Oblin Holdings Limited & OblinArk Limited

REVIEW OF THE POTENTIAL IMPACT OF INSTALLING THE OBLINARK AT LEMONROYD WEIR

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1 INTRODUCTION

Oblin Holdings Limited are seeking to install a novel hydro-kinetic power barge (henceforth referred to as the OblinArk) at Lemonroyd Weir (**Figure 1**) on the River Aire near Leeds at NGR: SE 38187 28167.

Figure 1. Lemonroyd weir and fish pass (photo courtesy of Brannan Tempest, Oblin Holdings Ltd.).

Full planning permission for the installation of the OblinArk at Lemonroyd Weir has been granted by Leeds City Council, subject to a number of conditions, one of which is that the development shall not commence until details of a monitoring programme to determine the impact of the development on fish migration (with particular reference to the impact on the efficiency of the currently installed fish pass; **Figure 1**) have been submitted and approved by the local planning authority in consultation with the Environment Agency (EA). Subsequently the approved monitoring programme must be implemented. This is in response to a number of legislative drivers requiring the protection of fish. For example part II, section 12 of the Salmon and Freshwater Fisheries Act (1975), as amended by the environment act of 1995, states: “If any person uses any contrivance or does any act whereby salmon or trout are in any way liable to be scared, hindered or prevented from passing through a fish pass” they shall be guilty of an offence. Furthermore, the European Union adopted Council Regulation No 1100/2007/EC ‘establishing measures for the recovery of the stock of European eel’, transposed into domestic legislation in England by The Eels (England and Wales) Regulations 2009. This regulation requires Member States to develop national Eel Management Plans, with the objective of “reducing anthropogenic mortalities so as to permit with high probability the escapement to the sea of at least 40% of the silver eel biomass relative to the best estimate of escapement that would have existed if no anthropogenic influences had impacted the stock”.

After conversing with local EA staff (Pete Turner, EA North East Fisheries Technical Officer), it was confirmed that their major concern was the potential for the OblinArk to prevent upstream and downstream passage of fish by acting as a behavioural deterrent, hindering movement past the device, and/or diverting fish away from the entrance of the currently installed fish pass. Currently the salmonid and eel runs are small at Lemonroyd weir due to a number of impoundments downstream, and the EA are implementing a series of works to provide fish passage up to and beyond Lemonroyd weir (Pete Turner, EA, *pers.*

comm.), thus migratory salmon, sea trout and eels must be considered when determining the impact of the OblinArk on fish. Additionally, course fish species requiring a variety of habitats to complete their life cycle (e.g. bream, chub, and barbel) require consideration for fish passage.

1.1 Project aims

The following main project aims will be addressed in this document:

- Determine the potential level of impact the installation of the OblinArk would have on fish passage at Lemonroyd weir.
- Seek to apply findings to installation of an OblinArk more generally, i.e. at other locations.

2 SITE AND PROPOSED INSTALLATION DESCRIPTION

Lemonroyd Weir is an approximately 25m wide (i.e. bank to bank) rectangular Crump weir gauging station operated by the EA, with a single flight Denil fish pass immediately adjacent to the left hand side of the weir (**Figure 1** and **Figure 2**). The river channel width is approximately 60m immediately downstream of the weir, and around 80m at 22–57m downstream of the weir, with a water depth of approximately 3m at the centre of the channel. High velocity water flow is present immediately downstream of the weir, and from aerial photography it can be seen that turbulent water extends to approximately 50m downstream of the weir (although this will inevitably vary with river flow conditions throughout the year).

A 180kw OblinArk, comprising a 24m long, 2.7m wide barge, with a 0.6m draft, is proposed to be installed at Lemonroyd weir, and is capable of generating 1,103,760kwh per year (equivalent to supplying 230 average houses per year). The barge comprises two floating pontoons with waterwheels (henceforth referred to as turbines) placed between them (**Figure 2**). The area below the turbines is open. The barge will be located between 25–50m downstream of the weir (Brannan Tempest, OblinArk, *pers*. *comm*.), with the exact location determined during fine tuning once the OblinArk is installed. A key feature is that the barge floats in the channel whilst being held in place by being tethered to the weir structure by mooring lines, thus minimising extensive civil engineering structures and works often associated with conventional run-of-river hydro schemes.

