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KENT WEIRS

BOWSTON WEIR OPTIONS APPRAISAL AND DESIGN

FINAL REPORT

Prepared for

South Cumbria Rivers Trust

Prepared by

cbec eco-engineering UK Ltd
JBA Consulting

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The Green House,
Beechwood Business Park North,
Inverness, IV2 3BL
(01463) 718831
info@cbecoeng.co.uk
www.cbecoeng.co.uk

designing with nature

natural flood management | river/floodplain restoration | hydropower support | fisheries management

cbec eco-engineering UK Ltd

The Green House,

Beechwood Business Park North,

Inverness, IV2 3BL

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1. BACKGROUND

1.1 INTRODUCTION

cbec eco-engineering UK Ltd (cbec) and JBA Consulting (JBA), with the support of Prof. Malcolm Newson were contracted by the South Cumbria Rivers Trust to assess river restoration measures that eliminate or minimise barriers to longitudinal connectivity at two locations within the Kent River catchment, as part of the delivery of the Cumbria Restoration Strategy.

The assessments, which have been undertaken to evaluate the options/ design in relation to each weir, include geomorphology, ecology, flood risk, heritage, structural stability and landscape. The weirs which were assessed are:

- Bowston Weir located at SD 49706 96809 (see Figure 1.1).
- Helsington Weir located at SD 51315 90526

This report focuses on Bowston Weir only and provides an overview of the approach taken to determine a suitable and sustainable final design for the site. As a result of historical engineering undertaken throughout the River Kent (including multiple weir structures), natural physical processes in this part of the system are considered to be significantly altered. As a consequence, the channel lacks the physical features and associated habitats that would naturally occur. With improved physical processes in operation, the river would develop a range of conditions, including areas of stabilising erosion, active sediment deposition and areas where deposited sediments would begin to stabilise. These areas provide a range of different water depths, flow velocities and substrate types, which in turn produces a range of micro-habitats for different invertebrate and fish species. Without this hydraulic variety, stable and unstable depositional and erosional features, the river can only provide a very limited range of habitat types, resulting in a limited range of fauna.

A previous phase of the project involved an options assessment, which compared the relative benefits and disbenefits of various options for the site. As part of this process, the following options were assessed at Boston Weir:

- Full weir removal
- Weir modification: Installation of rock ramp / weir infilling
- Do Nothing

The full options appraisal assessment is provided in Appendix A. The options and results were discussed with South Cumbria Rivers Trust (SCRT), and a decision made to progress with the full weir removal option, through to a detailed design phase.

This report describes the design approach, providing information on the various site surveys undertaken (i.e. geomorphic, ecological, topographic and cultural heritage) in Sections 2 – 5. The iterative 1D flood risk modelling and 2D morphodynamic 'sediment transport' modelling are described in Sections 6 and 7, respectively. The final design is discussed in further detail in Section 8, alongside relevant information required to inform the planning and consenting process.

Ultimately, the final site design aims to contribute towards the implementation of the Cumbria River Restoration Strategy and the River Kent SSSI/ SAC objectives by promoting recovery towards 'reference state' morphological processes in the River Kent.

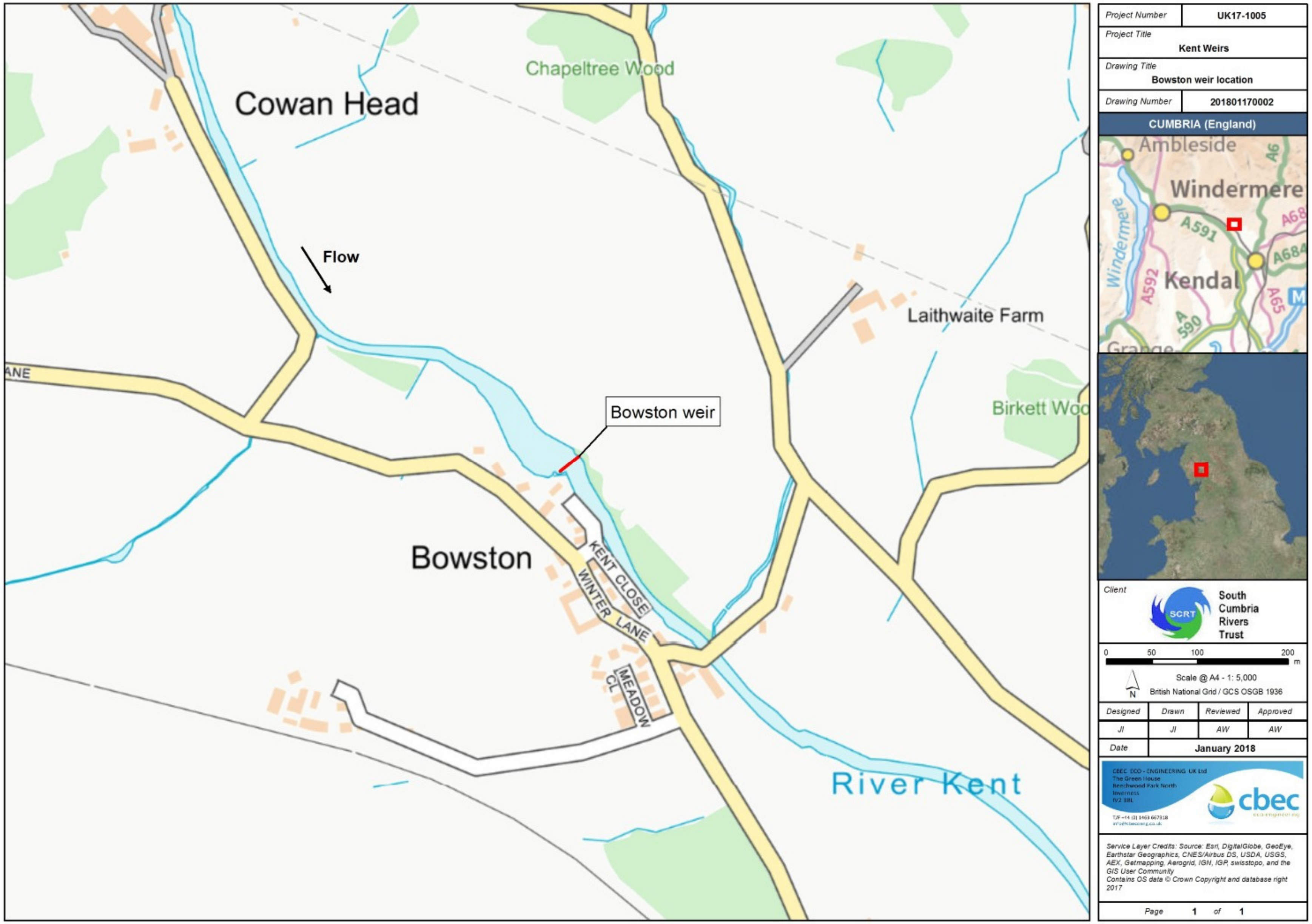


Figure 1.1 Site overview

2. GEOMORPHOLOGY

2.1 WALKOVER METHODOLOGY

A fluvial audit of an extended section of the River Kent was undertaken on 8th March 2017. The walkover covered a ~1.2 km section of the river from OS NGR SD 49338 97145 (upstream), to (SD 49983 96509 (downstream). This allowed for the collection of data relating to the morphology and fluvial processes within both the immediate vicinity of the weir and at the wider scale.

Locations and characteristics of physical features were recorded using an Android-based field data collection app, which allows field data to be automatically processed within a GIS environment. High resolution photographs were also taken throughout the site and can be provided separate to this report.

The types of features and characteristics recorded during the walkover are listed below.

- Reach scale channel morphology (using a classification scheme that draws on aspects of other recognised procedures - Montgomery and Buffington 1997, Brierley and Fryirs, 2000).
- Indicators of the sediment transport regime (e.g. the form, texture and vegetation cover of bed forms and bar features).
- Sediment sources/ storage (e.g. tributaries, bank erosion, within-channel storage in barforms), noting dominant sediment sizes.
- River engineering pressures (e.g. culverts, bank protection, canalisation/ realignment, embankments, hydraulic structures, bridge crossings, etc.).
- Floodplain morphology and land use.
- Vegetation - both in-channel vegetation (e.g. 'large woody material', macrophytes) and riparian/bankside cover, as well as invasive alien species.
- Opportunities for restoration and Natural Flood Management (NFM).

2.2 SUMMARY OF RESULTS FROM GEOMORPHOLOGICAL FIELD-BASED ASSESSMENT

The findings of the geomorphic assessment are presented in **Table 2.1**.

Table 2.1: Reach L5 engineering, physical characteristics and opportunities.

Reach	**Bowston Weir**
Length (m)	1220
Setting	Confined bedrock channel in upper reach, transitioning to open agricultural setting on left bank, whilst confinement is maintained on right bank as river approaches Bowston village.
Morphological pressures	• Historic channel modifications throughout reach associated with Bowston village. • Sediment supply is partially disrupted by a large weir at very upstream of the study area (OS NGR SD 49204 97381). • Extensive bank protection on right bank throughout reach associated with access track (upper section of reach) and Bowston village infrastructure in the mid and lower sections of the reach. • Bowston Weir in central part of reach causing extended section of impounded flow, with associated impact on channel bed structure/ morphology and interruption to downstream sediment transfer. • Two large fish pass structures (one central channel, one on right bank) associated with the weir. • Remnants of old pipeline (and associated concrete pillars) were noted in channel downstream of weir (damaged during previous flood event). • Minor/ low concrete weir ~40 m downstream of Bowston Weir, spanning channel - not considered a barrier to fish passage. • Large stone bridge (double span with central pier) towards downstream section of reach.
Physical behaviour and characteristics	• Sudden gradient change due to both upstream and Bowston Weir structures, with areas of low gradient alluvial channel both upstream and downstream of weir. • Moderately confined channel, particularly at upstream end of reach and downstream of Bowston Weir, where valley sides become more sloping. • Reach type was cascade in upper section by Cowan Head, changing to plane bed/ pool riffle further downstream. This transitioned to slow glide due to impounded flow. Channel was plane-bed in nature downstream of Bowston Weir. • Dominant substrate alternated between cobble and gravel throughout the reach, with some sections of increased boulders. • The furthest upstream extent of the surveyed reach, along with a ~40 m section of channel between Bowston Weir and the smaller downstream weir, was predominantly bedrock, with exposed outcrops in places. • Immediately upstream of Bowston Weir, an increase in fine material (silt/ sand) was noted.

Reach	Bowston Weir
	• Some deposition was evident in the channel margins upstream of the weir but was less frequent further downstream. One extensive area of gravel deposition is located on the right bank upstream of the weir. • Bank erosion was limited due to bank protection. • One small tributary/ drain upstream of Bowston Weir on the left bank, exiting a culvert under the access track before entering the main channel. Minor sediment input was recorded here. • One main tributary was recorded in the reach, just upstream of Bowston Bridge. This is located on river left and contributes gravel and cobble-sized material to the mainstem River Kent (although no confluence bar was evident, suggesting that input is not significant). • Whilst sediment storage was the dominant process upstream of Bowston Weir (where the weir provides opportunities for deposition), the extent of this was limited by the reduced sediment supply from upstream. Immediately downstream of the weir, transportation processes dominate.
Geomorphological considerations for design	• The general approach of the restoration design should be to encourage the reinstatement of natural geomorphic processes through the removal of the barrier to sediment transport and fish passage as a result of Bowston Weir. • Whilst it may not be possible to achieve a fully functioning pool-riffle system given the constraints to lateral migration and vital infrastructure at the site, the ultimate design should encourage the evolution of channel morphology through the site. • It is recommended that the design includes improvements to the general dynamism of the channel, increased topographical variability, and enhanced hydraulic and sedimentary heterogeneity to improve biological/ ecological diversity. • Downstream of the weir, an increase in valley confinement (on approach to Bowston Bridge) means the channel is more laterally constrained, and sediment deposition would naturally be reduced here compared with upstream. Here, the proposed design approach should be to maintain and improve geomorphic processes, whilst avoiding any significant aggradation of the bed. • The design should consider the risk of head-cut migrating upstream from the current weir location, encouraging channel instability. Efforts should be made to mitigate this in the design channel through implementation of features to control gradient.

Reach	Bowston Weir
Photographs	 Photo 1: Weir at upstream end of reach at Cowan Head  Photo 2: Bedrock channel at Cowan Head

Reach	Bowston Weir
	 Photo 3: Wall/ bank protection on right bank protecting access track/ road  Photo 4: low, unconfined left bank floodplain upstream of Bowston Weir

Reach	Bowston Weir
	 Photo 5: Bed sediment upstream of impounded section of channel  Photo 6: Impounded section of channel upstream of Bowston Weir  Photo 7: Bowston Weir and associated fish passes/ bank protection

Reach	Bowston Weir
	 Photo 8: View upstream towards minor weir, showing right bank protection.

2.3 BED SAMPLING ASSESSMENT

To analyse sediment grain size distribution in the channel bed surrounding Bowston Weir, quantitative bed sediment sampling was undertaken. This complemented the sediment facies mapping performed during the geomorphological walkovers and provided the project team with additional understanding of sediment transport processes present within the study reach. This is of particularly importance to inform the understanding of key geomorphic processes at the Bowston site, including the impacts of any controls on the sediment transport regime. The information was ultimately used to further inform sediment transport modelling (Section 7), and the production of detailed designs.

2.3.1. Bed Sediment Sampling Approach

Samples of the channel bed surface grain size distribution were taken using the methodology described in Wolman (1954). Samples were collected on 9th March 2017, with flow conditions moderately high during the survey period. A second phase of sample collection was undertaken on 31st October 2017 in lower flow conditions. Choice of sample location was informed by the geomorphological walkover, so as to provide a suitable representation of the character of the bed within each study area.

Sediment samples of at least 100 pebbles were collected within a pre-defined area, using pacing (downstream to upstream) to define a grid sampling pattern. The intermediate axis of each pebble was measured using a 'gravelometer' and classified into half-phi Wentworth size classes.

2.3.2. Bowston Weir Results

Ten samples were taken in total throughout the Bowston Weir study reach (Figure 2.1). The nature of the flow at the time of the surveys and the bedrock character of the channel immediately downstream of the Bowston Weir hindered the collection of any samples within the immediate downstream vicinity of the weir. For the samples collected, the D_{16}, D_{50} and D_{84} (i.e. the 16th, 50th and 84th percentile particle sizes) were calculated. These are standard metrics that are often used to characterise particle size distributions. The values are shown in **Table 2.2**.

Table 2.2 Bowston sediment sample statistics

Sample ID	Sample date	Coordinates		Type	D_{16} (mm)	D_{50} (mm)	D_{84} (mm)
		x	y				
1	31/10/17	349367	497127	Bed	24.2	61.3	185.1
2	31/10/17	349416	497022	Bed	11.0	54.0	95.8
3	31/10/17	349454	496968	Bar	38.0	69.6	114.0
4	31/10/17	349573	496949	Bed	10.2	20.8	109.0
5	31/10/17	349647	496906	Bed	24.6	51.0	82.3
6	31/10/17	349730	496828	Bed	18.2	55.9	87.2
7	31/10/17	349766	496747	Bed	21.5	88.7	155.7
8	31/10/17	349866	496626	Bed	19.3	62.7	121.7
9	09/03/17	349464	496959	Bar	32.00	51.00	88.82
10	09/03/17	349641	496862	Bar	18.6	54.0	86.1

The results indicate some general patterns of sediment distribution across the site. This includes a slight fining of bed material on approach to the weir in comparison to upstream and downstream areas (samples 4, 5, 6, 9 and 10 recorded D_{84} values in the 'small cobble' category). In comparison, there was a notable a coarsening of bed material downstream of the weir, (sample 7 recorded a D_{50} of small cobble, and a D_{85} of coarse cobble). Within the impounded section of the channel immediately upstream of Bowston, an increase in silt was evident. Depth of the water and silt within this section made sampling of central channel areas unsafe. However, the marginal samples taken confirmed that this section of channel has a bed of coarse gravel and cobble-sized sediment.

These results suggest that the general substrate sizes of the River Kent within the study reach, are gravels and cobbles of varying coarseness, with the impounded section of channel consisting of a slightly finer gravel/ cobble bed dominated by a thick top layer of silt. It must also be noted that the weir at Cowan Head has some control on sediment supply to this downstream area, however, sediment is able to mobilise past the weir during flood events (as occurs with Bowston weir currently). The sediment sampling data collected provides a baseline dataset from which future surveys could be undertaken, to monitor/ assess localised changes to sediment post-works.

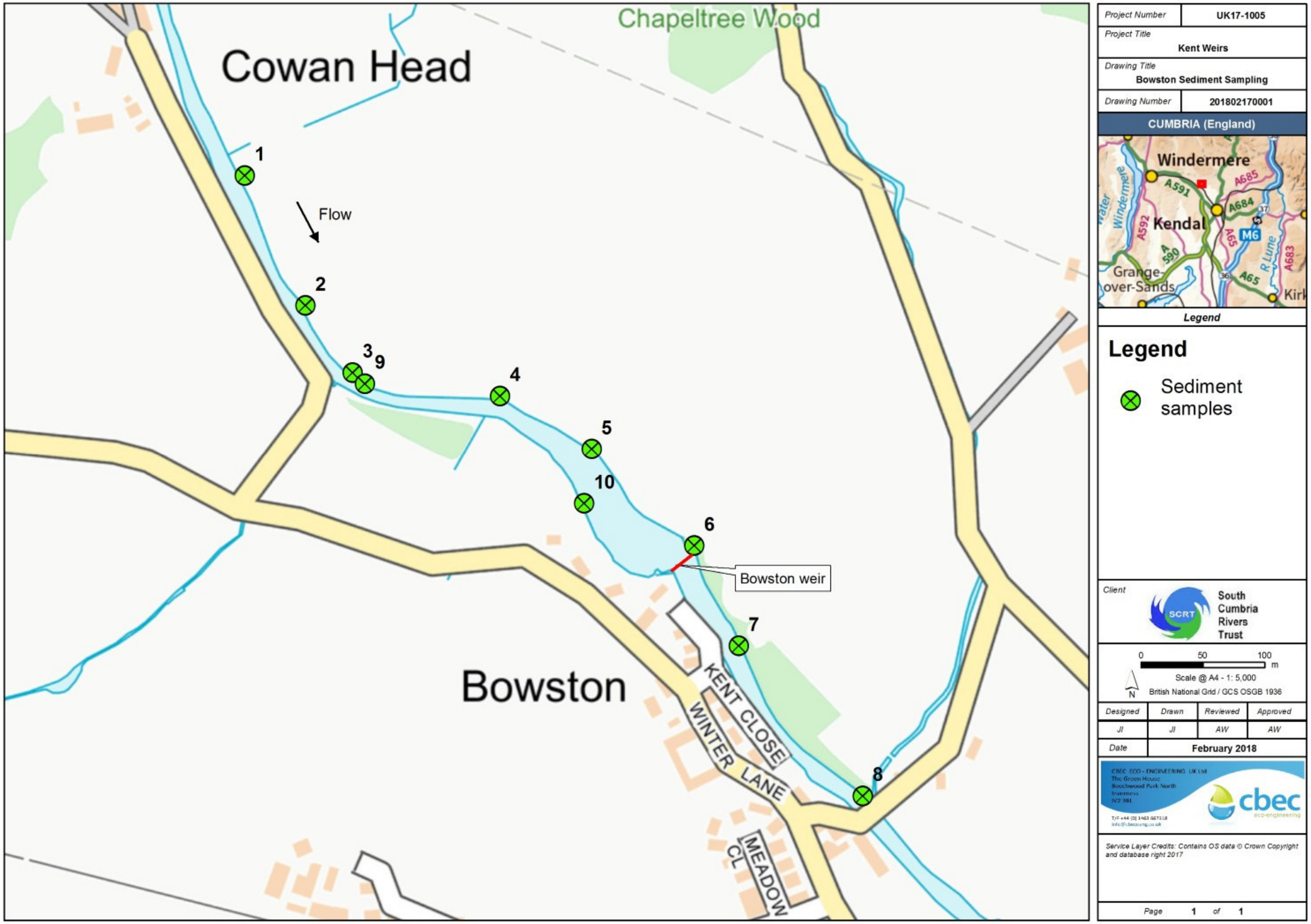


Figure 2.1 Bowston sediment sample locations

3. ECOLOGY

3.1 METHODOLOGY

3.1.1. Desk-based Assessment

Prior to undertaking the survey, searches of databases containing readily available information on ecological records and important sites for nature conservation were made. The following sources of information were included in these searches:

- GOV.UK website;
- MAGIC mapping service (www.magic.gov.uk);
- Natural England GIS data (www.gis.naturalengland.org.uk/pubs/gis/GIS_register.asp);
- Details of locally (non-statutory) designated nature conservation sites were supplied by Cumbria Biological Data Centre (CBDC); and
- Protected and non-native invasive species records were obtained from CBDC.

3.1.2. Nature Conservation Sites

Statutory Designated Sites

Sites with statutory designations receive varying degrees of legal protection under UK statute and European Directives. There are a number of statutory designations used for sites of high nature conservation value in the UK, which are applied depending upon the importance of the site in a local, regional, national or international context.

Statutory nature conservation sites within 2 km of the works area were recorded. Statutory designations recorded include:

- Ramsar Sites (International designation);
- Special Area of Conservation (SAC) and Special Protection Area (SPA) (European designations);
- National Nature Reserves (NNR) and Sites of Special Scientific Interest (SSSI) (National designations); and
- Local Nature Reserves (LNR) (Local designation).

Non-statutory Designated Sites

Non-statutory sites are afforded no statutory legal protection, but are normally recognised by local planning authorities and statutory agencies as being of local nature conservation value. The protection afforded to such sites is usually discretionary, through Local Plan policies. Non-statutory sites are designated by the local authority, usually in partnership with the County Wildlife Trust (or equivalent).

3.1.3. Site Survey

A site visit was undertaken on the 8th March 2017 by an experienced ecologist. Both sides of the watercourse and surrounding habitat were surveyed in the vicinity of the weir, wherever access was possible.

For many species (e.g. bats, otter and white-clawed crayfish), the ecologist made an assessment of the suitability of the surrounding habitats to support these species. Based upon this assessment, potential constraints to the project were identified and recommendations for avoidance/mitigation have been made. All survey methodology and legislative guidance relating to protected species is outlined in Appendix B.

Habitats within and immediately adjacent to the works area were surveyed using the Phase 1 Habitat standard methodology (JNCC, 2007). The habitat extents have not been mapped in relation to this project, however, all habitat descriptions are provided at Section 3.2.2.

During the walkover survey, any signs or sightings of other notable species were also recorded. In addition, any environmental features that might constrain the works were recorded (e.g. access restrictions).

3.1.4. Survey Limitations

Due to the early timing of the survey in March 2017, the vegetation communities present had died back over the winter period and certain species proved harder to identify and record. However, the general vegetation community type was identified from the taxa present, despite the potential for some species to have been missed due to senescence.

This report's findings rely heavily on desk study information due to time and budget constraints. Therefore, many conclusions rely on the validity of desk study data sources.

3.2 SURVEY RESULTS

3.2.1. Desk-based Assessment

Statutory Designated Sites

There are two statutory designated sites located within 2km of the River Kent.

1. Bowston Weir is located within the Special Area of Conservation (SAC). The primary reason for selection includes several Annex I habitats:

3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation. There are several Annex II species which are present as a primary qualifying feature of the site including:

- 1092 White-clawed Crayfish *Austropotamobius pallipes*

Additional Annex II species which are present as a qualifying feature of the site, but are not a primary reason for selection include:

- 1163 Bullhead *Cottus gobio*
- 1029 Freshwater Pear Mussel *Margaritifera margaritifera*

2. Bowston Weir also falls within the River Kent and Tributaries Site of Special Scientific Interest (SSSI).

The SSSI is important for native white-clawed crayfish and contains a variety of habitats which support this species. The River Kent and its Tributaries contain extensive beds of water-crowfoot *Ranunculus* spp. and alternate-flowered water-milfoil *Myriophyllum alterniflorum*, providing a further habitat and food source for crayfish (Natural England, 2005). The Kent is also important for its water quality which is generally high, with beds free of extensive algal growth providing optimal conditions to support populations of bullhead. The upper tributaries of the designated site are also important for pearl mussel and support only one of two populations found within England (Natural England, 2000).

Parts of the statutory designations fall within the Lake District National Park.

Non-Statutory Designated Sites

Within 2 km of Bowston Weir there are nine non-statutory designated sites which include sites of local geological, invertebrate and wildlife interest. The sites are detailed in Table 3.1.

Table 3.1 Non-statutory Designated site within 2km of Bowston Weir.

Site Name	Designation	Distance
Spring Hag Wood	County Wildlife Site, Site of Invertebrate Significance	1.69 km northwest of the site
Side House Wood	County Wildlife Site	1.41 km north northwest of the work site
Beckmickle Ings	County Wildlife Site	1.02 km northwest of the work site
Ashes Lane Mire	County Wildlife Site	1.65 km west of the work site
Bowston Hall Meadow	County Wildlife Site	0.15 km west of the work site
Ratherheath	County Wildlife Site	1.36 km southwest of the work site
Rather Heath Tarn	County Wildlife Site, Site of Invertebrate Significance	1.50 km southwest of the work site
Moss Side Tarn	County Wildlife Site	1.61 km southwest of the work site
Gatehead Anticline	Local Geological Site	1.30 km southwest of the work site

Protected species

Numerous protected species records have been provided by CBDC within 2 km of Bowston Weir. Table 3.2 details the protected species which have been recorded and the protection they receive.

Table 3.2 Protect Species within 2km of Bowston Weir

English Name	Scientific Name	Distance	Year	Designation
White clawed crayfish	*Austropotamobius pallipes*	2 km southeast of the site	2013	WACA-Sch5_sect9.5a Bern-A3 HabDir-A2*, HabDir-A5
Atlantic salmon	*Salmo salar*	2 km southeast of the site	2004	HabDir-A2*, HabDir-A5 Bern-A3
European bullhead	*Cottus gobio*	1.72 km southeast of the site	2012	HabDir-A2*
Smooth newt	*Lissotriton vulgaris*	1.94km east southeast of the site	2012	Bern-A3 WACA-Sch5_sect9.5a
Great crested newt	*Triturus cristatus*	1.94 km east southeast of the site	2012	Bern-A2 HabDir-A2*, HabDir-A4 WACA-Sch5_sect9.4b, WACA-Sch5_sect9.5a, WACA-Sch5Sect9.4c
Common toad	*Bufo bufo*	0.24 km east of the site	2012	Bern-A3 WACA-Sch5_sect9.5a
Daubenton's bat	*Myotis daubentonii*	2.00 km southeast of the site	2013	Bern-A2 CMS_A2, CMS_EUROBATS-A1

English Name	Scientific Name	Distance	Year	Designation
				HabDir-A2*, HabDir-A4 WACA-Sch5_sect9.4b, WACA-Sch5_sect9.5a, WACA-Sch5Sect9.4c
Common pipistrelle	*Pipistrellus pipistrellus*	2.00 km southeast of the site	2013	Bern-A2 CMS_A2, CMS_EUROBATS-A1 HabDir-A2*, HabDir-A4 WACA-Sch5_sect9.4b, WACA-Sch5_sect9.5a, WACA-Sch5Sect9.4c
Soprano pipistrelle	*Pipistrellus pygmaeus*	2.00 km southeast of the site	2013	Bern-A2 CMS_A2, CMS_EUROBATS-A1 HabDir-A2*, HabDir-A4 WACA-Sch5_sect9.4b, WACA-Sch5_sect9.5a, WACA-Sch5Sect9.4c
European otter	*Lutra lutra*	Found at the weir location	2010	Bern-A3 ECCITES-A HabDir-A2*, HabDir-A4 WACA-Sch5_sect9.4b,

English Name	Scientific Name	Distance	Year	Designation
				WACA-Sch5_sect9.5a, WACA-Sch5Sect9.4c
Eurasian badger	*Meles meles*	1.18 km southeast of the site	2014	Bern-A3
Polecat	*Mustela putorius*	1.12 km southwest of the site	2015	Bern-A3 HabDir-A5 HabReg-Sch4
Eurasian red squirrel	*Sciurus vulgaris*	1.24km northwest of the site	2014	Bern-A3 WACA-Sch5_sect9.2, WACA-Sch5_sect9.4.a, WACA-Sch5_sect9.4b, WACA-Sch5_sect9.5a, WACA-Sch5Sect9.4c
Brown hare	*Lepus europaeus*	0.40 km east of the site	2016	UKBAP, LBAP

Invasive Non-native Species

The data search from CBDC returned records of flora and fauna listed on Schedule 9 of the Wildlife and Countryside Act 1981 (as amended). Details of non-native plant species are detailed in Table 3.3.

Table 3.3 Non-native Invasive Species within 2 km of Bowston Weir

English Name	Scientific Name	Distance	Year	Designation
Eastern grey qquirrel	*Sciurus carolinensis*	1.89 km south of the site	2015	GBNNSIP, NE_EA_INNS, Non-native, WCA9
American mink	*Neovison vison*	1.34 km west of the site	2001	GBNNSIP, NE_EA_INNS, Non-native, WCA9
Canada goose	*Branta canadensis*	Precise location unknown	2013	GBNNSIP, NE_EA_INNS, Non-native, WCA9
Japanese knotweed	*Fallopia japonica*	1.24 km south southeast of the site	2015	GBNNSIP, NE_EA_INNS, Non-native, WCA9
Himalayan balsam	*Impatiens glandulifera*	0.01 km west of the site	2010	GBNNSIP, NE_EA_INNS, Non-native, WCA9

Fish Populations

The closest fish sampling point is downstream of Bowston Bridge, approximately 200m downstream of the proposed works location. Atlantic salmon *Salmo salar*, brown/sea trout *Salmo trutta*, bullhead *Cottus gobio,* minnow *Phoxinus phoxinus*, stone loach *Barbatula barbatula* and 3-spined stickleback *Gasterosteus aculeatus* were all recorded in this location in 2014.

Macroinvertebrates

The closest macroinvertebrate sampling station on the River Kent is at Bowston Bridge, approximately 200m downstream of the proposed works location. The most recent records for this sampling location are from October 2008 and show an ASPT score of 6.41, BMWP of 186, NST of 29, an invertebrate life family score of 7.71 and an inveterate life species score of 8.27.

Macrophytes

The closest macrophyte sampling station on the River Kent is at Bowston Bridge, approximately 200m downstream of the proposed works location.

3.2.2. Ecological Walkover Survey

A Phase 1 survey of Bowston Weir and its immediate surrounds was conducted on 8th March 2017. The habitat surrounding Bowston is predominantly improved grassland pasture intersected by fences and dry stone walls, with areas of broadleaved woodland present in the wider area, with occasional mature broad-leaved tree lines present along the river banks. A Phase 1 Habitat Map depicting the location of the weir and the local landscape is included in **Figure 3.1**.

The surveyed area refers to the entire extent of the area mapped. The habitats identified on site are all described in further detail below. Phase 1 habitat codes and target note information is given in **Appendix B**.

Habitats

The village of Bowston is located on the right bank adjacent to the weir. The left bank is dominated by improved grassland which is under grazing and is intersected by dry stone walls. The left bank is not fenced and there is evidence of bank slumping and consequently the riparian margins are limited and under developed. The left bank is tree-lined along the majority of its length upstream to Cowan Head with species such as willow *Salix sp*., alder *Alnus glutinosa* and silver birch *Betula pendula* present. There is also a small copse of mature trees trees next to weir on the left bank which may require removal including oak *Quercus robur*, willow and sycamore *Acer pseudoplatanus*. Approximately 20 m downstream of the weir is a small area of sub-mature woodland scrub. There are also several small broadleaved woodland copses in the wider area surrounding the site. The right bank, downstream of the weir, is composed of a dry stone retaining wall which is contains numerous gaps and ledges. Immediately upstream, gabion baskets are present on the right bank. The right bank is also heavily embanked with a sub-mature tree line present. There is also a small reedbed present which is dominated by common reed *Phragmites australis*, branched bur-reed *Sparganium erectum* and soft rush *Juncus effuses.*

The morphology of the river, due to the presence of river gravels and cobbles, is suitable for supporting vegetation communities of *Ranunculion Callitricho-Batrachion* species composition. However due to the time of year the survey was undertaken, aquatic macrophytes were not recorded.

A number of species were recorded in the vicinity of the weir including creeping bentgrass *Agrostis stolonifera,* water forget-me-not *Myosotis scorpioides* and the bryophytes *Fontinalis antipyretica*, and *Platyhipnidium riparoides*.

The fields of improved grassland contained numerous ephemeral pools, some of which were noted to be spring-fed. A small deep pond is located adjacent to the weir; however, this was not considered to be suitable to support breeding great crested newt due to the lack of egg-laying vegetation sites present.

Protected Species

The habitat surrounding the weir site was assessed as being suitable to support white-clawed crayfish, otter, red squirrel and fish. Records of salmon and bullhead were highlighted as part of the data search and river gravels were noted which could potentially be used for spawning in the vicinity of the site.

The river morphology provides an optimal habitat to support white-clawed crayfish due to the presence of river gravels and unreinforced banks which allow for burrowing. There are records of this species within the Kent with the closest record located approximately 2 km from Bowston Weir. However, anecdotal evidence of sightings close to Cowan Head have also been reported (*pers comms*).

It should be noted that some of the mature trees have the potential to support roosting bats with numerous mature ivy-covered trees recorded in the vicinity of the weir. It is also highly likely that bat species are using the River Kent as a foraging and commuting route. The woodlands, tree lines and dry stone retaining wall also provide nesting and foraging habitat for numerous bird species with dipper *Cinclus cinclus* recorded foraging along the retaining wall at the survey site.

The riparian habitat surrounding the weir was assessed as being suitable to support otter. This reach of the Kent contains optimal habitat to support a holt, as the majority of trees present in the survey area are semi-mature in age and overhang the watercourse, providing potential to support a holt site.

Non-native Invasive Species

Due to the time of year the survey was undertaken, no non-native invasive species were recorded during the site walkover. However, the data search highlighted records of Himalayan balsam in the immediate vicinity of the site.

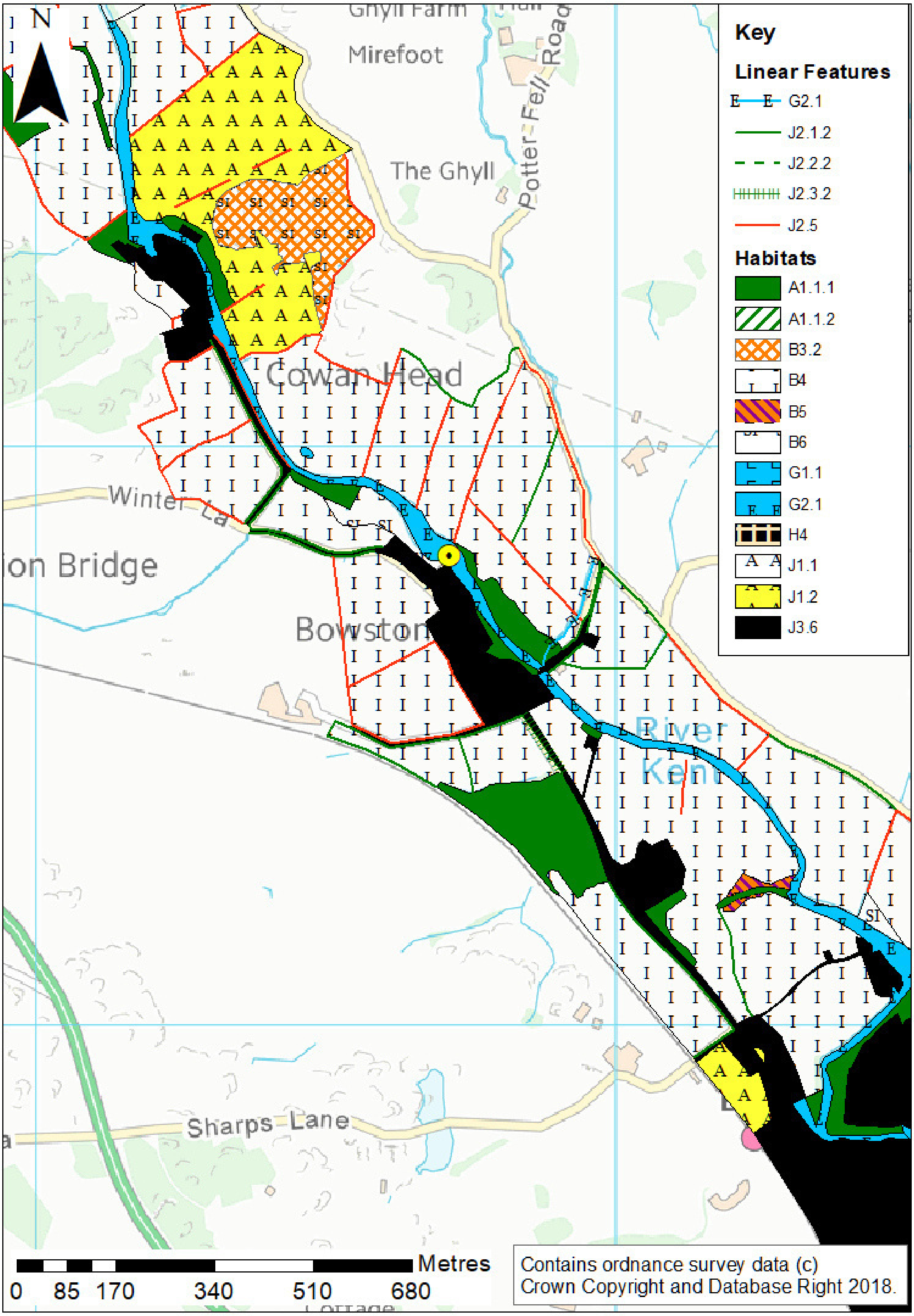


Figure 3.1 Bowston Weir Phase 1 Habitat Map

3.3 ECOLOGICAL RECOMMENDATIONS

The desk-based assessment and site survey highlighted the potential for protected species to be adversely affected by the final design option. It may be necessary to re-survey prior to any works beginning on site to ascertain species presence and the requirement for a protected species licence. A protected species assessment is summarised in Table 3.4 below.

Table 3.4 Bowston Weir Protected Species Summary Assessment

Species	Likelihood of presence (high/medium/low)	Further surveys required?	Optimal survey period	Comments
Otter	High	Yes	Survey anytime	Potential lay-up / holt sites in vicinity of works
White-clawed crayfish	High	Yes	July – September	Surveys and mitigation can only be conducted in this time period.
Breeding birds	High	Yes	March - September	Dependent on tree removal prior to works beginning on site.
Migratory / Coarse Fish	High	Yes	Varied, given known spring, summer & winter runs of fish.	Redd survey to determine whether reaches immediately downstream of the weirs are used for spawning.

3.4 OTHER CONSIDERATIONS

There are numerous considerations which should be taken into account when working in water which include the following.

3.4.1. Biosecurity

Crayfish 'plague' is a virulent fungal disease caused by the micro-organism *Aphanomyces astaci,* and its spread is a major cause of the rapid decline in white-clawed crayfish populations throughout Europe. The disease can be spread by the movement of infected crayfish, most notably the invasive American signal crayfish *Pacifastacus leniusculus*, and also by the movement of fish or contaminated equipment. The fungal spores can remain viable for 6-22 days without a host under wet or damp conditions. As it is very easy to spread crayfish 'plague', biosecurity of the proposed works is of the utmost importance. It is essential to minimise the risk of this activity spreading the disease upstream, or to other river systems. Consequently, a number of precautions need to be taken:

- Prior to entering the water channel all equipment for use in and around the watercourse, should be disinfected and cleaned using a suitable disinfectant (Virkon S), rinsed and then left to dry;

- All disinfecting operations should take place at sufficient distance from the watercourse that no disinfectant or contaminated water can enter the watercourse;
- All equipment should be thoroughly cleaned and disinfected before use at another site; and
- All disinfecting should follow Defra Guidelines from the Defra 'Check, Clean, Dry' Campaign (http://www.nonnativespecies.org/checkcleandry/index.cfm).

3.4.2. Pollution Prevention Measures

The following pollution prevention measures should also be adhered to in order to reduce the risk of any pollution incidents occurring and adversely impacting upon watercourses:

- Relevant Pollution Prevention Guidelines (PPG) produced jointly by the Environment Agency, Scottish Environment Protection Agency (SEPA) and the Environment and Heritage Service of Northern Ireland should be followed;
- Appropriate sediment control measures should be employed;
- Any chemical, fuel and oil stores should be located on an impervious base within a secured bund with a storage capacity 110% of the stored volume;
- Biodegradable oils and fuels should be used where possible;
- Drip trays should be placed underneath any standing machinery to prevent pollution by oil/fuel leaks. Where practicable, refuelling of vehicles and machinery should be carried out on an impermeable surface in one designated area well away from any watercourse or drainage (at least 10m);
- Emergency spill kits should be available on site and staff trained in their use;
- Operators should check their vehicles on a daily basis before starting work to confirm the absence of leakages. Any leakages should be reported immediately; and
- Daily checks should be carried out and records kept on a weekly basis and any items that have been repaired/replaced/rejected noted and recorded. Any items of plant machinery found to be defective should be removed from site immediately or positioned in a place of safety until such time that it can be removed. All items of plant should be checked prior to use before each shift for signs of wear/damage.

