FLOATING OFFSHORE WIND CONSTRAINT MAPPING IN THE CELTIC SEA

UNDEB EWROPEAIDD
EUROPEAN UNION

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Offshore Renewable Energy Catapult is the UK's leading technology innovation and research centre for offshore wind, wave and tidal energy (www.ore.catapult.org.uk) and has played an active role in the rapid recent evolution of the Floating Offshore wind sector in the UK, that has nowhere been more evident than in the Celtic Sea.

In 2019 The UK Government set an ambitious target to deliver 40GW of Offshore Wind by 2030 in an effort to reduce greenhouse gas emissions to zero by 2050 whilst offering specific manifesto support to 'enable new floating wind farms'. Floating Offshore Wind offers an opportunity to exploit the offshore wind resource available in water depths that can not be accessed by Fixed offshore wind. Key markets have been identified in Europe, the USA and Japan with the potential for 7,000GW (GlobalData 2020) to be deployed globally, generating approximately 30,000TWh/yr which is well in excess of current global electricity demand (23,105 TWh in 2019 - Enerdata.net 2020).
In response to this challenge and an ambition to meet the Committee on Climate Change's recommendation of 75 gigawatts by 2050, the ORE Catapult's *Macroeconomic Benefits Report* identified Scotland, Wales and South West England as key areas that could benefit from floating offshore wind, creating 17,000 jobs and generating £33.6 billion for the UK economy by 2050.

In 2020 the ORE Catapult partnered with ITPEnergised to further understand the spatial potential for the deployment of Floating Offshore Wind in the Celtic Sea, seeking to identify potential deployment areas of least constraint and supporting a more strategic approach to the future sustainable development of this sector. This report was funded with support from the European Regional Development Fund (ERDF) through Welsh Government, and the Marine Energy Engineering Centre of Excellence (MEECE) based in Pembroke Dock, Wales. MEECE is a multi-million-pound collaboration between ORE Catapult and Welsh universities, funded by ERDF.

Report aims and key intentions:

- As a follow-on from the supply chain report on the 'Benefits of Floating Offshore Wind to Wales and the South West.' (ORE Catapult 2020), which identified Floating Offshore Wind opportunities for the Welsh supply chain. This new report is intended to give context to those opportunities, and a focus for innovation projects that could deliver new technologies, products and processes that could help Welsh supply chain companies commercialise those opportunities.
- To support the Welsh Government and other authorities in taking a proactive approach to understanding the spatial potential for the development of Floating Offshore Wind in the Celtic Sea. This will form a starting point for informed further discussion with stakeholders and a clearer understanding of the opportunity, its potential scale, possible location(s) and critical wider interests for full consideration.
- To identify potential areas of least constraint that can influence the development of spatial planning policies, including the Welsh National Marine Plan and SW Marine Plan, and a more strategic approach to supporting the development of this important opportunity. This is not a techno-economic analysis though there are known synergies with these approaches and common features that were considered. The intention was not to determine the ultimate technical viability and final location of future Floating Offshore Wind deployments, as these will be directly affected by specific technology selection and individual developer requirements.
- To support the acceleration and streamlining of the leasing and licensing process to decrease conflict and reduce permitting timeframes to match industry aspirations. This

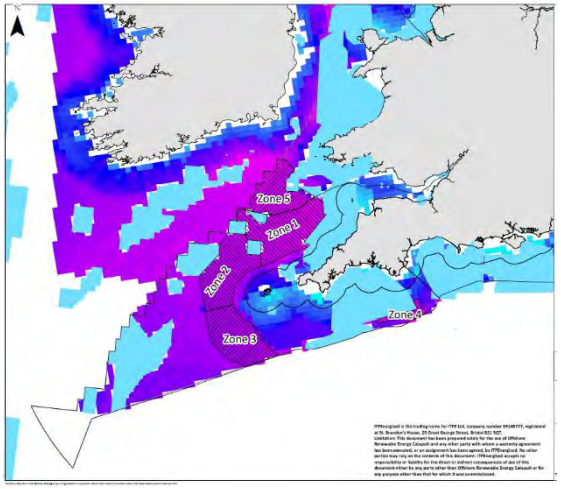
includes assisting the Crown Estate, in their early stage planning for the identification of key resource areas to support future Floating Offshore Wind leasing rounds.

- To identify gaps, align and focus ongoing and future research and data collection across the Celtic Sea to inform factors such as site design features and the collection of higher resolution data sets for critical interests such as marine mammal distributions.
- To help rationalise sector development benefits including supply chain and skills development opportunities across Wales and the SW as well as LCOE cost reduction modelling strategies.

Initial project outcomes:

A 25,000km² area of least constraint has been identified in the Celtic Sea, with 5 specific Zones in the SW Marine Plan area and Welsh National Marine Plan area.

Initial potential deployment figures have been generated as a result of the report based on the utilization of a 15MW Floating Offshore Wind turbine and other known Offshore Wind turbine packing densities. This has enabled projected deployment ranges to be generated for the investigated areas.



Celtic Sea Zones:

Total Area: 25,000km²

Turbine Deployment capacity range: High (4.8MW/km²) – 120GW
Mid (3MW/km²) – 75GW
Low (2MW/km²) – 49.9GW

We hope this report is a useful basis for further studies by public sector bodies and project developers and can provide an initial focus to help the UK secure the potential benefits that can be derived from the development of a successful Floating Offshore Wind sector.

Floating Offshore Wind Constraint Mapping in the Celtic Sea

Summary Report

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1.0	2020-03-26	M. Knight, L. Smith, G. Bawn, T. Gibson	R. Spice	A. Bright	Draft Issue
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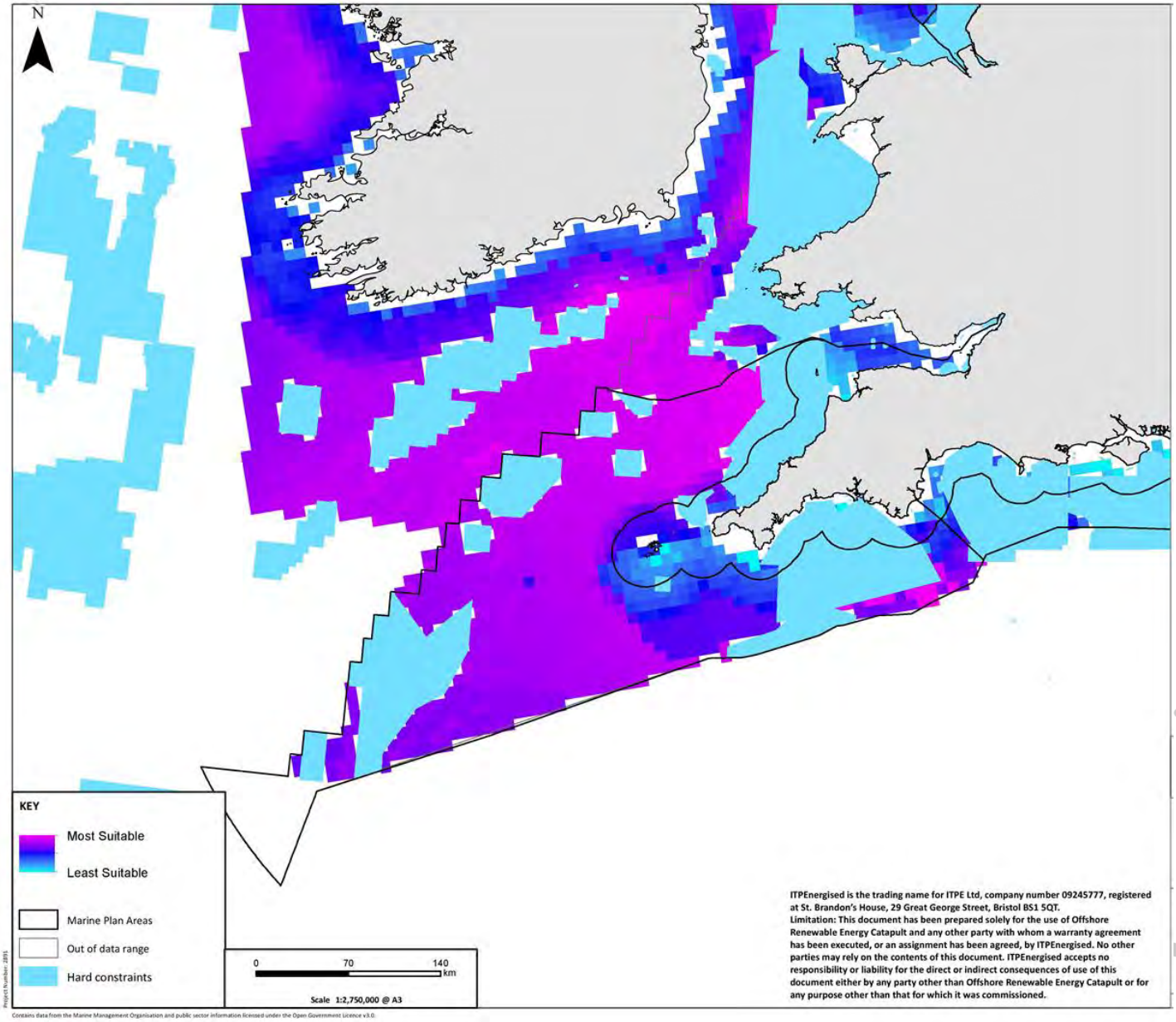
4.0	2020-04-09	M. Knight, L. Smith, G. Bawn, T. Gibson	G. Bawn	L. Smith	Military exercise zones weighted
5.0	2020-07-09	M. Knight, L. Smith, G. Bawn, T. Gibson	G. Bawn	L. Smith	South West and Wales terminology updated

Executive Summary

ITPEnergised (ITPE) has undertaken a high-level constraint analysis of the Wales and South West region, with respect to floating offshore wind developments, on behalf of the Offshore Renewable Energy Catapult (OREC). The aim of the work was to identify the areas of least constraint in the region and wider Celtic Sea in order to inform the OREC's response to the UK Government's consultation on the South West Marine Plan.

The constraint analysis used has identified hard constraints and weighted other constraints, resulting in a heat map showing areas of least constraint in the figure below.

Over 25,000km^2 of the Celtic Sea in total is an area of low constraint suitable for development, while an area of low constraint of over 18,000km^2 within the SW Marine Plan offshore area is potentially suitable for floating offshore wind developments. Given the South West's excellent wind resource, the falling costs of offshore wind and the UK's commitments to Net Zero, ITPE recommends that the OREC responds to the government's consultation outlining the case for Floating Offshore Wind in the region.



Four key zones have been identified which highlight the areas with the least constraint in the South West of England and one in Wales. It is recommended that other factors that are needed for a viable floating offshore wind project, such as grid connection options, proximity to ports and the road to consent are investigated to further understand the viability of floating offshore wind off the South West coast.

Contents

1. Introduction

The Wales and South West (SW) Region of the UK has an excellent offshore wind resource with average wind speeds of approximately 9.5m/s, which is suitable for high yields, indicating that wind energy will be commercially viable in the region. This resource has so far not been utilised primarily due to the area's relatively deep-water, which increases project costs, making offshore wind previously uneconomical in the region. However, due to falling costs of offshore wind technology, and advancement of floating offshore wind (FLOW) projects seen in Scotland and Portugal, Wales & the SW have the potential to harness this wind resource and make a significant contribution to the UK Government's Net Zero target (to be achieved by 2050) and offshore wind commitments (40GW by 2030). Further, evidence of the Government's commitment to floating offshore wind in particular is shown in the Department for Business, Energy and Industrial Strategy's (BEIS) proposed amendments to the Allocation Round 4 of the Contracts for Difference (CfD) scheme; the draft amendment[1] outlines FLOW as a key emerging technology in meeting the UK Government's Net Zero targets by 2050.

In January 2020, the UK Government issued draft marine plans, including a draft South West (SW) Marine Plan, for consultation. It is Offshore Renewable Energy Catapult's (OREC) intention to respond to this consultation outlining the opportunity for FLOW in Wales & the SW Regions; ITPEnergised (ITPE) has been commissioned by OREC to investigate this potential and provide OREC with the information necessary for an informed response to the Government's consultation of the SW Marine Plan.

A number of maps have been produced to support this report. These are shown in Appendix A and referenced by their figure numbers.

1.1 Purpose and aims

The primary aim of the work was to assess the areas of least constraint available in the SW Region and the wider Celtic Sea for the development of FLOW projects.

It is important to note that outside of the areas of least constraint identified in this study, it is not necessarily unsuitable for FLOW projects, only that the technological and consenting constraints may be greater.

Key zones of least constraint have been identified and the area of these zones assessed (See Figure 6.14). Rather than highlighting the areas FLOW development is technically feasible, these zones will contain the areas of least constraint where initial development zones could be created; these key areas represent the more promising FLOW potential in the region where developers may consider looking first to develop their initial projects.

[1] https://www.gov.uk/government/consultations/contracts-for-difference-cfd-proposed-amendments-to-the-scheme-2020

2. Methodology

2.1 Weighting Method

ITPE have produced a heat map (Figure 6.13) to identify the key areas of least constraint outlining the more favourable areas for FLOW development. The results of this weighting are discussed in detail in Section 4 of this report.

Initially, hard constraints were removed from the weighting process. Discussion on which constraints have been defined as "hard" and the reasons for this are given in Section 2.2 below.

The remaining constraints were evaluated using pairwise comparison of different data layers. This is shown in Table 2-1. Each constraint was evaluated against all other constraints and a score given for each:

- If the constraint in the row is much more important than the constraint in the column, the score given is 9.
- If they are both determined to be equally as important, the score given is 1.
- Where the constraint in the row is less important than the constraint in the column the fractions 1/1 to 1/9 can be used.

For example, if the Wind Speed row is compared against the Seabed current column, a high number is given as wind energy is more important than current in identifying a potential offshore wind site. Qualitative description of the weightings are shown in Figure 2-1.

Table 2-1: Constraint Weighting

	Shipping Routes	Wind Speed (mean)	Depth	Annual Average Wave Power	Seabed Current Power	Wrecks	Visual 30km	Visual 45km	Aviation Radar	Fishing Density	Military exercise zones	Combined Weighting
Shipping Routes	1	1/7	1/8	1/2	1/2	1/7	1/6	1/3	1/4	1/2	1/5	0.024
Wind Speed (mean)	7	1	1/2	5	5	1/3	2	3	5	4	1/3	0.165
Depth	8	2	1	3	3	1/4	3	4	4	5	1/3	0.179
Seabed Current Power	2	1/5	1/3	1	1	1/4	1/4	1/5	1/4	2	1/4	0.040
Annual Average Wave Power	2	1/5	1/3	1	1	1/4	1/4	1/5	1/4	2	1/4	0.040
Wrecks	7	3	4	4	4	1	1/2	1	4	5	1/3	0.186
Visual 30km	6	1/2	1/3	4	4	2	1	9	2	5	1/3	0.162
Visual 45km	3	1/3	1/4	5	5	1	1/9	1	3	4	1/4	0.093
Aviation Radar	4	1/5	1/4	4	4	1/4	1/2	1/3	1	6	1/2	0.080
Fishing Density	2	1/4	1/5	1/2	1/2	1/5	1/5	1/4	1/6	1	1/4	0.031
Military exercise zones	5	3	3	4	4	3	3	4	2	4	1	0.264

9	Extremely more important
8	
7	Much more important
6	
5	More important
4	
3	Slightly more important
2	
1	Equal importance
1/2	
1/3	Slightly less important
1/4	
1/5	Less important
1/6	
1/7	Much less important
1/8	
1/9	Extremely less important

Figure 2-1: Pairwise Comparison Key

Once each constraint was evaluated, their respective data layers are multiplied by the weighting calculated. The resulting, maps are shown in Appendix A – GIS Maps.

2.2 Data Rescaling

For the constraint maps produced in Appendix A – GIS Maps, the data layers used are rescaled so that a desirable value is adjusted to be a 1 and an undesirable to be a 0. For example, the maximum wind speed in the Celtic Sea will be given a value of 1 and the minimum 0. All other values will be scaled linearly between these two. Conversely, the area with the maximum wave power will be given a value of 0 and the minimum 1, as low wave power indicates a more desirable site. This ensures that a unit agnostic approach where all the constraints can be considered.

2.3 Data categories

Hard Constraints	Map 1	Military Danger Zones	
	Map 2	Ramsar sites	
		Marine protection Areas	
		Sites of Special Scientific Interest	
		Special area of conservation	
		Special protection areas	
	Map 3	Existing Lease sites	
Weighted Constraints	Shown with danger zones in Map 1	Military Exercise Zones	Inside military exercise zone = 0. Outside military exercise zone = 1
	Map 4	Shipping routes	1 = minimum density. 0 = maximum density
	Map 5	Fishing	1 = minimum density. 0 = maximum density
	Map 6	Wind Resource	1 = maximum speed. 0 = minimum speed
	Map 7	Wave power	1 = minimum power. 0 = maximum power
	Map 8	Current	1 = minimum force. 0 = maximum force
	Map 9	Bathymetry	1 = 60m. 0 = 200m. *Out of range: <60m depth = 0. >200m depth = 0.*
	Map 10	Wrecks	Within 500m buffer = 0. Outside 500m buffer = 1
	Map 11	Visual 30km	0km from shore = 0. 30km from shore = 1.
		Visual 45km	30km from shore = 0. 45km from shore = 1. *Out of range: <35km from shore = 0*
	Map 12	NATS Radar	Within radar coverage = 0. Outside radar coverage = 1
Outputs	Map 13	Overall Rating	
	Map 14	Potential Zones	
Reference Data	Map 15	Ports	
		Transmission Grid	
		Seabed	
	Map 16	Communications cables	
	Map 17	Habitat	
	Map 18	Marine mammal	
	Map 19	Nursery	
	Map 20	Spawning	
	Map 21	Shellfish	
	Map 22	Seabird Foraging	
	Map 23	Heritage	

Figure 2-2: Data summary

3. Constraints

3.1 Hard constraints

Data layers were designated as hard constraints where the consents required to develop a project in that location are unlikely to be granted or will require additional time and cost to gain consent through complex mitigation requirements. For example, this includes military danger areas and Ramsar sites. Hard constraints are removed from the area of analysis. Some hard constraints are also buffered to exclude the immediate area around them to ensure no inter connectivity.