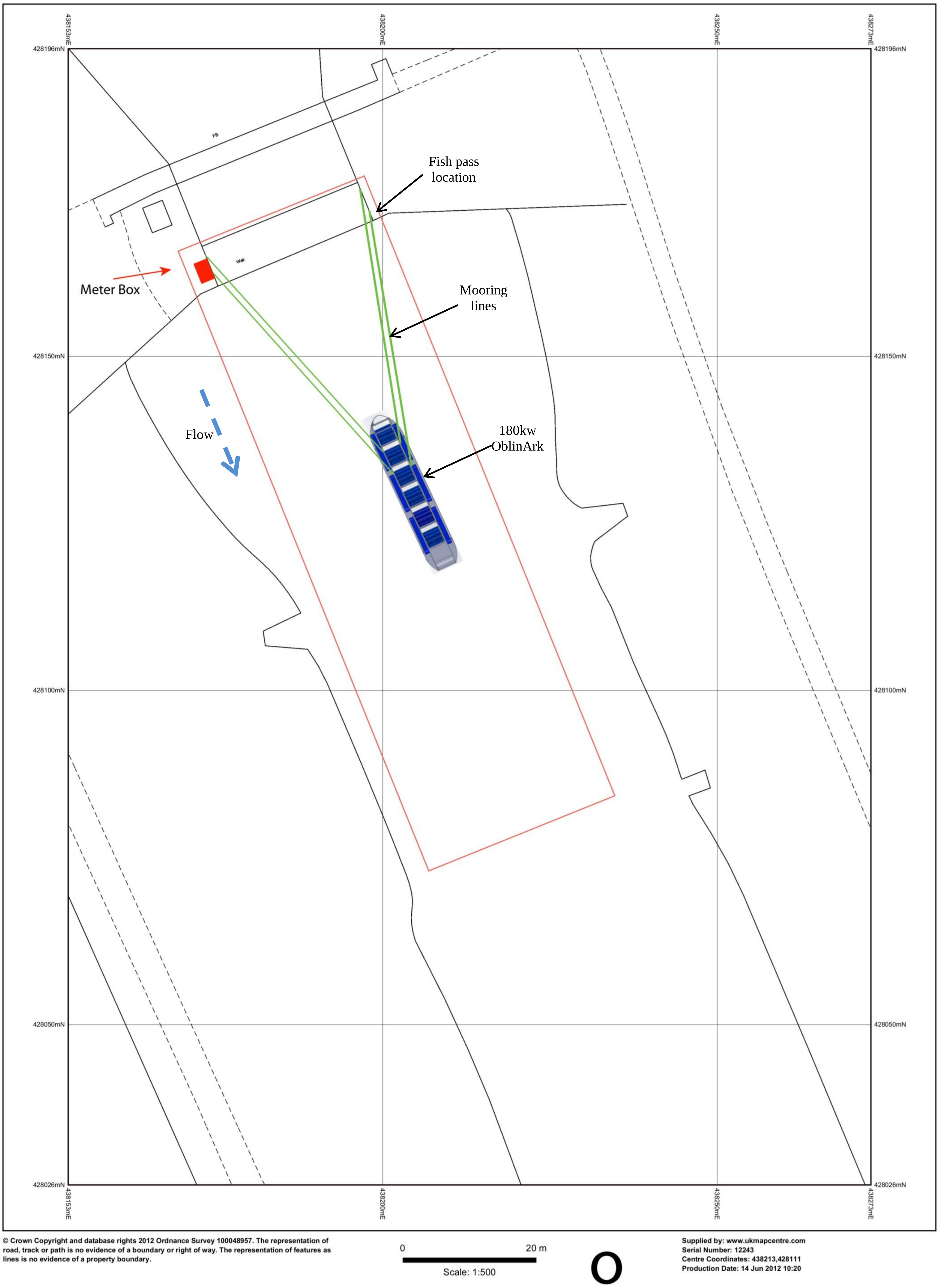

Figure 2. Plan view of the proposed installation of the OblinArk at Lemonroyd Weir (Courtesy of OblinArk Limited).