3.4.3. Permissions / Licencing

There are likely to be various permissions and licences that will need to be obtained depending on the options selected to take forward. The list below is not exhaustive but provides an indication of some of the likely permissions and consultation that will be required in order to undertake the weir removals. Upon selection of the desired option it is recommended that further consultation is sought with an environmental consultant so that all likely permissions and licences can be identified and attained.

- WFD assessment for compliance
- Assessment of impacts with Natural England for the SAC and SSSI
- Environmental Permit from the Environment Agency
- Protected Species licensing (dependent on results of further surveys and protected species to be impacted).

4. TOPOGRAPHIC/ BATHYMETRIC SURVEY

An accurate topographic/ bathymetric survey was required for the Bowston site, in order that subsequent flood risk and sediment transport modelling were valid. Two surveys were conducted at the Bowston Weir site, to produce a detailed dataset of the geometry of existing conditions. The first survey was undertaken in April 2017, during moderate/ high flow conditions, and involved the collection of limited cross-sectional data using topographic survey methodologies. The second survey was commissioned in order to inform detailed sediment transport modelling of the site. This follow-up survey involved both topographic and bathymetric methodologies, and was undertaken in October 2017.

Data collected adequately characterised the physical form/ hydraulic function of the site, including all channel structures (e.g. bridges, weirs, etc.). The survey representatively characterised variation in the horizontal (i.e. channel bends) and vertical (i.e. relative topographic highs, bars, riffle crests/ hydraulic controls, and lows, pool centres). Within survey cross sections, all significant lateral variation in channel geometry (e.g. channel thalweg, base of bank, top of bank, etc.) was recorded. Where complex topography dictated (e.g. at hydraulic structures), additional data were collected in a non-uniform gridded format (i.e. not cross-section based), with greatest point density around areas of highest elevation variability. Such a point scatter approach was essential to capture the salient aspects of channel morphology in more complex topographic areas, so that subsequent model output sufficiently represented site and design conditions.

The survey was completed to a specification that has permitted the application of high resolution hydraulic modelling around the weir structures and adjacent sections of channel upstream and downstream. The extent of the topographic survey of the site included in this project was determined by the physical characteristics of the structure in question as well as wider, reach-scale dynamics. As a general indication, the survey extents coincided with a straight section of river beyond the hydraulic influence of the weir (i.e. impoundment effects). The upstream extent (~ 440 m) from the weir was delineated by a riffle of higher elevation than the weir structure (SD 49379 97069) and the downstream extent (~ 380 m from the weir) was bounded beyond the Bowston (Kent) gauge station structure (SD 49948 96531). The total extension of the survey amounted to 820 metres of river section.

The resulting existing conditions Digital Elevation Model (DEM) of the site is presented in **Figure 4.1**. Specific details of the methodology and equipment used are provided in **Appendix C**.

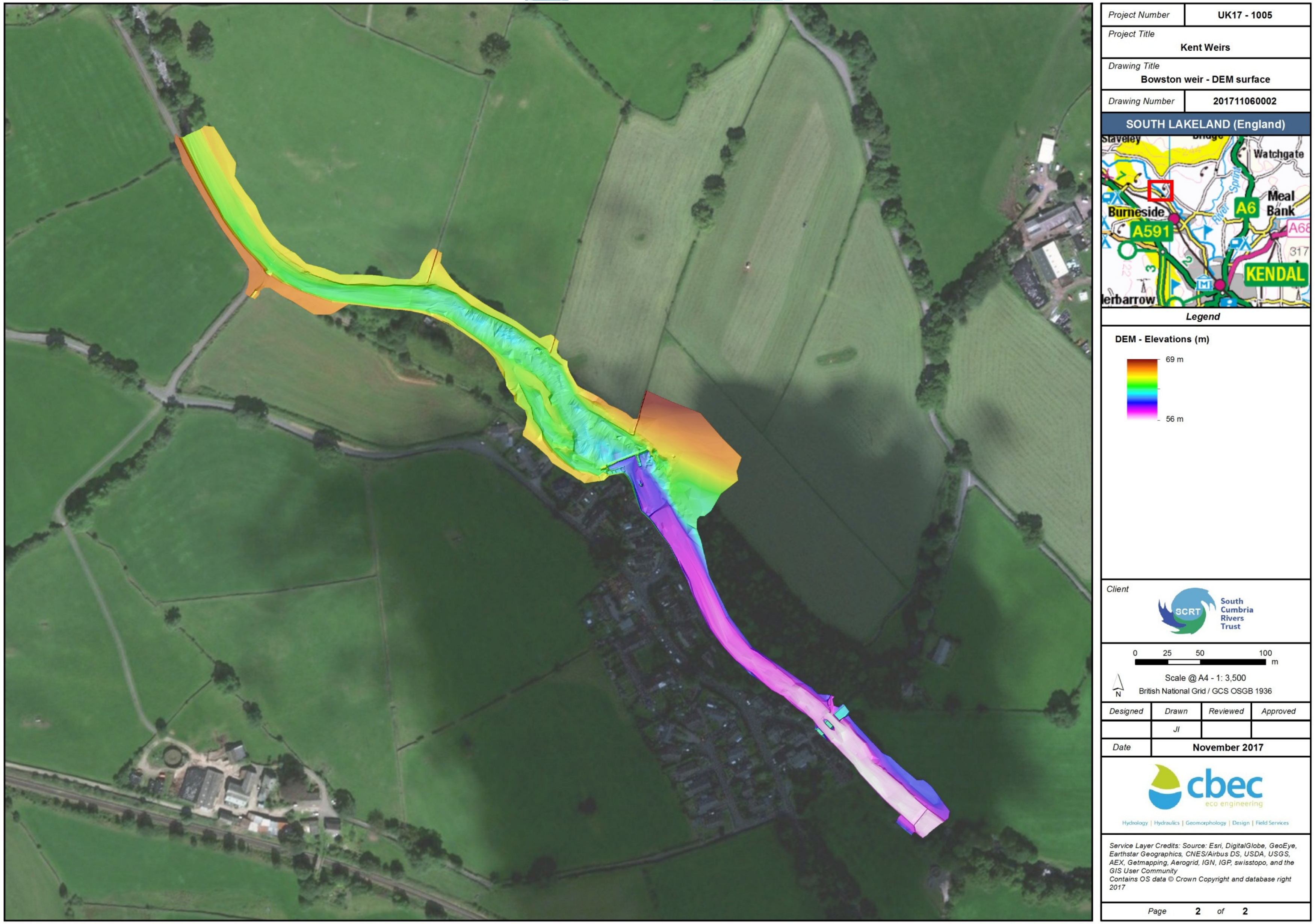


Figure 4.1 Bowston Existing Conditions DEM

5. CULTURAL HERITAGE ASSESSMENT

A cultural heritage assessment was undertaken using both desk-based and field investigations, to determine the impact of the various options assessed (including the selected design option) on the local heritage values of the site. Full details of the assessment are provided in **Appendix D**.

Whilst the survey results acknowledged that full weir removal would likely be detrimental to the local heritage, it was also recognised that, once balanced against other criteria, full retention of Bowston Weir may not be feasible.

The main findings and recommendations of the report were:

- Bowston Weir is not designated, but does hold historic significance for the area given its past links with local industry;
- If the weir is ultimately removed, photographic record of the weir should be made prior to the removal, in order to preserve by record any information to be lost; and
- Any further requirements for archaeological mitigation should be designed in liaison with the Cumbria County Archaeologist.

6. 1D HYDRAULIC MODELLING

6.1 AVAILABLE DATA

To analyse water levels, velocities and shear stress across the flow regime, a 1D hydraulic model has been developed. The ISIS model was based on the existing model of the River Kent supplied to JBA Consulting by cbec along with the previous model hydrology.

It was agreed beforehand that a hydrology update would not be carried out by JBA Consulting within the scope of the works. Therefore, it is assumed that the hydrology data provided are suitable for this study.

Detailed survey data for the reach at Bowston Weir collected in 2016 by the Environment Agency were also supplied.

6.2 SUMMARY OF EXISTING MODEL

The existing 1D ISIS model was originally built in 2000 by JBA Consulting but was updated in 2007 as part of a study to establish the existing standard of flood protection works in Kendal and assess the feasibility options for upstream storage. As part of the 2007 works the hydrology inputs in the model were updated using the Flood Estimation Handbook methods.

Floodplains in the 1D model were represented using cross section extensions based on available LIDAR data. Several spot level surveys were undertaken in areas where LIDAR coverage was poor or did not provide a sufficiently accurate representation of ground levels.

6.3 BASELINE MODEL BUILD

A baseline model representing the existing conditions at the Bowston Weir site has been built using the supplied River Kent model. The following amendments to this existing River Kent model have been made in developing the Bowston model:

- The model was trimmed at a suitable location downstream of Bowston Weir (Bridge Street road bridge - SD505958);
- A new downstream boundary was added to the model based on a stage through time relationship extracted from previous model results at the downstream extent;
- Supplied Environment Agency survey data were added to the model at three cross sections upstream of the weir, and five cross sections downstream of the weir. The Bowston Weir crest have also been updated with the new data; and
- Interpolated section “KENT07_2501i” has been removed from the model and chainages have not been amended to accommodate for this. This section is thought to have been left in the existing model in error, as the ISIS chainages did not match up with those expected when compared to both; measured lengths are in ArcGIS and the ISIS naming convention is used.

Figure 6.1 shows the extent of the of the trimmed Bowston model, model node locations and which sections have been updated with new survey.

6.4 SCENARIO MODEL BUILD

Using the baseline trimmed Bowston model, several scenario models have been developed based on designs provided by cbec, to understand how these changes would impact on the existing conditions at the site. These include:

- Full weir removal; and
- Weir modifications: rock ramp design / weir infilling.

The full weir removal was represented by removing the weir sections from the 1D model, with no other changes made to the existing geometry.

The rock ramp/ weir infilling model, was represented by introducing new sections to the model as per the rock ramp design (See **Figure 6.2**). Where new cross-sections extensions were required, LIDAR data were used to represent the wider floodplain. In total 20 cross sections were added between KENT07_2500 and KENT07_2330, to the model to represent the six-step design. For each step, three new ISIS sections were required, one spill unit, and two river sections, one upstream of the spill, and one downstream.

6.5 FLOOD RISK ANALYSIS

As part of a fluvial flood risk assessment, the baseline and design model were run for the 100 year event plus climate change. In line with current guidance, a 35% climate change allowance has been made. The results of the analysis show the design to be flood risk neutral. Broad scale reductions in upstream water levels were noted, along with a small localised increase in the downstream water level (up to 0.05 m). There was no impact on the maximum modelled water levels, or flood receptors at the site.

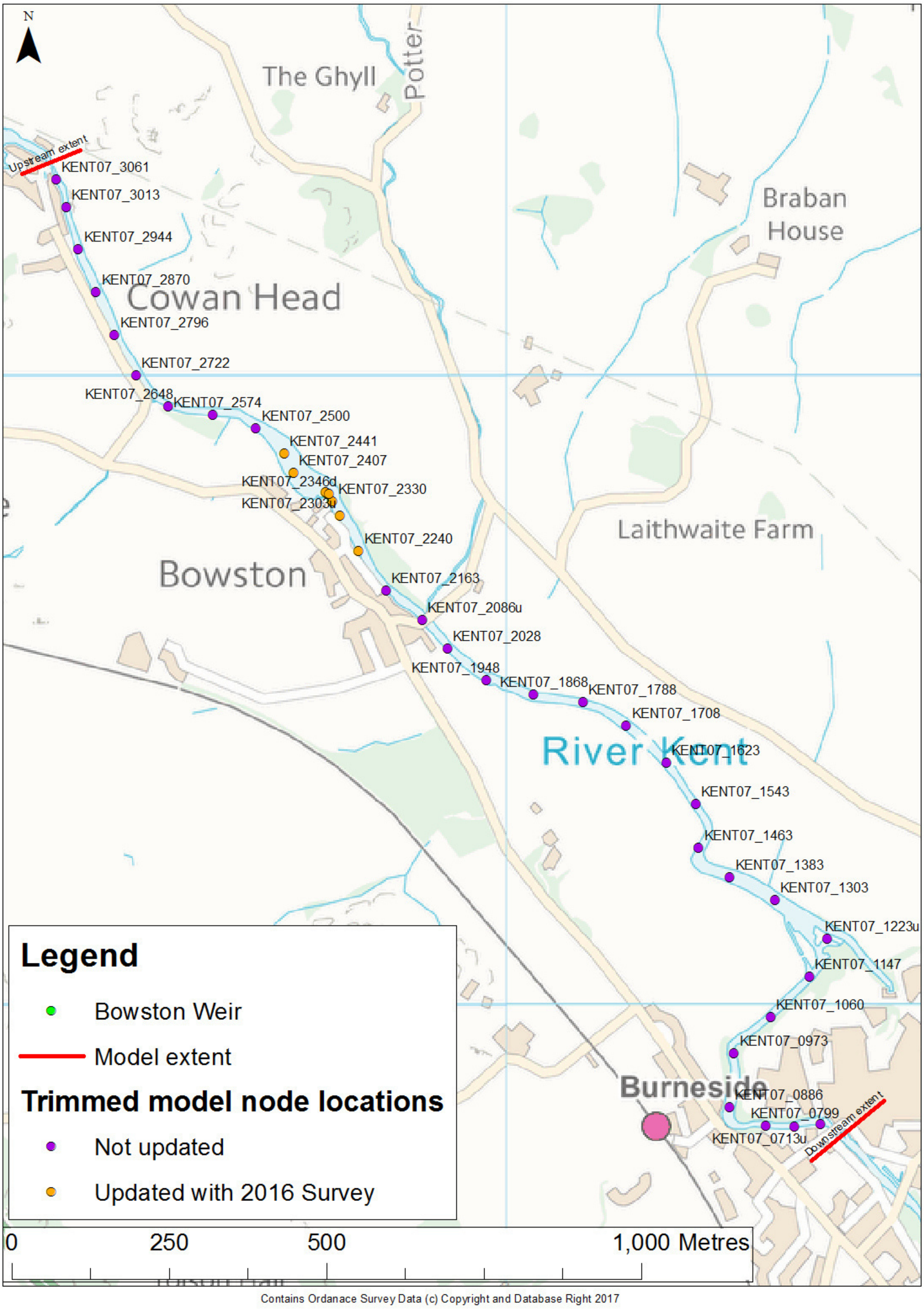


Figure 6.1 1D Model Extents

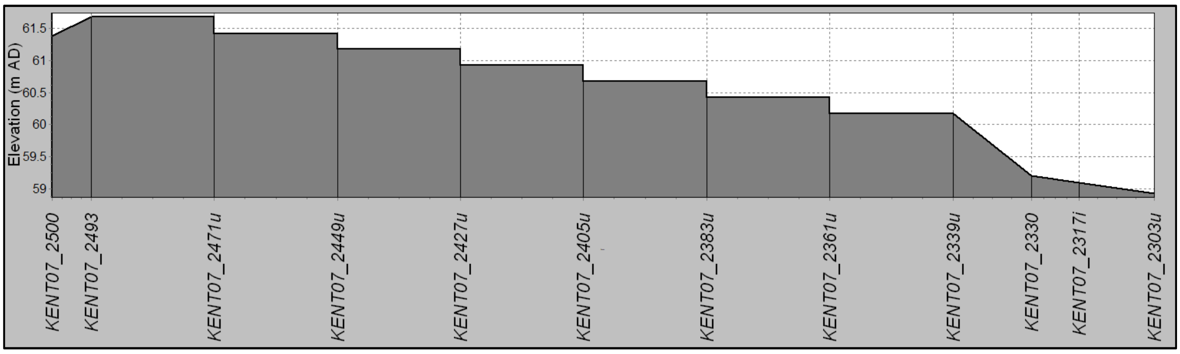


Figure 6.2 Minimum bed elevations of rock ramp design, long profile extracted from ISIS model.

6.6 BASELINE MODEL RESULTS

The model has been run for five different events; 2 year, 10 year, 50 year, 100 year and the 100 yr + climate change, and results have been extracted for the existing scenario at Bowston Weir. Three long profile

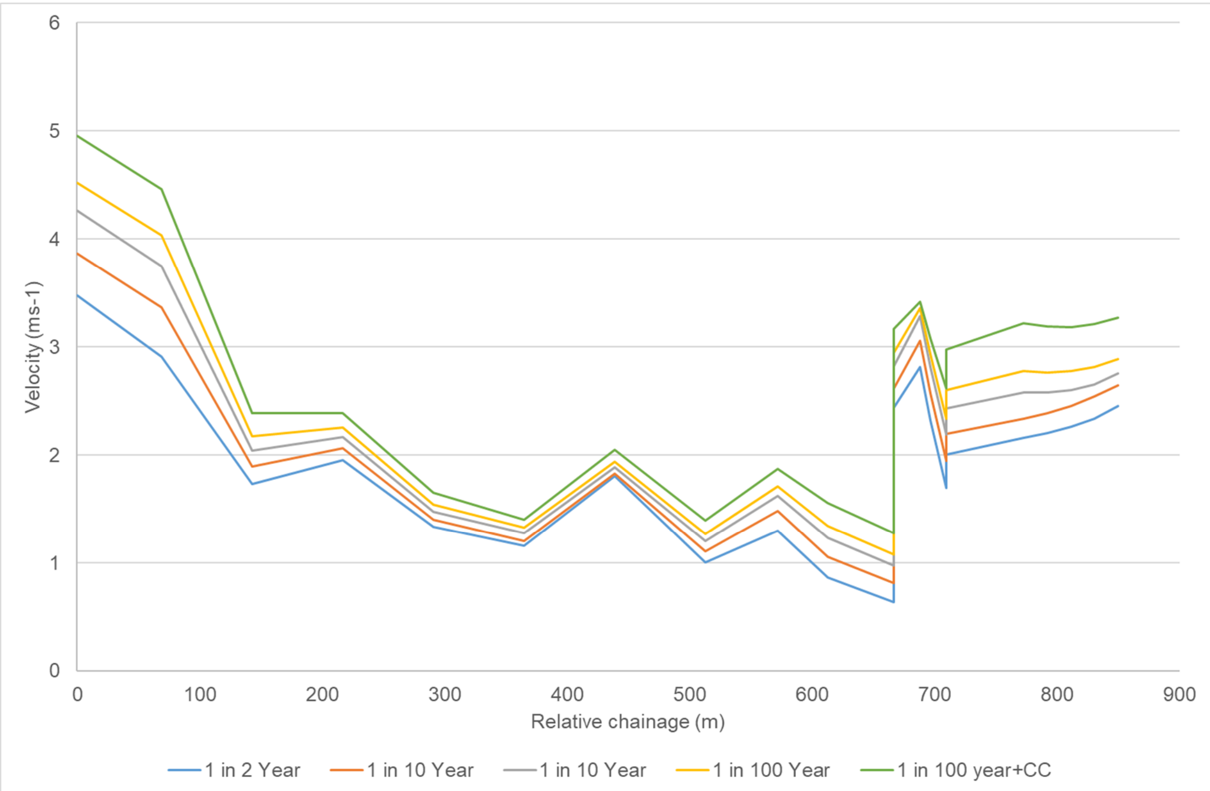


Figure 6.4) and shear stress (**Figure 6.5**) at the peak flow for each return period have been provided. Note shear stress for the 100year +climate change is not shown. These long profiles extend from ISIS node KENT07_3013 to KENT07_2163, **Figure 6.1**. The relative chainage for each section from the model start is provided in **Table 6.1**.

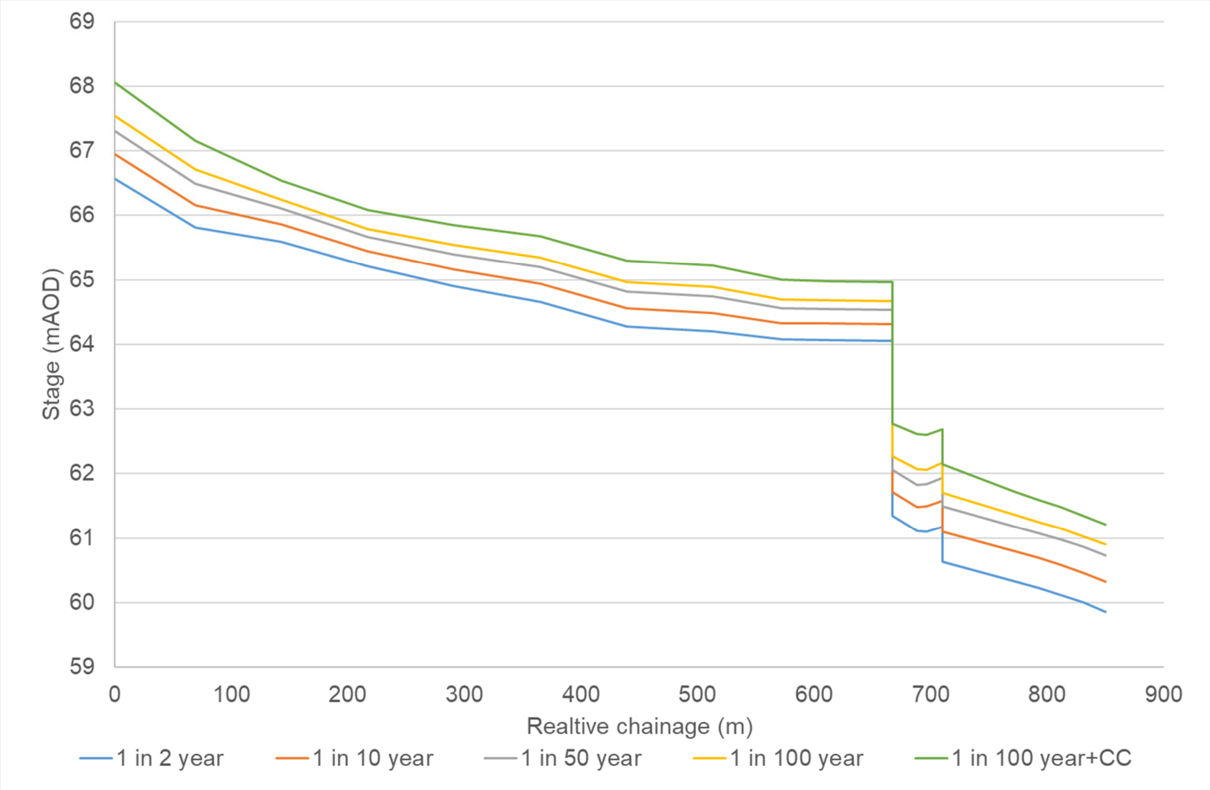


Figure 6.3 Long profile through Bowston model (ISIS node KENT07_3013 to KENT07_2163) showing stage (mAOD) at the peak flow for each modelled event.

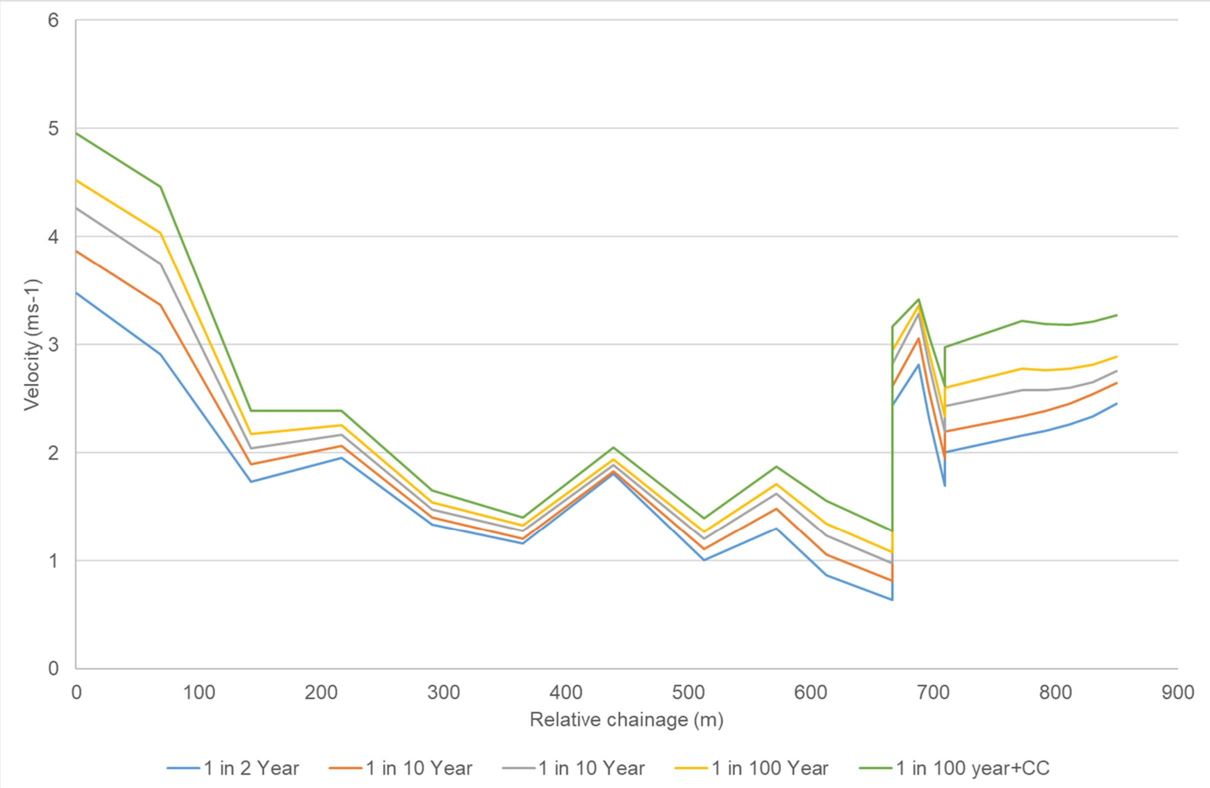


Figure 6.4 Long profile through Bowston model (ISIS node KENT07_3013 to KENT07_2163) showing average modelled velocity at the peak flow for each modelled event.

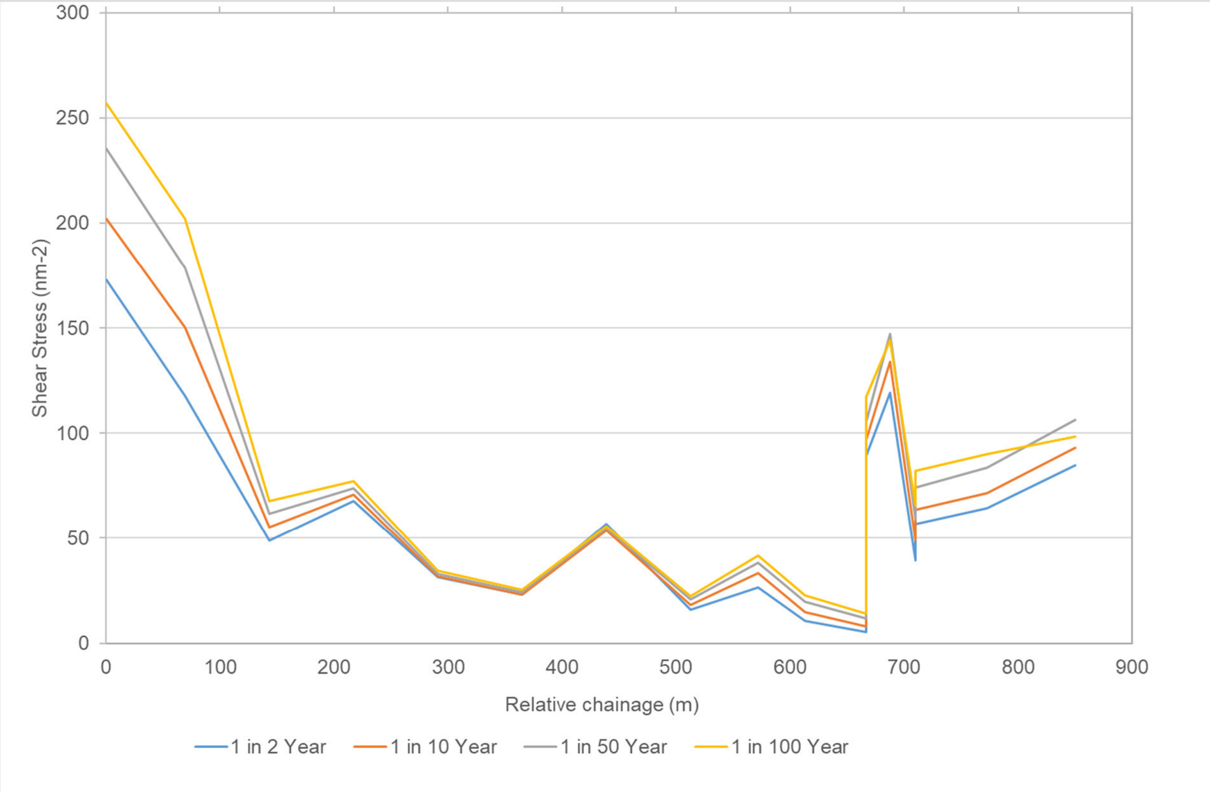


Figure 6.5 Long profile through Bowston model (ISIS node KENT07_3013 to KENT07_2163) showing shear stress at the peak flow for each modelled event.

Table 6.1 Relative chainage from the model stage for each baseline ISIS node in the long section profiles

Cross section reference	Chainage through long profile (m)
KENT07_3013	0.00
KENT07_2944	69.00
KENT07_2870	143.00
KENT07_2796	217.00
KENT07_2722	291.00
KENT07_2648	365.00
KENT07_2574	439.00
KENT07_2500	513.00
KENT07_2441	572.00
KENT07_2407	613.00
KENT07_2346u	667.00
KENT07_2346d	667.00
KENT07_2330	688.00
KENT07_2317i	696.50

KENT07_2303u	710.00
KENT07_2303d	710.00
KENT07_2240	773.00
KENT07_2221i	792.25
KENT07_2202i	811.50
KENT07_2182i	830.75
KENT07_2163	850.00

6.7 DESIGN MODEL RESULTS

The most recent iteration of the design model has only been run for two return periods; the 2year and the 100year + climate change. Two long profile sections showing the stage (**Figure 6.3**) and velocity (

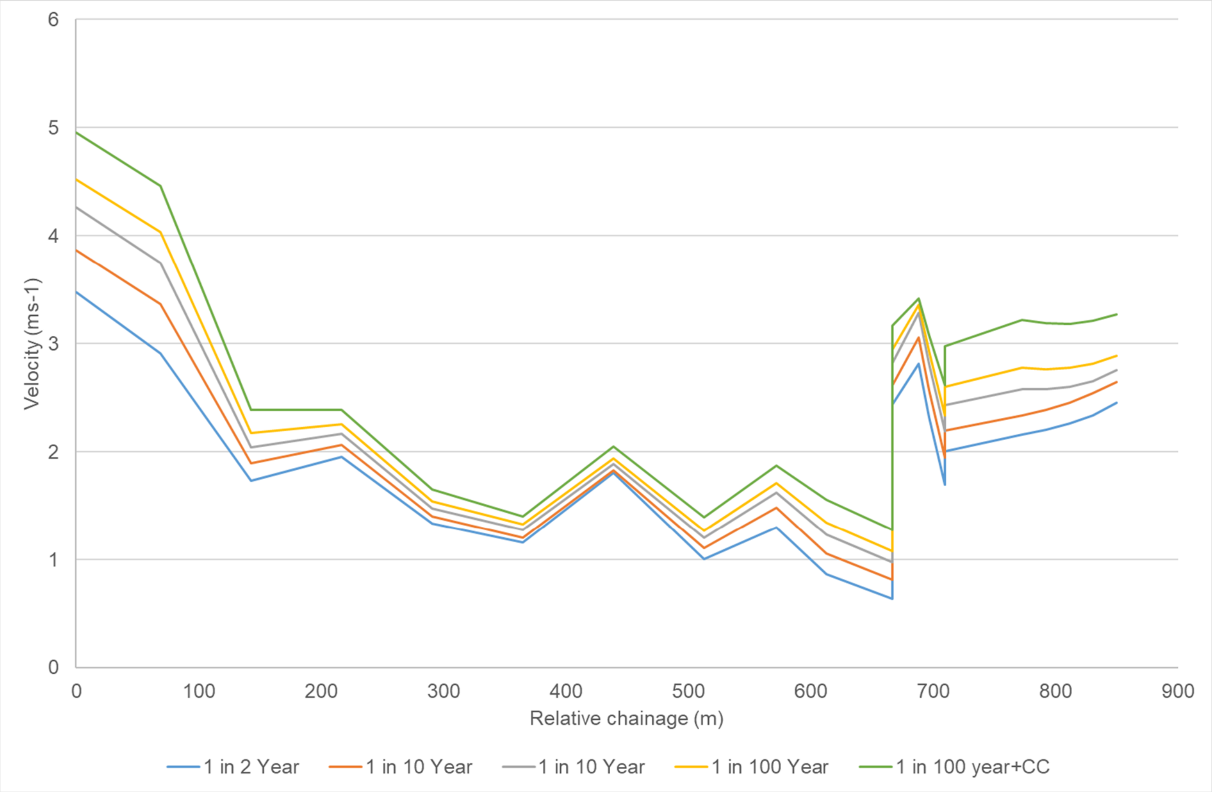


Figure 6.4) at the peak flow for each return period have been provided. These long profiles extend from ISIS node KENT07_3013 to KENT07_2163, **Figure 6.1**. The relative chainage for each section from the model start is provided in **Table 6.2**.

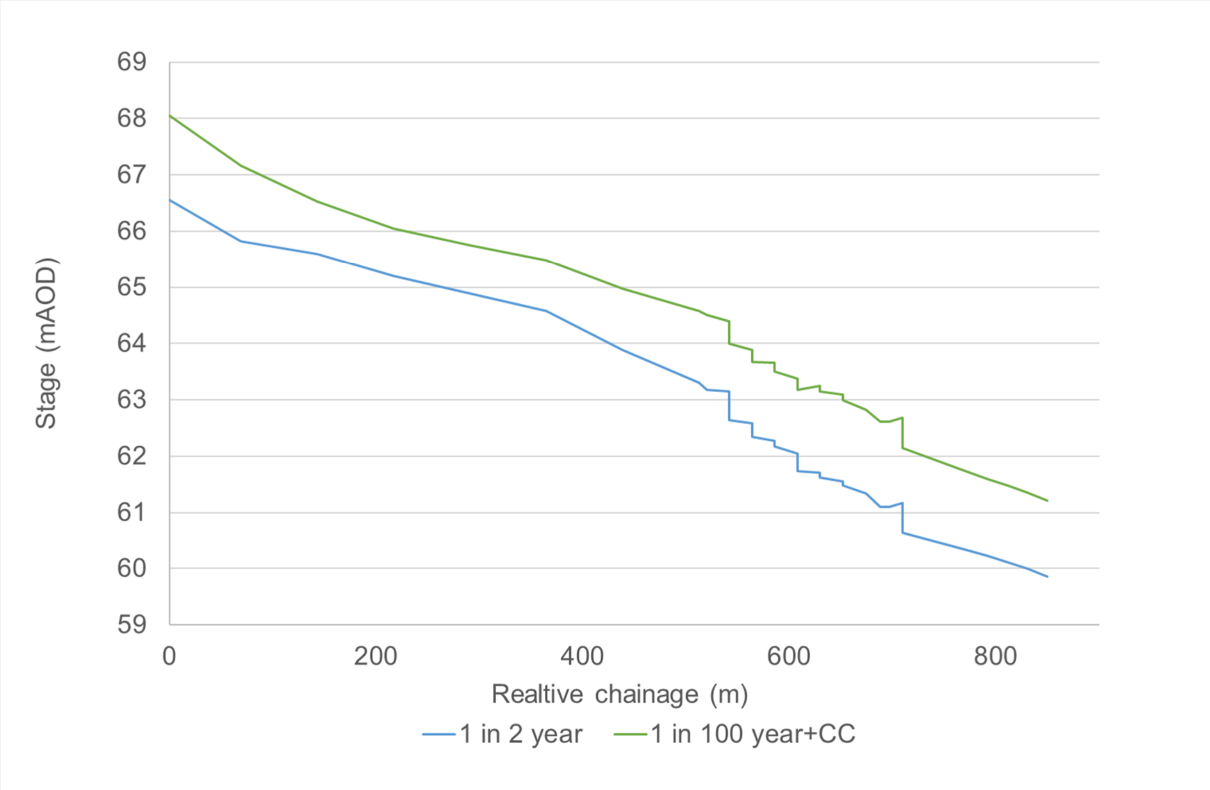


Figure 6.6 Long profile through Bowston design model (ISIS node KENT07_3013 to KENT07_2163) showing stage (mAOD) at the peak flow for each modelled event.

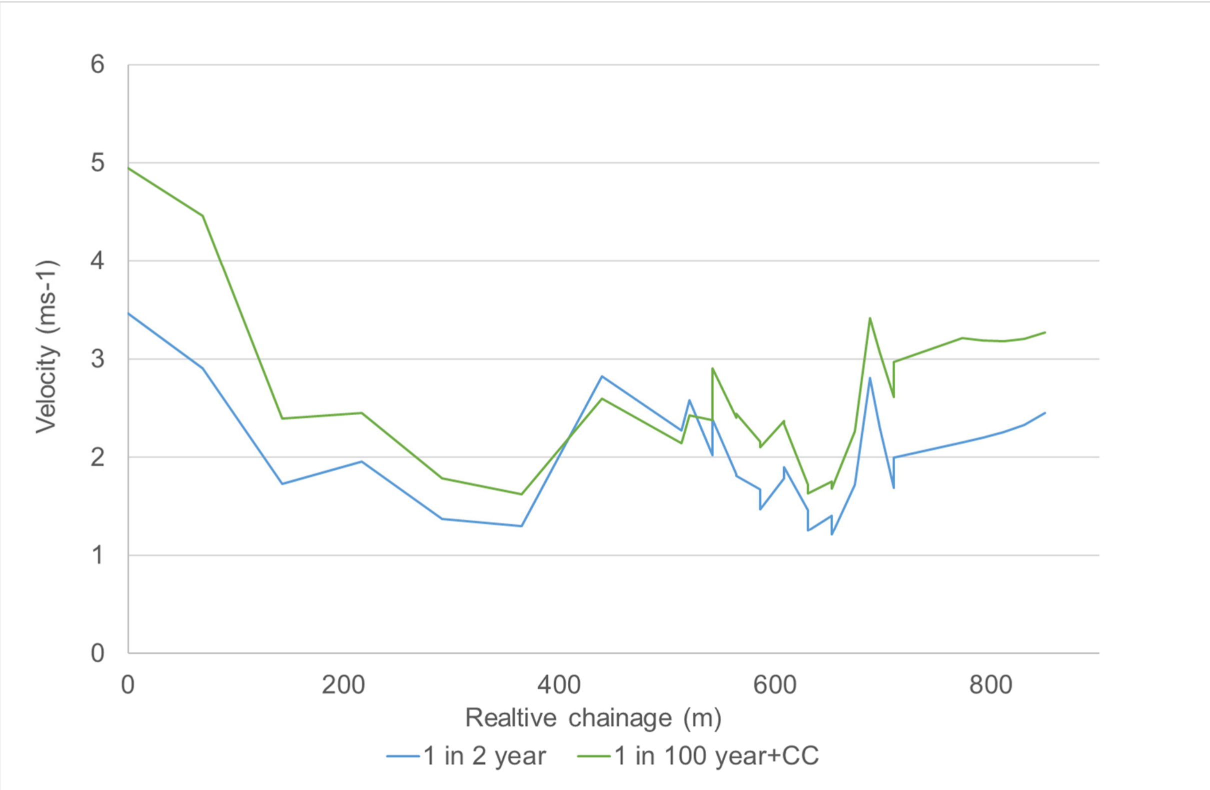


Figure 6.7 Long profile through Bowston design model (ISIS node KENT07_3013 to KENT07_2163) showing average modelled velocity at the peak flow for each modelled event.

