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Opportunity and environmental sensitivity mapping for hydropower in England and Wales

Non-technical project report

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Summary

This project assesses and maps opportunities for hydropower in England and Wales and the basic environmental sensitivity associated with exploiting them. It is the first phase of a wider programme of work that aims to make information available to developers and stakeholders, and to develop a more strategic approach to the sustainable deployment of hydropower in England and Wales.

The data presented here is based on the first phase, and is not intended to give site-specific data. It gives a national and regional level picture of the location and the size of the opportunity along with a coarse environmental assessment.

Findings

A total of 25935 ‘barriers’ have been identified and assessed. The term ‘barriers’ describes sites with sufficient drop to provide a hydropower opportunity. They are mostly weirs, but could also be other anthropogenic structures or natural features, such as waterfalls. The estimated average maximum power generation capacity on a barrier was 45kW, with a total potential capacity of nearly 1200MW, which could provide a maximum of about 1% of the UK’s projected electricity demand in 2020. In reality, the practical potential will be a fraction of this due to practical and environmental constraints.

This initial phase considers two environmental sensitivities: the presence of different fish species and whether the site has been designated as a Special Area of Conservation (SAC). Almost half (46%) of the barriers are classified as “highly sensitive”, mostly because of the presence of migratory fish species such as salmon and eel. About a quarter (26%) are “medium” and “low sensitivity”, and the remainder are unclassified due to a lack of data. There are considerably more environmentally compatible opportunities when we assume that a new scheme has a fish pass built into it. We identify over 4000 potential ‘win-win’ opportunities, which are sites where a hydropower scheme with a fish pass could deliver an improvement in the local environment as well as renewable electricity. This represents approximately half of the total power potential.

Table 1 Summary of results for England and Wales

Total number of barriers	25935
Maximum power potential/MW	1178
Average maximum power potential/kW	45
Number of potential win-win schemes	4190
Number of low environmental sensitivity opportunities	1092
Number of medium environmental sensitivity opportunities	5631
Number of high environmental sensitivity opportunities	12040

We hope that the evidence this project provides will ultimately enable a more strategic approach to the deployment of small-scale hydropower in England and Wales that maximises energy generation whilst ensuring the natural environment is protected and enhanced.

Conclusions

a) Small-scale hydropower has an important but limited role to play in renewable energy generation

Our findings suggest that small-scale hydropower at the barriers considered could deliver a theoretical maximum of 3660GWh electricity per year, or about 1% of the UK's projected electricity demand in 2020. Realistically, this potential will be considerably lower due to practical constraints, such as access to the local electricity distribution network, and environmental impacts.

This report has not considered the full potential for larger scale high head hydropower schemes. There may be opportunities where there is sufficient fall in river level over a distance of several hundred metres. These are considerably larger schemes that may have greater environmental impact, and cannot be readily identified using Geographic Information Systems (GIS) at the scale employed in this project. Small-scale high head hydropower also lies outside the remit of this work, but could be within the scope of future projects. These schemes in particular may be attractive as they present lower risks for fisheries.

b) Fish passage and fish-friendly design needs to be considered in all schemes

Almost half (46%) the barriers identified here are classified as high sensitivity, principally because salmon and eel are present. Good design of schemes can mitigate impacts, but may cost considerably more.

c) Opportunity hotspots exist, but small-scale hydropower has some potential throughout England and Wales

The opportunity maps show clear clustering of opportunities in the upland areas of England and Wales as expected. All regions except East Anglia show significant potential.

d) There is significant potential for win-win schemes that deliver hydropower and improvements in fish passage

Initial analysis suggests that about 4000 barriers were identified as potential win-wins. This represents half of the total power potential. Grants for fish passes alongside hydropower schemes could help unlock this potential.

1 Introduction

This report is based on *Mapping opportunities and environmental sensitivities for hydropower*, a technical report prepared by Entec on behalf of the Environment Agency. It summarises the key findings of this work and explores their implications and next steps.

The project mapped opportunities for hydropower alongside the environmental sensitivity associated with exploiting these opportunities to give a national overview. It identifies over 25,000 barriers in England and Wales and estimates the height of the barrier, the flow available, the maximum power potential, and the environmental sensitivity.

This is the first phase of a wider project. Subsequent phases will:

- Improve and ground-truth the data.
- Apply the analysis at a river catchment level to inform catchment strategies.
- Consider environmental sensitivities in more detail.
- Develop the data into a spatial tool that can be used by internal and external customers.

We hope that the evidence this project provides will ultimately allow us to develop a more strategic approach to the deployment of small-scale hydropower in England and Wales that maximises energy generation whilst ensuring the natural environment is protected and enhanced.

2 How to interpret the results of this project

The report gives national and regional level overviews of the potential opportunities available, their locations, and their relative environmental sensitivity to exploitation. Given the scale of the project and the data used, the results are not intended to replace any part of an individual site assessment, which is necessary for a full scheme appraisal. This project and planned future phases will inform but not replace site assessments, which will be expected to comply with the Environment Agency Hydropower Good Practice Guidance in all cases.

