Presentation 1 – Shaw, Janet

INSTREAM BARRIERS ASSESSMENT – A MULTIDISCIPLINARY APPROACH

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ABSTRACT
Instream barriers are a major obstacle for fish migration. The removal or modification of these structures is widely seen as a substantial environmental gain in the first round of River Basin Management Plans under the Water Framework Directive (WFD). Large scale surveys undertaken by the various statutory authorities have identified the location of many of these structures around UK rivers. For example, the Environment Agency has estimated that there are approximately 26,000 of these features throughout England and Wales. The current challenge is to prioritise catchments and to assess the identified structures to establish whether it is both technically and practically feasible to remove or modify them to improve the hydromorphological and ecological functioning of the river system.

This paper presents a multidisciplinary, integrated barrier assessment methodology that has been developed by Atkins and successfully applied on 40 sites for the Environment Agency and the Scottish Environment Protection Agency (SEPA). The rapid-style assessments included desk-based study and a site visit. Importantly, a range of linked factors were considered at each site. These included environmental factors such as terrestrial ecology, fisheries, hydromorphology and human-related factors such as engineering design and site access. Baseline conditions for each were recorded at the barrier sites themselves, and also along the upstream and downstream reaches to estimate the spatial zones over which the barrier was currently having an impact. This information was used as the basis for consultation within the Atkins team and with the client to identify the most suitable management option for each barrier based on potential risks versus environmental benefits and technical feasibility.. The options considered included i) do-nothing, ii) full removal, iii) partial removal, iv) formal fish pass and v) an informal or easement-type fish pass. After appraising each of the options and considering the technical feasibility of structural works, costs and impacts on flooding, an option was recommended and monitoring and mitigation recommendations were made. In certain cases, additional assessment works were recommended for the detailed design phase. For each barrier, the data and accompanying assessment were presented in a simple, structured format with photographs to provide a consistent and user-friendly output to the client and stakeholders.

The paper also presents case studies from the projects and examines the main constraints to recommending the WFD preferred option of full barrier removal. Alternative options that could be scoped into the works are also discussed.

Keywords : WATER FRAMEWORK DIRECTIVE; FISH PASSAGE; FISH PASS; BARRIER REMOVAL; BARRIER MODIFICATION; OPTIONS APPRAISAL; INTEGRATED APPROACH.

INTRODUCTION

During 2009 to 2011 Atkins has been working with the Environment Agency and the Scottish Environment Protection Agency (SEPA) to assess the viability of removing or modifying 40 barriers on 10 watercourses in England & Wales (in Herefordshire, Powys and Monmouthshire) and Scotland (in Perthshire, Ayrshire, Midlothian and West Lothian on the mainland, and in the Outer Hebrides). The barriers were all weir structures but there was a range in their types and sizes, between approximately 0.5m to 3m in height. River channel dimensions at the weir locations also varied widely between approximately 2m to 35m.

Figure 1 Example 1 - Unamed weir on the River Lugg, near to Prestigne (Powys) – Weir height approximately 0.5m, channel width at the weir 5m

Figure 2 Example 2 - Peggies Mill weir on the Lower reaches of the River Almond (Cramond near Edinburgh) – Weir height 3.5m, channel width at the weir 30m

Some of the assessments involved assessing multiple weirs located on the same watercourses. For example, 14 weirs were assessed on the River Lugg in Herefordshire over a 24km reach, and 10 weirs were assessed on the River Almond in Scotland over a 35km reach. Cumulative risks and issues also had to be identified as part of these assessments.