Table 6.2 Relative chainage from the model stage for each design ISIS node in the long section profiles

Cross section reference	Chainage through long profile (m)
KENT07_3013	0.00
KENT07_2944	69.00
KENT07_2870	143.00
KENT07_2796	217.00
KENT07_2722	291.00
KENT07_2648	365.00
KENT07_2574	439.00
KENT07_2500	513.00
KENT07_2493	520.00
KENT07_2471u	542.00
KENT07_2471d	542.00
KENT07_2449u	564.00
KENT07_2449d	564.00
KENT07_2427u	586.00
KENT07_2427d	586.00
KENT07_2405u	608.00
KENT07_2405d	608.00
KENT07_2383u	630.00
KENT07_2383d	630.00
KENT07_2361u	652.00
KENT07_2361d	652.00
KENT07_2339u	674.00
KENT07_2330	688.00
KENT07_2317i	696.50
KENT07_2303u	710.00
KENT07_2303d	710.00
KENT07_2240	773.00
KENT07_2221i	792.25
KENT07_2202i	811.50
KENT07_2182i	830.75
KENT07_2163	850.00

6.8 SENSITIVITY TESTING

Sensitivity testing on the downstream stage through time boundary was completed by increasing the stage at each time interval within the 100 year event by 0.5 m. The results show the increase in stage has no influence on the stage and velocity through the long profile sections, **Table 6.3**.

Note, sensitivity testing was carried out on a previous iteration of the baseline model, and therefore, the results at this stage are for indicative purposes only.

Table 6.3 Results of sensitivity testing on downstream boundary compared to baseline results.

Cross section reference	T100 - Maximum modelled water level (mAOD)	T100 Sensitivity test - Maximum modelled water level (mAOD) HBDY test	T100 - Average modelled velocity at peak flow (m s^{-1})	T100 Sensitivity test - Average modelled velocity at peak flow (m s^{-1})
KENT07_3013	67.54	67.54	4.51	4.51
KENT07_2944	66.70	66.70	4.02	4.02
KENT07_2870	66.24	66.24	2.17	2.17
KENT07_2796	65.79	65.79	2.25	2.25
KENT07_2722	65.54	65.54	1.54	1.54
KENT07_2648	65.35	65.35	1.33	1.33
KENT07_2574	64.97	64.97	1.94	1.94
KENT07_2500	64.89	64.89	1.27	1.27
KENT07_2441	64.70	64.70	1.71	1.71
KENT07_2407	64.68	64.68	1.34	1.34
KENT07_2346u	64.66	64.66	1.08	1.08
KENT07_2346d	62.23	62.23	3.01	3.01
KENT07_2330	62.11	62.11	3.27	3.27
KENT07_2317i	62.11	62.11	2.76	2.76
KENT07_2303u	62.17	62.17	2.34	2.34
KENT07_2303d	61.71	61.71	2.59	2.59
KENT07_2240	61.41	61.41	2.71	2.71
KENT07_2221i	61.30	61.30	2.68	2.68
KENT07_2202i	61.21	61.21	2.67	2.67
KENT07_2182i	61.12	61.12	2.68	2.68
KENT07_2163	61.02	61.02	2.70	2.70

7. SEDIMENT TRANSPORT MODELLING

7.1 INTRODUCTION

Following the selection of the full weir removal option to progress to detailed design, a fully 2D hydraulic and fully 2D mobile-bed model was created for the River Kent at Bowston Weir and for a design reach with weir removed. This was to provide confidence in the design, and to estimate how removal of the weir might influence sediment transport in the reach. This type of model computes shear stress in the channel, and computes whether sediment of certain size classes will move. The model then computes how the bed levels change in response to this sediment transport. Mobile bed modelling gives an indication of bed stability, and future evolution patterns of the reach.

Any sediment transport model results should be taken with caution, as mobile bed, sediment transport modelling can at best only provide an approximate guide to patterns of erosion and deposition, and are very dependent on estimates of sediment supply and current sediment distribution.

7.2 HYDRAULIC MODEL SETUP

7.2.1. Boundary Condition

At the upstream end of the model, a hydrological boundary condition is provided, consisting of a time series of discharge versus time. For the 2D model the hydrological inflows were derived by JBA and extracted from their 1D ISIS model, which was used for an initial design assessment, and for flood risk assessment of the design. cbec also undertook a check on the peak flows derived for the 1D ISIS model, and the peak flows were largely in agreement with those computed by JBA. For consistency, the JBA derived flows were used in the analysis.

Table 7.1 Hydrological inputs to the model. Peak flows.

Return period [y]	JBA derived flow [$m^3 s^{-1}$]	cbec derived flow [$m^3 s^{-1}$]
2	63.07	62.53
10	90.35	89.55
100	140.44	132.26

For the purpose of sediment transport modelling, an inflow is needed that generates high shear stress, while at the same time being a relatively frequent flow. Typically, the bankfull flow (close to the 1:2 year flood) is regarded as the 'channel forming flow' and produces sedimentation indicative of long term future trends. To provide an indication of long term channel erosion and aggradation patterns, sediment transport modelling was undertaken using a constantly applied 1:2 year peak flow, rather than modelling the specific response to a certain isolated extreme flood. Modelling was also undertaken for the higher flood events, and erosion and aggradation patterns were similar to those resulting from the constant 1:2 year peak flow.

All hydraulic models require a water surface boundary condition at their downstream end. The downstream boundary of the 2D model was chosen so as to coincide with a flat V-notch weir gauge (station number 73017), for which the NRFA contains a published set of rating curves from low to high flow. This gauge contains up to and including the 1:100 year flow and so can be used to provide a rating curve for the 2D model. This rating is shown in **Figure 7.1**.

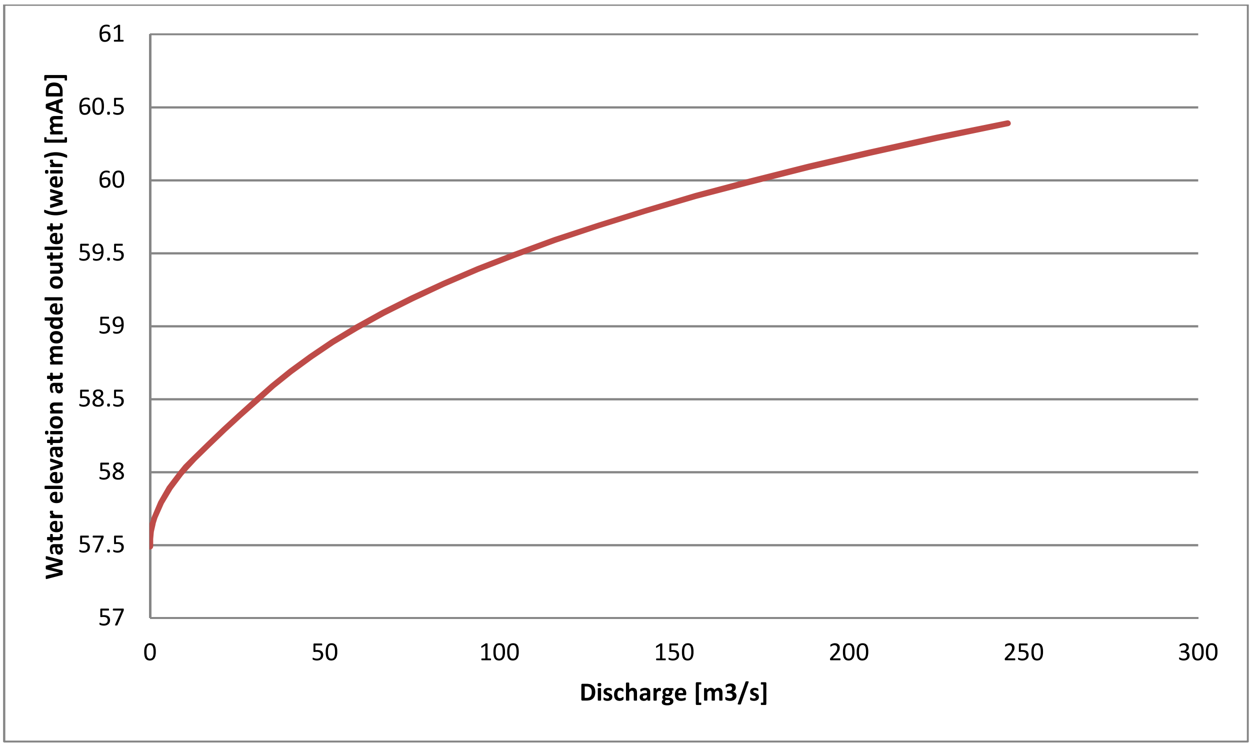


Figure 7.1 Rating curve for the 2D model boundary (source NRFA, gauge 73017).

7.2.2. Hydraulic Model Mesh and Solver

A digital elevation model consisting of in-channel surveyed data and floodplain LiDAR elevations and drawings/surveys of the weir structure was created, triangulated and break-lined in AutoCAD Civil 3D. This surface was then meshed for hydraulic computations using Aquavaeo SMS 11.1. Channel fitted quadrilateral and unstructured triangular cells were used to grid the model domain, with cells forced to align along the weir crest, weir structure, bridge abutments and channel banks. At least ten cells were used across the channel. This mesh was divided into roughness zones, and a Manning friction assigned to each zone (see section 7.2.6). The 2D hydraulic model with the applied boundary conditions was solved using SRH-2D, with the zero equation parabolic turbulence model. A timestep of 1 s was used in all unsteady model runs. SRH-2D is a full, shock-capturing, shallow water equation solver, and it can compute the flow over weir flows fully in 2D (i.e. without using a 1D structure) and so captures full momentum transfer through the structure, necessary for sediment transport. The bridge downstream had piers modelled fully in 2D, also to allow full momentum transfer through the structure.

7.2.3. Calibration

The in-channel part of the 2D hydraulic model was calibrated using surveyed water levels at low flow. Baseline friction values were initially assigned using normal methods of site photographs, the UK CES roughness advisor and the Strickler equations, and adjusted for low flow values using Limerinos' method, with hydraulic radius and wetted area extracted from the hydraulic model, run with the gauged flow measured on the day of survey. Model results were compared to observed water levels and the baseline frictions adjusted slightly to suit. This method provides consistent frictions for low and high flows. Standard UK CES friction values were used for roughness zones on the floodplain, with a high value of 0.3 used for buildings, however, no buildings were inundated in any of the sediment transport model runs.

The model calibration against in-channel water elevations is excellent (with an RMS error value of <0.08 m, well within usually accepted model tolerances).

Table 7.2 In channel frictions used in the 2D model

Roughness zone	Low flow Manning n (Limerinos)	Flood flow Manning n
Upstream channel	0.047	0.036
Immediately upstream of weir	0.035	0.033
Immediately downstream of weir	0.060	0.038
Downstream channel	0.051	0.037

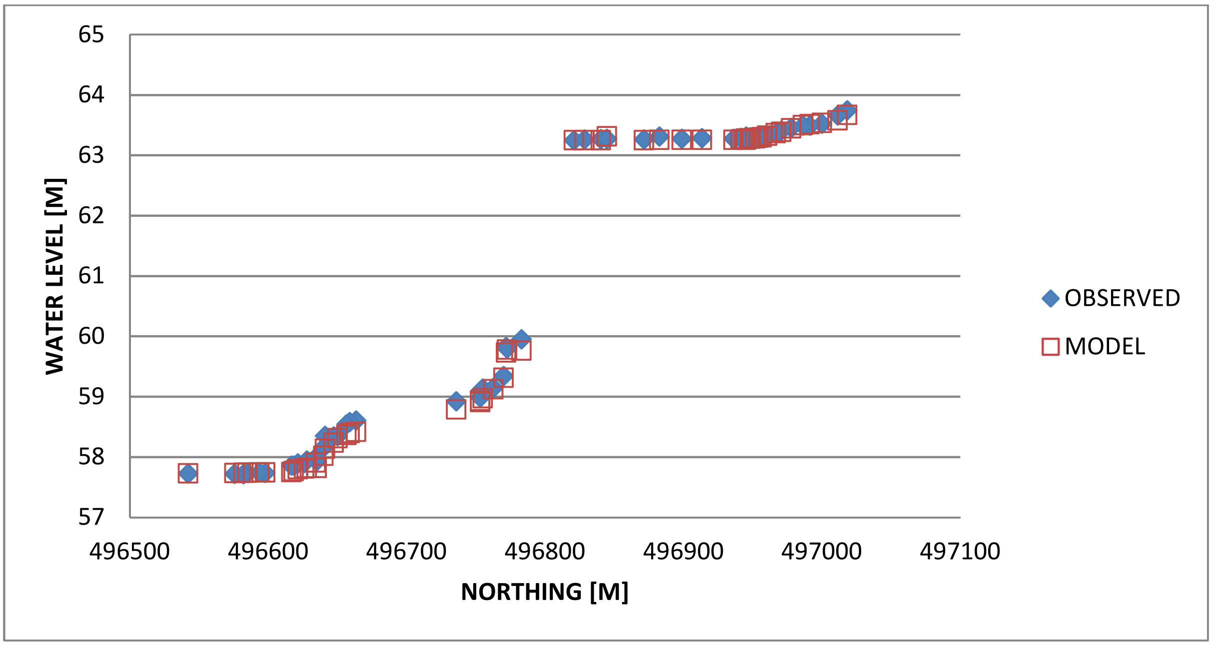


Figure 7.2 In channel calibration of 2D model. Existing conditions water levels.

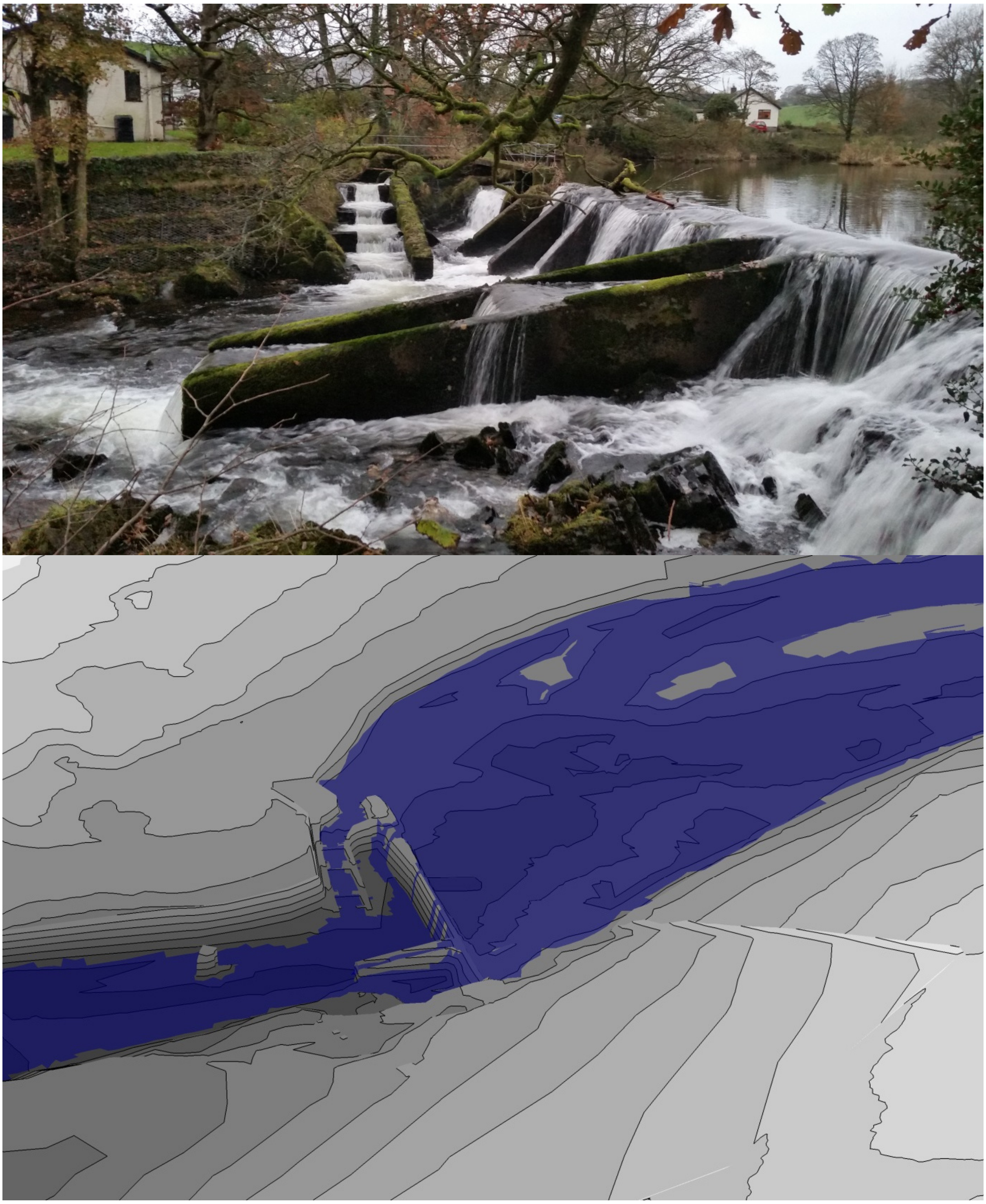


Figure 7.3 Photograph of the complex weir topography at Bowston (upper) compared to simulation of water levels at the weir at a similar flow predicted by the 2D model.

7.3 MOBILE BED MODEL

The unsteady 2D hydraulic model was used as the basis for a 2D unsteady sediment transport/mobile bed model. The SRH-2D model uses Wu's mixed bed (gravel and sand) sediment transport model, one of the most accurate sediment transport formulae for gravel bed rivers, and highly appropriate to the sediments found in the reach, with cobbles, boulders, finer gravel and sands all present. Bed adaptation length was set as a constant value of 45 m, corresponding to the length of observed bar features on the reach.

Non-erodible (weir) and bedrock zones were identified during the in-channel survey and these were set to have zero erodibility in the model, although deposition could take place on top of them. For erodible zones a total active bed thickness of 1 m was used, given the known presence of bedrock limiting further scour in the channel. This bed layer thickness could not be verified in the field and is an assumption only. Some areas of the bed are likely to have much thinner active gravel layers, due to the presence of bedrock but. Care must therefore be taken in interpreting maximum erosion depths.

The SRH-2D mobile bed module computes the flow of sediment throughout the reach as a function of bed shear stress and channel water velocity and depth. The module iteratively adjusts the bed to account for predicted erosion and deposition.

7.3.1. Observed Sediments in the Reach

Sediment sampling was undertaken at ten locations throughout the reach (Section 2.3) using standard sampling procedures.

Sediment size distributions were not found to vary significantly throughout and so a single size distribution was used in the sediment transport model. These sizes were split into seven size classes, each with their own evolution equation in the model. **Table 7.3** shows these seven size classes and their % fractions in the active layer.

Table 7.3 Size classes obtained from averaging sediment samples; these classes are used in the sediment transport model.

Size class [mm]	% fraction
0.1-4	3
4-8	5
8-16	31
16-32	21
32-64	9
64-128	23
128-256	8

7.3.2. Sediment Supply Assumption

The absolute amount of sediment supplied to the reach could not be determined. The actual sediment supply is likely to lie between the following two inlet conditions:

1. Capacity inlet conditions, where standard capacity equations are used to estimate the maximum amount of sediment mobilized at the inlet cross section.
2. Zero sediment supply

There is a significant impoundment weir at Cowan upstream, and sediment supply from this weir is likely to be limited. There are also extensive bedrock sections upstream of the model reach, and there is bank protection present in many areas. All of these factors suggest that sediment supply to the design reach is limited (although not absent). Erosion and aggradation patterns are therefore likely to be mainly a function of local channel adjustment to the weir removal, with sediments upstream experiencing more stress and being mobilized and deposited downstream, with the reach as a whole adjusting to plane bed.

To determine the sensitivity of the model to the upstream sediment supply assumption, the design model was run for capacity inlet conditions (i.e. a high sediment input) and zero sediment supply. Subject to 12 h inflow at the 1:2 year peak, the predicted erosion and deposition patterns were similar for both conditions, except for differences in the upper part of the reach. The capacity inlet condition produces more aggradation of sediment in the upstream 200 m of bed than the zero sediment supply case. Given that the sediment supply to the reach is likely to be limited, further modelling was undertaken using the zero sediment supply condition.

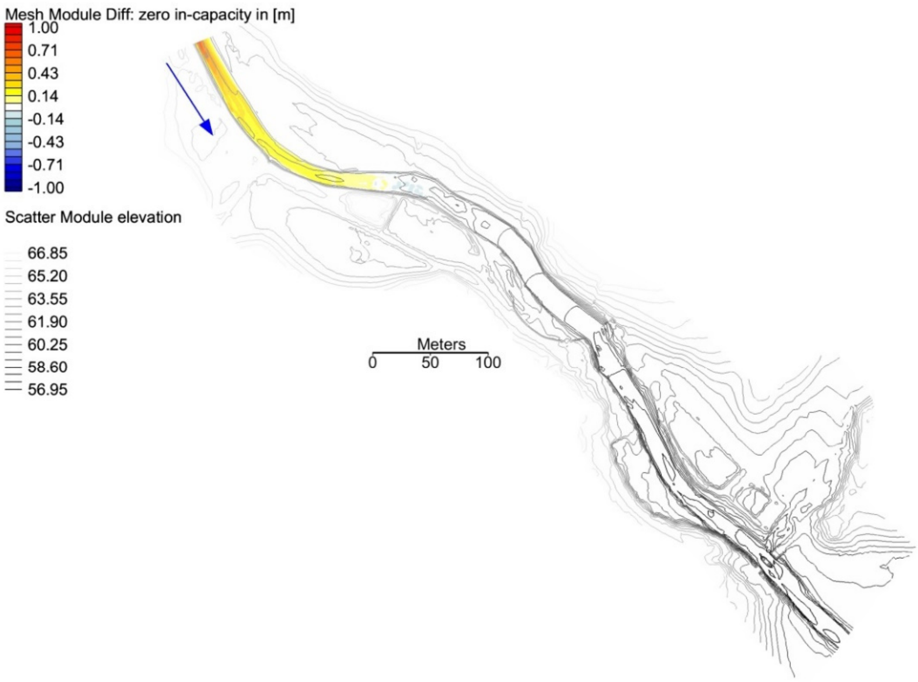


Figure 7.4 Predicted difference in erosion and deposition between the zero sediment supply case and the capacity sediment supply case, after 12 h at 1:2 year peak flow. An increase in aggradation for the capacity inlet condition is seen for the upper 200 m of the model reach, with no significant differences in the design area.

7.4 MODELLING RESULTS

7.4.1. Predicted Bed Mobility

This section discusses the predicted change to bed profile and water levels as a consequence of sediment transport. While results have been created using a state of the art sediment transport model, with as much local site data as practicable, the uncertainties and sensitivities in sediment transport modelling are such that these results should be seen as a 'best guess' guide only. It should also be borne in mind that the sediment results are dependent on a largely uncertain sediment supply from upstream. No assessment of bank stability was possible- the model only predicts bed vertical evolution. Adequate bank reinforcement must form part of the construction, where necessary, but note that the existing right bank is already largely protected by existing measures.

7.4.2. Predicted Evolution of Existing Conditions

With the weir in place, and (worst case) capacity sediment supply assumptions from upstream, deposition is predicted upstream of the weir, relatively static conditions are predicted at, and immediately downstream of, the weir and some deposition is predicted upstream and immediately downstream of the road bridge. The results are presented for a constant 1:2 year peak flow but the patterns of erosion and deposition are predicted to be similar for all high return periods.

The pattern of erosion and deposition is shown in **Figure 7.5** and **Figure 7.6**. Overall, as expected, the model predicts depositional processes upstream of the weir and transport/erosion processes downstream, with a mixture of erosion and deposition at the bridge.

Notable is the large amount of deposition in the upstream section. This deposition is likely to be an over estimate as a result of assumed capacity supply conditions. Of greatest concern is the predicted erosion through the bridge and deposition upstream and downstream of the bridge, potentially putting the bridge at risk. This conclusion is dependent, however, of the depth of mobile sediment at the bridge, and presence of a bedrock foundation.

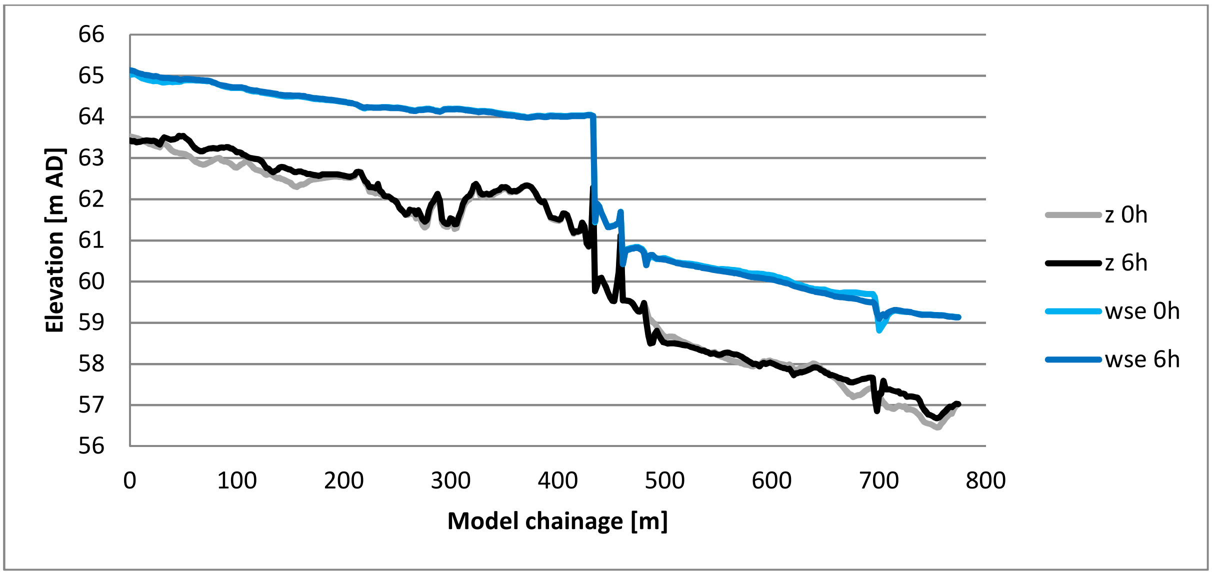


Figure 7.5 Long section of predicted erosion and deposition for the existing condition subject to a constant 1:2 year 'channel forming' flow (for 6 h).

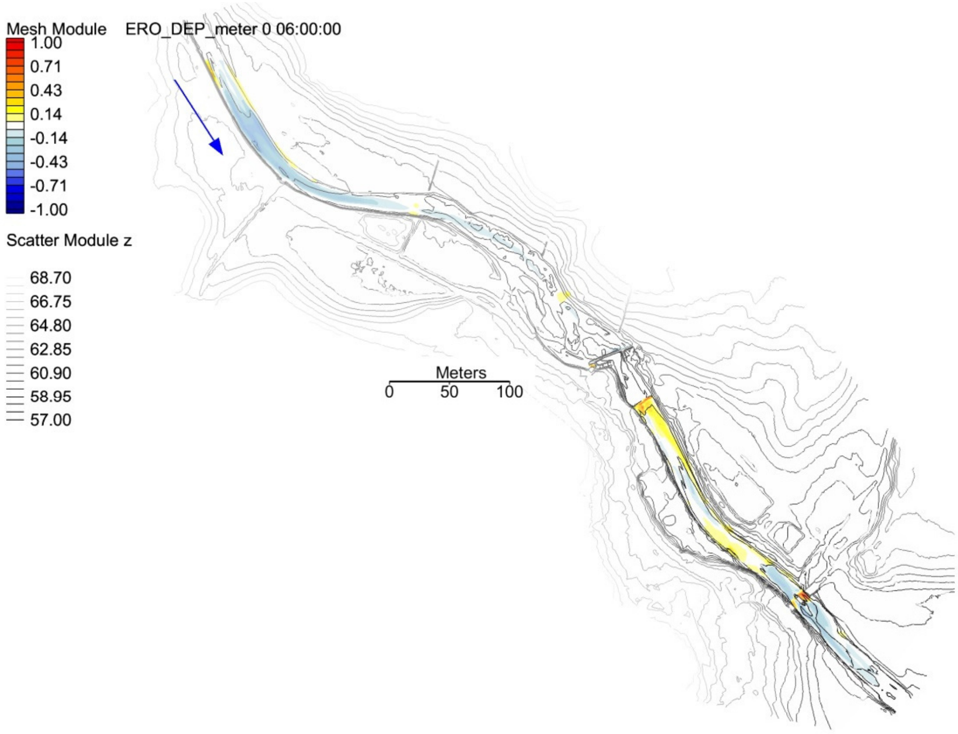


Figure 7.6 Predicted erosion and deposition pattern for the existing condition subject to a constant 1:2 year 'channel forming' flow (for 6 h). Cold colours are deposition, warm colours are erosion.

7.4.3. Predicted Evolution of Design Conditions

The design reach is initially provided with a series of grade control steps, composed of large material and interlocking blocks (which are essentially non-erodible). The slope of the channel bed without the weir is approximately 1.0% on average. Geomorphic theory would suggest an overall plane bed for this reach, and so it is expected that the channel will adjust with the steps becoming buried grade control measures, preventing any future head-cut from migrating upstream.

As expected for the initial design condition, there is significant adjustment of the design channel when subject to a constant 'channel-forming' 1:2 year flow peak. This erosion and deposition pattern is shown in **Figure 7.7** and **Figure 7.8**.

The model predicts an adjustment towards erosion processes upstream of the grade control 'steps', with these steps adjusting towards plane bed (filling in from the eroded material downstream). The grade control steps limit any head cut in the area immediately upstream of the current weir. No migrating head cut progression was evident in the mobile bed model results for design, for either sediment supply condition. Channel slope reduces slightly (with no sediment supply from upstream) to 0.9% after the extended period of bankfull flow. With sediment supply from upstream, it is likely that the upstream levels would not reduce as much. The slope through the step section does not change, and remains at 0.9% throughout the modelled bed evolution. Water surface slope is also 0.9% during the bed evolution.

Notably, deposition is predicted in the channel downstream of the bedrock section, downstream of the current weir. While this process is to be expected for a weir removal, it should be noted that aggradation of the downstream bed has an implication for flood risk, given that it will reduce channel capacity adjacent to properties in Kent Close.

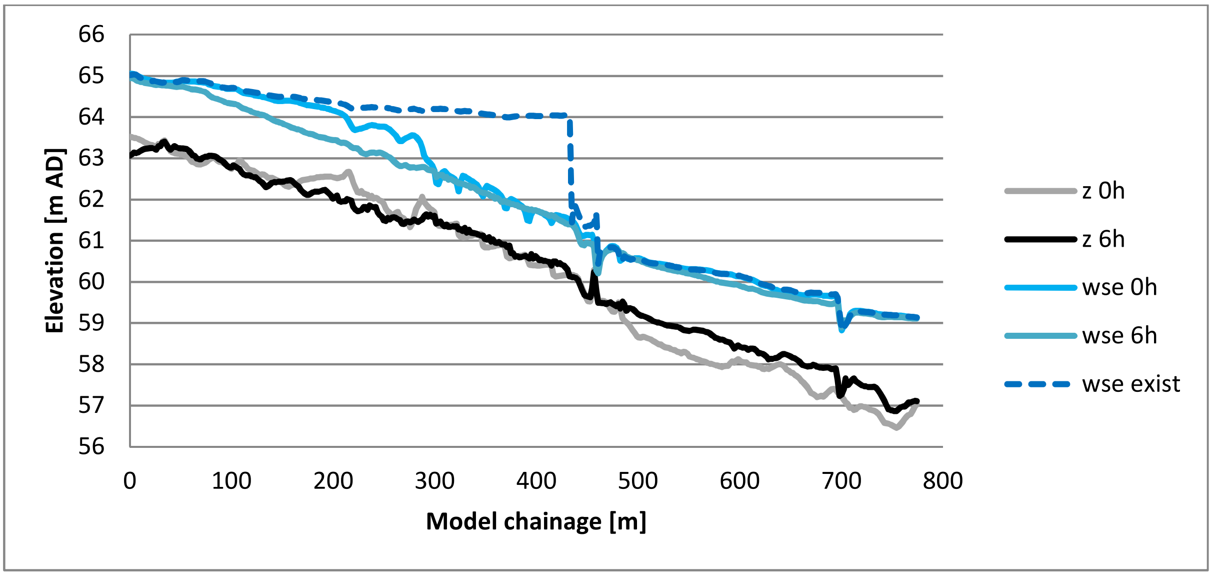


Figure 7.7 Long section of predicted erosion and deposition for the design condition subject to a constant 'channel-forming' 1:2 year peak flow (for 6 h). This model run is for zero sediment supply, but only differs from the capacity sediment supply in the first 200 m.

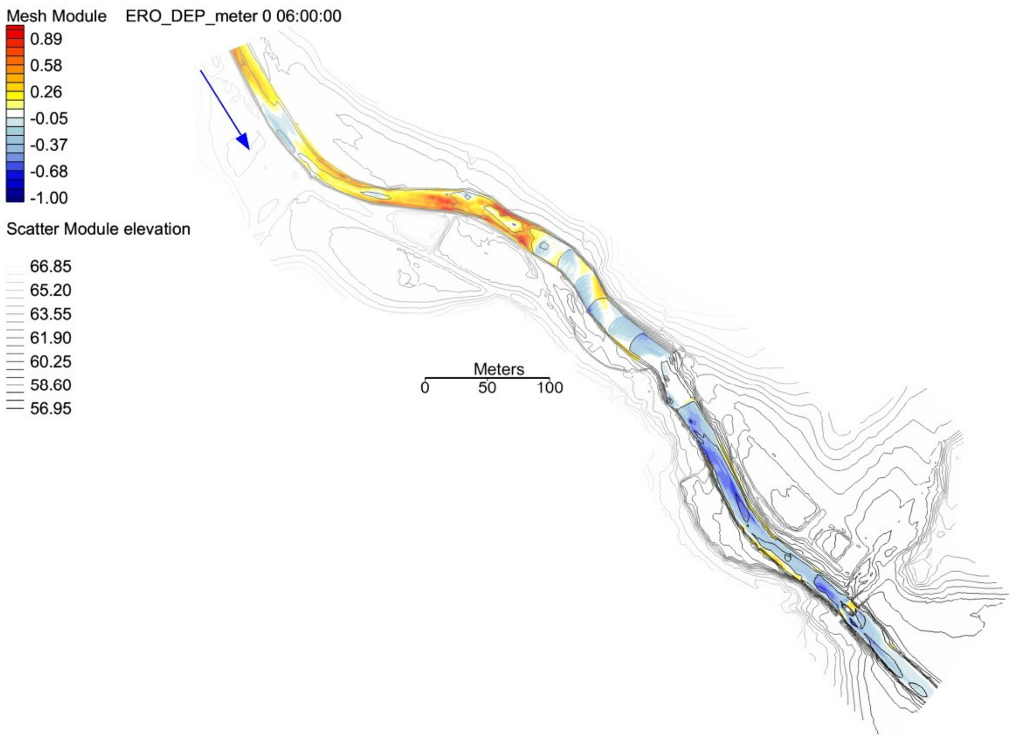


Figure 7.8 Predicted erosion and deposition pattern for the design condition subject to a constant 'channel-forming' 1:2 year peak flow (for 6 h). Cold colours are deposition, warm colours are erosion. This model run is for zero sediment supply, but only differs from the capacity sediment supply in the first 200 m.

The sediment transport model predicts that there is a relatively large amount of erosion upstream of the grade control steps. Some of this eroded material is deposited between the steps, developing a plane bed at the height and slope of the bed crests. However, the rest of this eroded material is transported downstream of the weir and is deposited downstream of the bedrock section, adjacent to Kent Close and, to a lesser extent, at the bridge. While the relative amounts of deposition close to the bridge are similar between existing and design conditions, the design condition experiences more channel bed aggradation adjacent to properties downstream of the current weir. A sediment management regime is recommended here to ensure that material does not aggrade to the extent that flood risk is impacted.

To reduce the amount of sediment transported downstream, design modifications could be made to armour the bed upstream of the steps, in the indicated region of erosion. The shear stresses at this upstream area indicate that material below 256 mm in size has a Shield's stress of 0.06 and is expected to be mobilized. Material greater than 256 mm in size should be relatively stable. The predicted maximum mobilized particle diameter is mapped in **Figure 7.9**.

If the bed upstream of the most upstream step is armoured, so that it is composed of non-erodible material, then the riffle crest heights are maintained and form a hydraulic control. Erosion upstream is reduced. Material from upstream then does not bury the steps significantly, and significantly less material aggrades downstream of the current weir. The erosion/deposition pattern after a six hour constant 'channel forming' flow is mapped in **Figure 7.10**, and long sections of bed level are shown in **Figure 7.11.**

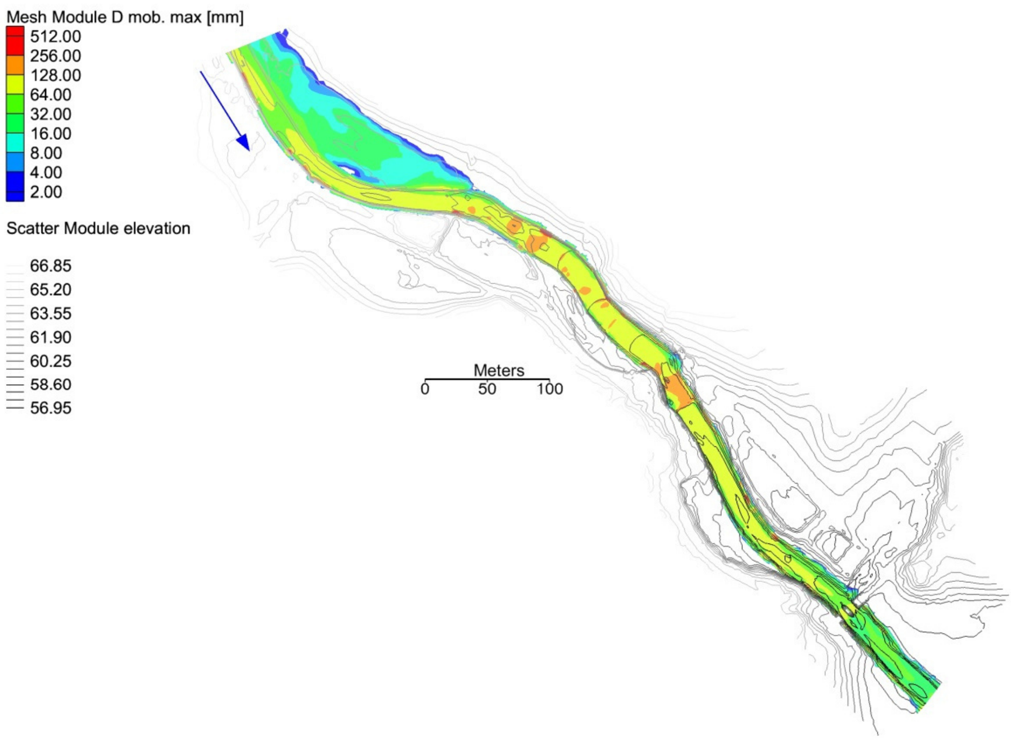


Figure 7.9 Predicted maximum mobilized sediment size (computed using Shield's curve, with critical stress = 0.06) for the design reach. Armouring the 50 m high stress region upstream of the steps should limit erosion of this sediment and reducing deposition downstream.

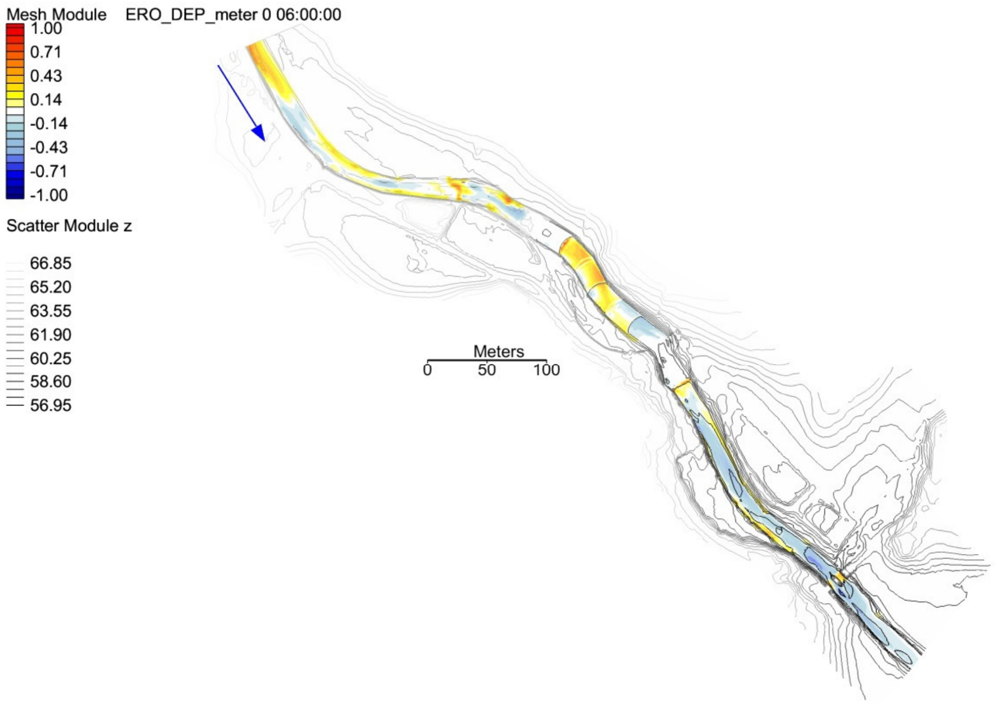


Figure 7.10 Predicted erosion and deposition pattern for the armoured design condition subject to a constant 'channel-forming' 1:2 year peak flow (for 6 h). Cold colours are deposition, warm colours are erosion. This model run is for zero sediment supply. The armouring is modelled as a non-erodible bed for 50 m upstream of the most upstream design step.