3 EA DISCUSSIONS, REQUIREMENTS AND CONCERNS

Pete Turner (EA Fisheries Technical Officer in North-East and Yorkshire) raised the main concerns of the proposed OblinArk installation at Lemonroyd weir on 12/09/2012. These involved the potential impacts on the passage efficiency of the currently installed single flight Denil fish pass at Lemonroyd weir. Of particular concern was the potential acoustic effect of OblinArk in diverting fish from their normal route of migration, and whether the device would produce bubbles sufficient to create a bubble curtain. Pete Turner also stressed that there was no previous monitoring of the Denil fish pass's efficiency, and therefore no baseline data to determine the potential effect of the OblinArk installation on the effectiveness of the fish pass.

4 POTENTIAL IMPACTS OF THE OBLINARK ON FISH

4.1 Direct mortality/injury from blade strike

Direct mortality due to blade strike is not of concern to the EA (Pete Turner, EA, *pers. comm.*). Compared to other hydro-power technologies, the design of the OblinArk means that it is not dependent on an impoundment that will concentrate flow through the turbines, physically blocking aquatic biota passage via an alternative route than the turbines, and thus it is considered that environmental impacts are minor. There is no base/floor below the turbines, and the paddles move relatively slowly at the velocity of the water, thus damage to fish due to blade strike and grinding (i.e. fish becoming trapped between the blade/paddle and a stationary hard surface) are reduced compared to other low head hydropower schemes where the gap between the blades and the stationary infrastructure are reduced to a minimum. Trials in the field using a similar technology (a free stream energy converter – FSEC) found that the majority of fish (91.7% of 130 radio tagged fish of various species) did not pass through the FSEC, but moved around the device (Karlsson, 2012). Injuries due to blade strike of those fish which did pass through the FSEC were minimal (of 186 fish passing through the FSEC, three were classified as being potentially damaged due to blade strike. Therefore the maximum rate of injury due to blade strike of fish passing through the FSEC was 1.6%), and in line with Archimedes Screw turbines (1.4% maximum injury rate) (Karlsson, 2012; Vowles & Kemp, 2012), which are exempt from fish screening in England and Wales, requiring only a trash rack with a 100mm spacing (Environment Agency, 2009). Archimedes screws, however, concentrate the flow of water through them, whereas water passing through the OblinArk (and FSEC) is a lower proportion compared to the river channel and fish are capable of avoiding the turbines (i.e. 91.7% of tagged fish did not pass through the FSEC; Karlsson, 2012), therefore the actual risk of injury due to blade strike from the OblinArk is further reduced. Furthermore, the risk of contact and injury with the OblinArk's paddles is reduced compared to the FSEC, due to the FSEC having a closed base below the turbines (whereas the OblinArk is open), which forms an impoundment. Thus, upon entering the FSEC the fish are more likely to pass near the blades as they can not dive down to avoid the turbines, whereas they can more readily avoid the OblinArk's paddles. Additionally the OblinArk's paddles are constructed from soft polypropylene with rounded edges that reduce the risk of damage to fish which come into contact with them (Brannan Tempest, OblinArk, *pers*. c*omm*.).

4.2 Fish passage and behaviour

The presence of any anthropogenic structure in a watercourse may create stimuli (e.g. visual, hydraulic and/or acoustic) which could induce a behavioural response in fish (Popper & Carlson, 1988). A concern of the EA (Pete Turner, EA, *pers*. *comm*.) is that avoidance response to encountering the OblinArk may affect the natural migration of fish past the device, and also divert upstream migrating fish away from the currently installed fish pass.

