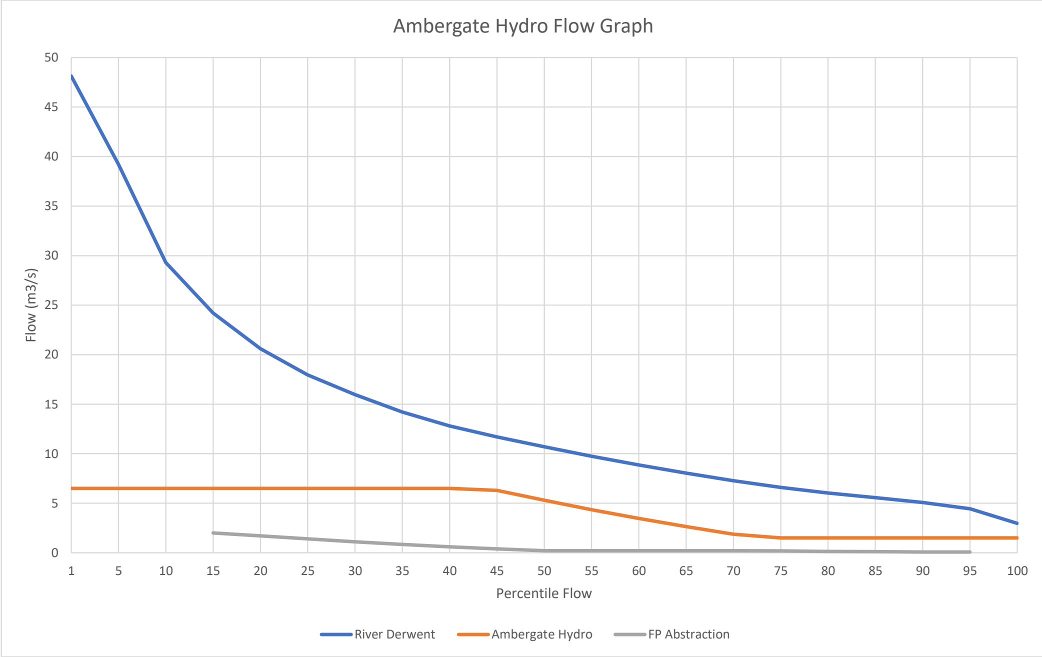
Percentile Flow	River Derwent	Ambergate Hydro	FP Abstraction
1	48.13	6.5	
5	39.21	6.5	
10	29.3	6.5	
15	24.2	6.5	2
20	20.6	6.5	1.7
25	17.96	6.5	1.4
30	15.97	6.5	1.1
35	14.2	6.5	0.84
40	12.8	6.5	0.6
45	11.7	6.3	0.39
50	10.7	5.3	0.202
55	9.74	4.34	0.202
60	8.87	3.47	0.202
65	8.04	2.64	0.202
70	7.28	1.88	0.202
75	6.59	1.5	0.19
80	6.04	1.5	0.126
85	5.56	1.5	0.104
90	5.08	1.5	0.083
95	4.44	1.5	0.075
100	2.97	1.5	

Issued by	J Needle
Date	21/06/2023
Version	2.0



March 2022

Findings of a water vole (*Arvicola amphibious*) survey in and around the mill stream at Ambergate wireworks, Derbyshire, DE52HE

Author Howard Morris BSc MSc

Version 1

Issued by Howard Morris

1. Overview

This report has been compiled to accompany a transfer licence application for a new Hydroelectric turbine installation at the Ambergate wire works. The scheme will utilise much of the existing infrastructure but some new work will be undertaken including the installation of an outfall screen and tailrace fish escape. Thus it is prudent and legally required to establish whether the site contains any relevant protected species which may be affected by any works undertaken.

2. Species specific information

The water vole is our largest native vole species and unfortunately has suffered a catastrophic decline in population over the past 30 years (Dean 2021).
It has full legal protection under the amended Wildlife and Countryside Act 1981. This makes it an offence to:

- kill, injure or take them
- possess or control them (alive or dead)

It is also an offence to intentionally or recklessly:

- damage or destroy a structure or place used for shelter or protection
- disturb them in a place used for shelter or protection
- obstruct access to a place used for shelter or protection

Additionally water voles are listed as a rare and most threatened species under Section 41 of the Natural Environment and Rural Communities Act (2006). And consequently must be regarded when any planning decisions are made (Gov.uk).

3. Site assessment

The survey site is contained within the larger Ambergate wire works complex which is located at grid reference SK34135225, the centre of the survey site area is SK34465177. This is all contained within Figure 1, the survey site is highlighted in green. The survey site sits adjacent to the River Derwent, being also immediately to the west of the A6, approximately 500m North of the village of Ambergate. The larger site is a former wire manufacturing complex which now has diversified in its usage, still retaining a large number of utilised buildings as well as having some areas of dereliction. The focal point of the survey site is the tailrace which flows out from underneath the old buildings on the western side of the River Derwent. The tailrace extends for approximately 880m and ranges from 7-11m in width, it merges with the Derwent at Halfpenny Bridge in Ambergate village. Its construction is that of a near vertical sided stone/concrete lined channel. The sides fluctuate from around 0.9-5.4m in height. The flow is controlled by inlet gates but when open the proposed system is designed to pass 6.5m^3/s.

Above the survey site the Western bank is for the most part very steep and stretches up into woodland with some historic overgrown pastureland. The Eastern bank is less steep and also limited in width due to its proximity with the river Derwent, ranging from 11-33m.

The survey site vegetation is that of deciduous woodland, made up of an upper canopy of Oak (*Quercus spp*), Sycamore (*Acer Pseudoplatanus*), Ash (*Fraxinus excelsior*), Alder (*Alnus glutinosa*) and Birch (*Betula spp*) with an under story of Hazel (*Corylus avellana*), Yew (*Taxus baccata*), Laurel (*Prunus laurocerasus* and Holly (*Ilex aquifolium*) the ground cover includes Bluebells (*Hyacinthoides non-scripta*), Ramsons (*Allium ursinum*), Bramble (*Rubus fruticosus*), Greater Tussock Sedge (*Carex paniculata*), Dogs Mercury (*Mercurialis perennis*), Ivy (Hedera helix) and Himalayan balsam (*Inpatiens glandulifera*).

4. Desk study

A desk study examining local records of water vole populations yielded positive results within 500m, the positive results pertain to the Cromford canal. The Cromford canal is a designated SSSI and LNR and has been identified as an important remaining habitat island for populations of water voles in the county (Derbyshire wildlife trust).

5. Survey

The survey was undertaken on the 18th of March 2022 between 10.30 and 14.30. There was little to no wind and it was a sunny day with a temperature of 15^{o}c. The equipment used included a camera, laser tape measure and notebook.

The survey took the form of a habitat suitability appraisal of the tailrace and adjacent 2m of bank including the area allocated for the tailrace fish escape installation (see figure 1) and a walkthrough survey of the same site to identify any potential field signs. Both banks of the tailrace were surveyed all the way to the confluence with the river Derwent. The survey was conducted from the top of each bank.

Field signs were informed by (Dean 2021) and could include droppings, feeding signs, burrows, runs, nests and prints.

The methodology for habitat suitability was informed by (Dean 2021, Gaskin 2016 and Harris et al. 2009) all three sources offer a similar approach identifying features which are crucial for water vole habitation. Harris et al (2009) and Gaskin (2016) include disturbance/poaching (predators or humans) as an additional factor of the suitability matrix whereas Dean (2021) does discuss the importance of this but does not include it directly within the habitat suitability model. Gaskin (2016) also includes habitat connectivity as an important factor which in turn is supported by the work of Bonesi et al. (2002). I have chosen to focus mainly on the model which Dean (2021) uses. This is due to the similar nature of approach in all three models combined with the fact that this is the most up to date survey handbook. The fact that Harris et al. (2009) focussed their work on a specific geographical area (the coastal environment) also allowed me to lean more towards the work of Dean (2021).

In addition it should be noted that the owner of the property (Trilithon Lodge) at the Southern end of the tailrace provided anecdotal personal descriptions of historic water vole activity in her garden.

6. Survey results

The suitability of the habitat is judged to fall within the 'Suitable but poor' category.

It was apparent from high level flood debris that the tailrace was totally submerged in the last high water event (February 2022), a great amount of the eastern banks will also have been submerged just leaving a few isolated areas of higher ground which will have remained dry. The western bank will have had some submersion but it is steep and so dry ground would not be too far from the tailrace.

No positive field signs of water voles were observed, field signs of Otter (*Lutra lutra*) including multiple spraints and prints were however noted.

7. Interpretations

Desk study
Although water vole populations are present within 500m of the survey site it should be noted that the known population site of the Cromford canal lies on the eastern side of the Derwent valley with a railway line, main road and river between it and the survey site. These three physical obstacles are not insignificant for migration of water voles in an east to west direction.

Field sign
There were no positive water vole field signs recorded. Positive signs of Otter were noted (prints and spraint) and anecdotal visual sightings of Mink (*Neogale vison*) were also noted. These signs of predators indicate another potential barrier to the site being suitable for water voles as well as having a negative impact on allowing migration from other more suitable habitats.

Habitat suitability
The outcome of the habitat suitability survey is that the habitat is 'suitable but poor'. This is mainly due to the flood conditions in the tailrace. However the near vertical nature of the bank sides, swift flow of the water, lack of emergent vegetation, shading, presence of predators as well as isolation from known colonies are all negative suitability attributes. Over the past 4 years there have been at least two high water events significant enough to submerge a large proportion of the tailrace and adjacent banks up to 2m in parts. Dean (2021) suggests that such frequencies of flooding have a negative impact on the suitability of the habitat for colonisation and regular habitation of water voles.

8. Limitations

The survey was undertaken in mid-March which is outside of the time period for peak vole activity (Dean 2021 & Strachan and Jefferies 1993), consequently this means a reduction in the occurrence of potential field signs.

9. Conclusion

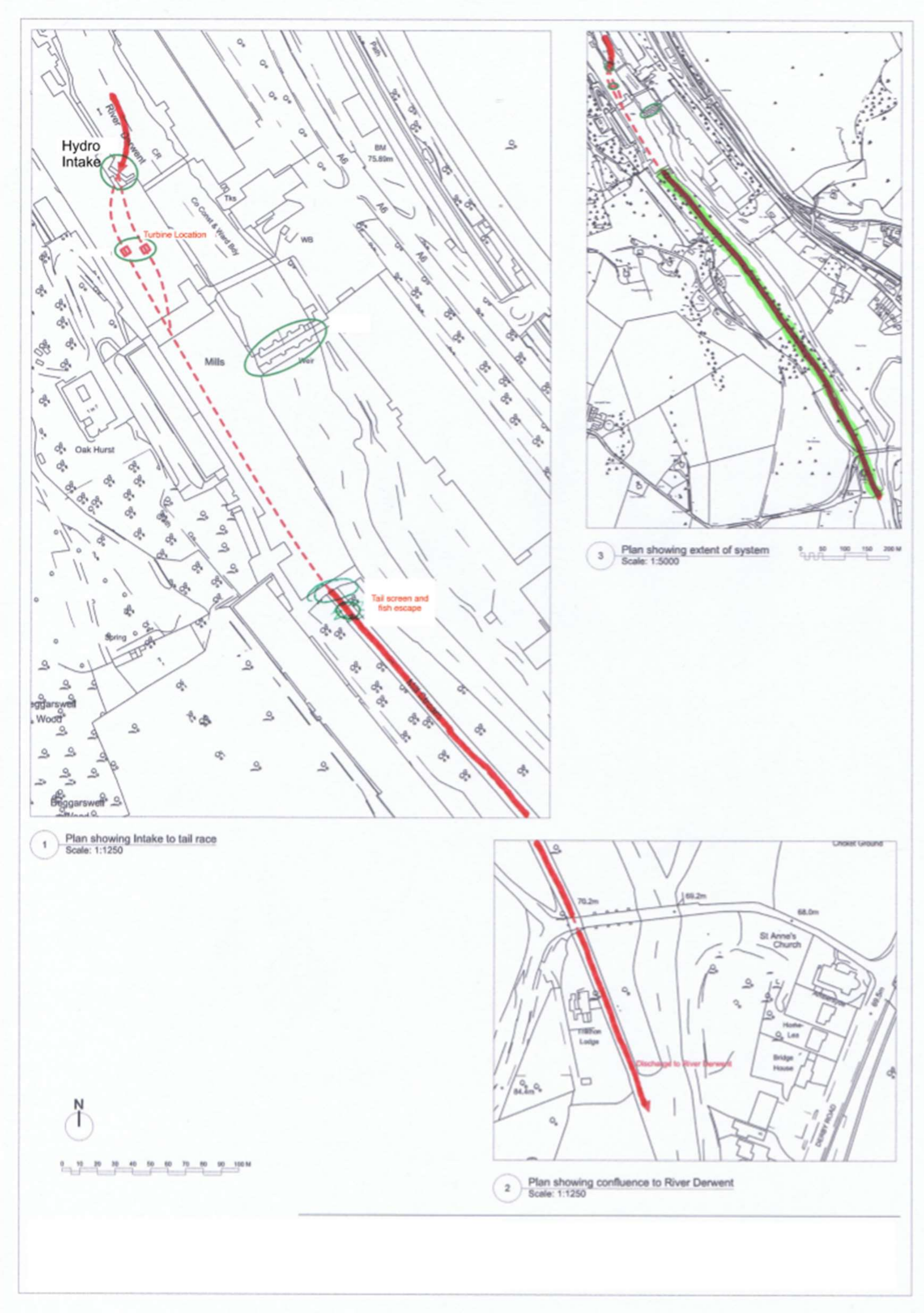
In conclusion the survey site area appears to be for the most part unlikely to support water voles, and is certainly not of the best habitat standard for habitation by water voles. Some anecdotal evidence from the owner of Trilithon Lodge does suggest historic water vole presence and this does make some sense as this specific area can be treated somewhat separately due to its differing physical and vegetation conditions (a private garden with lawns and earth banks with less of a severe incline) voles would be able to escape the rise in water levels which is still notably a negative impact here and yet find suitable areas for feeding in the rest of the garden.

Although no mink field signs were noted it should be mentioned that the author has observed mink in the locality and the landowner of the survey site also mentioned sightings of mink which along with field signs of otter are not positive factors for the presence of water voles

Also it should be noted that Bonesi et al. (2002) suggest isolated habitat areas which are of a good habitat viability standard are seemingly unlikely to support water vole populations, this reinforces the importance of connectivity which is hampered by physical barriers at the survey site.
Water voles have a preference for certain food sources (Neyland, 2011) none of these were noted at the survey site although the time of year was not conducive to establishing all types of vegetation present.

It is recommended that a follow up field signs survey possibly with camera traps on any more suitable habitat areas be undertaken later in the year during the optimum survey season of mid-April until the end of September (Dean 2021). This is in direct relation to the present field sign survey being conducted outside of the optimum time period for observing activity and thus any results should be treated cautiously (Dean 2021).

Figure 1. Wider site and survey site map.



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21/03/2022

Version 1

Form WR330 Section B11.1: Rights of Access and Planning Permission

Our responses to the questions raised are not succinctly answered by the drop-down menu options. Please find our response below:

- **Abstraction location name**

  Hydro Intake

- **Access rights**

  The full site is in ownership of one member of the group.

- **If you do not have access rights when do you expect to get them?**

  Not applicable

- **Planning Permission needed**

  We understand that no planning application will be required, for the following reasons:

  Intake – this will be regarded as replacement/renewal of equipment.

  Installation of generating equipment will be regarded as 'Permitted Development' under Part 13, Schedule 2 of the Town and Country Planning (General Permitted Development) (England) Order 2015.

  Outfall works – informal enquiries suggest that planning permission will not be required for this part of the project.

  Water abstraction operations could be contingent on attaining formal approval that planning permission is not required.

- **Status of planning permission**

  Not considered to be necessary.

Additional note regarding the World Heritage Site

Enquiries noted in point 4 (above) include telephone conversations with Adrian Farmer (Heritage Co-ordinator, Derwent Valley Mills World Heritage Site). Adrian agreed that planning permission would not be necessary and that the Derwent Valley Mills World Heritage Site Co-ordination Team would welcome the project.

18/03/2022

Version 1

Project Design and Parameters: Ambergate Hydro

There exists at the ex-wireworks site an excellent opportunity to create renewable hydro-electricity. The main elements that should make this project viable are the existence of substantial civil structures in the form of intake, culverted channels, turbine pits and discharge channel, and an on-site demand for the generated electricity.

The civil works were last used in connection with two water turbines (now removed) in the 1960's. The two machines were each rated to produce 175kW from a flow of 6.5 cumec. The turbines were removed to provide more space for wire production machinery. Modern fish protection standards set guidelines for the maximum approach velocity targets for screening. The old screens once passed 13 cumec, but this quantity is no longer permissible for the area available. We have calculated that if both intake screens were made to supply one turbine pit then a flow rate of 6.5 cumec is achievable through the screens.

Having passed through the turbine, the water would flow through the discharge culvert and emerge at the downstream end of the mill buildings. We propose to allow this flow to return to the river via the existing tail channel as originally intended. This channel would now in effect become part of the water system, providing a living habitat and a small degree of improved flood handling.

Hydrology

The Whatstandwell gauging station is located a short distance upstream of the site and provides an excellent baseline reference for the site flows. The actual site flows are modified by the presence of an offtake / discharge point belonging to Severn Trent water. In response to an earlier pre-application, The Environment Agency provided modified Qm and Q95 figures which take into account the activities of Severn Trent. The gauged Q95 was increased by 0.39 m3/s making 4.798 m3/s and the Qm reduced by 0.27m3/s making the site Qm 14.454 m3/s. Overall, the ability for Severn Trent's activities to affect the health of the river or impinge on the proposed hydro is minimal, bearing in mind that they are limited in their maximum abstraction and have to operate within their Hof. Values such as Qmean and Q95 are long term statistical figures, whereas year by year the river can stray from its statistical figures by +/- 30% or more. The natural variation dwarfs the odd 0.39cumec but is accommodated by nature.

The site characteristics put it under Flow table C, where the maximum take is Qm. Our maximum proposed turbine flow is 6.5 m2/s, less than half (45%) of that allowed by table C and will have a correspondingly smaller potential to affect the river ecology over the deprived reach.