The European Union Water Framework Directive (WFD) requires member states to achieve 'good' water status for surface waterbodies and 'good ecological potential' water status for all surface waterbodies that are heavily modified. Instream barriers, such as weirs and culverts have been identified as a significant pressure to the physical river habitat. The Environment Agency have estimated that there are approximately 26,000 of these features throughout England and Wales. The structures prevent fish from moving to upstream and downstream habitats to feed or spawn. Lack of fish numbers and diversity of species has contributed to numerous surface waterbodies failing their WFD assessment. Improving river connectivity by barrier removal or structure modification will assist in increasing the number of surface waterbodies achieving a WFD Good Ecological Status Target by the 2015 deadine in the first round of the River Basin Management Plans. This was the main driver for these barriers to be selected for assessment. Other drivers for this type of river restoration directly relate to improving fish migration, helping to achieve specific fish spawning targets, maintaining the site condition status of designated sites and also include economic drivers to reduce future maintenance cost of an owner's assets.

The instream barrier assessment offers a rapid-style integrated barrier assessment methodology which incorporates both a desk based study and site visit. Assessments for the Environment Agency and SEPA projects considered a range of linked factors at each site, which included hydromorphology, technical feasibility (engineering design and site access) as well as terrestrial ecology and fisheries. Assessments involved an Atkins in-house multidisciplinary team. The assessments for the two projects used a similar approach but did include some differences such as the inclusion of an independent fisheries expert within the Atkins team to provide fish habitat and barrier passability assessment for the SEPA study, versus the in-house prior knowledge of the Environment Agency Fisheries team for the Environment Agency project.

METHOD FOR ASSESSMENT

The Environment Agency's and SEPA's approaches to assessing the barriers were different. The Environment Agency's fisheries team had identified a series of structures on tributaries of the River Wye which presented passability problems for salmonids. The EA therefore requested a rapid type assessment by an engineer and a hydromorphologist to determine whether it was feasible to remove or modify the structure. If not, a fish pass solution was to be considered. A member of the Environment Agency's Fisheries Team accompanied the team on the site visits. SEPA requested an assessment of a series of barriers (at various locations) by a team of specialists. They wanted an assessment of a number of options per barrier and for the issues, risks and benefits to be presented in a clear and concise way. For situations where numerous sites were located on the same river, SEPA sought recommendations for how the works might be prioritised.

The methodology outlined below outlines the general details that were taken into account in both project methods. Where factors were only taken into account in one of the projects, they have been highlighted.

Background Information search

A desk based study was completed which identified background information about the site and its catchment hydrology, geology, WFD surface waterbody status, ecological/environmental constraints and the details (where available) about the barrier's ownership and its historic and current use.

Site Surveys – all assessments

Site visits were undertaken for each of the barriers by a multidisciplinary team of specialists. The factors that were considered as part of the assessments are shown in Figure 3.

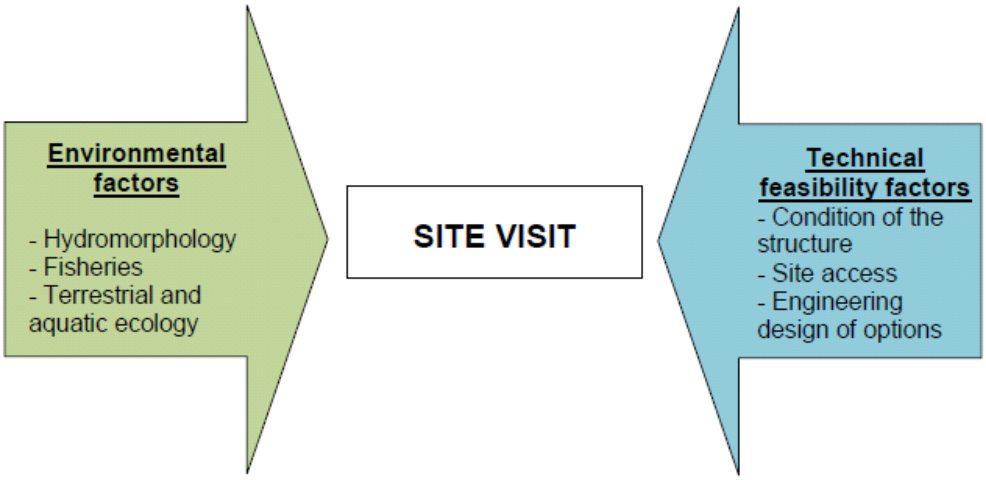

Figure 3 – Factors considered during site assessments

Note – Prior to the Environment Agency Wales site assessments the Fisheries team had already identified fish passability issues and suitable habitats. Ecology was to be considered in the future for sites taken forward for further appraisal. The Atkins site visit assessment therefore did not examine those factors, but they were taken account of at the options appraisal stage.