The response of fish to various stimuli differs with species and the same stimulus can have profoundly different, and potentially opposite effects, e.g. a specific sound signal may act as an attractant to some species, and a repellent to others. However, research concerning the behavioural response of fish to many stimuli (e.g. sound, light, hydraulics) is limited to a few species, and caution should be taken when extrapolating the behaviour of one species to that of another (Popper & Schilt, 2008).

It is understood that the OblinArk turbine blades have been designed to minimise noise, turbulence, and changes to the hydrodynamic environment, however currently measurements of these potential stimuli levels are not available for a full sized OblinArk, but will be assessed assuming successful installation at Lemonroyd weir (Brannan Tempest, OblinArk, *pers. comm.*). The FSEC, a similar barge-mounted hydro-power turbine to the OblinArk, has been tested both in the laboratory and in the field to determine the response of fish to the presence of the device (Vowles & Kemp, 2012). Due to the similar nature and operation of the FSEC to the OblinArk, the results from these studies are highly relevant to the OblinArk installation, both at Lemonroyd weir and more generally throughout the UK. Laboratory trials of the FSEC using multiple species (not specified) utilised video capture to determine fish response, whereas in the field radio tagging and mark recapture (of perch, eel, roach, pike, and sea trout) techniques were used. It was concluded from these trials that the hydraulic, acoustic, and visual presence of the FSEC did not alter fish behaviour or delay migration, and fish would typically pass around or under the floating structure (Vowles & Kemp, 2012; Karlsson, 2012). Up- and downstream moving radio-tagged fish were seen to show no hesitation in passing the FSEC in the field, with no difference when compared to control conditions in the absence of the FSEC (Karlsson, 2012). Therefore it is unlikely that the similar technology of the OblinArk would adversely affect fish behaviour. Notwithstanding this, although unlikely to be produced at levels to significantly influence fish behaviour at Lemonroyd weir (due to the site specific conditions, e.g. wide and deep river channel), the impact of a number of potential stimuli produced by the OblinArk which may influence fish behaviour are discussed here.

Visual impact – Fish have been seen to respond to visual cues associated with structure. For example, downstream migrating Pacific (Kemp *et al*., 2008; Kemp *et al*., 2005a) and Atlantic (Welton *et al*., 2002) salmon smolts avoid overhead cover, at least during daylight conditions. Thus, there is potential that fish may be diverted away from their normal migration route due to the presence of the OblinArk at Lemonroyd weir. If fish behaviour is influenced by the visual presence of the OblinArk, it is unlikely to cause significant diversion so that the fish do not find the fish pass entrance, due to the large width of the channel (60–80m) in relation to the size of the OblinArk (2.7m is around 3.4–4.5% of the channel width, leaving a corridor of approximately 57–77m on either side of the OblinArk) allowing fish to easily circumnavigate the barge, and also because the device will be suitably far downstream (between 25–50m) so that it will not effect fish behaviour in the immediate vicinity of the fish pass entrance. Supporting this conclusion, flume based trials to determine the fish response to the presence of an FSEC during daylight and night found no difference in fish response between the two conditions, suggesting there was no visual impact (or at least the visual impact was minimal compared to other behavioural stimuli) of the structure on behaviour (Andrew Vowles, Southampton University, *pers. comm.*).

Acoustics – The OblinArk is designed to produce minimal noise when the blades are rotating (Brannan Tempest, OblinArk, *pers. comm.*), because any noise produced represents inefficiency in the turbines. If noise produced by the OblinArk is significantly high then it is possible that the fish will demonstrate an avoidance response to the device. The use of sound to manipulate fish behaviour and divert them away from e.g. hydropower intakes has been investigated and seen to be effective in some instances (Popper & Carlson, 1998). The response of fish to anthropogenic generated sound, however, varies greatly between species, size, and the sound source, and it is almost impossible to extrapolate the response to sound from one species, size, or sound source to another (Popper & Hastings, 2009). In the case of the OblinArk, where diverting fish away from the turbines and thus reducing the risk of blade strike is favourable, if noise levels induce a significantly high avoidance response then there is a risk that it will prevent fish moving up- or downstream of the device. Similarly to the visual impact however, it is unlikely that noise levels will cause significant diversion at Lemonroyd weir so that the fish do not find the fish pass entrance, due to the large channel width and the installation of the device between 25–50m downstream of the toe of the weir (thus not having an impact on fish behaviour in the immediate vicinity of the fish pass entrance). An investigation to determine the response of downstream migrating European eel and chub to the acoustic environment created by a fixed in place hydropower turbine (where all flow passes via the turbine) which is similar to the turbines on the OblinArk, and known as a hydrostatic-pressure converter (HPC), was undertaken by Vowles & Kemp (2012), and concluded that fish did not avoid the HPC, and thus that it did not induce a behavioural stimulus.

