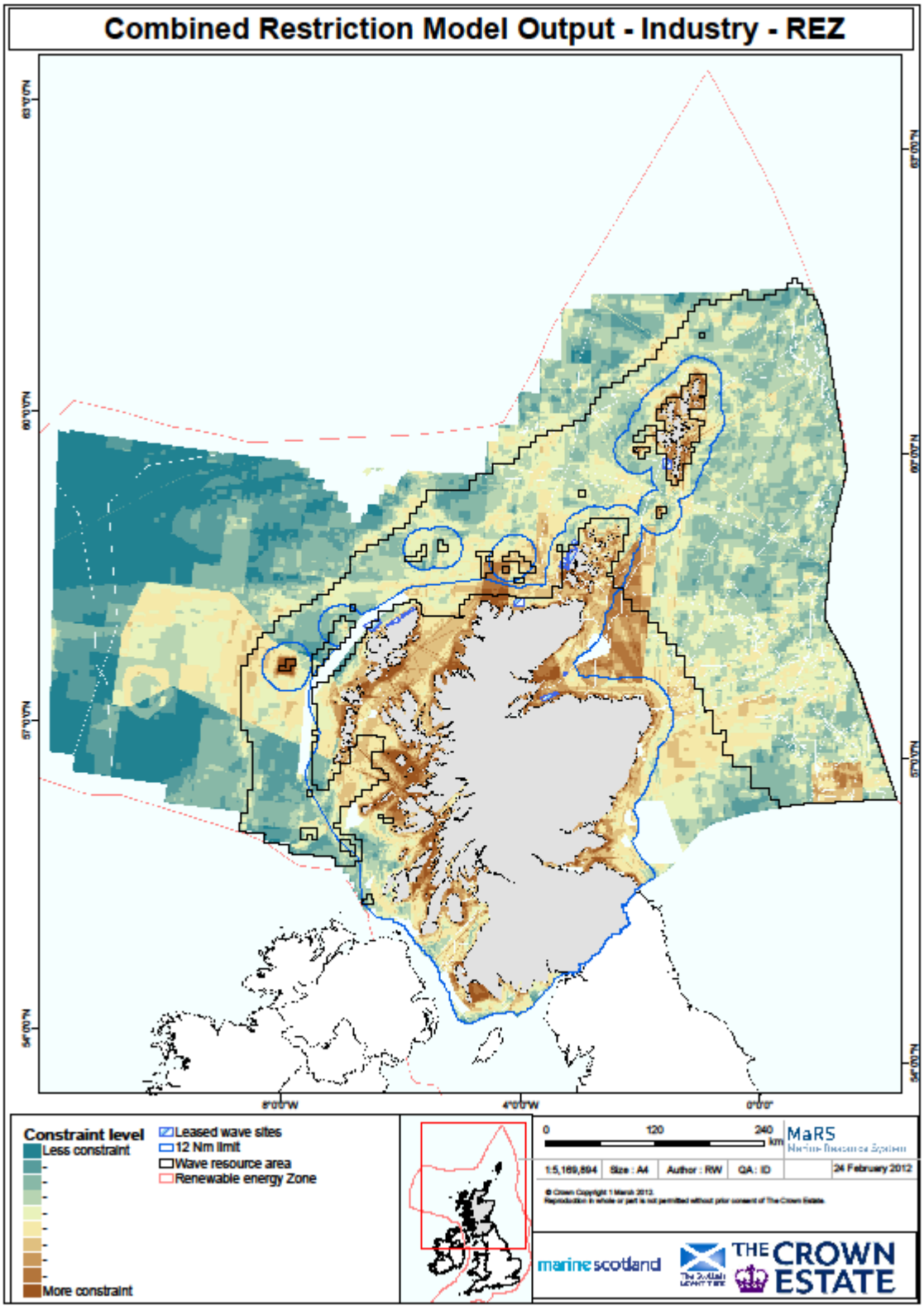

Figure 7 Combined restriction model, emphasising the industry theme.