The individual roles of the specialists were as follows:

- Civil engineer - to assess the feasibility of removing or modifying the barrier including access to the site.
- Hydromorphologist - to assess the likely impacts to river processes caused by modifying the structure, and to identify any potential risks to environmental or structural receptors.
- Ecologist *(SEPA project)* - to assess the sites for terrestrial and aquatic species.
- Fisheries specialist *(SEPA project)* - to assess the passability of the barriers to different fish species and to identify fish habitat along the site reaches.
- EA Wales Fisheries Team *(EA project)* – provided advice on passability of the barriers for fish using prior local knowledge of the sites under a range of flow conditions.

Where possible the site assessments were carried out by the individual specialists at the same time to ensure consistency in the baseline recorded. The team met with local staff from the regulatory authorities, interested parties and/or the landowners at the majority of sites. This assisted in clarifying and collating detailed background information about the weir. Site visits to individual barriers typically lasted one to two hours. Where barriers were assessed in

close proximity to one another, if access routes allowed, river reaches between the barriers were walked to enable the specialists to get a better understanding of the catchments.

During each site visit the specialists completed an assessment sheet, which had been designed to capture detailed baseline information and to maintain consistency of what was recorded across the sites visited. Photographs were also taken as a record of the site structure, and hydromorphological features and ecological habitats.

Site survey hydromorphology assessment – an example

An assessment checklist was used to record a detailed baseline picture of the site. The first step was to determine the current impact zone of the barrier both upstream and downstream. In most cases the upstream impact zone was assumed to be the length of reach over which ponded-type flow was noted. Downstream reach lengths were generally estimated based on the length of the reach before the channel was observed to re-naturalise or return to a stable state. A baseline of the channel was then recorded:

- Upstream of the impact zone,
- Inside the impact zone above and below the barrier, and
- Downstream of the impact zone.

The baseline involved making quantitative estimates and qualitative descriptions of key characteristics of the barrier itself and the channel. This included estimates of gradient, channel width and depth, and details of channel planform, bed substrate type, channel features, bank dimensions and composition, vegetation types and locations, flow type and sediment dynamics. The barrier dimensions were also estimated. Bank erosion was noted and an estimate of bank and bed stability was also given along the study reach. On site, a number of key questions where considered which included:

- How stable is the current channel i.e. bed scour and mobility, bank erosion?
- Is weir removal feasible and what other options are available?
- How will the flow patterns change with each option?
- How will the change affect erosion of the bed and banks, and in-channel deposition? (in particular, over what length?)
- Are there any opportunities for river enhancement e.g. habitat improvements or other works which would promote re-naturalisation?

An indication of the types of hydromorphological features identified in the site visits are shown in Figure 4.

Figure 4 – Almond Valley Weir, River Almond – Annotated photos of the barrier highlighting some of the hydromorphological features identified on the site visit.

Reporting

Site reports shared a consistent format to allow quick reference and comparison of the issues between sites. Each specialist of the multi-disciplinary team provided input into the barrier baseline section of the report. Details recorded included:

- Site location e.g. Location map, ownership details, WFD waterbody status.
- Land-use and geology background descriptions.
- Structure description and visual assessment of its condition.
- Geomorphology baseline description of the physical state of the river outside and inside of impact zone.
- Ecology assessment *(SEPA works)* e.g. protected species search results and site visit habitats and invasive species descriptions.
- Fisheries assessment *(SEPA works)* e.g. fish habitats assessment, structure passability assessment and targets for future fish passage.