Appendices 6.1, 6.2 and 6.3 highlight the hard constraints which were removed from consideration.

3.1.1 Military Exclusion Zones

Much of the Celtic Sea is designated for potential military use by the UK Hydrographic Office. This is divided into “danger” and “exercise” zones. Achieving consent in “danger” zones is very unlikely as the MoD will be likely to ‘object’ to applications in these areas and they are therefore registered as a hard constraints. Achieving consent in “exercise” zones can be difficult but may be possible through detailed consultation with the MOD, therefore ‘exercise’ areas have been included in the assessment as weighted constraints.

During OREC’s discussion with the RNAS (Royal Navy Air Service) Culdrose in 2019, two specifically active areas of Military exercise zones located in the SW, were outlined. These have been designated as a highly weighted constraint for the purposes of this work. OREC have confirmed that RNAS Culdrose stated that all the areas to the west and south west of their specified zones (shown in pink in Figure 3-1 and large scale in Figure 6.1) are not likely to clash with potential Floating Wind activity and so are not weighted in this work as development in these areas would likely be deemed acceptable. The remaining exercise zones will be included as potential development areas but given a high weighting. Exercise zones are discussed further in section 3.2.1. Figure 6.1 shows the military zones and how they have been evaluated.

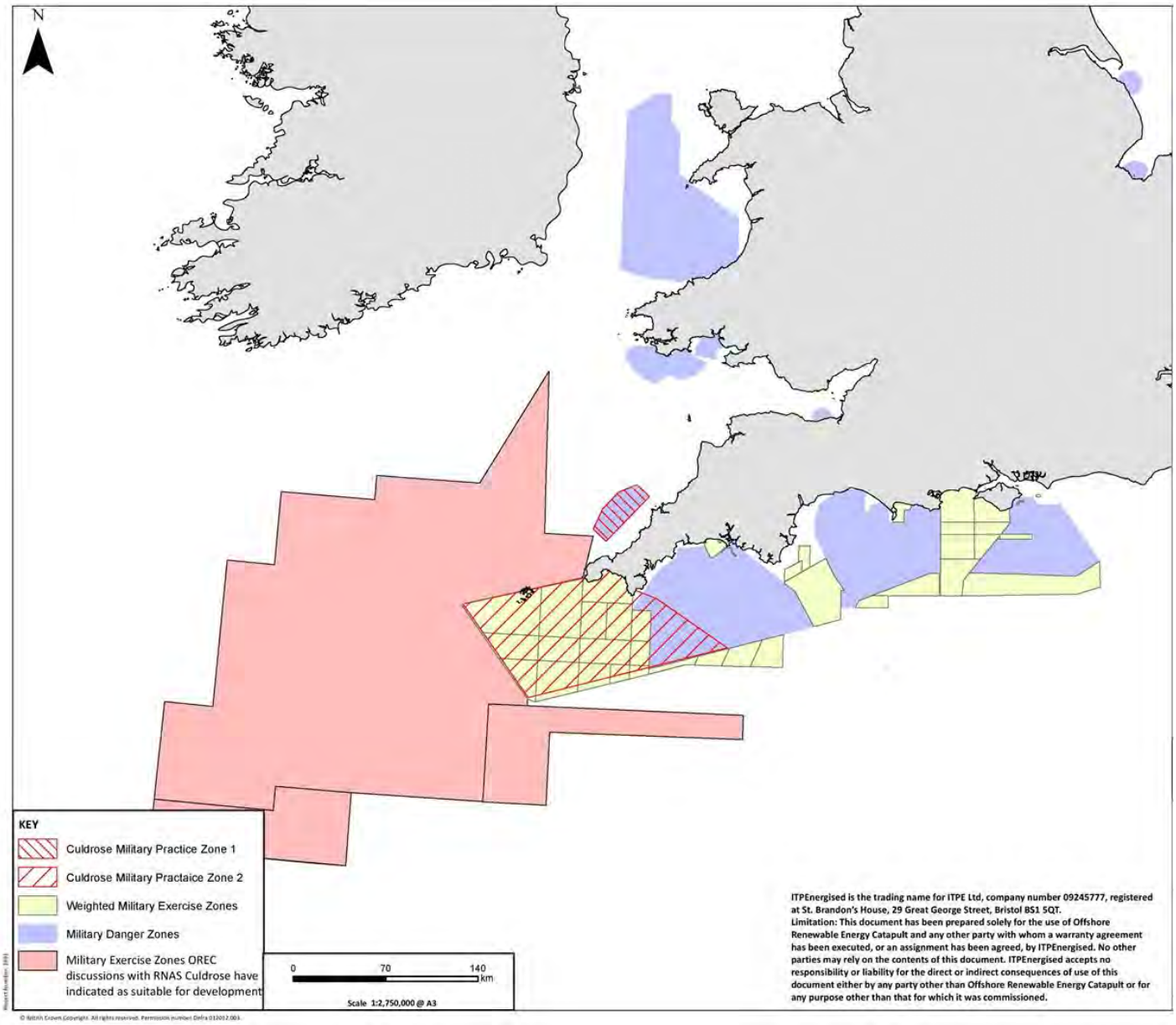


Figure 3-1: Military area designations (large scale in Figure 6.1)

3.1.2 Environmental Designations

Within this work environmental designations noted as hard constraints include those listed in Table 3-1.

Table 3-1: Environmental Hard Constraints

Designation	Description
Marine Conservation Zones (MCZ)	Marine Conservation Zones are protected area of seas and oceans. They can be conserved for a variety of reasons, including biodiversity conservation and economic resources, or protected species. They are designated under the legal framework of the UK Marine and Coastal Access Act 2009.
Sites of Special Scientific Interest (SSSI)	A statutory conservation designation, denoting a protected area within the UK and the Isle of Man, under the legal framework of the Wildlife and Nature Conservation Act 1981. A

	SSSI represents an area of land which is considered to be of special interest by virtue of its fauna, flora, geological or geomorphological interest.
Special Area of Conservation (SAC)*	A statutory designation that protects one or more special habitat and/or species listed in the European Union Council Directive 92/43/EEC.
Ramsar Sites	Wetlands of international importance designated under the criteria of the Ramsar Convention on Wetlands (1975) for containing representative, rare or unique wetland types or for their importance in conserving biological diversity.
Special Protection Areas SPA	Protected areas for birds in the UK SPAs are classified in accordance with European Council Directive 2009/147/EC on the conservation of wild birds, known as the Birds Directive. SPAs are selected to protect one or more rare, threatened or vulnerable bird species, birds (as listed on Annex I of the Birds Directive) and regularly occurring migratory species.

*There is some precedent for development in SAC zones within the SW region. In particular the West Anglesey Development Zone, where a number of tidal turbine technologies have been deployed, is within the North Anglesey Marine SAC. However, it is generally accepted that development in these areas will not be possible, for example, the Pembrokeshire Development Zone appears to have been specifically located to avoid the West Wales marine SAC and Bristol Approaches SAC. Therefore, The North Anglesey Marine SAC was incorporated as a weighted constraint, while the other SACs were hard constraints.

The environmental protection zones are shown in Figure 6.2.

3.1.3 Existing site leases

Any areas which have already been granted leases by The Crown Estate (TCE) or Centre for Environment, Fisheries and Aquaculture Science (CEFAS) were identified as hard constraints. This includes leases for offshore wind, wave and tidal testing, oil and gas, mineral aggregate extraction, disposal sites, meteorological equipment, oil & gas pipelines and electrical cables and interconnectors. The cables were given a 500m buffer. As informed by ITPE experience, this is considered a suitable buffer to avoid an adverse impact of development upon cable infrastructure. Figure 6.3 shows the existing lease areas. There are currently no offshore wind areas leased by TCE in the Wales & SW area of study. Simply Blue Energy in partnership with Total are currently progressing their Erebus project in the Celtic Sea, however this has not been included in this analysis as it is in the early stages of development. It is important to note that the TCE Wave Lease Sites, the Pembrokeshire Development Zone and Wave Hub are being developed to allow FLOW technology developers to test their systems. These sites aim to allow for the development of new technologies and/or early pilot arrays.

3.2 Weighted constraints

3.2.1 Military Exercise Zones

Achieving consent in “exercise” zones can be difficult but may be possible through detailed consultation with the MOD, therefore ‘exercise’ areas have been included in the assessment as high weighted constraints. The exception being the zones RNAS Culdrose informed OREC are not likely to be objected to based on the use of the zones, (discussed in section 3.1.1). This means areas outside of these exercise zones will be much more favourable. In future work and with discussion with the MOD, it is possible that the weighing could be relaxed in certain areas. Both danger and exercise zones are shown in Figure 6.1.

3.2.2 Shipping Routes

Figure 6.4 shows the shipping density. Shipping density was used to identify areas of high traffic. Shipping routes were given a low weighting in the analysis as through consultation with both shipping operators and

the Maritime and Coastguard Agency (MCA) they may be able to be diverted, however, it should be noted that his will be easier for local smaller vessels rather than large commercial routes.

The data is shown in hours per square km per month. It can be seen that the principle shipping routes are down the centre of the English Channel. These are commercial shipping routes for large vessels and there will be complex re-routing issues to consider, in this area, than the less dense routes or routes for small vessels. The route between Holyhead and Dublin is also a key commercial shipping lane with high density and should be kept clear if possible. There is a relatively large density of traffic between Cornwall and the Isles of Scilly, heading north towards Ireland. FLOW development along this route may disrupt shipping and so potential projects along this route may need to consider that appropriate shipping corridors between turbines are planned as part of the project design process and ensure that consultation is undertaken with both the MCA and relevant shipping owners.

3.2.3 Fishing Density

The density of fishing vessels was assessed. Figure 6.5 shows the number of Automatic Identification System (AIS) messages per square km ranging from a low of 0 (or no-data) to a high of 1955, indicating the areas of highest fishing activity. Areas to the south and north west of Cornwall have the highest density. Further consultation with the relevant fishing stakeholders would aid in understanding the effect of FLOW development on these fishing zones.

Fishing density was given a medium weighting in the analysis and will have an effect on the overall rating; practically however, fishing density may not necessarily rule out areas for development. For any proposed development further analysis should be done on the impact to fishing vessels and consultation undertaken with all relevant fishing stakeholders.

3.2.4 Wind Speed

Wind speed is shown in Figure 6.6. Wind speed is an important factor in the success of any FLOW project. Wind speed across the Celtic Sea, and much of the UK, is relatively high, with averages being regularly above 9m/s at a height of 100m, which is deemed a suitable windspeed for high yield. It can be seen in Figure 6.6 that the further from shore the higher average wind speeds will be. Although, towards the western edge of the SW Marine Plan area wind speeds reach the highest values, the wind resource across the whole of the region presents excellent opportunity for wind power. Site selection is therefore not so reliant on wind speed in this area as all locations have good resource.

3.2.5 Waves and Current

Figure 6.7 shows the average wave power in kW/m for the Celtic Sea. It shows that the further distance from shore, the average wave power will increase. It highlights that almost all regions of the Celtic Sea will be subject to significant waves. Two separate sources were used for the Irish and UK wave data from data.gov.ie and MetOcean respectively. The data sets largely match, however small variation can be seen between the two. This did not have significant impact on the results. The data used shows the annual average of power rather than wave height. This gives a better representation of areas of high wave activity as a long-term average of wave height will not capture information on where the highest waves can be expected.

Figure 6.8 shows the current force per square meter in the Celtic sea. The highest currents are produced as the tide is forced between bodies of land and or around headlands. The regions around the Bristol Channel, Pembrokeshire and Holyhead can be seen to have the highest tidal speeds.

As current and wave power increases, there will be an increase in the loads experienced by an offshore structure. Further to this, as wave power increases, with greater height and also stronger currents, induced by high tidal ranges, together with weather patterns, particularly those experience in winter months, will have an impact on the windows when offshore structures can be constructed and also accessed for operational & maintenance purposes. This will need to be considered as part of the economic viability of a site.

3.2.6 Depth

Based on ITPE expertise and discussions with OREC, ITPE have chosen to prioritise areas with depths between 60m and 200m as they are deemed most suitable for FLOW development. The bathymetry is shown in Figure 6.9. Areas in light blue highlight depths shallower than 60m and deeper than 200m which will receive a weighting of 0, indicating their assumed unsuitability for FLOW. 200m was assumed as the upper limit for this study, however as technology develops this limit may well be exceeded. For any locations under 60m, it will be much more viable to use established fixed bottom wind technologies. This was indicated BEIS' "Contracts for Difference for Low Carbon Electricity Generation Consultation on proposed amendments to the scheme"[2].

3.2.7 Wrecks and Subsea Infrastructure

Figure 6.10 shows wrecks within the UK Economic exclusion zone (EEZ). A 500m buffer around subsea wrecks and infrastructure was created. All the areas within this buffer were given a score of 0 while all outside were given a score of 1. Although this layer was weighted highly, it is unlikely to have a significant impact on the areas suitable for development as they only take up a small area each. Further to this, micro sighting of anchors and cables is possible to avoid any small subsea infrastructure.

3.2.8 Visual Impact

Visual constraint was divided into two sections, 30km from shore and 45km from shore; Figure 6.11 shows the 30km and 45km distance from the UK coast. Projects (assumed 200m to tip, based on the existing turbines currently under manufacture) beyond 45km from shore are assumed to be out of sight of the shore due to the effect of 'disappearing from the horizon' (this may have to be increased for larger turbine sizes), while projects 30km from the shore may be visible in certain weather conditions, dependent upon scale of the development proposed, Therefore two data layers were used. Developments within the 30km boundary are less likely to achieve consent. The 30km boundary was given a medium weighting while the 45km boundary was given a low weighting.

3.2.9 Aviation Radar

Areas which are within aviation radar coverage (NATS primary radar) have been weighted to a medium-high level. Consenting in these areas will be complex as any development will have to prove that it is not affecting radar coverage and if there is any radar interruption detailed mitigation measures put in place. However, consenting in these areas may be possible if appropriate consultation with NATS and relevant stakeholders is undertaken and mitigation is implemented. Radar zones are shown in Figure 6.12.

3.3 Constraints not evaluated

A number of constraints pertinent to offshore wind developments are out of scope for this work and have not been included in the weighting methodology. These constraints are discussed below.

3.3.1 Grid Capacity

The location of potential cable landing sites has not been assessed. It was assumed that for any potential developments, landfall could be achieved at some location along the coast. This assumption may be incorrect for some of the identified zones; therefore, future work could assess the suitability of the cable landing sites based on grid capacity, environmental constraints and landfall technology type. The length of offshore cable which will need to be deployed to reach the transmission grid will have a significant effect on project economics and so should be further considered by developers. The UK transmission grid and substations are shown for reference in Figure 6.15.

[2] gov.uk/government/consultations/contracts-for-difference-cfd-proposed-amendments-to-the-scheme-2020

3.3.2 Ports

Figure 6.15 shows the UK and Ireland ports. Further analysis on which ports will be able to conduct manufacture or maintenance of FLOW in the region would give greater insight into the capability which could be established in the region. OREC's report "Benefits of Floating Offshore Wind to Wales and the South West"[3] looks at existing ports which could be utilised.

3.3.3 Seabed composition

The composition of the seabed has not been used to constrain the available areas. However, Figure 6.15 shows the seabed composition. This has been provided as a reference for future technology development to better understand what anchor types may be necessary for the locations. The majority of the SW Marine Plan area is course substrate and sand. For any potential project, more detailed assessment of the seabed at a higher resolution will be necessary to support anchor selection and design.

3.3.4 Communications cables

Figure 6.16 shows the locations of communications cables in Wales & the SW. It can be seen that much of the area is crossed by communications cables. Any potential development is likely to be in an area where communications cables are present. It was decided that it will not be necessary to constrain by communications cables in this study as careful selection of the location of seabed infrastructure during project development can avoid interference with communications cables. It will therefore be necessary to microsite anchors and moorings to ensure there is no interference with these cables in future assessment.

3.3.5 Marine mammal data

The data available is shown in Figure 6.18. This dataset includes unclassified incidental sightings of cetaceans from the United Kingdom Royal Navy ships. In ITPE's discussions with OREC on 25 March 2020, it was decided that data available on marine mammal concentration is of too low resolution to be included in this analysis. Because of this it was not included in this process. Further development of the sites will require more detailed analysis of the areas in question. Detailed marine mammal surveys should be carried out at this point.