It should be noted that the River Derwent already has a heavily modified flow regime, we have already seen the effect of the local Severn Trent activity which raised the apparent Q95, it is also worth bearing in mind that without the Upper Derwent Reservoir compensation flows the Q95 would be very much less than that measured at Whatstandwell.

The Fishtek executive summary points out that if Q95 were to be adopted as Hof, then the depth of water across the stone and concrete apron would be insufficient to provide the depth of water needed across the apron for upstream fish passage until the flow in that section reaches 5.4m3/s. With a 'normal' abstraction regime of taking the flow between Hof and $Q_{turbine\ max}$, this condition would not occur until around Q42. This can be significantly improved by adopting a different abstraction philosophy.

We propose 1) That we leave a minimum of 1.7 m3/s flowing down the tail lade all of the time.

2) To restrict the turbine flow to achieve the 1.7 m3/s flow until the water passing down the main river reaches 5.4 m3/s.

3) to maintain that main river flow until the turbine reaches full power.

Under this regime, the apron flow would reach the required depth at a river flow of 5.4 m3/s at around Q71 and therefore be passable for 29% more of the year than under the scheme proposed in the last pre-application by 'Advyce'.

Screening and intake bywash

Please see document '6) AMBERGATE HYDRO: INTAKE'

This scheme re-uses the overall infrastructure built for an earlier scheme, there is no opportunity for re-alignment. We have halved the flow rate that it once handled in order to meet current approach velocity guidance. The drawing shows 2 bar screens with 12.5mm apertures, standard for this size of river and turbine. Small fish can theoretically pass through the turbine with a high chance of avoiding damage, I am told that from a behaviour point of view, small fish are very unlikely to pass through a 12.5mm screen. Each screen has a wetted area of 3.644m x 4.570 = 16.65m2 and will have a mechanical cleaner. The area required to meet velocity of 0.25m/s is 26m2, increase by 25% =32.5m2

The actual total area is 33.3 m2 leading to a clean screen approach velocity of 0.195m/s.

The intake screens are located along the side of the river and the maximum intake velocity low, providing little chance of fish entrapment, the residual flow in the river provides an element of sweeping flow.

Outfall screening and tailrace escape

Please see '7) AMBERGATE HYDRO: OUTFALL

Fish will not be prevented from entering the tailrace from the river, instead, screening will be provided a short distance downstream of the culvert outfall as shown on the drawing.

A short section of Larinier fishpass will be provided to enable any fish who so wish to find a route upstream and back to the main river The water level in the lade at the culvert outfall is normally lower than that of the adjacent river. A longer term level monitoring of the conditions at this point is required before a final drawing can be produced. We would be happy if the details of this structure became subject to a license condition.

Main river fish passage

The main weir at Ambergate is normally impassable by upstream bound fish. There is a small chance that an individual could pass upstream during flood conditions when the control gates are lowered but even then they would have to overcome high water velocities to achieve this. At times of high flow, the turbine is likely to be off line and the existing conditions unaffected. If the turbine was operating it would have a negligible effect on the pass-ability of the weir. The site owner, who is a knowledgeable angler with many contacts, has no experience or reports of Salmon being sighted at or above Ambergate. The waters are certainly **<u>not</u>** 'frequented' by Salmon or sea trout. We therefore do not plan for the inclusion of a fishpass on the main weir. However, we would be willing to provide assistance and possibly a proportion of funding towards the provision of a fish pass as part of a wider group as envisaged by your Matt Buck during a recent meeting. The site owner (who is part of the Ambergate Hydro Group, the applicants) has also indicated his willingness to permit the construction on the pass on his property.

18/03/2022

Version 1

Introduction: Ambergate Wireworks Hydro Abstraction License Application.

Notes to give background to this Hydro power abstraction license application.

This application

This application builds on the pre-application submitted by the community group 'Advyce', they have a representative as part of the applicant group of individuals. Your reference NPS/WR/028708.

Timing of application

We are very aware that the Environment Agency is to introduce a new application charge from 1st April 2022, and that this charge is estimated to be of the order of £15,000,00. (The new charge has not been published at the time of writing, 18/03/2022. This is purely an application fee, there is no guarantee of a useable license being issued as a result of the application. It will be very unlikely that a potential developer of a small hydro power scheme will want to risk this level of application fee and consequently there will be very few future applications from this sector.

You will understand therefore that this application has had to be hurried in its submission and may be lacking in some areas. Please work with us in finding ways around such problems. It is also worth noting that this site has been considered by yourselves on other relatively recent occasions, so should not require as much input from yourselves as a completely new application might.

Government aims

The Prime Minister has recently stated an aim for the Country to become more energy independent and a majority of cabinet ministers back a big push for more renewables and an expansion of nuclear.

Whilst the amount of energy available from hydro in the UK is modest, it's contribution to the whole is valuable in that it provides diversity of supply and more consistent output than say wind (gusty and subject to still periods) or solar (it doesn't work at night!) Hydro installations are also unobtrusive and long lasting.

EA aims, public expectation

The very title of your organisation suggests to the great majority of the population that the EA exists to work on improving the environment generally. That means encouraging the development of all things that lead to environmental benefits as well as protecting other aspects of the environment.

However, those of us who interact with you find that you have many laws that you must enforce but no legal requirements to encourage the development of hydro schemes. This leads to a major imbalance in the decision making process. I ask that in considering this application you introduce some balancing elements in order to weigh up the overall effect that the station might have over the coming years.

Site description and earlier applications

The site is situated on the River Derwent, a short distance downstream of the Whatstandwell Gauging station. It has a long history of water power, the last incarnation of which passed 2 x 6.5 cubic metres per second. The plant was removed in the 60's when electricity was cheap and climate change concerns hadn't been thought of. The site operator at the time needed the floor space for new production plant.

Water flows into two culverted channels each via a large sluice gate and screens. Each channel supplied a currently empty turbine pit, after which the channel continues further along under buildings to emerge later to pass water into a ~950m long tail channel. This channel runs parallel to the main river and re-joins the same just downstream of the local river bridge.

As far as I am aware, downstream of Ladybower reservoir, there are 5 operational hydro sites on the Derwent plus eight other now defunct sites. Of the 0perating sites, 3 are licensed to use considerably more water that proposed at Ambergate, three have long depleted reaches, the narrowest screen bar spacing is 12.5 mm, and the majority of the sites can operate all year round. One other of the operating sites has in recent years held a licence to abstract 9 cubic metres per second. Five of the disused sites each had two or more machines and would have passed more flow than that proposed at Ambergate. The potential for a 6.5m3/s scheme at Ambergate to cause environmental harm is minimal, but the potential environmental gains significant.

The lead applicant

Jon Needle has been active in GB hydro since 1988, being the founder of Derwent Hydroelectric Power Limited. He is an associate member of the BHA and has previously held the position of Chairman of that organisation. In that time he served as part of the team formed to formulate the Environment Agency's Hydropower good practice guidelines 2 (GPG2). This was an odd affair as the Angling Trust was invited by the EA to be part of the decision making team; an unorthodox arrangement I believe. Jon has spoken in support of hydropower at an Environment Agency Board meeting regarding GPG2, where the opposing proposal from the Angling Trust was defeated.

The Good Practice Guidelines are exactly that: guidelines not definitive rules. That point was laboured at every meeting, although this this often gets overruled (as feared at the time).

The future of Ambergate Hydro.

In a time of uncertainty of energy supplies, and of a desire to de-carbon the same, it is imperative that sites like Ambergate wireworks are harnessed for the general good of all. We hope that we can find a way to permit this scheme along the lines proposed.

Please note that we are willing to enter into dialogue over any areas of this application.

Flood Risk Activity Permit

We are aware that, before construction, we will need to acquire a flood risk activity permit. At this stage however it seems pointless to actually apply for a permit without first securing an abstraction license.

At the same time we are confident that the installation will not be contentious. Bearing in mind that this project makes use of existing infrastructure such that there will be no large scale civil works to be done, we can confirm that:

1) The construction of the scheme will not result in a loss of flood storage.
2) Turbine flow will by-pass a stretch that is locally known to be prone to flooding (The A6 / Hurt Arms pub area), slightly reducing the flow in the main channel.
3) The turbine flow also makes use of a separate arch in the downstream road bridge, also relieving the restriction to a degree.
4) It is possible to isolate the works area from the river flow, making the installation works safe from the point of view of construction pollution.

FISHTEK CONSULTING

Fisheries Impact Assessment

Ambergate Hydropower Project

Client: *ADVyCE Ltd*

Date: November *2013*

Adam Fryer *BSc, MSc, MIFM*

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Document title: *Ambergate Weir Hydropower Proposal Fisheries Impact Assessment*
Status: Final *Draft*
Date: 04th *December 2013*
Project Code: *AHPFIA04/12/2013/AF*
Client: *Amber and Derwent Valley Community Energy Ltd.*
Produced by: *Adam Fryer*
QC: *Pete Kibel*

Executive Summary

*ADVyCE Ltd (*Amber and Derwent Valley Community Energy Ltd.) proposes to install a hydroelectric scheme at Derwent works, a plastic fabrication factory on the right bank of the River Derwent. The factory is the location of a disused hydro power scheme and the new project would utilise the existing structures by installing 1 or 2 Kaplan turbines in existing turbine pits beneath the factory floor. A weir adjacent to the factory currently maintains the upstream water level.

Water would be abstracted from 130 m above the weir and reintroduced 150 m below the weir, creating a potentially deprived reach (PDR) 280 m long. The maximum abstraction rate will be 6 or 13 m^3/s and the hands off flow (HOF) remaining within the PDR and any fish passage facility is proposed as 2.2 m^3/s.

*ADVyCE Ltd c*ommissioned Fishtek Consulting to conduct a fisheries impact assessment for the proposed scheme, focusing primarily on potential impact to spawning and juvenile habitat and fish migration. Quantitative data obtained on site was used to assess the impacts and mitigation suggested where an impact was deemed likely. The findings are used to make recommendations on a suitable flow regime at the site.

Historic fisheries data indicates that the river is dominated by coarse fish and migratory salmonids and eels do not frequent the site. However, on-going works within the river aimed at improving fish passage has seen an increase in the range of migratory species and there is anecdotal evidence that migratory salmonids are reaching the weir south of Ambergate at Belper.

A site survey was conducted on 19/09/13 when river flow was approximately Q90. Depths, velocities and substrate type were recorded throughout the PDR and old leat channel, which formed the discharge tailrace for the previous hydroelectric scheme and bypasses the river for 960 m.

The channel above the weir was deep and slow flowing and it is likely that the benthos is comprised predominantly of silt and therefore provides no suitable spawning habitat. The channel below the weir had depths and velocities typically between 0.4 - 0.6 m and 0.4 - 0.8 m/s respectively. The channel is formed from concrete and laid stone and lacks natural substrate and therefore offers no spawning potential. At the lower end of the PDR, beyond the concrete and laid stone channel, the channel becomes more naturalised and is comprised predominantly of boulders providing very limited spawning areas for rheophilic species.

There is some, albeit marginal in extent spawning potential for phytophilic coarse fish at the site, with a low coverage of true aquatic macrophytes and some submerged terrestrial macrophtytes towards the true left bank.

Given the very limited availability of juvenile and spawning habitat within the PDR, it is not expected that the proposed abstraction regime, either 6 or 13 cumecs, will have a significant impact on juvenile or spawning habitat availability.

The existing leat channel is relatively shallow and slow flowing and comprised mainly of silt. There is almost no phyotphilic or rheophilic spawning opportunity; the channel does provide suitable brook lamprey habitat, and this species have been found upstream of the site at Hathersage. As a minimum, it is recommended that a residual flow somewhere is the region of 150 l/s should be maintained through the leat.

The River Derwent is extremely impounded and has very limited gravel riffles for spawning of rheophilic species. Habitat restoration works within the leat, involving the formation of gravel bars and a higher residual flow (or routine flushing flows) would generate useful additional habitat that would benefit the wider Derwent catchment.

Kaplan turbines can cause significant mortality to fish that pass through them; the general injury mechansims are physical injury caused by blade strike and grinding, pressure changes and shear forces within the turbine flow lines. Environment Agency guidelines therefore stipulate that Kaplan turbines should be sufficiently screened in order to minimise risk. Intake screening should consist of rectangular horizontal or vertical bars with 12.5 mm bar spacing. The screen should ideally orientate at an angle of ≤ 20 ° to the direction of flow and the approach velocity should be no greater than 0.25 m/s. It should extend from the river bed to above the flood flow level and should be designed to allow for efficient cleaning either manual or automated raking.

The tailrace screen should also consist of rectangular bars, although the screen should be upright and bar spacing can be as much 30 - 40 mm. As for the intake screen, tailrace screening should run from the river bed to above the flood flow level.

The weir is likely to be a complete barrier to upward migrating fish and while the proposed abstraction cannot make the situation any worse, it is recommended that a multi species Larinier fish pass, consisting of three 10 m long flights and two resting pools, is installed on either the left or right hand side of the weir. Best practice guidance recommends 10% of the turbines maximum take in the fish pass, however, this is not an easy site to install a fish pass and it is likely that it would be smaller than this, possibly a 600mm wide Larinier, taking 200-300 l/s.

The proposed HOF flow will result in shallow depths across the laid stone and concrete channel that may limit upstream fish migration. It is recommended that either a low flows channel, approximately 2-3 m wide and 0.5 m deep, is formed from the fish pass entrance to the downstream end of the PDR, or a low pre-barrage is built to increase depths to 300 mm. Alternatively the scheme could revert to a higher HOF, somewhere in the region of 5.4 m^3/s, that would maintain a reasonable minimum depth.

The Good Practice Guidelines for Hydropower are currently under revision and new guidelines are likely to come into effect as of spring 2014. It is likely that these guidelines will have a stricter default position, although sites may be allowed to deviate from this depending on site sensitivity. Providing the recommended mitigations for fish passage are adopted, it is not expected that the projected change in the Good Practice Guidelines would affect the proposed abstraction regime, given that the PDR has low ecological sensitivity and a high base flow.

Contents

1. Background and Introduction

This report assesses the potential impact on fisheries ecology of a proposed hydropower development at Derwent works on the River Derwent. *ADVyCE Ltd (*Amber and Derwent Valley Community Energy Limited) commissioned Fishtek Consulting to conduct a Fisheries Impact Assessment of the proposed scheme, focusing on the potential impacts to spawning habitat and fish migration and to recommend measures to mitigate any potential impact.

1.1 Site description

The site is currently owned by the Litchfield Group and operates as a plastics fabrication factory. The factory is adjacent to Amberagte weir that maintains upstream water levels and provided flow to the historic hydro power scheme; now defunct. The location of the site and view of the weir are given in figure 1.1.

The site was previously the location of a micro-hydroelectric scheme, which was installed in the 1930's, and two Francis turbines were located in turbine pits below the factory floor. The turbines were decommissioned and removed several decades ago. *ADVyCE Ltd* is exploring the possibility of re-instating a new micro-hydroelectric scheme largely utilising the existing structures.

The River Derwent rises at Howden Moor and flows through the Derwent valley, passing through both rural and urban areas before flowing into the River Trent at Derwent Mouth. The river once contained a healthy fish population, which included Atlantic salmon (*Salmo salar*) and sea Trout (*Salmo trutta*). However, the river was one of the cradles of the industrial revolution and the formation of weirs along its length and high levels of effluent discharge created unfavourable conditions for fish and resulted in a population crash, with the loss of migratory species.

The implementation of stricter legislation and directives, in particular the EU Water Framework Directive (Directive 2000/60/EC) and the Nitrates Directive (91/676/EEC), has seen a huge improvement in water quality over the last 30 years and fish populations have undergone a significant recovery. The River is currently dominated by coarse fish. Migratory salmonids cannot reach upstream as far as Ambergate due to a series of impoundments that block migration, although there is anecdotal evidence that migratory salmon and sea trout are beginning to frequent the lower reaches of the Derwent.

The Environment Agency, Trent Rivers Trust, West Cumbria Rivers Trust and Derby City Council have been working to improve fish passage on the Trent and Derwent. Fish passes have been installed on weirs at Darley Abbey and Borrowash (13 and 16 km downstream from Ambergate respectively) and there is a drive to install more fish passes to mitigate the remaining barriers in the Derwent catchment. It is therefore important that the scheme does not cause detrimental effects to fish migration and any opportunity to improve the current situation should be explored.

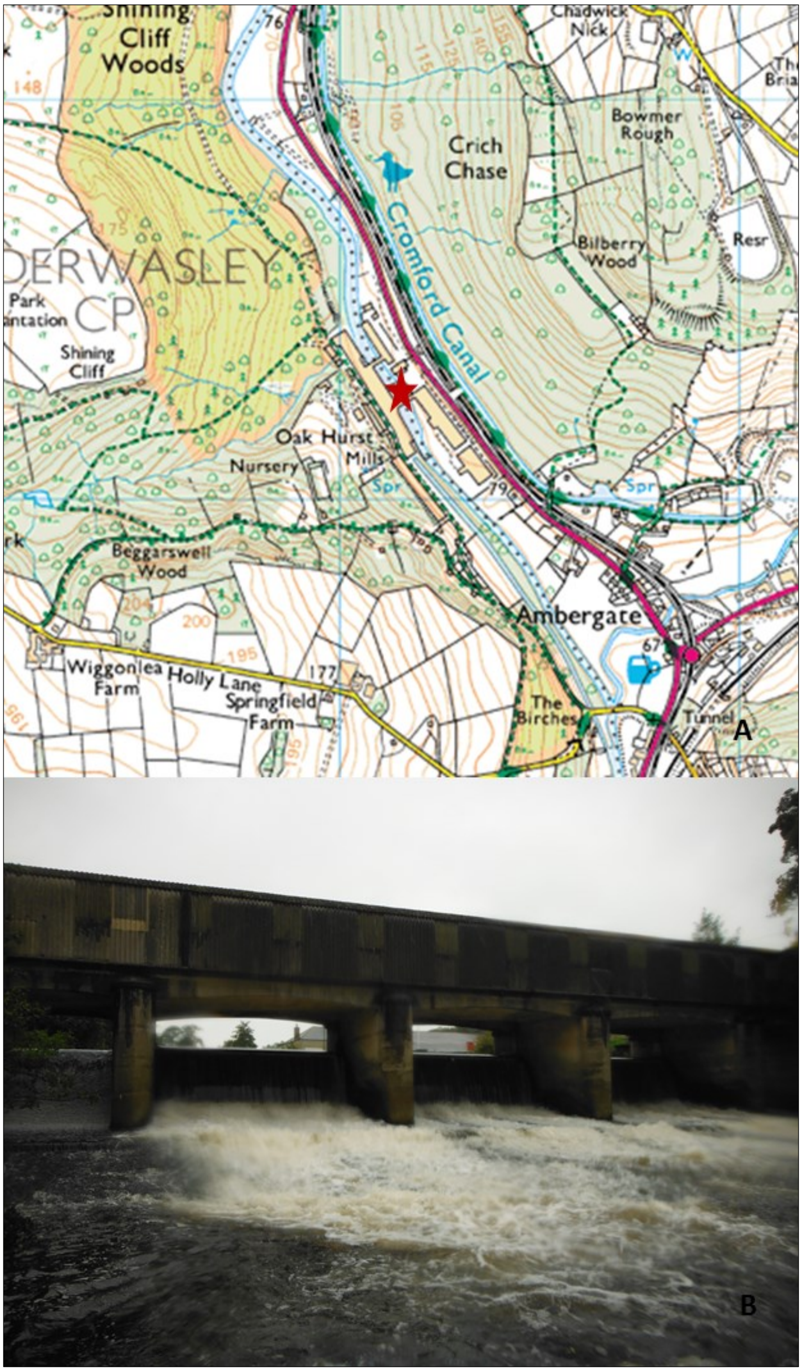


Figure 1.1: Map displaying the location of the site (A) and a photograph of the weir looking upstream from the weir pool (B). NGR SK3415852236.