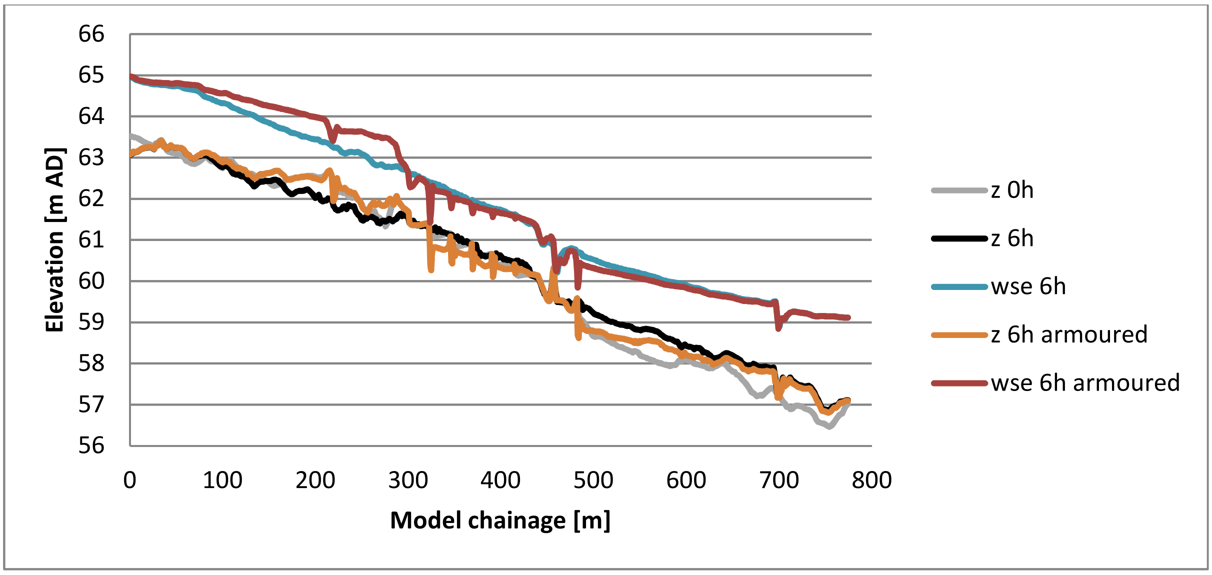
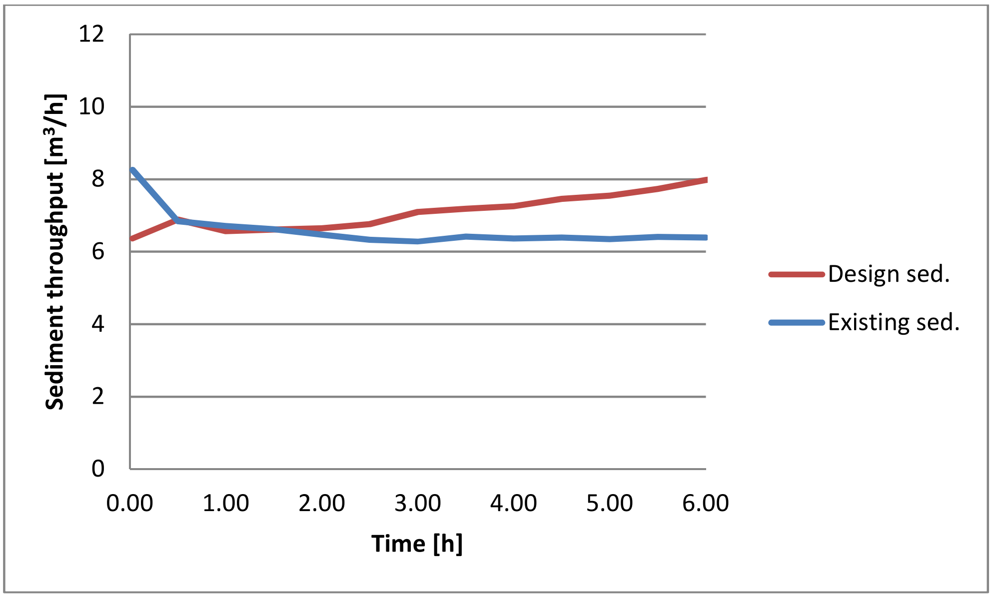


Figure 7.11 Long section of predicted erosion and deposition for the design condition subject to a constant 'channel-forming' 1:2 year peak flow (for 6 h). This model run is for zero sediment supply, but only differs from the capacity sediment supply in the first 200 m. The original and armoured design cases are shown.

7.4.4. Sediment Prediction

The sediment transport model can also be used to investigate the total throughflow of sediment and composition of sediment exiting the reach. The design reach is expected to have reduced fines over time, whereas the existing reach is expected to increase its proportion of fines, trapped behind the weir. The other size classes are not predicted to change much from the existing condition, as shown in **Figure 7.12**. A higher volume of fines exit the model domain for the design condition compared to those entering during this bankfull flow period. The existing weir essential limits any sediment throughput from upstream. Whereas the design condition, with the weir removed, allows a more natural sediment transport through the reach.



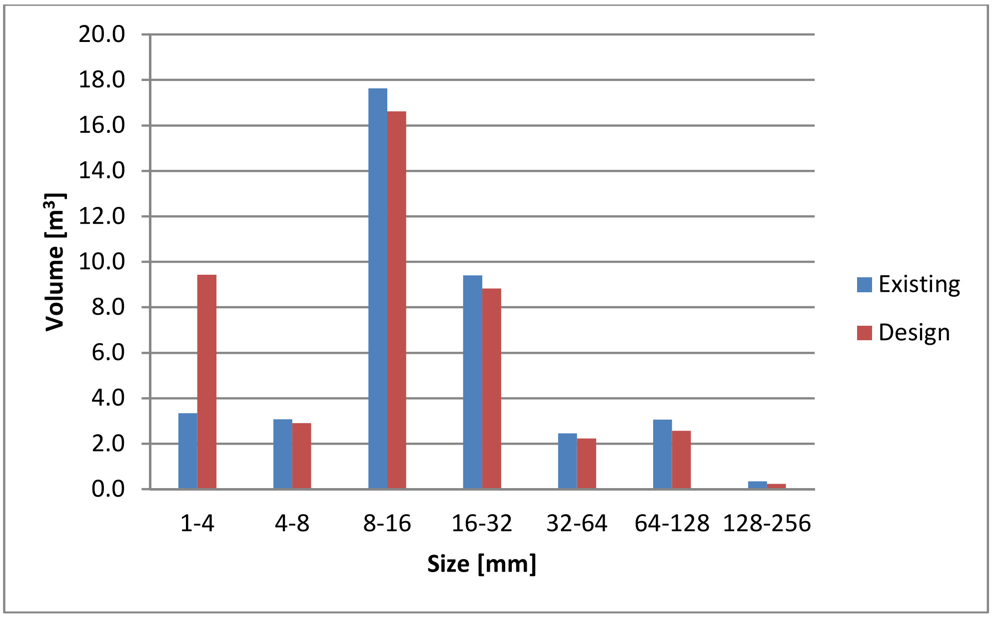


Figure 7.12 Predicted rate of sediment throughput (upper frame) and total sediment volumes exiting the reach during a 6h bankfull flow run (lower frame).

7.4.5. Stability Prediction

Because the weir has been removed for design, the channel is expected to adjust, even with the presence of grade control structures such as the steps. However, the following comments can be made with confidence:

- The reach has a reasonable slope of 0.9-1.0% for stability;
- No migrating head cuts are seen in the model results. However, the zero sediment supply assumption leads to erosion in the upper part of the reach; and
- The steps exist as buried grade controls, preventing head-cut migration through that area.

There is a relatively large area of erosion predicted upstream of the steps, as the channel adjusts to a 0.9% slope. This material is largely deposited in between steps, burying them, and in the reach downstream. The model was run for an extended bankfull flow (for twelve hours in total) to examine erosion and deposition rates. For the existing condition, absolute rates are low, as would be expected for an essentially stable/static reach. For the design condition, although initial rates of deposition and erosion are high, the rate of deposition decreases with time during the twelve hour bankfull flow period. Extrapolating these results, the design condition is heading closer to equilibrium over time. Water surface slope remains at around 0.9% for the modelled 6 h of bankfull flow and sediment transport.

The rate of change of the design to an extended 12 h, channel-forming, bankfull flow is mapped at each hour by computing the difference in bed level that occurred in the previous hour of simulation. These bed difference maps are shown in **Figure 7.13** to **Figure 7.15**. Most of the bed adjustment takes place in the first part of the bankfull flow run, indicating that the channel, although adjusting, is essentially stable. A similar conclusion can be made for the armoured design case, where the riffles for the 50 m reach upstream of the steps are prevented from eroding.

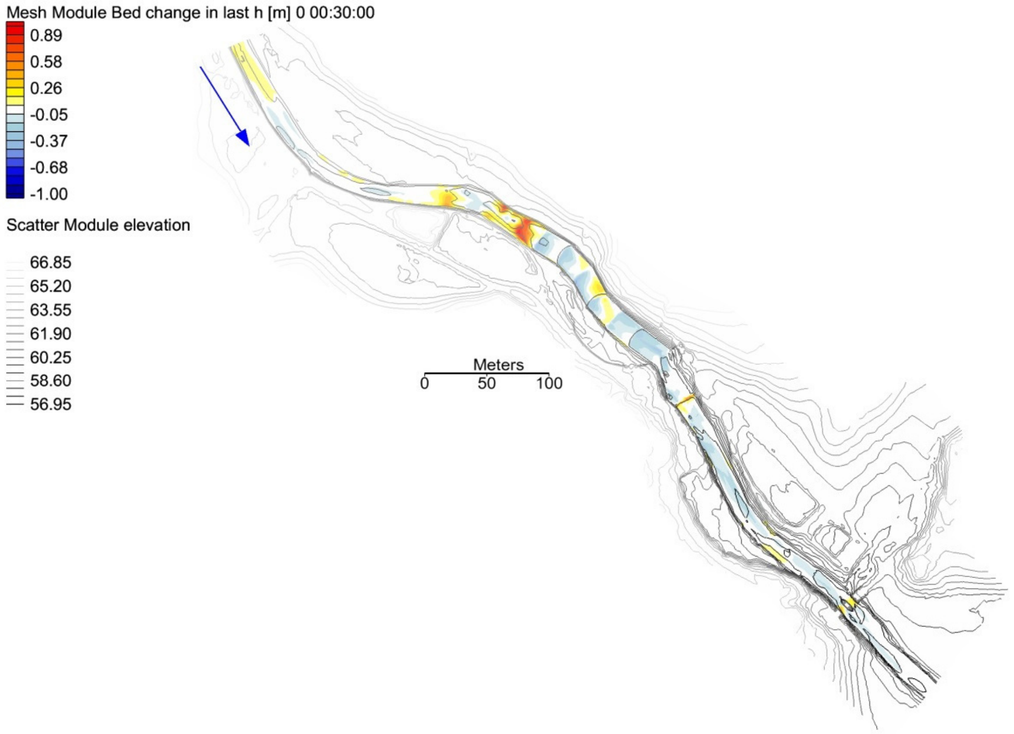


Figure 7.13 Predicted change to channel bed between 0 and 1 h.

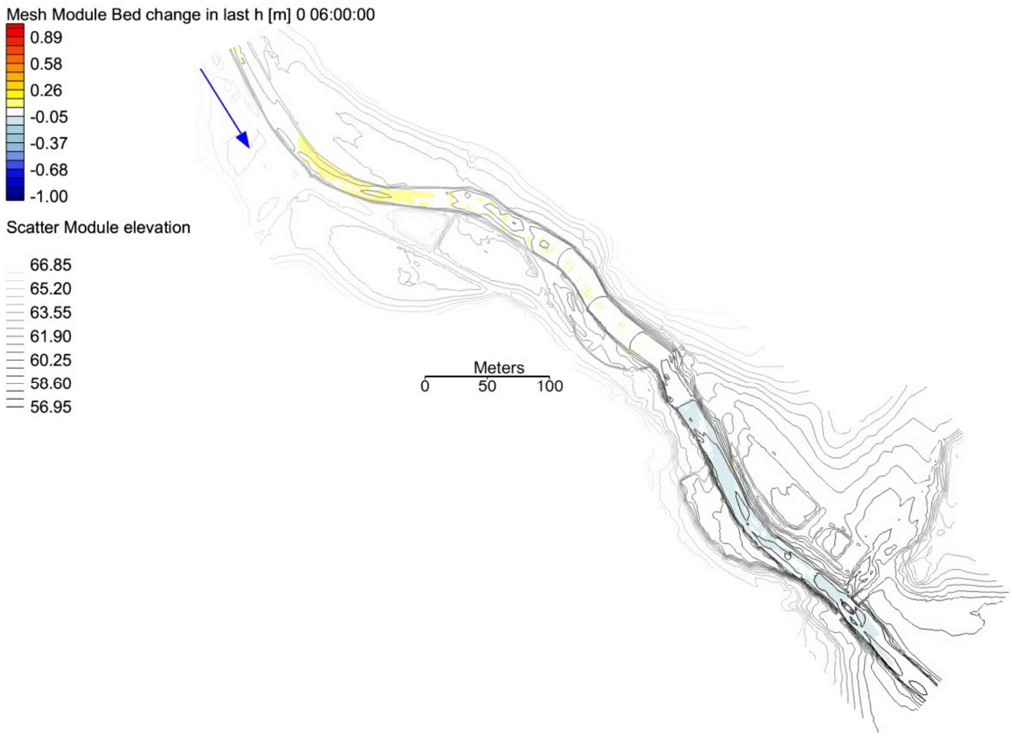


Figure 7.14 Predicted change to channel bed between 5 and 6 h.

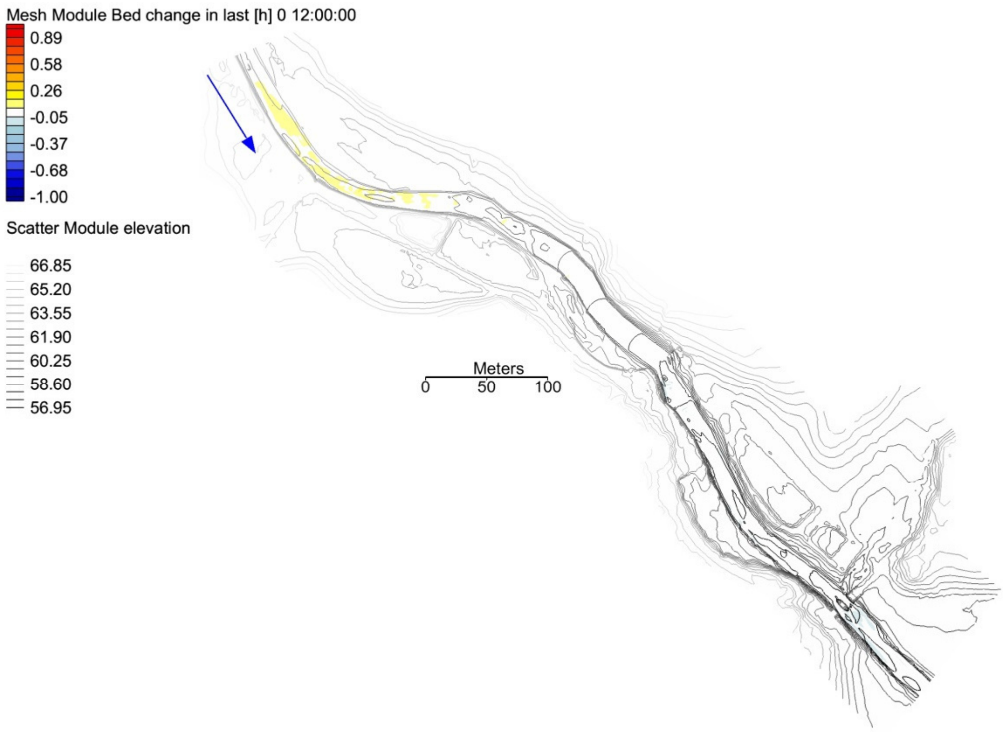


Figure 7.15 Predicted change to channel bed between 11 and 12 h.

7.5 CONCLUSION

A fully 2D hydraulic model and sediment transport/mobile bed model was created for the Kent at Bowston. Two conditions were modelled: the existing condition with the Bowston Weir in place, and a design condition with a series of grade control steps in place of the weir. To determine the medium to long term sediment behaviour at the weir, the mobile bed channel was subjected to a constant 'channel-forming' 1:2 year flow.

State of the art sediment transport and mobile bed modelling was used, with as much local data as practicable. Nevertheless, assumptions of sediment supply, depth of erodible sediment and other assumptions have had to be made and bed evolution itself is difficult to model accurately, and so all sediment transport and bed evolution results should be treated with caution, despite the results here being a defensible 'best estimate'.

The predicted evolution of the existing condition shows potential aggradation of the bed upstream of the weir if there is appreciable sediment supply from upstream. Very little sediment is predicted to cross the existing weir, and any that does is flushed through the bedrock section immediately downstream. Of most concern in the existing conditions prediction is that the channel through the arches of the bridge are predicted to scour, and aggradation is predicted upstream and downstream of the bridge. This pattern at the bridge is dependent on the available depth of erodible sediment and the presence of bedrock foundations.

It is predicted that there will be significant initial adjustment of the design condition, with the grade control steps becoming buried, as expected from geomorphic theory, for a basal channel slope of 1.0%. No head-cuts were observed to progress for the design, and the buried grade control steps should prevent these forming. Most of the adjustment takes place in the initial few hours of a bankfull flow event; the rates of channel change reduce with time, as the channel adjusts towards a new equilibrium slope.

Initially, the design channel experiences significant erosion upstream of the steps, mostly at two riffles. The eroded material fills in the downstream steps, but also aggrades in the channel downstream of the current weir. As the downstream reach is adjacent to properties, then this aggradation may prove detrimental to future flood risk, if gravel management in this reach is not undertaken. It is suggested that this reach is monitored, and aggraded material is removed should it reduce channel capacity or increase water levels. For the modelled 6 h of bankfull flow, the water surface slope does not change significantly from 0.9%.

Armouring of the bed upstream of the steps with coarser material is likely to be beneficial in reducing erosion and subsequent transport of these sediments downstream. Shear stress computations over these riffles indicate that armouring material of size >256 mm in diameter placed at these riffles will reduce the upstream erosion, and subsequent downstream deposition. If the sediments at the upstream riffles are prevented from mobilizing, then the upper steps are likely to remain as distinct steps proud of the bed.

8. FINAL DETAILED DESIGN

Following the iterative modelling process, final designs were produced for the site. Schematics for the site and proposed weir removal are provided in Appendix E. These include the step design (see the separate Method Statement for a detailed description of this) and enhanced bank protection upstream. Additionally, (**Section 8.1**) provides details of the general approach for the design, alongside indicative non-technical visualisations of the site pre and post-construction. Information on landscape, structures and services considerations are given in **Sections 8.2** and **8.3**.

8.1 SELECTED DESIGN APPROACH

A main component of the design is the removal of the large weir at Bowston. At the weirs current location, the physical character (channel geometry/ morphology and sedimentology) of the River Kent has adjusted to the base level control provided by the structure; this has resulted in a shallower gradient channel upstream, associated with an historic aggradation of the bed. By removing this feature and replacing with a series of smaller 'step' features, the channel will inevitably respond in relation to this new base level. The increased flow resistance provided by the introduced step features will encourage deposition of alluvial material through this section of the site. The step features may remain partially exposed at some locations but would generally become covered, therefore effectively acting as a series of buried grade controls that limit the risk of bed erosion/ head cut migrating upstream.

Both the right and left bank upstream of the weir will be reprofiled following removal of the structure, to avoid an excessively wide channel and overly steep river banks. Immediately upstream of the weir, the design aims to reinstate the right bank building the bank line out further into the channel, bringing it in-line with the current position of the same bank immediately downstream of the weir. Where feasible, the coarse material excavated from behind the weir structure prior to removal would be used to create/ build-up the new right bank. It is likely that a certain proportion of the excavated material will be silt/ fine sediment. As described in the method statement supplied separately to this report, it has initially been assumed that this material will be exported off site, however, there may be the option to re-use the material locally if this would be of benefit to the landowners /farmer on either bank.

Sediment transport modelling has shown that the area immediately upstream of 'step 1' is likely to erode, with the scoured material depositing immediately downstream of the weir location under significant flood events, consequently increasing water levels in this area[1]. Therefore, in order to manage flood risk downstream, some mitigation needs to be put in place to limit the erosion of the bed immediately upstream of Step 1. For this, the design involves the addition of coarse material into the bed in this area (using an appropriately sized sediment mix with a median intermediate particle diameter size of ~250 mm). This material would represent an alluvial grade control, limiting erosion/ scour of the bed immediately upstream of step 1 and preventing the upstream propagation of a head

[1] This result demonstrates the value of morphodynamic (i.e. sediment transport) modelling, allowing us to make a best prediction of how the morphology of the site will adjust in relation to changes in sediment transport processes as a result of the design. The model has provided crucial insights as to likely channel response both within the specific design site and *ex-situ* (i.e. the predicted incision of the channel bed upstream of step 1, to which an additional design element represents a mitigative solution).

cut (i.e. channel incision) that would deliver sediment downstream (i.e. to likely aggrade the bed downstream of the design with the associated implications for flood risk there).

Immediately downstream of the weir, the bed consists predominantly of bedrock for ~40 m, forming a natural grade control. The design does not require any immediate/ short term work in the channel downstream of Bowston Weir. However, although the proposed design should minimise the delivery of sediment to downstream areas, monitoring of channel geometry and sedimentology in the section adjacent to the right-bank properties along Kent Close should be undertaken (particularly in the period immediately after construction and in response to flood events).

8.1.1. Additional Considerations

A weir/ sediment management plan has been produced and provided to South Cumbria Rivers Trust separate to this report. The document details key considerations, mitigation measures and monitoring options specifically relating to the movement of sediment during and post-weir removal.

8.1.2. Photo-realistic Visualisations

The visualisation provided in **Figure 8.1**[2] was produced using a high-quality image of the site as the main backdrop, overlain with features and details that convey the changes proposed.

[2] It is important to note that this is only an interpretation of how the proposal might look and not an 'as-built' view.

Figure 8.1 Indicative visualisation of final weir removal

8.2 PROPOSED CHANGES TO THE LANDSCAPE

Construction phase

During construction, the main activity and infrastructure would include:

- Site compound location and access to the river;
- Closure and / or diversion of public footpaths;
- Movement of construction equipment, materials and vehicles around the site;
- Demolition of the weir and fish pass;
- Removal of vegetation;
- Bank widening and protection; and
- Bed regrading and installation of buried steps for grade control.

Operational phase

During operation, the main activity and infrastructure would include:

- Establishment of new vegetation; and
- Maturing and colonisation of the rock steps.

8.2.1. Local Planning Policy

The planning authority is South Lakeland District Council (SLDC) and the South Lakeland Local Plan (2010) will be the relevant document to refer to when submitting a planning application.

The Local Plan is a collection of plans and policies that set out the long-term vision, objectives and policies for the district and those of note included amongst this collection are:

- The Core Strategy sets out the strategic planning policies.
- Neighbourhood Plans help communities develop their own plans which can establish general planning policies for their area.

A policy identified in the Core Strategy with relevance to the proposed weir removals:

CS8.1 Green infrastructure, which amongst its aims includes:

- *Attain high standards of environmental design that fit with the surrounding countryside*

and landscape setting;

- *Protect species and habitats and create new habitats and wildlife corridors where biodiversity conservation and enhancement is affected by development;*
- *Ensure the protection and enhancement of watercourses and wetlands which are important contributors to the network of blue and green corridors for wildlife, recreation and the amenity needs of the community.*

It is worth noting that a steering group is working on preparing a Neighbourhood Plan for the parishes of Strickland Roger and Strickland Ketel which will be known as the Burneside Neighbourhood Plan. The approval for the Plan was given in June 2016

Bowston will fall under this Plan and the boundary line between the two parishes is along the centre of the river Kent.

As the area covered by the Burneside Neighbourhood Plan straddles the Lake District National Park (LDNP) boundary it has been formally approved by both the Park Authority and by SLDC; South Lakeland will remain as the lead authority.

Approval for the plan was given in June 2016 followed by a 'Call for Sites' exercise completed at the end of January 2017. No further dates are provided on the SLDC website and the Screening Report accompanying the application is not dated but states:

"The Plan is currently at an early stage of preparation. Supported by an earlier Burneside Vision document, a document has been drawn up setting out the aspirations, aims and objectives for the Plan. It is on these that this initial screening opinion is based and it is important to note that further screening will be required as the Plan takes further shape."

The Report also states:

"The Burneside Neighbourhood Plan (the Plan) will set out the local planning policy framework for Burneside Neighbourhood Area. If the Plan is 'adopted' by the local planning authority, it will become part of the Development Plans for South Lakeland District and the LDNP. It will be used in the decision-making process for assessing planning applications within Burneside Parish."

The potential extra level of planning policy should not be seen negatively when considered against one of the draft objectives listed in the Screening Report:

- *"Re-connecting with, giving prominence to and enhancing accessibility to the River Kent Special Area of Conservation."*

8.2.2. Designations

Bowston does not fall within the boundary of the LDNP and is not covered by an Area of Outstanding Natural Beauty. Similarly, it is not within a Conservation Area, although the river Kent is a designated Special Area of Conservation.

There is no means of identifying which trees are covered by a Tree Preservation Order (TPO) on the SLDC website. In order to confirm if a TPO is in force or not the council would need contacting directly with specific details of the trees to be removed.

The weir itself, built in 1948, is not a listed structure and there are no listed buildings in the immediate surrounding area. *Bowston Bridge* downstream of the site is grade II listed as is *Laithwaite Farmhouse* approximately 350m north east of the weir.

8.2.3. Receptors

Visual receptors are people that may experience views of the landscape. These may include residents and visitors to local properties, roads and footpaths. Desktop and site studies have been used to identify the key visual receptors likely to be affected by the proposal, to include the following:

- Residential, individual properties and settlements;
- Public Rights of Way and other recreational receptors; and
- Roads.

Observations made during the site visit coupled with the localised nature of the proposed development suggest it is highly unlikely that notable visual effects will occur outside the immediate vicinity of the site.

8.2.4. Public Rights of Way (PROW)

There is a PROW on both banks of the river and reference numbers and names are taken from the Cumbria County Council's Illustrative map of public rights of way:

PROW 575002 runs along the left bank from Burneside Mill to the point at which it meets the unnamed road approximately 1.4km north of the weir. When approaching the weir from the south, it is not visible until 50m away due to the significant tree cover along the riverbank. The crest of the weir is observable when approaching from the north, although the view is more glimpsed because of intermittent tree cover along this section of the footpath. The most significant change will be to the appearance of the river upstream rather than the loss of the weir itself and the extent of the change is not known at this stage.

PROW 575020 relates to the section of footpath that runs along the right bank just by the properties north of the weir, *Kent Dene, Fairviews* and *Timerondale*. The footpath follows the river to Kendal Road on the south side of Staveley, which is also part of the longer Dales Way route. Due to its start point north of the weir, it is anticipated that the greater impact will be from the change in the river's morphology rather than the loss of the weir structure itself.

8.2.5. Road Receptors

Residential traffic for the Kent Close cul-de-sac will be slow moving and views of the scheme will be prominent. Residential traffic for the properties accessed directly from Winter Lane will also be slow moving but there are limited direct views of the weir and only a number of these properties will have a clear view of the river.

Local traffic using Winter Lane will have no views of the scheme. Local traffic crossing Bowston Bridge have no views of the existing weir however some of the proposed weirs and subsequent change in the river's morphology will be observable.

8.2.6. Residential Receptors

A total of 15 properties are located on the right bank in the immediate vicinity of the weir but there are no properties on the left bank.

There are approximately 8 detached properties along Kent Close with those numbered 5 to 8 located downstream of the existing weir. It is anticipated that these properties will have a restricted, even fully obscured view of the weir due to the topography of the street, the vegetation along the river bank, the type of property or a combination of all three. The property at number 5 has a first-floor balcony that may afford views of the existing weir and as a consequence of this vantage will have views of the subsequent change in the river's morphology.

The properties numbered 1 to 4 are the nearest to the weir, with 1 Kent Close located immediately adjacent to the weir, orientated along a south-west to north-west axis. Views of the weir are from the back of the house, albeit at a slightly oblique perspective, and the garden. The style of property is a bungalow with no modifications made to the structure to offer a more elevated view of the existing weir. The change in the river's morphology and the proposed series of weirs will be observable from this property.

The properties numbered 2 to 4 have two stories and all 3 have had balconies added to first floor rooms. The orientation of these properties is in a more west to east direction, running parallel with the weir meaning, that views of the existing weir at numbers 3 & 4 may only be possible from their balconies at the front of the house (against the 'grain' of the orientated view). However they will have direct views out over the river downstream of the existing weir and as such the change in the river's morphology will be observable.

Of these 3 properties, the one at the end of the row, number 2 Kent Close, is the nearest to the existing weir and has been able to orientate its views more towards the weir. A balcony and medium sized conservatory have been constructed on the side of the property that faces more directly towards the weir. The view is partially screened by ornamental trees within the property's own garden as well those in the garden at number 1. The change in the river's morphology and the loss of the existing weir will be observable from this property.

There are some small terraced areas, with patio furniture, immediately along the bank of the river, which are opposite to the properties numbered 2-4 and it would be fair to assume that these areas belong to these properties as an extension of their garden. The proposed changes will be clearly observable from these areas.

A row of stone cottages on *Winstanley Row* immediately off Winter Lane, are orientated in a similar direction to 1 Kent Close. Views of the weir itself are obscured due to topography and built form, however glimpsed views of the river upstream of the weir are expected from the first-floor windows of numbers 3 & 4.

Further along Winter Lane, just past *Winstanley Row* are 3 detached properties; *Kent Dene, Fairviews* and *Timerondale*.

Kent Dene has views towards the weir although some screening may occur due to the semi-mature trees on the river bank, however the impact of the weir removal is expected to be high.

Fairviews and *Timerondale* have a more face-on view off the river and weir crest with limited screening from vegetation and the impact of the weir's removal and subsequent change to the river's morphology is expected to be substantial.

Views from the Grade II listed *Laithwaite Farmhouse* are obscured by topography and vegetation.

8.2.7. <u>Mitigation</u>

Given that the scheme comprises of the full removal of the weir and fish pass to alter the river's morphology it will not be possible to screen any views for the local residents or footpath users.

However, an iterative design process that considers the specific qualities and wider context of the site will reduce both adverse landscape and visual effects.

Measures should include the following:

- Replacement tree planting;
- Improved amenity features including use of information boards explaining the benefit of the changes and the positive impact on the ecology of the river; and
- Installation of seating or viewing areas.

8.3 STRUCTURAL AND SERVICES

8.3.1. Visual Inspection - Current condition of Bowston Weir

Weir Attributes

- River Slope approximately = 0.01 m/m
- Weir Height = 3 m
- Backwater effect $0.7.\frac{D}{s} = 210m$
- Observed backwater = 300 m
- Weir width approximately = 38 m

Nearby Structures

- House immediately downstream on the right bank
  - Set back approximately 5 m
  - 4.6 m above channel bed
- Construction access via right bank field upstream
- Construction access via left bank field
- Large over hanging tree immediately adjacent to weir on left bank
- Power lines upstream of weir
- Farm structure 175 m upstream. Side may have been used to deposit old dredging material
- Weir 765 m upstream
  - Significant slope between weirs. No influence anticipated
- Bridge 250 m downstream
  - Channel flowing rapidly through bridge
- Weir 350 m DS

Land use either side

Left bank inside of meander, low lying fields becoming steeper 400m upstream.

Right bank outside of meander, raised level using masonry retaining walls. Rock head visible intermittently up to 400m upstream where rock head becomes predominant.

Construction

The weir is constructed from stone/masonry with buttresses situated along its width. The weir is likely to be founded on rock due to rock head being observed on site. The adjacent fish pass is also likely to be founded on rock head as the right bank appears to act as the right wall to the fish pass.

Defects

No defects were visible from the river bank. The weir is covered in vegetation therefore it is possible small defects cannot be seen through the moss and small plants.

Without dewatering the weir, it cannot be assessed for defects any further. There is no apparent risk of failure observed during the visual inspection.

Leakage

Due to the volume of water flowing it cannot be observed whether the weir is leaking.

Movement

There is no visible sign of movement.

Without survey equipment or a history of weir levels it cannot be confirmed whether the weir has moved or settled.

General Condition

It is evident that work could be undertaken to bring it into better condition such as de-vegetate and rake out and repoint any dilapidated masonry resulting from vegetation growth. There is no sign that the weir is in danger of failure that can be seen from the visual inspection.

Maintenance and Inspection

It is recommended that if the weir is to remain it shall be de-vegetated annually pending visual inspection and if a principal inspection has not been undertaken in the past 10 years one should be undertaken.

Inspection Schedule

It is not known at present what the inspection schedule is for the structure. It is recommended that an inspection schedule be put in place if there is not one in place at present. The maintenance of the weir should follow the inspection recommendations should the weir not be removed.

Inspection procedures are recommended to be in accordance with the Canal & Rivers Trust Asset Inspection Procedures (AIP2014)

Anticipated inspection schedule

- Monthly or 3 monthly visual length inspection
- Annual Inspection – At which point the condition grade may be changed following any changes in condition
- Principal Inspection – At risk based intervals between 3 and 20 years or when annual inspection dictates the structure is at risk.

Influence on nearby structures resulting from removal of weir and fish pass

Initial risks identified at options appraisal stage included the following points. Mitigation measures/ considerations are detailed in Section 8.3.2:

- Where it is anticipated that the works will destabilise the river bank, remedial measures are to be undertaken such as replacement of retaining walls and/or placement of scour protection (an area of note is the proximity of the private property on the right bank to the fish pass).
- Dependent on the design of the demolition works, scour will occur on the left bank and to the river bed if there are areas where rock head is not present.
- The right bank is likely to become unstable unless it is either regraded or part of the substructure of the weir is left in the bank.
- From observations on site that can be seen in Figure 8.2, it can be deduced that the existing fish pass adjacent to the weir may be founded on the same shallow rock that the property and weir are likely built on. If this is so the fish pass may be deconstructed without influencing the private property. Closer investigation is required at design stage to ensure this is so. Failure to do so could result in failure of the garden wall and subsidence of the residents garden, even damage to the property itself.
- The construction and foundations of the existing fish pass and weir are to be confirmed. It is advisable that the fish pass is dewatered for closer inspection by a structural engineer. Where

it is inconclusive a core may be taken to determine the foundation make up with an aim to discover conclusively that the resident's property will not be affected.

- The risk of the foundations of the weir are of lesser consequence but will influence the demolition design. They shall be left at bed level if rock head is not observed throughout the river bed.
- There is a constriction in the flow as it passes the right bank property. This will likely be removed for the majority of flows by virtue of lowering the water level by removal of the weir. Protection will still however need to be placed at this constriction point to train high flows around the property.

Figure 8.2 View of Bowston Weir from the left bank

8.3.2. <u>Design - Mitigation Against Risk</u>

Following identification of potential risks during the structural assessment, the subsequent design for removal of the weir and associated structures has been developed in such a way to minimise risk of issues associated with the points identified. Specific measures include:

- The addition of 'toe' bank protection along both banks in the vicinity of the weir to avoid unwanted scour.
- The realignment/ reinstatement of the right bank upstream of the weir, to bring the upstream section of bank in line with the bank immediately downstream from the weir by the private

property. This removes the existing channel constriction here, significantly reducing the risk of scour to the bank.

- During demolition, the majority of the existing right bank fish pass structure can be retained, with the bank reinstated/ infilled around the structure to provide an additional level of stability to that section of bank.
- During construction, we strongly recommend that an experienced cbec geomorphologist(s) makes regular visits to the site to supervise construction, ensuring that the design is built to specification. This minimises risk of issue during the build phase and allows any construction-related queries or issues to be discussed between the relevant contractors and the client.

8.3.3. Anticipated Removal Sequence

Details of the construction process are provided within the preliminary Construction Method Statement submitted separate to this report. Final sequence of works (which considers and minimises risks in terms of sediment release, ecological disturbance and health and safety, etc, are to be provided to SCRT by the successful build contractor.

9. REFERENCES

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APPENDIX A

OPTIONS APPRAISAL ASSESSMENT

OPTIONS APPRAISAL

DEVELOPMENT OF OPTIONS

Following completion of the ecological, geomorphological and structural assessments in the field, an initial high-level list of options was formulated. These are shown in **Table A1**. This was used to inform discussions with SCRT and to identify a selection of feasible options for Bowston weir to take through to the full options appraisal and modelling assessment.

Table A1 Bowston Weir Options Overview

Option Number	Description
1	Full Removal of Bowston Weir
2	Weir Modification: Installation of rock ramp and / or weir infilling
3	Do Nothing

It should be noted that the feasibility of these options is subject to the flood risk modelling to be completed, archaeological assessment, sediment contamination and service searches. Other identified options could be assessed should others prove to be impossible due to the outcomes of these assessments.

TABLE A2: APPRAISAL OF OPTIONS – FULL REMOVAL

Full Removal		
Geomorphology	Benefits	A significant improvement to longitudinal connectivity is expected to benefit geomorphological processes and associated in-channel habitats. Hydrologically, the option to fully remove the weir will eliminate impacts associated with impoundment of flows, over-deepening and alteration of natural flow regimes. Morphologically, this option is expected to significantly benefit the downstream transfer of sediments and habitat elements. Reach-scale flow and sediment regimes are currently highly impacted by Bowston weir. Uniform glide flows were recorded for approximately 240m upstream of the weir structure. Analysis of available topographic, geological and valley setting data indicate that a dynamic pool-riffle reach could be expected under reference conditions. Under ideal circumstances, the full removal of the Bowston weir would significantly contribute towards approximating this reach to its reference conditions by promoting an increase in flow heterogeneity, with associated beneficial effects on the availability and quality of in-channel habitats. The reach upstream of the weir presents evidence of impacts to its reference sedimentary processes. A geomorphological walkover and Wolman sampling strategy indicated that bedforms and sediment depositional features are impacted from their reference-state extent and complexity. Full removal of the weir is expected to contribute towards the reinstatement of a dynamic sediment transport and deposition regime, with a tendency towards the formation complex bedforms and localised deposition of coarse sediment. Similarly, sediment recruitment processes throughout this reach are limited by the artificial change in channel gradient and stream power associated with the presence of the Bowston weir. Increased opportunities for sediment recruitment through bank erosion associated with an increase in channel gradient and stream power following the removal of this barrier are expected. Finally, the full removal of the barrier to longitudinal connectivity is expected to yield maximum benefits to easement of fish passage through this reach. Currently, fish passage at this barrier is deemed to be limited for all species bar migrating salmonids.

Geomorphology	Disbenefits	While the removal of the structure at Bowston weir is expected to result in significant improvements to geomorphological processes through this reach of the River Kent, the presence of important infrastructure in its vicinity justifies a careful consideration of potential geomorphic impacts. Given the height of the weir (approx. 3m), removal of the structure is expected to result in increased potential for downstream channel bed aggradation and bed incision/ knick-point migration upstream of the existing structure. The increase in stream power associated with the weir removal will locally increase sediment transport capacity and competence (total volume and maximum mobilisable particle size) in the reach. This is expected to result in a likely increase of sediment deposition and bed aggradation downstream of the existing structure (as sediment stored behind the weir is transported downstream), with an associated increase in flood risk for neighbouring properties and detrimental impacts to the quality of in-channel habitats for notable species. In addition, analysis of the topography and channel slope of the reach has indicated that a potential for rapid geomorphic adjustment following the removal of the weir is present. The distance between the nearest upstream hydraulic control (bedrock section in vicinity to Cowan Head weir) and the nearest downstream hydraulic control (small rock step immediately downstream of Bowston weir) is approximately 620m, with an average channel slope 0.6. Given the height of the weir structure to be removed, regrading of the channel bed is likely to be required for an extent of approximately 305m (as seen in Figure 2) to an average channel slope of 0.9, leading to an increase in stream power and shear stress to the channel bed and banks. In turn, this change in the geomorphic regime is expected to result in an increased capacity for erosion and undercutting of the river banks, potentially leading to widespread bank collapse. In addition, it is anticipated that this increase in sediment recruitment and transport capacity may result in incision of the channel bed as the river adjusts to its new hydromorphological regime. Literature analysing the geomorphic impact of weir removal projects has highlighted that this upstream incision of the channel bed response is frequent under most hydrological regimes and substrate conditions. In the case of the Kent, this is likely to produce a 'knickpoint" migration response, as the channel bed 'retreats' upstream as a result of increased stream power. In the case of the Bowston weir reach, this increased potential for bank erosion and bed incision, coupled with lower water levels following weir removal, has the potential to compromise the integrity of important infrastructure in the vicinity of the current weir structure. Any significant drop in water levels (leading to dewatering/ undermining of tree stability), undercutting of the banks or significant channel incision may compromise the integrity of the wall that protects Dales Way and guarantees access to the Cowan Head apartment complex. Therefore, measures to limit the projected increase in stream power and erosion/ incision potential will be required, limiting the full recovery of a naturalised flow and sediment regime following the removal of the weir structure. At this preliminary assessment stage, it is proposed that the mitigation against the increased risk of bank erosion and longitudinal migration of the channel bed should take the form of a series of rock 'steps' to 'break-up' the channel slope and contribute towards a decrease in stream power during flood events.