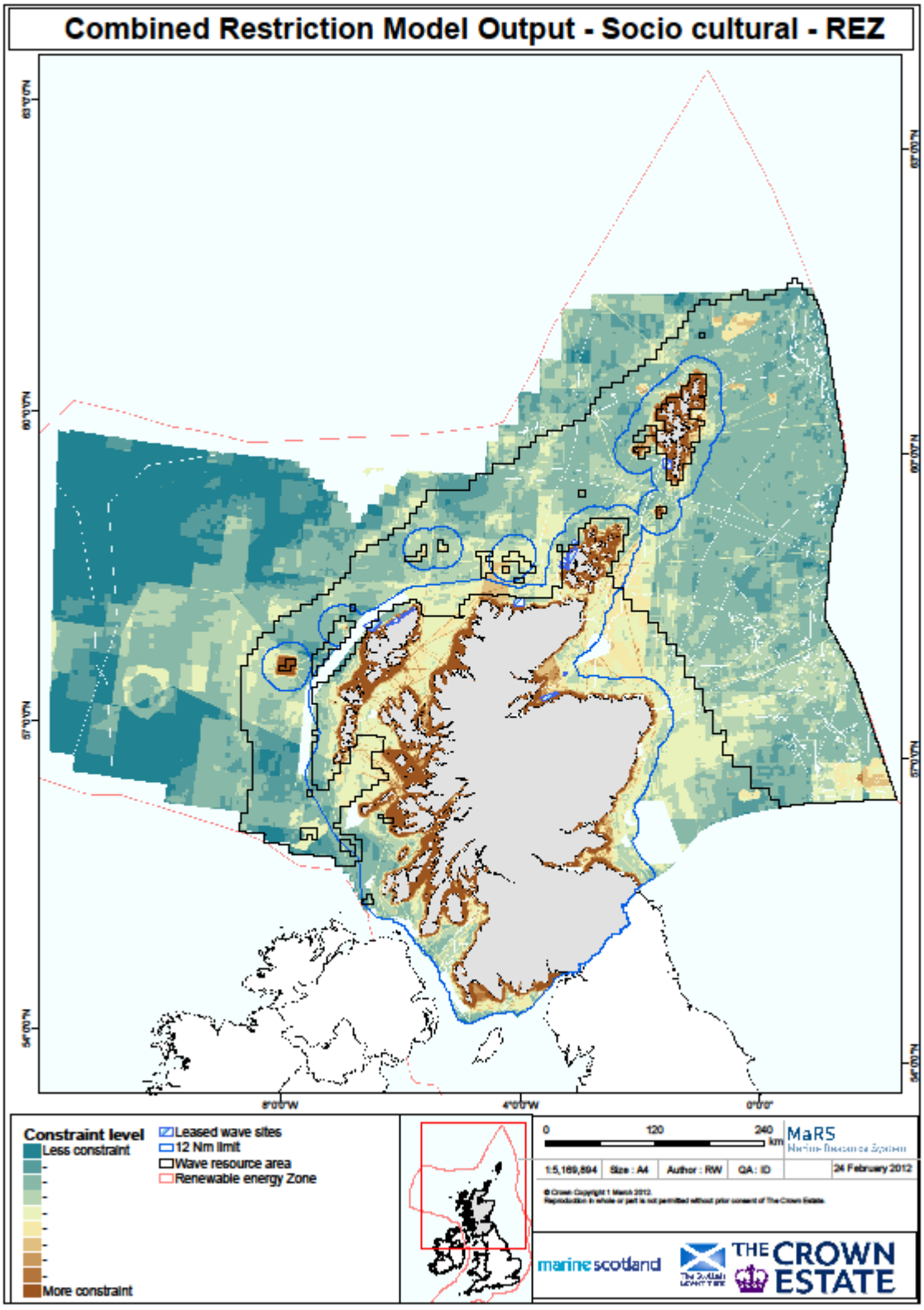

Figure 8 Combined restriction model, emphasising the socio-cultural theme.

5 Identification of Areas of Search for Wave Energy Plan Option Areas

The similarities between the outputs from the four combined models described in Section 4 above led to the equal weight model being used for the identification of areas of search for wave energy plan option areas in Scottish waters. The area considered was limited to the area identified as having potentially adequate wave power resource (Figure 1). A further filter was applied by water depth to reflect the ranges of depths for which development projects are currently under discussion (0 – 60m, and 60 - 90 m).

