UUWR_32

PR24 Draft Determination: UUW Representation

Area of representation: Cost and PCD - Water WINEP

August 2024

This document outlines the UUW response to the draft determination for UUW_60 “Water WINEP”

Reference to draft determination documents: PR24-DD-W-Investigations, PR24-DD-W-Water-Framework-Directive, PR24-DD-W-INNS, PR24-DD-W-Eels-Fish-Passes, PR24-DD-W-Drinking-water-Protected-Areas, PR24-DD-W-Eels-Fish-entrainment-Screens, PR24-DD-W-Biodiversity

United Utilities

Water for the North West

1. Key points

- **WINEP is a regulatory obligation:** UUW has used the regulatory guidance, and has worked with the relevant regulators (Environment Agency, Natural England, Natural Resources Wales) to identify projects that are required.
- **At DD Ofwat applied a significant downward adjustment of £28.944m against a £107.693m programme.** This cost downward adjustment is focussed on the delivery of biodiversity projects (SSSI, moorland management, peat bog improvements and so on), as well as the major capital infrastructure removal projects in West Cumbria (Crummock, Overwater and Chapel House), which are long multi-AMP projects. Ofwat challenged United Utilities to provide further evidence on optioneering, cost build up, and cost efficiency. This additional evidence is included in section 4 of this document.
- **Three projects have been added to the WINEP since the original submission in 2023:** Three additional AMP8 WINEP projects have been identified since business plan submission. An addendum to the original Water WINEP enhancement document has been produced, setting out the detail of the three new projects and is included as UUWR_80.

2. UUW's PR24 proposal

United Utilities Water (UUW) must ensure it meets environmental obligations in AMP8, as identified through the Environment Agency's (EA) Water Industry National Environment Programme (WINEP) and Natural Resources Wales' (NRW) National Environment Programme (NEP).

The AMP8 Water WINEP will deliver £728.842m of environmental value benefit over the next 30 years, for an AMP8 financial investment of £107.693m in our business plan submission (environmental benefit based on DEFRA methodology).

Three additional AMP8 WINEP projects have been identified since business plan submission. In these cases these are AMP8 requirements which have come to light as a result of the findings of AMP7 WINEP project investigations. The outcome of the AMP7 investigations was not available at the time of business plan submission (for some projects) and these requirements have only come to light since submission. The additional costs of these projects are £18.062m for Yearl Weir, £4.994m for Bleawater, and £0.051m for Naden Gauging Weir. These projects and their costs were to be added to the enhancement case addendum, planned to be submitted at DD representation (included in document UUWR_80).

The costs of AMP8 water WINEP projects have been built from the bottom up, based on historic costs of similar projects delivered over several AMPs or cost build ups undertaken as part of an AMP7 investigation. The costs associated with different types of project (grouped by driver) are discussed in detail in our October 2023 business plan document UUW_60 Water Enhancements, Water WINEP, Section 6 cost efficiency, page 38 to 76. Benchmarking and 3rd party assurance of cost efficiency is shown on page 75.

3. Draft determination position

WINEP projects are classified by regulators against a variety of 'driver codes' these being the regulatory requirements that each project is designed to meet. Ofwat group certain collections of thematically driver codes into separate data table lines.

Ofwats' Draft determination in relation to the Water WINEP is shown in Table 1 below. The table is split by Ofwat data table line names;

Table 1: Summary of FBP versus DD costs and allowances

WINEP Project Type (by data table line name)	FBP Cost (not including the 3 new WINEP projects identified since FBP submission)	Ofwat DD allowance
Investigations	£26.686	£22.16
INNS	£4.343	£3.605
Eel + fish passes	£2.018	£1.675
Eel screens	£2.606	£2.163
DrWPA	£7.163	£5.73
Biodiversity	£48.569	£29.141
WFD	£16.309	£13.537

Source: UUW_60 enhancement document submitted in October 2023 and Ofwat PR24-DD-W-Winep documents

Ofwat applied downward adjustments to costs for investigations due to the application of industry average unit rates.

Ofwat applied a 17% challenge to our proposed costs for the management of Invasive Non-Native Species (INNS) based on industry standard bench marks.

Ofwat applied downward adjustments to costs for eel and fish passes due to the application of industry average unit rates.

Ofwat applied downward adjustments to costs for eel screens due to the application of industry average unit rates.

Ofwat undertook a 'deep dive' analysis into the business case for Drinking Water Protected Areas (DRWPA). A 20% downward adjustment was applied. Minor concerns were noted with the gateways for optioneering (did not explain alternative options that had been considered), and cost efficiency (we did not provide detailed cost build ups).

Ofwat undertook a 'deep dive' analysis into Biodiversity projects. A 40% downward adjustment was applied to these projects. Downward adjustments were applied to Biodiversity due to some concerns at the gateway for optioneering (limited alternative options and CBA shown for West Cumbria compensatory measures), some concerns regarding the cost efficiency of West Cumbria infrastructure removals projects.

Ofwat applied downward adjustments to costs for water Framework Directive projects due to the application of industry average unit rates. WFD projects are typically low cost, changes to abstraction licences. However in a small number of cases, these projects also include the installation of compensation flows, a construction activity which incurs costs of a different magnitude from licence changes. The application of unit rates fails to take this difference into account.

Ofwat has proposed a PCD associated with the delivery of biodiversity projects, and have specifically requested additional data on project benefits and measurable outputs to be included in the DD representation.

4. Issues and implications

Ofwat's DD has allowed £78.011m, compared to our business plan submission value of £107.693m. This is a reduction of £29.682m.

The WINEP is a regulatory obligation, which we have no choice but to deliver. If we do not have enough allowed enhancement cost to deliver these projects, then the projects may have to be supported through botex, which would be a potential dis-service to customers, as investment would be diverted from service supporting maintenance to the delivery of regulatory driven projects.

We believe that our Water WINEP plan is well assured, and that costs have been robustly and efficiently estimated.

4.1 Our "WINEP Investigations" projects are based on accurate market data, and some are unique projects to which industry unit rates are not appropriate.

Ofwat applied a downward adjustment to investigations due to the application of industry average unit rates, derived from a financial model.

The costs for investigations have been built up based on historic out-turn costs, following a detailed scope and optioneering exercise which as set out in Section 6.9, Table 17, Page 68 of the supplementary document UUW_60 Water Enhancement Cases. We consider our approach to be robust and accurate.

Of particular concern however is that some of these rates may have been applied without consideration to project specific considerations. The application of standard modelled unit rates is not appropriate in these cases, as both the project scope, and the estimated efficient cost, will significantly deviate from industry averages. Specific cases are listed below.

For example we requested £0.709m for an investigation into nitrate levels in drinking water from the Cliburn Boreholes (project 08UU100205), and similarly we requested £0.973m for nitrate levels at the Wirral Boreholes (project 08UU100216). Ofwat allowed an industry standard £0.4m per project for these projects. However, these are not 'standard' groundwater investigations, as each site has multiple boreholes spread over a large area. This multiple source / large area factor increases investigatory costs, which appears to not have been taken into account.

In the case of investigation project U800100220, Invasive Non-Native Transfer Mitigation Trials, we requested £0.729m, but Ofwat has allowed an industry standard rate of £0.328m This project is not a standard investigation. The project involves trials of new technology, to prevent INNS being transported between catchments via aqueducts. The project involves both an investigatory phase (determining what technology is available) and a construction / operational trials phase of using a suitable technology. The above average cost of this project is a reflection that it is not purely an investigation, and we believe Ofwat should reconsider the assessment of cost on that basis.

Elsewhere in the thematic area of INNS, project 08UU100221 "Phase 2: INNS Raw water transfer investigation and options appraisal", we requested £1.384m, but Ofwat allowed a standard unit rate of £0.328m. This project is a major undertaking, reviewing every possible transport route for INNS life-cycle stages across our network. The project will investigate many hundreds of transfer points, network wash-outs, and other potential points of INNS release, and develop a major programme for future investment (AMP9 and beyond) to prevent those risks from occurring. This project will involve very considerable site surveying, and engineering optioneering work, and is by no means a standard investigation. More detail on this project was provided in Appendix A, Page 113 of our October 2023 business plan document UUW_60 Water Enhancement Cases.

Of even greater concern for United Utilities, is an investigation project, where the investigation is a prelude to a significant construction project **which is also required to be delivered in AMP8**.

In the case of 08UU100219 , United Utilities proposed a cost of Fylde Aquifer Re-Charge Investigation Phase 2. United Utilities proposed a forecast cost of £4.949m (pre-efficiency), whereas Ofwat allowed an industry standard WFD investigation rate of £0.487m. This project involves not only an investigation into the location and operation of managed aquifer re-charge, but also the actual construction and operation of a pilot plant. This is a very strategically important project for local communities, for United Utilities and for the Environment Agency. We aim to reduce flood risk, by capturing and storing excess surface water, both reducing the risk of community flooding, and improving the environment by 'topping up' groundwater water resources. We, customers and our regulators consider this technology has the potential to be transformative and offer multiple benefits.

United Utilities submitted a query to Ofwat regarding this project (Query OFW-IBQ-UUW-029). Ofwat advised that the project costs should be split between investigation, and WFD implementation data table lines. We have therefore followed this guidance, and placed the £0.49m for the investigatory phase against data table line CW3.36, and placed the £4.414m implementation phase against data table line CW3.16.

It will not be possible to proceed with the project unless funding is permitted to support both the investigatory phase, and crucially, the construction and operation phase of the project. We would urge Ofwat to support this innovative project, and to not apply a unit rate to this project specifically.

4.2 Fish passes and eels screens projects, and projects related to INNS implementation, have been downward adjusted by 17% without a deep dive analysis having been carried out

Ofwat has applied a 17% downward adjustment to our fish passage, and eels screens projects, and implementation projects related to INNS. These projects were not subject to a 'deep dive' analysis by Ofwat.

We consider that our costs for these projects were built up robustly, based on historic prices. More detail of how the cost estimates for these projects were built up can be found in Section 6.4 and Section 6.6 of October 2023 business plan submission document UUW_60 water Enhancement Cases.

Our drive towards greater efficiency will continue into the tender process and contract award phases of the project. A detailed statement on United Utilities approach to managing capital investment and engineering procurement is provided in Appendix A.

4.3 Drinking Water Protected Areas (DrWPA) additional optioneering evidence

Both United Utilities and the Environment Agency have duties regarding ensuring that there are sufficient water resources available for customers in the North West, and that those water resources are appropriately managed. This includes ensuring that water resources do not become unusable due to contamination from the environment.

Drinking Water Protected Area WINEP projects are a mechanism by which water companies can be funded to influence land management practices in the catchment, to minimise the risk of land use practices leading to contamination of water sources.

United Utilities proposed a series of DrWPA projects across the North West, to a total value of £7.163m.

Ofwat undertook a 'deep dive' analysis into one selected DrWPA project, 08UU100146 Errwood and Fernilee & Wybersley Colour – Goyt. In the PR24 Draft Determination, document PR24-DD-W-Drinking_Water-Protected-Areas.xlsx, worksheet "Deep Dive_UUW", cell D21, Ofwat stated; "*Whilst the enhancement request is relatively low materiality, the company has one scheme (Errwood, Fernilee and Wybersley (colour) which looks expensive on a cost per action basis and is the focus of the deep dive*. *The company states in a query response that this scheme covers two catchments, the River Goyt and the River Bollin, which brings it more in line with costs for other companies where costs per action appear to relate to one catchment.*"

We concur that this project covers multiple catchments (as our Wybersley WTW can be fed source water from a number of different reservoirs, in different reservoir chains), and that the comparatively large catchment area is the driver for costs.

In the PR24 Draft Determination, document PR24-DD-W-Drinking_Water-Protected-Areas.xlsx, worksheet "Deep Dive_UUW", cell D21, Ofwat goes on to state; "*The company state optioneering was done during 2020-2025 as part of the associated investigation projects, which determined the preferred solutions. However, only one viable option is identified for the Errwood, Fernilee and Wybersely scheme, which is then stated as both the preferred (best value) and least cost option. The company does not provide sufficient and convincing evidence that it has considered a suitable number of alternative options, aligning with WINEP guidance and expectations for PR24 enhancement requests.*"

The report quoted by Ofwat is "*UNITED UTILITIES WYBERSLEY, ERWOOD AND FERNILEE (SWSGZ3202 / SWSGZ3201) SAFEGUARD ZONES RAW WATER COLOUR INVESTIGATION OF ERRWOOD, FERNILEE, HORSE COPPICE AND BOLLINHURST RESERVOIRS FINAL REPORT MARCH 2022*", prepared by Penny Anderson Associates Ltd, consultant ecologists. That report contains a very comprehensive list of options that were explored, as part of a package of ecological measures to reduce colour in the raw water from these catchments. The options appraisal section of that report is reproduced in Appendix B of this document.

The options presented in the report in Appendix B are the lowest cost option to address the issue of colour in the raw water, whilst meeting the Environment Agency DrWPA driver. It may have been possible to resolve the colour issue by other means (such as abandoning these water sources, and replacing them with alternative sources), but such engineering solutions would not meet the requirements of the DrWPA driver. Furthermore they would not have addressed the route cause of the issue, the discolouration in the raw water itself.

Table 2: Comparison of costs of alternative sources versus catchment solutions

Possible solution	Approximate cost	Comments
DrWPA compliant catchment management	£4.187m	Based on costs of the proposed project.
Abandon source, replace with new cheapest option sources	£226.3m	Based on a peak week production capacity of 73 ML/day, and a cost of £3.1m per ML/day for cheapest groundwater source from WRMP24.

Source: UUW cost of new sources per ML/D from WRMP24

In the PR24 Draft Determination, document PR24-DD-W-Drinking_Water-Protected-Areas.xlsx, worksheet "Deep Dive_UUW", cell D21, Ofwat goes on to state; "*While the company provides evidence of how it arrived at its option costs and provides third-party assurance of its cost estimates, it does not provide sufficient and convincing evidence that the proposed costs are efficient………. a cost build up example is provided in the supporting enhancement case. The company states that the other two schemes are on based on third-party bottom-up build based on 2020-2025 investigation fundings and outturn project costs for similar schemes. However, the cost build up is not provided. The company should provide sufficient and convincing evidence to clearly show how it has arrived at its option costs."*

The Ofwat reference to another two schemes we interpret as referring to the other two DrWPA_ND projects in the AMP8 WINEP programme, namely "08UU100157 Hodder / Stocks colour phase 2", and "UU100003 Huntington and Sutton Hall (River Dee Turbidity)".

The pre-efficiency cost build up for project 08UU100157 Hodder / Stocks colour phase 2 as requested by Ofwat is shown in Figure 1. The pre-efficiency cost build up for project UU100003 Huntington and Sutton Hall (River Dee Turbidity) as requested by Ofwat is shown in Figure 2.

Figure 1: Project 08UU100157 optioneering and cost assessment

Risk & Value options development phase: 08UU100157 evidence on projectwise under PR24T 1020 Options Development Report:

Generic High Level Solution (GHLS) Preference Hierarchy		Option (unconstrained)				
GHLS	**Description**	**Viable Option?**	**Commentary if no viable options**	**Option title**	**Description (Max 160 Characters)**	**Type of Solution**
Monitor & Respond	*Accept risk with agreed contingency plan*	Not Viable	Does not meet the requirement			
Operational Intervention	*Solve Need by identifying targeted maintenance to restore performance*	Not Viable	Does not meet the requirement			
Optimise Asset	*Solve Need by improving performance of existing equipment*	Not Viable	Does not meet the requirement			
Partnership	*Solving need by assistance of third parties, i.e. assisting farmers reduce pollution of watercourses*	Viable		*Partnership Option 1*	Develop an option for the implementation to improve river morphology and minimise the impact of Stocks Reservoir on the River Hodder	Catchment Intervention
Refurbish Asset	*Major asset refurbishment to restore asset life and performance*	Not Viable	Does not meet the requirement			
Replacement	*Replace asset(s) on like for like basis*	Not Viable	Does not meet the requirement			
		Not Viable	Does not meet the requirement			

- Commentary from Engineering:

D00000581	Hodder/Stocks colour phase 2	Prevent deterioration to raw water quality concentrations of colour in Hodder/Stocks to remove 'at risk' status for that substance in the drinking water protected area	DrWPA_ND			base Costs produced by external consultants based on outturn costs from similar schemes that have been undertaken. UU Estimating updated costs to bring in line with PR24 cost base

- Cost build up: generic catchment template build up. Chosen part catchment interventions category; 5 years; simple sampling.

						3rd party project management and delivery costs								Client Indirects (UU Eng, sampling and PM time, insurance)						
Type of Project	Description		Scheme Length (1-5 years)	Sampling Type (Simple / Complex)	No locations (Complex only)	Direct	Indirect	Award Value	UU Contribution %	UU Award Value	Risk / Uncertainty 5%	Outturn 4% (Changes after contract award)	Out turn Solution Cost	Project Management	Sampling / Monitoring	Insurance (0.75% of direct costs)	Total Project Cost	O/H at 15%	Overall UU CAPEX cost	Post UU internal efficiency
No	Includes whole catchment and neighbouring landowners	Extra Large	5	Simple		£2,000,000	£500,000	£2,500,000	96%	£2,400,000	£120,000	£100,000	£2,620,000	£600,000	£4,250,000	£18,000.00	£7,488,000	£1,123,200	£8,611,200	£7,511,954
No	Peatland Restoration Schemes	Large	5	Simple		£1,000,000	£500,000	£1,500,000	50%	£750,000	£37,500	£60,000	£847,500	£500,000	£2,500,000	£0.00	£3,847,500	£577,125	£4,424,625	£3,859,808
No	Farming intervention schemes	Medium	5	Simple		£900,000	£1,000,000	£1,900,000	15%	£285,000	£14,250	£76,000	£375,250	£450,000	£1,250,000	£0.00	£2,075,250	£311,288	£2,386,538	£2,081,889
No	Full catchment interventions	Medium	5	Simple		£600,000	£500,000	£1,100,000	71%	£781,000	£39,050	£44,000	£864,050	£450,000	£250,000	£0.00	£1,564,050	£234,608	£1,798,658	£1,569,053
Yes	Part Catchment Interventions	Small	5	Simple		£600,000	£0	£600,000	25%	£150,000	£7,500	£24,000	£181,500	£450,000	£150,000	£0.00	£781,500	£117,225	£898,725	£784,000

Source: UUW risk and value process

Figure 2: Project UU100003 optioneering and cost assessment

Risk & Value options development phase: UU100003 evidence on projectwise under PR24T 1020 Options Development Report:

Development of unconstrained options list

Generic High Level Solution (GHLS) Preference Hierarchy		Option (unconstrained)				
GHLS	**Description**	**Viable Option?**	**Commentary if no viable options**	**Option title**	**Description (Max 160 Characters)**	**Type of Solution**
Monitor & Respond	*Accept risk with agreed contingency plan*	Not Viable	Does not meet the Project Requirement			
Operational Intervention	*Solve Need by identifying targeted maintenance to restore performance*	Not Viable	Does not meet the Project Requirement			
Optimise Asset	*Solve Need by improving performance of existing equipment*	Not Viable	Does not meet the Project Requirement			
Partnership	*Collaborative funding from multiple Water Companies/organsations to deliver catchment interventions*	Viable		*Partnership Option 1*	Collaborative funding from multiple Water Companies/organsations to deliver catchment interventions	Partnership
Refurbish Asset	*Major asset refurbishment to restore asset life and performance*	Not Viable	Does not meet the Project Requirement			
Replacement	*Replace asset(s) on like for like basis*	Not Viable	Does not meet the Project Requirement			
New Asset	*Build New Asset when all other options are not possible or lowest TOTEX*	Not Viable	Does not meet the Project Requirement			
Integrated Approach	*Integrated solution across asset boundaries such as process network boundary, process, Bioresources or catchment level solutions. An integrated solution is a Systems Thinking*	Not Viable	Does not meet the Project Requirement			
Combination of generic high level solutions	*Example - SuDS and a storage tank to address CSOs*	Not Viable	Does not meet the Project Requirement			

Screening of unconstrained options

Unconstrained to constrained

Option title	Does the solution meet the requirements?		Is the solution technically feasible?		Does the solution look delivera	
	YES / NO	*Description*	*YES / NO*	*Description*	*YES / NO*	*Description*
Partnership Option 1	Yes	Collaborative funding from multiple Water Companies/organsations to deliver catchment interventions	Yes	Collaborative funding from multiple Water Companies/organsations to deliver catchment interventions	Yes	Collaborative fundi multiple Wat Companies/organsa deliver catchm intervention

Commentary from Engineering:

D00000423	Huntington and Sutton Hall (River Dee Turbidity)	W_DrWPA_NDIMP1

Costs based on historical outturn costs for implementing similar schemes within UU. UU Estimating updated costs to bring in line with PR24 cost base

						3rd party project management and delivery costs								Client Indirects (UU Eng, sampling and PM time, insurance)						
Type of Project	**Description**		**Scheme Length (1-5 years)**	**Sampling Type (Simple / Complex)**	**No locations (Complex only)**	**Direct**	**Indirect**	**Award Value**	**UU Contribution %**	**UU Award Value**	**Risk / Uncertainty 5%**	**Tender to Outturn 4% (Changes after contract award)**	**Out turn Solution Cost**	**Project Management and UU Engineering Staff costs**	**Sampling / Monitoring**	**Insurance (0.75% of direct costs)**	**Total Project Cost**	**O/H at 15%**	**Overall UU CAPEX cost**	**Post UU internal efficiency**
Yes	Includes whole catchment and neighbouring landowners	Extra Large	5	Complex	13	£4,000,000	£1,000,000	£5,000,000	33%	£1,650,000	£82,500	£200,000	£1,932,500	£600,000	£877,500	£12,375.00	£1,477,500	£221,625	£1,699,125	£1,688,000
No	Peatland Restoration Schemes	Large	1	Simple	5	£1,000,000	£500,000	£1,500,000	22%	£330,000	£16,500	£60,000	£406,500	£100,000	£500,000	£0.00	£1,006,500	£150,975	£1,157,475	£1,149,896
No	Farming intervention schemes	Medium	1	Simple	10	£900,000	£1,000,000	£1,900,000	15%	£285,000	£14,250	£76,000	£375,250	£90,000	£250,000	£0.00	£715,250	£107,288	£822,538	£817,152
No	Full catchment interventions	Medium	1	Complex	12	£600,000	£500,000	£1,100,000	71%	£781,000	£39,050	£44,000	£864,050	£90,000	£360,000	£0.00	£1,314,050	£197,108	£1,511,158	£1,501,263
No	Part Catchment Interventions	Small	1	Complex	10	£270,000	£380,000	£650,000	50%	£325,000	£16,250	£26,000	£367,250	£90,000	£300,000	£0.00	£757,250	£113,588	£870,838	£865,136

Source: UUW risk and value process

In addition to the details requested above, a detailed statement on United Utilities approach to managing capital investment and engineering procurement is provided in Appendix A.

4.4 Our Biodiversity projects have been thoroughly optioneered and costed through investigation projects in AMP7

The United Utilities AMP8 WINEP programme includes 12 projects which are classified under the Biodiversity driver line. These projects fall into two broad groups.

The first are projects which form part of the West Cumbria Compensatory Measures package, where we are obliged to carry out environmental improvement measures, as part of the compensation that we must pay for continuing to abstract from Ennerdale between 2014 and 2021. These projects involve the removal of dams and weirs, and abstraction apparatus, in order to re-naturalise protected environments.

The projects involved in the West Cumbria Compensatory Measures projects are:

- Crummock Water infrastructure removal 08UU100150,
- Chapel House infrastructure removal 08UU100149,
- Overwater infrastructure removal 08UU100152,
- Ennerdale infrastructure removal 08UU100151.

The Ennerdale project is different, in that the actual demolition activity associated with the project is scheduled for AMP9.

The costs associated with the West Cumbria Compensatory Measures projects have all been built up as a result of detailed investigations and method development in AMP7. A key feature of the AMP7 projects is to achieve regulatory approval for the methods to be used in the AMP8 infrastructure removal phase. These habitats are subject to some of the most protected status' possible (SAC and SSSI) and our options for what actions may be taken are severely restricted by regulatory environmental protection concerns.

The second type of Biodiversity project is where we work with partners to restore SSSI landscapes to good condition, where we are the land owners across all or most of the SSI area.

Ofwat undertook a 'deep dive' analysis into the West Cumbria Compensatory Measures projects, and Ofwat made a 40% downward adjustment against the costs associated with these projects.

In the PR24 Draft Determination, document PR24-DD-W-Biodiversity.xlsx, worksheet "NWT", Cell C20, Ofwat states; "*there is limited evidence to demonstrate that the proposed schemes are the most cost beneficial and best value for customers for most schemes. Limited comparative cost-benefit analysis data is presented, and whilst the enhancement case sets out the optioneering process, only one option has been presented for most of the schemes.*"

In terms of the West Cumbria Compensatory Measures projects, United Utilities' scope for optioneering is limited to the engineering techniques used to carry out the removal. We do not have the freedom to select options other than infrastructure removal. We cannot, for example, choose to do nothing, or choose to continue abstraction, as such options would not be permitted as part of the Compensatory Measure package agreed following the Inquiry in Public regarding abstraction in West Cumbria that was held in 2014. The limits to our optioneering are codified in Measure Specification Forms for the projects, which are formal scope definition documents issued to United Utilities by the Environment Agency. The relevant Measure Specification Forms are attached in Appendix D.

In the PR24 Draft Determination, document PR24-DD-W-Biodiversity.xlsx, worksheet "NWT", Cell C20, Ofwat goes on to state; "*A third-party optioneering report has been provided for the company's most material scheme 'Crummock Water' (08UU100150), where detailed optioneering, scheme scope and benefit has been presented. However, similarly detailed reports have not been provided for the other two 'West Cumbria compensatory measures schemes': 'Overwater' (08UU100152) and 'Chapel House' (08UU100149).*"

We acknowledge this omission. Overwater is a natural lake (which is also classified as a reservoir, due to be artificially deepened by a weir) which drains via Overwater Beck into Chapel House Reservoir. As these reservoirs are in a chain, (one immediately upstream from the other), a single optioneering report was produced for both water bodies. This optioneering report was undertaken by a 3rd party (Jacobs), and this report is provided in full in Appendix C of this representation as requested.

In the PR24 Draft Determination, document PR24-DD-W-Biodiversity.xlsx, worksheet "NWT", Cell C28, Ofwat further states; "*The company states that the three 'West Cumbria compensatory measures' schemes are largely bespoke projects based on site-specific circumstances. It claims that benchmarking was therefore unable to be conducted and costs for each solution were developed internally, using a bottom-up estimating approach. Cost build-ups have been provided for these schemes; however, detailed cost-breakdowns have not been included in the submission.*"

We acknowledge Ofwats' comments regarding cost breakdowns.

The cost breakdown for project "Overwater infrastructure removal 08UU100152" is shown below:

Table 3: Cost breakdown for Overwater 08UU100152

Component cost line items	Component costs (£)
Access and compound	346,079
Temporary roadway	198,651
Removal of weir direct activity cost	151,199
Sandbagging / damming for working area	42,147
Removal of demolished material	265,073
Excavation of pipework / ducting	226,671
Access dust supression and grit removal	148,709
Hardstandings	33,627
Underground chamber works	22,686
Valve removal	12,999
Pipework and headwall removal from site	33,717
Material removal other costs (licences, disposal etc)	187,452
Environmental restoration	2,639,276
UU surveying	92,380
UU engineering	231,086
UU other services (land management, overhead etc)	377,159
Insurance, compensation events etc	54,088
Total	**5,063,000**

Source: UUW cost estimate

The Environmental Restoration action relates to our obligations under Schedule 7A of the Town and Country Planning Act 1990 (as amended by Schedule 14 of the Environment Act 2021). Where planning applications are submitted to change the environmental conditions of a designated site. The applicant has an obligation to ensure that there is a 'net gain' in biodiversity of +10% or more for 30 years or longer, according to DEFRA endorsed biodiversity assessment criteria. At Overwater this obligation relates to the change in shoreline that will occur when the dam is removed, and the lake level drops. The activity may include planting and sculpting of the shoreline, in order to provide new habitats for fish, otters, wading birds, plants and insect life and so on.

The cost breakdown for project “Chapel House infrastructure removal 08UU100150” is shown below:

Table 4: Cost breakdown for Chapel House 08UU100150

Component cost line items	Component costs
Tree removal	54,679
Access road	851,310
Access and working area (boggy ground)	1,162,866
Footpath diversion	466,501
Remove wave wall	641,625
Separate access and compound Eastern Bank	993,770
New timber footbridge and footpath	356,448
Sheet piling	367,812
Sand bagging	436,761
Temporary bridge	474,124
Demolish and remove weir	1,923,725
Pumping	1,465,508
Lake shore wall removal	234,246
Park Beck training wall	636,717
Park beck bridge removal	368,088
Remove 1 concrete vehicular bridge	45,888
Additional fencing / walling	38,919
New water boat launch concrete slab	66,812
Screen / cap raw water intake	59,241
Pipe removal and plugging	150,989
UU services (engineering, overhead etc)	1,349,971
Total	**12,146,000**

Source: UUW cost estimate

The cost breakdown for project “Crummock Water infrastructure removal 08UU100149” is shown below:

Table 5: cost breakdown for Crummock Water 08UU100149

Component cost line items	Component costs (£)
Access road	766,995
Separate access road for farm	372,825
Temporary footpath	63,403
Overpumping of residual flow while working	164,030
Raise and strengthen the bywash channel	115,273
Raise 200m additional bywash channel wall	115,273
Excavate new river channel	114,092
Sediment remediation (extensive)	1,383,983
Dam embankment removal	2,565,346
Landscaping	164,171
Demolish valve house and other assets	44,946
Decomission bywash channel post project	569,027
New permanent road	589,551
New road bridge	633,292
New bridge abutments	366,131
New timber footbridge and footpath	129,560
UU services (engineering, overhead etc)	5,118,100
Total	**13,276,000**

Source: UUW cost estimate

4.5 Projects regarding our obligations under the Water Framework Directive have project specific drivers, and the application of industry standard rates is not appropriate.

Water Framework Directive projects are generally focused on ensuring sustainable abstraction from water sources. WFD projects are typically low cost investigations in one AMP, followed by a low cost abstraction licence cap the following AMP.

United Utilities requested £16.309m for WFD projects, based on bottom up estimated costs based on historic out-turns. Ofwat applied a standard 17% downward adjustment to all United Utilities WFD project costs. No deep dive analysis was carried out on United Utilities WFD project costs.

Some of these rates may have been applied without consideration to project specific considerations. The application of standard modelled unit rates is not appropriate in these cases, as both the project scope, and the estimated efficient cost, will significantly deviate from industry averages. Specific cases are listed below.

The following projects are non-standard, in that they not only include the standard costs of licence change, but also include actual construction costs associated with the provision of compensation flows (stream support) as well. It would be inappropriate to apply industry standard rates to these projects, as their scope and cost is wholly different to the majority of WFD projects undertaken in the UK.

The specific projects which also include construction costs are:

- 08UU10021 Manley Common boreholes,
- 08UU100022 Manley Quarry boreholes,

- 08UU100023 Mouldsworth boreholes.

We recommend that Ofwat re-asses the costs associated with our WFD projects, with particular reference to the projects specified above, whereby industry standard rates are not appropriate.

With regard to these non-standard WFD projects, an activity build up of line items that contribute towards the overall cost estimate of the project are provided in Table 11. Pages 45 and 46, of UUW_60 Water Enhancement business cases from our October 2023 submission. This detail describes the construction activity involved with these projects, and how this differs from other WFD projects, where only simple administrative tasks related to licence changes are required.

In addition, these costs were subject to additional assurance, as set out in UUW_60 Appendix E "Second line assurance and cost build up" on Page 124, where the cost build up was challenged for efficiency, and to ensure that no base maintenance costs were included in the project scope. The second line assurance found that the cost estimates associated with these projects were valid.

4.6 Price control deliverable mechanism

In the PR24 Draft Determination, document PR24-DD-W-Water-WINEP-PCDs.xlsx, worksheet "Biodiversity-UUW", Cell C11, Ofwat further states; "*Further detail on locations and descriptions of environmental improvements for these actions are expected in response to draft determinations.* "

Ofwat then list data that was presented on the total catchment area of Biodiversity projects. Ofwat divided the costs of the projects by the hectarage provided to derive a PCD rate.

The total catchment area was provided in order to provide Ofwat with intelligence on the size and scope of the task at hand. It was not however, indicative of the actual hectarage that would benefit from the AMP8 projects as proposed.

The actual area that we intend to improve is as follows:

Table 6: Hectarage of Biodiversity projects scheduled for AMP8

<table>
<tr><th>Project</th><th>Hectare benefitting in AMP8</th><th>Comments</th><th>Post efficiency and RPE costs (£)</th></tr>
<tr><td>River Eden (08UU100145)</td><td>40</td><td>Hectarage benefit based on AMP8 plan</td><td>195,021</td></tr>
<tr><td>Bowland (08UU100158)</td><td>600</td><td>Hectarage benefit based on AMP8 plan</td><td>2,065,886</td></tr>
<tr><td>Haweswater (08UU100159)</td><td>1,000</td><td>Hectarage benefit based on AMP8 plan</td><td>909,853</td></tr>
<tr><td>West Pennines (08UU100161)</td><td>500</td><td>Hectarage benefit based on AMP8 plan</td><td>1,727,208</td></tr>
<tr><td>Poaka Beck (08UU100162)</td><td>50</td><td>Hectarage benefit based on AMP8 plan</td><td>841,497</td></tr>
<tr><td>Upper Duddon (08UU100163)</td><td>500</td><td>Hectarage benefit based on AMP8 plan</td><td>841,497</td></tr>
<tr><td>Thirlmere (08UU100164)</td><td>1,000</td><td>Hectarage benefit based on AMP8 plan</td><td>3,152,466</td></tr>
<tr><td>Ennerdale infrastructure removal (08UU100151)</td><td>4,390</td><td rowspan="4">This is the total hectarage of the catchment. The action is to remove the weir, but the benefit is accrued across the entire catchment area.</td><td>2,227,157</td></tr>
<tr><td>Crummock infrastructure removal (08UU100150)</td><td>13,617</td><td>12,246,360</td></tr>
<tr><td>Chapel House infrastructure removal (08UU100149)</td><td>14,884</td><td>13,386,449</td></tr>
<tr><td>Overwater infrastructure removal (08UU100152)</td><td>5,676</td><td>5,095,665</td></tr>
</table>

Project	Hectare benefitting in AMP8	Comments	Post efficiency and RPE costs (£)
South Pennines (08UU100160)	1,600	Hectarage benefit based on AMP8 plan	5,096,011

Source: UUW project forecasts

On that basis we recommend a Price Control Deliverable rate of £47.785m / 43,857 hectares = £1,089.57 per hectare.

5. Approach for final determination

We recommend that Ofwat re-asses our Water WINEP costs, on the basis of the additional evidence provide here, and reinstate the cost allowance to the full £107.693m requested.

Of particular note, we recommend the following;

That Ofwat takes into account the project specific issues regarding investigation projects, as set out in Section 4.1 of this document. These project specific considerations demonstrate that the application of a standard unit rate is inappropriate for projects of this type. Ofwat to reinstate the full requested costs of £22.283m (adjusted with the reclassification of Fylde Aquifer phase 2).

With regard to fish passes an eel screens, and INNS implementation, we believe that our costs were estimated robustly, based on historic out-turn, and we recommend reinstatement of the full value of £4.624m for the eels and fish projects, and £4.343m for the INNS projects respectively.

In regard to Drinking Water Protected Areas, we have provided the additional information and detail that was requested by Ofwat at Draft determination. That information is set out in detail in Section 4.4 of this report. This information includes the optioneering reports, cost build ups, and other additional details as requested, including considerable 3rd party optioneering reports. On this basis we recommend that, having answered the challenges posed, the full costs of £7.163m should be permitted.

The costs permitted for Biodiversity projects are of particular concern to us. The West Cumbria Compensatory Measure projects are some of the most high profile environmental projects being undertaken in AMP8. The methods (and costs) for the AMP8 projects have been determined through a very thorough investigations programme in AMP7. At business plan submission we did not provide all of the available data concerning cost build up, optioneering and efficiency. We have now provided Ofwat with all of the relevant details regarding these projects (as requested), and we request that the full allowance of £48.569m is reinstated, in order to support our delivery of these extremely critical projects.

Similar to our representation regarding Investigation projects, some of our WFD projects are non-standard, and it is not appropriate to apply industry standard unit rates to these non-standard projects. We recommend that the full allowance is reinstated to WFD projects, being £20.764m (adjusted with the reclassification of Fylde Aquifer phase 2).

As requested, we have provided additional detail regarding the benefits of Biodiversity projects, and how they relate to the Price Control deliverable mechanism. We recommend that the PCD mechanism is amended in line with this additional information.

Appendix A United Utilities approach to capital investment

At Price Review stage, the United Utilities Commercial, Engineering and Capital Delivery department will review the capital investment programme to determine the typical type, size, value and complexity of solutions required for the assets to be renewed or maintained across the water and wastewater infrastructure and non-infrastructure programme to ensure the procurement strategy is fit for purpose to deliver an efficient programme.

We will then review the procurement strategy to determine what type of commercial construction, supply, engineering and consultancy frameworks need to be procured to ensure that UU has the most appropriate partners in place to deliver the capital programme below budget and to the right timescales.

Each framework will go through a rigorous procurement process so that each of the bidders commercial/value, technical, health and safety, relevant experience and staff CV’s can be assessed and scored, to ensure that the Framework partners chosen will have demonstrated through a competitive process, their proven technical expertise and efficient commercial pricing.

In addition, when these framework partners are utilised, dependent on the need, then they will either undergo a further mini-competition through the framework or they will price a single source solution, but in either approach their pricing levels will be in accordance with their competitive framework pricing levels, and they will be checked and validated against the UU independent internal estimate, and challenges will be made as necessary to ensure commercial value is maximised and technical compliance.

If the framework approach is not appropriate for any project, UU also procures direct to the market where it seeks competitive tenders from a range of suppliers/contractors and allows market forces to ensure a competitive price is obtained. These are also validated against the UU independent internal estimate.

Once the Contract has been awarded to the successful bidder, the contract is rigorously managed by the UU project team in accordance with the Contract. The UU Project Manager, Quantity Surveyor, Construction Supervisor and Engineering representative will ensure that any additional variations are kept to a minimum and valued appropriately, all costs and payments are in accordance with the contract and the contractor is being monitored on site to ensure efficient delivery of construction plant and equipment and to UU specification and standards.

Each project will be audited by UU’s cost assurance consultants to ensure that only legitimate costs are paid.

Final accounts at the end of each project are agreed timely and there is a clear escalation process to deal with any disagreements or disputes by use of senior representatives.

UU continuously seeks lessons learnt to improve efficiency in future processes and seeks innovation to continuously improve leaner solutions and ways of working.

Appendix B Options appraisal for project 08UU100146

UNITED UTILITIES WYBERSLEY, ERWOOD AND FERNILEE (SWSGZ3202 / SWSGZ3201) SAFEGUARD ZONES RAW WATER COLOUR INVESTIGATION OF ERRWOOD, FERNILEE, HORSE COPPICE AND BOLLINHURST RESERVOIRS FINAL REPORT MARCH 2022

7. OPTIONS APPRAISAL

Targeted Interventions to Improve Colour, Turbidity and Habitat Condition

7.1 A range of land management techniques and interventions are available for improving vegetation and habitat condition, hydrology and ultimately, water quality in upland Pennine water supply catchments. Many of these have already been implemented across areas of the Goyt and elsewhere by UU as part of earlier initiatives such as the SCaMP Project. These include:

Artificial linear open drain (grip) blocking;

Natural drainage gully blocking in degraded peatlands;

Peat reprofiling;

Restoration of bare and degraded peat via revegetation and/or the use of geotextiles;

Plug planting of key blanket bog species, including *Sphagnum* mosses;

Harvesting of mature conifer woodland, especially on blanket bog and transitional organomineral

soils;

- Restoration of commercially clear-felled areas (including soil reprofiling);
- Stock removal and grazing management;
- Targeted woodland planting (valley cloughs and riparian buffer zones);
- Cessation of dwarf shrub heath burning on blanket bog; and,
- Livestock and deer exclusion fencing.

7.2 Each of these interventions can be applied either singularly, or in tandem with other measures at locations across the Goyt and Lyme safeguarding zones to attempt to improve long-term water quality. However, efforts need to be targeted to be cost-effective and, as the colour risk modelling has demonstrated that the blanket bog peat-dominated sub-catchments of the Upper Goyt and Wildmoorstone Clough supply by far the highest colour load and overall risk, then the highest priority interventions should be concentrated on improving these blanket bog peat-dominated areas.

The Benefits of Blanket Bog Restoration

7.3 Chapman *et al*. (2017) provides a useful summary of the positive outcomes resulting from the restoration of peatlands and these have been discussed in many of the previous UU SCaMP monitoring reports, as well as the UU Lake Vyrnwy Raw Water Colour Investigation Study (2014).

A summary of the key mechanisms is outlined below:

Increased vegetation cover (reseeding and plug planting of bare peat):

- Diverse vegetation cover, including large proportion of *Sphagnum,* slows the flow of water across the catchment. This reduces runoff and downstream flooding (see Holden *et al*. 2012, Gao *et al*. 2017). It also reduces flux of high DOC/coloured water by optimising microbial degradation of DOC prior to arriving at WTW (Holden *et al*.2013);
- Diverse vegetation cover stabilises soil temperature and controls microbial production of DOC potentially resulting from an increase in air temperature; and

- Complete vegetation cover reduces erosion of POC which can be deposited in reservoirs and transformed to DOC/colour in transit through the river and reservoir network.

Blocking of drainage ditches:

- Raises water table which (i) slows the flow of water from catchment and (ii) results in decline in decomposition of peat to DOC and CO2 (Chapman *et al.* 2017 part 1); and
- Reduces peat erosion and loss of POC.

Maintaining a more stable water table that is nearer to the peat surface:

- High peat water table levels, which are more able to buffer the effects of drying-wetting cycles that produce colour/DOC; and
- Drought leads to a lowering of peat water table. If the water table is higher, blanket peatland is more resilient to drought. If the water table is low (as in degraded peat) then drought conditions within the peat are experienced more frequently and this leads to a subsequent increase in DOC production and water colour.

7.4 Therefore, restoration of the peatland can:

- Reduce water colour/DOC production through peat decomposition (humification);
- Reduce peat erosion (particulates (POC)) into reservoirs and river systems;
- Slow the flow (water flows more slowly through and across the catchment) and helps reduce downstream flood risk; and
- Mitigate against climate change, as less CO2 is emitted to the atmosphere (instead, the carbon is stored in peat).

7.5 With these benefits in mind, there is a clear rationale is for targeted restoration measures and other interventions in order to improve the overall condition and function of these upland habitats, as well as concentrating efforts on identified ‘hotspots’ of colour and turbidity; with the latter often leading to reductions in other undesirable water quality issues such as algae and faecal coliforms.

7.6 The raw and flow standardised water colour risk modelling reported in Section 6 has categorised each supply sub-catchment in terms of risk (Figures 6.1 and 6.2). Further investigations have determined the nature of that risk and the exponential increase in colour risk between the predominantly mineral soil-dominated sub-catchments of the Lyme area and Fernilee Reservoir, which contrast sharply with the deep peat-dominated supply sub-catchments of the Upper Goyt, Wildmoorstone Clough and Shooters Clough (North and South), which all supply water directly into Errwood reservoir.

7.7 With this in mind, a range of options for restoration and other interventions can now be developed and targeted to specific sites using the evidence provided by the colour risk modelling exercise.

Restoration Methods and Interventions

7.8 As outlined above, restoration methods and interventions are based around methods to restore the natural hydrological and ecological function of the peat body. Each of the measures described in this section is designed either to avoid bare peat being exposed to degeneration processes (e.g. erosion) and/or to raise the water table and restore the hydrological integrity of the peat as far as possible.

7.9 The principal aims of these methods are to restore vegetation cover (on bare and eroding peat), hydrological function and active peat forming vegetation. These methods are now briefly described in the context of the Goyt and Lyme catchments.

Rewetting

7.10 Water management techniques for lowland and upland peatlands most often involve a process known as rewetting (Brooks and Stoneman 1997, O‘Brien *et al*. 2007). Where artificial drainage ditches (grips) or eroding gullies are blocked to allow water levels within the peat to return to more natural levels, as far as is possible.

These natural water levels are closer to the peat surface and show less seasonal fluctuation making the peat less vulnerable to prolonged drying.

7.11 Blocking methods are generally more achievable for grips but less so in deeper gullies, which are often large, complex features frequently eroded down to, or below, the mineral soil bedrock boundary.

Grip Blocking

7.12 The standard method of grip blocking makes use of peat scooped up from areas adjacent to the drain and packed as a plug into the drain with the vegetation surface upper most (Worrall *et al.* 2007). Heather bales stuffed into the grips can also be used and, more occasionally, plastic sheet piling, as on a limited area of the Upper Fernilee sub-catchment installed prior to the SCaMP Project. These are more appropriate on level or gently sloping ground with low flows in small grips. Plastic dams are effective but are considered more intrusive and are more expensive.

7.13 Particularly large grips may be dammed using both peat and plastic/wood for support. By blocking with peat dams at regular interval along the grip, water can generally be diverted out of the grip and across on to the peat surface.

7.14 A programme of grip blocking has already been completed on the Upper Goyt as part of the earlier SCaMP Project, principally around the Derbyshire Bridge area.

Gully Blocking

7.15 On degraded blanket bog, peat erosion, for example after wildfires, can lead to the formation of drainage channels known as gullies. These gullies most often form on the edges of peat bodies where the contributing area and slope is greater. They may be small, narrow or very wide, and in many cases extensively eroded down to bedrock with large quantities of peat lost from the system.

7.16 The techniques to re-wet gullied peatland are varied and depend on the depth and width of the gullies and the rate of flow of water in them. Shallow gullies can be dammed to the top, but deeper ones are less likely to be completely dammed. Those where there is still a significant peat floor can be dammed using peat, stone, wood or plastic dams. Heather bales can be used at the top of the system where gullies are very shallow and small, and water flows low. Where the gully floor is eroded to the underlying mineral material, or in large gullies with more significant water flow, then stone dams are a practical option. These are not normally designed to fill the gully but can hold significant pools behind them. It is very important to stabilise and revegetate any bare peat on gully sides at the same time as damming to slow sediment input and erosion. Stone dams are proving to be an effective method of gully blocking, as work carried out on the Ashway Gap catchments at Chew Reservoir demonstrate.

7.17 More recent NFM-focussed restoration projects have used large, felled tree trunks to create leaky dams as a gully blocking technique. In very wide flat gullies, the use of stone dams may become very expensive and so the creation of leaky dams using felled conifer tree trunks becomes far more practical. Large stakes are used to pin the trunks in place and allow two or more trunks to be stacked on top of each other, where required. This method was trialled successfully in the Defra Slowing the Flow NFM Project in the Vale of Pickering (2008 to 2014) as a means of providing online flow storage and attenuation for small, rapidly responding forest streams, but the suitability and application to large, complex moorland gully systems is obvious.

7.18 Although a commonly used technique, gully blocking is of relatively limited applicability across the Goyt due to the generally intact nature of the peat. However, some significant gully systems are present across the highest headwaters of the Upper Goyt and Wildmoorstone sub-catchments and site walkover surveys carried out in heavy rainfall/high runoff conditions showed that these areas contribute a very high proportion of colour to stream flow overall.

7.19 One of the problems with gully and grip blocking is to understand where the diverted water passes after blocking. Damming drainage channels increases the risk of diverting more water into peat pipes and thus failing in its objectives of re-wetting a site. It will be important to make detailed field assessments of the likely density of peat pipes as part of any detailed restoration plan. These can be identified by the local topography (where collapsed surfaces are visible) or where they appear at the surface in holes and gullies. A detailed peat pipe assessment has not been carried out as part of this study, but it is known that the peat deposits across the Upper Goyt generally are not prone to extensive piping and macro-void flow, as seen in other areas of the Pennines.

Revegetation

7.20 Re-vegetation is essential where extensive areas of bare peat have developed. The principle that is applied is to identify the factors that prevent natural colonisation. This may involve excluding grazing (wild and domestic stock) (Anderson and Radford 1994). If this is inadequate, the next level of intervention is to add the desired plants (e.g. through heather brash, planting divots, plug plants, seed or *Sphagnum* diaspores). In situations where peats are bare and eroding, they may require stabilisation with heather brash or geojute or coir rolls to facilitate re-vegetation. In exceptional circumstances, where peats have been so badly affected by past aerial pollutants, they may require chemical modification with lime and fertilisers prior to establishment of bog vegetation.

7.21 These techniques have been most extensively used to re-vegetate dry peat with heather, but more recent work has begun to establish large numbers of micro-propagated plants including blanket bog species. The different techniques are briefly described below, but the combination of any will need to be assessed on site and through peat soil analysis.

Application of Lime, Seed and Fertiliser

7.22 The application of a lime, seed and fertiliser mix to bare, eroding peat is a standard practice in moorland restoration and is certainly applicable to very small, localised pockets of bare and degraded peat across small areas of the Upper Goyt, Wildmoorstone Clough and Rake Clough sub-catchments.

7.23 The target soil pH for restoration is considered to be pH 3.5 to 4.0. Phosphorus and potassium may be added at low levels. Nitrogen, although it has been added, is not always required because of high atmospheric inputs. Lime and a slow-release high phosphorus fertiliser is applied at the same time as a nurse crop with a second application in the second year. The use of a nurse crop of grasses depends on the stability or not (e.g. through frost heave) of the bare peat and its scale. Where a grass nurse is needed, it usually comprises non-native species or varieties of fescue, bents and rye-grass that respond to the nutrient and lime additions, stabilise the peat for about five years and then die out to be replaced by moorland-specific species.

7.24 Fertilised swards have also been shown to remain attractive to stock. This treatment should not, therefore, be used without stock grazing control.

Peat Stabilisation Using Geotextiles

7.25 Peat stabilisation using geotextiles, such as geojute, is particularly useful where the bare peat is on a steep slope (such as edges of deep eroding gullies) and subject to severe frost heave and erosion by wind and rain. It is used on severely eroded and sloping sites, more typically at the edge of a gully. It is most commonly combined with a nurse species seed mix. The geojute, fibrous mesh webs (3cm pore diameter) increases 300% by weight when wet and physically holds the peat down, but does disintegrate with time, leaving stabilised peat surfaces, helping vegetation establish successfully. Again, the potential scale of application for this technique is limited across the Errwood sub-catchments, but could, in places, contribute significantly to blanket bog restoration.

Peat Stabilisation and Introduction of Heather Using Seed or Brash

7.26 Heather brash can be used to stabilise small patches where heather is available. This material is cut from local donor areas in the October to December period when seed is still in the capsules on the plant and spread at a ratio of 1:2 over the degraded recipient area. This technique is often used in conjunction with the application of lime, seed and fertiliser and so could again have at least some potential for use on Upper Goyt and Wildmoorstone Clough sub-catchments.

Re-introduction of Sphagnum and Other Mosses

7.27 A high and stable water table is an essential precondition for restoring a *Sphagnum*-rich active blanket bog. The elimination or control of other degrading factors is also required, such as: burning, trampling, excessive grazing (particularly high stock density combined with supplementary feeding), low pH (<3), high inputs of nitrogen and phosphate from receiving waters and/or atmospheric deposition.

7.28 *Sphagnum* reintroduction into moorland environments is now a well-established technique and has been applied widely in the Pennines, principally by 'Moors for the Future' and the Yorkshire Peat Partnership. The spread of pelleted *Sphagnum* plants encapsulated in a soft, water retaining bead (Beadamoss) by 'Moors for the Future' has been shown to establish best where there is a skeletal framework of other plants to provide micro-niches and some protection for the plants to develop and where the water tables are appropriate to the species being introduced. On bare peat surfaces, this treatment would be combined with the introduction of transplants of common cottongrass, cross-leaved heath and crowberry, as well as nurse seed grasses, and probably geojute, to stabilise the peat and a lime and fertiliser mix (Anderson *et al.* 1997, Carroll *et al.* 2009). More recently, *Sphagnum* inoculation using micro-propagated plants has been shown to be more effective than Beadamoss in several restoration programmes.

7.29 *Sphagnum* re-introduction is a technique that is certainly applicable to the Goyt and Fernilee Reservoir catchments, especially after other phases of restoration have been completed.

Planting of Blanket Bog Species

7.30 Planting of other blanket bog species, (e.g. common cottongrass, hare's-tail cottongrass, crossleaved heath and cloudberry) are all possible as micro-propagated plants. These species may also colonise naturally if in the adjacent vegetation. It may be desirable to add more dwarf shrubs as, in moderation, these may be typical of blanket bog communities, including crowberry and bilberry. These are also available as micro-propagated plants. The largely intact nature of the vegetation cover across the Goyt and Fernilee mean that planting could potentially be restricted to small areas of bare peat, though those areas dominated by one species (e.g. heather) will also benefit from this type of restoration.

Vegetation Management

7.31 Where semi-natural or introduced vegetation is present and the objectives are to restore an active peat forming *Sphagnum*-rich surface layer, steps need to be taken to remove or significantly modify the existing vegetation.

Removal of Scrub and Woodland

7.32 On coniferous plantation sites trees are removed prior to rewetting via drain blocking. Ideally trees should be harvested using grab lines to avoid further compaction and disturbance of the peat (or peaty soil) from harvesting equipment. All brash is either removed from site or used to fill any drains (as well as suitably located dams). Similar approaches are used on lowland raised bogs with deciduous tree encroachment. On smaller sites, hand pulling of seedlings can be used to control regrowth.

7.33 This method is recommended for targeted areas of the Deep Clough area of the Fernilee sub-catchment where coniferous forest encroachment onto open moorland has been observed.

7.34 Recent clear felling across the Fernilee sub-catchment shows that after felling, the soil and remaining woody debris are left undisturbed in-situ. There is certainly scope to take a more proactive approach to soil and hydrological restoration of these areas, as cleared areas are left bare and are left to naturally re-colonise, often with self-seeding conifers, rather than more desirable moorland or blanket bog vegetation. In addition, walkover surveys conducted by PAA in areas clear felled within the last five years also show that an extensive network of drainage grips remain unblocked and active in these areas and these grips continue to contribute significant quantities of colour to stream flow.

7.35 Work has already taken place to remove significant areas of dense rhododendron scrub around Horse Coppice Reservoir, with further work planned at both Horse Coppice and Bollinhurst. This, together with revegetation of bare areas with an appropriate grassland seed mix and deer fencing will help, for example, to mitigate against high quantities of fine mineral sediment input into Horse Coppice Reservoir via Coalpit Clough Stream, which is currently an issue due to heavy poaching of the stream banks and nearby paths by the Lyme Park deer herd.

Removal or Reduction of Grazing

7.36 Shepherding, wilding or fencing is normally required to prevent grazing and trampling damage to introduced peat bog vegetation, at least for a period of up to ten years whilst the blanket bog communities re-establish. It is known that a grazing management plan has been in place across the Goyt since 2005 as part of the SCaMP Project, but it is unclear whether a similar plan is in place at Lyme.

7.37 Again, recent fine sediment pollution incidents recorded at the Coalpit Clough sub-catchment as part of this investigation show the effect that intensive grazing and trampling pressure of the Lyme Park deer herd can have on water quality detected in Horse Coppice Reservoir, and deer and stock exclusion and buffering of key drainage features are recommended at both Coalpit Clough, Bollinhurst Wood and the Elmhurst Tunnel Intake (the Drinkwater supply to Horse Coppice Reservoir) which lies within the grounds of Lyme Park.

Cessation of Burning

7.38 Prescribed burning on active peat bog is considered to be poor land management practice. Again, it is understood that dry dwarf shrub heath burning is no longer carried out across the Upper Goyt catchments, but evidence mapped as part of this study clearly shows the widespread effects on managed burning on vegetation in the past.

7.39 Mowing has replaced burning as the principal dwarf shrub heath management technique across the Upper Goyt. Mowing largely has the same effect as burning, but with none of the undesirable side effects including the production of char, removal of basal vegetation cover (mosses) and burning of the upper organic layer of soil, all of which are known to adversely impact on hydrology and water quality.

Grassland Reversion

7.40 Grassland reversion is a vegetation management technique used as a means of improving vegetation cover and soil condition for the reduction or stabilisation of colour production and runoff production. Here, overgrazed, grassland-dominated areas are reverted back to more favourable moorland vegetation types including dwarf shrub heath, a moorland species mosaic and, ultimately, active blanket bog vegetation, where possible.

7.41 When combined with drain blocking, peaty upland soils and blanket peat will re-wet, potentially reducing soil organic humification rates and thereby reducing the production and release of coloured DOC.

7.42 The method could be used, for example on large areas of the upper Drinkwater Meadow sub-catchment, where significant areas of land were historically ‘improved’ and subsequently overgrazed. These processes have led to the peaty topsoil becoming more vulnerable to seasonal drying and temperature, leading to elevated soil humification rates, especially during the drier spring, summer and autumn months. This process is one of the contributing factors to the elevated (and increasing) levels of colour output observed from Drinkwater Meadow and the Bollinhurst sub-catchments.

Management to Reduce Purple Moor-grass Dominance

7.43 Where purple moor-grass is dominant, interventions and management can be introduced to reduce its cover and abundance, encouraging a more diverse vegetation to re-establish. For smaller areas on peat, a regime of rotational mowing is recommended, taking account of the sensitive ground conditions. Progressive treatment of the target area over several years is appropriate. The effect of the mowing regime on the vegetation should be monitored carefully and adjusted as necessary to ensure it does not impact on positive indicator species or impact on any deep peat.

7.44 Mowing can sometimes suppress re-growth of other important moorland species, including cottongrass, and this is likely to be detrimental to blanket bog habitat over the long-term (as a positive indicator species will start to decline). As such, suitable adjustments can be made to protect these existing desirable species. This can include setting the mower blades to a higher level, mowing less frequently or mowing around areas where existing desirable plant species might occur. Alternatively, cessation of mowing and the introduction of spring cattle grazing may help reduce purple moor-grass dominance and encourage greater habitat diversity. A combination of a reduced mowing regime with re-introduced sheep grazing may also have the desired effect, although sheep grazing may not be sufficient to bring about the required reduction in purple moor-grass dominance. Again, long-term vegetation monitoring should take place to ensure management can be adjusted as required.

7.45 Depending on the existing diversity of the target area, additional propagules can also be added once the purple moor-grass dominance has begun to reduce. For example, planting plug plants of *Sphagnum*, adding cross-leaved heath seed and/or re-introducing common cottongrass as plug plants are highly beneficial.

Mowing and Scarifying to Diversify Acid Grassland

7.46 Applying a suitable mowing regime on acid grassland can encourage greater diversity of both physical structure (vegetation height) and vegetation community. Cuttings should be removed off site.

7.47 Subsequent scarification of selected areas and sowing the seed/plant plugs of a range of forbs typical of the habitat would help to increase species diversity. Seed should ideally be from a locally-collected sources, or otherwise from a reputable supplier of native British seeds. The seed mix could include species such as yarrow, harebell, lady’s bedstraw, bird’s-foot-trefoil, devil’s-bit scabious and mountain pansy. The latter may be difficult to obtain.

7.48 Establishment should be carefully monitored and any remediation undertaken as required, such as controlling non-target potentially ‘weedy’ plant species, re-application of seed, etc.

7.49 Summer grazing can also be introduced, either as a management option instead of scarifying/reseeding, or as a follow-on management to maintain the diversity after seed has established. Depending on the outcomes required, cattle grazing could be used in spring/early summer to open the sward, remove biomass and increase gaps for seed germination, or summer-only sheep grazing can be employed to generally reduce the biomass. Sheep grazing on its own may not affect the desired improvements in sward diversity, therefore, combining scarification/re-seeding with follow-on sheep grazing may be preferable.

7.50 Cutting and scarifying work should avoid the bird breeding season or measures be put in place to ensure no species at risk of harm were present on site at the time of works. Mowing could, however, be detrimental to the numerous small mammals present on the acid grasslands, so phased mowing in stages and progressive scarification is recommended to maintain local populations.

Implications for Land Use and Management at Goyt and Lyme

7.51 The investigation has shown that those sub-catchments producing the most consistent water colour are those which have seen a significant amount of historical upland land management in terms of artificial drainage and vegetation management through cutting and historical burning. It is also clear that these catchments also contain small, but significant areas of degraded and bare peat.

7.52 The next step of the project involved the development of a detailed potential restoration and interventions map, focusing on the sub-catchments where colour generation is a key problem, in order to identify all potential receptor sites where re-wetting, revegetation and other measures could contribute to decreasing the generation and release of water colour.

Targeted Restoration and Intervention Map

7.53 Using the catchment characterisation and colour risk modelling results as a starting point, a GISbased mapping exercise was undertaken with the aim of identifying and mapping the specific areas in which one or more of the measures described above could be most effectively applied.

7.54 The mapping exercise has considered the earlier works completed on the Goyt as part of the SCaMP project between 2005 and 2007. Principally, grip blocking, stock exclusion and cessation of burning was used on two main areas of the Upper Goyt supply catchment near Derbyshire Bridge. As these areas have already received significant and extensive restoration work, they have largely been excluded from this review and mapping exercise, except for a small number of high priority targets, identified from earlier investigations.

7.55 Figure 7.1 shows the type, location and extent of potential interventions identified. In total, ten principal measures and interventions were considered appropriate for the Goyt and Lyme water safeguard zones, based on current habitat condition, hydrology, drainage and water quality results. These included:

• Gully blocking;

• Grip blocking;

• Bare peat restoration using geotextiles, lime, seed and fertilizer and nursery planting

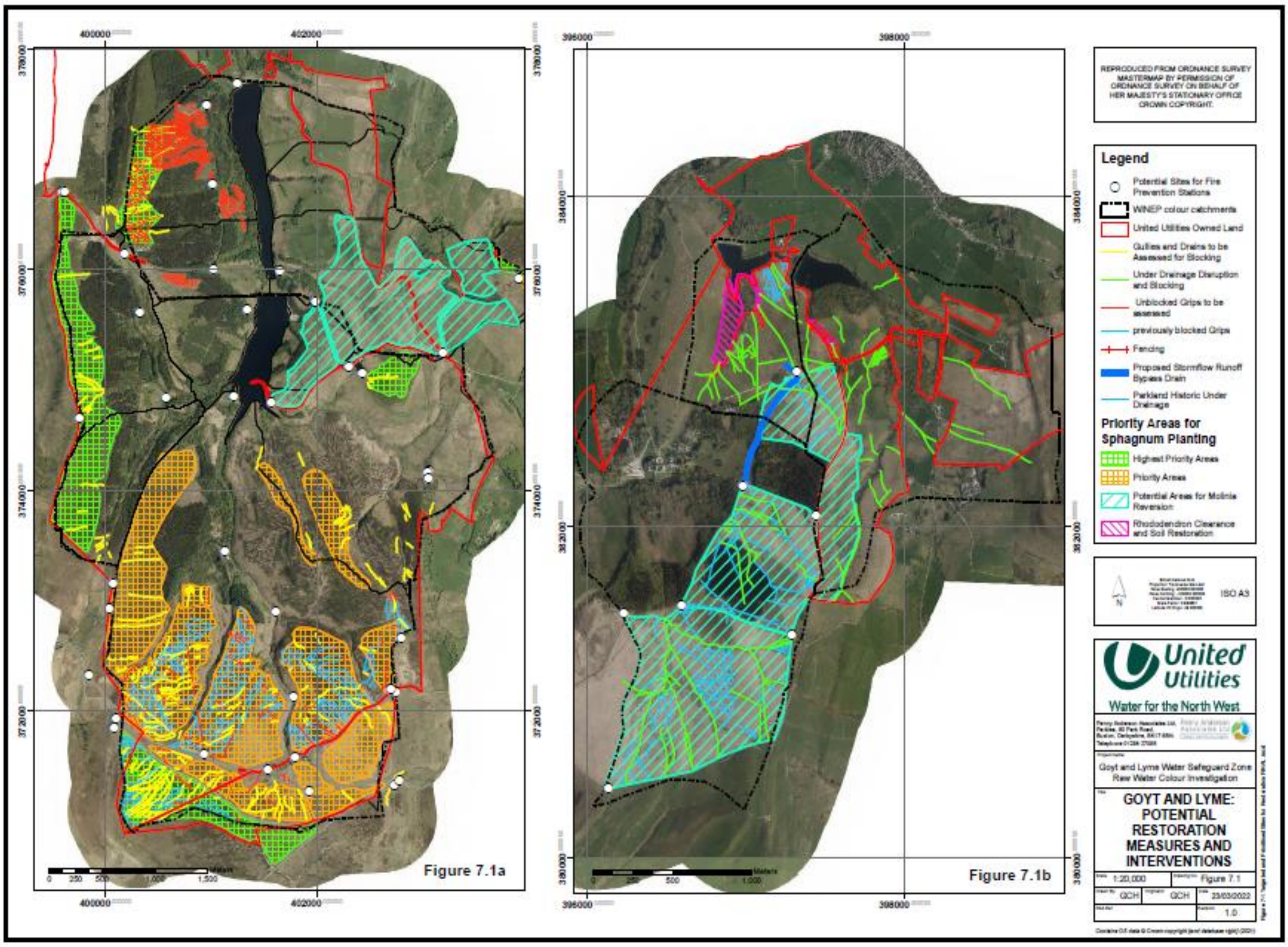
(particularly associated with large gullies);

• Soil restoration and grip blocking in clear-felled commercial forestry areas;

• Grassland reversion of historically under-drained poor quality grassland areas;

Sphagnum planting; and,

• Blanket bog species planting.



7.56 Figure 7.1 maps the location and extent of those areas that require attention. As can be seen, restoration prescriptions vary considerably between the Goyt and Lyme areas, reflecting the different physical and water colour characterises of each area.

7.57 The feature data collected and shown in Figure 7.1 was then used to develop cost estimates for the different measures and interventions in each area and this information is set out in Tables 7.1 and 7.2 below.

Ground Truthing

7.58 GIS-based mapping provides an efficient, targeted spatial framework for restoration measures. However, not everything can be seen from the air and so ground-based surveys and assessments are critical in determining the relationships between colour 'hot-spots' and land use/management and in targeting and prioritising interventions going forward.

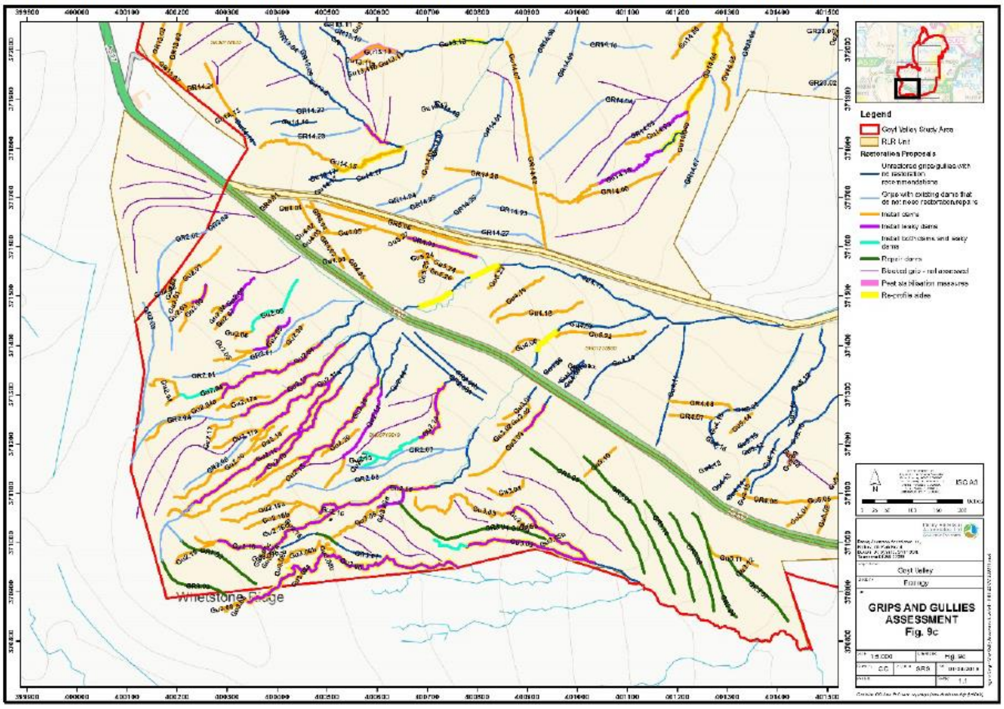
7.59 As part of this ground truthing process, it will be necessary to identify whether degraded areas of peat contain evidence of peat piping, which could compromise attempts to re-wet the peat, by diverting water into other routes where degeneration can continue. Holden (2009) suggests that higher densities of peat pipes can be associated with gripping on peatland and this needs to be verified across significant areas of the Upper Goyt, Wildmoorstone and Deep Clough sub-catchments.

The Goyt Valley Feasibility Study

7.60 The Goyt Valley Feasibility Study, prepared by PAA for UU in 2018, contains detailed surveys, mapping and assessments of many of the features identified in this study as targets for restoration. The study focused on the supply sub-catchment of the Upper Goyt, which was assessed and mapped to a very high level of detail, with individual features mapped.

7.61 The information contained within this earlier report will save a significant amount of time, effort and cost in any potential ground truthing process, as much of the detailed, time-consuming survey and assessment works has already been completed as part of this earlier study. Figure 7.2 contains a figure extracted from the Goyt Valley Feasibility Study and shows a headwater area of the Upper Goyt sub-catchment, where a detailed assessment of grips and gully features has already been carried out.

Figure 7.2 Extract from the Goyt Valley Feasibility Study (2018) Showing Detailed Grips and Gullies Features Assessment



7.62 The Goyt Valley Feasibility Study completely covers the areas of the Upper Goyt and Wildmoorstone Clough supply sub-catchments. These are identified in this study as being two of the highest risk areas for colour generation. A similar level of survey and assessment would be required for the remaining areas across Errwood and Fernilee, and the same process needs to be carried out across the Lyme area.

7.63 It is understood that Dinsdale Moorland Specialists (DMS) have prepared a costings and implementation plan for restoration work in the Upper Goyt supply sub-catchment. Again, the information contained within this report will also save a considerable amount of time and money in the targeting of restoration efforts and other interventions.

Discarded Options

7.64 The review has determined that all the intervention measures outlined above could potentially be applied at specific sites across the Goyt and Lyme areas. In this respect, no restoration options have been omitted at this point.

Appendix C Options appraisal for projects Chapel House infrastructure removal (08UU100149), and Overwater infrastructure removal (08UU100152)

Ehen Compensatory Measures

United Utilities

Chapelhouse Reservoir and Over Water - Technical Report for Main Stage B

0 | Final

January 2020

Research Measure 6

JACOBS

Ehen Compensatory Measures

Project No: B27030AP
Document Title: Chapelhouse Reservoir and Over Water - Technical Report for Main Stage B
Document No.: 0
Revision: Final
Date: January 2020
Client Name: United Utilities
Client No: Research Measure 6
Project Manager: Damian Smith
Author: Various

Jacobs U.K. Limited

5 First Street
Manchester M15 4GU
United Kingdom
T +44 (0)161 235 6000
F +44 (0)161 235 6001
www.jacobs.com

Document history and status

Revision	Date	Description	By	Review	Approved
01		Working Draft for UU review	KK/RK/MV/DP	KK/AF	DS
02	January 2020	Final for client approval	JM/NW	KK/AF/SC	DS
03	June 2020	Final	KK	DS	

Contents

Executive Summary

United Utilities (UU) have commissioned Jacobs to undertake an investigation in the engineering feasibility of removing abstraction infrastructure at Chapelhouse Reservoir and Over Water, together with a high-level impact assessment of the infrastructure removal. This study forms part of Research Measure 6 of an overall package of Compensatory Measures aimed at improving habitat for Atlantic salmon. These measures are required to compensate for adverse impact that abstraction for public water supply and a potential future drought order at Ennerdale Water has on designated features of in the River Ehen Special Area of Conservation (SAC). The designated features include freshwater mussel and Atlantic salmon, which are protected under the Conservation of Habitats and Species Regulations 2017.

At key stages throughout the study Jacobs have involved UU and the Project Steering Group (PSG), consisting of the Environment Agency (EA) and Natural England (NE), National Trust and West Cumbria River Trust.

The study has been split into three stages:

- **Scoping Stage** involving a high-level baseline study and gap analysis by each discipline (engineering, geomorphology, hydraulics and ecology), definition of scope in terms of infrastructure to be included in the study and determination of an approach to the Main Stages of the project. This was agreed with the PSG before proceeding to the Main Stages of the project.
- **Main Stage A** involving completion of baseline assessments for each discipline, an options appraisal and identification of a shortlist of potential options agreed with the PSG. At the PSG's request, a 'lead option' (outlined below) was chosen for detailed assessment and carried forward into Main Stage B.
- **Main Stage B** involved detailed assessment of the lead option and design iterations to identify a preferred option.

A detailed account of the Main Stage A process, including the optioneering exercise and Multi-Criteria Analysis to select the preferred option, is provided in the Jacobs (2018) report. The preferred option taken forward to the Main Stage B assessment is the removal of Over Water weir, Chapelhouse Reservoir dam, the River Ellen catchpit and river embankment and the re-naturalisation of the River Ellen through its old river valley. The preferred option is likely to improve hydrological functioning and connectivity along the River Ellen for Atlantic salmon, improve habitat and morphological processes, whilst also reducing flood risk within the catchment.

This report provides an updated baseline assessment to support the development of an outline design. An outline design has also been developed, with a more detailed investigation into the impacts of the design undertaken by the four core disciplines informing the study (engineering, hydrology and hydraulics, geomorphology and ecology). The outline design has had three design fixes, each addressing the need for change as the design evolved.

Overall the results of the study show that full removal of all abstraction infrastructure and the reinstatement of the River Ellen are technically feasible. It is recommended that there is continued input from a Reservoirs Inspection Engineer at the detailed design stage. The impacts to hydrology, ecology and geomorphology are unanimously beneficial, and with the provision of a flood storage element to the design there would also not be any significant increase in flood risk downstream.

The designs referred to in this report are outline design only and "not for construction" as they will require further study to refine and develop the design. Recommendations are provided at the end of this report for next steps.

1. Introduction

1.1 Background

The River Ehen in West Cumbria is designated as a Special Area of Conservation (SAC) and Site of Special Scientific Interest (SSSI). It is also within the Lake District National Park, which gained UNESCO World Heritage Status in 2017. Freshwater mussel (*Margaritifera margaritifera*) and Atlantic salmon (*Salmo salar*) are both of high conservation importance and are the primary and qualifying reasons, respectively, for the designation of the upper River Ehen as a SAC. The River Ehen supports the largest population of freshwater mussels in England. The SAC is divided into two management units and both are currently assessed as being in 'unfavourable declining' condition due to insufficient freshwater mussel recruitment making the current population unsustainable.

Ennerdale Water, upstream of the River Ehen SAC, and part of Ennerdale SSSI, is currently a key source of public water supply for West Cumbria. United Utilities is licensed to abstract water from Ennerdale Water under the Water Resources Act 1991. The Ennerdale Water abstraction licence has recently undergone a series of reviews by the Environment Agency (EA) through the Habitats Directive[1] 'Review of Consents' process. The current abstraction and a potential future drought order at Ennerdale Water have been determined to have potentially significant negative impacts on both interest features of the River Ehen SAC. In December 2013, the EA confirmed the decision 'to revoke the Ennerdale Water abstraction licence as soon as is reasonably practicable, and to investigate options with regard to timing of weir removal and withdrawal of the compensation flow'. Evidence from the severe stress event affecting mussels in the spring and early summer of 2012 contributed to the decision.

United Utilities (UU) will continue to significantly decrease public water supply abstraction from Ennerdale Water until the complete removal of abstraction is possible in 2022, when the West Cumbria water resource zone will be connected to the UU Integrated resource zone via the Thirlmere Transfer pipeline. There is over-riding public interest to continue to provide public water supply until the replacement source is fully connected. In accordance with Article 6(4) of the Habitats Directive, compensatory measures need to be secured because it cannot be concluded that continued abstraction would not lead to an adverse effect on site integrity.

It should be noted that the Habitats Directive has been transposed into UK law by the Habitats and Species Regulations 2017, which is currently being updated in line with the UK leaving the EU on the 31st January 2020.

UU, in conjunction with Natural England (NE) and the EA, has developed a package of compensatory measures that would reduce, or offset, adverse impacts on the River Ehen SAC as a result of continued abstraction from Ennerdale Water, and a potential drought order, whilst the alternative public supply is put in place. This package includes both physical ecological measures and research measures and was submitted to DEFRA in February 2014. A legal agreement exists, signed in July 2015 between UU, NE and the EA describing each physical and research measure, programme and governance of the package. The aim of the agreed package of measures is to restore habitat which enables the sustainable recruitment of freshwater mussels and salmon, primarily in the River Ehen SAC, and to undertake research and monitoring to understand how this outcome could best be achieved. There are also studies which form part of the Ehen Compensatory Measures package involving habitat improvement elsewhere in West Cumbria outside of the Ehen catchment which is where this study comes in.

This study has been undertaken as part of Research Measure 6. It presents an investigation of the removal of abstraction infrastructure at Chapelhouse Reservoir and Over Water within the River Ellen catchment. This area was selected by the project steering group as abstraction for public water supply will cease once the Thirlmere Transfer scheme is operational (by March 2022).

1.2 Study Scope

This study considers the potential removal of abstraction related infrastructure at Chapelhouse Reservoir and Over Water. The aim of the removal of the infrastructure is to re-naturalise flow regimes and to provide environmental improvements for salmon in the River Ellen. The investigation of infrastructure removal at Chapelhouse Reservoir and Over Water were combined during the scoping stage as they are considered to be interlinked, with the effectiveness of works at Over Water considered to be highly dependent on any works carried out on Chapelhouse Reservoir.

This study fulfils parts of Research Measure 6 'Environmental Engineering Assessment of infrastructure removal'.

A preliminary scope was agreed with the Project Steering Group (PSG) (comprising representatives from UU, NE and the EA) in October 2015 and received final agreement at the PSG meeting held in May 2016. Following this meeting, the Scoping Report (Jacobs, 2016) was signed off by the PSG in June 2016.

It was also agreed with the PSG that the study itself would be delivered in two stages. More details of the activities undertaken at each stage are given in Section 2:

- **Main Stage A** - the completion of baseline assessment for the study area and identification of a shortlist of potential options; and,
- **Main Stage B** – the detailed assessment of shortlisted options and selection of a preferred option.

Main Stage A was completed in September 2018 (Jacobs, 2018). This Technical Report has been produced at the end of Main Stage B of the Chapelhouse Reservoir and Over Water assessment. This report supersedes the Main Stage A report (Jacobs, 2018) and the contents include:

- detailed baselines for each of the four key disciplines (engineering, hydrology and hydraulic modelling, geomorphology and ecology);
- impact assessments for the preferred option identified during Main Stage A; and,
- an outline design of the preferred option.

1.3 Aims and Objectives

The key aim of this Main Stage B study is to define the preferred option following the optioneering exercise at Main Stage A. This study fulfils parts of Research Measure 6 'Environmental Engineering Assessment of infrastructure removal'. This will be supported by the provision of an outline concept design for the removal of the abstraction infrastructure at Chapelhouse Reservoir and Over Water. In total, three design fixes are summarised, providing justification for the design changes as discussed with UU and the PSG.

The following objectives have been outlined:

- Complete a geomorphological and hydraulic assessment at Chapelhouse Reservoir, Over Water and the River Ellen.
- Undertake engineering feasibility assessments at Chapelhouse Reservoir, Over Water and the River Ellen for the removal of the following infrastructure associated with abstraction:
  - Over Water weir and embankment;
  - Over Water intake pipes;
  - Chapelhouse Reservoir dam;
  - Chapelhouse Reservoir old spillway and fish pass;

- Chapelhouse Reservoir new spillway;
- embankment carrying the River Ellen along the western edge of Chapelhouse (i.e. the bypass channel); and,
- catchpit and sluice on the River Ellen upstream of Chapelhouse Reservoir.

- Undertake preliminary ecological assessments.

Other aspects that could support a multi-disciplinary assessment of the preferred option include landscape, archaeology and social impacts. During the scoping phase it was agreed these aspects would not form part of the study scope but should be considered later during the Environmental Impact Assessment stage.

1.4 Relevant Legislation and Policies

The following legislation has been considered throughout this assessment.

1.4.1 The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017

The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 enacts the European Union Water Framework Directive (WFD) (2000/60/EC) into UK law. The regulations have an overarching objective of requiring all water bodies in Europe to attain Good or High Status/Potential.

1.4.2 Conservation of Species and Habitats Regulations 2017

The Conservation of Species and Habitats Regulations 2017 transposes the European Union Habitats Directive (92/43/EEC) into UK law.

European protected species (EPS), such as otter (*Lutra lutra*), are protected in the UK under this legislation. Otter are widespread throughout Cumbria and are present in the River Ellen catchment, with field signs recorded in the River Ellen during the 2017 walkover surveys. The regulations make it an offence to deliberately capture, injure or kill an EPS; deliberately disturb an EPS; damage or destroy a breeding site or resting place of an EPS; or damage or destroy an SAC or SPA. This would apply to the Lake District High Fells Special Area of Conservation (SAC). This SAC encompasses the River Ellen upstream of Chapelhouse Reservoir, including Crag Wood, and Longlands Beck upstream of Longlands.

1.4.3 Reservoirs Act 1975

Both Over Water and Chapelhouse Reservoir have been classified as large raised reservoirs under the Reservoirs Act 1975. As a result, the Environment Agency as enforcement authority must be notified of any modifications or discontinuance under the Act. The Act requires that United Utilities, as Undertaker, employ a Construction Engineer to design and supervise the *Works*.

1.4.4 Natural Environment and Rural Communities (NERC) Act 2006 (England)

The NERC Act (England) 2006 provides a legal framework to promote biodiversity in England and protect natural areas and wildlife. Section 41 of this act identifies Species and Habitats of Principal Importance in England. These species are those that are considered the rarest and most threatened species in England. For a subset of these species, Priority Actions have been identified to assist in their recovery. Atlantic salmon (*Salmo salar*), brown/sea trout (*Salmo trutta*), European eel (*Anguilla anguilla*), otter, river lamprey (*Lampetra fluviatilis*) and sea lamprey (*Petromyzon marinus*) are all listed under Section 41, and Priority Actions have been identified for otter and European eel.

1.4.5 Wildlife and Countryside Act 1981, Section 28

The Wildlife and Countryside Act (WCA) sets out the framework for designating Sites of Special Scientific Interest (SSSIs). Over Water SSSI, and the boundary of the SSSI includes terrestrial features surrounding the reservoir and the outlet channel to the crossing of the minor road (approximately 90m). This SSSI has four reportable features: mesotrophic lakes, standing waters, upland neutral grassland and wet woodland. These features are divided into nine live units which are assigned a habitat type and the condition is assessed for each unit. Three of these units (all wet woodland) are currently in 'Favourable' condition, three (neutral grassland and wet woodland) are 'Unfavourable – No Change' and the remaining three are 'Unfavourable – No Change'.

The WCA is also the primary legislation governing invasive and non-native species. It is an offence to allow the spread of any non-native plant species listed in Schedule 9 of the WCA. Species listed in Schedule 9 include, but are not limited to, New Zealand pygmyweed (also known as Australian stonecrop) (*Crassula helmsii*) and Nuttall's pondweed (*Elodea nuttallii*).

1.4.6 Natura 2000 Site Improvement Plan

There is a Natura 2000 Site Improvement Plan (SIP) in place for the Lake District High Fells Special Area of Conservation (SAC). The SIP seeks to address issues identified within the catchment which could impact on the notable features of the SACs. These include water pollution, siltation, invasive species, change in woodland management and hydrological changes.

1.5 Study Area

The general study area has been defined as the River Ellen and its catchment from its source to 2km downstream of Chapelhouse Reservoir at Uldale, as well as the Over Water catchment.

The study area extents differ between each of the four disciplines, as the impacts associated with infrastructure removal will vary and occur over different spatial scales. Table 1-1 provides an overview of the proposed study area extents. Figure 1-1 illustrates the study area extents for hydraulics, geomorphology and ecology, whilst Figure 1-2 illustrates the location of the various abstraction infrastructure that forms the engineering study area.

Table 1-1: Chapelhouse Reservoir and Over Water study area extents per discipline

Discipline	Study area
Engineering	The abstraction infrastructure within the scope includes: the weir/spillway and abstraction pipes at Over Water, the dam including spillway, stilling basin, wave wall and fish pass at Chapelhouse Reservoir, the by-wash embankment along the western edge of Chapelhouse Reservoir, and the catchpit and new channel realignment on the River Ellen upstream of Chapelhouse Reservoir.
Hydraulics	The hydraulic model will need to include the entire catchment area of the River Ellen and Over Water from source to Chapelhouse Reservoir and from Chapelhouse Reservoir to at least 2km downstream of Chapelhouse Reservoir.
Geomorphology	The geomorphology study area will include the River Ellen from source to Chapelhouse Reservoir, the Over Water outlet, the River Ellen from Chapelhouse Reservoir to 2km downstream and Longlands Beck from source to confluence with the River Ellen. To inform the geomorphology desk study the entire catchment area of the River Ellen has been considered.
Ecology	The ecology study area will include the River Ellen from source to Chapelhouse Reservoir, Over Water, the terrestrial and aquatic margins of Over Water, the Over Water outlet, the River Ellen from Chapelhouse Reservoir to 2km downstream, adjacent wetland to Chapelhouse Reservoir and Longlands Beck from source to confluence with the River Ellen.

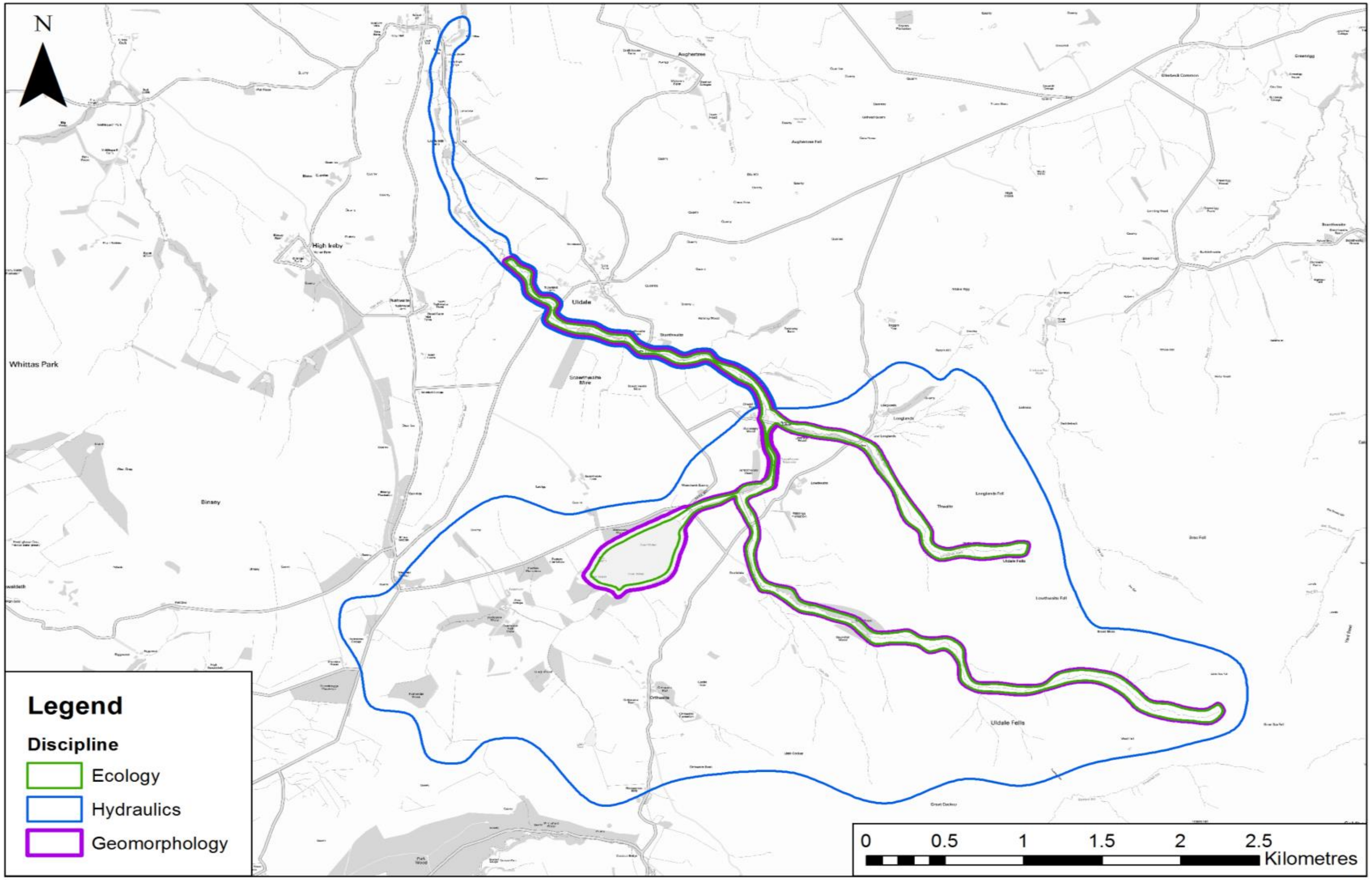


Figure 1-1: Study area of Over Water and Chapelhouse Reservoir for hydraulics, geomorphology and ecology disciplines (see Section 4.2)

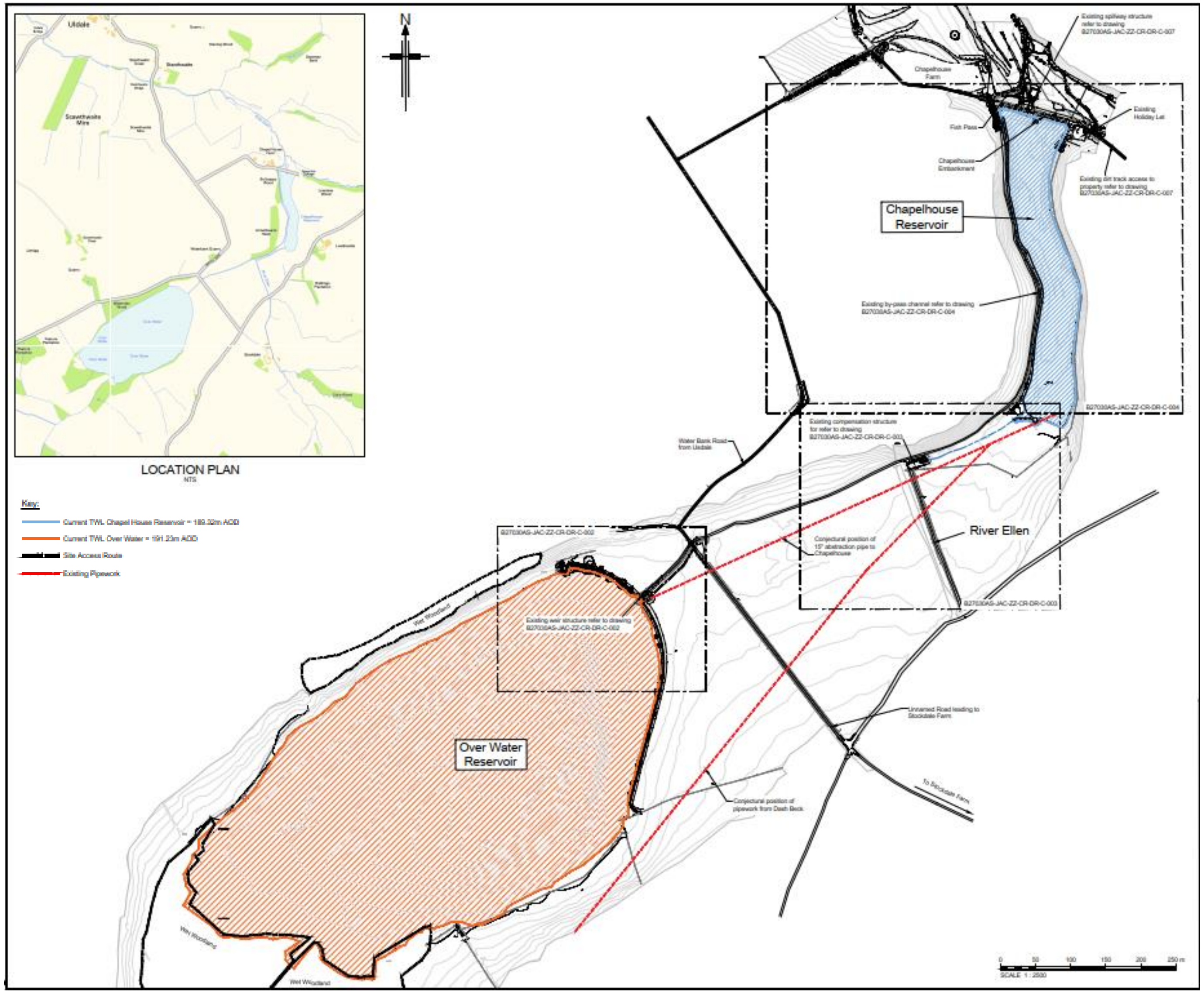


Figure 1-2: Location of abstraction related infrastructure included in scope for Over Water and Chapelhouse Reservoir

2. Approach

2.1 Overview

The study has used a multi-disciplinary approach involving various stakeholders at key points throughout the option development process (outlined in Figure 2-1). The Jacobs only elements of the investigation have been coordinated by a technical lead with contributions and guidance from subject matter experts in engineering, hydrology, hydraulic modelling, geomorphology and ecology. This has involved a combination of separate discipline specific investigations and multi-disciplinary workshops throughout the phase of the study to make sure of a preferred option developed with consideration of all technical aspects.

UU have also participated throughout the assessment as part of the technical team, proving highly beneficial in providing a wider contextual perspective during the options development process.

The approach that has been undertaken for this study was agreed with the PSG and is summarised in Figure 2-1 with more details in Section 2.3.

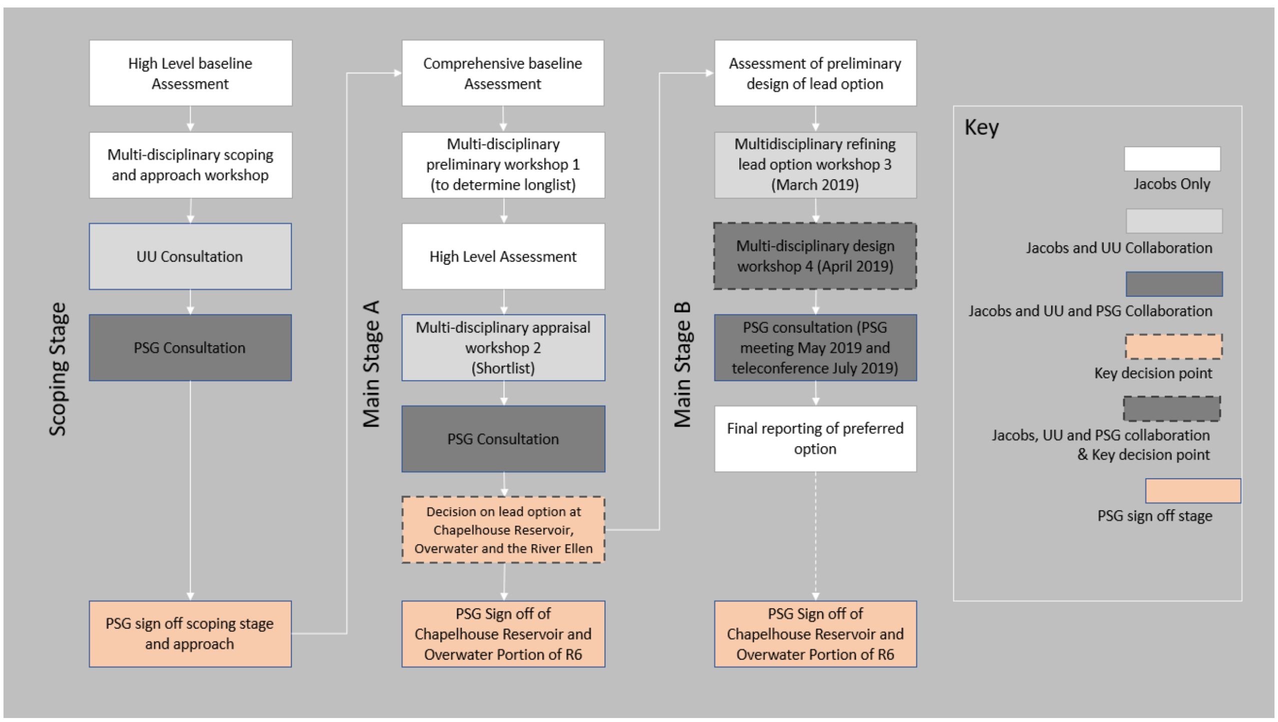


Figure 2-1: Summary of Study Approach (UU= United Utilities and PSG = Project Steering Group)

2.2 Desk Study and Site Work

A desk-based study has been carried out to inform this assessment, reviewing existing information for the study area. The following are the key data sources:

- Environment Agency Catchment Explorer (Environment Agency, 2019a, b, c);
- North West River Basin Management Plan (Environment Agency, 2015);
- Contemporary OS maps (Natural England, 2018);
- Geology maps (BGS, 2019);

- Aerial photography (Natural England, 2019);
- Historical maps (National Library of Scotland, 2019);
- Designated areas (Natural England, 2019); and
- Hydrological information (CEH, 2019).