1.2 Details of site proposal

ADVyCE Ltd propose to install one or two Kaplan turbines in the existing pits beneath the current Derwent works factory. Water would be abstracted from the current intake located 130 m upstream of the weir, discharged through intake tunnels beneath the factory floor, passed down the Kaplan turbines to be positioned in the turbine pits, and discharged through the tale-race tunnel. The tailrace tunnel currently feeds into a 870 m long leat, that discharged water back into the Derwent below the Bridge on Holly Lane (NGR: SK 34683 51355), approximately 1000 m from the offtake.. The new proposal would reduce the deprived reach by 870m by returning water to the river immediately below the tail race tunnel. The PDR (Potentially Deprived Reach) would be about 280 m long; 130 m above the weir and 150 m below the weir. A layout of the site, showing the proposed intake and outfall locations is given in figure 1.2.

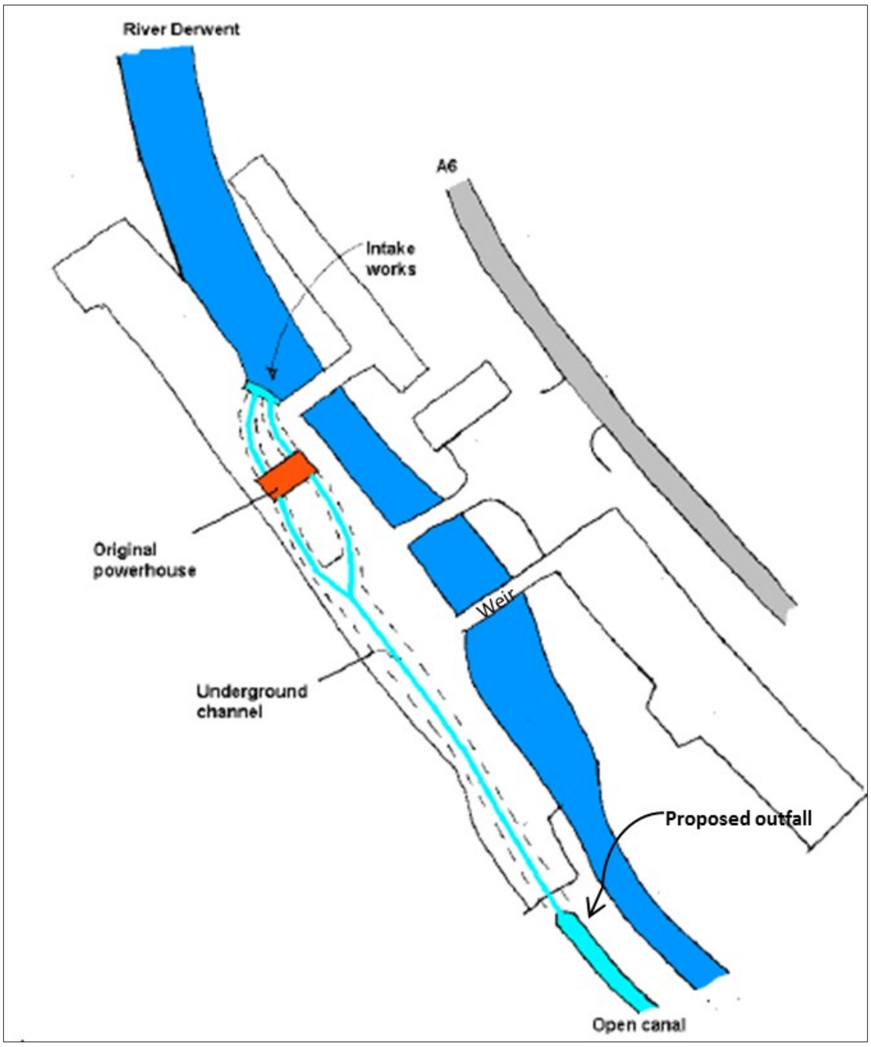


Figure 1.2: Site layout showing the intake and outfall locations, tailrace tunnel and original powerhouse.

One or two 1.2 m diameter Kaplan turbines, installed in the reinstated turbine pits, will abstract 6 or 13 m^3/s respectively, as stated in the feasibility study (see Ambergate Feasibility Report v2). Gross head will be 4.55 m and the scheme will have a capacity to generate between 185-305 kW of hydroelectricity, resulting in an annual generation of between 1.3-1.8 GWh. A minimum compensation flow, or Hands-Off Flow (HOF) of 2.2 m^3/s has been proposed. This will be split between the weir crest and any fish pass facility.

1.3 Site flows

The Flow Duration Curve (FDC) for the River Derwent at Whatstandwell, approximately 2.5 km upstream from Derwent Works (NGR: SK 33105 54545), is given in figure 1.3 and was generated based on long term gauged data. Q10, Qmean and Q95 flow at the site are 30.72, 15.53 and 4.51 m^3/s respectively, giving a Q95:Qmean ratio of 0.29:1 – a relatively high base flow.

The abstracted and PDR flows across the range of exceedance values for single or twin turbine abstractions are given in figure 1.3. Below the point of turbine satiation, flow within the PDR will be regulated by the abstraction and will only become variable when the turbines are satiated. For a single turbine this will be between Q99 and Q65 (35% of the time) and for a double turbine between Q99 and Q30 (70% of the time).

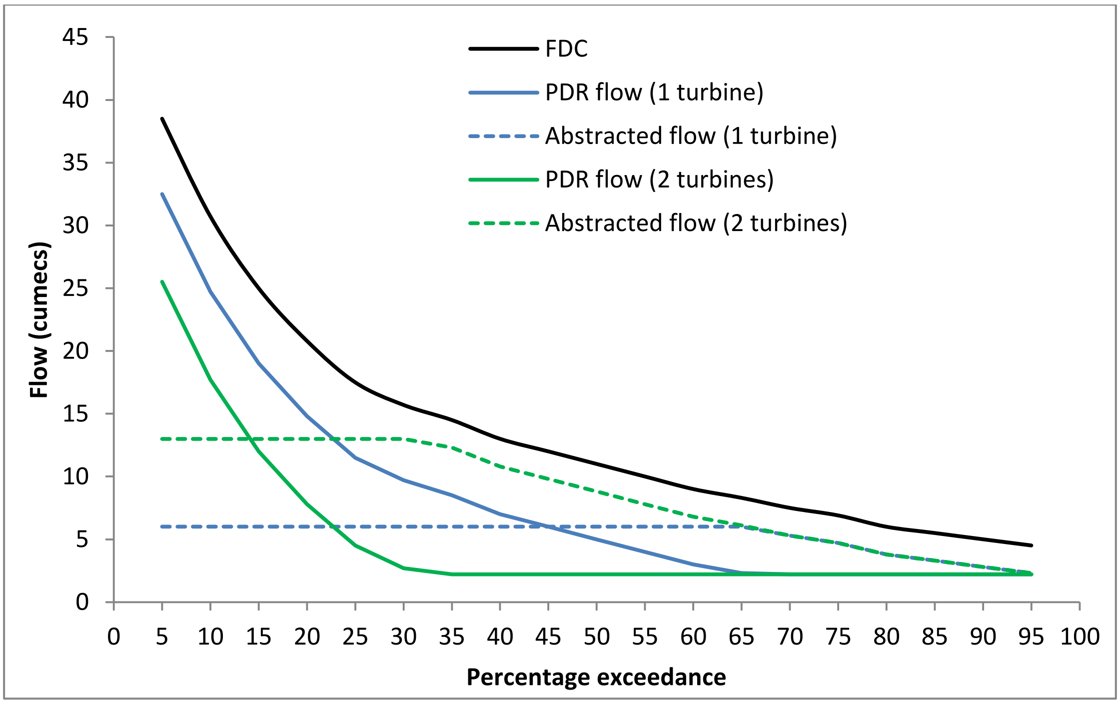


Figure 1.4: FDC for the River Derwent at Whatstandwell and abstracted and PDR flow for a single or twin turbine abstraction.

1.4 Report Brief and aims

The purpose of this report is to provide an assessment of the current fisheries ecology of the site and identify the potential fisheries impacts of the proposed hydropower scheme, with a particular focus on spawning and juvenile habitat availability and fish passage. Several key areas were investigated in order to assess the current situation and to establish the likely impact of the proposal. These are as follows:

- Current fisheries ecology in the River Derwent with reference to the site in question.
- Current spawning habitat quality and quantity within the PDR and existing outfall leat and the potential impacts to spawning habitat as a result of reduced flow in the PDR.
- Risk to fish of becoming entrained within the turbines and the screening requirements to prevent entrainment.
- The current potential for fish to migrate upstream at the site and the potential impact on fish migration.

The WFD (Water Framework Directive - Directive 2000/60/EC) stipulates that the ecological status of surface waters should not deteriorate, with a target for all inland and coastal waters to achieve a 'Good Ecological Status' by 2015. The general ecological standard required to achieve a Good status is "the biological community which would be expected in conditions of minimal anthropogenic impact".

The Environment Agency currently classifies the River Derwent as a moderate status water body (overall and ecological) and it is targeted to achieve Good Ecological Potential by 2027. It is therefore essential that the proposed scheme does not adversely impact upon the river and its fish population and any opportunity to improve fish habitat or migration should be explored.

2. Fisheries ecology in the River Derwent, specifically at Ambergate weir

The Environment Agency routinely conducts electrofishing surveys of the River Derwent. Survey data from 3 sites nearest Ambergate, (Cromford, Ambergate and Whingfield Park) were requested from the EA. The location of each site is given in figure 2.1. A range of coarse fish species and brown trout were found at the sites. A full list of the species caught at each site is given in table 2.1.

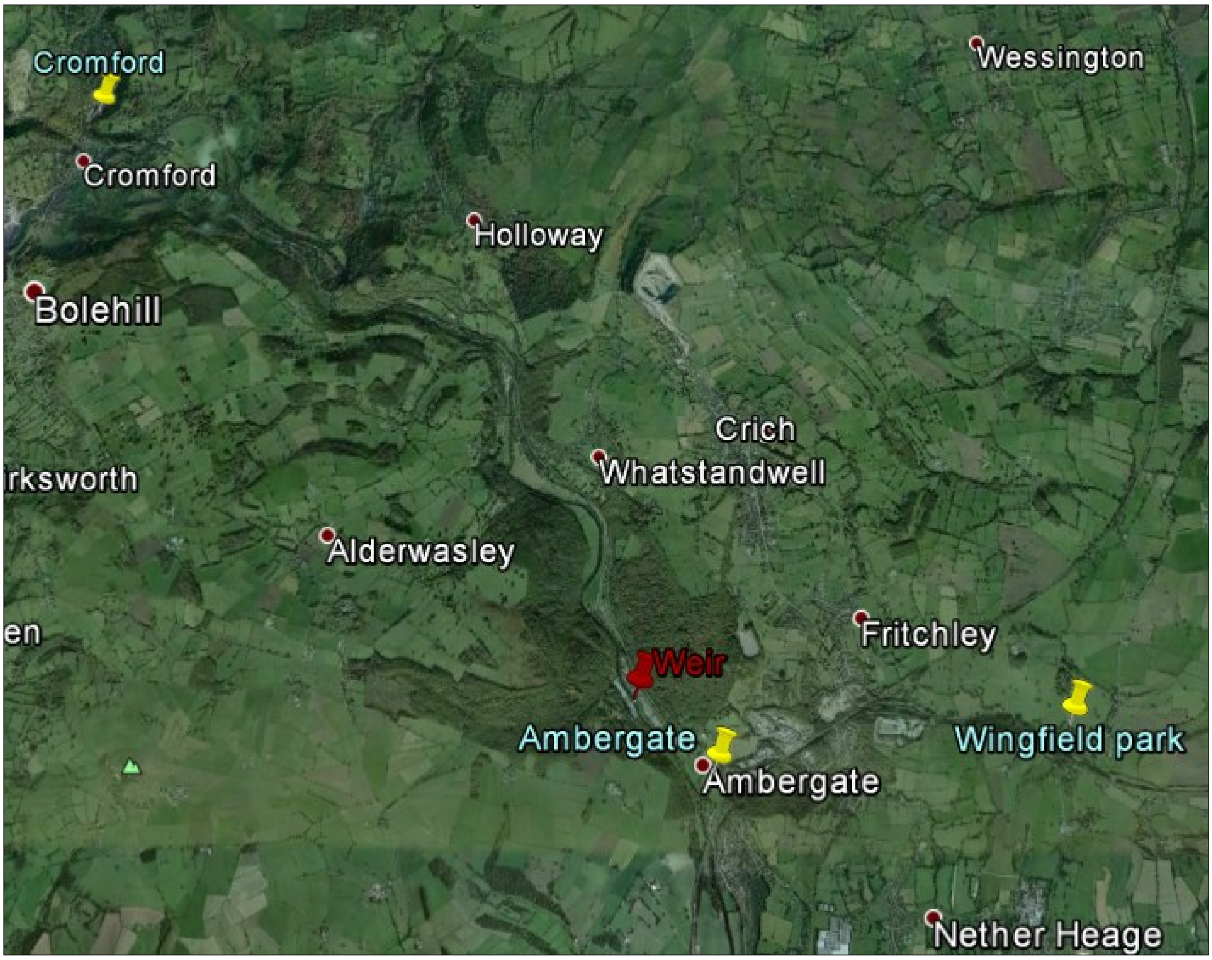


Figure 2.1: Locations of sites electrofished by the Environment Agency in recent years within 10 km of the weir at Ambergate.

Table 2.1: Summary of Environment Agency electrofishing survey data within 10 km of Ambergate weir over the past 5 years.

Species	**Amberagte**		**Cromford**		**Wingfield Park**	
	Present/absence	**Mean length (mm)**	**Present/absence**	**Mean length (mm)**	**Present/absence**	**Mean length (mm)**
Stone loach [*Barbatula barbatula*]	✓	57	✓	-	✓	84
Brown trout [*Salmo trutta*]	✓	213	✓	-	✓	296
Barbel [*Barbus barbus*]	✓	382	✓	-	✓	445
Chub [*Leuciscus cephalus*]	✓	397	✓	-	✓	357
Dace [*Leuciscus leuciscus*]	✓	24	✗	-	✓	109
Mirror carp [*Cyprinus carpio*]	✓	405	✗	-	✗	-
Ruffe [*Gymnocephalus cernuus*]	✓	94	✗	-	✗	-
Pike [*Esox lucius*]	✓	630	✓	-	✗	-
Bullhead [*Cottus gobio*]	✓	50	✓	-	✓	66
Minnow [*Phoxinus phoxinus*]	✓	49	✓	-	✓	61
Perch [*Perca fluviatilis*]	✓	233	✓	-	✓	162
3-spined stickleback [*Gasterosteus aculeatus*]	✗	-	✓	-	✓	35
Gudgeon [*Gobio gobio*]	✗	-	✗	-	✓	115
Roach [*Rutilus rutilus*]	✗	-	✓	-	✓	41
Common bream [*Abramis brama*]	✗	-	✓	-	✗	-
Grayling [*Thymallus thymallus*]	✗	-	✓	-	✗	-

Although migratory salmonids (sea trout and Atlantic salmon) have long been absent from the River Derwent, continuing improvements in water quality and efforts to improve fish passage throughout the Trent and Derwent catchments have resulted in early signs of recovery for these species. A population of juvenile Atlantic salmon has recently been observed in the Derwent north of Derby and there is anecdotal evidence that some Atlantic salmon reached as far upstream as Belper weir during 2012 (Charles Crundwell - Environment Agency, personal communication), located just 3.5 km downstream of Ambergate. It is likely that migratory salmonid populations will extend up to Ambergate weir as fish passes are planned on the remaining barriers downstream.

Eels (*Anguilla anguilla*) have not been recorded in any of the electro fishing surveys within 10 km of the site and it is unlikely that they are present in this stretch of the Derwent, although they are known to be present within the River Trent. It is anticipated that eel populations in the Trent and Derwent will increase over the next 10 years as more eel passes are installed on barriers within the catchments.

Sea and river lamprey *Petromyzon marinus and Lampetra fluviatilis* do not frequent the catchment (Charles Crundwell, Environment Agency, personal communication), although brook lamprey (*Lampetra planeri*) have been found at Hathersage, approximately 30 km upstream from Ambergate. The slow flow and deep silty mud in the old leat may provide suitable habitat for brook lamprey, although it is unknown if any are present within the leat.

In order to identify any potential impacts of the proposed scheme on current and future fish populations it is essential to understand their ecology. Atlantic salmon and sea trout are anadromonous species, which means that they ascend rivers from the sea to spawn. Brown trout are potadromous (resident) and spend their entire life cycle within freshwater.