Change in hydrodynamics – Variation in the hydrodynamics immediately downstream of the OblinArk could affect fish behaviour in a number of ways. For example downstream migrating salmon smolts will avoid rapid accelerations in flow (Kemp *et al*., 2008; Kemp *et al*., 2005b); whereas downstream migrant European eels appear to demonstrate little response (positive or negative) to similar conditions (Russon & Kemp, 2011). Upstream migrants (particularly when considering the salmonids) are attracted to areas of distinct flow, and this behaviour is exploited to help create efficient fish passes (Armstrong *et al*., 2010). Presumably, the operation of the turbines will take energy from the water passing through the OblinArk, which would reduce the water velocity passing through the turbines, whilst marginally increasing velocity on either side and below. The level of variation in water velocity passing around the device will increase in narrower and shallower channels. Thus it is conceivable that upstream migrants may be attracted to the distinct flow at downstream end of the OblinArk rather than the fish pass entrance. As already stated however, the design of the OblinArk turbines will mean that it is likely that the water velocity and much of the hydrodynamic conditions will vary little from the conditions upstream, and thus the competing attraction flow provided by both the significantly greater volume of water passing over Lemonroyd Weir, and presumably by the efficient design of the current fish pass, is likely to be greater than changes to flow caused by the presence of the OblinArk. Flume based trials of the HPC, found that downstream flows were characterised by relatively constant flow velocities, which would be unlikely to mask the attraction flows emanating from adequately designed fish passes (Vowles & Kemp, 2012). In addition, Vowles & Kemp (2012) found that grayling and trout were not attracted to the tailrace of the HPC, further indicating that an appropriately designed fish pass should still operate in the presence of the device. Assuming the OblinArk is unlikely to provide an attraction flow for upstream migrant fish and thus from a hydraulic perspective it is improbable that it will reduce the attraction of fish towards the currently installed fish pass entrance.

Bubble curtains - There is potential (although minimal due to the design of the blade to reduce turbulence – Brannan Tempest, OblinArk, *pers. comm*.) that a bubble curtain is formed directly downstream of the OblinArk. Bubble curtains have the potential to deter fish movement via what is thought to be a combination of visual, auditory and shear-current stimuli (Solomon, 1992; Turnpenny & O'Keeffe, 2005). However, when applying bubble screens designed specifically to deter fish movement, efficiencies are mixed dependent on species and location, and are general low in the field (Turnpenny & O'Keeffe, 2005). High velocity and turbulent water can lead to break-up of the sheet of bubbles which reduces efficiency (when attempting to prevent fish movement). The fast flowing and turbulent water present immediately downstream of Lemonroyd weir (and spanning approximately 50m downstream) is therefore likely to reduce the risk that the OblinArk will produce a sheet of bubbles that will prevent fish passing the device, or deter them from finding the fish pass entrance. Furthermore, due to the narrow width of the barge (2.7m) compared to the channel width (60–80m) and indeed the width of Lemonroyd weir itself (25m) it is unlikely that the OblinArk will produce a bubble curtain that spans the entire channel width. The 3m deep water also means that bubbles are unlikely to penetrate significantly down the water column. Thus, assuming a small bubble curtain was produced downstream of the OblinArk, fish which avoid it would easily pass around or below it, with little effect on their upstream or downstream movement, and would not affect the ability of upstream migrants in locating the fish pass entrance. Additionally, any bubbles formed downstream of the device are unlikely to form a sufficiently coherent sheet to deter fish.