3.3.6 Nursery and spawning areas

Spawning and nursery grounds of selected fish in UK waters are shown in Figure 6.19 and 6.20. It can be seen that the majority of the Celtic Sea waters are spawning and nursery ground for many different fish species. It was therefore decided that constraining by these areas would not be valuable. Instead more detailed survey of future project sites should evaluate more specifically the species of fish in that area.

3.3.7 Shellfish waters

The presence of coastal shellfish waters has not been used to constrain potential sites as they are all sufficiently nearshore to not have an impact. They should however be used to evaluate potential cable landfall locations in future studies. Shellfish waters are shown in 6.21 for reference.

3.3.8 Seabird foraging areas

Figure 6.22 shows SSSI and SPA seabird mean foraging ranges. This map gives an indication of the areas where seabird activity will be. It can be seen that much of the SW is within these areas. It was therefore decided that constraining by these areas would not be valuable. Instead more detailed survey of future project sites should evaluate more specifically the foraging activity in that area and identify the key species of the areas and any HRA requirements that a developer may need to consider.

[3] https://s3-eu-west-1.amazonaws.com/media.newore.catapult/app/uploads/2020/01/30090825/8996-OREC-Wales-Report-WEB.pdf

3.3.9 Heritage sites

Figure 6.22 shows Welsh and English heritage coast and heritage wrecks as reference. As with shellfish waters this has not been used to constrain the mapping in this study but should be used to assess future cable landfall locations in future studies.

3.3.10 Leisure Activates

The RYA produce a map showing the density of leisure boating activates[4]. This map shows areas of high activity around the nearshore areas of the south coast. The areas of high density. Leisure activity was assessed but not included in the weighted analysis as the high concentrations are all nearshore and unlikely to interfere with the areas suitable for FLOW development.

4. Results

4.1 Heat Maps

4.1.1 Combining data layers

As described in Section 2, the weightings and data layers were combined to produce an overall weightings map with a theoretical scale from 0 to 1. This weightings map indicates the areas with the least constraint where development zones could be prioritised.

4.1.2 Maps

Figure 4-1 shows the combination of the weighted data layers, more detail can be seen in Figure 6.13. Areas coloured in light purple indicate areas which are deemed most suitable for FLOW development, while blue areas indicate areas that are not unsuitable for FLOW but are of higher constraint. Hard constraints removed are shown in light blue and indicate areas where achieving consent will be difficult and timely. There is a large amount of area within the SW Marine Plan Offshore area with relatively low barriers to development based on the constraints analysed. This provides significant opportunity for the technology and for energy generation in the Celtic Sea as a whole and Wales & the SW in particular. Over 25,000km^2 of the Celtic Sea in total is an area of low constraint suitable for development, while an area of low constraint of over 18,000km^2 is available within the SW Marine Plan offshore area.

[4] https://www.rya.org.uk/knowledge-advice/planning-environment/Pages/uk-coastal-atlas-of-recreational-boating.aspx

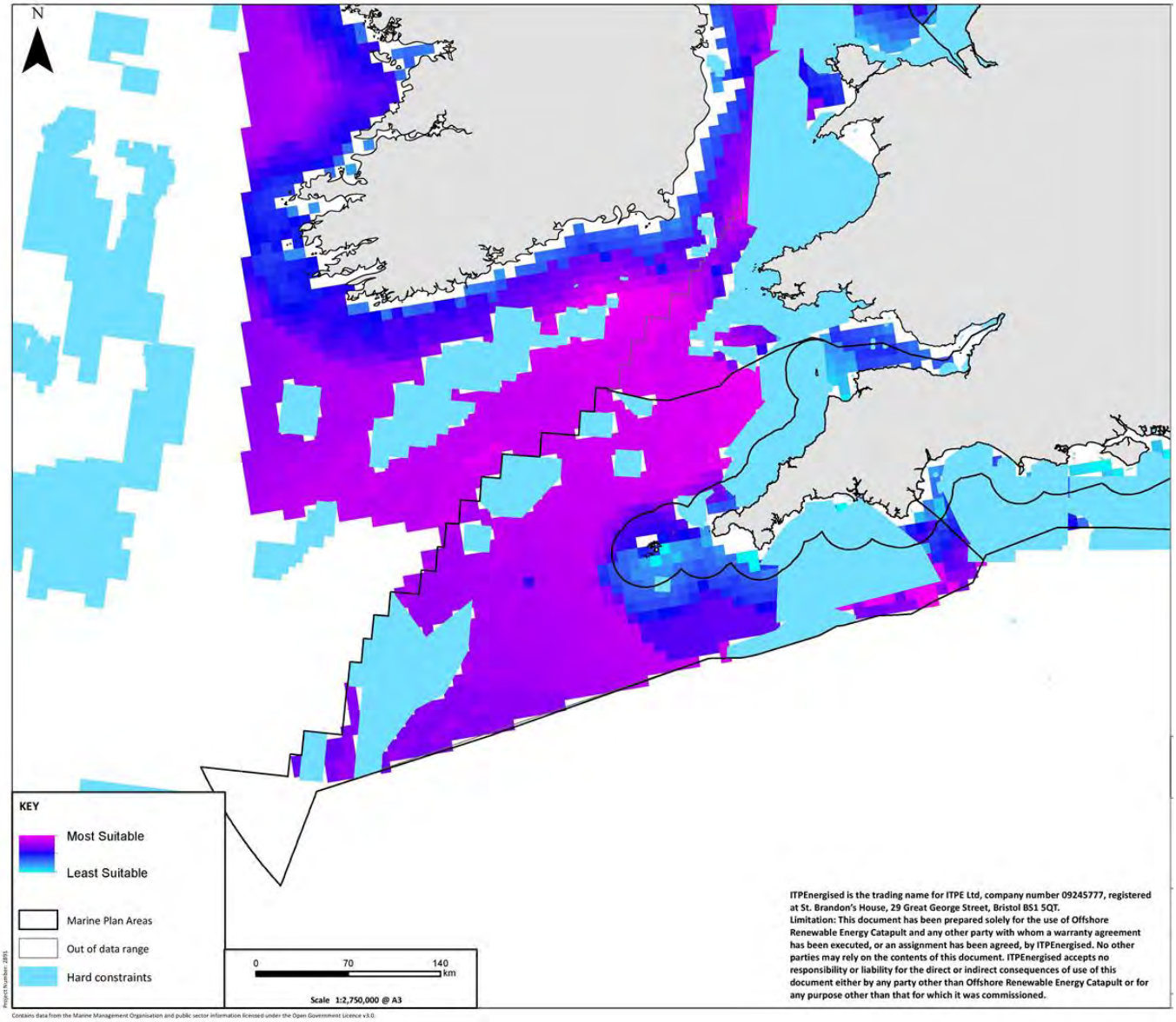


Figure 4-1: Areas of least constraint identified (large scale shown in 6.13)

4.2 Zone Identification

Following the production of the combined data layer, potential development zones have been identified (See Figure 6.14). Rather than highlighting the areas FLOW development is possible, these zones contain the areas of least constraint where initial development zones could be created; these key areas represent the more promising FLOW in the region.

Five key zones have been identified and are shown in Figure 4-2, more detail can be seen in Figure 6.14. These zones highlight the areas which have the least constraint rather than the only areas where FLOW can be developed. In particular Zone 1 has a high rating and could be suitable for development. It extends from the boundary of the SW marine Plan boundary to its north down to where the colour contour darkens closer to the coast. MCZ and SAC areas constrain it on its eastern side. It then extends to three MCZ zones on its west side. The boundary between zone 1 and zone 2 is drawn between these MCZ areas where the suitability index colour darkens slightly.

Zone 2 follows a light colour area around down to its south where it meets zone 3. This is a subjective boundary where the suitability index colour darkens slightly. Zone 3 extends from the base of zone 2 on its northern edge down to the SW Marine Plan boundary in the south. It is bounded on its east side by the darkening of the suitability index colour due to the military exercise zone. The western boundaries of both zone 2 and 3 are subjective and drawn where the suitability index colour darkens slightly. It is feasible that these areas can be extended to the west, but increased consenting and technological risk is likely.

Zone 4 is a small zone close to the edge of the military danger zones on the South Coast. Where not subject to hard constraints, the area shows high potential. It is however close to the English Channel shipping lanes and within an area with high fishing density. If the weighting of these two constraints were to be changed then the attractiveness of this zone may decrease.

Zone 5 is outside the SW Marine Plan area in Welsh waters. It is bounded by the EEZ limit on the west side while it avoids a SPA site on its east side. The northern limit has been drawn at a point where the suitability index colour becomes darker. It is feasible that this area can be extended to the north, but increased consenting and technological risk is likely.

Table 4-1: Zone Areas

Zone	Area [km^2]
Zone 1	6300
Zone 2	5588
Zone 3	5312
Zone 4	800
Zone 5 - Wales	3983

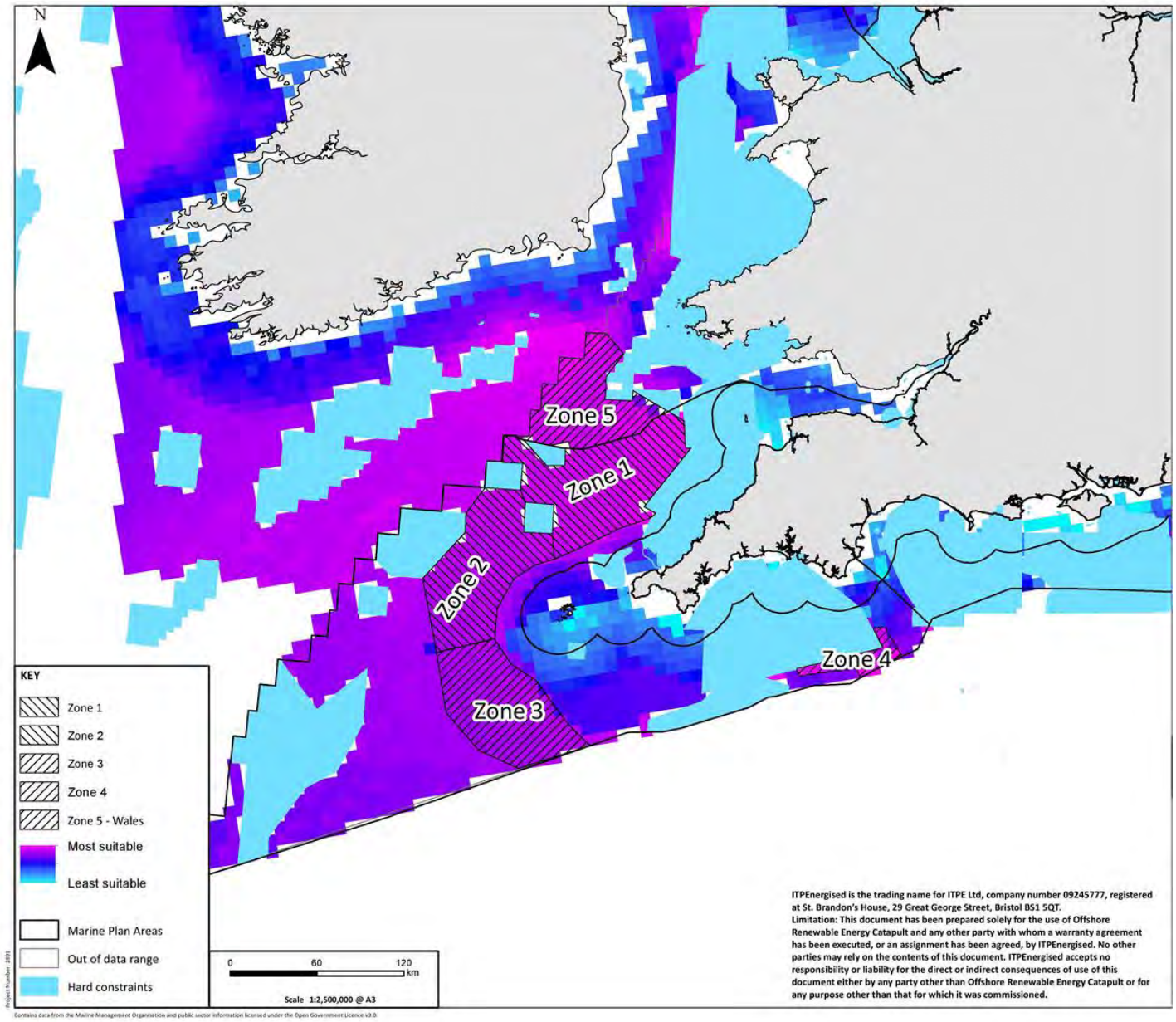


Figure 4-2: Key development zones (large scale shown in 6.14)

5. Conclusions

Wales and the SW has an excellent offshore wind resource with average wind speeds >9.5m/s at a hub height of 100m. With the falling cost of offshore wind, the advancements in floating offshore wind technology, and the necessity of high capacity, clean energy to contribute to the UK's effort towards net zero, it is clear Wales and the SW should be of interest to offshore wind developers.

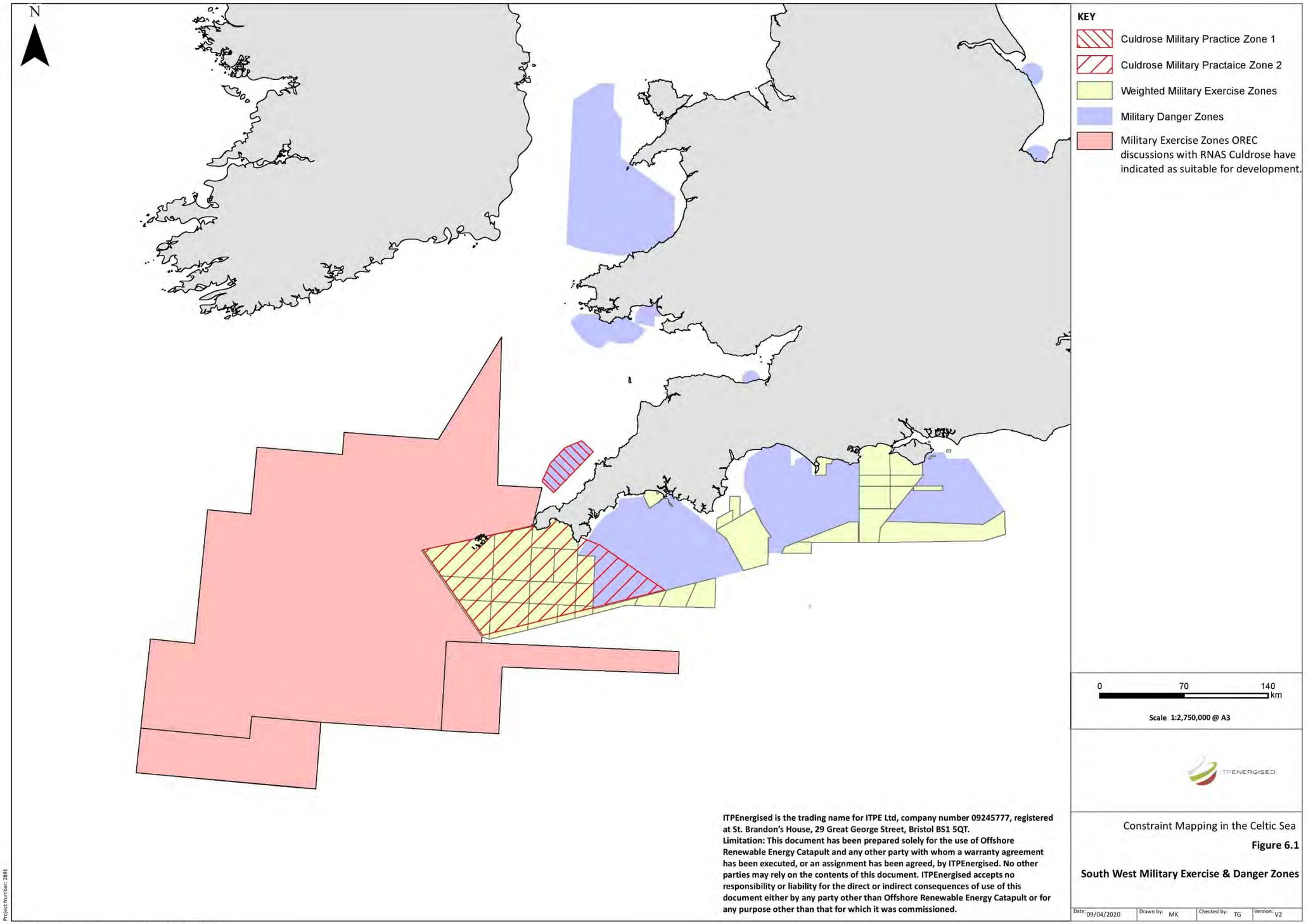
In this work, ITPE has shown a large region in the SW Marine Plan offshore area which is potentially suitable for FLOW development. ITPE has identified over 18,000km^2 of area in the SW Marine plan area potentially viable for FLOW developments, and 25,000km^2 in the wider Celtic Sea. Additionally, four zones of low constraint have been identified off the SW coast with a fifth in Welsh waters.