Brown trout and Atlantic salmon have similar spawning requirements and will migrate within a river in order to find suitable spawning habitat. Table 2.2 summarises the typical spawning requirements of these species based on the available literature. Variability in spawning preferences can partly be attributed to the fact that females prefer substrate no larger than 10 % of their body length, as well as a low (< 8) percentage of fine material (Lindberg, 2011). Sea trout are known to display similar spawning habitat requirements to that of brown trout and Atlantic salmon (Crisp, 1996).

Table 2.2: Typical spawning requirements of Atlantic salmon and Brown trout as reported in the available literature.

Species	velocity (m/s)	depth (m)	Substrate size (mm)	Source
Atlantic salmon	0.53	0.38	n/a	Beland et al., 1982
Atlantic salmon	0.2 - 0.8	0.2 - 0.75	20 - 100	Lindberg, 2011
Atlantic salmon	0.35 - 0.65	0.2 - 0.5	16 - 64	Louhi et al., 2008
Brown trout	0.2 - 0.55	0.15 - 0.45	16 - 32	Kondolf & wolman, 1993; louhi et al., 2008
Brown trout	0.2 - 0.5	0.2 - 0.3	n/a	Armstrong et al. 2003

After hatching, salmon remain within the redd for up to two months. As fry and under-yearling parr they typically require habitat with substrate sizes of 16 - 64 mm, and velocities and depths of 0.5 - 0.65 m/s and approximately 0.2 m respectively (Lindberg, 2011). As yearlings and older parr they typically inhabit deeper water (0.6 – 0.75 m) with greater velocities (0.6 - 0.75 m/s) and slightly coarser sediment (Hendry & Cragg-Hine, 1997). The juxtaposing of this variable habitat and the positioning of holding pools for pre-spawning adults are also a significant salmonid requirement.

In addition to migratory species, potential impacts to rheophilic and phytophilic coarse fish, eels and brook lamprey must also be considered. Rheophilic coarse fish (which include bullhead (*Cottus gobio)*, minnow (*Phoxinus phoxinus*), chub (*Leuciscus cephalus*), dace (*Leuciscus leuciscus*), stone loach (*Barbatula barbatula*), grayling (*Thymallus thymallus*) and barbel (*Barbus barbus*) at this site) have similar requirements to brown trout, requiring areas of shallow depth, rapid flow and gravel substrate on which to spawn (Mann, 1996). The common minnow (*Phoxinus phoxinus)*, for example, requires a substrate of 20 – 30 mm in diameter and velocities of between 0.2 - 0.3 m/s (Bless, 1992). Some coarse fish, including barbel can spawn within higher velocity water, although velocities above 0.5 m/s are generally too high for rheophilic spawning.

In contrast, phytophilic fish species (which include roach (*Rutilus rutilus)*, perch (*Perca fluviatilis)* and pike (*Esox lucius*) tend to adhere their eggs to submerged macrophytes. Spawning usually occurs in shallow depths, although species preferences vary. Some fish prefer to lay their eggs on permanently submerged macrophytes, whereas others prefer flooded terrestrial grasses (Mann, 1996; Lelek, 1987). Phytophilic fish typically prefer to spawn in low velocity water (< 0.2 m/s) although some species, such as roach, are highly adaptable and are able to spawn in a range of water velocities and on different substrate types, including gravel (50 – 150 mm diameter) and a range of submerged macrophytes (Mann, 1996).

There is an abundance of literature reporting the habitat preferences of juvenile coarse fish species. Copp (1992) observed that the habitat used by particular coarse fish juveniles corresponds to the spawning habitat of the adults of that species. For example, upon hatching many cyprinids, including roach, typically resist displacement and adhere to the vegetation from which they have hatched (Copp, 1990). Similar microhabitat preferences corresponding to adult spawning preferences have been observed in rheophilic coarse fish species (Mann, 1996) and brown trout (Armstrong et al., 2003).

In faster flowing water, larval coarse fish are often displaced and take up residence in areas of lower velocity. For example, during its larval stage roach (*Rutilus rutilus)* can only maintain their position in the water column in velocities of below 6.9 cm/s (Lightfoot & Jones, 1979). Therefore, many larval fish will remain low in the water column and in relatively shallow, low velocity waters, often close to where they hatched. Research has shown the importance of slow, lentic sites for these larvae and juvenile coarse fish (Nunn et al., 2007), as well as the presence of submerged macrophytes or ligneous material (Copp, 1992; Copp, 1997; Baras and Nindaba, 1999).

European eels (*Anguilla anguilla*) are catadromous, which means that they spend most of their life in freshwater and migrate to the sea to spawn. Much of the ecology of this species is still unclear, although it is known that they enter freshwater from the sea as glass eels and migrate upstream to find suitable habitat to grow out and mature. As glass eels and elvers they typically prefer small, well vegetated and slow flowing tributaries where they are safe from predation. As they grow into yellow eels (freshwater maturation stage) they venture to faster flowing, larger channels in search of more abundant food sources. European Eels are protected by the Eels regulation 2009 (Council Regulation (EC) No 1100/2007), which places a responsibility on developers and operators of sites to preclude eels from passing into the abstracted flow wherever a risk to eels has been identified. In addition, eel passage must be provided at sites that present barriers to migration. This is obviously contingent on eels being present in the first place.

Brook lamprey are almost indistinguishable from river lamprey when they are a similar size and display similar spawning requirements, using gravel beds - sometimes with part sand or cobble composition - as a preferred spawning substrate (Lucas et al., 2009; Maitland, 2003). Furthermore, they require a moderate current (Gardiner, 1995) and will spawn at a large range of depths from 0.2 - 1.5 m (Maitland, 2003).

Lamprey larvae (ammocoetes) disperse downstream within a few days of hatching and prefer low velocity sites (~ 0.2 m/s), with shallow depths (3 - 30cm) and a sand or slit based substrate with a high organic content (Hardisty & Potter, 1971 from Maitland, 2003).

The creation of migration barriers and the reduction of spawning habitat as a result of anthropogenic activity is a major cause of fish and eel population decline. It is essential that any proposed hydropower scheme does not cause a significant detrimental impact upon habitat availability or the migration of fish species, and where possible, options to improve the current situation should be explored.

3. Impacts of Kaplan Turbines on fish

Hydroelectric turbines present three main risks to fish:

1. Entrainment – When fish are drawn into the turbine forebay or lead-in channel and pass down the turbine as a result of being passively transported in the direction of flow, potentially resulting in strike impact from the rotating parts or impact by severe pressure changes.

2. Impingement – Where fish come into contact with a screen, trashrack or trapped debris at the intake, resulting in abrasion or even mortality from prolonged or repetitive exposure.

3. Delay – Fish can be prevented from migrating either upstream or downstream for short or long periods as a result of screening or outfalls inducing attraction or avoidance behaviour in fish. Increased stress, energy loss and predation can be attributed to such behaviour, reducing overall probability of survival.

The potential severity of each of these risks varies for different types of turbines. For example, entrainment down an Archimedies screw turbine for UK riverine fish is considered negligible and risk of mortality is very low given their fish friendly nature; screws have low probability of strike impact and no pressure change as they are open to the atmosphere (Kibel, 2007; Kibel & Coe, 2008, Kibel et al. 2009).

Kaplan turbines present a greater risk to fish than Archimedean screw turbines and can result in high levels of damage or even mortality to entrained fish as result of direct impact with rotating parts, severe pressure changes or shear stress (Abernethy et al., 2002). Mortality rates appear to be species specific, for example Moursund et al. (2003) concluded that pacific Lamprey transformers (*Entosphenus tridentatus*) did not sustain any injury or mortality whilst passing through a Kaplan turbine under the same shear stresses that were found to injure or kill juvenile salmonids. This is likely to be due to their lack of swim bladder and incredible flexibility. Injury rates also depend on the size of the turbine and very large Kaplans (> 5 - 6 m diameter) can pass fish up to 300 mm with more than 90 % survival.

Mortality rates typically between 5 - 20 % have been found for salmonids passing through run-of-river Kaplan Turbines in France (Larinier, 2001) and similar rates have been identified in coarse fish. Due to this risk the Environment Agency stipulates the requirement of specific screening for Kaplan turbines within England and Wales, as outlined in the Good Practice Guidelines (Environment Agency, 2009).

4. Screening requirements

In England and Wales, the abstraction of water for hydroelectric purposes is subject to requirements under the Salmon and Freshwater Fisheries Act (SAFA, 1975) to install screens or other effective barriers to prevent the entrainment of fish.

There are a range of barriers available, including physical exclusion screens and behavioural deterrents. Behavioural deterrents act to promote an aversive stimulus that discourages fish from approaching the screen and include a range of acoustic, electric and photic solutions

For Kaplan turbines, physical exclusion screens are required in order to preclude fish from entering the turbine altogether. Strict guidance is available for the type of screen required, which largely depends upon the water course, type of turbine, total maximum abstraction and species to be excluded (Environment Agency, 2012; Turnpenny et al., 1998).

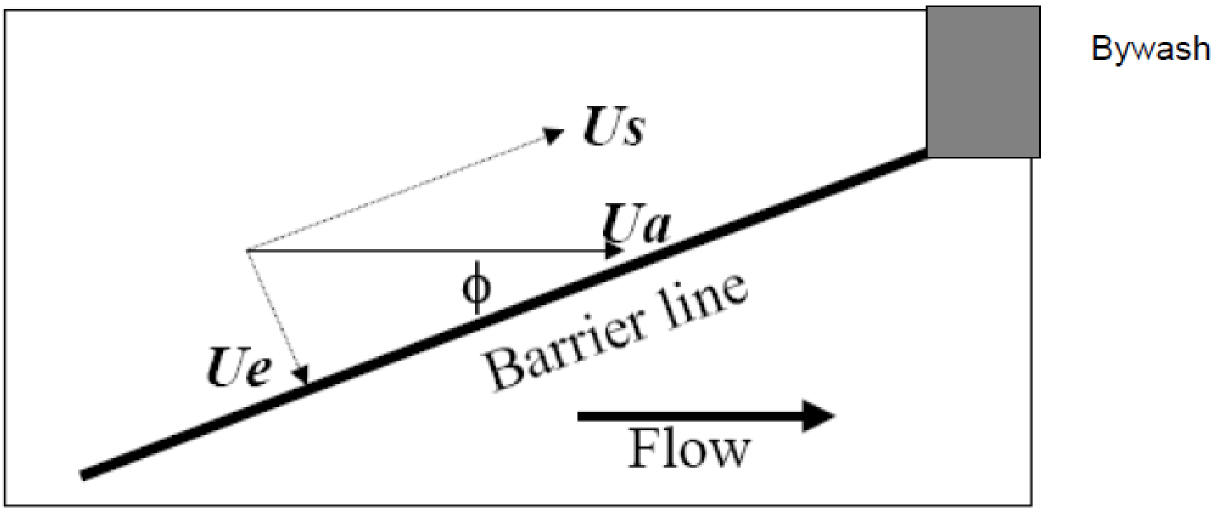
It is essential that screens not only prevent fish from entering the turbine fore-bay, but also prevent fish from becoming entrained against the screen itself. Therefore, as well as the spacing between bars, the angle at which the screen is positioned relative to river flow and the velocity of water passing through and across the screen must also be carefully considered.

4.1 Screen Angle and approach velocity

Screens placed across the river and at right angles to flow are the least effective for fish protection, as fish are more likely to experience difficulty locating a bypass and are prone to become trapped against the screen. Ideally an intake, and hence a screen, should be flush to the river bank and therefore perpendicular to the flow with a substantial sweeping flow in the main channel. Alternately, and at sites where there is little or no sweeping flow, it is possible to angle screens relative to flow in order to create a virtual sweeping flow that allows fish to be washed downstream. Either arrangement may be suitable at this and is likely to depend upon the total maximum abstraction and the maintained HOF. The design that is proposed shows a screen perpendicular to the flow (see figure 1.2).

Figure 4.1 displays the flow velocity components in front of an angled fish barrier, where Ua is the axial channel velocity, Ue (equal to $U\sin\Phi$) is the fish escape velocity (also known as the approach velocity), and Us (equal to $U\cos\Phi$) is the sweeping velocity along the face of the screen. The maximum acceptable approach velocity towards any part of the screen depends upon angle Φ and the swimming performance of the fish, which varies between species and fish sizes and is influenced by water temperature.

Providing angle Φ is ≤ 20 °, then for the species known to be present at Ambergate (coarse fish and non-migratory salmonids) the approach velocity should be no greater than 0.25 m/s. The maximum approach velocity for adult eels (>30 cm), lamprey and adult migratory salmonids is 0.5, 0.3 and 0.6 m/s respectively, and therefore, a velocity aimed at coarse fish will encompass these species should they make a significant recovery within the Derwent.



4.1 Flow velocity components in front of an angled fish barrier.

4.2 Screen spacing

Assuming that the screen angle is ≤ 20 ° to the direction of flow within the main channel, and velocities are maintained below 0.25 m/s, a reasonable sweeping flow will allow fish to continue beyond the screen within the river channel and a separate by-wash facility should not be required. Based on this arrangement, Environment Agency Good Practice Guidelines stipulate that a screen with bar spacing of 12.5 mm is required for the range of species known to be present at the site.

12.5 mm spacing will also future proof the screens should migratory salmonids or eels make a significant recovery in the River Derwent, since the same spacing is required for salmonids as well as for silver and yellow eels (>30 cm); it is unlikely that smaller eels (glass eels or elvers) will ever be present this far up the catchment as it is over 30 Km upstream form the confluence with the River Trent.

Rectangular section bars or perforated plates are preferred to round section bars. The latter is more likely to trap fish by their gills and if used a smaller aperture is usually required. Bars should be sufficiently stiff in order to maintain the design spacing and can run vertically or horizontally. Tie-back bars may need to be fixed across the back of the screen in order to maintain rigidity.

Screens should run from the river bed – being slightly embedded – until above flood flow levels in order to exclude fish at all times. Screens will often be inclined by 10° from vertical, making them easier to rake. Raking can be performed manually, although on large screens where there is a risk of substantial debris collection, automated debris rakes are often used to continuously prevent screens from becoming blocked.

4.3 Tailrace screens

At many hydroelectric sites, tailrace channels often discharge greater flow than in the main river, potentially attracting fish towards the tailrace. This may delay or stop their upstream migration and screens are needed in order to prevent fish from entering a turbine and to direct them upstream.

Tailrace screens should be upright, located close to the edge of the river bank and at the point where water discharges back into the main river. They should be formed from square metal bars; round bars are more likely to gill fish. Screens should have 30 - 40 mm bar spacing and should consider local topography and flood levels. Fish should not be able pass over the screens in high flows, in doing so they are likely to become trapped as the water recedes.

5. Hydrology and morphology within the PDR

5.1 Methods

River morphology and hydrology were measured on 19/09/13 when river flow was approximately Q90, as recorded at Matlock gauging station (Station number: 2103), approximately 10 km upstream of Ambergate. The weir was divided into cross-sectional transects from the weir toe to 150 m downstream just below the proposed turbine discharge point; a total of 75 points were sampled. Transects were sampled in a downstream direction and the following information was recorded at each point:

- Depth (m) was measured from the surface to the bed using a depth gauge. Depths above 2.5 m recorded as so.
- Water velocity (m/s) was measured using a Flow Mate doppler flow meter.
- A substrate sample was obtained from the river bed using a remote grab.

Sediment was classified on site according to the Wentworth scale (Wentworth, 1922), as displayed in table 5.1. Note that samples with predominant particle sizes of less than 0.5 mm or greater than 256 mm were recorded as such, focussing on the mid-range sizes which have been established as suitable for juvenile and spawning habitat for the fish present at the site (Kondolf & Wolman, 1993; Kondolf, 2000; Mann, 1996).

Table 5.1: Classification scale of substrate types based on predominant particle size (adapted from Wentworth, 1922).

Particle size (mm)	Substrate classification
<0.5	Silt and clay
0.5-1	Fine sands
1-2	Coarse sand
2-8	Fine gravel
8-16	Medium gravel
16-32	Coarse gravel
32-64	Large gravel and cobble
64-256	Cobble
>256	Boulder

5.2 Results

Figure 5.1 displays the depths and velocities throughout the PDR at approximately Q90 flow. Upstream of the weir the channel is deep and slow flowing. Downstream of the weir depths and velocities are more variable and typically range between 0.4 - 0.6 m and 0.4 - 0.8 m/s respectively.

Figure 5.2 displays the substrate type found within the weir pool. From the toe of the weir to the end of the stone channel wall (approximately 150 m downstream from the weir) the channel is comprised entirely of laid stone and concrete and there is no natural substrate whatsoever. Below the channel wall the river becomes naturalised and substrate consists of a mixture of boulder and cobble.

It was not possible to obtain a substrate sample above the weir since the depth was greater than the limit of the sampling gear (>2.5 m), although it is likely to be comprised of fine material such as silt, sand and mud, given the low velocities above the weir and the presence of the weir preventing flushing of the benthos.

5.3 Changes in hydrology and morphology within the PDR as a result of turbine installation

The abstraction of water from above the weir will not have a significant impact on depths or velocities upstream of the weir, since velocity in this area is already low and upstream water level is controlled by the radial gated weirs, which will continue to maintain levels post turbine installation.

Below the weir there will be no change in substrate type, although depending on the flow regime - in particular the HOF – depths and velocities are likely to be reduced over much of the FDC. A HOF of 2.2 m^3/s has been proposed for the scheme, approximately 2.8 m^3/s lower than the flow measured during the site survey. This HOF will be maintained until the point of turbine satiation, above which additional flow will remain within the main channel.

Depths given in figure 5.1a are towards the lower limit for upstream fish migration in places. Should a fish pass be installed at the site a much lower HOF may result in depths that could significantly impact upon upstream fish migration, resulting in fish becoming delayed beneath the PDR. Any fish pass facility must be sited in an area that fish can access. A more detailed analysis on the effects of the proposed HOF on upstream fish passages is given in section 8.

