By Brook Project Phase 1 - 2013/14.

Prepared for the Environment Agency by BART

1. Executive Summary

1.1 Background

During 2012, the Bristol Avon Rivers Trust (BART) worked with Area EA staff to identify and agree a sub-catchment within the Bristol Avon area, in which to carry out a collaborative river restoration project. The sub-catchment identified was the By Brook and a project was developed whereby BART would act as delivery partner to the EA, to help deliver improvements towards WFD Good Ecological Status (GES).

The By Brook is a tributary of the Bristol Avon, located to the North East of Bath, which comprises a cluster of 7 surface waterbodies. Of these waterbodies, two are classified as WFD Moderate and two as WFD Poor. These are Priority 1 and Priority 2 Waterbodies and as such, the aim is for these to reach Good Ecological Status by 2015. The primary failing element in all four waterbodies is fish, which is rated as “Poor” throughout, with one waterbody also failing for phosphate (moderate).

In its upper reaches, above Castle Combe, the By Brook catchment is predominantly arable farming. From Castle Combe to Box, agriculture is almost entirely livestock-based, primarily beef and dairy, which becomes interspersed with some arable farming in the lower reaches, including maize.

The main By Brook channel has been heavily modified throughout history, primarily for the milling of corn during Roman times, but later for the “fulling” of wool and the production of paper. The last recorded working mill, Chaps Paper Mill, Slaughterford, which included the Rag Mill discussed in this report, ceased operations in 1964. Many of the weirs and sluices associated with the industrial heritage of the By Brook still exist today and it is these barriers to fish migration that are thought to be one of the primary factors in the failure of sections of the By Brook for fish, under the Water Framework Directive.

The section of the By Brook that was the primary focus for this work was between Ford at the upper end and Box, with the addition of the EA owned Middlehill Gauging Station and Shockerwick Weir, which are located downstream of Box.

1.2 Project actions

Extensive walkover surveys were carried out throughout the project area and findings were captured on a continually developing GIS database of the catchment.

Widespread engagement with farmers, landowners and local interest groups was a primary focus for the project. This activity was undertaken with varying intensity, depending on the level of habitat degradation or environmental risk identified during walk-over surveys and the scale of mitigation works required.

A network of river-fly monitors were trained and provided with the necessary monitoring equipment, which will enable them to collect vital ecological data into the future. To promote an interest in the By Brook amongst future generations, a “Love My River” day was held for school children and their parents in Box village hall. This was a great success with over 30 children and their parents visiting the event and learning about river ecology and process whilst having fun.

Eleven fish migration barriers were surveyed and feasibility-level plans to enable fish passage via the construction of Larinier or pool-and-traverse type fish passes were prepared for consultation with the adjacent landowners and relevant fishing clubs. At the request of the EA, the concept-level designs for the three most downstream structures, Shockerwick, Middlehill and Box Mill, were developed into second-stage working designs. In addition to the Larinier and concrete pool-and-traverse fish pass options for Box Mill, an option comprising the modification of an existing back-channel was also developed for consideration.

The most heavily impacted section of river in terms of fish migration is that between Ford and Slaughterford, which is the only section of river in the project area that requires stocking of Brown Trout to maintain it as a fishery. This short section of the By Brook has five structures that prevent the resident trout from accessing the diversity of habitat necessary to maintain the population. In addition to the Larinier and pool-and-traverse fish pass designs developed for this stretch, concept-level plans, using combinations of enhanced riffles and the construction of naturalised by-pass channels along the original river course have also been developed. These have several advantages over the construction of engineered concrete fish passes, such as an increase of habitat diversity, improved aesthetics and the retention of historic structures, and have been well-received by the landowner and fishing club.

The Lid Brook, a small (*ca.* 4 km^2) tributary of the By Brook upstream of Box, was quickly identified as a high-risk area, particularly in terms of soil erosion from intensive livestock production with unrestricted access to the watercourse. BART worked with the landowners and farmers along the tributary to erect stock-proof fencing, provide controlled access for cattle drinking and to re-locate field access and cattle watering stations, to less vulnerable locations.

In order to understand the impact of these issues, water quality monitoring was carried out on the Lid Brook over two 24 hour periods of wet weather during the 2013/14 winter period. In each 24 hour period, approximately 3 tonnes of soil were lost from the catchment and washed into the By Brook. During the same period, 46 tonnes of suspended sediment were measured in the main By Brook channel, along with 85kg of phosphorus. Soil and nutrient loss at this scale has important implications for the future productivity and economic viability of agriculture within the catchment and the resulting sedimentation has disastrous consequences for the ecology of the both the Lid Brook and downstream waters. However, perhaps of equal importance is the economic consequences in terms of contribution to sedimentation and flood risk at downstream locations of the main River Avon at Bath and Bristol.

In total, £144,000 of Environment Agency funding was spent on these activities. This was matched by approximately £31,000 of in-kind contributions from BART and other stakeholders.

1.3 Next steps

During Phase 2 of the By Book Project, BART will continue to build on the relationships that have been developed so far amongst the farmers, landowners and fishing clubs. Engagement will focus heavily on developing an understanding amongst the agricultural community of the environmental and economic impacts of some of the less catchment-friendly land management practices identified during the project. Further riparian protection measures will be undertaken where possible.

The concept-level plans for fish migration and habitat restoration in the section between Ford and Slaughterford that were developed in Phase 1 of the project will be will be progressed to a stage that funding can be sought more widely for their implementation.

We are confident that the approach taken in this work represents the best value-for-money approach to achieving WFD GES and a continuation of support for these works will yield tangible improvements and provide a showcase example of effective partnership working.

Contents

2. Introduction

2.1 Background

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The By Brook is a 12 km tributary of the Bristol Avon with two sources to the Northeast of bath, the Burton Brook and the Broadmead Brook, which rise in South Gloucestershire at Tormarton and Cold Ashton respectively. They join just north of Castle Combe in Wiltshire and flow South and West to meet the Bristol Avon at Bathampton. The By Brook comprises a cluster of 7 surface waterbodies of which, two are classified as WFD Moderate and two as WFD Poor. These are Priority 1 and Priority 2 Waterbodies and as such, the aim is for these to reach Good Ecological Status by 2015. The primary failing element in all four waterbodies is fish, which is rated as “Poor” throughout, with one waterbody also failing for phosphate.

The project area (Figure 1. By Brook Project area, showing the Lid Brook where most of the river protection works were undertaken and the approximate beats of the four fishing clubs that control the fishing in this section of the By Brook.) primarily covers these failing waterbodies, which include the By Brook between Ford (ST 83812 74507) in the north and its confluence with the Bristol Avon in the South (ST 78576 66993) and three tributaries, the Broadmead Brook, the Doncombe Brook and an un-named tributary.

During the development of the project, BART members carried out extensive walk-over surveys and began an engagement process with local stakeholder groups and individuals, including landowners, farmers, local angling clubs, wildlife trusts and the well developed and enthusiastically attended “Friends of the By Brook Valley” (FOBV).

This work began to build upon the foundations of a working relationship between BART and local stakeholders, whose continued support will be essential in making lasting improvements. In addition, the work identified widespread issues relating to land management practices, habitat degradation and fish migration impediment, which together provided the focus for a project plan that will, over time, deliver significant improvements to the river’s ecological status.

2.2 Project overview

The primary aims of the 2013/14 phase of works in the By Brook catchment were to:

- build upon our understanding of the issues impacting on the By Brook’s ecological status
- develop constructive working relationships with the farming community, such that more ecologically sensitive practices that have a positive impact upon the catchment would be adopted and embraced by the By Brook’s farmers
- carry out riparian protection and habitat improvement works where permissions can be gained and develop plans with landowners for implementation in following phases

- develop plans for enabling fish migration across the many barriers that remain following the river's once thriving industrial heritage.

The project was carried out over 9 months between July 2013 and March 2014.

To lead the engagement process and deliver the project on the ground, BART employed an experienced Catchment Officer for two days per week for the duration of the project.

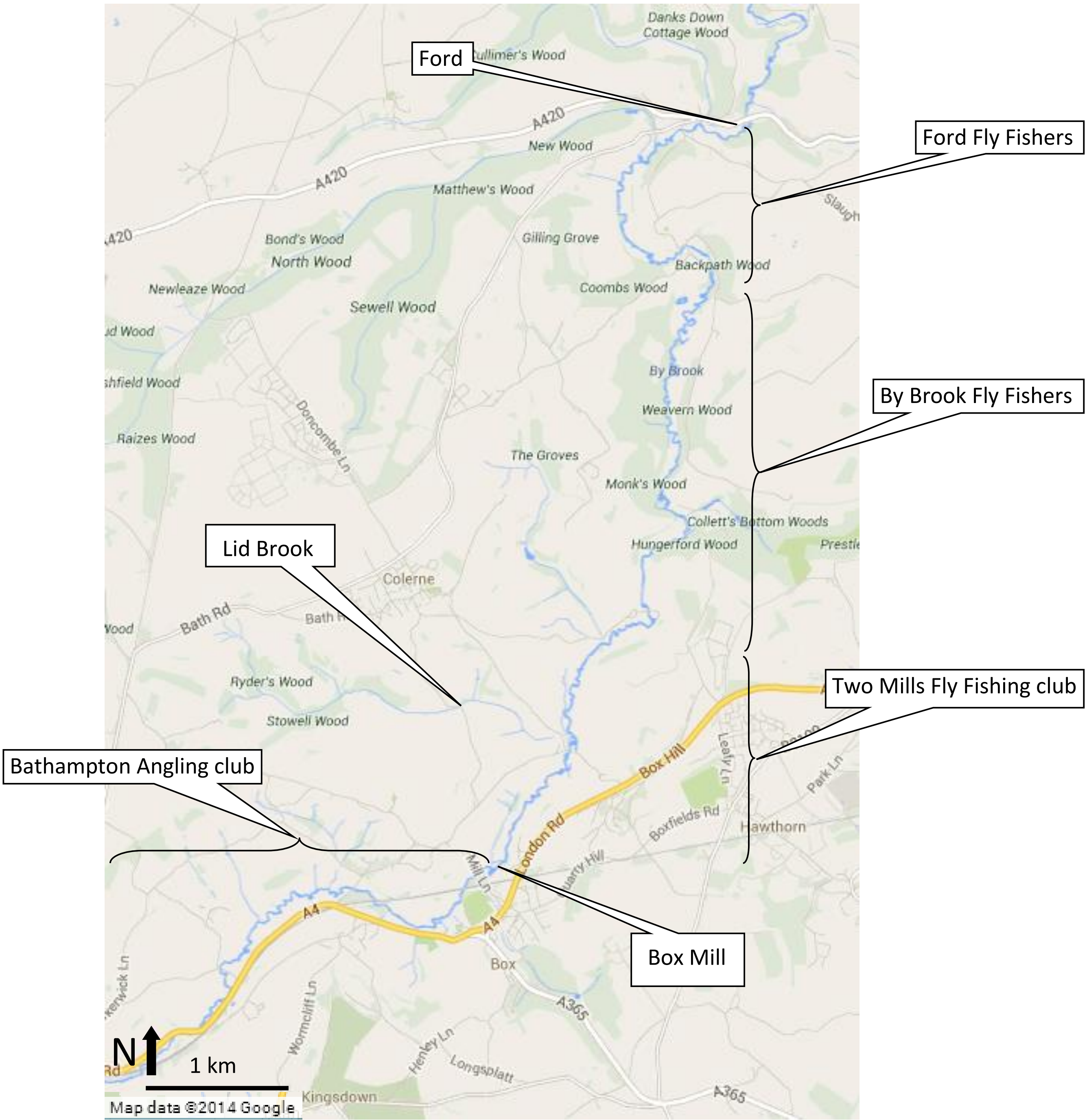


Figure 1. By Brook Project area, showing the Lid Brook where most of the river protection works were undertaken and the approximate beats of the four fishing clubs that control the fishing in this section of the By Brook.

3. Financials

A budget and monthly schedule was agreed at outset totalling £182,690 of which, in kind contributions were to be made to the value of £28,200. This meant a cash spend from the Environment Agency of £154,490 in total. A summary of the monthly invoices provided by BART, which total £144,490 is given in Table 1. At the project end date there was an under-spend in cash terms of £10,000, which resulted from difficult weather conditions, which prevented some planned works from being undertaken. This underspend was highlighted by BART and the Agency were notified early, to enable the funds to be used elsewhere by the EA.

Table 1. By Brook project spend invoiced to the Environment Agency

Budget line	**Spend**
Project Officer	£ 18,000
Project Management	£ 20,000
Travel	£ 2,700
Eng & Con	£ 2,000
Monitoring	£ 17,500
Consents	£ 1,000
FP 1	£ 22,190
FP 2	£ 20,800
Training	£ 1,000
Crossings	£ 5,000
Fencing	£ 34,300
Total	**£ 144,490**

In addition to the contribution provided by the EA (Table 1), in-kind contributions totalling £30,587 were recorded during the project comprising:

- Landowners £13,787
- Richard Vivash £5,000
- BART £10,800
- Fishing Clubs £1,000

It is likely this is an underestimate as the levels of engagement have been high and many informal contributors have not been included. The contribution could have been higher but poor weather meant that a number of opportunities were lost. However, in-kind contribution continues to accrue, even though phase 1 has been completed, as the relationships we have built need to be nurtured and there is considerable pre-planning and on-going discussion regarding next steps.

The under spend of the EA budget was caused as a result of a combination of two main factors:

1) This was phase one of a project, with many new relationships to build and confidences to be won. Levels of awareness regarding improvement opportunities and the trust necessary to implement those opportunities takes time to build and a single-phase project cannot convince

everyone to make changes simultaneously. A number of opportunities remain to be addressed in future phases of this project and we are confident that, as the benefits to those farmers who have already engaged in the project are seen by others, greater take-up will follow.

2) The project took place in a record breaking year for rain and flooding. This not only made access and work difficult but also presented challenges to landowners and farmers meaning they had less opportunity to engage because of their own workloads. As we are sure the EA are aware, flooding makes conversations about environmental improvements more difficult as confidence is already low. Two improvement projects originally agreed by the landowners were shelved (we hope temporarily) as a direct result of a "fear" factor that the changes might be detrimental in times of flood. It will take time to overcome these difficulties.

Financial management of the project was robust, with stakeholders kept fully informed throughout. Overall value for money is for the Environment Agency to assess but BART believes the work completed has been achieved significantly below a market valuation.

A very open relationship was built between the BART project Manager, Ian Mock, and Jeremy Taylor of the Environment Agency, who provided oversight and guidance. Sufficient time was made available by Jeremy to allow a full discussion of progress as it was being made, which enabled change to be managed in a pro-active way to deliver best value to both the Environment Agency and the catchment. The considerable support given by Jeremy Taylor and his Environment Agency colleagues was instrumental in the success of the project and BART would like to sincerely thank Jeremy and his colleagues for their support.

4. Engagement

Engagement with landowners, farmers, angling clubs and other stakeholder groups with an interest in the By Brook was essential to achieving any improvements and was therefore a central activity for BART's Project Officer and the wider team throughout the project. This engagement work is seen as on-going and will continue throughout the following phases of the project. Trust-building takes time and is an essential pre-requisite to gaining support and agreement to carry out works on the ground.

All farmers with riparian frontage within the catchment were contacted and visited by BART's Project Officer and these were followed up with a continuing process of engagement, focussed on encouraging catchment-sensitive farming practices and gaining approval for riparian protection works to be carried out. Due to the sensitivities involved, individual details will remain confidential. However, it was clear that many of the farms could benefit from developing nutrient management plans and there is considerable scope for infrastructure improvement to safeguard the environment on several farms. Similarly, it was clear that the catchment could benefit greatly from a concerted effort to raise awareness of both the environmental and long-term financial consequences of commonly encountered land management practices.

Landowner agreements were signed by four farmers to enable works to be carried out at key locations and, given the time available, real progress was made in developing an understanding amongst the farming community of the importance of this work, both to the environment and to the economic viability of their farms. However, it is unlikely that lasting improvements will be made unless this relationship and the continued education amongst the farming community is developed as a priority in the future phases of the project. Hence, building on the progress made so far will be a primary focus for the next phase of the project.

Numerous meetings, walk-over surveys and project development workshops were held with the four fishing clubs that control beats within the project area, to help develop and agree river restoration plans. These were: Ford Fly Fishers, By Brook Fly Fishers, Two Mills Fly Fishing Club and Bathampton Angling Club. Further details of proposed and completed works are given in Chapter 7.

Friends of the By Brook Valley (FoBV) meetings were attended by BART members who gave regular presentations and updates on the project's progress. This influential group provided an opportunity to engage with a wide-range of interested parties in a single forum and BART have so far been given great support from the group.

Numerous meetings were held with owners of fish migration barriers and interested parties to raise awareness of the issues, to enable survey work to be undertaken and to gain support for potential mitigation works.

River fly monitoring training sessions were held for local interested parties to develop a network of "River Watchers" who will regularly monitor invertebrate populations into the future.

A "Love My River Day" was held in Box on April 12th for children, parents to encourage an interest in the river and over 30 kids and their parents had fun learning about the river and its ecology. The Wild Trout Trust, Environment Agency, Avon Invasive Species Forum and Wiltshire Wildlife Trust had stands with fun and interactive games, including creating your own farm model, badge making, Easter bunny hunt, and trays of river bugs to look at and identify. However, the most popular of all was the emriver model. The emriver model (Figure 2) provides a way of simulating normal riverine processes such as sediment transport and deposition processes. It also provides a way of visualising the impacts of different river and riparian issues such as the impact of weirs, and the effect of dredging. The model is both educational and fun and certainly kept most of the children captivated for a number of hours!

Figure 2. Kids having fun while learning about fluvial dynamics on the emriver model at the BART "love your river day".

5. Fish passage feasibility work

Fish diversity in the middle reaches of the By Brook is the primary WFD failing element, which is currently classified as poor. Initial investigations, prior to the project's inception, coupled with more detailed surveying during the project have identified 14 fish migration barriers in the stretch between Ford, at the upper end and the confluence with the Bristol Avon at Bathampton, which marks the lower end of the failing stretch (Table 2).

These migration barriers, together with the associated straightening and deepening of the river channel in several locations, are thought to impact the natural fish populations in four main ways:

1. Prevention of access by migratory salmonids and eels to the upper reaches of the By Brook for spawning

2. Prevention of natural up-stream migration of coarse fish, particularly for spawning, which, as well as reducing fish species diversity, may also have implications on food availability in the form of coarse fish fry, to enable the trout to reach their full growth potential

3. Segmentation of habitat, preventing local populations of brown trout from accessing habitat diversity required for full life-cycle, necessary to sustain a viable and healthy population

4. Sedimentation of spawning gravels and resultant changes in macrophyte assemblages, due to the slowing of flow and resultant sedimentation, upstream of some structures.

Table 2. Fish migration barriers discussed in this report

Site No.	Site Name	NGR	Waterbody	Priority	Ownership / Responsibility
1	Ford Mill	ST8421274819	GB109053087390	2	Shaun Williams
2	Weir d/s Ford	ST8374874517	GB109053027380	1	Ford FFC/Lord King/EA/ByBrook Ltd
3	Sluice d/s Ford	ST8381174512	GB109053027380	1	Ford FFC
4	Slaughterford Gate (EA Steel Sluice)	ST8369173873	GB109053027380	1	EA
5	Rag Mill (Slaughterford)	ST8385273794	GB109053027380	1	Ford FFC
6	Chapps Paper Mill	ST8425373788	GB109053027380	1	Karen Crawford
7	Weavern Mill (Farm)	ST8405671729	GB109053027380	1	Richard Merrymead
8	Widdenham Mill (Farm)	ST8376471018	GB109053027380	1	Pete Evans
9	Drewitts Mill	ST8322869848	GB109053027380	2	Peter Gabriel
10	Box Mill (Real World Studios)	ST8257168937	GB109053027380	1	Peter Gabriel
11	Middlehill Gauging Weir	ST8141568810	GB109053027380	1	EA
12	Shockerwick Mill (old) Weir	ST8041968165	GB109053027380	1	TBC
13	Railway Sluice	ST7978767394	GB109053027380		EA
14	Bathford Paper Mill	ST7899967171	GB109053027380		EA

The two furthest downstream barriers, Bathford Paper Mill and the Railway Sluice, were outside of the BART area of responsibility in the first phase of the By Brook project. Of the remaining thirteen structures, two were dilapidated and no longer thought to present a barrier to fish migration. These were Drewitts Mill, owned by Peter Gabriel and Chapps Paper Mill, owned by Mr and Mrs Crawford. Each of the remaining eleven structures were surveyed for fish passage and feasibility-level designs were prepared by Mike and Matt Beach Fish Pass Engineers, giving possible routes for pool and traverse or Larinier-type fish pass options. Full details and drawings for these are given in Appendix 1: Fish pass feasibility designs.

While these options are likely to be acceptable in some locations, in others, more natural and holistic solutions would be preferable. In some locations, the existing structures are in a very poor state of repair, have no historic value and no longer serve any purpose. In these circumstances, it is recommended that complete, or at least partial removal of the structure is considered as the best option.

The most heavily impacted stretch of river in relation to fish passage is the stretch between Ford at the upstream end and Slaughterford (Figure 3), in which there are 4 barriers (previously 5 until recently when Chapps Mill was partially removed). Here, the By Brook is segmented into short sections that do not provide the diversity of habitat necessary to sustain viable populations of the predominant natural species of Brown Trout *Salmo truta*. This is the only stretch of the By Brook that receives regular stocking of farmed, triploid trout, to supplement the natural population.