Ecology	Benefits	Reinstatement of river bed morphology could potentially increase diversity of aquatic macrophytes, especially *Ranunculion Callitricho* Batrachion communities as well as macroinvertebrates and diatom assemblages within the reach, allowing improvement to aquatic ecology. Increase fish and eel passage (pending records). Reduce overcrowding of fish populations downstream, therefore river becomes naturally regulated fishery. Opportunities for riparian zone planting to create heterogeneous bankside habitat along left bank. Compensatory tree planting for any removed. Bat and bird box installation on retained trees. Artificial Otter holt installation.
	Disbenefits	WFD assessment likely to be required (to be confirmed with discussion with EA). NE consents for designated sites likely to be required (to be confirmed upon discussion with NE). Potential for non-native invasive species to be present in the vicinity of the structure (need more data to fully analyse this). There is also potential to open up higher reaches to colonisation by non-native aquatic flora and fauna aiding their spread. Biosecurity should be incorporated into the scheme and possibly invasive species management plans. Timing of works to avoid / mitigate for fish spawning and migrations. High potential for White-clawed crayfish requiring survey, mitigation plan and licence from NE prior to works on site. If present, works can only be carried out between July – September inclusive Vegetation removal required (No TPOs present in site vicinity) – undertake removal outside nesting bird season (March to September inclusive). Bat potential of trees for removal requires assessment and potential mitigation. Riparian mammal survey required prior to works commencing if more than 12 months from date of the scoping survey. Pollution prevention measures to be implemented (e.g. overpumping/sediment traps). It is also advisable to monitor Dissolved Oxygen downstream of works to prevent fish stress and kills. Arboricultural assessment of retained trees to establish root protection zones and any requirement for tree works.

Engineering and Landscape	Benefits	Improved visual amenity for residents and footpath users. The removal eliminates the risk of weir failure or damage. Maintenance is eliminated or drastically reduced. Despite stakeholder opinion it is likely the amenity of the area will be subjectively improved through replanting of trees and naturalisation of river. Consideration to public safety and visual impact shall be given when constructing the river banks. Risk of harm to public is reduced due to removal of deep water and large drop over weir. Noise levels nearby will be lowered from removal of large water drop over weir.
	Disbenefits	The full removal attributes the higher costs and involves significant in-channel works. The temporary works for which could increase the project costs further than anticipated at this stage. The costs may be reassessed once an outline design is produced with detailed drawings of the proposed works. Early contractor involvement could allow the cost and impact of the works to be more accurately assessed. Removal of the weir could potentially destabilise to adjacent retaining walls and furthermore the nearby building. This is to be assessed further on receipt of the topographical survey and once the outline design is produced. The undermining and destabilisation of the retaining walls may result in further works that are not currently costed for. The risk allowance in the cost may allow for this aspect. The adjacent land on both banks is anticipated to be utilised and therefore the removal results in a large disruption to the stakeholders on both sides of the channel. On completion, the works will require minimal if not zero maintenance except possibly after substantial events that are in excess of the design flow levels used. Inspections of the nearby structures and condition of the protection works is envisaged. Parish Boundary line runs down centre of river. Possible local issues requiring negotiations with 2 bodies; Strickland Ketel on west bank and Strickland Roger on east bank. Dales Way public footpath on both sides of the bank. Potential footpath closures and re-instatement post operations. Site compound location, access issues and presence of plant and equipment. Noise levels and visual intrusion during construction. Visual impact through change in river's appearance for residents downstream of the weir.

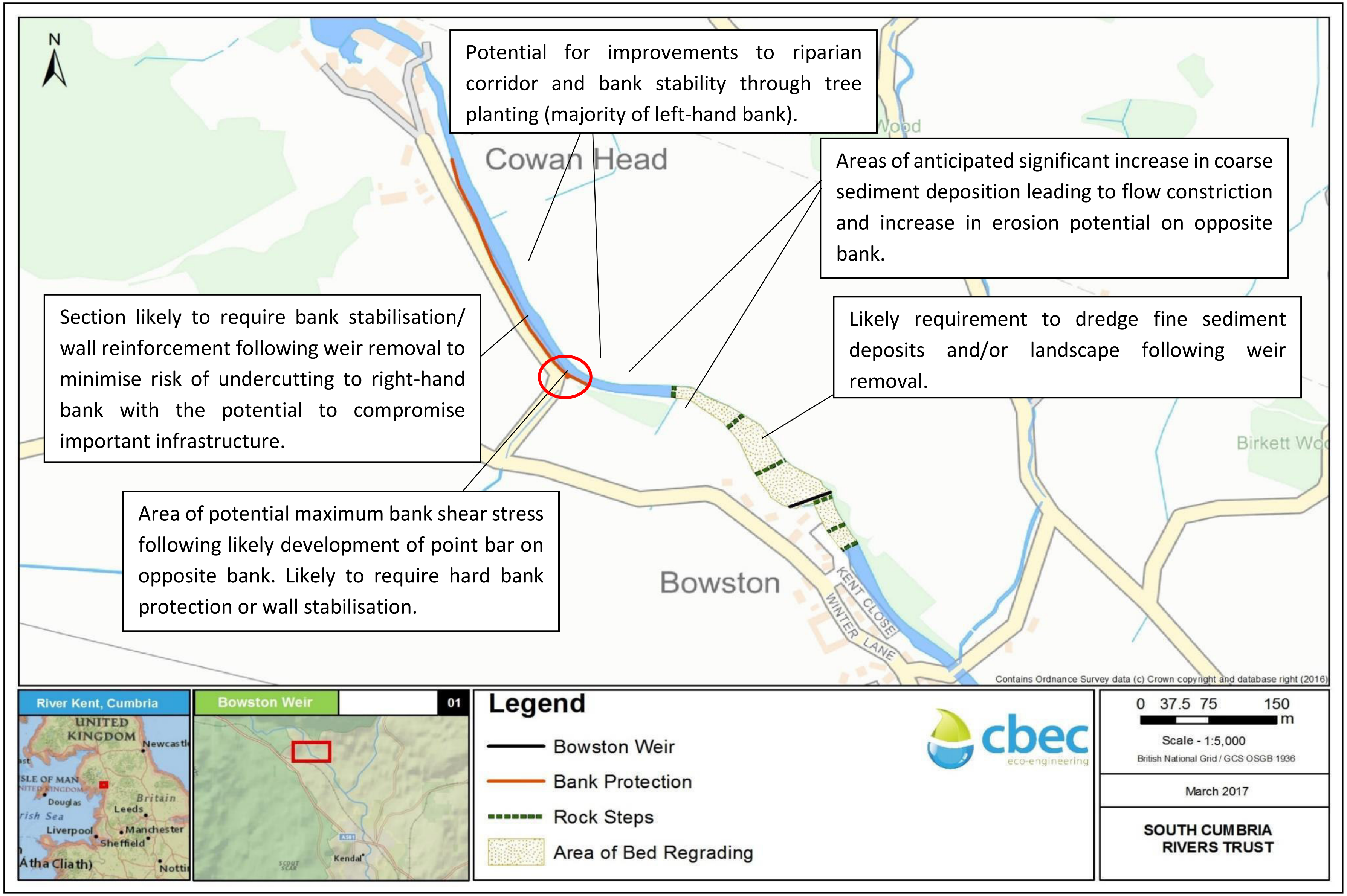

Figure A1: Bowston Weir: Mitigation associated with "full removal" option

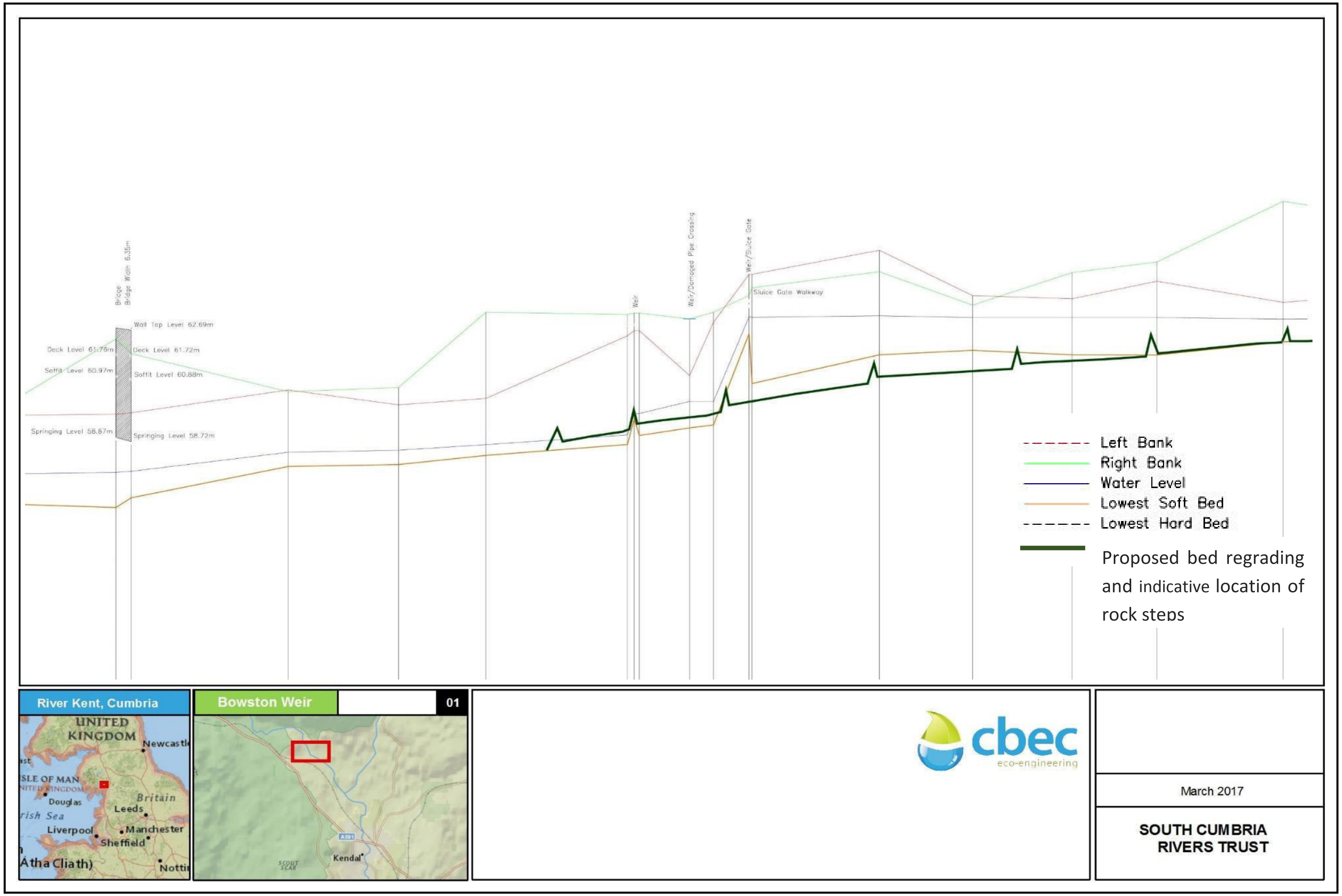

Figure A2: Bowston Weir: Indicative schematic of bed regrading and rock steps associated with "Full Removal" option (Adapted from EA topo survey maps)

Table A3: Indicative Costs – Full removal

Bowston Weir	Unit	Rate	Quantity	**Total**
Site Clearance - Access track & Site compound area	Ha	£5,000	0.17	£ 850
Tree removal	nr	£500	3	£ 1,500
Demolition of 30m wide masonry/stone weir +50%	cu.m	£15	375	£ 5,625
Imported rock (bank protection) Supply & Installation - Infilling area upstream of building & scour protection for 200m +25% minus Reuseable Rock (375cu.m)	cu.m	£60	625	£ 37,500
Imported Rock (rock steps in channel) Supply & Installation - 6No 1x2x30 steps	cu.m	£60	360	£ 21,600
Grass seeding	sq.m	£3	3100	£ 9,300
Tree planting 1 row	m	£50	100	£ 5,000
Miscellanous - reinstatement / fencing etc	m	£50	50	£ 2,500
Disposal of river deposits to licensed facility within 15km - 200x10x0.5	cu.m	£35	1000	£ 35,000
Reuse (double handling) rock/masonry	cu.m	£15	375	£ 5,625
SUB-TOTAL				**£ 124,500**
General Items (site set up, overheads, profit etc)	%	40		£ 49,800
Scheme Design and Project Management	%	10		£ 12,450
GRAND TOTAL:				**£ 186,750**

TABLE A4: APPRAISAL OF OPTIONS - WEIR MODIFICATION: INSTALLATION OF ROCK RAMP / WEIR INFILLING

<table>
<tr><th colspan="3">Weir Modification: Installation of rock ramp / weir infilling</th></tr>
<tr><td rowspan="2">Geomorphology</td><td>Benefits</td><td>Modification of the weir structure at Bowston is anticipated to comprise the localised reduction of the height of the weir crest (installation of a notch in the structure), supplemented by the creation of a rock ramp to ease fish passage (including coarse species and eel) through this structure.

The reduction of the weir crest height will have a corresponding effect of lowering water levels upstream of the structure. This will locally increase water surface slope upstream of the structure, contributing towards the reduction of the impoundment effect associated with the Bowston weir and contributing towards the renaturalisation of the flow regime through this section of the River Kent.

In addition, this localised acceleration of flows is expected to contribute towards the renaturalisation of sediment dynamics through this reach by increasing stream power and sediment transport capacity in the vicinity of the weir structure.

Sediment recruitment capacity will also likely increase in the section immediately upstream of the weir as the magnitude of flood events required to transport sediment over the weir decreases.

Importantly, the option to modify the structure entails a smaller risk of rapid geomorphic adjustment in the section upstream of the structure, minimising the risk of bank collapse and structure failure (as summarised the “full removal” option above).</td></tr>
<tr><td>Disbenefits</td><td>While this option will contribute towards the restoration of longitudinal connectivity through this reach of the River Kent, full renaturalisation of the flow and sediment regimes will be hindered by the partial maintenance of the barrier.

Should dewatering of the weir and localised dredging not be possible during the installation of the proposed modifications, fine sediment deposits located immediately upstream of the structure are likely to be rapidly mobilised following the localised increase in stream power, with potential negative impacts to the quality of downstream in-channel habitats.

Restoration of longitudinal connectivity is likely to be further hindered by limitations to the easement of fish passage. Should this option be progressed, the flow constriction at the weir ‘notch’ is likely to result in ‘supercritical’ flows which will limit upstream migration potential during high flows, particularly for non-salmonids. This option is, therefore, considered to offer only limited benefits in relation to existing conditions at the weir.

In addition, a full assessment of fish passability through the weir ‘notch’ and associated rock ramp structure is likely to require the implementation of a 2D hydraulic modelling approach.</td></tr>
<tr><td>Ecology</td><td>Benefits</td><td>Rock-ramps can provide suitable habitat for eel and lamprey passage, however an increase in migration of these species is dependent on design.</td></tr>
</table>

		Depending on construction and gradient of installation of rock ramps, they can encourage vegetation growth resulting in opportunities for macrophyte beds to develop. Gradient and climbing substrate of rock ramp can also increase fish passage. Opportunities for riparian zone planting to create heterogeneous bankside habitat. Bat and bird box installation on retained trees. Potential opportunity for kingfisher nest boxes. Artificial Otter holt installation. Compensatory tree planting for any removed. Bat and bird box installation on retained trees.
	Disbenefits	WFD assessment likely to be required (to be confirmed with discussion with EA). NE consents for designated sites likely to be required (to be confirmed upon discussion with NE). Arboricultural assessment of retained trees to establish root protection zones and any requirement for tree works. Similarly, trees should be removed outside the nesting bird season (march to September inclusive). Potential to open up higher reaches to colonisation by non-native aquatic flora and fauna. Potential for non-native invasive species to be present in the vicinity of the structure (need more data to fully analyse this fully). Biosecurity should be incorporated into the scheme and production of an invasive species management plans. Timing of works to avoid / mitigate for fish spawning and migrations. White-clawed Crayfish survey required and confirmed a mitigation plan and licence from NE would be needed. Riparian mammal survey required prior to works commencing if more than 12 months from date of the scoping survey. Pollution prevention measures to be implemented (e.g. overpumping/sediment traps). It is also advisable to monitor Dissolved Oxygen downstream of works to prevent fish stress and kills. Potential, temporary loss of some macro-invertebrate habitat during in-channel works. WFD assessment likely to be required (to be confirmed with discussion with EA). NE consents for designated sites likely to be required (to be confirmed upon discussion with NE).

		Potential for non-native invasive species to be present in the vicinity of the structure (need more data to fully analyse this). There is also potential to open up higher reaches to colonisation by non-native aquatic flora and fauna aiding their spread. Biosecurity should be incorporated into the scheme and possibly invasive species management plans. Timing of works to avoid / mitigate for fish spawning and migrations. High potential for White-clawed crayfish requiring survey, mitigation plan and licence from NE prior ot works on site. Vegetation removal required (TPOs need to be checked) – undertake removal outside nesting bird season (March to September inclusive). Bat potential of trees for removal requires assessment and potential mitigation. Riparian mammal survey required prior to works commencing if more than 12 months from date of the scoping survey. Pollution prevention measures to be implemented (e.g. overpumping/sediment traps). It is also advisable to monitor Dissolved Oxygen downstream of works to prevent fish stress and kills. Arboricultural assessment of retained trees to establish root protection zones and any requirement for tree works.
Engineering and Landscape	Benefits	Reduced tree loss. Stability of nearby structures may remain unchanged if the increased flow velocity does not influence them. Demolition works are reduced as is the required dredging of the channel to provide the required bed profile. Weir maintenance and other attributed activities may be removed if weir is sufficiently buried.
	Disbenefits	Limited scope to implement riparian planting post partial removal. Parish Boundary line runs down centre of river. Possible local issues requiring negotiations with 2 bodies; Strickland Ketel on west bank may reduce amenity due to the weir being modified and Strickland Roger on east bank. Dales Way public footpath on both sides of the bank. Potential footpath closures and re-instatement post operations. Site compound location, access issues and presence of plant and equipment. Noise levels and partially buried. A visualisation may be beneficial to demonstrate the visual intrusion. Visual impact through change in river’s appearance for residents upstream of the weir. Visual impact of proposed works. Due to the height of the weir it is possible the required imported rock requirement will increase due to raising the levels immediately downstream to meet the notch level. A cut and fill between upstream and downstream may be employed to avoid this issue.

Table A5: Indicative Costs - Weir Modification: Installation of rock ramp / weir infilling

Bowston Weir	Unit	Rate	Quantity	Totals	
Site Clearance - Access track & Site compound area	Ha	£5,000	0.17	£	850
Tree removal	nr	£500	3	£	1,500
Demolition of masonry/stone weir *25%	cu.m	£15	63	£	945
Imported rock (bank protection) Supply & Installation - Infilling area upstream of building & scour protection for 200m +25%	cu.m	£60	1000	£	60,000
Imported Rock (rock steps in channel) Supply & Installation - 6No 1x2x30 steps	cu.m	£60	360	£	21,600
Grass seeding	sq.m	£3	3100	£	9,300
Tree planting 1 row	m	£50	100	£	5,000
Miscellanous - reinstatement / fencing etc	m	£50	50	£	2,500
Disposal of river deposits to licensed facility within 15km	cu.m	£35	0	£	-
Reuse rock/masonry	cu.m	£17	0	£	-
SUB-TOTAL				**£**	**101,695**
General Items (site set up, overheads, profit etc)	%	40		£	40,678
Scheme Design and Project Management	%	10		£	10,170
GRAND TOTAL:				**£**	**152,543**
Risk	%	60		£	91,526
GRAND TOTAL INCLUDING DESIGN STAGE RISK:				**£**	**244,068**

TABLE A6: APPRAISAL OF OPTIONS: DO NOTHING

Do Nothing		
Geomorphology	Benefits	None
	Disbenefits	The maintenance of the current barrier to longitudinal connectivity is anticipated to contribute to the long-term degradation of in-channel habitats by hindering natural sediment dynamics. In addition, the maintenance of the structure will contribute to the continual degradation of fish habitats and populations by limiting habitat availability and migratory dynamics for non-salmonid species.
Ecology	Benefits	No anticipated change in existing baseline condition. Opportunities for enhancements include: Riparian zone planting to create heterogeneous bankside habitat. Bat and bird box installation on retained trees. Artificial Otter holt installation.
	Disbenefits	No anticipated change in existing baseline condition failure to meet WFD objectives.
Engineering and Landscape	Benefits	Retained weir lessens the impact of the water pipe downstream. No tree loss. No closure of footpath No impact on residents or footpath users. Stability of retaining walls and other nearby structures remains unchanged. Amenity of the site is unchanged.
	Disbenefits	Limited scope to implement riparian planting. Weir maintenance and other attributed activities continue. The risk and costs involved in maintaining the asset continue.

OPTION APPRAISAL MATRIX

APPRAISAL OVERVIEW

The options appraisal aims to pull together all the analysis undertaken within each stage described above. In order to appraise the options an Appraisal Matrix has been undertaken.

The Matrix Appraisal tool provides a method to evaluate each option on its ability to meet key project criteria. A simple numerical value is assigned to each of the key criteria dependent on how well each option meets the specific objective, and therefore it acts as a high-level scheme appraisal tool, which aims to assist in the future decision-making process. The criteria against which the options are assessed will include technical performance, future maintenance, and geomorphological, ecological and landscape/visual impacts. The Matrix tool enables the higher-level evaluation of alternative courses of action and aims to capture the key dimensions of the decision-making problem, involving human judgment and preferences based on the evidence collected.

Scoring Criteria

- 3 – significant positive impact (compared to existing)
- 2 – moderate positive impact
- 1 – minor positive impact
- 0 – neither positive or negative impact
- -1 – minor negative impact
- -2 – moderate negative impacts
- -3 – significant negative impact
- Hybrid classification – Denotes that anticipated impact is dependent on details of final design/ mitigation strategy or that additional assessments are required

BOWSTON WEIR – OPTIONS APPRAISAL MATRIX

Table A7: Summary of the MCA outcomes for each weir removal / modification option against each assessment criteria.

Bowston		**Option 1 - Full removal**	**Option 2 - Do Nothing**	**Option 3 - Weir Modification: Installation of rock ramp / weir infilling**
Assessment Criteria	Hydromorph condition / diversity (SSSI and WFD targets)	3 Potential for renaturalisation of flow and sediment regimes. Maximum benefit to easement of fish passage	-1 Potential for long-term degradation of sedimentary regime and in-channel habitats	1 Limited benefits to reinstatement of naturalised flow/ sediment regime and easement of fish passage
	Ecological condition / diversity (WFD targets etc)	2 Increased longitudinal ecological connectivity. Reinstatement of river bed morphology would be beneficial to diversity of aquatic ecology. Development of more diverse riparian vegetation. Potential to damage interest features of SAC, SSSI	0 No change in existing baseline anticipated	1 Limited increased longitudinal ecological connectivity (dependent on degree of barrier modification)
	Flood risk impact (locally and u/s d/s)	0/-1 Risk for increased sediment deposition downstream of existing structure. Risk can be minimised with appropriate mitigation measures, thus reducing the score to “0”	0 No change in existing baseline anticipated	0 No change in existing baseline anticipated

Bowston		Option 1 - Full removal	Option 2 - Do Nothing	Option 3 - Weir Modification: Installation of rock ramp / weir infilling
	Risk to Infrastructure	-1/-3 Risk to significant infrastructure requiring extensive engineering of restored reach, adding cost to the of this option and limiting its beneficial hydromorphological effects	0 No change in existing baseline anticipated	-1/ 0 Upstream impact to geomorphic processes unlikely to significantly change existing baseline conditions in proximity to important infrastructure.
	Engineering feasibility – construction	-2 Large amount of in channel works requiring access from both river banks	0 No change in existing baseline anticipated	-1 Similar amount of in channel works to removal with less or no offsite disposal. Possible slight increase in imported rock.
	Engineering feasibility – maintenance	2 Reduced maintenance compared to do nothing.	0 No change in existing baseline anticipated	-1/1 Reduced maintenance but parts of weir to remain which may pose a risk of collapse/ require maintenance. Dependant on design some maintenance may be required.
	Impacts to archaeology / historic environment	0 Despite currently known historic value or archaeological value.	0 No change in existing baseline anticipated	0 Despite currently known historic value or archaeological value.

Bowston		Option 1 - Full removal	Option 2 - Do Nothing	Option 3 - Weir Modification: Installation of rock ramp / weir infilling
	Contaminated sediment impact	0/-1 Desk based study of contaminated sediment sources could not rule out the presence of contaminated sediment. Mitigation for minimising/ avoiding potential release of contaminated sediment available but likely to significantly increase cost of measure.	0 No change in existing baseline anticipated	0/ -1 Potential for limited remobilisation of contaminated sediment. Mitigation measures available
	Landscape / visual impacts	-1 Public opinion is that the areas amenity will be degraded. Any removal or modification will need the buy in of the stakeholders. Subjectively it may be assumed that the amenity may be improved by introducing areas for the residents to appreciate the river such as benches and picnic areas situated in pleasing locations etc.	0 No change in existing baseline anticipated	-1 Public opinion is that the areas amenity will be degraded. Any removal or modification will need the buy in of the stakeholders. Subjectively it may be assumed that the amenity may be improved by introducing areas for the residents to appreciate the river such as benches and picnic areas situated in pleasing locations etc.
	Capital cost of scheme	-2	0	-1

Bowston		**Option 1 - Full removal**	**Option 2 - Do Nothing**	**Option 3 - Weir Modification: Installation of rock ramp / weir infilling**
		High cost. Anticipated to be in the region of approximately £300,000.00 Approximate estimating method used working from an outline bill of quantities. Adjusted historic cost method shows similar cost	No change in existing baseline anticipated	High cost. Anticipated to be in the region of approximately £250,000.00 Approximate estimating method used working from an outline bill of quantities.
	Maintenance cost	2 No further weir maintenance required. Minimal future maintenance required. Inspection schedule required due to proximity of residential buildings on in channel retaining walls	0 No change in existing baseline anticipated	1 Minimal further weir maintenance required as severity of weir failure is significantly reduced. Minimal future maintenance required. Inspection schedule required due to proximity of residential buildings on in channel retaining walls
TOTAL		**1/-3** (depending on final details of proposed design and subsequent assessments)	**-1**	**1/-4** (depending on final details of proposed design and subsequent assessments)

APPENDIX B

ECOLOGICAL ASSESSMENT

B1.1 Protected Species

Otter

The European Otter *Lutra lutra* is a European Protected Species (EPS) protected under the Conservation of Habitats and Species Regulations 2010 (as amended), making it an offence to:

- deliberately capture, injure or kill an Otter
- deliberately disturb an Otter such as to affect local populations or breeding success
- damage or destroy an Otter holt, possess or transport an Otter or any part of an Otter,
- sell or exchange an Otter

Otters also receive protection under the Wildlife and Countryside Act 1981 (as amended), this makes it an offence to:

- intentionally or recklessly disturb any Otter whilst within a holt
- intentionally or recklessly obstruct access to a holt

The Otter survey method was based on the standard works of RSPB (1994) and Chanin (2003). This involved examining watercourse banks and prominent features for spraints (droppings) and footprints, where access allowed. A search was also made for possible holt and couch (resting) sites, where access allowed. Otters are extremely difficult to observe, and this method provides the most effective and efficient means of investigating presence or absence.

Breeding Birds

All wild birds are protected under the Wildlife and Countryside Act 1981 (as amended). This makes it an offence to:

- intentionally take, damage or destroy the nest of any wild bird whilst it is in use or being built
- take, destroy or possess the egg of any wild bird

Additionally, certain species receive additional protection under Schedule 1, which makes it an offence to intentionally or recklessly disturb birds and also their young at, on or near an active nest.

A thorough survey of existing structures and vegetation for nest sites was made. An assessment of the potential of the habitats present to support breeding birds was also made.

Badger

The main legislation protecting Badgers *meles meles* in England and Wales is the Protection of Badgers Act 1992. Under the 1992 Act it is an offence to:

- wilfully kill, injure, take or attempt to kill, injure or take a Badger
- possess a dead badger or any part of a Badger
- cruelly ill-treat a Badger
- use badger tongs in the course of killing, taking or attempting to kill a Badger
- dig for a Badger
- sell or offer for sale or control any live Badger
- mark, tag or ring a Badger
- It is also an offence to interfere with a Badger sett by:
- damaging a sett or any part thereof
- destroying a sett

- obstructing access to a sett
- causing a dog to enter a sett
- disturbing a badger while occupying a sett

The 1992 Act defines a Badger sett as: "any structure or place which displays signs indicating current use by a Badger".

The survey site was searched for signs of the presence of Badgers including setts, comprising of either single isolated holes or a series of holes, likely to be interconnected underground. Setts were classified in the field as:

- Main - Several holes with large spoil heaps and obvious paths emanating from and between sett entrances.
- Annexe - Normally less than 150m from main sett, comprising several holes. May not be in use all the time, even if main sett is very active.
- Subsidiary - Usually at least 50m from main sett with no obvious paths connecting to other setts. May only be used intermittently.
- Outlier - Little spoil outside holes. No obvious paths connecting to other setts and only used sporadically. May be used by foxes and rabbits.

In addition to the presence of active setts, the following signs of activity were also searched for: latrines, footprints, hairs, snuffle holes and evidence of feeding activity and well-worn paths through vegetation. Badgers will use a number of setts throughout their territory at different times of year; any large holes with the potential to be used by Badgers, but not showing obvious signs of recent activity, were therefore also recorded.

Great Crested Newt

The Great Crested Newt *Triturus cristatus* is an EPS under the Conservation of Habitats and Species Regulations 2010 (as amended). This makes it an offence to:

- kill, capture or disturb a Great Crested Newt
- take or destroy the eggs of a Great Crested Newt
- damage or destroy the breeding or resting places of Great Crested Newt

It also receives additional protection under the Wildlife and Countryside Act 1981 (as amended) making it illegal to possess or control any Great Crested Newt, living or dead.

Habitat features with the potential to support this species were recorded. Such features can include: ponds with habitat suitable for breeding newts within 500m of the proposed works; piles of logs, stones or other debris; cracks in the ground; stone or rubble covered ground, and any other features that could support newts.

Where ponds identified within 500m could be accessed, an assessment was made as to whether the aquatic habitat had the potential to support Great Crested Newts using the Habitat Suitability Index methodology (HSI; Oldham *et al*. 2000). The HSI is a scoring method which is a means of evaluating habitat quality for Great Crested Newts using ten suitability indices. The HSI provides a numerical index between 0 and 1, where 0 indicates unsuitable habitat and 1 indicates optimal habitat.

Reptiles and Amphibians

Legal protection varies considerably for different species. Smooth Snake *Coronella austriaca*, Sand Lizard *Lacerta agilis* and Natterjack Toads *Epidalea calamita* are European Protected Species receiving the same protection as Great Crested Newt. Under the Wildlife and Countryside Act 1981 (as amended) Adder *Viperus berus*, Grass Snake *Natrix natrix*, Common Lizard *Zootoca vivipara* and Slow Worm *Anguis fragilis* are protected from intentional killing or injuring. Additionally, Common Frogs *Rana temporaria*, Common Toads *Bufo bufo* and other newt species are prohibited from sale.

An assessment of the habitat suitability of the area for reptiles was made, involving inspection of the site for key habitat features such as refuges, open sandy areas and interfaces between different habitat types (English Nature, 2004 and Froglife, 1999).

Water Vole

The Water Vole *Arvicola amphibius* is protected under the Wildlife and Countryside Act 1981 (as amended). This makes it an offence to:

- intentionally kill, injure or capture a Water Vole
- possess or control a Water Vole, living or dead, or any part of a Water Vole
- intentionally or recklessly damage, destroy or obstruct access to any place of shelter, or disturb a Water Vole within such a place
- sell or offer for sale a Water Vole living or dead, or part of a Water Vole

The standard Environmental Assessment field survey method outlined in Strachan *et al*. (2011) and Dean *et al*. (2016) was used. Field signs were searched for along watercourses within the survey area, and an assessment made of the suitability of the habitat for Water Voles. The most important, diagnostic field sign for Water Voles is the presence of latrine sites. These are locations repeatedly used by Water Voles to deposit their droppings, often in prominent locations along the bank. Other field signs include the presence of burrows, feeding sites and footprints. Although these other signs provide indications of presence and are useful supporting evidence to latrines, they are of limited value on their own.

Bats

All UK bat species are EPS under the Conservation of Habitats and Species Regulation 2010 (as amended). It is an offence to:

- deliberately kill, injure or capture any bat
- intentionally or recklessly disturb a bat, or deliberately disturb a group of bats
- damage or destroy, or intentionally or recklessly obstruct access to, a bat roosting place
- possess, or sell (living or dead) any bat or part of a bat

Structures or trees likely to be impacted by the proposed works were inspected to determine their potential value for roosting bats, as specified in the Bat Conservation Trust (BCT) Bat Surveys - Good Practice Guidelines (Collins, 2016). This includes looking for cracks, crevices, loose bark, holes and splits and for evidence indicating bat presence including dark stains running below holes or cracks, bat droppings, odours, or scratch marks.

Red Squirrel

The Red Squirrel *Sciurus vulgaris* is listed on Appendix 3 of the Bern Convention and is protected under Schedules 5 and 6 of the Wildlife and Countryside Act, 1981 (as amended). Under the Wildlife and Countryside Act it is a criminal offence to:

- intentionally kill, injure or take (capture) a red squirrel
- intentionally or recklessly damage or destroy any structure or place a red squirrel uses for shelter or protection or disturb a red squirrel while it is occupying such a place
- possess a dead or live wild red squirrel unless you can show that the animal was taken legally
- sell, or offer for sale, a wild red squirrel or any part of a wild red squirrel
- set in place a trap, snare, electrical device for killing or stunning or any poisonous, poisoned or stupefying substance; use a decoy, gas or smoke, bows or cross bows, explosives, automatic weapons or mechanically propelled vehicles which are of such a nature and so placed as to be calculated to cause bodily injury to a red squirrel.

White-clawed Crayfish

White-clawed Crayfish *Austropotamobius pallipes* are protected under Schedule 5 of the Wildlife and Countryside Act 1981 (as amended), therefore it is an offence to:

- Intentionally or deliberately capture or kill, or intentionally injure White-clawed Crayfish.
- Possess a White-clawed Crayfish, or any part of it, unless acquired lawfully.
- Sell, exchange or transport or offer for sale a White-clawed Crayfish or any part of it.

In addition, the species is protected internationally under the Conservation of Habitats and Species Regulations 2010 which implements the European Union's 'Habitats Directive' (Council Directive 92/43/EEC (a) on the Conservation of Natural Habitats and of Wild Fauna and Flora). In Great Britain the White-clawed Crayfish is listed on Annexes II and V of this EC Directive. The species is also listed under Appendix III of the Bern Convention.

White-clawed Crayfish is a UK BAP priority species and a Species of Principle Importance under Section 41 of the NERC Act 2006. It is government policy that local authorities consider the conservation status of such species when determining planning applications.

Invasive Non-native Species

Schedule 9 of the Wildlife and Countryside Act 1981 (as amended) lists 62 plant species, or groups of plants, and 69 animal species for which it is an offence to release or cause to spread in the wild. Of particular note are Japanese Knotweed *Fallopia japonica*, Himalayan Balsam *Impatiens glandulifera*, Giant Hogweed *Heracleum mantegazzanum* and Signal Crayfish *Pacifastacus leniusculus*.

Any invasive non-native species observed during the survey were recorded. For stand-forming plant species, the extents of such stands were noted.

B 1.2 Ecology - Phase 1 Habitats

Table B1: Phase 1 Habitat Codes

Phase 1 Code	Description
A1.1.1	Woodland - Broadleaved - Semi-natural
A1.1.2	Woodland - Broadleaved - Plantation
B3.2	Grassland and Marsh - Calcareous - Semi-improved
B4	Grassland and Marsh - Improved Grassland
B5	Grassland and Marsh – Marshy Grassland
B6	Grassland and Marsh – Poor Semi-improved
G2.1	Open Water - Running Water - Eutrophic
J1.2	Miscellaneous - Cultivated / Disturbed land - Arable
J1.2	Miscellaneous - Cultivated / Disturbed land – Amenity Grassland
J2.5	Miscellaneous - Boundaries - Wall
J3.6	Miscellaneous - Built-up Areas - Buildings
J4	Miscellaneous - Bare Ground
J2.1.2	Miscellaneous - Boundaries – Hedges - Intact – species poor
J2.2.2	Miscellaneous - Boundaries – Hedges – Defunct - species poor
J2.3.2	Miscellaneous - Boundaries – Hedges – with trees – species poor

B1.3 Ecology – Photographic Plates Bowston Weir

Photograph		Details
1		Bowston Weir from Right bank (downstream)
2		Bowston Weir from left bank (downstream)

3		View of Bowston weir form upstream
4		View of mature trees on left bank which may require removal

5		Small pond adjacent to weir on left bank
6		Upstream extent
7		

8		Downstream extent (looking upstream from road bridge)
9		Downstream view from roadbridge

10		Upstream left bank landscape character. Photograph showing ephemeral pools

APPENDIX C

TOPOGRAPHIC/ BATHYMETRIC SURVEY METHODOLOGY

TOPOGRAPHIC/ BATHYMETRIC SURVEY METHODOLOGY

RTK GPS (*Leica GS14 and GS08*) and *Leica GS14 Base Station* equipment was used to capture wadeable/ accessible areas of the study reach. Where possible, the RTK-GPS rovers received corrections from the *GS14 Base Station* (i.e. rather than through SmartNet) improving accuracy of the survey. In areas where tree canopy and/ or other obstacles restricted RTK-GPS utility, survey data was collected using a *Trimble S6 Total Station*, with back-sight checks performed on each station setup to monitor survey accuracy. The Total Station was also used to collect reflector-less points where additional information around the weir(s), bridge and other related structures, was required, but was not possible to access safely on foot.

To collect data within unwadeable areas of channel (i.e. immediately upstream of Bowston weir), a bathymetric surveying was conducted using a *Hydrone Remote Control Vehicle (RCV)* mounted with a Sonarmite and prism. This was tracked by the Total Station, which was positioned at a safe location on the river bank with clear line of sight through the area being surveyed. The RCV is a large and robust craft that allowed for a more stable position in the water, minimising potential error caused by rippled/ waved water, and eliminating the requirement for extensive post processing. The craft also allowed for a greater density of data point collection.

Where rod-based surveying was possible, cross-sections through the channel were surveyed at 5 – 10m centres, to ensure sufficient accuracy in the resulting existing conditions DEM. In the wider river corridor and floodplain areas, a grid-based methodology was used, to provide optimal coverage of the site and to avoid triangulation-related errors in the subsequent surface modelling stage.

Additional data was collected at specific areas of more complex morphology/ topography (e.g. structures, bar features) and along discrete linear features (e.g. top of bank). This combined strategy ensured efficient triangulation and contouring within post-processing software, and ultimately delivered a more accurate Digital Elevation Model (DEM) of the site.

All points were collected in the OSGB36 (15) coordinate system geoid model, following the latest ordnance surveyed guidelines, in order to permit potential subsequent resurveys. Following post-processing, a Digital Elevation Model (DEM) was produced, from which a full topographic map was developed in ArcMap GIS software. The resulting 3D surfaces provided the physical boundary conditions throughout the study reach for the subsequent 1D and sediment transport modelling, and detailed design.