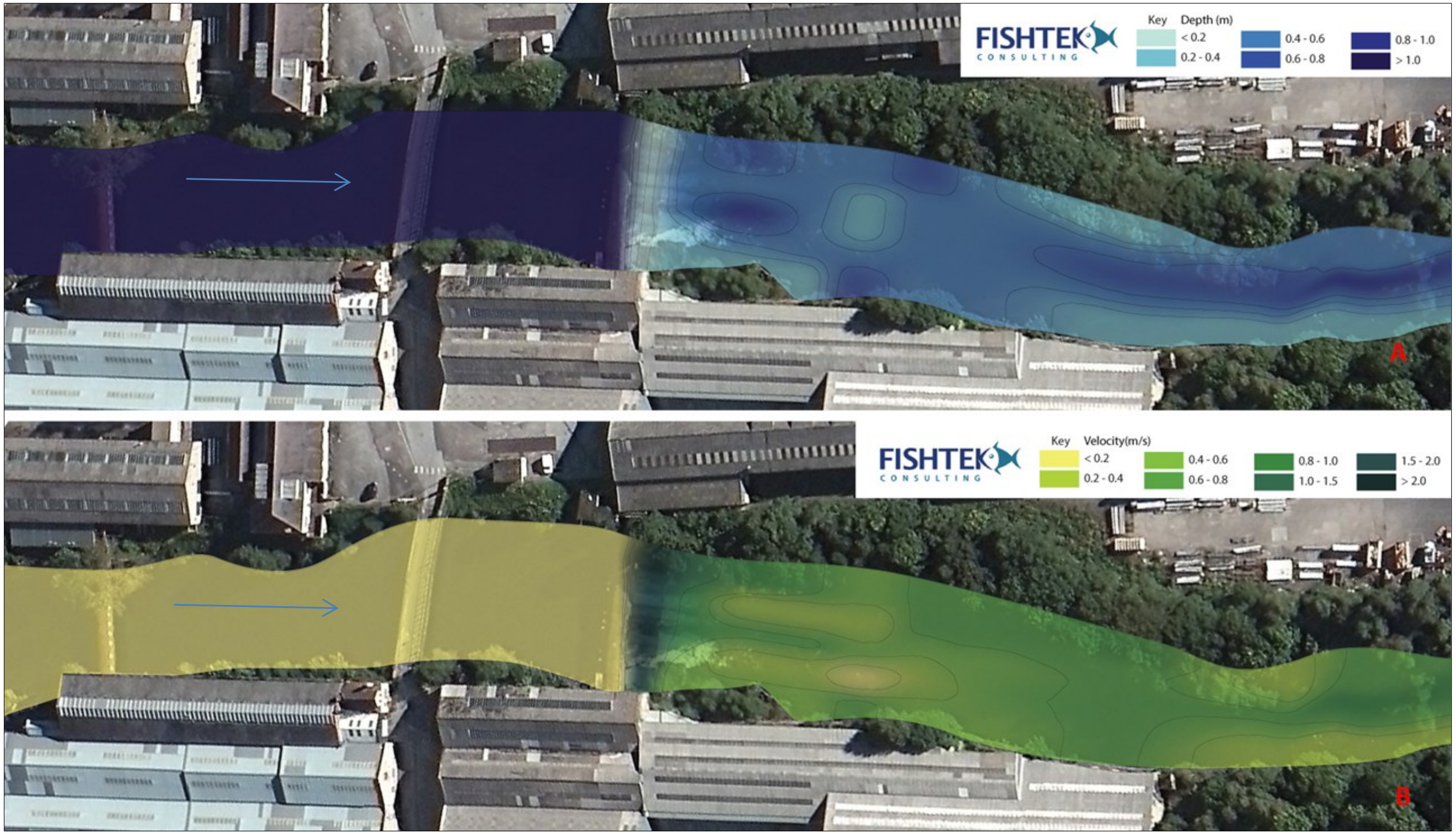


Figure 5.1: Depth (A) and velocity (B) schematic of the PDR at Q90 flow.

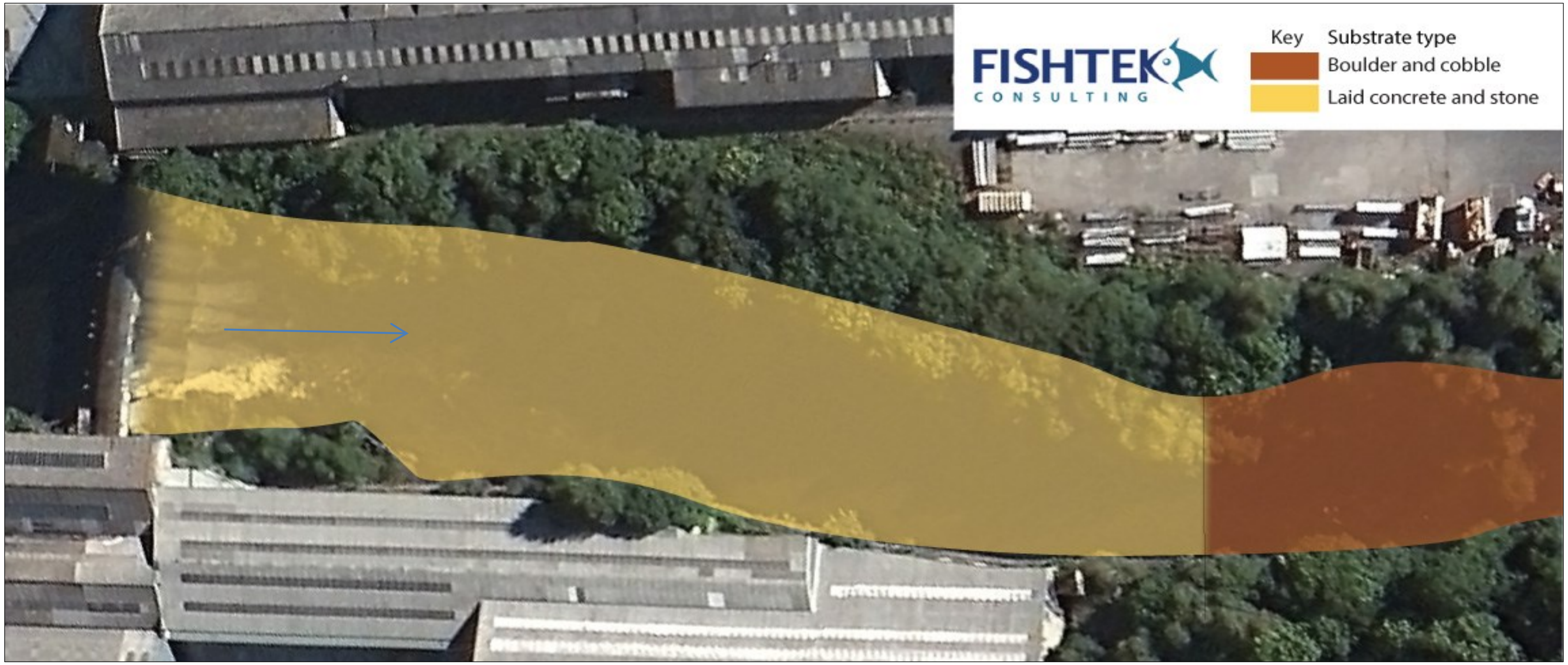


Figure 5.2: Schematic diagram displaying substrate type within the PDR beneath the weir.

6. Spawning and juvenile habitat quality within the PDR

6.1 Methods

In order to quantify the quality of spawning habitat at each sampling point an index was developed, based on the spawning habitat preferences of brown trout and coarse fish. The index was based on depth, velocity and the predominant substrate type.

With reference to the optimum parameters for the species detailed in section 2, each sampling point was assigned a score of 1 – 3 for each measurement of depth, velocity and substrate type. Table 4.1 displays the scoring system used. Substrate classification has been based on the predominant substrate type(s) present. Where depth was too great to obtain a substrate sample a score of 3 was given, since it is unlikely that suitable habitat would be available at this depth.

Table 4.1: Scoring system used to score coarse fish and brown trout habitat quality.

Score	Depth	velocity	Substrate type
1	≥0.2-0.8	≥0.2-0.8	Gravel/ small cobble
2	<0.2 /0.8-1.5	<0.2	Gravel or small cobble mixed with boulder/sand/ clay/ large cobble
3	≥1.5	>0.8	Sand/clay/boulder/ large cobble/ bedrock/ above sampling depth

The index used to assess habitat quality was calculated as follows:

I = V+D+S

Where V = Velocity score, D = Depth score and S = Substrate score.

Each sampling site achieved a total score of between 3 and 9. Each of these total values were categorised into the following in order to rate the site for its spawning suitability:

- 3 = Very good
- 4 = Good
- 5 = Above marginal
- 6 = Marginal
- 7 = Below marginal
- 8 = Poor
- 9 = Very poor

This scoring system enabled a robust and objective assessment of the quality of spawning habitat in each sampling location and subsequently throughout the weir pool. Areas of habitat with scores below five (above marginal) are unlikely to provide any spawning opportunity.

6.2 Results

Depths and velocities above the weir are outside the suitable range for spawning fish and this area offers no spawning potential. Furthermore, it is likely that fine sediments predominate, which ware unsuitable for both rheophilic and phytophilic spawners.

Figure 6.1 presents spawning habitat quality within the PDR beneath the weir. Depths and velocities are largely within the suitable range for fish spawning, although much of the channel is comprised of laid stone and concrete that provides no spawning potential. Beyond the laid stone channel there is a small section of river that is more naturalised, although large material including boulder and cobble predominates, which is also unsuitable for rheophilic spawning.

There may be some opportunity for phytophilic spawning within the PDR as there was evidence of submerged terrestrial and true aquatic macrophytes. Figure 6.2 displays an image of a typical patch of freshwater macrophyte (*ranunculus sp.*) found at the site, although these were sparsely scatted and covered < 1% of the PDR. Submerged terrestrial macrophytes on the true left bank in the lower PDR may also offer some marginal spawning habitat to phytophilic fish.

6.3 Potential impacts to spawning habitat as a result of turbine installation

Given that there is currently very limited spawning potential within the PDR, it is not expected that the scheme will cause a significant impact to the availability of spawning habitat, providing the tailrace joins the river immediately below the laid stone and concrete channel. Although it was not surveyed in detail, it is worth noting that immediately below the deprived reach, where the river channel becomes naturalised again, there are significant areas of gravel/cobble that may provide suitable spawning habitat.

The old leat currently re-joins the river 960 m downstream of the weir. ADVyCE are not considering re-using the leat (this would maximise the head), a sensible decision from a fisheries perspective as this avoids the potential to deprive almost 1km of natural river channel with good areas of spawning and juvenile habitat. It is likely that a significantly higher HOF would be necessary if a longer PDR was created. Based on Best Practice Guidelines (Environment Agency, 2010) a HOF equivalent to at least Q85 would be required, although this could be higher if any spawning habitat or migration routes particularly sensitive to a reduction in flow were identified.

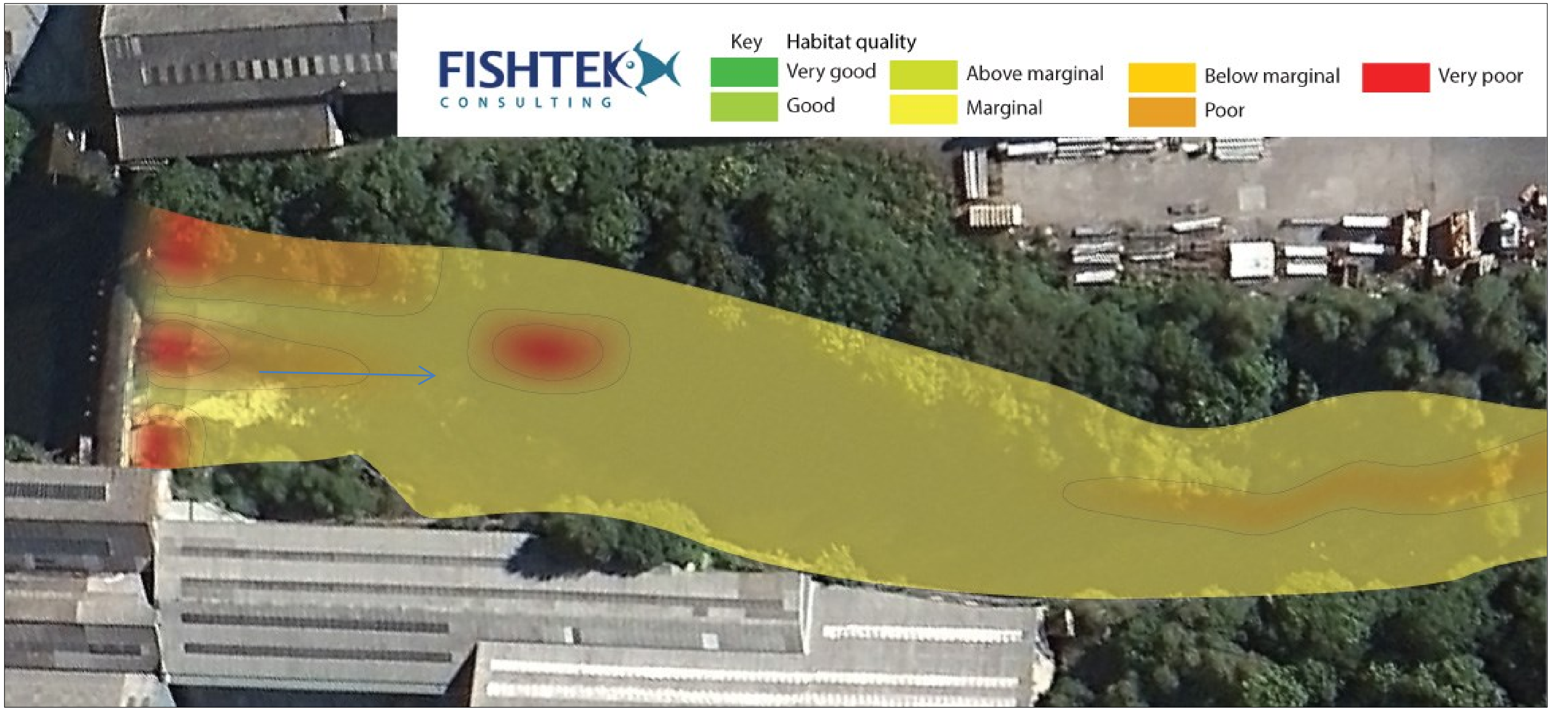


Figure 6.1: Spawning habitat quality within the PDR below the weir.

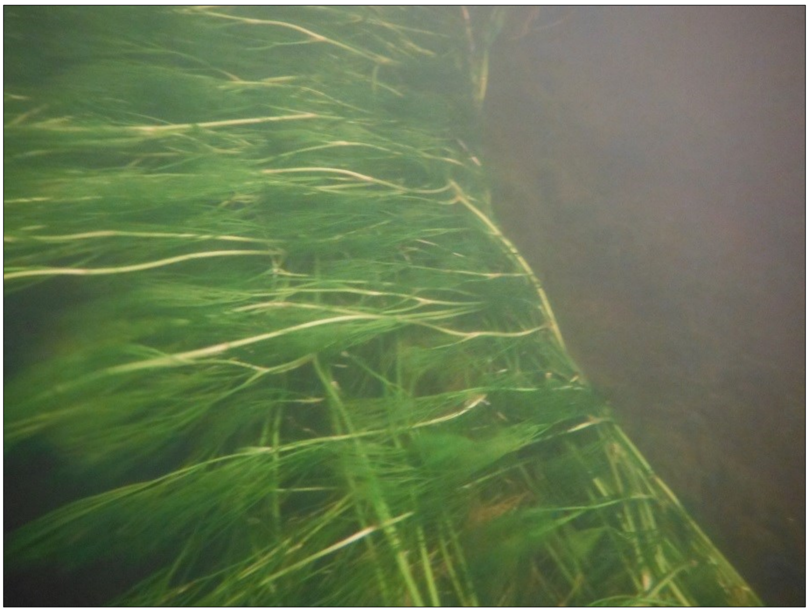


Figure 6.2: Image of a typical patch of aquatic macrophyte found within the PDR (*ranunculus sp)*.

7. Current fish habitat availability within the leat

The entire length of the leat, from the outflow of the tailrace tunnel (NGR SK 34196 52115) to the confluence with the main river (NGR SK 34678 51427) was assessed for fish habitat. The majority of the leat was shallow (0.2 - 0.3 m) and slow flowing (< 0.2 m/s) and spot gauging data (depth and velocity) along the channel was used to calculate a discharge of 150 l/s during the survey. The substrate was comprised predominantly of silt with woody debris, including fallen trees throughout the leat. Vertical stone walls run along either side of the leat for the entire length of the channel. The leat gradient is very shallow (< 0.2%), except towards the confluence with the main channel, where the final 30 m has a steeper gradient and higher velocity of approximately 0.4 m/s. An image of a typical section of leat channel and the leat confluence with the main river is given in figure 7.1.

Figure 7.1: Image of a typical leat section (A) and of the confluence of the leat with the main channel (B)

There is no spawning potential within the leat for phytophilic or rheophilic fish, although the channel may offer some refuge to juvenile fish during periods of high flow. The leat also provides good quality habitat for brook lamprey, which have been found upstream of Ambergate at Hathersage and may frequent the leat.

7.1 Residual flow in the leat and habitat creation

A residual flow in the leat at least equivalent to the flow observed on the day of the site visit (150 l/s) should be maintained post turbine installation in order to maintain the current situation.

The lower-mid Derwent is largely impounded and there is a paucity of suitable fish spawning and juvenile habitat. It would be beneficial for the fisheries ecology of the river Derwent if the leat was used to create gravel spawning habitat for rheophilic species including barbel, chub, dace, grayling, trout, lamprey and potentially migratory salmonids, anticipating their spread up the catchment. Sections of the leat could be de-silted and a series of gravel beds formed in order to replicate typical ‘riffle-pool’ type habitat. Velocity across the gravel patches would need to be higher than within the pools to prevent them from silting up. A gradient of 1% across the gravel sections would create velocities in the region of 0.5 m/s. It would also be useful to be able to flush the leat periodically to clean the gravel.

A detailed design with hydraulic calculations would be required to calculate the exact flows, however, an outline approach could be as follows: The prescribed flow in the leat to be maintained at 150l/s. While the turbine is operating, a proportion of the turbine discharge water would be diverted (via a flow control sluice gate) through the leat, as currently the invert at the top of the leat is below the turbine outflow. Assuming a width of 5 m, optimum depth of 0.4 m and a flow of 0.5 m/s, about 1m^3 of water would be required. This would be available for >99% of the year if the HOF is set at 2.2 m$^3_{/s}$ as proposed.