There are several sensitive and complicating factors relating to the ownership, public accessibility, historic value and maintenance liability of the existing structures along this stretch. These have been considered in much detail and have been the subject of an on-going engagement process with the interested parties. Due to the sensitivities involved and on-going status of these negotiations, some of the detail will remain confidential at this stage.

In addition to these sensitivities, there is public access to most of the structures in this stretch and three of them act as crossing points. This would increase the visual prominence of the hard-engineered Larinier and pool-and-traverse type fish passes and would increase the cost of these options, as additional foot bridges would have to be constructed across each of them.

To account for these sensitivities and the on-going maintenance liabilities of the existing structures, more naturalised and holistic proposals are being developed for this section of the By Brook (Section 5.13). This proposal combines improved fish passage, enhanced river habitat, improved visual aspect, retention of historic structures and reduced maintenance liability for landowners and the Environment Agency, along what is currently a heavily impacted and modified stretch.

The By Brook has a population of native white-clawed crayfish and work to understand the population health, pressures (from encroaching signal crayfish) and geographical spread in the Brook is on-going. Any works to enable fish passage will have to demonstrate that it will not adversely impact upon the resident white-clawed population or will have to include mitigation actions, which may include re-location.

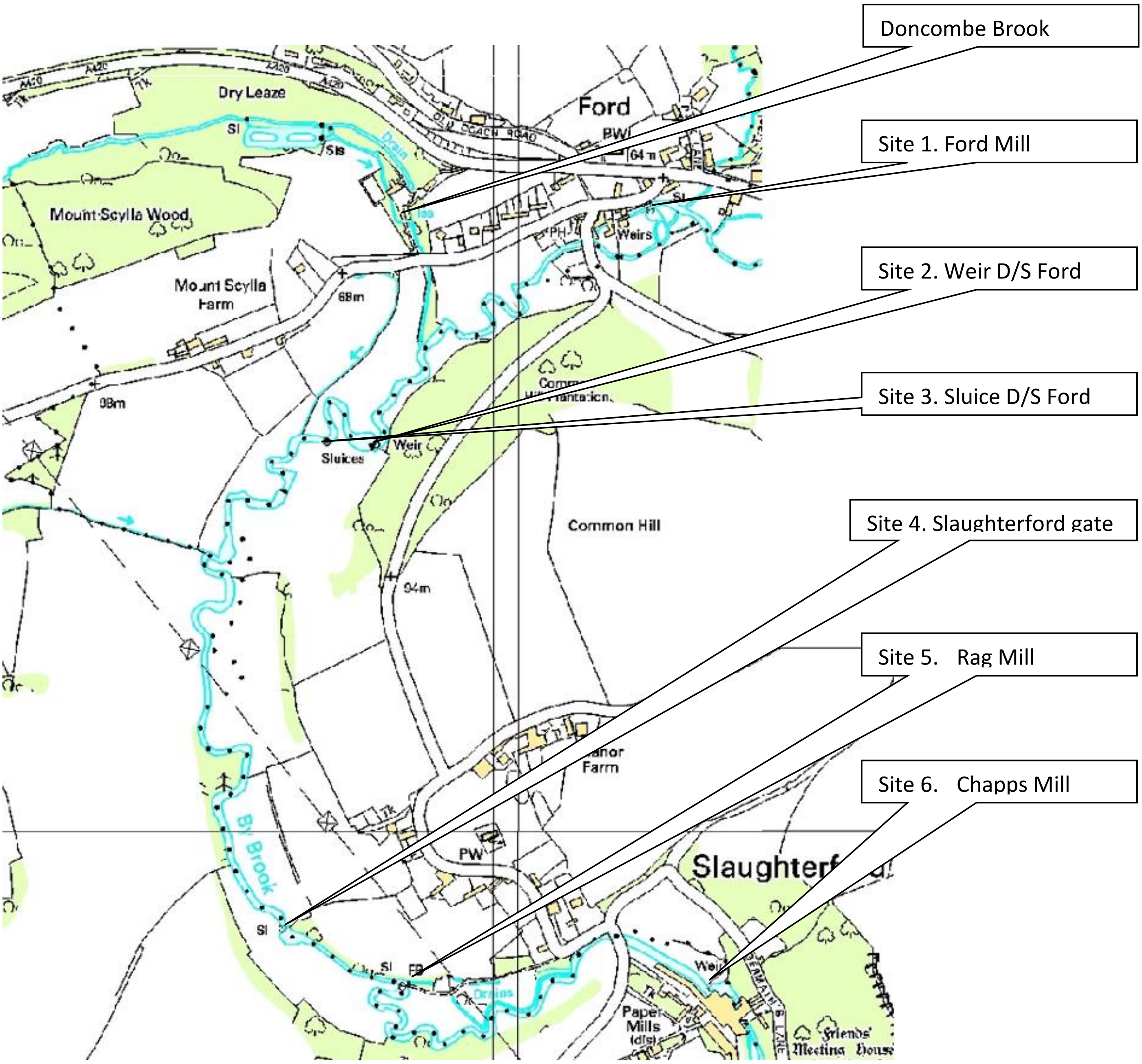


Figure 3. Fish migration barriers on Ford Fly Fishers' stretch of the By Brook

5.1 Site 1. Ford Mill

Ford Mill (Figure 4 andFigure 5. Ford Mill watercourses showing position of Ford Mill weir) is owned by Mr Shaun Williams. The structure is the furthest upstream fish barrier in this study area and is in a very poor state of repair. Some make-shift attempts have been made to shore-up the structure using sandbags but this is a temporary solution and it seems likely that, unless significant, longer-term repairs are undertaken, the structure will partially collapse in the near future.

Figure 4. Ford Mill Weir showing partial collapse on the far side

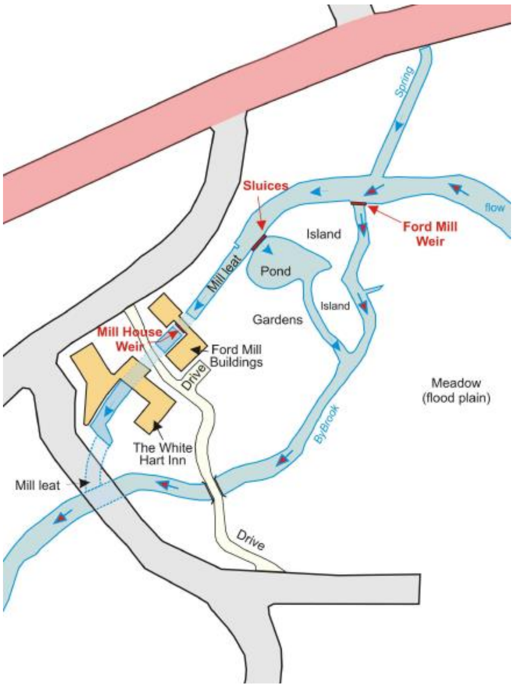


Figure 5. Ford Mill watercourses showing position of Ford Mill weir

Ford Mill weir forms part of a complex, historic milling system, which currently provides an important visual amenity for the White Hart Inn at Ford and the old Ford Mill buildings, which are now residential. The Mill leat discharges back into the main river channel beneath the road bridge immediately downstream of the White Hart. Removal of the weir would impact on the visual character of the existing buildings and is therefore not considered as a viable option.

The proposed solution comprises a series of pre-weir structures, constructed from natural stone and a 7 metre Larinier style fish pass (Appendix 1: Fish pass feasibility designs from Mike and Matt Beach fish pass engineering consultantsSite 1. Ford Mill Weir). A prerequisite to any works being carried out to facilitate fish passage would be for the weir to be fully repaired by the owner. This work could be carried out in conjunction with the fish passage works to reduce overall cost by having one set of machinery, one pre-lims cost and a single contractor. Given this situation, budget costs have not been prepared for this site. However, a budget cost of £9-10k has been given to carry out all necessary surveying, detailed design, engineering drawings and permissions preparation, to enable the scheme to go ahead.

The river downstream from this site for approximately 2 km is heavily impacted in respect of fish passage by five (previously six until recently) further structures between here and downstream of Slaughterford (sites 2 -7). There is only one tributary along this stretch, which is the Doncombe Brook.

5.2 Site 2. Weir downstream of Ford

The weir downstream of Ford (Figure 6) is owned by Lord and Lady King but maintenance and repair is the responsibility of Ford Fly Fishers, who rent the fishing rights along this stretch of the By Brook. Feasibility design options for both pool and traverse and Larinier type fish passes have been prepared (Appendix 1: Fish pass feasibility designsSite 2. Weir D/S Ford). Budget costs for detailed preparation and installation are expected to be between £70 and £90k, depending on the choice of footbridge.

The weir and sluice infrastructure is in generally sound condition but there is considerable erosional force during spate conditions.

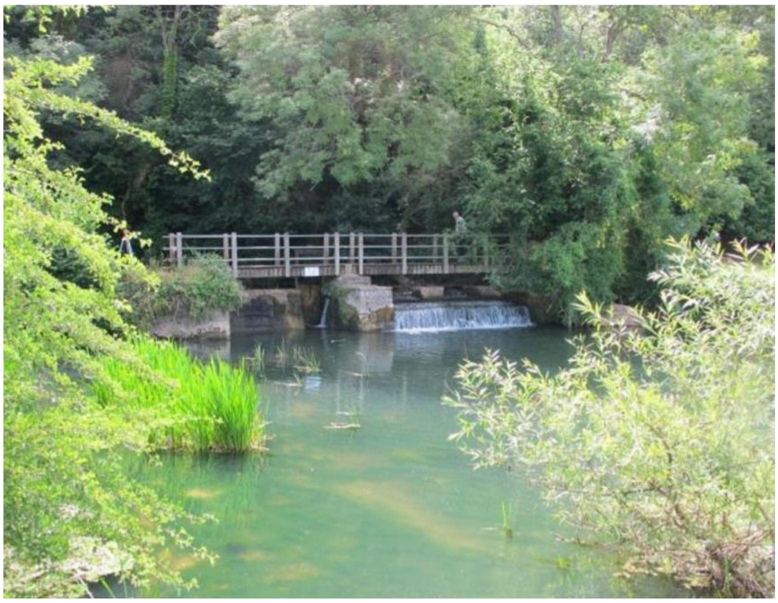


Figure 6. Weir D/S Ford

As can be seen in Figure 6, the structure also comprises a footbridge, which forms the river crossing on a public right of way. This has implications for the installation of a fish pass from both aesthetic and cost perspectives, as public access would have to be maintained during construction and a footbridge would also have to be constructed as part of the fish pass installation.

The next structure (Site 3, Sluice D/S Ford) is located within 150 metres downstream of Site 2. During flooding episodes, floodwater breaches the bank 50 metres upstream of Site 2 and follows the natural landscape depression, thought to be the original stream course and re-enters the main channel close to Site 3. It is recommended that a landscape-scale solution to improve fish passage, ecological diversity and flood storage at both sites, incorporating the re-instatement of a meandering channel with a natural pool and riffle structure, be developed in detail for consultation with principle stakeholders. Initial site topographical surveying to enable the development of a concept design has already been undertaken during Phase 1, and this will be developed for consultation during Phase 2.

5.3 Site 3. Sluice downstream of Ford

Site 3, Sluice D/S Ford, (Figure 7) is a substantial concrete structure with a steel sluice, situated approximately 150m downstream of Site 1. Site 3 was re-built using concrete during 2006/7, following previous collapse. The structure is thought to have been constructed originally to maintain a depth of water at the upstream structure (Site 2), to prevent under-cutting of the weir. The structure is of no historic or aesthetic interest and does not form a public access river crossing. However, the structure does provide fishable water for the Ford Fly Fishers, who control sluice level and have responsibility for the structure's upkeep, for approximately 100 metres upstream of the sluice and the club is keen to maintain this if possible.

Figure 7. Site 2, Weir downstream of Ford

Both fish pass options given in Appendix 1: Fish pass feasibility designs from Mike and Matt Beach fish pass engineering consultants include a lowering of the weir height, which will impact to some extent the length of fishable water upstream of the structure. This has been discussed with and would be acceptable to Ford Fly Fishers. However, as there are no other functional, historic or aesthetic reasons for retaining the structure it is questionable if the installation of an engineered fish pass would be the most cost-effective or sensible method of enabling fish passage. That said, complete removal of the structure would render the upstream stretch virtually unfishable and would lower the level of water in the upstream weir-pool and may cause structural damage to the upstream weir (Site 2). For these reasons, removal is not favoured by the fishing club who have responsibility for the maintenance and sluice level control.

As introduced for Site 2 above, the installation of a naturalised bypass channel, possibly following the original stream course is an option favourable to all stakeholders engaged to date and is under development.

5.4 Site 4. Slaughterford Gate

Slaughterford Gate (Figure 9a and Figure 9b) is a steel weir structure currently owned by the Environment Agency, which was originally constructed to provide a reservoir for the historic rag mill, which formed part of the next structure downstream (Site 5 Rag Mill).

Water level control has been non-operational since an electrically-driven automatic sluice control mechanism became jammed several years ago. Upstream of the structure is a widened and straightened section of river, approximately 150 meters long, with a maximum depth of around two metres. This stretch is favoured by anglers for its ease of fishing but offers little in the way of habitat diversity and is very sluggish. The degree of siltation of the bed is unknown but there is severe bankside poaching from livestock.

Slaughterford Gate is the subject of on-going negotiations between the EA, By Brook Ltd (the current owners of the river bed at this point) and Lord King, the adjacent landowner. Responsibility for maintenance currently lies with the EA and this is also the subject of these negotiations. The currently preferred option amongst those proposed by the EA to the owner, is the removal of the steel sluice, to be replaced by boards, which it is understood would be the responsibility of the FFF to maintain and adjust. This solution would not, in itself, enable fish passage and it is unlikely that these works could not be undertaken under current regulations and EA guidance, without additional measures to enable fish passage also being included.

The structure also forms a river crossing with public access (Figure 9b). Hence, any engineered fish pass on either side of the structure would also require the construction of a footbridge and public access would have to be maintained during construction.

Figure 9a. Slaughterford Gate from downstream showing steel sluice with approximate 1.8 metre drop

Figure 9b. Slaughterford Gate from upstream showing non-functional electric level control mechanism, public footpath crossing and widened section of river above sluice.

Two potential fish pass solutions, both comprising hard-engineered, pool and traverse structures, have been proposed as feasible options (Appendix 1: Fish pass feasibility designsSite 4. Slaughterford Gate Steel Sluice). However, due to the large drop in level to be overcome, both options require substantial infrastructure, which would cause the loss of a small area of grazing and this, combined with the visual impact make these options unlikely to be acceptable to either landowner. It is expected that either of these options would cost in the region of £80 - £100k to complete.

During winter flooding episodes, floodwater bypasses the sluice on both sides. On the right hand bank, floodwater escapes the current channel approximately 100 metres upstream of Site 4 and follows a natural landscape depression, assumed to be the original stream course, re-entering the channel downstream of Site 5, the Rag Mill. On the left hand side, floodwaters breach the channel some distance upstream of Site 4 but re-enter the main channel immediately to the left of the sluice. This is currently causing substantial erosion at this point, which may cause future structural damage to the sluice.

It is recommended that a natural infrastructure solution be considered to address both flood control and fish passage across this structure and the downstream Rag Mill. Detailed topographical surveys to inform this concept have been undertaken and a feasibility-level proposal is presented in section 5.13. This has been discussed in detail with the landowners, who are in favour of this option being taken forward.

5.5 Site 5. Rag Mill

The Rag Mill weir, which includes a public footbridge across the By Brook (Figure 10), is owned by By Brook Ltd and maintenance is the responsibility of FFF, as part of their lease agreement. The structure comprises a stepped concrete weir with removable boards and is currently in a poor condition. A significant proportion (an estimated 60% on the day of survey) of the flow actually flows through the structure, instead of over the weir. Ford Fly Fishers have received verbal estimates for the required repair works, which are in the order of £10,000. The weir currently receives 100% of the river flow, except in extreme high flow conditions when, as described above, a proportion of floodwater bypasses both this and the upstream Slaughterford Gate sluice. This puts a great deal of pressure on the weir structure, which will result in a continual maintenance burden for the fishing club, or collapse of the structure in the coming years.

Figure 10. Rag Mill Weir

Two possible hard-engineered solutions are presented in Appendix 1: Fish pass feasibility designsSite 5. Rag Mill, one each side of the weir, both comprising pool and traverse structures and a public footbridge. If either of these options were to be implemented, it would also be essential to carry out comprehensive repairs to the weir structure to ensure a lifespan commensurate with the expected life of the fish pass. However, neither of these options would address the continued erosional pressure on the structure during high flows, resulting from the existing modified river channel configuration. Following consultation with the Ford Fly Fishers in the light of these considerations, it is recommended that the natural-infrastructure proposal, given in section 5.13, be implemented to address both this site and the upstream Slaughterford Gate fish passage issues.

5.6 Site 6. Chapps Paper Mill

Chapps Paper Mill weir was not surveyed as part of this work as it has been partially demolished and is no longer an obstruction to fish migration.

5.7 Site 7. Weavern Mill (Farm)

Weavern Mill weir is a concrete structure, hidden by dense woodland, which is in a state of considerable disrepair and serves no current purpose. Potential options for fish passage are given in Appendix 1: Fish pass feasibility designs from Mike and Matt Beach fish pass engineering consultantsSite 7. Weavern Mill However, given its poor state of repair, it is recommended that the best option is removal, at least in part, to enable a natural re-alignment of the channel bed and to allow fish passage.

5.8 Site 8. Widdenham Mill (Farm)

Widdenham Mill is owned by Widdenham Farm and there is no current appetite by the owners to have a fish pass constructed. Potential fish pass options have been prepared (Appendix 1: Fish pass feasibility designsSite 8. Widdenham Farm Weir) for future discussion but it is not recommended that further resource be directed towards this at the present time.

5.9 Site 9. Drewitts Mill

Drewitts Mill is owned by Peter Gabriel and has been allowed to deteriorate such that it is no longer a barrier to fish migration.

5.10 Site 10. Box Mill (Real World Studios)

Box mill is also owned by Peter Gabriel and lies within the curtilage of the Real World Studios (Figure 11). This structure comprises four steel sluices which maintain a hydrostatic head of over 2.8 metres, making this the largest fish migration barrier on the By Brook. Consultation with the owner's representative at the Real World Studios regarding works to enable fish passage has been favourable and engagement is on-going. As a result, and following discussions with EA colleagues, a second-phase of more detailed design work was undertaken, along with budget-level costing.

The recommended option that was taken forward for phase-2 design was a 2-stage Larinier Super-Active fish pass, with elver pipe, along the course of an existing back-channel (Appendix 1: Fish pass feasibility designs from Mike and Matt Beach fish pass engineering consultantsAppendix 2: Stage 2 designs for Box Mill, Middlehill Gauging Station and Shockerwick weir

Site 10: Box Mill (Real World Studios)). The estimated cost for completion of these works, including all prelims is *ca.* £150,000.

Figure 11. Box Mill at Real World Studios

In addition to the Larinier Super-Active fish pass option outlined in Appendix 1: Fish pass feasibility designs from Mike and Matt Beach fish pass engineering consultants, this site has also been surveyed in detail for the construction of a more naturalised solution, using an existing back-channel. A concept drawing detailing this option is given in Appendix 1: Fish pass feasibility designs from Mike and Matt Beach fish pass engineering consultants Appendix 2: Stage 2 designs for Box Mill, Middlehill Gauging Station and Shockerwick weirSite 10: Box Mill (Real World Studios) 2-stage Larinier Super-Active fish pass with elver pipe. This option, whilst being more naturalised in appearance than the Larinier proposal, would have a fall of approximately 1:50, which presents some engineering and fish passage complications. In addition, more detailed surveying of flows may show that the outflow from this existing channel is insufficient in its current location to be attractive to fish.

Nevertheless, it is an option worth considering and will be on the table for continued discussions with the mill owner and the EA.

5.11 Site 12. Middlehill Gauging Station

Middlehill Gauging Station (Figure 12) is owned by the Environment Agency and was included in this work at their request. Survey and fish pass design work was carried out and a single Larinier super-active fish pass was proposed as these are registered as calibrated hydrometric structures. Following further consultation with EA colleagues, a second phase of detailed design was undertaken (Appendix 2: Stage 2 designs for Box Mill, Middlehill Gauging Station and Shockerwick weirSite 11: Middle Hill gauging station) and budget costs were prepared, which suggest a total estimated cost of around £120k. The EA are also considering an option comprising baffles within the weir structure, which would form a series of pools and riffles to enable fish passage.

Figure 12. EA-owned Middlehill Gauging Station

5.12 Site 13. Shockerwick Mill

Shockerwick Mill (Figure 13 a & b) is a concrete structure of unknown purpose, with a steel sluice. The operational purpose and regime for the sluice is unknown but it is clearly operated as can be seen by the changed position in Figure 13. To enable fish passage across the structure, a combination of lowering the weir crest and installing structures downstream of the weir to reduce the hydrostatic head, coupled with a short pool and traverse fish pass alongside the weir structure, is proposed (Appendix 2: Stage 2 designs for Box Mill, Middlehill Gauging Station and Shockerwick weirSite 12: Shockerwick weir). The expected cost of this work is in the region of £140k. If removal of the weir is considered preferable, care must be taken in surveying and understanding any potential risks to the upstream bridge supports, which can be seen in the background of Figure 13. The landowner has not yet been consulted over these proposals and Bathampton Angling Association have not yet given their support. If fish passage across this structure is to be realised, consultation early in Phase 2 is recommended.