Figure C1. Hydrone RCV in action (left)

APPENDIX D

CULTURAL HERITAGE ASSESSMENT

(BOTH BOWSTON AND HELSINGTON WEIRS INCLUDED)

FAS HERITAGE

Bowston and Helsington Weirs

Kendal

Cumbria

Heritage Assessment

Draft Report

Aptil 2017

HERITAGE ASSESSMENT

BOWSTON AND HELSINGTON WEIRS

KENDAL

CUMBRIA

SITE CODE: RKW17

REPORT CODE: FAS2017 691 RKW672

NGR: SD 4971 9682 and SD 5131 9052

DRAFT REPORT

April 2017

v0.1

FAS HERITAGE
Unit 8 Fulford Business Centre
35 Hospital Fields Road
York
YO10 4DZ
Tel (01904) 652000
Fax (01904) 749014
mail@fas-heritage.co.uk
www.fas-heritage.co.uk

CLIENT	JBA CONSULTING Epsom House Chase Park Redhouse Interchange Doncaster DN6 7FE
REPORT PREPARED BY	Nicola Toop BA MA PhD MCIfA
REPORT REVIEWED BY	Cecily Spall BSc MA MCIfA

REPORT AUTHORISED BY	Justin Garner-Lahire BA

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Summary

This document presents the results of a Heritage Assessment (HA), prepared to inform options for river restoration at two weir sites on the River Kent, at Bowston and Helsington. The assessment was undertaken by FAS Heritage on behalf of JBA Consulting in March and April 2017.

The aim of the HA is set out the heritage significance of each of the weirs and their immediate setting, and to assess the impact that the proposed options would have on that significance. Recommendations have been set out for the necessary mitigation that would be required for each of the proposed options (full removal, partial removal or modification, do nothing).

Bowston Weir

Bowston weir lies at Bowston Bridge, *c*.1 mile north of Burneside and *c*.6 miles north of Kendal (NGR: SD 4971 9682). The weir is a concrete structure with two fish passes, which lies to the rear of domestic gardens along Kent Close to the southwest, and adjacent to open pasture to the northeast. The weir was constructed in the late 19th century to provide water power for Bowston Mill, part of a paper-making industry along the River Kent. Bowston Mill was established to prepare rope and rags for the paper mills at Cowan Head and Burneside; the three were connected by a tramway. Associated mill buildings were removed following closure of the mill in the 1960s, and residential development has now removed all vestiges of the former structures.

The weir is not designated, but has some historic significance as a legible element of the local paper industry, which still forms part of the local economy today. Retention *in situ* would allow the historic significance of the weir to be retained. If the weir is to be modified or removed, a photographic record would be recommended, to preserve by record the form of the structure itself, and its relationship with structural elements in the immediate area.

Helsington Weir

Helsington weir is situated to the south of Kendal, west of a meander of the River Kent. The weir lies north of Helsington Mills and west of Watercrook Farm, in an area that is predominantly pasture (NGR: SD 5131 9052). Heslington weir lies adjacent to the Watercrook Roman fort (a Scheduled Monument), in an area with high potential for remains of Roman and later date.

The weir dates to the 19th century, and was constructed by architect Francis Webster to increase water power to mills at Heslington Laithes. The mill complex may have had medieval origins, but the surviving elements date to the 19th century, when the two mills were employed in the working of marble, and the grinding of snuff. The latter is now a Grade II Listed Building. The weir has some heritage significance as a surviving 19th-century industrial feature, but this significance is enhanced by group value; the weir and the leat that it supplies form part of the setting of the Listed mill building, and allow the mill complex as a whole to be appreciated (albeit largely masked by modern road construction business).

Full removal would see loss of the 19th-century structure, and would have an impact on the setting of the Grade II Listed Building, by eroding legibility of the historic mill complex. Lowering the crest (removal of concrete cap) or creating a notch would preserve the legibility of the mill layout, but

would also potentially see de-watering of the mill leat, which again would have an impact on setting. It is recommended that the local Conservation Officer be consulted regarding the scheme. A pre-intervention photographic record of the weir would be recommended to record the weir in its current condition. [need to check curtilage/Listed Building Consent requirements]

Groundworks associated with weir removal, bank stabilisation, access tracks or site compounds all have the potential to affect below-ground remains in the area. The area has high archaeological potential and an appropriate scheme of archaeological mitigation should be put in place to preserve by record any hitherto unrecorded archaeological remains that would be affected. Works to the left bank may require Scheduled Monument Consent; Historic England should be contacted early on in the process in order to agree any archaeological requirements.

Acknowledgements

FAS Heritage would like to thank Mark Brennand (Cumbria County Council) and Kimberley Jennings (JBA Consulting) for assistance during the preparation of this report.

1.0 INTRODUCTION

This document presents the results of a Heritage Assessment (HA), prepared to inform options for river restoration at two weir sites at Bowston and Helsington on the River Kent, near Kendal, Cumbria. The assessment was undertaken by FAS Heritage on behalf of JBA Consulting in March and April 2017.

1.1 LOCATION AND LAND USE

Bowston weir lies at Bowston Bridge, *c*.1 mile north of Burneside and *c*.6 miles north of Kendal (NGR: SD 4971 9682). The weir is a concrete structure with two fish passes, which lies to the rear of domestic gardens along Kent Close to the southwest, and adjacent to open pasture to the northeast (Figure 1; Plate 1 and 2).

Helsington weir is situated to the south of Kendal, west of a meander of the River Kent. The weir lies north of Helsington Mills and west of Watercrook Farm, in an area that is predominantly pasture (NGR: SD 5131 9052)(see Figure 1; Plate 3 and 4).

1.2 AIMS AND OBJECTIVES

The aim of this HA is set out the heritage significance of each of the weirs and their immediate setting, and to inform the impact that proposed options would have on that significance. This is in line with Paragraph 128 of the National Planning Policy Framework which states:

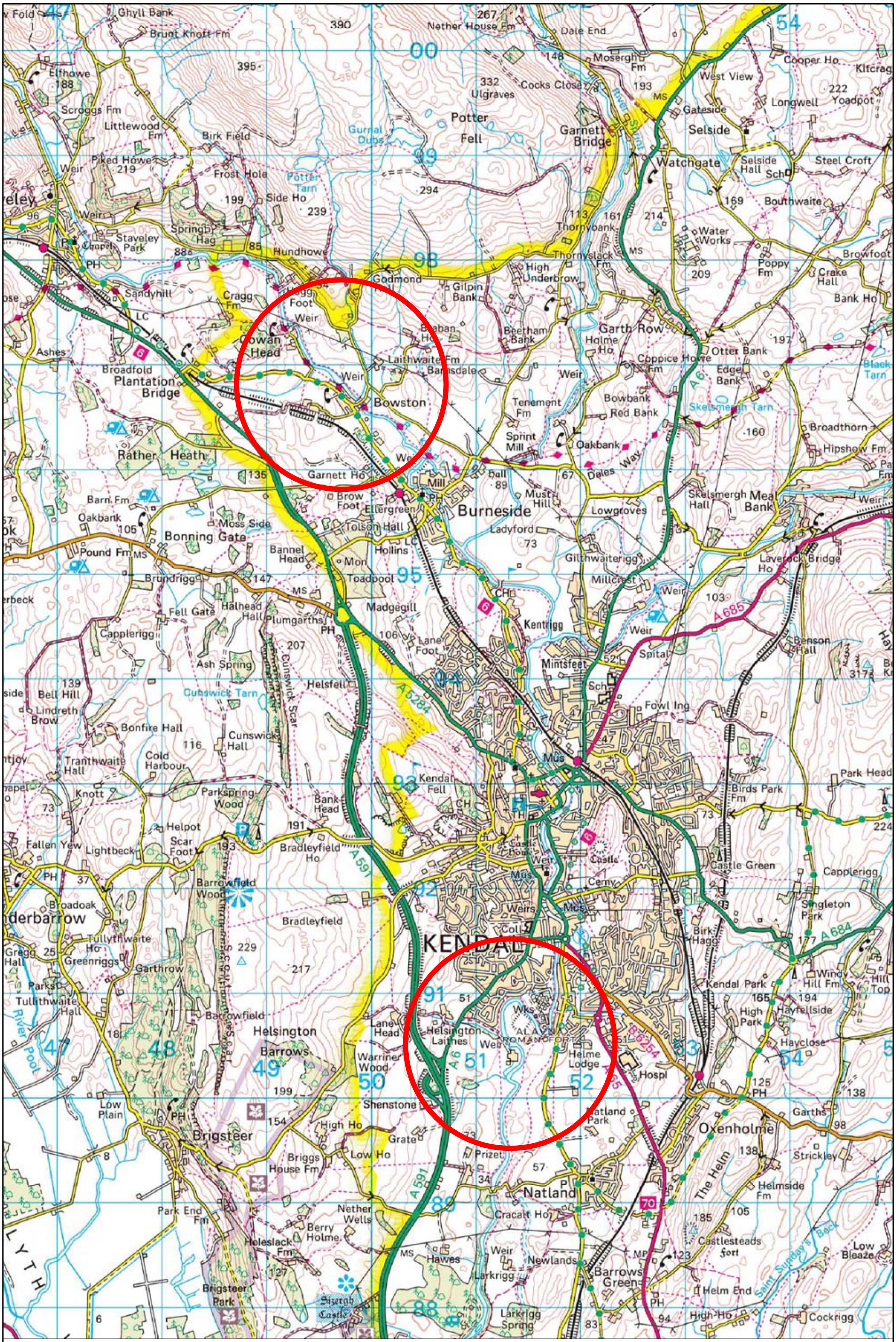
> 'In determining applications, local planning authorities should require an applicant to describe the significance of any heritage assets affected, including any contribution made by their setting. The level of detail should be proportionate to the assets' importance and no more than is sufficient to understand the potential impact of the proposal on their significance.'

Plate 1 Aerial view of Bowston © 2016 Infoterra Ltd & Bluesky

Plate 2 Bowston weir, looking southwest

Plate 3 Aerial view of Helsington © 2016 Infoterra Ltd & Bluesky

Plate 4 Helsington weir, looking west



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Location of weirs and study areas	Scale 1:50000		Figure 1

The significance of a heritage asset is defined as:

> 'The value of a heritage asset to this and future generations because of its heritage interest. That interest may be archaeological, architectural, artistic or historic. Significance derives not only from a heritage asset's physical presence, but also from its setting.' (NPPF Glossary)

1.3 LEGAL FRAMEWORKS AND PLANNING GUIDANCE

1.3.1 Legal frameworks

The assessment aims to address the requirements of relevant legal frameworks and planning policy pertinent to the site and its proposed development. The following apply:

National and Regional Planning Framework

- Town and Country Planning (Listed Buildings and Conservation Areas) Act, 1990
- National Planning Policy Framework (DCLG 2012)
- Ancient Monuments and Archaeological Areas Act, 1979

Guidance

- National Planning Policy Guidance (NPPG)
- Historic England, 2015. Good Practice Advice in Planning Note 3: The Setting of Heritage Assets

2.0 RESEARCH METHODOLOGY

The assessment has been prepared with reference to the Chartered Institute for Archaeologists (2014) *Standard and Guidance for Historic Environment Desk-Based Assessment* and also takes into account Historic England, 2015. *Good Practice Advice in Planning Note 3: The Setting of Heritage Assets*.

2.1 DESK-BASED RESEARCH

2.1.1 Sources

The following were consulted as part of the process:

- Cumbria Historic Environment Record
- Historic England Archive
- Historic maps
- Published and unpublished sources

2.1.2 Study area

For the purposes of the appraisal, a 1km radius study area was established around each weir (see Figure 1).

2.1.3 Gazetteer

Each component or feature of the historic landscape identified within the study area (through desk-based research or on the ground) has been allocated a unique number, and plotted onto Ordnance Survey mapping. Gazetteer entries for each of the features are included as Appendix A (Bowston) and Appendix B (Helsington), and are cross-referenced throughout the text with the prefix BHA for Bowston and HHA for Helsington.

2.1.4 Site visit

Site visits were undertaken on 29th March 2017. Due to water levels it was not possible to make a detailed assessment of the fabric of the weirs.

2.2 ASSESSMENT OF SIGNIFICANCE AND IMPACT

2.2.1 Assessment of significance

Heritage significance has been assessed taking into account:

- archaeological interest
- architectural interest
- artistic interest
- historic interest

Contribution of setting to the significance of the heritage asset

Consideration is also given to the level to which setting contributes to the significance. Attributes of setting which contribute to the significance of each heritage asset have been identified, drawn from the check-list provided by Historic England (2015).

The following grades of significance have been employed:

- **Exceptional significance** - resources which can be demonstrated to have international or national significance, special relevance to British history or culture, and/or are of extraordinary or unique archaeological, architectural, artistic or historic merit. This will include World Heritage Sites, Scheduled Ancient Monuments (or those monuments which otherwise meet scheduling criteria) all Listed Buildings Grades I and II*, Registered Historic Parks and Gardens grades I and II*, and Registered Historic Battlefields;
- **Considerable significance** - resources with importance within a national or regional context, due to special archaeological, architectural, artistic or historic interest. This category will include Conservation Areas, Grade II Listed Buildings and Registered Parks and Gardens Grade II;

- **Moderate significance** - resources of local importance. This might include heritage assets with archaeological, architectural, historic or artistic interest, but which do not meet the criteria for designation;
- **Some significance** - resources of limited local importance, due to their high frequency, lack of provenance or limited survival. This might include resources of local significance that have been partially destroyed by past land use, whether by agricultural activity or built development;
- **Unknown significance** - resources of uncertain importance based upon their type or condition.

2.2.2 Assessment of impact

The impact of development upon the significance of a heritage asset may be adverse or beneficial. The significance of a heritage asset might be affected by direct physical impact, including destruction, demolition and alteration, but may also be affected by changes to its setting. This could include changes to the historic character of an area, alterations to views to and from a site, accidental damage from construction work, temporary loss of amenities (largely arising during development work and including air and noise pollution, visual intrusion, increased traffic, changes in the character of a landscape or townscape).

Categories of impact have been graded thus:

- **Substantial** - elements which contribute to the significance of the heritage asset, including its setting, are substantially harmed or lost;
- **Moderate** - elements which contribute to the significance of the heritage asset, including its setting, are harmed;
- **Slight** - there is change to elements which contribute to the significance of the heritage asset or its setting, but that harm is minimal;
- **Beneficial** - those elements which contribute to the significance of the heritage asset, including its setting, are enhanced or better revealed;
- **No change** - no change.

Following consideration of the value of the heritage asset, the attributes which contribute to its significance and the likely magnitude of the impact of development on those attributes, an assessment can be made of the overall effect of the proposed development on each asset and on the heritage resource as a whole. This is broadly based on the assumption that the most significant effect will result in circumstances where the very highest impact occurs to very important remains.

3.0 BOWSTON WEIR

3.1 BASELINE CONDITIONS

3.1.1 Designated heritage assets

Listed Buildings

Three designated heritage assets were identified within the study area (Figure 2). Bowston Bridge, which lies *c.*250m downstream of the weir, is a Grade II Listed Building (BHA 1; NHLE 1289250). Although close to the weir site, the bridge is not intervisible with the weir, nor does the weir contribute to its historic setting, and so no impact is anticipated. [to check re scour]

Also within the 1km study area are the Grade II Listed summerhouse north of Whitefoot (BHA 2; NHLE 1336089) and Laithwaite Farmhouse (BHA 3; NHLE 1289228). These would not be affected by any of the proposed options.

No further designated heritage assets were identified within the study area.

3.1.2 Non-designated heritage assets

A search of the Cumbria Historic Environment Record (CHER) identified a further 13 non-designated heritage assets within the study area, primarily of 19th-century date and relating to a series of mills established along the river in this location (Figure 3).

3.1.3 Events

One event was recorded in the area, being a desk-based assessment for an overhead line between Kendal and Staveley (Gerry Martin Associates 2015).

3.2 ARCHAEOLOGICAL AND HISTORICAL BACKGROUND

No evidence for activity pre-dating the medieval period was identified within the study area.

3.2.1 Medieval to post-medieval

Much of the evidence for medieval and post-medieval activity within this immediate area relies on documentary evidence and historical accounts, including those of Thomas Machell, rector of Kirkby Thore in the mid-17th century. A chapel is postulated to have existed in Chapeltree Wood, to the north of the weir, but no further evidence for this is recorded (BHA 4). At Cowan Head, to the northeast, a pre-17th-century lodge and deer park are recorded by Machell (BHA 5 and 6). To the southeast, a 16th-century, post-medieval date is recorded for Garnett House, Burnside (BHA 7).

Evidence for extraction and industry of post-medieval date is recorded in the immediate landscape, in the form of a gravel pit to the west (BHA 8), and two potash kilns to the north, close to Cowan Head (BHA 11) and (BHA 12).

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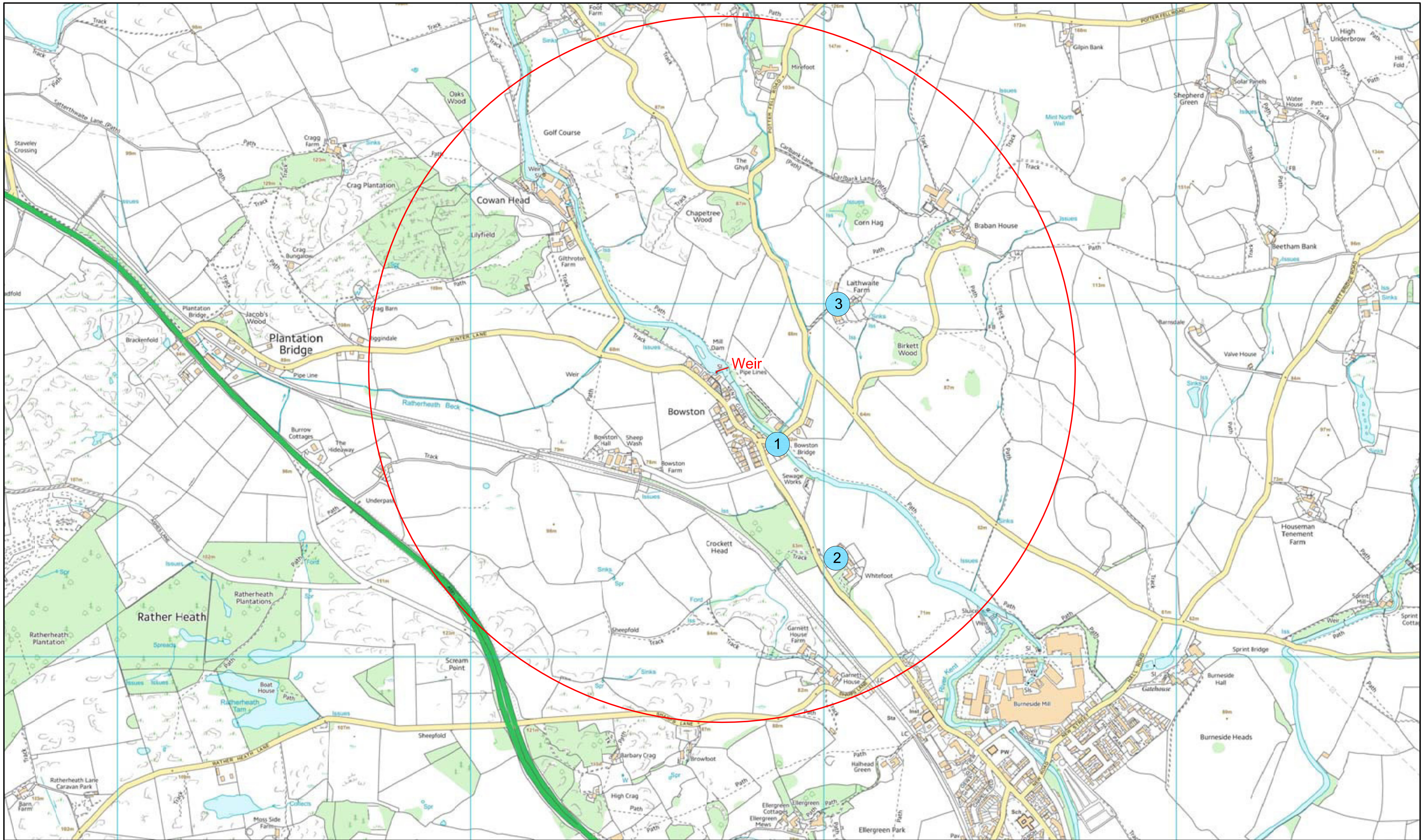
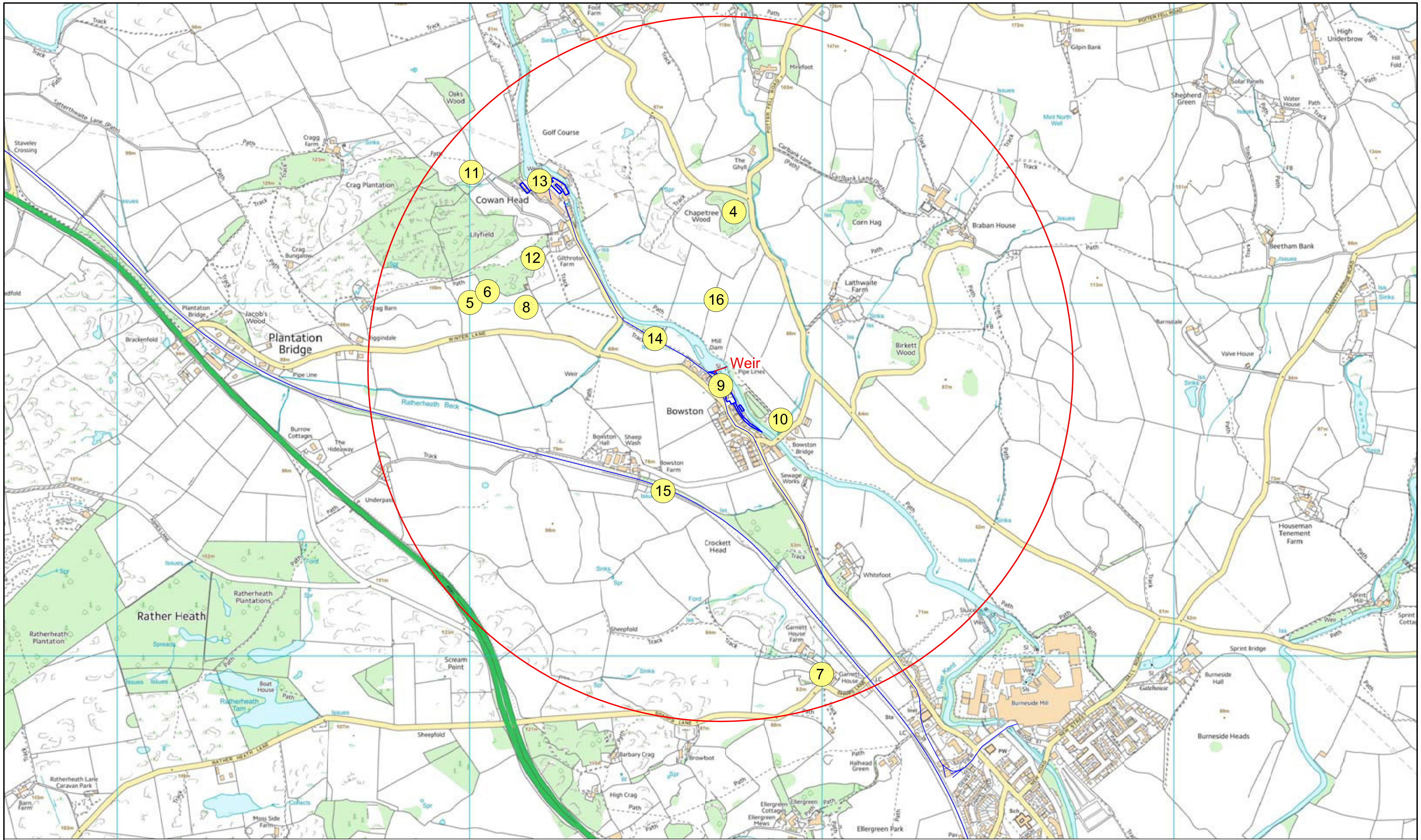


FAS HERITAGE

Bowston - designated heritage assets

Scale 1:15000

Figure 2



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FAS HERITAGE

Bowston - non-designated heritage assets

Scale 1:15000

Figure 3

Bowston Old Mill, a possible precursor to Bowston Paper Mill, is recorded from Somervell's description close to the weir site, and the CHER records a possible 16th-century reference to a walkmill in this location (BHA 10). No mill is recorded on the maps of 1770, suggesting that it did not continue in use into the 18th century.

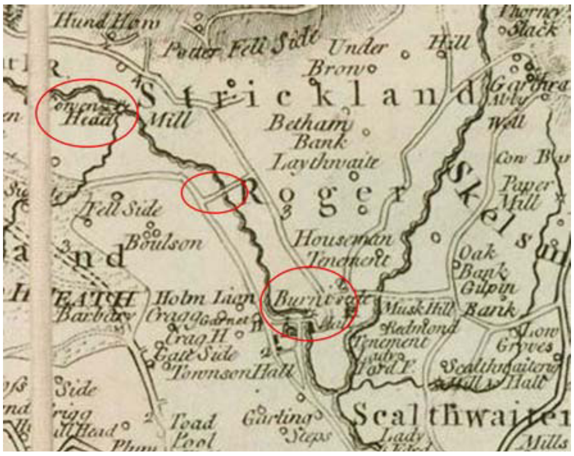


Plate 5 Extract from Jeffrey's 1770 map of Westmoreland, showing Cowan Head, Bowston Bridge and Burneside

3.2.2 18th to 19th century

Burneside and Cowan Head Mills

Jeffrey's map of 1770 show mills at Cowan Head (BHA 13) and Burneside (Plate 5). Cowan Head Mill (BHA 13) was documented as a fulling mill in 1735; in 1746 a local publisher, Thomas Ashburner, converted it for paper-making. Burneside Mill, to the south of the study area, was the site of a manorial mill; by the 18th century, a sharp edge or sickle mill and a fulling mill occupied the same mill race. Burneside was subsequently converted for use as a corn mill by John Wakefield, and included a preparation plant for a newly built cotton mill in 1770. The latter business suffered due to competition from the Lancashire cotton mills, and proved uneconomic (Hutt, D. cited on http://www.cumbria-industries.org.uk), and in 1828, the cotton mill was leased from the Wakefields by Hudson and Foster, who installed a second-hand paper machine at Burnside, and at Cowan Head.

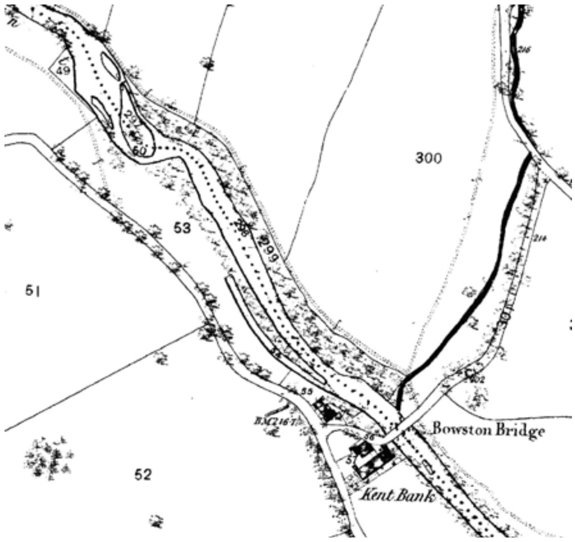


Plate 6 Extract from Ordnance Survey, 1862

No mill is depicted at Bowston at this date; the 1862 Ordnance Survey edition shows no structures associated with milling, although the leat is shown, either indicating that it had been partially constructed, or represents a survival of an earlier mill at the site (Plate 6).

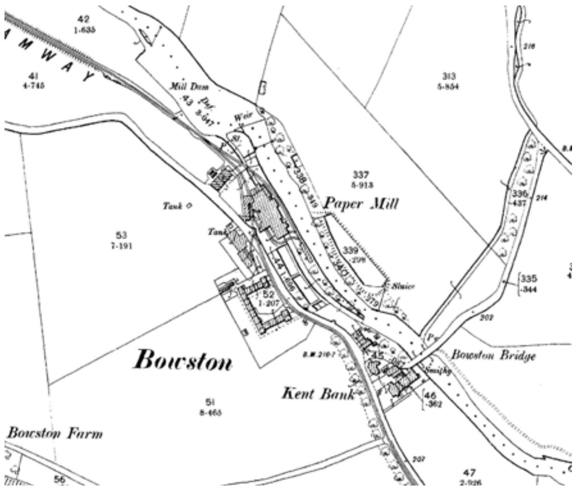


Plate 7 Extract from Ordnance Survey, 1898

James Cropper's Paper Mills

In the mid-19th century, James Cropper established a paper industry on this stretch of the River Kent; the business continues at Burneside Mill today. In 1845, he rented the Burneside Mill from the Wakefield family, and the Cowan Head Mill from the Wilsons. In 1880, he also purchased Bowston Mill, which had been constructed in 1874 for the preparation of rags and ropes for the other two mills (BHA 9). Bowston weir was presumably constructed as part of this development; the 1898 Ordnance Survey map shows the weir to be extant, with the mill buildings extending along the right bank of the river (Plate 7). A tank and sluice are shown on the left bank. Surviving elements include the weir, sluice, and tanks which now serve as part of a sewage works (Plate 8 and 9; Figure 4). Bowston Mill closed in the 1960s, when the industry began to use waste paper, rather than rags, in the pulp; Cowan Head closed in 1977 after which date production was focussed at Burneside.

Plate 8 LiDAR data with Ordnance Survey overlay

The 1898 Ordnance Survey map shows the tramway, which had been constructed in 1879 to address the issue of moving materials and finished product to, from and between the three mills (BHA 14). The narrow-gauge tramway was replaced with a standard gauge line in 1927, and linked to the Windermere-Oxenholme branch line. The line was closed in 1965, although the siding to Burneside was used for coal for a few more years.

Plate 9 Area of former tanks, looking south

Railway

In 1845, an Act for creating the Kendal and Windermere railway was passed (BHA 15), and the line was built as a branch to the Lancaster and Carlisle Railway (now the West Coast Main Line). By 1847 the route through Windermere station was complete.

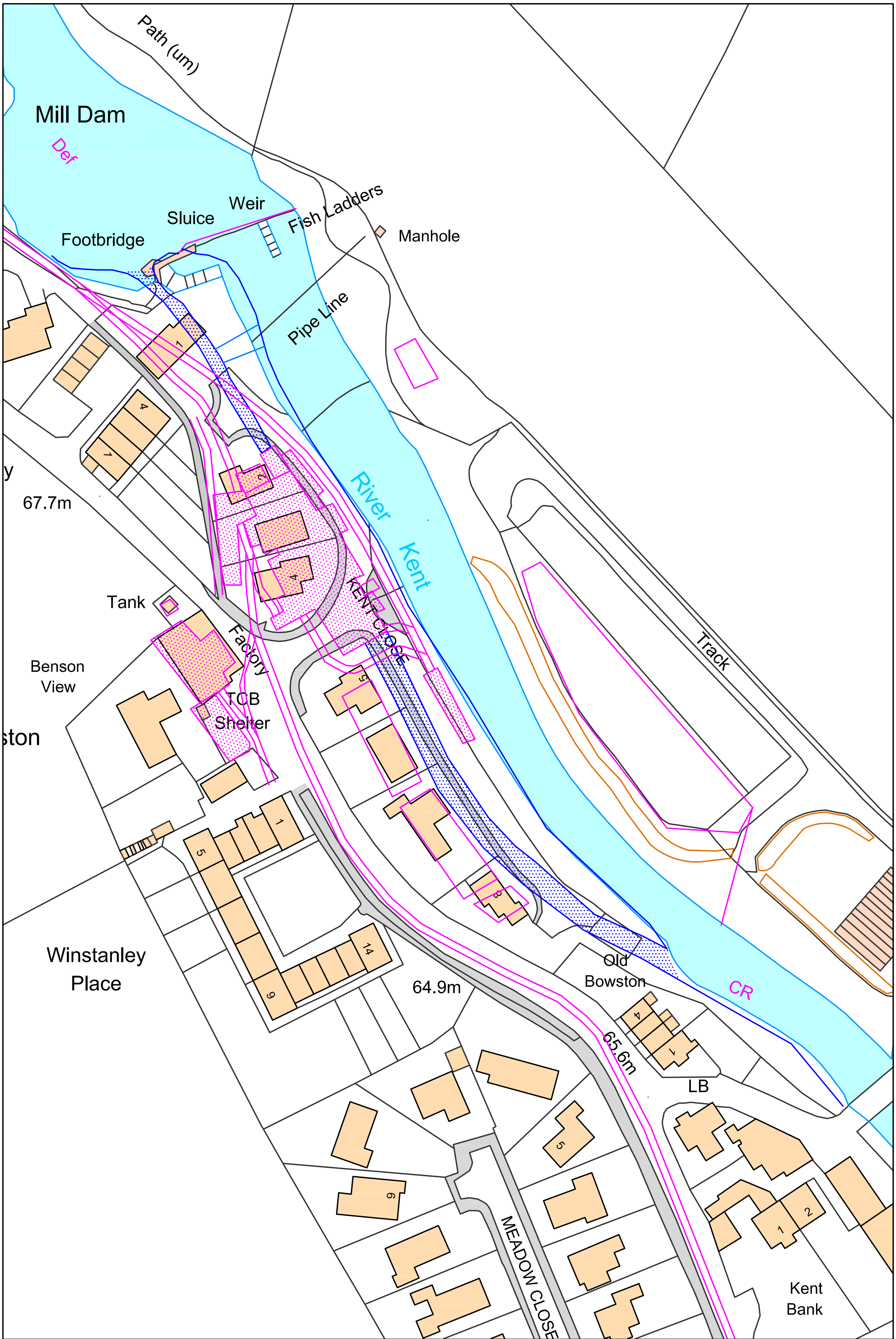
3.2.3 20th century

Bowston Paper closed in the early 1960s, and by 1973, Ordnance Survey editions show that the buildings of the mill had been removed. Part of the former mill leat is depicted next to the weir, crossed by a footbridge. Modern housing has since been constructed on the site of the former mill.

The weir is shown on Ordnance Survey maps throughout the 20th century. The western fishpass is depicted on maps from 1914, while the eastern is shown from the 1970s.

3.2.4 Undated

An undated cairn is located in a field north of the site at Burneside (BHA 13).



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Bowston - historic map regression (1898) | Scale 1:1250 | Figure 4

3.3 ASSESSMENT OF SIGNIFICANCE

The proposed works would affect a localised area around the weir, including work to the river bed downstream, and consolidation work upstream. Within these areas, the only documented heritage asset is the weir itself as a representative of the former mill complex, and so assessment of significance focuses on the structure itself.

Bowston weir is the main surviving element of the 19th-century Bowston Mill, which itself formed part of James Cropper's paper-making business, established from 1845 on this stretch of the River Kent. While production continues at Burneside Mill to the south, and buildings have been converted at Cowan Head to the north, Bowston Mill was more comprehensively removed after its closure, and is represented only by the weir, sluice and elements of tanks on the north (left) bank. It is not clear to what extent the weir structure represents its original 19th-century form (or incorporates earlier fabric), but its location and form reflects the historic layout and function of the (now lost) mill.

As such, the weir has moderate historic and archaeological significance, in allowing the location and power source of the former Bowston Mill to be identified clearly within the landscape. This significance has been eroded by the loss of the associated mill buildings to modern residential development. The weir also has some aesthetic value, as a notable feature of this length of the river, in terms of its visual and auditory impact.

The archaeological potential of the immediate vicinity of the weir, or the banks upstream, remains unknown.

3.4 ASSESSMENT OF IMPACT

The proposed options for the weir include:

- Full removal of the weir
- Modification of the weir – lowering of crest and installation of rock ramp/weir infilling
- Do nothing

3.4.1 Full removal

Full removal of the weir would result in substantial impact on the non-designated heritage asset, which is considered to be of moderate (local) significance as surviving evidence for Bowston Mill. Removal and regrading of the river bed would reduce legibility of the former layout of Bowston Mill.

3.4.2 Modification of the weir

Modification of the weir would see an alteration of its existing form, but the structure and original function would remain legible within the landscape. Potential impact on the weir structure as a heritage asset would therefore be moderate.

3.4.3 Do nothing

Doing nothing would have no impact on heritage significance.

Table 1 Summary of assessment

HA no	Heritage asset	Status/Significance	Assessment of impact		
			Option 1: Full removal	Option 2: Modification of weir	Option 3: Do nothing
BHA 9	Bowston Mill	Moderate – weir represents surviving evidence for now lost mill	Substantial – loss of surviving element of weir. Preservation by record recommended	Moderate – legibility retained. Pre-intervention record recommended	No impact

3.5 RECOMMENDATIONS

Preservation *in situ* is the preferred option for any heritage asset, in order to retain integrity, legibility and significance. Retention of the weir would therefore be the preferred option, as it would preserve the vestiges of the historic mill complex that was focussed on this stretch of the River Kent from the late 19th until the late 20th century.

It is recognised that potential harm to the heritage values of the structure (full removal or modification) must be weighed against other factors, and that full retention may not be practicable. It is recommended that a photographic record of the weir be made prior to the removal or modification of the weir, in order to preserve by record any information to be lost. Any further requirements for archaeological mitigation should be designed in liaison with the Cumbria County Archaeologist.

4.0 HELSINGTON WEIR

4.1 BASELINE CONDITIONS

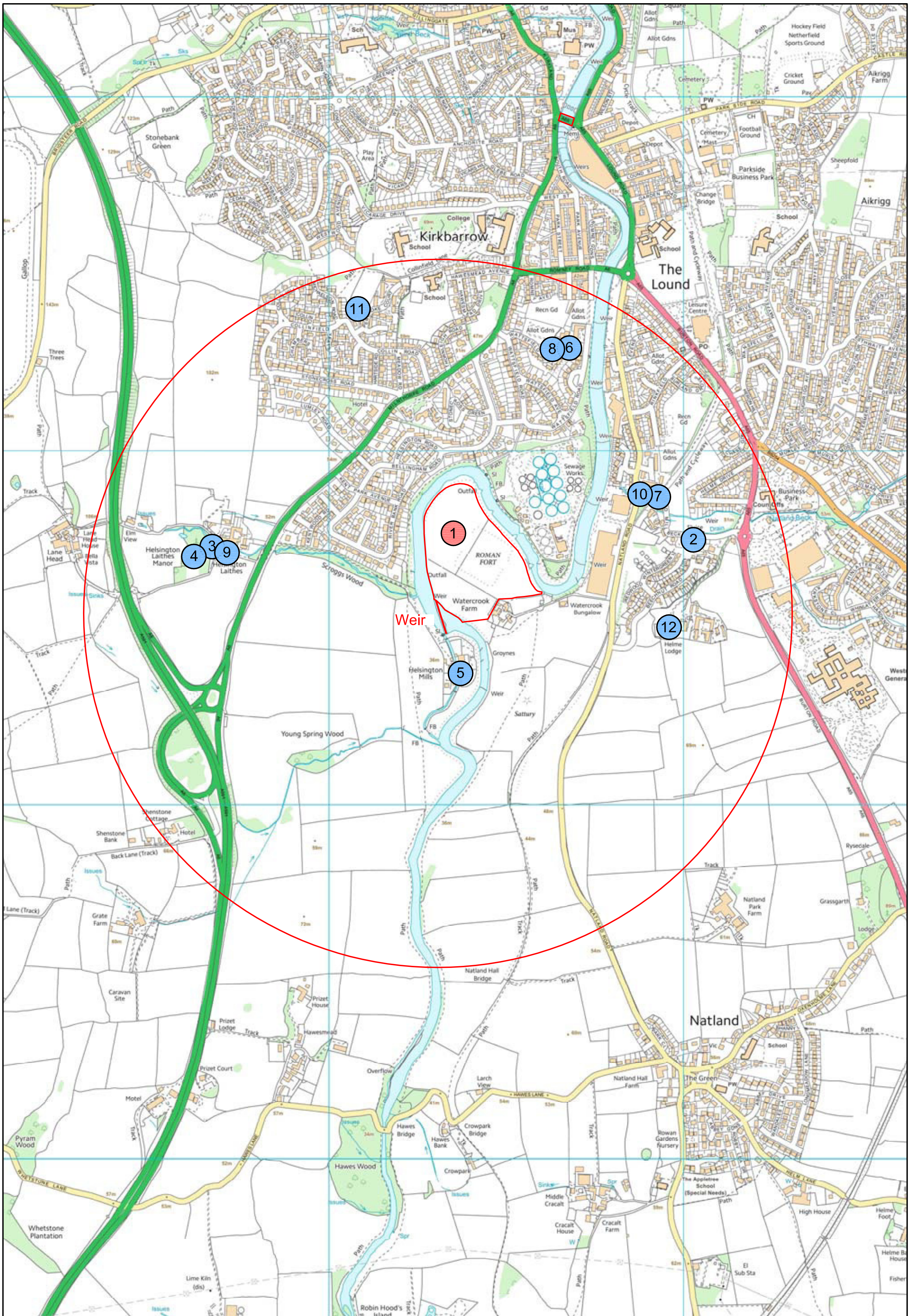
4.1.1 Designated heritage assets

Scheduled Monument

One Scheduled Monument was identified within the study area (Figure 5). The Scheduled Area of the Roman fort of Watercrook and associated settlement encompasses almost the entirety of the loop of the River Kent, and abuts the northern end of Helsington weir (HHA 1).