This baseline review and impact assessment has also been informed by site walkovers undertaken, including a geomorphological reconnaissance survey and ecological field surveys in 2015 and 2017. Habitat features, geomorphological processes and features were mapped using handheld devices, with a detailed photographic record taken.

2.3 Consultation

Consultation with the key stakeholders has been undertaken throughout the development of the Main Stage B report. This has included UU, NE and the EA as part of the PSG. The following outlines the key meetings:

- **Workshop 3**: March 2019
  - Design Fix 1 was presented to UU and a discussion held between all disciplines.
  - Design Fix 2 was developed from this point forward.
- **Workshop 4**: April 2019
  - Design Fix 2 was presented to UU and the disciplines presented their initial impact assessments.
  - Design Fix 3 was developed from this point forward.
- **PSG meeting**: May 2019
  - Design Fix 3 was presented to PSG and discussions held around the impact assessments, in particular potential for increases in flood risk.
  - Final outline design was decided and developed from this point forward.
- **Teleconference with PSG:** July 2019
  - Two flood storage options presented and discussed. Agreement reached on offline storage option and completion of the outline design.

3. Catchment Overview

3.1 Infrastructure

Chapelhouse Reservoir and Over Water operate as a reservoir cascade, with Chapelhouse Reservoir situated less than 1km downstream of Over Water. The main features of each system are summarised in Table 3-1.

Table 3-1: Main Features of Over Water and Chapelhouse Reservoir

	Over Water	Chapelhouse Reservoir
Grid Reference	NY 250 350	NY 260 358
Type of dam	Concrete weir and earth embankment	Earth embankment
Capacity	542,000m^3	99,000m^3
Maximum crest height	1.1m	8m
Crest length	450m	100m
Crest level	192.10m above ordinance datum (mAOD)	192.36mAOD
Top water level	191.03mAOD	189.1mAOD
Overflow	Concrete Weir	Two broad crested weirs
Freeboard	1.07m	1.26m

Additional infrastructure associated with the two systems and within the scope of this assessment include:

- Over Water intake pipes;
- Chapelhouse Reservoir spillways (old and new) and fish pass; and,
- River Ellen embankment, catchpit and sluice.

The weir and culvert on Longlands Beck, a tributary of the River Ellen, were initially considered as part of Main Stage A and were subsequently scoped out of further assessment in this Main Stage B report (Jacobs, 2018). The two assets were scoped out because the potential improvements were not considered, in discussion with the PSG, to provide significant benefit or contribute towards the aims and objectives of the project.

3.2 Over Water and Chapelhouse Reservoir Catchment

Over Water and Chapelhouse Reservoir are situated in a reservoir cascade, with Chapelhouse Reservoir situated less than 1km downstream of Over Water. Both sit approximately 12km north of Keswick and 2km south of Uldale in the Allerdale District of Cumbria at OS grid references NY 250 350 (Over Water) and NY 260 358 (Chapelhouse Reservoir).

Over Water is a natural lake (or tarn) formed by glacial processes with a total catchment area of approximately 5km^2. The catchment consists predominantly of agricultural land, which drains directly into Over Water via a number of watercourses. The footprint of the lake has been artificially increased from historical extents observed on mapping from the 1880s by the construction of a concrete weir. The weir serves as an overflow, allowing water from the lake to enter Over Water Beck, which flows north-east into the River Ellen bypass channel and around Chapelhouse Reservoir along its left bank. Drawdown mains also provide a hydraulic connection between Over Water and Chapelhouse Reservoir (see Fig 1-2).

Chapelhouse Reservoir is retained by an earth fill embankment running perpendicular to the River Ellen, which was constructed in 1920. The catchment area of the reservoir is approximately 9.5km^2 and is primarily composed of agricultural land and upland grasslands. The River Ellen provides a secondary source of water to Chapelhouse Reservoir via diversion structure and catchpit located to the south-east of the reservoir.

The headwaters of the River Ellen are located approximately 4km to the south-east of Chapelhouse Reservoir within the Uldale Fells. From its headwaters, the River Ellen flows west in a single thread channel that exhibits a naturally straight planform confined within a steep river valley set within a wider glacial valley. The planform becomes more sinuous as the River Ellen passes through Crag Wood, before the channel is artificially straightened through pasture fields downstream of the wood where it is joined by Dale Gill. The River Ellen then flows north along a confined artificial (bounded by brickwork) channelised length, which opens upstream downstream of a road bridge into a straightened channel through to the catchpit. At this point the channel then either passes along the western side of Chapelhouse Reservoir in an artificial channel or flows into the Chapelhouse Reservoir via a small channel. Downstream of the reservoir, the River Ellen is joined by Longlands Beck, a watercourse with an equally steep gradient that has a sinuous planform through a wider glacial valley. From this confluence the River Ellen has a generally straightened planform with sinuous reaches. The channel is located at the base of a relatively confined glacial valley, with a narrow floodplain. The channel is also locally controlled by lengths of bank reinforcement. The River Ellen flows north-west, then west at Ireby until it flows into the Irish Sea at Maryport, approximately 22km west of Over Water.

3.3 Geology and Soils

The bedrock underlying the catchment is diverse, with Hope Beck and Kirk Stile Formation mudstones and siltstones underlying the catchment upstream of Chapelhouse Reservoir. The catchment to the east and west of Chapelhouse Reservoir (including the headwaters of Longlands Beck) is underlain by a mixture of igneous rocks from the Eycott Volcanic Group which include lapilli-tuff, andesite and volcaniclastic-sandstone. Downstream of Chapelhouse Reservoir, conglomerates of the Marsett Sandstone Formation underlie the River Ellen, whilst limestones of the Frizington Limestone Formation are present to the north of the River Ellen. Superficial deposits present within the catchment are predominantly glacial tills and Devensian diamictons. Exceptions to this include alluvium deposits (present south-west of Over Water and downstream of Chapelhouse Reservoir along the River Ellen river corridor) and gravel, alluvial fan deposits between Over Water and Chapelhouse Reservoir.

Catchment soils are predominantly either freely draining, loamy soils (referred to as Soilscape 17; Cranfield Soil and Agrifood Institute, 2016) or loamy/clayey soils with impeded drainage (referred to as Soilscape 13; Cranfield Soil and Agrifood Institute, 2016). Soilscape 13 is present to the south-west of Over Water, between Over Water and Chapelhouse Reservoir, and throughout the River Ellen Valley downstream of Chapelhouse. Soilscape 17 is present throughout the rest of the catchment.

3.4 Historical Changes

A description of historical changes made to the River Ellen, Over Water and Longlands Beck are held in Appendix A. The planform of the River Ellen channel has remained relatively stable between its headwaters and Uldale since 1863, except where changes to the channel were made to accommodate the construction of Chapelhouse Reservoir and associated infrastructure in the 1900s. Changes include the diversion and straightening of the channel and the removal of Hoodbank Wood which occupied the footprint of what is now Chapelhouse Reservoir.

3.5 Water Environment (Water Framework Directive) (England and Wales) Regulations 2017

The study area lies within the Ellen (upper) surface Water Framework Directive (WFD) water body. Both Over Water and Chapelhouse Reservoir are also classified as individual lacustrine (lake) WFD water bodies. The baseline WFD information for all three WFD water bodies is displayed in Table 3-2 and Table 3-3.

Table 3-2 : WFD baseline information for Ellen (upper) surface water WFD water body (based on 2016 Cycle 2 data, Environment Agency, 2019a)

Category	Description
Water Body ID	GB112075073630
Hydromorphological designation	Not designated artificial or heavily modified
Catchment area	33.7km^2
Length	15.6km
Overall Water Body Status	Good
Ecological Status	Good
Chemical Status	Good
Biological Quality Elements	
Fish	High
Invertebrates	Good
Macrophytes and Phytobenthos Combined	Not recorded
Hydromorphological Supporting Elements	
Hydrological regime	Does Not Support Good (a result of surface water abstraction)
Morphology	Supports Good
Physico-chemical Quality Elements	
Ammonia	High
Biochemical Oxygen Demand	High
Dissolved Oxygen	High
pH	High
Phosphate	Good
Temperature	High

Table 3-3: WFD baseline information for the two lake WFD water bodies in the study area (based on 2016 Cycle 2 data, Environment Agency, 2019b and 2019c)

Category	Description	
Water Body Name	Over Water	Chapelhouse Reservoir
Water Body ID	GB31228806	GB31228796
Hydromorphological Designation	Heavily modified	Heavily modified
Mean Depth	2.3m	3.3m
Surface Area	0.2m^2	0.016km^2
Catchment Area	5km^2	9.7km^2
Overall Water Body Potential	Moderate	Moderate
Ecological Status	Moderate	Moderate
Chemical Status	Good	Good
Biological Quality Elements		
Chironomids	Good	Not recorded
Macrophytes and Phytobenthos Combined	Moderate	Not recorded

Category	Description	
Phytoplankton	Good	Not recorded
Physico-chemical Quality Elements		
Acid Neutralising Capacity	High	Not recorded
Ammonia (Phys-Chem)	High	Not recorded
Salinity	High	Not recorded
Total Phosphorus	Moderate	Not recorded
Supporting Elements (Surface Water)		
Expert Judgment	Moderate	Moderate
Mitigation Measures Assessment	Moderate or less	Moderate or less

4. Specific Baseline Assessments

4.1 Summary

Comprehensive baseline assessments have been undertaken on the following four technical topics: engineering, hydrology and hydraulics, geomorphology and ecology. These focus on the discipline specific observations from site surveys and desk studies. These were undertaken from 2015-2019 as part of the Main Stage A and Main Stage B phases. Each baseline assessment summarises the baseline characteristics, potential opportunities and constraints.

Section 4 provides the baseline characteristics that will support the understanding of the potential impacts of the infrastructure removal in the River Ellen catchment. For the purposes of this study, the baseline is taken as 2018, the time at which site surveys were undertaken.

4.2 Engineering

4.2.1 Description of Infrastructure

Over Water

Over Water is a natural lake, the level of which has been artificially raised by the construction of a concrete weir on the line of the original outlet (Figure 4-1). The weir is 9.15m long with a level of 191.03mAOD, raising the natural lake level by approximately 1.2m. The weir forms the overflow, channelling flows via a masonry channel into Over Water Beck.

A 430m long earth embankment runs along the north-east shore of Over Water (Figure 4-2), tying into either end of the weir. The crest level of the embankment is 192.2mAOD, giving the reservoir a capacity of 542,000m^3 and a surface area of 0.24km^2. The reservoir's recorded capacity designates it as a large raised reservoir under the Reservoirs Act 1975. As a result, the Environment Agency must be notified of any modifications or discontinuance under the Act.

The total catchment area for Over Water is approximately 5km^2 and consists predominantly of farmland. There is no inlet pipework to Over Water, with the reservoir being fed by several small watercourses. The drawdown/abstraction pipework consists of a 375mm diameter cast iron pipe with an inlet set at 189.75mAOD. The draw-off main runs to Chapelhouse Reservoir and discharges below the water level at the head of the reservoir.

Figure 4-1: Over Water overflow

Figure 4-2: Over Water embankment

Chapelhouse Reservoir

Chapelhouse Reservoir is retained by an earth fill embankment running perpendicular to the River Ellen. The dam is approximately 100m long with a maximum height of 8m (approximately 191mAOD), giving the reservoir a capacity of 99,000 cubic metres. The downstream face has a maximum gradient of 1 in 2 and is grass covered (Figure 4-3). The upstream face has a maximum gradient of 1 in 2.7 and is protected by stone block pitching.

The crest of the dam is 4m wide and carries a concrete access road, with a 500mm high concrete wave wall situated on the upstream side of the crest (Figure 4-4). Similar to Over Water, the storage volume of Chapelhouse Reservoir exceeds 25,000 cubic metres, hence the Reservoirs Act 1975 applies.

The original overflow from Chapelhouse Reservoir consists of a side weir with masonry training walls, which are 9m wide with an invert level of 189.07mAOD. The spillway discharges into the downstream end of the River Ellen bypass. From here, the river runs around the left-hand side of the dam in a masonry road culvert before flowing down a shallow stepped channel culminating in a weir, where it then joins a more naturalised River Ellen channel. The shallow stepped channel acts as a 'pool and traverse' fish pass and has a series of stepped pools separated by cross walls with notches. However, the channel does not fit the specifications set out in the Fish Pass Manual (withdrawn 2015) (Armstrong *et al*., 2010) and, therefore, is likely to inhibit fish passage in most flow conditions.

The masonry road culvert restricts the flows in the river and thus outflows from the old spillway during higher order events. There is a metal pedestrian footbridge which crosses the River Ellen at the upstream extent of the fish pass.

The 'new' spillway located at the centre of the dam was constructed in 1983 and acts as a secondary spillway to the 'old' spillway. The new spillway is 20.5m long, with a crest height of 189.1mAOD, placing it marginally higher than the main spillway. Overflows are channeled through concrete wingwalls before being discharged over the weir into a tapered spillway chute.

The spillway chute runs through a twin-span concrete bridge which supports the road along the embankment crest. From here the discharge flows down a steep concrete spillway chute to a stilling basin at the downstream toe of the embankment. The stilling basin then discharges into the River Ellen downstream of the fish pass weir.

Figure 4-3: Chapelhouse reservoir downstream slope

Figure 4-4: Chapelhouse reservoir embankment crest

River Ellen Embankment, Catchpit and Sluice

The River Ellen runs in a bypass channel elevated above the left-hand side of Chapelhouse Reservoir before flowing through a masonry road culvert and down a shallow stepped channel/fish pass. The river is then joined by Longlands Beck downstream of a second small weir.

The bypass channel is approximately 2m wide with steep side slopes and is masonry-lined along its entire length. At its downstream end, where the river runs past the old spillway, the channel is heavily modified with masonry walls on both the right and left banks and masonry arch struts directing flows into the road culvert.

On the right bank of the channel, an earth embankment extends along the full western perimeter of Chapelhouse Reservoir, separating the river channel from the reservoir. A narrow footpath runs along the crest of the earth embankment; however, this footpath is not open to the public and provides access only for United Utilities to reach the catchpit and carry out inspections. On the left bank of the channel, the ground is heavily vegetated and rises steeply.

Approximately 600m upstream of Chapelhouse Reservoir dam, where the channel from Over Water and the River Ellen meet, a catchpit and control structure has been constructed in the last ten years. The reinforced concrete structure regulates flows from the River Ellen, with silt-laden water and compensation flows continuing along the River Ellen, joining the flows from Over Water. The excess flows are then diverted into Chapelhouse Reservoir as required. Actuated penstocks, control valves and mag flow meters control the flow rate. A ramp at the north-eastern corner provides maintenance access to the catchpit, with a series of pedestrian footbridges traversing the structure. Upstream of the catchpit, the Over Water channel has been lined with stone, likely as part of the historical improvements.

4.2.2 Findings of Structural and Geotechnical Studies

The embankment, overflow and associated infrastructure are inspected at ten-year intervals and supervised annually as set out in the Reservoirs Act 1975. A review of the most recent reports showed all elements of the reservoir were in satisfactory condition.

Under the current supply arrangement, the abstraction pipework from Over Water is used to feed water to Chapelhouse Reservoir which in turn supplies water to a water treatment works. This flow through the abstraction pipework at Over Water is controlled through three chambers located immediately downstream of the dam by a series of control valves and penstocks, some of which are believed to be automated. It is understood from discussions on site with UU Operations Staff that the pipework and control devices are working satisfactorily. It should be noted that abstraction by gravity via this pipework was not possible during summer of 2018 during a period of dry weather. In this instance, over pumping from Over Water into the abstraction system was carried out to maintain abstraction for public water supply.

Ground investigations have been carried out and conclude that the area near to the overflow weir and abstraction pipework consists of soft material close to the surface before transitioning materials described as clay. This is consistent with what would be expected at a reservoir site. A detailed description of the ground investigation results can be found in the Geotechnics (2018) Ground Investigation report.

4.2.3 Opportunities and Constraints

Opportunities

Several opportunities have been identified as part of the Engineering baseline assessment. As both Over Water and Chapelhouse Reservoir are classified as large raised reservoirs under the Reservoirs Act 1975, removal of impounding infrastructure would remove United Utilities legal responsibilities regarding the reservoir under the Reservoirs Act 1975. Decommissioning/removal of existing infrastructure would also remove operational and maintenance costs associated with these assets, as well as reducing the risk posed to public safety from asset failure and drowning.

Support of local cultural heritage could be provided through the preservation of the original spillway, a section of wave wall and associated pitching and the railway tracks used during the construction of the dam at Chapelhouse.

Constraints

The most significant constraints associated with any infrastructure removal would likely be the cost and technical complexity of doing so. As identified previously, Over Water and Chapelhouse Reservoir are large raised reservoirs, consequently, any modifications or discontinuance of the reservoirs the undertaker (of works) to employ a Construction Engineer to design and supervise any alterations under the Reservoirs Act.

During the construction phase of any future works, there would likely be some considerable risks associated with working in and around water, including flooding of site compounds and working areas. Safety to the public and access to properties and Public Rights of Way would also need to be considered through the construction phase and beyond.

Consideration would also need to be given to the sequencing of works to ensure that baseflows are maintained in watercourses, and that the level in Over Water can be lowered for the removal of abstraction infrastructure. Ground conditions would also need to be assessed following the drawdown of Chapelhouse Reservoir, as the depth of sediment on the solum of the reservoir is unknown and would also have to be dried before any works could be undertaken.

Private ownership of land to the south-east of the road between Stockdale Farm and Longlands Beck would constrain any designs for restoration/re-alignment of the River Ellen to United Utilities land.

4.3 Hydrology and Hydraulics

The hydrology and hydraulic baseline assessments have been undertaken to determine the scenarios for the normal flow range, including low flows (see hydrological assessment in Appendix B), and flood risk (see hydraulics assessment in Appendix C).

4.3.1 River Flow and Lake Level Baseline

The headwaters of the River Ellen have been used for water supply for over 100 years. This has culminated in the current baseline system, which is conceptualised in Figure 4-5. The system comprises:

- a raised natural lake (Over Water);
- a reservoir (Chapelhouse);
- the diversion into the system of water from outside of the natural catchment (abstractions from Hause Gill, Dash Beck and Longlands Mine Adit to Chapelhouse Reservoir);
- transfers (from Over Water to Chapelhouse Reservoir); and,
- diversions and realignments of channels to manage the water across the system.

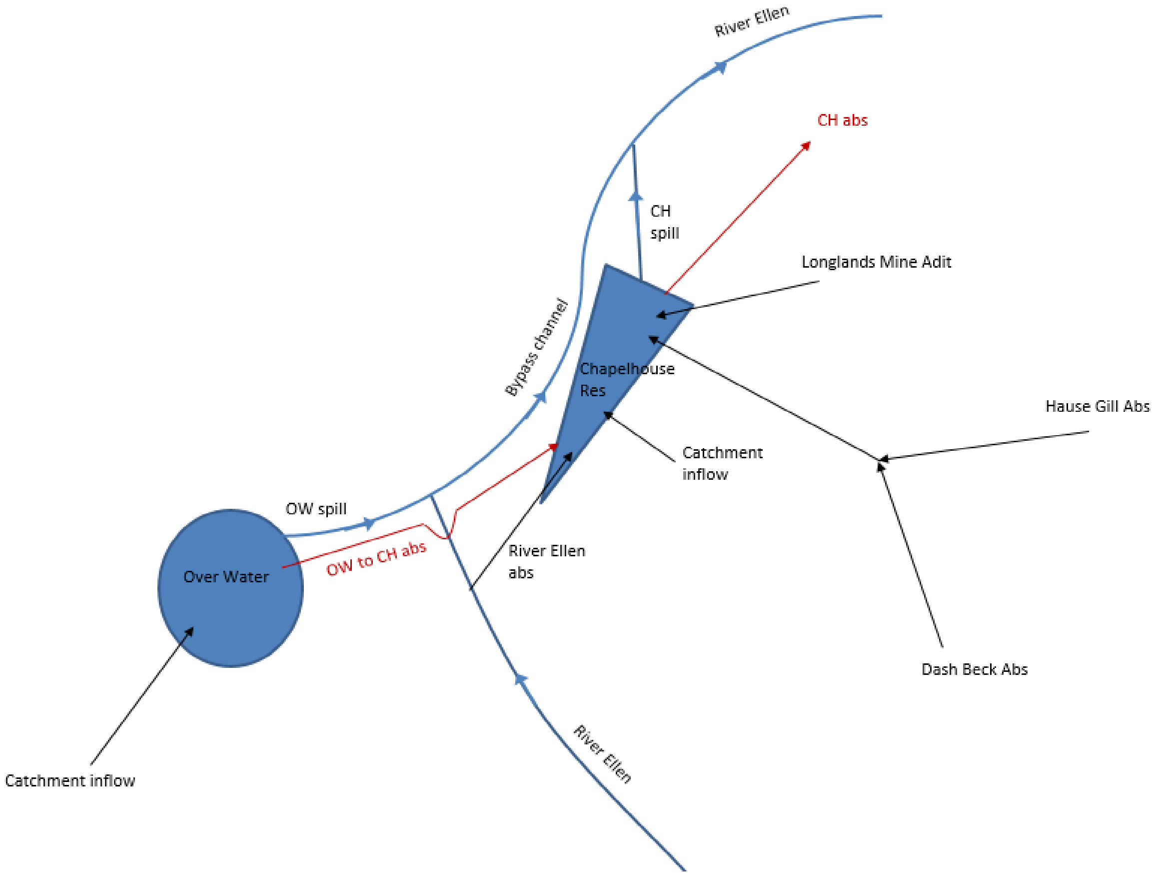


Figure 4-5: Conceptual model of current Over Water and Chapelhouse Reservoir

The baseline is considered without abstraction, as by 2022 abstraction will cease and the licenses for Over Water, Chapelhouse, Hause Gill and Dash Beck would be surrendered on completion of the West Cumbria Supplies project (2022 assumed date). The West Cumbria Water Supplies Project Environmental Statement (Jacobs, 2016) concluded that the change in abstraction from Over Water would result in less frequent and lower magnitude changes in water level; a reduction in circulation and water quality in Chapelhouse Reservoir and a more naturalised flow regime in the River Ellen.

Hydrological models were constructed of the system to support the understanding of the baseline flow and level conditions. Full details on the approach and baseline are outlined in Appendix B, including graphical representations of the normal and low flow regimes. Predicted flow seasonality of both the River Ellen and the Over Water Beck are shown in Figure 4-6 and Figure 4-7. Predicted low flow conditions are experienced throughout the Summer months as a consequence of abstraction and impounding infrastructure, with no flow conditions common on the Over Water Beck during this period.

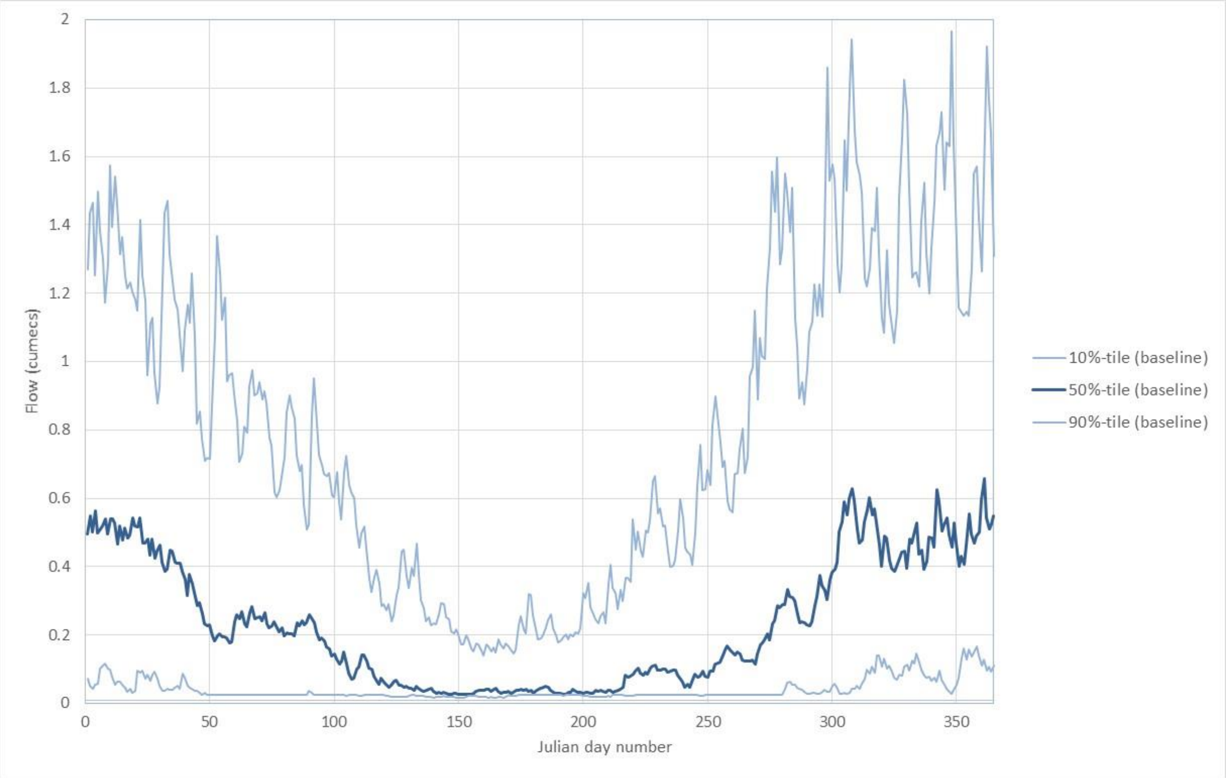


Figure 4-6: River Ellen flow (downstream of Chapelhouse system) - predicted baseline flow seasonality

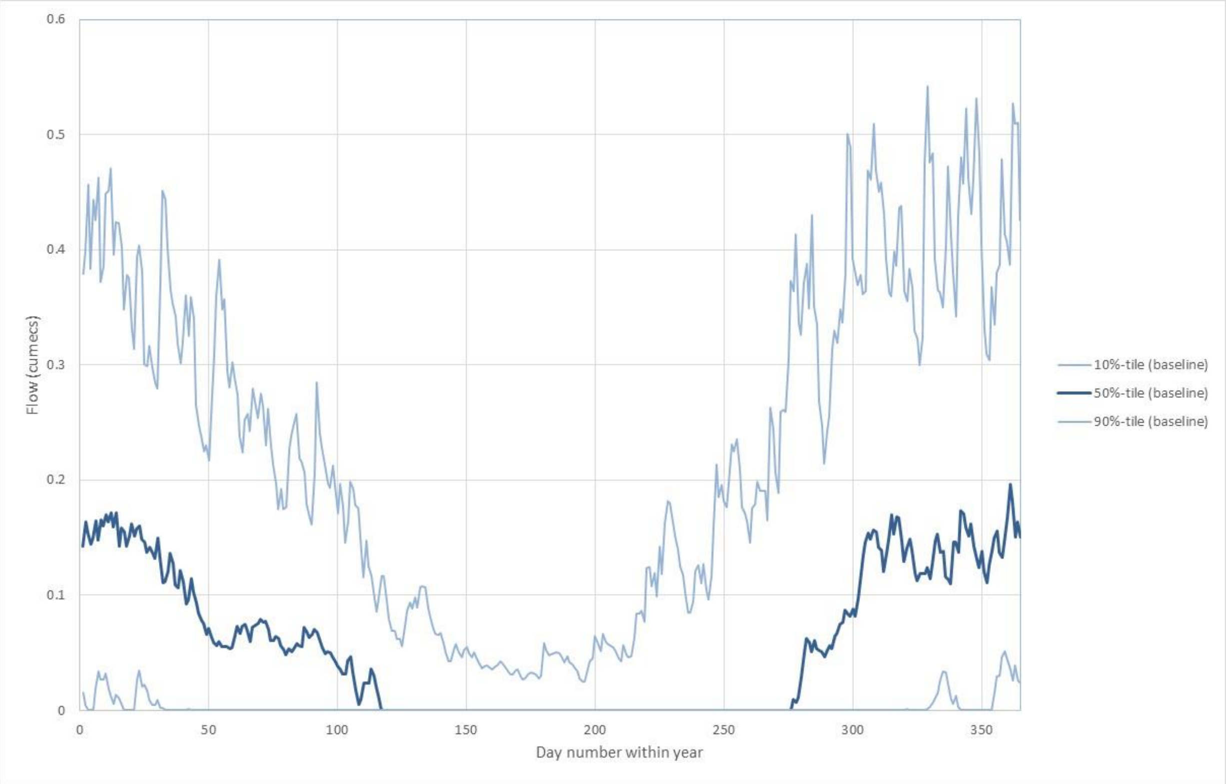


Figure 4-7: Over Water Beck flow - predicted baseline flow seasonality

4.3.2 Flood Risk Baseline

To define the existing and design flood risk for the study area, a hydraulic model of the River Ellen, Over Water and Chapelhouse Reservoir has been constructed, with the extent shown in Figure 4-8. Further information on the development of the hydraulic model can be found in Appendix C.

For the purposes of defining the existing flood risk for the study area, the abstraction of flow from Over Water to Chapelhouse Reservoir via the abstraction pipeline was not considered. This is due to the negligible influence this abstraction has on flood risk, with a maximum abstraction rate of 0.05 m^3/s (4.5 Ml/Day). For comparison, the maximum outflow from Over Water during the 50% AEP and 1% AEP + Climate Change events is 1.19 m^3/s and 2.55 m^3/s respectively. The assumption of not considering the abstraction of flow from Over Water for the flood risk baseline is therefore an appropriate representation of the system once the abstraction has ceased and also represents the current baseline flood risk as the abstraction rate is insignificant compared to peak flow during flood events.

The hydraulic model has been run for 50%, 10%, 2%, and 1% AEP (Annual Exceedance Probability) events plus a single climate change (CC) flood event. The maximum flood extents for the 50%, 10% and 1% AEP+CC events are shown in Figure 4-9 for two areas of interest respectively located between Over Water and Chapelhouse Reservoir (upstream model domain), and at Ireby (downstream model domain). Baseline maximum flood extents for all other events are shown in Appendix C.

50% AEP Event

The model results show a significant amount of flooding within the river floodplain in the upstream model domain, with flow overtopping the banks of the River Ellen immediately upstream of the catchpit. In the downstream model domain at Ireby, there is some localised inundation of the floodplain towards the downstream end of the modelled domain.

1% AEP Event

In the 1% AEP event there is significant flooding of the floodplain in both modelled domains. In the upstream domain, flow overtops both banks of the River Ellen upstream of the catchpit, with extensive overland flow towards Chapelhouse Reservoir. In the downstream domain at Ireby, flow overtops the banks throughout the model domain. Of particular note is the inundation of a single property (The Old Mill) in Ireby. The modelled flood extents do not increase during the 1% AEP +CC event, however, there is an increase in depth.

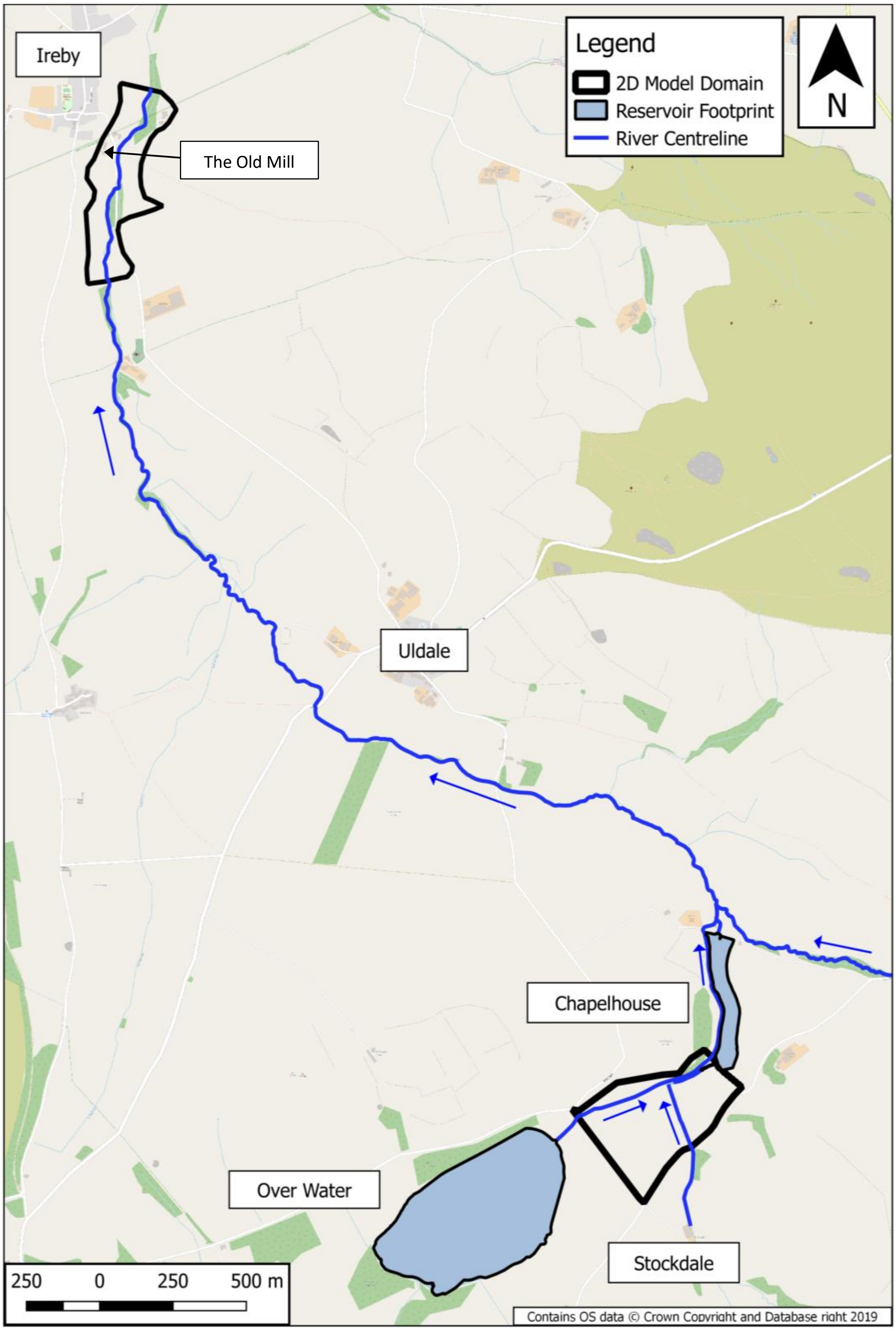


Figure 4-8: River Ellen Hydraulic Model Extent

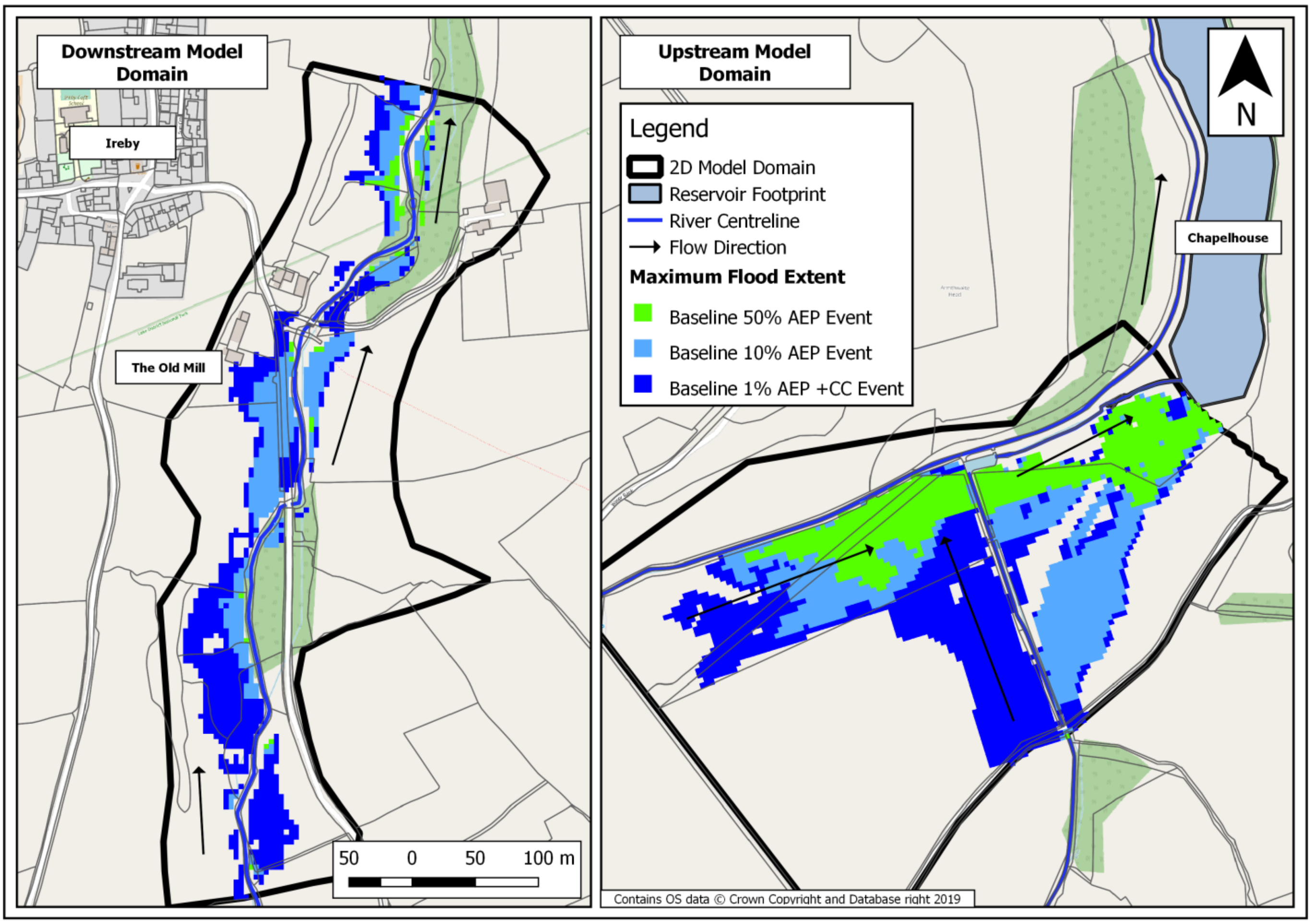


Figure 4-9: Maximum flood extents for the 50%, 10% and 1% AEP +CC flood event

4.3.3 Opportunities and Constraints

Opportunities

Flood risk could be reduced in the upper reaches of the catchment as the removal of key infrastructure such as the catchpit and the Chapelhouse dam associated with the realignment of the river channel should increase channel capacity and allow flood flow to travel faster (albeit potentially leading to increased flood risk downstream).

With regards to normal and low flows, the following opportunities have been identified:

- Re-establishing a near-natural flow regime along Over Water Beck (connecting Over Water to the downstream fluvial system). Reduction in occurrence of no flow conditions during the summer months.
- Re-establishing a near-natural lake level regime for Over Water. This will prevent the current tendency for summer drawdowns below the outflow level of the lake.
- Re-establishing a near-natural flow regime along the River Ellen downstream of the confluence with the Over Water Beck resulting in the increase of summer low flows on the River Ellen immediately downstream of the Chapelhouse system.

Constraints

Flood risk to the communities located downstream of Chapelhouse Reservoir could increase with the removal of Chapelhouse Reservoir acting as upstream storage in baseline flood conditions. The baseline modelling suggests that a single property in Ireby is also at risk of flooding. This has been considered further in Section 6.

With regards to normal and low flows, the following constraints for infrastructure removal have been identified:

- Following the removal of the Over Water outflow weir there is potentially slightly more exposure of the lake shoreline during the winter\wet periods when the lake is full.
- Loss of summer flood storage as significant summer drawdowns cease - increase in River Ellen high flow peaks.

4.4 Geomorphology

A more detailed methodology and baseline are detailed in Appendix D. Key geomorphology receptors have been identified as the following; the Longlands Beck is summarised in Appendix D but has not been included in this baseline as it was scoped out of further assessment in Main Stage A (Jacobs, 2018):

- Over Water;
- Chapelhouse Reservoir; and,
- River Ellen (source to Uldale).

4.4.1 Geomorphological Characteristics

Figure 4-10 provides a conceptual model developed for the study area. The following provides an overview of the channel characteristics, sediment processes and geomorphological features.

Over Water (including Over Water Beck)

Over Water is fed by a number of small drainage ditches and watercourses which are typically straight in planform with uniform cross-sections. The main tributary to Over Water flows into the reservoir from the south which is heavily modified and exhibits a straightened planform with earth lined channel boundary.

The footprint of Over Water has been artificially increased following construction of a weir at the north-east corner of the lake in 1904. A beach extends around the north and east shores of the lake, consisting primarily of medium to coarse gravel (8mm-32mm in diameter). The beach transitions to wetland around the south and west margins of the lake, within which reeds and wet woodland are present.

Over Water Beck is fed by Over Water when the weir is overtopped, and as a result experiences periods of no flow when the level of Over Water is low. The channel exhibits a largely straight planform with a uniform cross-section. Notable modifications include the presence of rip-rap immediately downstream of the weir, and bank reinforcement where the channel is culverted beneath a local access road. Despite these modifications, there is evidence of some natural adjustment where deposits of gravel have started to form marginal bars downstream of the culvert. Also present downstream of the culvert are small dams formed of woody material which would likely increase local flow diversity.

Chapelhouse Reservoir

Chapelhouse Reservoir is an artificially formed lake, lined by trees and tall scrub on the western and eastern shores, with a steep bank consisting of cobbles and boulders sloping down to the water edge. The reservoir does not exhibit any notable morphological features. The reservoir is fed from Over Water via drawdown pipes and from the River Ellen via an overflow channel.

River Ellen

The River Ellen was noted to have four distinct reaches within the study area, these are as follows:

- Upstream - the channel from the source to Stockdale Farm;
- Modified channel - the channel from Stockdale Farm to immediately upstream of Chapelhouse Reservoir;
- Bypass channel - the channel as it passes to the west of Chapelhouse Reservoir; and,
- Downstream - the channel downstream of Chapelhouse Reservoir.

The baseline for each of these reaches is summarised in Table 4-1, further detail can be found in Appendix D.

Table 4-1: River Ellen baseline summary

Reach/ Characteristic	Upstream	Modified	Bypass	Downstream
Planform	Straight, becoming sinuous through Crag Wood.	Artificially straightened.	Artificially straightened.	Sinuous.
Channel cross-section	Varied.	Uniform.	Uniform.	Overwide and rectangular immediately downstream of Chapelhouse Reservoir, becoming more varied further downstream.
Bed substrate	Bedrock upstream of Crag Wood, with cobbles, pebbles and some gravels present as the channel passed through Crag Wood.	Limited gravels, largely coarser material (pebbles and cobbles).	The channel has been artificially cut into the bedrock, with some gravel/pebble point bars present.	Predominantly consists of consolidated cobbles, with a lack of the finer sediments observed in upstream reaches.
Geomorphological features and processes	Cascades and waterfalls upstream of Crag Wood, with step-pool sequences present through Crag Wood. The channel was actively eroding and depositing, with further bank erosion caused by cattle poaching.	Limited to an elongated pool-riffle sequence and some marginal deposits resulting in localised channel narrowing.	Gravel and pebble point bars cause localised channel narrowing, whilst bank failure along the left bank is also evident. However, the confined nature of the channel largely precludes any significant geomorphological features from occurring.	Channel adjustment was noted downstream of the confluence with Longlands Beck. A pool-riffle sequence was observed. Both banks were being eroded, with several knickpoints observed during the reconnaissance survey, potentially a result of channel adjustment to historical modifications. The channel was actively depositing, with point and side bars consisting of cobbles present along the reach.
Riparian vegetation	Sparse vegetation cover located upstream of Crag Wood, with dense tree cover present through Crag Wood. Downstream of Crag Wood, tree cover becomes sparser with grasses dominating the riparian zone.	A mixture of isolated trees and wild grasses.	A mixture of isolated trees and wild grasses.	Tree cover is present along much of the reach, with grassed banks also evident.
Modifications	Agricultural pressures noted, however, no direct channel modifications observed.	Artificially straightened as a result of historical agricultural practices and construction on Stockdale Farm, construction of an access road and Chapelhouse Reservoir. Channel through Stockdale Farm significantly modified and primarily artificial. The downstream length of the reach flows into a concrete catchpit.	The channel has been artificially created, with the downstream length lined with stone walls and a concrete bed. A stepped fish pass takes the bypass channel down the face of the dam at Chapelhouse Reservoir.	A weir is present immediately downstream of Chapelhouse Reservoir.

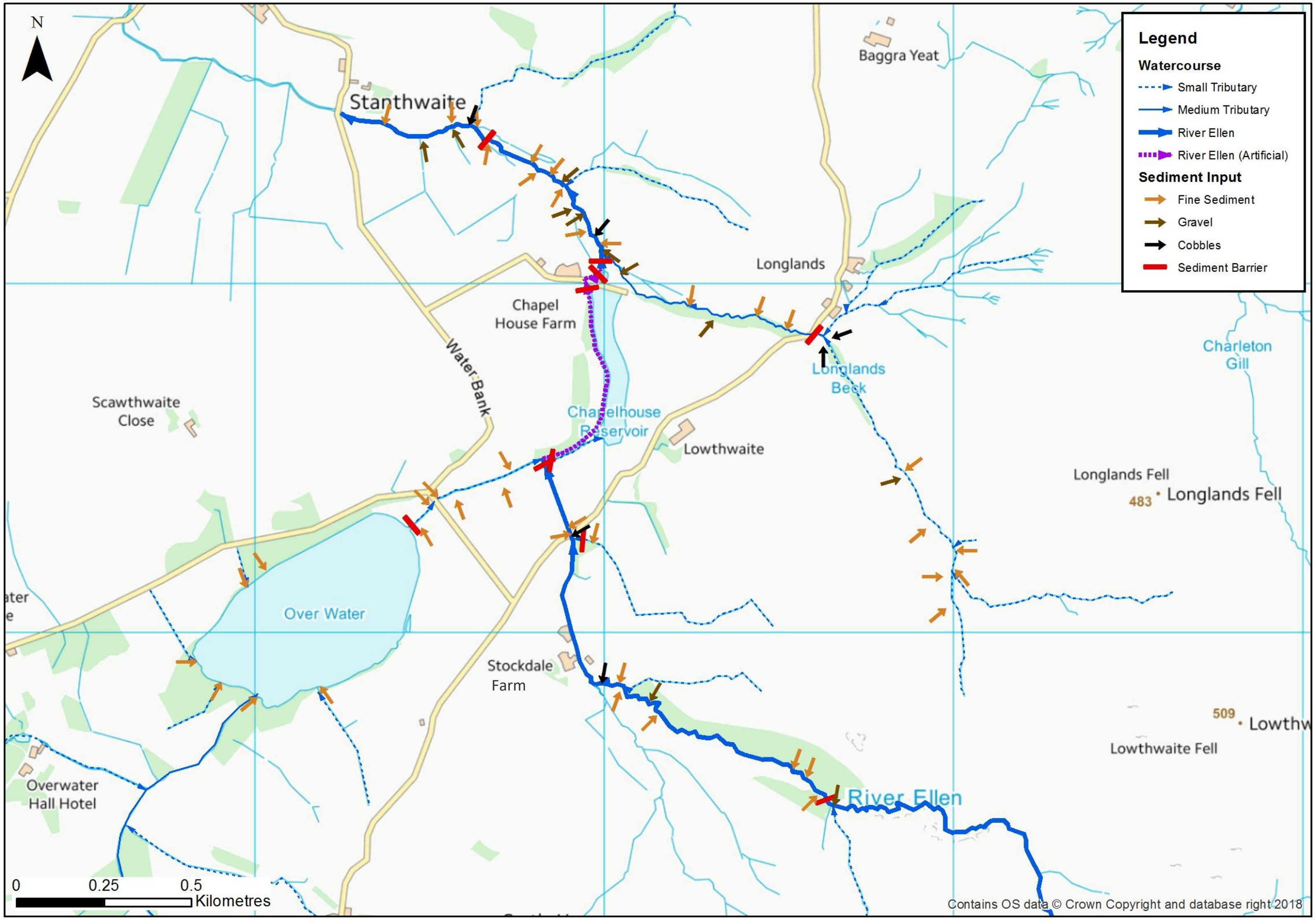


Figure 4-10: Geomorphology Baseline Conceptual Model

4.4.2 Baseline Sediment Regime

The key sediment source within the catchment has been identified as the River Ellen catchment upstream of Stockdale Farm. Here the channel appears to be actively eroding and depositing material, although volumes could be limited by the consolidated nature of the bed substrate. The volume of finer sediment (silts, sands and gravels) moving to the downstream catchment are likely to be limited by the presence of the catchpit and Chapelhouse Reservoir.

To estimate sediment yield an approach using catchment area (developed by the Environment Agency (1998) has been used. The method involves predicting the sediment load as a function of catchment area to provide an annual sediment yield. This method is a coarse way of estimating sediment yields, so the results are indicative and need to be applied with a degree of caution. Average sediment yields from UK upland areas are considered to range from 30-50 tonnes per km per year.

Estimation of the volume of sediment deposited in Chapelhouse Reservoir has not been possible, as the proportion of flow diverted from the River Ellen into Chapelhouse Reservoir via the overflow channel (and the sediment load of this flow) is unknown. The volume of sediment that has entered Chapelhouse Reservoir via abstraction sources e.g. Over Water, Dash Beck etc. is also unknown.

Table 4-2 provides an overview of the estimated annual yields for the River Ellen upstream and downstream of Chapelhouse Reservoir, Longlands Beck and the main tributary of Over Water. The bedload yields calculated are below the UK average with the exception of River Ellen (downstream) reach.

Estimation of the volume of sediment deposited in Chapelhouse Reservoir has not been possible, as the proportion of flow diverted from the River Ellen into Chapelhouse Reservoir via the overflow channel (and the sediment load of this flow) is unknown. The volume of sediment that has entered Chapelhouse Reservoir via abstraction sources e.g. Over Water, Dash Beck etc. is also unknown.

Table 4-2: Estimated sediment yields using the Environment Agency (1998) equation

Site	Description	Catchment area (km^2)	Annual bedload yield (tonnes/km^2/year)	Annual bedload yield (tonnes/year)	Annual suspended load yield (tonnes/km^2/year)	Annual suspended load yield (tonnes/year)
River Ellen (upstream)	Encompasses the River Ellen catchment upstream of Chapelhouse Reservoir	4.21km^2	27.6	116.2	61.7	259.8
River Ellen (downstream)	Encompasses the River Ellen catchment from headwaters to Uldale	14.78km^2	107.3	1585.9	264.7	3912.3
Longlands Beck	Encompasses the Longlands Beck catchment	2.16km^2	13.4	28.9	28.4	61.3
Over Water tributary	Encompasses the key tributary feeding into the south-eastern edge of Over Water	1.75km^2	10.7	18.7	22.3	39.0

4.4.3 Lateral and Longitudinal Connectivity

Lateral connectivity (i.e. connectivity with the wider floodplain) along the River Ellen is typically unimpeded throughout the study area, with the exception of two lengths of channel. The first is between Stockdale Farm and the local road, with the second being from the catchpit to downstream of Chapelhouse Reservoir (the artificial length of river). In these two reaches historical channel modifications have confined the channel preventing connectivity with the floodplain. The Over Water Beck is also artificially incised and therefore has a limited connectivity with its floodplain.

Longitudinal connectivity is impeded throughout the study area by the infrastructure associated with Over Water and Chapelhouse Reservoir, as well other road crossings and weirs. This infrastructure is likely to have modified flow and sediment processes since the early 1900s to which the channels are noticeably adjusting (e.g. through knickpoint formation, consolidation of bed substrate and trapping of fine sediments).

4.4.4 Opportunities and Constraints

Opportunities

Several opportunities for improving the geomorphology baseline have been identified as part of the baseline assessment.

- Removal of infrastructure would significantly improve longitudinal connectivity through the catchment, allowing for a more natural sediment regime to return to the catchment. Infrastructure removal would also promote a more natural flow regime, both locally and up- and downstream of the removed infrastructure. Re-naturalisation of sediment and flow regimes would likely diversify morphological features, and in turn positively impact on fluvial habitats and biotopes.
- Similarly, there could be the opportunity to carry out restoration of the catchment. This could include restoration of Over Water to a natural lake, and of the Over Water Beck and the River Ellen to near-natural conditions. Restoration would likely improve fluvial processes, as well lateral and longitudinal connectivity through the catchment.
- Throughout the catchment opportunities for improvement to the management of the riparian zone were identified. Management approaches could include selective planting of native trees and larger shrubs to improve local bank stability and increase channel shading, coppicing where the channel is excessively shaded, and establishment of buffer strips to reduce poaching of bank tops and act as fine sediment traps.

Constraints

The main constraints likely to be associated with the removal of the infrastructure within the River Ellen catchment on geomorphology include:

- Loss of agricultural land where a more natural catchment and channel is encouraged, either through channel migration or repeated flooding.
- Impact on the operation and maintenance of downstream infrastructure as a result of increases in sediment load and flow diversity e.g. exceedance of culvert design capacities.

4.5 Ecology

Full details on the methodology and ecological baseline conditions are provided in Appendix E.

The key **river species** (and habitats that support these species) for this assessment are Atlantic salmon, brown/ sea trout, brook lamprey (*Lampetra planeri*), river lamprey, sea lamprey, European eel and Eurasian otter. Of these, Atlantic salmon, sea trout, river lamprey, sea lamprey and European eel migrate between freshwaters and the sea, and brown trout and brook lamprey move within freshwaters only.

The key **lake species** of interest are those listed within the Over Water SSSI citation and other sensitive species known to reside in or utilise resources within Over Water and Chapelhouse Reservoir (Appendix E). Specific species include the rare cladoceran, *Ilyocryptus acutifrons*, and osprey (*Pandion haliaetus*).

4.5.1 Habitat Requirements for Key Species

The core habitat requirements for Atlantic salmon are shown in Table 4-3, and requirements for other species considered in this assessment are summarised in Appendix E.

Table 4-3: Habitat requirements of adult and juvenile Atlantic Salmon (Hendry and Cragg-Hine, 2003)

Juvenile fish <1 year old (fry)	
Water depth	≤20cm
Water velocity	50-65cm/s
Substrate type *winter *summer	Gravel and cobble (16-64mm) Cobble up to boulder (64-256mm)
Juvenile fish >1year old (parr)	
Water depth	20-40cm
Water velocity	60-75cm/s
Substrate	Cobble up to boulder (64-256mm)
Adult spawning	
Water depth	0.17-0.76cm (in main stem rivers often much deeper)
Water velocity	25-90cm/s
Substrate	Mix of cobbles (grain size 22–256 mm), pebbles (2–22 mm) and finer material (< 2 mm)

A literature review of habitat requirements for aquatic macrophytes was also undertaken, to ascertain the baseline conditions that are optimal for the maintenance and growth of macrophytes. Macrophytes can modify local conditions by trapping sediments and altering nutrient flows, whilst also providing important supporting habitat for other ecological receptors (e.g. *Illyocryptus acutifrons*). Key habitat requirements are summarised in Appendix E. Macrophyte communities vary in their tolerance to periods of drought but will generally adapt to gradual changes in water level, provided key areas of macrophyte growth remain regularly wetted.

4.5.2 Key Species Habitat Baselines

The following summarises the baseline conditions found in the study area for the aquatic species and taxa groups identified in the study area.

Atlantic Salmon

The River Ellen is designated as one of England's main salmon rivers (Environment Agency, 2018a). Recreational fishing for Atlantic salmon is active in the River Ellen, but rod catch returns for the past 13 years show a substantial decline since 2010, including only one Atlantic salmon caught in 2014, 2016 and 2017 and none caught in 2015 (Environment Agency, 2018b). The EA undertook routine fish surveys throughout England from 2005-2018. Atlantic salmon were recorded throughout the River Ellen as far upstream as Uldale (Environment Agency, 2019d). Atlantic salmon are known to be present in Chapelhouse Reservoir and in the River Ellen upstream of

Chapelhouse Reservoir, indicating that despite the poor nature of the pass, this species is able to migrate upstream of the Chapelhouse Reservoir fish pass (Grontmij, 2012); although it is expected to inhibit passage in most flow conditions. No historical information was available on the presence of Atlantic salmon in Over Water, the Over Water Beck or the bypass channel.

The site surveys found that the River Ellen, both upstream and downstream of Chapelhouse Reservoir, provided a range of flow types and habitats for all Atlantic salmon life stages (Appendix E). Substrates of a suitable size for spawning were observed in the River Ellen downstream of Chapelhouse Reservoir, but these were often very compacted and therefore would be suboptimal for Atlantic salmon spawning. Livestock poaching was also observed throughout the River Ellen catchment, increasing fine sediment input to the channel. However, salmonid parr (not identified to species) were observed in the River Ellen downstream of Chapelhouse Reservoir, indicating that salmonids are successfully spawning in the River Ellen.

Three small weirs were recorded along the River Ellen downstream of Chapelhouse Reservoir, which have been deemed as passable by adults migrating upstream and smolts migrating downstream. A waterfall was recorded in the River Ellen upstream of Chapelhouse Reservoir (immediately upstream of Crag Wood) which would likely be a barrier to upstream migration under most flow conditions, however, is expected to be passable during high flows.

Most of the bypass channel and the Over Water Beck were only suitable for migratory passage of Atlantic salmon. A small area of habitat immediately downstream of Over Water would have provided suboptimal juvenile habitat, however, this reach of the Over Water Beck was dry at the time of the site surveys.

The weir at the outlet of Over Water was assessed as being passable to upstream and downstream migrating Atlantic salmon during high flows. However, there is no indication that salmon migrate along the bypass channel and Over Water Beck to Over Water and beyond to utilise the limited suitable riverine habitat upstream of the reservoir.

River Lamprey and Sea Lamprey

River lamprey and sea lamprey are both anadromous (albeit with slightly different life histories) and require the same critical habitat for spawning and the development of ammocoetes (juveniles). Consequently, both species are considered together. Limited information is available on the distribution of river and sea lamprey in the catchment, however, the EA have recorded lamprey (species unspecified) in the River Ellen as far upstream as Uldale (Environment Agency, 2019d).

During site walkovers, silt beds suitable for ammocoetes were observed in the River Ellen downstream of Chapelhouse Reservoir only. Gravels that would be suitable for both lamprey species to spawn in were recorded in the River Ellen upstream and downstream of Chapelhouse Reservoir. Spatial connectivity between spawning and ammocoete habitats is important for lamprey, and suitable spawning habitat was observed close to the ammocoete silt beds, indicating good connectivity between habitats.

Three weirs were recorded in the River Ellen downstream of Chapelhouse Reservoir, and these were assessed as likely being a barrier to upstream migration of lamprey under low flow conditions. Additionally, the lower step of the Chapelhouse Reservoir fish pass is likely a barrier to upstream lamprey migration under low flows.

Brook Lamprey

Brook lamprey have similar life history and habitat requirements to river lamprey; however, brook lampreys are not migratory and live in freshwater for their entire lives. Limited information is available on the distribution of brook lamprey in the study area, but this species has been recorded as present in the River Ellen at Chapelhouse Dam (Casterbridge Fisheries, 2013) and upstream of Chapelhouse Reservoir (West Cumbria Rivers Trust, 2014).

The juvenile and spawning habitat identified as being suitable for river and sea lamprey will also be suitable for brook lamprey. Brook lamprey are smaller than river and sea lamprey and have poorer swimming ability, consequently the barriers to river and sea lamprey will also prevent passage of brook lamprey.

European Eel

European eel is catadromous, living in freshwaters during their adult lives before returning to sea to spawn. Adults and elvers (juveniles) were recorded by the EA throughout the River Ellen as far upstream as Uldale (Environment Agency, 2019d), and an NBN Atlas search returned a record of an eel in the River Ellen upstream of Chapelhouse Reservoir (Biological Records Centre, undated-a). In addition, a 2008 study indicated that the potential production of eels from the River Ellen catchment exceeded that under reference or pristine conditions and that the River Ellen meets the escapement target (40%) for eel fisheries (Aprahamian and Walker, 2008).

Suitable habitat for European eel was observed throughout the study area, with one adult eel observed in Over Water during the 2017 site surveys. The presence of eel in Over Water indicates that whilst the three weirs observed in the River Ellen and the Chapelhouse Reservoir fish pass are likely obstacles to migration in some flow conditions, they are not complete barriers to upstream migration of European eel.

Brown and Sea Trout

Brown trout are known to be present in the River Ellen upstream and downstream of Chapelhouse Reservoir (Biological Records Centre, undated-b), and in Chapelhouse Reservoir (Grontmij, 2012) and Over Water (Cascade Consulting, 2016). The River Ellen is an active sea trout fishery and rod catch results fluctuate between 2007-2017, but the overall catches reported between 2013-2017 were generally lower than those reported between 2005-2012 (Environment Agency, 2018b). Brown trout are resident in freshwaters throughout their life cycle, although they will migrate within freshwater, whereas sea trout are anadromous and migrate to sea before returning to freshwater as adults to spawn. Brown/sea trout have similar habitat requirements to juvenile and adult Atlantic salmon, therefore the habitat conditions reported earlier in this section are also applicable to this species.

European Otter

There is limited information available on the presence of otter in the study area. The Otter and Rivers Project 1991-1994 reported that in Cumbria that the best quality rivers had only low or transient otter populations, whilst a subsequent survey conducted in 1998 indicated that otters are present throughout the River Ellen (Environment Agency, 1999). An EA otter survey carried out in 2009-2010 recorded the presence of otters near the study area (Environment Agency, 2018c). A 2015 survey conducted by United Utilities recorded field signs of otter (spraints) in the Over Water Beck near the outlet of Over Water and in the bypass channel alongside Chapelhouse Reservoir.

During the site surveys, field signs of otter (spraints and possible prints) were observed in the River Ellen upstream of the catchpit, the Over Water Beck near the weir and in the overflow channel to Chapelhouse Reservoir. No resting places were recorded during the site surveys, however, suitable habitat for otter resting places was observed in the River Ellen.

Lake Habitats and Associated Species

Over Water is a natural tarn, the level of which has been raised (see Section 3 for more details). Wet woodland borders the northern, southern and south-western shores, whilst neutral grassland is found along the eastern shore (Natural England, 2017). The reservoir is a known feeding location for osprey, which breed beside Bassenthwaite Lake (approximately 5km south-west).

The condition of the nine live units in Over Water SSSI was last assessed in 2010, with the Standing Open Water and Canals habitat assessed as Unfavourable-Declining due to the absence of three characteristic species for the site (*Myriphyllum alterniflorum*, *Nymphaea alba*, and *Isoetes lacustris*) and the presence of the non-native macrophyte, New Zealand pygmyweed. The reservoir is also failing to meet its water quality targets due to high levels of phosphorus and chlorophyll a, due largely to the livestock grazing in its catchment (Atkins, 2015). The two neutral grassland units were assessed as Unfavourable-No Change due to hydrological modifications (presumably Over Water weir), exposed substrates and the presence of New Zealand pygmyweed *(Crassula helmsii)*. Three of the six wet woodland units have been designated as Unfavourable (either Declining or No Change), in part due to an unacceptable proportion of non-native trees present in all three units as well as the presence of non-native American skunk cabbage (*Lysichiton americanus*) in two units and the high proportion of birch (*Betula* spp.) (as opposed to alder (*Alnus* spp.) and willow (*Salix* spp.)) in the third unit (Natural England, 2017). The remaining three areas of wet woodland, two along the northern border and one along the southern border of Over Water, are in Favourable condition.

The Freshwater Biological Association (FBA) surveyed Over Water in 2016 and recorded the presence of the cladoceran *Ilyocryptus acutifrons*. Although this species is not protected, it is rare in the UK and only occurs in several of the smaller lakes in the Lake District (Alvarez-Codestal, 2016).

The invasive, non-native species New Zealand pygmyweed was recorded in Over Water in 2010, with extensive coverage noted along the north-eastern shores during the FBA and 2017 Jacobs surveys. Other non-native species recorded at Over Water are Nuttall’s pondweed, which was recorded by the FBA survey and was also observed during the Jacobs surveys at several locations in the Over Water Beck. The FBA also recorded the presence of two American skunk cabbage individual plants, with one located along the southern shore and one along the western shore. American skunk cabbage was previously widespread around Over Water, with tens of thousands of individual plants removed from the wet woodland as recently as 2013 (West Cumbria Rivers Trust, 2013).

There is limited information available on the fish communities in Over Water, however, brown trout (both stocked and resident) and European eel were identified as present (Cascade Consulting, 2016). A dead eel was observed on the shore of the reservoir during the 2017 Jacobs walkover survey.

There are no conservation designations assigned to Chapelhouse Reservoir. The reservoir is known to support Atlantic salmon, sea trout, brown trout and lamprey (species unidentified), and suitable otter habitat is present around the reservoir (Grontmij, 2012; Cascade Consulting, 2016). A marsh with emergent vegetation was recorded at the southern extent of the reservoir, whilst Nuttall’s pondweed was recorded at the outlet to the bypass channel during the site surveys.

4.5.3 Opportunities and Constraints

Opportunities

Several opportunities for improving the ecology baseline have been identified as part of the baseline assessment.

- The lower section of the Chapelhouse Reservoir fish pass currently acts as a barrier to salmonids during low flows and a barrier to lamprey upstream migration. Removal of infrastructure in the catchment would ease passage of all fish species to the upper reaches of the River Ellen. Similarly, the removal of the weir at Over Water would improve access for migratory fish. Infrastructure removal would encourage flow and sediment regimes to return to near-natural states, which would improve the quality and diversity of habitat for fish species including Atlantic salmon, brown/ sea trout and brook, river and sea lamprey.
- Carrying out river restoration of the River Ellen and Over Water Beck, in particular promoting variable flow and substrate conditions, would likely improve habitat quality and availability throughout the catchment. This would be beneficial for all fish species, in particular juvenile salmonids, whilst habitat suitable for spawning would also likely increase.

- Native macrophytes are expected to benefit from any habitat enhancements that increase flow and substrate diversity in the River Ellen. The non-native macrophytes New Zealand pygmyweed and Nuttall's pondweed are both adapted to slow flows or standing water (Great Britain Non-Native Species Secretariat, 2015a and 2015b). Restoring a naturally flowing channel would likely reduce habitat availability for these non-native species, whilst also providing more diverse conditions for native river and stream macrophytes.
- Much of Over Water is bordered by wet woodland, some of which is in Unfavourable condition due in part to the presence of non-native species in the woodland. Planting around Over Water following the removal of the weir and lowering of the reservoir level could encourage wet woodland expansion to the new shoreline. Native species would be planted in this instance to increase the proportion of native species in the woodland. Riparian planting along the River Ellen and Over Water Beck would also improve habitat availability for otter and fish.
- Over Water is a SSSI and as such any modification to its operation must comply with the targets and objectives set out by NE (2009) for the site. This includes the target which states "There should be a natural hydrological regime". Restoring a naturally flowing channel would directly contribute towards the attainment of the target for the SSSI.

Constraints

The main constraints likely to be associated with the removal of the infrastructure within the River Ellen catchment on ecology include:

- Nuttall's pondweed is known to be present in both Over Water and Chapelhouse Reservoir, and New Zealand pygmyweed has been recorded in Over Water. Infrastructure removal works could exacerbate the spread of non-native species, potentially impacting on the WFD status of the water body. This should be managed by developing a robust invasive non-native species management plan prior to any works commencing. This plan should be developed in consultation with appropriate bodies, such as NE and the EA, and could include measures such as the elimination (where possible) of non-native species and prevention of the downstream spread of non-native plant species, for example by adhering to the Check, Clean, Dry principles during any construction works.
- At present it is unknown how much fine sediment is contained within Over Water or Chapelhouse Reservoir, and there is the potential for fine sediment mobilisation with the removal of impounding infrastructure/ any channel realignments or modifications. Understanding how these sediments could be mobilised and deposited, would be required to ensure minimal risk of habitat smothering.
- Over Water is a SSSI and as such any modification to its operation must comply with the targets and objectives set out by NE (2009) for the site. This would include maintaining the presence of *Ilyocryptus acutifrons* and no net loss in the extent of wet woodland and swamp, marsh and fen habitats, both of which are reliant on maintaining the current water level in Over Water (itself a specific target for the SSSI). Favourable Condition tables can be reviewed, and Natural England have indicated that this would be done when Over Water is re-naturalised. This would therefore not be a constraint on the re-naturalisation of Over Water. However, it would deliver compliance with the target to restore/maintain natural hydrology (identified as an opportunity above).

5. Overview of Optioneering

5.1 Determining the Long List of Options

Following the baseline assessments for all disciplines in Main Stage A, a multi-disciplinary internal workshop (Workshop 1) was held to determine a long list of options. The instructions for the workshop were to put forward all options, regardless of any initial views on technical feasibility, stakeholder acceptability or economic factors. This was to ensure that no options were overlooked.

The majority of options relate to one of four specific areas; Over Water, Chapelhouse Reservoir, the River Ellen, and Longlands Beck, with a number of sub-options investigated for each area. One sub-option relates to the removal of all structures at all sites, with the reinstatement of the River Ellen to a historical planform. Table 5-1 lists the options considered as the long list.

Table 5-1: Summary of options considered in the MCA

Area	ID	Option description
General	G1	Do nothing - Allow natural decay
	G2	Do minimum - Maintain current weir condition
	G3	Full removal of all structures (reinstating River Ellen back to historical planform)
Over Water	O1	Full removal of weirs
	O2	Partial removal of weirs
	O3	Remove bank and bed reinforcement downstream
	O4a	Improve downstream section (upstream of weir) - regrade
	O4b	Improve downstream section (upstream of weir) - low flow slot
	O4c	Improve downstream section (upstream of weir) - riparian habitat
	O4d	Improve downstream section (upstream of weir) - re-meandering
	O4e	Improve downstream section (upstream of weir) - gravel augmentation
	O5a	Improve section between road and catchpit - regrade
	O5b	Improve section between road and catchpit - low flow slot
	O5c	Improve section between road and catchpit - riparian habitat
	O5d	Improve section between road and catchpit - re-meandering
	O5e	Improve section between road and catchpit - gravel augmentation
	O6	Downstream of bridge remove bank reinforcement and narrow channel
Chapelhouse Reservoir	C1a	Catchpit – remove and connect River Ellen to existing bypass channel
	C1b	Catchpit - remove and connect River Ellen to Chapelhouse
	C2	Catchpit – naturalise if possible and remove some reinforcement
	C3	Full removal of dam (including catchpit and bypass channel) - reinstating old River Ellen planform
	C4a	Partial removal of dam - leaving catchpit and reconnecting channel to Chapelhouse Reservoir

Area	ID	Option description
	C4b	Partial removal of dam - removing catchpit and reinstating historical River Ellen planform to Chapelhouse Reservoir
	C4c	Install a culvert through the existing dam for a newly created River Ellen channel to pass through
	C5a	Removal of both weirs downstream of Chapelhouse dam
	C5b	Removal of upstream weir (downstream of Chapelhouse dam)
	C5c	Removal of downstream weir (downstream of Chapelhouse dam)
	C6	Fish pass on downstream weir (downstream of Chapelhouse dam)
	C7	Improve bypass
	C8	Create a new bypass channel on east of reservoir
River Ellen	E1	Re-naturalise – cut across field downstream of road towards the reservoir (meandering planform)
	E2	Re-naturalise - straightened length
	E3	Gravel augmentation to improve habitat
	E4	Weir and bank reinforcement removal
Longlands Beck	L1	Remove weir under road by Low Longlands
	L2	Remove infrastructure on channel edge
	L3	Riparian planting on right bank downstream of wood
	L4	Stop dredging

5.2 Multi-Criteria Analysis

A summary of the method, scoring criteria and results of the Main Stage A Multi-Criteria Analysis (MCA) are provided in Appendix F. The following provides an overview of the MCA process for each discipline.

5.2.1.1 Engineering

The options presented in the MCA would generally improve the engineering baseline from both a liability and maintenance perspective, however, to do so would likely incur considerable construction costs. Management of health and safety (especially during construction) would need attention, with consideration of option buildability also required. There would likely be short-term impacts on the channel and surrounding lands during the construction works, however, these would be offset by the longer-term benefits of reinstating near-natural catchment processes.

5.2.1.2 Hydrology and Hydraulics

The options presented in the MCA would generally have negligible effects on the flood/hydrology baseline with the exception of the full removal of the impounding structures such as the catchpit and Chapelhouse Dam. Such options would favour the routing of flow downstream leading to a potential increase in flood risk to the downstream communities under high flow conditions.

5.2.1.3 Geomorphology

The options presented in the MCA would generally have a favourable effect on the geomorphological baseline. Whilst there is potential for short-term impacts on the channel during any construction works, these would be outweighed by the significant long-term benefits. In particular, the full removal of infrastructure and return of the River Ellen to its historical planform would allow for fluvial processes to return to a more natural pre-dam condition.

5.2.1.4 Ecology

The options presented in the MCA would generally have either a favourable or neutral effect on the ecological baseline. Removal of infrastructure (particularly Chapelhouse dam) and reinstatement of the River Ellen channel is expected to be a significant benefit to Atlantic salmon (the focal species of the study) and other fish species, as these measures will restore natural conditions and permit free passage within this part of the catchment. River restoration measures would likely improve the quality and diversity of in-channel habitats throughout the catchment resulting in direct benefit to Atlantic salmon and other fish species.

Removal of infrastructure would reduce the availability of lacustrine habitat in the catchment, which could affect the SSSI status of Over Water, though it is anticipated this would be balanced by the overall improvement to the hydrological regime. Consequently, appropriate mitigation measures (such as planting native species to encourage wet woodland establishment) and consultation with NE and the EA would be required to ensure that no habitat or species loss is incurred. However, the reduction in available lacustrine habitat will reduce the overall amount of habitat available for New Zealand pygmyweed and Nuttall's pondweed. New Zealand pygmyweed was observed extensively in the shallow margins of Over Water east of the weir, so lowering the water level will eliminate some areas that are currently inhabited by this species. Targeted planting of native species, combined with the anticipated eradication of non-native species, is expected to promote the establishment of a native community in the newly exposed shoreline.

5.2.2 Summary of Results

During the PSG meeting on the November 2017, the findings of the Main Stage A assessment (baseline and high-level MCA) were presented by Jacobs. This was also followed up with an interim Summary Report. The PSG confirmed that they agreed with the shortlisted options put forward for detailed assessment in Main Stage B, with the lead option being made up of the following elements:

- full removal of Over Water weir;
- removal of Chapelhouse Reservoir dam, catchpit and bypass channel; and,
- reinstatement of the River Ellen channel to its historical planform.

This decision marked the end of Main Stage A and the beginning of Main Stage B; the detailed assessment stage.

6. Design Iterations

6.1 Overview

The subsequent approach undertaken for the development of the outline design was to produce a series of "design fixes" and hold check point discussions with UU and the PSG to reach a preferred outline design agreed by all stakeholders. Table 6-1 summarises this process which is assessed in more detailed in Sections 6.2 - 6.4. The final outline design drawings are shown in Appendix G of this report.

Table 6-1: Summary of design fixes

Design Fix	Description	PSG Comments
Design Fix 1	It was proposed that the existing weir at Over Water would be removed and a new natural outlet channel with a base level of 190.70mAOD formed. This channel would connect with Over Water Beck, sections of which would be improved. The embankment adjacent to the weir would also be removed. Full removal of Chapelhouse Reservoir dam (including associated infrastructure) to allow for the realignment of the River Ellen along the base of the reservoir footprint. This would include the removal of the catchpit structure to allow for the restoration of the natural confluence between the Over Water Beck and the River Ellen. The realigned River Ellen would follow (as closely as possible) the original planform of the River Ellen, prior to construction of the dam. The channel would be two-staged and contain features such as gravel bars and woody debris. The existing bypass channel would be backfilled. No road bridge would be provided to the property on the right bank, instead a new upgraded access along from the unnamed road would be provided.	Presented to the PSG during workshop 3 on 12/3/2019. It was raised by the PSG during workshop 3 that it would be preferable that the trees on the left side of the embankment at Over Water be kept. To address this, it was agreed that the man-made section of the embankment will be lowered only on the right side of the overflow. In addition, DF1 was found to increase pass forward flow downstream of Chapelhouse Reservoir and subsequently increased flood depths, albeit slightly, at the single property in Ireby. The PSG commented that for ease of discussions going forward, this risk should be mitigated. Consequently, it was agreed that as part of the next design fix further work was required to reduce this impact.
Design Fix 2	The design was refined following PSG Workshop 3 as follows: • inclusion of two high flow channels along the realigned River Ellen; • modification to channel planform through floodplain between Stockdale Farm and Chapelhouse Reservoir; • only remove the embankment at Over Water which is located to the south of Over Water Beck; • stone protection to toe of breach at Chapelhouse removed; and, • show where the Public Right of Way diversion would be.	Presented to the PSG during workshop 4 on 4/4/2019. During the PSG workshop 4, it was decided that the increased flood flow experienced at the property in Ireby was not acceptable. This flooding was still present with the modifications to the planform of the channel of the River Ellen. The PSG instructed Jacobs to investigate ways to mitigate any flooding of the property at Ireby.
Design Fix 3	The proposed modifications to the existing watercourse structures showed an increased efficiency in the channel and, therefore, a slight increase in flooding has been identified downstream of the dam at Chapelhouse Reservoir. This was eliminated by looking at the following: • The creation of high flow channels offline from the main channel which in flood conditions would be utilised and provide a degree of attenuation. Modelling determined that these channels alone would not be sufficient to attenuate the levels of flood flows.	Presented to the Environment Agency and PSG in a telecom/webex session on 5/7/2019 It was agreed by the PSG that the preferred option for the final design would consist of the offline storage pond on the basis that the online option disrupted the flow down the River Ellen, which would contradict the aim of the project. The online storage option also had the potential to have a large visual impact on

Design Fix	Description	PSG Comments
	• Development of two potential flood storage options, namely an offline storage or an online storage. A series of conceptual sketches were prepared for discussion with the PSG. The remainder of the design remained unchanged from the previous design fixes.	the area as it would need to span most of the valley floor. The decision to go with the offline option was agreed with all parties. Modifications to the conceptual layout were made in conjunction with the PSG, including the positioning of the outlet channel.
Final Design Fix	The final outline design fix consists of the following elements: • Full removal of Chapelhouse Dam (including associated infrastructure) • The realignment of the River Ellen consisting of a two-staged channel containing features such as gravel bars and woody debris • The creation of a single high flow channel offline from the main channel slightly upstream of the existing Chapelhouse dam • Construction of an offline flood storage area, replacing the upstream section of high flow channel proposed during DF2 • Removal of existing weir and section of embankment at Over Water • Realignment of Over Water Beck from Over Water to confluence with the realigned River Ellen. • Backfill of the redundant bypass channel • Removal of all redundant infrastructure • Provision of new farm access bridge • Upgrade existing access to private property • Permanent diversion of existing public right of way	Presented in this report.

6.2 Design Fix 1

Table 6-2 outlines the key findings of the detailed assessment of Design Fix 1 from each of the disciplines as discussed during Workshop 3 in March 2019.

Table 6-2: Detailed assessment of Design Fix 1 (DF1)

<table>
<tr><th></th><th>Removal of Over Water weir</th><th>Removal of Chapelhouse dam, catchpit and bypass channel</th><th>Reinstatement of River Ellen channel</th></tr>
<tr><td>Engineering</td><td>Impact on baseline: Minor negative

The extent of the enabling works and capital costs that would be required to facilitate weir removal contribute to a negative impact.

Health and safety risks could be overcome through appropriate planning and management, with the most significant risks likely to be those associated with the need for flow control to allow working in water and demolition.

Removal of the weir and modification of the outlet levels would return Over Water to a natural lake, and therefore remove any statutory liability United Utilities currently have under the Reservoirs Act 1975. Full removal of the weir and abstraction infrastructure would also preclude the need for any future operational expenditure.</td><td>Impact on baseline: Moderate negative

Predominantly because of high anticipated construction costs, enabling works and significant health and safety risks that would require extensive planning and management. This would include establishing access routes to the various elements of the scheme, whilst maintain access for farming operations. The location of any compounds would have to be agreed between UU and the Contractor but may include one main compound with subsidiary compounds. Health and safety risks would include the risk of flooding from the River Ellen during construction, however, these risks could be mitigated in part by using the current bypass channel/catchpit to allow the breaching stage of the works and reinstatement of the River Ellen to be done in the dry. Any existing services currently carried across the crest and downstream face of the dam would need to be diverted prior to breaching works being undertaken.

Using the reinstated River Ellen channel would allow for the catchpit structure and bypass channel to be decommissioned in the dry. Material from the breach could be used for infilling, however, if this is deemed unsuitable material would need to be imported.

Following the drawdown of Chapelhouse Reservoir, there would be a volume of sediment retained in the solum of the reservoir. This would need to solidify prior to any works being carried out in the solum, with some sediment removal off site required as this material may not be suitable for forming the realigned channel of the River Ellen. The drying process would be impacted if the River Ellen were to flood during this period.

The original masonry spillway on the left flank of the dam is to be retained. This would provide historical significance as a demonstration of the site's former industrial heritage.

Drawdown of Chapelhouse and breaching the existing dam would remove the presence of a large reservoir, and therefore any statutory liability United Utilities currently have under the Reservoirs Act 1975. Any future operational expenditure would likely be minimal compared to current operational costs.</td><td>Impact on baseline: Minor negative

Predominantly because of moderate construction costs and enabling works. It is anticipated that the formation of the new channel will be carried out "offline" from the current watercourse (which would flow along the current diversion channel) and connection would only be carried out at the completion of the works.

Additional costs could be incurred where agricultural land needs to be purchased to accommodate the River Ellen where it is realigned upstream of Chapelhouse Reservoir. The land in question, to the south of the existing Chapelhouse Reservoir is owned by Stockdale Farm.</td></tr>
<tr><td rowspan="2">Hydraulics</td><td rowspan="2">Impact on baseline flood risk: Low beneficial

As a direct consequence of removing the weir, the maximum water levels in Over Water and Over Water Beck were found to decrease. For example, the maximum water level within Over Water is reduced from 191.72mAOD to 191.35mAOD when compared to the baseline scenario for the 1% AEP +CC event. This was found to be beneficial to the flood risk in vicinity of the confluence of Over Water Beck and the River Ellen.</td><td>Impact on baseline flood risk: Minor Negative

During all AEP events, the onset of peak discharge downstream of Chapelhouse Reservoir was found to occur earlier than in the baseline scenario.

In the 50% AEP event, maximum pass forward flow downstream of Chapelhouse Reservoir was found to increase from 4.60m^3/s to 5.37 m^3/s following dam removal, which represents an increase of approximately 16%.

In the 1% AEP +CC event, maximum pass forward flow was slightly reduced from 16.58m^3/s in the baseline to 16.51m^3/s, however the timing of peak discharge was reduced from 5.25 hrs to 5.1 hrs.

16%.</td><td>Impact on baseline flood risk: Negligible

Maximum flood depths in the upstream modelled domain were found to reduce from baseline depths. Inundation of the floodplain within the upstream modelled domain remained, with some marginal increase in extent.

It was noted that much of the upstream flooding was caused by the upstream road bridge, not by the reinstatement of the River Ellen.</td></tr>
<tr><td colspan="2">With Design Fix 1 in place, flood inundation of the upstream floodplain of the Upper River Ellen was found to be removed during the 50% AEP event. However, flow was found to bypass the realigned Upper River Ellen in all AEP events of a larger magnitude than the 10% AEP event, resulting in flood inundation of the surrounding agricultural fields.

This option is shown to minorly increase flood extent throughout the downstream model domain near Ireby during the 50% and 10% AEP events. However, this minor increase was not found to impact any properties. In all events greater or equal to the 2% AEP event, flood extent was found to be similar to baseline within the downstream model domain. However, flood depth was found to increase slightly in all simulated events, with a maximum increase of 80mm during the 50% AEP event and a few millimetres during the 1% AEP +CC event. Both the 1% AEP event and the 1% AEP +CC event were found to increase flood depths very slightly at the single property at the Old Mill in Ireby.</td></tr>
<tr><td rowspan="2">Hydrology</td><td>Impact on baseline: Moderate beneficial

The cessation of abstraction of water from Over Water will result in the Over Water Beck no longer experiencing no-flow conditions that are especially prevalent during the summer in the baseline situation.

Lake level regime would also change, with winter levels being lower and more variable than the baseline. However, summer levels could be higher and less variable than the baseline following cessation of abstraction. Large summer drawdowns of over 1m (prevalent in the baseline) would no longer occur.</td><td>Impact on baseline: Low beneficial

The removal of the dam will enable naturalisation of the flows that contribute directly to this portion of the river.</td><td>Impact on baseline: Negligible

It would be unlikely that the reinstatement of the River Ellen channel would impact on baseline hydrological conditions.</td></tr>
<tr><td colspan="2">Removal of weirs, dams and abstraction infrastructure would naturalise flow conditions along the River Ellen. This would be most evident for the low to medium flows (flows less than Q50) and is therefore most likely to be noticeable during the summer months.</td><td></td></tr>
<tr><td>Geomorphology</td><td>Impact on baseline: Low beneficial</td><td>Impact on baseline: High beneficial

Removal of infrastructure would improve connectivity between the up- and downstream catchment, representing conditions analogous to those pre-reservoir construction.</td><td>Impact on baseline: Moderate beneficial</td></tr>
</table>

	Removal of Over Water weir	Removal of Chapelhouse dam, catchpit and bypass channel	Reinstatement of River Ellen channel
	Removal of the weir would improve connectivity between Over Water and the downstream catchment, representing conditions analogous to those of pre-weir construction. In the short-term, weir removal could cause the mobilisation of any un-consolidated sediment from Over Water. This would cause a short-term increase in sediment yield; however, this would likely return to baseline levels in time. Weir removal would reduce the occurrence of no-flow conditions in Over Water Beck, whilst variability in flow regime would increase. This would likely include the increase in peak discharge levels. Despite the potential for increase in peak discharge levels, significant scour/planform change downstream of Over Water is likely to be limited, as the downstream channel dimensions and slope remain largely unchanged from the baseline. Consequently, as a relatively low energy environment is maintained any morphological changes would likely be localised e.g. around existing depositional features.	Volumes of sediment transported downstream of Chapelhouse Reservoir would likely increase, both short-term with the mobilisation of unconsolidated sediment from the footprint of Chapelhouse Reservoir during the drawdown process, and long-term as the finer sediments currently trapped by (and removed from) the catchpit and Chapelhouse Reservoir, would pass downstream. Given the lack of finer sediments observed downstream of Chapelhouse Reservoir this would likely be a positive impact, as a more diverse sediment load would likely lead to a diversification in bed substrate and morphological features. The removal of the catchpit and overflow channel to Chapelhouse Reservoir would promote a more diverse flow regime downstream of Chapelhouse Reservoir, as water would no longer be diverted into the reservoir. Combined with an increase in sediment yield (as discussed previously), fluvial processes should diversify, potentially resulting in a range of morphological features forming downstream of Chapelhouse Reservoir.	The reinstatement of the channel to its historical planform, the placement of alternating gravel bars, to encourage natural fluvial features such as pools, riffles and more gravel bars, and incorporation of a two-stage channel in the design would promote diversity of local flow conditions and morphological processes. Based on site visit observations, the River Ellen currently occupies a medium energy environment which could support a meandering channel. Consequently, the reinstated channel would likely be sensitive to changes in flow and sediment yield in the short-term as it seeks to achieve equilibrium. This could manifest as lateral channel migration and formation of morphological features associated with meandering channels e.g. river beaches, although sensitivity to change would likely decrease over time as the channel adjusts towards a dynamic equilibrium. Where the reinstated channel passes through the footprint of Chapelhouse Reservoir, un-consolidated boundary sediments could be present which would likely be easily mobilised. Consequently, this area would act as a short-term sediment source, the yield from which would diminish overtime as un-consolidated sediments are transported downstream, and sediment cohesion is increased e.g. through the establishment of riparian and floodplain vegetation. The presence of unconsolidated sediments could encourage lateral migration in the short-term, although this would likely diminish over time for the reasons stated previously. Superficial gravel deposits are present through much of the catchment (including historical alluvial fan deposits) between the modified reach of the River Ellen and Chapelhouse Reservoir. Re-aligning the channel through this area would increase the opportunity for gravels to become entrained and transported downstream, diversifying the bedload of the River Ellen and encouraging formation of morphological features such as gravel bars and riffles. Significant improvement in lateral connectivity from the current baseline would also be attained by the reinstatement of the River Ellen channel and the abandonment of the bypass reach. This would provide the opportunity for a heterogenous riparian habitat to develop as a result of increased fluvial-terrestrial interaction.
Ecology	**Impact on baseline:** Overall negligible impact as minor positive and negative impacts would occur and balance each other out. The removal of the weir at Over Water would not significantly impact the ecology baseline, as the focal species of the study (Atlantic salmon) is currently able to access the reservoir, albeit not in all flow conditions. However, removal of the weir, provision of perennial baseflow flow in Over Water Beck and appropriate grading between Over Water Beck and Over Water will improve access for multiple fish species by allowing passage in all flow conditions. Over Water Beck would also be re-meandered and designed with multiple habitat types to improve fish habitat. Lowering of the lake level would likely impact the wet woodland habitat present on the northern and western shores which is a notified feature of the SSSI. Planting of native species and re-grading of the new shoreline would need to be considered in the final design to promote successful establishment of this woodland. The amount of suitable habitat available to New Zealand pygmyweed and Nuttall's pondweed (non-native species) would likely be reduced, potentially reducing the presence of both species in the area. Several non-native plants were identified in Over Water which would be removed prior to weir removal to prevent them spreading downstream and therefore comply with the Wildlife and Countryside Act (1981). Management of non-invasive species would be detailed in a Non-Native Species Management Plan.	**Impact on baseline:** Significant beneficial The existing fish pass is of poor design and inhibits migration in some flow conditions for all fish species, including Atlantic salmon. Removing the fish pass, combined with reinstating the River Ellen channel, would create a natural channel which would permit free passage for fish in all flows. Substrates suitable for spawning were observed in the River Ellen during walkover surveys in 2017, albeit these were often very compacted. Following removal of Chapelhouse dam, substrates in the River Ellen are expected to diversify which would also be a benefit to fish species as it would increase habitat heterogeneity in the river. Removal of the lacustrine environment would reduce the habitat available for non-native plant species adapted to very low flow or no flow conditions, such as New Zealand pygmyweed and Nuttall's pondweed, the latter of which is already present in the reservoir. Fine sediments stored in the catchpit and Chapelhouse Reservoir footprint would likely be mobilised and transported downstream following infrastructure removal. This would potentially result in the smothering of downstream habitats, consequently the downstream mobilisation of these sediments would need to be prevented.	**Impact on baseline:** Significant beneficial Reinstatement of the River Ellen would provide variable flow conditions and bed substrate, improving spawning beds and supporting juvenile habitat and, also, increasing overall habitat diversity for fish. Riparian planting as part of the channel reinstatement would also create habitat conditions that would be suitable for otter. To preserve and protect fluvial/riparian habitats from degradation, fencing would be established to prevent livestock from entering the channel and poaching the bank tops (a source of fine sediment). Likewise, structures crossing the channel e.g. new bridge for access to Chapel House Farm would span the entire width of the river, minimising impact on local fluvial habitat. Any re-alignments would need to be designed to ensure that depths and flows allow for fish migration, particularly during the time of year when fish are moving into the river for spawning.

A summary of the issues raised following Design Fix 1 is below:

- The extent of the enabling works and capital costs that would be required to facilitate the complete removal of Over Water weir and embankment would contribute to a negative impact.
- Design Fix 1 was found to have a negative impact on flood risk, with bypassing of the realigned River Ellen, increased flow downstream of Chapelhouse Reservoir and increased flood depths at the property in Ireby.
- The reinstated channel would likely be sensitive to changes in flow and sediment yield in the short-term, potentially manifesting as lateral channel migration and the formation of morphological features.
- Fine sediments stored in the catchpit, Over Water and Chapelhouse Reservoir would likely be mobilised and transported downstream following infrastructure removal, potentially resulting in the smothering of downstream habitats and downstream morphological changes.
- A management strategy for invasive non-native plants in Over Water would need to be developed prior to weir removal, to prevent them spreading downstream and in compliance with the Wildlife and Countryside Act (1981). Management of non-native species would be detailed in a Non-Native Species Management Plan, to be developed in consultation with relevant stakeholders (e.g. Natural England, Environment Agency).

6.3 Design Fix 2

Following Design Fix 1, the outline design was refined to include the design modifications described in Table 6-1, with the inclusion of two high flow channels along the Upper River Ellen. Design Fix 2 was presented during Workshop 4 in April 2019.

Table 6-3 summarises the key impacts of the design changes for each of the four disciplines where they differ from Design Fix 1; if the impacts are similar to Design Fix 1, no update is provided.

Table 6-3: Detailed assessment of Design Fix 2

	Removal of Over Water weir	Removal of Chapelhouse dam, catchpit and bypass channel	Reinstatement of River Ellen channel
Engineering	In order to prevent working within woodland on the north shore of Over Water, only the embankment located to the south of Over Water Beck is now being removed. The impacts would be the same as those identified for DF1.	A public right of way was identified as running across the crest of Chapelhouse dam. This will be required to be diverted as part of the works and include a small footbridge constructed to facilitate crossing of the River Ellen. It is likely that a temporary diversion will be required initially during the construction phase. The permanent diversion would minimise the impact of the works on adjacent assets.	Stone protection at the toe of the breach in Chapelhouse dam would no longer be required, as it would be unlikely that the reinstated channel would migrate to such an extent where toe protection would be required. This would remove the need for additional construction/material costs.
Hydraulics	Same impacts as identified for DF1.	Flow downstream of Chapelhouse would increase under DF2 compared to both the baseline and DF1, again with the onset of peak discharge occurring earlier in a high flow event than in the baseline. Modelled hydrographs for 50% AEP, 10% AEP and 1% AEP (plus climate change) events are held in Appendix C.	Same impacts as identified for DF1
		In Design Fix 2, the removal of Chapelhouse Reservoir and reinstatement of the River Ellen to include high flow channels was found to increase flood depths at Ireby during all AEP events. The increase in flood depths was in the region of 10 to 50mm. In particular, this modification was found to increase flood inundation at the single flooded property at Ireby in both the 1% AEP and 1% AEP (plus climate change) events by depths of 23mm and 19mm respectively.	
Hydrology	Same impacts as identified for DF1	Same impacts as identified for DF1	Same impacts as identified for DF1
Geomorphology	Same impacts as identified for DF1	Same impacts as identified for DF1	The addition of two high flow channels to the design since DF1 along the realigned River Ellen will result in the bifurcation of flow around two river islands during high flow events. To accommodate the high flow channels, the channel slope has been increased from DF1. As a result, localised stream power would likely increase from that in DF1, with the stream power (and therefore potential for channel adjustment) significantly higher through the high flow channel than the normal flow channel. Consequently, the channel could transition from a meandering to a braided planform, with the high flow channel conveying flow with increasing frequency over time. The planform of the proposed River Ellen channel would now follow a slightly straighter planform than is present in historic maps. This could promote a more efficient system for sediment transport regime than proposed in DF1, although the presence of gravel bars could mitigate this to some degree.
Ecology	It is assumed that all non-native plant species would be eradicated prior to works commencing on the weir. However, a non-native species management plan should be developed for the	Same impacts as identified for DF1	Same impacts as identified for DF1, as sufficient depth and flow would be maintained under all flow conditions to allow for fish migration.

	Removal of Over Water weir	Removal of Chapelhouse dam, catchpit and bypass channel	Reinstatement of River Ellen channel
	construction works which will outline the risks associated with non-native species and measures to put into place should any be discovered. This plan would be produced in consultation with NE and the EA. Only the embankment present to the south of Over Water Beck would be removed in DF2, reducing the impact on the trees located within the SSSI unit to the north side of the Over Water Beck compared with DF1.		

A summary of the issued raised following Design Fix 2 is below:

- The public right of way across the crest of Chapelhouse dam will be required to be diverted as part of the works and a small footbridge constructed to facilitate crossing of the River Ellen.
- The modifications made during Design Fix 2 were unable to mitigate against the increased pass forward flow downstream of Chapelhouse Reservoir and the subsequent increased flood depths at the single property in Ireby, during all AEP events.
- The addition of two high flow channels would likely result in localised increases in stream power and therefore the potential for channel adjustment would be greater, meaning the channel could transition from a meandering to a braided planform.
- The planform of the proposed River Ellen channel would now follow a slightly straighter planform than is present in historic maps, potentially promoting a more efficient system for sediment transport regime than proposed in Design Fix 1.
- A non-native species management plan would be required for the construction works which will outline the risks associated with non-native species and measures to put into place.

6.4 Design Fix 3

Following Design Fix 2 and Workshop 4, the preferred option was further refined to account for the increased flow efficiency in the channel as a result of the design modifications and the subsequent increase in flooding has was identified downstream of the dam at Chapelhouse Reservoir. This included the testing of two potential flood storage options, offline storage and online storage. A series of conceptual sketches were prepared for discussion with the PSG in July 2019 (see Figure 6-1).