The volume of gravel required for the entire leat would be significant. Assuming 5 m average width, 1000 m length and average gravel depth of 300 mm, there would be 1500 m^3 of gravel, or 3000 tons, (average specific gravity of stone ~2). This is unlikely to be feasible, although restoring smaller sections of the leat may be achievable and would provide very useful habitat. To restore approximately a quarter of the leat would require 700 tonnes of gravel and would cost approximately £20,000. There may be an opportunity here for the various parties to work collaboratively to bring a significant benefit to the Derwent catchment. Figure 7.1 gives a before and after view of a habitat restoration project similar to that proposed for the leat at Ambergate.

Figure 7.1: Before and after images of a typical spawning habitat restoration.

8. Upstream Fish passage

8.1 Current situation

Depending on the configuration of a barrier, fish will either attempt to pass upstream by leaping beyond the barrier, burst swim up and over the barrier; or a combination of the two. In either scenario the limiting factors for upstream passage are barrier height, burst swimming speed of the fish relative to the flow velocity - which itself is a function of fish size and water temperature - and depth over the barrier.

The Environment Agency's SWIMIT software (Version 3.3) predicts burst swimming speeds of around 1.5 m/s for coarse fish including chub, dace and roach of 15 cm fork length at 10°C. Adult brown trout can typically burst swim at speeds of between 9.2 - 14.2 bls^{-1} (body lengths per second) at temperatures between 9 - 14°C, therefore a 20 cm adult brown trout can burst swim at speeds of up to 2.8 m/s (Clough & Turnpenny 2001). Minimum depth required for upstream passage of coarse fish is typically 0.2 m (Environment Agency 2010).

Figure 8.1 displays the configuration of the weir and the area immediately downstream, as well as depths and velocities across this area at Q90 flow. The weir consists of three radial gates with vertical head drops, as well as two steep ogee side weirs. Depth over the weir apron was very shallow (< 5 cm) and velocities extremely high (> 4 m/s). Although depth increased slightly across sills 1 and 2 and velocity decreased slightly, it was still beyond the swimming ability of the target fish species known to frequent the site. Furthermore, there is a head drop across the sill of approximately 0.15m. Shallow depths and high velocities on and below the sill mean that it is unlikely that fish will be able to reach the weir toe, let alone pass over the weir itself.

Environment Agency guidelines stipulate that the maximum head drop over a potential barrier should be no more than 0.3 and 0.6 m for coarse fish and migratory salmonids respectively. Given that the weir has a gross head of almost 4.5 m and approach depths are very shallow, we can assume that the weir is a complete fish stopper.

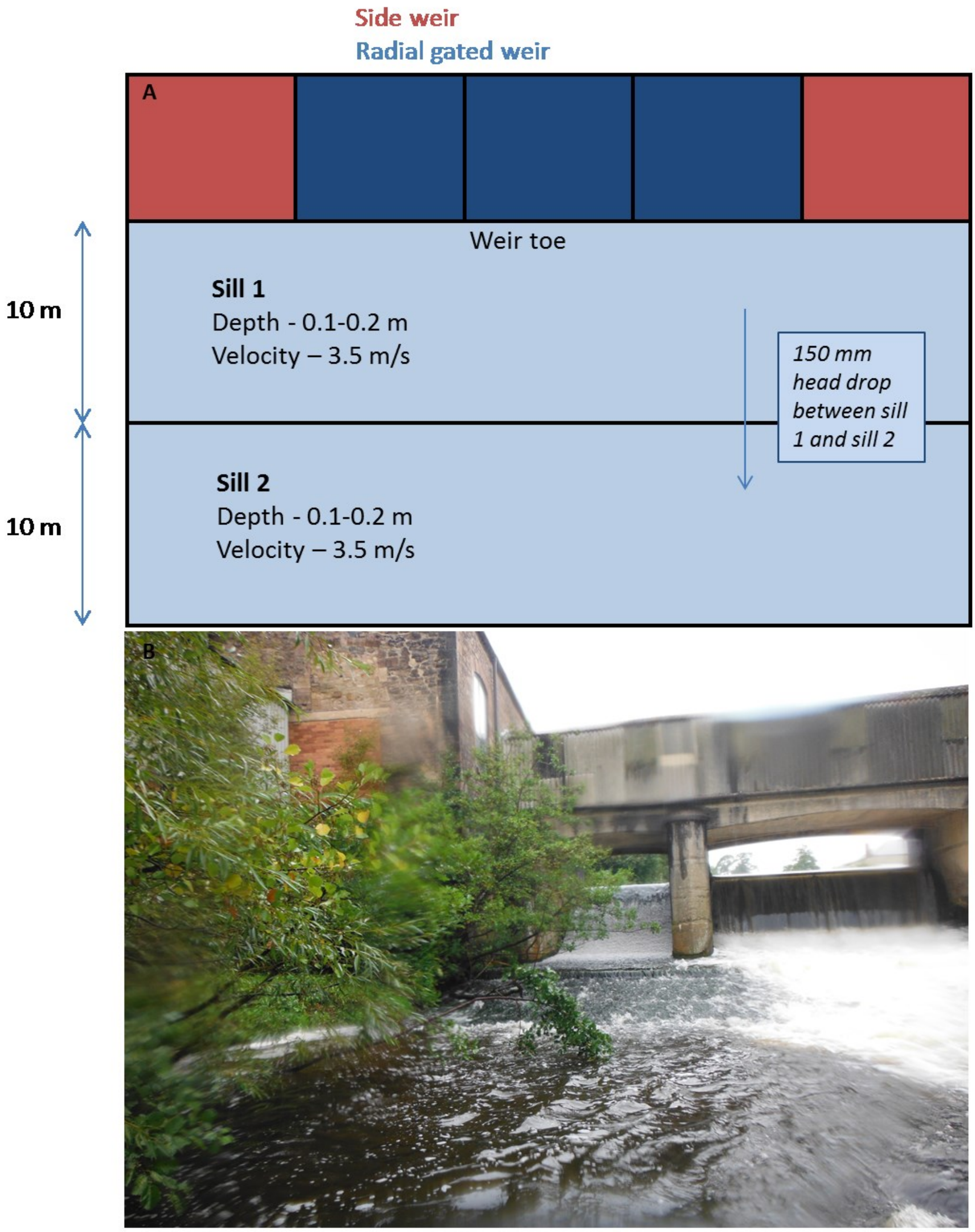


Figure 8.1: Configuration of the weir and the area immediately downstream including depths and velocities (A) and an image of part of the weir (B) at Q90 flow; the sill is visible in the foreground.

8.2 Potential impact

The proposed abstraction at either the 6 or 13 m^3/s rate will not have any impact on upstream migration as fish are currently not able to pass over the weir. However, lower discharge over the weir will result in shallower depths across the laid stone and concrete channel, potentially limiting fish's ability to migrate beyond the downstream end of the PDR. If a fish pass is constructed, it is important that fish are able to ascend the channel at the lower end of the PDR and reach the entrance to the fish pass.

The provision of a multi species fish pass at the weir would provide fish passage across most of the FDC. In view of the fish passes that have been built downstream recently (Longbridge, Darley Abbey), a fish pass at Ambergate would be useful for opening up more habitat upstream of the weir and improving habitat connectivity.

8.3 Fish passage options

It is recommended that a technical fish pass is installed on either the left hand side or right hand side of the weir, discharging below the concrete sill at least 20 m downstream of the weir toe. A multi-species pass, such as a Larinier fish pass, would provide a migration route for course fish and salmonids.

The Larinier fish pass was developed in France in the 1980's (Larinier & Miralles, 1981). It is a popular technical fish passage solution given its suitability for a wide range of species and its relatively low maintenance needs. Larinier passes can be constructed in a range of widths and with various baffle heights. Baffles are organised along the base of the pass and help to generate a heterogeneity in flows that is exploitable by a range of fish species. The maximum recommended slope of a Larinier pass is 15 %.

Baffles are generally fabricated from 10-12 mm thick galvanised steel or marine grade aluminium and have a fully radiused top edge. Although other materials have been used to create baffles, including green oak, these do not have the structural strength or longevity of metal baffles.

Larinier passes generally have a slope of between 10 – 15 %, with a maximum head drop over a single flight of 1.5 m for coarse fish and 1.8 m for salmonids. At sites where head drops are greater than the maximum recommended for a single flight, multiple flights can be used, although rest pools must be incorporated into the design. Rest pools should typically be at least 3 times the length of the largest species likely to be using the pass and must effectively dissipate energy densities to within a range manageable by the target species, typically <100 W/m^3 for coarse fish.

Due to the position of the baffles on the base of the pass and the highly turbulent water created by the vertical helical currents as water passes over the baffles, the baffles themselves cannot be seen when the pass is operational. In addition, the base mounted baffles reduce the susceptibility of Larinier passes becoming blocked with debris, particularly when compared to other baffle passes. An image of a Larinier pass is given in figure 8.2.

Figure 8.2: Image of an operational Larinier fish pass, showing the highly turbulent flow in the pass.

Based on Environment Agency Good Practice Guidelines (Environment Agency, 2009), a fish pass facility should discharge 5 - 10 % of maximum turbine flow; preferably towards the upper end of this range in order to ensure good attraction flow to the pass. Depending on the maximum abstraction of the hydro scheme (6 or 13 m^3/s) a Larinier fish pass at Ambergate weir would need to discharge 0.6 or 1.3 m^3/s (based on the current abstraction values). The pass would consist of three flights, each approximately 10 m long with a rest pool at least 2 m x 3 m between each flight. Above the point of turbine satiation upstream water level may increase, resulting in more discharge through the pass. However, the regime of the radial gated weirs could be adjusted in order to ensure that depths within the pass are within the guideline limits of the target species; up to 0.5 m at Q20 for coarse fish and up to 0.9 m at Q10 for salmonids. A 3 flight Larinier fish pass at the Ambergate weir should cost somewhere in the region of £150,000 -200,000. In order for the full benefits of a fish pass to be seen, the weirs downstream at Belper and Milford would also require fish passage facilities.

The efficiency of a fish pass depends on many factors, including the ease at which fish can locate the entrance to the pass. In order for fish to locate the pass entrance it must not only have good attraction flow, achieved by discharging a reasonable proportion of river flow, but approach depths and velocities must be within the manageable range of the target species.

Manning's formula can be used to calculate depths and velocities in an open channel at a given flow. The formula is as follows:

$$\mathbf{Q = (1/n)\ A\ R^{2/3}\ S^{1/2}}$$

Where: *A= Flow area (m^3/s)* *R= Hydraulic radius (m)*
S= Slope (m/m) *n = Manning's roughness coefficient*

Using the proposed HOF of 2.2 m^3/s, average depth across the laid stone and concrete channel (from the lower sill to the end of the PDR) will be 0.15 m. This is below the minimum depth required for the upstream migration of most coarse fish species (Environment Agency, 2010) and depths should be at least 0.2 m, preferably 0.3 m, in order to allow for uninterrupted migration across the abstraction range. Average velocity across the channel will be 0.45 m/s based on the same flow, and therefore within the manageable range of the target species.

In order to increase the approach depth for fish over the shallow concrete channel downstream of the weir, either a higher HOF is required, a low flow channel could be formed, or a pre-barrage could be used to increase depths by 150 mm. A HOF of 5.4 m^3/s, would be necessary to achieve an average depth of 0.3 m and an average velocity of 0.62 m/s.

Alternatively, a channel 0.5 m deep and 2-3 m wide, leading from the downstream end of the laid stone and concrete channel to the fish pass entrance could be formed. The slope of the low flow channel should follow the current channel gradient in order to ensure that velocities do not increase. A roughened bed will also help to reduce velocities by increasing the roughness coefficient (n) and can be achieved by embedding coarse material in concrete used to form the channel. A channel with these dimensions would take up to 1.2 m^3/s and would cost approximately £25,000.

Another option would be to install a pre-barrage at the downstream end of the shallow concrete section to maintain sufficient depth for fish migration. The pre-barrage would need to be 150 – 200 mm high with several notches 3 – 4 m wide and 200 mm deep forming a free space within the barrage. This would create a 200 mm water to water head drop across the barrage that would be manageable for even small coarse fish species. At higher flows, the downstream water level should increase at a similar rate to the upstream level ensuring that the head drop does not increase significantly when flow in the river increases above the turbine satiation point. An informal pre-barrage formed from boulders would cost somewhere in the region of £10,000 and a more formal structure would cost approximately £20,000.

9. Amendments to the Good Practice Guidelines

The Environment Agency are currently reviewing their Good Practice Guidelines for Hydropower (Environment Agency, 2009) in order to further safeguard against potential impacts to riverine ecology and ensure WFD objectives are not compromised. The proposed new guidelines, which are likely to come into force by spring 2014, has stricter default position but allows for sites to deviate from this depending on site sensitivity, including the level of risks to WFD objectives, fish passage, protected species/habitats and the rights of water users.

Table 9.1 displays the 'starting point' for abstraction licensing and the 'indicative departures' for low head sites with a depleted reach. For a site with a high base flow and low ecological sensitivity, such as Ambergate, a Q97 HOF with a proportional take of 45 % above the HOF and a maximum take equivalent to 1.3 x Qmean is recommended. However, there may be scope for departure from the starting point providing the following is met:

- Must not prevent the achievement of WFD objectives at water body level
- Must maintain or improve fisheries and fish passage
- Must not have unacceptable impacts on protected sites or species, including fish, at a population level
- Must not have unacceptable impacts on the rights of other water users, including anglers.

It's unlikely that the scheme will impact upon water users since it's located on grounds owned by the Litchfield group. Also there is no evidence that protected species frequent the PDR and it is not a protected site.

As previously discussed, the scheme may result in restricting fish passage beyond the turbine outfall, and therefore, should there be a departure from the starting point, one of the previously discussed fish easement options should be implemented; the PDR may offer little spawning opportunity but it still contributes to the carrying capacity of the site and fish may frequent this area for feeding or refuge. It is also recommended that a fish pass is installed at the weir as previously discussed.

Should these recommendations be met, it is more likely that the scheme will be granted a departure from the starting point, as it will improve fisheries ecology and fish passage at the site. As displayed in table 9.1, a typical departure for a high base flow site will allow for a Q95 HOF and a 100 % abstraction above the HOF, with a maximum abstraction equivalent to Qmean, although depending on the site, an abstraction of up to 100% of available flow up to Qmean may be permitted. Providing the fish passage recommendations are met, the proposed HOF of 2.2 m^3/s will be suitable from a fisheries perspective.

Table 9.1 – Starting point for abstraction licensing procedures (table A) and indicative departures from the starting point for low head sites with a depleted reach (table C).

TABLE A – STARTING POINT						
	High sensitivity ASB3		**Medium sensitivity ASB2**		**Low sensitivity ASB1**	
River type *Q95 / Qmean*	*Low & medium* base flow *Below 0.2*	*High base flow* *0.2 & above*	*Low & medium base flow Below 0.2*	*High base flow* *0.2 & above*	*Low & medium base flow Below 0.2*	*High base flow* *0.2 & above*
Hands off flow (HOF)	Q95	Q97	Q95	Q97	Q95	Q97
Maximum take	1.3 x Qmean	Qmean	1.3 x Qmean		1.3 x Qmean	
% take above HOF	35%		40%		45%	
Notes: More protective allocation of flow distribution will be required if: • A weir pool is of high importance to the water body status or wider catchment; or • Fish passage is likely to be reduced by a reduction in flow						

TABLE C – LOW HEAD WITH DEPLETED REACH Indicative departures from Table A				
	River flow regime type			
Baseflow type Baseflow index (Q95/Qmean)	Flashy river Less than 0.1		Medium / low Between 0.1 & 0.2	High/very high From 0.2 upward
	Fish migration issues	No fish migration issues		
Hands-off flow Maximum abstraction	Q90 Q40	Q90 Qmean	Q95 Qmean	Q95 Qmean
% take above HOF	100%	100%	100%	100%

10. Conclusions and recommendations

Fish must be precluded from entering Kaplan turbines (Environment Agency guidelines) and therefore screening is required at the intake and outfall locations. Intake screens should have 12.5 mm spacing and consist of horizontal or vertical rectangular bars. The screen angle should ideally be ≤ 20 ° to the direction of flow and the approach velocity should be no greater than 0.25 m/s. It should extend from the river bed to above the flood flow level to ensure that fish cannot pass over the screen at higher flows.

The tailrace screen should also consist of rectangular bars, with a spacing of 30 – 40 mm and the screen should extend from the river bed to above a flood flow level equivalent to a typical one in ten year event.

The habitat between the weir toe and the proposed location for the tailrace outfall is heavily modified and essentially a man-made concrete and stone channel. There is very little if any spawning habitat and extremely limited juvenile habitat. It is not expected that the proposed abstraction regime at either 6 or 13 m^3/s with a HOF of 2.2 m^3/s will have any significant adverse impact on juvenile or spawning habitat.

The leat is slow flowing and very silted and while less suitable for coarse fish offers good habitat for brook lamprey, which may frequent the site. A minimum residual flow of approximately 150 l/s should be maintained within the leat at all times.

Given the paucity of suitable spawning and juvenile habitat within the river Derwent, the leat could be improved to create some very useful habitat. Works would involve the formation of a number of gravel sections with a reasonable gradient in order to create a semi-natural 'riffle-pool' type habitat. This habitat would benefit spawning and juvenile rheophilic coarse fish species and migratory salmonids should they return to this part of the catchment. A higher flow would be required in the leat to prevent siltation of the gravels. A flow control structure such as a notch or sluice gate could be used to control flow into the channel. Water supplied to the leat would be channelled from the turbine discharge.

The weir is currently a complete barrier to all upward migrating fish species. The wider Derwent catchment would benefit greatly from a multi-species Larinier fish pass at Ambergate. The pass could be located on either bank and would consist of three 10 m long flights with two rest pools. Construction would not be easy, although a concrete channel accommodating a small Larinier may be feasible built adjacent to one of the weir wing walls. The pass would extend downstream from the concrete spillway weir to the deeper water below the shallow concrete apron.

In order to maintain sufficient depths over the concrete and laid stone channel for upward migrating fish to reach the fish pass entrance, either an increased HOF of 5.4 m^3/s is required, or if the lower HOF is used, a low flows channel 0.5 m deep and 3 m wide should be formed between the fish pass entrance and end of the laid stone and concrete channel. Alternatively, a pre-barrage could be installed at the downstream end of the concrete channel in order to increase approach depths for fish.