The following options were considered in turn by the team of specialists:

- Do-nothing scenario
- Full removal
- Partial removal
- Formal fish pass
- Informal or an easement-type fish pass

The do-nothing provided a baseline appraisal against which the other options could be assessed. For each option there was a consideration of aspects under 6 factors, identified during the options appraisal process. These are shown in Figure 5.

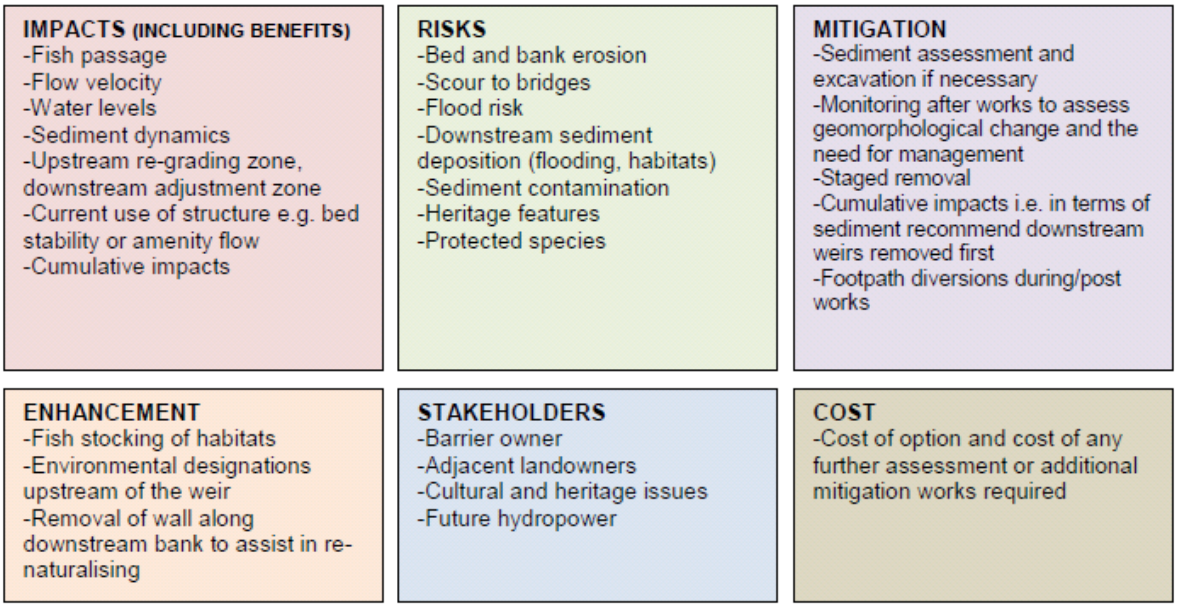

Figure 5 Options appraisal - generalised examples of aspects considered for each option

A scoring approach in terms of risks and benefits was applied to the SEPA assessments. This provided transparency in the decision making process and facilitated the process of prioritisation.

The reports also detailed the feasibility of barrier removal or modification by considering issues of practicality, construction access, flood risk and impacts to protected species and environmental designated sites.

Full weir removal was considered to be the most effective means of delivering the project objectives – i.e. reinstate fish passage and natural fluvial processes. If the overall risks associated with full removal were considered too high, then other options were considered. This included partial removal (e.g. lowering of the weir, or staged removal over time to allow monitoring/ management of impacts as necessary), and formal or informal fish passes.

In cases where multiple sites were being considered on one river, the cumulative impacts of potential works were considered. The suggested sequence of barrier removal or modification was to progress in a downstream to upstream direction, to allow fish movement upstream in a phased manner. The risk of sediment build up behind downstream structures would also be reduced if this downstream to upstream method was applied. In practice this preferred sequence of works to be completed could not always be recommended because of practical considerations.

Once an option had been recommended, additional recommendations for further work were made. This included developing a detailed feasibility study, topographic surveys, sediment assessments, and flow surveys. Subsequent stages leading up to the start of any works would include detailed design and ecological surveys.