5.1 Wave Energy Areas in 0 – 60m Depth of Water

Areas with potential for wave energy developments in water depths of 0 – 60m within the resource area (Figure 9) and with low overall levels of constraint are mainly in the west of Scotland, south west of Mull and west of the Outer Hebrides. Other smaller areas are found west of Shetland and north of Orkney. Inshore waters around Orkney and Shetland generally have higher levels of constraint, although the significance of this will be influenced by the characteristics of the devices being considered for deployment.

5.2 Wave Energy Areas in 60 - 90m Depth of Water

Areas with potential for wave energy developments in water depths of 60 – 90m within the resource area (Figure 10) and with low overall levels of constraint are more widely distributed to the west of Scotland and in an area north of Orkney and west of Shetland. An area of low constraint is also found in the North Sea east of Aberdeenshire, although technical constraints are relatively high in this area.

5.3 Wave Energy Areas in 90 – 200m Depth of Water

There is currently little developer interest in areas with water depths greater than 90m. However, areas with potential for wave energy developments in water depths of 90 – 200m (Figure 11) and with low overall levels of constraint are very extensive within the resource area. Large areas of these deeper waters are found to the west, north and north east of Scotland, and generally show low to medium levels of constraint. Although much of this area is outside the depth range of current developer interest, there is clearly considerable potential for development beyond the immediate term.

The potential locations for wave energy developments are limited to the locations where the wave climate is sufficiently energetic. However, large areas of sea to the west, north and north east of Scotland experience a sufficiently energetic wave climate to make the wave resource suitable for exploitation. The resource areas for wave energy include the exposed waters along the western-facing coastline facing the width of the North Atlantic (particularly west of the Hebrides), waters to the north of the Scottish mainland and around Orkney and Shetland, and also areas in the central part of the northern North Sea.

Consideration of the resource areas, and the constraints on development arising from environmental, industry and socio-cultural factors discussed above, lead to the identification of four key areas of search for wave energy development options in Scottish waters (Figure 12). The areas are limited to water depths of less than 90m, to broadly reflect the depths for which developer interest is currently being expressed. The areas are:

A. West of the Hebrides
B. North West of Cape Wrath
C. Orkney and Shetland
D. North Sutherland coast

The geographical extent of these areas A – C is large enough for there to be opportunities for fully commercial scale development of wave energy projects. Area D is relatively small and close to the boundary of the resource area. The resource areas, and areas of search, for wave energy developments occur both within and beyond Scottish Territorial Waters In detail, there is variation between low and moderate levels of constraint within these broad areas, and more detailed assessment through Regional Locational Guidance will be required to derive plan options for wave energy.

This analysis should not be taken to imply that there are no useful wave resource areas elsewhere around Scotland. The identification of resource areas has been based upon wave energy maps taken from the DECC Renewables Atlas (DECC, 2008). The wave information in that Atlas is presented as a grid of data, with cell size of 1.8 km. Resource areas smaller than this may well not be represented, and uncertainties in the boundaries of resource areas up to the scale of a few cells, or immediately adjacent to the coast, may be poorly represented. One consequence is that the boundary of the resource area appears to skirt round the coast of, for example the Western Isles and Orkney. In such areas, where precise local data are not available to the assessment, cells at the coast should be

considered to have similar levels of resource and constraint as adjacent cells away from the influence of this coastal artefact.

It is also likely that some smaller wave energy devices may be able to function economically in areas of less than 20 kw/m available energy. Such areas will not have been captured by this scoping study, but in favourable locations may offer considerable potential for small (and perhaps medium) scale developments for testing or commercial purposes.