Figure 13a. Shockerwick weir in normal winter flow conditions with open sluice and Figure 10b.

5.13 Proposed landscape-scale solution for Slaughterford Gate and Rag Mill

In addition to the standard fish pass options presented for Sites 4 and 5 earlier, two potential larger-scale solutions have been developed to concept-level and discussed with the landowners (The King family) and the Ford Fly Fishers. Both these options use natural infrastructure to enable fish passage. Neither option is sufficiently developed to enable accurate costing at present but it is thought likely that they would be similar in cost to the combined fish pass options discussed above.

The first of these comprises a series of naturalised riffles, using local Cornbrash stone, to raise the water level, in conjunction with the replacement of the Slaughterford Gate steel weir with a notched board and a reduction in the height of the Rag Mill weir (Figure 14 andFigure 15). This would enable fish passage, without the addition of hard-engineered fish passes. The second of these proposals involves the construction of a by-pass channel (Figure 16), which would follow the natural low-lying ground, thought to be the original river course, where flooding currently occurs during spate conditions.

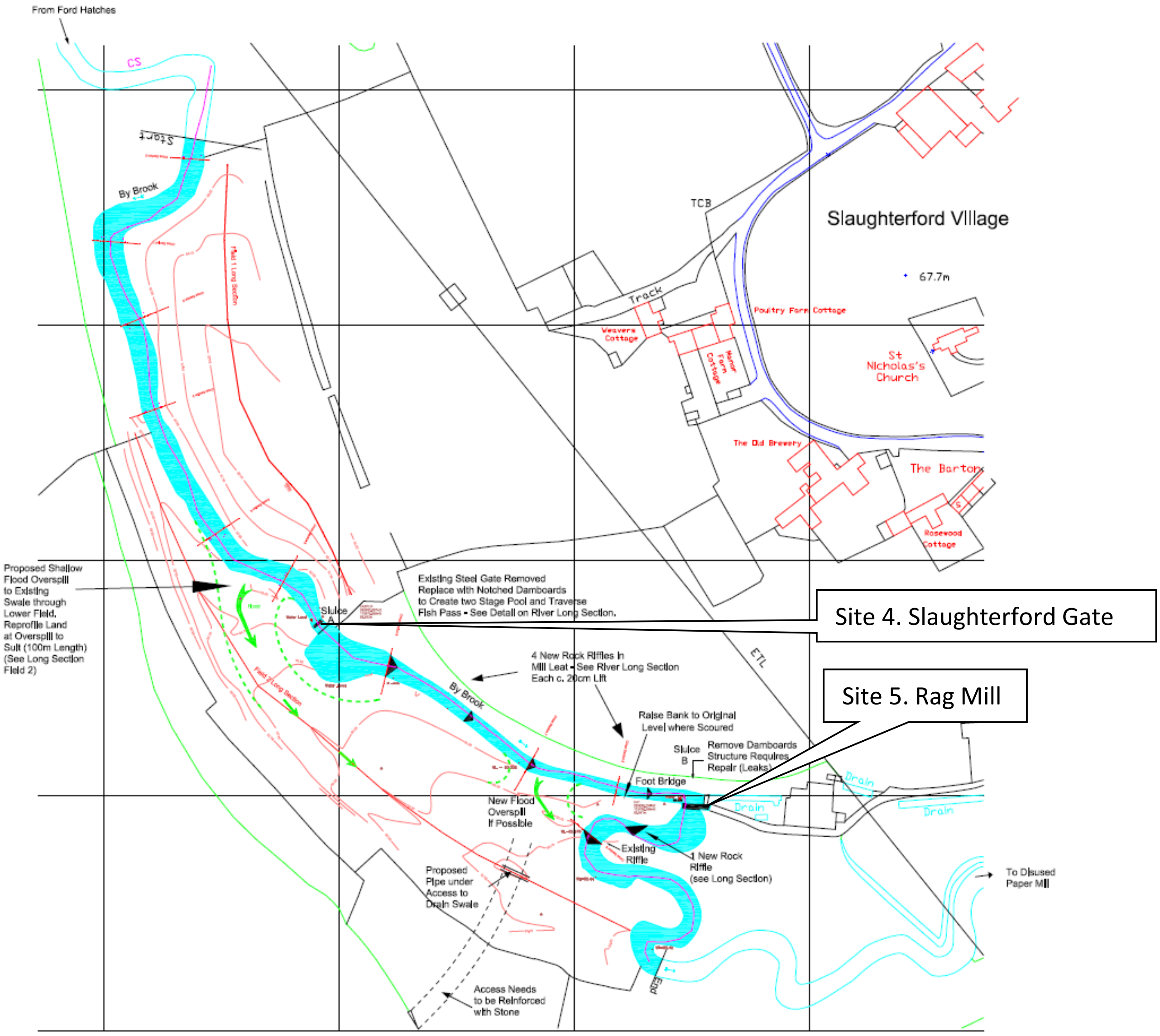


Figure 14. Plan view of riffles option for fish passage across Slaughterford Gate and Rag Mill weirs

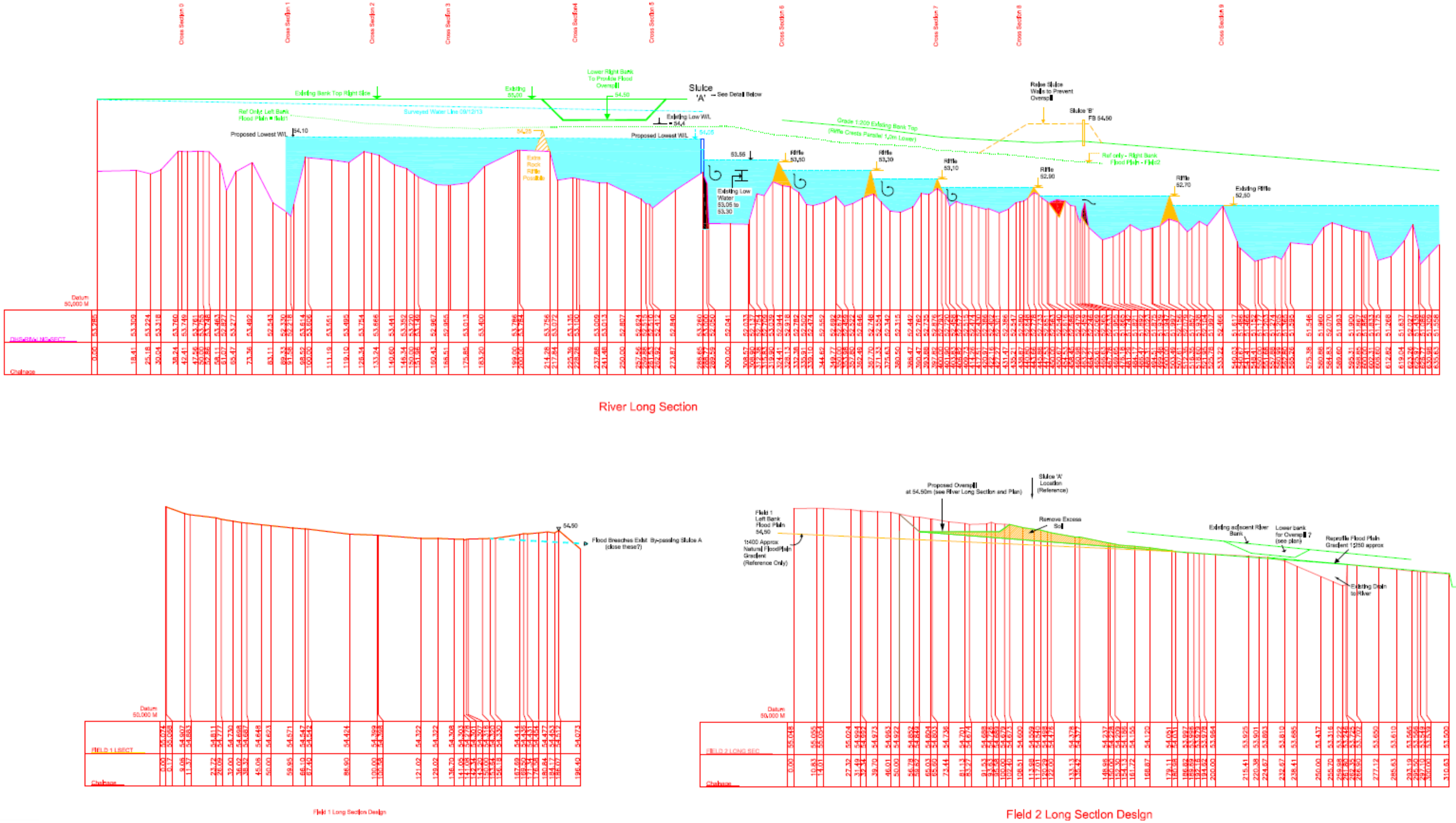


Figure 15. Long-section view of riffles option for fish passage across Rag Mill and Slaughterford Gate weirs

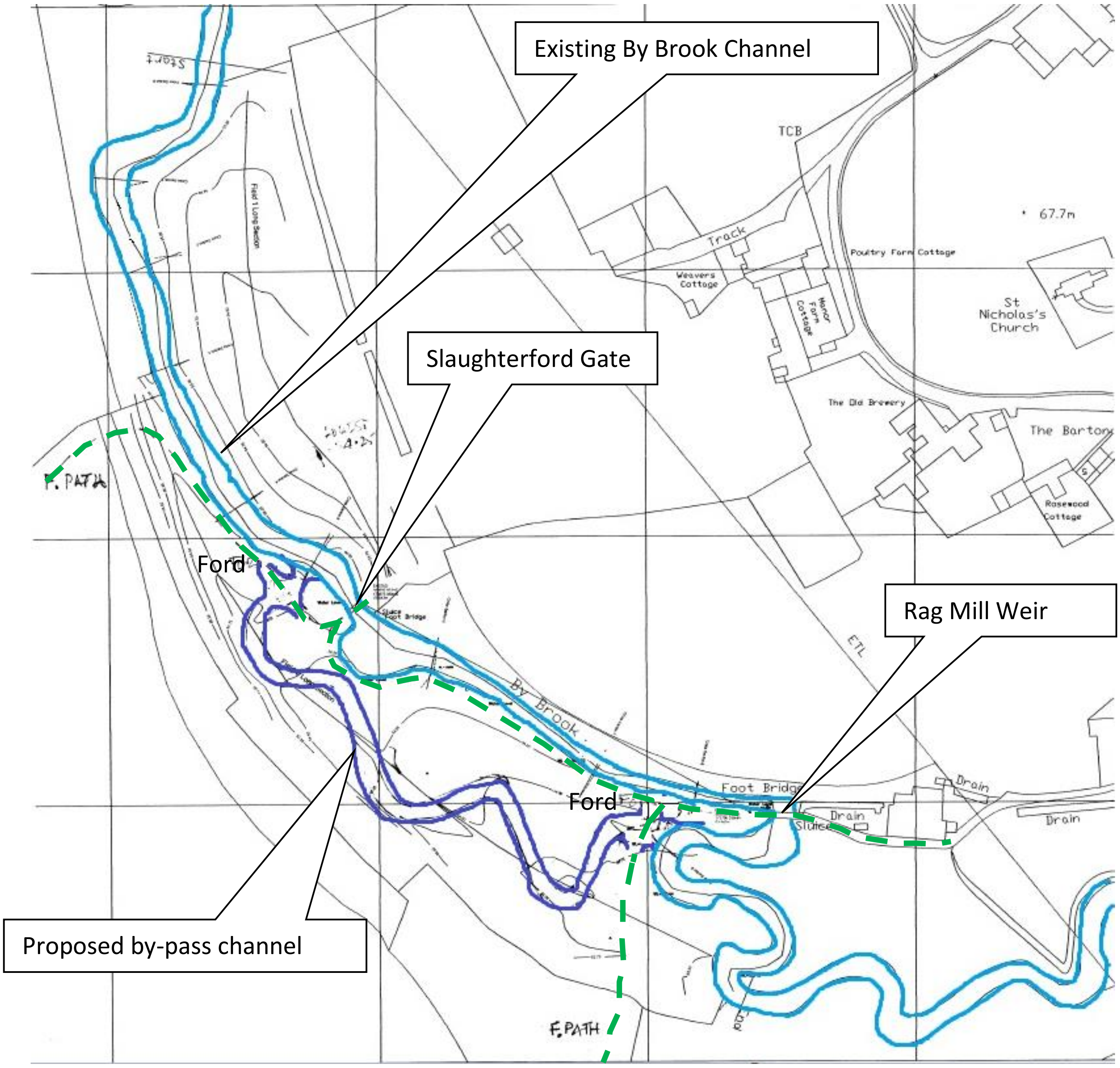


Figure 16. Plan view of proposed by-pass channel for Slaughterford Gate and Rag Mill weirs

The by-pass channel option shown in Figure 16 is the current preferred option with the landowners and is also acceptable to the fishing club. This option has several advantages over either the do-nothing option or the constructed fish pass options shown in Appendix 1: Fish pass feasibility designs from Mike and Matt Beach fish pass engineering consultants.

These include:

- Naturalised solution that greatly enhances habitat diversity
- Increased flood capacity
- Retention of historic Rag Mill
- Reduction in erosional forces on Rag Mill
- Replacement of Slaughterford Gate steel weir with lower notched-board
- Eases possibility of transfer of ownership and responsibility of Slaughterford Gate from EA

6. Ecological surveying

6.1 Fish

6.1.1 Historic EA fish survey data

Past fish survey data were collated and analysed to see if any trends in fish populations at any monitored sites could be established. Unfortunately, the sampling has been too infrequent to draw any firm conclusions. No European eels have been recorded at any locations above Box Mill since 2003, when a single specimen was recorded at Weavern Farm.

6.1.2 By Brook Project fish monitoring

Fish surveys were carried out on behalf of BART by Ahern Ecology in two locations; Fish Survey Site 1, U/S of Box Mill and Fish Survey Site 2, between Fish Pass Site 1 (Ford Mill) and Fish Pass Site 2 (Weir D/S Ford). Macrophyte and invertebrate sampling was also carried out at the same time. Detailed results are given in Appendix 4: Fish, macrophyte and invertebrate sampling data from U/S Box Mill and D/S Ford Mill As would be expected, Brown Trout were the dominant species at both sites.

At fish survey Site 1 (Upstream of Box Mill), 3-spined sticklebacks, stone loach, and minnows were found in small numbers and bullhead were more common. Four brook (or river) lamprey in the ammocoete (juvenile) stage were also found. At Site 2 (D/S Ford Mill), only minnows, 3-spined sticklebacks and bullhead were found.

Under natural conditions, a range of larger course fish species, including dace, chub, roach, gudgeon and grayling would all be expected to be found, certainly above Box Mill and, to a lesser extent, at Ford. In fact, in 1999, gudgeon, dace and roach were recorded at Drewett's Mill, upstream of Box.

It is recommended that further fish sampling be carried out at key locations along the By Brook, both to develop a clearer understanding of species currently present and to enable changes to be measured following fish migration enhancement works.

6.1.3 Angling club catch records

Angling club catch records were collected from Ford Fly Fishers, By Brook Fly Fishers and Bathampton angling clubs and assessed as part of this work. Ford Fly Fishers' data are not reported as the occurrence of non-native stocked fish, which were not separately recorded, make these data unhelpful for understanding natural fish populations. Similarly, the Bathampton data are not presented as these were too inconsistent and over too short a period to enable statistical analysis.

6.1.3.1 By Brook Fly Fishers

Catch records dating back to 1974, giving an invaluable insight into the health of the indigenous brown trout population, have been collected by the By Brook Fly Fishers club and are presented in Figure 17 and Figure 18. These data include both total numbers of fish caught each year and number of outings, which has enabled a standardised metric of fish caught per unit of effort to be calculated. The records also provide data on the number of fish taken from the fishery for the table each year and, since 1996, the number of fish over 8 inches in length. While 8" is an arbitrary value, the data could be extrapolated to give an indication of changes in the population structure over time.

Total fish caught (Figure 17) has varied considerably during the sample period from 880 in 1996 to a minimum of 261 in 2012. However, this has largely been a function of fishing effort as the number of fish landed shows a strong correlation (0.699) with the number of outings Figure 18. Hence, these records indicate that there has been no significant change in the overall numbers of fish caught per outing of 4.2 (+/- 0.87 s.d.) in the 40 years since records began. Assuming that there has been no change in the effectiveness of the fishing tackle and methods used, or in the calibre of angler using them over this time, this would suggest that there has been no change in the overall population density. This suggests that there are sufficient spawning and nursery sites, in good enough condition to maintain good recruitment.

In contrast to this, the "over 8" data appears to paint a slightly different picture. Despite a particularly good year in 2011 when 211 fish over 8" were taken in 87 outings, there appears to have been a continual decline in the number of larger fish of over 8" landed per outing. This apparent decline was not found to be significant over the entire period and the increase seen in 2009 – 11 may indicate a recovery. Hence, caution must be taken in drawing any conclusions. However, when considered in the light of the "fish taken" data (Figure 18), the proportion of larger fish becomes much more interesting.

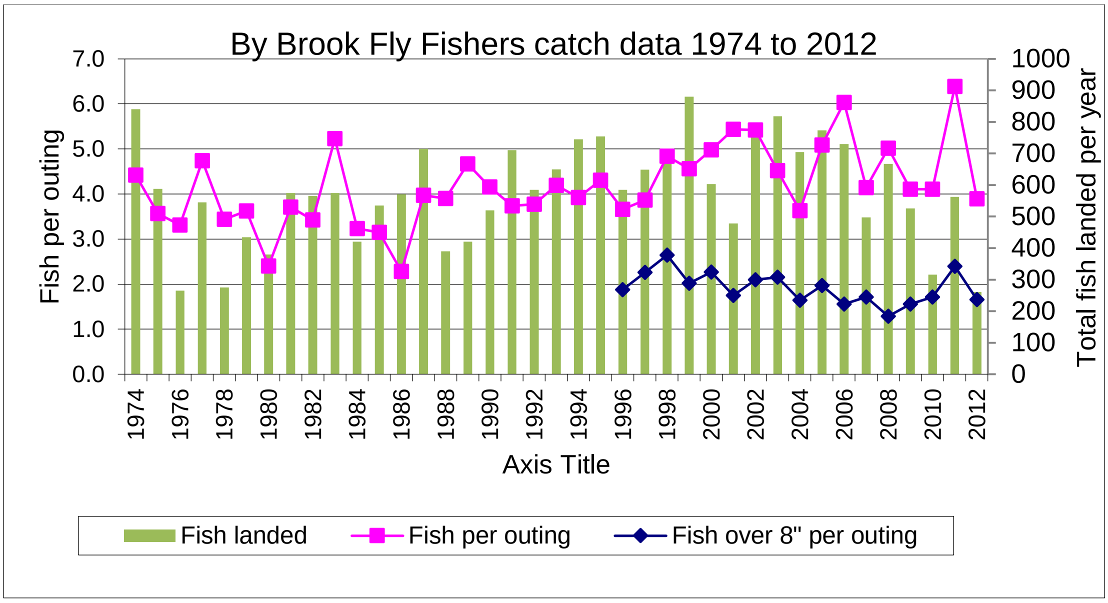


Figure 17. Catch records from the By Brook Fly Fishers club 1974 - 2012, showing total number of fish taken each year, number of fish per outing and, since 1996, number of fish over 8" taken per outing.

A preference for catch and return was encouraged in the club from around 2000, since which time the overall number of fish taken from the water each year has continually declined from an average of approximately 200 per year in the 1990's to 15 in 2012 (Figure 18). The number of fish taken as a proportion of those caught has also declined over this time. The switch to catch and release would have removed a substantial selective pressure against larger fish, as there are now close to 200 large fish not being removed each year, compared to the initial 25 years during which catch data were recorded.

This practice would have been expected to have resulted in an increase in the proportion of larger fish amongst the population as a whole. However, the number of fish greater than 8" as a proportion of the total catch shows no increase over this period, suggesting that other pressures are preventing fish from reaching the larger size classes previously encountered. We have no evidence to suggest what these pressures might be but food availability may be a contributing factor.