ITPE recommends:

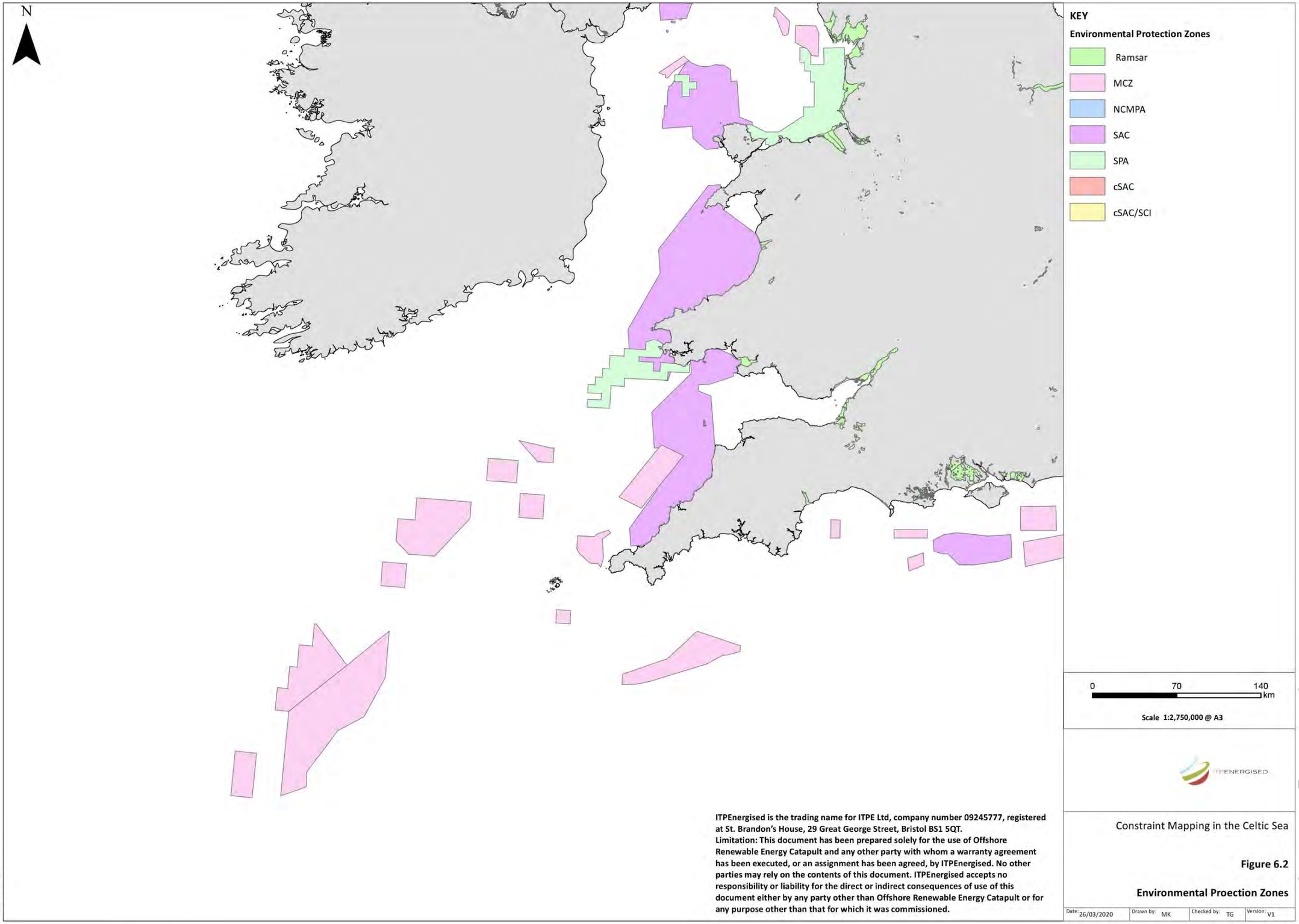
- OREC responds to the Government's consultation on the SW Marine plan outlining ITPE's findings, the potential for FLOW in the area and how FLOW development in the region can help the UK towards net zero.
- Further analysis of viable wind farm areas including factors that will affect economic viability. For example, proximity to ports and options for grid connection of wind farms should be investigated.
- OREC considers a stakeholder engagement plan.
- OREC builds on its analysis in their supply chain report and investigates the socio-economic benefits of FLOW wind developments in the SW and wider Celtic Sea further.
- More detailed assessment of access requirements and the weather windows which could be expected in a Celtic Sea development would help in the understanding of potential turbine downtime and time to repair.
- OREC responds to BEIS' consultation on the CfD scheme in support of FLOW, the creation of a new "Pot 3" so that FLOW does not compete with fixed OSW for CfDs, and seeking assurances in the size of "Pot 2".
- OREC coordinates its response to marine plan consultations with Renewable UK and the wider industry.