CASE STUDY 1 – HEREFORDSHIRE WYE FISH OBSTRUCTIONS SURVEYS

The Environment Agency Wales requested 26 river obstructions on River Wye tributaries to be assessed to determine whether it would be feasible to modify them by either full or partial removal (weir lowering or by a breach in the structure). If after assessment these WFD preferred options could not be recommended, alternative fish pass solutions were to be examined in a subsequent project phase. These initial assessments were completed by a civil engineer and a fluvial geomorphologist. Environmental assessment was to be considered in a later project phase.

Kentchurch Weir – a summary of the full removal option aspects identified during assessment

Kentchurch weir: Stone/concrete faced with concrete apron of 1.7m height and 35m width, 5m length. A central section of the weir had been lowered. Originally constructed to provide water to an estate gardens.
Location: 25km upstream of Monmouth, on the River Monnow, a tributary of the River Wye.
Landuse: Arable/grazed farmland

Figure 6 – Kentchurch Weir, River Monnow

Impacts

- Benefits would be fish passage and natural sediment dynamics would be reinstated.
- Channel re-grading and adjustment would occur up and downstream of the structure.

Risks

- There is a risk of erosion to the right bank upstream of the weir which has areas of no vegetation. However, there are no risks to structures e.g. upstream bridges.
- Flood risk - low to medium
- Potential for right abutment collapse and right bank avulsion, which could lead to a change in planform for the channel.
- Sediment transport and downstream deposition with risk to habitats from fine sediment smothering.

Mitigation

- Ongoing monitoring and management by fencing to allow vegetation rejuvenation to stabilise the right bank.
- Sediment assessment to determine quantities.
- Abutment removal to reduce unpredictability of collapse.

Preferred option = full weir removal
(Assuming flood and downstream sediment movement risks to be confirmed as low after further modelling and assessment.)

Subsequently Atkins undertook hydraulic flood modelling work to assess the potential flood risk impacts of removing Kentchurch weir. This report concluded that the works were not considered to have a significant adverse impact on flood risk, and that impacts could be reasonably managed by monitoring bed levels downstream of the structure and taking appropriate action as necessary (e.g. the removal of accumulated sediments). At the time of writing the site has now progressed with removal being the preferred option, planned for summer 2011.

CASE STUDY 2 – SEPA BARRIERS ASSESSMENT

SEPA requested a site specific assessment to consider barrier removal or modification (including fish pass options) for 14 barriers. Each of the following options was appraised in turn: do-nothing, full removal, partial removal, formal fish pass, informal or an easement-type fish pass. Impacts, risks and benefits were identified and a scoring system developed to help recommend options and prioritise the order of works to be completed. SEPA wanted a holistic assessment from the outset requiring a consideration of the geomorphology and terrestrial/aquatic/fish ecology of the system as well as the feasibility and logistical and impacts of the options. An ecologist and a fisheries specialist were therefore brought onto the assessment team.

Kirkton Weir – a summary of full removal option aspects identified during assessment

Kirkton weir: a broad-crested weir an estimated 25 - 28m wide and with a drop in head of 2m, and crest length 0.8m. The weir forms an arc and directs flow towards the lade take-off penstock on the left bank. Water is abstracted by the Almond Valley Heritage Centre to drive a demonstration water wheel.

Location: This weir is located on the River Almond on the western edge of Livingston. It is approximately 29km from the Firth of Forth Estuary. Downstream of the site the River Almond flows through the urban areas of Livingston and on towards Cramond. Upstream of the site the catchment becomes increasingly rural.

Land-use: Almond Valley Heritage Centre is sited on the left bank, and the area right bank is used as a business park with commercial and light industrial units (set back by approximately 10m from the weir).