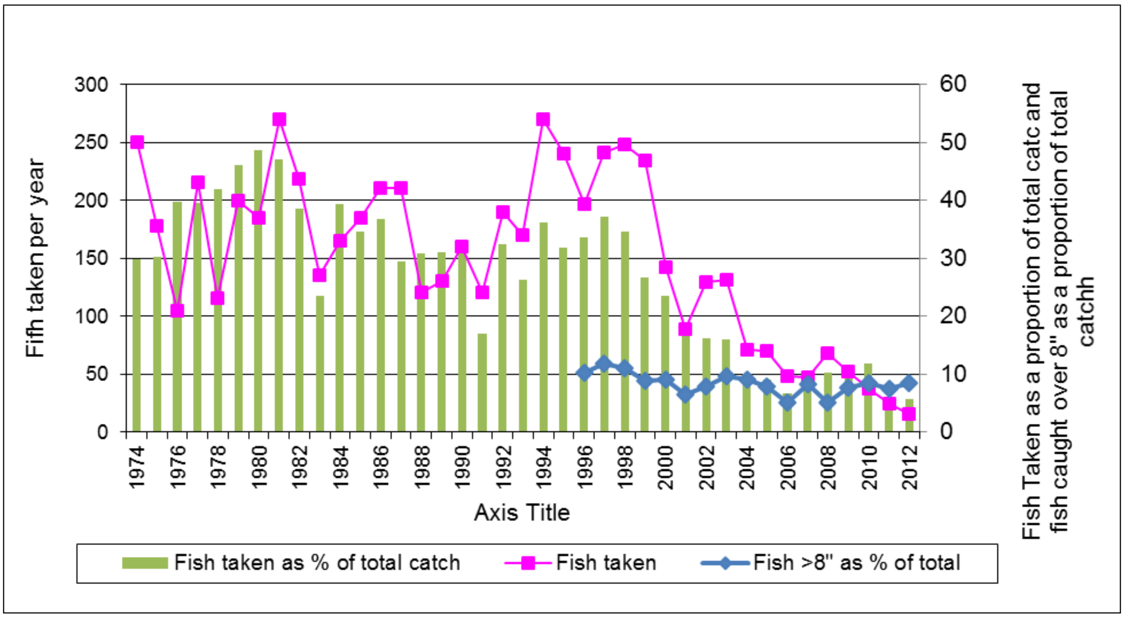


Figure 18. Fish taken for consumption from By Brook Fly Fishers' beat, as total and as proportion of catch 1974 – 2012, and fish caught over 8" as proportion of total catch 1996 to 2012.

6.2 Crayfish

An initial crayfish survey was undertaken By Lydia Robins, working for Avon Wildlife Trust, on behalf of the SW crayfish Partnership, to ascertain presence and absence of native white-clawed and invasive signal crayfish populations at each of the proposed fish pass locations. This was the first part of an on-going assessment of By Brook crayfish populations, which will be used to inform the fish passage programme of works to ensure the best possible outcome for the resident white claw crayfish population.

In all, 58 traps were set, in 20 locations and left for either one or two nights (Appendix 5: By Brook crayfish monitoring results). Seven signal crayfish were caught in two traps at adjacent locations and eleven white-clawed crayfish were caught in six traps in four locations. No crayfish were recorded in 33 traps in 13 locations. All seven signal crayfish were caught, upstream and downstream of Site 2. Weir downstream of Ford). White-clawed crayfish were also caught at this location. Three white-clawed crayfish were caught between Site 4. Slaughterford Gate) and Site 5. Rag Mill). Seven White-clawed crayfish were recorded around Box Mill but no crayfish of either species were caught in 22 traps, at locations downstream of this point, to the railway sluice, just upstream of the confluence with the Bristol Avon.

Further work to augment these findings is currently being undertaken, which, it is hoped, will form the basis of a robust mitigation plan for the remaining native white-clawed crayfish population.

6.3 Invertebrates

Fly life training provided through the project has helped to develop a network of volunteers with the skills and equipment required to begin collecting a meaningful data set of invertebrate life in the By Brook, into the future. Data collected by this network of volunteers will become part of the public record, available to all, through the Wiltshire and Swindon Biological records centre.

In addition, Ahern Ecology collected invertebrate data at the two locations where fish surveying was carried out (U/S Box Mill and D/S Ford Mill) (Appendix 4: Fish, macrophyte and invertebrate sampling data from U/S Box Mill and D/S Ford Mill). These data have been shared with Environment Agency staff for interpretation.

Invertebrate sampling was carried out by Bath Spa University students on the Lid Brook as part of the works discussed in section 7.2. Four sites were sampled (Figure 19). Sites A and B were upstream of Colerne STW where severe cattle poaching has been mitigated by fencing works carried out during December and January. Site C was just downstream of Colerne STW and Site D was downstream of Saltbox Farm. The BMWP scores for Sites A, B, C and D were 60, 36, 42 and 19 for respectively, indicating a heavily impacted and deteriorating ecological quality with distance downstream. The score of 19 recorded at Site D, downstream of Saltbox Farm indicates poor/polluted/impacted under the BMWP classification scale.

It is intended that invertebrate sampling at these sites will become a regular activity for Bath Spa University students in future academic years to build up a long-term data set.

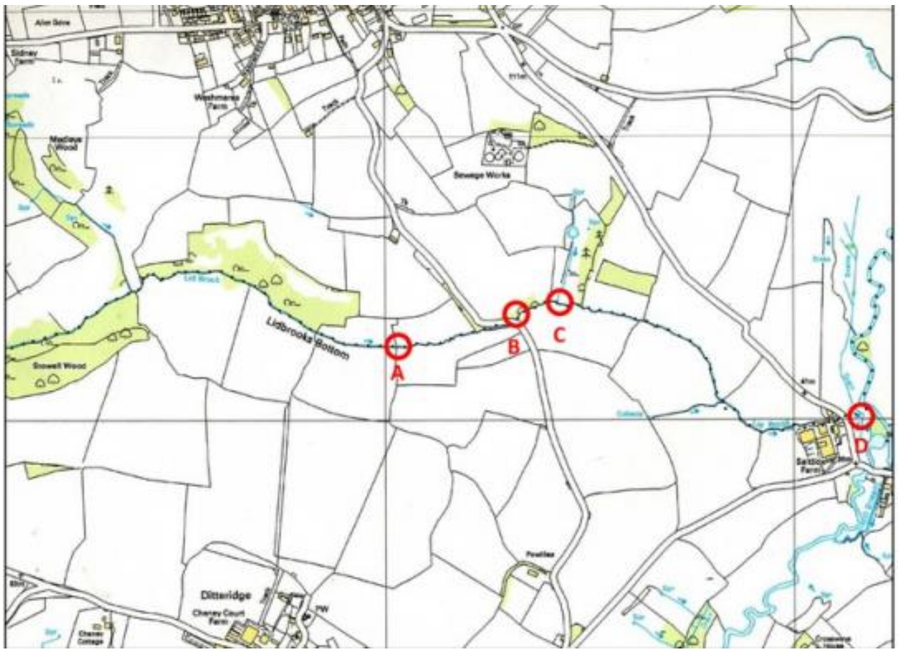


Figure 19. Invertebrate sampling sites on the Lid Brook monitored by Bath Spa University students, reproduced from student coursework report.

6.4 Water Quality

Water quality monitoring was carried out on the Lid Brook and on the By Brook, D/S of the Lid Brook confluence during two 24 hr wet-weather events on December 18/19 2013 and Jan 31/Feb 01, 2014 (Figure 23). The Lid Brook was chosen for this work as it has been identified as one of the most heavily impacted watercourses in the catchment, in terms of riparian damage from livestock poaching (Figure 21) and so was a primary focus for fencing and remedial works during phase 1 of the By Brook project. The intention is that these data will form part of a simple bio-geo-chemical baseline understanding of the state of the Lid Brook, ahead of implementation of remedial works, against which, future improvements can be measured.

This study showed that, during the 48 hrs over which samples were taken, approximately 6 tonnes of soil were lost from the Lid Brook catchment, almost 2/3rds of which was lost from the lower section of less than 1 km in length.

During the same period, approximately 46 tonnes of soil were recorded as suspended sediment in the By Brook. Associated with this sediment was approximately 85 kg of phosphorus.

Given that rainfall conditions sufficient to mobilise sediment to a greater or lesser degree than those monitored were an almost daily occurrence over the winter period, soil loss from the catchment over the winter period was likely to have been in the several hundreds of tonnes at the very least.

While a proportion of this would have been expected as part of the natural process of soil movement, it is clear that a significant proportion was the direct result of poor land management practices, as evidenced in the Lid Brook.

Soil and nutrient loss on the scale uncovered in this work has serious consequences, not only on the ecology of the Lid and By Brook system but also on future agricultural productivity within the catchment. In addition, sedimentation of this material in slower reaches of the River Avon, such as the Bath and Bristol canals and marinas where it will deposit, has significant cost implications and may increase flooding potential.

7. Catchment improvement works

7.1 Ford Fly Fishers – Proposed habitat improvements

Ford Fly Fishers (FFF) club control the fishing on the By Brook from Ford, downstream to Slaughterford. As discussed earlier in this report, this stretch is segmented into short sections of river, separated by weirs and sluices and is heavily impacted in places by cattle poaching and a lack of riparian vegetation. In addition, the channel has been artificially widened and straightened for much of its length, leading to a loss of diversity and siltation of the natural spawning gravels. As a result, the FFF beat is unable to support a viable population of wild trout and is regularly stocked with triploid fish to maintain the water as a fishery. This is in stark contrast to the By Brook Fly Fishers' stretch immediately downstream, which is much less impacted by engineered structures and maintains a flourishing population of native brown trout.

The FFF club are responsible for maintenance and repair on three of the four structures impacting on fish migration in their stretch (Sites 2, 3 and 5; Table 2). Responsibility for Site 4 (Slaughterford Gate) currently resides with with the Environment Agency and is the subject of current negotiations discussed earlier.

6.1 b) Site Plan

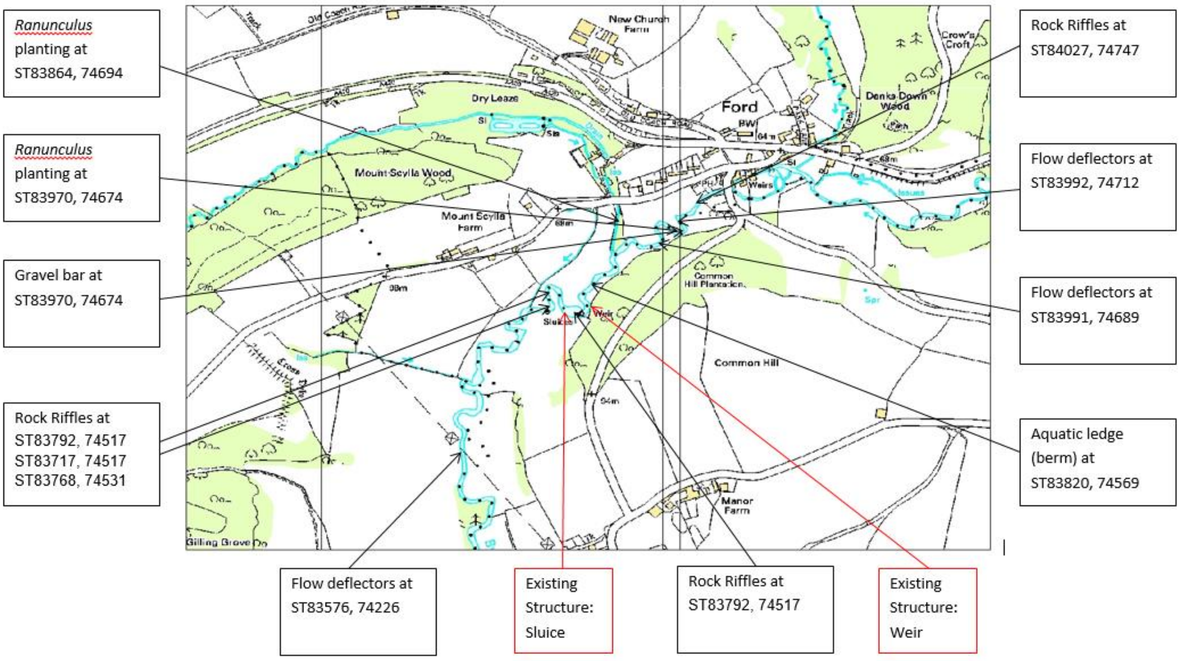


Figure 20. Planned river habitat improvement works on FFF stretch, below Ford

A programme of ecological improvement works (Figure 20) has been developed in collaboration with the FFF Club. However, this will not be progressed until a decision is made regarding the chosen fish migration mitigation option, which may impact this stretch and result in alternative measures being implemented.

7.2 Lid Brook river protection works

The Lid Brook was identified early on in the project as a key area for attention. The Brook receives treated effluent from Colerne STW (Owned by Wessex Water). The lower three quarters of the Lid Brook is intensively grazed by dairy stock, which are owned by Saltbox Farm, situated at the lower end of the Lid Brook, close to the confluence with the By Brook. This entire length of the brook was characterised by a lack of fencing and severe damage to the riparian strip and surrounding woodland Figure 21.

Land ownership is mixed but the engagement process was very successful, enabling significant improvement works to be progressed quickly. Several hundred meters of fencing (shown in red on Figure 21) was installed in collaboration with landowners and farmers. Mr Gooding of Westwood Farm, in the upper catchment, was so responsive to the advice given by BART's Catchment Officer regarding the need for fencing that he agreed to undertake all works at his own expense.

In addition, a combination of controlled in-stream cattle drinking access points and off-stream drinking was provided for stock watering. At the lower end of the brook, opposite the entrance to Saltbox farm, a gateway and watering trough that was situated immediately adjacent to the Lid Brook and had caused severe erosion was moved and re-constructed to enable recovery.

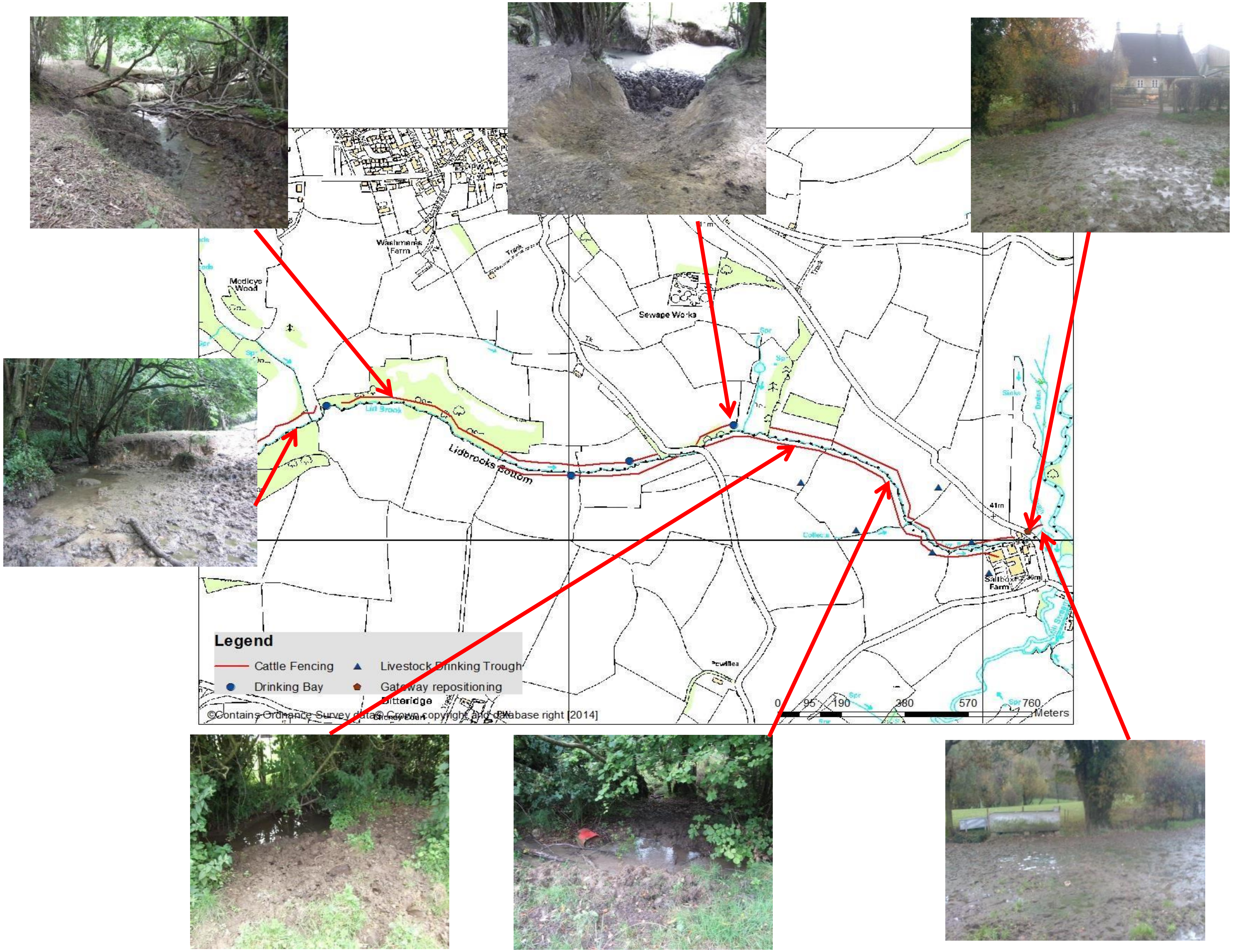


Figure 21. Lid Brook map showing images of habitat destruction identified during walkover surveys and mitigation measures undertaken

8. Conclusions

This project has highlighted a range of issues impacting upon the ecological status of the By Brook from agricultural practices to fish migration barriers and has made substantial progress in scoping and undertaking mitigation measures which, over time, could significantly improve both the ecological quality and WFD categorisation of the river.

A number of options to improve fish passage across all the barriers on the project area have been developed for consultation and a way forward is progressing for the worst impacted areas. These include river restoration proposals that, as well as enabling fish passage, will greatly enhance the ecological diversity of the most heavily impacted stretches, increase flood storage and maintain the historic interest in the remaining milling infrastructure.

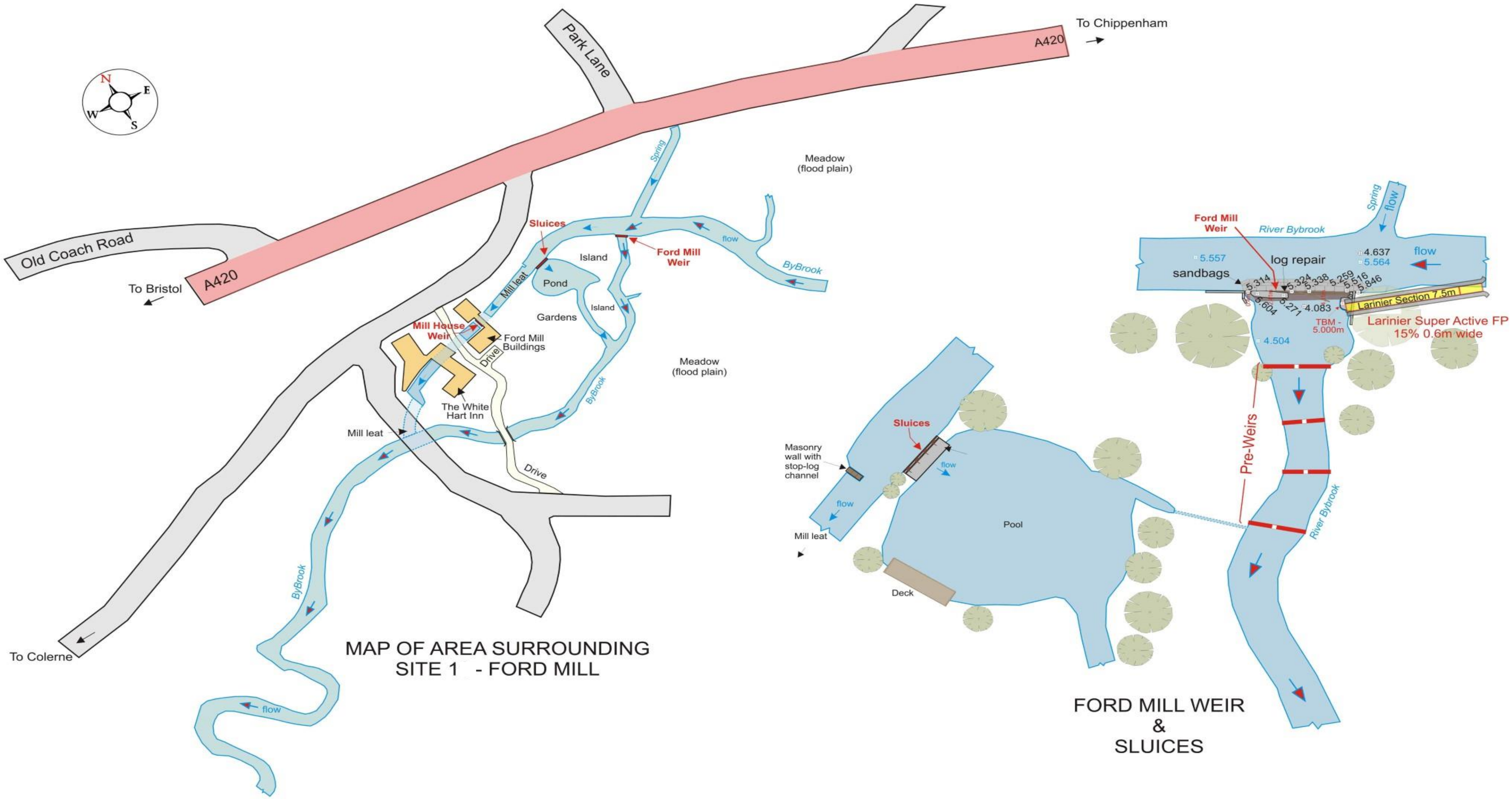
A positive working relationship has been developed with the farming community, fishing clubs and local interest groups that has enabled mitigation works to be developed and undertaken in key locations. It is imperative that these relationships be developed and nurtured in future to build on the progress made so far and to ensure that improvements are lasting.

Water quality and ecological monitoring on the Lid Brook has clearly shown the scale of impact that unrestricted cattle access can have on small river systems. This information will provide a good baseline and will prove to be a powerfully persuasive tool in the continued engagement process with key landowners.