6. Appendix A – GIS Maps

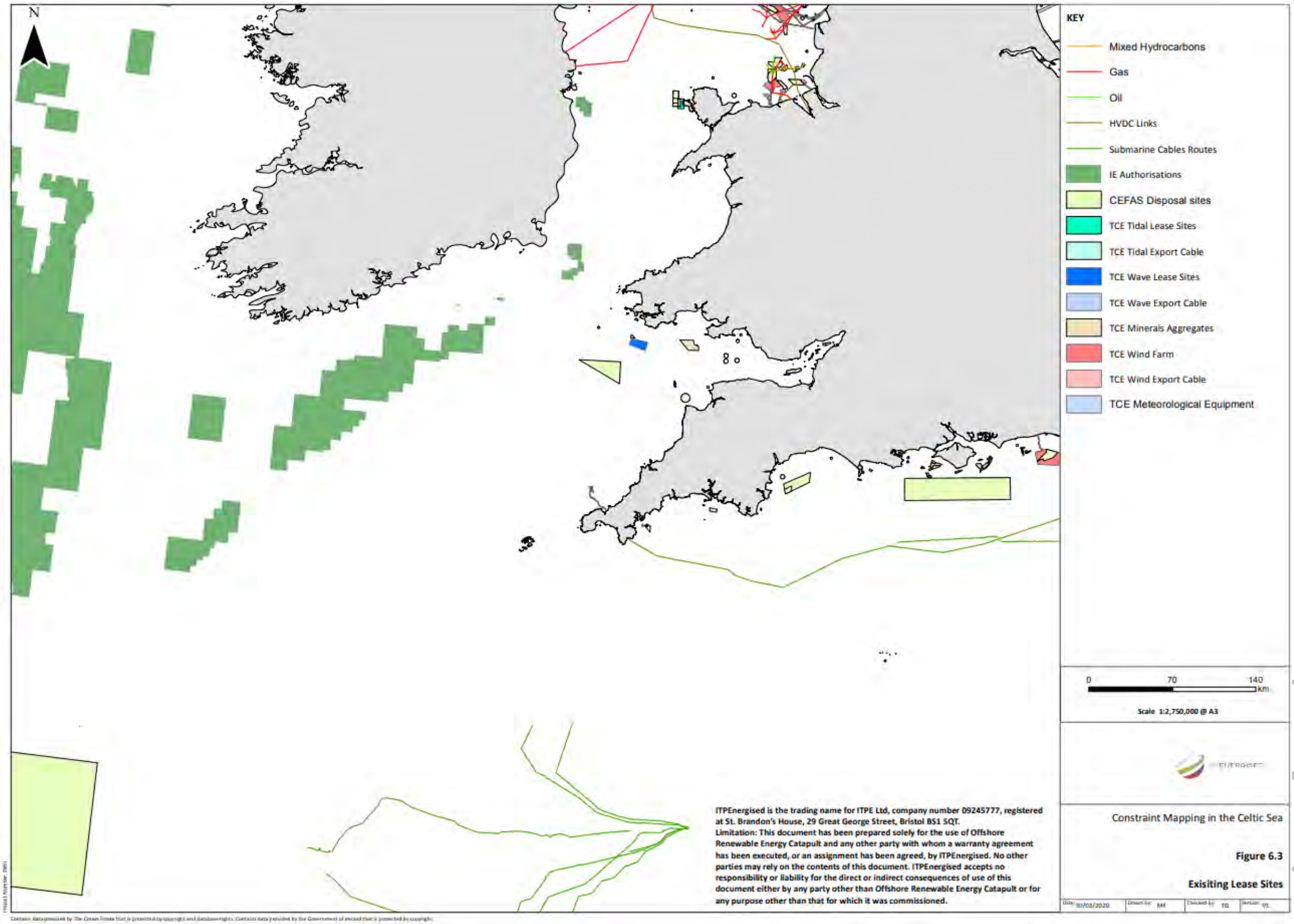
6.1 Military Exercise and Danger Zones



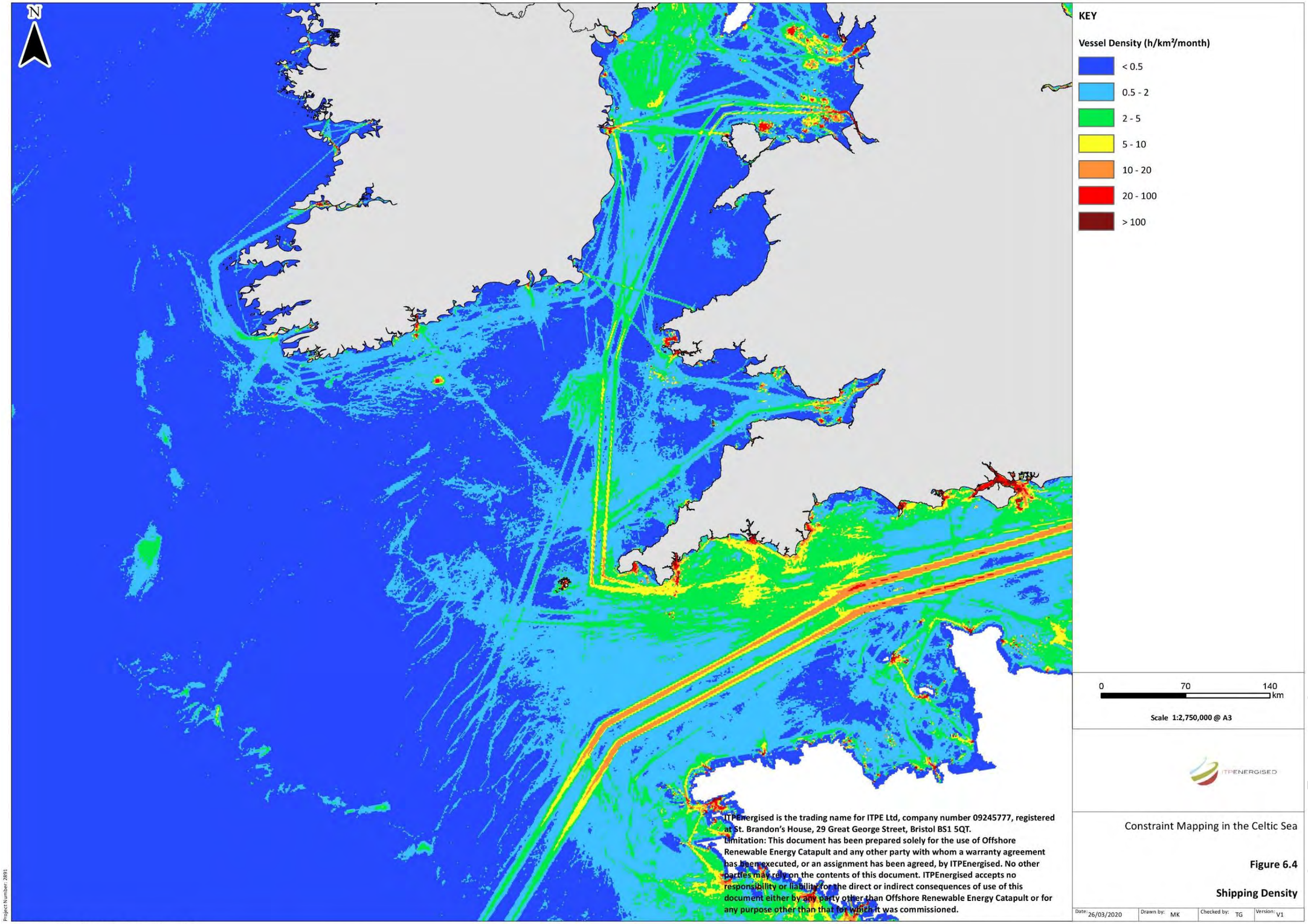
6.2 Environmental Protection Zones



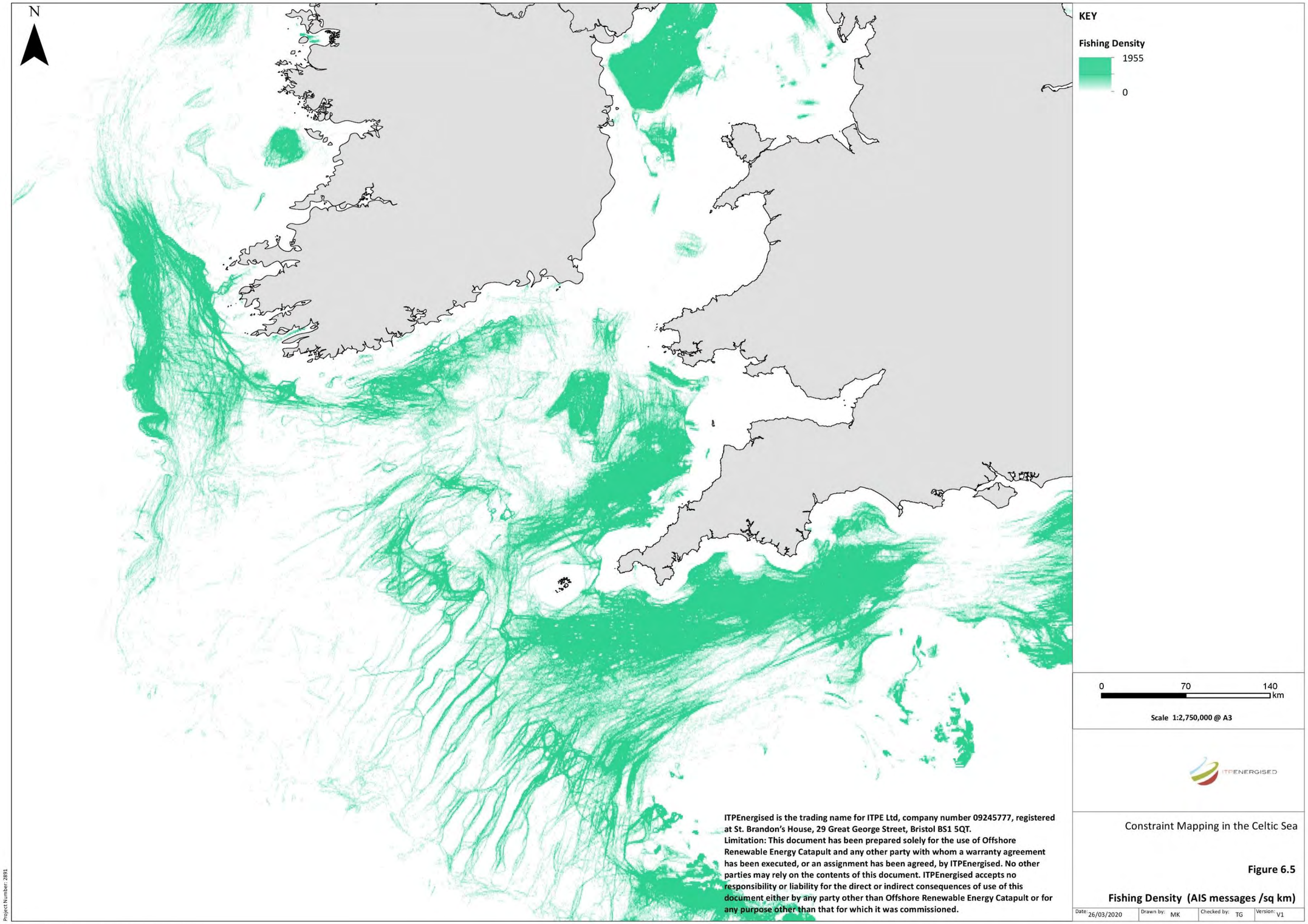
6.3 Existing Lease Sites



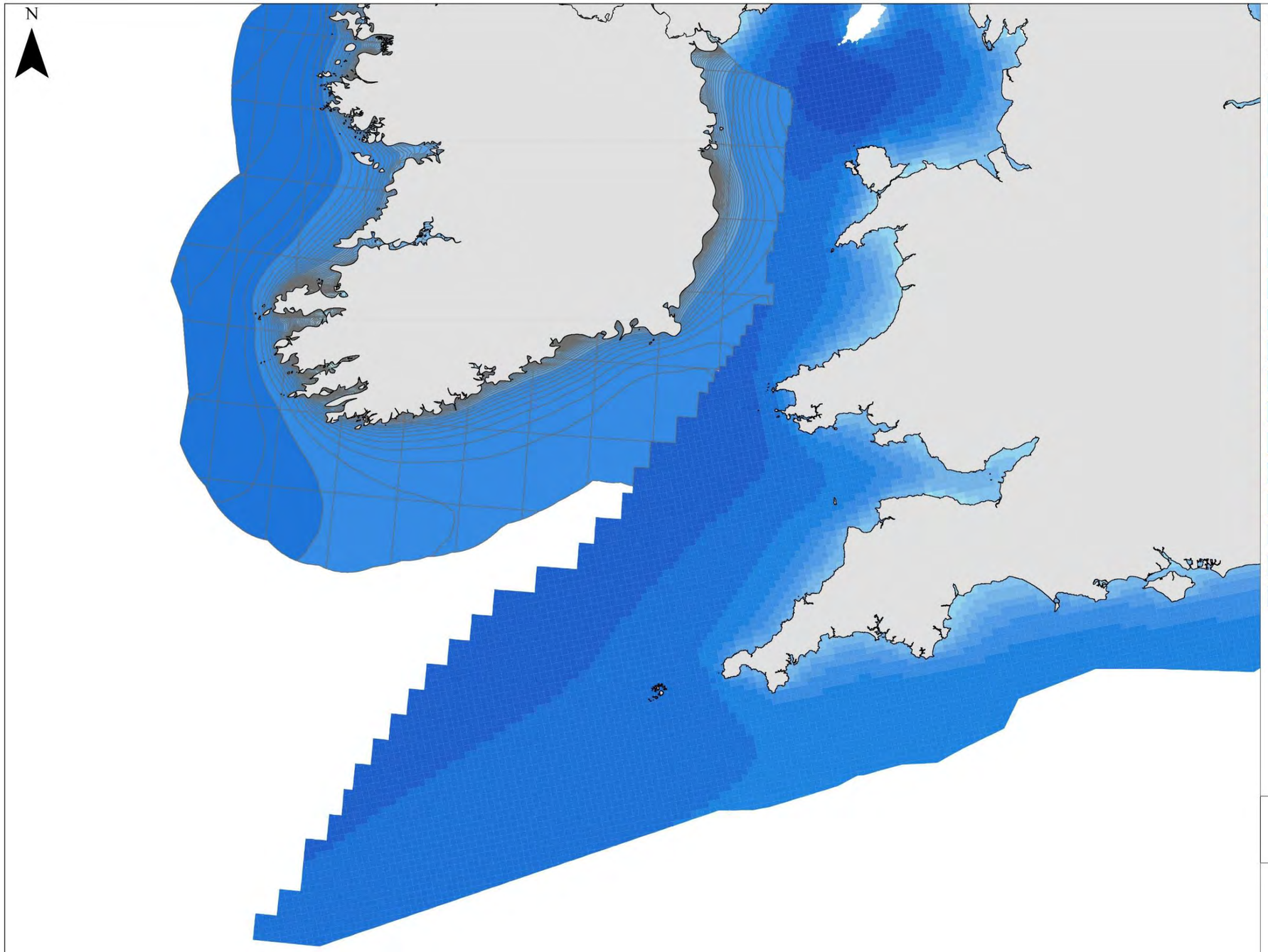
6.4 Shipping Density



6.5 Fishing Density



6.6 Wind Resource Data



Constraint Mapping in the Celtic Sea

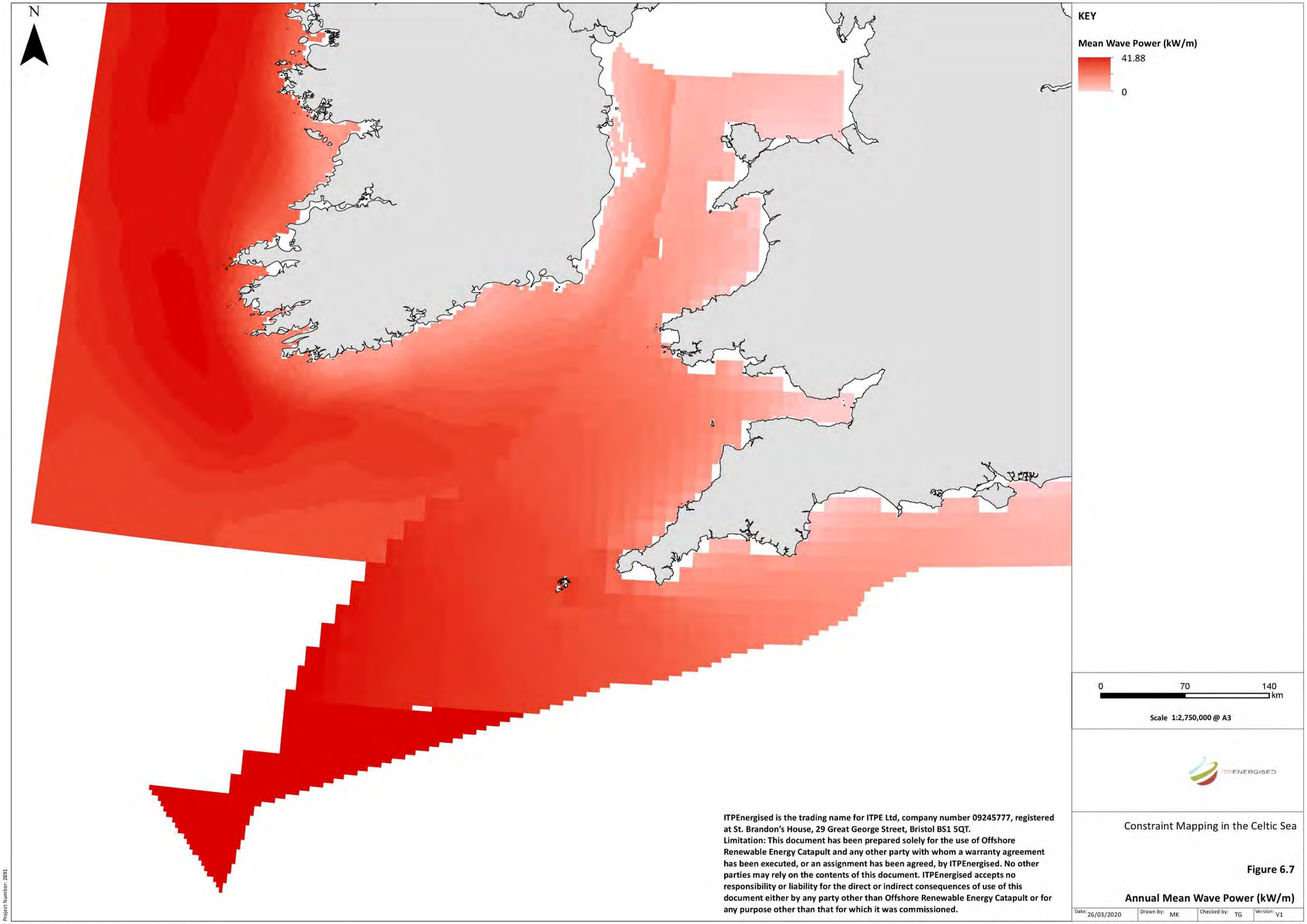
Figure 6.6

Wind Speed Data

Date:	Drawn by:	Checked by:	Version:
26/03/2020	MK	TG	V1

Project Number: 2891

6.7 Wave


N
KEY
Mean Wave Power (kW/m)
41.88
0
0
70
140
km
Scale 1:2,750,000 @ A3
ITPENERGISED
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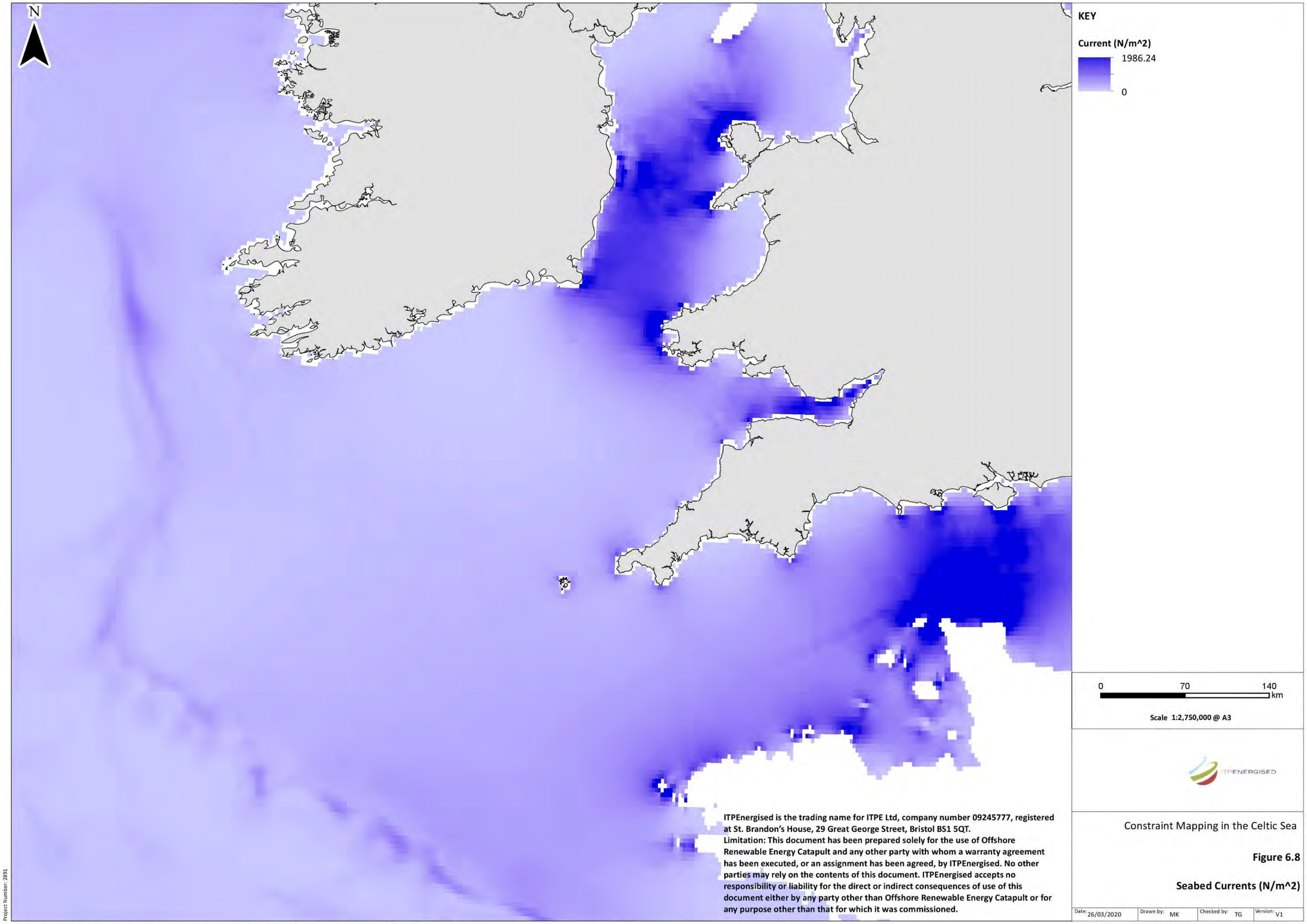
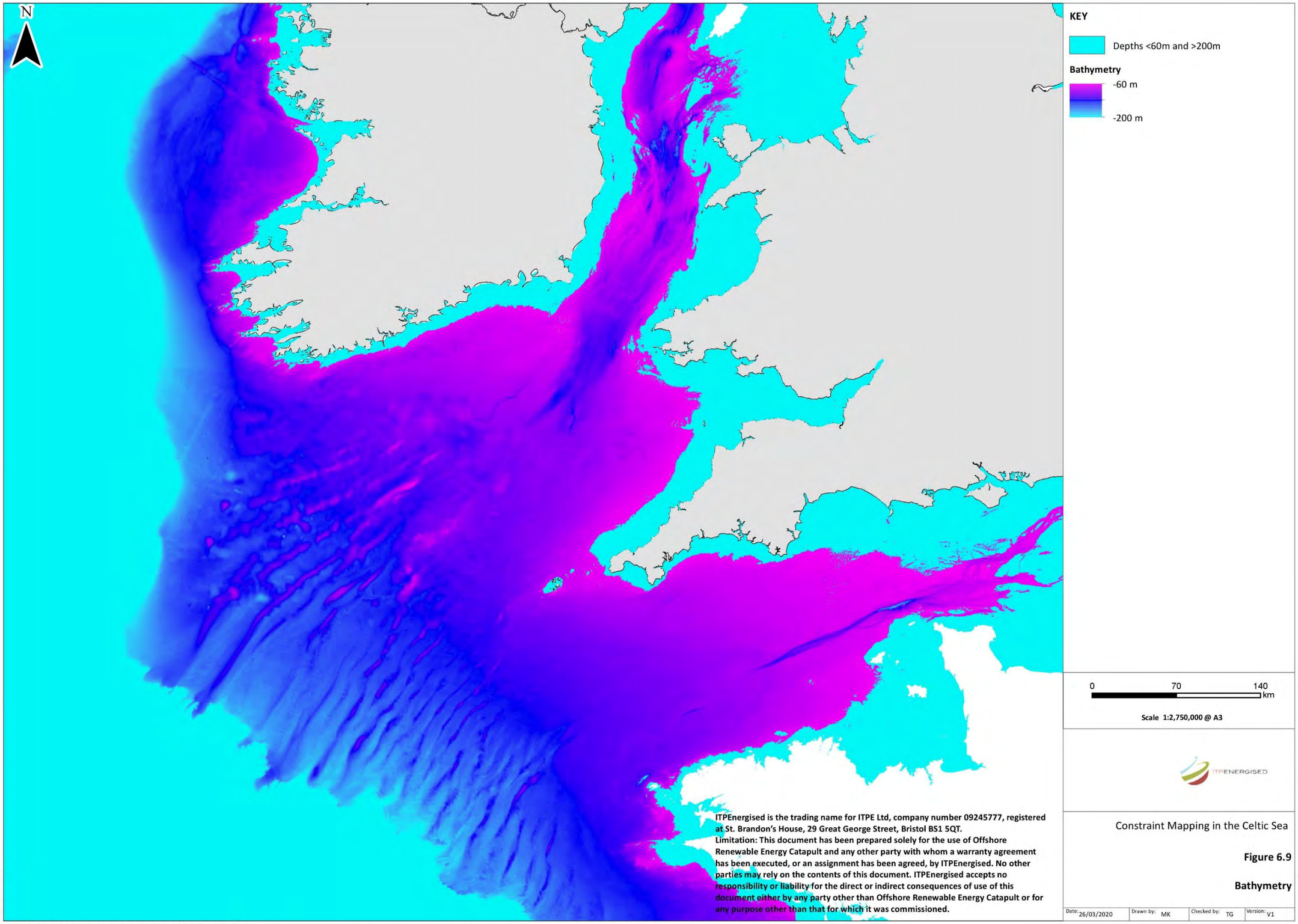
Constraint Mapping in the Celtic Sea
Figure 6.7
Annual Mean Wave Power (kW/m)
Date: 26/03/2020
Drawn by: MK
Checked by: TG
Version: V1
Project Number: 2891
Reproduced from http://www.renewables-atlas.info/ © Crown Copyright.