As the project has used national GIS data that is based on various sources there is some error inherent in the results. One-third of the sites where older ‘Synthetic Aperture RADAR (SAR) data was used for the height estimate include an error of up to one metre. The remaining two-thirds use ‘Light Detection and Ranging’ (LIDAR), which is accurate to 25cm. This means that the data for an individual site may be inaccurate, but at the national and regional level the error will be averaged out to an extent.

The methodology used in this report is not intended for use in individual permit applications or determinations.

3 Environment Agency perspective

The Environment Agency strongly supports the UK and Welsh Assembly Governments' targets for renewable energy. We recognise that hydropower schemes can help meet renewable energy and greenhouse gas reduction targets.

We are therefore supporting the deployment of sustainable hydropower by making it quicker and easier to get approval for a scheme and by identifying and mapping potential hydropower opportunities. We are also looking to install renewable energy, including hydropower, on our own land and infrastructure and are urging other public sector organisations to do the same.

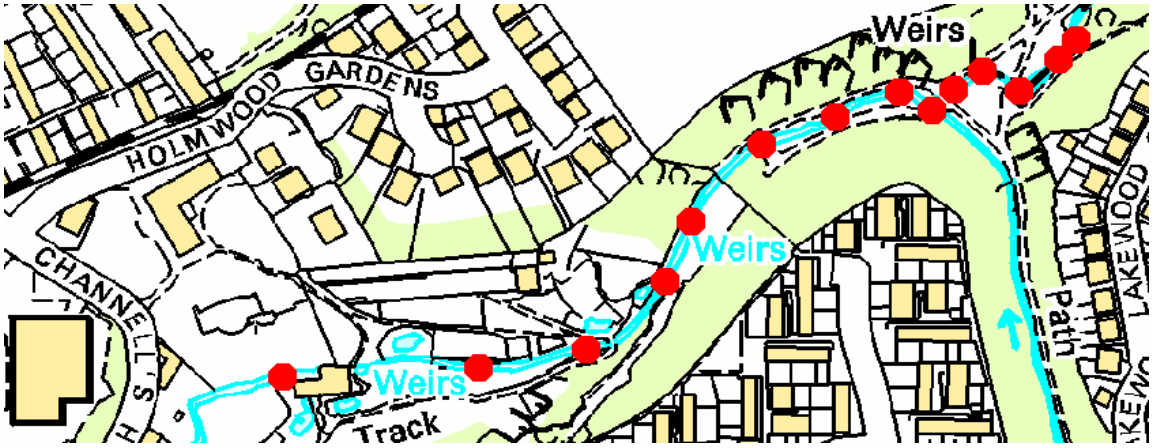
Hydropower schemes must, however, be sustainable and must meet legislative requirements. Poor schemes can threaten fish populations and other aspects of river ecology if they cause reduced flow in rivers or if fish pass through and are damaged or killed by a turbine. To avoid this, schemes must build environmental protection into their location and design. Key environmental features for all schemes include:

- A fish-friendly turbine, such as the Archimedes screw, and/or adequate screening of the turbine.
- Safe routes of upstream and downstream passage for fish where appropriate.
- Sufficient flow in any depleted reach to maintain the ecology, the fishery, and its amenity value.

4 Methodology

Our first task was to identify and map all existing barriers within rivers in England and Wales. Barriers are used as a proxy for a hydropower opportunity in this project because new small scale schemes are usually sited on existing barriers and do not create new impoundments. We used OS Mastermap and the Digital River Network to compile spatial data. A total of 25,935 barriers were identified and mapped, including weirs, locks, waterfalls, dams and barrages. Figure 1 shows an example of the data layer.

Figure 1 Barrier identification



We have used the term 'barrier' to identify a site where there is sufficient height in river level to provide a hydropower opportunity. These sites are mostly weirs, but could be other man-made structures, or natural features such as a waterfall. These sites are potentially a barrier to fish movement and migration, but data to evaluate the restriction to fish passage was not available during this phase of the work. We plan to incorporate this information into the next phase of hydropower opportunities mapping.

4.1 Calculating the hydropower opportunity

The hydropower opportunity was calculated using height and flow data, and fishery and protected areas data was used to assess environmental sensitivity. Table 2 shows the data sources used.

Table 2 Data sources used in this project

	Data Source
Head	LIDAR
	SAR
Flow	Water Resources GIS
	Concise Register of Gauging Stations
	Hi-flows
Environmental sensitivity	Fish Classification System 2
	Protected areas

For each barrier, we calculated the height, or 'head' using LIDAR and SAR data. LIDAR has a vertical accuracy of 25cm, and SAR has an accuracy of 100cm. We therefore used LIDAR in all instances where it was available, accounting for 64% of barriers, and SAR for the remaining barriers. To reduce the error, we developed a number of methodologies that extracted height information from a range of points up and downstream of the barrier. The most appropriate methodology was used to calculate the height for each point.

We used a number of data sources to estimate flow as there is no nationally consistent dataset. As flow varies throughout the year and some flow always needs to bypass a scheme, we used the average flow (Qmean) minus the flow that is exceeded 95% of the time (Q95). This is the most realistic reflection of the flow available at a particular barrier for the purposes of this exercise, but in reality the available flow will be site-dependent. The Environment Agency's Water Resources GIS database provided initial background flow estimates that we verified using data from gauging stations across the country, showing a high level of accuracy. This data allowed estimates of flows at barrier points to be derived using a number of different methodologies developed for differing circumstances.