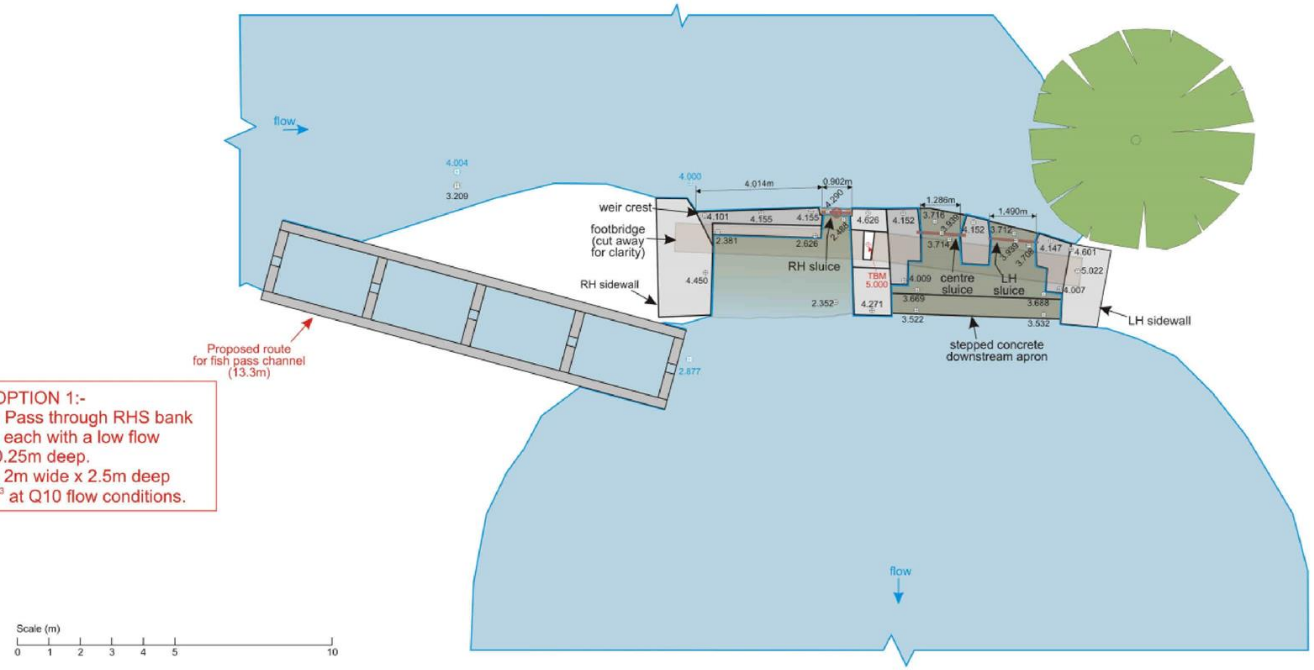
We are confident that the approach taken in this work represents the best value-for-money approach to achieving WFD GES and a continuation of support for these works will yield tangible improvements and provide a showcase example of effective partnership working.

Appendix 1: Fish pass feasibility designs from Mike and Matt Beach fish pass engineering consultants

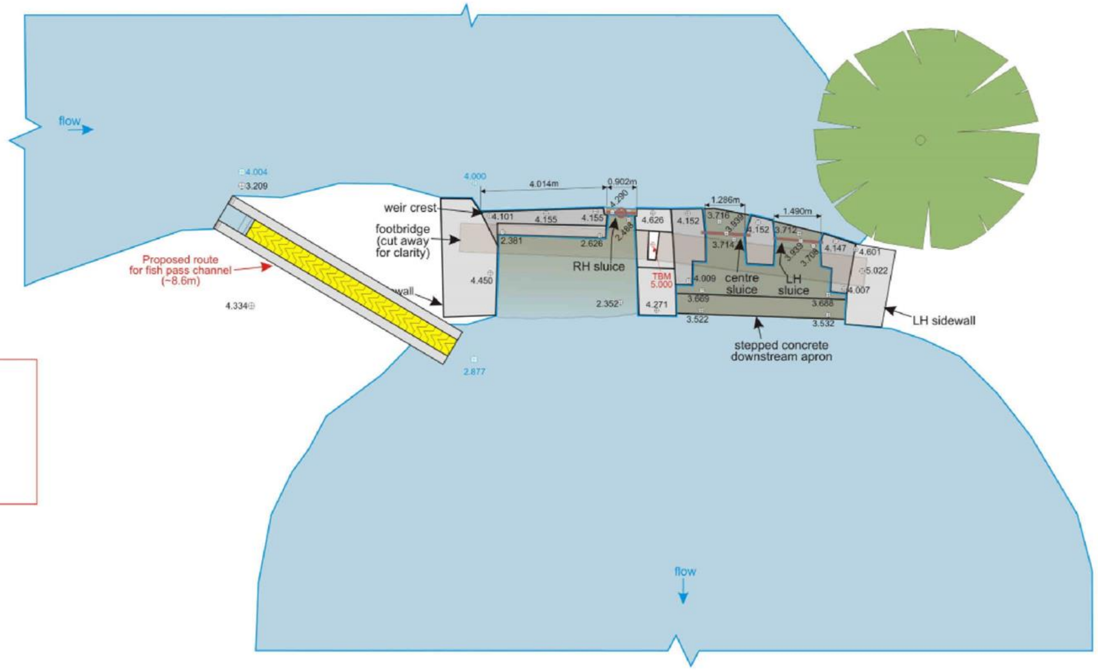
Site 1. Ford Mill Weir



Site 2. Weir D/S Ford



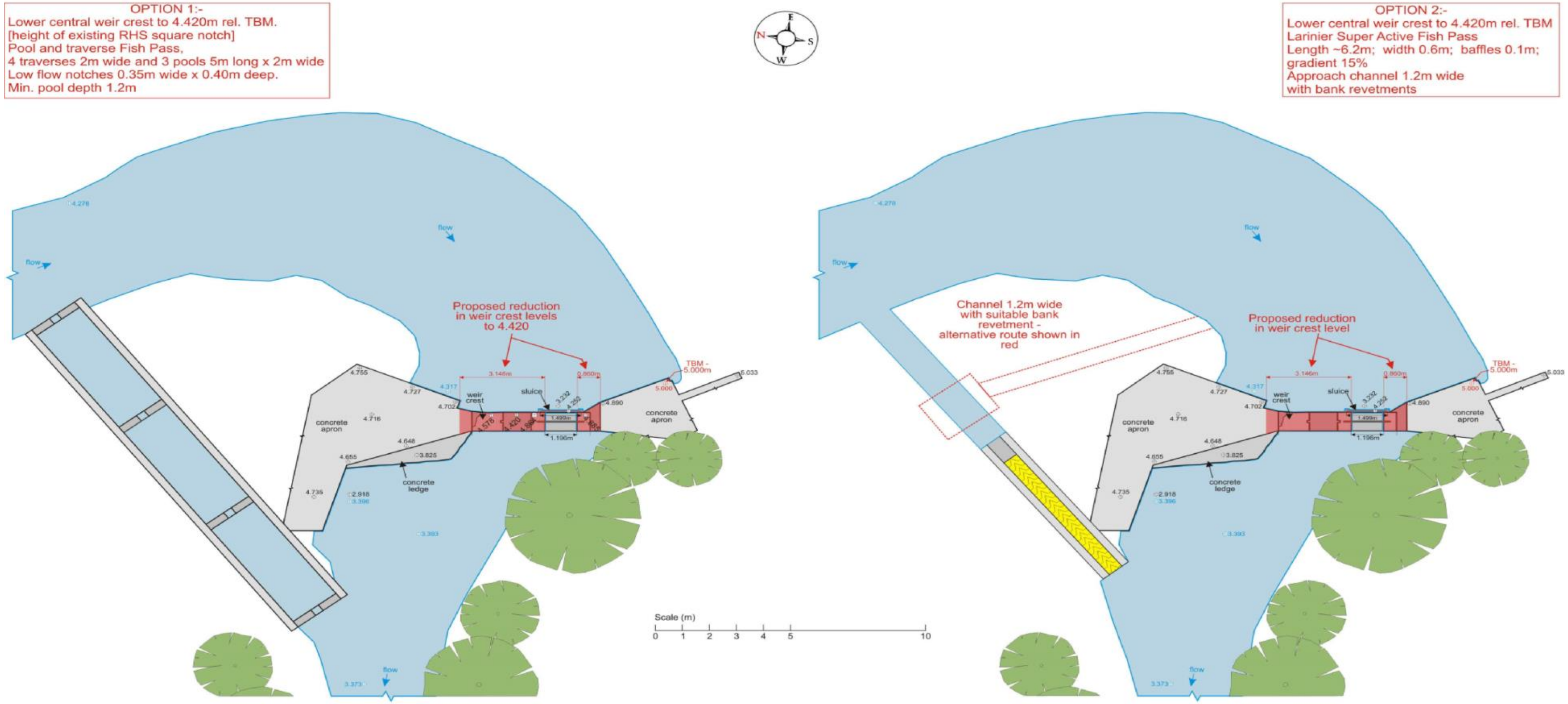
OPTION 1:-
Pool & Traverse Fish Pass through RHS bank
5 traverses 2m wide, each with a low flow notch 0.30m wide x 0.25m deep.
3 pools 2.95m long x 2m wide x 2.5m deep
Turbulence: 149W/m³ at Q10 flow conditions.



OPTION 2:-
Larinier Super Active Fish Pass
Single flight ~7.6m long, 0.6m wide, baffles 0.1m high, slope of 15%.

ha at Q95 = 0.14m
ha at Q10 = 0.50m

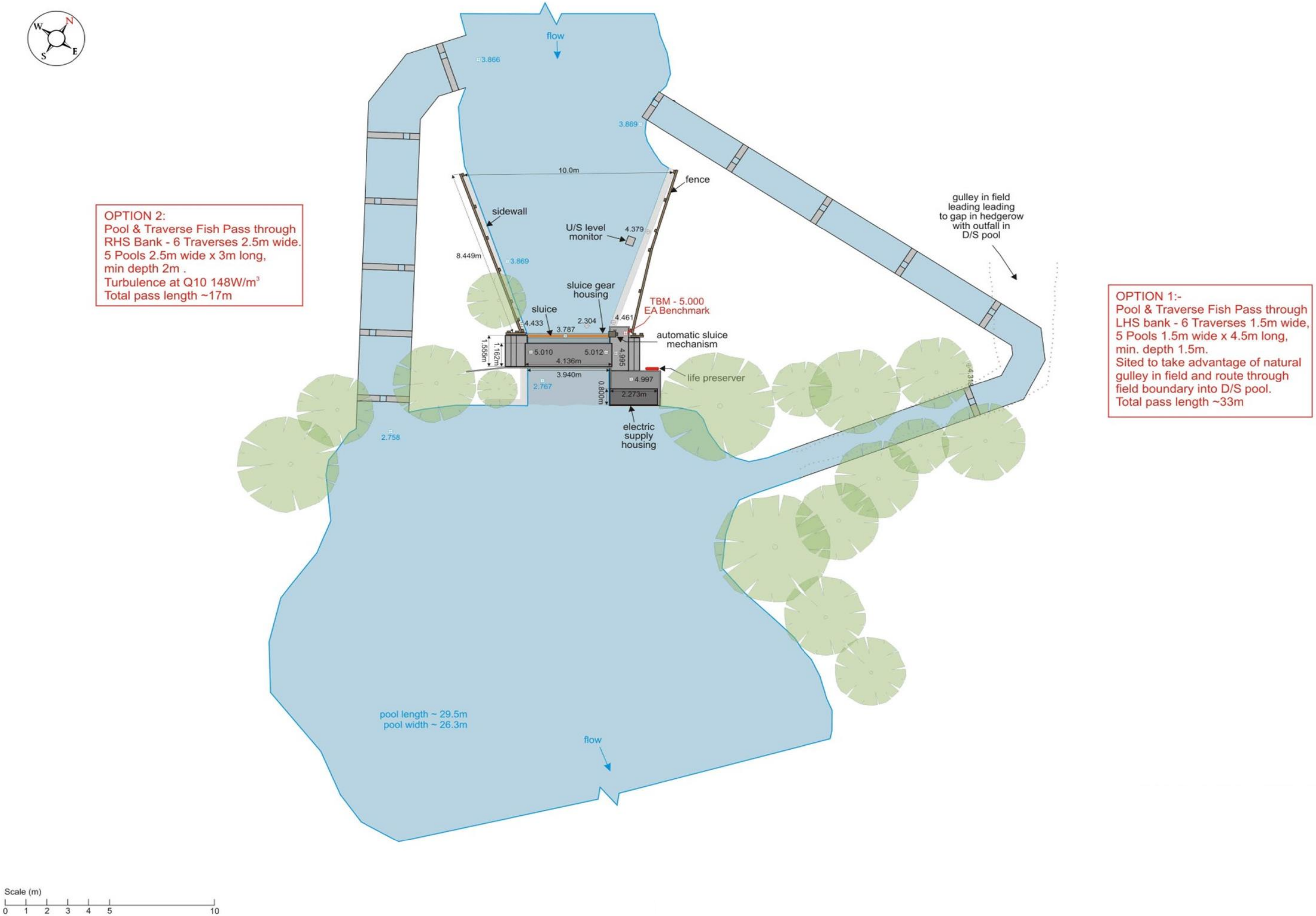
Site 3. Sluice D/S Ford



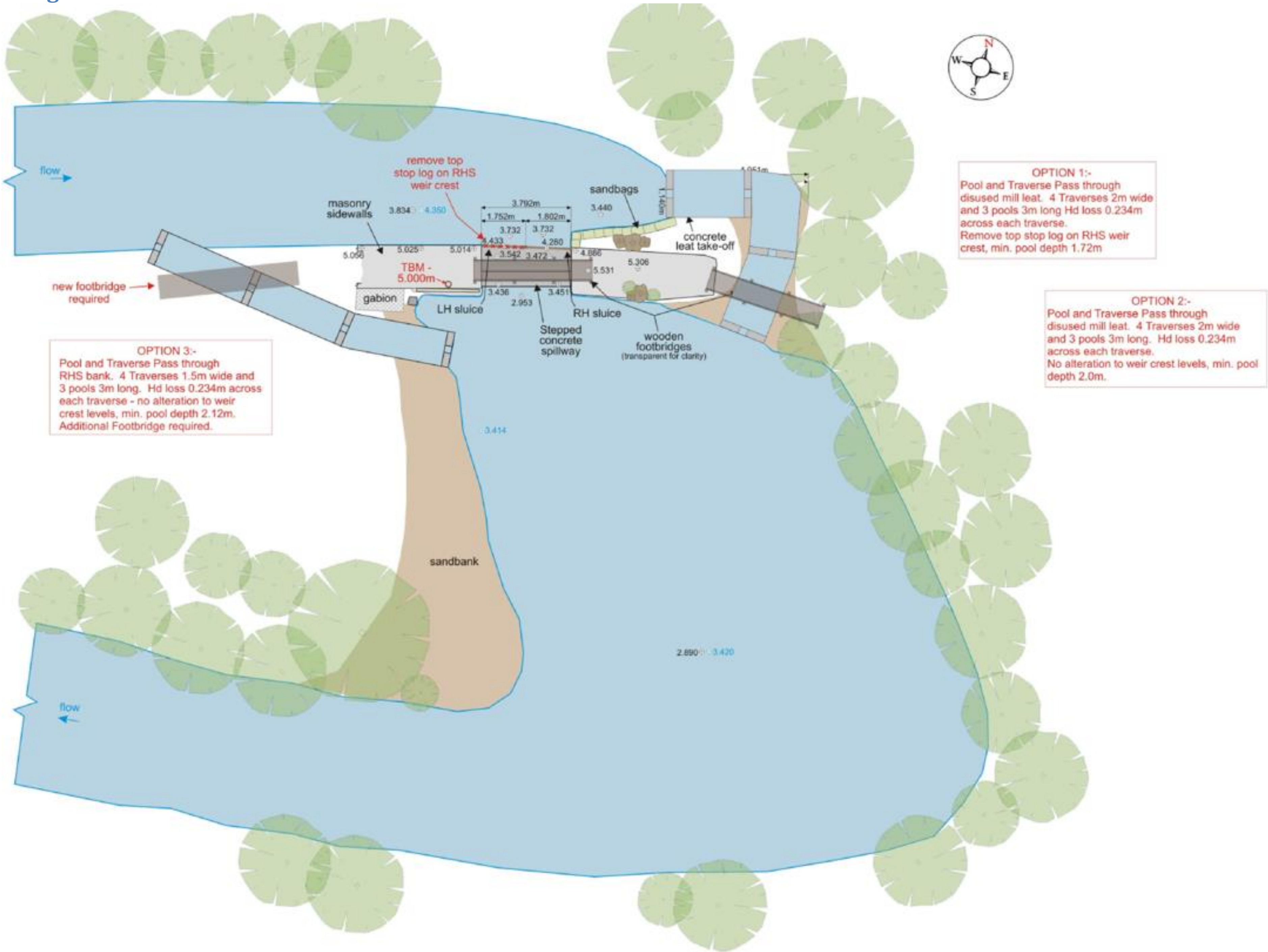
SITE 3 POOL & TRAVERSE FISH PASS - OPTION 1