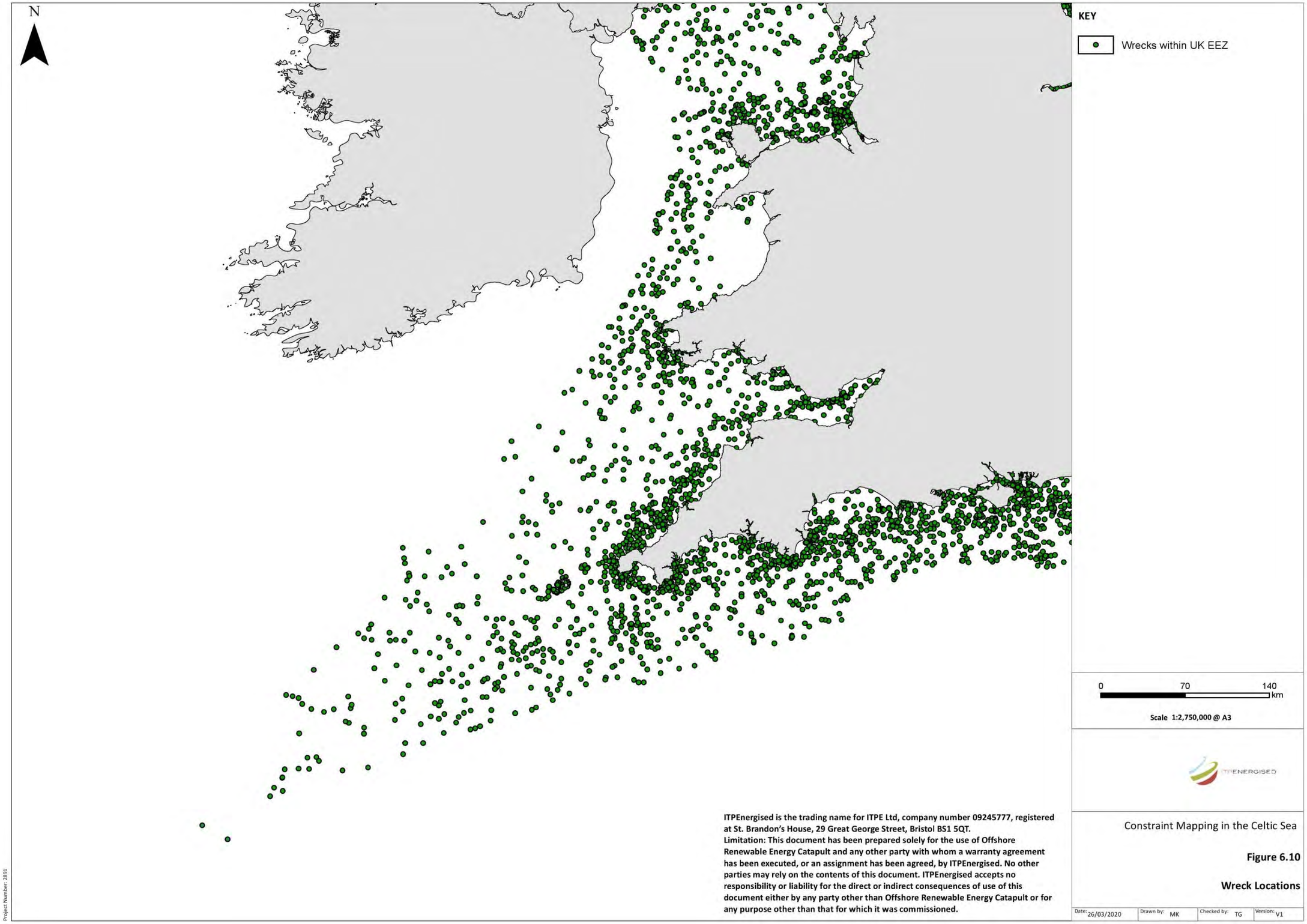
6.8 Current



6.9 Bathymetry



6.10 Wrecks


N
KEY
Wrecks within UK EEZ
0
70
140
km
Scale 1:2,750,000 @ A3
ITPENERGISED
Constraint Mapping in the Celtic Sea
Figure 6.10
Wreck Locations
Date: 26/03/2020
Drawn by: MK
Checked by: TG
Version: V1
Project Number: 2891
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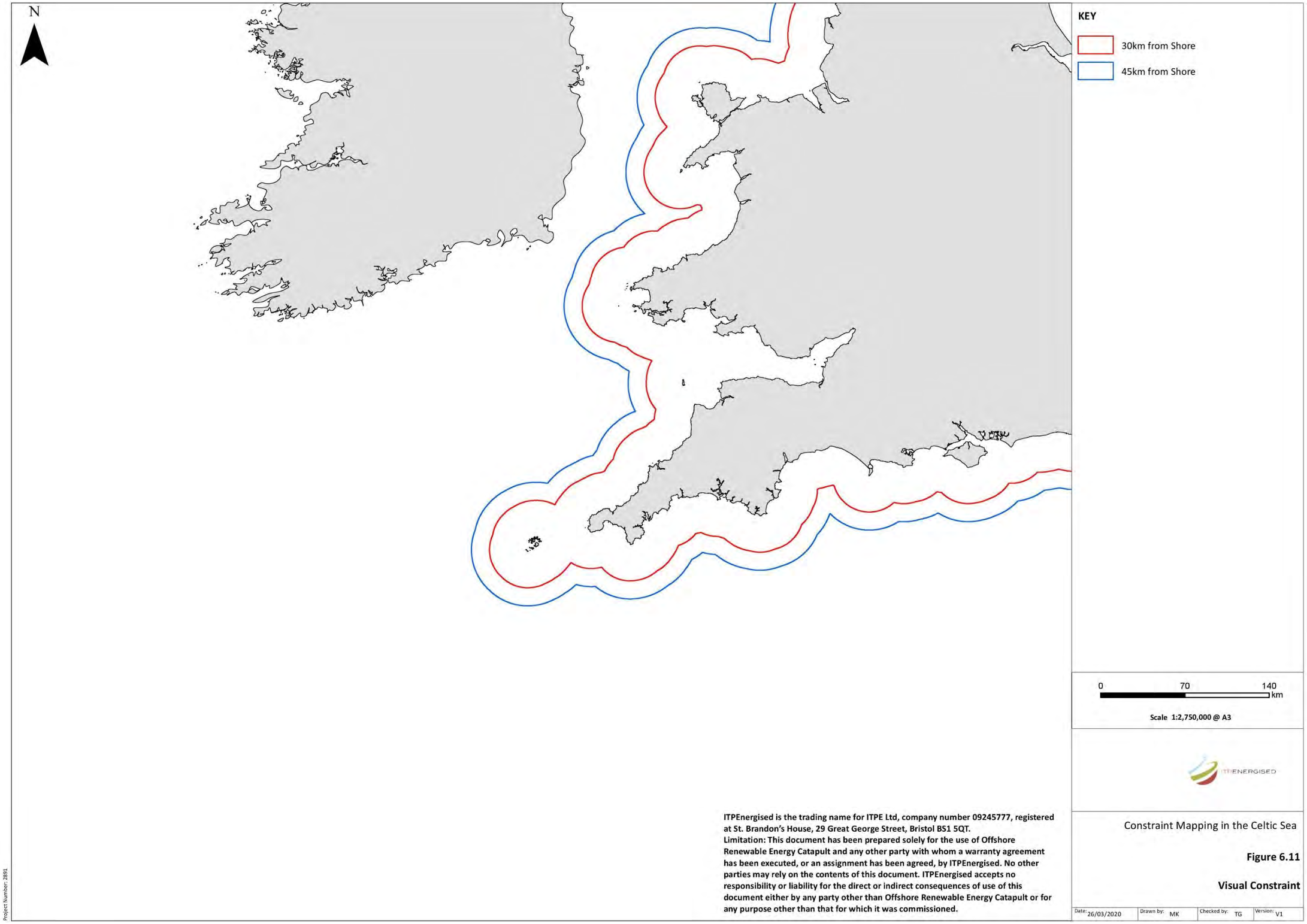
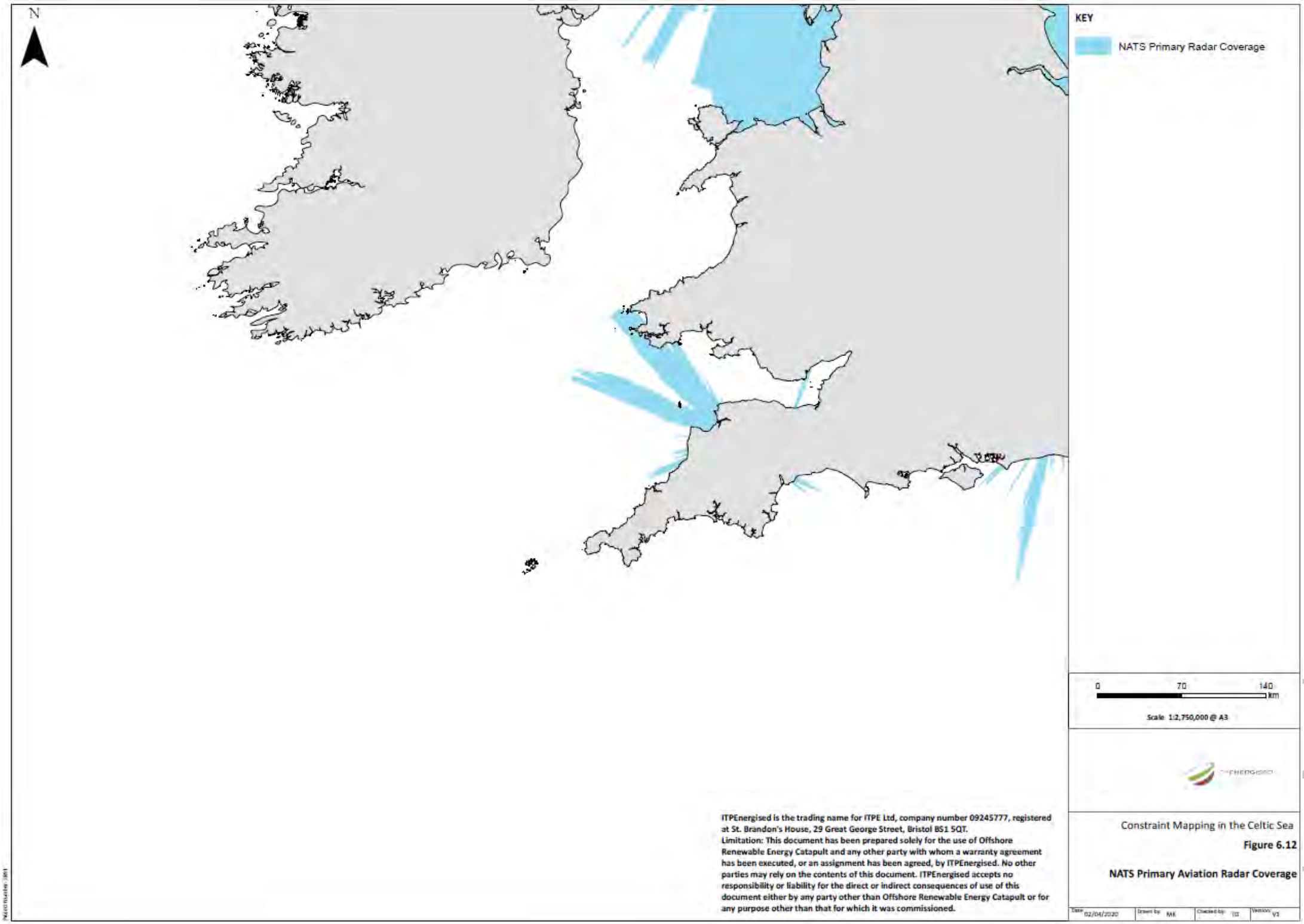
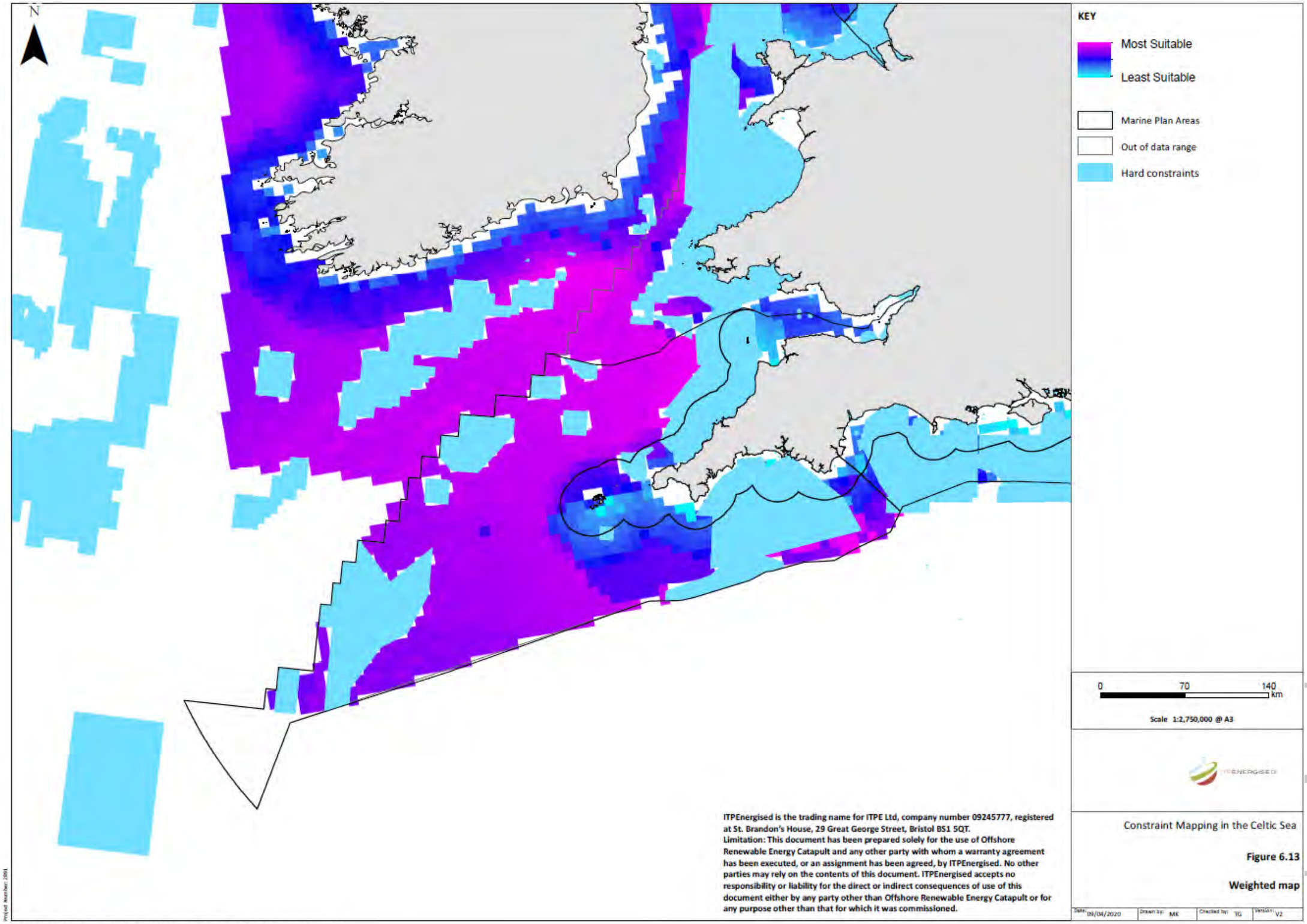
6.11 Visual Constraint