Head and flow values were used to generate potential power outputs, expressed in terms of the total capacity.

4.2 Environmental sensitivity classification

To assess environmental sensitivity at a national level, we used national data on fish and protected areas. The fish species we considered are shown in Table 3. They are split into four categories according to their need to move up and down river systems to complete their lifecycles. This categorisation is based on expert opinion but is not meant to be definitive. The Environment Agency compiles Fish Classification Scheme data for the Water Framework Directive. The outputs can be used to indicate the expected distribution of selected species where there are no man made pressures. We classified the probability of species presence into three bands:

- High – probability of a particular species being present is >0.66
- Medium - probability of a particular species being present is >0.33 and <0.66
- Low - probability of a particular species being present is <0.33

Table 3 Fish species considered in the sensitivity classification

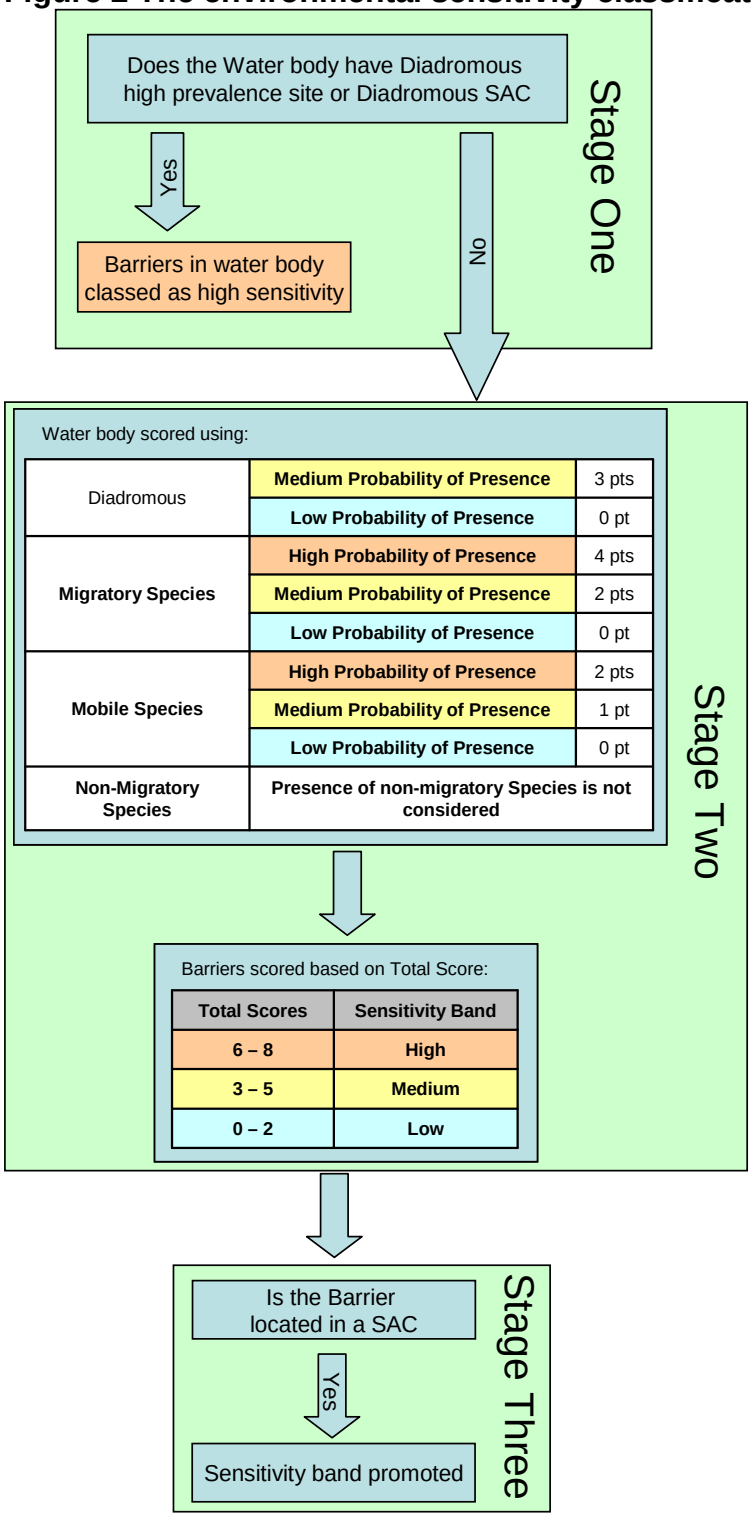
Diadromous Species	**Migratory Species**	**Mobile Species**	**Non-Migratory Species**
Salmon	Barbel	Bleak	Bream (silver)
Shad (Allis and Twaite)	Dace	Bream (common)	Loach (Spined and Stone)
Lamprey	Grayling	Carp	Stickleback (3 and 9 Spined)
Eel	Chub		Carp (Crucian)
	Pike		Gudgeon
	Trout		Perch
			Roach
			Rudd
			Bullhead
			Tench
			Minnow

To give an overall assessment of environmental sensitivity, we applied a three stage process:

- **Stage 1** classified barriers as high sensitivity where there is a high probability that diadromous species (fish that travel between salt and fresh water) are present at or downstream of the barrier.
- **Stage 2** classified the remaining barriers as low, medium or high sensitivity according to the probability that migratory and mobile species are present at the barrier. Stage 2 also accounted for low and medium probability that diadromous species are present.
- **Stage 3** promotes any barriers within or downstream of a relevant SAC to a higher sensitivity classification band.