SITE 3 LARINIER SUPER ACTIVE FISH PASS - OPTION 2

Site 4. Slaughterford Gate Steel Sluice



Site 5. Rag Mill



Site 7. Weavern Mill

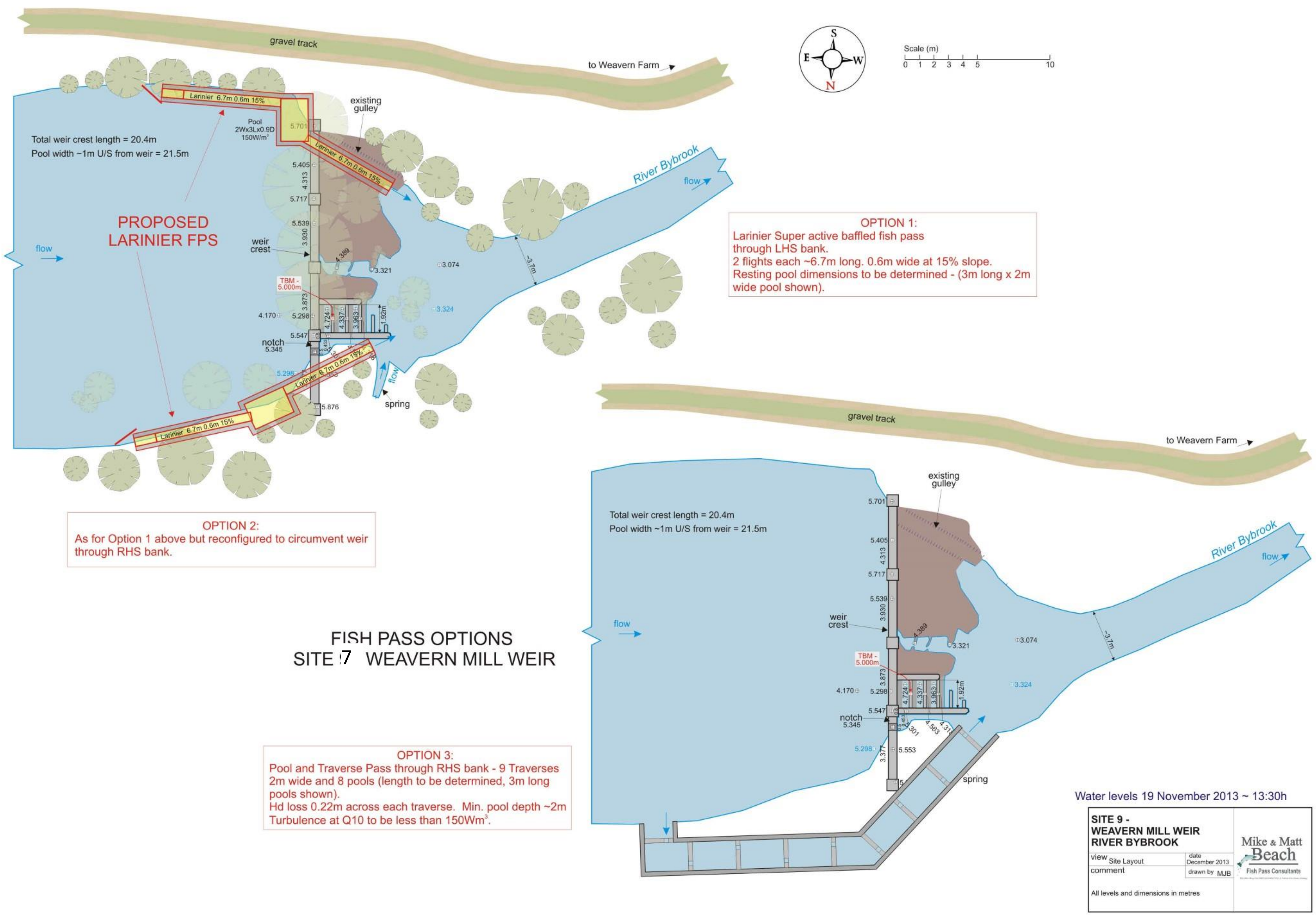
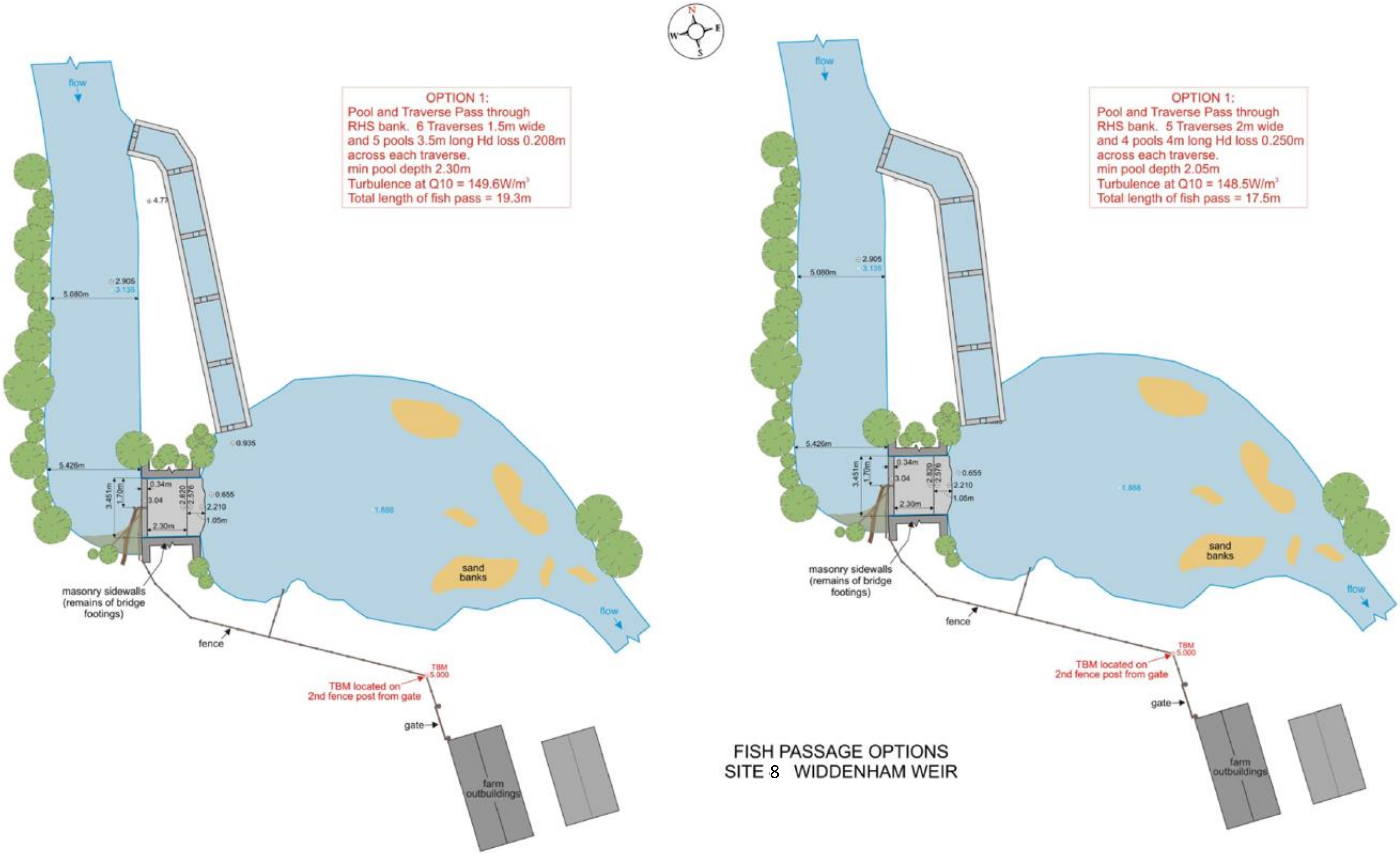
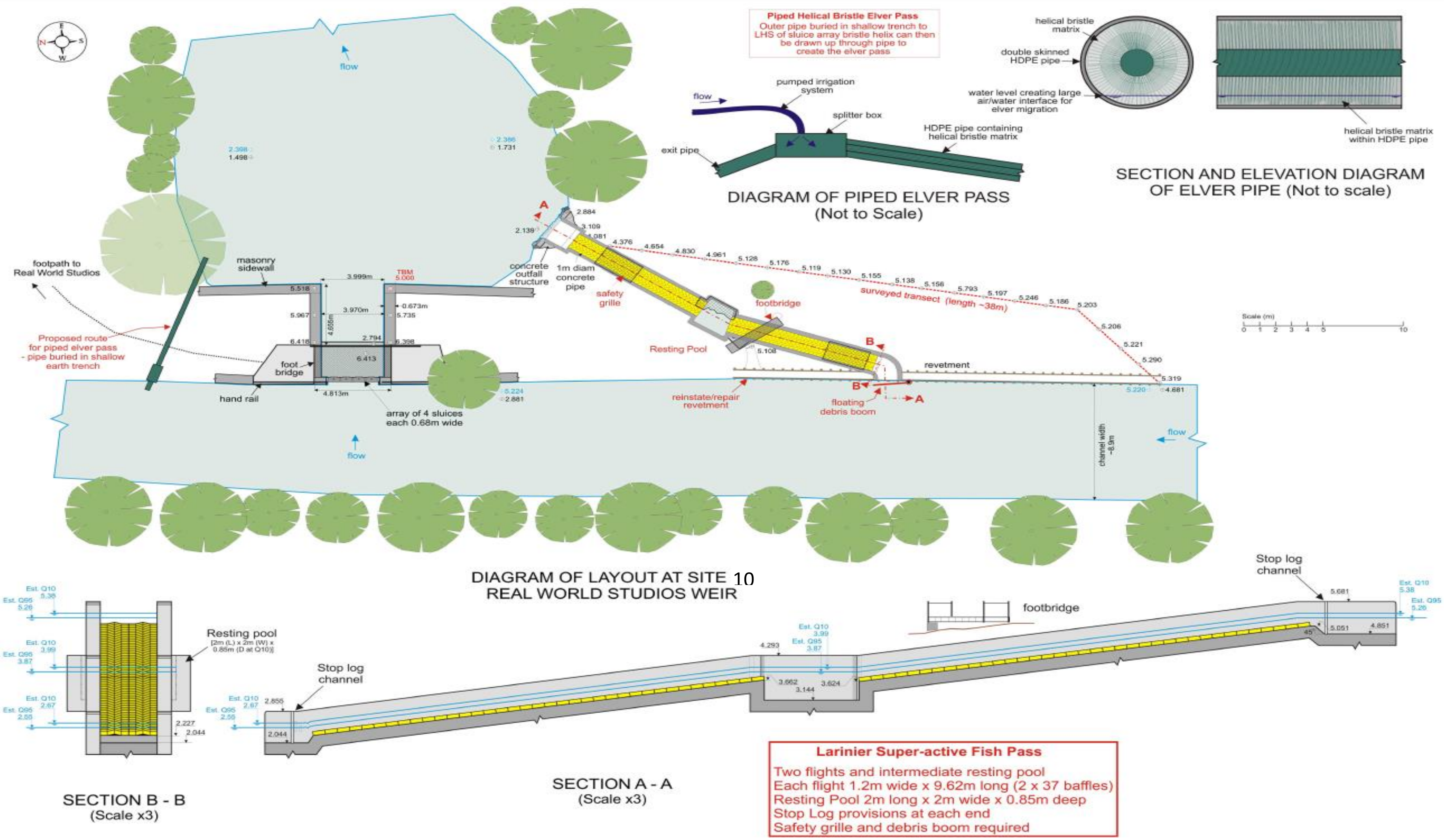


Figure 4. Site 9 - Weavern Mill Weir

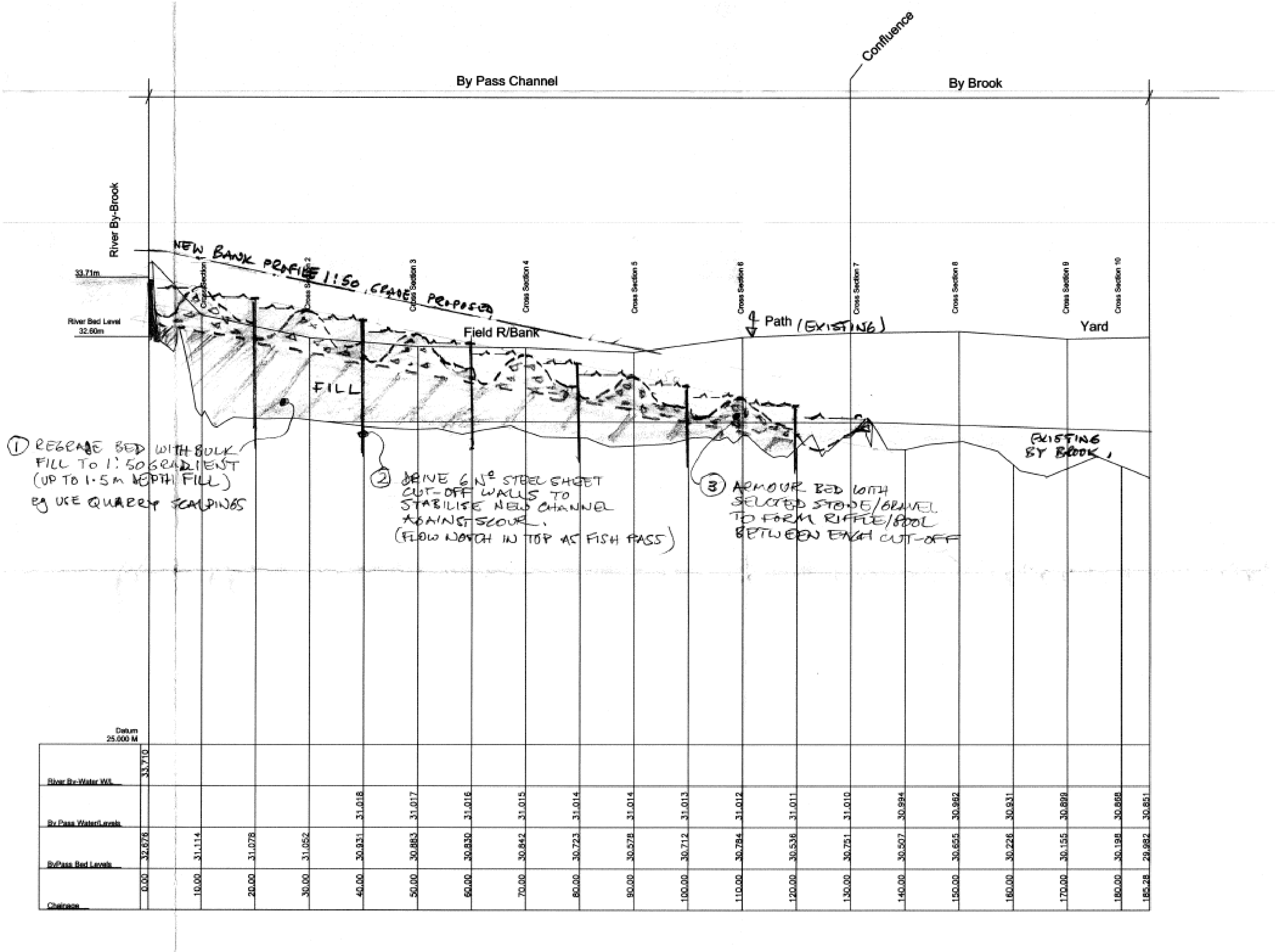
Site 8. Widdenham Farm Weir



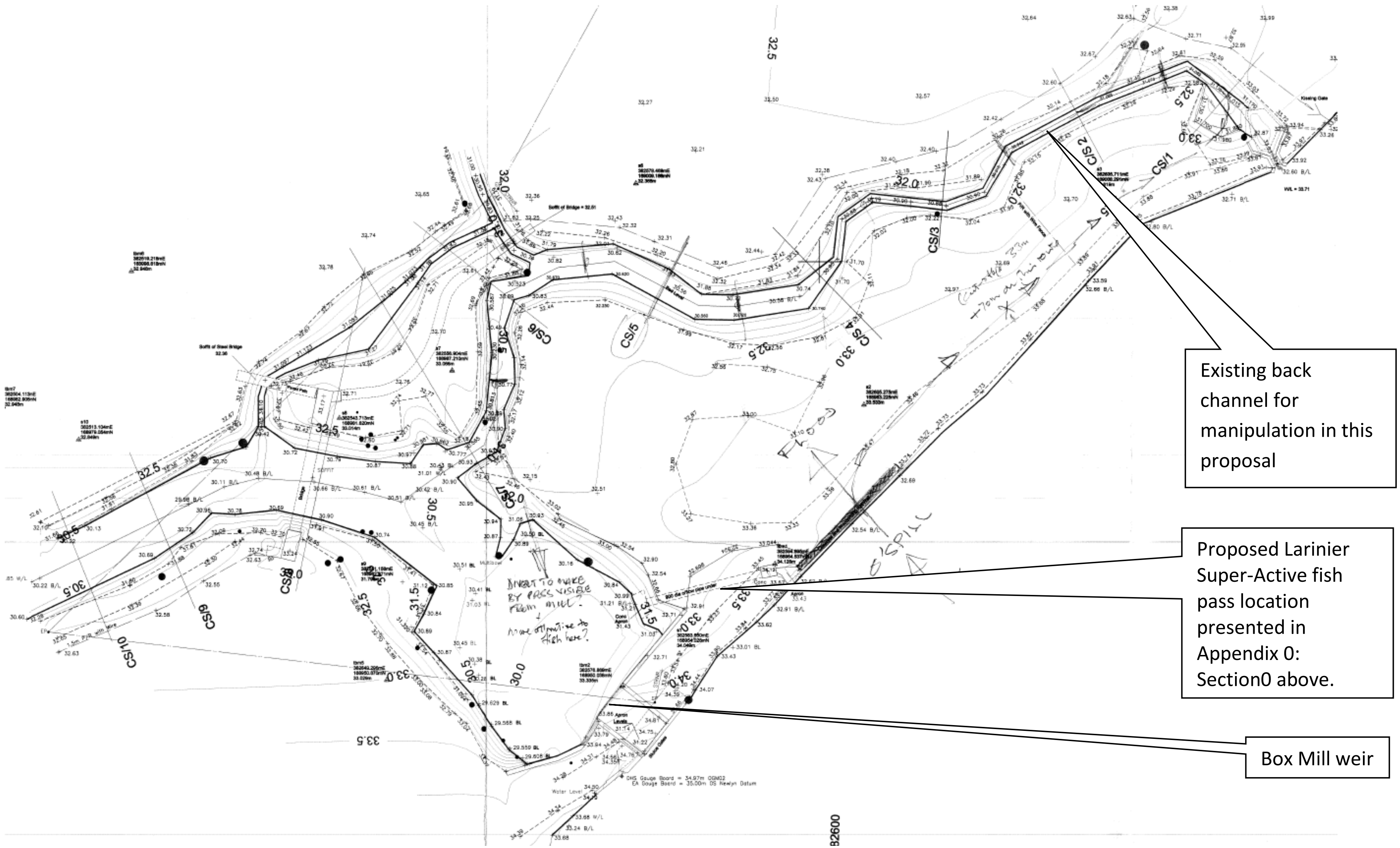
Appendix 2: Stage 2 designs for Box Mill, Middlehill Gauging Station and Shockerwick weir



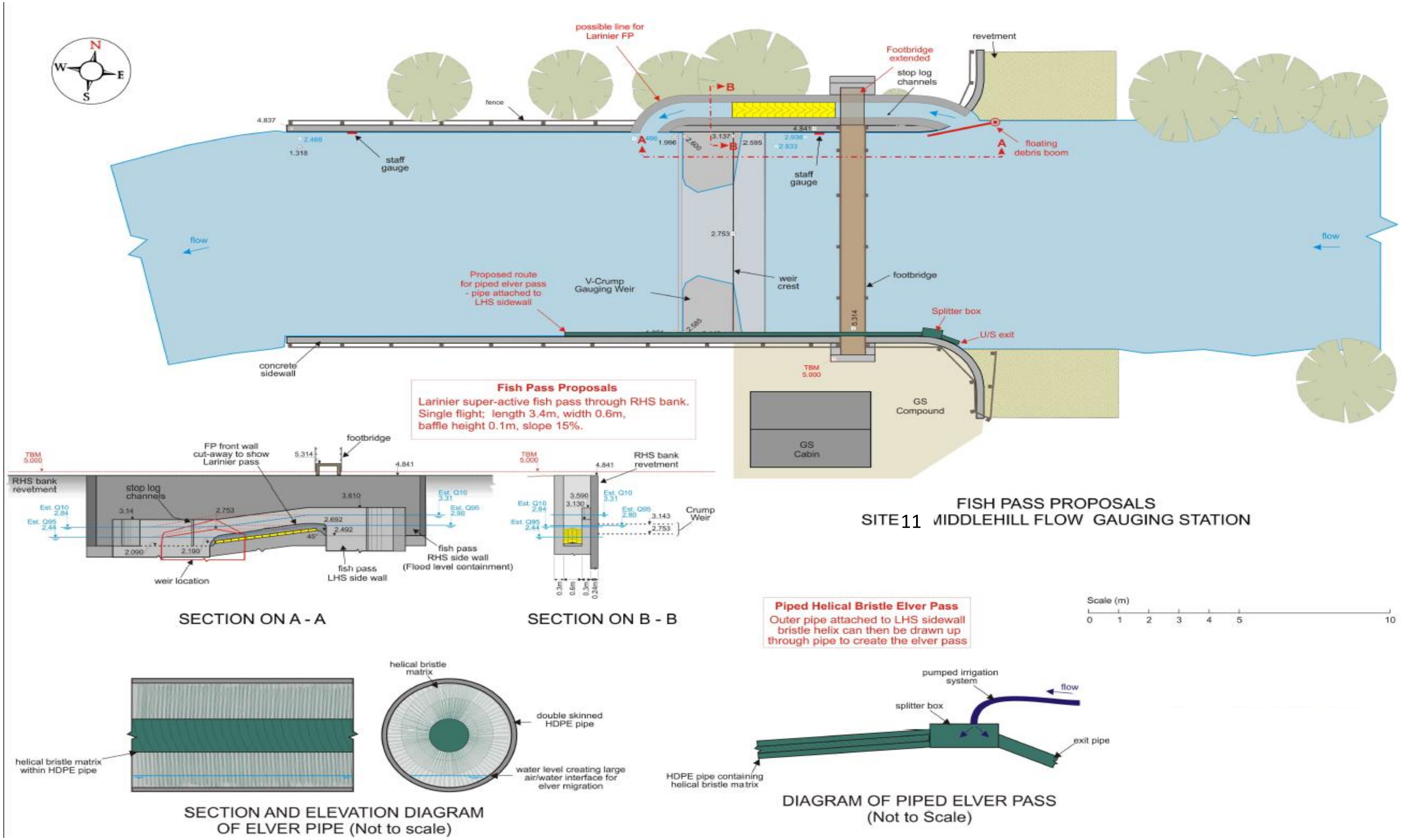
Site 10 Box Mill Real World Studios back-channel option concept sketch



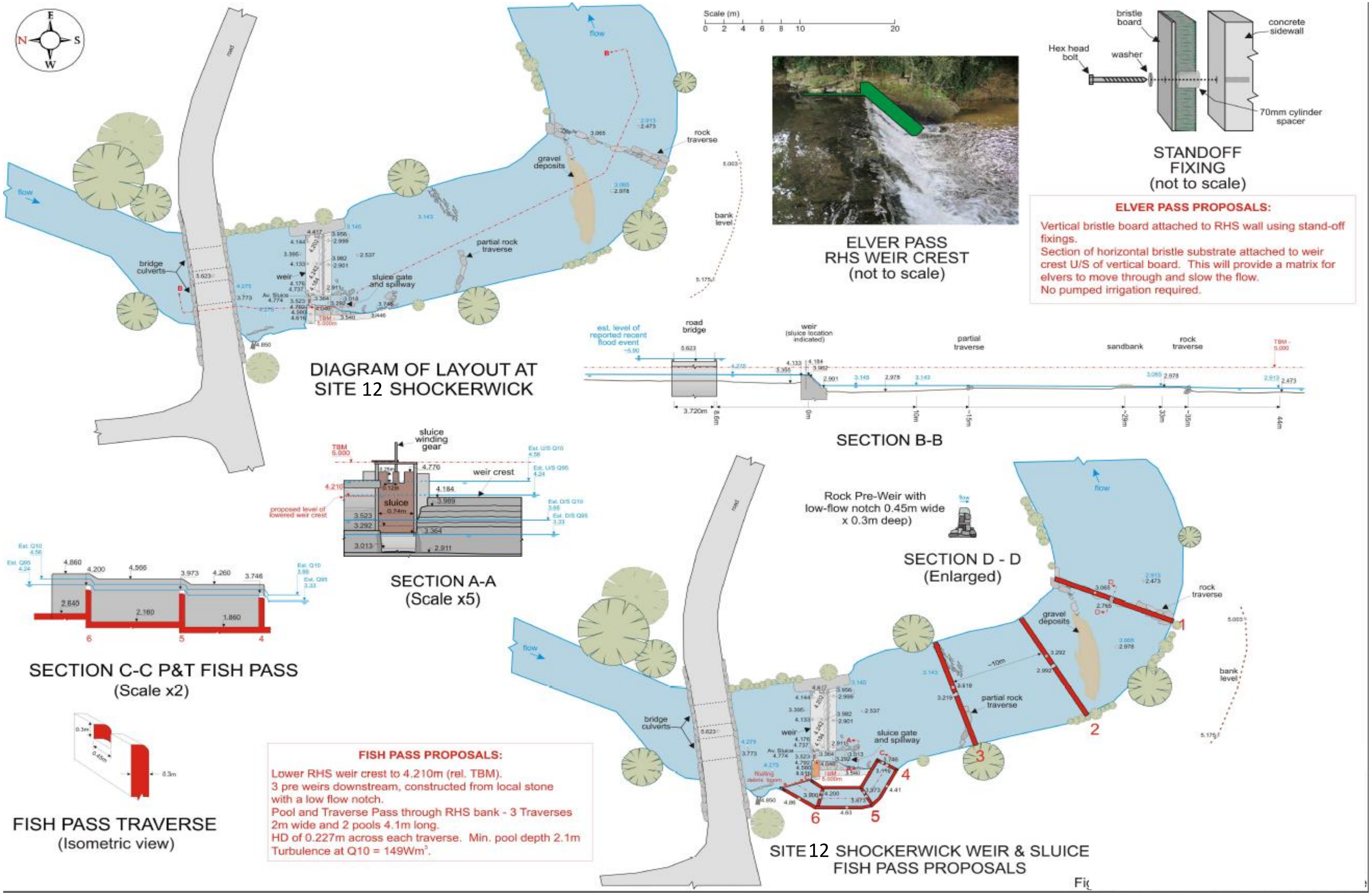
Site 10 Box Mill Real World Studios back-channel option topographic plan



Site 11: Middle Hill gauging station



Site 12: Shockerwick weir



Appendix 3: Water quality monitoring on the Lid Brook and By Brook

Water quality monitoring was carried out on the Lid Brook and on the By Brook, D/S of the Lid Brook confluence during two 24 h wet-weather events on December 18/19 2013 and Jan 31/Feb 01, 2014 (Figure 23). The Lid Brook was chosen for this work as it has been identified as one of the most heavily impacted watercourses in the catchment, in terms of riparian damage from livestock poaching (Figure 21) and so was a primary focus for fencing and remedial works during phase 1 of the By Brook project. The intention is that these data will form part of a simple bio-geo-chemical baseline understanding of the state of the Lid Brook, ahead of implementation of remedial woks, against which, future improvements can be measured.