The key findings/impacts of each discipline for Design Fix 3 are presented in Table 6-4.

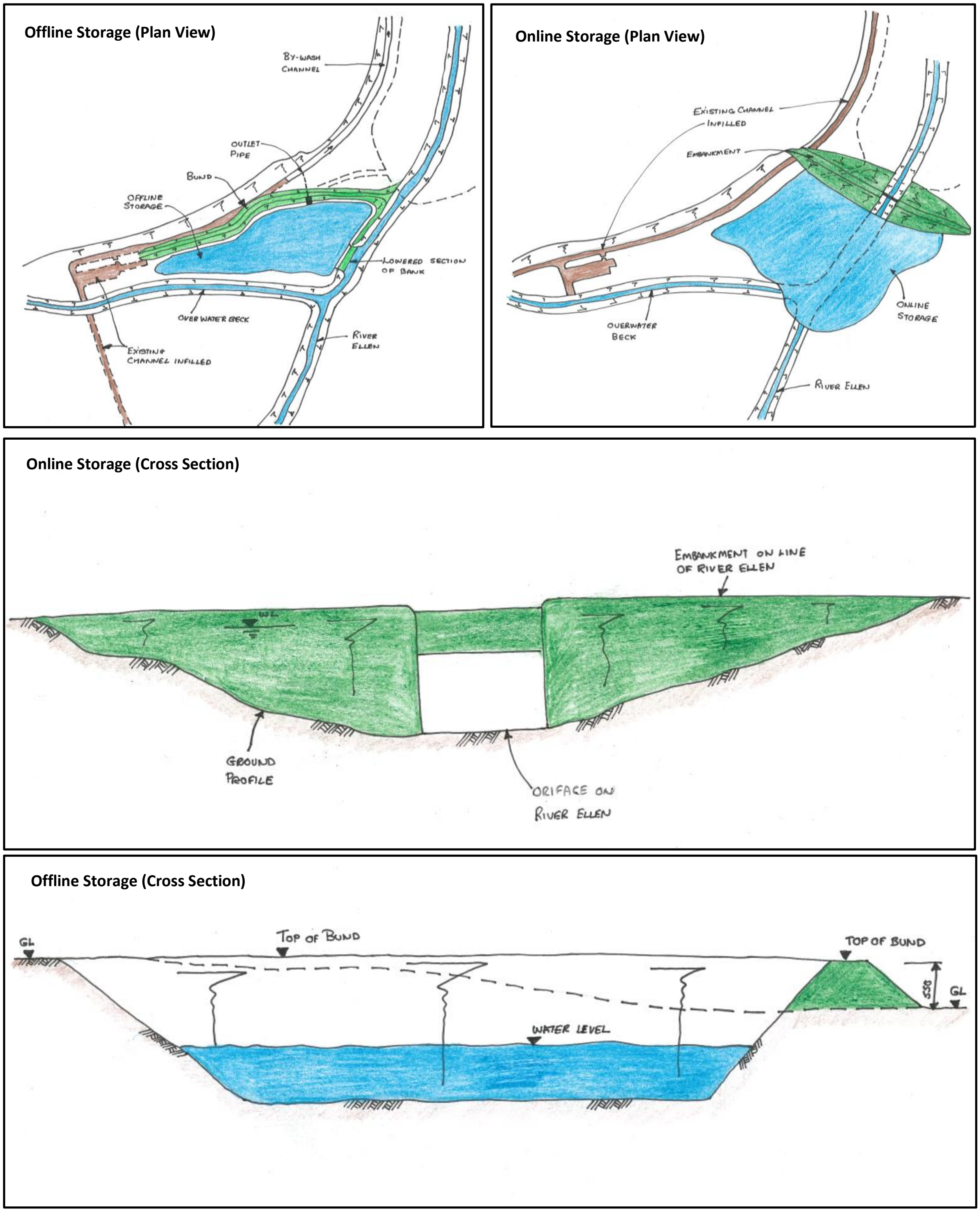


Figure 6-1: Conceptual design of flood storage areas.

Table 6-4: Detailed assessment of Design Fix 3 (DF3)

<table>
<tr><th>DF3</th><th>Removal of Over Water weir</th><th>Removal of Chapelhouse dam, catchpit and bypass channel</th><th>Reinstatement of River Ellen channel</th></tr>
<tr><td>Engineering</td><td>Same impacts as identified for DF1 and 2.</td><td>Same impacts as identified for DF1 and 2.</td><td>The modifications to the existing watercourse have increased efficiency in the channel and therefore a slight increase in flooding has been identified downstream of the dam at Chapelhouse. To eliminate this the design team have looked at the following two options:
1. The creation of high flow channels offline from the main channel which in flood conditions would provide a degree of attenuation. However, through modelling of the channels it was determined that these channels could not provide sufficient attenuation.
2. Alternative Flood Storage - Development of two potential flood storage options, offline storage and online storage. A series of conceptual sketches were prepared for discussion with the PSG. It was agreed by the PSG that the preferred option for the final design would consist of the offline storage pond on the basis that the online option disrupted the flow down the River Ellen, which would contradict the aim of the project of return the Ellen to a near-natural watercourse. The online storage option also had the potential to have a large visual impact on the area as it would need to span most of the valley floor.</td></tr>
<tr><td rowspan="2">Hydraulics</td><td rowspan="2">Same impacts as identified for DF2</td><td>Same impacts as identified for DF2
Reinstatement of the bypass channel within the hydraulic model to allow drainage of the offline storage area was found to have no impact on flood risk.</td><td>The online flood storage option was found to beneficially attenuate flows immediately downstream of the existing Chapelhouse Reservoir dam. For example, during the 1% AEP +CC event, peak discharge was reduced from 16.58 m^3/s to 16.35 m^3/s. However, this design option was not taken forward due to not meeting the aims of the project. The offline flood storage option was also found to reduce pass-forward flow by attenuating flows upstream of Chapelhouse Reservoir, during all events of equal or greater magnitude than the 2% AEP event, with a maximum depth of 2.4m in the offline storage area.</td></tr>
<tr><td colspan="2">With the offline storage area in place under DF3, flood extents were found to greatly reduce during all AEP events within the upstream model domain. Additionally, the downstream flood extents and depths were found to be reduced or equal to the baseline scenario in both the 1% AEP and 1% AEP +CC events. However, during all events of equal or lesser magnitude than the 2% AEP event, flood extents in the downstream model domain were still found to increase when compared to baseline. This Design option was taken forwards in the final outline design.</td></tr>
<tr><td>Hydrology</td><td>Same impacts as identified for DF1 and DF2</td><td>Same impacts as identified for DF1 and DF2</td><td>Same impacts as identified for DF1 and DF2</td></tr>
<tr><td>Geomorphology</td><td>None of the changes to design since DF1 would likely result in a change to the impact assessment detailed</td><td>None of the changes to design since DF1 would likely result in a change to the impact assessment detailed</td><td>Since DF2, the upstream high flow channel has been designed out, however, as the downstream high flow channel remains, so to do the impacts identified in DF2 (Table 6-3).
To accommodate the flood storage area, the Over Water Beck would be designed with a more sinuous planform than in DF1 or DF2, which would encourage a more geomorphologically diverse environment.
Inclusion of a flood storage area is unlikely to significantly alter the assessment made in DF1, although the channel planform would likely be straighter than that designed in DF1. The likely impacts associated with this are discussed in Table 6-3.
The flood storage area would alter floodplain-channel interactions when compared with DF1. The extent and location of floodplain inundation would diminish for the 10% and 2% AEP events. This would reduce lateral connectivity from conditions in DF1, however, lateral connectivity would still be improved when compared with the baseline. There could also be potential implications on sediment deposition, with some material becoming trapped in the storage area. The outflow pipe would be designed as such to encourage sediment movement when the storage area drains; however, it is likely that some future maintenance during lower water levels could be required and this would need to reviewed during the detailed design phase.
It is possible that localised scour could occur where the outlet channel from the flood storage pond connects to the main River Ellen channel.
The impact on baseline would likely remain moderately beneficial.</td></tr>
<tr><td>Ecology</td><td>Same impacts as identified for DF2</td><td colspan="2">There is a risk that the offline storage area could trap fish from the River Ellen during high flows, as water is temporarily retained, and the outflow pipe has a one-way valve which would prevent fish escaping. Under normal conditions the storage area would be dry. Design of the reinstated River Ellen could reduce this risk by designing in pools or other refuge features at strategic locations. For example, the area in close proximity</td></tr>
</table>

DF3	Removal of Over Water weir	Removal of Chapelhouse dam, catchpit and bypass channel	Reinstatement of River Ellen channel
		to the inlet could be made less attractive to fish, for example by removing overhanging vegetation which could provide refuge. Maintenance responsibilities would need to be reviewed and agreed as part of the detailed design.	

6.5 Final Outline Design of Preferred Option

Following Design Fix 3 and the subsequent discussions from the PSG the final design will consist of the following elements (see Appendix G for Final Outline Design Drawings):

- **Full removal of Chapelhouse Dam (including associated infrastructure)**

  The existing dam and associated infrastructure at Chapelhouse are to be demolished to restore hydrological connectivity and will consequently remove the reservoir from the Reservoirs Act 1975. This will allow the reinstatement of the River Ellen on its original alignment through the solum of the former reservoir. The dam will be breached, and the slopes of the valley sides graded, including a berm to aid stability. The original masonry overflow at the bypass channel on the left side of the reservoir is to be retained to show the historical significance of the site following the removal of the dam. Elements of the existing structure such as the valve tower, bypass channel, fish pass and upstream catch pit structure must be fully removed as part of the scheme.

- **Realignment of the River Ellen**

  The River Ellen is to be realigned from the point where it enters the field through the unclassified road to the north of Stockdale Farm. From this point the Ellen will follow what is believed to be its original alignment through the solum before reconnecting with the existing channel downstream of the fish pass. The realigned channel will consist of a two-stage channel containing features such as gravel bars and woody debris. To assist with flooding the inclusion of a high flow channel and small island has been included in the channel.

- **Upgrade existing access to property**

  As part of the works to remove the dam embankment at Chapelhouse, the existing access to the property on the right flank will be removed. To provide access to the property it is proposed that the existing farm access track that leads to the property from the east be upgraded to provide a formal access.

- **Provision of new farm access bridge**

  The existing bridge is in a poor state and will be removed as part of the channel works. The new bridge will be such that it will allow the farmer access to his fields following removal of the dam embankment (currently access is via the crest).

- **Permanent diversion of existing public right of way**

  The public right of way currently runs along the crest of Chapelhouse Dam embankment, once this is removed it will be necessary to provide a permanent diversion route to allow the public right of way to be retained. The new route will include a pedestrian bridge to allow access over the River Ellen.

- **Construction of an offline flood storage area**

  To cope with additional flood flows being passed forward due to the removal of the dam embankment and the improvements to the channel of the Ellen, the formation of a flood storage area is required to attenuate flows in periods of flood. Flow into the pond is controlled by an inlet weir on the left side of the River Ellen, an 18m length is lower than the surrounding channel bank which in times of high flows allows water to pass into the flood storage area. The storage area is required to store approximately 3500m^3, however its current proposed configuration can retain approximately 8500m^3.At the detailed design phase the overall shape and footprint of the storage area could be refined so that the volume of the constructed pond is closer to the required storage volume. Flows for the storage area would be released through a 300mm pipe on the north side of the storage area. Propriety concrete headwalls would be positioned at either end of the pipe. A flap valve would be fitted to the downstream side to prevent flows from entering the pond from the outlet channel. The outlet channel should be constructed on the downstream side of the storage pond to transfer flows back into the main River Ellen Channel. Access would be provided to allow for maintenance.

- **Removal of existing weir and section of embankment at Over Water**

  Removal of the weir and modification of the outlet levels to return Over Water to a natural lake, and therefore remove any statutory liability United Utilities currently have under the Reservoirs Act 1975. The section of embankment at Over Water being removed is located to the south of Over Water Beck.

- **Realignment of Over Water Beck to confluence with the realigned River Ellen**

  Over Water Beck is to be realigned after it crossed the un-named road, this will be in the form of a two-stage channel similar to the main river Ellen channel.

- **Removal of all redundant infrastructure**

  Full removal of all associated infrastructure at both sites will also remove the need for any future operational expenditure. This will include existing underground pipework, valves, electrical supplies etc.

6.5.1 Summary of Changes to Hydraulics (i.e. Flood Risk)

With the Final Outline Design in place, floodplain water levels within the upstream model domain (i.e. from Over Water to the confluence of the River Ellen with the Longlands Beck) were found to reduce, with flood inundation of the upstream domain removed during the 50% AEP event and reduced across the floodplain in the upstream domain during all other events, when compared to baseline.

The offline storage area was found to store flood volumes during all events of equal or greater magnitude than the 10% AEP event. In the 1% AEP +CC event, the maximum depth within the storage area was 2.1m. This filled the storage area to a maximum water level of 189.78mAOD. The Final Outline Design was therefore found to reduce peak pass-forward flow in all events between 2% AEP and 1% AEP +CC due to the flood storage and subsequent hydrograph attenuation provided by the offline storage area.

However, during the lower magnitude events (50% AEP and 10% AEP), the peak pass forward flow was found to increase compared to baseline at this location. In the 50% AEP event, this is because maximum in-channel water levels did not exceed the level required to initiate spill into the offline storage area via the spillway. In the 10% AEP event, maximum water levels were sufficient to initiate spill, however the maximum possible depth of storage in the offline storage area during this event was 100mm and therefore did not provide attenuation.

As a result of the Final Outline Design, the maximum flood depths at the single property in Ireby were reduced in both the 1% AEP and 1% AEP +CC events by 7mm and 16mm respectively, thereby mitigating the increased flood inundation caused by the removal of the reservoirs. Additionally, maximum flood depths were found to be reduced in the 2% AEP event, although the single property was not inundated during this event. Similarly, to Design Fix 2, the final outline design was found to increase maximum flood depths in the downstream domain during the lower magnitude events (10% and 50% AEP), however no properties were flooded during these events. Figure 6-2 shows the water level difference map produced for the 1% AEP +CC event between the Baseline and Final Design scenarios in the downstream model domain (i.e. around Uldale). Maximum flood depth and extent maps for both the upstream and downstream model domains are given in Appendix C of this report.

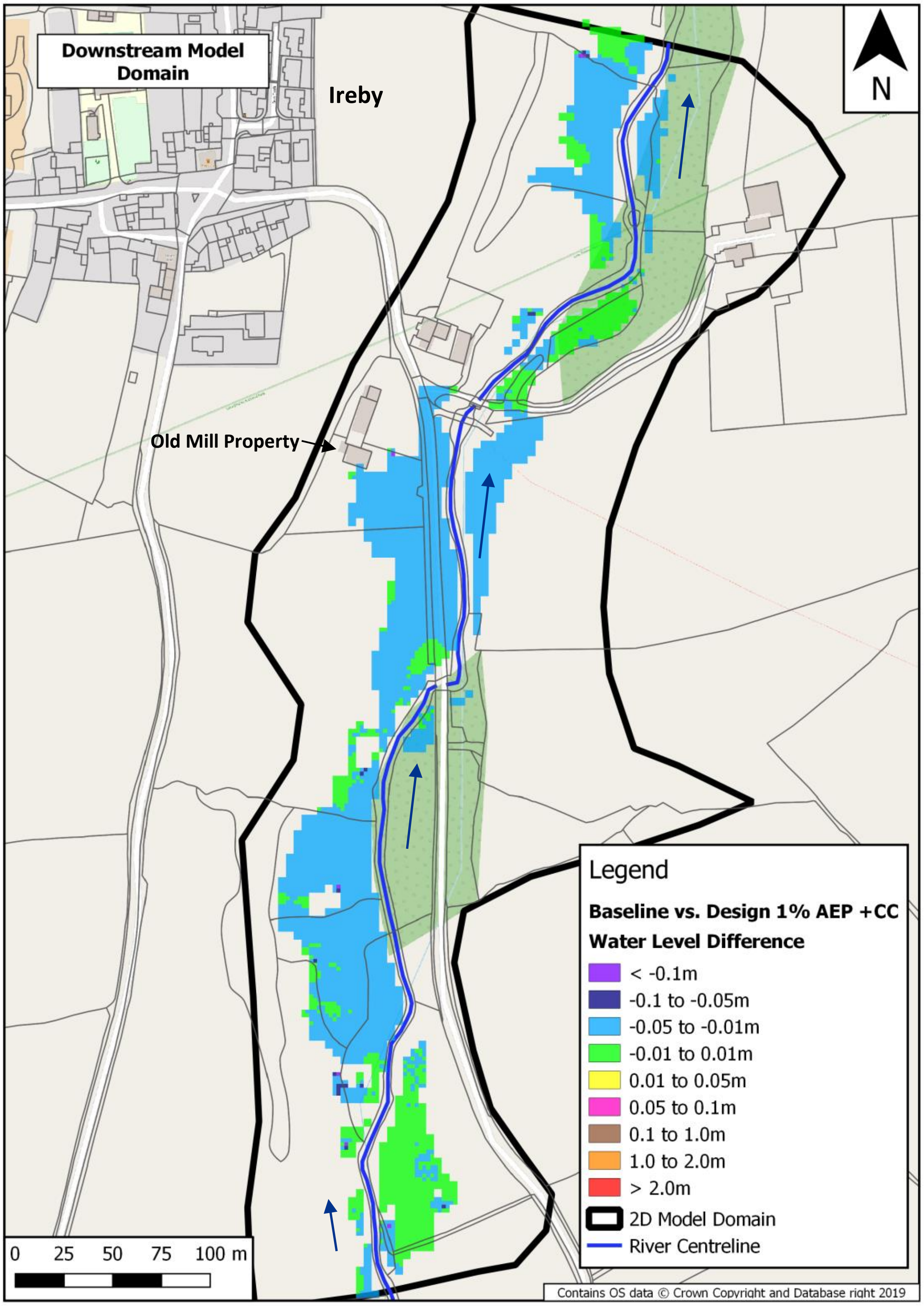


Figure 6-2: Final Outline Design Water Level Difference for the 1% AEP +CC Flood Event, within the Downstream Model Domain

7. Recommendations

To proceed from outline design to a more detailed design, the following recommendations are given for implementation during the next stage of the development:

- Consideration should be given to the final design of the bridges crossing the River Ellen, such that they are in keeping with the adjacent areas. In addition to this, confirmation of loadings and ground conditions should be confirmed prior to the final design.
- The ownership and maintenance regime for any new assets (mainly bridges and the flood storage area) should be considered to ensure health and safety legislation is complied with over the design life of the assets.
- The exact condition of the solum of the reservoir is unknown in terms of depth and type of sediment. It is therefore recommended that a detailed investigation of the solum conditions is undertaken prior to the detailed design. Surveys and testing of material can be carried out with the reservoir full to determine the depth of silt above the actual bed level of the reservoir and the composition of this material.
- Confirmation of the current and future status of any abstraction/supply pipework located at Over Water and Chapelhouse should be sought from UU prior to the detailed design as this may allow for minor reductions in scope. Where possible some of the pipework may be able to be located, cut and capped. The extent of this would be on an 'as found' basis.
- Consideration should be given to the re-use of suitable material from the breach of Chapelhouse dam and the formation of the flood storage area for the infilling of the existing bypass channel.
- A section of Chapelhouse dam and the River Ellen bypass channel could be retained to demonstrate the industrial heritage of the area. It has been suggested to UU that on completion of the works this be highlighted to the public, possibly through the use of information boards.
- During detailed design consideration should be given to widening the channel of the River Ellen at or near to the inlet to the flood storage area with appropriate planting to discourage fish from entering the flood storage area and to remain in the Ellen during flood flows.
- The detailed design would also give consideration to creating refuge features in the River Ellen to attract fish away from area of the inlet to the offline storage area to reduce the likelihood of fish passing into the storage area during high flows and being trapped. In tandem, careful design of the outlet pipe would need to be taken.
- Sediment transport equations should be applied to determine an appropriate sizing of bed material for placed static and/or mobile bars in the Over Water Beck and the River Ellen.
- Consideration should be given to the re-use of existing sediment where possible e.g. re-use of sediment from the bypass channel which is to be abandoned.
- A full Environmental Impact Assessment will be required to take works forward to detailed design. Such an assessment should cover environmental issues not covered to date, such as landscape, archaeological, social and noise.
- A detailed WFD Assessment should be completed at the next stage to avoid deterioration in the WFD water bodies potentially affected by the works. It is possible that Over Water could be reclassified to a non-HMWB following the cessation of water abstraction and removal of infrastructure, whilst Chapelhouse Reservoir would cease to exist as a water body. This would be seen as a positive outcome.
- Post-construction monitoring of the re-aligned River Ellen should be carried out immediately after completion to ensure that the channel responds in a manner that is consistent with the assessment carried out in Section 6. This would allow for the success of the scheme to be assessed against the initial aim, whilst also allowing for reactive management interventions to be identified (if required). This would include ecological surveys (e.g. fish), as well as geomorphological walkover surveys and fixed-point photography to monitor change over time.

- A Construction Environmental Management Plan (CEMP) should be developed ensure the protection the aquatic and terrestrial environment during construction. This would include mitigation measures where required, for example, to use of sediment traps to reduce the likelihood of fine sediment delivery downstream during infrastructure removal and reservoir drawdown.
- A non-native species management plan should be developed in consultation with relevant stakeholders such as NE and the EA. This plan will outline measures to manage non-native species identified in the study area and should clearly state the anticipated outcomes of those measures.
- A Habitat Regulations Assessment would be required for the SAC on the upper River Ellen above Crag Wood.
- A comprehensive land quality study should be undertaken of the area beneath the Chapelhouse Reservoir footprint to identify whether contaminants are present that could pollute the water environment when the reinstated River Ellen channel is created.
- An offline storage area is proposed adjacent to the River Ellen at the inlet weir. It is recommended that this area be designed as a pond that is planted to create suitable habitat for dragonflies, damselflies and amphibians, for example. This pond would increase overall biodiversity in the catchment and amphibians would provide additional prey for otters. The creation of a pond could, however, create suitable habitat for non-native plant species such as New Zealand pygmyweed and Nuttall's pondweed, and management of this risk should be investigated.
- This should include refinement of the model to represent in more details the proposed scheme using ad-hoc topographical survey and detailed design scheme drawings. Additionally, further investigation should be carried out to ensure that the increased pass-forward flow as a result of the final outline design during the low magnitude events, has no detrimental impact on flood risk to any communities located downstream of Ireby.
- A monitoring protocol should be established over a suitable timescale to assess the success of the reinstated River Ellen. This could include sampling of invertebrates, macrophytes and fish species and fluvial audits. Monitoring may extend over a period of 5 years and should be measured against pre-construction baseline conditions. This would allow a sufficient timeframe to confirm the success of the reestablishment of riverine conditions.
- As discussed in Appendix H of this report, the sequence and timing of infrastructure removal should be considered prior to the commencement of works to eliminate on site hazards. An early reservoir drawdown programme should be implemented to allow maximum time for the reservoir solum to dry out prior to the contractor commencing on site. Additionally, the sequence of dam removal is to be developed in conjunction with an All Reservoir Panel Engineer to manage flood risk throughout the works.
- As part of this high-level assessment, Jacobs have estimated the quantities associated with the civils works at Chapelhouse reservoir and Over Water. These quantities and associated costing assumptions can be found in Appendix I. These shall be used by United Utilities' quantity surveyors to provide an estimated cost for the works.
- Without a confirmed detailed design, we are unable to start the appropriate assessment process with respect to habitat regulations. Therefore, once a detailed design is confirmed, inclusive of construction methodology, the process can begin.

8. References

Alvarez-Codestal, S., Fletcher, M., Pentecost, A. and Pawley, S. (2016). Surveys of the invasive aquatic plant Crassula helmsii (extent and impact) and the rare freshwater crustacean Ilyocryptus acutifrons in Over Water, Cumbria.

Aprahamian, M. and Walker, A. (2008). Status of eel fisheries, stocks and their management in England and Wales. *Knowledge and Management of Aquatic ecosystems,* (390-391), p.07.

Armstrong, G.S., Aprahamian, M.W., Fewings, G.A., Gough, P.J., Reader, N.A., and Varallo, P.V. (2010). Environment Agency Fish Pass Manual: guidance notes on the legislation, selection and approval of fish passes in England and Wales (Withdrawn 2015). Environment Agency, Bristol.

Atkins (2015). Overwater SSSI Investigation into Perceived Enrichment of five Lakeland SSSIs.

British Geological Survey (BGS) (2019). Geology of Britain Viewer. Available online at: http://mapapps.bgs.ac.uk/geologyofbritain/home.html. (Accessed 14/02/2019).

Biological Records Centre (2018). Crayfish Occurrence Record 283092441. Available at: https://records.nbnatlas.org/occurrences/fb57ff33-72f6-4726-9c4f-5ebbbcb1cf8a (Accessed October 2018).

Biological Records Centre (undated-a). Occurrence ID 12027602. Available at: https://records.nbnatlas.org/occurrences/8db44d9c-47c1-4038-86e4-e356db89357b (Accessed 6 February 2019)

Biological Records Centre (undated-b). Occurrence ID 12027601. Available at: https://records.nbnatlas.org/occurrences/d278[f78-3a17-4911-baaf-ed472551fa43 [Accessed 4 February 2019)

Brookes, A., Eales, R., Fisher, J., Foan, C and Twigger Ross (2001). An Approach to integrated appraisal: Progress by the Environment Agency in England and Wales., *J. Env. Assessment. Policy Management*., 3 (01), pp. 95-122.

Cascade Consulting (2016). United Utilities Crummock Water Drought Order Environmental Scoping Report. Final Report to United Utilities

Centre for Ecology and Hydrology (CEH) (2019) National Flow Archive. Available online at: http://nrfa.ceh.ac.uk/data/search

Cranfield Soil and Agrifood Institute (2016). Available at: http://www.landis.org.uk/soilscapes/about.cfm (Accessed14/09/2017).

Environment Agency (2014). Examination in Public in connection with a draft Water Resource Management Plan prepared by United Utilities Water PLC – Environment Agency Statement of Case.

Environment Agency (2015) North West River Basin Management Plan (RBMP). Available online at: https://www.gov.uk/government/publications/north-west-river-basin-district-river-basin-management-plan. (Accessed 14/09/2017).

Environment Agency (2018a). Salmon stocks and fisheries in England and Wales, 2018. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/810720/SalmonReport-2018-assessment_final.pdf

Environment Agency (2018b). Salmonid and freshwater fisheries statistics for England and Wales, 2017. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/753925/Salmonid_and_Freshwater_Fisheries_Report_2017.pdf (Accessed 4 February 2019).

Environment Agency (2018c). Fifth otter survey of England 2009-2010. Technical Report. Available at; http://www.thepredationactiongroup.co.uk/images/EA_otter_survey_oct10.pdf (Accessed October 2018).

Environment Agency (2019a). Catchment Data Explorer: Ellen (Upper). Available at https://environment.data.gov.uk/catchment-planning/WaterBody/GB112075073630 (accessed May 2019).

Environment Agency (2019b). Catchment Data Explorer: Over Water. Available at https://environment.data.gov.uk/catchment-planning/WaterBody/GB31228806 (accessed May 2019).

Environment Agency (2019c). Catchment Data Explorer: Chapelhouse Reservoir. Available at https://environment.data.gov.uk/catchment-planning/WaterBody/GB31228796 (accessed May 2019).

Environment Agency (2019d). Freshwater Fish Counts for all Species, all Areas and all Years. Available at: https://data.gov.uk/dataset/f49b8e4b-8673-498e-bead-98e6847831c6/freshwater-fish-counts-for-all-species-all-areas-and-all-years (Accessed 26 August 2019).

Geotechnics (2018) Ground Investigation – Chapelhouse and Overwater Infrastructure Removal GI Factual Report for United Utilities Limited. Project Number PN183896. United Utilities

Grontmij (2012). Chapelhouse Impounding Reservoir - Construction-Environmental Control Plan.

Hendry, K. & Craggs-Hine, D. (2003) Ecology of the Atlantic salmon. Conserving Natura 2000 Rivers. *Ecology* Series No.7. English Nature, Peterborough.

Jacobs (2016) Ehen Compensatory Measures-Scoping report for R6 and R3 Bleaching weirs removal. Report for United Utilities

Jacobs, (2018). Ehen Compensation Measures: Chapelhouse Reservoir and Over Water – Summary Report for Main Stage A. Report for United Utilities (Research Measure 6)

Natural England (2017) Over Water SSSI. Available at: https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=S1000433&SiteName=&countyCode=&responsiblePerson=REBECCA%20GRAY&SeaArea=&IFCAArea= (Accessed 4 February 2019).

Natural England (2019) Multi-Agency Geographic Information for the Countryside (MAGIC) Interactive Mapper. Available online at: http://www.magic.gov.uk/MagicMap.aspx

National Library of Scotland (2019) Explore georeferenced map. Available online at: https://maps.nls.uk/geo/explore/#zoom=5&lat=56.0000&lon=-4.0000&layers=1&b=1

West Cumbria Rivers Trust (2013). What happens when you cross a skunk with a cabbage. Available at: https://westcumbriariverstrust.org/news/what-happens-when-you-cross-a-skunk-and-cabbages (Accessed 14 May 2019).

West Cumbria Rivers Trust (2014). Brook lampreys rescued at Chapel House Intake. Available at: https://westcumbriariverstrust.org/news/brook-lampreys-rescued-at-chapel-house-intake (Accessed 6 February 2019).

Appendix A. Historical Timeline

Table A-1 below is an extract taken from a United Utilities Geotechnical and Geoenvironmental Desk Study Report and has been used in this report as an appendix with written permission from United Utilities (United Utilities, 2018).

Table A-1: Historical Timeline (United Utilities, 2018)

Map Year (Scale)	Onsite Historical Features	Offsite Historical Features
1866 (1:2500) 1867 (1:10560)	Prominent marshland is shown within Over Water along the southern and western banks. The River Ellen flows along a sinuous single thread channel and through Chapel house with little modification. Hoodbank wood occupies the area where Chapelhouse Reservoir now exists. A gently sinuous channel flows through the western region of Hoodbank wood and joins the River Ellen downstream of Chapelhouse.	Agricultural fields occupy most of the western and southern banks of the Over Water. Two small plantations are shown on the respective banks. Waterbank Quarry is shown adjacent to the left bank of Over Water Beck. Woodland occupies the right bank of the River Ellen downstream of Chapelhouse.
1888 (OS six inch)	No significant change	No significant change
1892 (OS 25 Inch)	No significant change	No significant change
1900 (1:2500)	The River Ellen is diverted from its original course and solely flows through Hoodbank Wood.	Larger woodland presence along the western banks of Overwater. Riparian vegetation along the banks of the River Ellen, where the straightened, modified reach currently flows, are no longer shown.
1920 (1:63000)	No significant change	No significant change
1937 (1:25000)	River Ellen has been realigned and straightened downstream of Overwater, resembling its current planform. Chapelhouse Reservoir is shown in place of Hoodbank Wood. Channel that was cut off from the River Ellen, which formerly flowed along the western boundary of the former Hoodbank wood, has been reinstated as a bypass channel that flows along the left bank of Chapelhouse Reservoir. Dam was constructed in the 1920s.	Woodland plantation along the south-western bank of Over Water has increased in size, extending along its western bank.
1949 (1:10560)	No significant change	No significant change
1956 (1:10560)	No significant change	Waterside Wood extends to the east, following Water Bank and forms part of the riparian zone along Over Water Beck.
1972 (1:2500)	Headwall of weir shown at Over Water. Embankments along Over Water Beck and the modified reach of the River Ellen, upstream of Chapelhouse are shown. Catchpit at the confluence of the modified reach of the River Ellen and Over Water Beck. The catchpit is shown to separate the River Ellen and Over Water Beck. The River Ellen appears to flow via two channels, one which enters Chapelhouse Reservoir and a bypass channel that flows on the western boundary of Chapelhouse Reservoir. Over Water Beck flows into the bypass channel. Valve and water gauge at Chapelhouse dam shown on maps. River Ellen is realigned downstream of Chapelhouse Reservoir. Maps depict how the overflow of Chapelhouse	Woodland continues to extend along the riparian zone of Over Water, extending along its southern banks, Water Bank quarry is shown as disused. Rough pasture and deciduous trees are shown to line the River Ellen and the River Ellen bypass channel upstream of Chapelhouse Reservoir. Rough grasses are shown to line the banks of Chapelhouse reservoir. Woodland that lined the banks of the River Ellen downstream of Chapelhouse Reservoir is no longer shown.

Map Year (Scale)	Onsite Historical Features	Offsite Historical Features
	Reservoir spills into the bypass channel and flow along the realignment downstream. Footbridge crosses the River Ellen downstream of Chapelhouse Reservoir.	
1974 (1:10000)	No significant change	Waterside wood not shown downstream of overwater.

Appendix B. Hydrological Assessment

B.1 Introduction

The headwaters of the River Ellen have been used for water supply for over 100 years. This has resulted in the current baseline system (Figure B.1) that comprises a raised natural lake (Over Water), a reservoir (Chapelhouse), the diversion of water from outside of the natural catchment (abstractions from Hause Gill, Dash Beck, and Longlands Mine Adit to Chapelhouse Reservoir), transfers (from Over Water to Chapelhouse Reservoir), and diversions and realignments of channels to manage water across the system.

The operation of the system, including the rules governing the various abstractions, has been subject to long-term simulation in the United Utilities Aquator water resource model to assess the reliable yield of the system. Within this representation 54 years (1961-2014) of daily catchment inflows have been derived for each of the catchments. These flow sequences are believed to have been either transposed from nearby gauged catchments considered to be hydrologically similar to those in the Chapelhouse system or derived from rainfall-runoff modelling. Whilst the following considers the abstraction regime, an assessment is also made of the catchment without the abstraction. This is based on the premise that in 2022 the abstraction would cease and the licences would be surrendered, meaning that at the time of construction and operation of the infrastructure removal (2025), there would be no abstraction.

B.2 Aim and Objectives

The aim of this appendix is to assess the potential changes to the downstream river flow and lake level regimes at Over Water and Chapelhouse Reservoir following removal of abstraction infrastructure return of a near-natural hydraulic system.

The specific objectives are to:

- Assess how the outflow flow regime from Over Water will be changed as a result of the removal of the current weir, the establishment of a near-natural outflow channel, and the cessation of water abstraction.
- Assess how the lake level regime of Over Water will be changed as a result of the removal of the current weir, the establishment of a near-natural outflow channel, and the cessation of water abstraction.
- Assess how the River Ellen flow regime immediately downstream of the Chapelhouse system is likely to change following a cessation of all abstractions and the removal of all associated infrastructure, leaving the catchment in a near-natural state.

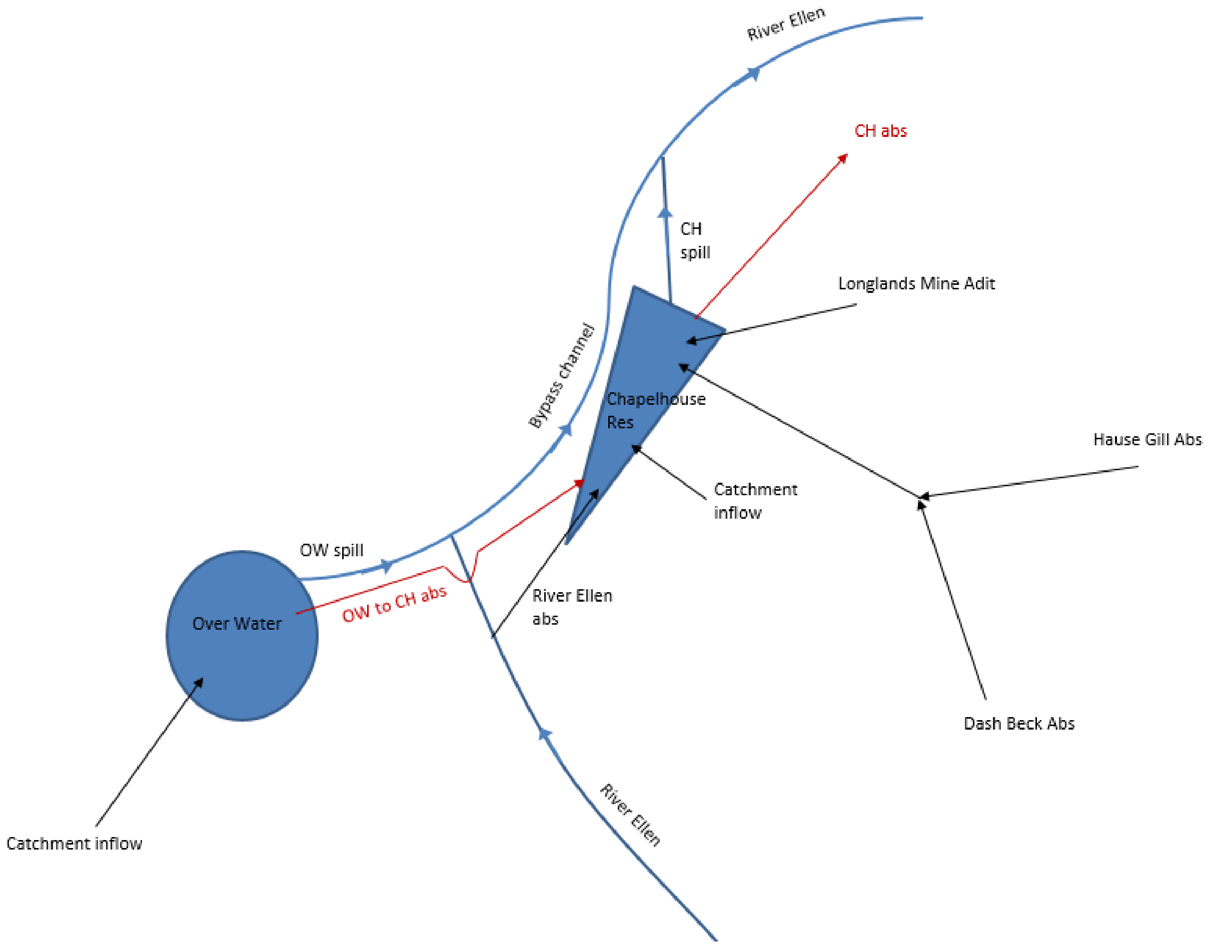


Figure B-1: Conceptual model of the current Over Water and Chapelhouse hydrological system

B.3 Approach

The method is based upon the routing of several decades of daily inflows through the lake; explicitly accounting for changes in storage (hence lake level) and the outflow channel characteristics for the calculation of outflow to the downstream river. In the simulation the water balance of the lake system is preserved, and the lake level is allowed to rise and fall depending on the sequence of inflows enabling the antecedent lake level to be allowed for. The methodology, its development and validation, is described in Jacobs (2010) and Price (2012). Rules regarding abstractions or transfers flow can be readily introduced into the daily water balance component of the model.

Use of the pre-existing Aquator model was considered but discounted for the following reasons. The Aquator model simulates the movement of water around and through the system, however, it models any excess of lake water above the outflow sill as being moved immediately downstream in the same time step – always returning the water level on such occasions to the weir crest level. In doing so it does not predict levels above the weir crest. In a system with a wide flat weir this may be of relatively limited importance, but in a narrower near-natural channel and one in which no water is abstracted, this would result in an unrealistic representation of the lake level which would always appear to be at the level of the weir crest. This is not representative of reality.

During the wetter times in the year the lake's level will rise and fall appreciably in response to rainfall on already wet catchments. Also, as noted below in Section B.3.1, the size of the system requires the simulation to use an operational model time step of less than one day to appropriately resolve the water balance at each timestep without leading to spuriously high predictions of levels in wet events or model instabilities. For these reasons the modelling of Over Water has not been undertaken within the Aquator model.

The information and data required by the routing method together with their sources are given in the following sections.

B.3.1 Daily Inflow

The derived inflow series (1961 – 2014) to Over Water was supplied by United Utilities from their water resources Aquator model of the system. Given the relatively small size of the lake and the need for the water balance calculations to be undertaken at a short time step to properly resolve fluctuating lake levels during higher flows, the daily data set was split into 4-hourly intervals. This allows the entire model to be run at a 4-hourly timestep, reducing routing instability and over-estimation of high lake levels.

The same process was followed for the other direct catchments.

B.3.2 Lake Surface Area

The surface area of the Over Water lake at weir spill level (191.24mAOD) was obtained from the analysis of the available bathymetry giving an area of 0.214km^2. In the model the surface area can vary as a function of water level based on the surface area – water level relationship obtained from the bathymetry provided to the project (Figure B-2).

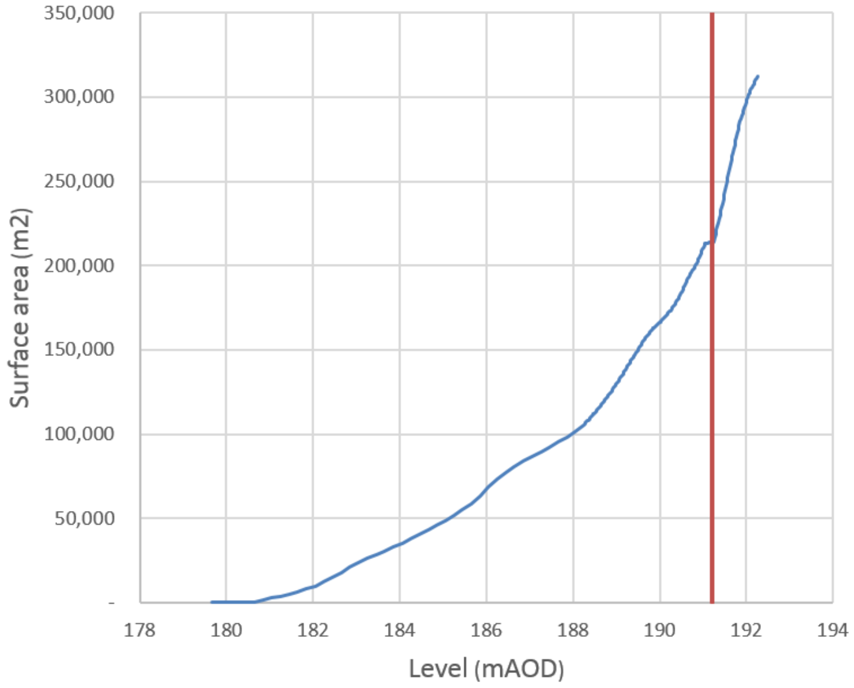


Figure B-2: Over Water surface area - water level relationship; the red line denotes the weir crest level

B.3.3 Outflow Level-Flow Relationships

Figure B-3 compares the cross sections of the channel forming the sill of the lake in the current baseline case (this is a 9m wide horizontal weir to the proposed near-natural case where the weir is removed and a channel with a 2m wide bed is established). The near-natural channel dimensions are estimated based upon a fluvial geomorphic estimate of the river and the dimension have been used in the design.

.

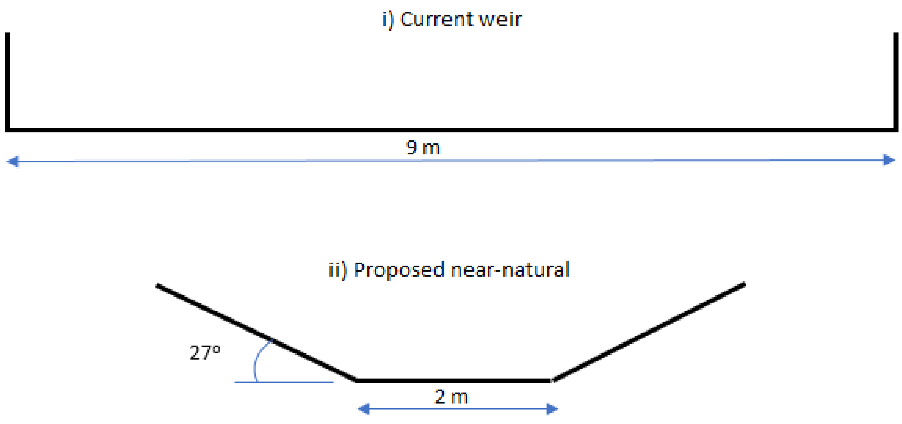


Figure B-3: Channel cross section of outflow sill for the current situation and the proposed near-natural state at Over Water Beck

The lake level-flow relationships for the two scenarios (baseline and design) were established within the hydraulic model (refer to Appendix C – Hydraulic Modelling Detailed Assessment). Due to the low slope gradient of Over Water Beck (watercourse from Over Water Lake to River Ellen) a degree of hysteresis is present in the Over Water outflow level-discharge relationship, depending on the relative size of flows in the two channels and the resulting hydraulic gradeline. The level-discharge relationships used in this study (Figure B-4) are based on the rating that averages the hysteresis effect.

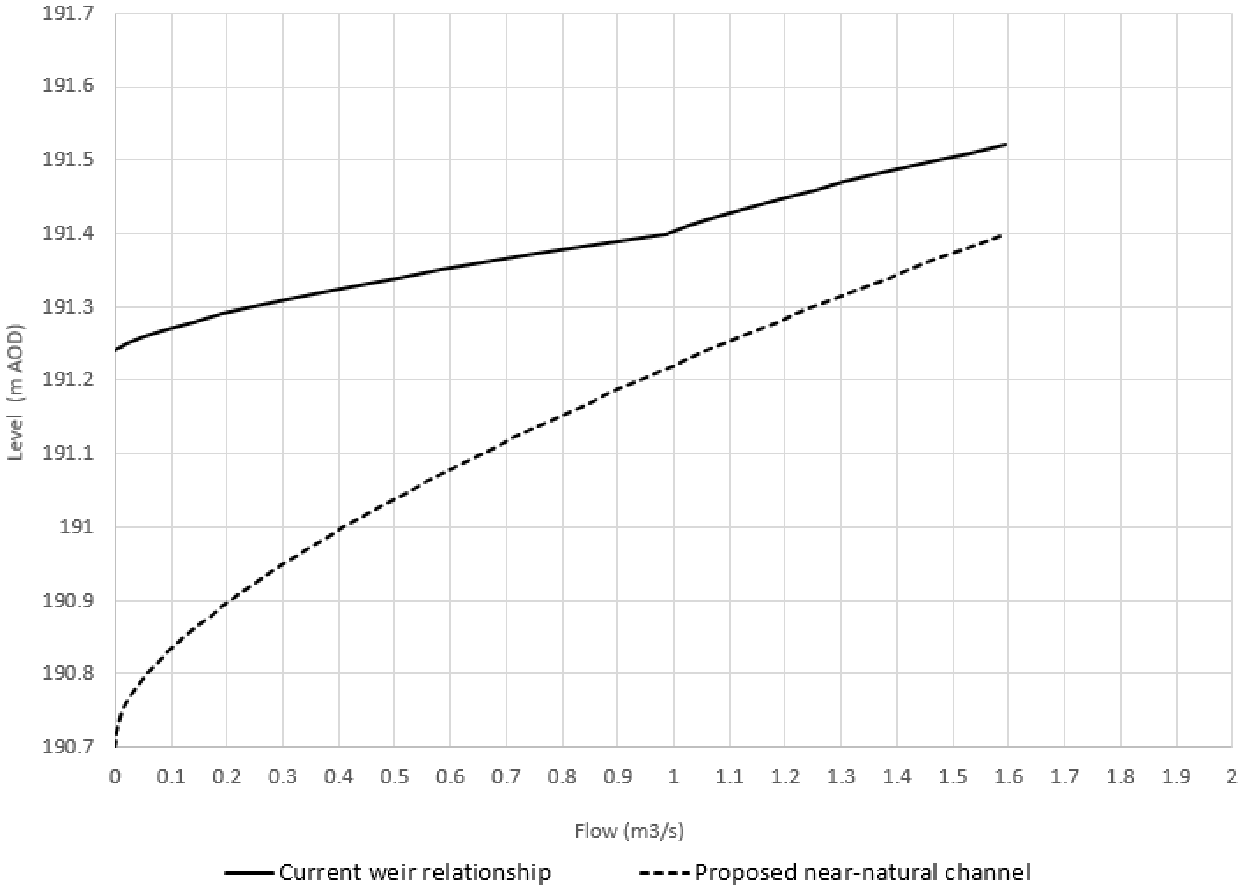


Figure B-4: Over Water level-flow relationship

B.3.4 Abstraction and Transfer Regime

The abstraction and transfer regimes are taken directly from the United Utilities water resources model. This reflects the operational rules that the system is judged to be run by, however, this may not reflect reality. To investigate this, manually read levels of Over Water and manually recorded transfers of water from Over Water to Chapelhouse were obtained from United Utilities. These records were provided at daily intervals.

Concurrent data from the Aquator model and the monitored record overlaps for the period 21 September 2000 to 31 December 2014, providing the opportunity to verify the accuracy of the model. Runs using the observed abstraction data and data from the United Utilities Aquator model were undertaken, with the simulated water levels compared to the observed data.

The following are observations regarding the observed daily data which are pertinent to the verification exercise discussed above:

i. The observed level data:

In most of the record the observations do not change from day to day. Rather they appear as blocks of multiple days assigned the same value. At the end of one block a new block value appears which can again remain constant for a relatively long period. This can result in unrealistic step changes in lake level which cannot be explained by short-period high rates of abstraction (based on cross reference to the provided abstraction records). Figure B-5 shows an example of this behaviour during 2003. This strongly suggests that observed levels have not been made at a daily frequency, but that in much of the record occasional observations have been recorded and extrapolated until another observation takes its place. This in many cases will mask the actual variability of the water level which will need to be recorded at close to a daily frequency if abstractions are to be accurately represented.

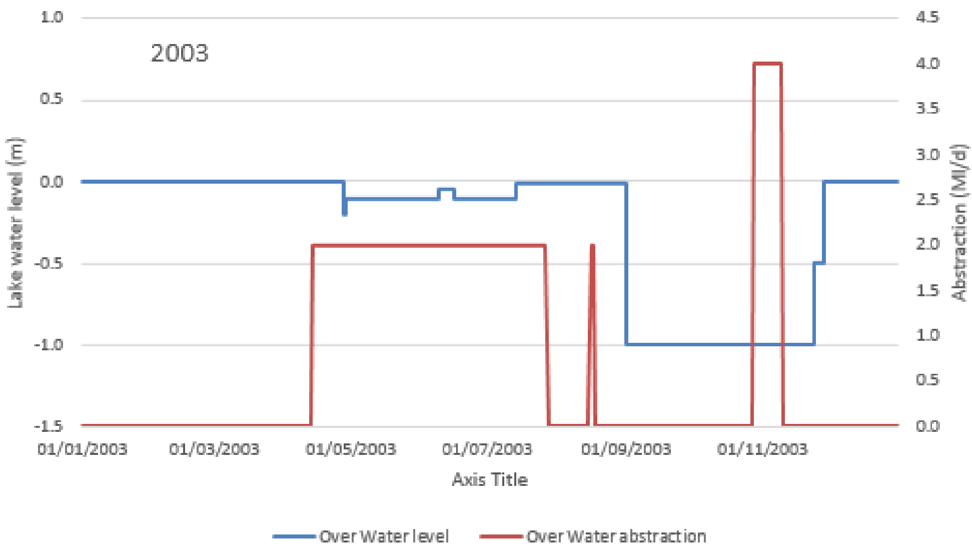


Figure B-5: Example of blocky nature of the observed record in 2003 for Over Water lake level and abstraction rate. Lake water level is relative to weir crest level.

The example in Figure B-5 is one of the more extreme examples of this within the 14 years of concurrent data available. Often the blocks last for several weeks. It is also noted that for most of the period only water levels at or below the weir spill level are recorded. This does not provide an accurate record of water levels, as for water to flow along Over Water Beck the lake level needs to be above the weir crest. Abstractions tends to occur during the summer, with the lake tending to be full during the winter. This level above the weir crest does not appear to have been recorded for most of the period with concurrent data.

There appears to have been a change to the monitoring approach of the lake level during the late autumn of 2013. After this time, the frequency with which level/abstraction data is recorded is usually between 1 - 3 days.

This new monitoring regime also records lake levels above the level of the weir. Figure B-6 shows the recorded daily levels for the year 2014. This demonstrates the improved data resolution and provision of lake levels above the level of the weir.

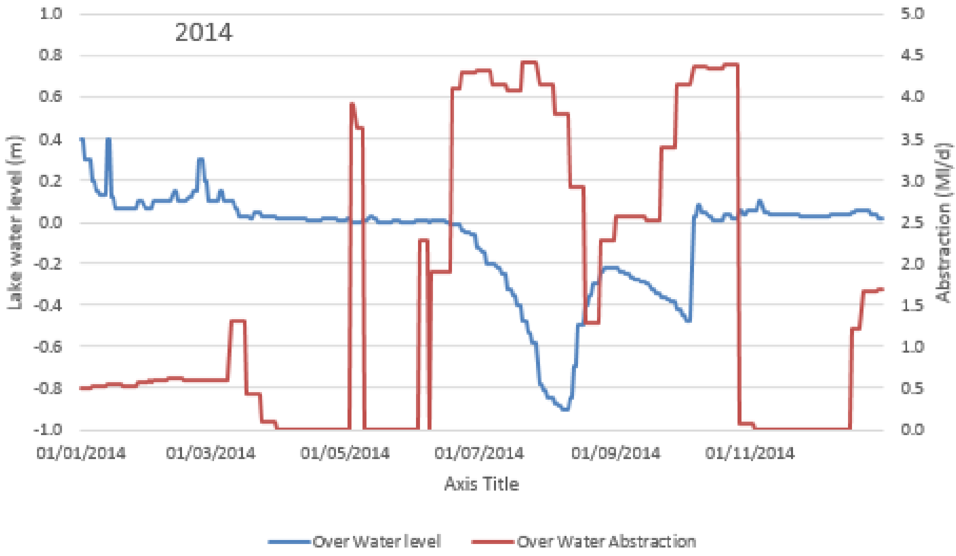


Figure B-6: Improved monitoring and recording regime for Over Water during 2014. Lake water level is relative to weir crest level.

ii. The recorded abstraction data

The frequency of recording the transfer rate from Over Water to Chapelhouse appears to have increased in 2013. It is observed that the first 7 years of the 2000 – 2014 period used in the verification assessment appears to have "blockier" periods of abstraction than the more recent period. Whether this is as a result of the aforementioned issues with data collection, or representative of reality, is not known.

Another potential concern is the state of the transfer pipe from Over Water to Chapelhouse. Figure B-7: Figure B-7 shows the largely blocked state of the pipe observed during the 2018 drought. It is not known if such a blockage would invalidate the estimate of the recorded transfers, or if the abstraction pipe was in this state during the 2000 – 2014 period.

Figure B-7: The partially blocked state of the Over Water intake pipe that transfers water to Chapelhouse, observed during the 2018 drought

B.3.5 Other Considerations

The water balance of the lake may be affected by the direct evaporation from the surface of the lake and similarly by the direct inflow of rainfall to the surface of the lake. This is most likely to be the case when the lake area represents a relatively large proportion of the catchment. Based on experience in Scotland this is a factor that may warrant inclusion for waterbodies that cover more than 5% of their catchment. Over Water covers approximately 4.3% of its catchment. Explicit accounting for direct rainfall and evaporation within the water balance of the lake is most likely to have a significance in drought conditions when rainfall is low, but evaporative losses can continue at a high rate for several\many weeks.

A sensitivity run of the model for the period 1 Jan 2000 to 31 Dec 2014 was run to investigate the likely significance of direct rainfall and evaporation fluxes to the predicted flows and lake level of Over Water. The catchment inflow was spatially scaled down to be representative of the runoff from the land portion of the catchment. Daily rainfall for the period was obtained from the GEAR rainfall gridded dataset (CEH, 2019). Open water evaporation was calculated based on an estimate of average annual potential evaporation for grass of 520mm and fitted to a sinusoidal wave that peaks at the summer solstice and falls to zero at the winter solstice. This was then converted to an open water estimate using the empirical conversion derived by Finch & Hall (2001). This gave an average annual loss of 615mm from the lake surface.

The routing model of the current arrangement was run with and without this refinement and compared. This sensitivity analysis (See annex B1 at end of this appendix) indicated that the model of Over Water is relatively insensitive to the explicit inclusion of the direct fluxes to and from the lake surface. Consequently, the modelling was run without this additional complexity.

B.4 Results

B.4.1 Validation of model against observed data

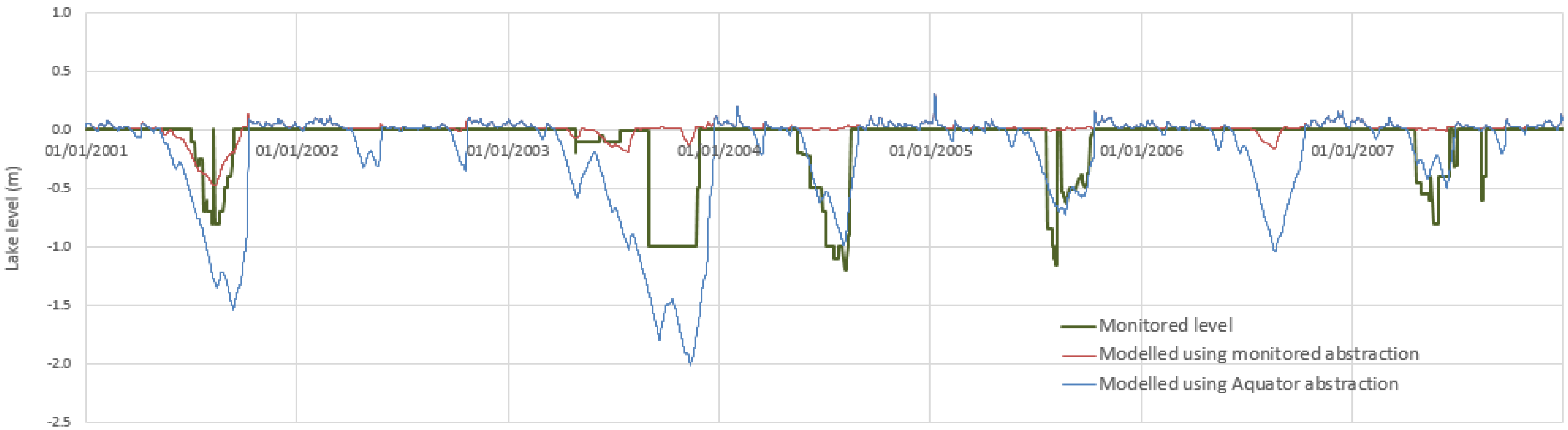
The Over Water model was run for the current (baseline) state of the system. Two abstraction scenarios were run since there is some uncertainty (as noted above) regarding the suitability of the observed record. The first abstraction scenario used the supplied daily record of abstraction. The second used that supplied in the Aquator model. Figure B-8 shows the modelled lake level in comparison to the observed (though refer to above section on the possible inadequacies of this record).

The simulation using abstraction data taken from the Aquator model seems to represent the years 2004, 2005, 2007, 2012, 2013 and 2014 well. It may also be the better representation of 2003, where it has been noted that only an incomplete picture of the drawdown is likely to be supplied by the infrequent level observations. The years 2002, 2006, 2010 and 2011 do not appear to be as well represented.

The simulation with the recorded abstractions used represents the years 2001, 2002, 2006, 2010, 2011, 2012, 2013 and 2014 well. The years 2003, 2004, 2005, 2007, 2008 and 2009 do not appear to be as well represented.

The data is difficult to interpret, with the believed lack of temporal resolution in the recorded data over all but the last year and a half hindering comparison. Figure B-9 shows the detail of how the simulations compare to the recorded level in the period with what is believed to be the more reliable observed data (2014). Both the size and the timing of the drawdown period are relatively well simulated, as is the water level above the weir through all but the very start of the year where the simulated level is lower than the recorded level.

The representation of the observed data that is thought to be more reliable gives some confidence in the ability of the model to represent reality. However, the validation evidence given is limited and it is suggested that the findings of this study be interpreted as only indicative.



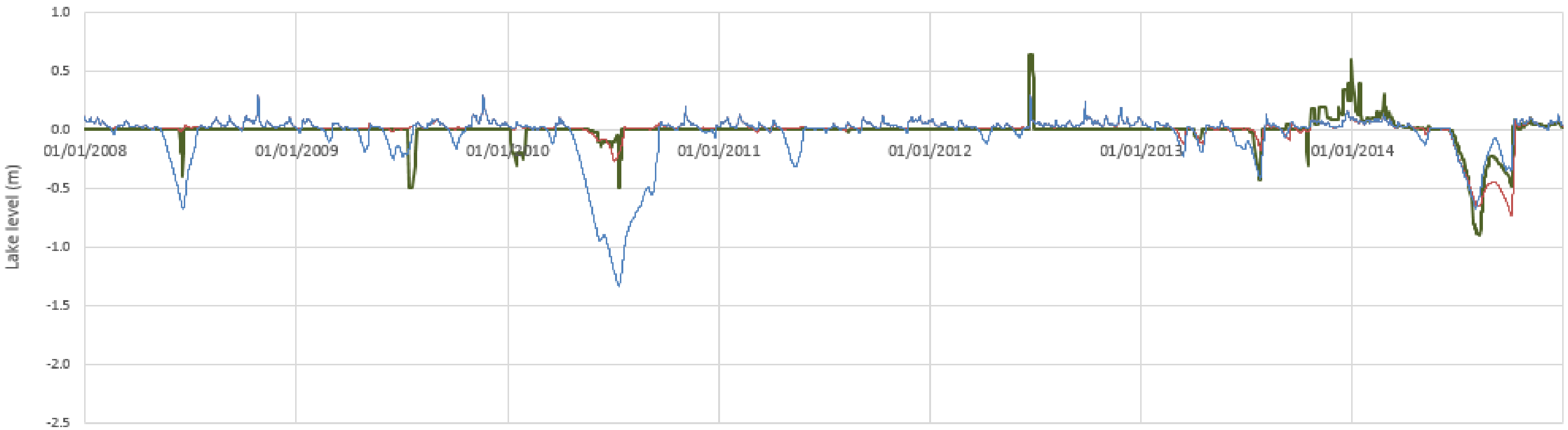


Figure B-8: Comparison of observed lake level to modelled lake level based on recorded "daily" abstraction (top graph) and abstraction rate used in the United Utilities water resource Aquator model (bottom graph). NB: Lake level is relative to weir crest

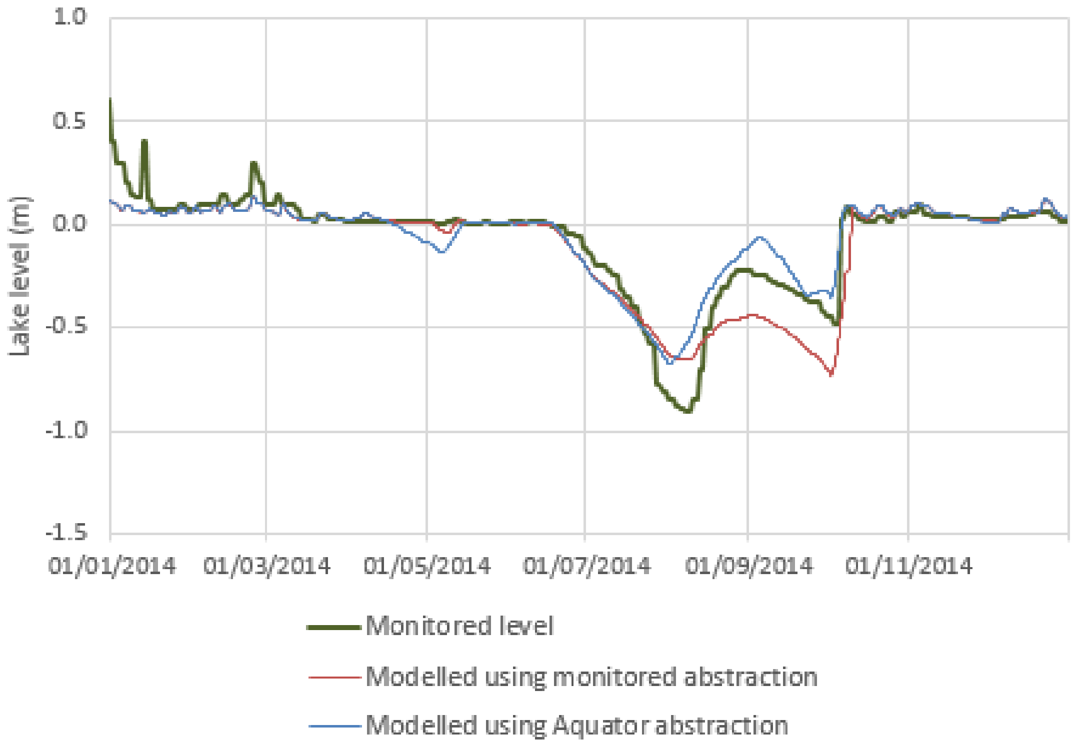


Figure B-9: Comparison of simulated Over Water level against observed data for 2014.

B.4.2 Long-Term Simulation of the Lake Level and Outflow Regimes

Given the issues regarding the observed abstraction data, the simulation of the current state of the system was undertaken based on the abstraction regime obtained from the Aquator model. The results are presented as flow-duration curves, or for the lake levels as level-duration curves, at the end of this section.

Flow-duration curves are a commonly used means of presenting flow regime characteristics; however, they supply no information upon the seasonality of the regimes. Therefore, the simulated flows\levels are also presented in a seasonal format in which the median flow\level on each day in the year (of the 54 years of simulated data) is plotted as an indication of the average flow for that day number in the year. The median can also be described statistically as the 50-percentile flow\level. For example: if all the 1st of Januarys from the 54 years of simulated data are ranked in terms of magnitude the middle (median) value is also known as the 50-percentile value. Similarly, a tenth of the way up the list of ranked numbers is known as the 10-percentile value; and the flow\level that is a tenth of the way from the top of the ranked list is the 90-percentile value. This approach to representing the output of the model enables the 50-percentile value for each day in the year to be plotted, together with its attendant 10 and 90-percentile values which provide a high and low measure of the variability predicted for that day number. It provides a seasonal insight into the possible variability of the predicted flows based around an understanding of the central average value.

Figure B-10 presents the predicted level regime of Over Water in the form of level-duration curves. Just as for the more commonly experienced Q95 low flow indices (which indicates the flow that is equalled or exceeded for 95% of the time) a L95 means the lake level that is equalled or exceeded for 95% of the time. The curves indicate that for the current system with abstraction the level of the lake will be at or below the weir crest approximately 40% of the time. During the rest of the time, there is water passing over the weir and down Over Water Beck, but that the rise in the water level above the weir crest is relatively small. This low rise in water level above the weir crest is a function of the efficiency that the current weir has for passing forward the water above the level of the weir crest. During dry periods the drawdown is predicted to be quite significant, for example the L95 can be up to 0.7 m below the weir crest. A third curve is plotted (the dashed blue line) where the current system is represented but without abstraction occurring. The level of the lake is then predicted to be maintained at or above the weir sill level all the time. It is worth noting that had the evaporative losses been incorporated into the model (as discussed in Section B.3.2) this would have likely caused the lake level in the more extreme droughts to go slightly below the weir crest level.

For the design scenario, the level regime is distinctly different to the baseline with abstraction case. The bottom of the channel is lower than the current weir sill: the downwards displacement of the curve reflects this. The curve is not predicted to go below the bed of the Over Water Beck, suggesting constant flow would be achieved, although the variability in lake level is simulated to be three to four times greater than under winter baseline conditions. However, during summer periods the design scenario would not experience artificially induced drawdowns of the level, providing a reasonably constant level when compared to the current baseline.

Figure B-11 captures the seasonality of the levels. The average (50-percentile) level from the 54-years of simulated data for the near-natural case is predicted not to go below the outflow channel bottom at any time during the year. The same is true of the 10-percentile level, which suggests that outflow will reliably occur throughout the year when there is no abstraction taking place. This in contrast to the baseline curves which predict that during most summers the level will go below the weir crest level, likely causing dry conditions along Over Water Beck.

The companion results for the outflow from Over Water are presented in Figure B-12 and Figure B-13. This shows that the forward flow along Over Water Beck occurs for a little less than 60% of the time under baseline conditions. This is in marked contrast to the design conditions where outflow is always predicted to occur, and the flow-duration curve is similar to that of the inflow. Figure B-13 predicts that the outflow tends to reduce to zero during the summer and early autumn under baseline conditions, whereas under design conditions flow occurs throughout the summer, albeit at lower magnitudes than during the wetter winter period.

Figure B-14 and Figure B-15 show the equivalent representation of flow in the River Ellen immediately downstream of Chapelhouse Reservoir. This suggest that a distinct betterment in the flow regime in the Ellen will occur, particularly for low to medium flows in the range of Q90 to Q50 under the proposed design. This improved flow regime is predicted to be particularly noticeable during the summer and early autumn.

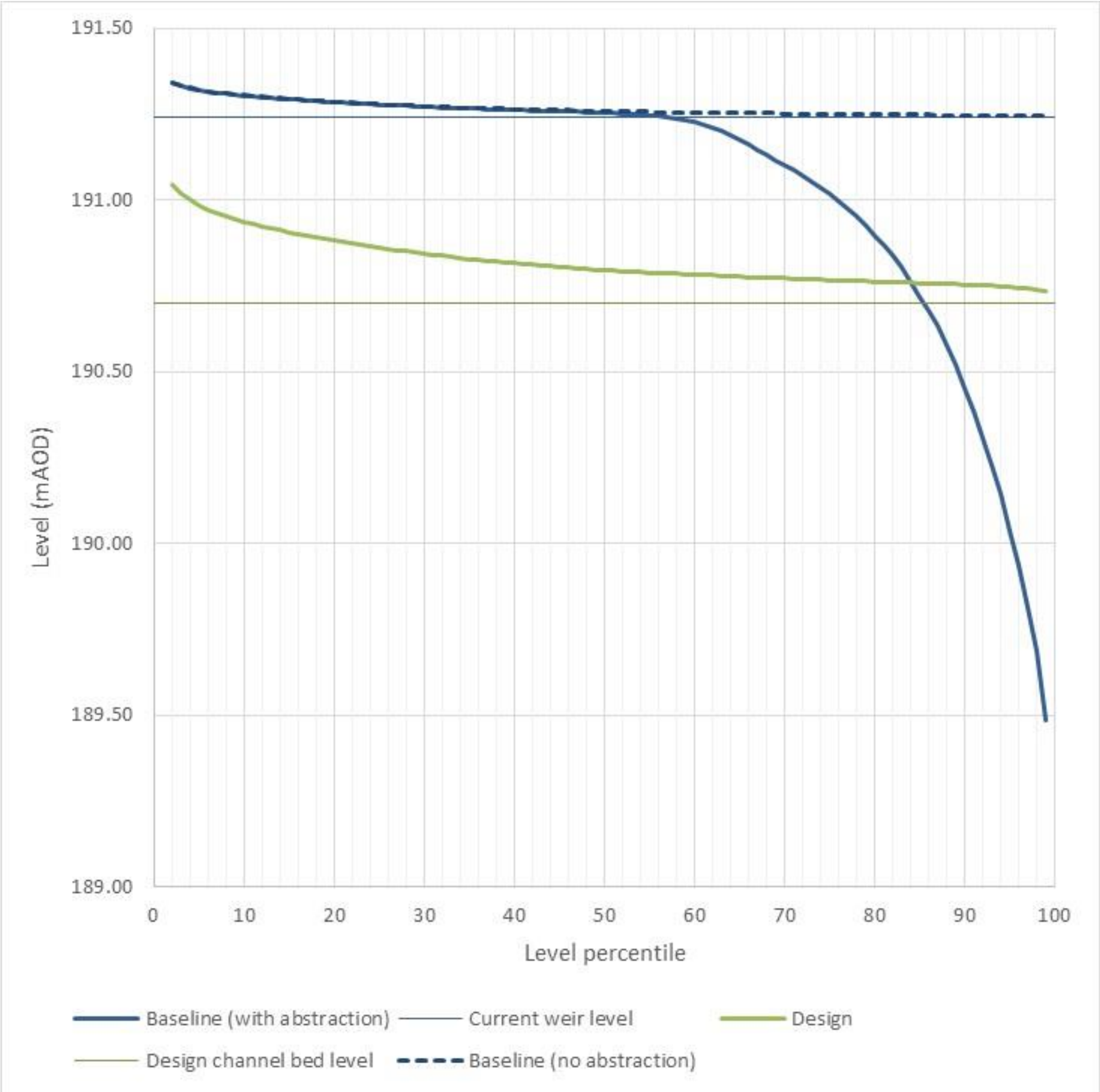


Figure B-10: Over Water level-duration curves for baseline and design scenarios.

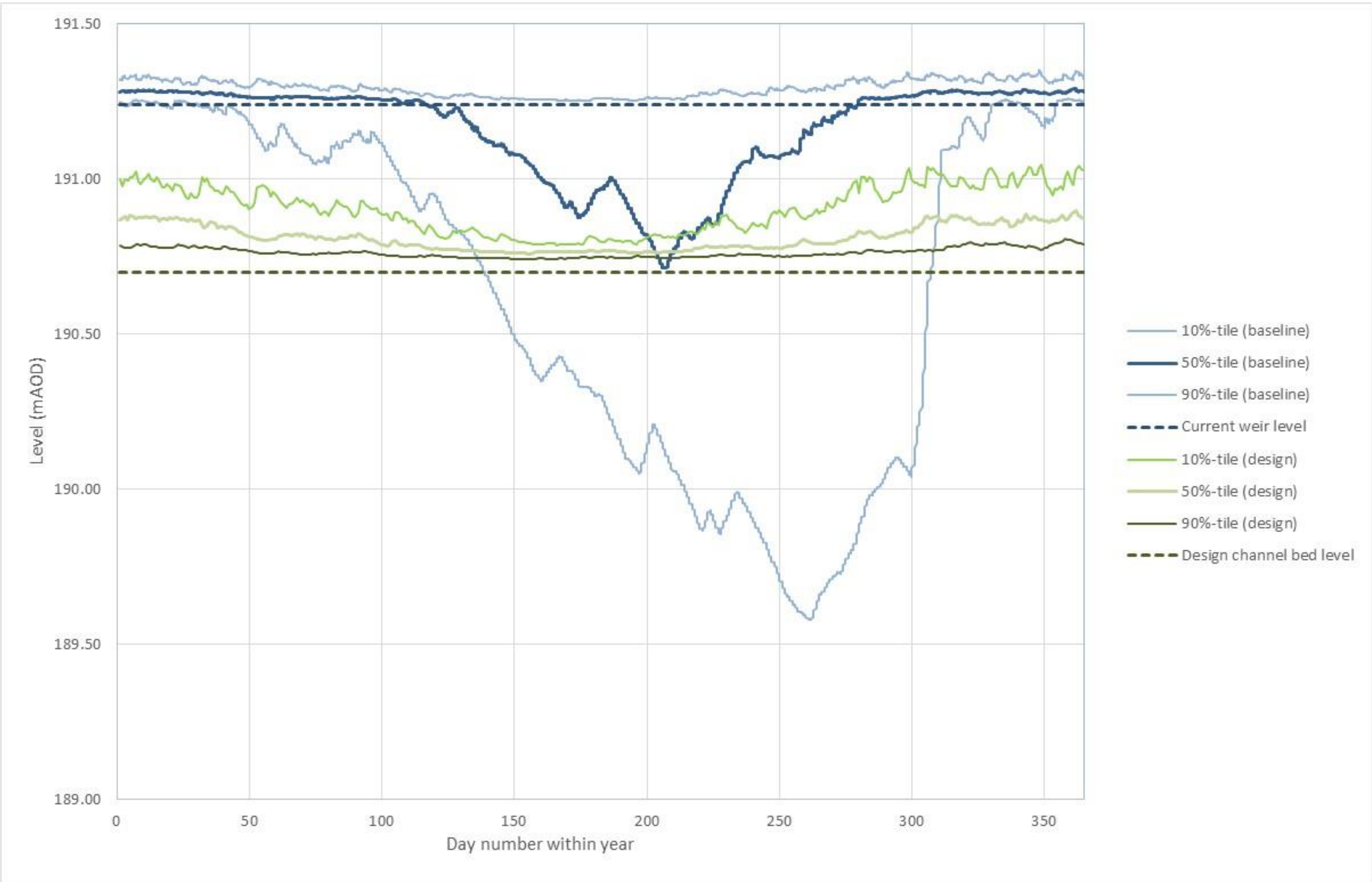


Figure B-11: Over Water predicted lake level seasonality for baseline and design scenarios

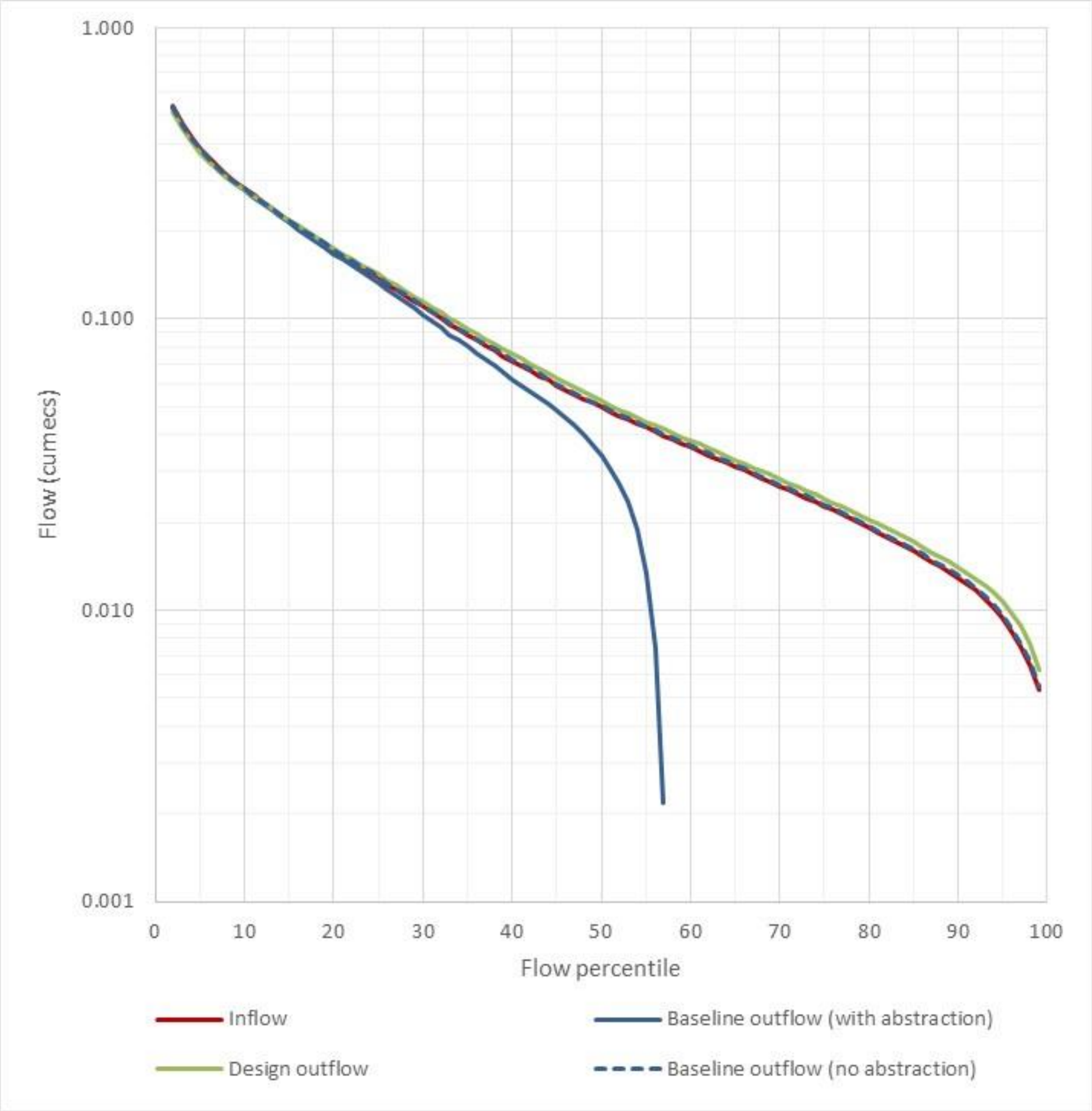


Figure B-12: Over Water Beck flow-duration curves for baseline and design scenarios

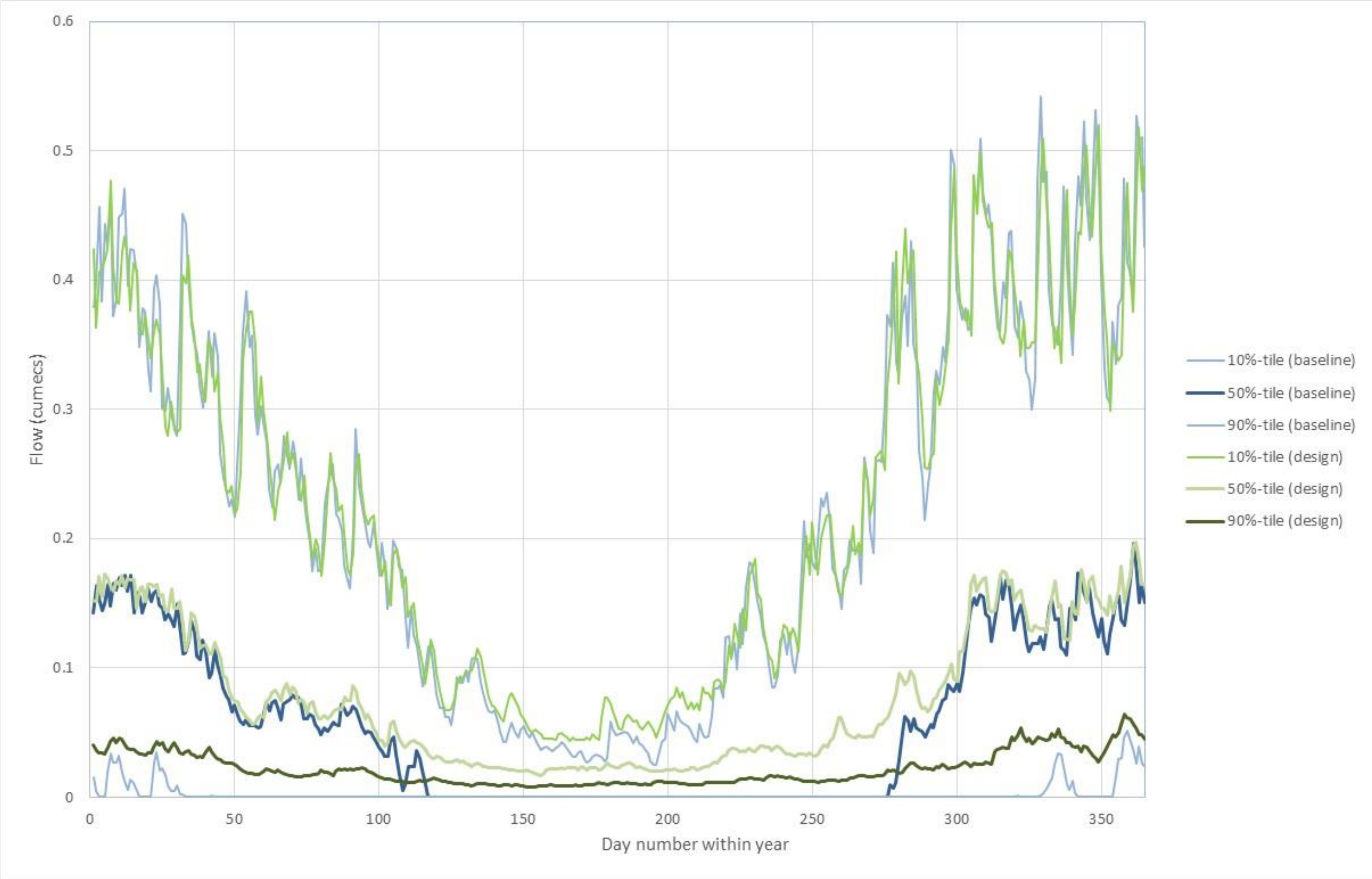


Figure B-13: Over Water Beck predicted flow seasonality for baseline and design scenarios

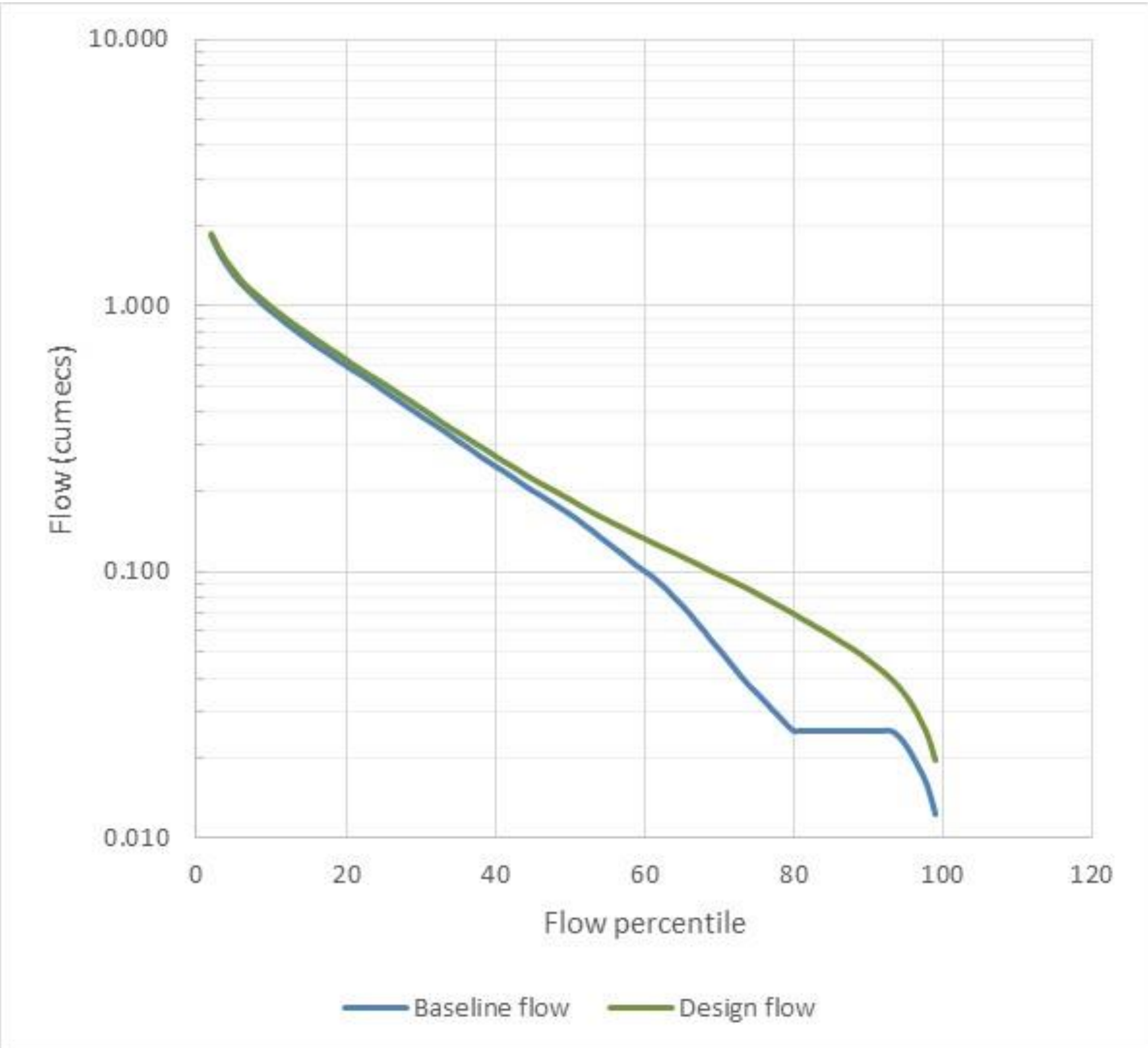


Figure B-14: River Ellen (immediately downstream of Chapelhouse Reservoir) flow-duration curves for baseline and design scenarios

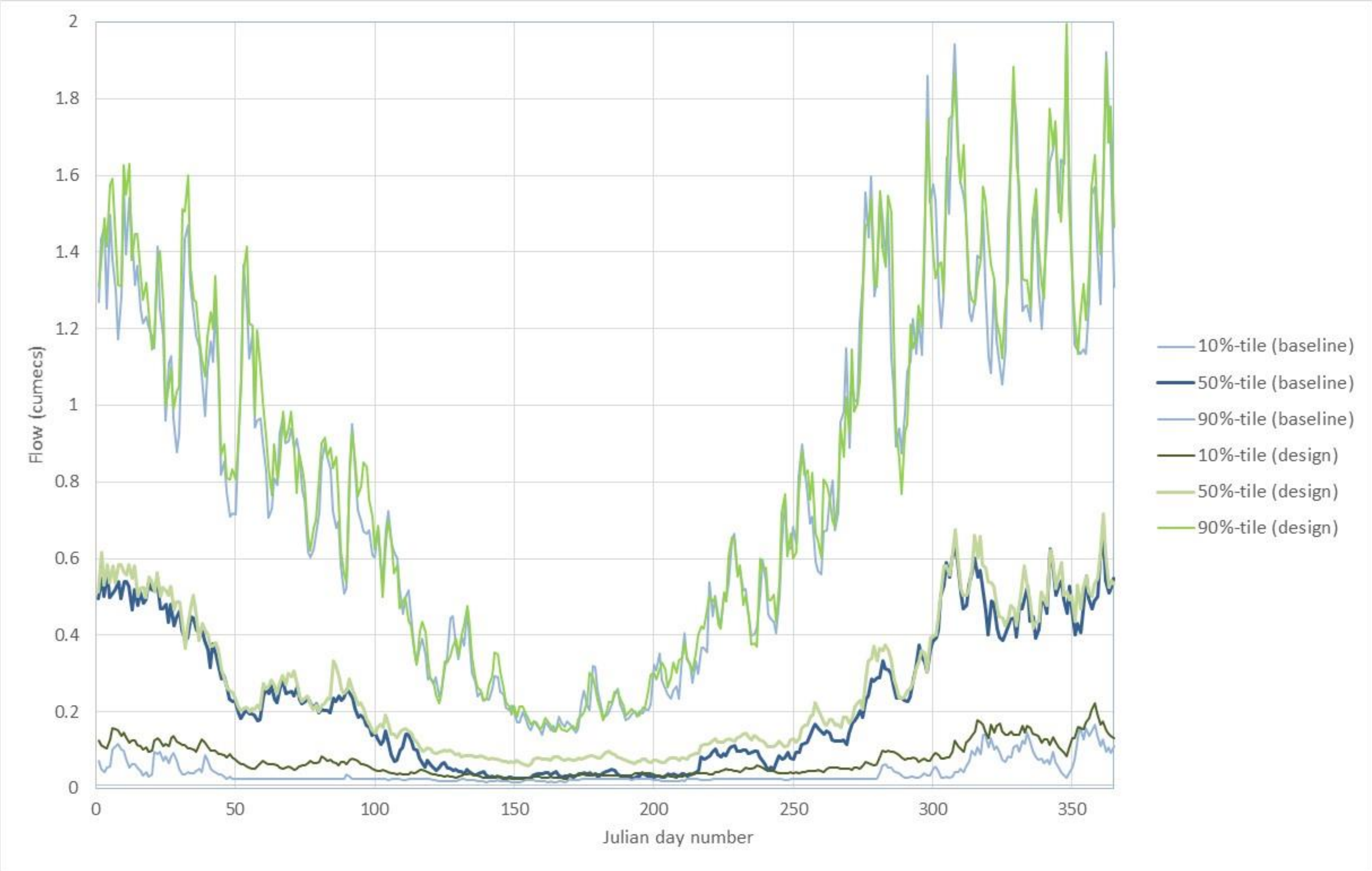


Figure B-15: River Ellen (immediately downstream of Chapelhouse) predicted flow seasonality for baseline and design scenarios

B.5 References

CEH (2019). CEH Gridded Estimates of Areal Rainfall (CEH - GEAR) data licensed from NERC – Centre for Ecology & Hydrology. Available online at: https://eip.ceh.ac.uk/apps/rainfall/gb.html (Accessed 19/05/2019)

Finch & Hall (2001). Estimation of Open Water Evaporation: A review of methods. *R&D Technical Report W6-043/TR*, Environment Agency.

Jacobs (2010). Development of a loch routing model approach for estimating the impact of lochs on flow statistics. Report for SEPA.

Price D.J. (2012). Scottish loch hydrology: improved understanding and recent methodological advancements. *British Hydrological Society's 11th National Symposium, Dundee*

Annex B1: Results of the sensitivity analysis of explicitly accounting for direct rainfall and evaporation to and from the surface of Over Water

Results of model sensitivity analysis to the explicit accounting of direct rainfall to and evaporation from the surface of Over Water. Period of record simulated = 1 Jan 2000 to 31 Dec 2014. The modelled flows and levels are presented as flow and level duration curves, showing that although there is a slight impact to the estimated lake level and outflow it is relatively slight and a secondary order issue compared to the removal of the abstraction and infrastructure.

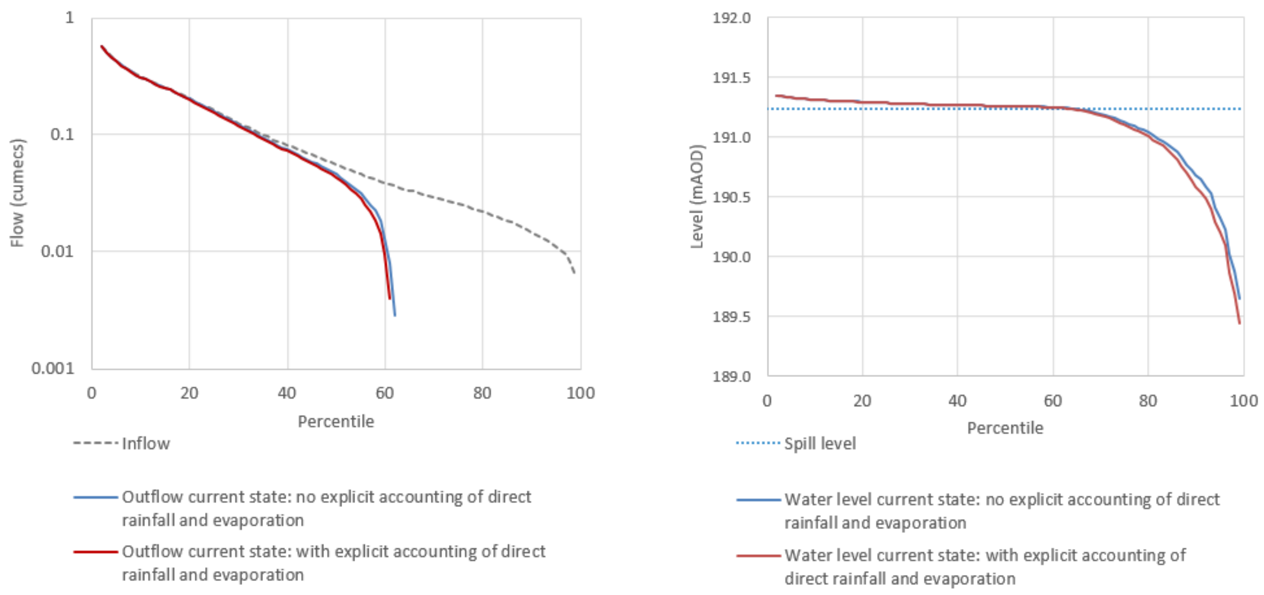


Figure B-16: Results of the sensitivity analysis to assess whether incorporating explicit accounting of direct rainfall and evaporation to and from the lake surface is necessary.

Appendix C. Hydraulic Modelling Detailed Assessment

This appendix includes information on how the hydraulic model for Chapelhouse has been constructed, the baseline and impact assessment of the preferred option.

C.1 Methodology

The hydraulic model developed for this study is a linked one-dimensional/two-dimensional (1D/2D) hydraulic model, with the river channel represented as a 1D component using Flood Modeller Pro and the floodplain represented in 2D using TUFLOW. The linked 1D/2D approach means that the model dynamically transfers the water between the river channel and the floodplain as a flood event unfolds. During Stage A of this project, a 1D only hydraulic model was developed for this study, which was used as the basis for the baseline model schematisation during this Stage B of the project.

The modelling area is shown in Figure C-1. The study area encompasses the River Ellen from Stockdale Farm to 2km downstream of Chapelhouse Reservoir at Ireby, whilst also including the catchment for Over Water Reservoir. The model extent was determined based on the requirements of the study and includes the following reaches of the River Ellen catchment:

- Upper River Ellen reach, which extends from Stockdale Farm to the catchpit (approximately 450m),
- Bypass channel, which carries the River Ellen flows from the catchpit to the fish pass adjacent to Chapelhouse Reservoir dam. The bypass channel runs parallel to Chapelhouse Reservoir (left bank) in a man-made channel over a distance of approximately 630m.
- Over Water channel reach, which extends from Over Water to the bypass channel (approximately 450m),
- Lower River Ellen reach, which extends from the downstream end of the fish pass, downstream of Chapelhouse reservoir, to Ireby (approximately 5km),
- Longlands Beck reach, which extends from an unnamed road, approximately 600m to the east of Chapelhouse dam, to the confluence with the Lower River Ellen,
- Abstraction channel, which connects the catchpit to Chapelhouse Reservoir (approximately 200m).

The model also includes an explicit representation of Over Water, Chapelhouse Reservoir and the catchpit as well as their respective flow control structures.