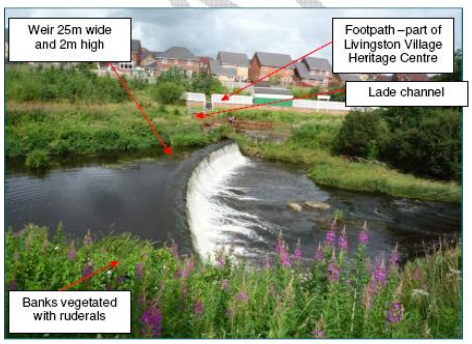

Figure 7 – Kirkton Weir, River Almond

Figure 8 - B7015 road bridge 200m upstream from weir

Impacts

- Water levels and flow velocities would be reduced upstream of the weir. This would impact adversely on the functioning of the Almond Valley Heritage Centre water wheel possibly by removing water supply under normal to low flow conditions.
- Channel re-grading and adjustment would occur up and downstream of the structure which in the long term could lead to changes to the upstream 'Almond Pools' which are approximately 500m upstream.

Benefits

- Fish passage, natural flows and sediment dynamics reinstated.
- Removal of long term maintenance cost.

Risks

- Risk of losing a culturally important asset.
- Significant risk of upstream channel bank erosion, especially to the right (higher and steeper) bank, which could impact on the business park car park.
- Significant risk of erosion to the foundations of the 200m upstream B7015 road bridge in the short-medium term.
- Risk of increased erosion within the pool below the weir site. Protection on the left bank to may be undercut which increases the risk of undercutting the foundations for the footpath and bridge within the Almond Valley Heritage Centre.
- Risk of erosion further downstream where property is located near to the channel banks.
- Flood risk – Increased conveyance through the reach leading to increased risk of flooding downstream.
- Sediment transport and downstream deposition with risk to spawning habitats.

Mitigation

- Sediment assessment to determine quantities and whether the material is contaminated.
- Monitoring of downstream stone wall/bank protection, upstream banks and B7015 road bridge foundations to see if management options i.e. wall/foundation reinforcement works or bank stabilisation are required.
- The timing of works needs to be considered to mitigate cumulative adverse impacts.

Stakeholder considerations

- Owned by West Lothian Council, but water abstracted by Almond Valley Heritage Centre (who are a long-term lease holder) to drive the water wheel. It is considered by the Almond Valley Heritage Centre and by visitors to be a key feature with both historic and biodiversity value.
- **Cost Band for full weir removal**
- (£150k - £299k) including sediment removal, bank stabilisation at the weir location and protection works.

Preferred option = formal fish pass

(Weir removal was only considered in order for the assessment to be auditable and to clearly present a process by which the impacts and benefits were fully outlined. The main constraint to weir removal or partial weir removal was therefore the abstraction of water by the Almond Valley Heritage Centre).

At the time of writing, the instream barrier assessments for SEPA are in the process of being finalised, and the next steps of detailed design and a programme of works have yet to be determined.

DISCUSSION

The instream barrier removal solution offers the maximum benefit to improve river connectivity as part of the Water Framework Directive. It would help to restore physical habitat and open up migratory routes for fish species. However, the instream barrier assessments undertaken have identified that there are several different risks or constraints which lead to this option being considered a high risk or inappropriate. Constraining factors to recommending the option of barrier removal that were identified in the assessments are:

Historical designations / Heritage value e.g. Boulitbrooke Weir, River Lugg - Boulitbrooke Bridge is a listed structure immediately upstream of the weir (Option recommended - fish pass)	
Gauging station located at weir e.g. Byton Weir, River Lugg (Option recommended - fish pass or fish easement)	
Adjacent infrastructure i.e. road and rail bridges e.g. Almond Valley Bridge Weir (Option recommended - informal easement-type fish pass	
Abstraction licence linked to weir e.g. Kirkton Weir, River Almond (Option recommended – formal fish pass)	
Potential for extensive upstream channel adjustment e.g. Sevenacres Weir, Lugton Water in Ayrshire, tributary of the River Garnock (Option recommended – construction of an informal easement (e.g. rock ramp)	

Other constraining factors, that have not been highlighted in the above table, which assisted in preventing the instream barrier removal option from being recommended were: landowners unwilling to consider a higher risk option, difficulty in accessing the site to complete the works, and high costs involved in the assessments, detailed design of the works, undertaking the works, and post monitoring. The potential for future hydropower at some of the weirs presented a risk to objection of weir modification from the landowner, but in the case of these assessments, it did not pose a constraint. There is however likely to be future conflict between the use of weirs for hydropower and the restoration of natural process by weir removal. Where existing fish passes were present, this was not a constraint to removing or modifying the barrier. It did however appear to promote the selection of replacing or modifying the existing fish pass rather than recommending removing the barrier.