This process is represented in Figure 2.

Figure 2 The environmental sensitivity classification process



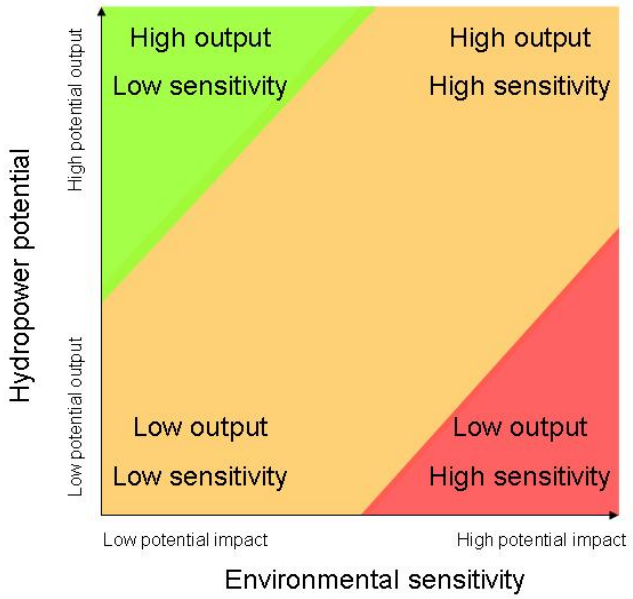
4.3 Classification of Opportunities

We brought together the opportunity and sensitivity data according to the environmental sensitivity-hydropower potential matrix shown in Figure 3. This approach assumes that a new scheme will have a negative impact on fish passage relative to the current situation.

As a separate exercise, we identified potential 'win-win' schemes. Whilst removing a barrier is usually the best thing to do to improve fish passage, this is not always possible due to cost, flood risk management or other reasons. The next best option to removing the barrier is to introduce a fish pass. We define win-wins as schemes that both provide a good hydropower opportunity and increase the status of the associated fish population, as a consequence of the appropriate mitigation measures, such as improving fish passage.

To find potential win-wins at the national level we identified opportunities of >10kW within a waterbody that is designated as heavily modified under the Water Framework Directive. Heavily modified waterbodies are those that are at risk of failing to achieve good ecological status as a result of modifications to their hydromorphological structure in the past. Given this high-level approach, it is important to note that we will need to analyse the status of fish populations at the local and catchment scale to genuinely identify opportunities that provide mutual benefit.

Figure 3 Environmental sensitivity - hydropower opportunity matrix



5 Results

This project identified and assessed a total of 25935 barriers. The average maximum power generation capacity on a barrier was 45kW, with a theoretical total potential capacity of 1178MW. In reality, the practical potential will be a fraction of this due to practical and environmental constraints. Table 4 shows further national level results.

Table 4 Summary results for England and Wales

Total number of barriers	25935
Maximum power potential/MW	1178
Average maximum power potential/kW	45
Number of potential win-win schemes	4190
Number of low environmental sensitivity opportunities	1092
Number of medium environmental sensitivity opportunities	5631
Number of high environmental sensitivity opportunities	12040