There are two 2D domains represented within the model as shown in Figure C-1. These 2D domains represent two areas of interest when considering flood inundation.

The model has been run for baseline and design scenarios in order to assess the impact of the proposed design on the existing (baseline) flood risk. The data used to inform the model is summarised in Table C-1.

Table C-1: Key data used for the model

Data	Description	Source
LiDAR DTM	1m horizontal resolution Digital Terrain Model (DTM) derived from topographic LiDAR.	UU 2018
Chapelhouse Bathymetry Survey	Bathymetric survey for Chapelhouse Reservoir	Atlantic Geomatics (on behalf of United Utilities) 2018
Over Water Bathymetry Survey	Bathymetric survey for Over Water	Atlantic Geomatics (on behalf of United Utilities) 2018
Topographic Survey Data	Topographic survey for the River Ellen, Longlands Beck, Over Water Channel and	Atlantic Geomatics (on behalf of United Utilities) 2018

Data	Description	Source
	the overflow structures of Chapelhouse and Over Water	
Hydrology	Inflows for the nine sub-catchments along the River Ellen and its Tributaries	Jacobs 2017

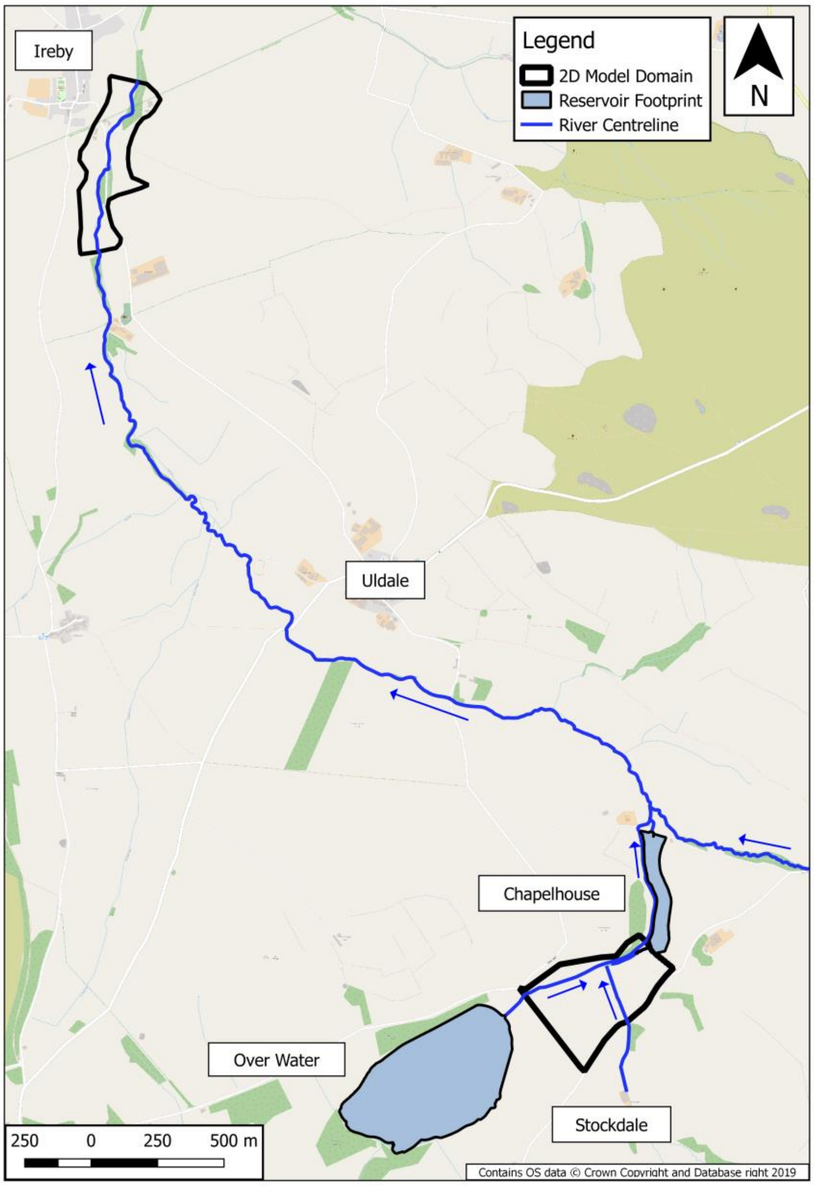


Figure C-1: River Ellen Hydraulic Model Extent

C.2 Hydrology

Hydrological inflows to the hydraulic model have been calculated for nine discrete sub-catchments draining into the Over Water and Chapelhouse Reservoir and along the modelled length of the River Ellen and Longlands Beck, using FEH (Flood Estimation Handbook) methodologies. Climate change was also considered, and an allowance was made based on the Environment Agency guidance. Hydrographs were produced for the 50%, 20%, 10%, 5%, 2%, 1.33%, 1%, 0.5%, 0.1% AEP (Annual Exceedance Probability) events and the 1% AEP event with Climate change.

During Stage A of this project, the flood flows routed through the hydraulic model were reconciled against the hydrological estimates at two target locations: at the confluence of Longlands Beck and the River Ellen, and at the downstream end of the model. Table C-2 shows the comparison between the modelled flows and the hydrological target flows at the targeted locations. The reconciliation shows that most of the modelled flows are within +/-10% of the predicted hydrological flows which is acceptable. These hydrology inflows were therefore taken forward during this stage of the project.

Table C-2: Table showing reconciliation of model flows with target flows from hydrological estimates during Stage A.

% AEP events	Peak Target Flow (m3/s)		Model Flow (m3/s)	% Change	Model Flow (m3/s)	% Change
	TF2	TF3	TF2		TF3	
50	4.94	10.20	3.92	-21%	9.70	-5%
10	7.99	16.80	7.90	-1%	17.11	2%
2	11.70	24.40	12.09	4%	26.13	7%
1	13.70	28.50	14.11	3%	30.40	7%

C.3 Baseline Model Schematisation

Chapelhouse, Over Water and the River Ellen are schematised in 1D using Flood Modeller Pro version 4.4.1. The 1D model covers all reaches stated in Section C.1 above. The 2D domains also mentioned in Section C.1 are modelled with TUFLOW version 2018-03-AB-iDP-w64 and are linked to the 1D domain via HXI (dynamic head transfer) boundaries. The reach of the River Ellen (bank to bank channel and adjacent floodplain) between the two 2D domains is schematised in 1D only. This is well suited for this modelled area as the River Ellen valley corridor is well defined throughout the reach.

C.3.1 1D Schematisation – Channel and floodplain

C.3.1.1 Topography

The representation of the river channel throughout the River Ellen and its tributaries, within the 1D model, was based on survey data obtained from United Utilities (Atlantic Geomatics, 2018). LiDAR DTM data was also used to extend the model cross-sections across the floodplain within the reaches whereby the model representation is 1D only.

Over Water and Chapelhouse Reservoir have been represented using an elevation-area curve in Flood Modeller Pro with dimensions estimated from LiDAR DTM data for elevations above current spill level of the reservoir. The elevation-area curves for both reservoirs, for elevations below this level were extracted from bathymetric survey from United Utilities (Atlantic Geomatics, 2018). The catchpit basin was represented using an elevation-area curve with dimensions obtained using surveyed contours. The initial conditions in the reservoirs have been assumed to be full at the start of all the simulations.

The LiDAR DTM ground elevations were used to schematise 1D spill units in two locations to allow linkage between the 1D and 2D model domains. The most upstream 1D spill unit is located at the crossing of the River Ellen by a small road to the North of Stockbridge, allowing spill as a result of the bridge structure, into the 2D domain. Secondly, a 1D spill has been schematised along the South bank of Chapelhouse reservoir to convey flows from the 2D domain into the 1D reservoir unit.

Additionally, 1D spill units are also schematised along the walls of the catchpit to allow flows from the 2D domain to enter/exit the catchpit itself. These spill units were schematised using the survey spot heights collected along the walls of the catchpit.

C.3.1.2 Hydraulic Friction

For the 1D hydraulic model, in-channel roughness (Manning's 'n' coefficient) values were determined primarily using the photographs taken during the survey and site visit. Roughness values adopted were taken from standard guidance[1]. Table C-3 shows the roughness values applied to each modelled reach.

Table C-3: Manning's 'n' roughness coefficients applied within the 1D model

Watercourse/Reach	Bed Manning's 'n'	Bed Material	Banks Manning's 'n'	Banks Material
Upper River Ellen	0.04	Narrow stone walled channel with rocky bed	0.035	Short pasture with occasional trees and fences
Chapelhouse Channel between the catchpit and Chapelhouse Reservoir itself	0.05	Straight uniform channel with long grass and stones	0.05, 0.035	Long grass and Marshland
Longlands Beck	0.05	Straight natural channel but with gravel, cobbles and some debris	0.035, 0.1	Short pasture with trees on left bank
Over Water Channel between Over Water and the catchpit	0.045	Straight uniform channel encroached by long grass on banks	0.035	Short pasture
River Ellen bypass channel between the catchpit and Chapelhouse Spillway	0.035	Fairly straight channel with rocky bed material	0.035	Short pasture
River Ellen between Chapelhouse Spillway and the downstream model extent at Ireby	0.04	Clean more natural channel with rocky areas	0.035, 0.1	Short pasture with occasional trees in some areas

C.3.1.3 Hydraulic Structures

Several hydraulic structures were schematised in 1D and they have been summarised in Table C-4. The 1D schematisations of Over Water overflow and Chapelhouse Reservoir overflow are shown in Figure C-2 and Figure C-3 respectively.

Table C-4: Hydraulic Structures in the Model

Structure	Node Label	Schematisation
Over Water Overflow	OVR01_0431u OVR01_0424u	The overflow from Over Water consists of the main broad crested concrete weir followed by a narrow secondary weir which allows flows to enter Over Water Channel. The upstream concrete weir is represented within Flood Modeller using a 1D Broad Crested Weir unit whereas the secondary weir is represented using a 1D Spill unit, based on topographic survey. The embankment of Over Water dam is represented using a 1D spill unit based on topographic survey. Overwater Channel is represented using 1D river cross-section units throughout the reach.
Over Water Channel road bridge	OVR01_0326bu	The road bridge downstream of Over Water overflow is schematised in Flood Modeller as a 1D Arch Bridge unit with an accompanying 1D Spill unit to represent the road surface and parapet of the structure.
Three catchpit sluice gates	ELN03_000s2u ELN03_000s3u ELN03_0000su	The three sluice gates at the catchpit control the diversion of flow from the Upper River Ellen to the Bypass Channel or to Chapelhouse Reservoir. These sluice gates are represented using 1D Vertical Sluice units.
Upper Ellen road bridge to the North-East of Stockbridge	ELN03_0221bu	The road bridge crossing the Upper River Ellen is schematised in Flood Modeller as a 1D Arch Bridge unit with an accompanying 1D Spill unit to represent the road surface and parapet of the structure. This 1D Spill unit is

[1] Chow, Ven Te (1959). Open-Channel Hydraulics. McGraw-Hill

Structure	Node Label	Schematisation
		linked to the upstream 2D domain via a Dummy HT Boundary unit and an SX boundary link in the 2D model; allowing flows overtopping the bridge structure to enter the 2D domain.
Upper Ellen footbridge	ELN03_0058bu	The foot bridge crossing the Upper River Ellen is schematised in Flood Modeller as a 1D Arch Bridge unit with an accompanying 1D Spill unit to represent the deck of the structure.
Two footbridges immediately upstream and downstream of Chapelhouse Reservoir Old Spillway	ELN02_0029bu ELN02_0018bu	Both road bridges upstream and downstream of Chapelhouse Old Spillway are schematised in Flood Modeller as 1D Arch Bridge units with accompanying 1D Spill units to represent the deck of each of the structures.
Chapelhouse Reservoir New Spillway	CHP01_0000su	The New Spillway from Chapelhouse Reservoir consists of a concrete weir followed by a tapered spillway chute. The New Spillway is schematised in Flood Modeller as a 1D Spill unit, encompassing both the weir and the embankment of Chapelhouse Reservoir dam.
Chapelhouse Reservoir Old Spillway	CHP01_000s2u	The Old Spillway from Chapelhouse Reservoir consists of a side weir which allows flows from Chapelhouse Reservoir to discharge into the River Ellen bypass channel. The Old Spillway is schematised in Flood Modeller as a 1D Spill unit.
River Ellen bypass channel Culvert to the West of Chapelhouse Reservoir dam	ELN02_0007c	The culvert beneath the road to the West of Chapelhouse Reservoir dam is a masonry arch road culvert with a total length of ~6.3m. The culvert is schematised within Flood Modeller using 1D Arch Conduit units accompanied by a Culvert Inlet unit, with appropriate inlet loss coefficient and an Open Outfall unit.
Small bridge downstream of Chapelhouse Reservoir Spillway	ELN01_4396bu	The road bridge downstream of Chapelhouse Reservoir Spillway is schematised in Flood Modeller as a 1D Arch Bridge unit with an accompanying 1D Spill unit to represent the road surface and parapet of the structure.
Five road bridges along the River Ellen, between Uldale village and the downstream model extent at Ireby.	ELN01_3383bu ELN01_2652bu ELN01_1002bu ELN01_0391bu ELN01_0234bu	The road bridges along the River Ellen, between Uldale village and the downstream model extent at Ireby are schematised in Flood Modeller as a 1D Arch Bridge unit with accompanying 1D Spill units to represent the road surface and parapet of the structures.

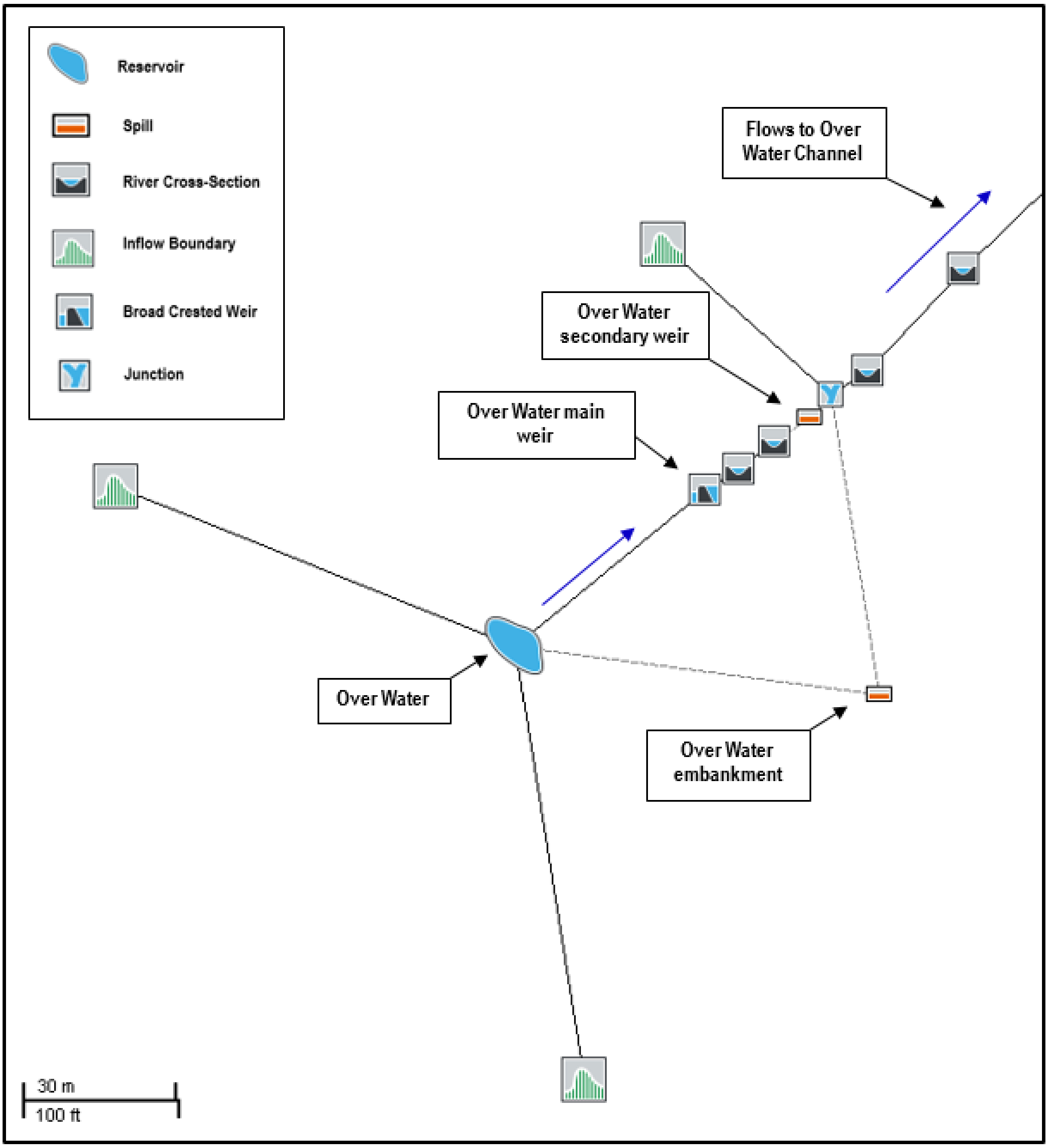


Figure C-2: Schematisation of the Overflow from Over Water

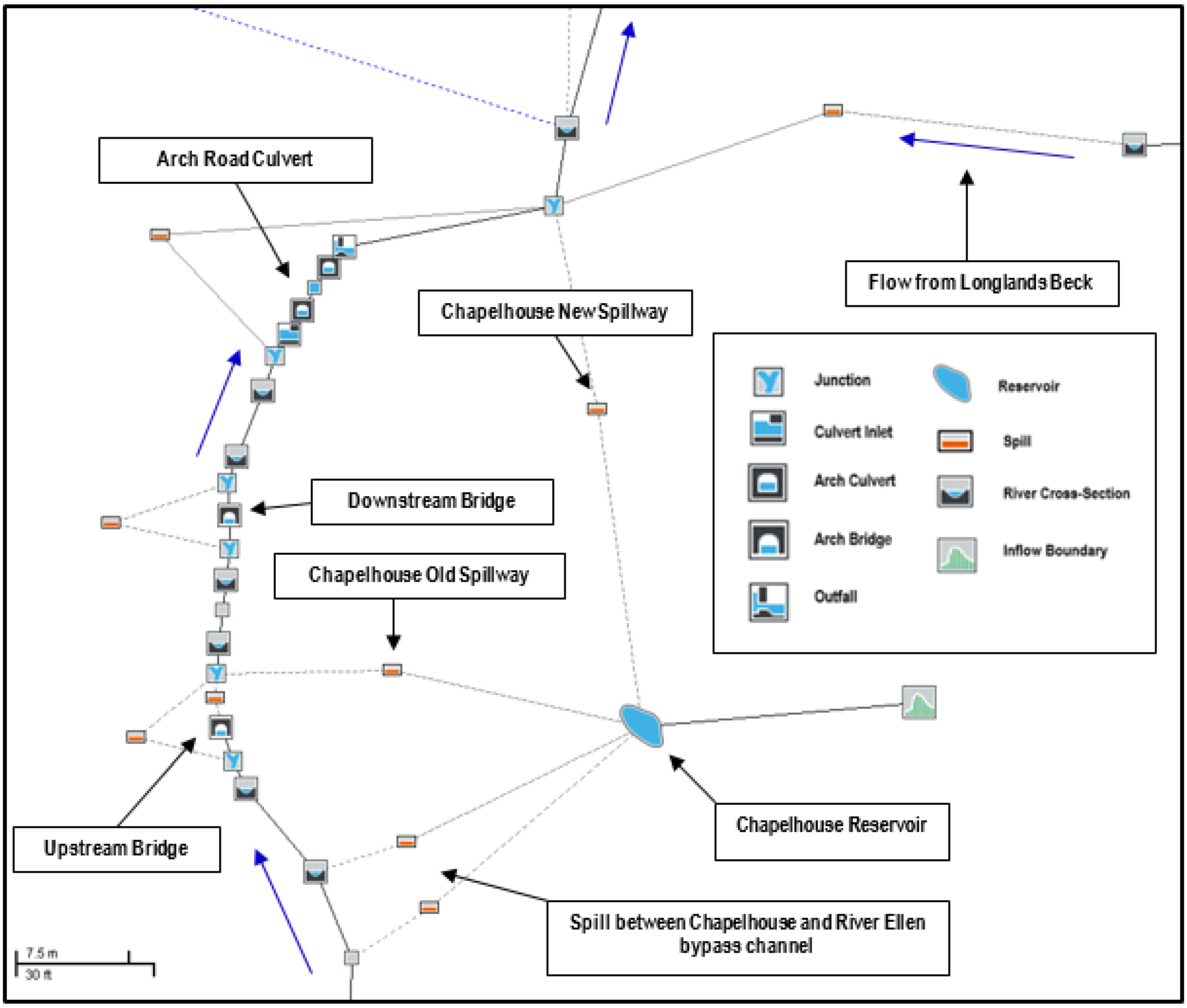


Figure C-3: Schematisation of the Overflow from Chapelhouse Reservoir and the surrounding structures

C.3.1.4 Boundary Conditions

The model inflow boundaries are based on the hydrology analysis carried out and are implemented as Flow-Time (Q-T) boundaries. At the downstream model extent, to the East of Ireby, a Normal Depth boundary is specified. Table C-5 describes all the boundaries in the model.

Table C-5: Boundaries in the Model

Type of Boundary	Flood Modeller Node	Description
Flow-Time Boundary	Inflow_1	Hydrological Inflow applied directly to Over Water representing the headwater tributary.
Flow-Time Boundary	Inflow_1A	Hydrological Inflow applied directly to Over Water representing the residual catchment up to the overflow of Over Water.
Flow-Time Boundary	Inflow_1B	Hydrological inflow applied immediately downstream of Over Water secondary weir representing the residual catchment between Over Water and the confluence of Over Water Channel with the Upper River Ellen.
Flow-Time Boundary	Inflow_2	Hydrological inflow applied to the upstream extent of the Upper River Ellen representing incoming flows from the upstream catchment.
Flow-Time Boundary	Inflow_2A	Hydrological inflow applied directly to Chapelhouse representing the residual catchment up to Chapelhouse New Spillway.

Type of Boundary	Flood Modeller Node	Description
Flow-Time Boundary	Inflow_3	Hydrological inflow applied to the upstream extent of Longlands Becks representing incoming flows from the upstream catchment.
Flow-Time Boundary	Inflow_4A	Hydrological inflow applied as a distributed lateral inflow representing a residual catchment to the River Ellen between the confluence with Longlands Beck and the downstream model extent at Ireby.
Flow-Time Boundary	Inflow_4B	Hydrological inflow applied as a distributed lateral inflow representing a residual catchment to the River Ellen between the confluence with Longlands Beck and the downstream model extent at Ireby.
Flow-Time Boundary	Inflow_4C	Hydrological inflow applied as a distributed lateral inflow representing a residual catchment to the River Ellen between the confluence with Longlands Beck and the downstream model extent at Ireby.
Downstream Normal Depth Boundary	ELN01_0000	Normal Depth Boundary applied at the downstream extent of the River Ellen model.

C.3.2 2D Schematisation – Specific Floodplain Areas

C.3.2.1 Topography

As already mentioned, there are two 2D domains within the 2D model; the upstream and downstream 2D domains (Figure C-1). The upstream 2D domain covers an area of 0.13km^2 located between the two road bridges crossing Over Water Channel and the Upper River Ellen and the upstream extent of Chapelhouse Reservoir. The downstream 2D domain covers an area of 0.10km^2, extending from Ireby at the downstream extent to 700m upstream. Both 2D domains are represented with grids of 4m cell size.

The topography for the 2D model is based on 1m resolution LiDAR provided by United Utilities. Where there were gaps in the LiDAR, these gaps were filled using the automated fill DTM tool within ArcMap.

C.3.2.2 Hydraulic Friction

The hydraulic roughness of the 2D model grid has been specified as a default roughness value for the rural land use covering the majority of both 2D domains. Hydraulic roughness values were then specified for roads and buildings only using the land use categorisations from OS Mastermap data, as shown in Table C-6.

Table C-6: Land use and Corresponding Roughness Coefficients

Land use	Manning's N
Default rural land use (mostly pasture)	0.040
Roads	0.025
Buildings	0.1

C.3.2.3 Boundary Conditions

No inflows were implemented directly into the 2D domains. Any flow across the 2D domain is as a result of the 1D channel being overtopped, simulating out of bank conditions. The 2D domain extents were set large enough to encompass all flood extents and ensure no occurrence of glass walling.

Within the downstream 2D domain, a Head-Discharge (HQ) boundary condition was applied at the downstream extent of the 2D boundary to allow flow out of the 2D domain at the downstream extent.

As described in Section C.3.1.1 above, 1D Spill units were schematised at the three locations stated. These 1D Spill units were linked to the 2D domain by applying an SX boundary condition at each location.

C.4 Outline Design Model Schematisation

During the outline design of Main Stage B, the following elements were required as modifications to the baseline model schematisation:

- full removal of Over Water weir;
- removal of Chapelhouse reservoir dam, catchpit and bypass channel; and,
- reinstatement of the River Ellen channel to its historical planform.

As described in Section **Error! Reference source not found.** of the main report, the outline design approach produced three design 'fixes'; Design Fix 1, Design Fix 2 and Design Fix 3; followed by the Final Outline Design of the Preferred Option. The modifications carried out to schematise these design fixes are given below.

C.4.1 Outline Design Fix 1

Outline Design Fix 1 is described in the main report. The model schematisation changes made to the model for Design Fix 1 for each relevant section of the model are recorded below.

C.4.1.1 Over Water Overflow Schematisation Changes

The proposed Over Water overflow for Design Fix 1 was schematised by firstly lowering the broad crested weir from an elevation of 191.2mAOD to 190.7mAOD. Secondly, Over Water Channel between the newly lowered weir and the downstream bridge was regraded, with the secondary weir removed. The initial condition of Over Water reservoir was lowered to the updated weir level.

C.4.1.2 Chapelhouse Reservoir Removal Schematisation Changes

The proposed Chapelhouse Reservoir removal for Design Fix 1 was schematised by removing the following units within the 1D hydraulic model:

- Upstream Spill unit linked via SX to allow flows from the upstream 2D domain into Chapelhouse Reservoir;
- Reservoir unit representing Chapelhouse Reservoir;
- Spill units representing both the Old and New Spillways from Chapelhouse Reservoir;
- River cross-section units representing the River Ellen bypass channel;
- Arch Bridge units representing the bridges upstream and downstream of Chapelhouse Old Spillway; and,
- Arch Culvert Conduit units and associated Culvert Inlet and Outfall units representing the arch road culvert to the West of Chapelhouse Reservoir dam.

C.4.1.3 River Ellen and Over Water Channel Realignment Schematisation Changes

Channel realignment of both the River Ellen and Over Water Channel was schematised using the Design Fix 1 Design Channel drawings. The model schematisation was firstly adapted to represent the proposed channel realignment by removing the catchpit and the associated sluice gates and spill units.

The realignment of Over Water Channel began ~90m upstream of the previous catchpit location, whereby the design channel tied into the existing channel, and extended 140m downstream of the catchpit to the confluence with the Upper River Ellen.

The realignment of the Upper River Ellen began approximately 121m downstream of the road bridge crossing to the South of Stockbridge, whereby the design channel tied into the existing channel, and extended 190m downstream to the confluence with Over Water Channel.

The proposed reinstatement of the River Ellen through the footprint of Chapelhouse Reservoir was schematised by extending the realigned design channel from the confluence with Over Water Channel to the existing River Ellen channel immediately downstream of the bridge to the north of Chapelhouse Reservoir Spillway.

The proposed realignment of the channel within this upstream reach and through the footprint of Chapelhouse Reservoir are shown in Figure C-4 and Figure C-5 respectively.

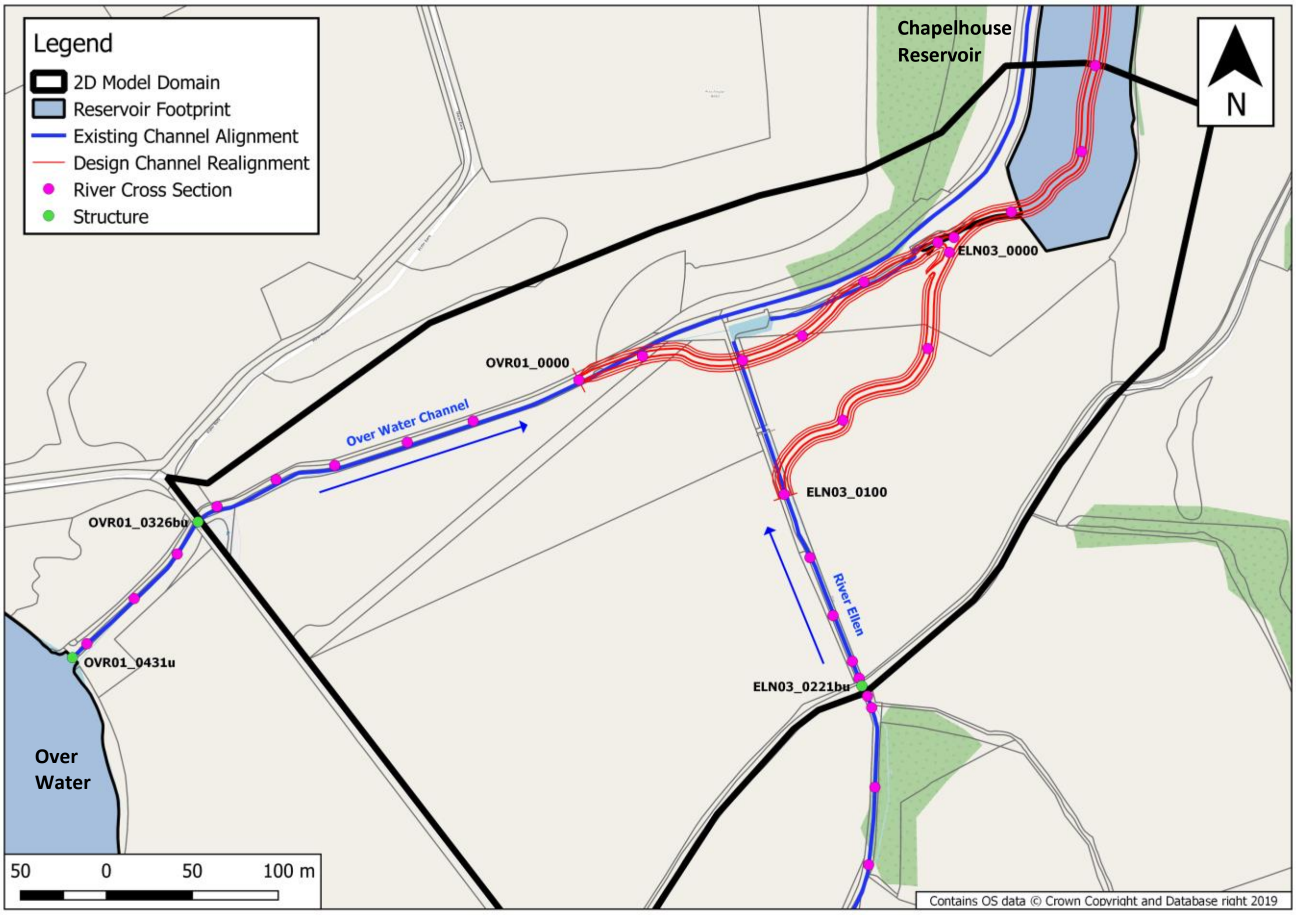


Figure C-4: Schematisation of the Design Fix 1 Channel Realignment within the Upstream Reach.

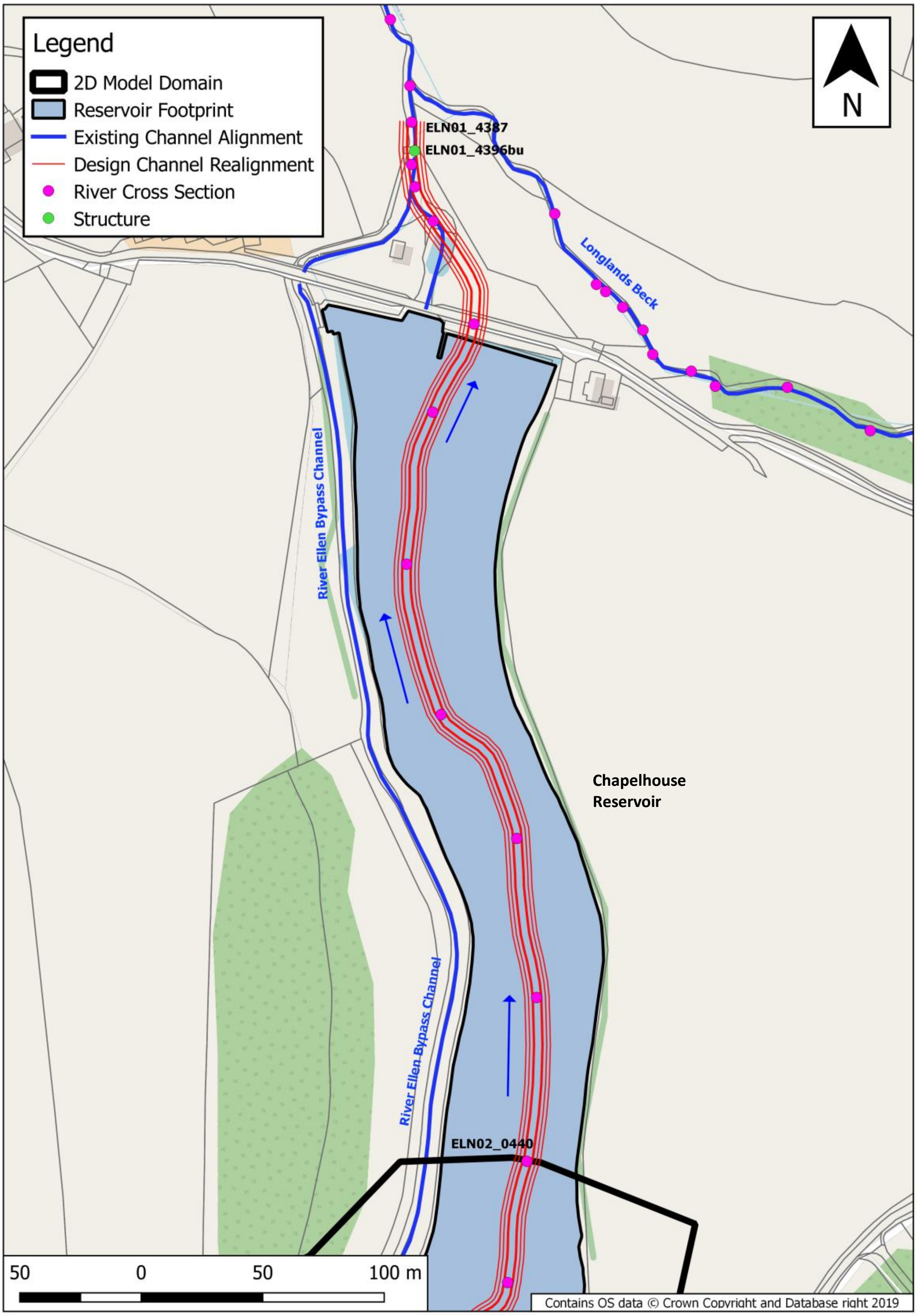


Figure C-5: Schematisation of the Design Fix 1 Channel Realignment within the footprint of Chapelhouse Reservoir

C.4.1.4 Design Channel Schematisation Changes

Figure C-6 shows a typical design cross section as represented within the 1D model, through Over Water Channel.

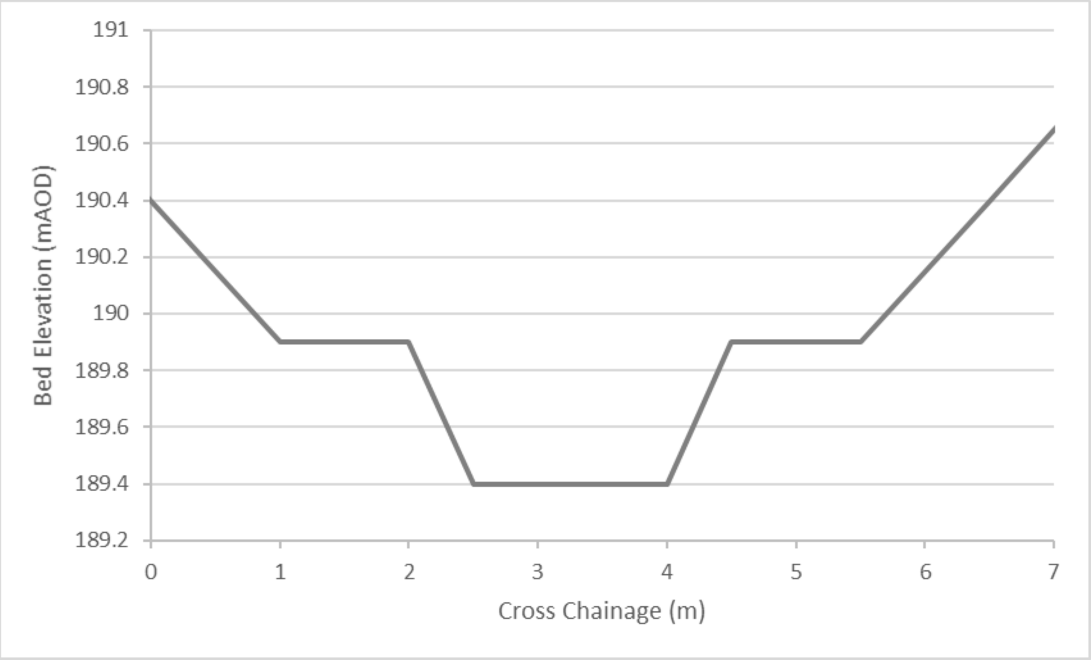


Figure C-6: Typical Design Channel Cross-section for Overwater Channel

The channel is a two-stage channel with a 1.5m wide low flow channel bed and the new bank sides are tied into natural ground levels while maintaining a constant slope of bank. The Upper River Ellen Design Channel had the same profile although the low flow channel had a greater width of 3m.

NOTE: Additional details are provided in the design drawings detailing gravel bar features and alternate channel geometry for left and right bends on meanders. These features are not significant for the hydraulic modelling of the overall channel capacity and have not been considered.

C.4.2 Outline Design Fix 2

Outline Design Fix 2 is described in the main report. The model schematisation changes made to the model for Design Fix 2 for each relevant section of the model are recorded below.

C.4.2.1 Over Water Overflow Schematisation Changes

Improvements were made to the schematisation of Over Water overflow by firstly replacing the Broad Crested Weir unit and the upstream River Cross-Section units of Over Water Channel with Design cross-sections. The Design cross-section schematised within Over Water Channel is shown in Figure C-7.

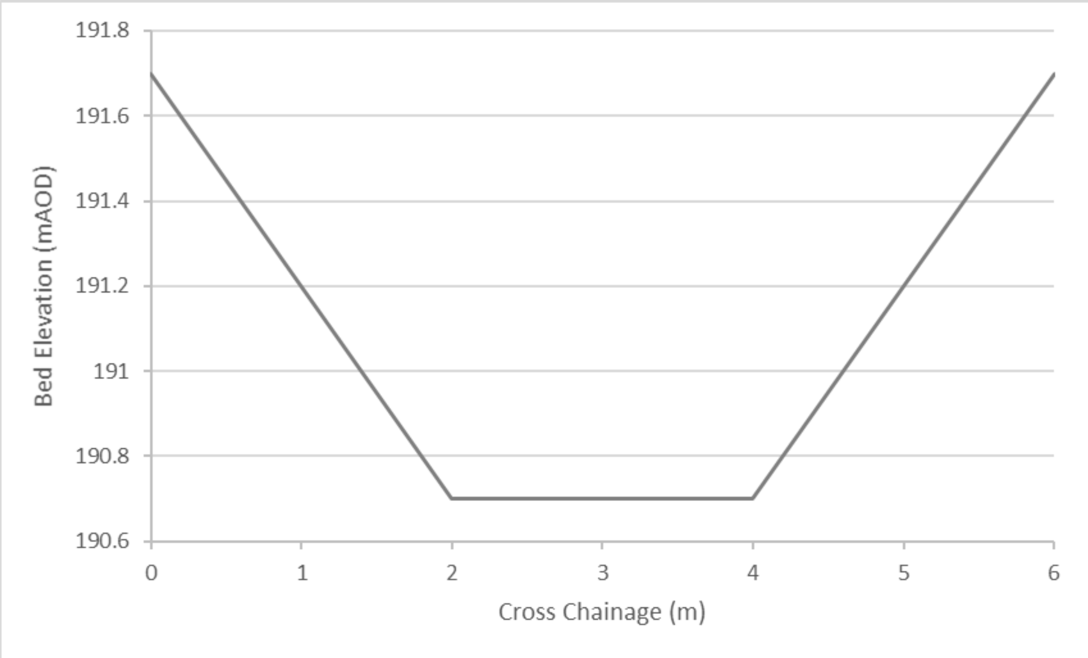


Figure C-7: Design Channel Cross-section for Overwater Channel Overflow from Over Water

C.4.2.2 River Ellen Channel Realignment Schematisation Changes

Channel realignment of the River Ellen was schematised using the Design Fix 2 Design Channel drawings. This required the Upper River Ellen design channel to be extended further upstream by approximately 65m, whereby the design channel tied into the existing channel. The alignment of the proposed channel was then adjusted by moving the Upper River Ellen design channel to the South-East, whilst the confluence with Over Water Channel remained unchanged from Design Fix 1.

Using the updated Design Fix 2 Design Channel drawings, the proposed braided channel within the Upper River Ellen was schematised using additional 1D cross-sections, containing the perched braided channel. The braided channel within the Upper River Ellen extended from 70m upstream of the confluence with Over Water Channel and tied back into the River Ellen within the footprint of Chapelhouse Reservoir 126m downstream. The proposed channel realignment during Design Fix 2 is shown in Figure C-8.

The proposed braided channel within the River Ellen through the footprint of Chapelhouse Reservoir was schematised by extending the existing design channel 1D cross-sections, to include the perched braided channel. The braided channel through this reach extended from 183m upstream of the existing Chapelhouse Reservoir dam and tied back into the River Ellen 123m downstream. Additionally, to better represent the floodplain of the proposed channel through the footprint of Chapelhouse Reservoir, the 2D domain was extended downstream to the location of the existing Chapelhouse Reservoir dam. The proposed channel realignment during Design Fix 2 is shown in Figure C-9.

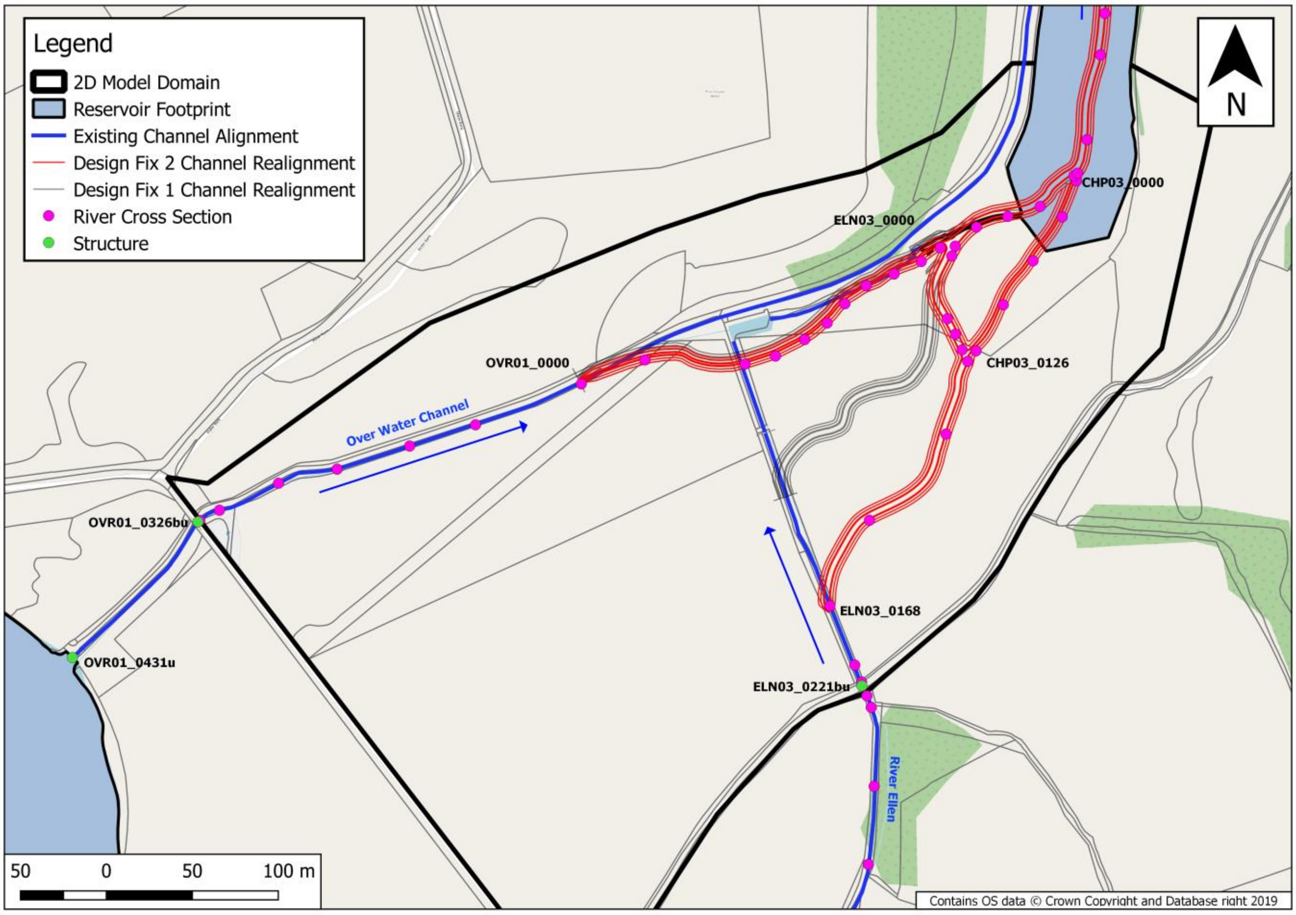


Figure C-8: Schematisation of the Design Fix 2 Channel Realignment within the Upstream Reach.

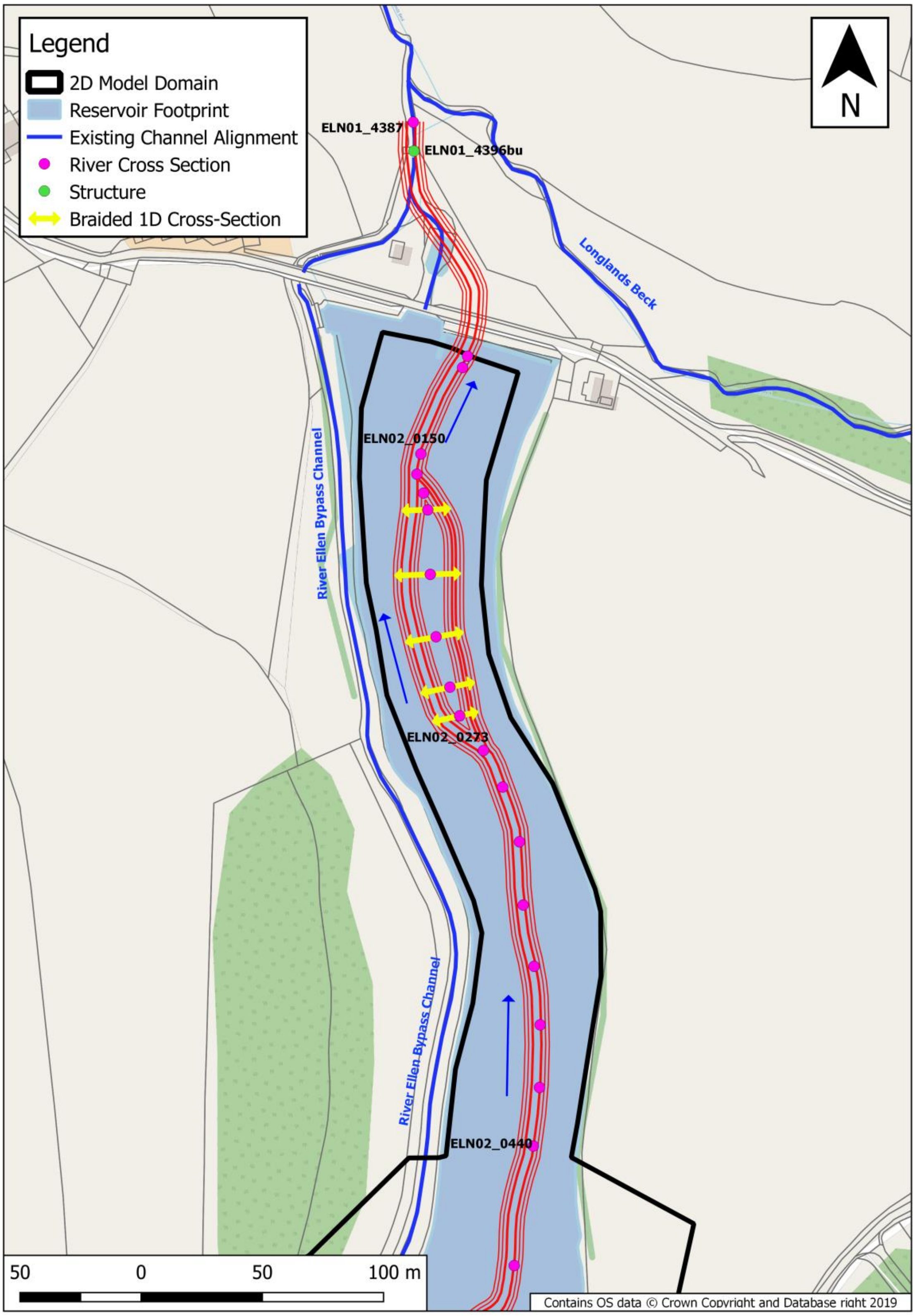


Figure C-9: Schematisation of the Design Fix 2 Channel Realignment within the footprint of Chapelhouse Reservoir

C.4.2.3 River Ellen Design Channel Schematisation Changes

Following realignment of the River Ellen design channel, the design channel cross-section required adaptation to tie the proposed two-stage design channel into the existing ground levels while maintaining the required bed gradient throughout the reach. The design channel cross-section was therefore reduced in depth by 200mm in areas where the cross-section was required to be adapted.

Additionally, the cross-sections of the perched braided channel were schematised within the model. Figure C-10 shows an example of the braided channel within the footprint of the existing footprint Chapelhouse Reservoir whereby the main channel and the braided channel were combined into a single cross-section.

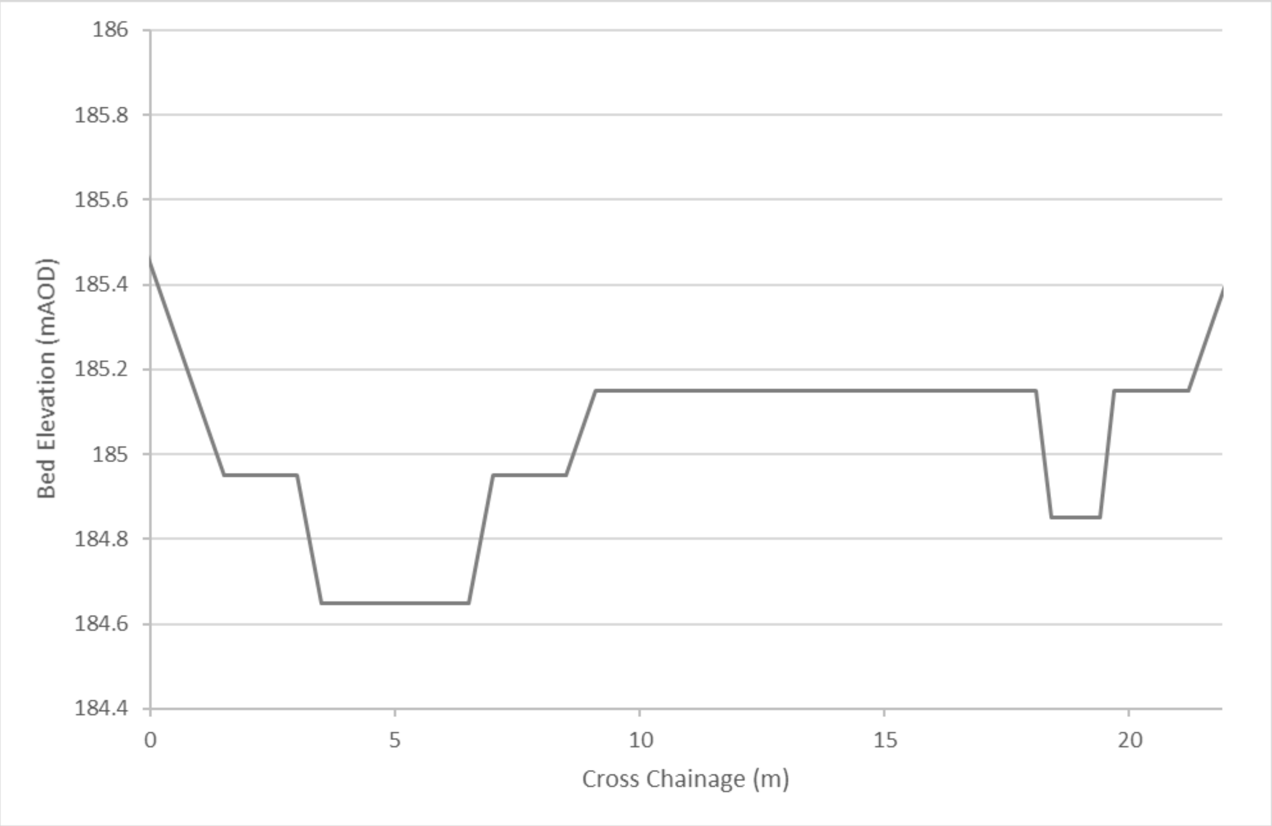


Figure C-10: Design Channel Cross-section for the River Ellen through the footprint of Chapelhouse Reservoir, including the braided channel.

C.4.3 Outline Design Fix 3

Design Fix 3 encompassed two flood storage options to mitigate against the increased downstream flood risk introduced during Design Fixes 1 and 2. These flood storage options were as follows:

- Online flood storage area upstream of Chapelhouse Reservoir using an in-channel orifice and bund to throttle the River Ellen and restrict pass-forward flow to the downstream area; and

- Offline flood storage area upstream of Chapelhouse Reservoir, linked to the channel via a spillway on the left bank. The outlet of the storage was to be connected to the existing bypass channel of Chapelhouse Reservoir to allow the storage area to drain.

Although Option 1, the online storage area, was found to be efficient in reducing pass-forward flow to the downstream area, this option was discontinued as it would disrupt the flow down the River Ellen, which would contradict the aim of the project of returning the Ellen to a near-natural watercourse. The online storage option also has the potential to have a large visual impact on the area as it would need to span most of the valley floor.

Option 2, the offline storage area, was decided on as the preferred option for the final outline design and was therefore taken forwards. However, during Design Fix 3, connecting the outlet of the offline storage area to the bypass channel was found to be unfeasible. This was modified during the final outline design stage.

C.4.4 Final Outline Design of Preferred Option

The final outline design of the preferred option is described in the main report and consisted of optimising the offline storage option modelled during Design Fix 3. The schematisation changes made to the model for the final outline design for each relevant section of the model are recorded below.

C.4.4.1 Over Water Overflow Schematisation Changes

The schematisation of the overflow from Over Water was unchanged from Design Fix 2.

C.4.4.2 River Ellen Channel Realignment Schematisation Changes

The downstream of Over Water Channel was realigned in the final outline design to relocate the confluence between Over Water Channel and the Upper River Ellen to within the private farmland upstream of Chapelhouse Reservoir. The alignment of the main Upper River Ellen channel upstream of the newly located confluence with Over Water Channel was unchanged from Design Fix 2. Between this confluence and the footprint of Chapelhouse Reservoir, the River Ellen was realigned to the East to allow sufficient area for the offline storage area, described below. Downstream of this point, the River Ellen was unchanged from Design Fix 2, throughout the footprint of Chapelhouse Reservoir.

C.4.4.3 River Ellen Offline Flood Storage Schematisation Changes

During the final outline design, the model schematisation was modified to represent an offline flood storage area upstream of the footprint of Chapelhouse Reservoir. This required the design channel cross-sections (ELN02_0627 and ELN02_0609) to be modified by lowering the left banktop elevations to create an 18m-spillway allowing flood flows into the offline storage area.

The offline storage area itself was schematised within the 2D model by lowering the ground elevations to a constant level of 187.68mAOD. The ground levels surrounding the storage area were raised to 190.25mAOD to allow sufficient freeboard within the storage area, with the exception of the spillway elevation that was enforced within the 2D model.

The outlet of the offline storage area was relocated to connect to the main River Ellen channel within the footprint of Chapelhouse Reservoir, as opposed to the bypass channel. The representations of the outlet pipe and channel from the offline storage area were simplified within the hydraulic model. The outlet was schematised within the 2D model as a single 300mm unidirectional pipe. The reach of open channel between the outlet pipe and the River Ellen proposed within the final outline design was not included due to having no influence on flood risk.

Figure C-11 shows the schematisation of the realigned design channel and offline storage area within the hydraulic model.

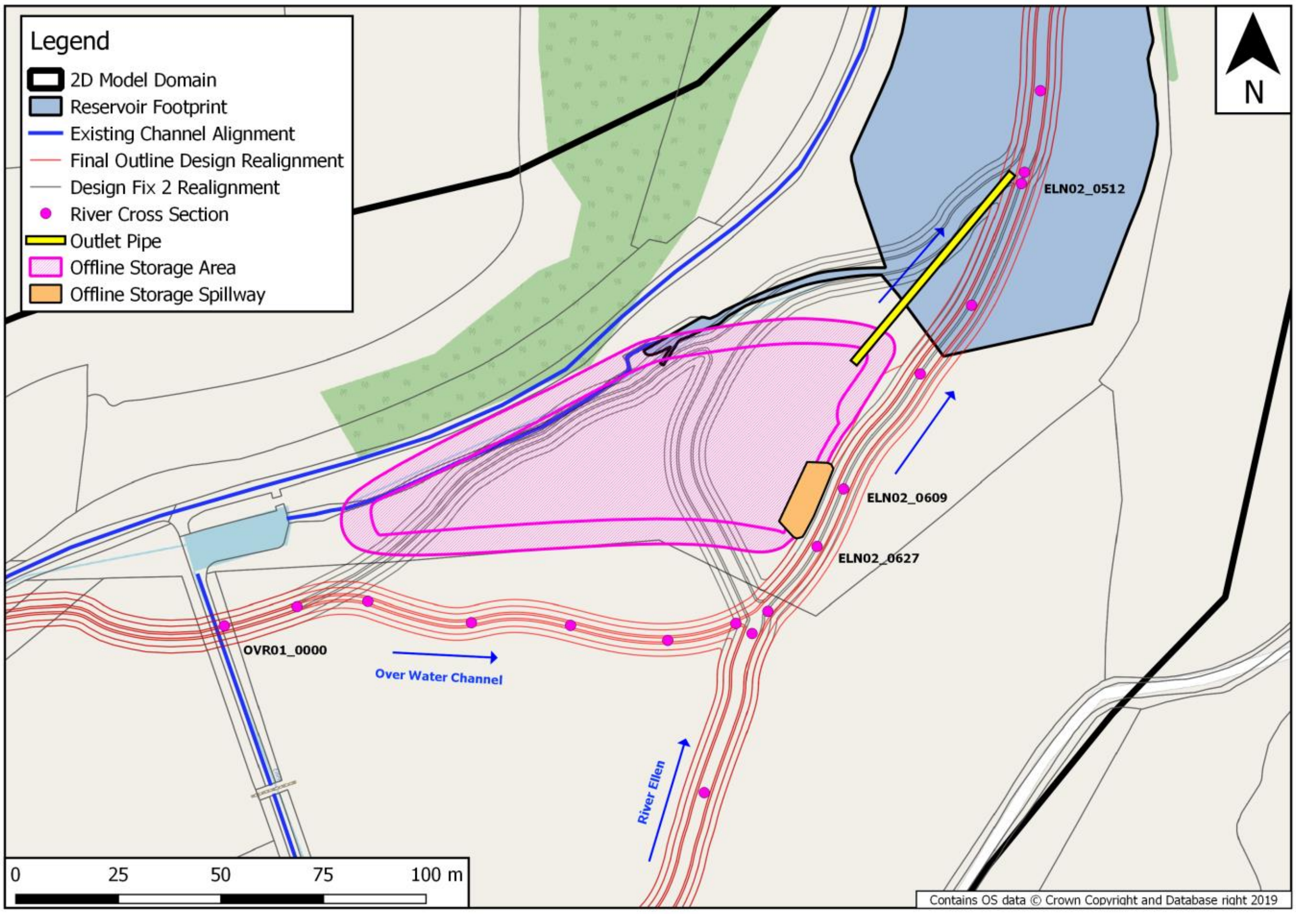


Figure C-11: Schematisation of the Final Outline Design Channel Realignment within the Upstream Reach and Offline Storage Area.

C.5 Model Proving

The following sections discuss the model performance and the verification process. In addition, details relating to the additional runs carried out to test the sensitivity of the model to key variables are also discussed.

C.5.1 Model Performance

Run performance was monitored throughout the model build process and then during each simulation carried out, to make sure a suitable model convergence was achieved.

The cumulative mass error reports output from the TUFLOW 2D model have been checked. Figure C-11 shows the mass balance plot for the 1% AEP baseline simulation. The recommended tolerance range is +/- 1% Mass Balance error. The change in volume through the model simulation can also be seen. It shows that the cumulative mass error is within tolerance throughout the peak of the modelled flood event. In addition, the change in volume is generally smooth, which is an indicator of good model stability.

The 1D model mass balance error as a percentage of the peak system volume is output by Flood Modeller. The overall mass error is less than 1% in all events and scenarios. These percentages are therefore considered acceptable based on modelling best practice.

Figure C-12, Figure C-13, Figure C-14 and Figure C-15 show the 1D model diagnostics as output by Flood Modeller, for the Baseline, Design Fix 1, Design Fix 2 and the Final Outline Design 1% AEP simulations respectively. The 1D model diagnostics indicate some spikes of non-convergence throughout the simulation.

This has been tracked to the Arch Culvert unit to the west of Chapelhouse Reservoir dam on the River Ellen bypass channel. Adding culvert replicates improved the model convergence marginally, but some spikes of non-convergence remained. As the remaining non-convergence has been found to have no significant impact on flow and stage throughout this reach, the residual instability is not significant for the flood risk assessment of the River Ellen, and no further improvements to the model were deemed necessary. If detailed analysis of flows around the River Ellen bypass channel (under the existing situation arrangement) are required in a future project, then further improvement to the model is recommended.

In all Design model simulations, this non-convergence is removed for the majority of the event, particularly removing the non-convergence recorded throughout the peak of the event, as shown in Figure C-15.

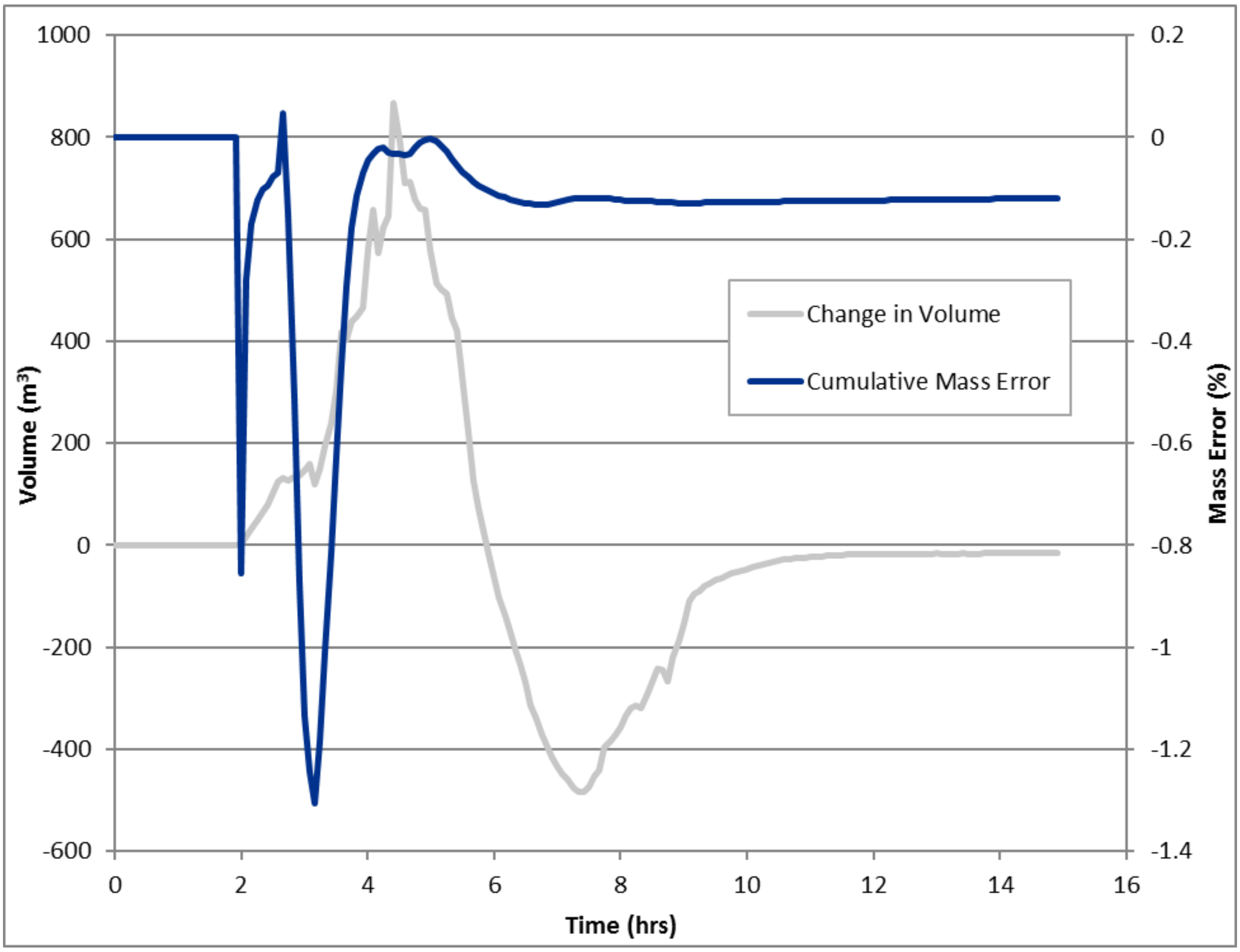


Figure C-12: Mass Balance for the Baseline 1% AEP Simulation

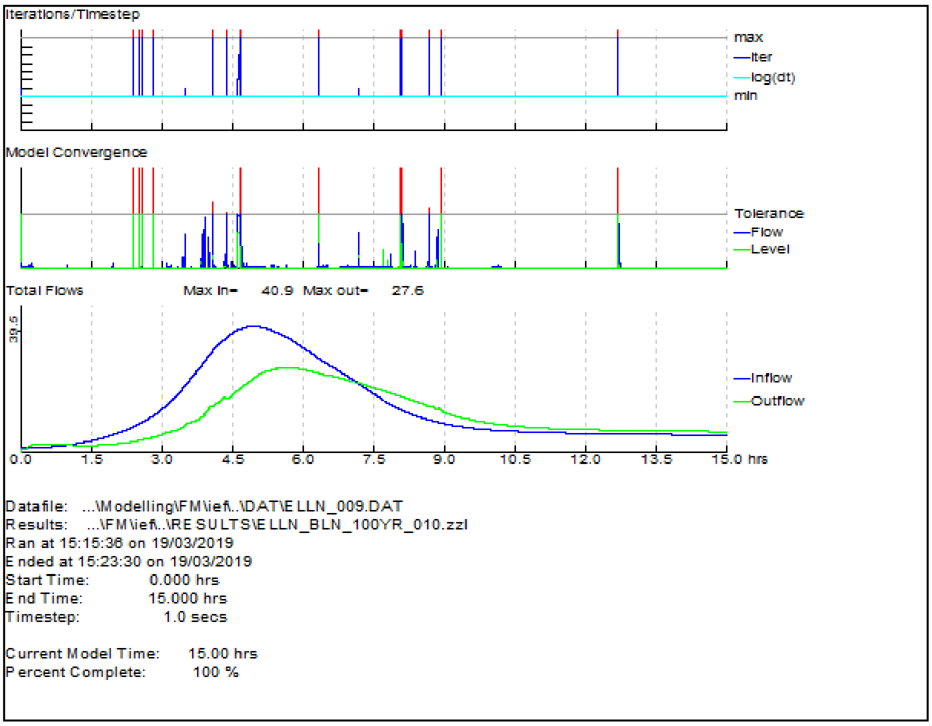


Figure C-13: Model Convergence in 1D for Baseline Scenario – 1% AEP event

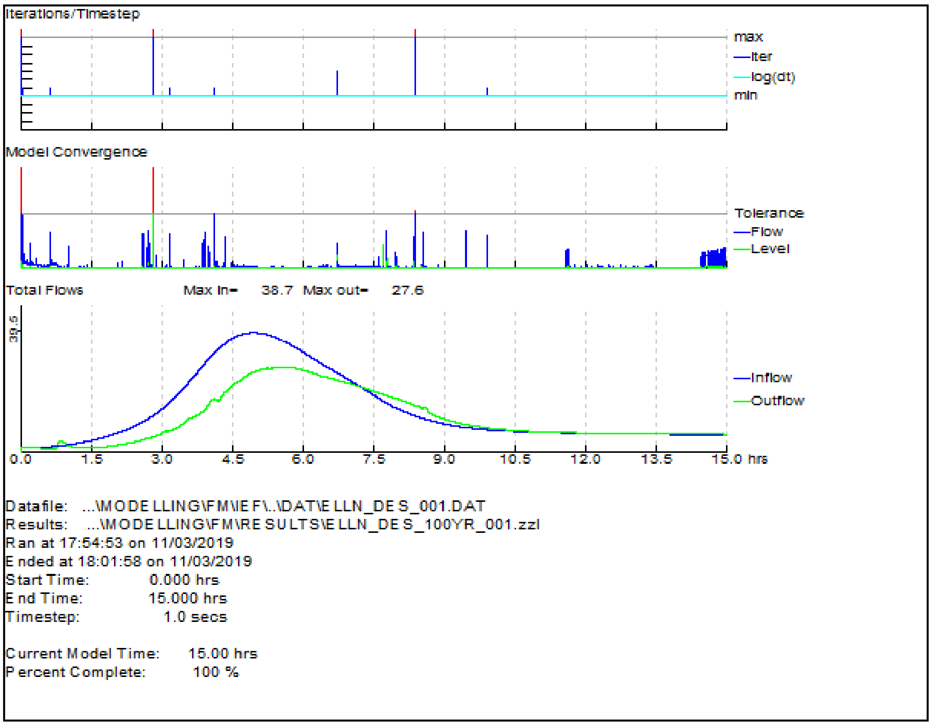


Figure C-14: Model Convergence in 1D for Design Fix 1 Scenario – 1% AEP event

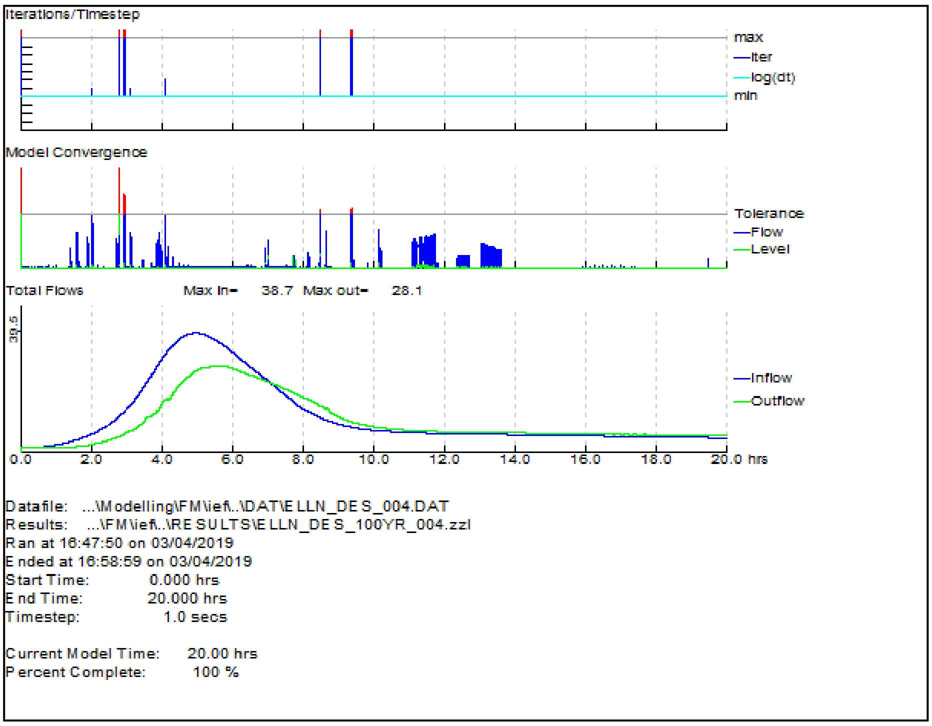


Figure C-15: Model Convergence in 1D for Design Fix 2 Scenario – 1% AEP event

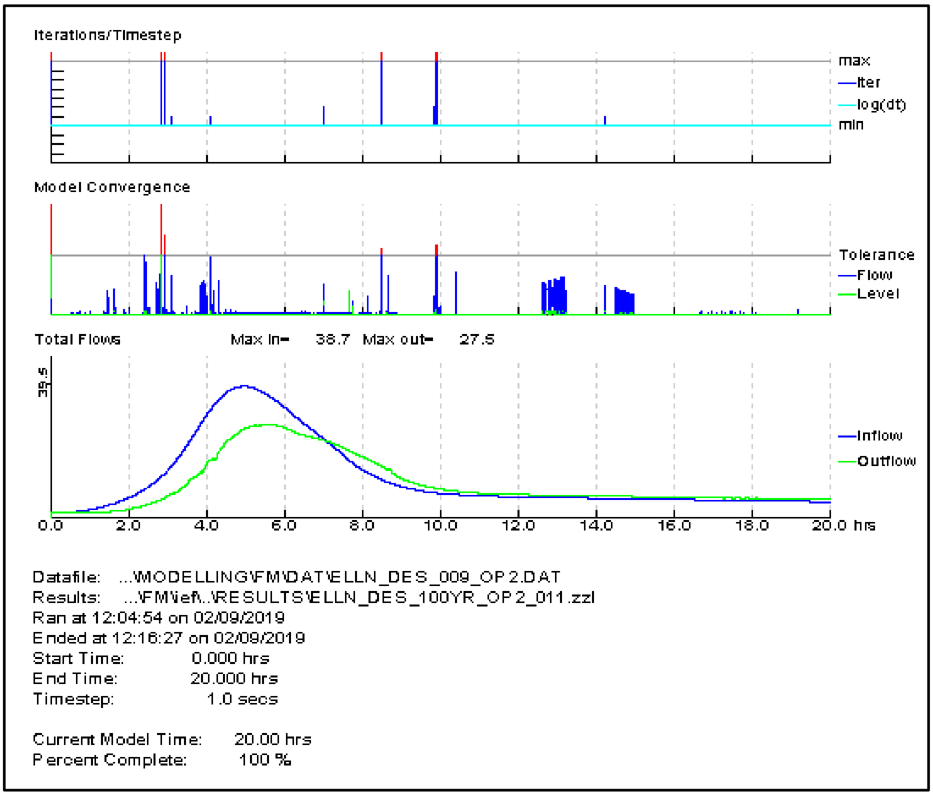


Figure C-16: Model Convergence in 1D for Final Outline Design Scenario – 1% AEP event

C.5.2 Calibration & Verification

No calibration or verification of the hydraulic model was possible as there are no available gauge data records with which to calibrate the model. There is also no Environment Agency Flood Map coverage, meaning model verification to published flood outlines was not possible.

Sense checks of the model results were carried out for all simulations. It worth noting Baseline model simulations have found a single property at the Old Mill in Ireby to be at risk of flooding. Using ground truthing information (site visit photographs, google street maps), the flood risk here is considered realistic.

C.5.3 Sensitivity Analysis

A sensitivity analysis was carried out to see how the model responded to changes in roughness and flow.

C.5.3.1 Roughness Sensitivity

The roughness of both the river channel and floodplain were tested varying Manning's 'n' values by ± 20%. The results for peak water levels in the 1D model are shown in Table C-7. An increase in roughness results in an increase in peak water levels in the channel as velocity is reduced. Hence there is more spill into the 2D resulting in larger flood extents. This can be seen on the flood extent comparison map in Figure C-17. Decreasing roughness allows more flow to stay in channel which reduces flooding. The results show that the modelled water levels are relatively sensitive to changes in roughness. However, the modelled flood extends do not respond significantly. Although, there are some high localised differences in water level, on average, the typical maximum change in water level is 55mm. Additionally, there is no significant increase in flood inundation to the flooded property at Ireby with the increased model roughness.

Table C-7: Roughness Sensitivity Results Relative to Baseline Water Levels

Sensitivity	Water Level Difference (m) with 1% AEP Event		
	Max	Min	Average
+ 20% Roughness	0.253	0	0.040
- 20% Roughness	-0.436	0	-0.055

C.5.3.2 Flow Sensitivity

Model Inflow sensitivity was tested by increasing and decreasing the model inflows by 20%. This was done by modifying the hydrological scaling factors. The results are shown in Table C-8. The flow adjustment causes a difference in water level, which is expected. The flood maps are also affected in some locations, however no significant increase in flood extent is shown with increased model inflows; as shown in Figure C-18. Additionally, there is no significant increase in flood inundation to the flooded property at Ireby with the increased model inflows.

Table C-8: Flow Sensitivity Results Relative to Baseline Water Levels

Sensitivity	Water Level Difference (m) with 1% AEP Event		
	Max	Min	Average
+ 20% Flow	0.263	0	0.070
- 20% Flow	-0.439	-0.001	-0.083

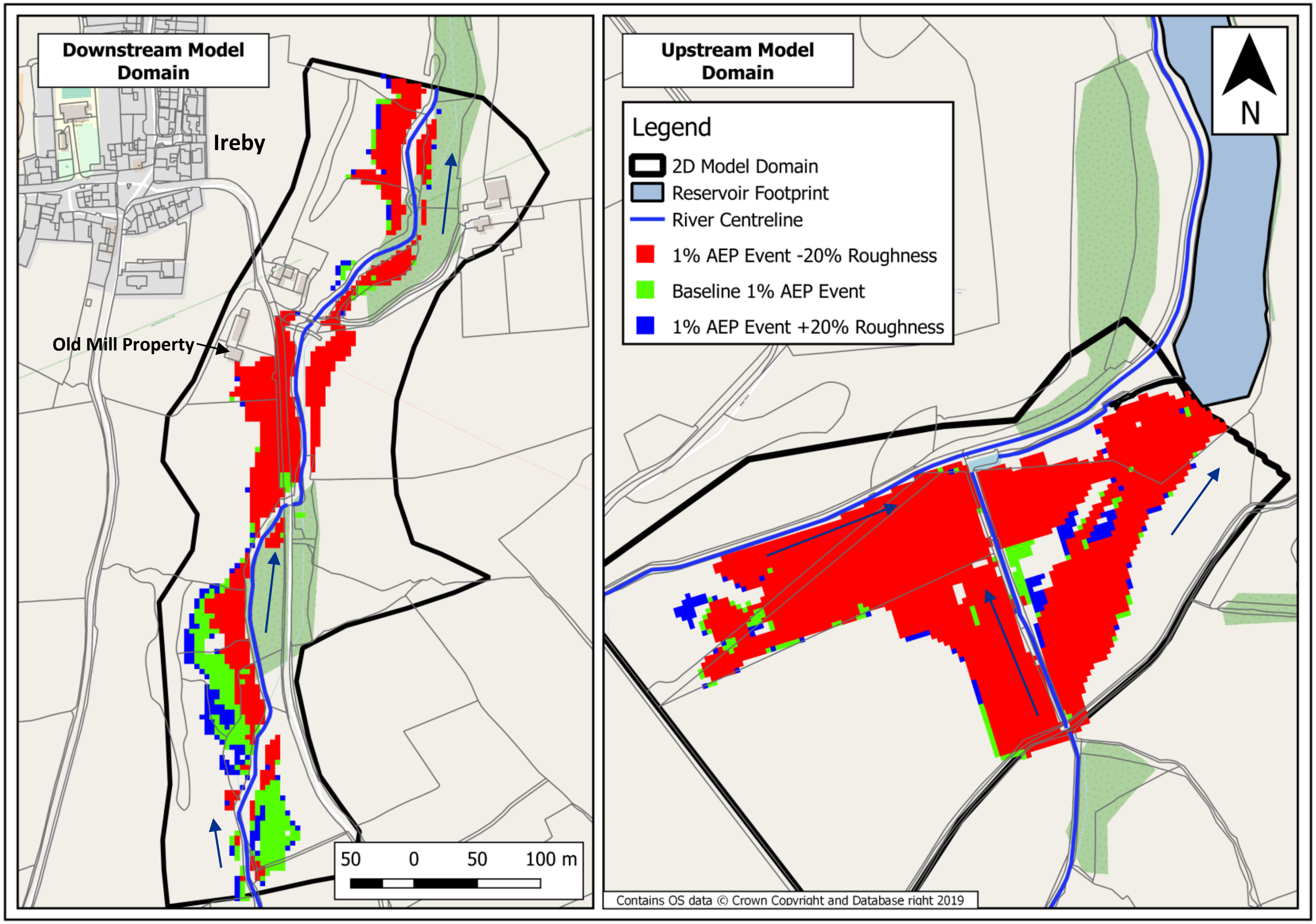


Figure C-17: Flood Extent for 1% AEP Event Roughness Sensitivity

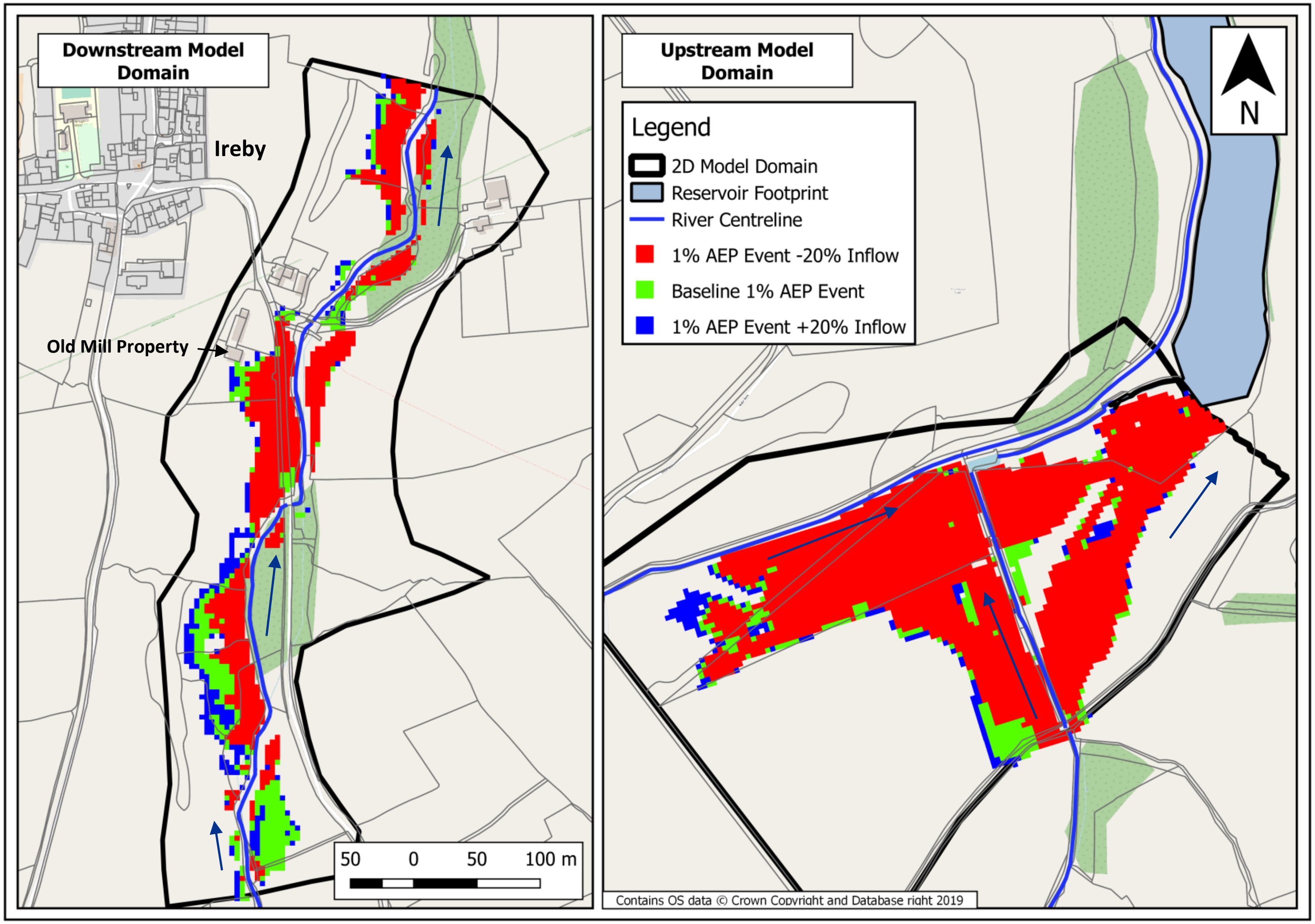


Figure C-18: Flood Extent for 1% AEP Event Inflow Sensitivity

C.6 Model Results

Table C-9 shows the series of flood events that have been simulated with the hydraulic model for the scenarios considered in this study.

Table C-9: Modelled Events

Scenario	50% AEP	10% AEP	2% AEP	1% AEP	1% AEP +CC
Baseline	✓	✓	✓	✓	✓
Design Fix 1	✓	✓	✓	✓	✓
Design Fix 2	✓	✓	✓	✓	✓
Design Fix 3	✓	✓	✓	✓	✓
Final Outline Design	✓	✓	✓	✓	✓
Roughness Sensitivity				✓	
Flow Sensitivity				✓	

C.6.1 Baseline Results

The hydraulic model has been run for 50%, 10%, 2%, 1%, and 1% AEP plus climate change (CC) flood events. The maximum flood extents for the 50%, 10% and 1% AEP +CC flood events are shown in Figure C-19 for the two areas of flood risk interest corresponding to the two 2D domains described in section C.3. Baseline maximum flood extents for all other events are shown in section C.9 of this appendix.

The model results show a significant amount of flooding within the river floodplain. In the 50% AEP event, flow is seen to overtop the banks of the River Ellen both immediately upstream of the catchpit and in the downstream reach at Ireby. In the 1% AEP event, flow overtops the banks throughout the Upper River Ellen and bypasses the channel and catchpit via overland flow. In the downstream reach at Ireby, flow overtops the banks throughout the 2D model domain. Most notably, the 1% AEP event causes flood inundation to the single property at the Old Mill in Ireby.

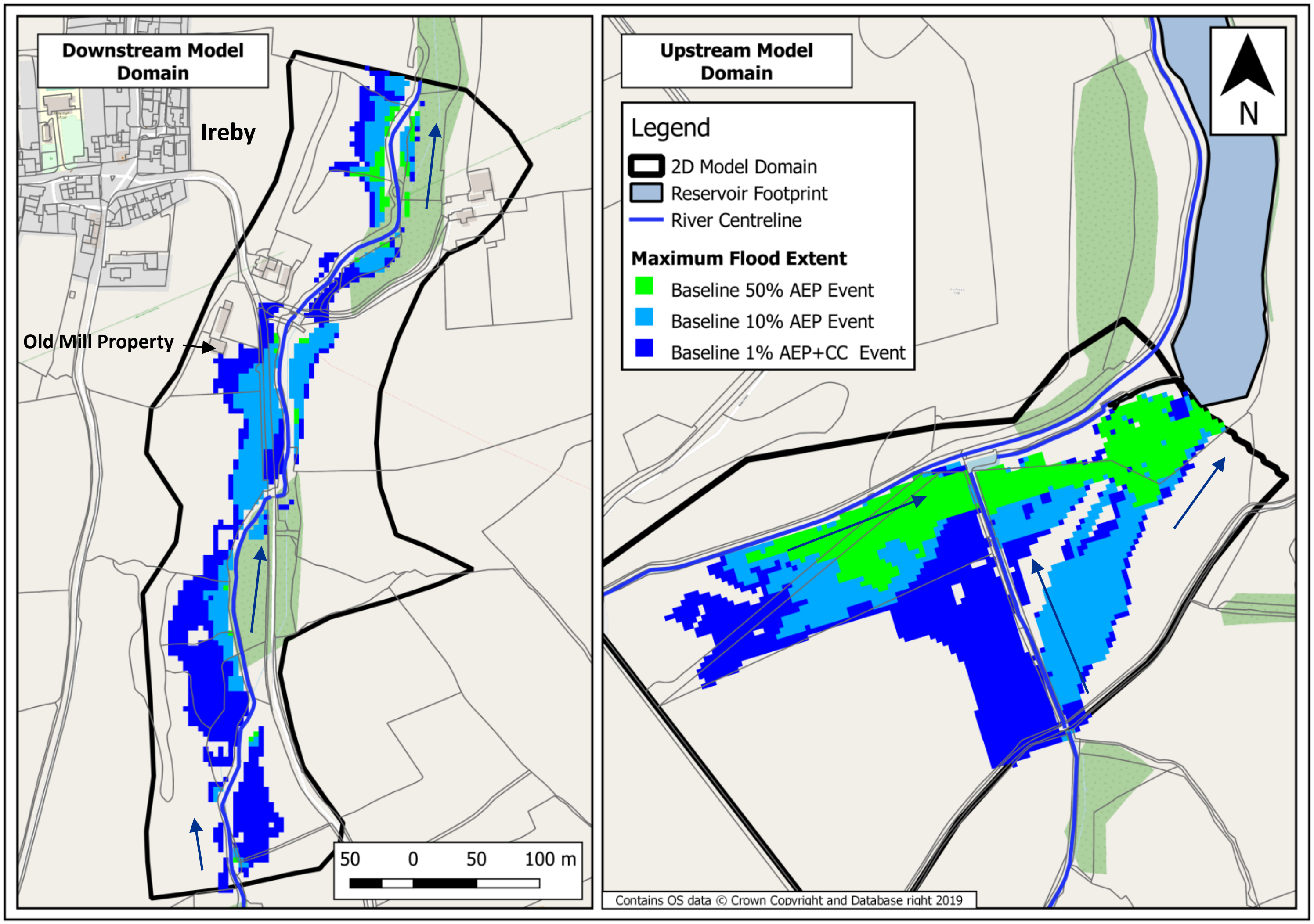


Figure C-19: Maximum flood extents for the 50%, 10% and 1% AEP +CC flood events

C.6.2 Design Fix 1 Results

With Design Fix 1 in place, flood inundation of the upstream floodplain of the Upper River Ellen was found to be removed during the 50% AEP event. However, flow was found to bypass the realigned Upper River Ellen in all AEP events of a larger magnitude than the 10% AEP event, resulting in flood inundation of the surrounding agricultural fields.

Design Fix 1 also resulted in increased flood risk in the downstream reach. Flood extent was found to increase slightly in all simulated events, with both the 1% AEP event and the 1% AEP +CC event increasing flood depths at the single property at the Old Mill in Ireby.

C.6.3 Design Fix 2 Results

With Design Fix 2 in place, water levels in the upstream floodplain of the Upper River Ellen were found to reduce. Similar to Design Fix 1, flood inundation of the upstream floodplain of the Upper River Ellen was found to be removed during the 50% AEP event. Although flood inundation of the upstream floodplain remained in all other AEP events, flood depths were found to reduce for the majority of the upstream floodplain when compared to baseline.

However, in the downstream reach flood extents/depths were found to slightly increase throughout the area in all events. This resulted in increases in flood inundation at the single property at the Old Mill in Ireby during both the 1% AEP event and the 1% AEP +CC by 23mm and 19mm respectively.

Figure C-20 shows the water level difference map produced for the 1% AEP +CC event between the Baseline and Design Fix 2 scenarios in the downstream domain. The dominating yellow colour indicates flood levels are predicted to increase by 10mm to 50mm for this event.

Water level difference maps for all simulated events are presented in Section C.10 of this appendix. Water level difference maps were not produced for the upstream domain due to the upstream 2D domain not being comparable between baseline and design, although maximum flood depths and extents are presented in Section C.9 of this appendix.

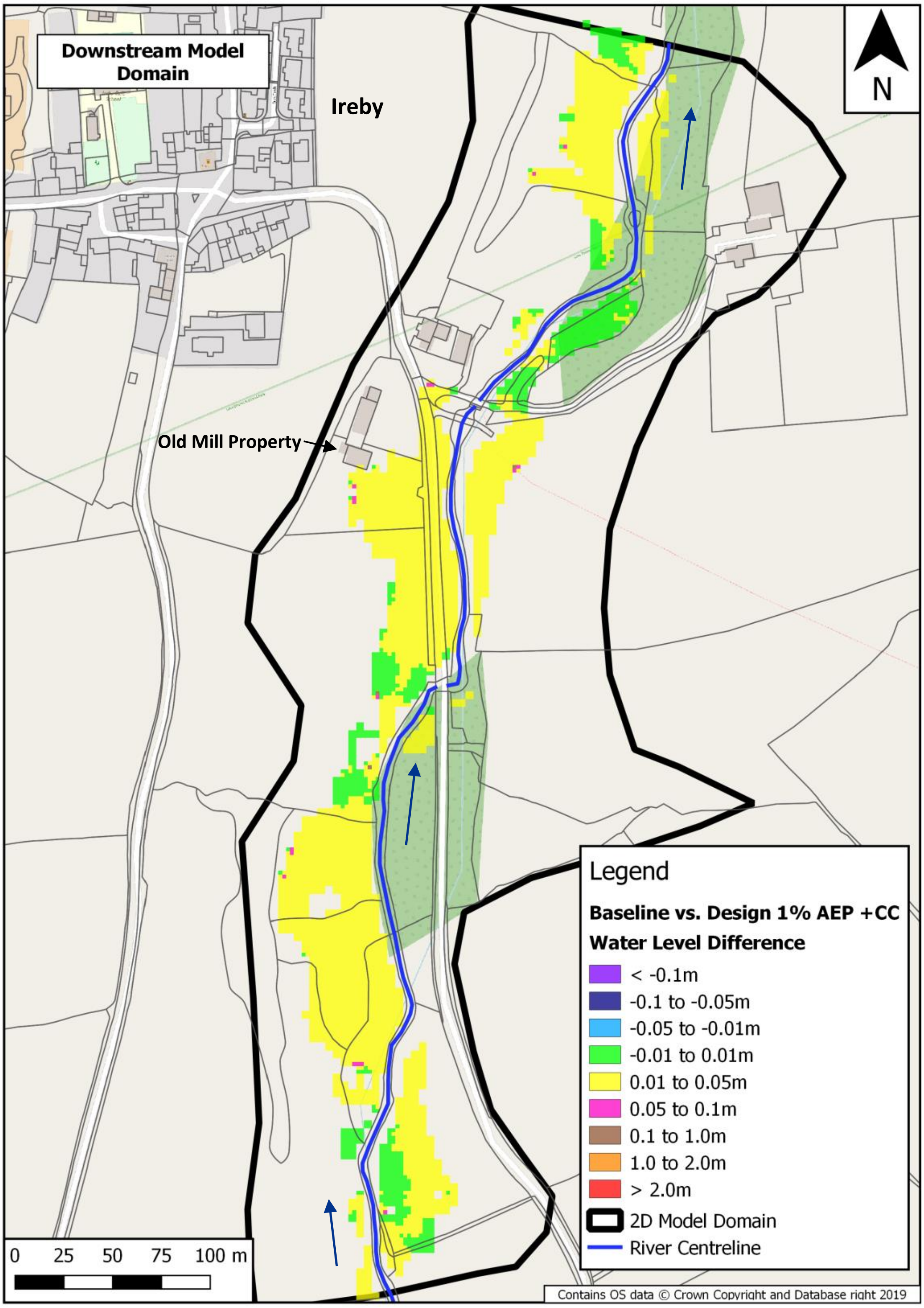


Figure C-20: Design Fix 2 Water Level Difference (Design minus Baseline) for the 1% AEP +CC flood event

Increases in downstream flood extent and depth as described above, is a direct result of the increase peak pass-forward flow due to the removal of the hydrograph attenuation provided by the existing reservoirs. Figure C-21 shows a comparison of hydrographs downstream of the existing Chapelhouse Reservoir dam. Peak discharge is shown to increase for all events when comparing the Design to the Baseline scenario. For example, in the 1% AEP +CC event, peak discharge at this location increases from 16.58m^3/s in the Baseline to 17.55m³/s in the Design scenario. Additionally, the timing of the peak is shown to be earlier as the attenuation of the reservoirs is removed.