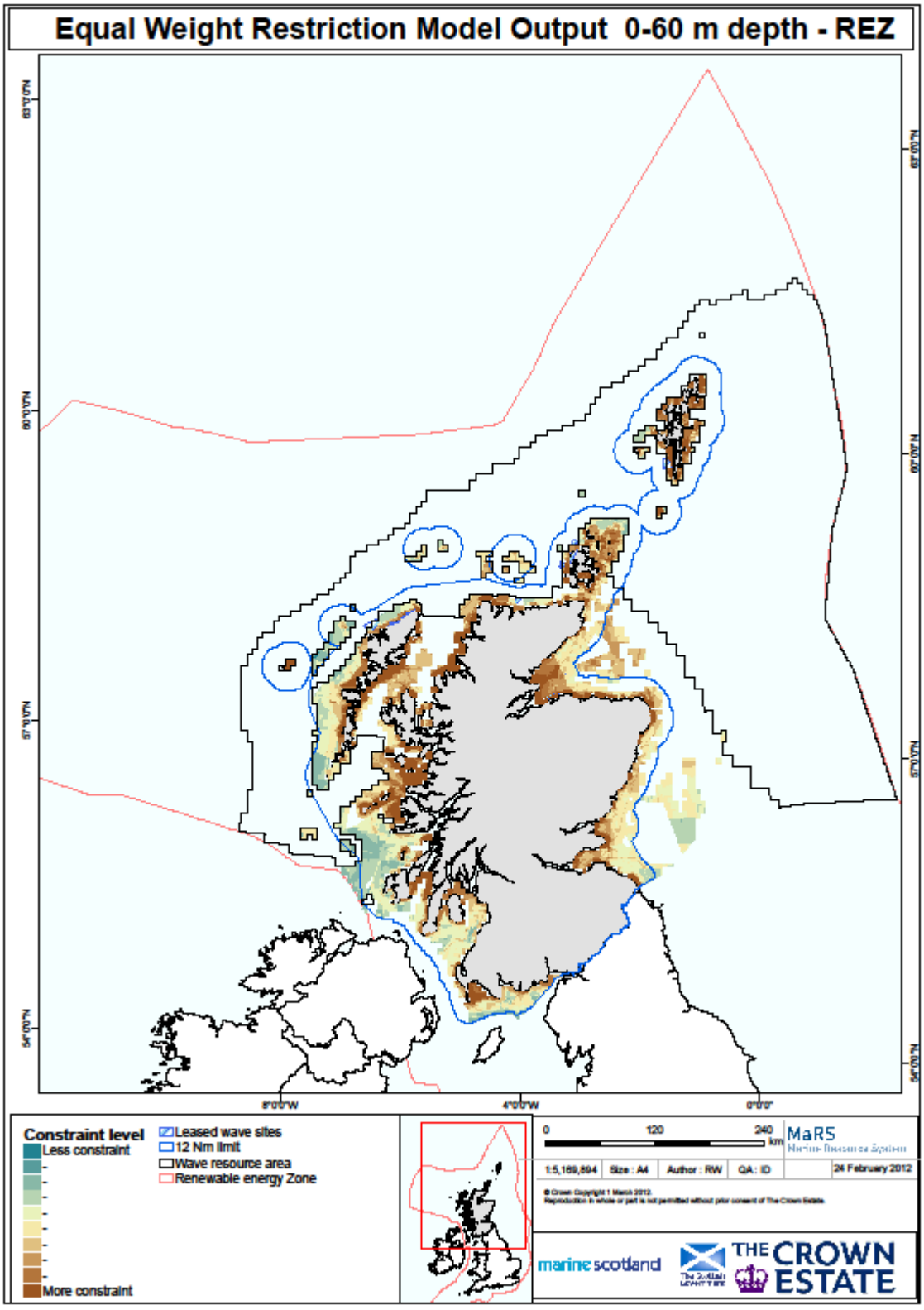

Figure 9 Levels of constraint on wave power developments in areas of 0 – 60m depth of water, in relation to the resource area for wave energy.