Regardless of whether or not a fish pass is installed, the lower HOF (2.2 m^3/s) will reduce the ability of fish to move freely within the concrete and stone channel below the weir toe. To mitigate this, a low pre-barrage with notches would be required to create sufficient depths for migration.

Providing the recommended mitigations for fish passage are adopted, it is not expected that the projected change in the Good Practice Guidelines would affect the proposed abstraction regime, given that the PDR has low ecological sensitivity and a high base flow.

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12. Appendix 1 – Glossary of terms

Ammocoetes – A lamprey in its larval stage

Anadromous - Migrating up rivers from the sea to spawn in fresh water

Base flow - The portion of river flow that comes from the sum of deep subsurface flow and delayed shallow subsurface flow

Benthos – The bottom of the river bed including the sediment

By-wash channel – A channel that carries water around an obstruction and often use for the safe passage of fish.

Catadromous – Migrating to the sea from freshwater to spawn.

Coarse fish – Any freshwater fish other than salmonids. These are typically resident, non-migratory species

FDC – Flow Duration Curve - A plot that shows the percentage of time that flow in a stream is likely to equal or exceed a specified value

Fish pass – A structure on or around a barrier to facilitate fish migration

HOF- Hands-Off Flow – The minimum flow to remain within a channel at all times, below which the turbine should not abstract

Macrophytes - An aquatic plant large enough to be seen by the naked eye

Phytophilic – An organism that prefers to live in slow flowing water

Potamodromous – A migration entirely in freshwater

PDR – Potentially Deprived Reach – A stretch of river that may experience reduced flow

Rhaeophilic – An organism that prefers to live in fast flowing water

Redd – A spawning nest made by a fish, especially salmonids

Salmonids – A fish belonging to the family Salmonidae, including Atlantic salmon, brown trout, sea trout and grayling in the UK

Satiated – To be full to a maximum capacity or completed saturated

Q – A symbol to denote percent exceedance. For example Q10 represents a flow that has only been exceeded 10 % of all days of the flow record

Version 2, 21/03/2022

Ambergate Hydro: Environmental Report

Contents

1. Water Framework Directive

At this stage of the project we cannot see any potential deterioration of the river status.

The Fishtek report confirms that the stretch of river following the weir (for a length of 150m) is laid stone and concrete, including the bed of the river, so we do not anticipate any change to the existing Weir Pool. Considering the new proposal and referencing the EA Geomorphology Assessment requirements:

- There is no new weir or impoundment.
- There will be no change in weir height or the level of impoundment upstream of the weir. The level is set with agreement with Severn Trent; a requirement for their abstraction point.
- A depleted reach already exists, with water currently flowing through the old sluice gates and tunnels for the full length of the tailrace. The new proposed scheme will use the full length of the existing man-made tailrace.
- Peak abstraction is 45% of mean river flow (Qm); well below the maximum abstraction ratio set out in Table C of the relevant guidance. Therefore, we do not anticipate any notable changes to the sediment flow based on current and historical flow patterns.
- The scheme is not close to a river improvement of restoration project.

Within the WFD, the ecological status of the watercourse is determined by the composition and abundance of 3 biological elements:

- aquatic flora
- invertebrates
- fisheries

The 3 physical elements which support the biological elements are:

- river hydrology
- river continuity
- the morphology of the riverbed and banks

Hydrology

Hydropower abstraction inevitably modifies the flows in any 'deprived' channel. The question is, does that modification cause any degradation or improvement to the riverine habitat for macrophytes, fish and invertebrates?

The key features of a supportive flow regime are:

1. protection of low flows (and hence wetted areas)
2. the presence of higher flushing flows for transporting sediment downstream and deterring long-term sediment deposition.
3. some variability in the flow regime

Of these, the two most critical factors for run-of-river hydro projects are the protection of low flows and maintained peak flows.

High flows govern the major gravel and sediment movements which create and sustain the diversity of habitat within the river channel, for both fish and invertebrates. Low flow protection preserves the wetted width for macrophytes at the watercourse margins and the wetted usable area for fisheries in order to maintain feeding and spawning habitat, as well as minimum water depths for up and downstream movement.

Protected low flows also maintain the basic character and diversity of the river to suit a wide range of invertebrate species with their differing preferences for slow moving pools, faster riffles and still backwater areas.

Some flow variability is also desirable, to reflect the natural variations that the aquatic environment has adapted to. Flow variability is a built-in feature for run-of-river schemes because they have a limited peak abstraction (as seen in the proposed EA Flows Guidance Table C), which inherently guarantees a significant level of variability as seen on an annual hydrograph. This flow variability is significantly improved by the proposed maximum take of 45% Qm, in comparison to the table C guidance.

Protective Measures

The proposed license will achieve these hydrological objectives by:

- limiting the maximum abstraction to 45% of Qm; and
- operating so as to maintain a minimum flow of Q84 (5.4m^3/s) over the weir and down the depleted reach whenever the river is running at Q70 (7.1m^3/s) or above.

Hydro-morphology

Hydro-morphology considers the physical form of the water environment and the processes of erosion, sediment transport and deposition which in turn determine the character and distribution of habitats within the river.

There will be little or no sediment transport and deposition at low flows. However, significant movement of gravel and coarse sediment is known to occur at very high flows, certainly above Q5% (i.e. several times Qm) and more usually above Q1%. These flow rates are too large to be significantly affected by the hydropower abstraction, which has been limited to 45% of Qm.

Fish Screening

The proposal meets current best practice and is in line with that proposed by Fishtek, see Section 4 for details.

Fish passage

Also covered in Section 4 (Fishtek). Note that the proposed peak abstraction is much lower than the maximum prescribed by table C. For much of an average year, the flow rate allocated to the deprived reach at Q84 is also larger than the Q95 specified in Table C. This leads to conditions that provide more depth of water, especially over the concrete apron, and maintains a good wetted area.

Ecology

In addition to the riverine study carried out by Fishtek, please note:

That the length of main river channel affected is now the river channel from the intake to the discharge of the man-made tail channel. Fishtek analyse the first few yards of this channel, and the remainder has the same visual characteristics. Fishtek have commented on the full length of the tail channel. It could be that the maintained flow and the small reduction in peak flows during the spring and autumn spawning seasons improve the conditions for spawning.

There are other hydro sites with medium and long depleted reaches on the Derwent, some with very small residual flows, and all licensed by the EA. As far as is known, the only ecological concerns relate to fish passage over ancient structures.

There is no reason why this Ambergate project should be treated differently, especially as it generally offers higher residual flows.

2. Protected Species

Please see the Water Vole study provided, where the presence of otters at the site is also noted.

3. Environmental Management

Care would be taken to ensure that no pollutants are washed down when the turbine is brought back in to use.

There is already a flow in the tailrace, mostly passing the old sluice gates, but also by surface water run offs from the woods adjacent to the site.

Tree growth along the banks of the tailrace has in a few cases caused damage to the stone walls of the tailrace. It is likely that some trees would need to be removed to allow the channel to be restored and prevent future collapse.

4. Other Water Users

This application is made by a group of individuals with strong connections to the applicants of 2018. The earlier applicants engaged with others holding abstraction licences locally such as Severn Trent and the new White Peak Distillery. We are confident that the new proposals will not impact either of these parties and have indirectly been offered support by both organisations.

Our contacts have engaged with many water users, including attending water catchment partnership meetings and events. Primarily, we have spoken to anglers and canoeists, along with other more general users of the river and adjacent footpaths and potential cycleways.

Version 1.0
16/03/2022

Details of calculated abstracted water volume (Form WR332 C8.2)

Figures given in m^3/s

Turbine design flow	6.5
Peak hourly abstraction	23,400
Peak daily abstraction	561,600
Peak weekly abstraction	3,931,200
Peak Annual abstraction	204,984,000

Walkover and Photographic Assessment of River Morphology at Ambergate Wireworks

January 2024

1. Introduction

A walkover survey was undertaken of the whole deprived reach on 29/8/2023, in order to determine the broad characteristics of this reach of river and identify the best locations for installing two timelapse cameras.

The flow rate during the survey (as measured at Whatstandwell a short distance upstream) was 6.3m³/sec, or roughly Q80.

A continuous flow passes down the 1km of turbine tailrace, due to one of the inlet sluice gates being kept slightly raised. This serves the purpose of preventing the tailrace from silting up and maintaining a sweetening flow for the local ecology. Although not formally measured, an approximate Velocity x Area assessment suggests that this tailrace flow is in the region of 1.5m³/sec.

Hence the flow in the main river on 29/8 is estimated as 6.3 – 1.5 = 4.8m³/sec.

2. Proposed division of Flows between river and tailrace

The proposed flow regime for the turbine operation is provided in the graph of Figure 1 (from the license application) and can be summarised as follows:

Q73 and below:
Turbine abstraction is fixed at 1.5m³/s; this therefore maintains the status quo between the river and the tailrace for the driest 27% of the year. At Q73, the flow division would be 5.4m³/s (river) vs 1.5m³/s (tailrace).

Q73 to Q50:
A constant 5.4m³/s will be maintained in the river as the turbine abstraction rises from 1.5 to 5.3m³/s. (This residual flow equates to Q85 on the Flow Duration Curve, but because of the maintained tailrace flow of 1.5m³/sec, a flow of 5.4m³/s is actually the flow rate that the river would normally see at Q73).

Q50 to Q40:
Flow division remains approximately equal such that at Q40 each watercourse will pass roughly 6.5m³/s.

Above Q40:
Turbine abstraction remains at the maximum 6.5m³/s as the river continues to rise.

Hence, as tabulated in Figure 1, the river always has at least the same flow (and for 90% of the time, more flow) than the tailrace i.e. a 50:50 flow-split or greater.

3. Overview of the Deprived Reach

The 1km of deprived reach, from Ambergate Weir to the downstream end of the tailrace, can be divided into 3 distinct sections:

1. Weir to start of tailrace.
This 130m reach has a solid base of concrete and laid stone, with no natural substrate. On 29/8/23 The flow was spread uniformly across the watercourse from bank to bank at pretty constant depth of around 0.6m with flow velocity in the region of 0.4m/s.

2. Non-impounded reach.

After the concrete ends, the following 150m reach of the river had a more natural appearance, with 2 short sections of mini-rapids 60m apart, where there is faster-flowing water and some exposed rubble (see appended photos). The visible riverbed substrate generally consists of a mixture of boulder and cobble.

The first rapids is created by a deposition of silt rubble in the left-centre of the watercourse, forcing the flow around each side. The left-hand riffle has a broad presence of submerged aquatic plant (presumed to be Ranunculus), as visible in from View C.

The second rapids is created by a larger deposition of boulders and gravel on the left bank forcing the flow along the right bank.

A camera was located at the downstream end of this reach (Location B), looking upstream towards the 2nd (more significant) rapids and beyond.

[NB. both of these mini-rapids may subsequently have been significantly altered by the record flood of Oct 20th.]

3. Impounded reach

The remaining 720m (70%) of the deprived reach is then 'flat water' i.e. deeper and very slow-moving, which continues downstream for ~4km to the impoundment at Belper Weir.

There are no further hydraulic features other than very slow-moving, full-width watercourse - similar to that above Ambergate Weir.

A second camera was situated at Location A, 130m downstream from Location B, so as to look upstream at the uppermost section of the impounded reach, to see if this retained its 'flat water' characterisation as flow increased.

4. Photographic Results

4.1 Pictures taken

Pictures were taken at the above 2 locations (A and B) at 09:30am and 15:30pm every day from 29/8 to 18/10.

Additional photographs were taken at various locations (C to F) during site visits of 29/8, 27/9, 18/10 and 25/10.

4.2 Prevailing flows

Figure 2 is the hydrograph from Whatstandwell providing the river flow over this two-month timeframe from 29/8 to 31/10.

The minimum river flow over this period was 5.08m³/sec (Q90) recorded on 10/9/23.

On 20/10 the river experienced a record flood, with the downstream reach rising roughly 5.5m and sweeping away the 2nd camera.

4.3 Results

The appended Annex provides photographs in groups summarised below. The map on the first page provides the key locations for camera positions A to F.

- Location A : low (Q80), moderate (Q55), and average (Q35) river flows at the upstream end of the 'flat water' impounded reach. There is no change in the nature of the river other than small increases in the otherwise uniform, slow water velocity.

- Location B: a series of photos comparing the before/after situation at the 2nd rapids as the river rises from Q75 to Q45 [i.e. these depict how the river will change if the turbine is switched on at that flow rate - the 'after' situation in all cases being close to the proposed fixed 5.4m³/s in the river]
- Location B: additional close-up photos at the 2nd rapids at Q80 (6 m³/s) and Q35 (14.5 m³/s)
- Location C – looking downstream at the 1st rapids at low (Q80) and average (Q35) river flows.
- Location D : low (Q80), average (Q35) and high (Q10) flows passing down the man-made reach downstream of the weir.
- Views E and F of the long impounded reach down towards Belper, looking upstream and downstream from the Hurt Arms bridge.

5. Observations and Conclusions

- The only features which provide variability of habitat within the whole deprived reach are the two mini-rapids and small shoals of rubble in sub-reach [2].
- Sub-reach [1] is a man-made channel with artificial, hard riverbed and consistent water depth.
- Sub-reach [3] is impounded back from Belper Weir, with slow-moving deep water exhibiting no riffles, gravel-bars or other notable features
- The pictures of sub-reach [2] in low flows show that the watercourse still retains plenty of width and wetted area when total river flow was down to 5.1m³/s (Q90) on the Whatstandwell Gauge. Subtracting the tailrace flow, this would have comprised a flow in the river of roughly 3.6m³/s. A substantial riffle is still in place at this flow rate, occupying approximately half the width of the river, and allowing fish to move freely up or downstream past this restriction.
- These low flows still supported a substantial patch of Ranunculus at the upper rapids, allowing it to remain fully submerged.
- The before/after comparisons from View B, where the 'after' scenario is close to the residual flow that would prevail in the river from Q73 to Q50, demonstrate that the basic characteristic of this reach of watercourse will not fundamentally change. At 12m³/sec on the flow gauge, when the turbine would reach peak power, the gravel bank at the 2nd rapids is still visible and creating the left-side riffle. After the turbine abstraction, the riffle will still be well supplied with flow and the main change is a small reduction in water depth down the reach (peaking at a drop of approximately 250mm when the turbine reaches maximum flow, estimated from the photos).
- The photos at View C similarly demonstrate that the 1st rapids will remain well supplied with flow, and the aquatic vegetation fully submerged, when the deprived reach is receiving the proposed residual flow.
- It can be concluded that the modest turbine abstraction (less than 50% of mean flow), combined with the proposed residual flow of Q85, will not create any changes which will alter the current characteristics and habitats within the river, bearing in mind the impounded or heavily modified status of all but 150m of the 4.5km reach between Belper and Ambergate.

WFD Status

It is therefore apparent that the operation of the proposed scheme will have no significant potential to cause negative geomorphological effects in terms of sediment movement, erosion, habitat changes, or passability for fish moving up or downstream. As a result, the scheme will not reduce the overall waterbody status or prevent the waterbody from reaching future objectives.