The wet weather events can be seen in the context of daily rainfall records and By Brook flow, throughout the 2013/14 winter period (Figure 22). Event 1 was at the beginning of a prolonged period of wet weather, which lasted until a few days after Event 2. The three exceptional wet weather events over the Xmas/New Year break were not monitored.

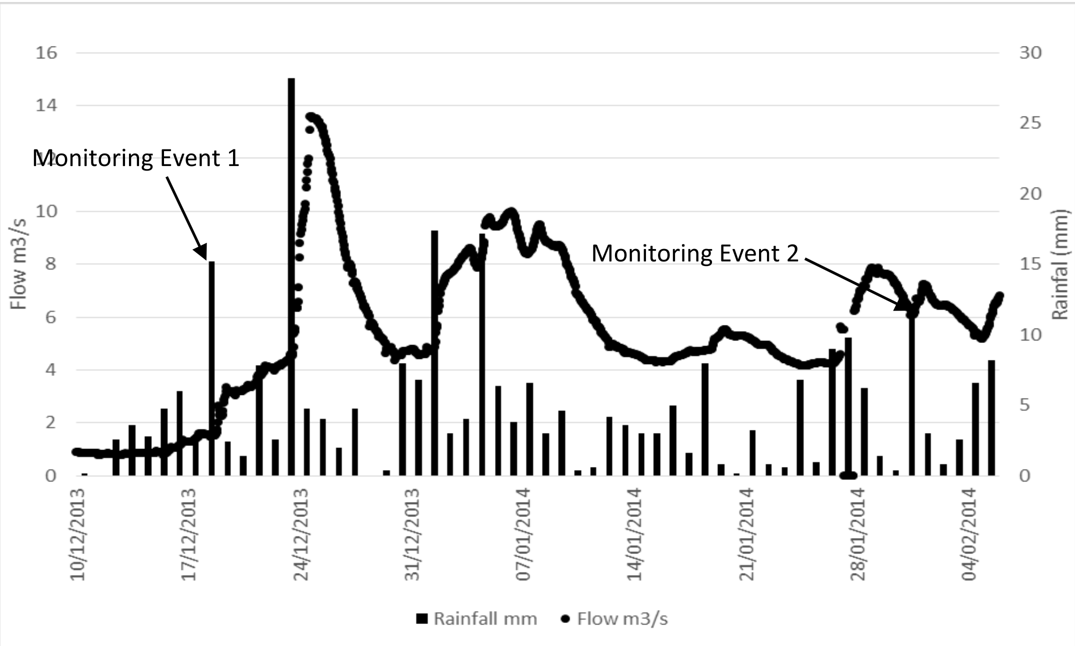


Figure 22. By Brook Flow (m3/s) and daily rainfall (mm) from Middlehill gauging station 10/12/2013 - 05/02/2014

8.1.1 Methods

ISCO auto-samplers were deployed at four locations (Figure 23) between Dec 16th 2013 and Feb 3rd 2014. Sites 1 and 2 were chosen to assess the impact of Colerne STW on dissolved orthophosphate (OP) and total phosphorus (TP) concentrations in the Lid Brook and to enable these to be eliminated from the impacts of diffuse agricultural sources. Site 2 was also used as a surrogate for U/S Saltbox Farm, for comparison with Site 3 (D/S Saltbox Farm) to assess the impact of the farmyard and surrounding land. Site 4, in the By Brook main channel, was used to assess water quality in the main By Brook, during the events monitored. Insufficient resource was available to include additional sites that would have enabled isolation of Saltbox Farmyard or a quantitative assessment of the impact of contaminants from the Lid Brook on the main By Brook.

Figure 23. Lid Brook sampling locations, also showing position of Saltbox Farm

Hourly samples were taken during two wet weather events (Figure 22) and analysed for a suite of nutrients and suspended solids. A Hydrolab Sonde and pressure monitors were used to collect additional physical and chemical parameters, including depth and velocity to enable flow and hence loadings of key contaminants to be derived.

All samples were analysed for dissolved orthophosphate PO_4^{3-} (OP), nitrate NO_3^-, (NO) ammonia NH_4^+ (NH) and total suspended solids (TSS). Selected samples were also analysed for total phosphorus (TP). Nitrate and ammonia results did not show anything of particular note and so are not presented.

Flow measurements were taken at Sites 2 and 3 during both events. However, the results for Site 3 were discarded due to interference from a backing-up effect from the main By Brook at this point. Instead, an assumption of a 20% increase in flow over the ≤1 km distance between sites was used for load-based calculations. This assumption will be verified in future monitoring and the figures re-visited. However, visible evidence, coupled with the data presented suggest that this is a reasonable but conservative estimate. For loadings in the main By Brook, flow data from Middlehill Gauging Station were used, along with an assumption based on a 10% reduction in flow at Site 4.

8.1.2 Results

8.1.2.2 Wet weather monitoring event 1: 18-19 Dec 3013

During the initial wet-weather monitoring event (Event 1), samples were successfully collected from sites 2, 3 and 4 only, due to technical issues with the auto-sampler at Site 1. Hence, the impact of Colerne STW could not be assessed and subtracted from diffuse agricultural inputs during this event. All 24 hourly samples from sites 1, 2 and 3 were analysed for OP but TP was only measured every four hours due to cost constraints.

In comparison with later wet weather, rainfall during this event was not exceptional (Figure 22). The rainfall event duration was approximately 8 hrs, peaking after 19:00 at 4 mm/h for 2 hrs, with light, showery drizzle for a 2 hrs preceding the main event. Total rainfall in the 8 h period, recorded at Middlehill station was 15.6 mm.

OP and TP behaviour during this event was relatively unremarkable. There was no difference in OP or TP concentrations U/S and D/S of Saltbox Farm prior to the rainfall event and concentrations returned to broadly similar levels quickly after the event (Figure 24). During the rainfall event, OP concentration reached a maximum concentration of 0.27 mg/l at Site 2 and 0.33 mg/l at Site 3. OP concentration. OP concentration following the peak flow was lower than prior to the event, due to additional dilution. TP was not measured at the peak of the flow curve but at 00:00 hrs, was three times greater than OP concentration at Site 2 and 4 times greater than OP concentration at Site 3. Flow increased rapidly from a baseline of *ca.* 60 l/s to 180 l/s in three hrs, before declining rapidly in the following three hrs to below 120 l/s, demonstrating the flashy nature of the catchment.

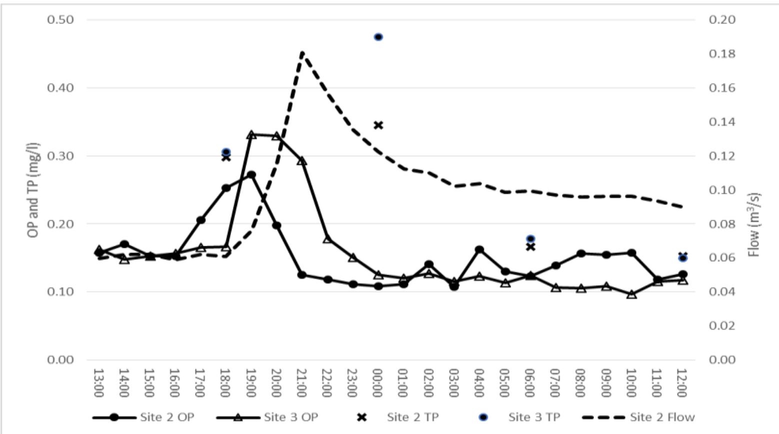


Figure 24. Dissolved phosphate (OP) and total phosphorus (TP) concentration (mg/l) and flow (m^3/s) U/S and D/S of Saltbox Farm during wet weather monitoring event 1: 18-19 Dec 2013

OP loadings were calculated from the two sites using flow measurements from Site 2, assuming a 20% increase between sites as described (Figure 25). During the 24 h sampling period, approximately 1,230 g OP was recorded at site 2 and approximately 1,620 g was recoded at Site 3. During this time, approximately 15.5 kg of OP was measured at Site 4 in the main By Brook channel (data not shown). As can be seen in Figure 25, loadings were broadly similar before and after the event, demonstrating that the decrease in concentration after the event shown in Figure 24 was the result of dilution. In addition, the similar loadings between Sites after the main flow peak supports the assumption of a 20% increase in flow as a reasonable, conservative estimate.

While OP loads were unremarkable, it would be expected that P mobilised during a wet weather event would be associated with particulate matter and therefore be captured as TP. Realistic estimations of TP loads were not possible during this event, due to too few samples being analysed for this parameter. This was addressed in the second monitoring event.

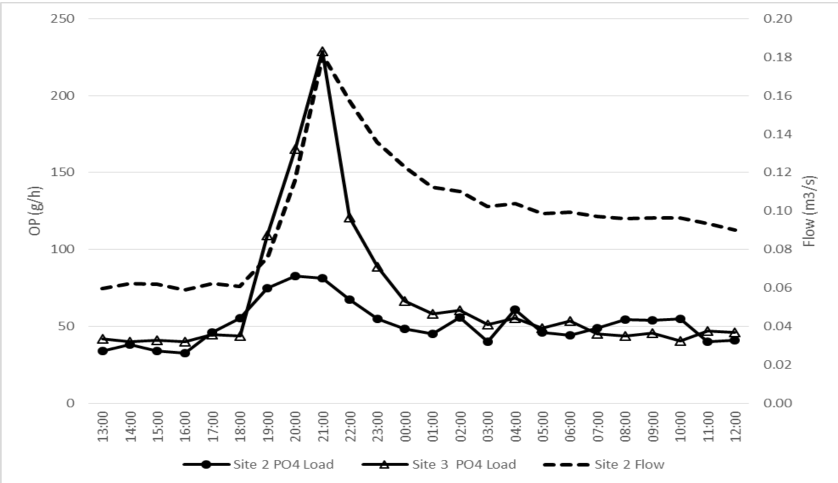


Figure 25. Dissolved phosphate (OP) and total phosphorus (TP) load (g/h) and flow (m^3/s) Lid Brook U/S and D/S saltbox farm 18-19/12/2013

In contrast to OP, total suspended solids provided some remarkable information on the rate of soil loss from this small sub-catchment (Figure 26). Prior to the rainfall event, TSS concentration was approximately 20 times greater at Site 3 than at Site 2, demonstrating a more continual sediment loss in the lower reaches of the Lid Brook. Sediment was mobilised rapidly following the onset of steady rainfall at approximately 18:00, increasing to 685 mg/l at Site 2 and over 1,000 mg/l at Site 3 during maximum discharge at 22:00.

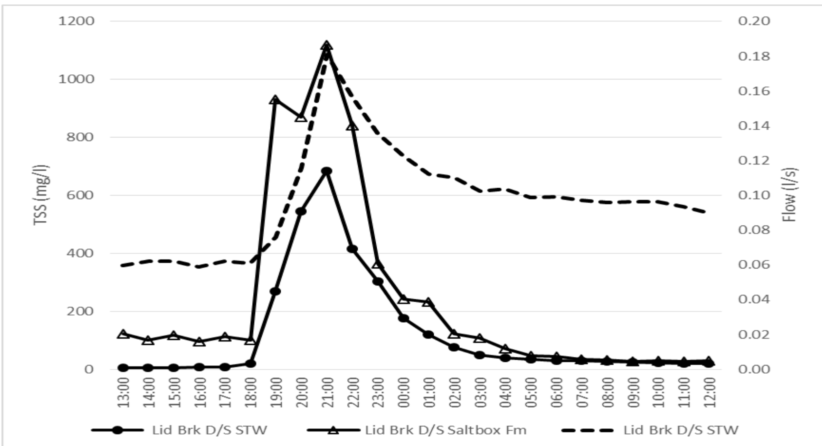


Figure 26. Total suspended solids (mg/l) and flow (m3/s) Lid Brook U/S and D/S Saltbox Farm 18-10/12/2014

TSS load, given in kg/h (Figure 27), demonstrates clearly the impact of land management practices in this small sub-catchment in terms of soil loss. During the 24 h sampling period, approximately 2 tonnes of soil were lost from the catchment U/S of Site 2 and a further tonne in the short (≤1km) distance to Site 3, the majority of which was lost in an 8 hr period from 18:00. In the 8 hrs following the onset of rainfall, approximately 3 tonnes of soil were lost from the catchment and washed into the By Brook.

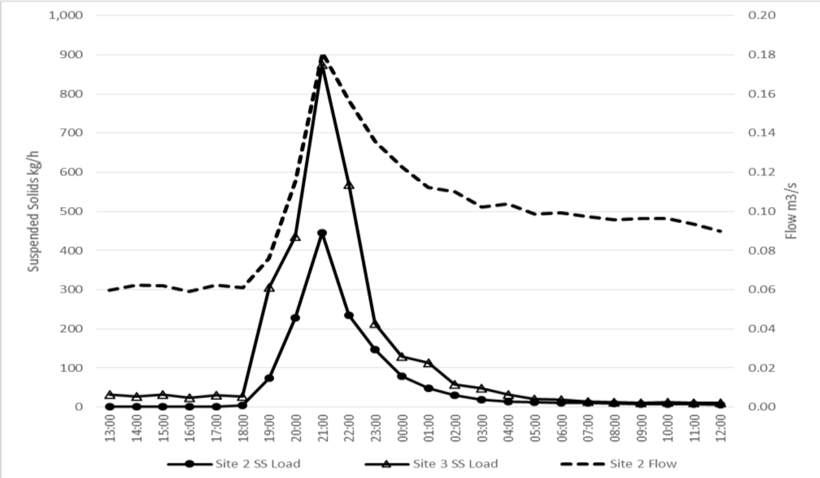


Figure 27. Suspended solids load (kg/h) and flow (m3/s) U/S and D/S of Saltbox Farm

TSS measured in the By Brook at Site 4 (Figure 28) showed that approximately 16 tonnes of sediment was lost from the catchment during the 24 h sampling period. Given that the Lid Brook represents such a tiny proportion of the total By Brook catchment as a whole, it is remarkable that almost 20% of the sediment load measured during this event came from the Lid Brook. That said, impacts of sediment load from higher in the catchment would not have been measurable at this point until after this monitoring period and it can be seen in Figure 28 that sediment load continued at an elevated level after the lid brook event was over.

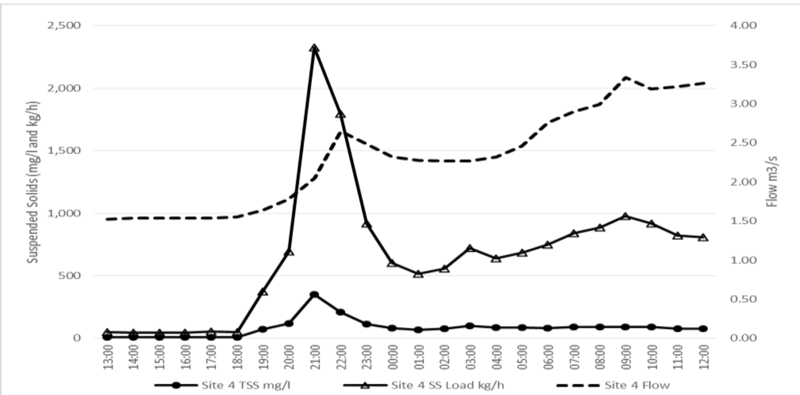


Figure 28. Suspended solids concentration (mg/l) and load (kg/h) with flow (m3/h) in the main By Brook during wet weather event 1

8.1.2.3 Wet weather monitoring event 2: 31/Jan-01 Feb 2014

Rainfall during the second wet weather event monitored as part of this work was slightly less intense but more persistent than the first event on Dec 18th. Maximum precipitation intensity was 2.6 mm/h and a total of 12.6 mm was recorded over a period of 15 hrs. This is reflected in the flow trace (Figure 29), which does not have the pronounced peak evident in Event 1 (Figure 24 toFigure 27). However, Event 1 occurred at the end of a long, dry spell and, while it produced a pronounced peak in flow, overall, flow during the Jan/Feb event was higher than December's.

During the second wet weather monitoring event, data were collected from all four sampling locations. Following the indication of elevated TP inputs associated with particulate matter in the four samples from each location analysed for TP in Event 1, TP was assayed in alternate samples in Event 2, to enable an understanding of TP dynamics and loadings to the system during wet weather.

Orthophosphate monitoring

OP concentration at Site 1, U/S of Colerne STW discharge point, was below the assay detection limit of 0.02 mg/l for all but two of the samples, taken at 16:00 and 17:00, during the peak of the event. Data given for Site 1 in Figure 29 were calculated using the difference between Site 1 and Site 2 in these samples as an indication of the contribution to OP concentration from Colerne STW, which has then been subtracted from the remainder of the Site 2 samples to estimate U/S, background OP concentration. This calculation was carried through to estimate loadings of OP to the Lid Brook during Event 2 (Figure 30). OP concentration resulting from the Colerne STW input was above 0.02 mg/l throughout the sampling period. The average increase in OP concentration at the D/S Saltbox Farm site was 0.2 mg/l, approximately the same as the contribution from Colerne STW. However, inputs from Colerne STW would continue during dry, low-flow periods, which would result in OP concentrations being further elevated, while inputs from Saltbox Farm would be expected to reduce.

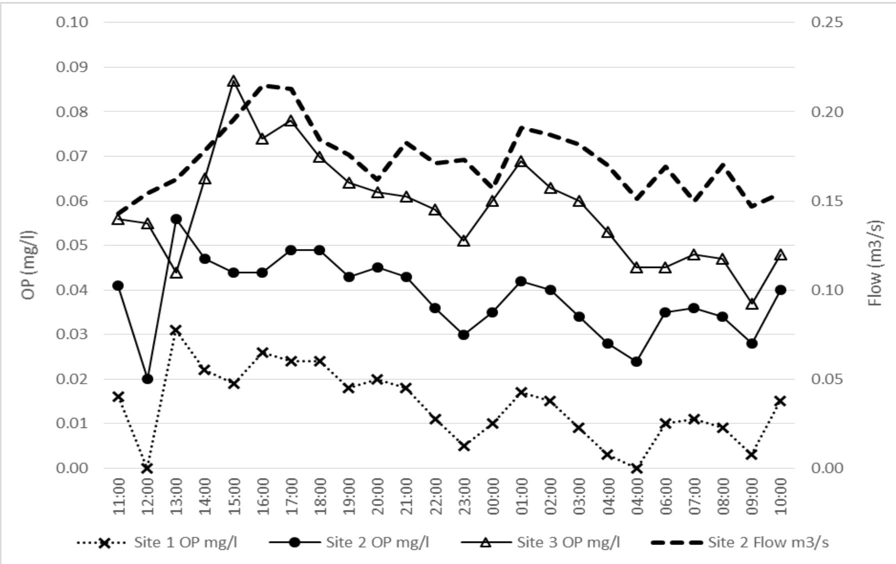


Figure 29. OP concentration sites 1, 2 and 3 during wet weather event 31/01 - 01/02/2014, with flow at Site 2. OP concentration for Site 1, U/S Colerne STW, (dotted line with markers) is calculated (see text).