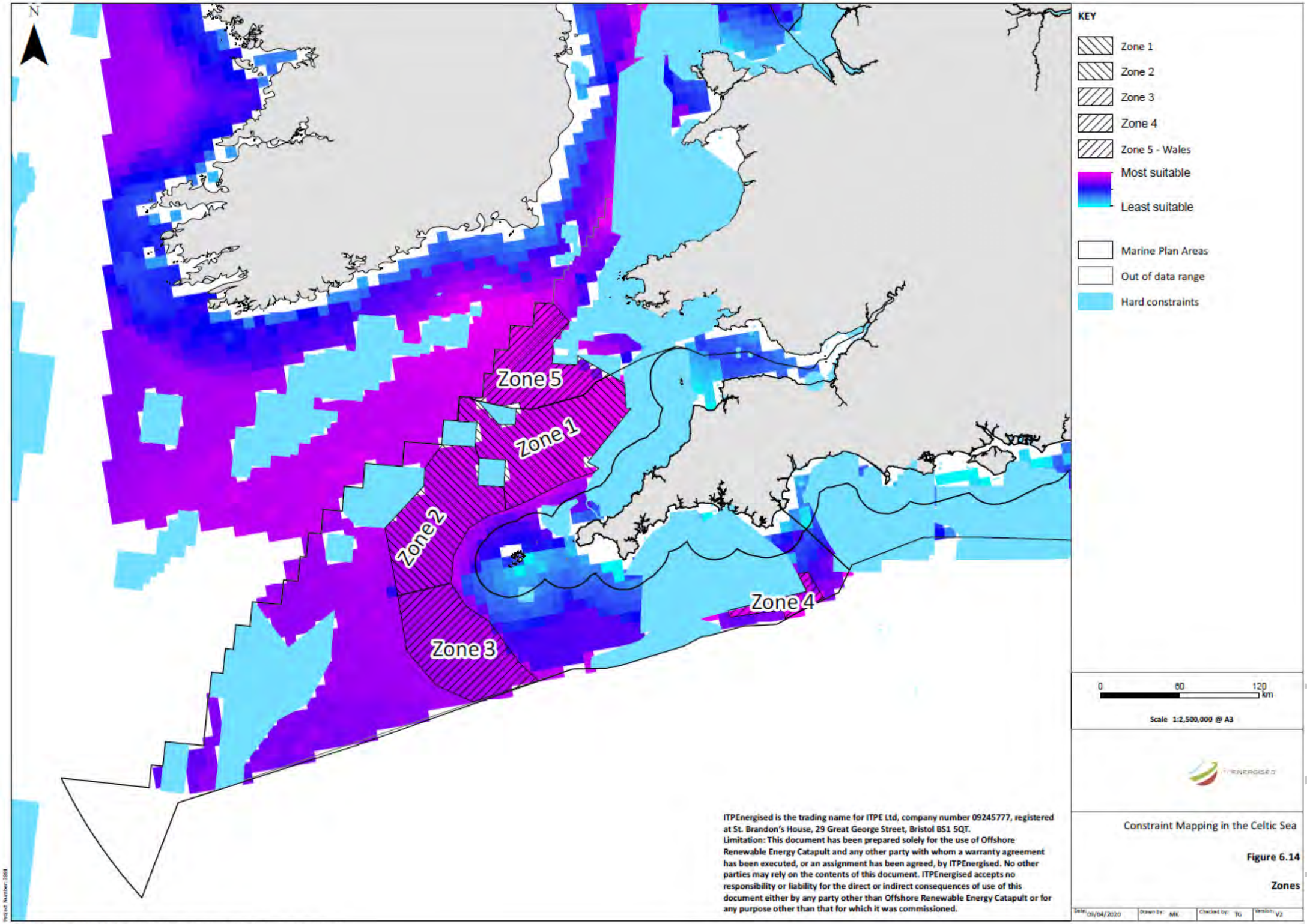
6.12 NATS primary radar coverage



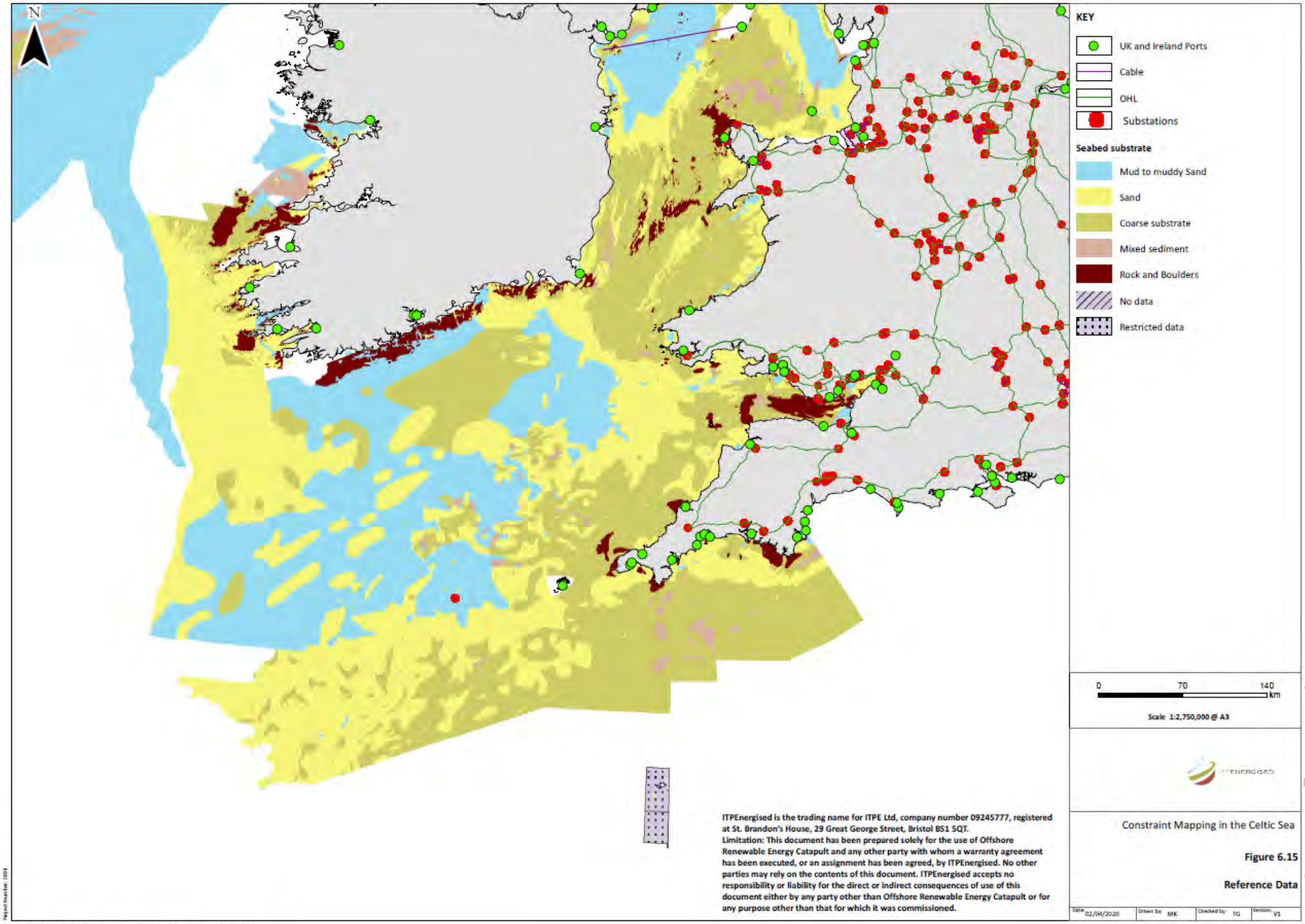
6.13 Weighted map



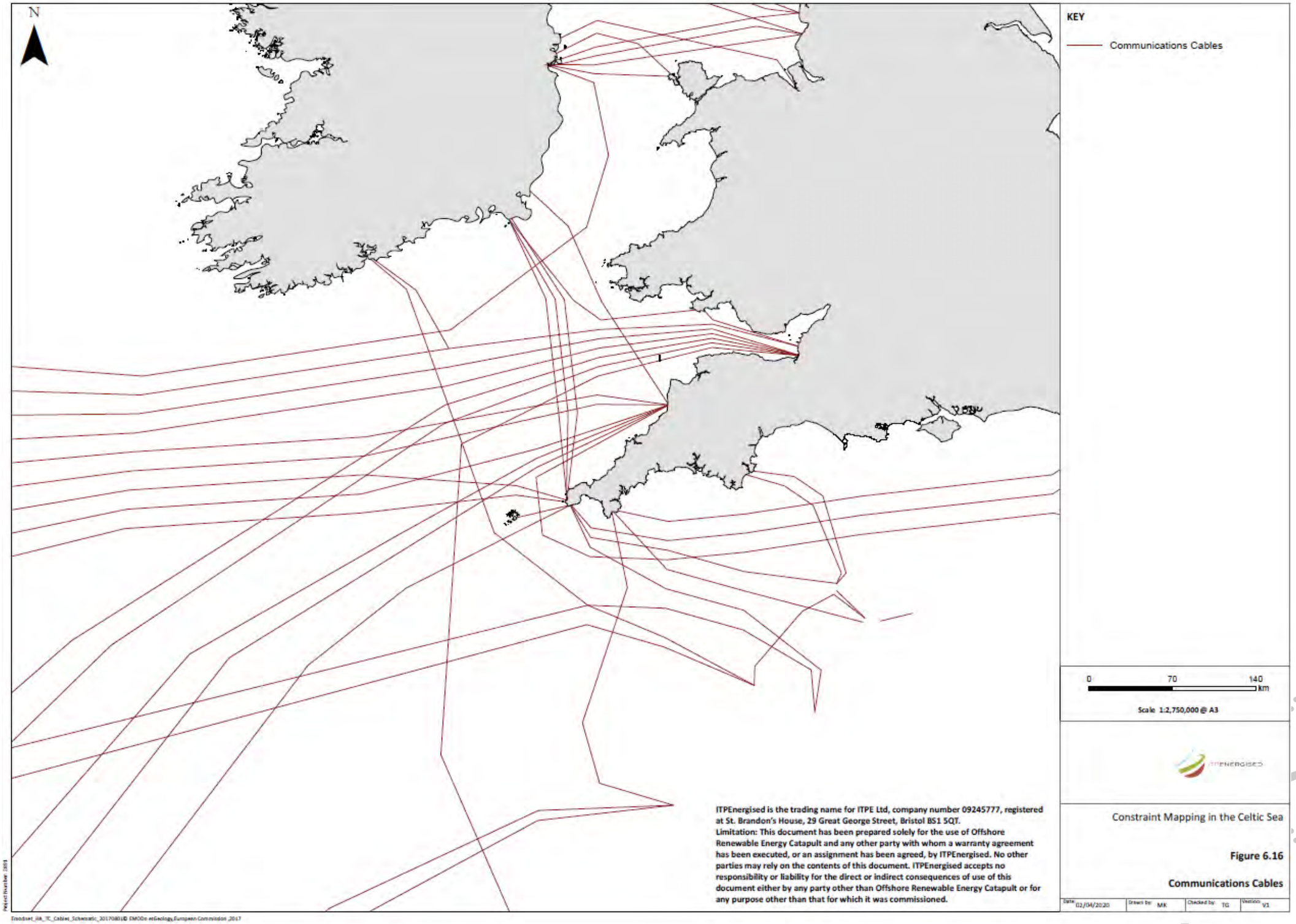
6.14 Identified Zones



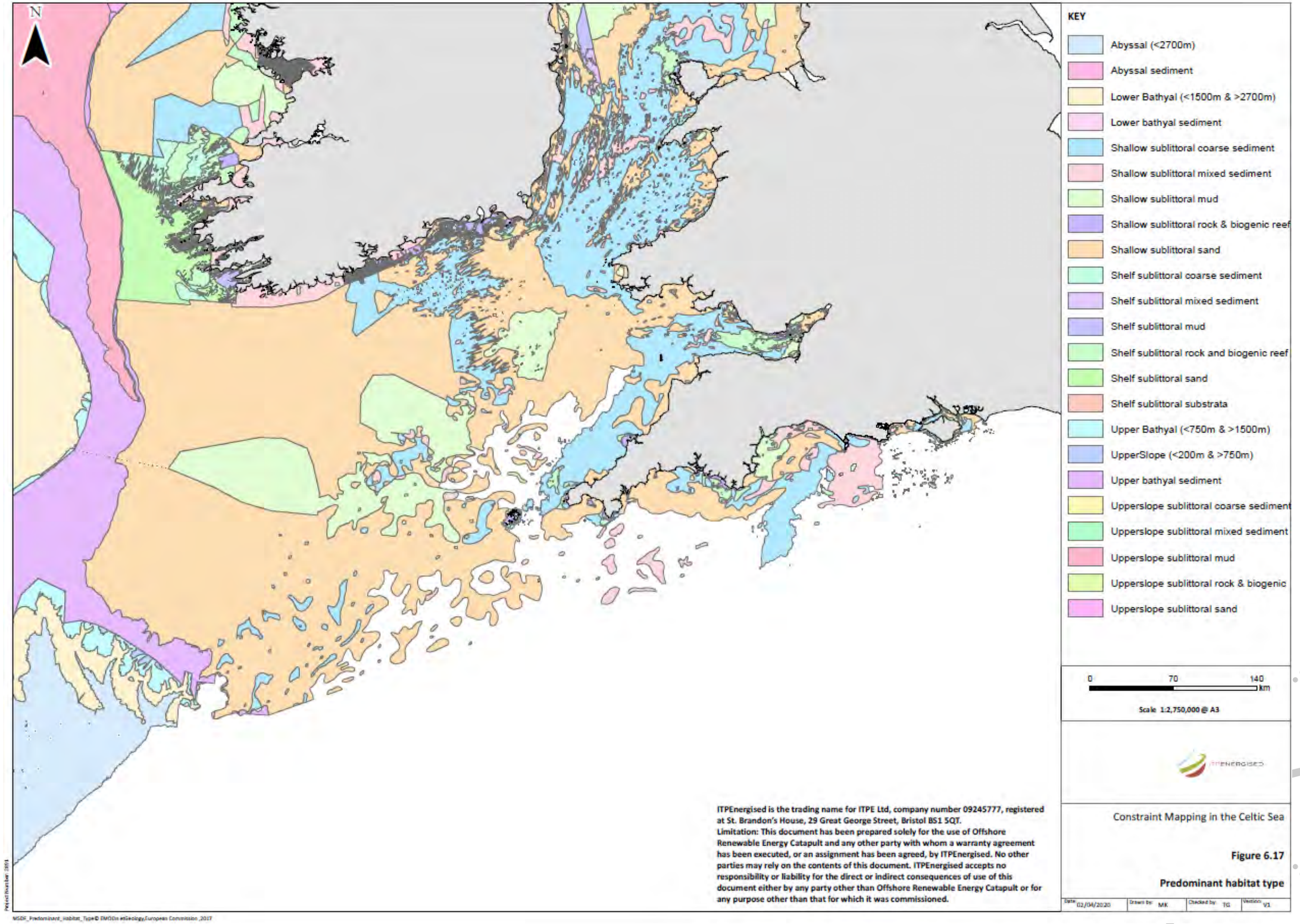
6.15 Reference Data



6.16 Communications Cables

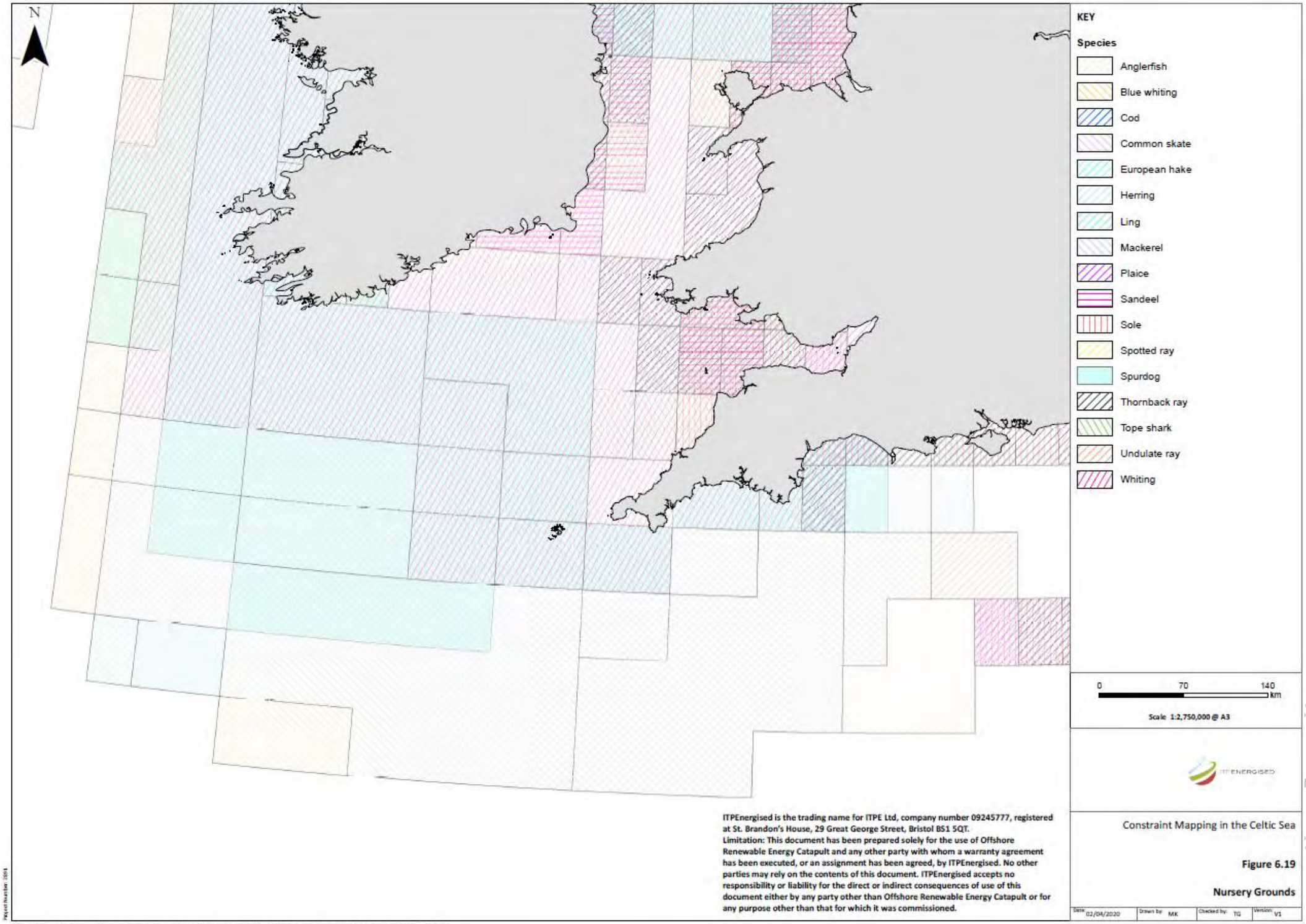


6.17 Predominant habitat type

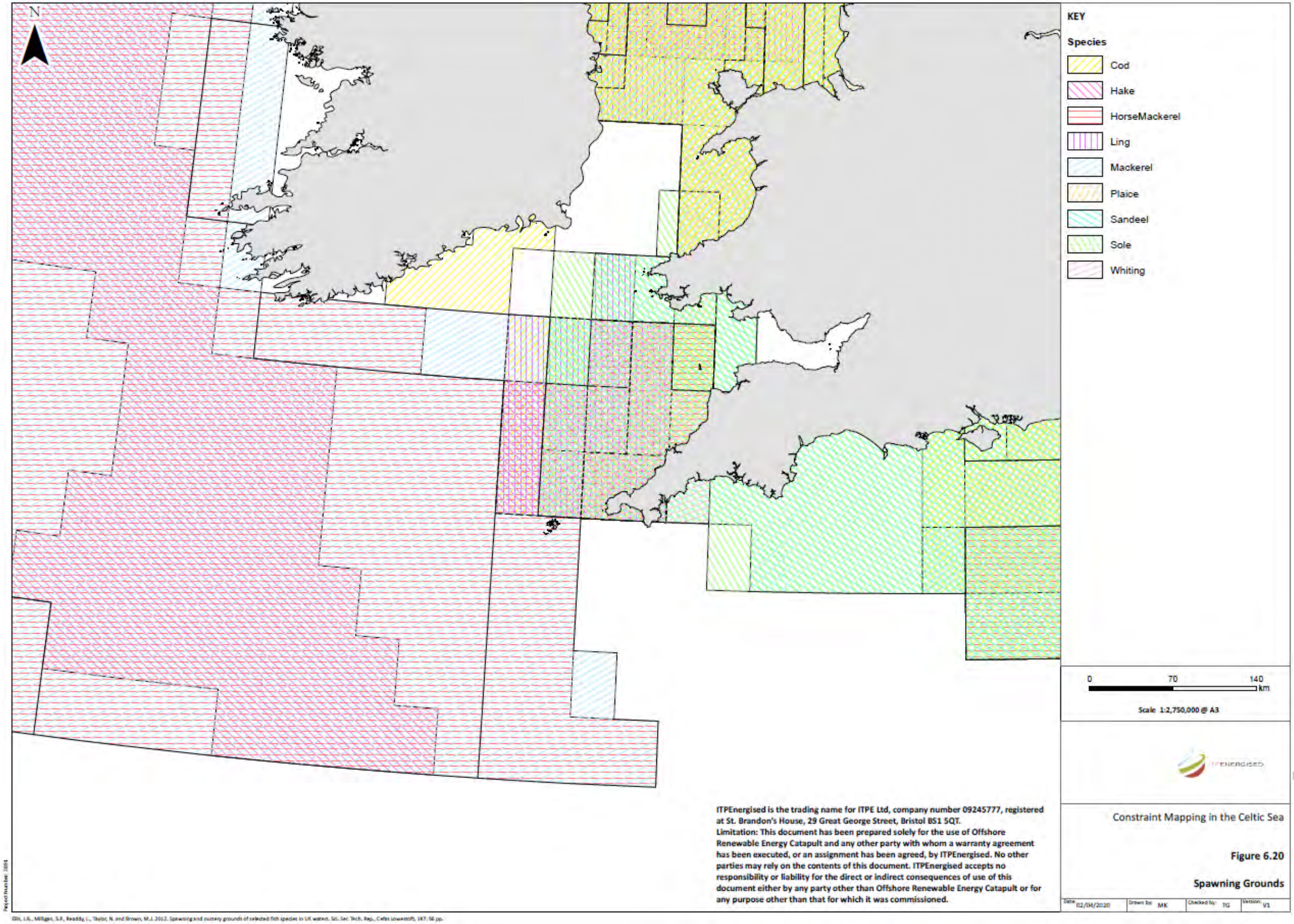


6.18 Marine mammal data

6.19 Nursery grounds

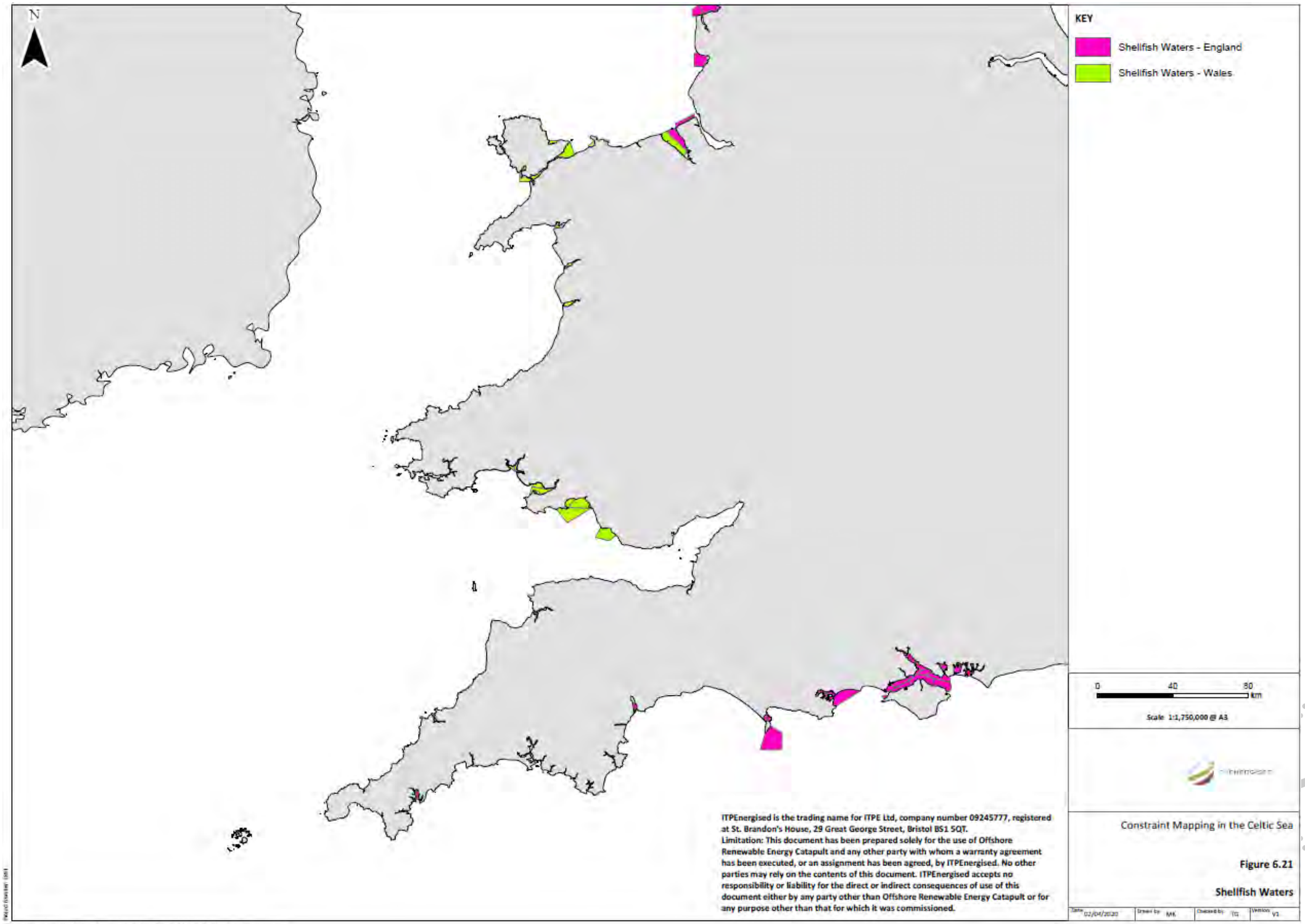


6.20 Spawning grounds

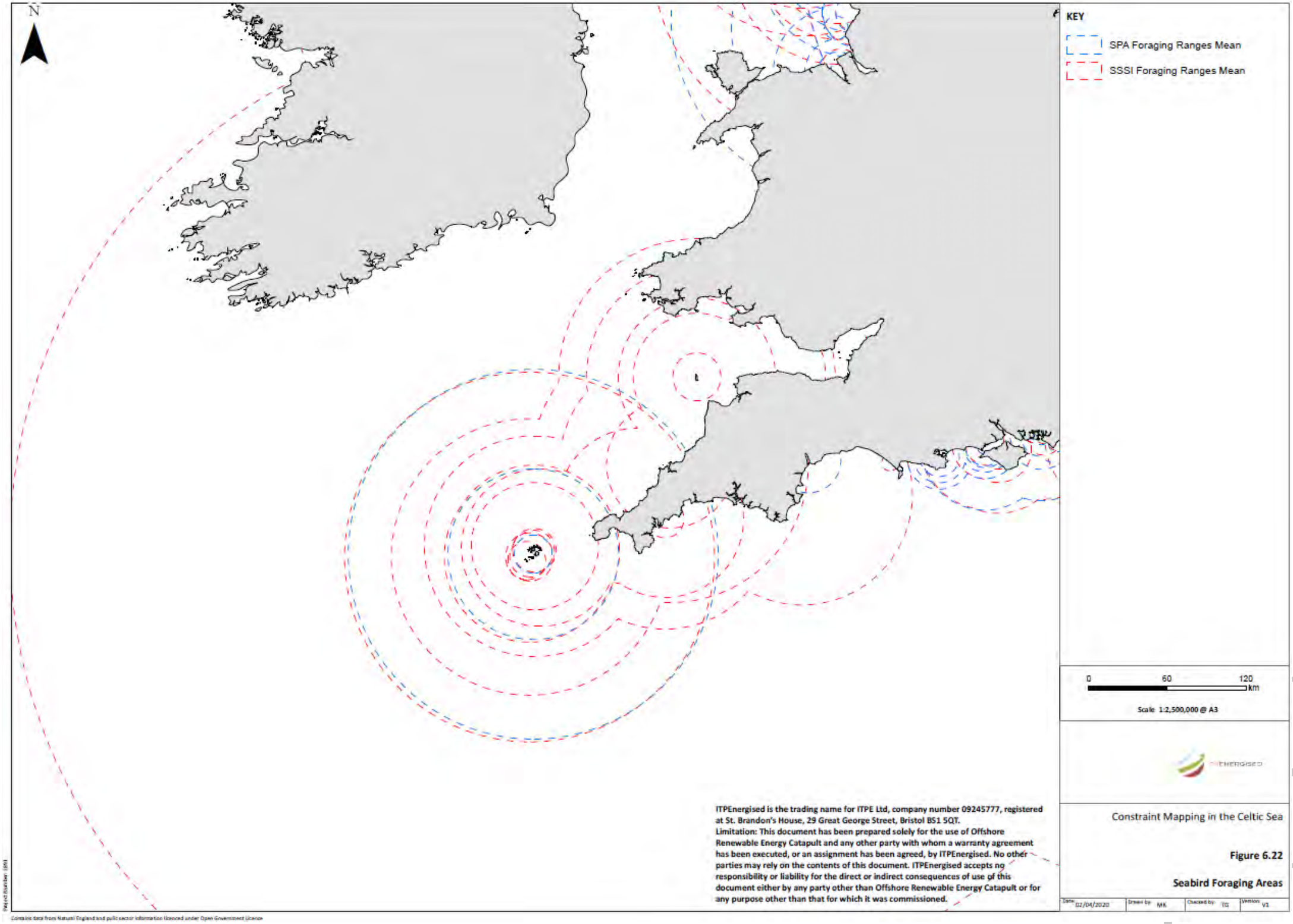


Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N. and Brown, M.J. 2012. Spawning and nursery grounds of selected fish species in UK waters. Sci. Ser. Tech. Rep., Cefas Lowestoft, 147: 56 pp.

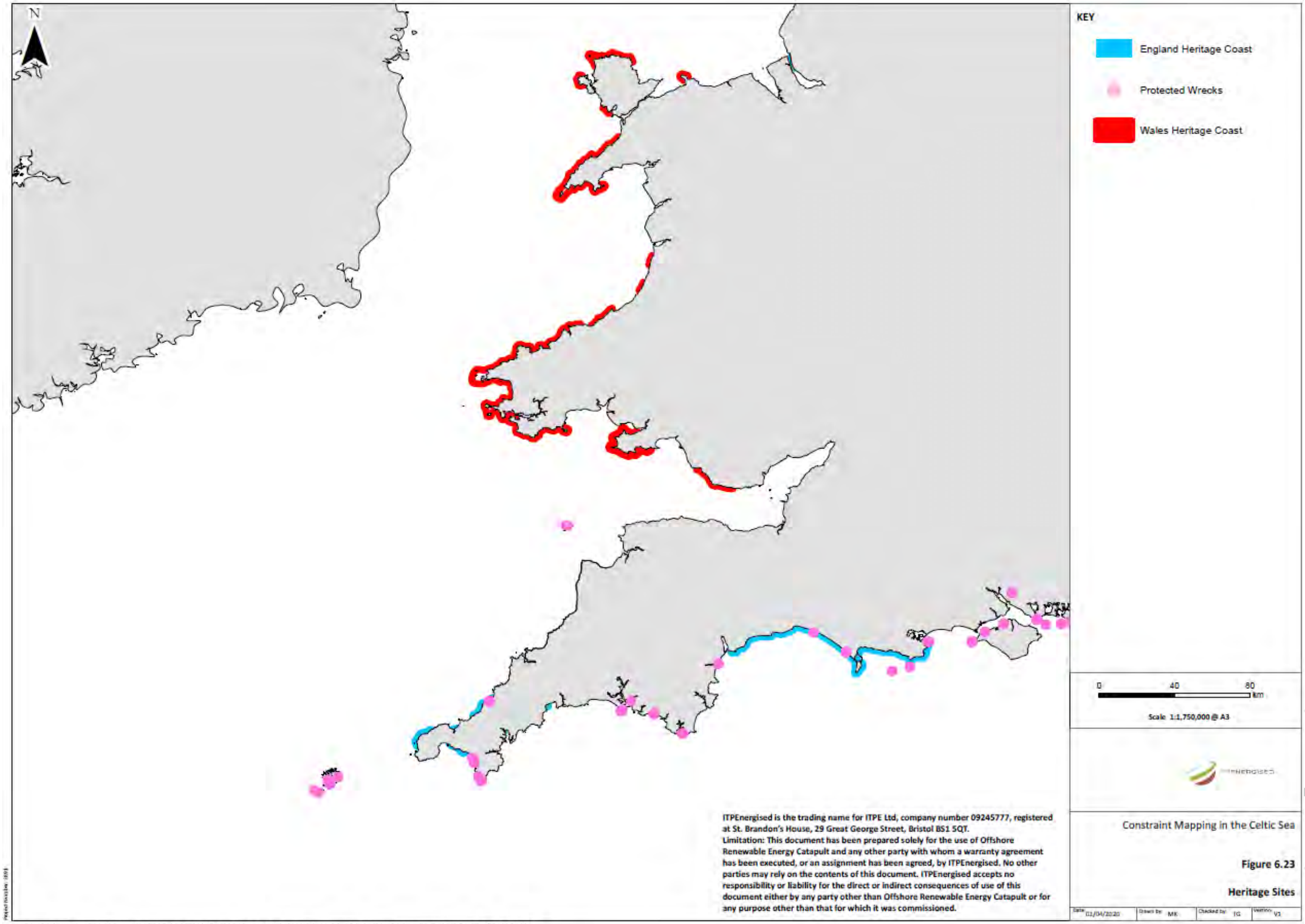
6.21 Shellfish Waters



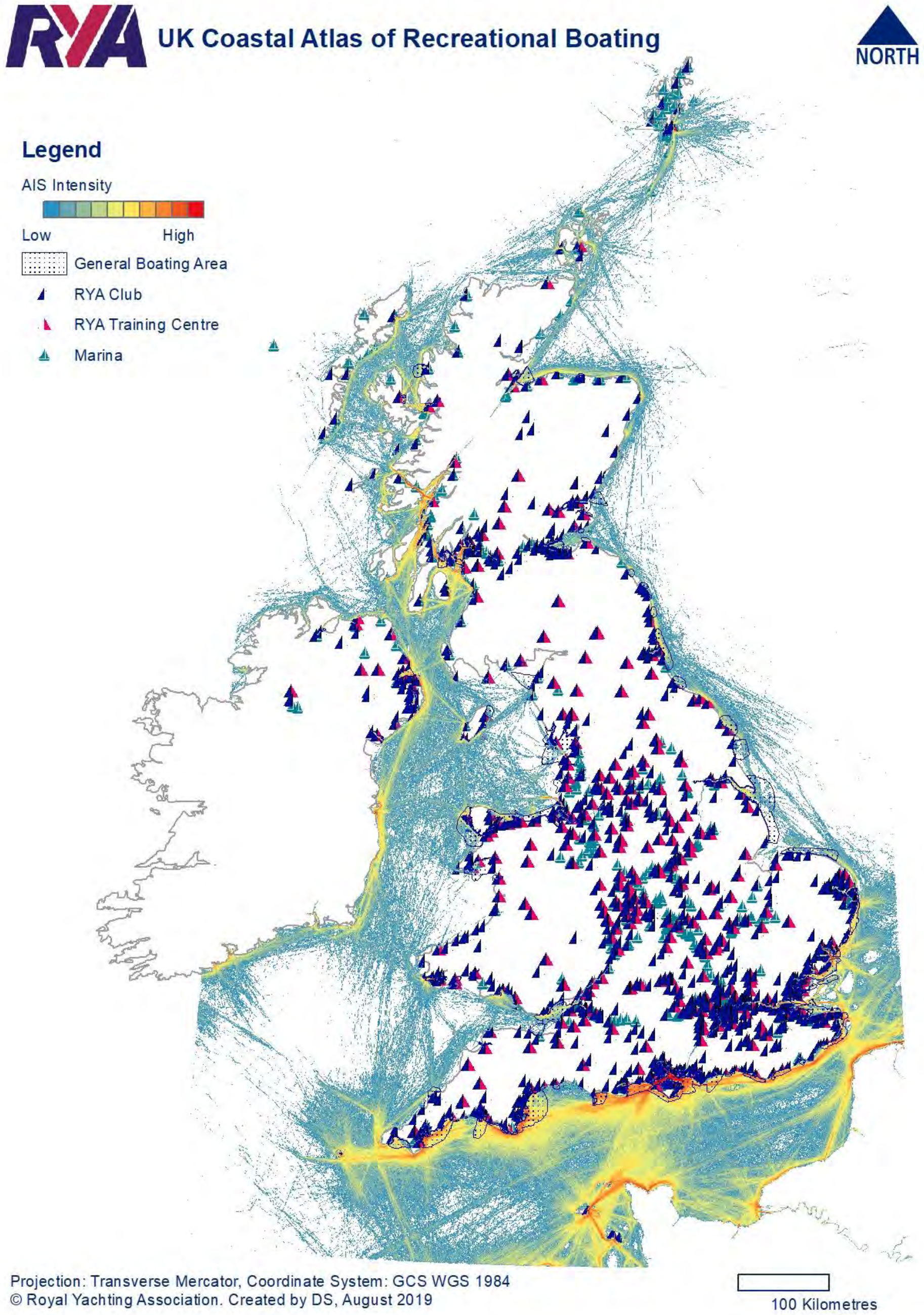
6.22 Seabird foraging areas



6.23 Heritage sites



6.24 Leisure Boating[5]



[5] https://www.rya.org.uk/knowledge-advice/planning-environment/Pages/uk-coastal-atlas-of-recreational-boating.aspx

7. Appendix B – Data Sources

Type	Data Layer	Source
Hard	Military Zones	OREC discussion with RNAS Culdrose and DEFRA
	Ramsar Sites	JNCC
	Marine protection areas	JNCC
	Sites of special scientific interest	JNCC
	Special area of conservation	JNCC
	Existing CE lease sites	The Crown Estate
Weighted	Shipping routes	EMODnet
	Fishing	EMODnet
	Wind speed	MetOffice & Sustainable Energy Authority of Ireland
	Wave power	MetOcean Data
	Current power	environment.data.gov.uk
	Bathymetry	environment.data.gov.uk
	Wrecks	Admiralty Data
	Visual	Distance from base mapping
	Grid	NGESO
	Ports	EMODnet
	Radar	NATS
Reference	Seabed Composition	EMODnet
	Communications cables	EMODnet
	Predominant habitat type	EMODnet
	Nursey grounds	Cefas
	Spawning grounds	Cefas
	Shellfish waters	DEFRA
	Heritage sites	Historic England
	Leisure boating	RYA

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