Listed Building

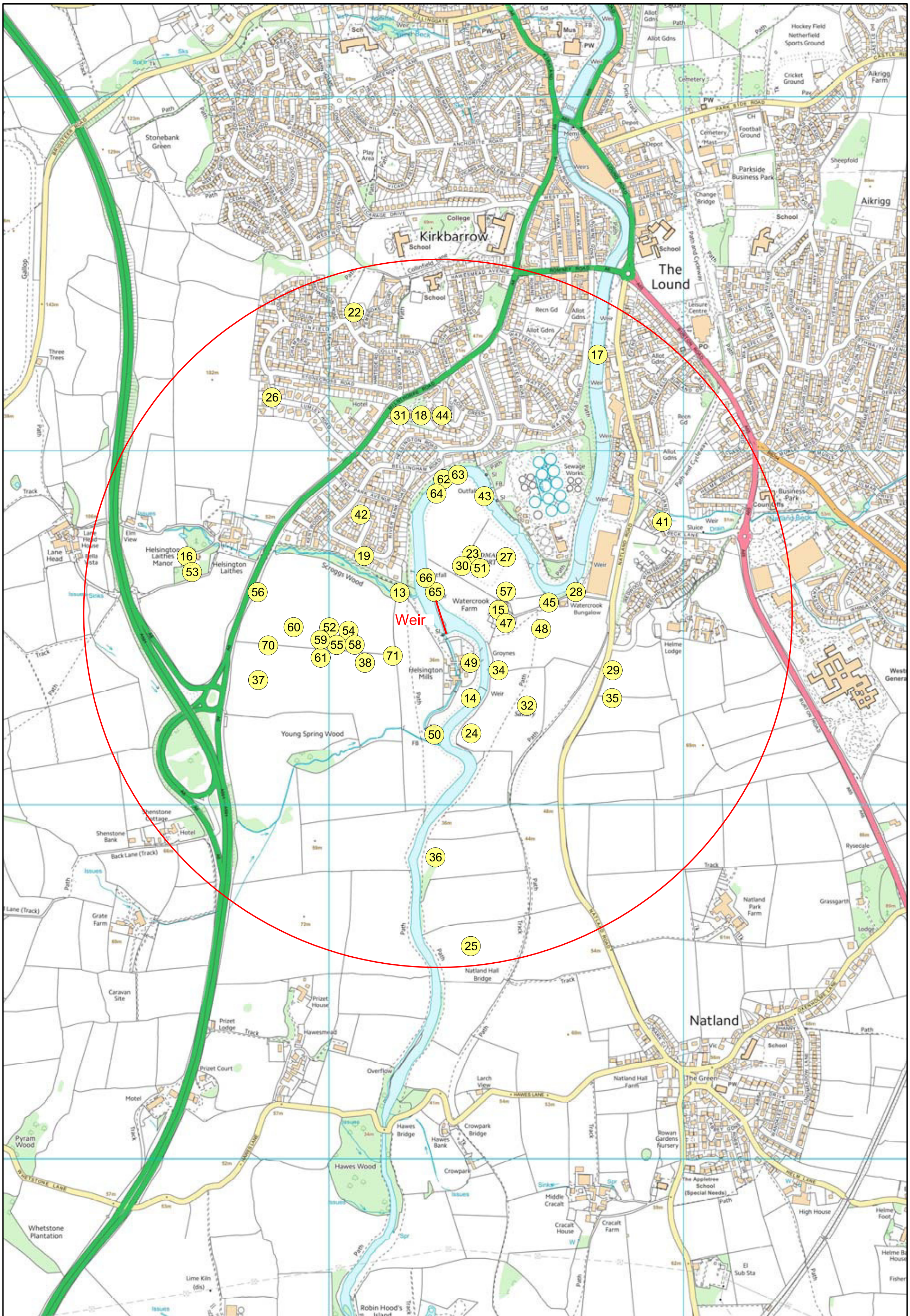
Eleven Listed Buildings were identified within the 1km radius study area, including eight Grade II Listed and three Grade II* Listed buildings. Of these, the closest is Helsington Mill (Grade II Listed; HHA 5) which lies to the immediate south of Helsington weir and is served by the leat fed from it.



Helsington - designated heritage assets

Scale 1:15000

Figure 5



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Helsington - non-designated heritage assets	Scale 1:15000		Figure 6

FAS HERITAGE

4.1.2 Non-designated heritage assets

A further 88 non-designated heritage assets were identified within the study area through searches of the CHER (Figure 6). These include a large number of finds of Roman and later coins and ceramic vessel fragments which have been grouped together in the gazetteer for ease of reference where they have the same findspot.

4.1.3 Events

A number of archaeological events have been recorded in the study area. Recent investigations detailed by the CHER include desk-based assessments and geophysical survey undertaken in advance of residential development. More pertinent to the current study are the 1970s investigations of the Roman fort of Watercrook, which took place prior to the widening of the river in 1974/5 (Plate 10).

4.2 ARCHAEOLOGICAL AND HISTORICAL BACKGROUND

4.2.1 Prehistory

Prehistoric activity is represented by flint finds found close to the river at Watercrook, southeast of the Roman fort. These included a flint blade, scraper and core which have been assigned a Neolithic date (HHA 48).

4.2.2 Roman

Watercrook Fort (HHA 1) occupies a strategic location on a plateau within the loop of the river, served by good communication networks; the agger of a Roman road (Kendal Fell Road) is represented by a slight earthwork leading northwest, skirting the western side of Kendal (HHA 30)(Potter 1979; Shotter 2000). The fort has been recognised since the 17th century, and in the early 18th century, Stukeley described the site: ‘the ramparts of the fort are very discernible, and there is a faint appearance of a ditch, though now much levelled’. In 1887, a summer of drought allowed the layout of the fort to be

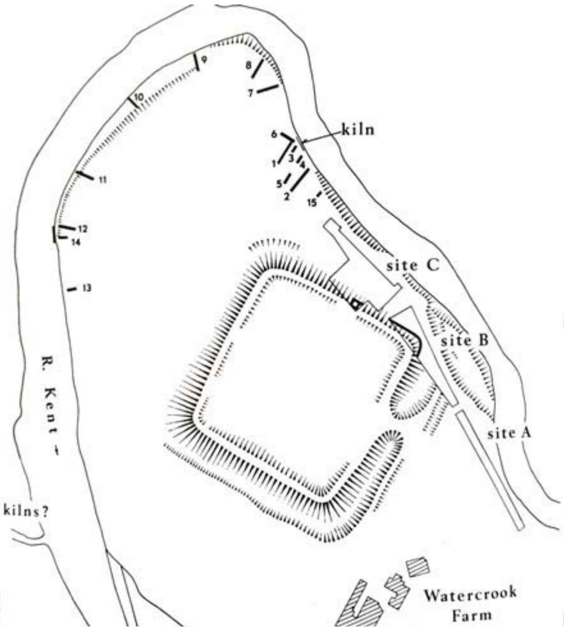

Plate 10 Location of trenches (from Potter 1979)

Plate 11 Aerial view looking southeast, taken J K St Joseph, 1949 (in Potter 1979)

Plate 12 LiDAR data showing the Roman fort

traced, and again in 1949, suitable conditions allowed the layout of the site to be discerned on aerial photographs (Plate 11). The associated settlement was situated between the fort and the water on the western side. Machell, vicar of Kirkby Thore in the 17th century, described a bath house associated with the fort (HHA 15); this has not been located but Collingwood (1908, cited in Potter 1979, 143) stated that the farmer at Watercrook had seen underground cavities and summits of arches appearing above the level of the ground in the shippon and at the corner of Watercrook House (HHA 28). The fort is still evident as an earthwork (Plate 12), and is visible at ground level.

The fort was investigated archaeologically in early 20th century; in 1931 by Colonel O H North, in 1944 by E J W Hildyard. The area north and northwest of the fort was subject to further trenching 1974-5, in advance of works to widen the river. The investigation identified the location of a former channel of the River Kent, and determined that the alluvial deposits post-dated the Roman period; a 'recent' limekiln was found to have been cut into these deposits to the northeast of the fort.

Associated with the fort, there are antiquarian observations of a tilery, situated across the river to the southwest of the fort (Potter 1979, 143)(HHA 13). Further 'curious earthworks' have been noted in this vicinity (HHA 19). South of the fort is the Potlands Roman cemetery (HHA 24), represented by urns containing cremated human remains, in the field that contains the Sattury (HHA 32), a mound of uncertain origin. North of the river, in what is now a built up area, Kirkbarrow Roman cemetery was identified in 1892 by two cinerary urns and a small vase discovered at Stone Cross; a third larger urn was discovered shortly afterwards (HHA 44). Within the wider landscape, evidence for a possible Romano-British settlement is visible on aerial photographs (HHA 36).

Investigations during the construction of a pipe trench south of the fort revealed spreads of Roman pottery and slight stratigraphy (HHA 34), and the CHER contains numerous records of finds of nails, brooches, a candlestick, seal boxes and keys, coins and pottery from the vicinity of the fort, and the land to the immediate west of the weir (HHA 23, 24, 27, 43, 45, 51, 52, 56, 57, 58, 60). Two altars have been reported from the immediate vicinity (HHA 46, 47). Coins were recovered from the area of Helsington Mills (HHA 49, 50). The land to the west of the river also produced a quantity of Roman ceramic, primarily Samian but also including colour-coated wares (HHA 62). Roman ceramic was found 'washed out of the river bank' in 2007, just north of the weir (HHA 65).

4.2.3 Medieval to post-medieval

Helsington was a rural medieval township of *c.*3300 acres, situated to the southeast of Kendal (part of the township containing Helsington Laithes became part of the borough of Kendal in 1935). The place-name at Domesday is recorded as *Helsingetune*; the origins of this name are not clear, and it can be interpreted variously as deriving from *heasling* (hazel copse), the tribal name of the *Haelsingas* or as 'farmstead of the *hals'*, denoting a neck of land or pass (Rose 2014). Whatever the derivation, the likely antiquity of the name would suggest a settlement in existence at this date - typically for the period, no early medieval sites are noted from the study area.

Many of the farmsteads in the area have medieval origins (although the extant buildings are later). Heslington Laithes farmhouse has its origins as a late 15th or 16th-century manor house (HHA 4), situated west of the weir and river. There was a cornmill at Heslington Laithes by 1297. Earthwork remains south of the building have been identified as the 'ancient manor', said to have included a walled-in spring, remains of a cloth mill and associated watercourse (HHA 16). At that time, Heslington Manor would have been more distinct from Kendal; Stone Cross, to the northeast, marks the former entrance to the town (HHA 18).

A mill at Natland Beck is referred to in documents from 1526 (HHA 41), and more widespread activity is represented by finds of coinage and ceramic from the area, including areas close to the weir. Medieval coins were found in the area west of the weir during fieldwalking (HHA 61). Further finds from this area included fragments of medieval cauldron, and a quantity of medieval or post-medieval ceramic (HHA 64). Fragments of pottery were found (with Roman material) north of the weir, 'washed out of the banks' (HHA 66).

4.2.4 Post-medieval to 19th century

Several of the buildings in the area have origins in the post-medieval period, including Natland Mill Back farmhouse (HHA 2), Collinfield farmhouse (HHA 11), Wattsfield farmhouse and cottage, with gate piers (HHA 6, HHA 8). Several of the bridges crossing the river and other watercourses have historic significance, reflected in their Listed status (HHA 3, HHA 7, HHA 9). As with previous periods, field-walking has recovered evidence for activity of this date across the landscape, including finds of ceramic (HHA 63), coins (HHA 53) and a seal cloth (HHA 59).

Plate 13 Limekiln found cut into alluvial deposits

Evidence for post-medieval industry includes extraction (HHA 40), and a bloom forge at Natland (HHA 42), close to the west of the river loop. During investigations in 1975, a stone-built structure was encountered which has been interpreted as a lime-kiln. The structure was cut into post-Roman silts, and has been associated with a period of robbing of the fort walls (Plate 13).

Heslington Laithes Mill

The mill at Heslington Laithes may have had its origins in the medieval period as a corn mill, but its more recent history began in 1800, when the mill site was development as a marble works by Kendal architect Francis Webster, who held the lease from the lord of the manor (this and much of the following

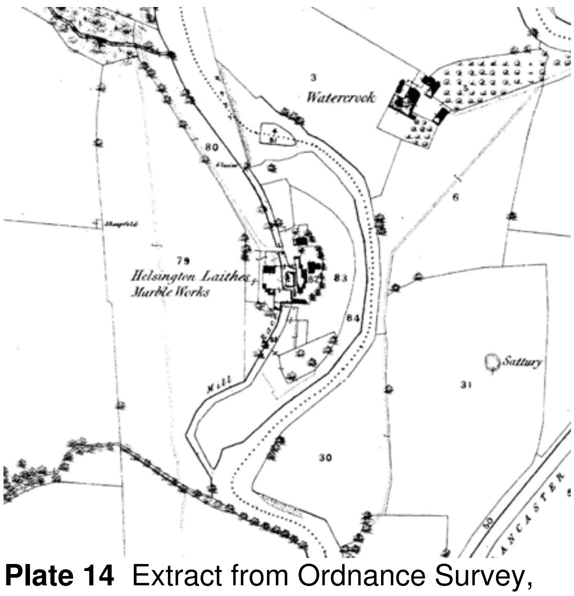

Plate 14 Extract from Ordnance Survey, 1860

account is provided in the draft *Victoria County History*, 2014). Two water-powered mills were constructed, and Webster is credited with creating the weir at Helsington to improve the water supply. A weir is shown on the 1860 Ordnance Survey edition (Plate 14), is no longer depicted in 1898 and then is shown in much greater detail in 1914 (Plate 15) – it is not clear whether this denotes discrepancies in the survey or a rebuilt structure, but all follow the current alignment of the weir.

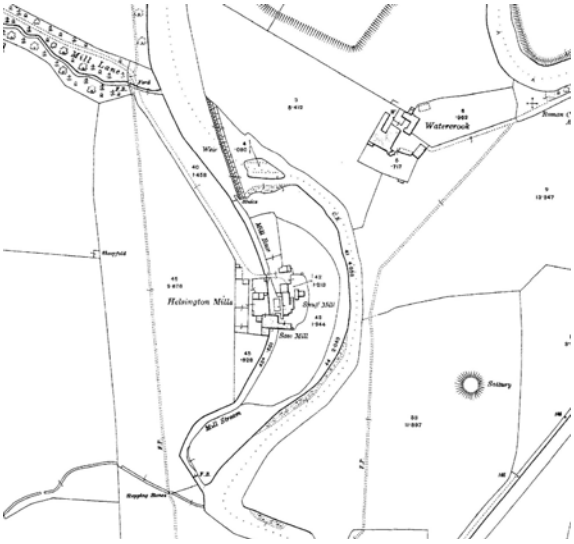

Plate 15 Extract from Ordnance Survey, 1914

The larger of the two mills at Helsington Laithes was used to polish local limestone. In 1895 it was acquired by J Chaplow and Sons who used the buildings as engineering workshops, and now operate a road construction business from the site (the water power was dismantled in the 1940s).

The smaller of the mill buildings originated as a saw mill, but in the 1880s was converted for use for the grinding of snuff by Gawith, Hoggarth and Co. Snuff continued to be produced at the site, which has been identified the last working water-powered snuff mill in the country, before its closure in 1991 (HHA 5). The surviving building is a Grade II Listed building, now used as a dwelling. The mill race is extant, fed from the weir by a sluice.

4.2.5 Modern

The Lancaster-Kendal Canal opened in 1797 (HHA 33), and was originally intended to link the Kendal to Wigan Canal, but the Preston to Wigan stretch was never completed. Competition from the railways soon saw the decline in the canal's use.

In 1975, the water board took the decision to widen the River Kent around the Watercrook loop. This resulted in a rescue excavation around the interior of the loop. The 1975 Ordnance Survey edition (1:1250) shows the irregular left bank of the river, particularly east of the Watercrook fort, which by the 1978-1991 edition had become more regular, with the existing flood bank shown.

4.2.6 Undated

Various sites have evidence for undated or unclassified earthworks (HHA 25, 26, 29, 35, 37, 38, 40)

4.3 ASSESSMENT OF SIGNIFICANCE

The proposed works include options to remove or modify the weir, and also works to the riverbanks around the Watercrook loop. The proposals have the potential to affect the weir structure itself, archaeological remains within the immediate area, and also the setting of the Grade II Listed mill structure, and so assessment of significance focuses on these elements.

Watercrook Roman Fort and associated archaeological deposits

Watercrook fort and settlement, with the archaeological remains and earthworks at the site, are recognised as being nationally significant, and have been protected as a Scheduled Monument; significance is therefore assessed as exceptional. The fact that archaeological remains of Roman date have been recovered from both sides of the river, and that ceramic of this date is reported to have 'washed from the river banks', indicates that archaeological potential extends across the area enclosed by the loop of the river. The level of disturbance caused by the 1970s flood alleviation works along the riverbank is not known, and so the significance of remains that may be affected cannot be accurately predicted.

Weir structure

The weir was constructed in the 19th century to increase waterpower to the Helsington Laithes Mills; the date of extant fabric is not clear as structure has subsequently undergone modification, including the creation of a concrete cap, but it is likely that it retains 19th-century, and possibly earlier, fabric.

In itself, the weir would be considered to have moderate significance as a surviving 19th-century structure associated with local industries. However, the structure has group value as part of a complex of mill weir, leat and surviving Grade II Listed mill building, with historical association with the Kendal architect Francis Webster. The weir contributes to the setting of the Grade II Listed building, itself of considerable architectural and historic significance.

4.4 ASSESSMENT OF IMPACT

The proposed options for Helsington weirs include:

- Full removal
- Removal of existing concrete cap (crest lowering)
- Partial removal (central notch)
- Bank stabilisation works

4.4.1 Full removal

Full removal of the weir would result in loss of a non-designated heritage asset of historic significance. The structure itself is not designated, but removal of the weir and the resulting dewatering or infilling of the mill leat would represent moderate harm to the legibility of the mill complex associated with the Grade II Listed building.

Groundworks associated with the removal of the weir (including creation of access tracks and compounds) would potentially affect below-ground archaeological remains, including Roman remains associated with the fort and settlement, and any precursor to the existing weir. Works to the left bank have the potential to impact archaeological remains within the Scheduled area. The right bank, while not scheduled, also has archaeological potential.

4.4.2 Removal of concrete cap/partial removal (central notch)

The removal of the cap, or creation of a central notch, would leave the structure largely intact and retain legibility of the mill complex. There may be dewatering of the leat itself, but the feature would remain legible. Impact on setting is assessed as slight-moderate.

Works to the left bank have the potential to impact archaeological remains within the Scheduled area. The right bank, while not scheduled, also has archaeological potential.

4.4.3 Bank stabilisation works

Bank stabilisation works have been proposed for stretches of the left and right banks of the loop of the river. The fact that finds have been recovered 'washed from the river banks' suggests the potential for artefacts, and possibly features, of archaeological significance along the banks. While the proposed works would result in minimal impact to the Scheduled Monument as a whole, impact will depend whether any structural features or significant deposits survive in these areas, and without appropriate mitigation would result in the loss of evidential value.

Table 2 Summary of significance and impact

HA no	**Heritage asset**	**Status/Signifiance**	**Assessment of impact**			
			Option 1: Full removal	Option 2: Removal of concrete cap	Option 3: Central notch	Bank stabilisation
HHA 1	Watercrook Roman Fort	Exceptional significance - Scheduled Monument	Possible impact on archaeological remains on the bank within the Scheduled Area – SMC required, and mitigation designed	Possible impact on archaeological remains on the bank within the Scheduled Area – SMC required, and mitigation designed	Possible impact in archaeological remains on the bank within the Scheduled Area – SMC required, and mitigation designed	Possible impact on archaeological remains on the bank within the Scheduled Area – SMC required, and mitigation designed
-	Heslington Mill weir	Moderate historic significance	Substantial impact – preservation by record recommended	Slight impact – legibility would be retained. Pre-intervention record recommended	Slight impact – legibility would be retained. Pre-intervention record recommended	-
HHA 5	Heslington Laithes Mill	Considerable significance – Grade II Listed Building	Moderate impact on setting – loss of weir and leat would erode legibility of former mill complex. Pre-intervention record recommended, retention of leat in designs as far as practicable	Slight-Moderate impact on setting – dewatering of leat would erode legibility of former mill complex. Pre-intervention record recommended, retention of leat in designs as far as practicable	Slight-Moderate impact on setting – dewatering of leat would erode legibility of former mill complex. Pre-intervention record recommended, retention of leat in designs as far as practicable	-

4.5 RECOMMENDATIONS

Watercrook Roman fort is a Scheduled Monument, and Scheduled Monument Consent will be required for any works that will affect the Scheduled area, including works to the weir or bank stabilisation works. It is recommended that Historic England be consulted at an early stage to determine any appropriate mitigation measures that may be required. As a minimum, it is recommended that any groundworks are subject to a programme of archaeological monitoring. Any impact on below-ground remains should be minimised through careful design of access routes, site compounds and working areas during the proposed works.

Preservation of the weir *in situ* would ensure that the archaeological and historic significance of the heritage asset is preserved. Removal of the concrete cap (presumably a late addition), or creation of a central notch would retain historic legibility.

Helsington Mills is a Grade II Listed Building, and while the works would not directly affect the structure or its curtilage, dewatering of the leat and the removal/alteration of the weir would affect its historic setting. It is recommended that the local Conservation Officer be consulted regarding appropriate design for the scheme. Although no longer functioning to provide water power, the extant leat forms part of the setting of historic mill complex, and so it is recommended that this feature be retained as a visible element within future designs.

Any works to the area – including groundworks, geotechnical works, bank stabilisation, creation of access routes and site compounds - have the potential to disturb hitherto unrecorded archaeological remains, and so it is recommended that a programme of archaeological mitigation be designed in liaison with the Cumbria County Archaeologist/Historic England as appropriate to minimise harm to the historic environment and avoid undue delays.

5.0 SUMMARY

5.1 BOWSTON

Bowston weir is late 19th-century in origin, created to provide power for Bowston Mill, which was used to prepare rags and rope for James Cropper's paper mills up- and down-stream at Cowan Head and Burneside respectively. Bowston Mill closed in the early 1960s and the buildings removed; the weir and some elements of former tanks are all that remains of the mill. The weir therefore has some historic significance as a legible element of a local industry, which still forms part of the local economy today.

Retention *in situ* would allow the historic significance of the weir to be retained. If the weir is to be modified or removed, a photographic record is recommended, to create an archival record of the form of the structure, and its relationship with structural elements in the immediate area. The Cumbria County Archaeologist should be consulted to agree an appropriate scope of works.

5.2 HELSINGTON

Heslington weir lies adjacent to the Watercrook Roman fort (a Scheduled Monument), in an area with high potential for remains of Roman and later date. The surviving weir dates to the 19th century, and was constructed to increase water power to Helsington Mills. The mill complex may have had medieval origins, but the surviving elements date to the 19th century, when the two mills were employed in the working of marble, and the grinding of snuff. The latter is now a Grade II Listed Building. The weir, and the leat that it supplies, form part of the setting of the Listed building, and allow the mill complex as a whole to be appreciated (albeit largely masked by modern road construction business).

Full removal would result in the loss of a non-designated heritage asset, and would affect the setting of the Grade II Listed Building. Lowering the crest (removal of concrete cap) or creating a notch would preserve the legibility of the mill layout, but would also potentially see de-watering of the mill leat, again having some impact on setting. It is recommended that the local Conservation Officer be consulted regarding the proposed scheme. A rapid pre-intervention record of the weir and associated features would be recommended to create an archival record prior to removal or modification.

Works within the Scheduled Area, including work associated with the weir, bank stabilisation, access or any further landscaping will require Scheduled Monument Consent; Historic England should be contacted early on in the process. Any impact on below-ground remains should be minimised through careful design of access routes, site compounds and working areas during the proposed works.

This is an area of high archaeological potential, and groundworks associated with works to the weir, including the creation of access tracks and site compounds, and any subsequent landscaping or habitat creation, will need to take into account impact on hitherto unrecorded archaeological remains. If extensive groundworks are to be undertaken, then an appropriate programme of archaeological mitigation should be agreed with the Cumbria County Archaeologist/Historic England, which may involve evaluation and/or archaeological monitoring.

6.0 REFERENCES

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APPENDIX A HERITAGE ASSETS – BOWSTON STUDY AREA

HA No	HER No	NGR	Site	Description	Status
1	NHLE 1289250	SD 4987 9660	Bowston Bridge	Bridge, probably 17th C, later enlarged on N side	LB GII
2	NHLE 1336089	SD 5003 9628	Summerhouse to N of Whitefoot	Summerhouse, probably mid-19th C	LB GII
3	NHLE 1289228	SD 50504 9700	Laithewaite Farmhouse	Farmhouse, 17th C with later additions	LB GII
4	CHER 4052	SD 4975 9726	Chapel-le-Wood Chapel, Strickland Ketel	According to Machell, the foundation of a chapel was scarcely discernible at a place called Chapel le Wood near Hundhow,… near to Godmond Hall	-
5	CHER 4053	SD 49 97	Gowan Head/Cowan Head Deer Park	According to Machell, Cowan Head Park had deer in it	-
6	CHER 4054	SD 49 97	Cowan Head/Gowan Head Park gates Lodge	According to Machell there was a pre-17th-century lodge here	-
7	CHER 5745	SD 5000 9595	Garnett House, Burneside	Garnett House, Burneside, said in part to have unusually thick walls which may be 16th C. The room within it is lined with 16th C panelling	-
8	CHER 17352	SD 4916 9699	Winter Lane Gravel Pit, Strickland Ketel	Winter Lane Gravel Pit lay on the N side of the Winter Lane in fields SE of Staveley	-
9	CHER 19365	SD 4971 9677	Bowston Paper Mill, Strickland Ketel	Bowston Paper Mill was near Bowston Bridge between Cowan Head and Burneside. The mill was built in 1874 but may have occupied the site of an earlier mill. New building was constructed to prepare rags and ropes for Cowan Head mill and Burneside Mill – connected via a tramway. Closed in the 1960s	-
10	CHER 17367	SD 4988 9667	Bowston Old Mill, Strickland Roger	Bowston Old Mill lay near Bowston Bridge, on the E side of the River Kent. Location from Somervell's description. The weir referred to is shown on the OS 2nd edition at NGR 349850 497160	-
11	CHER 17896	SD 4900 9737	Cowan Head Potash Kiln	Site of potash kiln, W of Cowan Head	-
12	CHER 17897	SD 4918 9713	Gillthroton Potash Kiln, Cowan Head	Site of a potash kiln	-
13	CHER 41233	SD4920 9735	Cowan Head Mill, Strickland Ketel	Fulling mill recorded at Cowan Head in 1735. Thomas Ashburner (local published) bought the mill in 1746 and converted it to make paper. 1879 a narrow gauge tramway linked Cowan Head with Cropper's other mills at Burneside and Bowston.	-
14	CHER 41234	SD 4927 9728	Cowan Head Tramway	Former tramway built in 1879, linking James Cropper's three paper mills at Cowan Head, Bowston and Burneside. Replaced by a	-

HA No	HER No	NGR	Site	Description	Status
				standard gauge line in 1927, and linked to the Windermere-Oxenholme branch line. Line closed in 1965, but the siding to Burneside was used for coal for a few more years	
15	CHER 41967	SD 5311 9019	Lancaster and Carlisle Railway	In 1845 the Kendal and Windermere railway was built as a branch line to the Lancaster and Carlisle Railway which now forms part of the West Coast Main Line.	-
16	CHER 44129	SD 4970 9701	Burneside	Possible site of a cairn in Field 33, exact location uncertain	-

APPENDIX B HERITAGE ASSETS – HELSINGTON STUDY AREA

HA No	HER No	NGR	Site	Description	Status
1	CHER 2078 NHLE 1007178	SD 5140 9070	Watercrook Roman Fort and Civil Settlement	Earthworks and building foundations. Greatly reduced by robbing and ploughing, but still prominent on SW side. Excavated 1944, revealing details of S angle of the fort with a turf and clay rampart and the intervallum road surface behind. Plan of fort seen in Aps. Initially occupied AD 90 – 100 with possible break AD 120, NE gate excavated in 1974-5.	SM
2	NHLE 1086584	SD 5203 9075	Natland Mill Beck Farmhouse and attached cottage	House, now house and cottage. 17th C with later additions	LB GII
3	NHLE 1137459	SD 5067 9073	Bridge carrying drive to NE of Helsington Laithes farhouse	Bridge, probably 18th century. Coursed, squared rubble with single elliptical arch	LB GII
4	NHLE 1145728 CHER4420	SD 5062 9070	Helsington Laithes Farmhouse	Manor house, late 15th C/early 16th C, partly rebuilt 1690. Wet dashed rubble on plinth.	LB GII*
5	NHLE 1145746 CHER 4310	SD 5137 9037	Helsington Laithes Mill	The last working water-powered snuff mill in the country. 19th C machinery, the undershot waterwheel provides all the power. Mill building probably mid-19th C. Slobbered limestone rubble walls. According to owner (1980s?) the mill produced half a ton of snuff per week. Mill closed in 1991.	LB GII
6	NHLE 1145641 CHER 5460	SD 5168 9129	Wattsfield Farmhouse and Cottage	Farmhouse and cottage. House 17th C , cottage 18th C. Later additions and alterations	LB GII*
7	NHLE 1145663 CHER 17605	SD 5193 9087	Natland Mill Beck Bridge over Lancaster/Kendal canal	Natland Mill Bridge lies near Natland Bridge on S side of Kendal. Documents refer to bridges from 1655. Bridge over canal later	LB GII
8	NHLE 1158049 CHER 5460	SD 5166 9129	Gate piers and forecourt wall to W of Wattsfield Farmhouse	Wattsfield Farmhouse gate piers – probably 18th C	LB GII
9	NHLE 1254289	SD 5069 9073	Bridge carrying farm road to NE of Helsington Laithes Farmhouse	Bridge, probably 16th or 17th C. Single semi-circular arch	LB GII
10	NHLE 1311843 CHER 22050	SD 5191 9087	Icehouse in SW angle of Natland Mill Beck Bridge and disused canal	Mid-late 19th C for Helm Lodge, but not shown on 1838 estate plan, in use by 1905.	LB GII
11	NHLE 1312242 CHER 5446	SD 5108 9140	Collinfield farmhouse	Farmhouse. Possibly mid/late 16th C, certainly early 17th C, extensively remodelled	LB GII*

HA No	HER No	NGR	Site	Description	Status
				1668.	
12	NHLE 1336097	SD 5196 9050	Helme Lodge	House, 1824. Francis and George Webster for W D Crewdson.	LB GII
13	CHER 2071	SD 5120 9060	Watercrook Pottery Kiln	Probable site of Roman pottery or tile kiln discovered in 1813 opposite the Roman camp by the edge of the brook. Urn without handles, and with a band of broached ornament was also found containing human ashes, iron and charcoal. Close to the kiln was a pit containing human remains, covered by debris from the kiln.	-
14	CHER 2073	SD 5140 9030	Watercrook Mound	Oval mound 88ft x 17 ft high, possibly natural	-
15	CHER 2079	SD 5148 9055	Watercrook Farm Bath House	Possibly on the site of Roman baths	-
16	CHER 2081	SD 5060 9070	Helsington Laithes Earthworks	Mounds and hollows. This was the 'ancient manor' of the parish of Helsington. According to J Marsh there is a walled-in spring, and remains of a cloth mill and its water course.	-
17	CHER 2467	SD 5176 9127	Wattsfield Ford	An 'ancient ford' the principal approach for travellers from the S before Nether Bridge was built	-
18	CHER 2474	SD 5126 9110	Stone cross, Milnthorpe Road	An ancient cross, known as 'stone cross' stood on the Milnthorpe Road. Extant in the 16th C. one of a group of crosses, on the main roads at entrances to Kendal.	-
19	CHER 2478	SD 5110 9070	Watercrook Enclosure	Aps revealed 'some curious earthworks' across the river from Watercrook near the site of kilns found in 1814. Earthworks appear to represent two faint subrectangular enclosures.	-
20	CHER 2479	SD 51 90	Brooch find, Watercrook	'late Celtic' S-shaped fibula found at Watercrook before 1907 and retained by Mr W C Fells	-
21	CHER 2480	SD 51 90	Nail find, Watercrook	Iron clench nail from 'some kind of watercraft' of Roma or later date found o the ground surface at Watercrook	-
22	CHER 2484	SD 5107 9139	Collinfield Lime Kiln	Remains of lime kilns recorded 'on removing a hillock' near Gilling Grove (prob wrong location)	-
23	CHER 2700	SD 514 907	Coin Find, Watercrook	A gold coin of Vespasian found at Watercrook. One side shows the head of the Emperor encircled with IMP CAESAR VESPASIANUS AVG.	-
24	CHER 3108	SD 514 902	Potlands Roman Cemetery	Probably site of roman burial ground. A Roman urn containing human ashes found close to the river at Watercrook in 1813, in a field called Potlands. Field also contains the	-

HA No	HER No	NGR	Site	Description	Status
				Sattury. Complete and unbroken Samian vessel found in the cemetery in 1980.	
25	CHER 3615	SD 514 896	Natlands Cropmark Site	Unclassified cropmark	-
26	CHER 3631	SD 5084 9115	Kendal Enclosure	An enclosure recorded by St Joseph. Rectilineqr feature was recorded during a geophysical survey in 2014 by OAN.	-
27	CHER 4103	SD 515 907	Quern find, Watercrook	Half upper stone of a beehive type quern, found in a wall in 1968. Within Scheduled area	-
28	CHER 4104	SD 517 906	Watercrook Architectural Detail	Alleged site of arches	-
29	CHER 4105	SD 5180 9038	Natland Beck earthworks	Unclassified site	-
30	CHER 4162	SD 5140 9070	Kendall Fell Road	Roman road associated with Watercrook Roman fort is indicated by the traces of an agger that follows a course NW from the fort. Traced along the valley W of Kendal after which it swings towards Staveley.	-
31	CHER 4225	SD 512 911	Stone cross burial	Bronze Age burial recorded in the Kendal Mercury, 1868	-
32	CHER 4419	SD 5156 9028	Sattury Mound	A mound called The Sattury, 440 yards SSW of the fort, probably a natural moraine. Stukeley mentions mortared stones found when the mound was ploughed, and the name is Old Norse for mound of the settlement	-
33	CHER 5332	SD 509 850	Lancaster-Kendal canal	Lancaster canal opened 1797. Originally plans to link Kendal and Wigan but the Preston-Wigan section was never finished. Competition from the railways soon saw the decline in the canal's use. Remained in use until partly blocked by the M6 in 1960s	-
34	CHER 6501	SD 5148 9038	Roman pottery finds, Watercrook	Excavation of a pipe trench S of Watercrook Roman Fort exposed pottery and small areas of shallow stratification. No major centre of activity identified	-
35	CHER 13597	SD 518 903	Natlands unclassified earthworks	Unclassified earthworks	-
36	CHER 14904	SD 5130 8985	Natland Romano-British farmstead	Site of possible farmstead and quarry visible on aerial photograph	-
37	CHER 15021	SD 5080 9035	Helsington Earthworks	Area containing mounds, as seen on aerial photographs	-
38	CHER 16580	SD 511 904	Young Spring Wood	Possible cropmark seen from aerial photographs	-

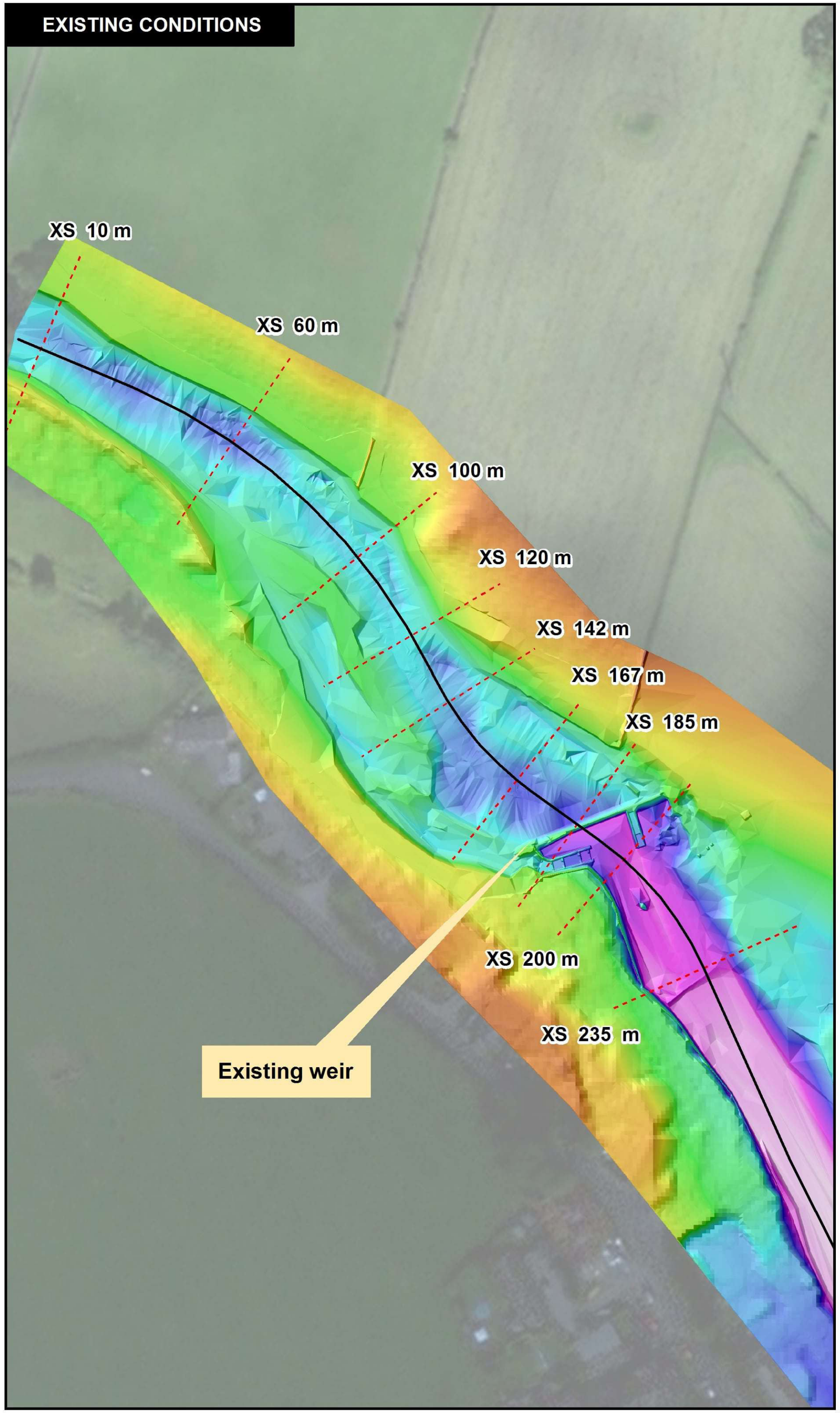
HA No	HER No	NGR	Site	Description	Status
39	CHER 16747	SD 51 90	Silver penny find	According to A Ellwood, a silver medieval penny found by a metal detectorist at Watercrook	-
40	CHER 17598	SD 5188 4098	Natland Mill Beck Sand Pits	Natland Mill Beck Sand pits – post-medieval	-
41	CHER 17599	SD 5194 9080	Natland Beck Mill, New Hutton	Natland Beck Mill lies on Natland Beck, beside Natland Mill Beck Lane. Mill dam on beck at SD 52429082. Referred to in documents from 1526	-
42	CHER 17733	SD 5109 9082	Natland Forge	Site of a bloom forge dating from 1750-1787	-
43	CHER 19005	SD 5144 9087	Coin finds, Watercrook Roman fort	Two Roman coins found 1958. One Trajan and one Claudius I	-
44	CHER 19006	SD 5132 9110	Kirkbarrow Roman cemetery, Stone Cross	Fragments of two cinerary urns and a small vase, all of Roman date, found at Stone Cross just N of Roman Fort in 1892. A third, larger cinerary urn was found shortly after. May be connected with, or part of cemetery for Roman fort	-
45	CHER 19007	SD 5162 9057	Candlestick find, Watercrook Farm	Roman candlestick found 1903	-
46	CHER 19008	SD 51 90	Altar and pottery finds, Watercrook	Roman altar 2ft 1" high, found in the riverbank surrounding Watercrook Roman fort in 1943. Exact location unknown	-
47	CHER 19009	SD 5150 9051	Roman altar, Watercrook	Roman altar found at Watercrook in 1687, now lost	-
48	CHER 19010	SD 516 905	Flint finds, Watercrook	A flint blade, scraper and core, possibly Neolithic, found near the River Kent at Watercrook	-
49	CHER 19084	SD 514 904	Coins finds, Helsington Mills	A group of four Roman coins were found approx. in this area, including coins of Hadrian, Claudius, Alexander, Probus	-
50	CHER 19085	SD 513 902	Coins finds, Helsington Mills	Four coins found in this approximate area – AS of Domitian, three Denarii	-
51	CHER 19116	SD 514 907	Coin finds, Watercrook Roman Fort	Two Roman coins found in the area of Watercrook Roman Fort – AE Sestertius of Antoninus Pius and AR Denarious of Trajan	-
52	CHER 42500 CHER 42502 CHER 42505 CHER 42567	SD 510 905	Coin finds, Helsington	AS or Dupondius of Antoninus Pius, AD145-61 Sestertius of Lucius Verus, AD 169 AS of Constantine I, AD 321-2 Silver denarius of Septimius Severus, AD 195-6	-
53	CHER 42501	SD 506 907	Coins find, Kendal	Silver Charles I sixpence, dated 1631-2, found in the vicinity of Heslington Laithes	-
54	CHER 505 905	SD 510 905	Spindle Whorl,	Cast lead spindle whorl	-