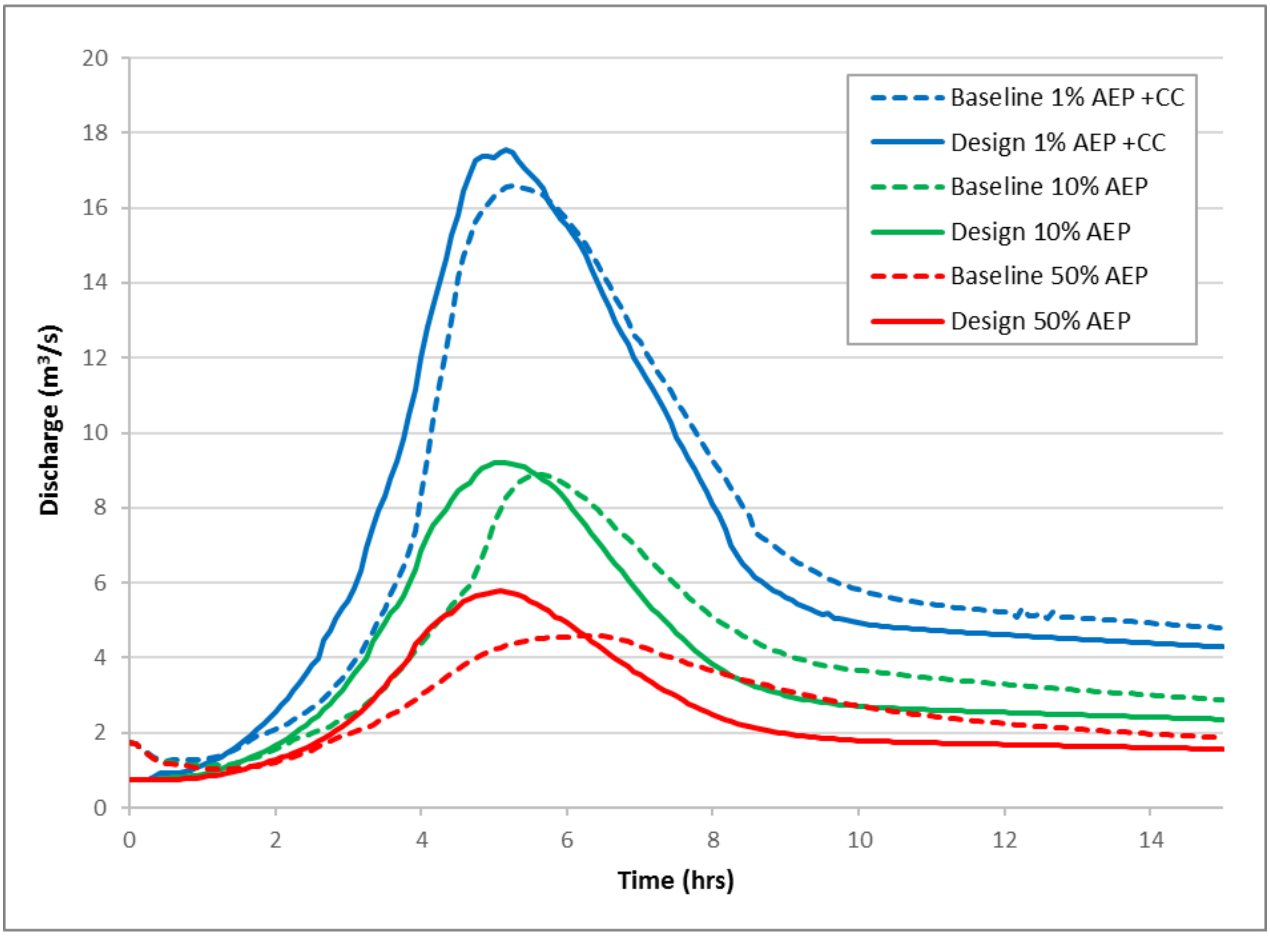


Figure C-21: Design Fix 2 In-Channel Flow Downstream of the Existing Chapelhouse Reservoir Dam

Figure C-22 shows the same comparison for the downstream reach at the location of the flooded property at Ireby. Similarly, peak discharge is shown to be increased in each event following the implementation of Design Fix 2. For example, in the 1% AEP +CC event, peak discharge at this location increases from 29.35m³/s in the Baseline to 30.25m³/s in the Design scenario

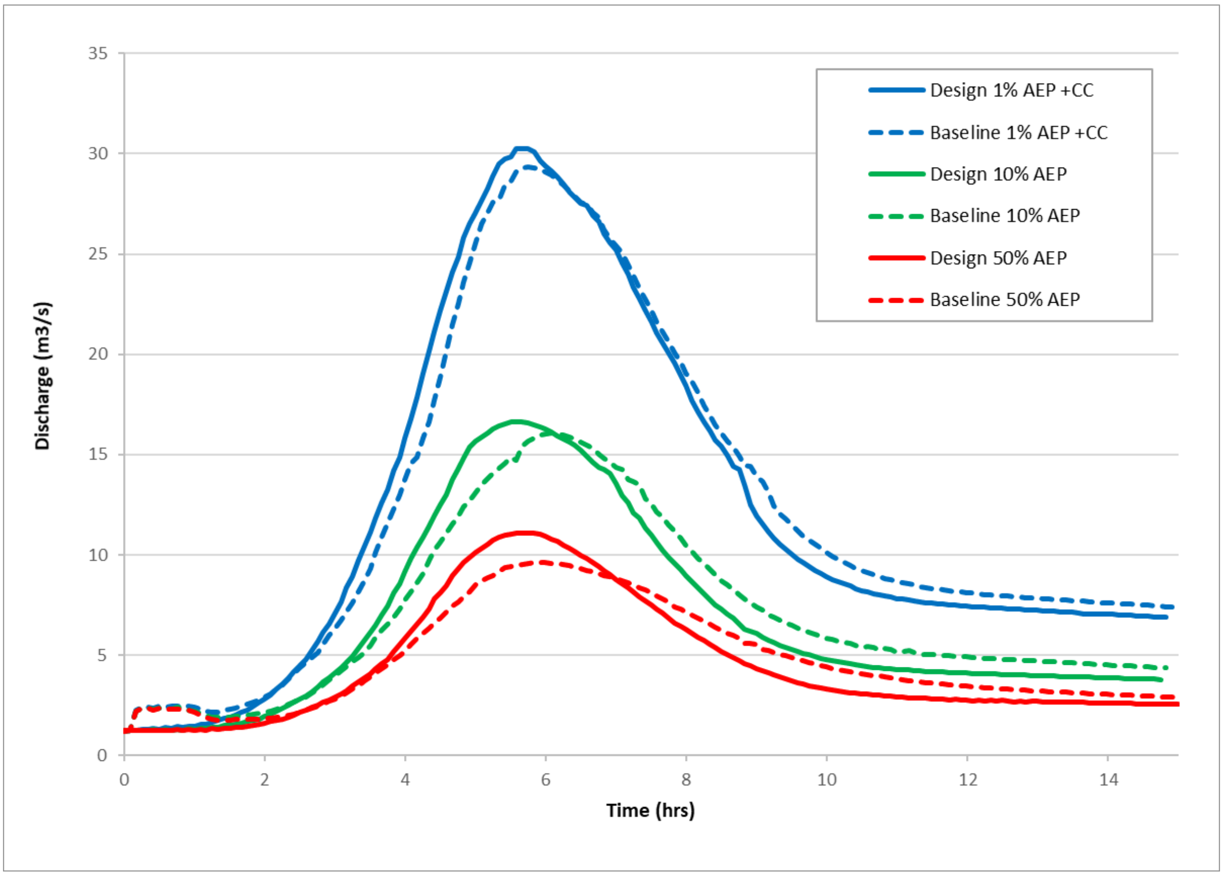


Figure C-22: Design Fix 2 In-Channel Flow within the Downstream Reach at the Location of the Flooded Property at Ireby.

C.6.4 Design Fix 3 Results

Results associated with Design Fix 3: online and offline flood storage options - are not presented in this document as they are superseded by the final outline design presented in the next section.

C.6.5 Final Outline Design Results

With the Final Outline Design in place, water levels in the upstream floodplain of the Upper River Ellen were found to reduce. Similarly to Design Fix 2, flood inundation of the upstream floodplain was found to be removed during the 50% AEP event and reduced across the upstream floodplain during all other events, when compared to baseline.

The offline storage area was found to store flood volumes during all events of equal or greater magnitude than the 10% AEP event. In the 1% AEP +CC event, the maximum depth within the storage area was 2.1m. This filled the storage area to a maximum water level of 189.78m AOD.

As a result of the Final Outline Design, the maximum flood depths at the single property in Ireby were reduced in both the 1% AEP and 1% AEP +CC events by 7mm and 16mm, thereby mitigating the increased flood inundation caused by the removal of the reservoirs. Additionally, maximum flood depths were found to be reduced in the 2% AEP event, although the single property was not inundated during this event. Similarly to Design Fix 2, the final outline design was found to increase maximum flood depths in the downstream domain during the lower magnitude events (10% and 50% AEP), however no properties were flooded during these events.

Figure C-23 shows the water level difference map produced for the 1% AEP +CC event between the Baseline and Final Design scenarios in the downstream domain. The predominantly light blue colour indicates flood levels are predicted to decrease by 10mm to 50mm for this event.

Maximum flood depths and extents for all Final Outline Design scenarios are given in Section C.9 of this report, whereas water level difference maps between the final design and the baseline scenario are provided in Section C.10. Water level difference maps were not produced for the upstream model domain due to the upstream 2D domain not being comparable between baseline and design.

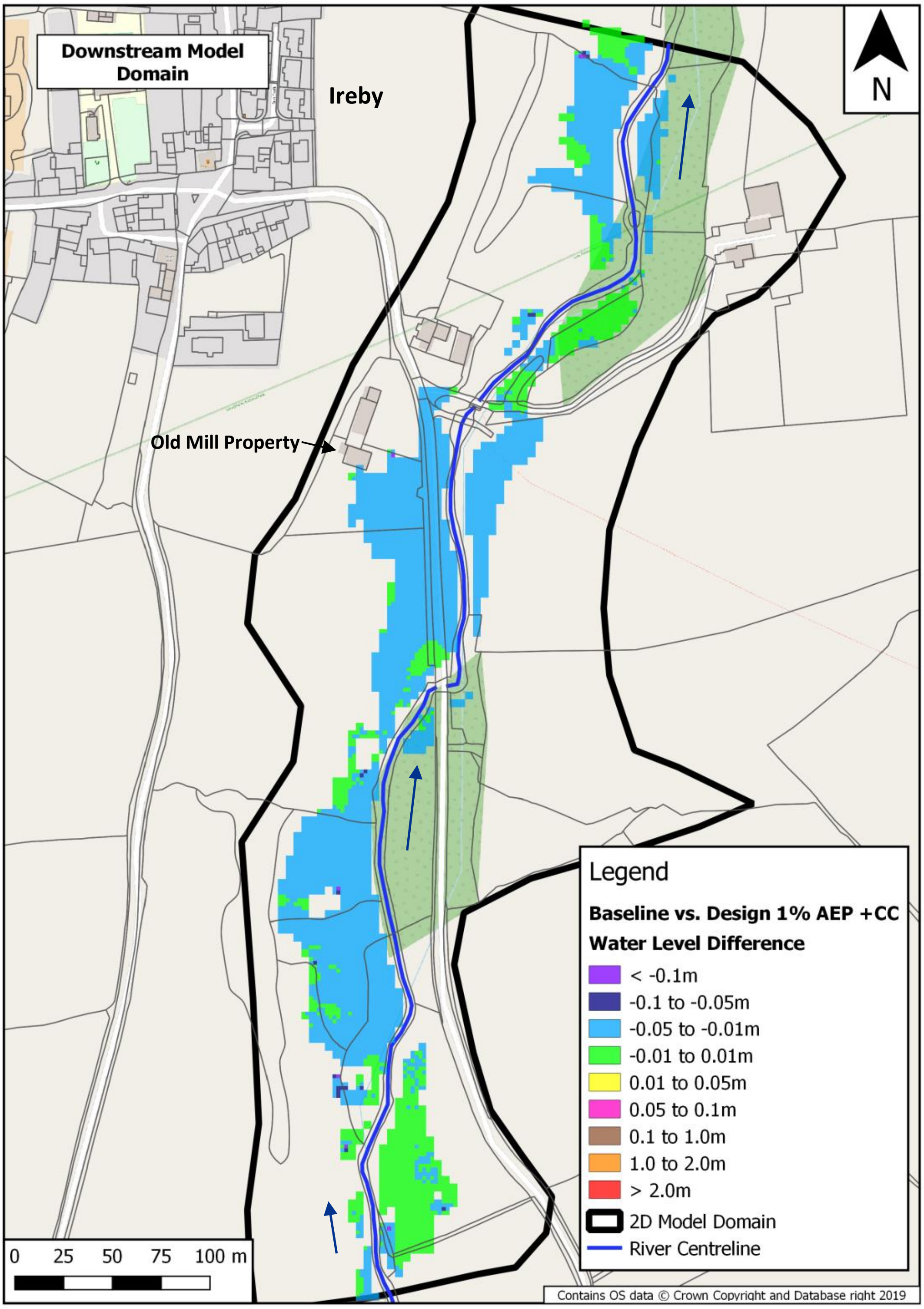


Figure C-23: Final Outline Design Water Level Difference for the 1% AEP +CC Flood Event

As a result of the Final Outline Design, the peak pass-forward flow for the 2% AEP, 1% AEP and 1% AEP +CC events decreased due to the attenuation of the flood hydrographs provided by the offline storage area. Figure C-24 shows a comparison of hydrographs downstream of the existing Chapelhouse Reservoir dam between the Design and the Baseline scenario. For example, in the 1% AEP +CC event, peak discharge at this location decreases from 16.58m³/s in the Baseline to 16.36m³/s in the Design scenario. Additionally, the timing of the peak is shown to be later than the baseline.

However, during the lower magnitude events (50% AEP and 10% AEP), the peak pass forward flow was found to increase compared to baseline at this location. In the 50% AEP event, this is because maximum in-channel water levels did not exceed the level required to spill into the offline storage area via the spillway. In the 10% AEP event, maximum water levels were sufficient to spill, however the maximum possible depth of storage in the offline storage area during this event was 100mm and therefore did not provide sufficient attenuation.

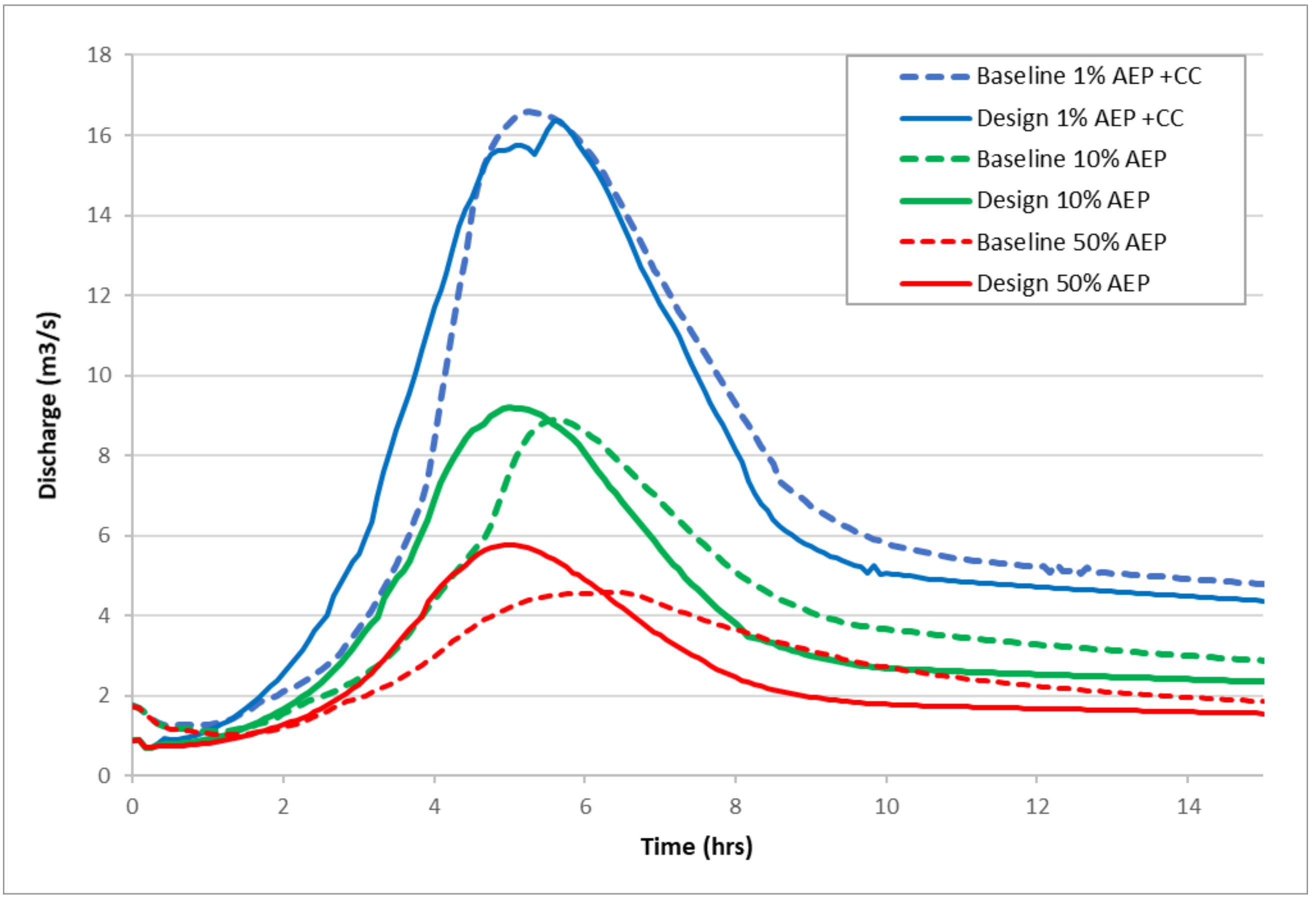


Figure C-24: Final Outline Design In-Channel Flow Downstream of the Existing Chapelhouse Reservoir Dam

Figure C-25 shows the same comparison for the downstream reach at the location of the flooded property at Ireby. Similarly, peak discharge is shown to be decreased in the 1% AEP +CC event following the implementation of the Final Outline Design. For example, in the 1% AEP +CC event, peak discharge at this location reduces from 29.35m³/s in the Baseline to 28.71m³/s in the Design scenario. This decrease in peak discharge was also found in both the 1% and 2% AEP events, whereas peak discharge was found to increase under design scenario in the 10% and 50% AEP events.

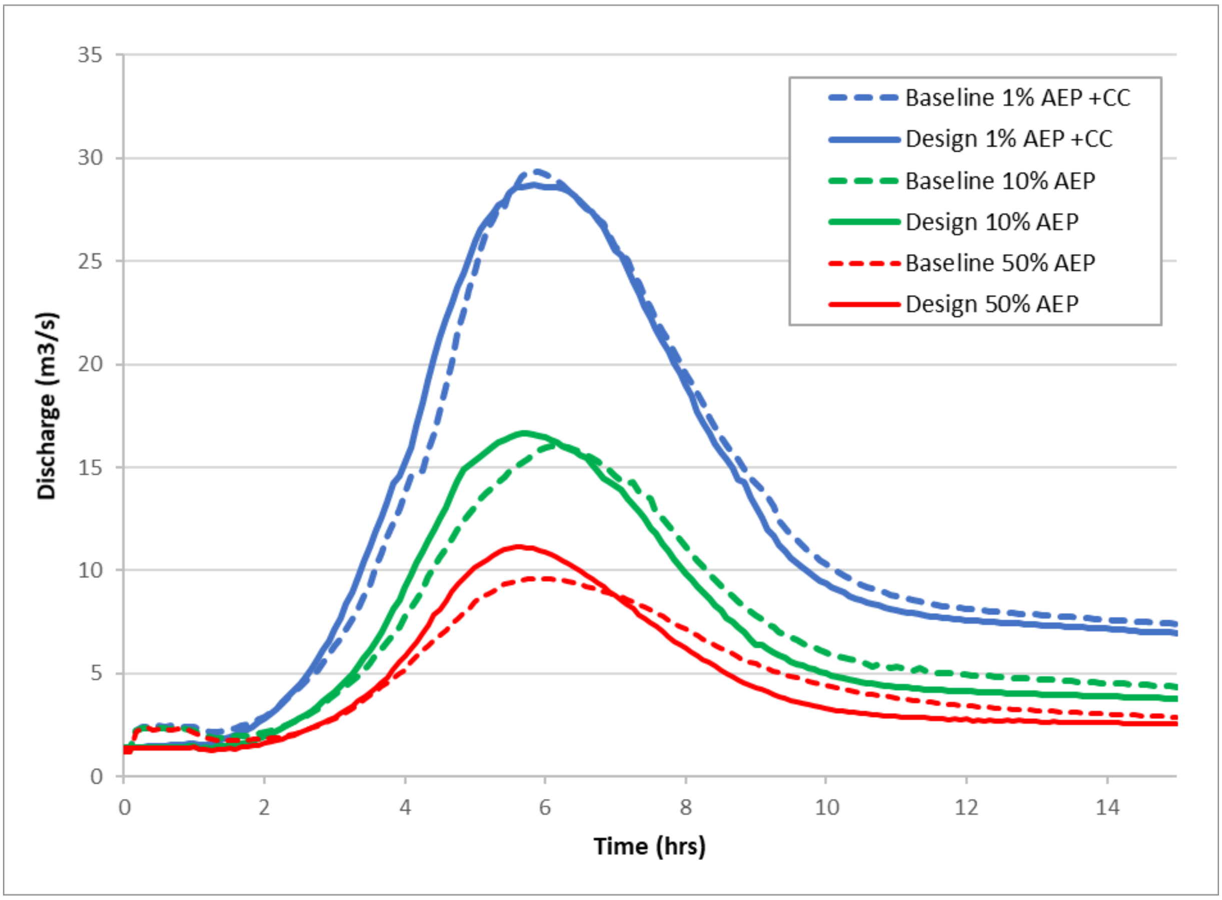


Figure C-25: Final Outline Design In-Channel Flow within the Downstream Reach at the Location of the Flooded Property at Ireby.

C.7 Modelling Assumptions and Limitations

Whilst the most appropriate available information has been used to construct the model, there are uncertainties and limitations associated with it. Efforts have been made to assess and reduce levels of uncertainty in each aspect of the modelling process. Additionally, the sensitivity analysis carried out allows for the understanding of potential uncertainty associated with key model parameters.

The key sources of uncertainty in the model and its limitations are summarised below:

- The accuracy and validity of the hydraulic model results are heavily dependent on the accuracy of the hydrological inflow data included in the model. The uncertainty related to the hydrological inflows is therefore a limitation of the model results.
- Some cross sections have been extended onto the floodplain using 1m LiDAR data. The LIDAR data is assumed to appropriately represent the floodplain.
- Channel roughness has been assigned using the best available information (site visit photos). The roughness values used are based on available guidance (Chow 1959).
- Hydraulic coefficients for structures have been applied using available guidance within the Flood Modeller software. The dimensions for structures have been based on survey measurements.
- The accuracy and validity of the hydraulic model results is heavily dependent on the accuracy of the topographic/bathymetric data included in the model. The most up to date topographic data was used wherever possible.
- The 2D model cell size is 4m, which has been chosen to provide a comprehensive understanding of the flood mechanisms and risk within the area of interests under the baseline and design scenarios.

- No specific model calibration to observed data has been carried out due to a lack of available gauge data records with which to calibrate the model. There is also no Environment Agency Flood Map coverage, meaning model verification to published flood outlines was not possible.
- A key limitation of the modelling carried out is that the assessment is limited to the extent of the River Ellen from Stockdale to Ireby. The impact of the design scenario on flood risk to the communities located downstream of this extent has therefore not been considered; which may require further attention particularly during low magnitude events (<2% AEP), as pass-forward flow is increased during these events. However, key communities such as Blennerhasset, Bulgill and Maryport are respectively located 9km, 18km and 25km downstream of Ireby. Therefore, it is likely that the increased pass-forward flow as a result of the design scenario will be partially attenuated before reaching these areas.

C.8 Conclusion and Recommendations

The results of the modelling analysis carried out to assess the impact of proposed scheme on the existing flood risk from the River Ellen between Stockdale and Ireby can be summarised as follows:

1. In the baseline scenario, there is significant active floodplain along the River Ellen. It is also shown that there is flooding to a single property at the Old Mill in Ireby.

2. The removal of all impounding infrastructures associated with Over Water and Chapelhouse Reservoir together with the realignment of the Upper River Ellen has the potential to reduce frequency and magnitude of flood risk in vicinity of the proposed scheme.

3. The removal of all impounding infrastructures associated with Over Water and Chapelhouse Reservoir together with the realignment of the Upper River Ellen has the potential to increase frequency and magnitude of flood risk at Ireby; particularly at the Old Mill property.

4. For events of a larger and equal magnitude than a 2% AEP event, this analysis has demonstrated that the provision of a 9680m^3 offline storage area located slightly upstream of Chapelhouse Reservoir footprint would mitigate the increase in flood risk at Ireby as described in point 3 above. However, during events of a lesser magnitude than a 2% AEP event, this analysis has demonstrated that the offline storage area cannot mitigate against this increase in flood risk.

The limitations associated with the modelling carried out have been discussed above. In summary, the modelling accuracy and validity are determined by the incoming topographic and hydrological data and by the assumptions applied to the modelling methodology. A key limitation of the assessment is that there is no consideration of the impact on flood risk to communities downstream of Ireby, which should be noted particularly during events of lower magnitude than the 2% AEP event where pass-forward flow is increased as a result of the design.

During a future detailed design and/or EIA phase of the project, further detailed modelling is recommended. This should include refinement of the model to represent in more details the proposed scheme using ad-hoc topographical survey and detailed design scheme drawings. Additionally, further investigation should be carried out to ensure that the increased pass-forward flow as a result of the final outline design during the low magnitude events, has no detrimental impact on flood risk to any communities located downstream of Ireby.

C.9 Flood Maps

C.9.1 Baseline

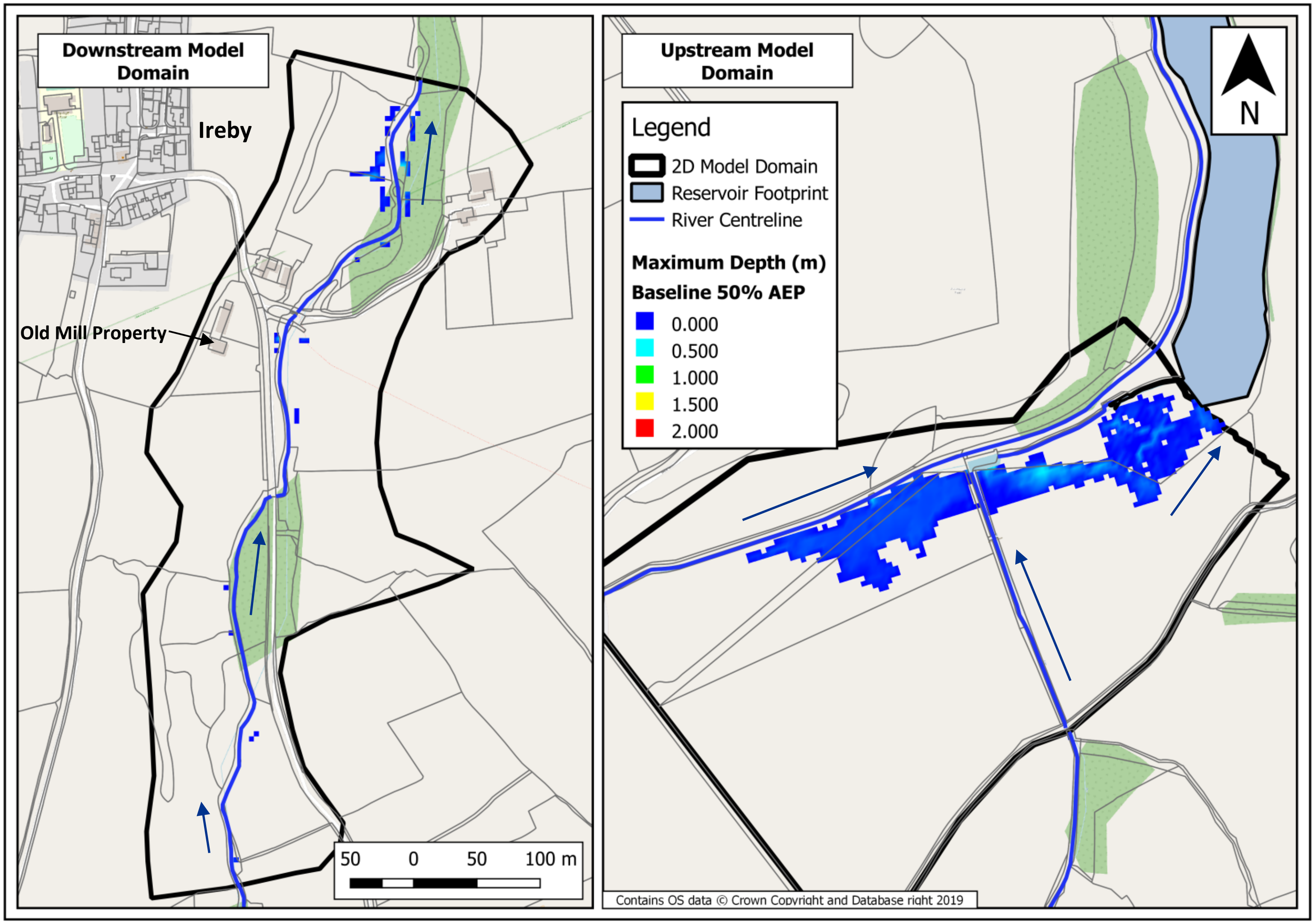


Figure C-26: Baseline Maximum flood depth for the 50% AEP Event

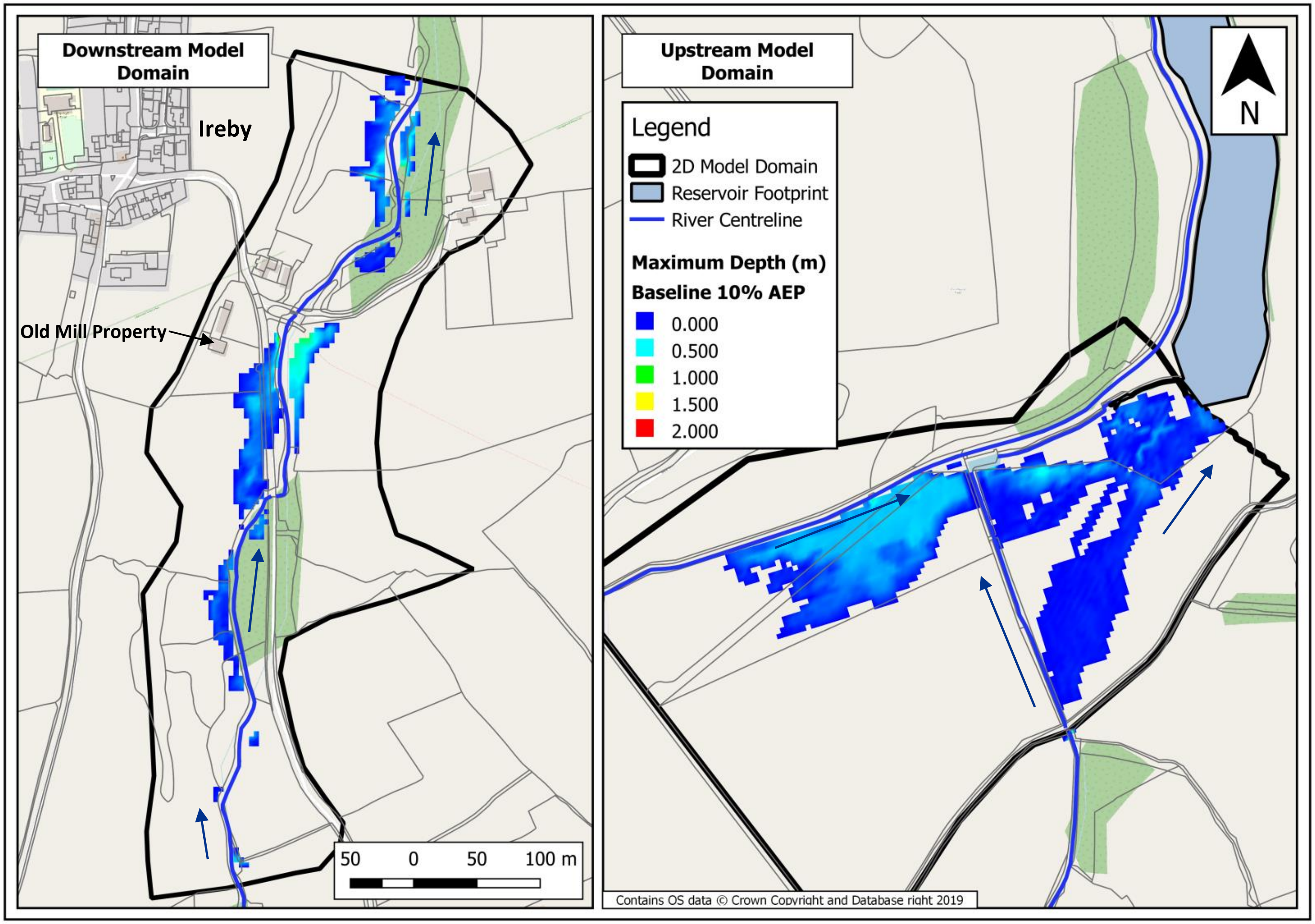


Figure C-27: Baseline Maximum flood depth for the 10% AEP Event

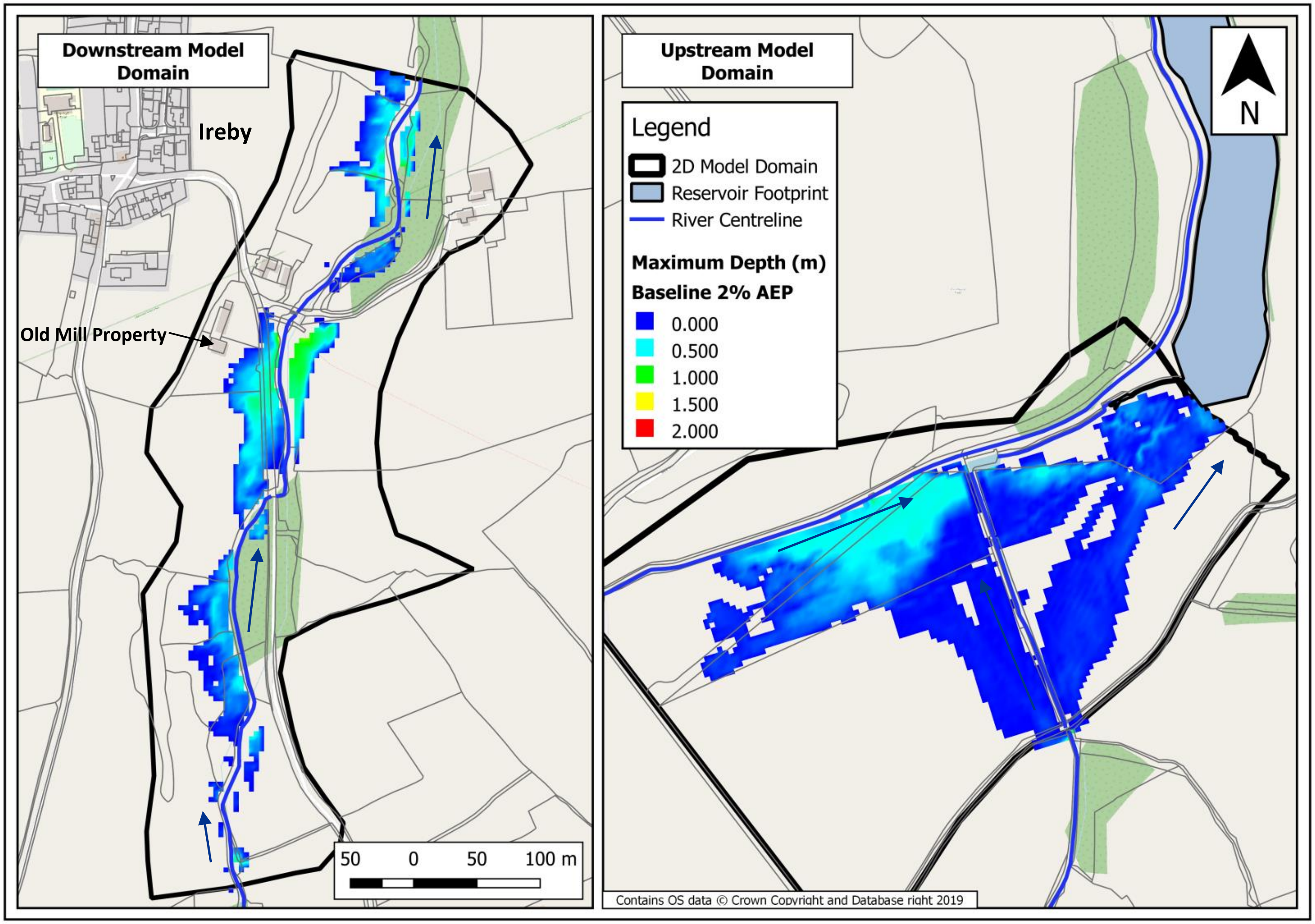


Figure C-28: Baseline Maximum flood depth for the 2% AEP Event

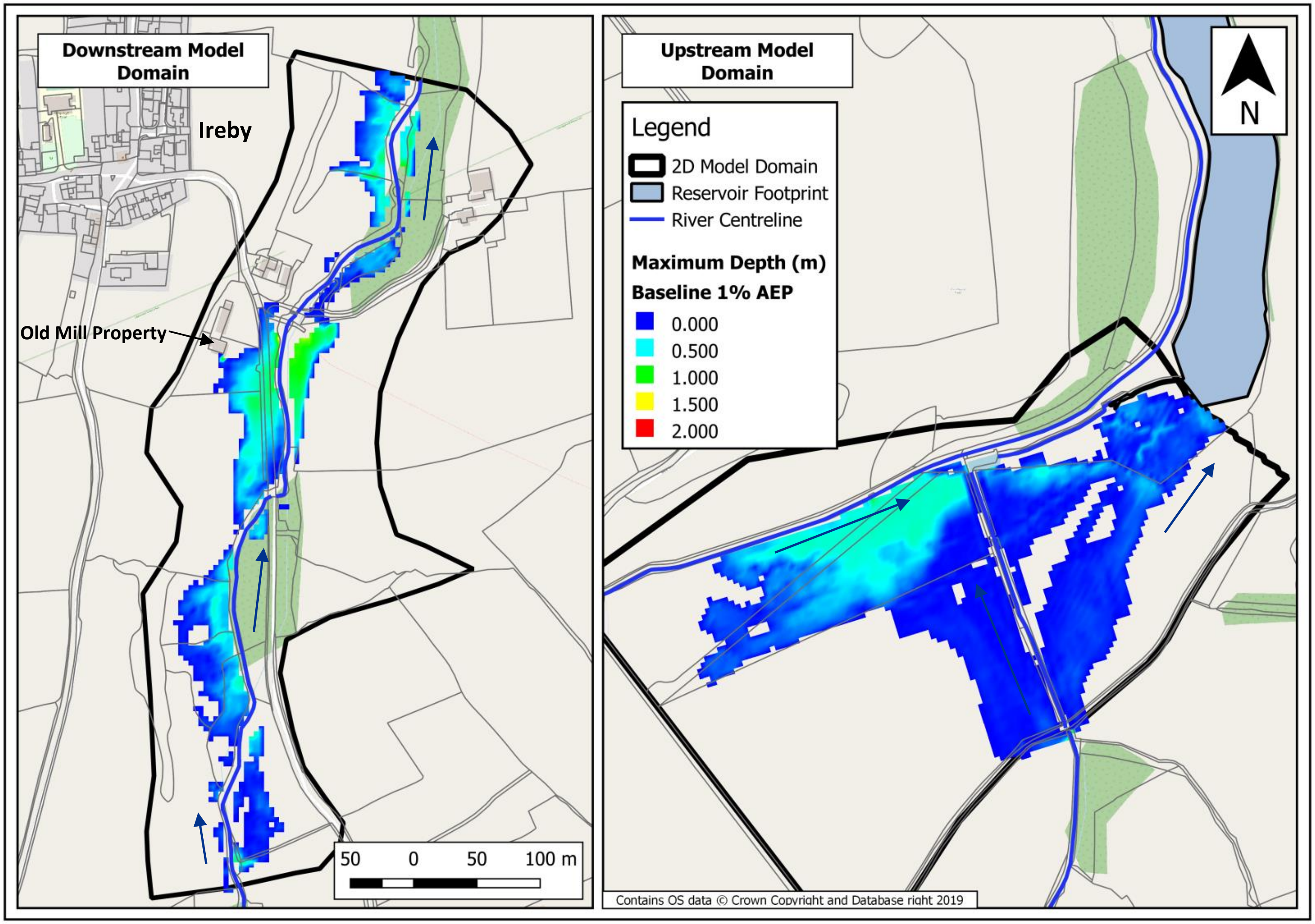


Figure C-29: Baseline Maximum flood depth for the 1% AEP Event

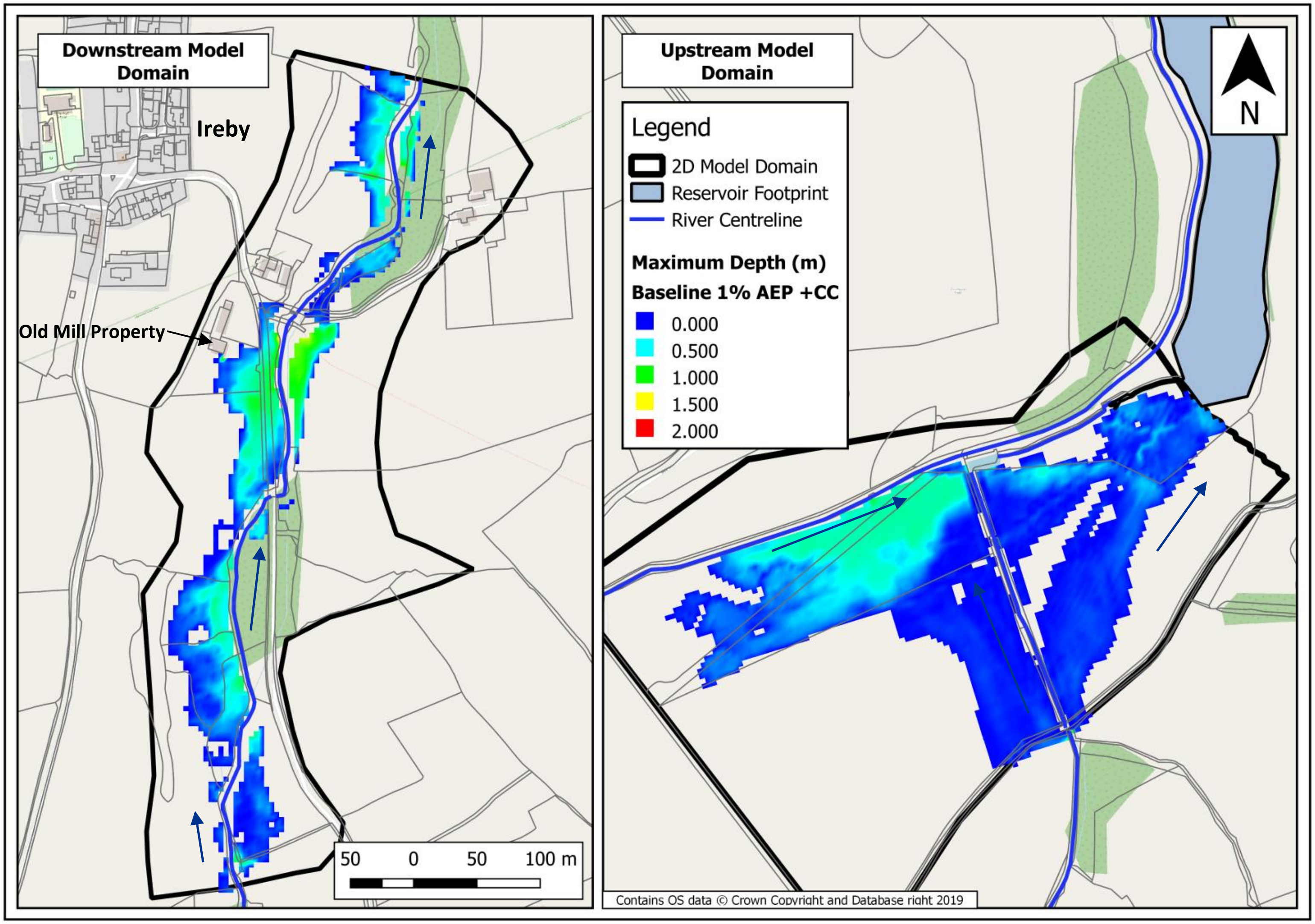


Figure C-30: Baseline Maximum flood depth for the 1% AEP Event +CC

C.9.2 Design Fix 2

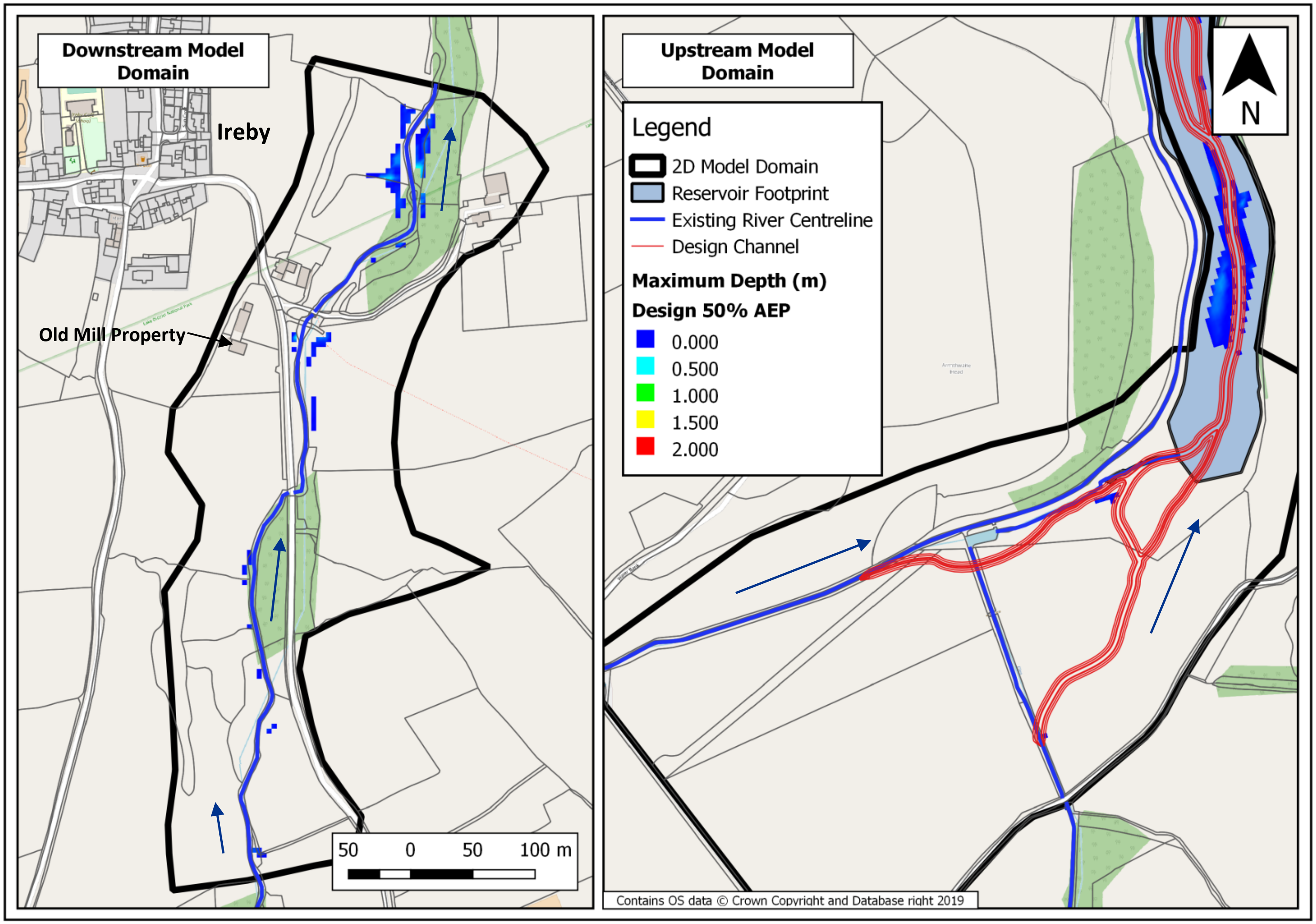


Figure C-31: Design Fix 2 Maximum flood depth for the 50% AEP Event

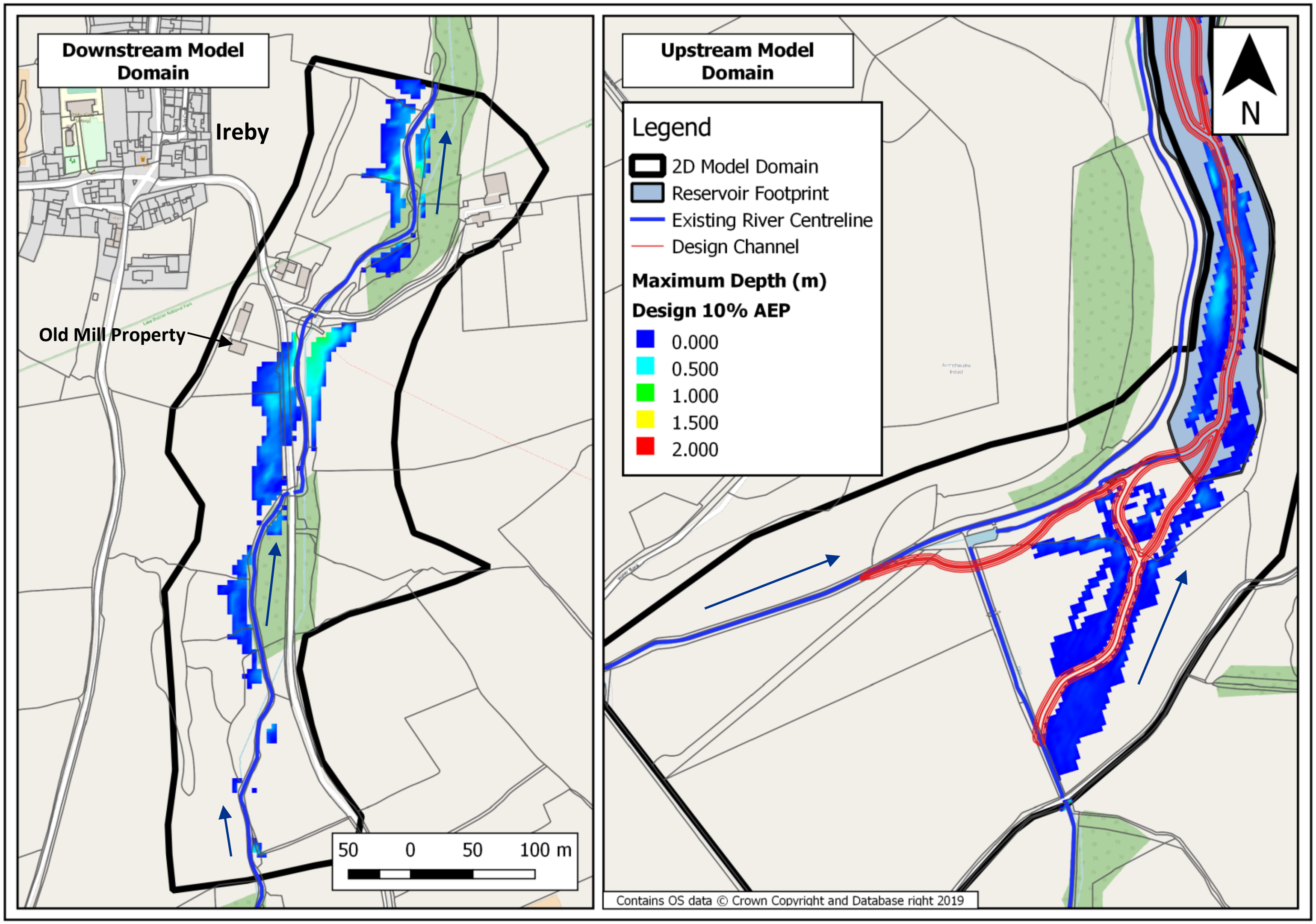


Figure C-32: Design Fix 2 Maximum flood depth for the 10% AEP Event

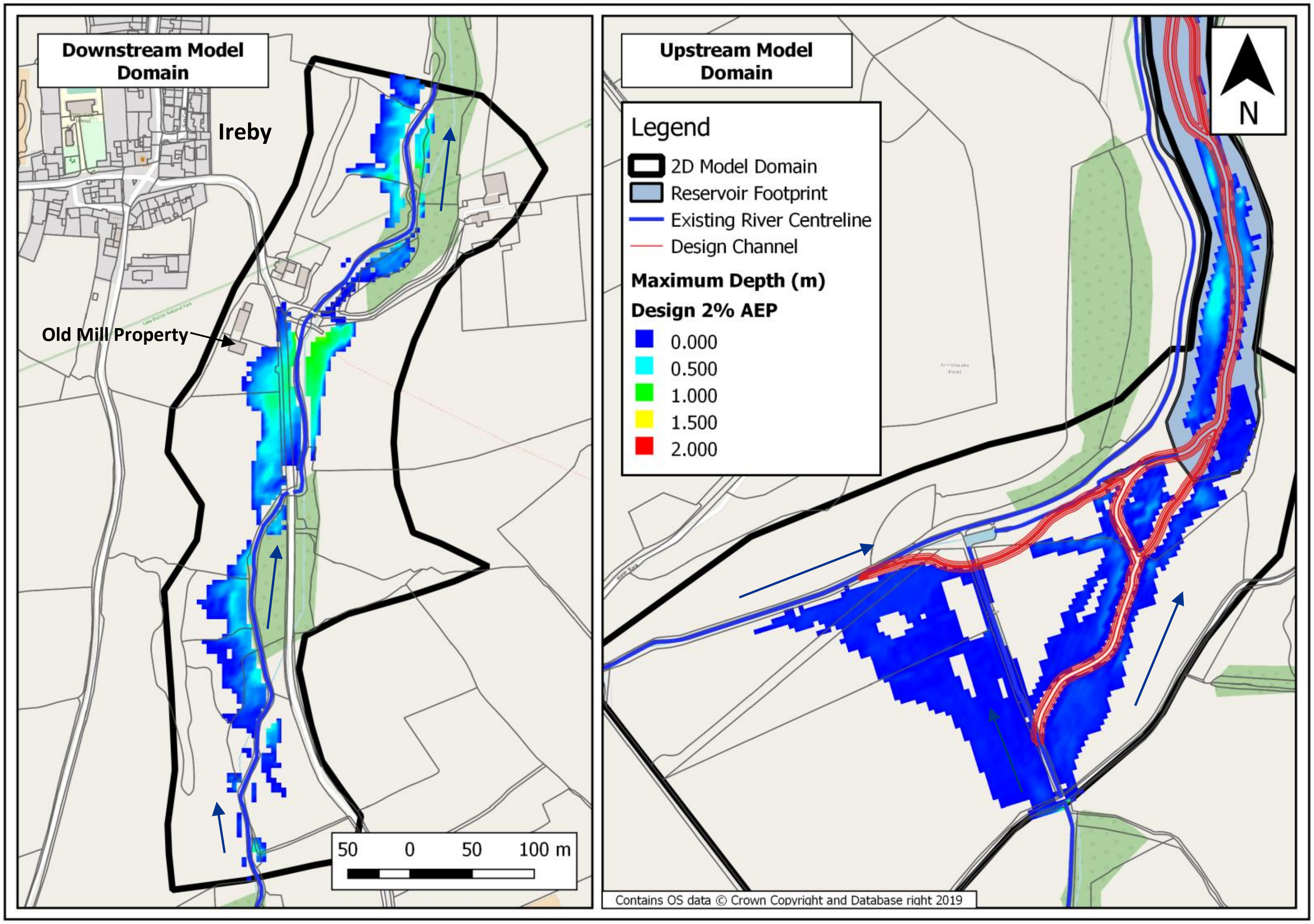


Figure C-33: Design Fix 2 Maximum flood depth for the 2% AEP Event

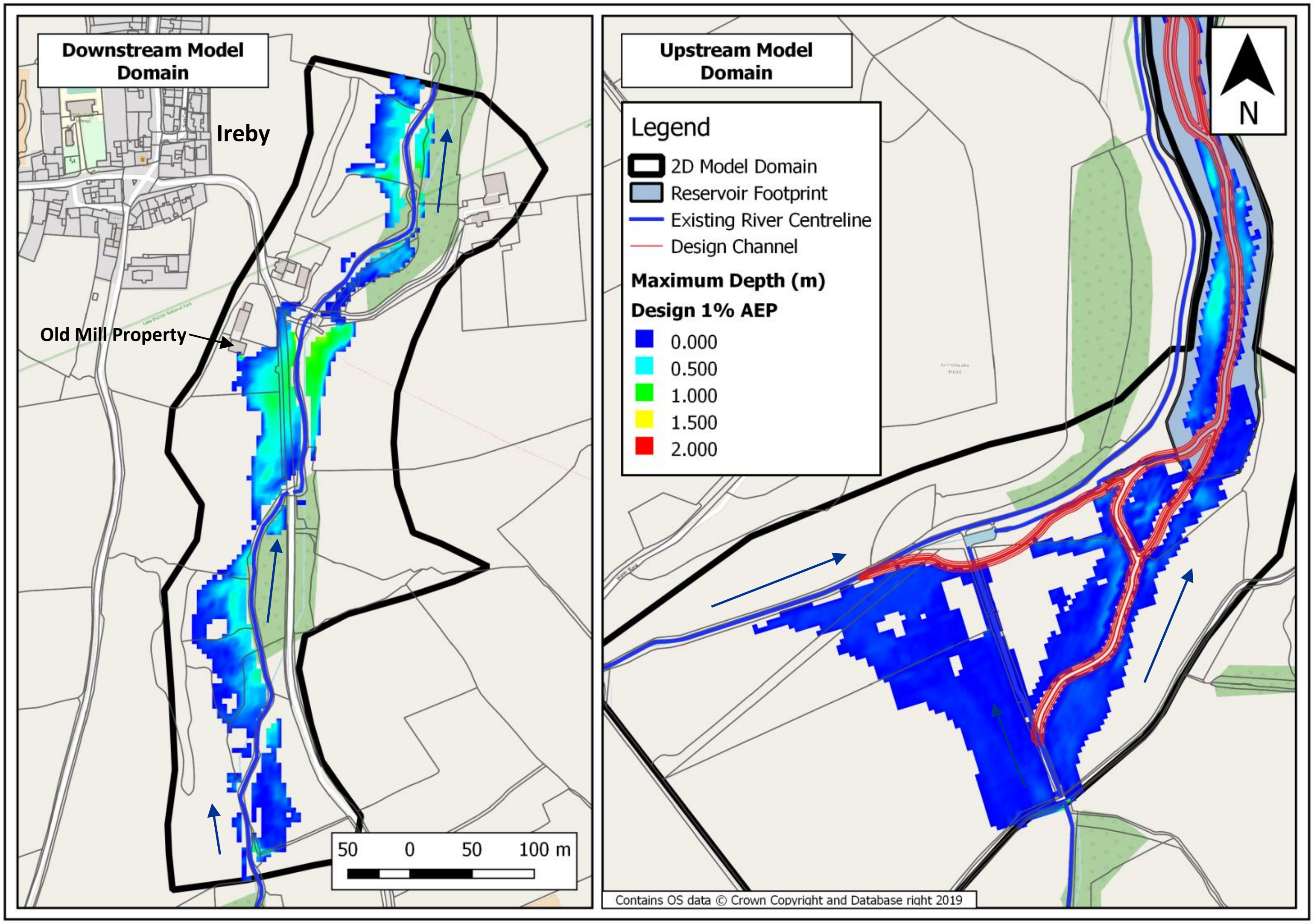


Figure C-34: Design Fix 2 Maximum flood depth for the 1% AEP Event

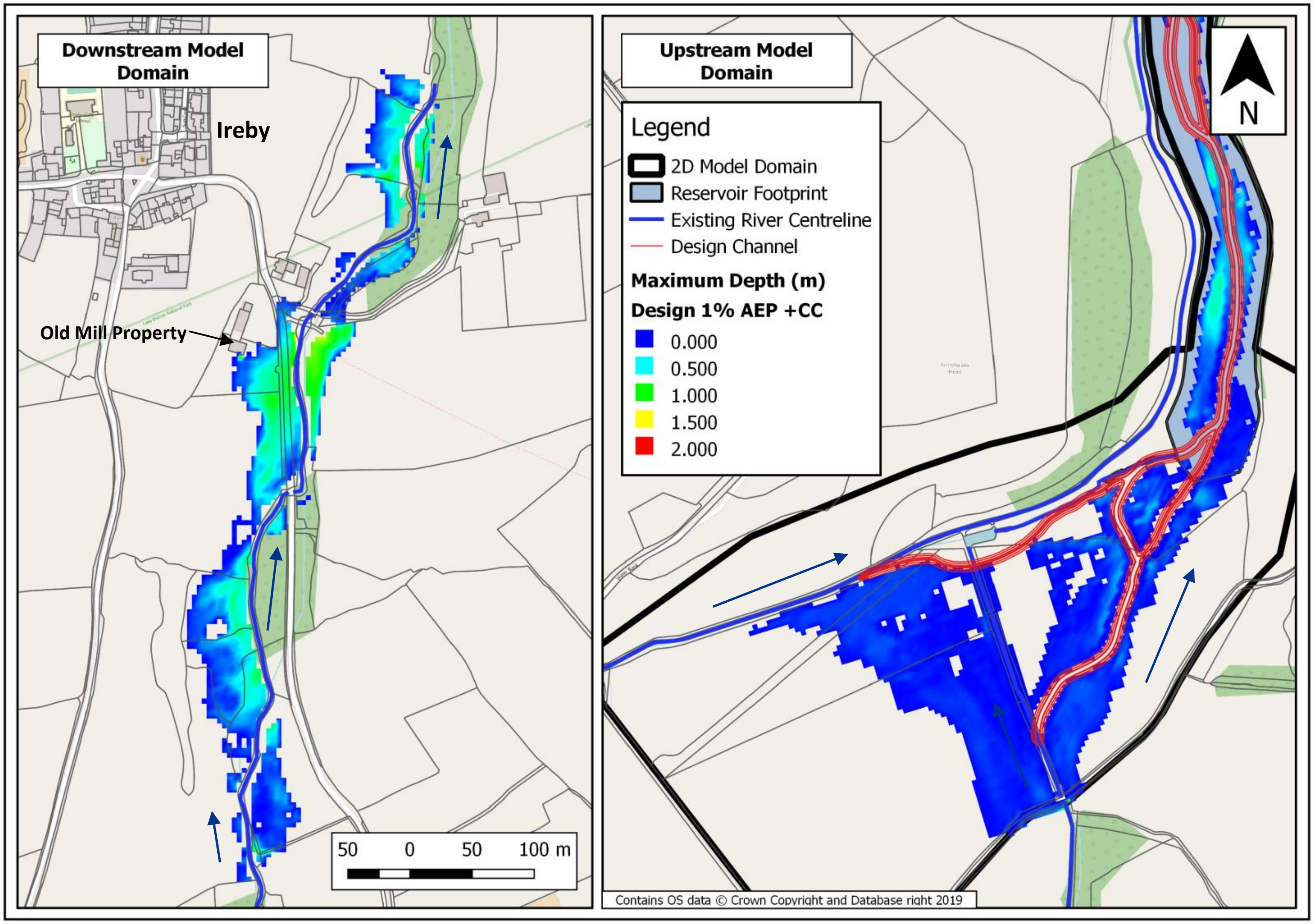


Figure C-35: Design Fix 2 Maximum flood depth for the 1% AEP +CC Event

C.9.3 Final Outline Design

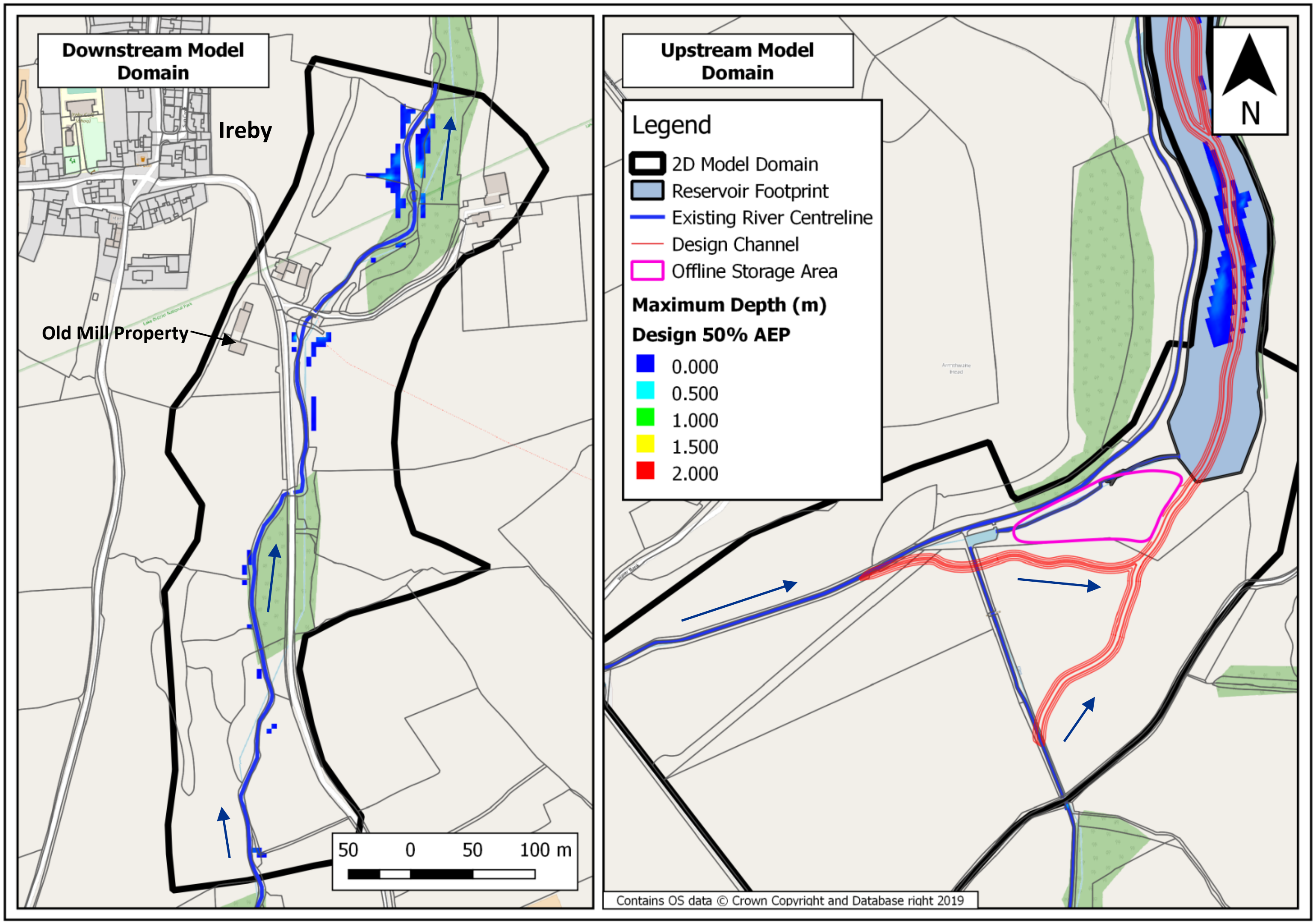


Figure C-36: Final Outline Design Maximum flood depth for the 50% AEP Event

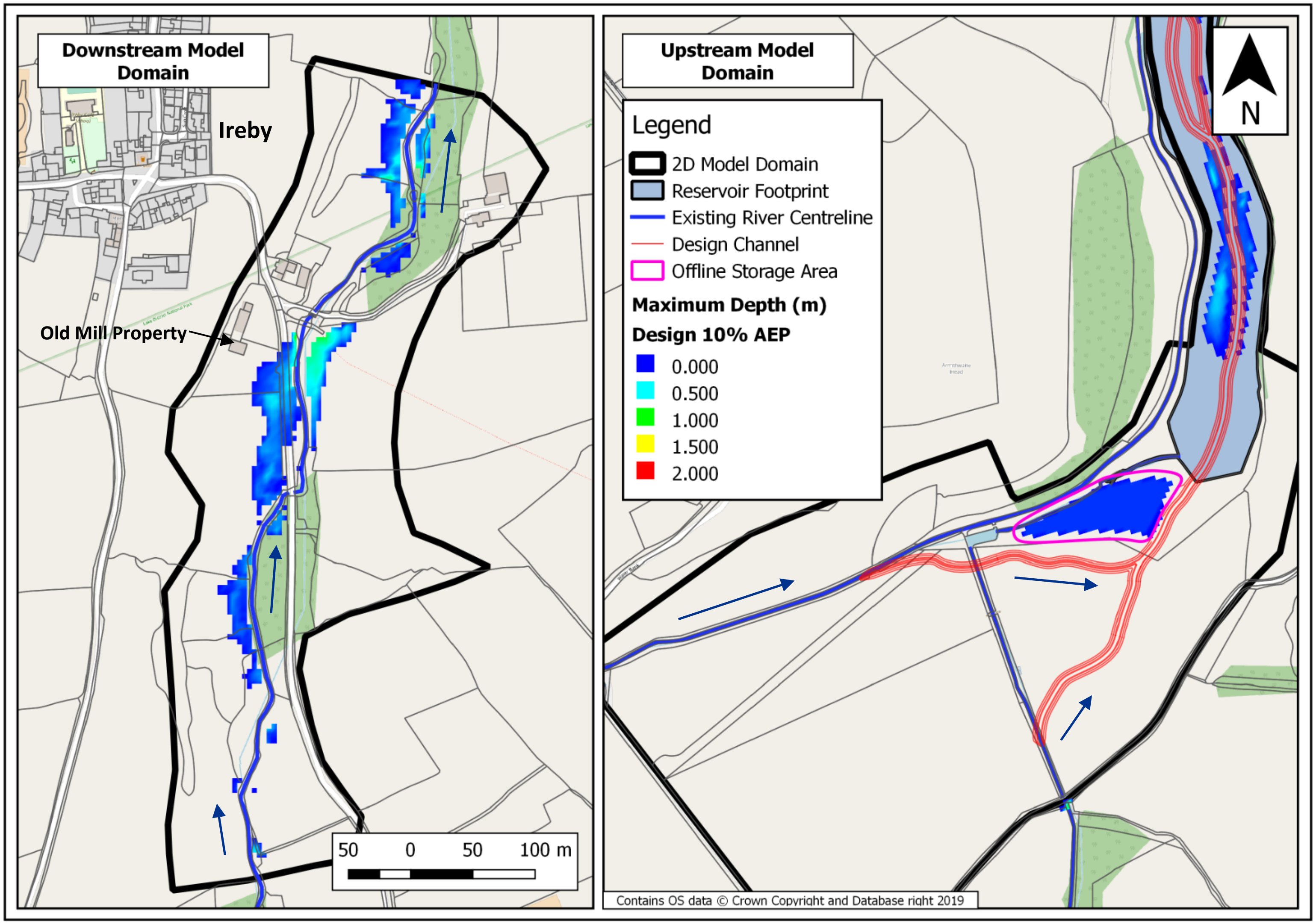


Figure C-37: Final Outline Design Maximum flood depth for the 10% AEP Event

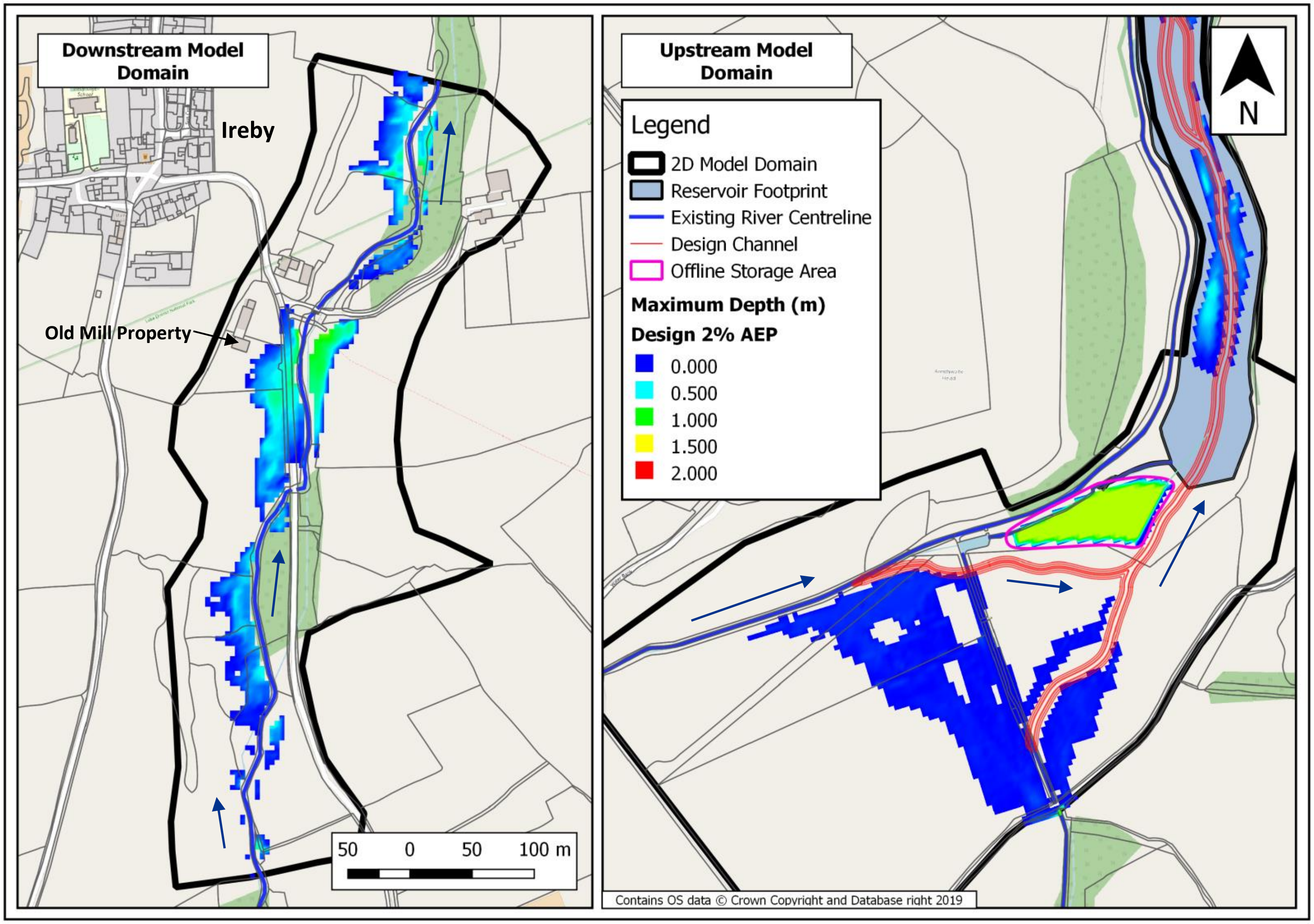


Figure C-38: Final Outline Design Maximum flood depth for the 2% AEP Event

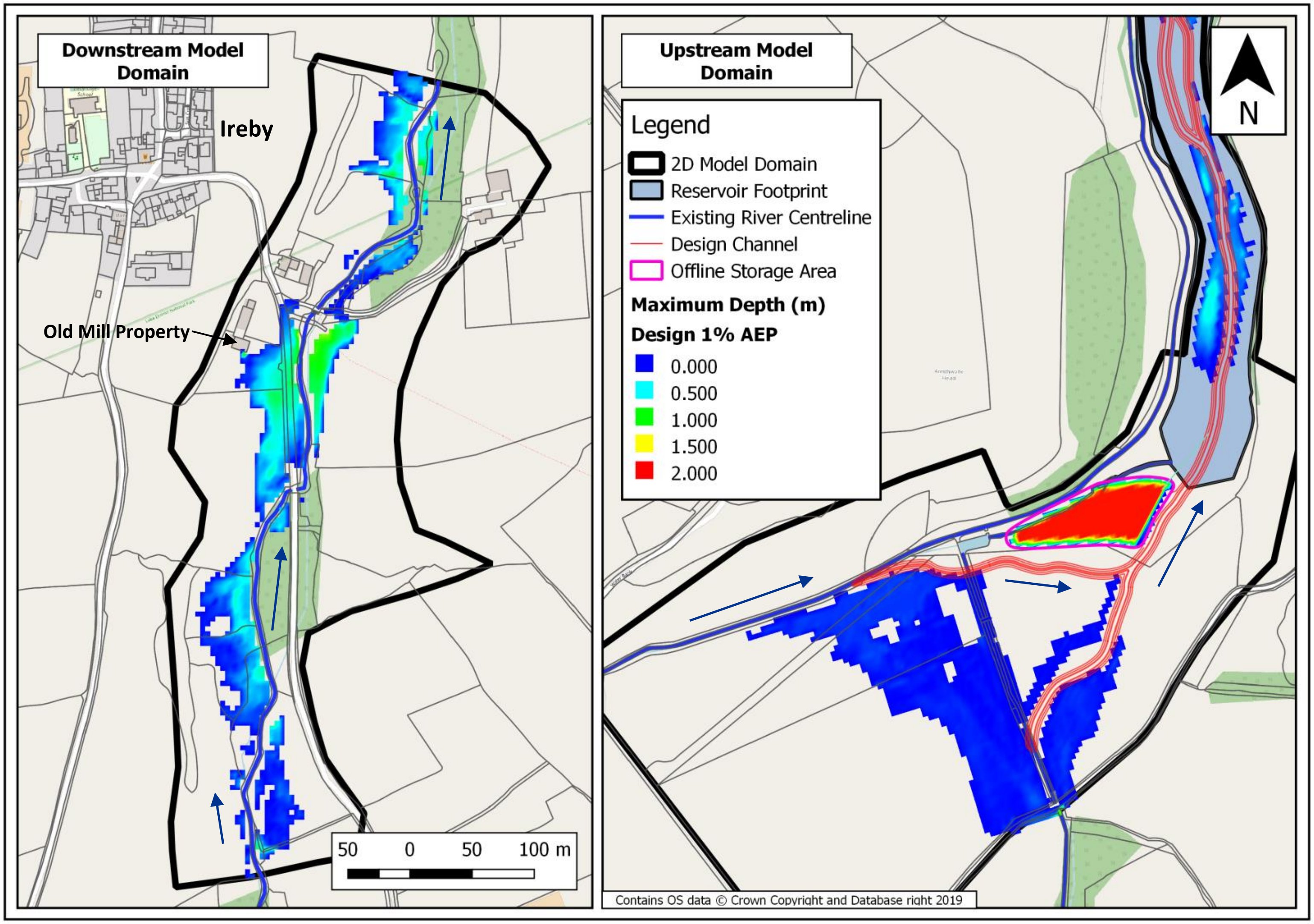


Figure C-39: Final Outline Design Maximum flood depth for the 1% AEP Event

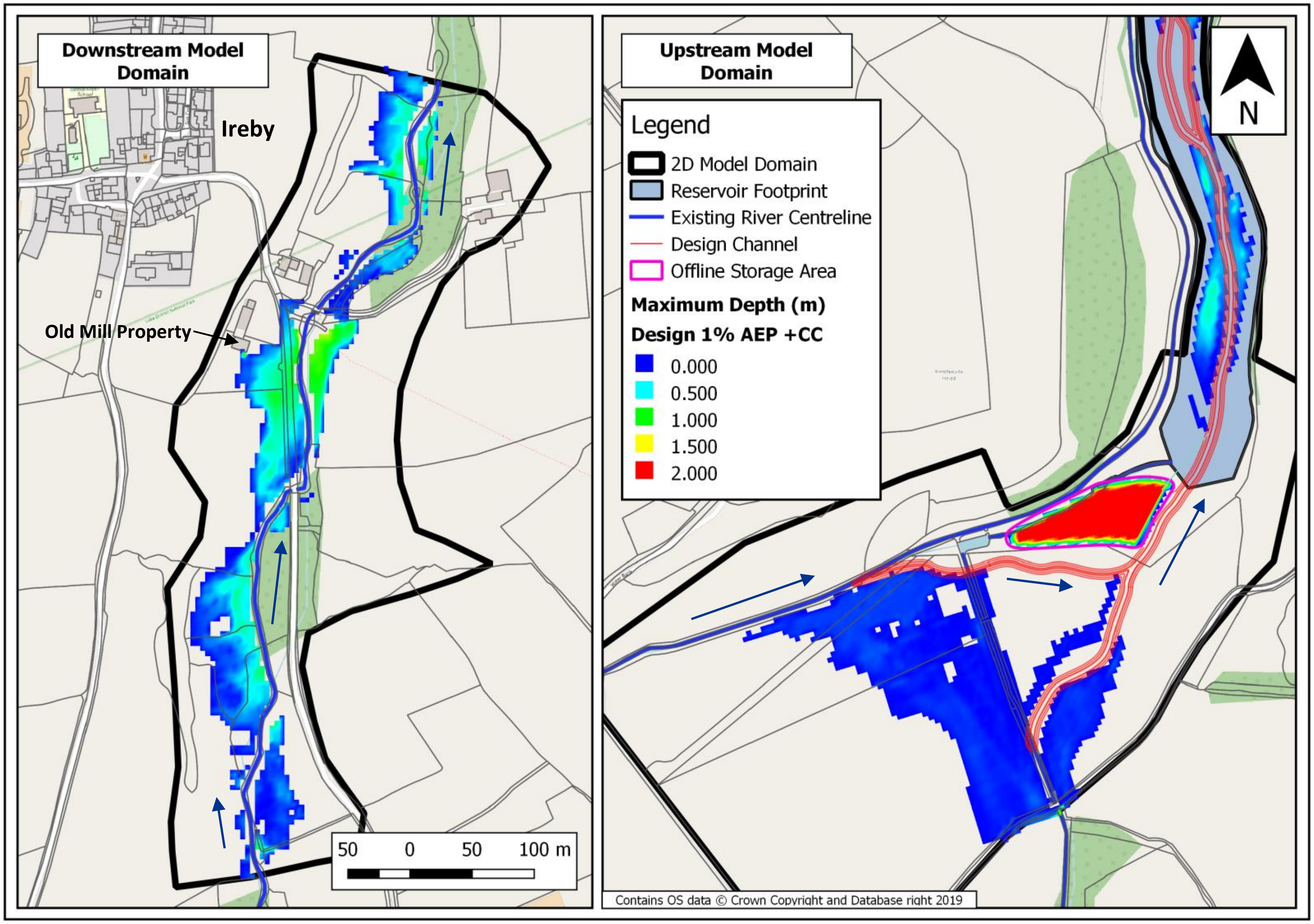


Figure C-40: Final Outline Design Maximum flood depth for the 1% AEP +CC Event

C.10 Flood Difference Maps

C.10.1 Design Fix 2

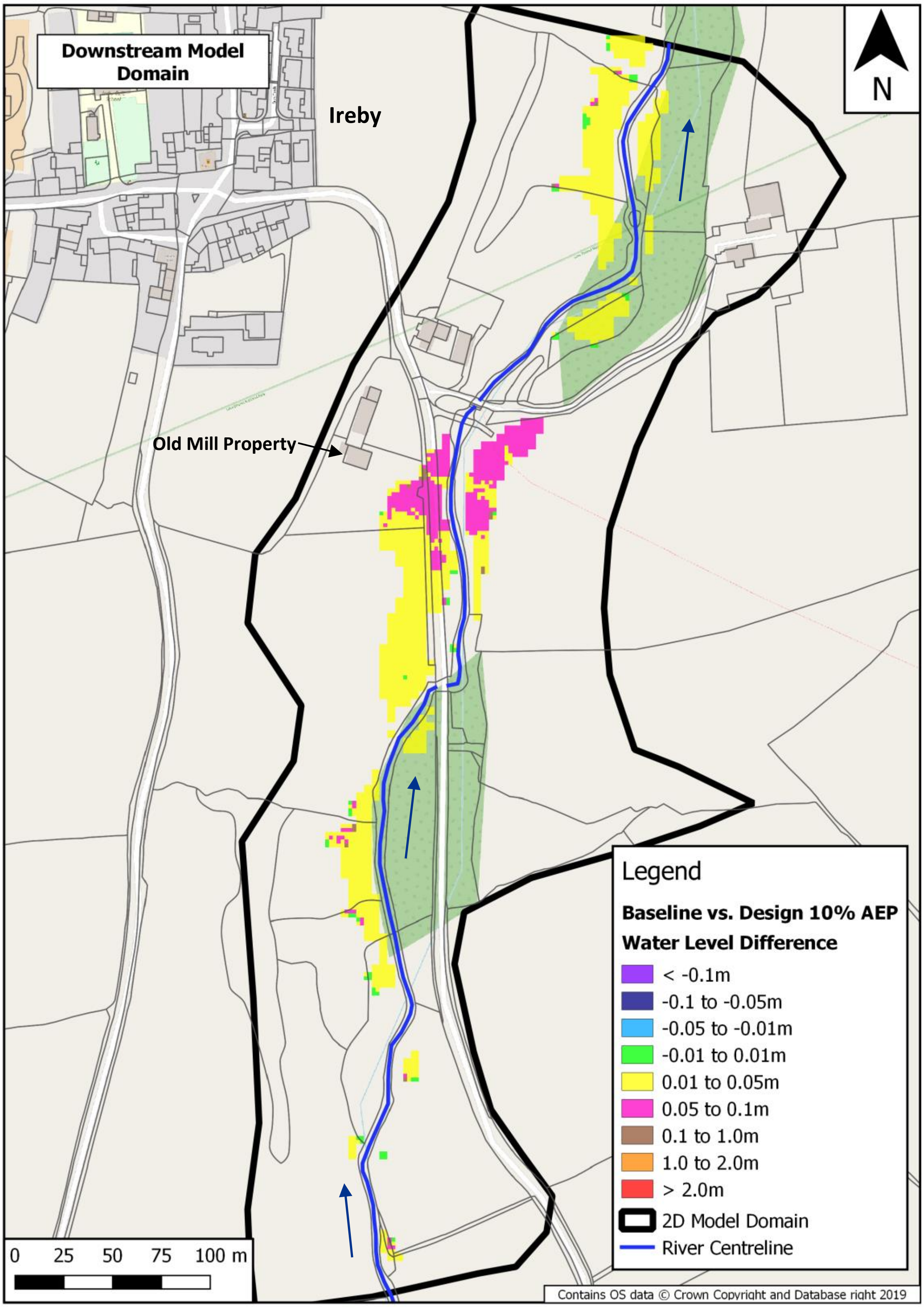


Figure C-41: Design Fix 2 Maximum water level difference map for the 10% AEP Event

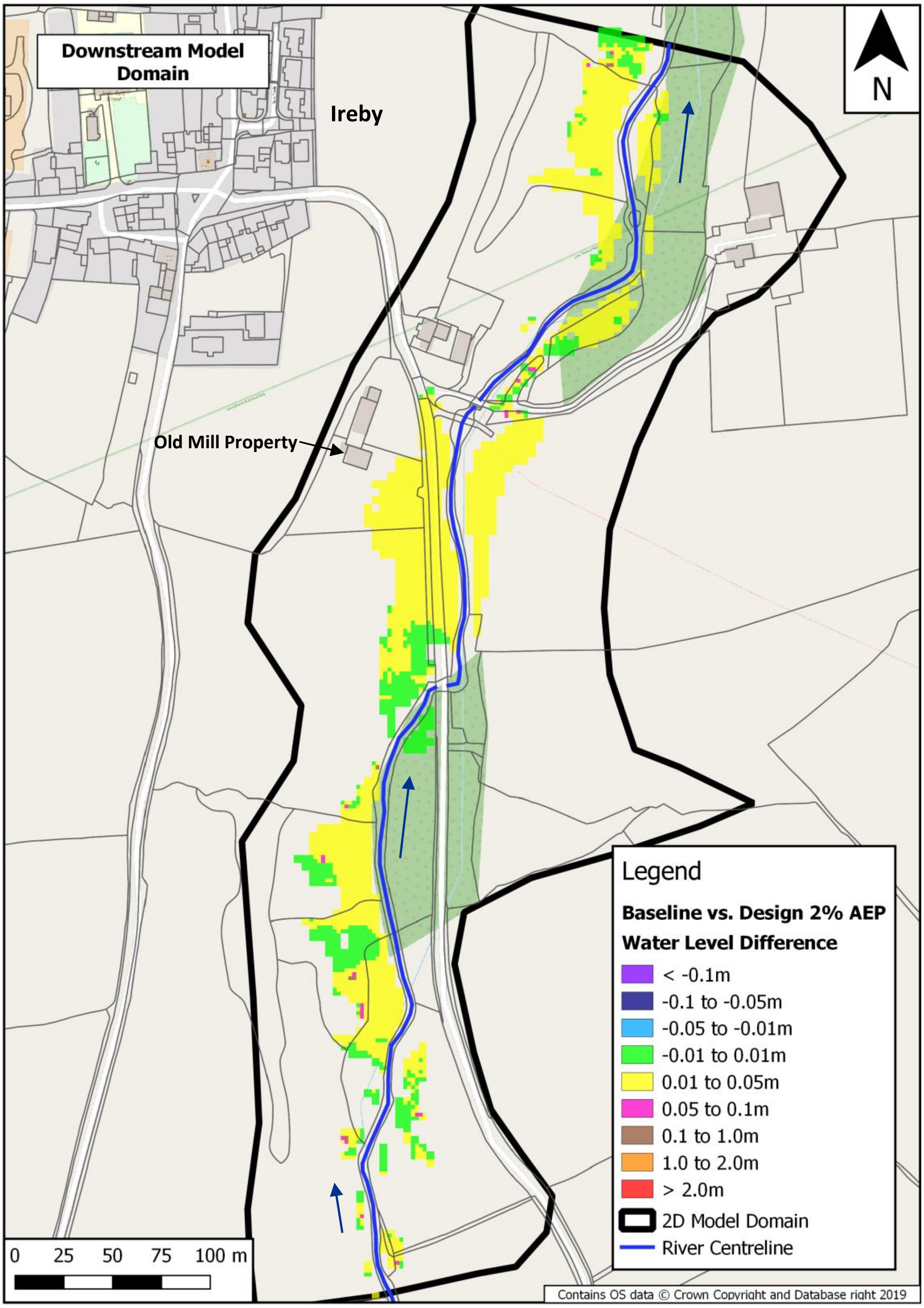


Figure C-42: Design Fix 2 Maximum water level difference map for the 2% AEP Event

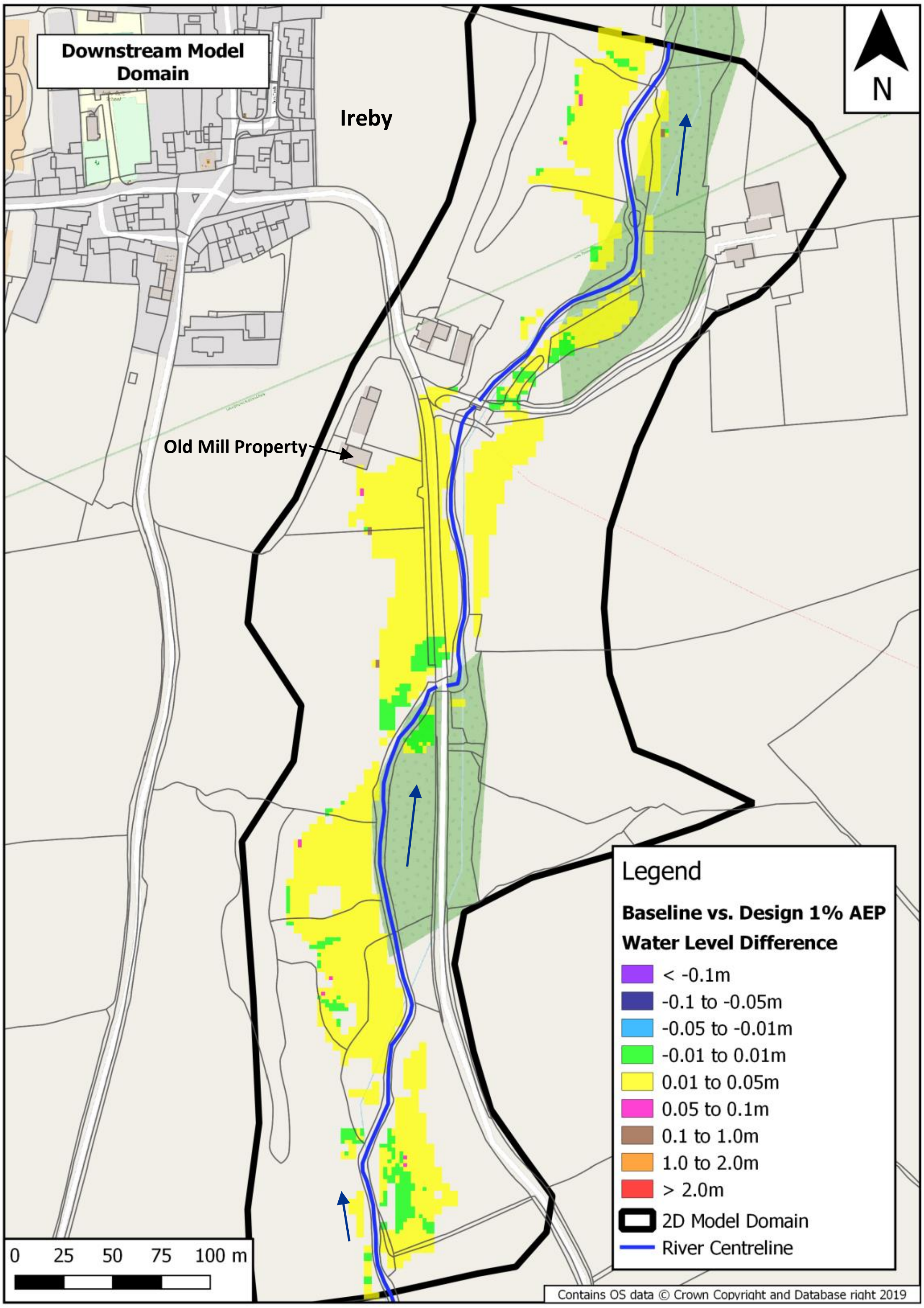


Figure C-43: Design Fix 2 Maximum water level difference map for the 1% AEP Event

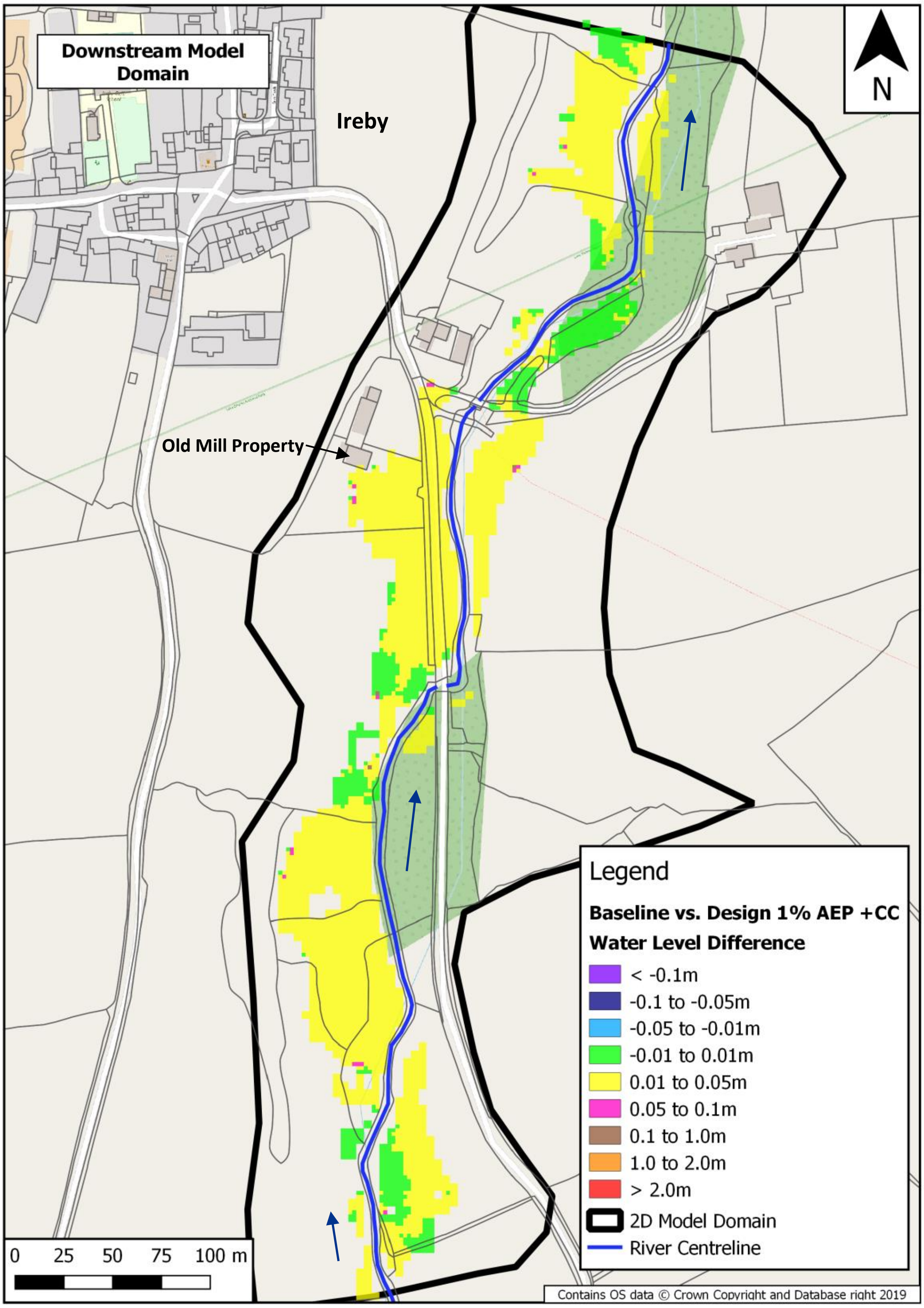


Figure C-44: Design Fix 2 Maximum water level difference map for the 1% AEP Event +CC