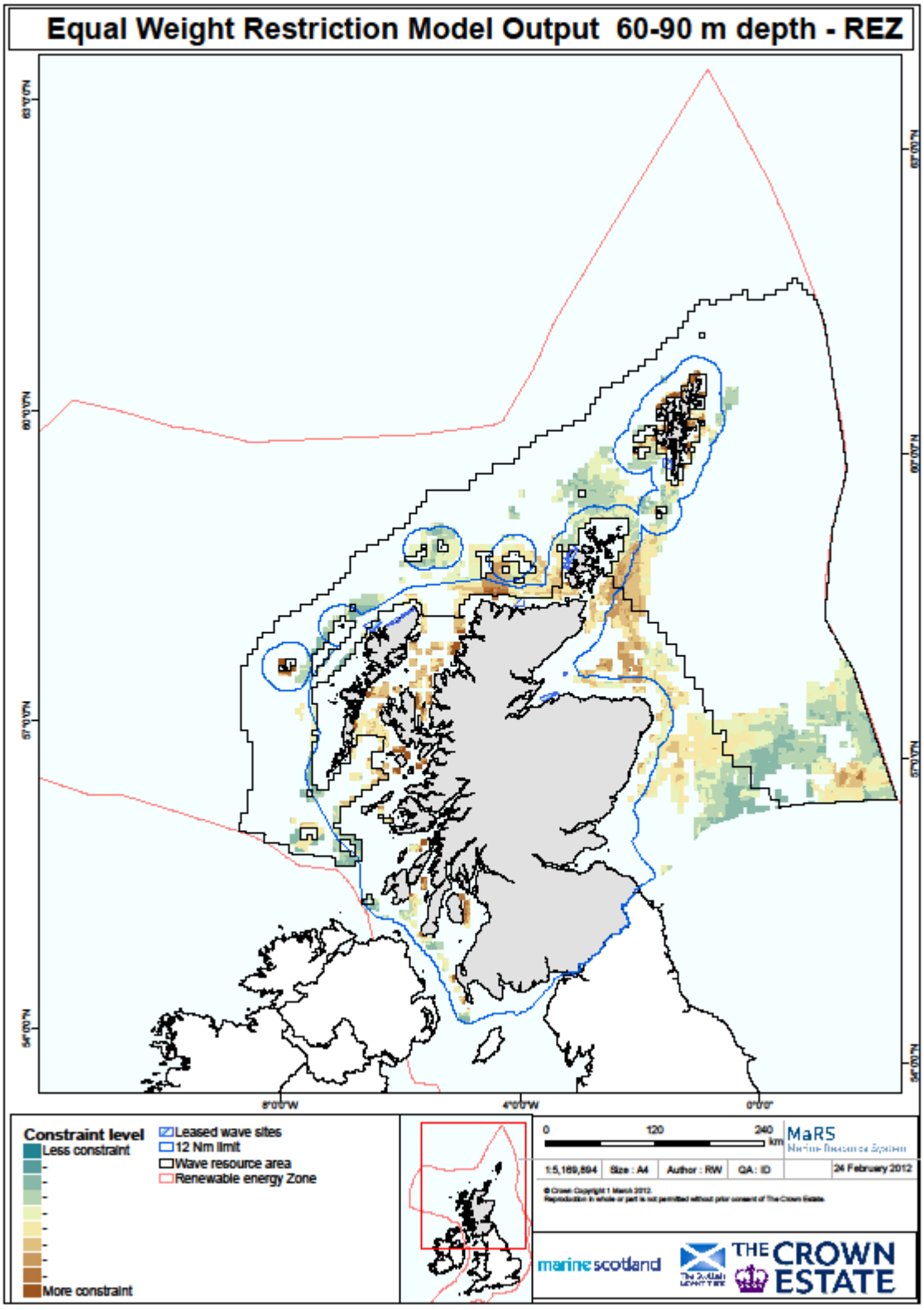

Figure 10 Levels of constraint on wave power developments in areas of 60 – 90m depth of water in relation to the resource area for wave energy.