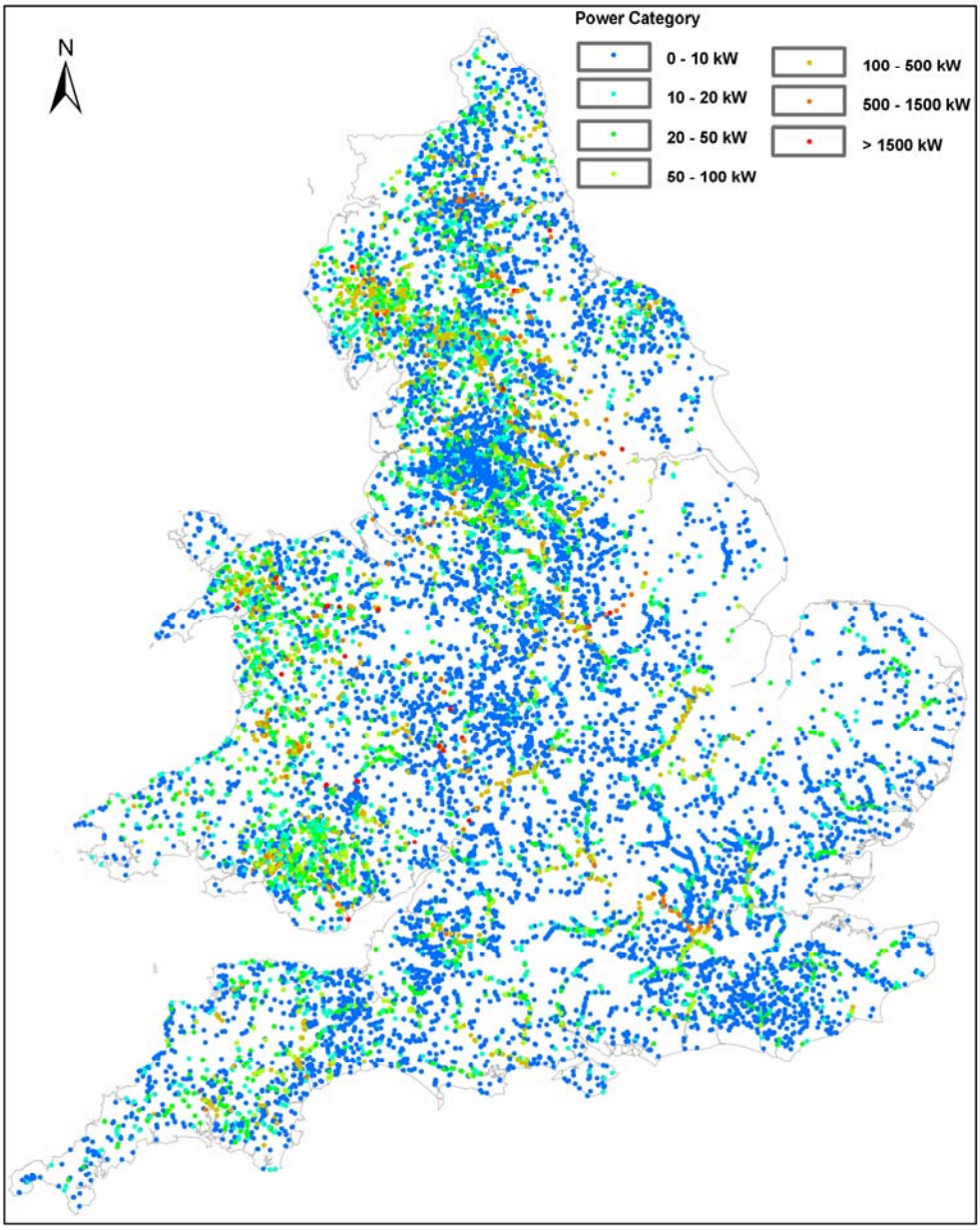
5.1 Power potential

We calculated the power potential for each barrier identified in the project. Table 5 shows the aggregated results and Figure 4 shows national maps. Summary statistics and maps for Wales and for each English region are presented in an Annex to this report.

Table 5 Total power potential in England and Wales

England	Number of Barriers	21823
	Total theoretical power potential/MW	782
Wales	Number of Barriers	4112
	Total theoretical power potential/MW	396
England & Wales	Number of Barriers	25935
	Total theoretical power potential/MW	1178

Figure 4 The theoretical maximum power potential in England and Wales



5.2 Environmental sensitivity

Diadromous species such as salmon and eel migrate between the sea and river systems to breed. They need to be able to pass safely through the river to be able to breed and are therefore severely impacted by barriers in river systems. The first stage of the sensitivity classification accounts for the presence of these species, resulting in 40% of barriers being classified as high sensitivity. Stage 2 considers the probability of presence of other migratory and mobile fish species, it results in a further 1600 barriers being classified as high sensitivity, 5650 as medium and 1043 as low. The final stage promotes a further 68 barriers to a higher sensitivity classification as they are located in a relevant SAC. 28% of barriers were not classified as data was unavailable. Table 6 shows the total number of opportunities in each classification and they are represented nationally in Figure 5.