C.10.2 Final Outline Design

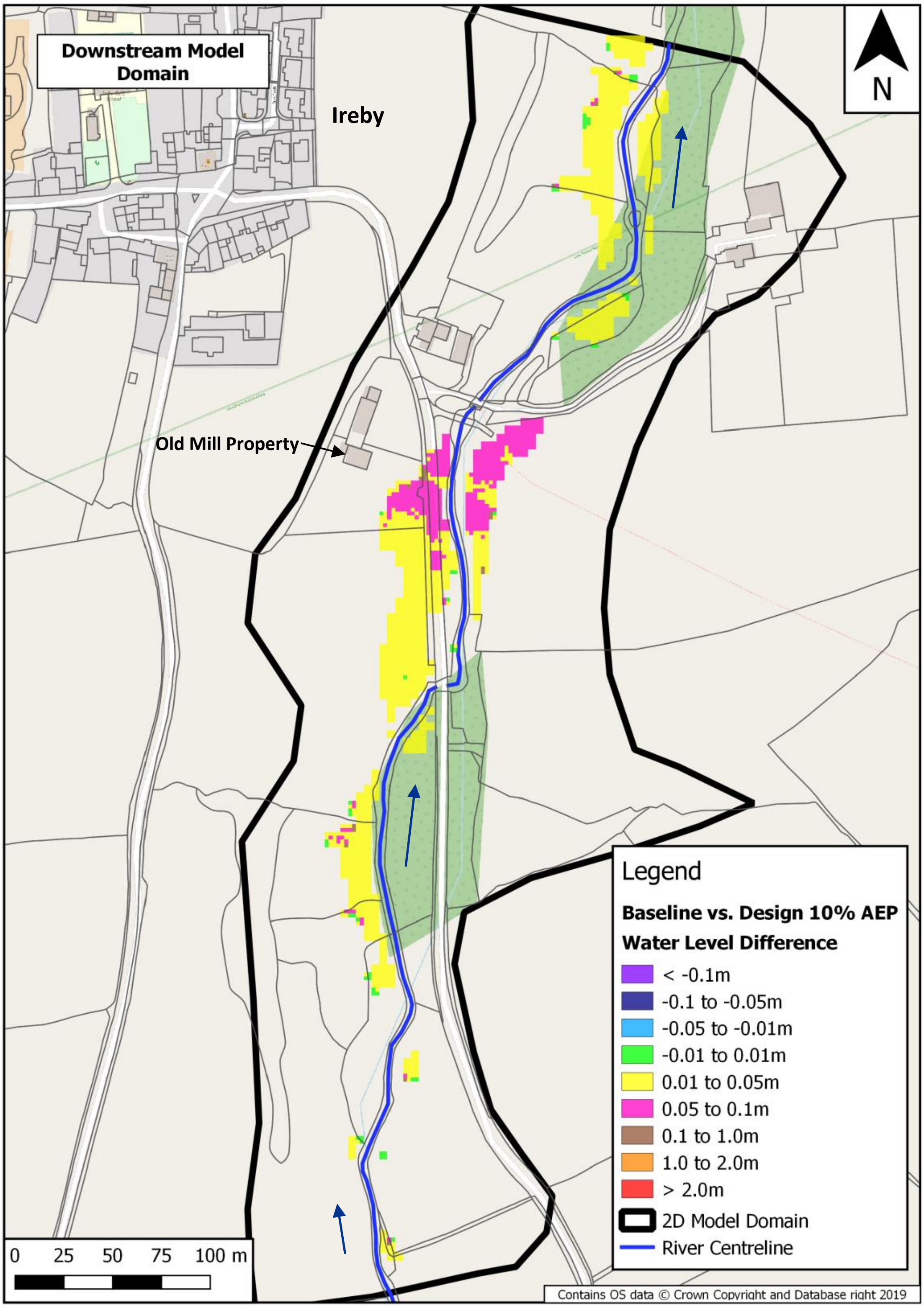


Figure C-45: Final Outline Design Maximum water level difference map for the 10% AEP Event

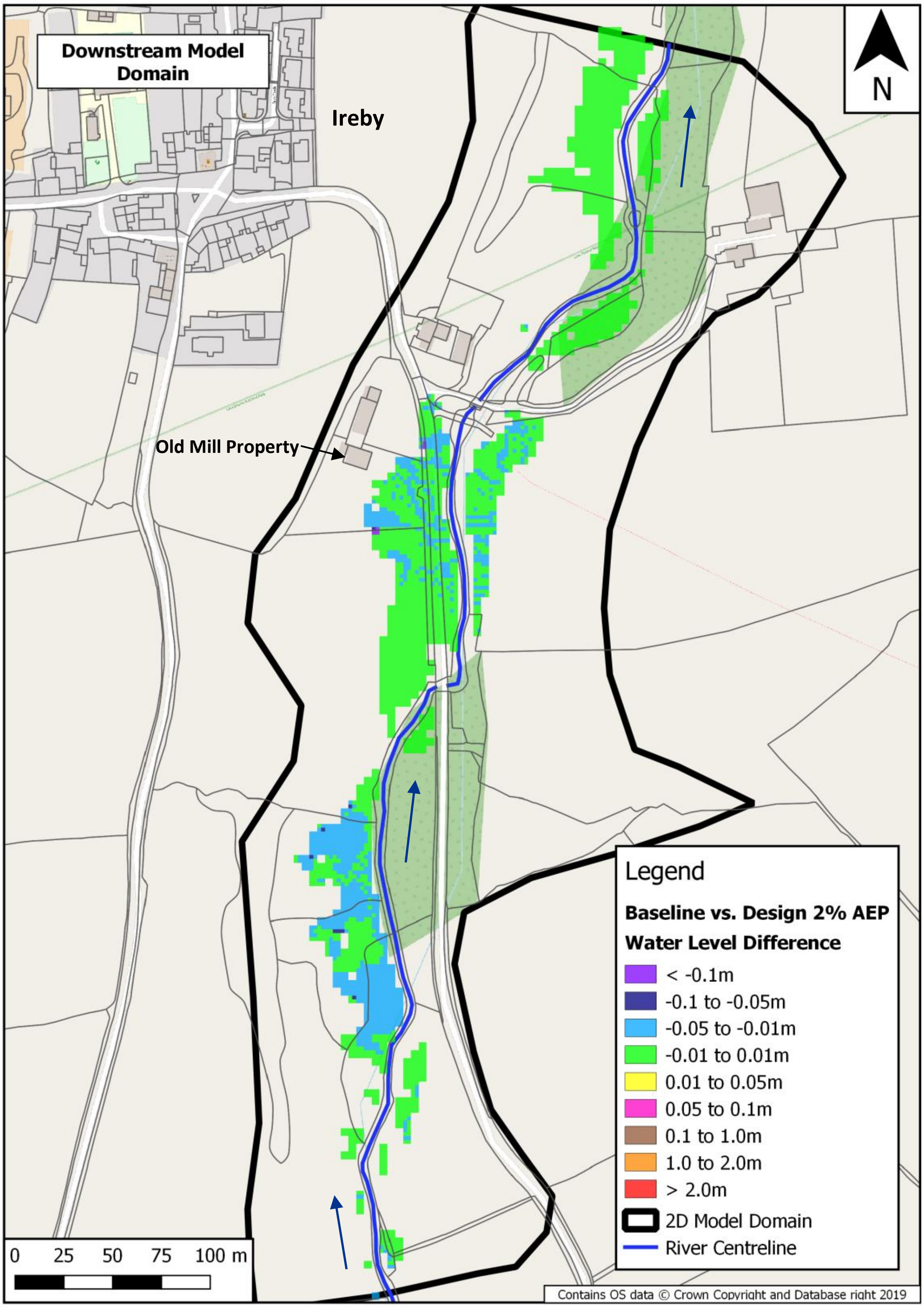


Figure C-46: Final Outline Design Maximum water level difference map for the 2% AEP Event

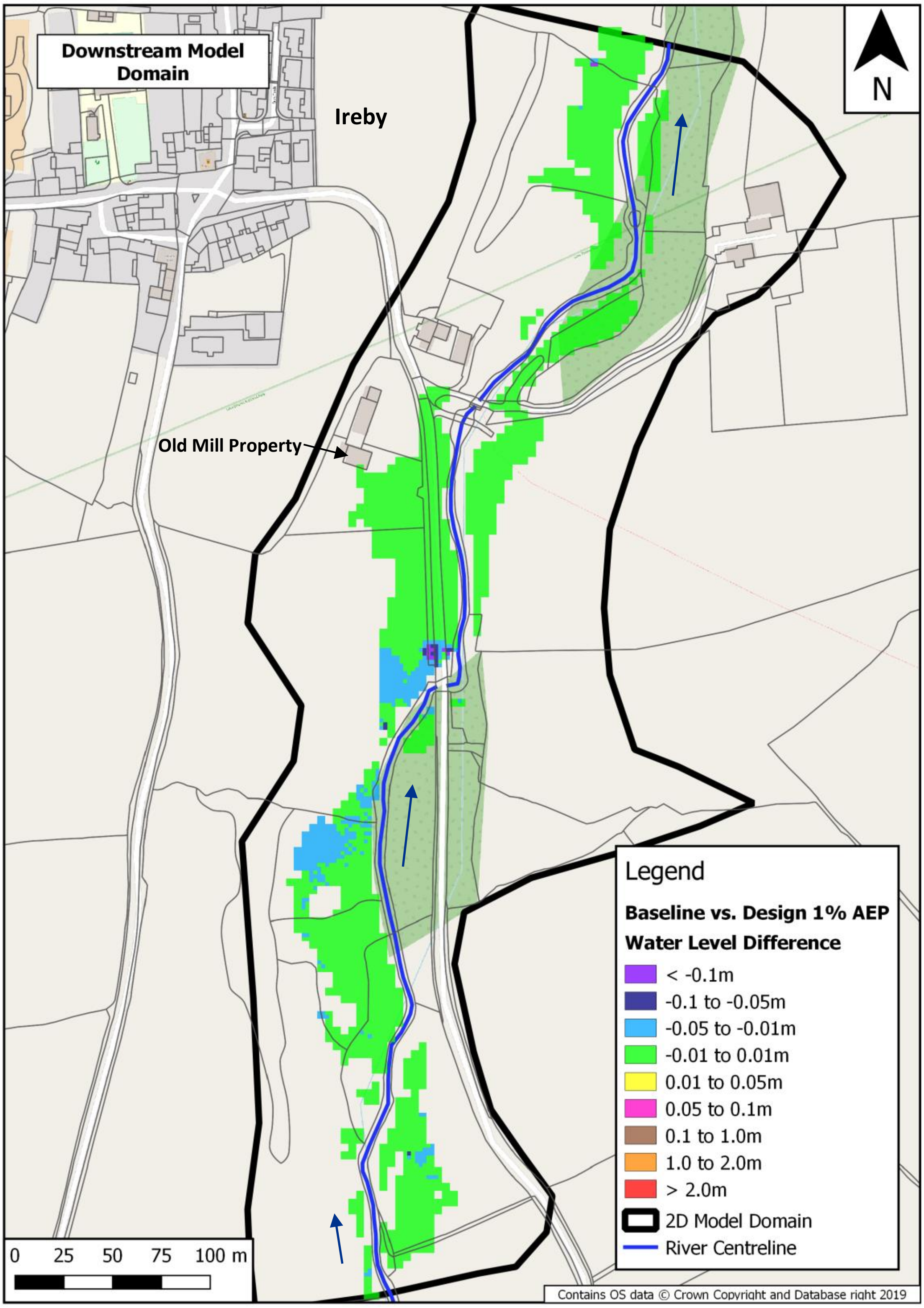


Figure C-47: Final Outline Design Maximum water level difference map for the 1% AEP Event

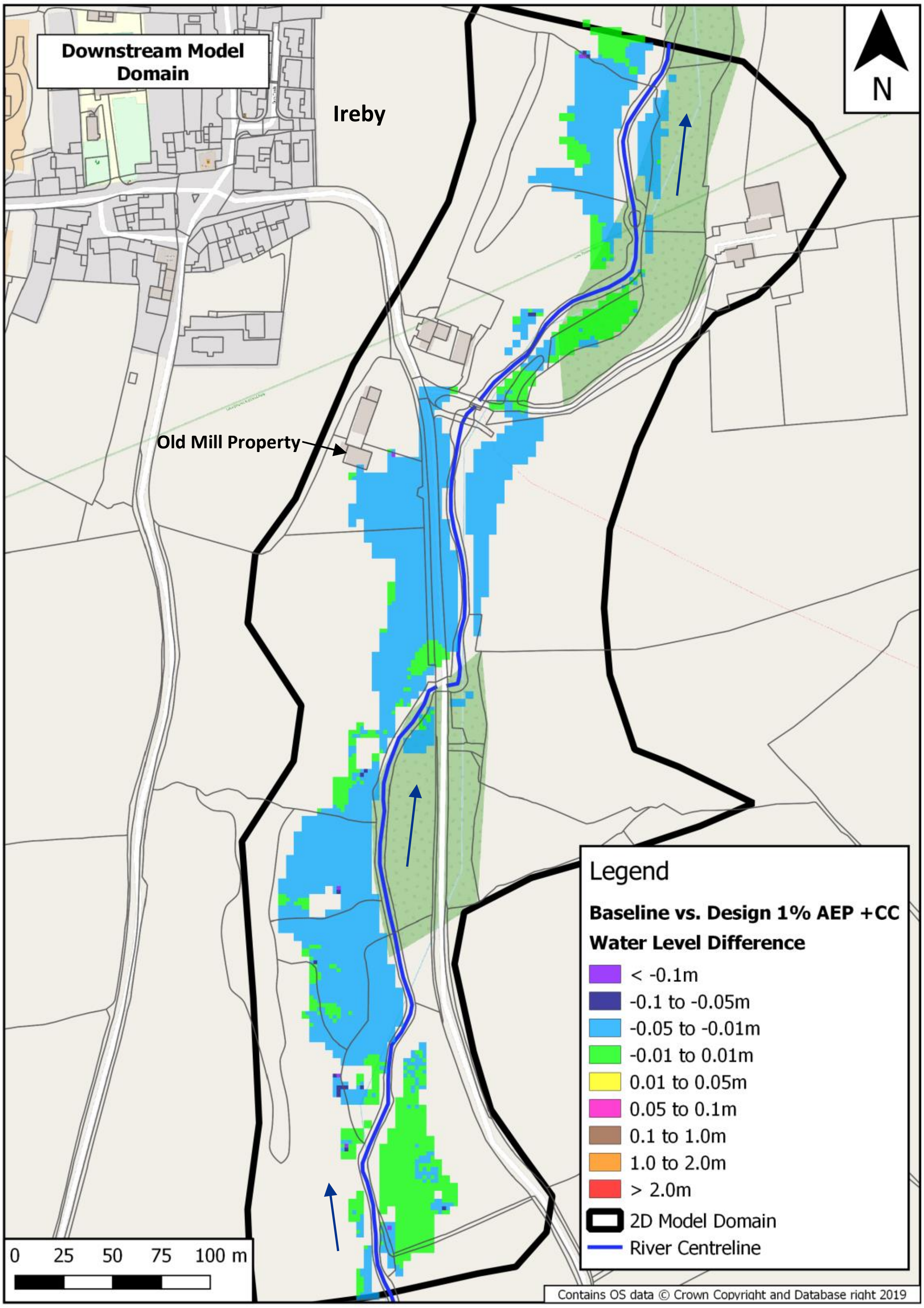


Figure C-48: Final Outline Design Maximum water level difference map for the 1% AEP +CC Event

Appendix D. Geomorphology Baseline Assessment

Please see the attached Appendix D document

Ehen Compensatory Measures

United Utilities

Geomorphology Baseline Assessment

B2705358/01/001 | R00

October 2017

JACOBS

Ehen Compensatory Measures

Project No:	B2705358
Document Title:	Geomorphology Baseline Assessment
Document No.:	B2705358/01/001
Revision:	R00
Date:	October 2017
Client Name:	United Utilities
Project Manager:	David Dickson
Author:	Katy Kemble

Jacobs U.K. Limited

4th Floor, Metro
33 Trafford Road
Salford
M5 3NN
United Kingdom
T +44 (0)161 873 8500
F +44 (0)161 873 7115
www.jacobs.com

Document history and status

Revision	Date	Description	By	Review	Approved
R00	Oct 2017	Draft for client comment	Katy Kemble	Andrew Brookes	David Dickson

Contents

1. Introduction

1.1 Background

The overall objective of the Ehen Compensatory Measures study is to identify and recommend measures to mitigate the effects of continued abstraction of water from Ennerdale Water, including the impacts of the abstraction infrastructure itself.

As part of the Scoping Study Jacobs has been commissioned to produce a methodology to undertake the assessment, approved by a Project Steering Group (PSG). The overall methodology is described in detail in the document 'Ehen Compensatory Measures-Scoping report for R6 and R3 Bleaching weirs removal (Jacobs, 2016)'.

A key part of the methodology is to establish a baseline for each discipline/topic encompassed by the study. This baseline information can then be used to develop criteria against which risks and opportunities presented by options can be assessed. This approach is founded on Multi-Criteria Analysis within widely accepted central Government guidance.

The specific aim of this Technical Note is to provide Geomorphology Discipline baseline for the Chapelhouse and Over Water Study Area. Options for Chapelhouse and Over Water are regarded as part of the compensatory measures for the Ehen even though not within the Ehen catchment per se.

1.2 Study Area

The study area referred to in this report encompasses the catchments upstream of Chapelhouse and Over Water, as well as the River Ellen downstream to Uldale. Figure 1.1 depicts the general overall study area encompassing the wider catchments of Chapelhouse Reservoir and Over Water, as well as the downstream extent of the River Ellen to Uldale.

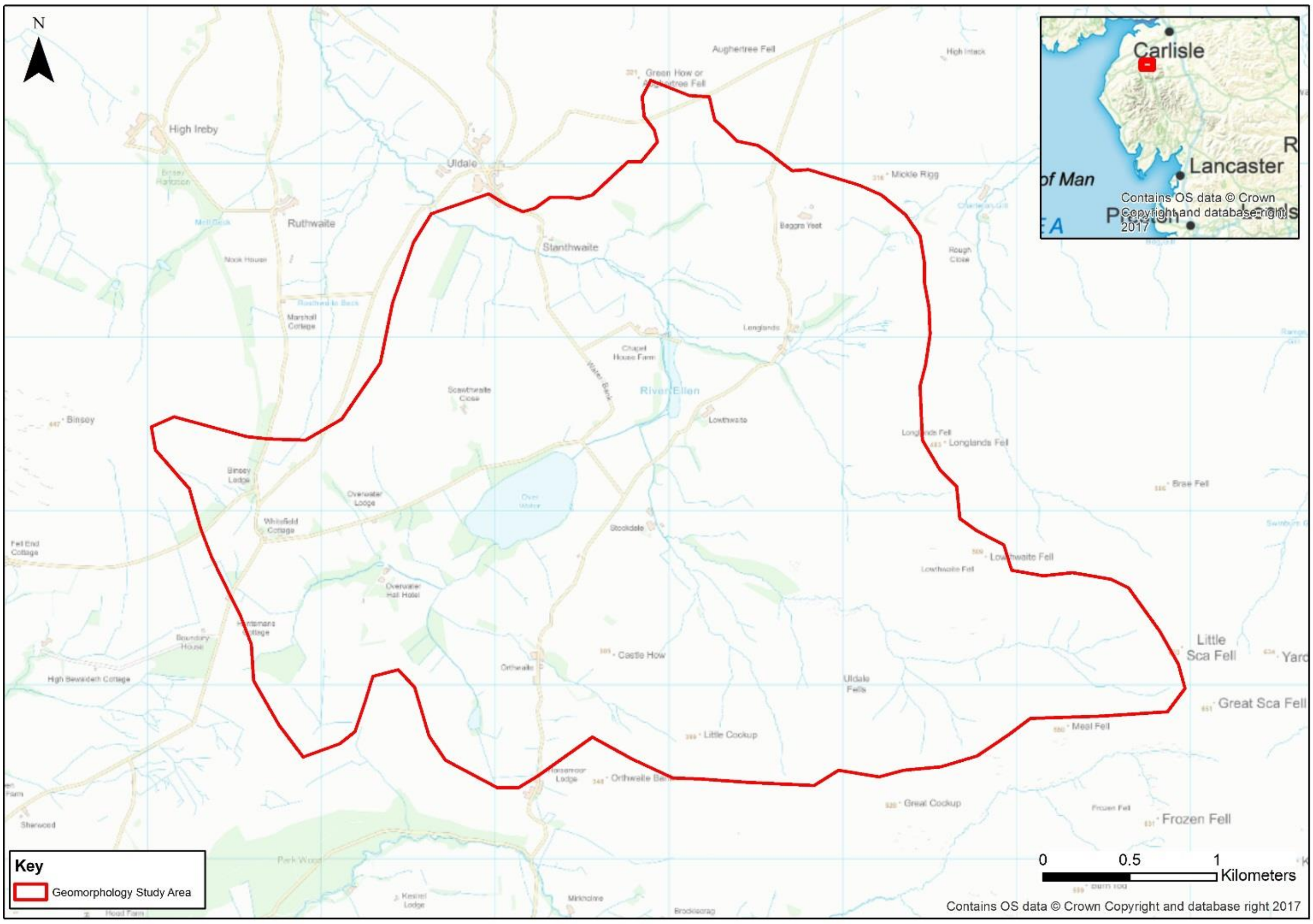


Figure 1.1 : Geomorphology Study Area

Within the Geomorphology Study Area, the following are the key receptors reported in this Technical Note:

- Chapelhouse Reservoir;
- Over Water Reservoir;
- River Ellen upstream of Chapelhouse Reservoir;
- Tributaries of Over Water Reservoir;
- Longlands Beck;
- Watercourse connecting Over Water and Chapelhouse Reservoirs; and,
- River Ellen downstream of Chapelhouse Reservoir to Uldale.

Figure 1.2 provides an overview of the location of the above receptors.

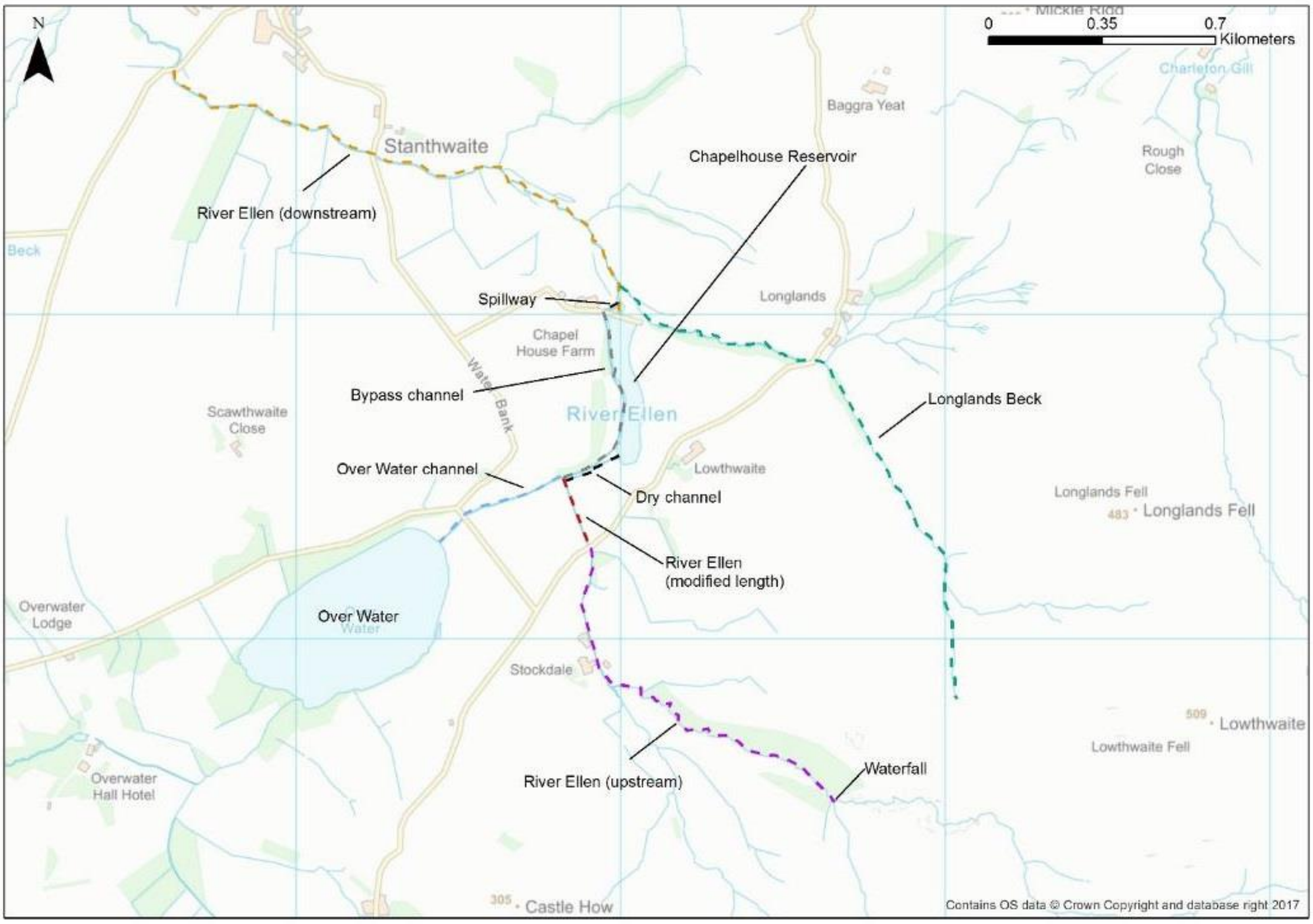


Figure 1.2 : Key geomorphology receptors within the wider Geomorphology Study Area

2. Approach/Methodology

2.1 Defining the Baseline

The baseline for this study is taken to be the present day scenario or situation *and* any additional actions required to maintain the current situation. For example, identifying what actions might be required to maintain a UU structure/asset in its current condition.

2.2 Methodology and Sources of Information

A desk based study has been carried out to inform the Technical Note, reviewing existing information for the proposed scheme and study area to develop the key baseline. The following are key sources of data used for the desk study:

- Ordnance Survey maps (Ordnance Survey, 2014);
- geological maps (British Geological Society, 2016);
- Catchment Explorer (Environment Agency, 2017)
- North West River Basin Management Plan (RBMP) (Environment Agency, 2015);
- designated areas shown on Multi-Agency Geographic Information for the Countryside (MAGIC, 2017); and
- aerial photographs (Bing, 2014); and
- historical maps (British Library, 2017).

A geomorphological reconnaissance survey was undertaken by a geomorphologist from the 22nd May 2017 to the 26th May 2017. The survey assessed the baseline condition of the watercourses and reservoirs identified within the Geomorphology Study Area. The survey provided an understanding of existing geomorphological conditions and the condition of the channel further upstream and downstream of the asset. A photographic record of the general character of the watercourse was also collected.

The findings of the desk study and walkover survey are presented in Section 3.

2.3 Criteria Forming the Baseline Assessment

The Scoping Study referred to previously identifies a provisional set of performance criteria against which options could be assessed (see Table 2.1). The criteria have been tailored to suit Chapelhouse and Over Water and the adjustments are shown in Table 2.1. This study collected baseline data relevant to informing the performance criteria used in the assessment of options.

Table 2.1 : Performance criteria for assessing geomorphology baseline

Multi-criteria Assessment Performance Criterion	Definition
River reactivity	Risk/likelihood of Chapelhouse Reservoir, Over Water and River Ellen undergoing significant channel change (i.e. changes to morphology and fluvial processes) both upstream and downstream
Impacts on sediment regime	Risk/likelihood of Chapelhouse Reservoir, Over Water and River Ellen undergoing a change of sediment regime (i.e. changes in erosion, rates of sediment transport and deposition)
Impacts on longitudinal and lateral connectivity	Risk/likelihood of Chapelhouse Reservoir, Over Water and River Ellen undergoing a change that could result in an increase or reduction in the channel connectivity upstream and downstream (longitudinal) or with its floodplain (laterally)

3. Baseline Assessment

3.1 Catchment Overview

The following provides an overview of the whole River Ellen catchment as context to the detailed assessment of the baseline within the Geomorphology Study Area.

The River Ellen catchment encompasses an area of approximately 127km^2 and is located in the north of Cumbria. The river has its source in the Uldale Fells 4km south east of Uldale. From here the river channel routes north and then west towards the coast, where it meets the Irish Sea through an estuary at Maryport. The river channel is fed by a network of tributaries and drainage channels along its length. In the upstream extent of the catchment the River Ellen flows over moorland, within a steep sided valley. Further downstream towards Uldale, the river corridor widens out and the land use typically changes with a scattered lining of trees along the banks and a greater influence from farming practices. The adjacent land use within the catchment below Uldale is typically rural consisting of pasture and arable agricultural practices. A few small villages and towns also lie along the river channel length, including Bleenhasset and Maryport.

Within the wider catchment, the River Ellen channel appears to typically have a meandering planform, with few significant modifications. River crossings for road infrastructure and small weirs for flow control and historical mills are typical modifications noted on OS mapping. In the upstream catchment the river channel is dammed by Chapelhouse Reservoir; a small tributary (Longlands Beck) joins the river immediately downstream of the reservoir spillway. A second reservoir also lies immediately upstream of Chapelhouse Reservoir, where a natural lake has been dammed to create additional storage at Over Water.

The upper extent of the catchment is underlain by sandstone, mudstone and siltstone. The lower reaches of channel, downstream of Chapelhouse Reservoir, are characterised by sedimentary conglomerates and limestone. Superficial deposits across the whole catchment consist of glacial till, with an area of peat between Over Water and Chapelhouse Reservoirs. Within the local river channel corridor, superficial deposits consist of alluvial gravels, sands and silts. The soils in the upstream catchment are noted to be freely draining acid loamy soils over rock (Cranfield University, 2016); downstream of Chapelhouse Reservoir, the soil type changes and are slowly permeable seasonally wet soils, with impeded drainage.

3.2 Relevant Legislation and Policies Affecting Fluvial Geomorphology within the Study Area

3.2.1 Habitats Directive

The upper reaches of the River Ellen in the Geomorphology Study Area within the Uldale Fells lies within the Lake District High Fells Special Area of Conservation (SAC). The SAC is designated for a range of heaths, grasslands and bogs. There is a Natura 2000 Site Improvement Plan (SIP) in place for the 'Lake District High Fells' which aims to tackle a number of issues identified within the catchment which may impact on the notable features of the SAC. These include water pollution, siltation, invasive species, change in woodland management and hydrological changes.

3.2.2 Water Framework Directive

The Geomorphology Study Area lies within one fluvial WFD water body catchment and encompasses two lacustrine WFD water bodies. Table 3.1 and Table 3.2 provide an overview of the WFD quality elements for the three WFD water bodies.

Table 3.1 : WFD river water body information for the study area – based on 2016 Cycle 2 data (Environment Agency, 2017)

Category	Description
Water Body Name	Ellen (upper)
Water Body ID	GB112075073630
Hydromorphological Designation	Not designated artificial or heavily modified
Water Body Length	15.6km
Catchment Area	33.7km^2
Overall Water Body Status	Good
Chemical Status	Good
Linked protected areas	Drinking Water Protected Area, Habitats Species Directive
Biological Quality Elements	
Overall	Good
Fish	High
Invertebrates	Good
Hydromorphological Supporting Elements	
Overall	Supports good
Hydrological Regime	Does not support good
Morphology	Supports Good
Physico-chemical Quality Elements	
Overall	Good
Ammonia	High
Biochemical Oxygen Demand (BOD)	High
Dissolved Oxygen	High
pH	High
Phosphate	Good
Temperature	High

Table 3.2 : Lacustrine WFD water body information for the study area – based on 2016 Cycle 2 data (Environment Agency, 2015)

Category	Description	
Water Body Name	Over Water	Chapelhouse Reservoir
Type	Lake	Lake
Water Body ID	GB31228806	GB31228796
Hydromorphological Designation	Heavily modified	Heavily modified
Catchment Area	500ha	965ha
Overall Water Body Status	Moderate	Moderate
Chemical Status	Good	Good
Linked protected areas	Drinking Water Protected Area	Drinking Water Protected Area
Biological Quality Elements		
Chironomids	Good	Not assessed
Macrophytes and Phytobenthos Combined	Moderate	Not assessed

Category	Description	
Phytoplankton	Good	Not assessed
Hydromorphological Supporting Elements		
Hydrological Regime	Not assessed	Not assessed
Physico-chemical Quality Elements		
Acid Neutralising Capacity	High	Not assessed
Ammonia	High	Not assessed
Salinity	High	Not assessed
Total Phosphate	Moderate	Not assessed
Supporting Elements		
Expert Judgement	Moderate	Moderate
Mitigation Measures Assessment	Moderate or less	Moderate or less

3.2.3 Wildlife and Countryside Act (1981), Section 28

The upper reaches of the River Ellen and Longlands Beck are located within the Skiddaw Group SSSI which is currently assessed as being in unfavourable recovering condition. The SSSI is classified for the dwarf shrub heath habitat. Over Water is also classified as a SSSI and is formed of nine units, covering broadleaved, mixed and yew woodland habitats, natural grassland habitats and standing water. Three of the units are currently in favourable condition, three in unfavourable (no change) and three in unfavourable (declining).

3.2.4 Other Designations

The entire Geomorphology Study Area lies within the Lake District National Park, which measures a total of 2362km^2, and the English Lake District World Heritage Site. The study area also lies within a Drinking Water Protected Area for surface water.

3.3 Historical Changes

3.3.1 River Ellen and Chapelhouse Reservoir

The planform of the River Ellen channel has remained relatively stable between its headwaters and Uldale since 1863, aside from the construction of Chapelhouse Reservoir and local changes associated with the reservoir in the 1900s (detailed below). Some changes appear to have been made to land drainage channels and the upland tributaries, with some becoming disconnected and others connected. These differences could either be a result of mapping inconsistencies, actual channel modifications on the ground or the erosion of new channels formed from overland flow paths (particularly in the upland area). However, in general the channel planform of the River Ellen and its tributaries between the headwaters and Uldale has remained relatively unchanged.

The adjacent land use also appears to have remained similar, with agricultural fields and some woodland shown on the mapping from 1863. A number of bridges appear to have been constructed over the river, typically located where fords had previously existed, including one at Stanthwaite, south of Uldale, by Uldale Mill Farm.

Under the existing Chapelhouse Reservoir footprint, early maps from 1863-1900 show an area of woodland, referred to as Hoodbank Wood. The channel of the River Ellen is slightly straightened beneath the road upstream of the existing reservoir, but otherwise has a sinuous planform through the fields and the centre of the current reservoir footprint. By 1900, a straightened secondary channel is depicted to the west of the natural channel of the River Ellen. This appears to be in the same location as the existing bypass channel shown in Figure 1.2. Mapping from 1956 then shows the reservoir to be in place with the old channel of the River Ellen removed and replaced with a straightened channel as per the existing mapping (Figure 1.2). Later historical maps from 1974-1979 then show the catchpit and sluices along the River Ellen, upstream of the reservoir, as per the latest OS maps.

3.3.2 Longlands Beck

The planform of the Longlands Beck channel appears to have shifted locally from mapping in 1866, with the progression of some meanders and creation of new meanders. This is of particular note around the wooded area of Lowraise Wood to the east of the rivers' confluence with the River Ellen.

In the headwaters of the Longlands Beck, the small feeder tributaries appear to also have adjusted. Some additional watercourses are noted to feed into the Longlands Beck on later and also present day mapping. This is likely to have resulted from downcutting through the peaty soil from overland runoff across the steep topography.

3.3.3 Over Water

Over Water is a natural lake (or tarn) formed by glacial processes. Mapping in the 1800s shows the lake had a smaller footprint compared to the existing reservoir. At that time the lake was fed by one key tributary to the south eastern corner, which appears to have remained similar in channel planform with some localised straightening. A boat house is depicted on historical mapping from 1900. This is located at the margin of the lake on the western edge, with landing stages present. By 1904 the lake was dammed and the footprint increased in size creating the reservoir seen on existing OS mapping, providing drinking water to Wigton.

3.4 Contemporary Channel and Reservoir Characteristics

3.4.1 Baseline Conditions

The following text discusses the contemporary characteristics of the receptors identified during the site work undertaken in May 2017 within the Geomorphology Study Area as outlined in Figure 1.2. Appendix A provides overview plans for each of the sites.

3.4.1.1 River Ellen and Chapelhouse Reservoir

For the purposes of reporting the River Ellen channel has been divided into four reaches, as shown in Figure 1.2, covering the channel upstream of Stockdale Farm, the channel immediately upstream of Chapelhouse Reservoir, the bypass channel (and Chapelhouse Reservoir) and the channel downstream of Chapelhouse Reservoir.

River Ellen (Upstream)

The River Ellen channel headwaters in the Uldale Fells was found to be characterised by a steep channel with small cascades and waterfalls formed in a predominately bedrock channel (Figure 3.1). The adjacent vegetation was noted as sparse, with grassed banks and scattered trees along the channel banks (Figure 3.2).

As the River Ellen channel progressed downstream, it entered a small wooded area (referred to as Crag Wood) where the gradient remained relatively steep and a step-pool sequence was observed. At the time of the survey the river appeared to be actively meandering through the woodland with evidence of eroding banks and deposition (Figure 3.3).

Downstream of this the woodland thinned out along the left bank and the channel was found to typically consist of grassed banks with some trees scattered along the bank tops. At a number of locations cattle were observed to have poached the banks, locally enhancing erosion. Here, the channel planform continued to meander through the agricultural fields, with a pool-riffle sequence (Figure 3.4). Active erosion and deposition were noted, with substrate consisting of cobbles, pebbles and some gravels (Figure 3.5). Sediment sources were found to be typically from erosion of the bank (silt and gravels) and poaching (silt).

The River Ellen between the modified length and Stockdale Farm was not surveyed due to access constraints.

Figure 3.1 : Waterfall at the upstream extent of the walkover survey (facing upstream)

Figure 3.2 : Steep valley sides confining channel in upstream catchment (facing upstream)

Figure 3.3 : River Ellen through Crag Wood

Figure 3.4 : River Ellen with pool-riffle sequence and eroding banks

Figure 3.5 : Deposition along the channel margins and evidence of channel poaching

River Ellen (Modified Length)

The River Ellen channel downstream of the access road near Stockdale Farm has been historically artificially straightened as a result of a combination of the construction of the road, past agricultural practices and the construction of Chapelhouse Reservoir (Figure 3.6). The river channel along this length was noted to have a uniform channel cross-section with limited morphological diversity. An elongated pool-riffle sequence was noted and the bed substrate found to consist of coarse material including pebbles and cobbles. Limited gravel substrate was noted. Some marginal deposits were observed, typically consisting of cobbles with some gravels and resulting in localised narrowing of the channel (Figure 3.7). The channel was found to have a limited vegetated riparian corridor, with some trees lining the banks and nettles forming the remainder of the vegetation. Both banks were fenced from the adjacent fields preventing poaching by livestock.

At the downstream extent the straightened channel was found to enter a concrete lined catchpit (detailed below). Where the channel entered the catchpit a deposit (point bar) had formed along the left bank consisting of pebbles and cobbles.

Figure 3.6 : Modified length of the River Ellen (facing upstream)

Figure 3.7 : Some deposits at the channel margins and a scattered tree lining along the banks (facing downstream)

Bypass Channel, Dry Channel and Chapelhouse Reservoir

The catchpit located on the River Ellen (Figure 3.8) was noted to be a concrete structure with three sluice gates releasing water downstream. The catchpit was observed to be filling with sediment, mostly silt and sand, with some woody material also noted trapped at the surface. The catchpit had a ramp on the eastern edge providing access for machinery to clear and maintain the trap.

Downstream of the catchpit two channels were observed to be present, the reservoir bypass channel to the north and a channel feeding the reservoir to the north-east. The channel feeding into Chapelhouse Reservoir was dry near to the catchpit at the time of survey. The channel was found to be approximately 0.3m to 0.5m wide, with gravel/pebble substrate and vegetated banks (Figure 3.9). Approximately 90m from the catchpit an old sluice structure was found located along the channel (Figure 3.10), apparently no longer functioning. Downstream of this, an outfall was observed to be discharging water into the channel, where it widened to measure approximately 1m (Figure 3.11). Within proximity to the reservoir the surrounding vegetation was typically marshland.

The bypass channel routes flow around the reservoir to the downstream River Ellen, providing the required compensation flow. The bypass channel was noted as approximately 2m wide and cut into the bedrock along the margin of the reservoir (Figure 3.12). Some narrowing was observed, consisting of gravel/pebble point bars, but typically the channel was artificially uniform and straight. Some evidence of bank failure was observed on the left bank, with material in the channel (Figure 3.13). The modified nature of the channel and straightened planform means that it acts primarily as a sediment transfer, particularly in higher flows. At the downstream extent at the reservoir dam, the bypass channel was noted as heavily modified and lined with stone walls and a concrete bed (Figure 3.14). A stepped fish pass was observed taking the bypass channel down the dam face to a weir (with a drop of approximately 1m).

Chapelhouse Reservoir itself was found to be lined by trees and tall scrub on the western and eastern sides, with a steep bank consisting of cobbles and boulders sloping down to the water edge. The reservoir was observed not to have any in-channel vegetation or notable morphological features.

Figure 3.8 : Catchpit on River Ellen (facing downstream)

Figure 3.9 : Dry channel downstream of catchpit (facing downstream)

Figure 3.10 : Redundant sluice structure (facing downstream)

Figure 3.11 : Wetted channel downstream of sluice (facing downstream)

Figure 3.12 : Bypass channel with small deposit (facing the left bank)

Figure 3.13 : Bypass channel (facing downstream)

Figure 3.14 : Reinforced channel (facing downstream)

Figure 3.15 : Stepped fish pass on dam face (facing downstream)

Figure 3.16 : Chapelhouse Reservoir (facing upstream)

River Ellen (Downstream)

The River Ellen channel immediately downstream of Chapelhouse Reservoir was found to be overwide, with glide flow and a large weir structure (Figure 3.17). The channel had a rectangular cross-section and a consolidated bed consisting of cobbles.

Downstream of the confluence of the Longlands Beck, the river channel regained a more natural pool-riffle sequence with some variations to the channel cross-section and flow processes (Figure 3.18). However, evidence of historical modifications (i.e. straightening) were still apparent, with small weirs noted along the length. There were also several knickpoints where the channel was adjusting (Figure 3.19). Erosion of the banks was noted throughout the length surveyed to Uldale, providing a source of silt, gravels and pebbles. The channel was noted to be actively depositing, with side bars and point bars, consisting of cobbles. The substrate was found to be predominantly cobble and the bed consolidated (armoured), with little evidence of mobile sediment. Downstream of the reservoir, there was a notable absence of finer material, gravels and pebbles compared to the upstream surveyed extent.

Figure 3.17 : Immediately downstream of Chapelhouse Reservoir (facing upstream)

Figure 3.18 : Pool-riffle sequence with coarser material (facing upstream)

Figure 3.19 : Knickpoint and bank erosion (facing downstream)

3.4.1.2 Longlands Beck

In the headwaters the Longlands Beck was observed to be a small often undefined channel, within a wider wetted moorland area (Figure 3.20). The channel was found to be typically consisted of gently sloping banks and a gravel/pebble bed. Further downstream, the channel became more defined and incised, with vertical earth banks, pebble bed and step-pool sequence (Figure 3.21). At this point the channel width was noted to be approximately 0.3m wide. As the river channel flowed towards Low Longlands it passed through a wooded area, where it widened to approximately 1m and slackened in gradient. A pool-riffle sequence was noted to be present, with some evidence of deposition at the channel margins (Figure 3.22).

At Low Longlands the river channel was found to be culverted beneath the local access road with a vertical weir located along the downstream edge (Figure 3.23). Downstream of the weir the river channel meanders through a densely wooded area. The channel was observed to have a pool-riffle sequence, with erosion noted on the outside of the meanders (Figure 3.24). Deposits were also noted, formed of cobbles, pebbles and some gravels. The bed was found to be typically consolidated and consisting of cobbles. Where the river channel emerged from the wooded area, active erosion was noted with some fencing having fallen into the river or having been set back. Several knickpoints were observed, suggesting the channel is still adjusting to historical modifications (Figure 3.25). Deposition was also noted with point and mid-channel bars observed, consisting of cobbles and gravels.

Where the Longlands Beck channel meets the River Ellen there was evidence of historical dredging with material observed along the bank tops forming small embankments (Figure 3.26). The channel appeared to have recently avulsed, with a redundant channel noted to the west of the channel currently feeding into the River Ellen.

Figure 3.20 : Headwaters of Longlands Beck channel (facing downstream)

Figure 3.21 : Incised channel (facing downstream)

Figure 3.22 : Longlands Beck channel through wooded area upstream of Low Longlands (facing upstream)

Figure 3.23 : Weir downstream of local access road (facing left bank)

Figure 3.24 : Wooded length, with eroding banks and pool-riffle sequence

Figure 3.25 : Extensive erosion and knickpoint (facing upstream)

Figure 3.26 : Material on channel bank tops (facing downstream)

3.4.1.3 Over Water

Figure 3.27 provides an overview plan generated from the site observations made of Over Water Reservoir during the geomorphological walkover surveys.

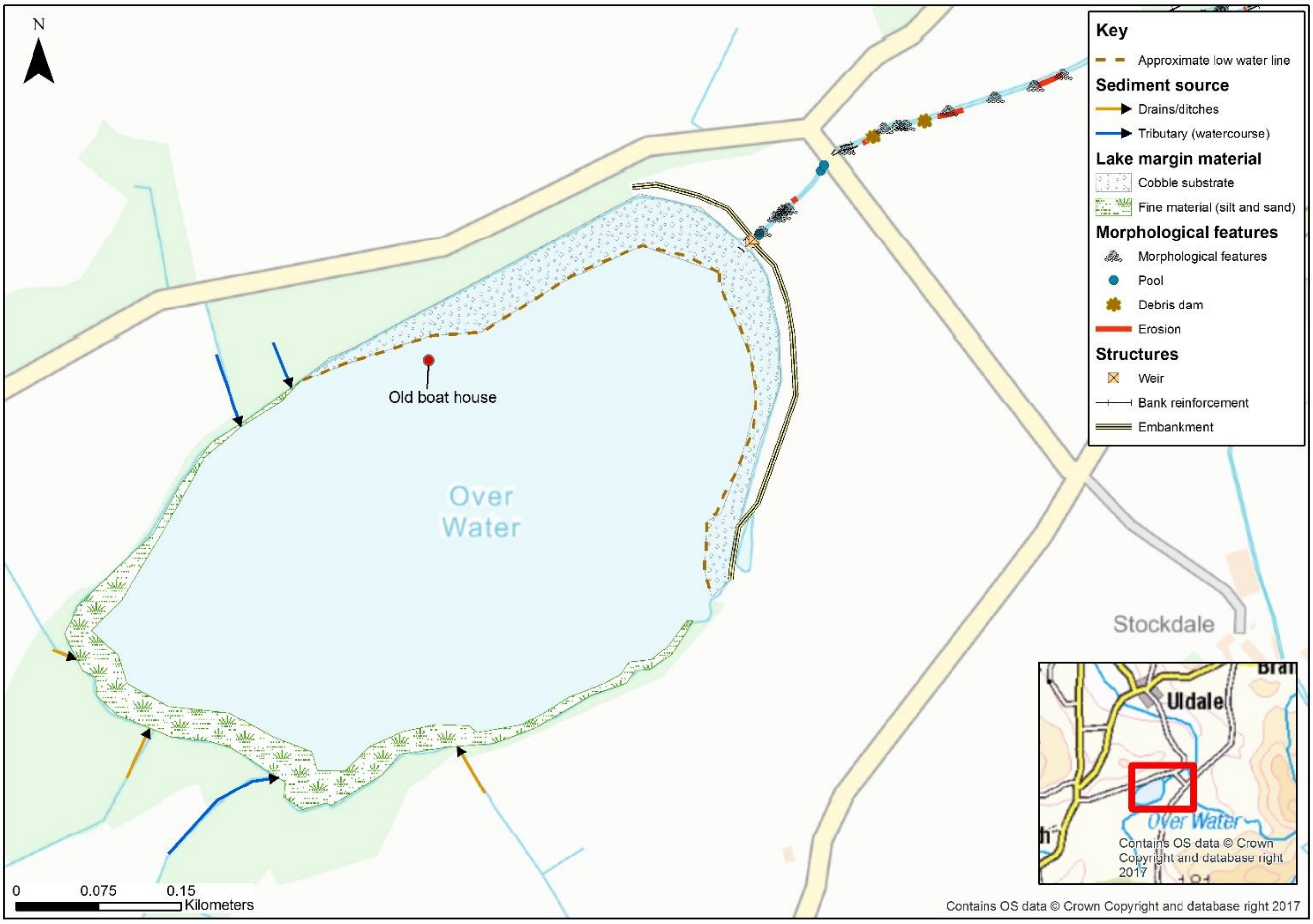


Figure 3.27 : Site walkover overview of Over Water Reservoir

Over Water has been artificially dammed and increased in size of footprint (Figure 3.28) with evidence of the old boat house on the northern shoreline showing the old water level. The infrastructure at the outlet of the reservoir was noted to be formed of a weir with two small drops (Figure 3.29). A small embankment extended out from the structure along the margins. At the time of survey, the water levels were observed as very low and there was no water flowing over the weirs from the lake. The embankments were noted to be grassed over, with some trees located along the bank top. The face of the embankment towards the reservoir sloped gradually down to a beach, consisting primarily of pebbles (ranging from 8mm to 32mm), with some silt and sand noted. Artificially placed boulders and stakes were also noted along the beach. The pebble beach extended along the north-eastern shore (Figure 3.27). It then transitioned along the southern, western and north-western edges of the lake to a boggy area of fine silt and sand, with reeds and wet woodland (Figure 3.27).

Over Water Reservoir is fed directly by a number of small drainage ditches, typically straight in planform with a uniform cross-section. Most of these were recorded as artificial and likely to act as a source of fine sediment to the reservoir. The key watercourse feeding the reservoir is located in the southern corner and was noted to be heavily modified, with a straightened planform and earth lined channel cross-section (Figure 3.30).

Downstream of Over Water Reservoir, a small straightened channel flows eastwards towards Chapelhouse Reservoir. For reporting purposes this has been referred to as the Over Water channel. Where the channel is crossed by the weir structure, a length of riprap has been placed in the channel bed (approximately 2m in length – Figure 3.31). Downstream of this the channel was noted to have a uniform cross-section measuring approximately 2m to 2.5m wide (bankfull) with a narrower low flow channel approximately 1m wide. The length upstream of the access track was found to be dry at the time of survey (Figure 3.32) with some terrestrial vegetation noted within the channel. There was evidence of the channel narrowing in the dry reach with marginal depositional features formed of gravels.

At the local access road, the river channel was found to be culverted with reinforced banks both upstream and downstream of the structure (Figure 3.33). The reinforcement had created an overwide channel, particularly downstream, and evidence of channel narrowing was noted as a response with a gravel deposit on the right bank. Downstream of the culvert towards the catchpit, the channel continues in a straightened planform with a modified cross-section (Figure 3.34). Water was noted flowing within the channel with some localised variations around woody material creating small dams across the channel. The channel was again noted to be narrowing with local deposition at the margins in the form of gravel point bars and some in-channel macrophytes.

Figure 3.28 : Over Water Reservoir (facing west)

Figure 3.29 : Weir infrastructure at downstream extent of Over Water (facing upstream)

Figure 3.30 : Key tributary of Over Water Reservoir (facing upstream)

Figure 3.31 : Over Water channel immediately downstream of reservoir (facing downstream)

Figure 3.32 : Over Water channel (facing downstream)

Figure 3.33 : Over Water channel culvert under access road (facing upstream)

Figure 3.34 : Over Water channel, straightened and modified (facing downstream)

3.4.2 Baseline Sediment Regime

Sediment yield is defined as the total sediment outflow from a basin over a specified period of time (Knighton, 1998). The methods used to establish the sediment yields in a catchment vary and are typically from site based measurements over long time periods, complex modelling, high level calculations or sediment budgets (visualisations). There are a large number of uncertainties with sediment yield analysis, models based on a large number of assumptions, measurements requiring detailed equipment and often being difficult to obtain and the large number of variables that can alter the sediment within a catchment. Precise sediment yields are difficult to measure and there is a general absence of long-term sediment monitoring in the UK to inform models/equations. The sediment yield calculations provide an understanding of the potential volume of sediment that could reach a reservoir from the catchment upstream. From this, estimates of the potential future volume of sediment deposition at a reservoir could be derived.

For the purposes of this study, the estimates of sediment yield have been undertaken based on an approach developed by the Environment Agency (1998) using catchment area. This methodology provides a means of estimating sediment yield where physically-based equations and measurements cannot be applied. The method involves predicting the sediment load as a function of catchment area, providing an annual sediment yield. The equations are based on a data set developed by the (then) National Rivers Authority. Due to the limited data in the UK and the nature of the basis of the equations, the results need to be applied with a degree of caution and are purely indicative.

Table 3.4 provides an overview of the annual yields for the River Ellen upstream of Chapelhouse Reservoir, Longlands Beck and the key Over Water tributary. Average yields given for the UK upland areas range from 30-50 tonnes per km per year, distinctly lower than other values from other parts of the world. The bedload yields calculated for the River Ellen channel upstream of Chapelhouse Reservoir, Longlands Beck and Over Water tributary are below the UK average and suggests that the river channels would not typically supply a continuous significant source of bedload sediment. The suspended load yields are also relatively low. However, the whole River Ellen catchment (i.e. upstream of Uldale) has a higher yield than the UK average and although the calculation has been based on numerous assumptions, it suggests that the River Ellen channel, Longlands Beck and other small tributaries combined could provide a large amount of sediment downstream.

Table 3.4 : Estimated sediment yields using the Environment Agency (1998) equation

Site	Catchment area (km^2)	Notes	Annual bedload yield (tonnes/km^2/year)	Annual bedload yield (tonnes/year)	Annual suspended load yield (tonnes/km^2/year)	Annual suspended load yield (tonnes/year)
River Ellen (upstream)	4.21km^2	Encompasses the River Ellen catchment upstream of Chapelhouse Reservoir	27.6	116.2	61.7	259.8
River Ellen (downstream)	14.78km^2	Encompasses the River Ellen catchment from headwaters to Uldale	107.3	1585.9	264.7	3912.3
Longlands Beck	2.16km^2	Encompasses the Longlands Beck catchment	13.4	28.9	28.4	61.3
Over Water tributary	1.75km^2	Encompasses the key tributary feeding into the south-eastern edge of Over Water	10.7	18.7	22.3	39.0

Sediment Sources

The key sources of sediment identified within the Geomorphology Study Area are from the River Ellen channel in the upstream reaches and, to a lesser extent, Longlands Beck and some of the smaller tributaries. This is supported by the tentative values outlined in Table 3.4.

The River Ellen upstream of Stockdale Farm was noted to be eroding and depositing, with some evidence of mobile sediments, although the channel bed was recorded as typically consolidated. The catchpit and presence of Chapelhouse Reservoir appear to reduce the movement of the finer sediment fractions (silt, sand and gravel) downstream. This has led to the downstream River Ellen channel consisting predominantly of cobbles and pebbles, with little replenishment of the finer material winnowed (stripped) out during higher flow events. However, it should be noted that the natural channel upstream of the reservoir did not appear to have significant amounts of gravel substrate.

Longlands Beck channel and the smaller tributaries are likely to provide some sediment to the catchment, with evidence of erosion occurring. However, due to the smaller nature of the catchment, this would be unlikely to be a significant source and likely to be primarily active during higher flow conditions.

In addition to the sediment sources identified above, the adjacent land use is also likely to provide a source of finer sediment to the channel, particularly from livestock poaching along the banks.

3.4.3 Baseline Longitudinal and Lateral Connectivity

Connectivity of the River Ellen channel, Longlands Beck and tributaries with the wider floodplain (i.e. lateral connectivity) was found to be typically present throughout the surveyed lengths. Within the upland areas the extent of the river channel corridor was noted to be reduced due to the steeper nature of the valley slopes. It is likely that floodplain connectivity is maintained within the confined valley floor. Lateral connectivity was found to be impeded within the significantly modified lengths of river channels, including the bypass channel and Over Water channel.

Longitudinal connectivity was noted to be impeded throughout the majority of the surveyed length by the infrastructure associated with Over Water Reservoir and Chapelhouse Reservoir, including the weirs, dams and sluice gates. Road crossings and small local weirs also impeded connectivity. The recorded infrastructure is likely to have progressively modified the flow and sediment processes over the last century, with the channel exhibiting evidence of adjustment to changed regimes and modifications (i.e. through the presence of knickpoints, consolidated bed substrate and absence of finer material).

3.5 Opportunities and Constraints

3.5.1 Opportunities

Throughout the geomorphological walkover survey a series of options have been developed to improve, re-naturalise and remove maintenance requirements within the study area along the River Ellen channel. The following text provides an overview of the types of options developed, with a full list given in Appendix B.

Infrastructure Removal

There are a number of options for removing part of or all of the infrastructure associated with both Over Water Reservoir and Chapelhouse Reservoir. The infrastructure is prohibiting the transport of most sediment fractions downstream as well as altering flow processes. The disconnection of the longitudinal connectivity is also prohibiting morphological processes which in turn would affect the biota and habitat within the channels. The removal of the infrastructure would look to re-create the connectivity within the system and remove man-made modifications.

River Restoration

Due to the presence of the reservoirs and controls placed within the River Ellen channel, there has been historical modification with an impact on the morphological processes. Restoration of the Over Water Reservoir to a natural lake, the Over Water channel and the modified length of the River Ellen channel in particular would re-connect the catchment with the downstream reaches. Restoration would also provide the potential to improve processes and habitat for species.

Riparian Planting

Throughout the catchment adjacent pressures have led to the removal or thinning of the vegetated riparian corridor. This has led to a reduction in the amount of woody material entering the river channel and shading of the channel preventing extensive macrophyte growth. Selective planting of trees and taller shrub would potentially provide some localised improvements to the river channel.

3.5.2 Constraints

The key constraints for the implementation of restoration measures in the form of infrastructure removal and/or in-channel improvements include:

- adjacent land use – loss of agricultural land;
- cost implications;
- available ‘space’ – removal of infrastructure and re-naturalisation could lead to channel adjustment and potentially the requirement of land on either bank as the channel adjusts; and,
- downstream infrastructure – re-connecting the river could lead to additional sediment movement and deposition downstream potentially effecting infrastructure and villages/towns.

4. Summary and Conclusions

The geomorphological walkover survey and baseline assessment have established the existing morphological conditions along the River Ellen channel, Longlands Beck, Over Water Reservoir and Chapelhouse Reservoir. The catchment has been historically modified, particularly by the large size infrastructure required for the two reservoirs. As a consequence, processes have been altered and the channel has begun to adjust to the change. Table 4.1 provides an overview of the current baseline conditions against the MCA performance criteria.

Table 4.1 : Summary table for the River Ellen catchment based on the site walkover (May 2017) and desk study

MCA Criteria	Assessment of Current Baseline Conditions
River/lake reactivity	**River Ellen** The River Ellen channel exhibited evidence of change, with erosion and deposition observed both upstream and downstream of Chapelhouse Reservoir. Knickpoints were also noted, suggesting the channel is still adjusting to previous modifications. **Chapelhouse Reservoir** The reservoir is an artificially created water body with little evidence of significant morphological change since its creation. **Over Water Reservoir** Over Water is constrained by the bordering woodland area and artificial embankment at the eastern edge. As the reservoir has been artificially raised from a natural lake, there has been some development of marshland around the margins. However, there has been very little significant morphological change since 1904 when the lake was dammed. **Longlands Beck** The Longlands Beck was observed to be actively eroding and depositing with evidence of knickpoints having formed as a result of historical channel modifications. The channel has the capacity to adjust, with substrate as large as cobbles appearing to have been eroded from the banks and transported downstream.
Impacts on sediment regime	**River Ellen** The sediment regime along the River Ellen channel is disconnected during the majority of water levels as a result of the catchpit upstream of Chapelhouse Reservoir. An absence of finer material and gravels was observed below the reservoir, although these were not abundant in the upstream reaches. **Chapelhouse Reservoir** The water feeding into the reservoir is predominantly received from an outfall (providing water from a separate catchment) with connectivity to the catchpit only provided in flood flows. As a consequence, sediment flux through the reservoir is likely to be limited and constrained. **Over Water Reservoir** Over Water is fed by a network of small tributaries which do not appear to have significantly changed over the last century. Fine sediment is likely to be the key input into the reservoir. The weir structure damming the outflow is likely to trap some sediment and alter downstream fluxes of sediment when flowing. **Longlands Beck** The upstream length of the Longlands Beck channel is disconnected from the downstream length by a large weir beneath the local access track, likely to alter sediment processes and connectivity downstream. However, erosion and mobile sediment were both observed downstream, likely to provide a source to the River Ellen channel.
Impacts on longitudinal and latitudinal connectivity	**River Ellen** The Chapelhouse Reservoir infrastructure is inhibiting longitudinal and lateral connectivity in locations, particularly around the bypass channel, dry channel, catchpit and modified extent of the River Ellen. This has had an impact on the downstream reaches of the River Ellen channel. **Chapelhouse Reservoir** The reservoir is artificial and lies within a confined valley, longitudinal and lateral connectivity is therefore limited.

MCA Criteria	Assessment of Current Baseline Conditions
	Over Water Reservoir The longitudinal connectivity of Over Water Reservoir is inhibited by the weir at the downstream end. Lateral connectivity is present with the wet woodland around the southern, northern and western edges, but the eastern edge is disconnected as a result of an artificial embankment. **Longlands Beck** Lateral connectivity was found to be typically limited along the Longlands Beck due to the natural characteristics of the channel and the steep valley sides. Near to the River Ellen confluence, historical modification was noted to have reduced the lateral connectivity. Longitudinal connectivity was found to be significantly impacted by the large weir at Low Longlands and again by smaller weirs and modifications for farm crossing further downstream.

5. References

Bing. 2017. Maps – bird's eye view. Available online at: https://www.bing.com/mapspreview. [Accessed 18/09/2017].

British Geological Survey (BGS). 2017. Geology of Britain Viewer. Available online at: http://mapapps.bgs.ac.uk/geologyofbritain/home.html. [Accessed 14/09/2017].

British Library. 2017. Ordnance Survey mapping. Reading Rooms, London.

Cranfield Soil and Agrifood Institute (2016). Available at: http://www.landis.org.uk/soilscapes/about.cfm [Accessed14/09/2017].

Environment Agency. 2015. North West River Basin Management Plan (RBMP). Available online at: https://www.gov.uk/government/publications/north-west-river-basin-district-river-basin-management-plan. [Accessed 14/09/2017].

Environment Agency. 2017. Catchment Data Explorer. Available online at: http://environment.data.gov.uk/catchment-planning/. [Accessed 16/09/2017].

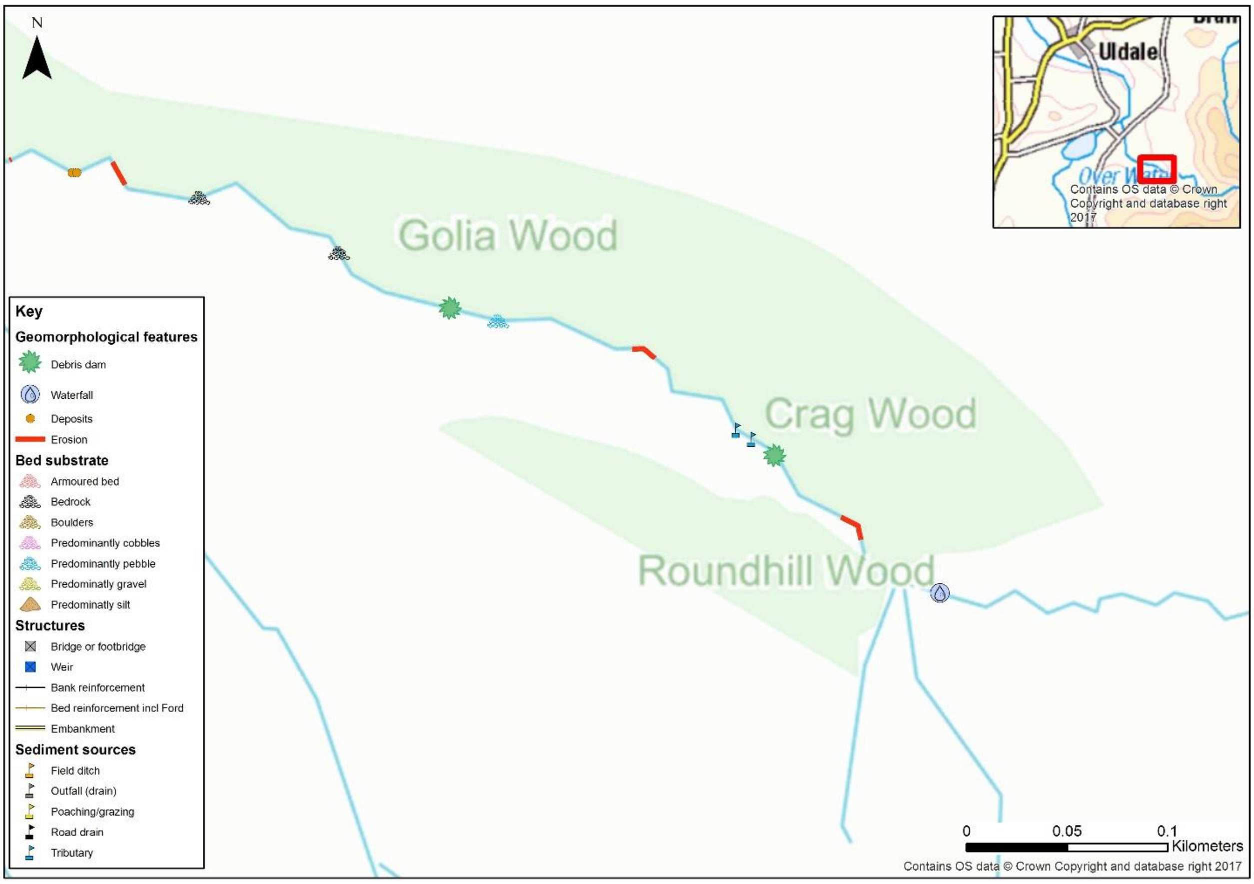
Jacobs (for United Utilities). 2016. Ehen Compensatory Measures-Scoping report for R6 and R3 Bleaching weirs removal.

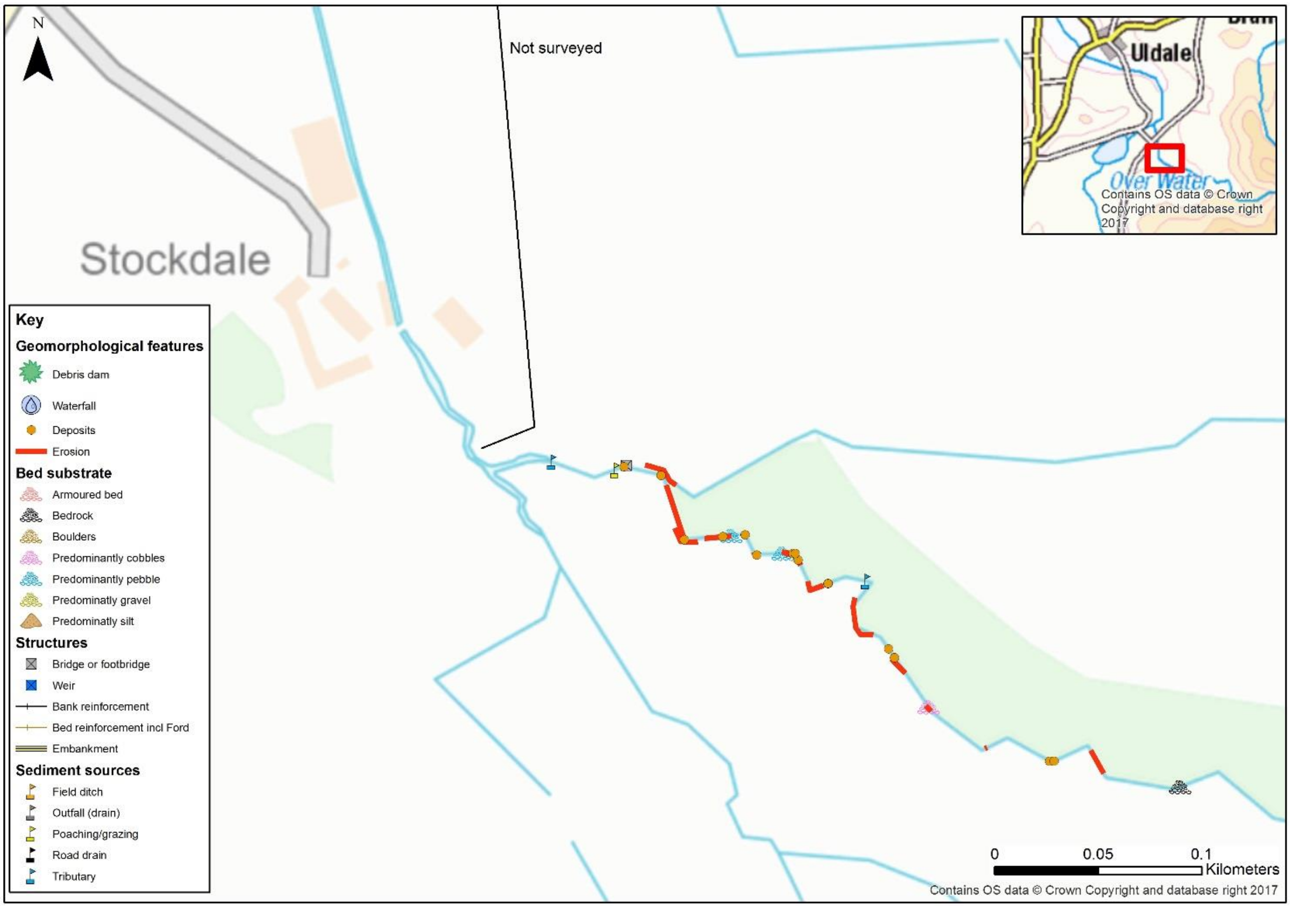
Jacobs (for the Environment Agency and Natural England). 2010. PSA3 Riverine SSSI Restoration Visions. November 2009 Flood Impact Survey.

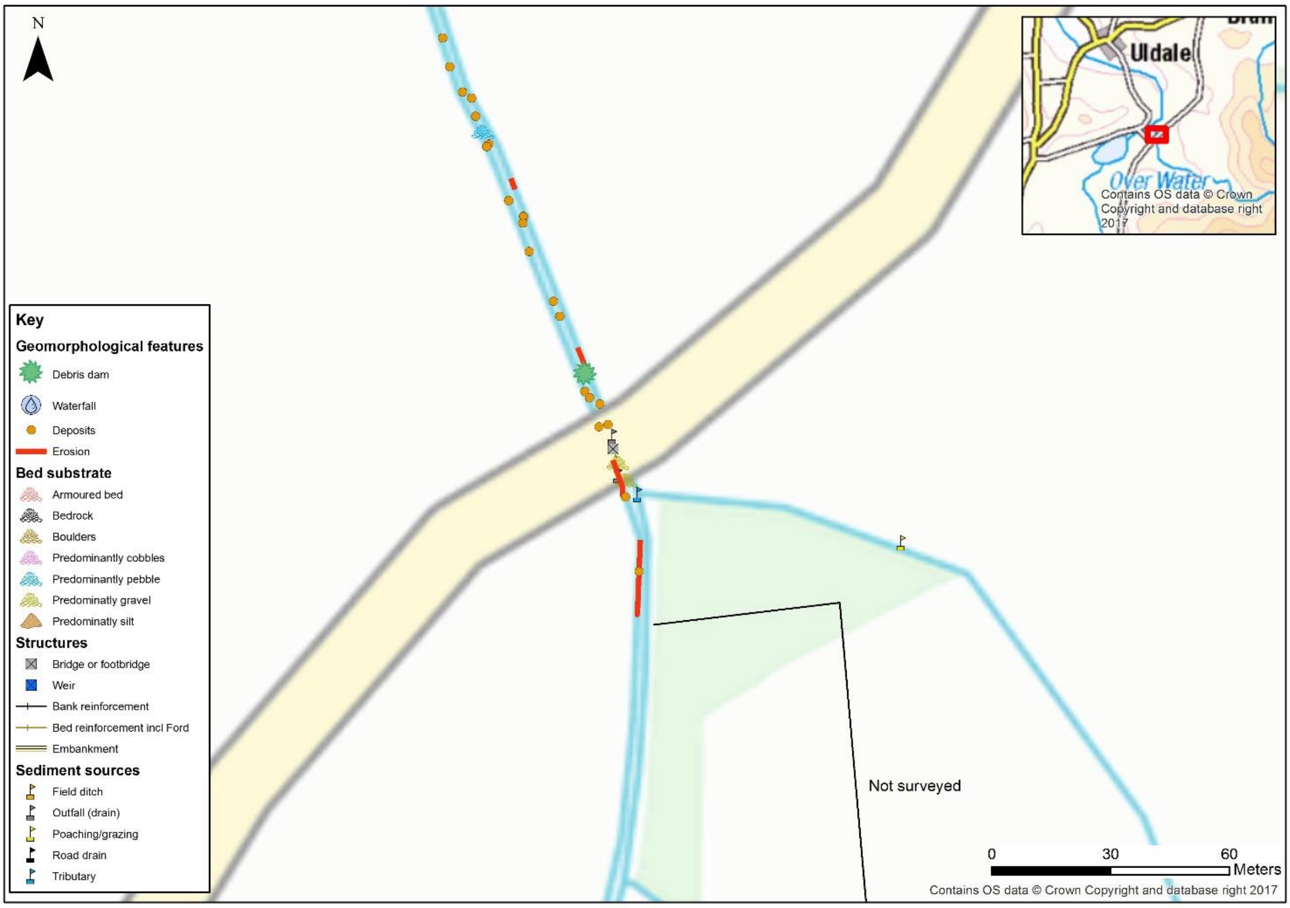
Multi-Agency Geographic Information for the Countryside (MAGIC). 2017. Interactive Mapper. Available online at: http://magic.defra.gov.uk/. [Accessed 12/09/2017].

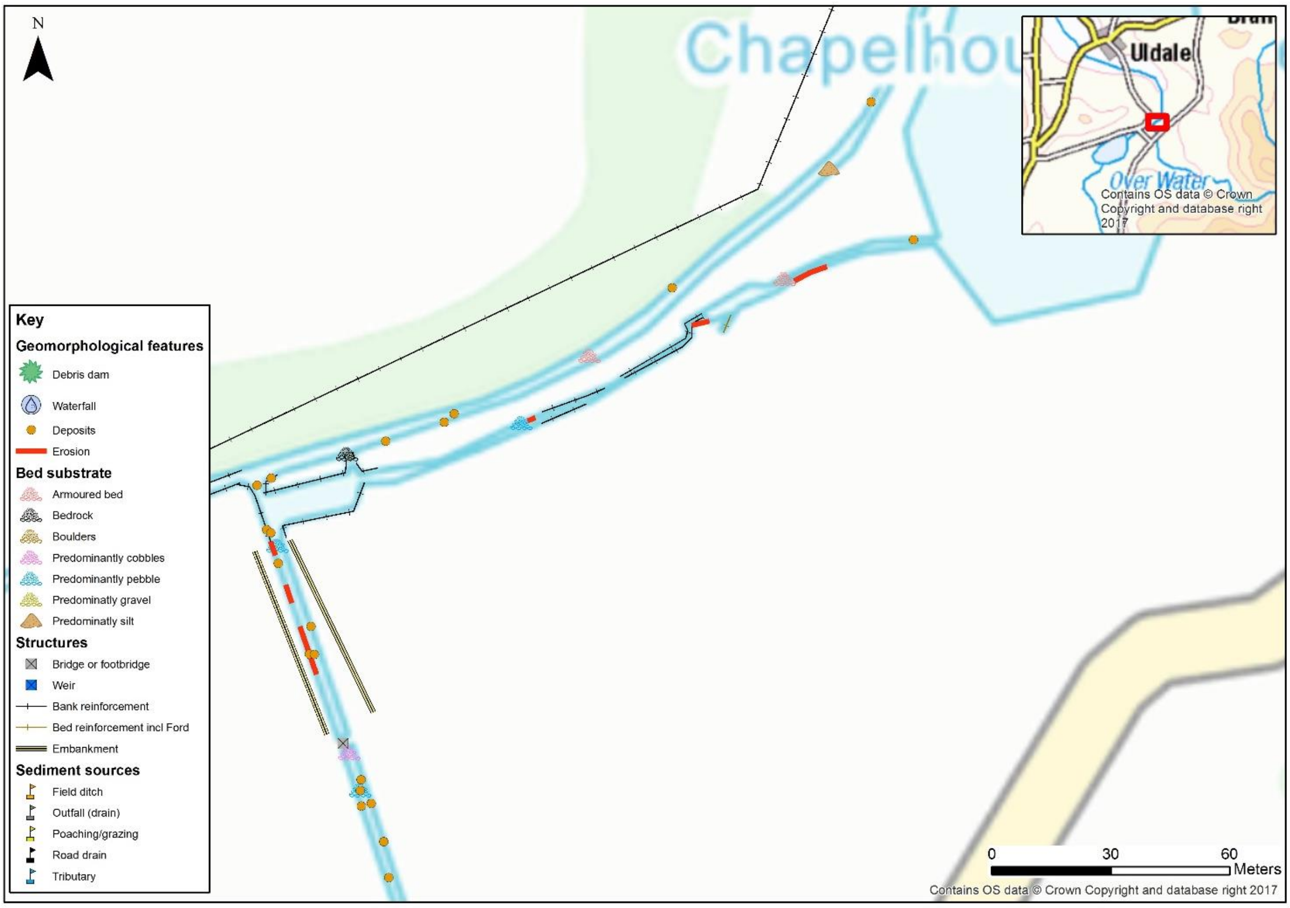
Annex A. Site Work Plans

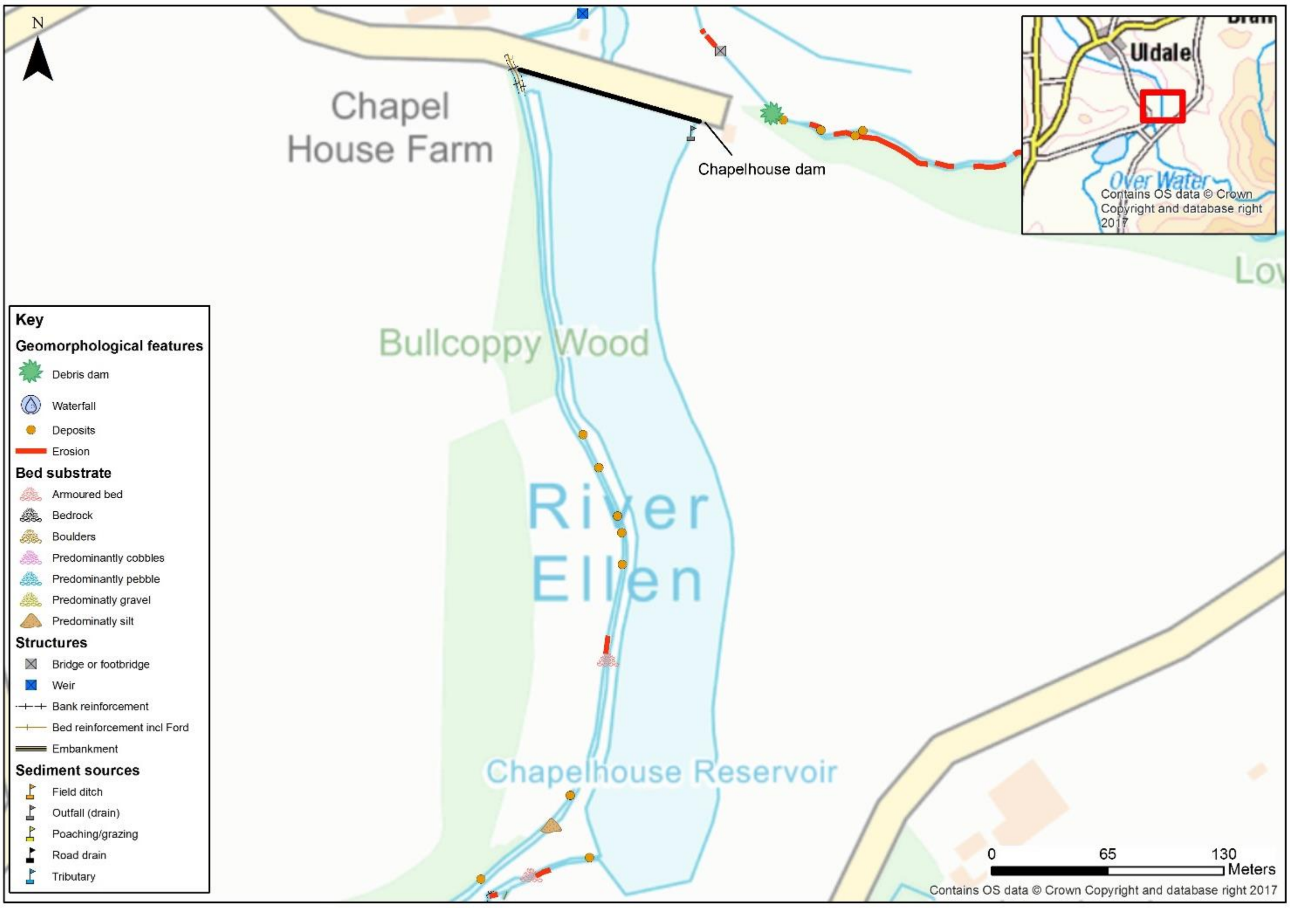
A.1 River Ellen and Chapelhouse Reservoir



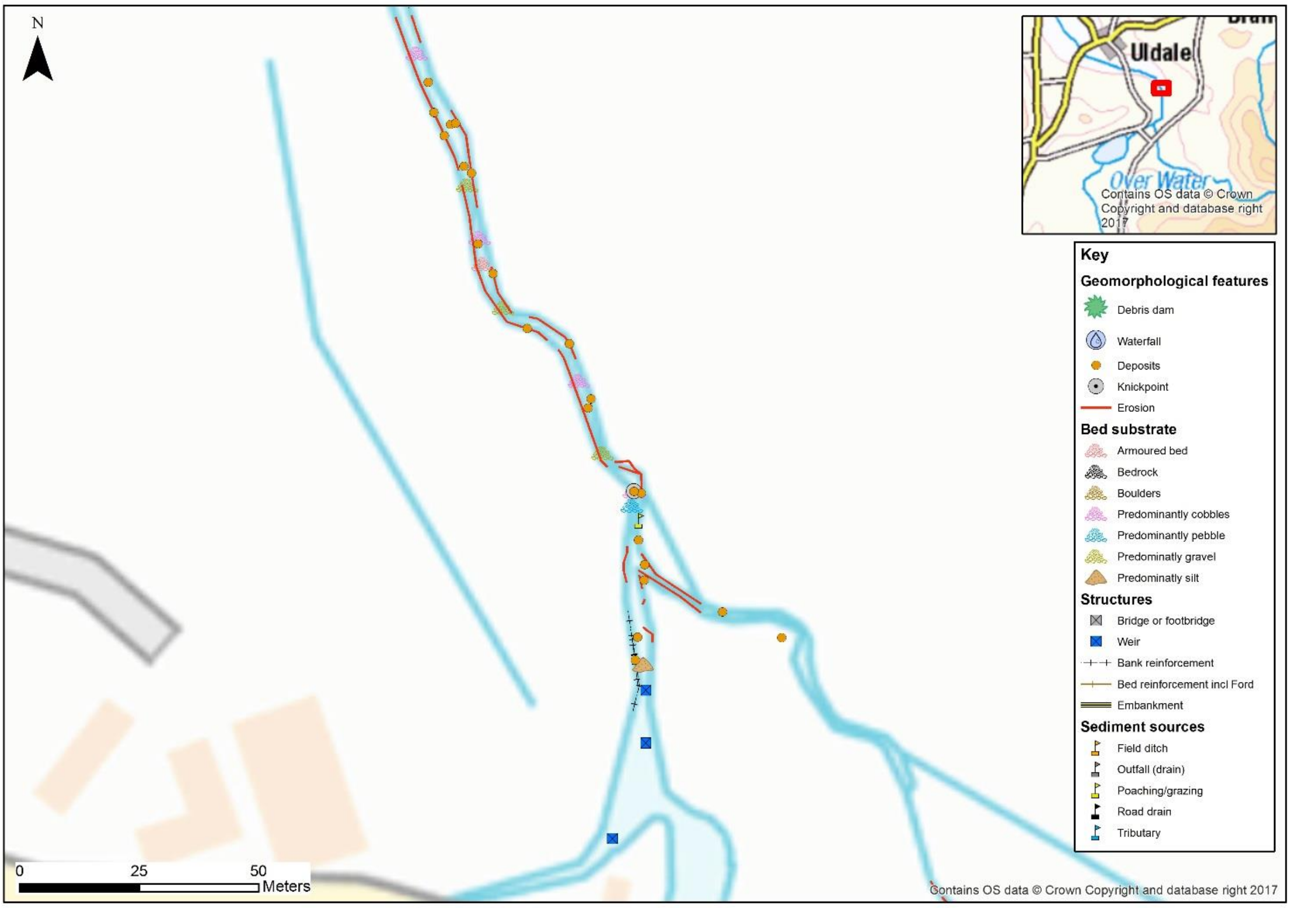

N
Not surveyed
Stockdale
Uldale
Over Water
Contains OS data © Crown Copyright and database right 2017
Key
Geomorphological features
Debris dam
Waterfall
Deposits
Erosion
Bed substrate
Armoured bed
Bedrock
Boulders
Predominantly cobbles
Predominantly pebble
Predominatly gravel
Predominatly silt
Structures
Bridge or footbridge
Weir
Bank reinforcement
Bed reinforcement incl Ford
Embankment
Sediment sources
Field ditch
Outfall (drain)
Poaching/grazing
Road drain
Tributary
0 0.05 0.1
Kilometers
Contains OS data © Crown Copyright and database right 2017

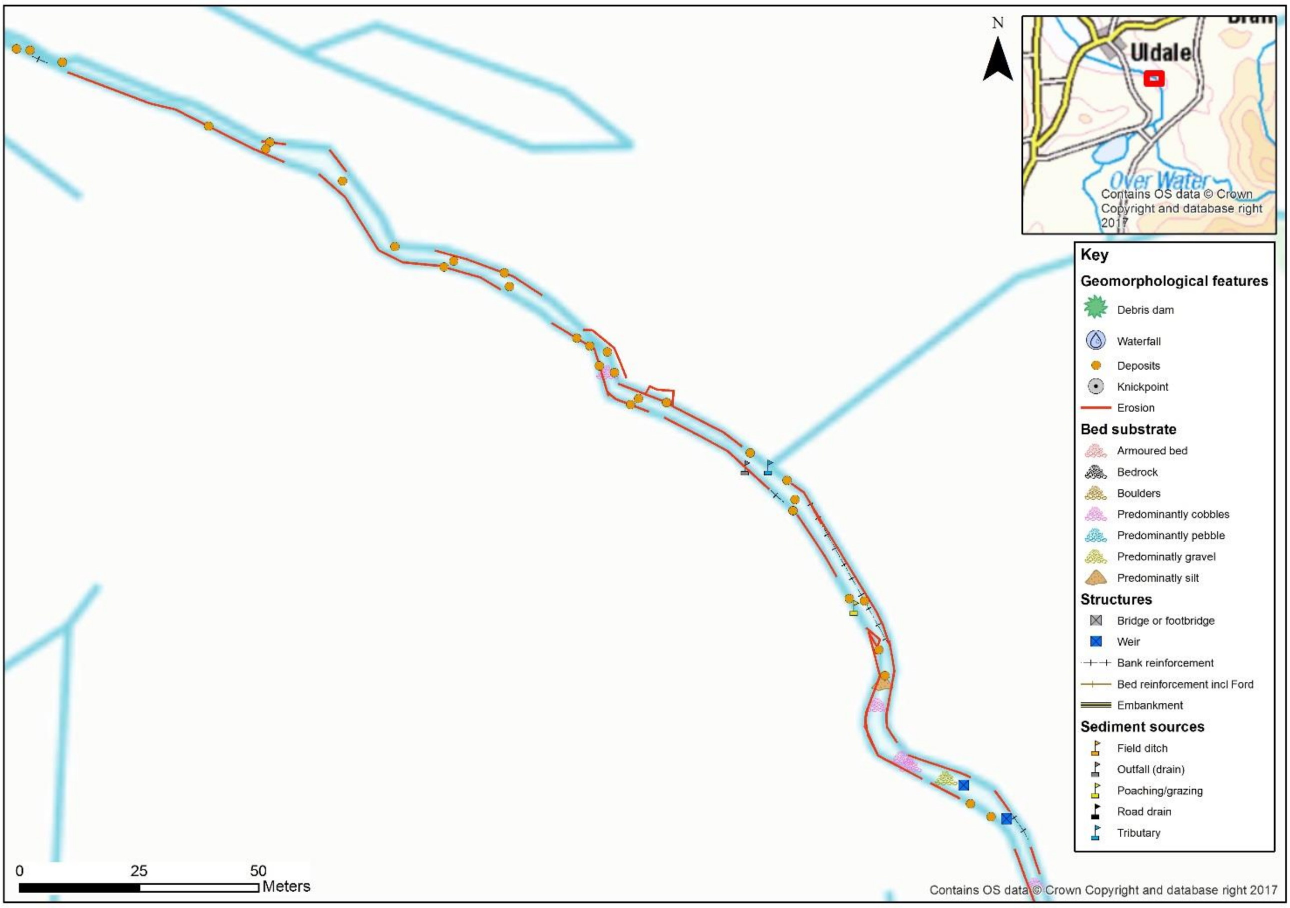

N
Uldale
Over Water
Contains OS data © Crown Copyright and database right 2017
Key
Geomorphological features
Debris dam
Waterfall
Deposits
Erosion
Bed substrate
Armoured bed
Bedrock
Boulders
Predominantly cobbles
Predominantly pebble
Predominatly gravel
Predominatly silt
Structures
Bridge or footbridge
Weir
Bank reinforcement
Bed reinforcement incl Ford
Embankment
Sediment sources
Field ditch
Outfall (drain)
Poaching/grazing
Road drain
Tributary
Not surveyed
0 30 60
Meters
Contains OS data © Crown Copyright and database right 2017

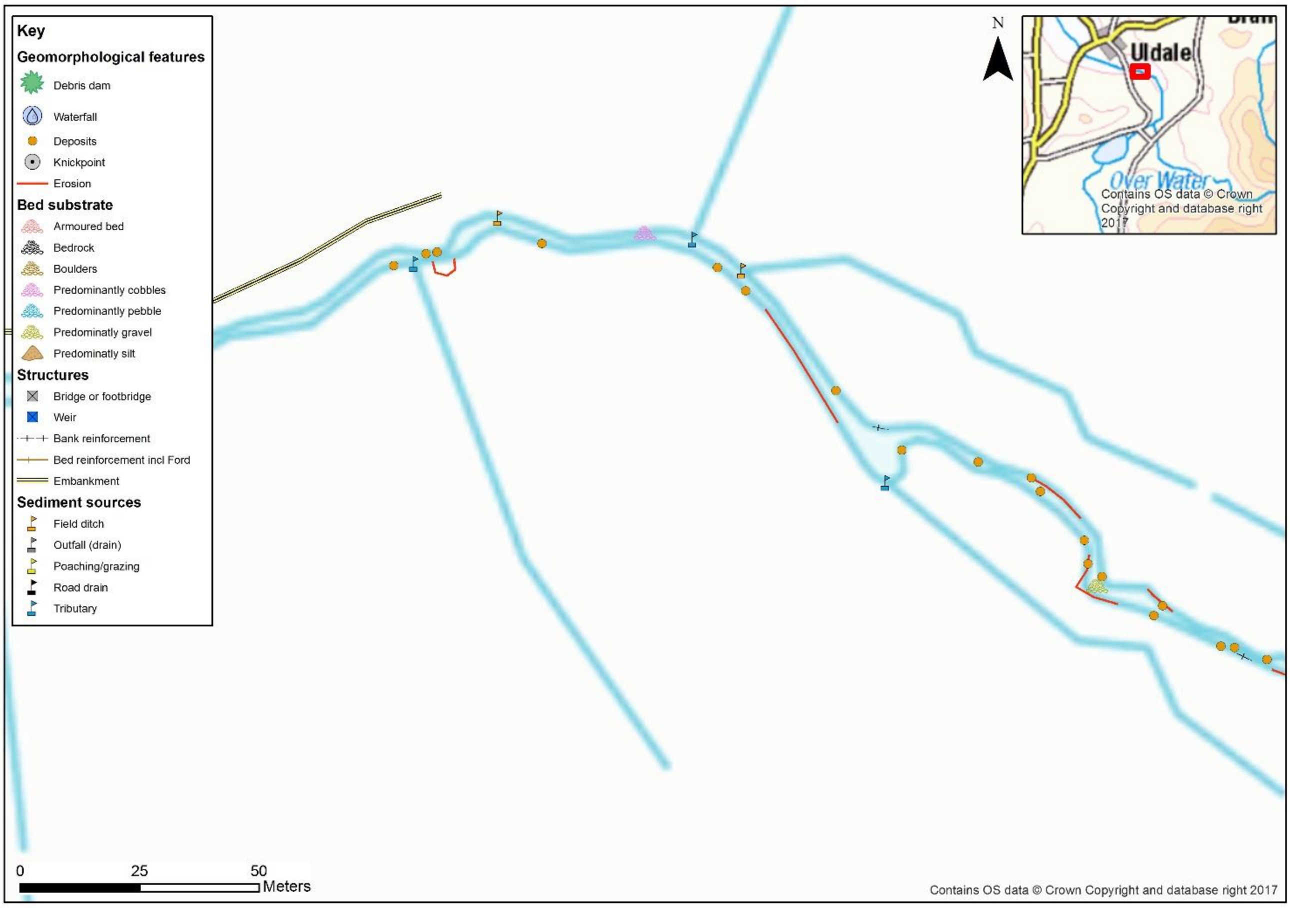

N
Chapelhou
Uldale
Over Water
Contains OS data © Crown Copyright and database right 2017
Key
Geomorphological features
Debris dam
Waterfall
Deposits
Erosion
Bed substrate
Armoured bed
Bedrock
Boulders
Predominantly cobbles
Predominantly pebble
Predominatly gravel
Predominatly silt
Structures
Bridge or footbridge
Weir
Bank reinforcement
Bed reinforcement incl Ford
Embankment
Sediment sources
Field ditch
Outfall (drain)
Poaching/grazing
Road drain
Tributary
0
30
60
Meters
Contains OS data © Crown Copyright and database right 2017

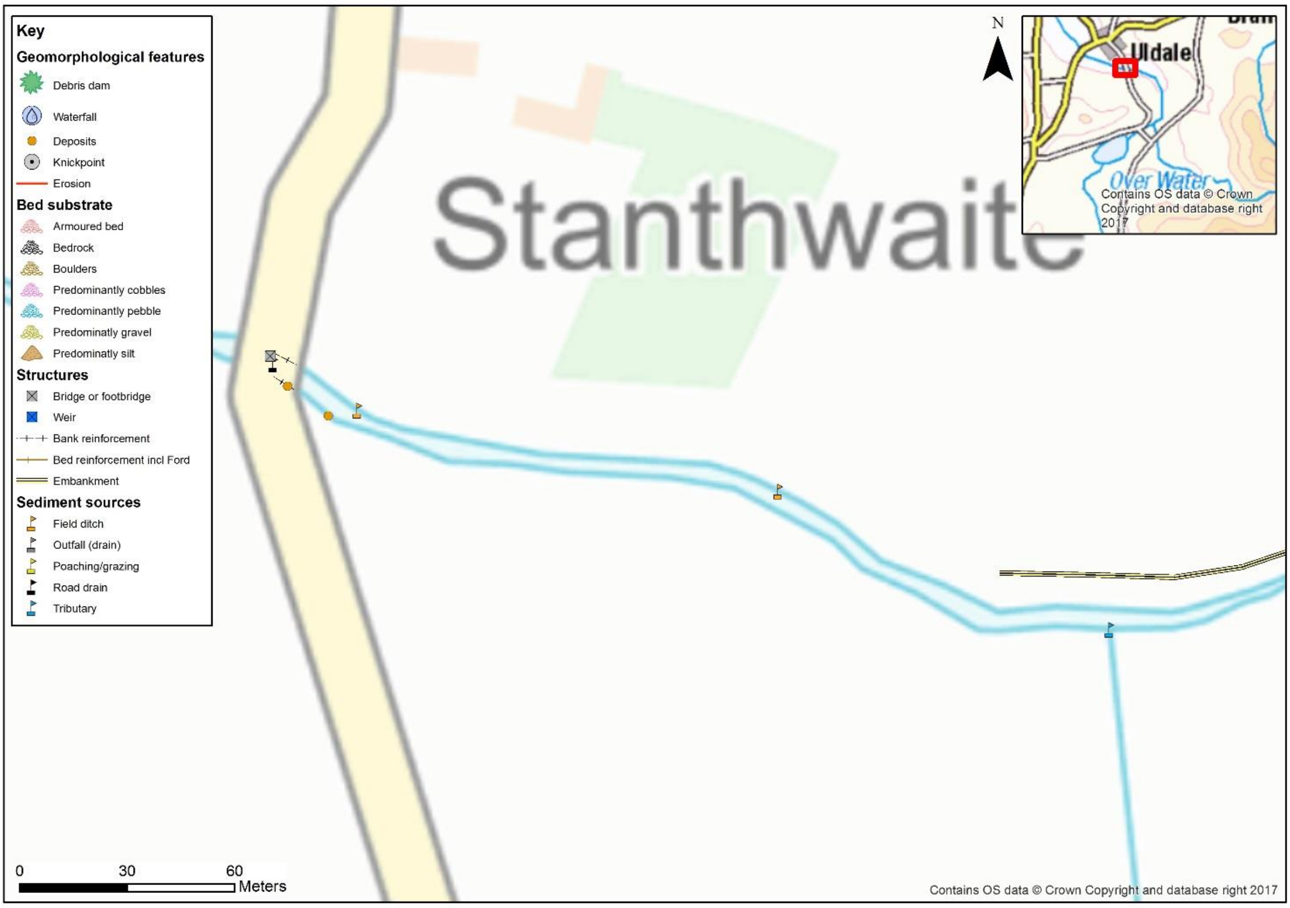


N
Chapel House Farm
Chapelhouse dam
Uldale
Over Water
Contains OS data © Crown Copyright and database right 2017
Bullcoppy Wood
River Ellen
Chapelhouse Reservoir
Key
Geomorphological features
Debris dam
Waterfall
Deposits
Erosion
Bed substrate
Armoured bed
Bedrock
Boulders
Predominantly cobbles
Predominantly pebble
Predominatly gravel
Predominatly silt
Structures
Bridge or footbridge
Weir
Bank reinforcement
Bed reinforcement incl Ford
Embankment
Sediment sources
Field ditch
Outfall (drain)
Poaching/grazing
Road drain
Tributary
0
65
130
Meters
Contains OS data © Crown Copyright and database right 2017

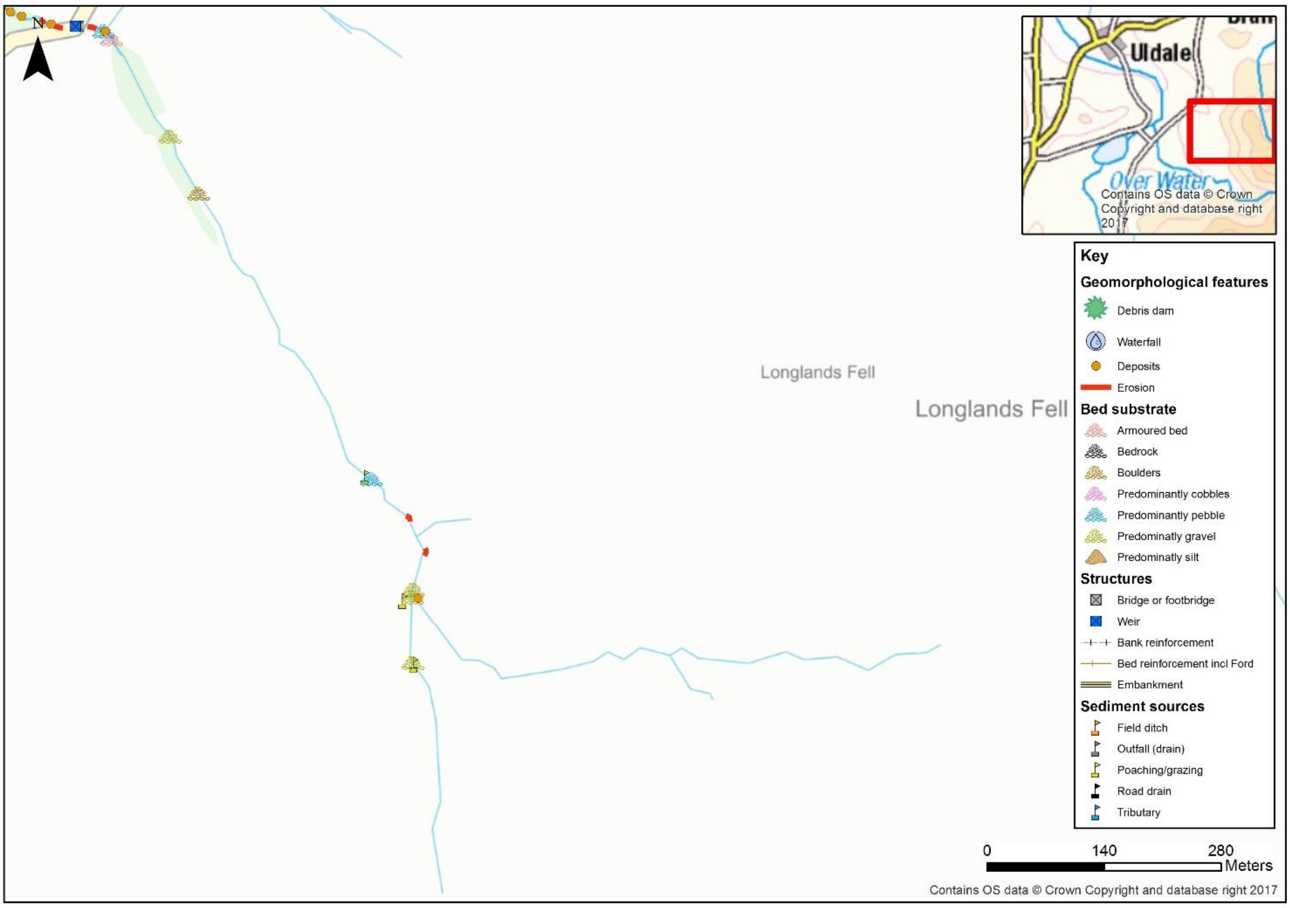

N
Uldale
Over Water
Contains OS data © Crown Copyright and database right 2017
Key
Geomorphological features
Debris dam
Waterfall
Deposits
Knickpoint
Erosion
Bed substrate
Armoured bed
Bedrock
Boulders
Predominantly cobbles
Predominantly pebble
Predominatly gravel
Predominatly silt
Structures
Bridge or footbridge
Weir
Bank reinforcement
Bed reinforcement incl Ford
Embankment
Sediment sources
Field ditch
Outfall (drain)
Poaching/grazing
Road drain
Tributary
0
25
50
Meters
Contains OS data © Crown Copyright and database right 2017

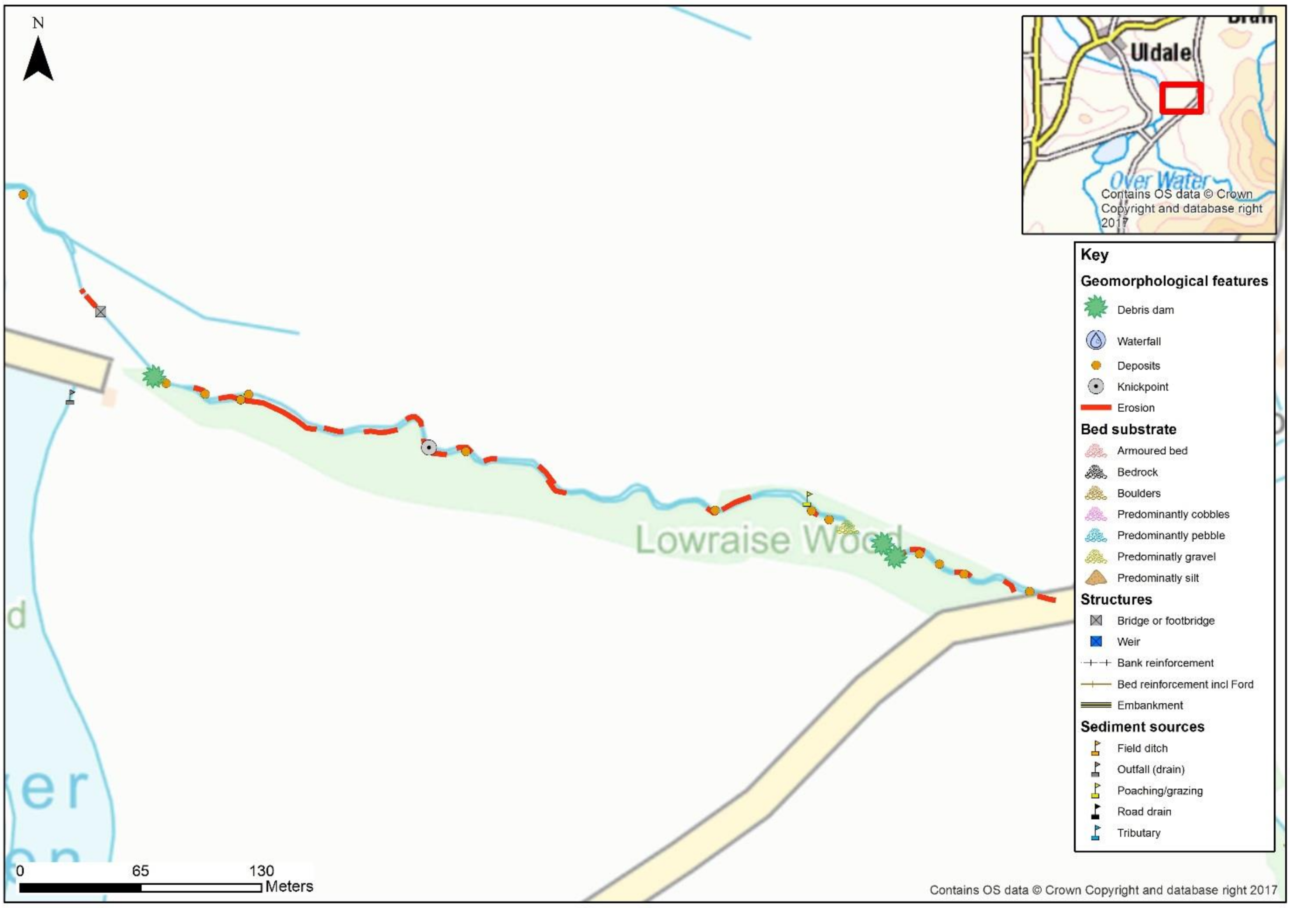

N
Uldale
Over Water
Contains OS data © Crown Copyright and database right 2017
Key
Geomorphological features
Debris dam
Waterfall
Deposits
Knickpoint
Erosion
Bed substrate
Armoured bed
Bedrock
Boulders
Predominantly cobbles
Predominantly pebble
Predominatly gravel
Predominatly silt
Structures
Bridge or footbridge
Weir
Bank reinforcement
Bed reinforcement incl Ford
Embankment
Sediment sources
Field ditch
Outfall (drain)
Poaching/grazing
Road drain
Tributary
0
25
50
Meters
Contains OS data © Crown Copyright and database right 2017


Key
Geomorphological features
Debris dam
Waterfall
Deposits
Knickpoint
Erosion
Bed substrate
Armoured bed
Bedrock
Boulders
Predominantly cobbles
Predominantly pebble
Predominatly gravel
Predominatly silt
Structures
Bridge or footbridge
Weir
Bank reinforcement
Bed reinforcement incl Ford
Embankment
Sediment sources
Field ditch
Outfall (drain)
Poaching/grazing
Road drain
Tributary
N
Uldale
Over Water
Contains OS data © Crown Copyright and database right 2017
0
25
50
Meters
Contains OS data © Crown Copyright and database right 2017


Key
Geomorphological features
Debris dam
Waterfall
Deposits
Knickpoint
Erosion
Bed substrate
Armoured bed
Bedrock
Boulders
Predominantly cobbles
Predominantly pebble
Predominatly gravel
Predominatly silt
Structures
Bridge or footbridge
Weir
Bank reinforcement
Bed reinforcement incl Ford
Embankment
Sediment sources
Field ditch
Outfall (drain)
Poaching/grazing
Road drain
Tributary
Stanthwaite
N
Uldale
Over Water
Contains OS data © Crown Copyright and database right 2017
0
30
60
Meters
Contains OS data © Crown Copyright and database right 2017

A.2 Longlands Beck




N
Uldale
Over Water
Contains OS data © Crown Copyright and database right 2017
Lowraise Wood
Key
Geomorphological features
Debris dam
Waterfall
Deposits
Knickpoint
Erosion
Bed substrate
Armoured bed
Bedrock
Boulders
Predominantly cobbles
Predominantly pebble
Predominatly gravel
Predominatly silt
Structures
Bridge or footbridge
Weir
Bank reinforcement
Bed reinforcement incl Ford
Embankment
Sediment sources
Field ditch
Outfall (drain)
Poaching/grazing
Road drain
Tributary
0
65
130
Meters
Contains OS data © Crown Copyright and database right 2017

Annex B. Long List of Potential Options

The following are the long list of options developed during the site work, not accounting for any potential constraints, costs or engineering practicalities. These will be taken forward and further assessed as part of the detailed study being undertaken.