5 EVALUATION OF OBLINARK MORE WIDELY

If the barge were installed immediately downstream of a fish passage route, and/or in a channel of similar width to the OblinArk or shallow depth, it would have the potential to inhibit both up- and downstream movement of fish due to any behavioural effects occupying the entire passage route (channel). Fixed low head hydropower devices such as the HPC, however, do not appear to cause a significant behavioural response in fish which would pass via a suitably designed adjacent fish pass (Vowles & Kemp, 2012). Thus in the case of the OblinArk, fish would still be able to pass under the flanking pontoons as if they were open bypass/fish pass channels, even under conditions where the channel is the same width as the device. The exact physical parameters which may hinder fish passage will be hard to determine, but a combination of sound, visual presence, hydraulic changes and (in the case of shallow water) physical "screening" due to the inability to pass the structure may prevent fish passage under the adverse conditions for installation described above. Thus, until further investigation is undertaken it is not recommended to install an OblinArk under these conditions. It is the understanding of APEM however, that the OblinArk is not designed to be installed in narrow and/or shallow channels due to a reduced efficiency of the device in shallow water (<1m), and increased likelihood of vandalism in narrow channels (Brannan Tempest, OblinArk, *pers*. *comm*.).

6 POTENTIAL REQUIREMENT FOR FUTURE STUDY

It is understood that no monitoring studies have been undertaken to determine the passage efficiency of the Denil fish pass installed at Lemonroyd weir. Thus there are no baseline data for fish pass effectiveness, to assess the effect of the OblinArk on fish passage. Any study examining the use of the fish pass would not be informative in terms of elucidating any impacts of the OblinArk.

Ideally any monitoring to determine an impact would include a pre-impact, or baseline data series, against which any changes in fish movement can be compared when the OblinArk is installed. This is not available for the fish pass however. Given the absence of data, the next most suitable option (other than undertaking work during the impossible situation where the OblinArk is present and absent simultaneously) would be to do a week on, week off *in situ* study. This would involve at least a one year long investigation (to account for seasonal effects) where the OblinArk is installed and removed on a weekly basis (i.e. one week present, and one week absent from the watercourse) and fish passage monitored (via e.g. radio telemetry, tagging studies). If such fish pass efficiency monitoring is deemed necessary to determine the effect of the presence of the OblinArk on fish passage, in the view of the developer, the likely costs involved would be prohibitive. Additionally, it is likely that the works required to regularly remove and install the OblinArk will themselves have a negative impact on fish pass efficiency, thus masking the actual effects of the OblinArk during normal operation.

7 CONCLUDING REMARKS

The installation of the 180kw OblinArk at Lemonroyd weir is unlikely to have a significant impact on the efficiency of the single flight Denil fish pass. This is due to the large river channel width and depth in relation to the OblinArk permitting fish to easily pass around or below the device if an avoidance response is demonstrated, and for upstream migrants to still readily locate the fish pass entrance. Further, the OblinArk is unlikely to be installed closer than 25m downstream of the weir and fish pass, which will also reduce the likelihood of the device having an impact on fish behaviour in relation to locating and entering the fish pass. In addition the work undertaken by Vowles & Kemp (2012) suggests that a similar hydro-power device (the FSEC) has minimal physical and behavioural impact on fish, both under experimental conditions in a flume and in a river channel. Thus the OblinArk is also unlikely to induce responses by fish that will negatively impact their migration (both during up and downstream movement) under conditions where the device would normally be installed.

In addition to potentially having a low negative impact on migrating fish there may be wider environmental benefits to the OblinArk over other hydropower technologies which generally operate on the basis of requiring an impoundment. Such benefits may include (but are not restricted to) the absence of any permanent infrastructure, and thus lower levels of physical modification, and the ability to relatively easily remove the installation if required on the basis of the emergence of unforeseen environmental or engineering problems.

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