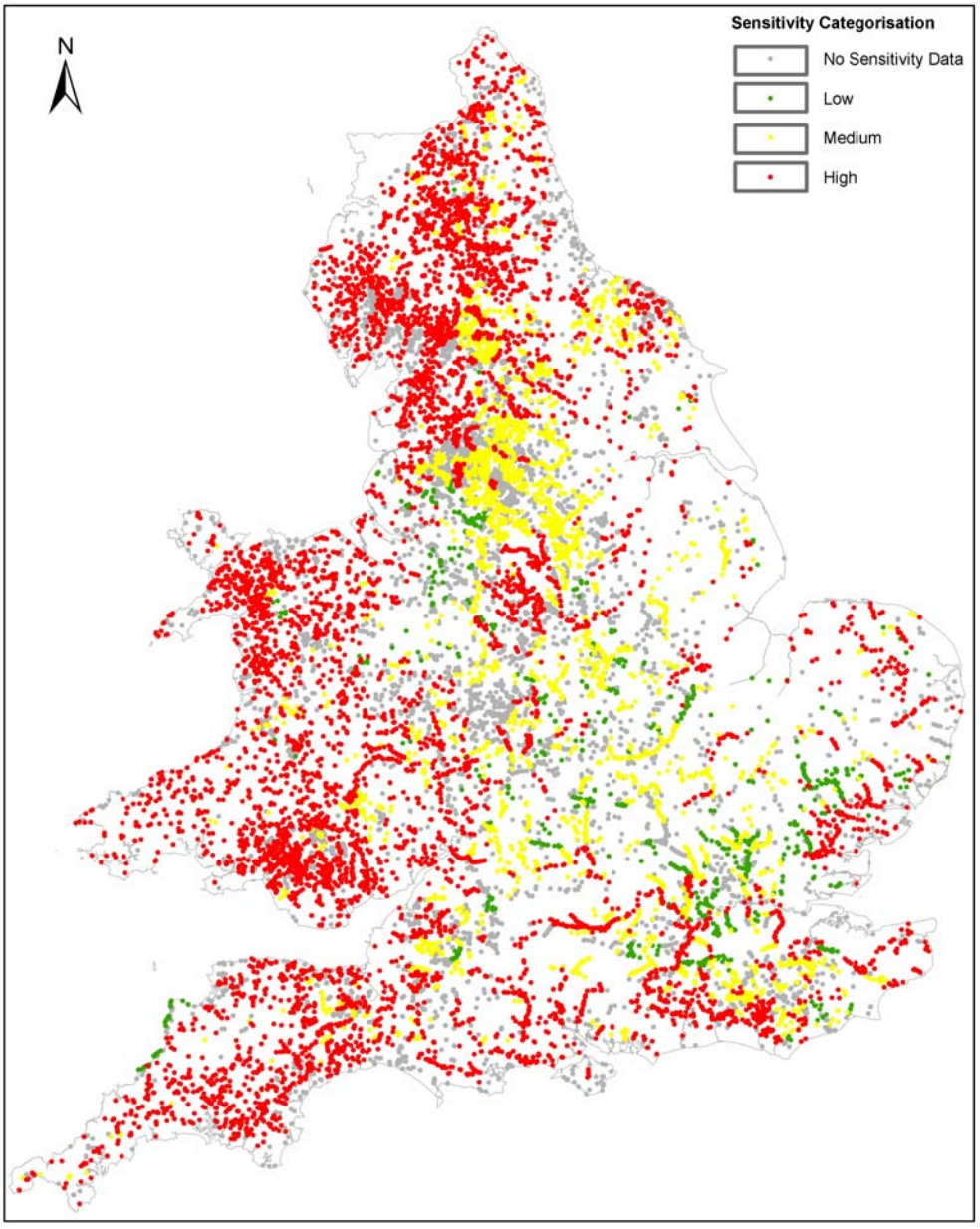
Table 6 National and regional environmental sensitivity results

	East of England	East Midlands	North East	North West	South East	South West	Wales	West Midlands	Yorkshire and the Humber	Total
Unclassified	285	729	301	1460	832	888	645	1106	926	7172
Low	278	128	1	145	358	75	20	81	6	1092
Medium	265	695	180	791	794	412	142	421	1931	5631
High	411	574	1160	2197	1083	1860	3305	712	738	12040

Further information is needed for an accurate and comprehensive assessment of environmental sensitivity, and this will be further developed in future work. The results here, however, do indicate that most hydropower sites require effective mitigation measures, as described in the Environment Agency's Good Practice Guidance for hydropower schemes.

The design and construction of barriers makes some more easily passable to different fish species. Information on the passability of barriers to different species was not available during this project, but we are planning further work in this area. In the future, we would like catchment strategies for improving fish passage to identify barriers where development of hydropower including a fish pass would have most environmental benefits.

Figure 5 Environmental sensitivity of hydropower opportunities



5.3 Classification of opportunities

Only 7% of the maximum power potential from small-scale hydropower fell into the “high output – low sensitivity” classification. This is explained principally by the large number of barriers with a high environmental sensitivity as a result of a high probability that salmon and eel are present. One fifth (22%) of the power potential comes from sites where the power potential is <10kW and the environmental sensitivities are high. These sites are unlikely to be attractive to developers as the potential income will be low, whilst the costs of designing, installing and maintaining a scheme are likely to be high. Figure 7 shows the spatial distribution of these opportunities.

5.4 Win-wins

The project identified a total of 4190 barriers as potential win-wins, with a theoretical maximum power capacity of 580MW. This is approximately half the total theoretical maximum power capacity for England and Wales. Figure 6 shows that win-win opportunities are available across the country, but there are particular concentrations along rivers such as the Severn, Thames, Aire and Neath.