Table B.1 : Long list of potential options developed on site

ID	Watercourse	Option
O1	Over Water Reservoir	Remove weirs
O2	Over Water Reservoir	Remove bank and bed reinforcement downstream
O3	Over Water Reservoir	Improve downstream section (upstream of weir) - five options:
O3a		a) Re-grade
O3b		b) Low flow slot
O3c		c) Riparian habitat
O3d		d) Re-meandering
O3e		e) Gravel augmentation
O4	Over Water Reservoir	Improve section between road and catchpit - has five options as above (a-e)
O5	Over Water Reservoir	Downstream of bridge remove bank reinforcement and narrow channel
C1	Chapelhouse Reservoir	Catchpit – remove and reconnect River Ellen (silt issues)
C2	Chapelhouse Reservoir	Catchpit – naturalise if possible and remove some reinforcement
C3	Chapelhouse Reservoir	Remove dam
C4	Chapelhouse Reservoir	Partial removal of dam
C5	Chapelhouse Reservoir	Make weirs passable downstream of fish pass
C6	Chapelhouse Reservoir	Improve bypass
C7	Chapelhouse Reservoir	Create a new bypass channel on east of reservoir
E1	River Ellen	Re-naturalise – cut across field downstream of road towards the reservoir (meandering planform)
E2	River Ellen	Straightened length – re-naturalise
E3	River Ellen (downstream)	Gravel augmentation to improve habitat
E4	River Ellen (downstream)	Weir and bank reinforcement removal
L1	Longlands Beck	Remove weir under road by Low Longlands
L2	Longlands Beck	Remove infrastructure on channel edge
L3	Longlands Beck	Riparian planting on right bank downstream of wood
L4	Longlands Beck	Stop dredging
-	Full removal of everything	
-	Combinations of options	
-	All	Riparian planting – as an add on

Appendix E. Detailed Ecology Baseline Assessment

Please see the attached Appendix E document

Over Water and Chapelhouse Reservoirs

United Utilities

Ecology Baseline Assessment

B2705358/01/001 | 03

15 February 2019

Client Reference

Over Water and Chapelhouse

Project No:	B2705358
Document Title:	Ecology Baseline Assessment
Document No.:	B2705358/01/001
Revision:	03
Date:	15 February 2019
Client Name:	United Utilities
Client No:	Client Reference
Project Manager:	David Dickson
Author:	N Washbourne

Jacobs U.K. Limited

4th Floor, Metro
33 Trafford Road
Salford
M5 3NN
United Kingdom
T +44 (0)161 873 8500
F +44 (0)161 873 7115
www.jacobs.com

Document history and status

Revision	Date	Description	By	Review	Approved
0.1	12 July 2017	Baseline ecology text Check of baseline ecology text by J McLeish	N Washbourne	S Coyle/ J Barnes	
0.2	20 September 2017	Updates to baseline ecology text	N Washbourne		
0.3	15 February 2019	Updates to baseline ecology text	N Washbourne	S Coyle	

Contents

1. Introduction

1.1 Background

Jacobs have been commissioned to investigate the feasibility of removing water abstraction-related infrastructure from Over Water and Chapelhouse reservoirs and nearby watercourses. To do this a multidisciplinary team is investigating Engineering and Geomorphological, Hydraulic/Flood Risk and Ecological opportunities and constraints.

The Study Area includes all or part of the following areas: River Ellen from source to Chapelhouse Reservoir, Over Water Reservoir, the terrestrial and aquatic margins of Over Water, Over Water Weir and outlet, the River Ellen from Chapelhouse Reservoir to 2 km downstream, adjacent wetland to Chapelhouse and Longlands Beck from source to confluence with the River Ellen (Figure 1.1).

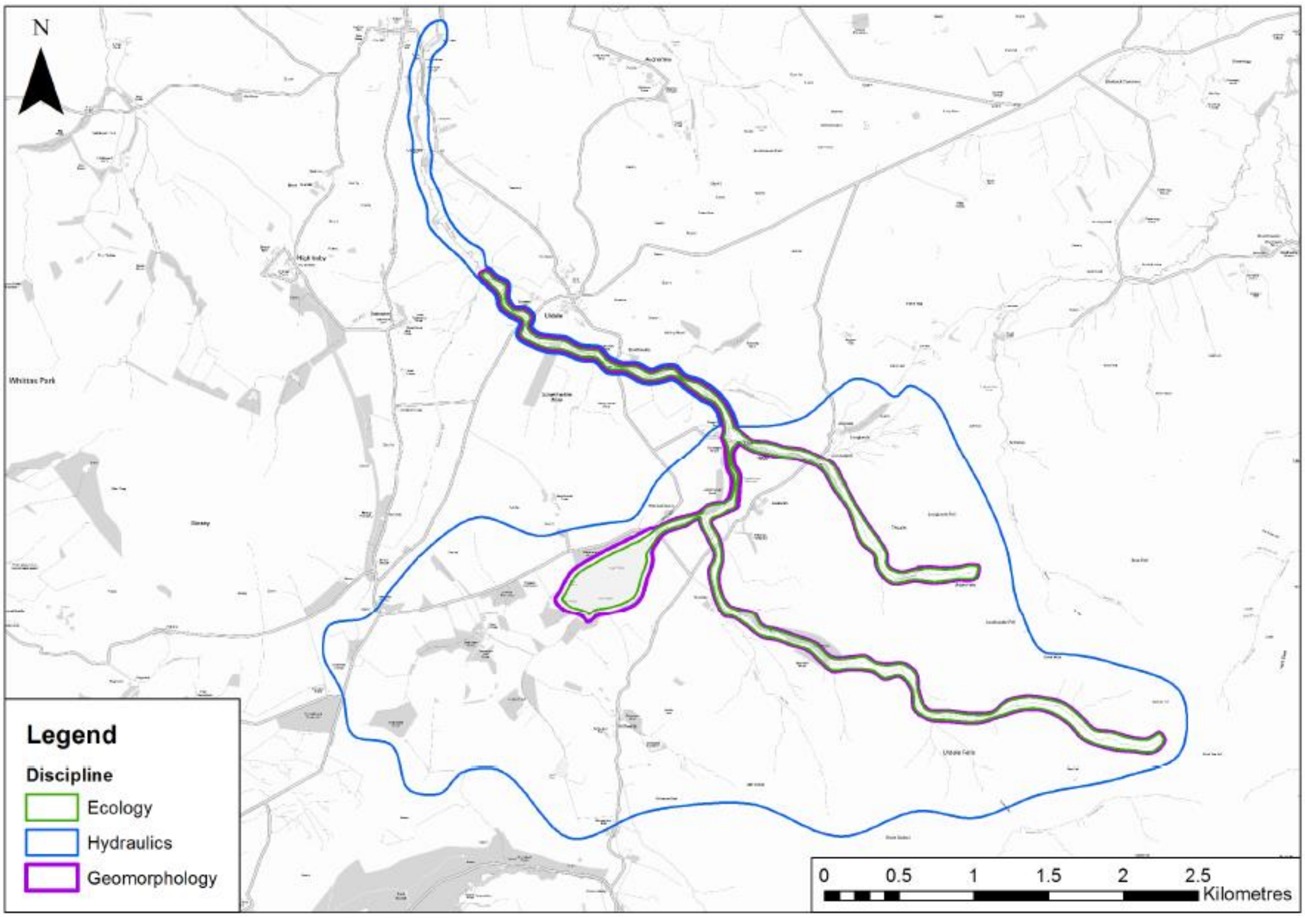


Figure 1.1 Over Water and Chapelhouse Reservoirs Study Area

The study will focus on the following infrastructure, as shown in Figure 1.2:

- Over Water weir, embankment and intake pipes;
- Chapelhouse dam;
- Chapelhouse old spillway and including the fish pass;
- Chapelhouse new spillway;
- the embankment carrying the River Ellen along the western edge of Chapelhouse; and
- the catchpit and sluice on the River Ellen upstream of Chapelhouse.

1.2 Aims and Objectives of Baseline Study

A key part of the study is to establish a baseline which the effectiveness and impact of options will be assessed against in a Multi-Criteria Analysis.

The aim of this Technical Note is to provide this baseline assessment for the Ecology Discipline for the Over Water and Chapelhouse reservoirs Study Area shown in Figure 1.2 below.

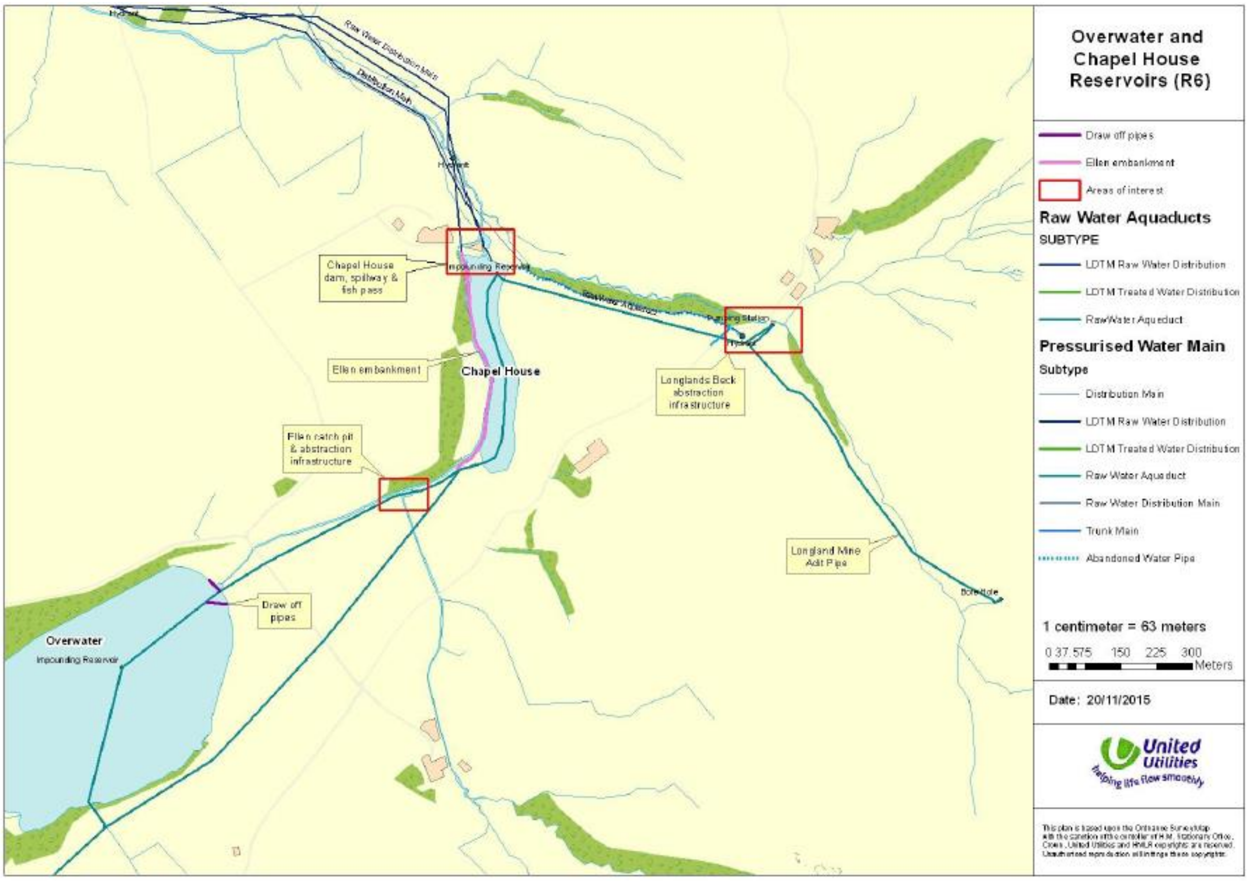


Figure 1.2 Water Abstraction Infrastructure at Over Water and Chapelhouse reservoirs

2. Approach/Method

2.1 Defining the Baseline

Current ecological conditions and the actions required to maintain them form the baseline of this study. In locations containing infrastructure or habitat modifications, any actions required to sustain the present conditions, including the maintenance and monitoring of United Utilities structures, should be considered. For example, to keep the Chapelhouse Dam fish pass in its current form, additional measures to allow passage of all migratory fish species may be needed.

The appraisal period for this project is 10-15 years from the implementation of the preferred option. Thus, the scores for options could differ from what they would be if they were assessed over a longer time period (e.g. 50 years).

2.2 Criteria Forming the Baseline Assessment

The Scoping Study identified the criteria in Table 2.1 as the factors that all options being considered will be assessed against. Therefore, the baseline for the ecology discipline will be defined for these criteria.

Table 2.1: Multi-Criteria Performance Criteria for Over Water and Chapelhouse Reservoirs

Multi-criteria assessment performance criterion	Assessment methodology for high level assessment
Maintained/ enhanced key river species habitat	Would the option cause an alteration in the status of the biological quality elements (under the WFD)? Would the option change the provision of suitable habitats for a functioning and sustainable aquatic community?
Maintained/ enhanced key lake species habitat (designated macrophyte species)	Would the option have the potential to affect lake habitats (water levels, water quality/ retention, hydromorphological processes) typical of the lake community? Would the option change the current quality standards?
Maintained/ enhanced populations of important lake species	Would the option have the potential to affect lake habitats (water quality/quantity/levels) for important botanical species? Are there opportunities between options to enhance the lake habitat (control of water levels, retention, water transfer, water quality) to increase presence/ abundance of important lake species?
Maintained/ enhanced passage of migratory fish	Would the option result in a change in the number of fish (including salmon and eel) able to ascend the Chapelhouse fish pass? Would the option increase the passability of the Chapelhouse structure and connectivity between Chapelhouse and Over Water for migratory species?

The key **river species** (and habitats that support these species) for this assessment are Atlantic salmon (*Salmo salar*), brown/ sea trout (*Salmo trutta*), brook lamprey (*Lampetra planeri*), river lamprey (*Lampetra fluviatilis*), sea lamprey (*Petromyzon marinus*), European eel (*Anguilla anguilla*) and Eurasian otter (*Lutra lutra*). Of these, salmon, brown/ sea trout, river and sea lamprey and eel are **migratory species**.

The important **lake species** of interest to this study are listed within the Over Water Site of Special Scientific Interest (SSSI) citation (Section 3) and sensitive species known to reside or utilise resources within the Over Water and Chapelhouse reservoir waterbodies.

3. Study Area Overview

The Study Area encompassed the River Ellen, Longlands Beck, Over Water Reservoir, Chapelhouse Reservoir, and the channel connecting the two reservoirs (Figures 1.2, A1-A5). The River Ellen originates in upland habitat south of Stockdale Farm and historically followed a natural course northeast from the farm through what is now Chapelhouse Reservoir. The river has since been modified substantially, so for this assessment the River Ellen is identified by a series of sub-reaches, as named and described below:

- River Ellen (upstream): the River Ellen as it follows a predominantly natural course from its upland origins south of Stockdale Farm to the unnamed road (Figure A3);
- River Ellen (channelised section): the straightened section of the River Ellen between the unnamed road and the catchpit (Figure A3);
- Dry Channel: small channel situated east from the catchpit that was dry at the time of surveys (Figure A2);
- Wetted Channel: a small channel flowing east from the downstream extent of the Dry Channel into Chapelhouse Reservoir. Flow to this channel originates from an outfall in the pasture (Figure A2);
- Bypass Channel: the channel flowing from Over Water Reservoir past the catchpit and Chapelhouse Reservoir and into the Chapelhouse fish pass (Figures A2-A5); and
- River Ellen (downstream): the River Ellen as it follows a predominantly natural course downstream of Chapelhouse Dam to the Irish Sea (Figure A1).

Chapelhouse Reservoir follows the historic natural course of the River Ellen. The reservoir was created in 1902 when the river was impounded by a dam (Atkins, 2009[1]). There are no conservation designations that encompass all or part of Chapelhouse Reservoir.

Over Water Reservoir is a natural tarn that was impounded by a weir in 1905 which subsequently raised the water level by approximately 1.2 m (Atkins, 2008[2]). Over Water SSSI encompasses Over Water Reservoir and the adjacent wet woodland and grassland areas (Natural England (NE), undated[3]). The reservoir and adjacent habitats were designated due to its high species diversity and recognised importance for breeding birds. The rare cladoceran macroinvertebrate, *Illyocryptus acutifrons*, which is found in few lakes in the area, is also present in Over Water Reservoir (Alvarez-Codestal *et al*., 2016[4]).

Over Water Reservoir and associated swamp habitats were surveyed in 2009 and 2010 to determine condition for the SSSI (NE, undated[3]). Key aquatic macrophyte species were not recorded in the reservoir during the surveys, the non-native macrophyte New Zealand pygmyweed (*Crassula helmsii*) was present and an unacceptable amount of sediment was exposed in the swamp habitats, and these factors led to a designation of Unfavourable declining for Over Water Reservoir and adjacent swamp habitats. The wet woodland areas on the northern shore of Over Water Reservoir and one area of the southern shore were assessed as being in Favourable condition in 2010. The wet woodland units at the southwestern extent of the reservoir were all assessed as being in Unfavourable condition in 2010 due to the tree assemblages and the presence of non-native species. The River Ellen (entire length within the study area), Chapelhouse Reservoir and Over Water Reservoir are all Water Framework Directive (WFD) water bodies. Chapelhouse and Over Water reservoirs are both Drinking Water Protected Areas and are also classified under the WFD as 'heavily modified' water bodies due to impoundments and other infrastructure. The most recent WFD classifications for water bodies in the study area are given in Table 3.1.

[1] Atkins (2009). United Utilities Chapel House Reservoir. Report on an inspection on Reservoirs Act 1975 Section 10(2) of the Act.
[2] Atkins (2008). United Utilities Over Water Reservoir. Report on an inspection under Reservoirs Act 1975 Section 10(2) of the Act.
[3] Natural England (undated). Over Water SSSI. Available at: https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=s1000433 (Accessed 4 February 2019).
[4] Alvarez-Codesal, S., Fletcher, M., Pentecost, A. and Pawley, S. (2016). Surveys of the invasive aquatic plant *Crassula helmsii* (extent and impact) and the rare freshwater crustacean *Ilyocryptus acutifrons* in Over Water, Cumbria.

Table 3.1: WFD Classifications from 2016 (EA, undated[5,6,7])

Parameter	River Ellen (upper)	Chapelhouse Reservoir	Over Water Reservoir
ID	GB112075073630	GB31228796	GB31228806
Hydromorphological designation	n/a	Heavily Modified	Heavily Modified
Overall status	Good	Moderate	Moderate
Chemical status	n/a	Good	Good
Fish	High	n/a	n/a
Macroinvertebrates	Good	n/a	n/a
Chironomids (CPET)	n/a	n/a	Good
Macrophytes and Phytobenthos	n/a	n/a	Moderate
Phytoplankton	n/a	n/a	Good
Total Phosphorus	n/a	n/a	Moderate

A geophysical survey was undertaken in November 2018 to identify the substrates present within Chapelhouse Reservoir and adjacent to both Chapelhouse and Over Water reservoirs (Geotechnics, 2018[8]). The surface substrates (upper 10 cm) within Chapelhouse Reservoir were identified as primarily clay with smaller amounts of sand, gravel, silt and decaying plant matter. In addition, a survey of the Chapelhouse Reservoir draw-off value in 2014 found that the base of the valve was buried in silt (Red7Marine, 2014[9]). The substrates adjacent to Chapelhouse Reservoir consisted of topsoil then a layer of coarser substrates (e.g. gravel, coarse sand, some cobble) over clay, and potential bedrock at 4.45 m. The substrates along the north-eastern shore of Over Water Reservoir were identified as topsoil over clay with varying amounts of sand and gravels, with gravels beneath the clay.

[5] Environment Agency (undated). Ellen (upper). Available at: http://environment.data.gov.uk/catchment-planning/WaterBody/GB112075073630 (Accessed 11 February 2019).
[6] Environment Agency (undated) Over Water. Available at: http://environment.data.gov.uk/catchment-planning/WaterBody/GB31228806 (Accessed 11 February 2019).
[7] Environment Agency (undated) Chapelhouse Reservoir. Available at: http://environment.data.gov.uk/catchment-planning/WaterBody/GB31228796 (Accessed 11 February 2019).
[8] Geotechnics (2018). Chapelhouse and Overwater Infrastructure Removal Factual Report for United Utilities Water Limited.
[9] Red7Marine (2014). Draw-off valve survey. Chapel House Reservoir.

4. Results – key river species and migratory species

4.1 Atlantic Salmon

4.1.1 Introduction

Atlantic salmon is listed in accordance with the requirements of Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006 (England) (NE, undated[10]), and is also listed under Annex II of the European Commission's (EC's) Council Directive 92/43/EEC (the Habitats Directive) (EC, 1992[11]). It is a qualifying species for the designation of the nearby River Derwent and Bassenthwaite Lake Special Area of Conservation (SAC) (Joint Nature Conservation Committee (JNCC), 2015[12]).

4.1.2 Desk Based Literature Review

The River Ellen is one of England's main salmon rivers, but the population in river is likely to be considered 'Probably at Risk' of not achieving conservation management targets (Environment Agency (EA), 2014[13]). The River Ellen catchment drains largely agricultural land used for livestock grazing, and diffuse pollution is one of the major pressures affecting aquatic habitat quality.

Recreation fishing for Atlantic salmon is active in the River Ellen, and rod catch returns data from the past 13 years show a substantial decline in rod catches since 2010, with only one reported salmon caught in 2014, 2016 and 2017 respectively, and none caught in 2015 (Figure 4.1) (EA, 2017[14], 2018[15]). It should be noted that this information is reliant upon accurate catch reports from recreational anglers and gives no measure of catch effort (i.e. number of active fisherman), so is not directly representative of current stock conditions.

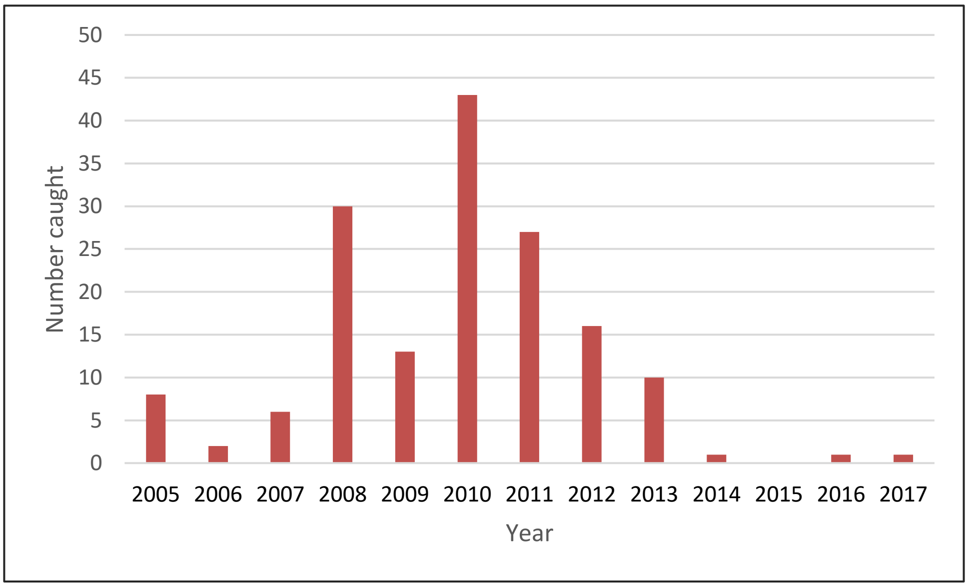


Figure 4.1: EA Rod Catch Data for Atlantic Salmon 2005 to 2017

---

10 Natural England (undated). Section 41 Species – Priority Actions Needed (B2020-008). Available at: http://publications.naturalengland.org.uk/publication/4958719460769792 (Accessed 4 February 2019).
11 European Commission (1992). Council Directive 92/43/EEC of 21 Ma 1992 on the conservation of natural habitats and of wild fauna and flora.
12 Joint Nature Conservation Committee (2015). NATURA 2000 – Standard Data Form for River Derwent and Bassenwaite Lake. Available at: http://jncc.defra.gov.uk/protectedsites/sacselection/n2kforms/UK0030032.pdf (Accessed4 February 2019).
13 Environment Agency (2014). Examination in Public in connection with a draft Water Resource Management Plan prepared by United Utilities Water PLC – Environment Agency Statement of Case.
14 Environment Agency (2017). Salmon and freshwater fisheries statistics for England and Wales, 2015. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/642200/Salmonid_and_Freshwater_Fisheries_Report_2015.pdf (Accessed 4 February 2019).
15 Environment Agency (2018). Salmonid and freshwater fisheries statistics for England and Wales, 2017. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/753925/Salmonid_and_Freshwater_Fisheries_Report_2017.pdf (Accessed 4 February 2019).

The EA undertake routine fish surveys throughout England, and Atlantic salmon were recorded throughout the river, to Uldale, from 2005-2017 (EA, 2018[16]). Atlantic salmon are known to be present in Chapelhouse Reservoir (Grontmij, 2012[17]) and in the River Ellen upstream of Chapelhouse Reservoir (Biological Records Centre (BRC), undated[18]) with one record from 1995 confirming their presence, thus indicating that these fish are able to migrate upstream and downstream past the Chapelhouse Reservoir fish pass. No historic information is available on the presence of Atlantic salmon in Over Water Reservoir or Longlands Beck. No information is available on the habitat types within the upper River Ellen catchment that may support Atlantic salmon life stages.

Atlantic salmon are anadromous, hatching and spending their juvenile life stages (fry and parr) in freshwater, migrating out to sea as smolts where they undergo rapid growth and, after a few years, returning to their natal rivers as adults to spawn. During their freshwater phases, habitat requirements of salmon are relatively specific with clean cobble/ pebble mixes being the preferred habitats. It is also essential that spawning grounds are clean of excessive fine sediments (Hendry and Cragg-Hine, 2003[19]). Favourable locations for spawning are likely to occur where there is a river gradient of ≤3% and sites are typically in transitional areas between pool and riffle where suitable course gravels and cobbles are present.

Relatively shallow depths (20-40 cm) and fast flows (50-75 cm/s) are optimal for juveniles (Table 4.1 and Appendix B) although migrating adults generally require higher flows, especially if there are obstructions to pass. Slow flowing systems with a high proportion of silt are not suitable for Atlantic salmon. In general, juvenile fish are more sensitive than adults as they are less mobile, however, much of the available data quantifying impacts relate to adults. Very good water quality is required at all stages of the salmon life cycle.

Table 4.1: Habitat Requirements of Juvenile and Adult Atlantic Salmon (Hendry and Cragg-Hine, 2003[19])

Juvenile fish <1 year old (fry)	
Water depth	≤20cm
Water velocity	50-65cm/s
Substrate type *winter *summer	Gravel and cobble (16-64mm) Cobble to boulder (64-256mm)
Juvenile fish >1 year old (parr)	
Water depth	20-40cm
Water velocity	50-75cm/s
Substrate	Cobble up to boulder (64-256mm)
Adult spawning	
Water depth	0.17-0.76cm (in main stems often much deeper)
Water velocity	0.25-0.90m/s
Substrate	Mix of fine materials (<2mm), pebbles and cobbles

[16] Environment Agency (2018). Freshwater Fish Counts for all Species, all Areas and all Years. Available at: https://data.gov.uk/dataset/f49b8e4b-8673-498e-bead-98e6847831c6/freshwater-fish-counts-for-all-species-all-areas-and-all-years (Accessed 5 February 2019).
[17] Grontmij 2012 - Chapelhouse Impounding Reservoir - Construction-Environmental Control Plan.
[18] Biological Records Centre (undated). Occurrence ID 12027603. https://records.nbnatlas.org/occurrences/2cf0a037-782d-4148-9b2d-045b8b7825d7 (Accessed 6 February 2019)
[19] Hendry, K. & Craggs-Hine, D. (2003). Ecology of the Atlantic salmon. Conserving Natura 2000 Rivers Ecology Series No.7. English Nature, Peterborough.

4.1.3 Site Visit Findings

Site visits were made to assess habitat suitability for salmon, and not to confirm presence of individuals or populations. The presence of suitable habitat for different life stages should not therefore infer presence of the species but rather the potential for the waterbody to support the species.

The River Ellen (upstream and downstream of Chapelhouse Reservoir) and Longlands Beck provided a range of flow types (e.g. riffle, run, pool) and habitats for all Atlantic salmon life stages (Figures A1, A3 and A4). A waterfall was observed in the upper reaches of the River Ellen, and this waterfall will act as barrier to upstream migration of Atlantic salmon in most flow conditions but is expected to be passable in high flows.

Substrate types of an appropriate size for spawning (i.e. pebble, cobble, some gravel) were present in the River Ellen (downstream) reach, however the riverbed was overall highly compacted which made much of the reach unsuitable for Atlantic salmon spawning. Some areas with suitable spawning habitat were also observed in the River Ellen (upstream) and in Longlands Beck (Figures A1-A4). Livestock poaching was observed in the River Ellen both upstream and downstream of Chapelhouse Reservoir, which will act as a source of fine sediments to the river and may negatively impact salmonid spawning habitat quality. Salmonid parr (not identified to species) were observed in the River Ellen and Longlands Beck downstream of the pumping house. This confirms the identification of optimal salmonid habitats through these reaches.

Upstream of the woodland near the pumping house, Longlands Beck is naturally a very small and shallow (5 cm average depth) upland stream and is unsuitable for Atlantic salmon (Figure A4) at all life stages. As such, it is expected that utilisation of the upper Ellen catchment in the study area by salmon will be restricted to the main river.

The Bypass Channel was only suitable for transiting Atlantic salmon, with habitats considered suboptimal for resident juvenile life stages and completely dry immediately downstream of Over Water Reservoir to the road during field surveys (Figures A2 and A5). The Dry Channel at the River Ellen catchpit was completely dry during surveys, although some areas with suitable spawning substrates were observed in the channel and overhanging tree roots would provide cover for fish under wetted conditions. It is unknown whether the lack of water results from water level management upstream or seasonal reduction in flow, and the frequency of the channel drying is also unknown. The downstream extent of the Dry Channel was a concrete basin, and alongside this basin was the upstream extent of the Wetted Channel, which originated from an outfall in the field immediately southwest of the basin. Substrates in the Wetted Channel varied along its length, with pebble and gravels common near the origin and silt becoming more prominent close to Chapelhouse Reservoir. The pebble and gravel areas observed in the Wetted Channel would be considered suboptimal for spawning as this channel was very small with low flows at the time of the field visit.

Three small weirs were recorded in the River Ellen (downstream) reach (Figure A1), all of which would be passable by adult Atlantic salmon during high flows, and by smolts migrating downstream. The fish pass at Chapelhouse is considered passable to salmon under normal flow conditions. The fish pass is maintained to ensure passage, most recently in 2013 (Water Briefing, 2017[20]). A large concrete weir (>1 m high) was observed in Longlands Beck at the pumping house and is only expected to be passable by adult salmonids in high flows.

A weir was observed at the outlet of Over Water Reservoir, but this is expected to be passable by salmonids in high flows. There is no indication that salmon migrate through the bypass channel to Over Water and onwards to utilise riverine habitat upstream of the reservoir. Immediately downstream of the Over Water Weir the Bypass Channel was dry during field surveys in 2017 and held little to no water during field surveys in 2015, so the intermittent flow in this channel may prevent full migration and utilisation of the riverine catchment above the Chapelhouse Reservoir.

[20] Water Briefing. (2017). Available at: https://www.waterbriefing.org/home/company-news/item/7548-united-utilities-completes-%C2%A33m-reservoir-upgrade?font-size=smaller (Accessed 5 February 2019).

4.1.4 Baseline Summary

4.1.4.1 Spawning

Limited habitat for spawning was recorded and was mainly restricted to discrete pockets scattered among compacted and larger substrates (Figures A1-A4). Juvenile salmonids (species unidentified) were recorded in the River Ellen (upstream) and River Ellen (downstream), and in Longlands Beck downstream of the pumping house. The presence of salmonid parr in the River Ellen and Longlands Beck indicates that fish are successfully utilising the limited habitat available for spawning in both watercourses.

4.1.4.2 Juvenile

Suboptimal supporting habitat for Atlantic salmon fry and parr was observed throughout the surveyed reaches, with the exception of the Bypass Channel and Dry Channel (Figures A1-A4).

4.1.4.3 Adult

Suitable habitat for migrating adults, including resting pools, was observed throughout the River Ellen and Longlands Beck (Figures A1-A4). Three weirs were recorded in the River Ellen (downstream), but records of Atlantic salmon upstream of these weirs and the Chapelhouse fish pass indicate that all are passable under certain flow conditions.

4.1.5 Main Opportunities and Constraints

No specific assessment has been made of the fish pass at Chapelhouse Reservoir. The structure has undergone routine maintenance, most recently in 2013, and as such is considered to be operating effectively under the conditions it was originally designed for. Observations from field surveys suggest that the lower steps may create a barrier to migration under low flow conditions but under normal flows this is not considered a significant impediment to salmon or sea trout upstream or downstream migration.

The catchpit and Chapelhouse Reservoir currently retain a large amount of finer substrates which originate in part from upstream erosion due to cattle poaching. Stock fencing and riparian planting in the River Ellen (upstream) reach could alleviate some of this erosion and prevent fine sediments from entering the river. Removing Chapelhouse Dam and creating a natural channel in the River Ellen between Stockdale Farm and the River Ellen (downstream) reach could restore natural substrate conditions in the River Ellen and increase Atlantic salmon habitat availability.

If full removal of the dam and reconnecting the River Ellen is not possible, then the Dry Channel and Wetted Channel could be improved to allow migration between the southern extent of Chapelhouse Reservoir and the catchpit to extend available habitat. This could involve connecting the two channels, altering discharges from the catchpit to create perennial flow in the Dry Channel, creating meanders and improving substrates.

Improvements to the Bypass Channel connecting Over Water Reservoir and the River Ellen could create additional habitat for juvenile salmonids and spawning. Downstream of the catchpit, substrates could be introduced that would create juvenile and spawning habitat. Upstream of the catchpit, the Bypass Channel could be improved by creating meanders and introducing larger substrates (e.g. gravel, pebble, cobble), and discharges from Over Water Reservoir could be altered to create perennial flow in the channel.

4.1.6 Risks and Uncertainties

Removing Chapelhouse Dam and reinstating natural flows in the catchment may not be sufficient to improve the compacted substrate conditions in the River Ellen (downstream) in the absence of any other restoration and should be combined with other works (e.g. substrate works, riparian planting, stock fencing) that have been demonstrated to create and maintain fish habitat.

It is unknown how much fine sediment is held within Chapelhouse Reservoir, and how or where fine sediments would settle in the catchment if the reservoir was removed. If the dam were to be removed, fine sediments in the reservoir should be moved off site to avoid them washing downstream into the River Ellen.

If Chapelhouse Dam and the River Ellen catchpit were removed, it is unknown how river levels downstream of the dam might be affected. For example, numerous weirs were recorded downstream of the dam, and should river levels drop, these weirs may become impassable to Atlantic salmon.

A section of the River Ellen was not surveyed by Stockdale Farm due to the presence of aggressive dogs at the property. Therefore, habitat conditions or the presence of barriers to migration for Atlantic salmon are unknown.

4.2 River Lamprey and Sea Lamprey

4.2.1 Introduction

River lamprey and sea lamprey are both listed in accordance with the requirements of Section 41 of the NERC Act 2006 (England) (NE, undated[21]), and are listed under Annex II of the EC's Council Directive 92/43/EEC (the Habitats Directive) (EC, 1992[11]). They are both qualifying species for the designation of the nearby River Derwent and Bassenthwaite Lake SAC (JNCC, 2015[12]). As the migratory forms (albeit with slightly different life histories), river and sea lamprey have been considered together, whilst brook lamprey (non-migratory form) is described separately.

River and sea lamprey are both anadromous and require the same critical habitat for spawning and the development of ammocoetes (juveniles) (Table 4.2). Spawning times for the two species differ and are dependent on temperature, and clean spawning gravels in flowing water are essential for spawning (Maitland, 2003[22]).

Table 4.2: Habitat Requirements for River and Sea Lamprey

Species	General	Adults	Spawning	Ammocoetes
River lamprey & sea lamprey	No barriers to migration Average gradient up to 5.7m/km, rare >7.6m/km Pollution sensitive	Stones and vegetation for hiding Migrate to spawning areas: October-December (river lamprey) April-May (sea lamprey)	Gravel and sand substrate with water flow through substrates Water temperature: 10-11°C (river) 15°C (sea) Eggs incubate 15-30 days	Fine substrates Low flows Metamorphosis July to September, immediate migration to sea at night

4.2.2 Desk Based Literature Review

Very little publicly accessible information is available on the presence of migratory lamprey species in the catchment, but the EA has recorded lamprey (not identified to species) in the River Ellen as far upstream as Uldale (EA, 2018[16]). No EA survey sites were located in the catchment upstream of Uldale so it is unknown if lamprey species are present within the study area. An NBN Atlas search did not return any records for river or sea lamprey within the study area.

Hatching ammocoetes migrate downstream to nursery areas in slow flowing reaches, and thus it is important that spawning and juvenile habitats be freely accessible to ammocoetes. Examples of potentially suitable habitat include large deposits of silt and sand on river or stream margins, detritus covering coarser substrates,

[21] Natural England (undated). Section 41 Species – Priority Actions Needed (B2020-008). Available at: http://publications.naturalengland.org.uk/publication/4958719460769792 (Accessed 4 February 2019).
[22] Maitland, P. S. (2003). Ecology of the River, Brook and Sea Lamprey. Conserving Natura 2000 Rivers Ecology Series No. 5, English Nature, Peterborough.

and patches of silt and sand found among tree roots, emergent vegetation, submerged woody debris or larger substrates. Ammocoetes burrow down into the silt/ sand substrate and spend up to five years developing in tunnels within the sediment. Older ammocoetes may prefer coarser sand and gravel during this time (Maitland, 2003[22]; Dawson *et al*., 2015[23]). Because of their habitat preferences, ammocoetes exhibit a patchy distribution at small and large spatial scales as they seek out suitable habitat. When ideal habitat is not found, ammocoetes will occupy less suitable habitat at lower densities, such as areas with mobile coarse sand and gravel (Dawson et al., 2015[23]).

After metamorphosis, young adults migrate downstream to estuaries (river lamprey) or open seas (sea lamprey), where they feed and develop into adults. Adults of both species then migrate upstream to suitable freshwater spawning habitat. Upon reaching spawning habitat, adult lampreys require suitable vegetative or rocky cover to providing hiding places where they will rest while waiting for suitable water temperatures for spawning. Adult lamprey die shortly after spawning is complete.

Due to their larger size, sea lampreys are considered better swimmers than river lamprey, although both are poorer swimmers than Atlantic salmon and are not able to leap over obstacles (Maitland, 2003[22]). Thus, some features (natural and anthropogenic) that salmonids can pass (including fish passes) are still migration barriers to lamprey species.

4.2.3 Site Visit Findings

Four silt beds for ammocoetes were recorded in the River Ellen downstream of Chapelhouse Reservoir, all of which were located near where small unnamed tributaries entered the river (Figure A1). These tributaries may be encouraging channel process (erosion and deposition) required to create silt deposition. Whilst silt and sand were also recorded in the Wetted Channel and in the Bypass Channel (upstream of the catchpit), it is likely that these areas will be suboptimal habitats for lamprey ammocoetes. Unlike the lower catchment, the silt in these locations are not considered discrete features, rather transient and overlaying other substrates. Gravels which could be used by spawning lamprey were recorded in the River Ellen (downstream), the River Ellen (channelised section), the River Ellen (upstream), the Wetted Channel and in Longlands Beck. It is likely that lamprey will utilise similar spawning habitats to salmonids.

Spatial connectivity is important between lamprey spawning and juvenile habitats. Between Uldale and Chapelhouse potential spawning habitat was observed upstream of silt deposits, indicating good connectivity. Three weirs were recorded on the River Ellen (downstream) reach, one of which was located at the downstream extent of the Chapelhouse Dam fish pass, and these may be a barrier to river and sea lamprey migration in low flows (Figure A1). The bottom step onto the Chapelhouse fish pass may also be a barrier under lower flow conditions. The weir at the pumping house on Longlands Beck will be a barrier to lamprey in all flows (Figure A4). Habitat is limited for migratory lamprey above the Longlands Beck pumping house.

4.2.4 Baseline Summary

The desk study and literature review did not return any records of river or sea lamprey further upstream in the catchment than Uldale. The absence of records should not infer total absence and may reflect a lack of monitoring of this part of the catchment. Habitat for adult lamprey was present throughout the surveyed reaches, although the weirs encountered on the River Ellen (downstream) and at the Chapelhouse Reservoir fish pass may present barriers to migration in some flows, and the weir on Longlands Beck will prevent upstream migration.

4.2.4.1 Spawning

Areas with substrates for spawning were recorded in the River Ellen both upstream and downstream of Chapelhouse Reservoir and in Longlands Beck. However, these areas were limited to small pockets of suitable habitat scattered among larger and very compacted substrates.

[23] Dawson, H., Quintella, B.R., Almeida, P.R., Treble, A.J. and Jolley, J.C. (2015). Chapter 3 The ecology of larval and metamorphosing lampreys. In: Docker, M. (ed.) The Biology of Lampreys, Springer.

4.2.4.2 Juvenile

Silt beds for ammocoetes were recorded in the River Ellen (downstream), the Wetted Channel, and the Bypass Channel (upstream of the catchpit). Many of these beds were located where small, unnamed tributaries entered the surveyed watercourses and thus the suitability and availability of this habitat over multiple seasons is unknown.

4.2.4.3 Adults

The desk study and literature review did not return any records of river or sea lamprey further upstream in the catchment than Uldale. Habitat for adult lamprey was present throughout the surveyed reaches, although the weirs encountered on the River Ellen (downstream) and at the Chapelhouse Reservoir fish pass may present barriers to migration in some flows, and the weir on Longlands Beck will prevent upstream migration.

4.2.5 Main Opportunities and Constraints

The weir at the downstream extent of the Chapelhouse Dam fish pass may act as a barrier to river and sea lamprey migration, so improvements such as increasing notch size could be made to this weir to allow for lamprey passage. Even minor modification to current structures may have significant benefits to the passage of lamprey, which do not have the explosive swimming ability to migrate over large in-channel structures.

Removing the two small weirs on the River Ellen (downstream) reach and altering the weir on the Chapelhouse Reservoir fish pass could benefit river and sea lamprey, as these weirs are potentially impassable by lamprey in some flows. Improvements could be made to the Chapelhouse fish pass weir to also allow lamprey passage. This would allow these species to use upstream spawning and ammocoete habitat. The weir on Longlands Beck at the pumping house could be fully or partially removed to allow migratory lamprey to access to the upstream habitat.

Removing Chapelhouse Dam and the catchpit and restoring the River Ellen back to a natural channel would allow river and sea lamprey to migrate more easily into the upper reaches of the River Ellen. A return to a natural flow regime downstream of Chapelhouse Dam could result in more gravel deposits and less compacted substrates, which would create more spawning habitat.

If full removal of the dam and reconnecting the River Ellen is not possible, then the Dry Channel and Wetted Channel could be improved. This could involve connecting the two channels, altering discharges from the catchpit to create perennial flow in the Dry Channel, creating meanders and improving substrates. Reconnecting these two channels will improve access to the upper reaches of the River Ellen, including the spawning substrates in the River Ellen (channelised section) reach.

4.2.6 Risks and Uncertainties

Very little information appears to be available on the distribution of river and sea lamprey in the study area, particularly upstream of Uldale. It is currently unknown if these species can migrate past the fish pass at Chapelhouse Reservoir, or the other weirs observed between Uldale and Chapelhouse Reservoir. Additionally, it is currently unknown if there are other barriers to lamprey migration on the River Ellen further downstream preventing these species from accessing the study area.

A section of the River Ellen was not surveyed by Stockdale Farm due to the presence of aggressive dogs at the property. Therefore, habitat conditions or the presence of barriers to migration for river and sea lamprey are unknown.

4.3 Brook Lamprey

4.3.1 Introduction

Brook lamprey is listed under Annex II of the EC's Council Directive 92/43/EEC (the Habitats Directive) (EC, 1992[11]) and is a qualifying species for the designation of the nearby River Derwent and Bassenthwaite Lake SAC (JNCC, 2015[12]).

4.3.2 Desk Based Literature Review

Very little publicly accessible information is available on the presence of lamprey species in the catchment. The EA provides data on routine fish surveys throughout England, including in the River Ellen as far upstream as Uldale, which is the furthest upstream survey site within this catchment (EA, 2018[16]). Lamprey (not identified to species) was recorded throughout the river, including at the upstream site at Uldale. An NBN Atlas search did not return any records for brook lamprey in the study area. In 2013, during restoration of the reservoir fish pass channel, brook lamprey was recorded in the River Ellen at Chapelhouse Dam (Casterbridge Fisheries, 2013[24]). Brook lamprey have also been reported by the West Cumbria Rivers Trust (WCRT) from the United Utilities intake above Chapelhouse Reservoir in 2014[25]. The WCRT indicate a high population of brook lamprey around the structure. The 2016 Environmental Statement for the West Cumbria Water Supply Thirlmere Transfer[26] indicated the potential for significant populations of brook lamprey to be present within Chapelhouse Reservoir.

Brook lampreys are resident in freshwaters throughout their entire life cycle but require the same critical habitat for spawning and the development of ammocoetes as river and sea lamprey (see Section 4.3.2 for full description). Brook lamprey do not feed as adults, and therefore only require vegetative or rocky cover to provide hiding places where they may rest while waiting for suitable water temperatures for spawning and a migration route free from barriers. If suitable spawning and ammocoete habitat are located close to each other, brook lampreys do not need to migrate large distances, although are capable of considerable migrations if required. Nests are often constructed immediately downstream of a large boulder or other obstruction mid-reach in the main stem or the bottom of a large tributary (Kelly and King, 2001[27]). General habitat requirements for brook lamprey are described in Table 4.3.

Brook lamprey are poorer swimmers than Atlantic salmon, river lamprey and sea lamprey, and thus some features (natural and anthropogenic) that those species can pass (including fish passes) are still migration barriers to brook lamprey.

Table 4.3: Habitat Requirements for Brook Lamprey

Species	General	Adults	Spawning	Ammocoetes
Brook lamprey	No barriers to migration Average gradient 0.2–0.6m/km Pollution sensitive	Stones and vegetation for hiding Migrate to spawning areas in spring at night	Gravel and sand substrate behind larger object Water temperature 10-11°C Eggs incubate 15-30 days	Fine substrates Low flows Metamorphosis July to September

[24] Casterbridge Fisheries (2013). Winter 2013 newsletter. Available at: http://www.riverworks.co.uk/wp-content/uploads/2013/12/Winter-news-letter-13.pdf (Accessed 6 February 2019).
[25] West Cumbria Rivers Trust (2014). Brook lampreys rescued at Chapel House Intake. Available at: https://westcumbriariverstrust.org/news/brook-lampreys-rescued-at-chapel-house-intake (Accessed 6 February 2019).
[26] United Utilities Plc. (2016). West Cumbria Water Supplies Thirlmere Transfer. Vol 4. Appendix 23.1: Mitigation Schedule.
[27] Kelly, F.L. and King, J.J. (2001). A review of the ecology and distribution of three lamprey species, *Lampetra fluviatilis* (L.), *Lampetra planeri* (Bloch) and *Petromyzon marinus* (L.): a context for conservation and biodiversity considerations in Ireland. Biology and Environment: Proceedings of the Royal Irish Academy, vol. 101B, no. 3, pp. 165-185.

4.3.3 Site Visit Findings

Four silt beds for ammocoetes were recorded in the River Ellen (downstream) reach, and substrates potentially suitable for spawning were also recorded in this reach as well as in the River Ellen (channelised section), River Ellen (upstream) reach and in Longlands Beck (Figures A1, A3 and A4). Silt and sand substrates were also recorded in the Wetted Channel and Bypass Channel (upstream of the catchpit), and ammocoetes will also be able to utilise these substrates, if required.

Due to their smaller size, brook lampreys have a poorer swimming ability than both river and sea lamprey. Thus, the two weirs encountered on the River Ellen (downstream) reach and at the Chapelhouse Reservoir fish pass are expected to be a barrier to brook lamprey migration in most flow conditions, including some flows which allow for river and sea lamprey migration.

4.3.4 Baseline Summary

A summary of the desk based and site visit findings is given in the sections below for the different age classes of brook lamprey.

4.3.4.1 Spawning

Areas with substrates for spawning were recorded in the River Ellen downstream of Chapelhouse Reservoir and upstream of the catchpit, and in Longlands Beck downstream of the pumping station.

4.3.4.2 Juvenile

Silt beds for ammocoetes were recorded in the River Ellen (downstream), the Wetted Channel, and the Bypass Channel (upstream of the catchpit).

4.3.4.3 Adults

Results from the desk study indicate that brook lamprey are present in the River Ellen as far upstream as Uldale, and brook lamprey were collected from the River Ellen at the Chapelhouse Dam fish pass. Adult habitat was recorded in the River Ellen between Uldale and Chapelhouse Reservoir, so it is possible that brook lampreys are currently present in this reach. Suitable habitat was also recorded in Longlands Beck downstream of the pumping station.

4.3.5 Main Opportunities and Constraints

See Section 4.2.5 for opportunities and constraints that will benefit lamprey spawning and ammocoetes. If weir removal is not possible, any alteration to allow passage must ensure that migration of brook lampreys are specifically considered, as brook lamprey are poorer swimmers than river and sea lamprey.

4.3.6 Risks and Uncertainties

Very little information appears to be available on the distribution of brook lamprey in the study area, particularly upstream of Uldale. It is currently unknown if brook lampreys are able to migrate past the fish pass at Chapelhouse Reservoir or the various other weirs upstream of Uldale. The presence of brook lamprey upstream of these potential barriers could indicate a relict population that predates barrier construction.

A section of the River Ellen was not surveyed by Stockdale Farm due to the presence of aggressive dogs at the property, and habitat conditions or the presence of barriers to migration for brook lamprey are unknown.

4.4 European Eel

4.4.1 Introduction

European eel is listed in accordance with the requirements of Section 41 of the NERC Act 2006 (England), and priority actions have been identified for this species (NE, undated[28]). European ell is also considered Critically Endangered by the International Union for Conservation of Nature (Jacoby and Gollock, 2014[29]).

4.4.2 Desk Based Literature Review

Limited information is available on the presence of European eel in the upper Ellen catchment. Adults and elvers (juvenile eels) were recorded by the EA throughout the river, including at the upstream site at Uldale, which is the furthest upstream survey site within this catchment (EA, 2018[16]). A study undertaken of 16 sites on the River Ellen indicates that despite artificial barriers to migration, the River Ellen remains a highly productive river for eel, with a classic structure for a stable population; numbers of individuals decreasing approximately exponentially with increasing size (Bark *et al*., 2007[30]). A 2008 study indicated that the potential production of silver eels from the River Ellen exceed that under reference/pristine conditions and the River Ellen meets the escapement target (40%) for eel fisheries (Aprahamian and Walker, 2008[31]).

An NBN Atlas search returned records of eel in the River Ellen as far upstream as Uldale, and returned one records from 1995 of eel in the River Ellen upstream of the catchpit (BRC, undated[32]). In 2014, eels were collected from the River Ellen in advance of gravel works on the intake at Chapelhouse reservoir (Casterbridge Fisheries, 2013[24]).

Eels are catadromous and live their adult lives in freshwater before returning to sea to spawn. Elvers (eel larvae) enter freshwaters in late winter to spring where they mature into adults and remain in freshwaters for as long as 40 years (Maitland, 2007[33]). Where there is access from the sea, eels are found in all freshwater habitats. During the daytime eels remain buried in mud or under macrophytes or stones but can be found on a variety of other substrate types (Maitland, 2007[33]).

Eels are incapable of swimming through strong laminar flows or jumping in excess of half their body length, so vertical structures prevent a barrier to upstream migration (Knights and White, 1998[34]). Thus, traditional fish passes may prevent upstream migration of eels, although utilisation of some fish pass types have been observed in larger (>30 cm) individuals. Eels can use boundary layers and rough substrates to facilitate migration, and the design of eel passes over barriers often incorporates brushes or bristles to encourage climbing as opposed to swimming (Solomon and Beach, 2004[35]). As eels increase in size so does their swimming ability and elvers over 10 cm in length can negotiate flows of 1.5-2.0 m/s^{-1}. Elvers up to 12 cm in length can climb surfaces (particularly if covered in moss or algae) although ability decreases with increasing size without the presence of a vegetated or uneven surface.

4.4.3 Site Visit Findings

Suitable habitat for eels was widespread through the study area. One desiccated adult eel was found in an area of wet woodland on the western edge of Over Water Reservoir.

---

[28] Natural England (undated). Section 41 Species – Priority Actions Needed (B2020-008). Available at: http://publications.naturalengland.org.uk/publication/4958719460769792 (Accessed 6 February 2019).
[29] Jacoby, D. and Gollock, M. (2014). *Anguilla anguilla*. The IUCN Red List of Threatened Species 2014: e.T60344A45833138. Available at: https://www.iucnredlist.org/species/60344/45833138 (Accessed 6 February 2019).
[30] Bark, A., Williams, B., and Knights, B. (2007). Current status and temporal trends in stocks of European eel in England and Wales. ICES Journal of Marine Science, 64: 1368 – 1378.
[31] Aprahamian, M. and Walker, A. (2008). Status of eel fisheries, stocks and their management in England and Wales. Knowledge and Management of Aquatic ecosystems. 390-391.
[32] Biological Records Centre (undated). Occurrence ID 12027602. Available at: https://records.nbnatlas.org/occurrences/8db44d9c-47c1-4038-86e4-e356db89357b (Accessed 6 February 2019).
[33] Maitland, P.S. (2007) Scotland's Freshwater Fish. Ecology, Conservation & Folklore, Trafford Publishing (UK) Ltd.
[34] Knights, B. & White, E.M. (1998) Enhancing immigration and recruitment of eels: the use of passes and associated trapping systems. Fisheries Management and Ecology, 5: 459-471.
[35] Solomon, D.J. and Beach, M.H. (2004). Fish pass design for eel and elver (*Anguilla Anguilla*). EA R&D Technical Report W2-070/TR1.

4.4.4 Baseline Summary

The River Ellen is an important North West catchment for eel, with a stable population allowing for a high escapement of eels. Habitat for adult eels was widespread throughout the study area. Eels were recorded in the River Ellen upstream of the catchpit and downstream of the fish pass, and a desiccated adult eel was found near Over Water Reservoir, indicating that eels are able to migrate past the weirs on the River Ellen and the Chapelhouse Reservoir fish pass in at least some flow conditions.

4.4.4.1 Juveniles and Adults

Elvers were recorded by the EA in the River Ellen as far upstream as Uldale, and an adult eel was observed in Over Water Reservoir during site surveys, indicating that the weirs recorded on the River Ellen (downstream) and at the Chapelhouse Reservoir fish pass are not barriers to upstream eel migration. Suitable habitat for elvers and adult eels were found throughout the study area. It is also likely that the Chapelhouse and Over Water reservoirs contain a population of eels that may be susceptible to changes in water level, habitat and asset removal.

4.4.5 Main Opportunities and Constraints

No specific assessment has been made of the fish pass at Chapelhouse Reservoir. The structure has undergone routine maintenance, most recently in 2013, and as such is considered to be operating effectively under the conditions it was originally designed for. Since 2009, the conservation of European eel within river catchments has gained importance within the national conscience, particularly regards maintaining open migratory pathways through catchments. Whilst the River Ellen maintains a high escapement of eel from the catchment to the sea, it may be that the existing fish pass could benefit from modifying or retrofitting to enhance eel migration into the upper catchment.

The weir at the downstream extent of the Chapelhouse Dam fish pass may act as a barrier to eel upstream migration in low flows, so improvements could be made to this weir such as increases in notch size to allow for passage in all flows. Removing Chapelhouse Dam and the catchpit and restoring a natural channel may allow for increased eel migration throughout the River Ellen catchment. Whilst the findings of this study have indicated the potential for habitat upstream of the current infrastructure there is continuing uncertainty over quantification of the benefit that different options may result in. Uncertainty arises from a lack of as well as dated baseline data. It will be important determine whether habitat improvement will result in a detectable change in status for key species and habitat.

Modification or removal of the Chapelhouse Dam and/or the smaller weir structures in the upper River Ellen, combined with improvements to the channel connecting the River Ellen with Over Water Reservoir would improve fish migration and could result in an increase in fish abundance through the upper catchment. The reservoir is used as a feeding ground for osprey (*Pandion haliaetus)*, so this would increase food availability for the species.

4.4.6 Risks and Uncertainties

Little information exists on the distribution of eels in the upper catchment. It is currently unknown if the weir at the bottom of the Chapelhouse Reservoir fish pass is a barrier to eels under low flow conditions. Modification of infrastructure may modify downstream water levels such that the minor weirs on the River Ellen become impassable.

The River Ellen was not surveyed along Stockdale farm due to the presence of aggressive dogs at the farm. Thus, habitat conditions or the presence of barriers to migration for eel are unknown.

4.5 Brown/ Sea Trout

4.5.1 Introduction

Brown/ sea trout is listed in accordance with the requirements of Section 41 of the NERC Act 2006 (England) (NE, undated[36]). The River Ellen supports an active recreational fishery for both brown and sea trout.

4.5.2 Desk Based Literature Review

The River Ellen rod catch results for sea trout from 2013-2017 were generally lower than what was reported from 2005-2012 (Figure 4.2, EA, 2017[14], 2018[15]). It should be noted that this information is reliant upon accurate catch reports from recreational anglers and gives no measure of catch effort (i.e. number of active fisherman), so is not directly representative of current stock conditions.

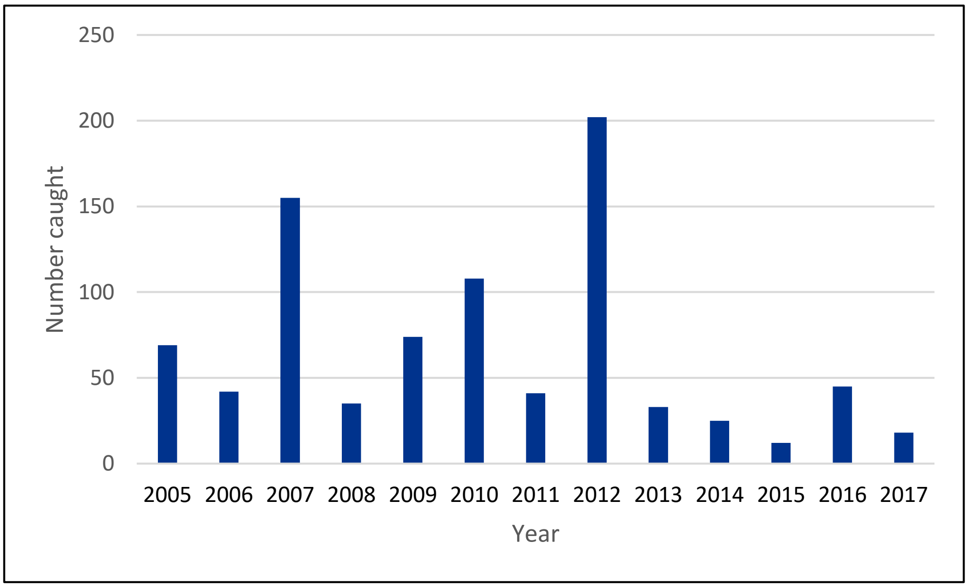


Figure 4.2: EA Rod Catch Data for Sea Trout 2005 to 2017

Brown/ sea trout are known to be present in the River Ellen and Chapelhouse Reservoir (Grontmij, 2012[17]). The EA provides data on routine fish surveys throughout England, and brown/ sea trout were recorded throughout the river, including at the furthest upstream survey site at Uldale, from 2005-2017 (EA, 2018[16]). Biological Records Centre data confirmed the presence of brown/ sea trout in the River Ellen downstream of Chapelhouse Reservoir, and also returned a record from 1995 of brown/ sea trout upstream of the catchpit (BRC, undated[37]).

Brown trout are resident in freshwaters throughout their entire life cycle, although they will migrate within watercourses to reach spawning areas. Sea trout are anadromous and have a similar life cycle to Atlantic salmon (Section 4.1.2). Interbreeding occurs between brown and sea trout, and habitat requirements for spawning and successful juvenile development are therefore the same. Trout share similar spawning preferences with Atlantic salmon, although trout will reproduce earlier in the season and use smaller headwaters (Armstrong *et al*., 2003[38]). Relatively shallow depths (20-30 cm) and moderate flows (20-50 cm/s) are optimal for juveniles (Table 4.4) although migrating adults generally require higher flows especially if there are obstructions to pass. In general, juvenile fish are more sensitive than adults as they are less mobile, being more dependent on specific habitats during development stages. However, much of the available data quantifying impacts relate to adults. Very good water quality is required at all stage of the trout life cycle.

[36] Natural England (undated). Section 41 Species – Priority Actions Needed (B2020-008). Available at: http://publications.naturalengland.org.uk/publication/4958719460769792 (Accessed 4 February 2019).
[37] Biological Records Centre (undated). Occurrence ID 12027601. https://records.nbnatlas.org/occurrences/d278ef78-3a17-4911-baaf-ed472551fa43 (Accessed 4 February 2019).
[38], J. D., Kemp, P. S., Kennedy, G. J. A., Ladle, M., & Milner, N. J. (2003). Habitat requirements of Atlantic salmon and brown trout in rivers and streams. Fisheries Research, 62(2), 143–170.

Table 4.4: Habitat Requirements of Juvenile and Adult Trout (adapted from Armstrong *et al.*, 2003[38])

Juvenile fish <1 year old (fry)	
Water depth	<20-30cm
Water velocity	0-20cm/s
Substrate type	Gravel and cobble (10-90mm)
Juvenile fish >1 year old (parr)	
Water depth	<20-30cm
Water velocity	20-50cm/s
Substrate	Gravel and cobble (10-90mm)
Adult spawning	
Water depth	6-82cm
Water velocity	10.8-80.2cm/s
Substrate	Mix of fine materials (8-128mm), gravels

4.5.3 Site Visit Findings

The habitats reported as suitable for Atlantic salmon juveniles and migrating adults are also suitable for brown/ sea trout (Section 4.1.3, Figures A1-A4). Brown trout will spawn in smaller substrates and shallower water than Atlantic salmon, and the pebble and gravels observed in the Wetted Channel are suitable for brown trout spawning, although the channel may not be suitable spawning habitat in all years due to low water levels. Potentially therefore there is proportionally greater opportunity for brown trout spawning and juvenile habitat within the upper River Ellen catchment, both above and below the Chapelhouse and Over Water reservoirs. Resident adult trout will use the numerous pools observed in the River Ellen and Longlands Beck. The upper sections of the Longlands Beck are considered too small to support a sustainable population of trout; however, habitat is suitable below the pumping house to support this species.

4.5.4 Baseline Summary

4.5.4.1 Spawning

Limited habitat for spawning was recorded in the surveyed reaches and was mainly restricted to pockets scattered among more compacted and unsuitable substrates (Figures A1-A4). However, the presence of salmonid parr (not identified to species) in the River Ellen and Longlands Beck indicates that salmonids are successfully spawning in both watercourses. Suitable brown trout spawning substrates were also observed in the Wetted Channel.

4.5.4.2 Juvenile

Supporting habitat for brown/ sea trout juveniles was recorded in the River Ellen and Longlands Beck (Figures A1-A4). Salmonid parr (not identified to species) were recorded upstream of weirs on the River Ellen (Section 4.1.3). The dry sections of the Bypass Channel and Dry Channel reduce the habitat potential for this species and risk seasonal fragmentation of populations if watercourse sections remain isolated regularly.

4.5.4.3 Adult

Resting pools for adults were observed throughout the River Ellen and in Longlands Beck downstream of the pumping station (Figures A1-A4). Brown/sea trout were recorded in the River Ellen upstream of all weirs, in Longlands Beck downstream of the pumping house and in Chapelhouse Reservoir.

4.5.5 Main Opportunities and Constraints

See Section 4.1.5 for a summary of opportunities and constraints for salmonids.

4.5.6 Risks and Uncertainties

See Section 4.1.6 for a summary of risk and uncertainties for salmonids.

4.6 Eurasian Otter

4.6.1 Introduction

Eurasian otter is listed in accordance with the requirements of Section 41 of the NERC Act 2006 (England), and priority actions have been identified for this species (NE, undated[10]). Otter is listed under Annex II of the EC's Council Directive 92/43/EEC (the Habitats Directive) (EC, 1992[11]) and is also qualifying species for the designation of the nearby River Derwent and Bassenthwaite Lake SAC (JNCC, 2015[12]).

4.6.2 Desk Based Literature Review

Little publicly available data on the presence of otter in the River Ellen catchment is available. The Otter and Rivers Project 1991-1994 reported that in Cumbria the best quality rivers had only low/ transient otter populations and a complete absence of otter in some areas. A subsequent survey in 1998 indicated that otters are present throughout the River Ellen (EA, 1999[39]) and the EA's 2009-2010 otter survey recorded the presence of otters near the study area (Crawford, undated[40]).

Surveys conducted in West Cumbria by the EA show a substantial increase in the percentage of sites with a positive record for otters in the River Ellen catchment from 1998 to 2005 (Table 4.5, Garner, 2005[41]).

Table 4.5: Results for otter presence in the River Ellen, 1998-2005

Survey Date	Number of Sites	Number of Positive Sites	Percentage of Positive Sites
May 1998	29	7	24.1
May 2002	29	12	41.4
May 2005	29	18	62.1

An NBN Atlas search returned records from 1996-2016 for otter in the 10 km grid square (NY23) that contains the survey area. In 2015, surveys were conducted by United Utilities which identified field signs of otter (spraints) in the bypass channel both near the outlet of Over Water Reservoir and alongside Chapelhouse Reservoir.

Otters will utilise a wide range of aquatic habitat types, and in freshwater habitat have been recorded on both still waters (e.g. canals, ponds, lakes, reservoirs) and streams and rivers (Channin, 2003[42]). Otters require suitable areas for resting which may consist of a hole in the ground (a holt) or a depression under the roots of a bankside tree or other vegetation (a couch). They breed throughout the year, and rear their young in holts, so suitable habitat to dig out a holt is a requirement for a breeding population of otters.

4.6.3 Site Visit Findings

During aquatic walkovers, surveyors recorded otter field signs and took note of overall habitat suitability. Multiple field signs were observed during field surveys, including a possible commuting route in the Dry Channel, possible prints in the dry area of the Bypass Channel near Over Water Reservoir, spraint in the River

[39] Environment Agency (1999). Local Environment Agency Plan West Cumbria Action Plan.
[40] Crawford, A. (undated). Fifth otter survey of England 2009-2010.
[41] Garner, J. (2005). The West Cumbria Otter Survey – May 2005. Technical Memorandum 827 (02/06).
[42] Channin, P. (2003). Ecology of the European otter. Conserving Natura 2000 River Ecology Series No. 10. English Nature, Peterborough.

Ellen (channelised section) and spraint and possible prints in the River Ellen (upstream) (Figures A2, A3 and A5). Suitable habitat for otter holts and couches was observed in the study area, particularly in Longlands Beck and the River Ellen (downstream), where trees were recorded at the edge of the river.

4.6.4 Baseline Summary

The result from the desk study demonstrated that otters are present in the study area. The field survey results supported this with field signs of spraint, a possible commuting path and possible prints in the River Ellen (upstream), River Ellen (channelised section), Dry Channel and Bypass Channel.

4.6.5 Main Opportunities and Constraints

Restoring a natural flow regime to the River Ellen, including between Over Water and Chapelhouse reservoirs, could create additional habitat for otters, especially if combined with riparian planting. Improving fish habitat and access in the study area will indirectly benefit otters as it will improve prey abundance in the study area.

4.6.6 Risks and Uncertainties

A section of the River Ellen was not surveyed by Stockdale Farm due to the presence of aggressive dogs at the property. Thus, habitat conditions for otter are unknown in this area and any field signs could not be recorded.

4.7 Results - Lake Habitats and Associated Species

4.7.1 Introduction

Over Water and Chapelhouse reservoirs are both small reservoirs in the Ellen and West Coast operational catchment of the EA's North West River Basin District. They are both classified under the WFD. Over Water Reservoir is also a designated SSSI.

4.7.2 Desk Based Literature Review

Over Water Reservoir is a natural tarn and its water level was artificially raised in the early 1900s with the building of a weir. The reservoir is bordered by wet woodland on its northern, southern and southwestern shores and by neutral grassland on its eastern shore (NE, 2017[43]). Land use in the catchment is primarily livestock grazing. The reservoir is also a known feeding location for osprey, which breed beside nearby Bassenthwaite Lake.

The condition of Over Water SSSI was last assessed in 2010, and the Standing Open Water and Canals habitat was assessed as Unfavourable-Declining due to the absence of three characteristic species for the site (*Myriphyllum alterniflorum, Nymphaea alba,* and *Isoetes lacustris*) and the presence of the non-native macrophyte, New Zealand pygmyweed (*Crassula helmsii*). The reservoir is also failing to meet its water quality targets due to high levels of phosphorus and chlorophyll *a*, due largely to the livestock grazing in its catchment (Atkins, 2015[44]).

In 2016, the Freshwater Biological Association (FBA) conducted surveys on Over Water and recorded the presence of *Nymphaea alba* in the reservoir, but did not record *Myriophyllum alterniflorum* or *Isoetes lacustris*, indicating that the latter two are still absent from the lake (Alvarez-Codesal *et al*., 2016[4]). The FBA surveys found that New Zealand pygmyweed was present and often abundant in shallower, littoral habitats (≤51 cm water depth) around the lake, especially in the north, northeast and east. Two additional non-native macrophyte species were also recorded during these surveys, Nuttall's pondweed (*Elodea nuttallii*) and American skunk cabbage (*Lysichiton americanus*). The study concluded that New Zealand pygmyweed may be a competitor for native macrophyte species.

[43] Natural England (2017). Over Water SSSI. Available at: https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=S1000433&SiteName=&countyCode=&responsiblePerson=REBECCA%20GRAY&SeaArea=&IFCAArea= (Accessed 4 February 2019).
[44] Atkins (2015). Overwater SSSI Investigation into Perceived Enrichment of five Lakeland SSSIs.

The FBA surveys also recorded the presence of *Ilyocryptus acutifrons*, a rare crustacean and species of interest in the SSSI, in the lake at a depth of 5.22 m (using the top of the weir as a reference for depth). It is a mobile crustacean that lives in near-shore vegetation and in the upper layer of mud in the bottom of lakes (Alvarez-Codesal *et al*., 2016[4]).

Limited data is available for fish communities in Over Water Reservoir was found during the desk study, however brown trout (both stocked and resident) and European eel were identified as present in the reservoir (Cascade Consulting, 2016[45]).

There are no conservation designations for Chapelhouse Reservoir. The reservoir is known to support Atlantic salmon, sea trout, brown trout and lamprey (species unidentified) and suitable otter habitat is present around the reservoir (Grontmij, 2012[17]; Cascade Consulting, 2016[45]).

4.7.3 Site Visit Findings

During site visits in 2017, the area had undergone a prolonged period of little to no rainfall and was in low flow conditions. Over Water Reservoir was very low at the time of survey, and immediately downstream of the reservoir, the Bypass Channel was dry and overgrown with terrestrial plants.

The southwestern area of Over Water Reservoir was characterised by fine sediments and emergent vegetation (Figure A5). This area was lined with wet woodland which provided shading to the shoreline. The northeastern shore line was exposed and substrates in the reservoir were composed of cobbles and pebbles with small amounts of gravels and sand in interstitial spaces. Macrophytes were observed in this area but were not emergent. Surveys confirmed the presence of New Zealand pygmyweed in Over Water Reservoir, and the extensive coverage observed by the FBA in 2016 was also observed during site visits in 2017. Nuttall's pondweed, a non-native macrophyte, was also observed at two locations around the reservoir, at multiple locations in the channel downstream of Over Water Reservoir upstream of the River Ellen catchpit and in Chapelhouse Reservoir at the small spillway into the Bypass Channel.

A marsh with emergent vegetation was noted at the southern extent of Chapelhouse Reservoir. The eastern shoreline was wooded and the western shore line was lined with vegetated earth and small trees.

4.7.4 Baseline Summary

The results of the desk study and site visit indicated that non-native New Zealand pygmyweed is abundant around the north-eastern area of Over Water reservoir, forming dense mats in some areas, with very low densities or absence in the southwestern area of Over Water Reservoir. The reason why New Zealand pygmyweed is not established in the southwestern area of Over Water is not known, but Alvarez-Codesal *et al*. (2016[4]) suggested that the prevailing south-westerly winds may be preventing this species from becoming established in this area. This species may act as a competitor for native macrophyte species.

The desk study and site visit also both reported the presence of non-native Nuttall's pondweed, and the desk study found that non-native American skunk cabbage was also present in Over Water Reservoir. Nuttall's pondweed was recorded in Chapelhouse Reservoir, and in the Bypass Channel near the Over Water Reservoir weir. Chapelhouse Reservoir also provided habitat for emergent vegetation at its southern extent.

The presence of *Ilyocroptus acutifrons*, as reported by the FBA, could not be verified during the 2017 site visit as this was beyond the scope of this study. However, as this species often resides in deeper areas in lakes and was recorded at depth in Over Water Reservoir, it is expected that the low lake levels observed during the 2017 walkovers did not substantially impact this species.

[45] Cascade Consulting (2016). West Cumbria Water Supplies Project – Thirlmere Transfer Environmental Statement Volume 2 Chapter 11: Ecology.

4.7.5 Main Opportunities and Constraints

4.7.5.1 Habitat enhancement

Native macrophytes are likely to benefit from improvements in any habitat enhancements that increase flow and substrate diversity. Non-native macrophytes were recorded in the channels connecting Over Water Reservoir and the River Ellen, but the species recorded (New Zealand pygmyweed and Nuttall's pondweed) are both adapted to slow flows or standing water (Great Britain Non Native Species Secretariat (GB NNSS), 2015a[46]; GB NNSS, 2015b[47]). Restoring a naturally flowing channel will reduce habitat availability for these non-native species and could create better conditions for native river and stream macrophytes.

Changes in water level management due to modification of assets may create an opportunity to enhance wetland habitat at the upstream end of Chapelhouse Reservoir. Enhancing connectivity with Over Water Reservoir may present an opportunity to enhance the botanical interest of Chapelhouse.

4.7.5.2 Water Level Management

Options that remove or modify water level management structures has the potential to allow greater movement of species through the system. This may be positive for lake dwelling resident or migratory fish species, including trout, salmon, pike, perch but may increase the risk in facilitating the spread of non-native species (rainbow trout and New Zealand pygmyweed).

4.7.6 Risks and Uncertainties

4.7.6.1 Catchment connectivity

Whilst Nuttall's pondweed is already known from both Over Water and Chapelhouse reservoirs, New Zealand pygmyweed was not recorded from Chapelhouse Reservoir. Opening up the catchment could therefore increase the spread of this species, which may reduce the potential of the waterbody achieving WFD targets. Lowering the lake level in Over Water Reservoir to its natural level would likely reduce the overall amount of habitat available for macrophytes and *Ilyocryptus acutifrons*. Maintaining the current water level in Over Water Reservoir is a site specific target for the SSSI (NE, 2009[48]), therefore any reduction in water level is likely to have an impact on the SSSI features and as such would require consultation with Natural England.

4.7.6.2 Habitat enhancement

It is currently unknown how much fine sediment is contained within Chapelhouse or Over Water Reservoirs and the potential for bed substrates to be mobilised through works to water level management structures. The mobilisation of fine sediments, and discharge into the riverine waterbody would need to be modelled and controlled to ensure there is no degradation in ecological status or habitat smothering.

4.7.6.3 Water Level Management

Any modification to the operation of Over Water reservoir must comply with any requirements identified by Natural England who regulate activities within the SSSI site. Water level management and modification to existing habitats and species will be closely assessed and any options should take cognisance of the effects of change on the designated species and habitats cited at Over Water Reservoir. A wet woodland borders much of Over Water Reservoir and swamp, marsh and fen habitat was identified in the southwestern extent of the reservoir, and no loss in the extent of these habitats is one of the conservation objectives for the site (NE, 2009[56]). If the reservoir level were to be lowered by modification/ removal to United Utilities assets downstream, it is unknown how this change in level would affect the woodland and if it would be able to re-colonise the areas that were formerly submerged.

---

[46] Great Britain Non Native Species Secretariat (2015a). New Zealand pigmyweed, *Crassula helmsii*. Available at: http://www.nonnativespecies.org/factsheet/downloadFactsheet.cfm?speciesId=1017 (Accessed 4 February 2019).
[47] Great Britain Non Native Species Secretariat (2015b). *Elodea nuttalli*. Available at: http://www.nonnativespecies.org/factsheet/downloadFactsheet.cfm?speciesId=1304 (Accessed 4 February 2019).
[48] Natural England (2009). Conservation objectives and definitions of favourable condition for designated features of interest. Consultation Draft.

Ilyocryptus acutifrons was recorded at a depth of more than 5.0m by the FBA in lake-bottom sediments. This species will also occupy vegetation on the shore line, but it is currently unknown if this crustacean is using shore vegetation in Over Water Reservoir. Maintaining the presence of this species is a conservation objective for Over Water Reservoir SSSI (NE, 2009[48]), so any modifications to United Utilities assets must not impact the availability of habitat for this species.

5. Summary & Conclusions

5.1 Key Findings

The desk study reported the presence of numerous protected species in the study area, and the site visit surveys confirmed the presence of supporting habitat for these species. Atlantic salmon and brown/ sea trout were recorded as present in the study area, but information on population size was not available. Salmonid parr were observed in the River Ellen and Longlands Beck during site visits. Below Chapelhouse Reservoir, the River Ellen provided suitable habitat for all age classes of Atlantic salmon, brown/ sea trout and lamprey species. Although a mix of substrate sizes was recorded in this reach, the riverbed was highly compacted in the River Ellen (downstream) limiting the potential for suitable habitat for fish spawning. Supporting habitat, including some spawning areas, for all age classes of Atlantic salmon, brown/ sea trout and lamprey species was recorded in the River Ellen upstream of Stockdale Farm.

Two weirs were recorded on the River Ellen downstream of the fish pass and one weir was recorded at the bottom of the Chapelhouse Reservoir fish pass. However, the presence of migratory salmonids upstream of these weirs indicates that they are passable in at least higher flow conditions. The fish pass at Chapelhouse Dam is passable by Atlantic salmon, brown/ sea trout and eels in at least higher flow conditions, as evidenced by the presence of these species upstream of it. A desiccated eel was observed on the margins of Over Water Reservoir, suggesting that the reservoir is accessible to this species.

Longlands Beck, downstream of the pumping station, also provided suitable habitat for all age classes of Atlantic salmon, brown/ sea trout and lamprey species. However, as with the River Ellen, only limited spawning habitat was noted in the beck. A significant weir is present on Longlands Beck at the pumping station, is expected to be passable by migratory salmonids in high flow conditions only.

The Bypass Channel between the fish pass and catchpit was only suitable for migratory fish, but upstream of the catchpit silt substrates were recorded which are suitable for lamprey ammocoetes. The channels connecting the catchpit with the southern end of Chapelhouse Reservoir were not suitable for fish as one was completely dry and the other originated from an outfall in a field. In addition, the Bypass Channel was completely dry and overgrown with terrestrial plants from Over Water Reservoir to the road crossing during site visits in 2017, which would prevent fish from accessing Over Water Reservoir for much of the year.

Brook lamprey were recorded in the River Ellen at Chapelhouse Dam. No records of river or sea lamprey were found for the study area. The absence of records does not infer total absence from the study area however it is likely that the Chapelhouse fish pass poses a barrier to lamprey migration under a range of flow conditions.

New Zealand pygmyweed, a non-native macrophyte, was abundant along the north-eastern shore Over Water Reservoir. Nuttall’s pondweed, another non-native macrophyte, was recorded in both Over Water and Chapelhouse reservoirs, and in the Bypass Channel close to Over Water Reservoir.

5.2 Key Risks

Removing infrastructure and reinstating natural flows in the catchment may not be sufficient to notably improve the compacted substrate conditions in the River Ellen (downstream) in the absence of any other restoration and should be combined with other works (e.g. substrate works, riparian planting, stock fencing) that have been demonstrated to create and maintain fish habitat.

Livestock poaching and bank erosion was present in the River Ellen upstream and downstream of Chapelhouse Reservoir, resulting in inputs of fine sediments to the river. If Chapelhouse Dam were removed, it is currently unknown how or where fine sediments from the upstream catchment would settle further downstream.

The geophysical survey identified fine sediments within Chapelhouse Reservoir, but the quantity of fine sediments in the reservoir is not known. If the dam were removed, any fine sediments in the existing reservoir must be prevented from entering the River Ellen.

If Chapelhouse Dam and the River Ellen catchpit were removed, it is unknown how river levels downstream of the dam might be affected. For example, two weirs were recorded downstream of the dam and fish pass, and should river levels drop, these weirs may become impassable to Atlantic salmon, lamprey species or eel. It is unknown if these weirs, or other barriers further downstream of the study area, are preventing upstream migration of river and sea lamprey into the catchment.

A wet woodland borders much of Over Water Reservoir, apart from the north and northeast, and these woodland areas are designated habitats of the SSSI. If the reservoir level were to be lowered to natural levels, it is unknown how this change in level would affect the woodland and if it would be able to re-colonise the areas that were formerly submerged.

Very little information was found on otter distributions in the study area, so their distribution and population status are currently unknown. Field signs did indicate they are present in the area, but it is not known if there is a breeding population in the study area.