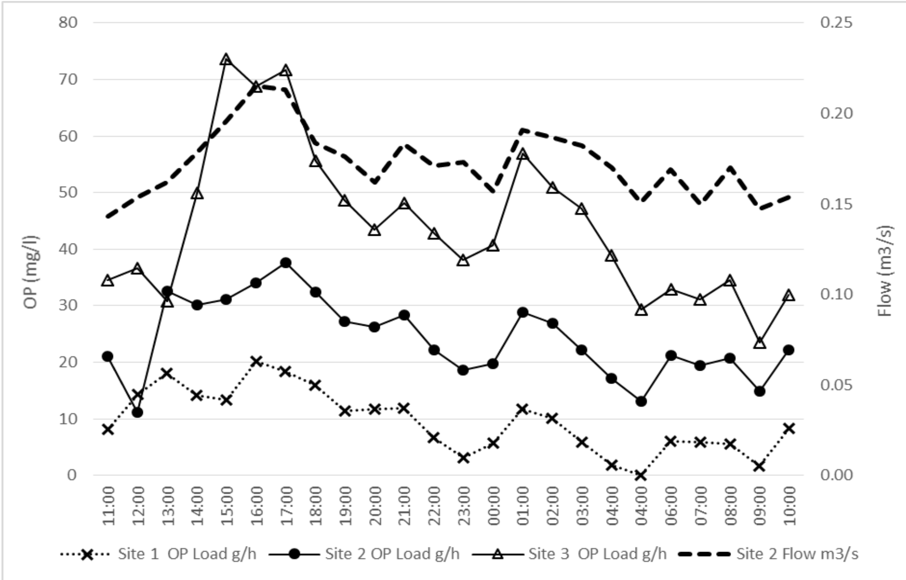


Figure 30. OP loadings to Lid Brook during wet weather event 2, 31/01-01/02/2014.

Total P monitoring

Maximum TP concentration, which coincided with maximum flow at 16:00, was 0.286, 0.316 and 0.462 mg/l at Sites 1, 2 and 3 respectively (data not shown). Total P load was 1,324, 1,803 and 4,353 g at Sites 1, 2 and 3 respectively, over the 24 h event. During the first hour of rainfall (sample 1, 12:00, Figure 31), TP load at site 3 was over 900% greater than at Site 2, probably indicating run-off directly from Saltbox Farmyard. The difference in TP load at Sites 2 and 3 reduced during the course of the event but averaged approximately 300% during the monitoring period. During peak flow, TP load was approximately 420 g/h, approximately 184 g of which entered the Lid Brook, downstream of Site 2. Mean TP load was approximately 60% higher D/S of Colerne STW (Site 3), than at the U/S site, indicating the scale of particulate-associated P inputs from Colerne STW that would not be picked up in statutory OP-based, consent-related monitoring.

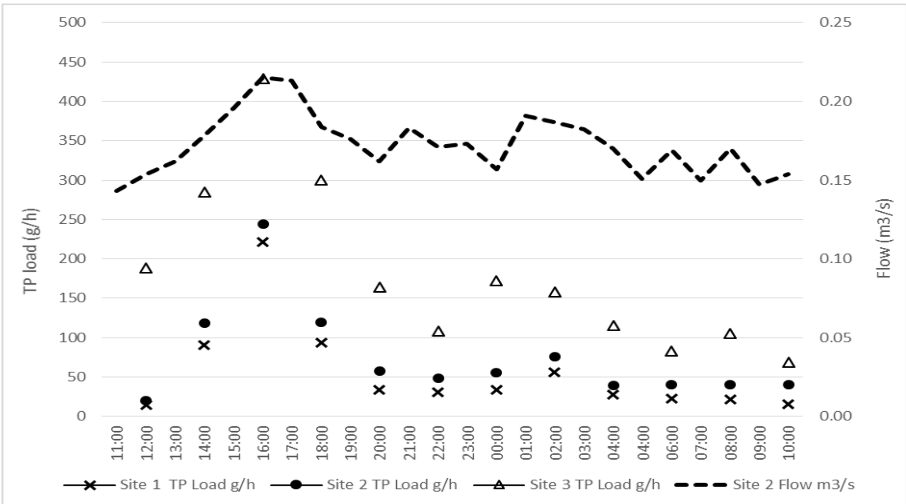


Figure 31. TP load at Sites 1, 2 and 3 during wet weather event 2, 31/01-01/02/2014

Suspended solids monitoring

A flush of solids were quickly mobilised in the Lid Brook, U/S of Colerne STW during the first few hours of rainfall (Figure 32), before equally quickly receding. In total, approximately one tonne of solids were transported past Site 2 during the 24 h monitoring period, approximately 65%of which occurred during the 6 h period between 13:00 and 19:00. TSS were much more variable and considerably higher at Site 3, reflecting inputs from the farmyard, roadway and heavily poached banks between Sites 2 and 3. Total solids load discharged at Site 3 during the 24 h monitoring period was approximately 3 tonnes, indicating a loss of 2 tonnes of soil in the <1 km distance between Sites 2 and 3, during the 24 period.

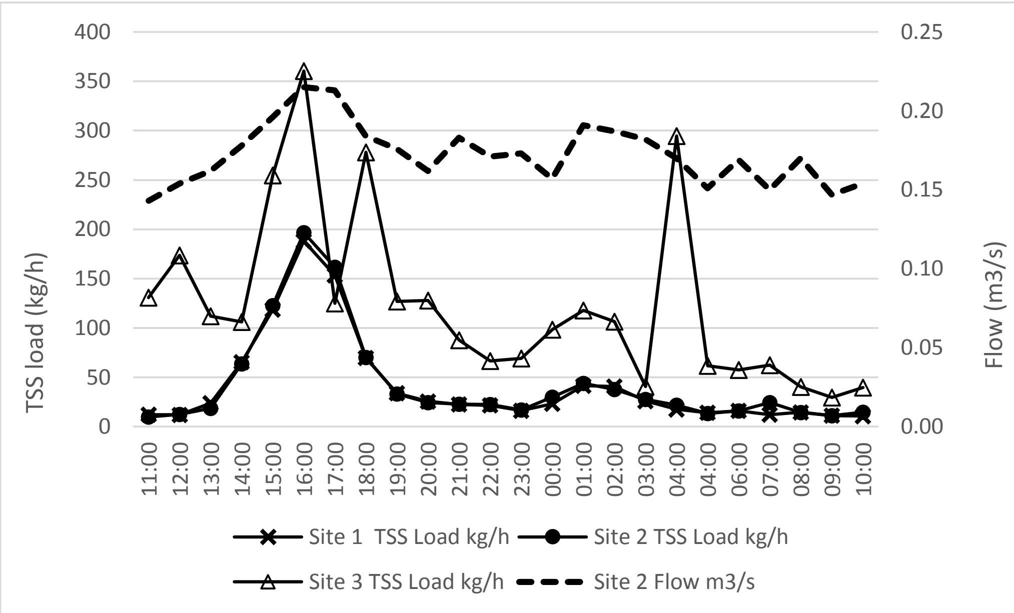


Figure 32. Total suspended solid load, Sites 1, 2 and 3 Lid Brook

By Brook monitoring

Otho-P, TP and TSS were also monitored in the By Brook, at Site 4, D/S of the Lid Brook confluence and flow was inferred from Middlehill gauging station, by subtracting 10% and assuming a 1 hr difference to calculate nutrient and suspended solid loads (Figure 33). Ortho-P concentration remained fairly constant throughout the 24 h monitoring period at 0.0345 +/- 0.00018 s.e., and was not greatly impacted by flow, indicating a general elevated background concentration. In contrast, TP was highly variable and, as would be expected, closely followed the TSS load. Total P load in the By Brook was approximately 53.3 kg over the 24 h monitoring period.

Total suspended solids load was approximately 26 tonnes over the 24 h monitoring period, peaking at around 2.4 tonnes per hour between 16:00 and 18:00. Approximately 3 tonnes of the total 26 tonnes of solids measured, came from the Lid Brook.

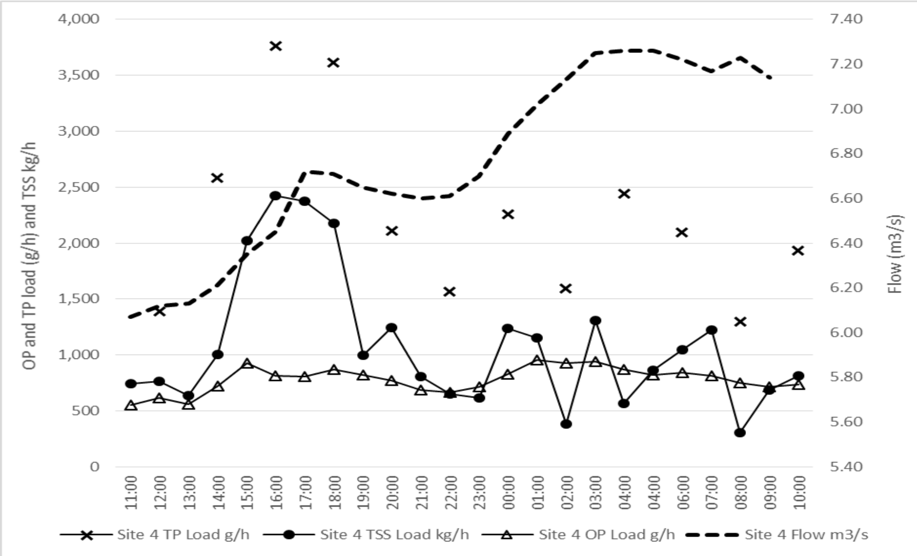


Figure 33. Ortho-P, TP and TSS load, Site 4, By Brook D/S Lid Brook confluence. Flow estimated from Middlehill gauging station (less 10%).

8.2 Conclusions

This study clearly shows the impact that unrestricted cattle access has on small watercourses and the implications this can have on soil and nutrient loss.

Soil loss in the By Brook catchment and particularly from the Lid Brook has been occurring at an alarming rate. During the 48 hrs over which samples were taken, approximately 6 tonnes of soil were lost from this small catchment, almost 2/3rds of which was lost from the lower section of less than 1 km in length. This represents a significant economic cost to the farmer and a reduction in the long-term viability of the farm, as well as being catastrophic to the ecology of the Lid Brook.

During the same period, approximately 46 tonnes of soil were recorded as suspended sediment in the By Brook, which has cost and flooding implications related to the sedimentation of canalised sections of the river and the numerous marinas around Bath and Bristol. Associated with this sediment was approximately 85 kg of phosphorus. As well as reducing agricultural fertility within the By Brook catchment, P input to the river system on this scale represents a significant contribution to its eutrophication.

Given that rainfall conditions, sufficient to mobilise sediment to a greater or lesser degree than those monitored, were an almost daily occurrence between mid-December and mid-February, soil loss from the catchment over the winter period was likely to have been in the several hundreds of tonnes at the very least.

While a proportion of this would have been expected as part of the natural process of soil movement, it is clear that this was largely the direct result of poor land management practices, as evidenced in the Lid Brook.

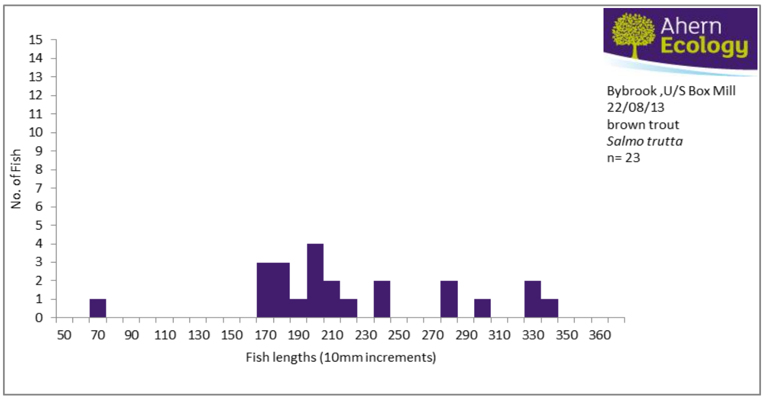
Appendix 4: Fish, macrophyte and invertebrate sampling data from U/S Box Mill and D/S Ford Mill

Fish data from U/S Box Mill

Site	Site 1: U/S Box Mill
River	By Brook
Date	22/08/2013

Minor Species	
MI	9 - 99
BH	99 - 999
SP3	9 - 99
SL	9 - 99

Run 1			Run 2			Run 3		
Species	Length (mm)	Comments	Species	Length (mm)	Comments	Species	Length (mm)	Comments
BT	176		BT	200		BT	231	
BT	213		BT	173				
BT	273		B/RL	150	Ammocoete			
BT	198		B/RL	130	Ammocoete			
BT	64							
BT	198							
BT	300							
BT	174							
BT	330							
BT	322							
BT	164							
BT	168							
BT	235							
BT	331							
BT	202							
BT	273							
BT	194							
BT	186							
BT	210							
BT	161							
B/RL	110	Ammocoete						
B/RL	120	Ammocoete						



Macrophyte data from U/S Box Mill

Site	Site 1: U/S Box Mill
River	By Brook
Date	22/08/2013
Macrophytes	Comments
Apium nodiflorum	Majority of macrophytes were found in marginal areas. A small proportion of the macropyte communtiy was composed of submerged vegetation. This is due to shading of the site. Species present are characteristic of slow flowing water bodies * Dominant in channel macrophyte **Dominant bankside macrophyte
Callitriche spp	
Carex spp	
Cladophera spp	
Epilobium hirsutum	
Iris psuedocoris	
Lemna gibba	
Mentha aquatica	
Myosotis scorpioides/laxa	
Phalaris arundinacea **	
Ranunculus spp	
Schoenoplectus lacustris	
Scrophularia auriculata	
Sparganium erectum *	
Typha latifolia	
Ulva spp	
Veronica beccabunga	
Veronica catenata	

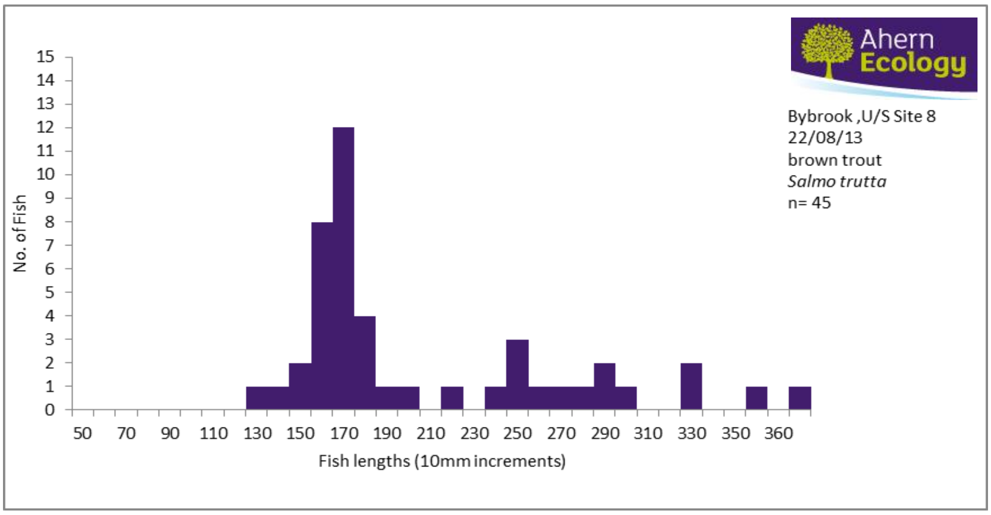
Invertebrate data from U/S Box Mill

Macro-Invertebrates			
Common Name	Family	BMWP Score	Abundance
Beetles	*Dytiscidae*	5	10 - 100
	Elmidae	5	<10
Snails	*Hydrobidae*	3	10 – 100
	Bithyniidae		<10
	Valvatidae	3	<10
	Planorbidae	3	<10
	Lymnaeidae	3	<10
Mussels	*Sphaeridae*	3	<10
Bugs	*Gerridae*	5	<10
Leeches	*Glossiphonidae*	3	<10
Crustaceans	*Gammaridae*	6	10 – 100
Mayflies	*Baetidae*	4	<10
	Ephemeridae	10	<10
	Ephemerellidae	10	<10
Worms	*Oligochaeta*	1	10 – 100
Damselflies	*Calopterygidae*	8	<10
Alderflies	*Sialidae*	4	10 – 100
Stoneflies	*Leuctridae*	10	<10
Trueflies	*Chironomidae*	2	100 – 1000
Caddisflies	*Limnephilidae*	7	<10
	Leptoceridae	10	<10
Biting midges	*Ceratopagoniidae*	Non scorers	<10
House flies	*Muscidae*	Non scorers	<10
Mites	*Hydracarina*	Non scorers	<10

Fish Data from U/S of Fish pass site 2, Weir downstream of Ford

Site	Site 2: U/S Weir below Ford	Minor Species	
River	By Brook	MI	9 - 99
Date	22/08/2013	BH	99 - 999
		SP3	9 - 99

Run 1		Run 2		Run 3	
Species	Length (mm)	Species	Length (mm)	Species	Length (mm)
BT	323	BT	266	BT	169
BT	330	BT	286	BT	240
BT	160	BT	300	BT	220
BT	160	BT	164	BT	151
BT	180	BT	170	BT	175
BT	271	BT	142	BT	241
BT	248	BT	363	BT	144
BT	164	BT	259	BT	284
BT	167	BT	168	BT	153
BT	161	BT	160		
BT	243	BT	137		
BT	163	BT	189		
BT	164	BT	178		
BT	196	BT	152		
BT	158				
BT	154				
BT	164				
BT	122				
BT	175				
BT	170				
BT	165				
BT	355				



Macrophyte Data from U/S of Fish pass site 2, Weir downstream of Ford

Site	Site 2: U/S Weir below Ford	
River	By Brook	
Date	22/08/2013	
Macrophytes	Comments	
Epilobium hirsutum	Abundant macrophyte cover. Species present are characteristic of slow flowing water bodies. *Dominant in channel macrophyte **Dominant bankside macrophyte	
Lemna gibba		
Lemna trisulca		
Lycopus europaeus		
*Phalaris arundinacea***		
*Potamageton perfoliatus**		
Sparganium emersum		
Sparganium erectum		

Invertebrate Data from U/S of Fish pass site 2, Weir downstream of Ford

Site	Site 2: U/S Weir below Ford		
River	By Brook		
Date	22/08/2013		
Macro-Invertebrates			
Common Name	Family	BMWP Score	Abundance
Beetles	*Dytiscidae*	5	<10
	Haliplidae	5	10 - 100
	Elmidae	5	10 – 100
Snails	*Hydrobidae*	3	10 – 100
Crustaceans	*Gammaridae*	6	10 – 100
Mayflies	*Baetidae*	4	<10
	Ephemeridae	10	<10
Worms	*Oligochaeta*	1	10 – 100
Alderflies	*Sialidae*	4	10 – 100
Stoneflies	*Perlodidae*	10	<10
	Leuctridae	10	<10
Trueflies	*Chironomidae*	2	10 – 100
	Dicranota	5	<10
Caddisflies	*Limnephilidae*	7	<10
	Sericostomatidae	10	<10
Biting midges	*Ceratopagoniidae*	Non scorers	10 – 100
Mites	*Hydracarina*	Non scorers	<10

Appendix 5: By Brook crayfish monitoring results

Table 4.1: Summary of surveys results and available records

Existing crayfish records			Watercobody	AWT survey results							
			Tributary Barrier no. (BART no.)								
NGR	*Ap* (year)	*Pl* (year)	By Brook U/S - D/S	*Ap* (no. caught)	*Pl* (no. caught)	AWT survey point (no. traps)	Trap nights	Total points	*VMZ	NGR	Other species
ST 84100 77100		2013									
ST 84613 74848		2013									
			12(N/A)							ST 84212 74819	
ST 83161 75777	2009										
ST 83880 74790	2006										
			Doncombe Brook			1(3)	2	2		ST 83869 74655	Kingfisher
				1	2	2(5)	2	4		ST 83858 74606	
ST 83840 74590		2013									
					5	3(4)	2	6		ST 83820 74510	
			11(8)							ST 83811 74512	
				1		4(4)	2	8		ST 83799 74528	Bullhead; fry sp.; Little Egret; Grey Heron; Cormorant; Kingfisher;
			10(7)							ST 83748 74517	
						5(2)	1	9		ST 83649 74074	
			9(6)							ST 8369173873	
				2		6(2)	2	11		ST 83764 73824	
			8(5)							ST 83852 73794	
				4		7(2)	2	13		ST 83823 73743	
						8(1)	2	15		ST 83838 73722	
ST 84100 73800	1999										
			7							ST 84264 73458	
			6							ST 84056 71729	
			5(4)							ST 83764 71018	
			4							ST 83228 69848	
ST 83200 69900	1992										
						9(3)	1	16		ST 83165 69870	
				2		10(3)	1	17		ST 82587 68958	Kingfisher
						11(2)	1	18		ST 82594 68947	
			3(3)							ST 82571 68937	
			Unnamed Stream	1		12(4)	2	20		ST 82554 68975	
ST 82500 68900	1998										
			Box Mill Leat			13(6)	1	21		ST 82438 68893	Dipper
			2(2)							ST 8141 5 68810	
ST 80800 68600	1986										
			1(1)							ST 8041 968165	
			EA RAIL SL							ST 7978 767394	
						14(4)	1	22		ST 79524 67289	
			UNKNOWN WEIR							ST 79139 67233	
						15(2)	2	24		ST 79082 67223	
						16(2)	2	26		ST 79048 67225	
			EA MILL BARRIER							ST 78999 67171	
						17(2)	2	28		ST 78892 67111	
						18(2)	2	30		ST 78830 67091	Fry sp.
						19(2)	2	32		ST 78816 67088	Fry sp.
			Bathhampton Mill leat			20(2)	2	34		ST 78804 67086	
				11	**7**	**20(57)**		**34**			

*Vulnerable monitoring zone

Possible VMZ: unable to confirm crayfish presence/absence. White-clawed crayfish possibly absent due to plague outbreak (Frayling, pers comm.).