Oliver Paish
Derwent Hydro Developments Ltd
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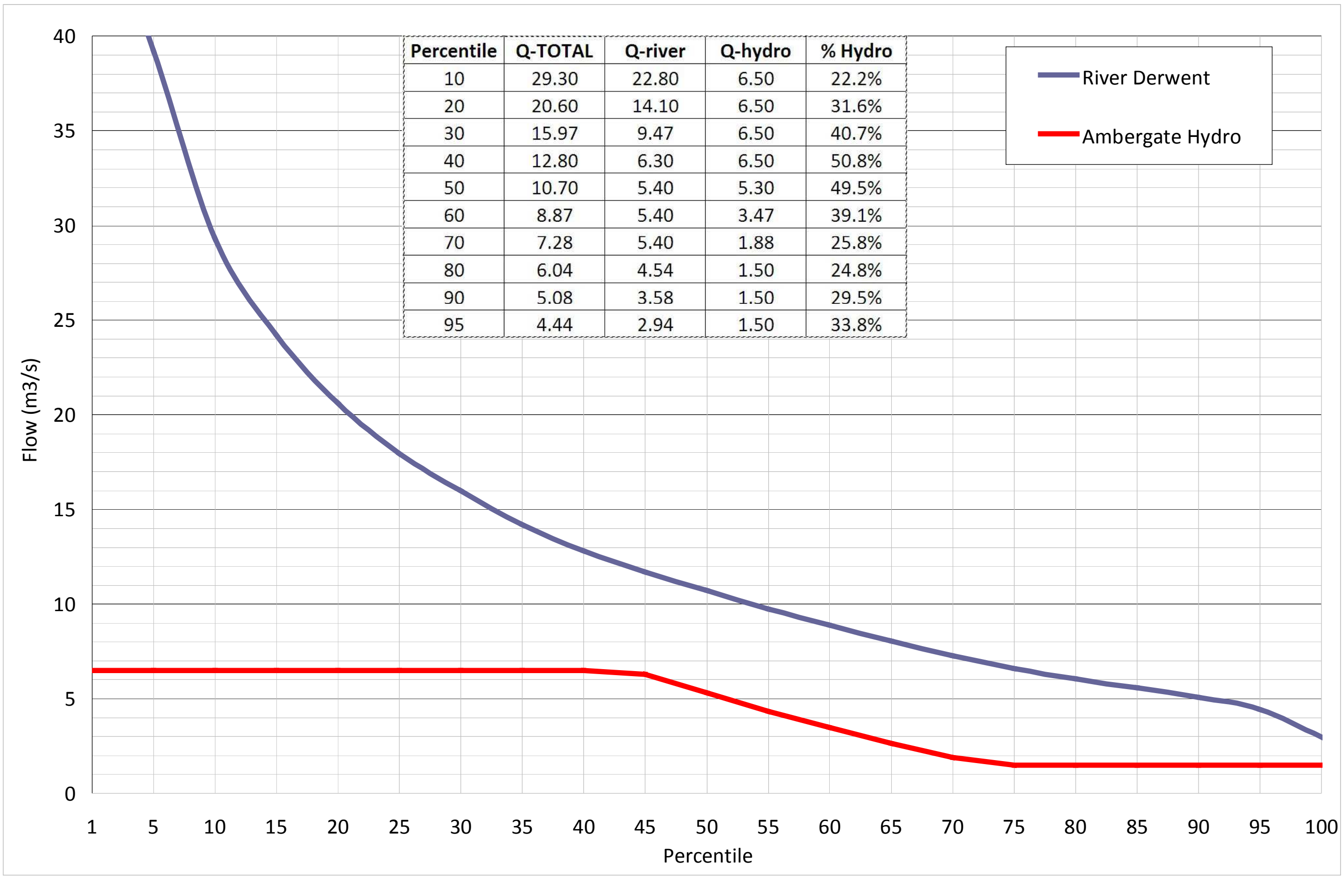
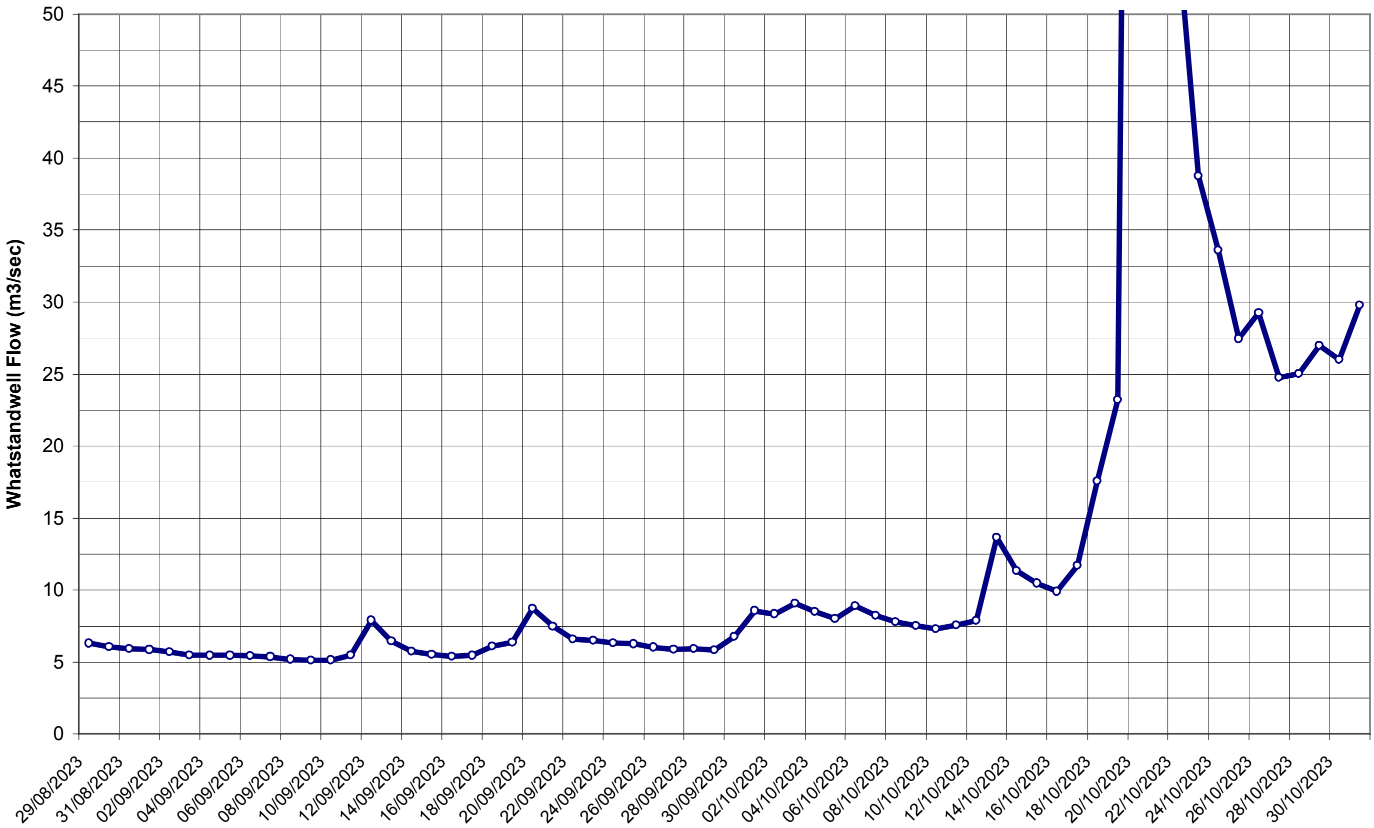
January 2024

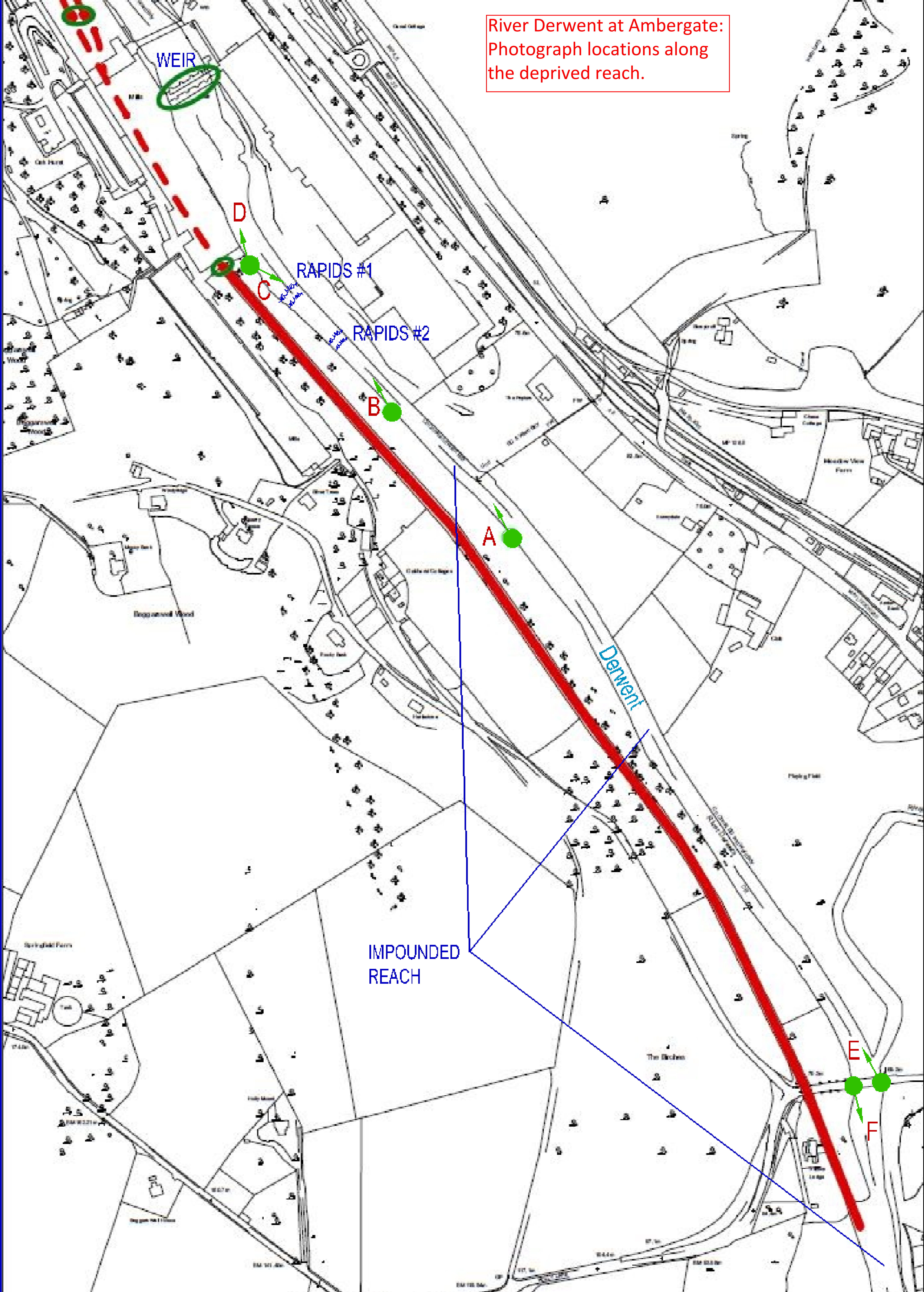
Figure 1 : Proposed hydro abstraction vs total river flow



Percentile	Q-TOTAL	Q-river	Q-hydro	% Hydro
10	29.30	22.80	6.50	22.2%
20	20.60	14.10	6.50	31.6%
30	15.97	9.47	6.50	40.7%
40	12.80	6.30	6.50	50.8%
50	10.70	5.40	5.30	49.5%
60	8.87	5.40	3.47	39.1%
70	7.28	5.40	1.88	25.8%
80	6.04	4.54	1.50	24.8%
90	5.08	3.58	1.50	29.5%
95	4.44	2.94	1.50	33.8%

Figure 2 : Hydrograph – River Derwent at Whatstandwell for Sept/Oct 2023




River Derwent at Ambergate: Photograph locations along the deprived reach.
WEIR
D
RAPIDS #1
C
RAPIDS #2
B
A
Derwent
IMPOUNDED
REACH
E
F
Boggarswell Wood
Springfield Farm
The Birches

IMPOUNDED

View A : 5.8m³/s at Whatstandwell (28/9/2023) - IMPOUNDED

View A : 9.5m³/s at Whatstandwell (3/10/2023)

IMPOUNDED

View A : 5.9m³/s at Whatstandwell (29/8/2023)

View A : 14.5m³/s at Whatstandwell (18/10/2023)

RAPIDS #2

View B : 5.08m³/s (Q90) at Whatstandwell (10/9/2023) – RESIDUAL FLOW AT Q90

View B : 6.5m³/s (Q80) at Whatstandwell (19/9/2023) – RESIDUAL FLOW AT Q45 to Q75

RAPIDS #2

View B : 6.5m³/s (Q80) at Whatstandwell (19/9/2023) – RESIDUAL FLOW AT Q45 to Q75

View B : 8m³/s (Q65) at Whatstandwell (8/10/2023)

RAPIDS #2

View B : 6.5m³/s (Q80) at Whatstandwell (19/9/2023) – RESIDUAL FLOW AT Q45 to Q75

View B : 9.11m³/s (Q60) at Whatstandwell (20/9/2023)

RAPIDS #2

View B : 6.5m³/s (Q80) at Whatstandwell (19/9/2023) – RESIDUAL FLOW AT Q45 to Q75

View B : 10.7m³/s (Q50) at Whatstandwell (15/10/2023)

RAPIDS #2

View B : 6.5m³/s (Q80) at Whatstandwell (19/9/2023) – RESIDUAL FLOW AT Q45 to Q75

View B : ~12m³/s (Q45) at Whatstandwell (14/10/2023) – FLOW FOR MAX TURBINE POWER

RAPIDS #2

View B : ~30m³/s (Q10) at Whatstandwell (25/10/2023) – POST FLOOD

RAPIDS #2

View B (Rapids#2) : 6m³/s at Whatstandwell (27/9/2023)

View B (Rapids#2) : 14.5m³/s at Whatstandwell (18/10/2023)

RAPIDS #1

View C (Rapids#1) : 6m³/s at Whatstandwell (27/9/2023)

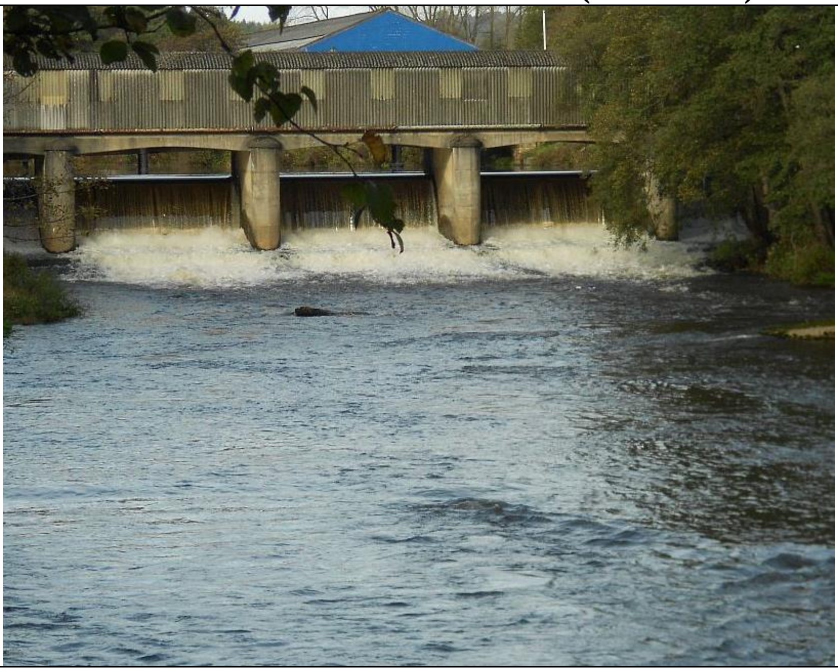
View C (Rapids#1) : 14.5m³/s at Whatstandwell (18/10/2023)

WEIR

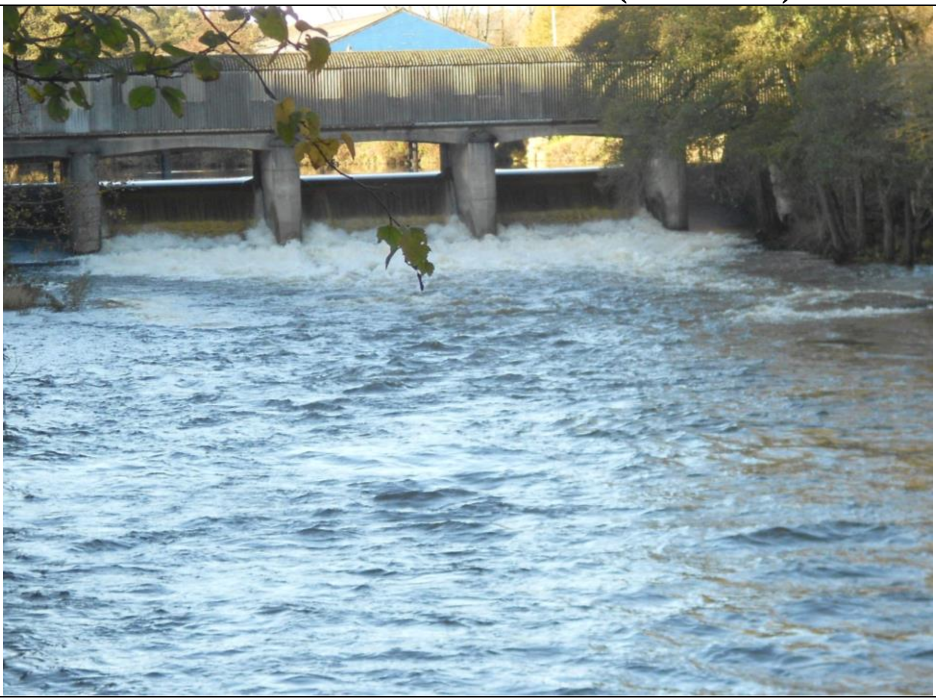
View D : 6m³/s at Whatstandwell (29/8/2023)

View D : 6m³/s at Whatstandwell (27/9/2023)

View D : 14.5m³/s at Whatstandwell (18/10/2023)



View D : 29m³/s at Whatstandwell (25/10/2023)



IMPOUNDED

View E : 6m³/s at Whatstandwell (27/9/2023) **-** looking upstream

IMPOUNDED

View F : 6m³/s at Whatstandwell (27/9/2023) - looking downstream

26/05/2023
Additional information

Project Design and Parameters: Ambergate Hydro

Ambergate turbine outfall upstream fish escape ladder – rational.

We propose to include a route upstream to enable any migratory fish which have entered the turbine outfall channel to pass back to the main river channel.

At the point where the subterranean turbine outlet channel emerges from the downstream end of the buildings it can be seen that there is a height differential between the main river channel water level and the turbine outlet channel. This differential varies with the total river flow and with the division of flow between the channels. The maximum differential is seen when the turbine flow (Tf) is low and the weir flow (Qw) is high. The maximum expected differential is ~1.0m.

Times of likely fish run. Migratory fish are most likely to attempt their upstream passage at moderate and higher river flows, they are unlikely to try at low flows.

Taking as reference the two E.A. built fishpasses on the Derbyshire Derwent at Borrowash Black Weir and Darley Abbey and the E.A. approved pass at the Longbridge Hydro scheme in Derby, we find the following:

<u>Borrowash:</u>

Pass is a 4 section installation, making it 2.4 m wide. It is situated on the left bank of the 'flood' weir. The mean flow here is around 18 cumec

<u>Derby :</u>

Pass is a 3 section, making it 1.8m wide. It is built on the right bank next to the turbine which provides a substantial attraction flow. Qm = 17.5 cumec

<u>Darley Abbey</u>

This one is also a 3 section (1.8m wide) pass. It is built on an island towards the centre of the river, Qm = around 17 cumec.

The fish escape pass proposed for Ambergate is to be located at the best possible location, the upstream end of the outfall screen. The maximum flow rate that the outfall channel will supply is the fully open turbine flow, 6.5 cumec, and in comparison with the existing passes the current proposed pass is well oversized and should be reduced in size, we suggest a new figure of 1.2m (2 section) installation will be more than sufficient.

We expect that the detail of this pass would be subject to a license condition.

JN. May 2023

Ambergate turbine outfall upstream fish escape ladder – further information.

We propose the use of a Larinier super-active baffle fishway, please note the proposed width of the pass has been reduced from 1.5m in the original application to 1.2m.

We would also propose reducing the turbine 'always on' minimum flow from 1.7 m3/s to 1.5 m3/s.

The calculation of required flow over the concrete apron downstream of the weir (made by Fishtec) then indicates that this flow is reached at around Q72. Note that this flow only facilitates passage upstream as far as the site weir, a pass to give access above this weir is subject to future discussions. It is then at flows of Q72 and above that the outfall escape pass is required to operate efficiently. The fish pass manual suggests that low end flow should produce an 'h' of some 150mm which results in a flow greater than 220 l/s in the pass .

The manual suggests an upper depth limit of 0.9m for large migratory salmonids, this would produce a flow of some 2.03 m3/s, it is this figure then that we will chose for licencing purposes.

J Needle June 2023.