6. Summary Table

MCA Criterion	Assessment of Current Baseline Conditions	Basis of assessment (Sources of Information)
Maintained/ enhanced key river species habitat	Substrates in the River Ellen (downstream) were highly compacted and these reaches provided limited spawning habitat for salmonids and lamprey, although juvenile and adult habitat was present. Between Chapelhouse Reservoir fish pass and the catchpit, the Bypass Channel was suitable for fish migration. Upstream of the catchpit, silt was present in the Bypass Channel which may be suitable for lamprey ammocoetes. The channels connecting Chapelhouse Reservoir and the catchpit supported very limited fish habitat, and do not provide access to the catchpit. One of the two channels was dry. Downstream of the pumping house, Longlands Beck provided mixed habitat for salmonids, including pockets of spawning habitat. No juvenile lamprey habitat was observed in the beck. Upstream of the pumping house, a short stretch of Longlands Beck provided mixed habitat for salmonids and lamprey, but upstream of this area the beck was too steep, shallow and small to be suitable for fish. The weir at the pumping house is considered a barrier to migration to most species. Immediately downstream of Over Water Reservoir, the Bypass Channel was dry at time of survey, so fish do not have access to Over Water Reservoir throughout the year. An adult eel was observed in Over Water Reservoir, indicating that the reservoir provides suitable habitat for eel. No other fish records were found for the reservoir; thus, it is unknown if other key fish species use Over Water Reservoir.	Walkover site surveys in 2017. Walkover site surveys in 2015. Bark, A., Williams, B., and Knights, B. (2007). Current status and temporal trends in stocks of European eel in England and Wales. ICES Journal of Marine Science, 64: 1368 – 1378. Biological Records Centre (undated). Occurrence ID 12027601. https://records.nbnatlas.org/occurrences/d278ef78-3a17-4911-baaf-ed472551fa43 (Accessed 4 February 2019). Biological Records Centre (undated). Occurrence ID 12027602. Available at: https://records.nbnatlas.org/occurrences/8db44d9c-47c1-4038-86e4-e356db89357b (Accessed 6 February 2019). Biological Records Centre (undated). Occurrence ID 12027603. https://records.nbnatlas.org/occurrences/2cf0a037-782d-4148-9b2d-045b8b7825d7 (Accessed 6 February 2019). Casterbridge Fisheries (2013). Winter 2013 newsletter. Available at: http://www.riverworks.co.uk/wp-content/uploads/2013/12/Winter-news-letter-13.pdf (Accessed 6 February 2019).Environment Agency (2017). Salmon and freshwater fisheries statistics for England and Wales, 2015. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/642200/Salmonid_and_Freshwater_Fisheries_Report_2015.pdf (Accessed 4 February 2019). Environment Agency (2018). Freshwater Fish Counts for all Species, all Areas and all Years. Available at: https://data.gov.uk/dataset/f49b8e4b-8673-498e-bead-98e6847831c6/freshwater-fish-counts-for-all-species-all-areas-and-all-years (Accessed 5 February 2019). Environment Agency (2018). Salmonid and freshwater fisheries statistics for England and Wales, 2017. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/753925/Salmonid_and_Freshwater_Fisheries_Report_2017.pdf (Accessed 4 February 2019). Grontmij 2012 - Chapelhouse Impounding Reservoir - Construction-Environmental Control Plan. West Cumbria Rivers Trust (2014). Brook lampreys rescued at Chapel House Intake. Available at: https://westcumbriariverstrust.org/news/brook-lampreys-rescued-at-chapel-house-intake (Accessed 6 February 2019).

MCA Criterion	Assessment of Current Baseline Conditions	Basis of assessment (Sources of Information)
Maintained/ enhanced key lake species habitat (designated macrophyte species)	Over Water currently contains supporting habitat for macrophyte communities around its shoreline, although the composition of the community differs in the southwest as compared to the northeast. The wet woodland along much of the southwest of the reservoir provides shelter and organic inputs to this area of the reservoir, whereas the north-eastern shoreline is exposed and mainly not lined with woodland. Over Water Reservoir is surrounded by wet woodland, which is an important habitat of the SSSI, and it is unknown if the wet woodland habitat would expand its habitat down to the historic shoreline if the weir were removed. Over Water Reservoir SSSI is in unfavourable condition in part due to high levels of phosphorous and chlorophyll *a* from agricultural activities in its catchment. No information on macrophytes communities in Chapelhouse Reservoir was found during the desk study, so it is unknown if the reservoir supports important macrophyte species or communities. However, this reservoir does provide suitable habitat for non-native Nuttall's pondweed.	Walkover site surveys in 2017.Alvarez-Codesal, S., Fletcher, M., Pentecost, A. and Pawley, S. (2016). Surveys of the invasive aquatic plant *Crassula helmsii* (extent and impact) and the rare freshwater crustacean *Ilyocryptus acutifrons* in Over Water, Cumbria. Atkins (2015). Overwater SSSI Investigation into Perceived Enrichment of five Lakeland SSSIs. Grontmij 2012 - Chapelhouse Impounding Reservoir - Construction-Environmental Control Plan. Natural England (2017). Over Water SSSI. Available at: https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=S1000433&SiteName=&countyCode=&responsiblePerson=REBECCA%20GRAY&SeaArea=&IFCAArea= (Accessed 4 February 2019).

MCA Criterion	Assessment of Current Baseline Conditions	Basis of assessment (Sources of Information)
Maintained/ enhanced populations of important lake species	Site surveys found that the southwestern area of Over Water Reservoir was characterised by fine sediments and emergent vegetation the north-eastern shore line was exposed and substrates in the reservoir were composed of cobbles and pebbles and only small submerged macrophytes were observed. Over Water Reservoir is a SSSI and in unfavourable condition due to the absence of characteristic species for the site and the presence of non-native macrophytes, particularly New Zealand pygmyweed. New Zealand pygmyweed, Nuttall's pondweed and American skunk cabbage, all non-native macrophytes, were recorded in desk and field studies in Over Water Reservoir. *Ilyocryptus acutifrons*, a rare crustacean, was recorded in Over Water Reservoir in sediments at least 5 m deep on the lake bottom, and this habitat type would remain in Over Water Reservoir if the weir were removed. No information was found on macrophytes in Chapelhouse Reservoir, so it is unknown if the reservoir supports important macrophyte species. Non-native Nuttall's pondweed was recorded in the reservoir during field surveys.	Walkover site surveys from 2017. Alvarez-Codesal, S., Fletcher, M., Pentecost, A. and Pawley, S. (2016). Surveys of the invasive aquatic plant Crassula helmsii (extent and impact) and the rare freshwater crustacean Ilyocryptus acutifrons in Over Water, Cumbria Atkins (2015). Overwater SSSI Investigation into Perceived Enrichment of five Lakeland SSSIs. Grontmij 2012 - Chapelhouse Impounding Reservoir - Construction-Environmental Control Plan. Natural England (2017). Over Water SSSI. Available at: https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=S1000433&SiteName=&countyCode=&responsiblePerson=REBECCA%20GRAY&SeaArea=&IFCAArea= (Accessed 4 February 2019).

MCA Criterion	Assessment of Current Baseline Conditions	Basis of assessment (Sources of Information)
Maintained/ enhanced passage of migratory fish	Two weirs were observed in the River Ellen downstream of Chapelhouse Reservoir, but the presence of Atlantic salmon, brown/ sea trout and eel upstream of them indicates that these weirs and the fish pass are passable in at least higher flow conditions. A waterfall was observed in the River Ellen upstream of Craig Wood and Roundhill Wood which is a natural barrier to lamprey migration and a barrier to salmonid migration in most flows. No migratory lampreys were recorded in the study area, so it is unknown if the weirs observed present a barrier to lamprey migration. The weir at the pumping house on Longlands Beck was a barrier to upstream migration of fish.	Walkover site surveys from 2017. Environment Agency (2018). Freshwater Fish Counts for all Species, all Areas and all Years. Available at: https://data.gov.uk/dataset/f49b8e4b-8673-498e-bead-98e6847831c6/freshwater-fish-counts-for-all-species-all-areas-and-all-years (Accessed 5 February 2019). Biological Records Centre (undated). Occurrence ID 12027603. https://records.nbnatlas.org/occurrences/2cf0a037-782d-4148-9b2d-045b8b7825d7 (Accessed 6 February 2019).

Annex A. Walkover Survey Results Figures

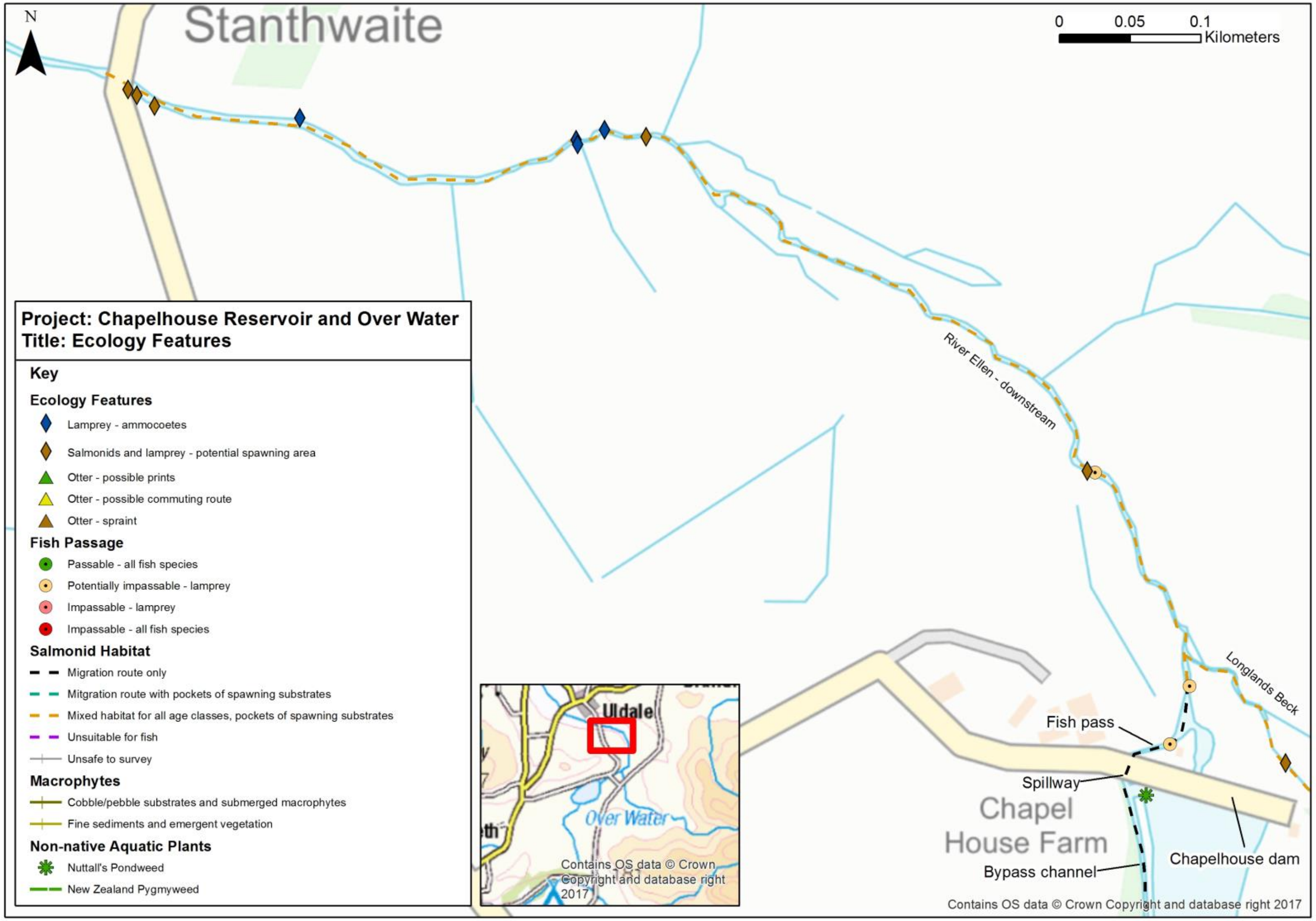


Figure A1 Ecology features in the River Ellen downstream of Chapelhouse Reservoir

JACOBS

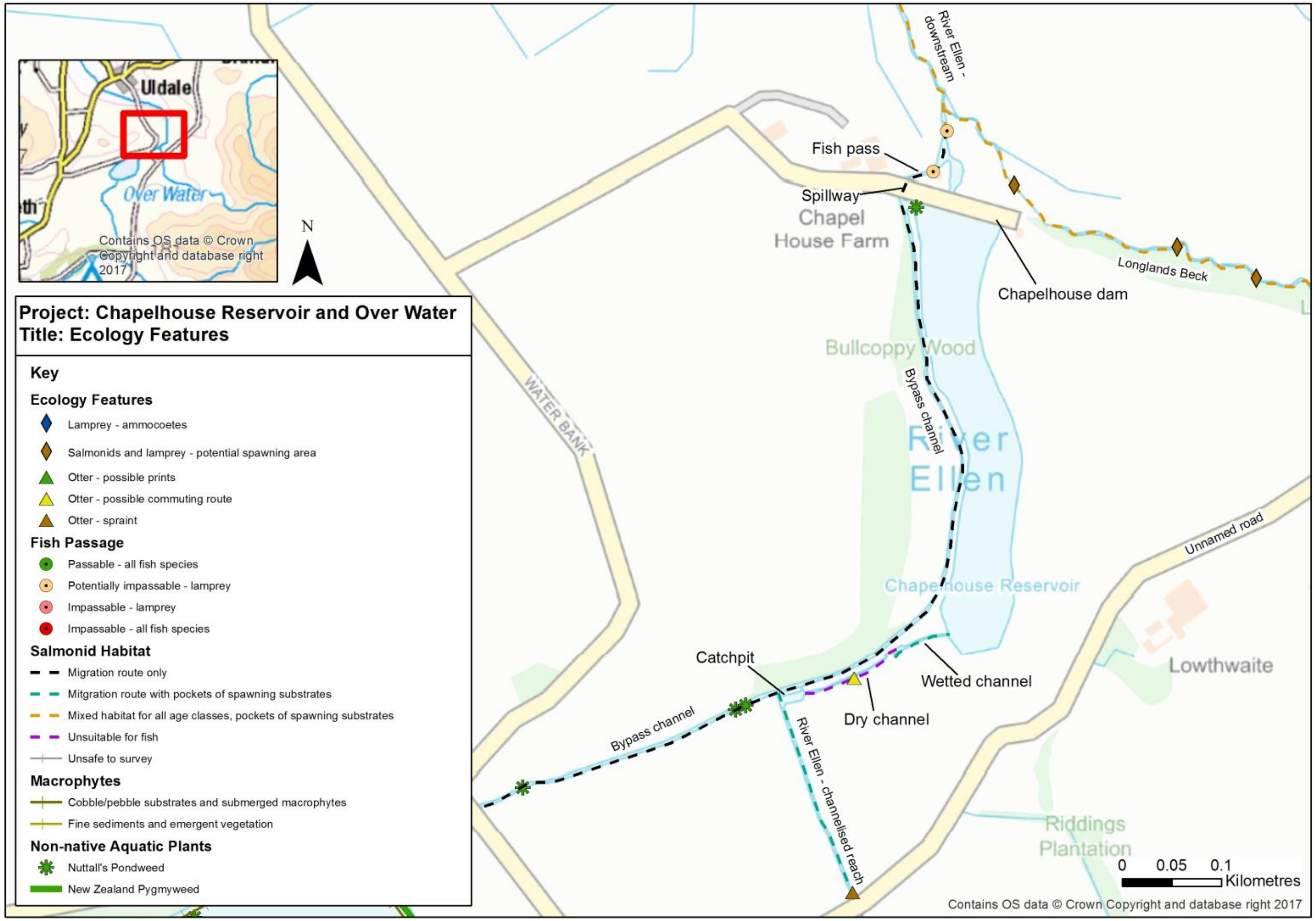


Figure A2 Ecology features in watercourses alongside and upstream of Chapelhouse Reservoir

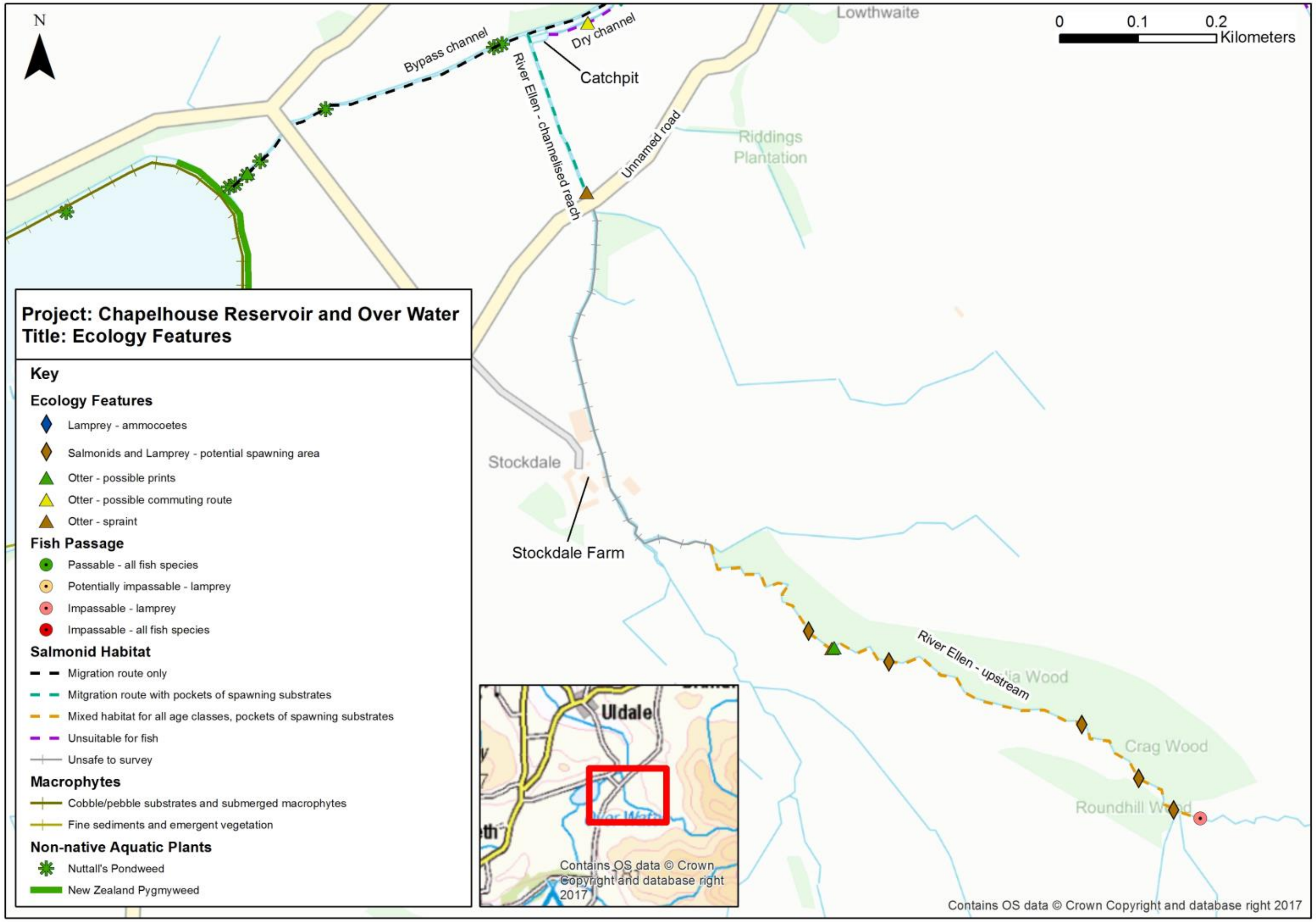


Figure A3 Ecology features in the River Ellen and tributaries upstream of Chapelhouse Reservoir

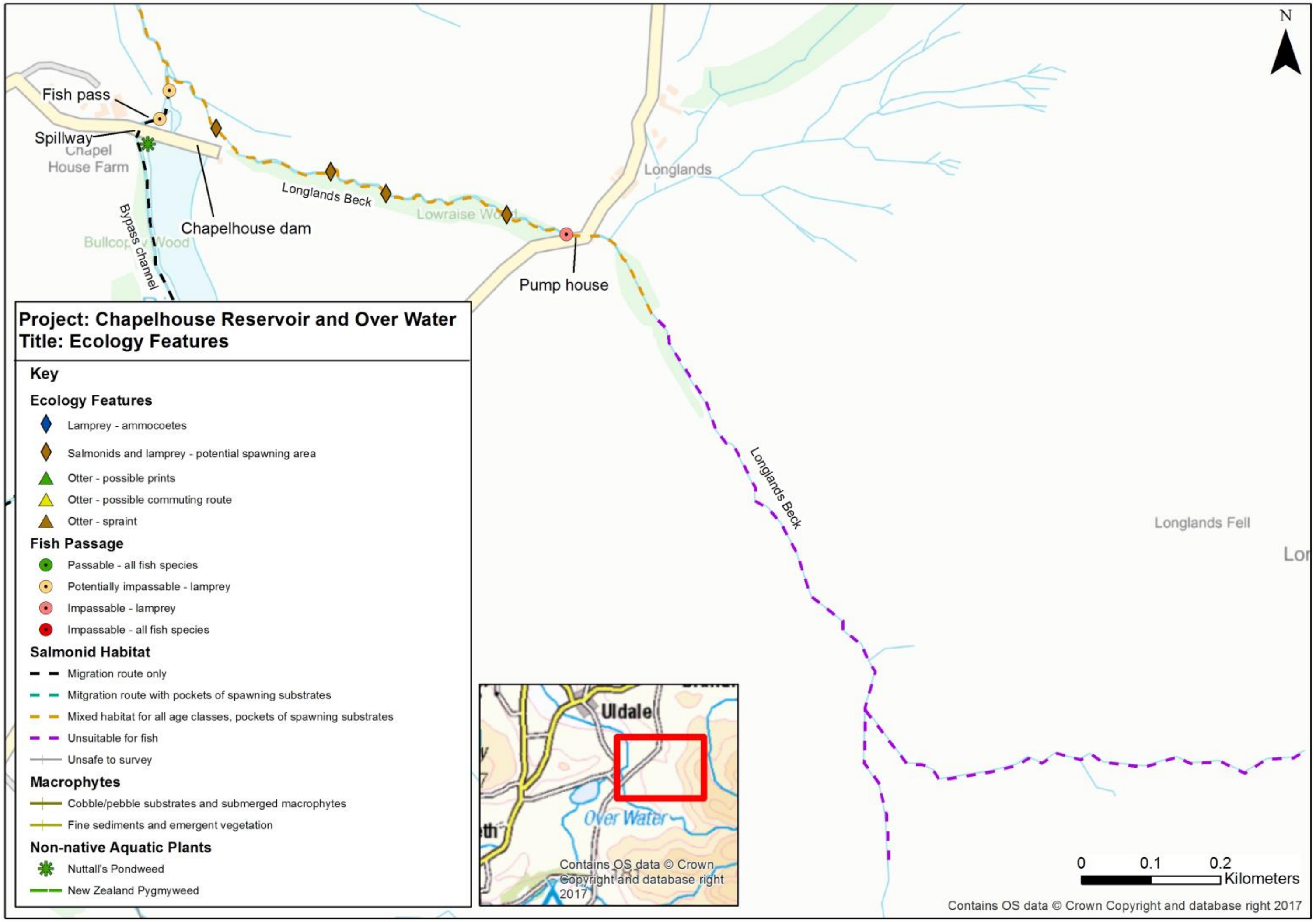


Figure A4 Ecology features in Longlands Beck

JACOBS

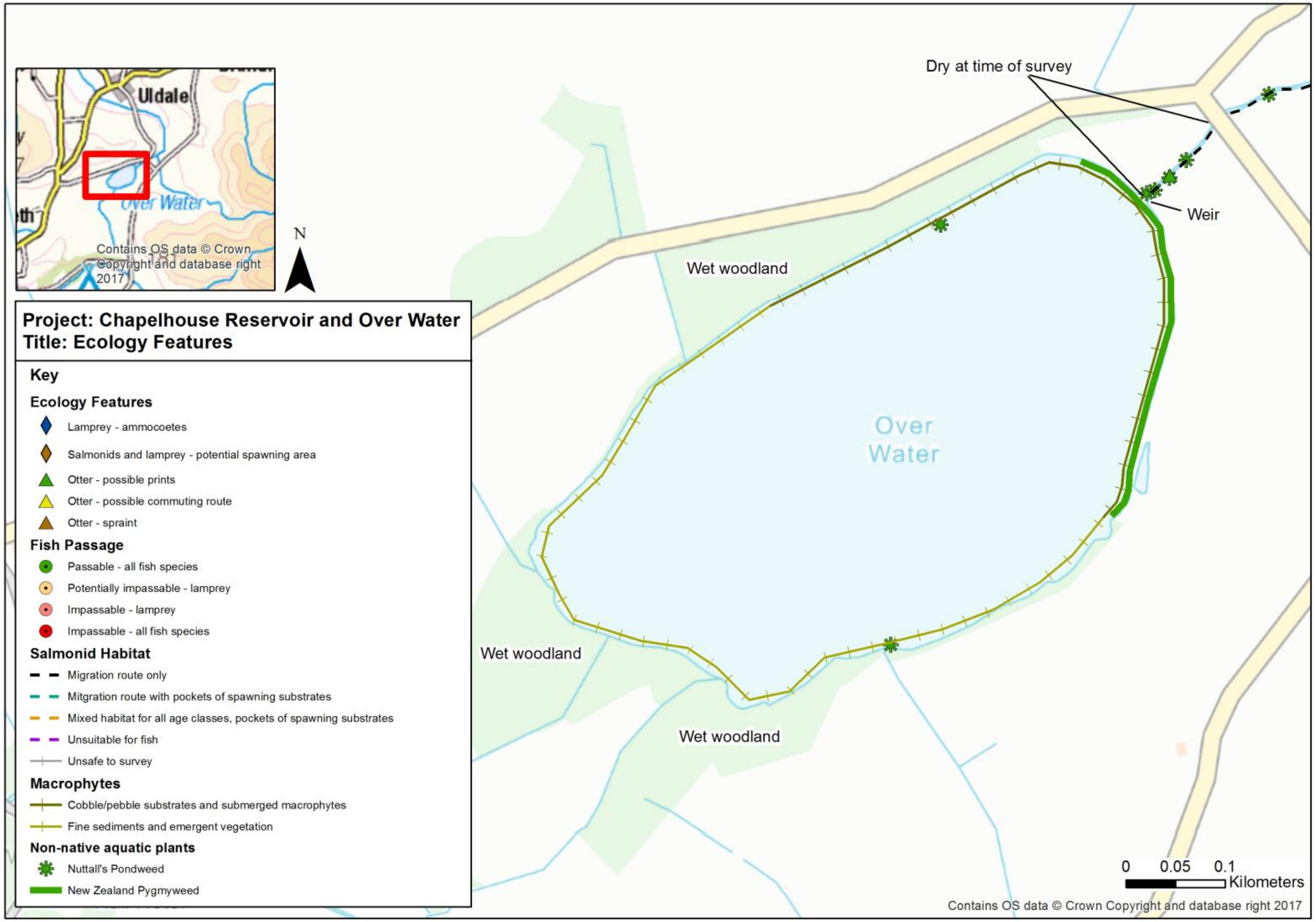


Figure A5 Ecology features in Over Water Reservoir

Annex B. Habitat requirements for species identified in Section 4.

Species	Water depth (cm)	Water velocity (m/s)	Bed substrate	Comments
Atlantic salmon (spawning)[19]	0.17-0.76	0.25-0.9	Mix of fine materials (<2mm), pebbles and cobbles	Excessive fine sediments are prohibitive to successful spawning. River gradients of ≤3% are required for spawning. Very good water quality is required. Adults return to sea.
Atlantic salmon (juvenile)[23]	<20 (<1year old) 20-40 (>1year old)	0.5-0.65 (<1year old) 0.5-0.75 (>1year old)	Gravel and cobble (16-64mm, <1year old, winter) Cobble to boulder (64-256mm, <1year old, summer and >1 year old all year round)	
River and Sea lamprey (spawning)[22]	-	Low flows	Gravels and sands (<16mm)	Spawning habitats must exhibit water temperature of 10-11°C (river) and 15°C (sea). Poor swimmers so unable to navigate in-channel barriers (natural or human). Sensitive to pollution. An average river gradient of 0.57%, occasionally up to 0.76%, is required.
River and Sea lamprey (juveniles)[22,33]	-	Low flows	Fine substrates (<2mm)	
River and Sea lamprey (adults)[22]	-	-	Stones and vegetation	
Brook lamprey (spawning)[22]	-	Low flows	Gravels and sands (<16mm) usually behind instream obstruction	Spawning habitats must exhibit water temperature of 10-11°C. Poor swimmers so unable to navigate in-channel barriers (natural or human). Sensitive to pollution. An average river gradient of between 0.02-0.06% is preferred.
Brook lamprey (juveniles)[22,332]	-	Low flows	Fine substrates (<2mm)	
Brook lamprey (adults)[22]	-	-	Stones and vegetation	
European eels (juveniles)[35]	-	Can negotiate flows of 1.5-2	-	Eel habitat is particularly hard to define, as the species is capable of thriving in all freshwater habitats, providing there is access to the sea. During the daytime eels remain buried under weeds or stones or in mud but can be found on a variety of other substrate types. Spawn in the Sargasso Sea.
European eels (adults)[33]	-	-	-	
Brown/ sea trout (spawning)[34]	6-82	0.1-0.8	Mixture of materials (8-128mm)	Brown/ sea trout habitat requirements are similar to Atlantic salmon, so there is a significant niche overlap between these species.
Brown/ sea trout (juveniles)[38]	<20-30	<0.2 (<1year old)	Gravel and cobble (16-64mm)	

		0.2-0.5 (>1year old)		As juveniles develop they will migrate further downstream, where they settle in feeding territories which they defend from other individuals.
Brown trout (adults)[38]	40-160	0.1-1.2	Pebble-boulder (64-256mm)	Adult brown/ sea trout are largely territorial but perform a short migration to suitable spawning grounds prior to undertaking spawning activity.
European otters[42]	N/A	N/A	N/A	Otters will utilise a wide range of aquatic habitat types, and in freshwater habitat have been recorded on both still waters (e.g. canals, ponds, lakes, reservoirs) and streams and rivers. Otters require suitable areas for resting which may consist of a hole in the ground (a holt) or a depression under the roots of a bankside tree or other vegetation (a couch). They breed throughout the year, and rear their young in holts, so suitable habitat to dig out a holt is a requirement for a breeding population of otters.
Aquatic macrophytes[49]	Regularly irrigated/immersed sediments	N/A	Sand and silt or terrestrial soil transition zones	Aquatic macrophytes are found in littoral zones or fully immersed in aquatic habitats. Desiccation tolerance is dependent on species, but all aquatic macrophytes require a regularly wetted habitat. Macrophytes function as both a nutrient source and sink, and their presence provides habitat for fish species of mixed age classes, and a food source for herbivorous aquatic macroinvertebrates.

[49] Tochner, K and Likens, G. E. (2009). Encyclopaedia of Inland Waters Vol 1. Academic Press, 2009.

Appendix F. Multi-Criterial Analysis Summary

A Multi-Criteria (MCA) approach has been undertaken to determine the preferred option, as outlined in the Scoping Report (Jacobs, 2018) and initially agreed with the PSG in 2016.

The government guidance on MCA has been broadly followed, developing a performance matrix for options judged against selected criteria. It should be noted that the methodology has evolved through an iterative approach and is slightly different to that which was discussed in the original Scoping Report (Jacobs, 2018), but follows a published approach developed for assessing acid waters in Wales (Brookes et al., 2001). The MCA approach attempts to avoid pitfalls such as double counting of criteria. The approach adopted can be used to undertake a statistical analysis of the performance matrix if required as an additional method of trying to discern between options.

The assessment will consider four technical disciplines, namely engineering, hydrology and hydraulics, geomorphology and ecology.

F.1 Scoring Criteria

The scoring criteria are shown below in Table F-1. It should be noted that the appraisal period for this study is approximately 40 years from implementation of a preferred option. This means options could score differently than if they were being assessed over a shorter or longer time period.

Table F-1: Scoring criteria used for MCA

Major Beneficial	+++	Significant benefits/opportunities for those criteria that **substantially improve the situation** over the base-case. Would be seen as a major positive effect of the option in the overall context of the study.
Moderate Beneficial	++	Clearly positive with **moderate benefits/opportunities,** that would be seen as favourable effect of the scheme/option
Low Beneficial	+	Probably/likely positive but **minor benefits/opportunities.** Would not be seen as a significant benefit of the scheme.
Negligible	=	No discernible effect, either positive or negative
Minor Negative	-	Some **minor negative effects** that would be acceptable in the wider context of the scheme. i.e. wider benefits judged against other criteria or with additional mitigation.
Moderate Negative	- -	Clearly negative with **moderate effects,** that would be seen as a risk to the viability of the scheme/option, but not necessarily a "showstopper". Risks could be mitigated for.
Major Negative	- - -	**Serious adverse effect** likely to be extremely difficult to overcome in the context of the scheme. A clear and high risk to the aims and objectives of the scheme/study without chance of mitigation.
Unknown	?	Not enough information to make an initial assessment.

F.2 Proposed Assessment Criteria

Table F-2 provides an overview of the assessment criteria for the MCA assessment for each of the four technical disciplines.

Table F-2: MCA performance criteria

Multi-criteria assessment performance criteria	Assessment methodology for high level assessment
Engineering	
Legislative requirements (Reservoirs Act, licensing)	Determine whether the option is governed by legislative requirements that would influence the cost and ease of implementation.
Health and Safety (preparation, demolition, construction)	Determine relative health and safety risk of option assuming industry standard methods of working. Review of principal construction hazards and ease of mitigation.
Buildability (access, temporary works)	Review OS plans, topographic survey and site visit to assess physical access constraints. Use option descriptions and as-built drawings (where available) to assess complexity of option implementation (scale, construction features, and hazards).
Technical merit (engineering performance)	Decide on short and long-term effectiveness of option in achieving desired engineering outcome. Assess complexity of engineering design (if required).
Impact on adjacent infrastructure	Determine short and long-term impact on neighbouring infrastructure (walls, structures, footpaths, fence lines etc.). Review OS plans, topographic survey and site visit to identify impacted features required.
Cost	Engineering judgement to assess the relative capital and design costs of each high-level option.
Maintenance and operation (short, medium, long-term)	Engineering judgement of short, medium and long-term operation and maintenance implications.
Hydrology and Hydraulics	
Impact on peak flood levels	Assessment into the risk/likelihood of current and future peak flood levels changes for a range of event magnitudes.
Impact on flood frequency	Assessment into the risk/likelihood of current and future flood frequency changes for a range of event magnitudes.
Impact on low flow regime	Assessment into the risk/likelihood of a change occurring from the baseline normal flow regime which includes low flows.
Impact on lake level regime	Assessment into the risk/likelihood of a change occurring from the baseline normal lake level regime.
Geomorphology	
River/lake reactivity	Risk/likelihood of Chapelhouse Reservoir, Over Water and River Ellen undergoing significant channel change (i.e. changes to morphology and fluvial processes) both upstream and downstream
Impacts on sediment regime	Risk/likelihood of Chapelhouse Reservoir, Over Water and River Ellen undergoing a change of sediment regime (i.e. changes in erosion, rates of sediment transport and deposition)
Impacts on longitudinal and latitudinal connectivity	Risk/likelihood of Chapelhouse Reservoir, Over Water and River Ellen undergoing a change that could result in an increase or reduction in the channel connectivity upstream and downstream (longitudinal) or with its floodplain (laterally)
Ecology	
Maintained/ enhanced key river species habitat	Risk/likelihood of change to the status of the biological quality elements under the WFD. Risk/likelihood of change in the provision of suitable habitats for a functioning and sustainable aquatic community.
Maintained/ enhanced key lake species habitat and populations	Risk/likelihood of the potential to affect lake habitats (water levels, water quality/ retention, hydromorphological processes) typical of the observed lake community. Risk/likelihood of change in current quality standards stipulated by legislation (e.g. WFD).

Multi-criteria assessment performance criteria	Assessment methodology for high level assessment
Maintained/ enhanced populations of important lake species	Risk/likelihood of the potential to affect lake habitats (water quality/quantity/levels) for important botanical species. Opportunity to enhance the lake habitat (control of water levels, retention, water transfer, water quality) to increase presence/ abundance of important lake species.
Maintained/ enhanced passage of migratory fish	Risk/likelihood of change in the number of fish (including salmon and eel) able to ascend the Chapelhouse fish pass. Opportunity to increase the passability of the Chapelhouse structure and connectivity between Chapelhouse and Over Water for migratory species.
Maintain/ enhance habitat for designated terrestrial receptors (otter)	Opportunity to increase habitat availability for terrestrial receptors.

Table F-3: Simplified MCA results

		Option Name	Engineering	Flood Risk and Hydrology	Geomorphology	Ecology[2]	Shortlisted	Justification
General	G1	Do nothing - Allow natural decay	+	- -	=	- -	No	Not a viable option due to requirements under the Reservoir Act 1975.
	G2	Do minimum - Maintain current weir condition	=	=	=	=	Yes	This has been adopted as the baseline scenario and as a result all impacts are neutral. Maintenance of the reservoirs would require continued supervision, monitoring and inspection under the Reservoirs Act 1975. This option would have ongoing costs for United Utilities to meet requirements.
	G3	Full removal of all structures (reinstating River Ellen back to historical planform)	- -	+	+++	+++	Yes	This option includes the removal of all infrastructure associated with Chapelhouse Reservoir and Over Water. This option was initially screened out at the MCA workshop as it was not considered overly beneficial for salmon to remove the infrastructure at Over Water (see options O1 to O6) although there would be a benefit to removing the infrastructure at Chapelhouse Reservoir (assessed individually as option C3). There is the potential for this option to be costly and have a long programme due to the issues relating to eradication of invasive macrophyte species at Over Water, with limited additional benefit for salmonids. However, this has been scoped in due to the potential for overall improvement for geomorphology, hydraulics and ecology (apart from existing lake species) and the preference of the stakeholders to see the option be fully assessed.
Over Water	O1	Full removal of weirs	-	+	+	+	Yes	These options were discussed assuming that the invasive species would need to be eradicated prior to any work feasibly being undertaken at Over Water. This would delay any potential work at Over Water until after the abstraction has ceased (2022) and remediation works are then undertaken. Flood risk around the catchpit would potentially increase for the 2yr-10yr events with implications for the landowner who currently has issues with the fields flooding. However, the flood risk downstream of Chapelhouse Reservoir would be marginally improved. The option has been screened out on the basis that there is limited salmon benefit and potential flood risk implications.
	O2	Partial removal of weirs	-	+	+	-	No	
	O3	Remove bank and bed reinforcement downstream	-	=	+	=	Yes	The option was initially screened out as it covers a very small area and would provide very little benefit to salmonids, however it has been screened back in at the request of NE.
	O4a	Improve downstream section (upstream of weir) - regrade	-	=	+	+	Yes	All of these sub-options for improvement along the straight channel from Over Water to the catchpit have the potential to provide habitat and improvement in geomorphological and hydrological processes. However, there is strong evidence to suggest that during summer months this channel has very low flows and is unsuitable for salmonids. Consequently, it is unlikely that these options would provide any long-term benefit and habitat for salmonids (the focus of the study). As a result, the options were initially screened out at the MCA workshop, however have been screened back in at the request of NE.
	O4b	Improve downstream section (upstream of weir) - low flow slot	-	=	+	=	Yes	
	O4c	Improve downstream section (upstream of weir) - riparian habitat	=	=	=	=	Yes	
	O4d	Improve downstream section (upstream of weir) - re-meandering	-	=	+	+	Yes	
	O4e	Improve downstream section (upstream of weir) - gravel augmentation	=	=	+	+	Yes	
	O5a	Improve section between road and catchpit - regrade	-	=	+	+	Yes	
	O5b	Improve section between road and catchpit - low flow slot	-	=	+	=	Yes	
	O5c	Improve section between road and catchpit - riparian habitat	=	=	+	=	Yes	

[2] All ecology results are pending low flow modelling results for Q90 and Q10

		Option Name	Engineering	Flood Risk and Hydrology	Geomorphology	Ecology[2]	Shortlisted	Justification
	O5d	Improve section between road and catchpit - re-meandering	- -	=	+	+	Yes	
	O5e	Improve section between road and catchpit - gravel augmentation	-	=	+	+	Yes	
	O6	Downstream of bridge remove bank reinforcement and narrow channel	- -	=	+	+	Yes	Limited benefit for salmonids and very locally focussed option. As a result, the options were initially screened out at the MCA workshop, however have been screened back in at the request of NE.
Chapel-house Reservoir	C1a	Catchpit – remove and connect River Ellen to existing bypass channel	- -	+	+	+	Yes	The option would have a positive impact on flood risk downstream. However, there is potentially minimal benefit locally to ecology (primarily fish). There are also potential implications on maintenance of other structures downstream due to sediment being transferred downstream.
	C1b	Catchpit - remove and connect River Ellen to Chapelhouse	- -	+	- -	+	Yes	Potential implications of sediment entering and settling out in Chapelhouse Reservoir, with sediment being lost from the bypass channel as well as flows.
	C2	Catchpit – naturalise if possible and remove some reinforcement	- -	=	=	+	Yes	The option would remove the existing catchpit and re-create a more natural sediment trap. This could include sediment management practices to re-introduce the sediment downstream. However, there are issues with management downstream and the potential implications to the surrounding landowners.
	C3	Full removal of dam (including catchpit and bypass channel) - reinstating old River Ellen planform	- -	-	+++	+++	Yes	There would need to be careful consideration of engineering issues during the outline design phase, but these are likely to be overcome in detailed design phase and with a good contractor. There are potential issues with access to the house on the eastern bank of the reservoir. However, overall improvement for geomorphology, hydraulics and ecology (apart from existing lake species).
	C4a	Partial removal of dam - leaving catchpit and reconnecting channel to Chapelhouse Reservoir	- -	-	+	+	No	Not considered feasible as it would not provide any benefit to the salmonids.
	C4b	Partial removal of dam - removing catchpit and reinstating historical River Ellen planform to Chapelhouse Reservoir	- -	-	++	++	No	The advantages are considered similar to the full removal but would still maintain some pooling of water and would need a fish pass up to the lowered dam level. The advantages over full removal would be fine sediment being trapped in the remaining lake, as well as this maintaining some lake habitat. However, for the potential cost it would be more beneficial to undertake the full removal.
	C4c	Install a culvert through the existing dam for a newly created River Ellen channel to pass through	--	-	+	++	No	This option would need extensive engineering and would require a wide box culvert with a screen. The cost of this would be high and the option was not considered to be feasible.
	C5a	Removal of both weirs downstream of Chapelhouse dam	-	=	+	++	Yes	Localised improvements to existing weirs, improving passability and connectivity.
	C5b	Removal of upstream weir (downstream of Chapelhouse dam)	- -	=	+	++	Yes	Localised improvements to existing weirs, improving passability and connectivity.
	C5c	Removal of downstream weir (downstream of Chapelhouse dam)	- -	=	+	++	Yes	Localised improvements to existing weirs, improving passability and connectivity.
	C6	Fish pass on downstream weir (downstream of Chapelhouse dam)	- -	=	=	+	No	Screened out as would not provide any significant improvement from the baseline conditions.
	C7	Improve bypass	- -	=	+	+	Yes	This option would likely support C3 'Full removal of dam (including catchpit, and bypass channel) – reinstating old River Ellen planform' and provides some scope for improvement along the River Ellen. However, this would be localised improvements.
	C8	Create a new bypass channel on east of reservoir	- -	=	++	+	No	Scoped out due to cost and feasibility. This is unlikely to lead to any significant improvements in Atlantic salmon habitat.

		Option Name	Engineering	Flood Risk and Hydrology	Geomorphology	Ecology[2]	Shortlisted	Justification
River Ellen	E1	Re-naturalise – cut across field downstream of road towards the reservoir (meandering planform)	-	=	++	+++	Yes	This would be the sub-option considered as part of the full dam removal, reconnecting the historical channel of the River Ellen. Would not be considered as a standalone option.
	E2	Re-naturalise - straightened length	-	=	+	++	Yes	Combination as an alternative with the bypass channel improvements, to provide improvements in the existing channel if dam removal is not possible. However, it does not constitute infrastructure removal.
	E3	Gravel augmentation to improve habitat	-	=	+	+	Yes	Not infrastructure removal; however, could provide some localised improvements if included as an additional option.
	E4	Weir and bank reinforcement removal	-	=	+	+	Yes	Included as an alternative option that could be implemented in combination with the other options identified.
Longlands Beck	L1	Remove weir under road by Low Longlands	- -	=	++	+	No	The weir is integral to the road bridge and would require extensive works for a minimal benefit as the channel upstream has limited salmonid habitat.
	L2	Remove infrastructure on channel edge	- -	=	=	=	No	This option does not address the aims of the study and would purely remove United Utilities infrastructure.
	L3	Riparian planting on right bank downstream of wood	=	=	=	+	No	This option is located on land not owned by United Utilities and therefore is unlikely to be feasible. It would provide some local improvements but would not work towards the aims and objectives of this study. Potential option for other sources of funding.
	L4	Stop dredging	=	=	+	=	No	This option is located on land not owned by United Utilities and therefore is unlikely to be feasible. It would provide some local improvements but would not work towards the aims and objectives of this study. Recommend land owner consultation and working on the ground by the Rivers Trust.

Appendix G. Engineering Design Drawings

This appendix includes the Engineering Design Drawings for the Final Outline Design of the Preferred Option, including the following elements:

- Full removal of Chapelhouse Dam (including associated infrastructure)
- Realignment of the River Ellen
- Upgrade existing access to private holiday let
- Provision of new farm access bridge
- Permanent diversion of existing public right of way
- Construction of an offline flood storage area
- Removal of existing weir and section of embankment at Over Water
- Realignment of Over Water Beck to confluence with the realigned River Ellen
- Removal of all redundant infrastructure

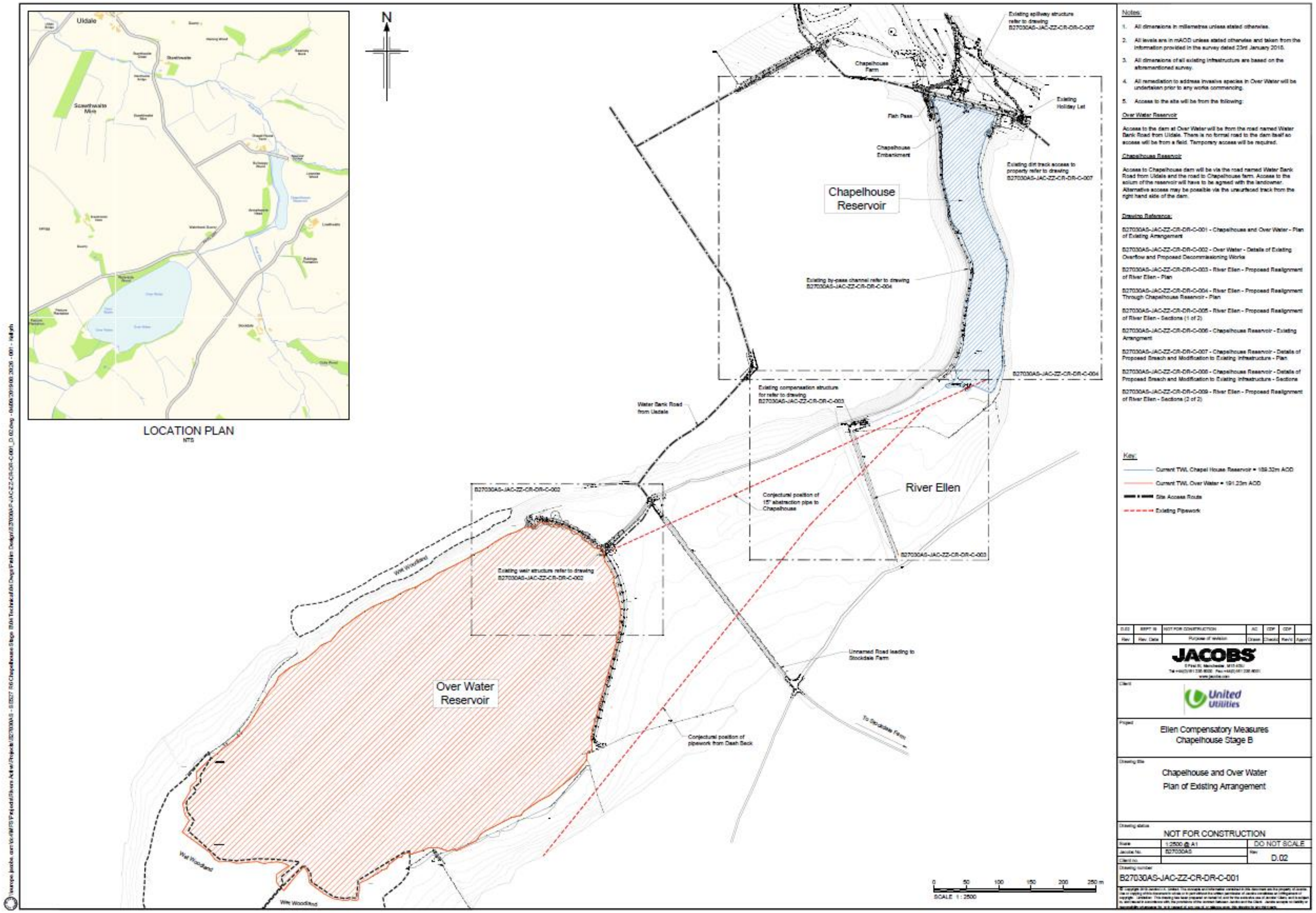


Figure G-1: Chapelhouse and Over Water Plan of Existing Arrangement (B27030AP-JAC-ZZ-CR-DR-C-001)

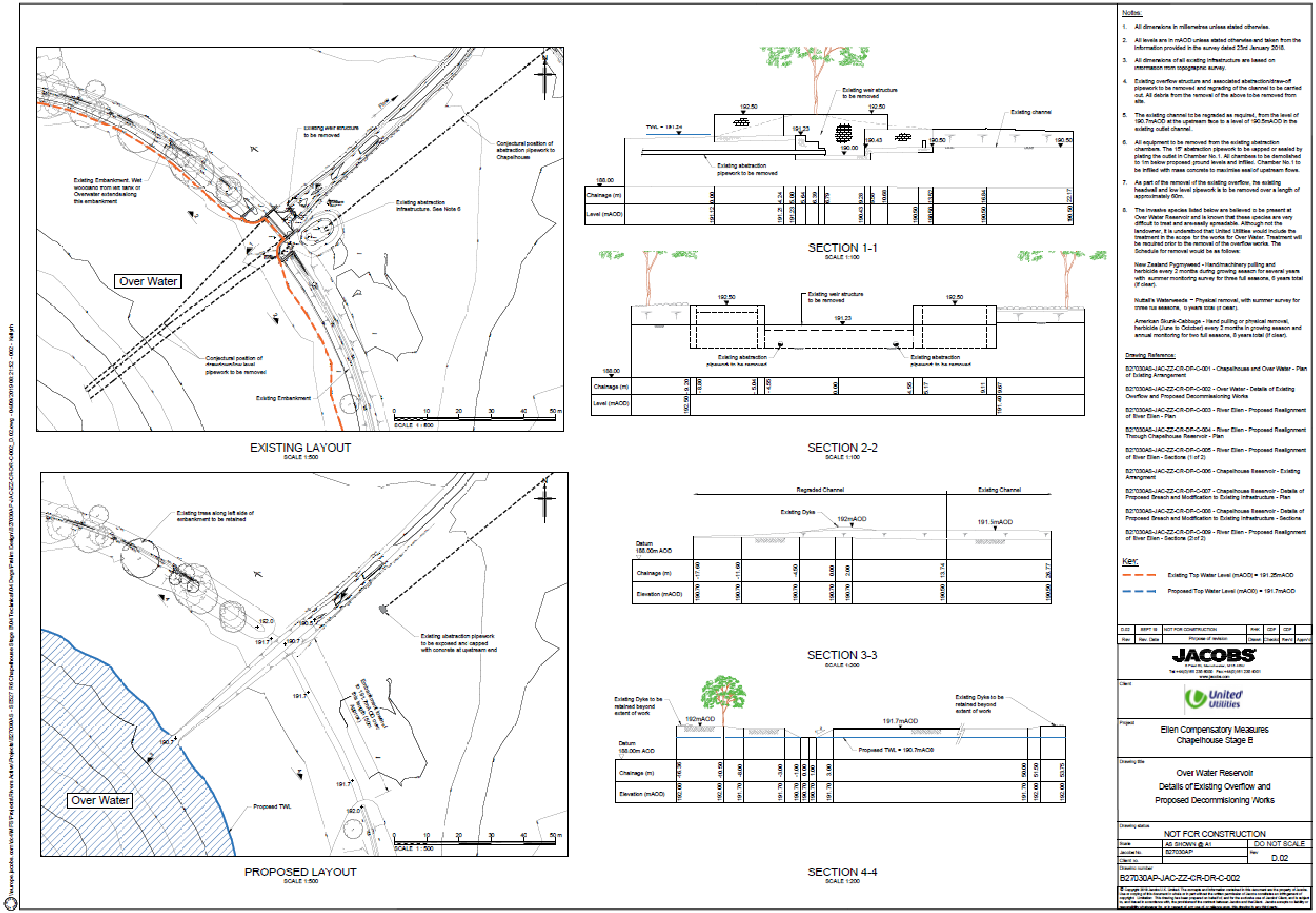


Figure G-2: Over Water Reservoir Details of Existing Overflow and Proposed Decommissioning Works (B27030AP-JAC-ZZ-CR-DR-C-002)

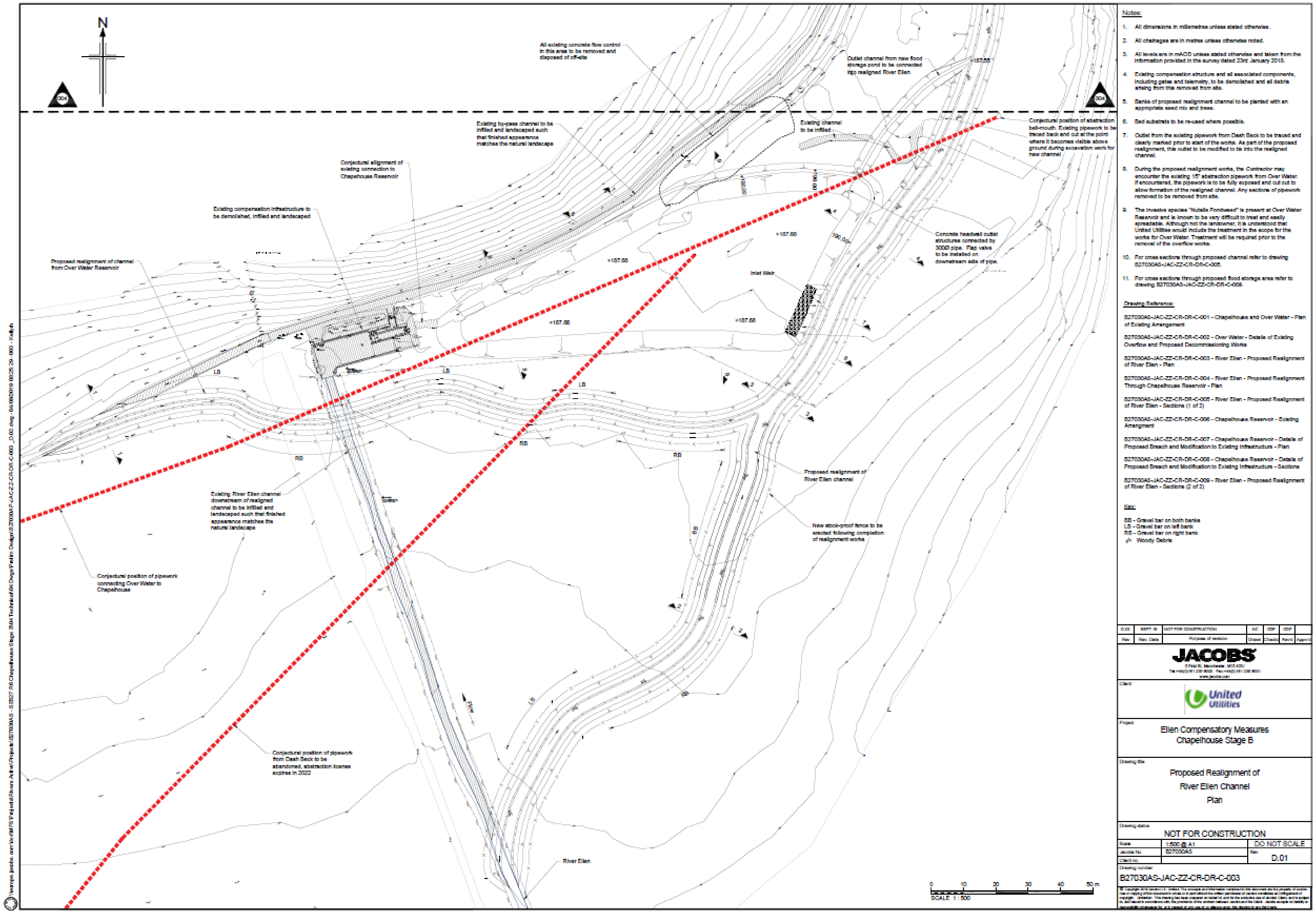


Figure G-3: Proposed Realignment of River Ellen Channel Plan (B27030AP-JAC-ZZ-CR-DR-C-003)

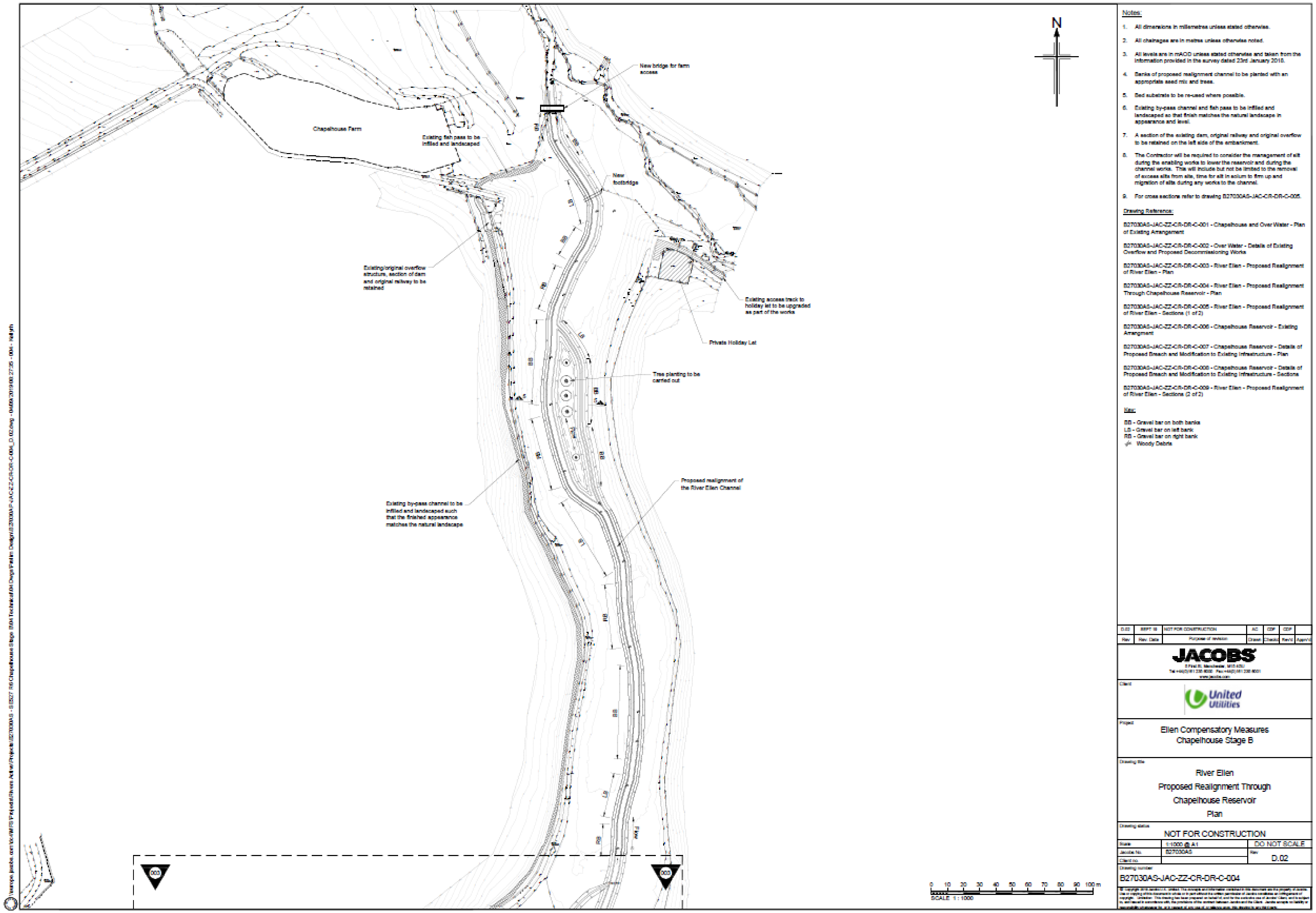


Figure G-4: River Ellen Proposed Realignment Through Chapelhouse Reservoir Plan (B27030AP-JAC-ZZ-CR-DR-C-004)

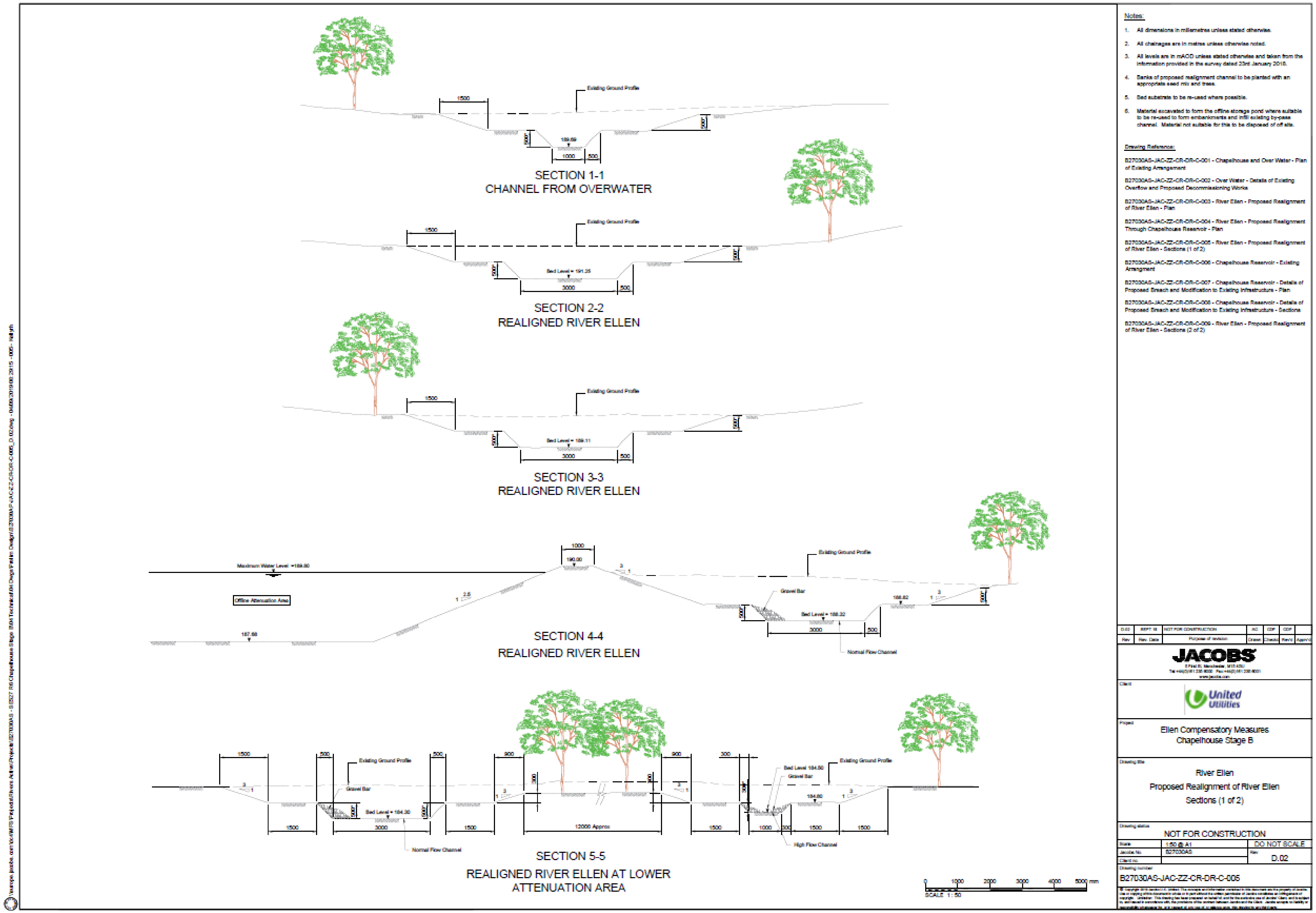


Figure G-5: River Ellen Proposed Realignment Sections (1 of 2) (B27030AP-JAC-ZZ-CR-DR-C-005)

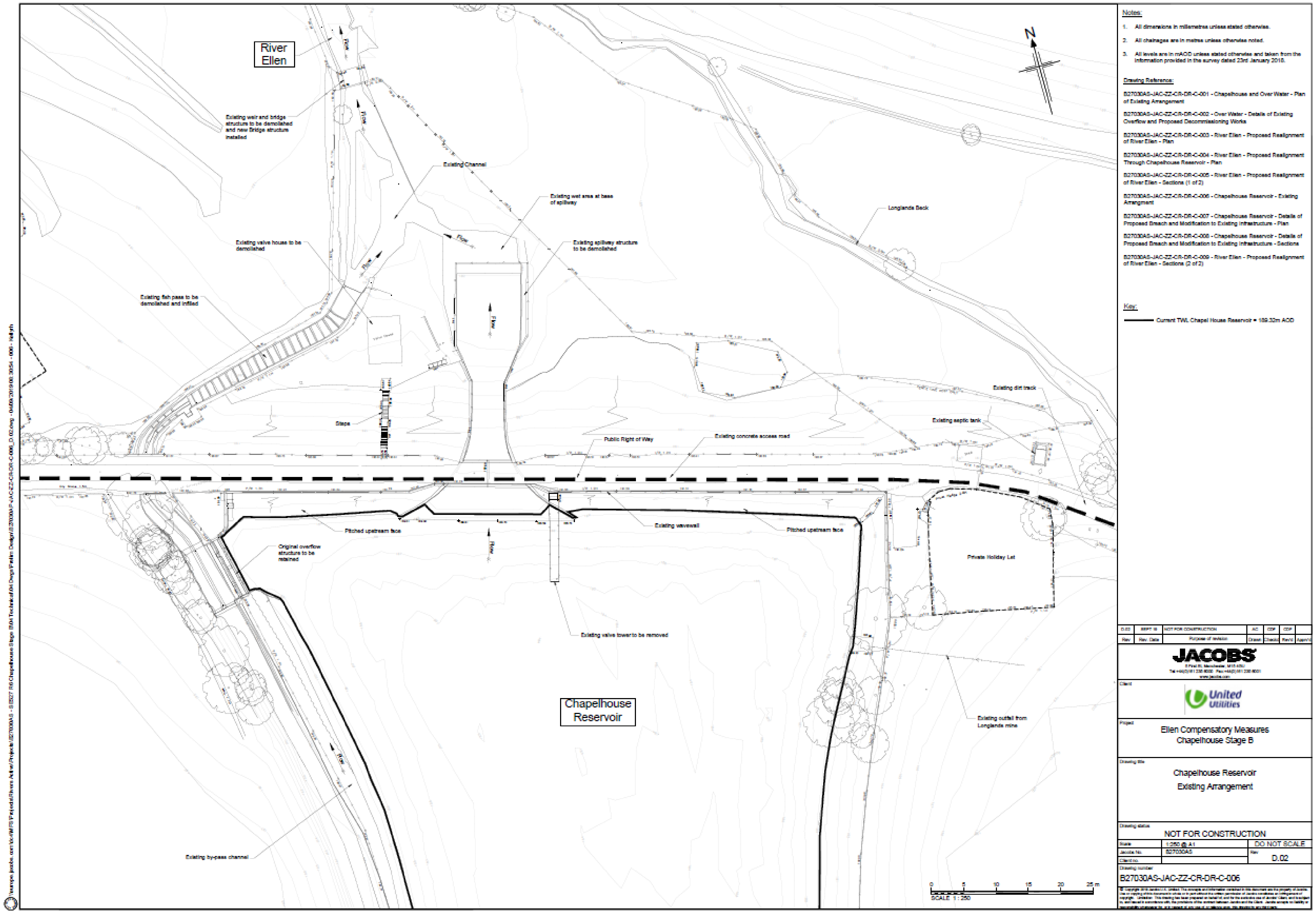


Figure G-6: Chapelhouse Reservoir Existing Arrangement (B27030AP-JAC-ZZ-CR-DR-C-006)

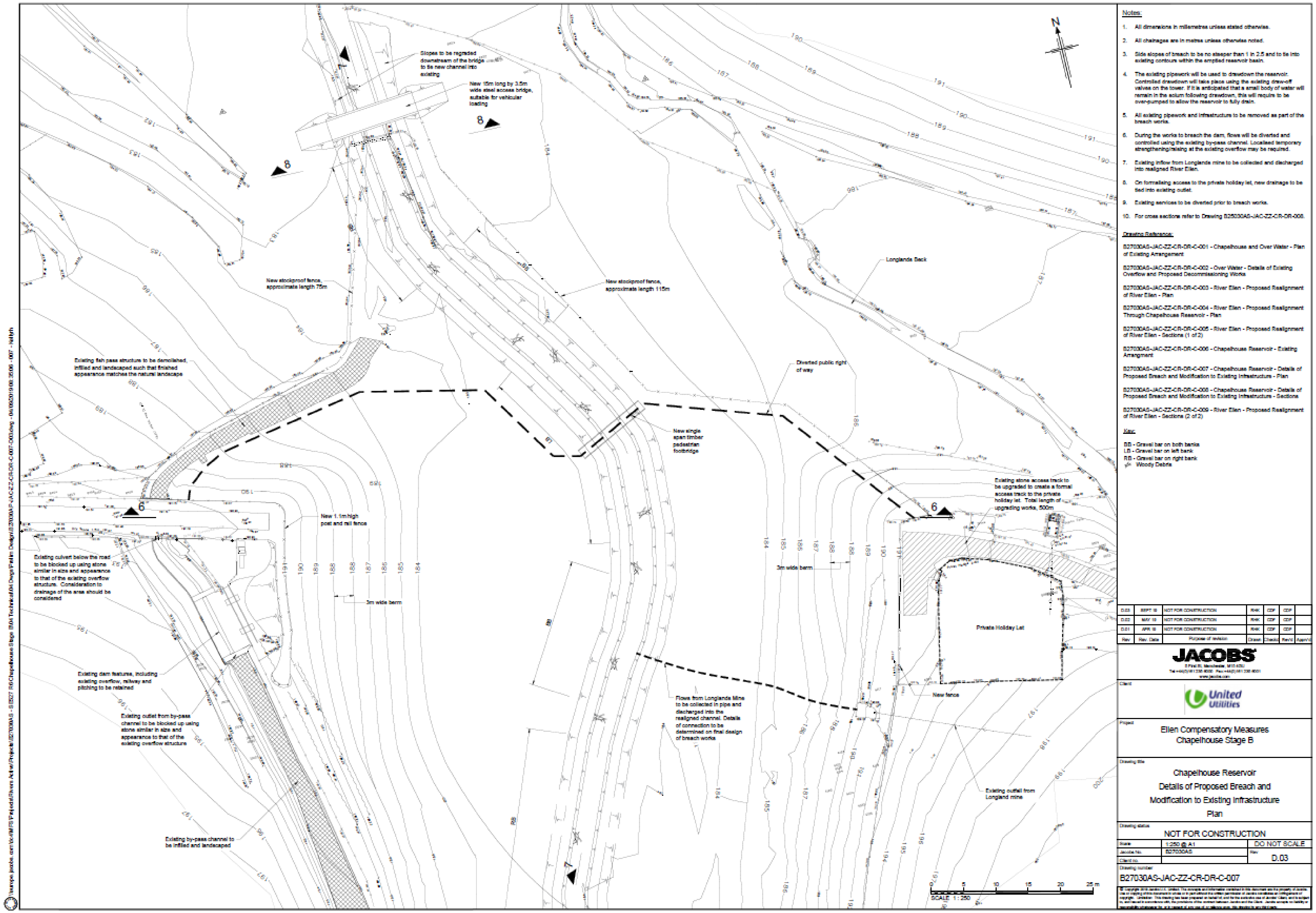


Figure G-7: Chapelhouse Reservoir Details of Proposed Breach and Modification to Existing Infrastructure (B27030AP-JAC-ZZ-CR-DR-C-007)

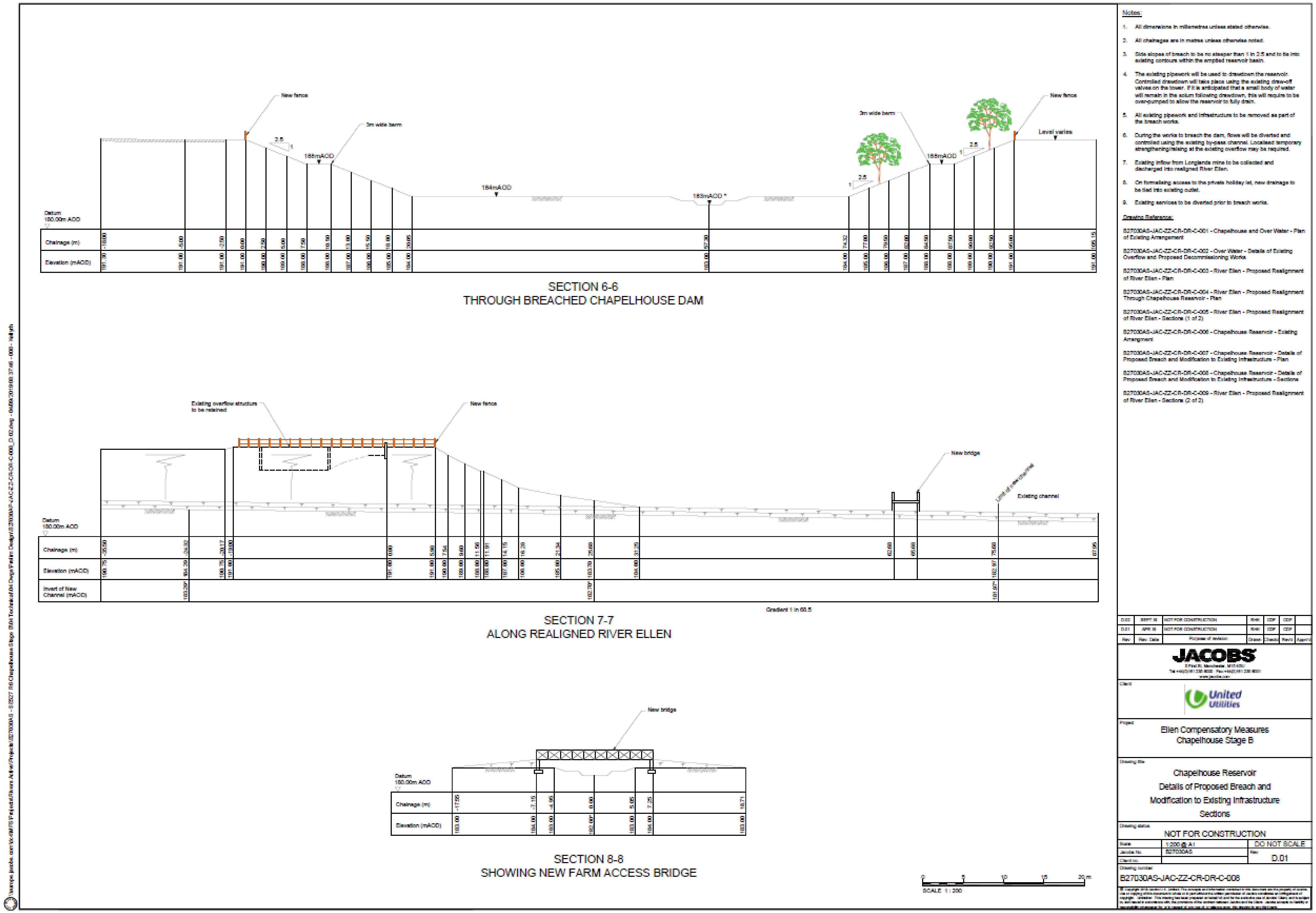


Figure G-8: Chapelhouse Reservoir Details of Proposed Breach and Modification to Existing Infrastructure Sections (B27030AP-JAC-ZZ-CR-DR-C-008)

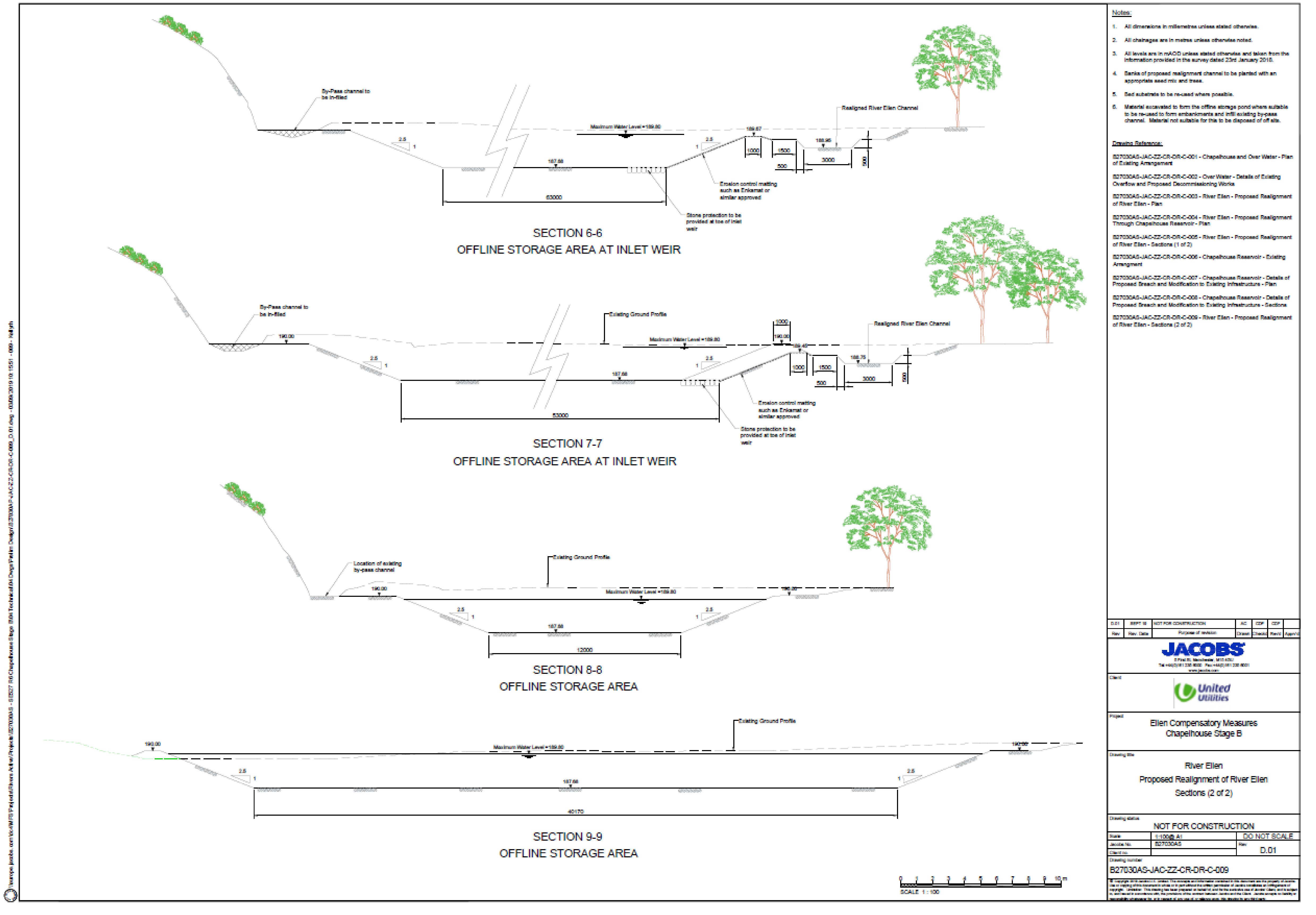


Figure G-9: River Ellen Proposed Realignment Sections (2 of 2) (B27030AP-JAC-ZZ-CR-DR-C-009)

Appendix H. Draft Hazard Elimination and Risk Reduction Form

DESIGN HAZARD ELIMINATION AND RISK REDUCTION (HE & RR) FORM

Project name:	Chapelhouse – Stage B	Design stage:	Engineering Discipline:	Civil	Structure:	Chapelhouse Reservoir Over Water Dam
Project No: B27030AP	Doc. Ref.:	Revision: Working Copy	Prepared by: R H Kelly	Date: 15/01/2019	Checked by: C D Fisher	Date: 29/01/2019

Ref.	Phase C/M/D /UaW	Topic	Potential Specific Hazards	Person(s) at Risk	Risk Rating (H/M/L)	Options and Practicability to Eliminate Hazards	Options and Practicability to Reduce Risk	Significant or Unusual Residual Risk remains?	Summary of Information to be provided? Drawing No(s). or other doc. (give ref.)	Con-firmed
General - Access										
	C	Access to all elements of the works is via single track country roads. This may limit the size of the plant that can access the working areas.	Traffic incidents with construction traffic and general public.	Contractors Staff and Members of the Public	L	There is no practical method of eliminating the Hazard as here are no other access routes to the various areas of the site.	Contractor shall develop a traffic management plan prior to the works starting on site	No		
	C	Public right of way currently runs across the dam at Chapelhouse Reservoir.	Members of the public may come into contact with the works.	Public	H	There is practical method of eliminating the hazards as the right of way runs directly over the crest.	The Contractor as part of the design will provide a permanent diversion to the right of way as shown on the drawings. During the works adequate segregation between the public and the working area will need to be provided.	No		
Chapelhouse Breach										
	D	Demolition of valve tower and associated valves and pipework.	The valve tower poses the potential to be a confined face during the demolition works.	Contractors Staff	M	None, the removal of the valve tower is an essential element of the works.	The Contractor shall develop a safe system of work when developing the demolition plan for the valve tower taking into account access constraints by lowering the dam.	Yes – Valve tower will become a freestanding structure once water is removed.		
	D	Demolition of access bridge to the valve tower.	Working from height hazard when accessing the valve tower.	Contractors Staff		None, the removal of the valve tower is an essential element of the works.	The Contractor shall develop a safe system of work that allows safe access to the valve tower following removal of the access bridge.	Yes – Valve tower will become a freestanding structure once water is removed.		
	D	Presence of asbestos in existing structures.	Demolition of existing valve house, where asbestos may be present. No asbestos plans have been located for this site,	Contractors Staff		None	The Contractor shall develop a safe system of work for the demolition of the structure considering the presence of asbestos.			

Ref.	Phase C/M/D /UaW	Topic	Potential Specific Hazards	Person(s) at Risk	Risk Rating (H/M/L)	Options and Practicability to Eliminate Hazards	Options and Practicability to Reduce Risk	Significant or Unusual Residual Risk remains?	Summary of Information to be provided? Drawing No(s). or other doc. (give ref.)	Con-firmed
			so it should be assumed that asbestos is present.							
	D	Removal of existing infrastructure.	Unknown load capacity of valve tower access bridge.	Contractors Staff		None	The Contractor shall develop a safe system of work for the demolition of the access bridge, considering the unknown load capacity.			
	C	Reservoir Drawdown.	Unconsolidated wet ground conditions within the reservoir solum.	Contractors Staff, Visitors and General Public.		Early drawdown programmed to allow maximum time for reservoir solum to dry out prior to commencing on site.	Contractor to install safety signs warning the public of deep silt hazards.			
	C	Formation of Breach	Unstable excavations when forming the breach.	Contractors Staff and Site Visitors.		Breach slopes have been battered back and berms included reducing the potential for collapse of slopes.	Contractor to ensure slopes of excavations are battered back no steeper than designed gradient.			
	c	Dam Breach	Construction run-off or sediment laden run-off from exposed solum polluting watercourses.	Environment and General Public.		Early Contractor involvement to plan surface water management and incorporating features into any temporary works design.	Contractor to implement a surface water management programme.			
	C	Dam Breach	Heavy rainfall during construction could cause a flood that potentially could cause the retained water to overtop the lowered dam profile, potentially washing out the dam. Alternatively, a blockage of the scour outlet could cause water levels to rise with similar consequences.	Contractors Staff and General Public.		Sequence of dam removal to be developed in conjunction with an all Reservoirs Panel Engineer to manage the construction flood risk.	Contractor to develop method statements for the excavations of the dam based upon the recommendations made regarding sequencing by the ARPE. The Contractor shall develop contingency plans to mitigate the risks associated with a blockage of the scour valve.			
	C/D	Live Services.	Live services exist on the crest and on the downstream face of the dam.	Contractors Staff.		Diversion of overhead lines and underground mains. Undertaker to arrange for service diversions prior to commencement on site by the Contractor.	Contractor to develop a safe system of work for operating near existing/diverted services.			
Overwater Weir Removal Works										
	D	Decommissioning of existing Abstraction infrastructure.	Inundation of existing chamber and confined space risk from working in deep chambers	Contractors Staff.		As part of the decommissioning works the Contractor is required to partly demolish the chambers. However, the confined space risk remains whilst the valves etc are removed from the deep chambers.	Contractor to develop a safe system of work that allows for the safe access to the chamber to carry out decommissioning works.			
	D	Demolition of existing weir structure.	Demolition of existing weir structure close to a body of water.	Contractors Staff.		Water level in Overwater to be drawn down as low as possible prior to commencement of the works.	Contractor to develop a safe system of work, that allows for the dealing of flood rise and the use of temporary			

Ref.	Phase C/M/D /UaW	Topic	Potential Specific Hazards	Person(s) at Risk	Risk Rating (H/M/L)	Options and Practicability to Eliminate Hazards	Options and Practicability to Reduce Risk	Significant or Unusual Residual Risk remains?	Summary of Information to be provided? Drawing No(s). or other doc. (give ref.)	Con-firmed
							measures to manage water levels.			
	C	Working in a live watercourse.	Risk of inundation of the works area.	Contractors Staff.	M	Working within the watercourse is unavoidable.	Contractor to identify suitable working methods to allow works to be carried out in the dry and a suitable procedure for excavation developed.	No		
	C	Unstable excavations when re-naturalising outlet channel (Overwater Beck).	During re-naturalisation at the weir the ground may become unstable.	Contractors Staff.	M	The design of the new channel is such that the slopes are not overly steep reducing the potential for collapse of the slopes.	The Contractor to ensure slopes of excavations are no steeper than that shown on the drawings, and that all works are carried out a suitable distance from the edge.	No		
	C	Contamination of downstream channel/reservoir due to plant movements in channel or reservoir bed.	The use of plant in the channel or reservoir bed could lead to diesel spills.	Environment.	H		The Contractor shall prepare a method statement outlining the measures to help eliminate this. This could include the use of spill kits and the positioning of generators etc.	No		
	C	Contamination of downstream channel/reservoir.	Possible migration of silts and materials during weir removal and channel re-naturalisation.	Environment	H	The purpose of the works is to remove the weir and re-naturalise the channel. So direct working in the channel is unavoidable.	The Contractor shall prepare a method statement outlining the measures to minimise the effect of or eliminate an environmental incident. Contractor to install settlement ponds to trap material and dispose off site.			
River Ellen – Re-naturalisation										
	C	Inundation of the working area.	The re-naturalisation works to the River Ellen runs through an area that will receive flood flows in a storm event.	Contractors Staff.		Modelling shows that flood flows inundate the area by flood waters coming over the adjacent road. This flow does not enter the existing channel.	Contractor to develop a safe system of work, that allows for the dealing of flood rise and the use of temporary measures to manage water levels.	No		
	C	Unstable excavations when forming the re-naturalised channel and flood storage area.	During the channel works the ground may become unstable.	Contractors Staff.		The design of the new channel and storage area is such that the slopes have been battered back reducing the potential for collapse of the slopes.	The Contractor shall ensure slopes of excavations are battered back no steeper than that shown on the drawings and all works carried out a suitable distance from the edge.	No		
	C	Discovery of contaminated material during re-naturalisation of the River Ellen and Overwater Beck.		Contractors Staff.	L	Initial ground investigation for the area suggests that no contaminated materials exist.	Contractor to adopt precautionary material management protocols.	No		

Ref.	Phase C/M/D /UaW	Topic	Potential Specific Hazards	Person(s) at Risk	Risk Rating (H/M/L)	Options and Practicability to Eliminate Hazards	Options and Practicability to Reduce Risk	Significant or Unusual Residual Risk remains?	Summary of Information to be provided? Drawing No(s). or other doc. (give ref.)	Con-firmed

Phase
C= Construct
M= Maintain / Clean
D= Demolish and/or Adapt
U aW = Use as Workplace

	Severity of Injury
H:	Major, Fatal or long term disabling injury or illness.
M:	Moderate injury or illness
L:	Minor injury/ illness

	Probability (Prob.)
H:	Highly likely
M:	Likely event
L:	Possible

Risk Rating (RR)

Prob.(LMH)			
	M	H	H
	L	M	H
	L	L	M
	Severity (LMH)		

Note – the purpose of Risk Rating is to determine which risks are significant. It is a subjective process, not an absolute or precise determination.

Hierarchy of Mitigation

1. Eliminate hazard (design out)
2. Reduce risk at source (amend design)
3. Provide risk information (add to design)

Appendix I. Bill of Quantities and Costing Statement

I.1 Introduction

United Utilities (UU) commissioned Jacobs to prepare a high-level estimate for the cost of the civils works at Chapelhouse Reservoir and Over Water based upon the conceptual design prepared in 2019.

A brief description of the works to be carried out are given below:

River Ellen

The existing engineered channel of the River Ellen is to be re-naturalised. The channel will be a two-stage channel and will include gravel berms and natural debris.

Over Water

The existing weir at Over Water is to be removed and the Over Water Beck returned to its natural level and alignment.

Chapelhouse Reservoir

The existing embankment at Chapelhouse Reservoir is to be completely removed to allow the re-naturalised River Ellen Channel to run through the former reservoirs solum.

I.2 Material Take-Off

The material take-off has been conducted using information, such as drawings, made available to Jacobs by UU. A reference list of drawings and documents used in the material take-off have been included below:

Document / Drawing Number	Document / Drawing Title
B27030AS-JAC-ZZ-CR-DR-C-001	Chapelhouse and Over Water - Plan of Existing Arrangement
B27030AS-JAC-ZZ-CR-DR-C-002	Over Water - Details of Existing Overflow and Proposed Decommissioning Works
B27030AS-JAC-ZZ-CR-DR-C-003	River Ellen - Proposed Realignment of River Ellen - Plan
B27030AS-JAC-ZZ-CR-DR-C-004	River Ellen - Proposed Realignment Through Chapelhouse Reservoir - Plan
B27030AS-JAC-ZZ-CR-DR-C-005	River Ellen - Proposed Realignment of River Ellen - Sections (1 of 2)

Document / Drawing Number	Document / Drawing Title
B27030AS-JAC-ZZ-CR-DR-C-006	Chapelhouse Reservoir - Existing Arrangement.
B27030AS-JAC-ZZ-CR-DR-C-007	Chapelhouse Reservoir - Details of Proposed Breach and Modification to Existing Infrastructure - Plan
B27030AS-JAC-ZZ-CR-DR-C-008	Chapelhouse Reservoir - Details of Proposed Breach and Modification to Existing Infrastructure - Sections
B27030AS-JAC-ZZ-CR-DR-C-009	River Ellen - Proposed Realignment of River Ellen - Sections (2 of 2)

Estimates have been produced using the drawings prepared in September 2019, which detailed the conceptual design.

The materials take-offs have been produced broadly (though not in strict conformance) in accordance with the CESSM3 method of measurement to provide a Bill of Quantities (BoQ) for estimating.

I.2.1 Inclusions

The materials take off includes the following:

- Earthworks – excavation and trimming of excavated surface, filling with compacted suitable material to form the new channels.
- Demolition – all demolition of existing structure and infrastructure including removal from site.
- Vegetation Clearance – the removal of trees and vegetation that is required to be removed to facilitate the works.

I.3 Assumptions

The following assumptions have been made in the preparation of this high-level cost estimate:

- Access to the site is unrestricted;
- Land required is already owned by UU.
- Drawings provided by UU are representative of the as-built reservoir and no further modifications have been made. It should be noted that a full suite of drawings was not available.
- Channel Cross sections are consistent over full length of the River Ellen realignment.
- Volume of flood storage area is based upon information from flood model results.

I.4 Exclusions

The following items are excluded from this estimate:

- Planning or design costs;
- Land purchases/compensation;
- Temporary Works, such as dewatering pumps etc.;
- Toxic/hazardous material removal including removal of toxic or hazardous parts of building fabric and hazardous materials or components from existing services installations;
- Removal and/or treatment of contaminated ground material;
- Eradication of invasive plant growth;
- Extraordinary site investigation works including archaeological investigation, reptile/wildlife mitigation measures and other site investigation works;
- Employer finance costs, costs in connection with funding of project;
- Fixtures, fittings and equipment;
- Fees, planning fees, building control fees, oversailing fees, fees in connection with party wall awards, fees in connection with rights of light agreements, fees in connection with other agreements between the employer and neighbors to facilitate the project, other fees in connection with licenses, permits and agreements;
- Insurance other than main contractor's works insurance;
- Land acquisition costs;
- Marketing costs, public relations events, site based advertising and public relations literature;
- Planning contributions, direct financial contributions in connection with planning consent, and environmental improvement works;
- Employer's project team and design consultants' fees;
- Main contractor's design fees;
- Main contractor's pre-construction fees including management and staff, specialist support services fees, temporary accommodation, services and facilities, charges, overheads and profit;
- Inflation;
- Value Added Tax.

I.5 Detailed Bill of Quantities

Area	Item No	Item	Unit	Quantity
Chapel House	1	Demolition of Existing Spillway Channel - Concrete Section	m^3	180
	2	Demolition of Existing Concrete Wave Wall	m^3	35
	3	Demolition of Existing Concrete Roadway and steps	m^3	180
	4	Demolition of Existing Concrete Valve House	m^3	40
	5	Demolition of Concrete Base of Fish pass Structure	m^3	75
	6	Disposal of Concrete Elements	m^3	510
	7	Demolition of Masonry Walls at Fish Pass	m^3	75
	8	Disposal of Masonry Walls at Fish Pass	m^3	75
	9	Stone Pitching Removal from Upstream Face	m^3	210
	10	Demolish Existing Valve Tower and Remove Pipework	Sum	
	11	Excavation to breach Dam at Chapelhouse	m^3	20300
	12	Disposal of Grout Curtain (Assume 10% of fill)	m^3	2030
	13	Disposal of Excavated Embankment Material	m^3	18270
	14	Reprofiling Works and material movement to form breach sides	m^3	4500
	15	Provide Masonry seals to archways at Existing Overflow	m	5
	16	Provide New Stockproof Fence at Bypass Channel	m	190
	17	Supply delivery and erection of New Timber Footbridge 15m span	Sum	
	18	Supply delivery and erection of New Vehicular Access Bridge 15m span	Sum	
	19	Assumed quantities of sediment to excavated from Solum	m^3	7500
	20	Connection of Longlands Mine discharge to realigned channel - Assume 300mm dia pipe in trench at nominal depth	m	40
River Ellen Works	21	Excavation to create renaturialised River Ellen channel	m^3	52000
	22	Reuse of suitable excavated material to fill in Bypass and Existing River Ellen Channel	m^3	2500
	23	Disposal of Excavated Material to form new Channel	m^3	49450
	24	Excavation to create renaturialised Overwater Beck channel	m^3	1000
	25	Disposal of Excavated Material to form new Channel at Overwater Beck	m^3	1000
	26	Excavation for Offline Flood Storage	m^3	9700
	27	Disposal of Excavated Material from Offline Storage Pond	m^3	9700
	28	Reuse of suitable excavated material to form built up area at storage pond	m^3	50
	29	Excavation to create Outlet Channel from Flood Storage	m^3	250
	30	Disposal of Excavated Material from Outlet Channel	m^3	250
	31	Stone Protection to Toe of Inlet Weir	m^3	16
	32	Provision of Enkamat or similar erosion control at inlet weir	m^2	200
	33	Flood storage outlet structure - 2 x concrete headwalls and 300 dia pipe with coplastic flap valve	Sum	

Area	Item No	Item	Unit	Quantity
	34	Demolition of Flow Diversion Structure - Concrete	m^3	210
	35	Disposal of Concrete Elements	m^3	210
	36	Decommissioning and Removal of Penstocks and Controls and abstraction/abandoning of pipework crossing proposed channels	Sum	
	37	Provision of stockproof fencing to Overwater Beck and River Ellen realignments	m	750
Over Water	38	Demolition of Existing Weir - Concrete Section	m^3	60
	39	Disposal of Concrete Elements	m^3	60
	40	Demolition of Masonry Walls at Overflow	m^3	55
	41	Disposal of Masonry Walls at Overflow	m^3	55
	42	Excavation to lower section of dam at Over Water	m^3	125
	43	Disposal of Excavated Material from lowered section	m^3	125
	44	Excavation to form outlet channel	m^3	240
	45	Disposal of Excavated Material from lowered section	m^3	240
	46	Reuse of material following removal of weir to reprofile shoreline	m^3	150
	47	Removal of compensation pipework to overflow	m	200
	48	Demolition of Existing Manholes to 1m below new Ground level	m^3	15
	49	Disposal of Concrete Elements	m^3	15
	50	Infill MH1 with mass concrete	m^3	10
	51	Concrete Plug to 15"existing pipe work @ MH3 (assume a length of 10m)	m^3	1.1
	52	Decommissioning and Removal of Penstocks and Controls	Sum	
Misc	53	Tree Removal from both sites (Assume 10no Trees)	Nr	10
	54	Landscaping to realigned channels	Sum	
Access	55	Provide stone to resurface existing access to private holiday let (3m wide x 0.25 deep x 500 length)	m^3	450
	56	Divert public Right of Way at Chapelhouse (3m wide x 0.25 deep x 150 length) including preparing/trimming formation and geotextile over	m^3	60
	57	Provide stone access path to bypass channel (1.5m wide x 0.25 deep x 30 length) including preparing/trimming formation and geotextile over	m^3	12