The rapid assessments methodology explained in this paper can be used to identify the risks and the benefits and make recommendations based on expert opinion. For the SEPA project a scoring approach was used to appraise the risks and benefits which led to a prioritisation of options, and helped to determine prioritisation for works to be completed where several barriers were present on one river. It is ultimately the role of the Environment Agency and SEPA to weigh up the risks against the benefits and to make the final decision, based on additional assessment where necessary. The determination of what constitutes too high a level of risk to proceed with full removal will be refined with experience as more instream barrier assessments get completed.

Shared knowledge between those undertaking the works, and also post-scheme monitoring, will help generate efficiency in the option appraisal process for the future.

Partial barrier removal, either by reducing the height of the weir or by breach of the weir, was assessed by the methodology as having less risk, but also less benefit when compared to full barrier removal. Where full barrier removal was considered high risk, a fish pass solution was generally recommended instead of partial removal. This was because it was difficult to predict the amount by which the risks, benefits and costs would be reduced for partial compared to full weir removal. The benefits were anticipated to be marginal and works considered likely to only facilitate passage of some fish species.

Future pilot works of partial barrier removal, or a staged full barrier removal, where feasible, may offer an acceptable compromise to help restore some natural system processes as well as assist in fish movement.

If full or partial removal is not feasible, several fish pass options are available. The options range from formal fish pass solutions such as Larinier fish passes, which can allow migration for salmonids and coarse fish species, to informal fish passes such as rock ramps and easements (e.g. timber baulks). Any fish pass is unlikely to be as effective for all fish species as a natural river channel, but significant improvements in barrier passability can be achieved.

As part of the works packages, additional enhancements have been suggested which will also help to achieve habitat improvement objectives under the WFD. These include options such as:

- removal of invasive species
- removal of obsolete man made structures from the channel e.g. redundant eel traps
- removal of obsolete man made structures from the channel banks e.g. where erosion risks are considered low to replace a stone wall with a soft engineered option such as planting of mature vegetation

These types of enhancements can assist in restoring the rivers to a more natural state and will help to achieve WFD Objectives. It is therefore important to record possible enhancement opportunities when completing barrier assessments so that future projects adjacent to the site, although perhaps not directly related to the river, can very easily be identified and incorporated into future plans.

CONCLUSION

In order to assist in achieving WFD hydromorphological and ecological objectives, and to satisfy other fisheries related drivers, there is a current challenge to prioritise catchments, and to assess identified in-stream barriers. These assessments will help establish whether it is both technically and practically feasible to remove or modify certain instream barriers.

The in-stream barrier assessment project methodologies, as described in this paper, demonstrate that a multi-disciplinary, integrated barrier assessment methodology is required to take into account all environmental, social, economic and technical feasibility related factors.

There is a need to consider a full range of options in a transparent and consistent process. Examples have highlighted the range of aspects considered. A wide range of constraints to barrier removal have also been highlighted including heritage value and infrastructure protection, but the potential for other conflicting usages, such as small scale hydropower, might also need to be considered in the future. Other options to be considered when barrier removal is not practical or feasible are partial removal or the adoption of a fish pass solution. Partial weir removal is rarely recommended because of the difficulties in quantifying the risks, benefits and costs. Feedback on future works trialling this approach would be useful to help better inform the decision making process. Enhancements need to be considered in any assessment type project so that they can be progressed where funding is available.

ACKNOWLEDGEMENTS

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