Figure 6 Classification of opportunities

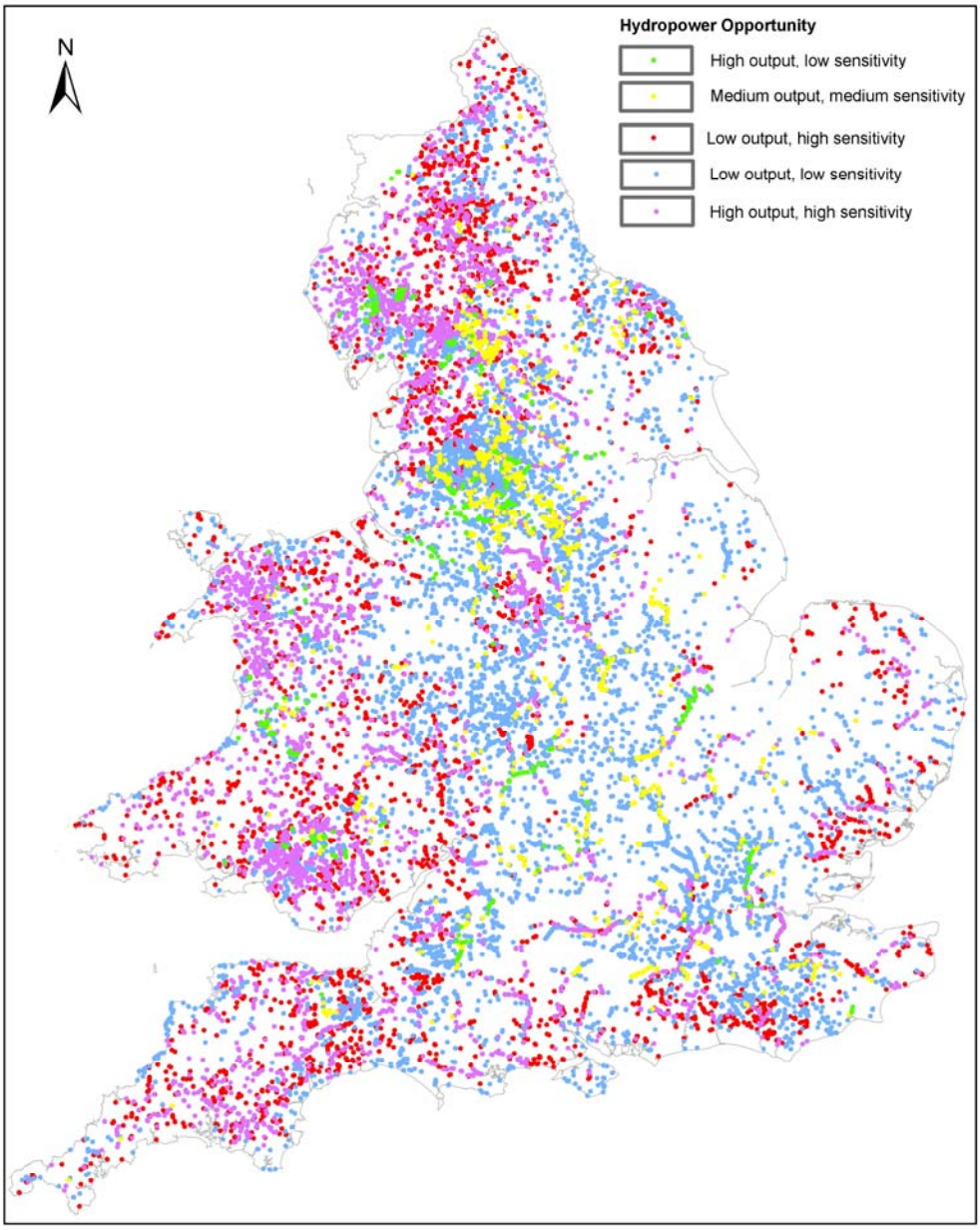
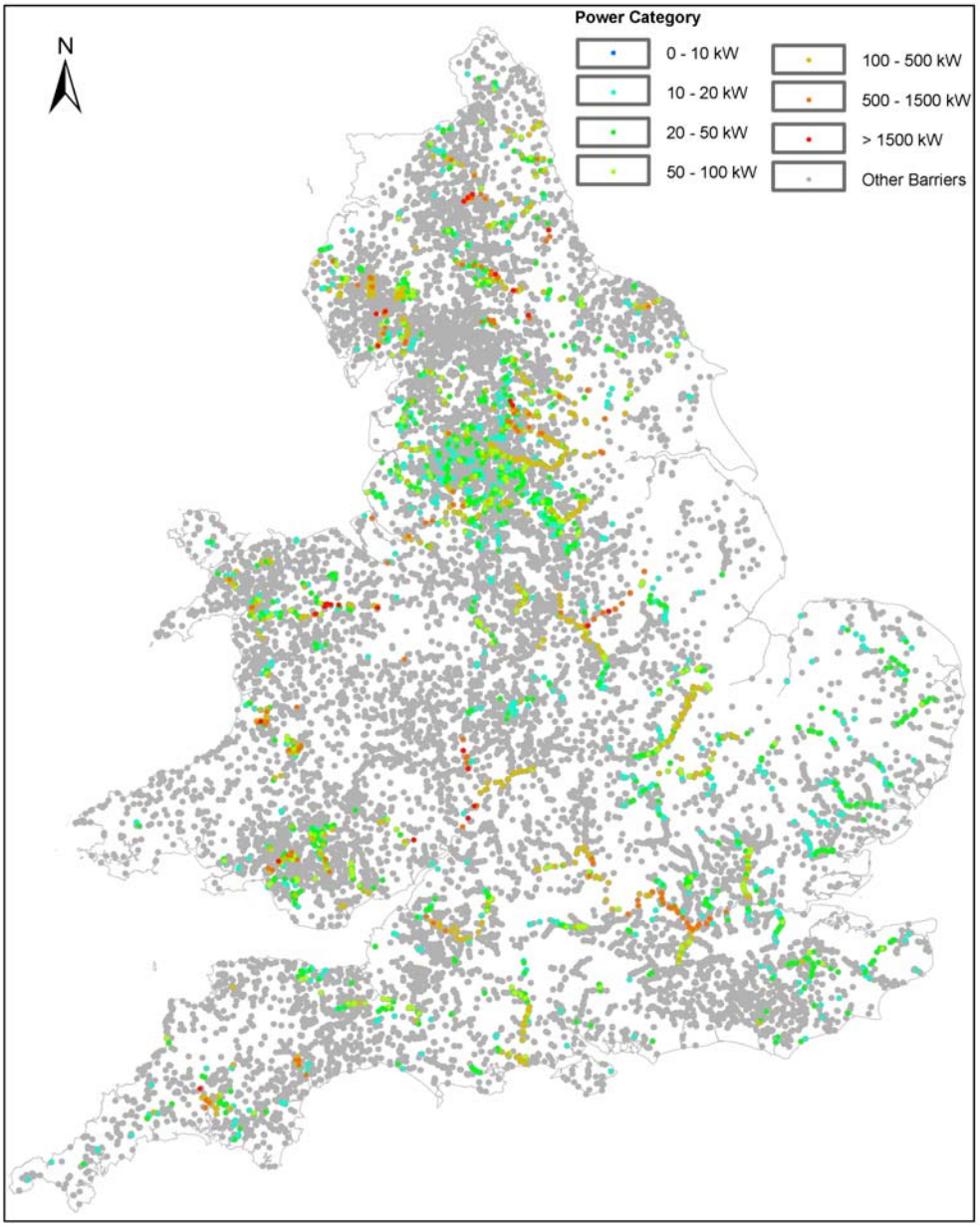