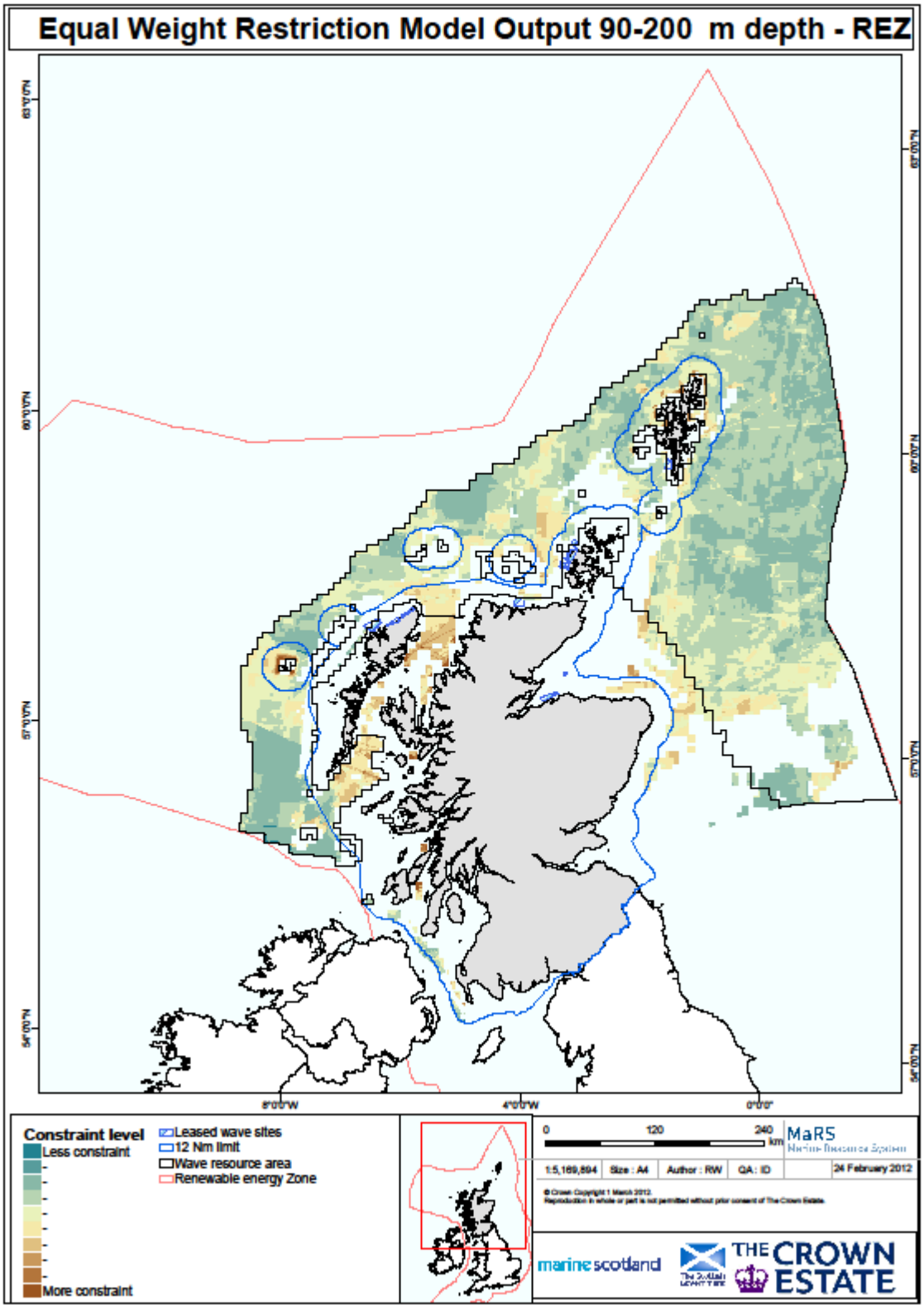

Figure 11 Levels of constraint on wave power developments in areas of 90 – 200m depth of water in relation to the resource area for wave energy.