Figure 7 Potential win-win opportunities



6 Conclusions

a) Small-scale hydropower has an important but limited role to play in renewable energy generation

The theoretical maximum power potential of 1178MW indicates that small-scale hydropower has an important but limited role to play. This is equivalent to approximately 1900GWh to 3660GWh, or approximately 1% of the UK's projected electricity demand in 2020.

Despite these small figures, hydropower offers a number of other advantages. It is a reliable and proven technology and is particularly attractive to local communities. Furthermore, the UK's target of generating 15% of its energy from renewables by 2020 is extremely ambitious. In the Renewable Energy Strategy (2009), the Department for Energy and Climate Change suggest that 31% of electricity will need to be renewable to meet this target. This means we will need to exploit all available renewable energy sources to their sustainable maximum.

The theoretical maximum inevitably overestimates the realistic power potential from small-scale hydropower. We may not be able to develop many barriers, either because of physical constraints, such as access to the electricity distribution network, or environmental constraints. However, this project has also omitted some opportunities, particularly for high head schemes.

This study has not included the cumulative impacts of multiple hydropower schemes on fish migration, which will be a key limit on potential growth. Even the best designed schemes that have high survival and passage rates individually may have deleterious impacts on fish populations in a river system if a series of such schemes are present.

b) Fish passage and fish-friendly design needs to be considered in all schemes

The environmental sensitivity classification methodology developed here is basic and limited to fishery and SAC data, but it demonstrates the highly sensitive nature of small-scale hydropower deployment in England and Wales. Almost half (46%) the barriers identified here were classified as high sensitivity, principally as a result of the probability of salmon and eel presence. However, well-designed schemes can mitigate impacts and can even improve the environment if they provide better passage for migratory and other fish.

c) Hotspots of opportunities exist, but small-scale hydropower has potential throughout England and Wales

The opportunity maps show clear clustering of opportunities in the upland areas of England and Wales as expected, but all regions have considerable potential. The only exception to this is East Anglia which has a total theoretical potential of only 13MW, and an average scheme potential of 10kW. Wales has a theoretical maximum potential of 396MW, and the most important English regions are the North West, with 196MW, and Yorkshire and Humber with 179MW.

Table 7 shows the Local Authority areas with the most opportunities. Almost all of these opportunities are in areas of high environmental sensitivity and hydropower developments in these areas will need to be designed to allow proper fish passage.

Table 7 - Local Authority areas with the highest theoretical power potential

Local Authority	Number of barriers	Total power potential/ MW	% of power potential classified as high sensitivity	% of power potential classified as potential win-win
Powys	1008	148	93%	7%
South Lakeland	842	76	85%	32%
Northumberland Unitary Authority	956	56	98%	51%
Neath Port Talbot	324	49	100%	28%
Richmondshire	583	49	82%	35%
Gwynedd	735	47	98%	24%
Conwy	283	38	96%	3%
Durham Unitary Authority	490	35	97%	70%
Allerdale	204	31	89%	48%
Denbighshire	111	30	100%	97%

d) There is significant potential for win-win schemes that deliver hydropower and improvements in fish passage

When hydropower schemes include a fish pass they can lead to improvements in passage for fish, potentially opening up previously inaccessible stretches of river to migratory species such as salmon and trout. Over 4000 barriers were identified as potential win-wins, which represents half of the power potential. This figure is presented with the caveat that this study was unable to assess the current passability of these barriers. The potential for a win-win will reduce if some are already passable. Although this remains a very significant number of opportunities, effective fish passes can be relatively expensive to design and install. This can be prohibitive for smaller schemes. Grants for fish passes alongside hydropower schemes could help deliver these win-win benefits, particularly community schemes that may otherwise lack the resource.

7 Next steps

This project is the first phase of a wider programme of work. Our overall aims are to:

- Develop and deliver a strategic approach to hydropower deployment at the catchment level.
- Make information available to developers and stakeholders about the opportunities available and the environmental sensitivity associated with them.

Before we can achieve these aims, we need to improve the national level data and analysis developed in this project. We are therefore planning future work to verify the height, flow and power potential data at a range of sites and to improve the environmental sensitivity analysis and classification.

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