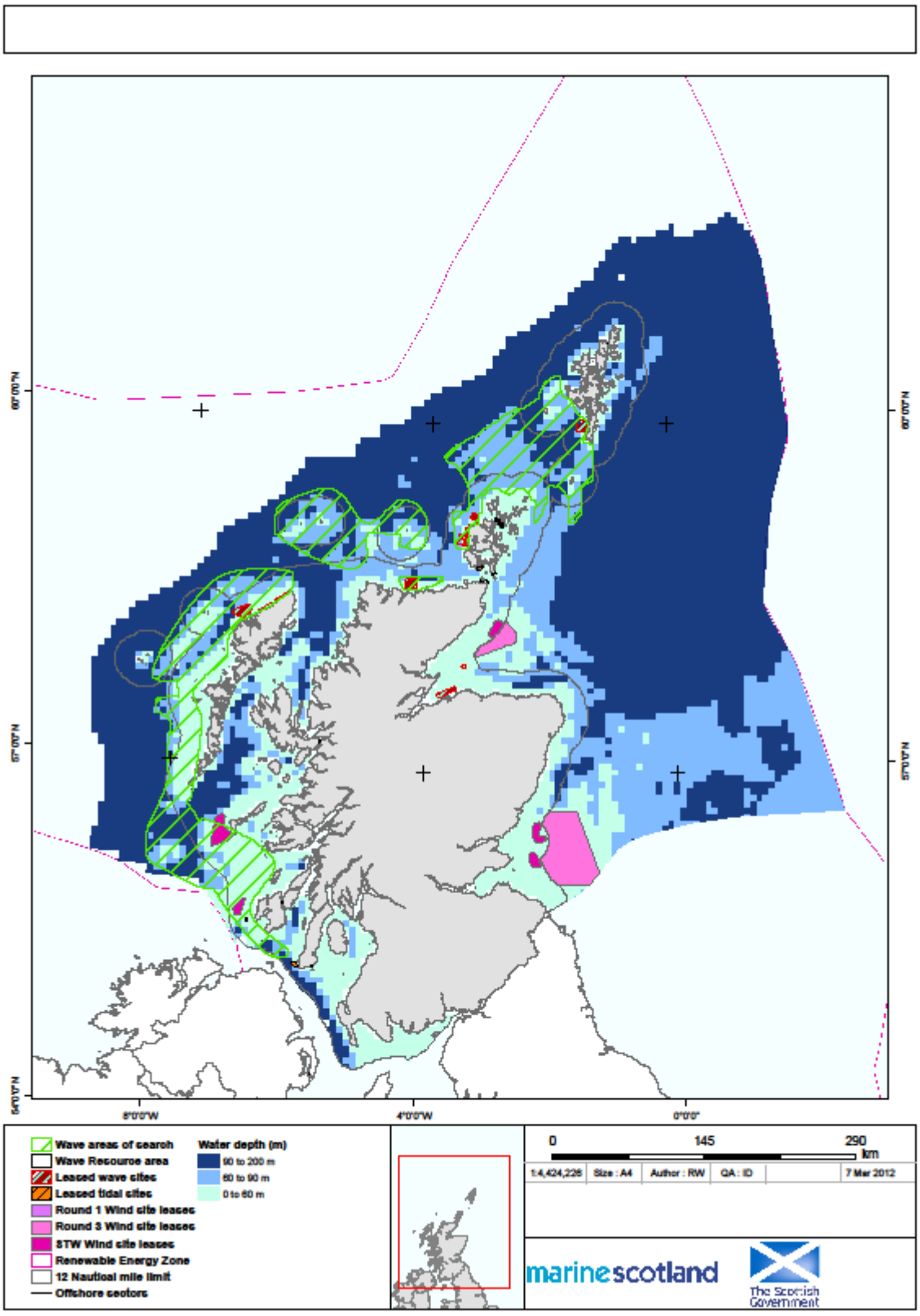

Figure 12 Areas of search for Plan option areas for wave energy development in waters of 0 – 90m depth within the wave power resource area.

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 marine waters for wave energy projects. The Scoping Study utilised the improved data layers and data handling methods that have been developed since the Scoping Study for the Saltire Prize, and building on the experience of the Scoping Study for offshore wind development.

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. The similarities in the approaches being used for scoping studies for wind, wave and tidal energy will allow a more consistent view to be taken of development opportunities and offer the potential for interactions between opportunities to be taken into account in marine planning across the renewables sectors.

As the potential for wave, wind and tidal stream energy development 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 wind farm proposals in the Moray Firth, and off the Firths of Forth and Tay will be the background against which cumulative impacts of wind developments further offshore, or of tidal stream and wave energy projects in areas closer to the coast will have to be considered. Similarly, proposals that emerge from the Northern Ireland renewables leasing round may interact with development opportunity proposals in the south and south west of Scotland.

The output maps presented in this report cover the whole of Scottish waters. However, the detail of the information available on available wave energy at the national scale leads to some local detail being difficult to discern. The next stage in the development of a Sectoral Plan for wave energy in Scottish waters is therefore to address each of the potential development areas in more detail through a Regional Locational Guidance process.

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