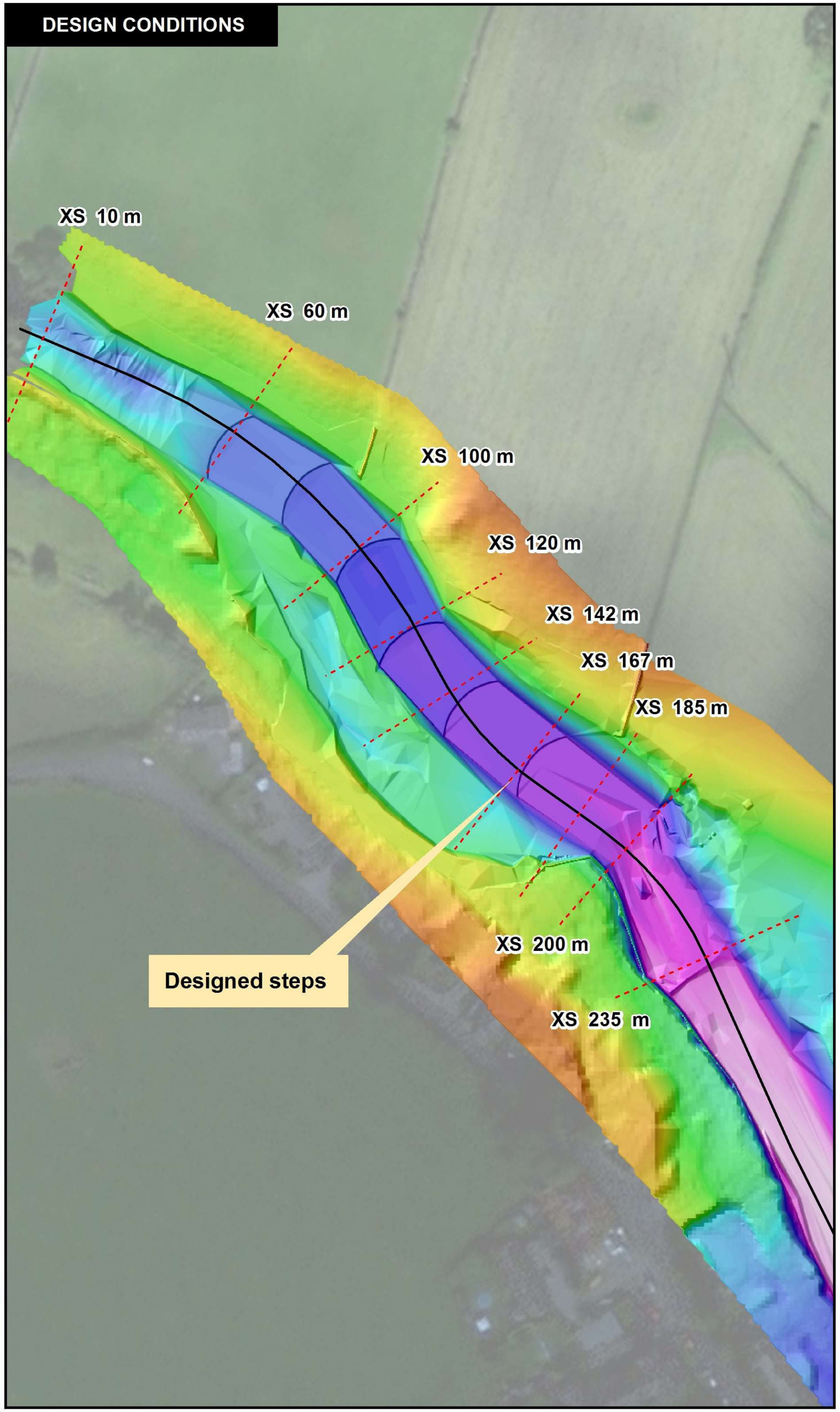
HA No	HER No	NGR	Site	Description	Status
			Helsington		
55	CHER 42510 CHER 42516 CHER 52563	SD 510 905	Medieval Cauldron /vessel finds	- Fragment of a rim of copper alloy cauldron, dated to the medieval period - Handle of a cauldron found in 2002 - copper alloy pot leg from a medieval cauldron, ewer or skillet found in 2002	-
56	CHER 42513	SD 508 906	Coin find, Helsington	Dupondius or AS of Helena (AD337-41)	-
57	CHER 42515	SD 515 906	Coin find, Natland	AS or Dupondius of Constantine II (AD 324-6) found in 2006 near Watercrook Farm	-
58	CHER 42518 CHER 42586 CHER 42593	SD 510 905	Roman seal box /key finds	Roman seal box decorated with leaf or heart shaped design found in October 2002 Copper alloy head of a Roman lock pin, dated AD 50-200 Cooper alloy head of a Roman lock pin, dated to AD 50-200	-
59	CHER 42564	SD 510 905	Seal find, Helsington	Two part seal cloth which sonsist of two round discs of lead connected by a strip of lead. The back bears 6 or 9 while the front has the weavers privy seal. Date AD 1600-1700	
60	CHER 42566	SD 509 905	Brooch find	Cast copper alloy Roman zoopmorphic (bird) brooch, 2nd C AD. Found opposite Watercrook Roman fort at Helsington	-
61	CHER 42568	SD 510 905	Coin find – medieval	Silver penny of Edward I, Lord of Ireland 1254-, King 1272-1307. Coin dates to 1279-1302	-
62	CHER 42596 CHER 42599 CHER 42601 CHER 42602 CHER 42607 CHER 42610 CHER 42611 CHER 42615 CHER 42616 CHER 42628 CHER 42629 CHER 42630 CHER 42631 CHER 42632 CHER 42633 CHER 42634 CHER 42635 CHER 42636 CHER 42637	SD 5132 9092	Vessel find - Roman	Fragment of Samian ware vessel found on the bank of the River Kent during fieldwalking in 2008 Fragment of Samian ware pedestal foot ring vessel on the bank of the River Kent during fieldwalking in 2008 Fragment of very thin vessel sherd, possibly Samian Small fragment of samian ware vessel – boy sherd from near the foot ring Very eroded fragment of Samian ware Large fragment of Samian ware vessel, probably part of Dragendorf bowl type 37 Small fragment of Samian ware, rim sherd Worn fragment of Samian ware vessel, undecorated body sherd Small fragment of Samian ware vessel, wall/body sherd Small fragment of Samian – wall/body sherd Small fragment of wall/body sherd of Samian Small fragment of vessel of early Roman date Undecorated rim sherd of Samian vessel, possibly a shall dish or bowl	-

HA No	HER No	NGR	Site	Description	Status
				Very worn vessel fragment of Samian Large vessel fragment, bottom sherd of Samian ware with some of the pedestal foot ring remaining Small, fragile sherd of Roman period ware – colour-coated, white fabric Small, fragile sherd of Roman period ware – colour-coated, white fabric Large fragment of a vessel of Roman or later date Fragment of Samian body sherd	
63	CHER 42597 CHER 42598 CHER 42638 CHER 42647	SD 5132 9092	Vessel find – early modern/modern	Small vessel sherd probably from early modern period, 18th-19th C, found on the bank of the River Kent during fieldwalking in 2008 Large vessel sherd probably from early modern period, 18th-19th C, found on the bank of the River Kent during fieldwalking in 2008 Small fragment of vessel or pipe, probably modern Modern vessel fragment, probably flower pot	-
64	CHER 42606 CHER 42614	SD 5132 9092	Vessel find – medieval	Sherd of vessel of probable late or post-medieval date, found on the bank of the River Kent during fieldwalking in 2008 Large fragment of a vessel dating to the late medieval, post-medieval or early modern period – green glazed earthenware jug or pot	-
65	CHER 42609	SD 5130 9060	Vessel find - Roman	Rim sherd of Roman Samian ware vessel, possibly Dragendorf form no. 37, 'washed out of the river bank' in 2007	-
66	CHER 42639	SD 513 906	Vessel find – post-medieval	Small vessel sherd of brown-glazed red earthenware of 17th- to early -18th-century date, washed out of the river bank in 2007	
67	CHER 42878	SD 51 90	Coin find	Elizabeth III sixpence	-
68	CHER 42879	SD 51 90	Writing equipment – medieval	Fragment of horn book with letters of the alphabet placed on horizontal lines, *c.*1540	-
69	CHER 42881	SD 51 90	Coin find – Roman	Very worn denarius, possibly Severus Alexander	-
70	CHER 43640	SD 5083 9045	Pottery and slag finds	Fragment of Samian and piece of undiagnostic slag recovered from animal burrow in 2010	-
71	CHER 43641	SD 5118 9042	Sheepfold	A sheepfold shown on the OS maps of 1863 and 1938. No remains noted in 2010	-

APPENDIX E

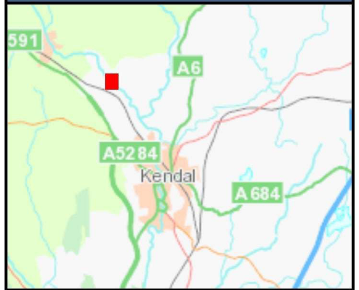
DESIGN DRAWINGS





Project Number	**UK17 - 1005**
Project Title	**Kent weirs**
Drawing Title	**BOWSTON WEIR - SURFACES**
Drawing Number	**201802070001**

CUMBRIA (England)



Legend

DEM Surface

Elevation (metres)

High : 68 m

Low : 58 m

Client

0 25 50 m

Scale @ A4 - 1: 2,000

N

British National Grid / GCS OSGB 1936

Designed	*Drawn*	*Reviewed*	*Approved*
LC	*JI*	*AW*	
Date	**February 2018**		

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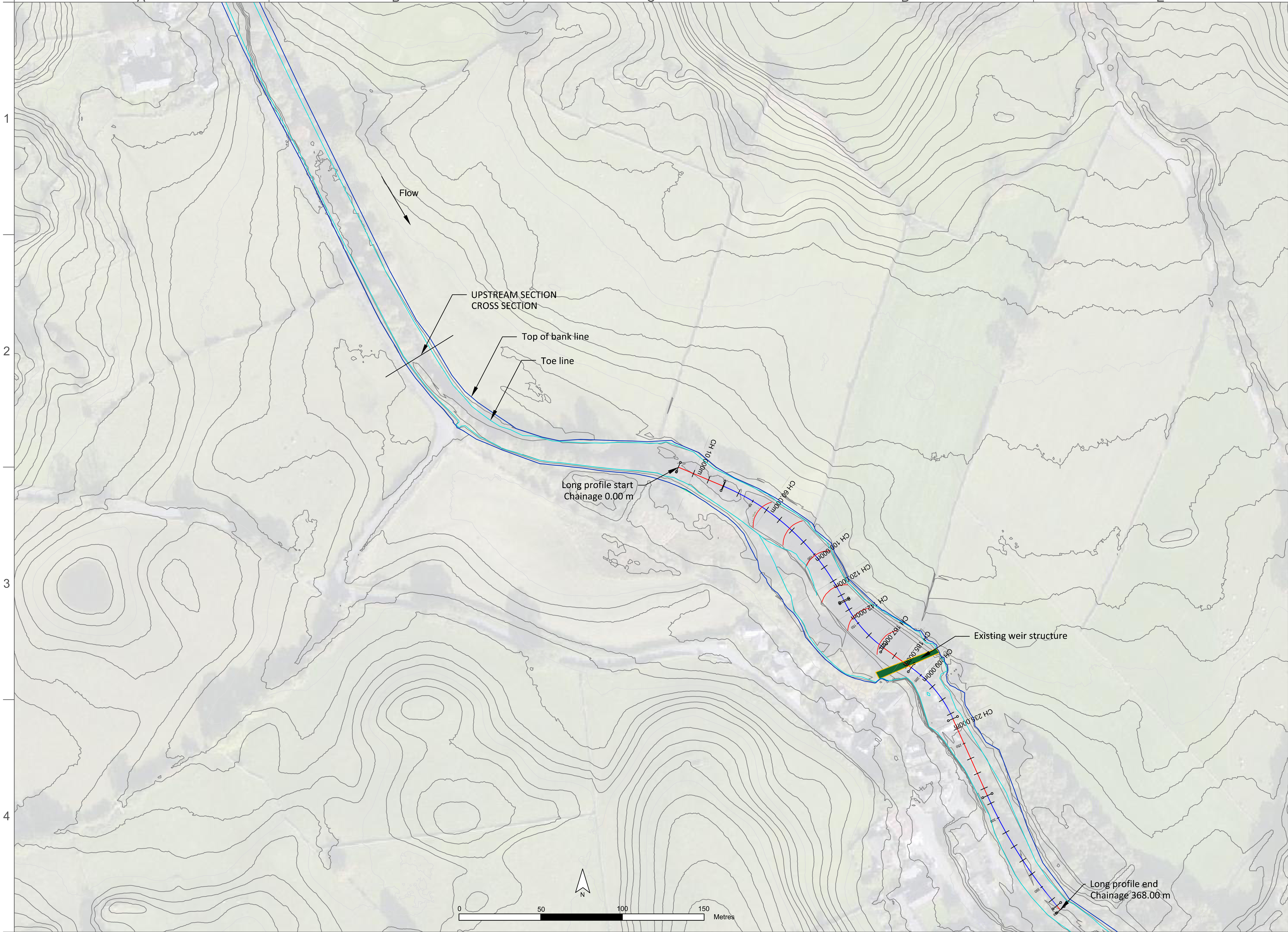

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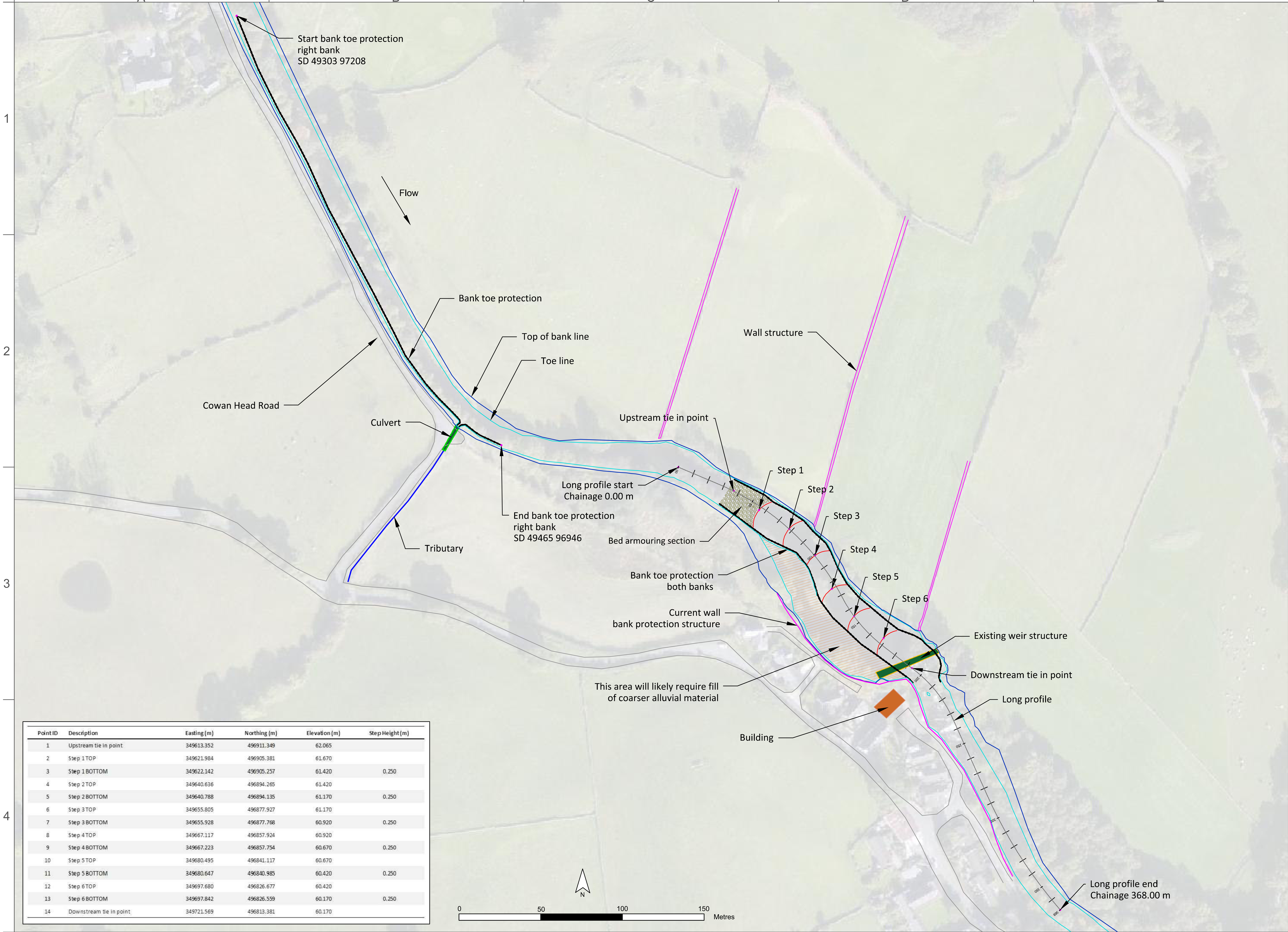
UK
BOWSTON
Restoration design
PLAN OVERVIEW

FILE NAME
Kent Weirs

JOB NUMBER
UK17 - 1005

DATE
February 2018

SHEET NO.
1 OF 7



Point ID	Description	Easting (m)	Northing (m)	Elevation (m)	Step Height (m)
1	Upstream tie in point	349613.352	496911.349	62.065	
2	Step 1 TOP	349621.984	496905.381	61.670	
3	Step 1 BOTTOM	349622.142	496905.257	61.420	0.250
4	Step 2 TOP	349640.636	496894.265	61.420	
5	Step 2 BOTTOM	349640.788	496894.135	61.170	0.250
6	Step 3 TOP	349655.805	496877.927	61.170	
7	Step 3 BOTTOM	349655.928	496877.768	60.920	0.250
8	Step 4 TOP	349667.117	496857.924	60.920	
9	Step 4 BOTTOM	349667.223	496857.754	60.670	0.250
10	Step 5 TOP	349680.495	496841.117	60.670	
11	Step 5 BOTTOM	349680.647	496840.985	60.420	0.250
12	Step 6 TOP	349697.680	496826.677	60.420	
13	Step 6 BOTTOM	349697.842	496826.559	60.170	0.250
14	Downstream tie in point	349721.569	496813.381	60.170	

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UK
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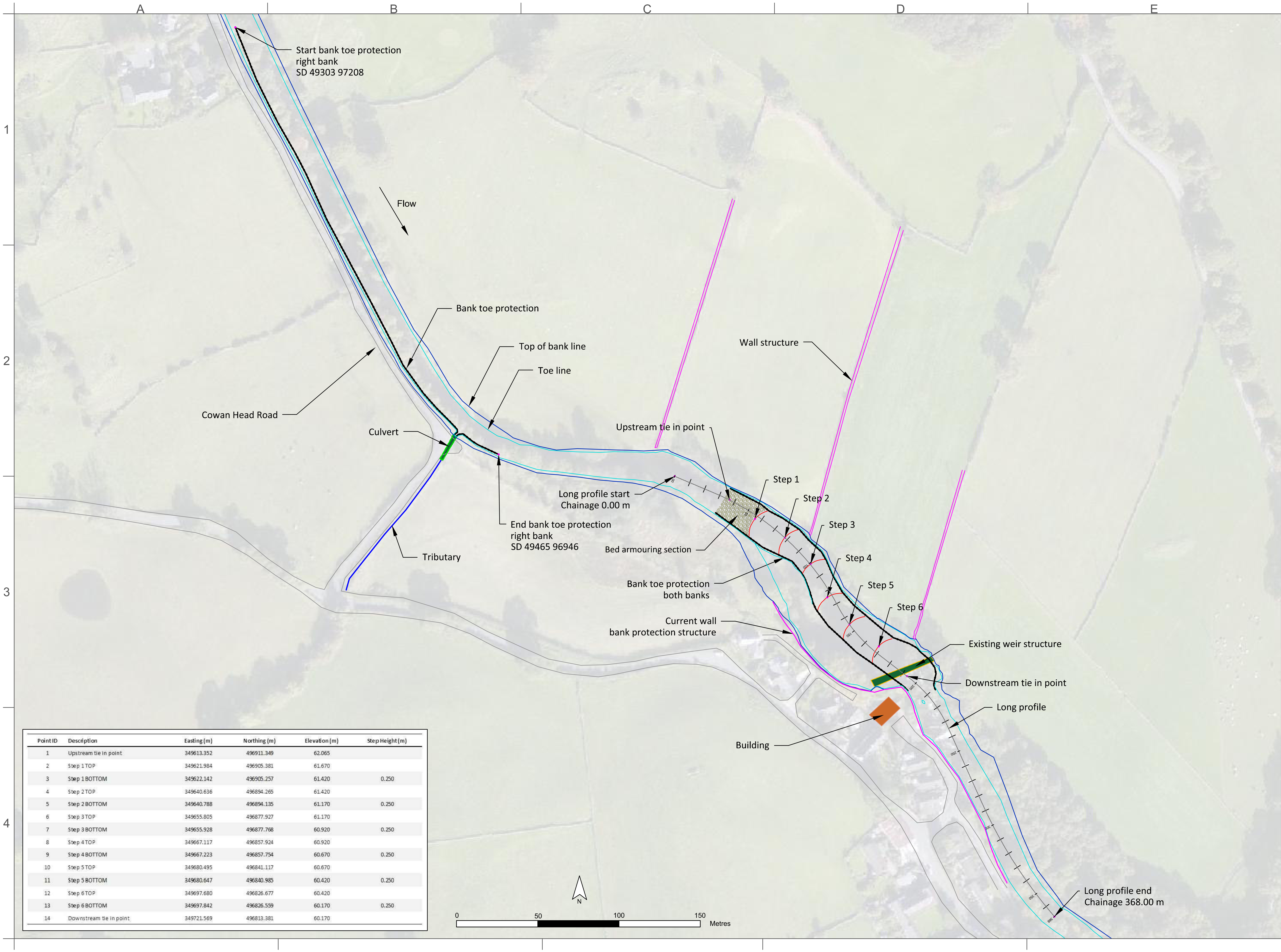
Restoration design
PLAN VIEW DETAIL

FILE NAME Kent Weirs
JOB NUMBER UK17 - 1005
DATE February 2018
SHEET NO. 2 OF 7



Point ID	Description	Easting (m)	Northing (m)	Elevation (m)	Step Height (m)
1	Upstream tie in point	349613.352	496911.349	62.065	
2	Step 1 TOP	349621.984	496905.381	61.670	
3	Step 1 BOTTOM	349622.142	496905.257	61.420	0.250
4	Step 2 TOP	349640.636	496894.265	61.420	
5	Step 2 BOTTOM	349640.788	496894.135	61.170	0.250
6	Step 3 TOP	349655.805	496877.927	61.170	
7	Step 3 BOTTOM	349655.928	496877.768	60.920	0.250
8	Step 4 TOP	349667.117	496857.924	60.920	
9	Step 4 BOTTOM	349667.223	496857.754	60.670	0.250
10	Step 5 TOP	349680.495	496841.117	60.670	
11	Step 5 BOTTOM	349680.647	496840.985	60.420	0.250
12	Step 6 TOP	349697.680	496826.677	60.420	
13	Step 6 BOTTOM	349697.842	496826.559	60.170	0.250
14	Downstream tie in point	349721.569	496813.381	60.170	

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ALIGNMENT - (1) - LONGSECTION
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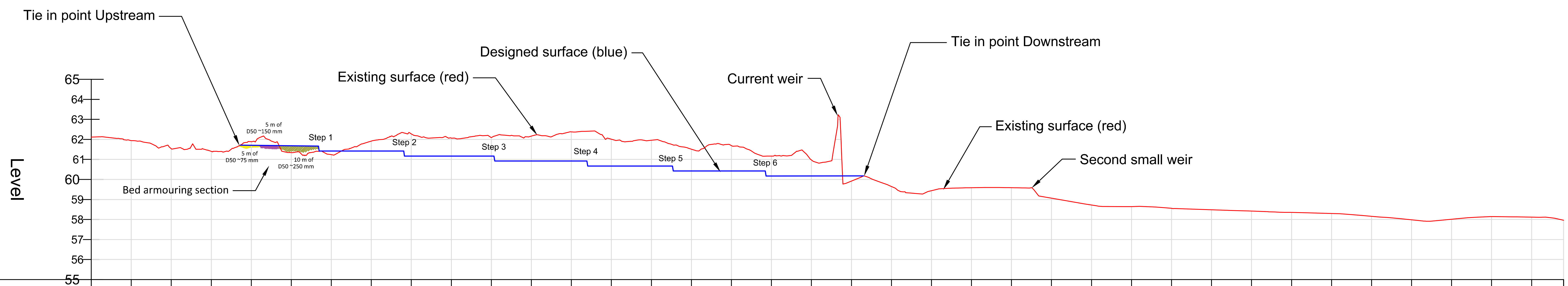

Chainage	00.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000	120.000
Existing Levels	62.118	61.943	61.535	61.403	61.888	61.340	61.238	61.916	62.273	62.067	62.094	62.164	62.375

Chainage	130.000	140.000	150.000	160.000	170.000	180.000	190.000	200.000	210.000	220.000	230.000	240.000	250.000
Existing Levels	62.011	61.958	61.511	61.691	61.169	60.971	59.916	59.648	59.437	59.589	59.590	59.066	58.725

Chainage	260.000	270.000	280.000	290.000	300.000	310.000	320.000	330.000	340.000	350.000	360.000	367.989
Existing Levels	58.643	58.559	58.487	58.419	58.353	58.303	58.157	57.985	58.011	58.144	58.117	57.958

Horizontal Geometry R: Curvature radius L: Section length									
	L =29.572	R: 145.465 L: 103.968	L =0.781	R: 76.328 L: 37.509	L =20.755	R: 77.428 L: 40.704	L =51.559	R: 284.114 L: 79.881	L =3.262

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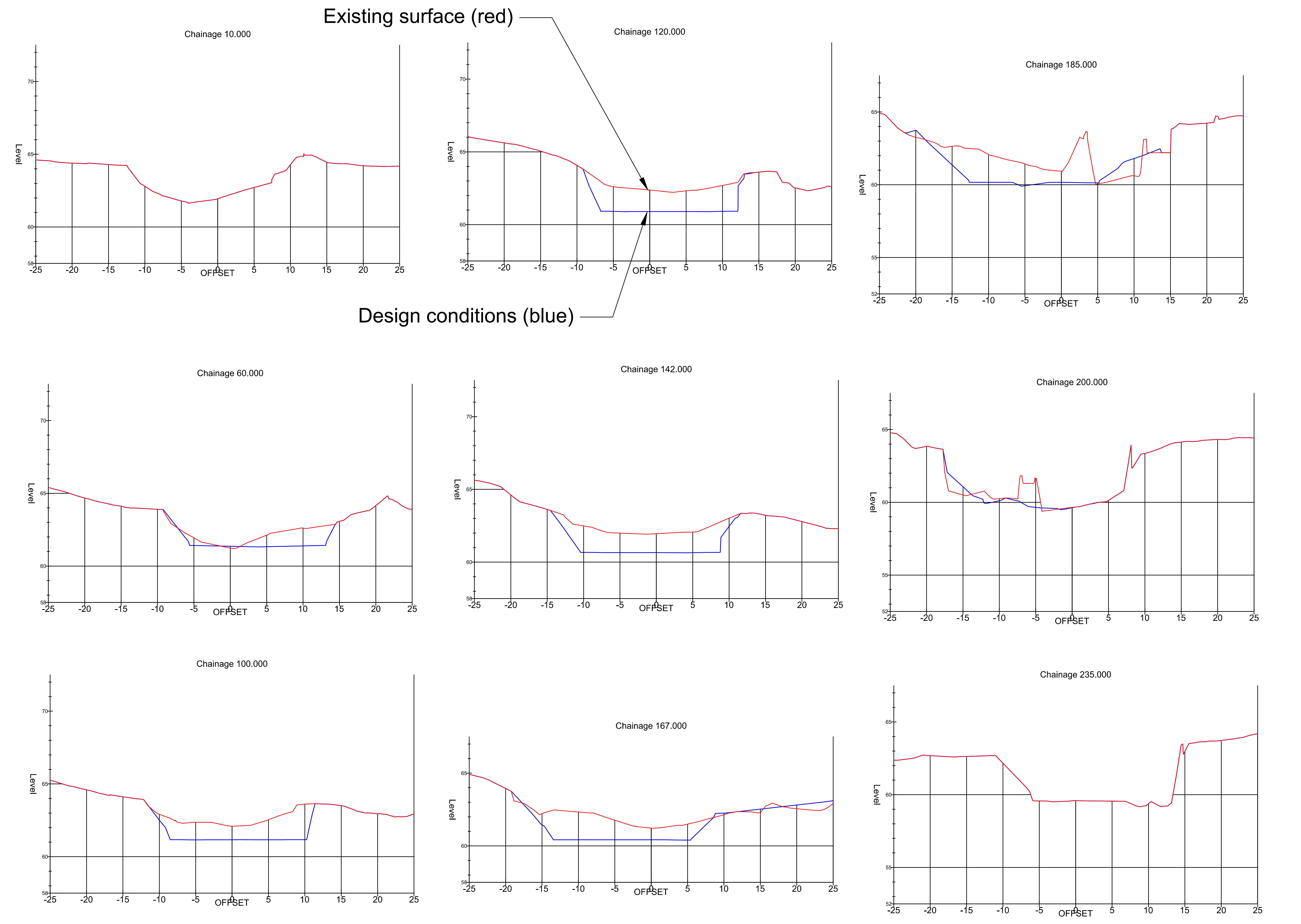

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DRAWN	JI
REVIEWED	
APPROVED	

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UK

BOWSTON Restoration design

CROSS SECTIONS

FILE NAME Kent Weirs

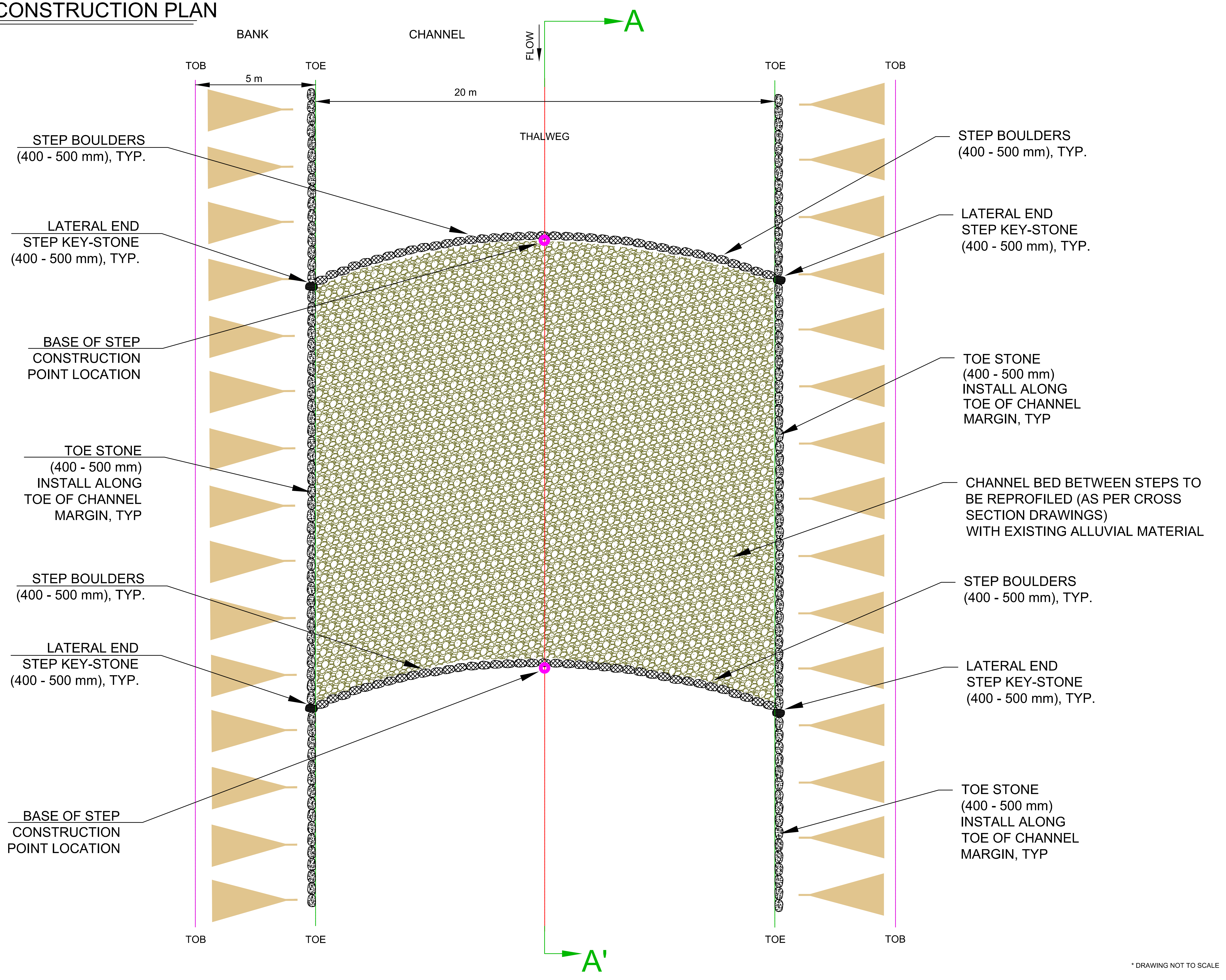
JOB NUMBER UK17 - 1005

DATE February 2018

SHEET NO. 2 OF 2

1 STEP CONSTRUCTION PLAN

N.T.S.



* DRAWING NOT TO SCALE

DOCUMENT RELEASE: SUBMITTAL

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STEP CONSTRUCTION PLAN

FILE NAME: Kent Weirs

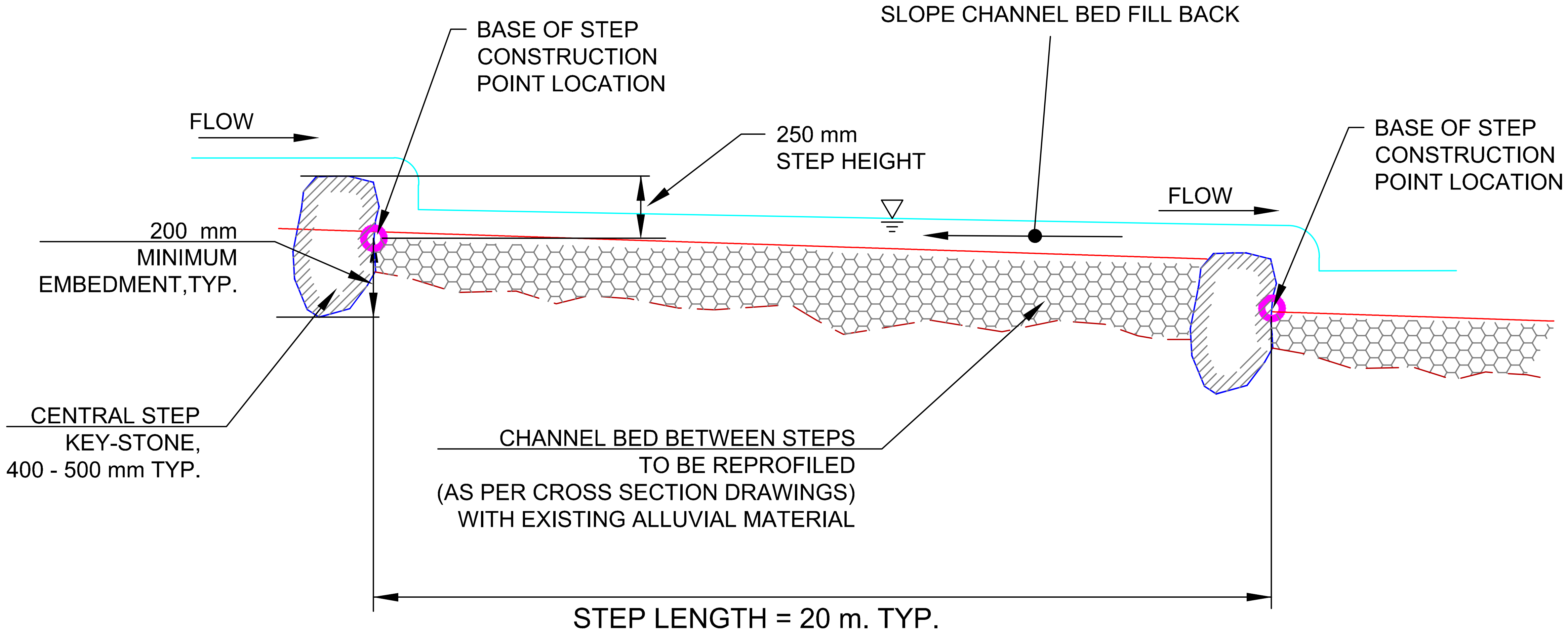
JOB NUMBER: UK17 - 1005

DATE: February 2018

SHEET NO. 5 OF 7

A TYPICAL STEP PROFILE

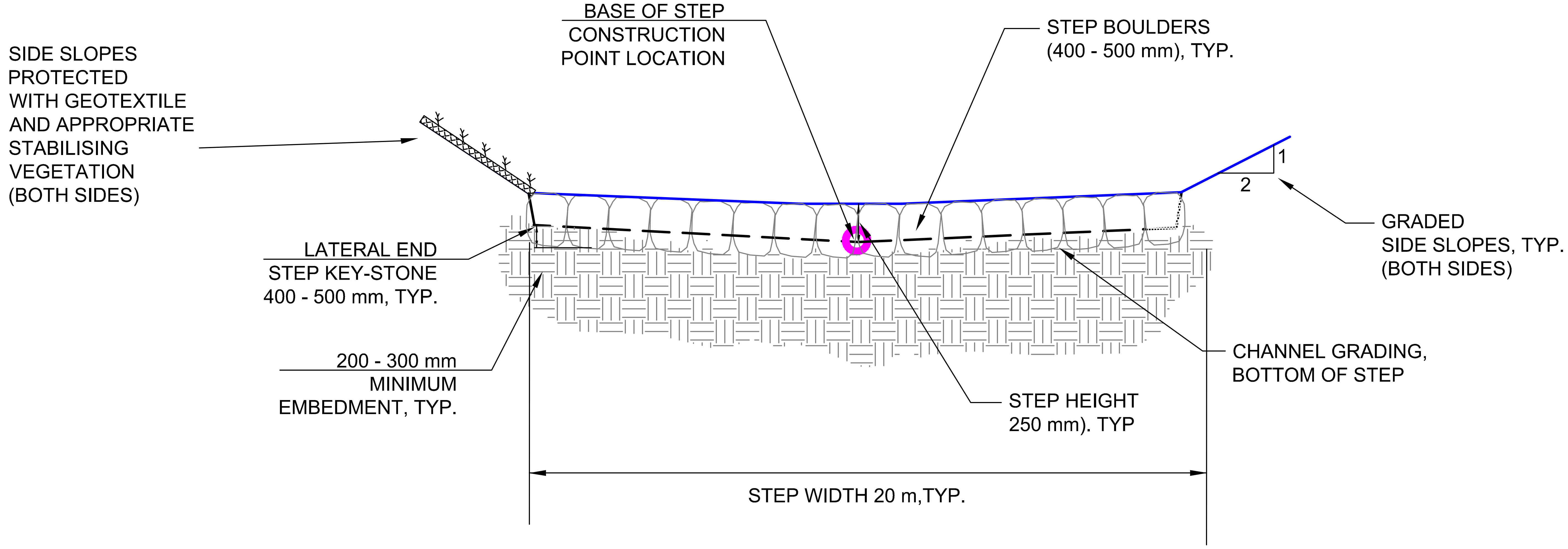
N.T.S.



* DRAWING NOT TO SCALE

B TYPICAL STEP CROSS SECTION

N.T.S.



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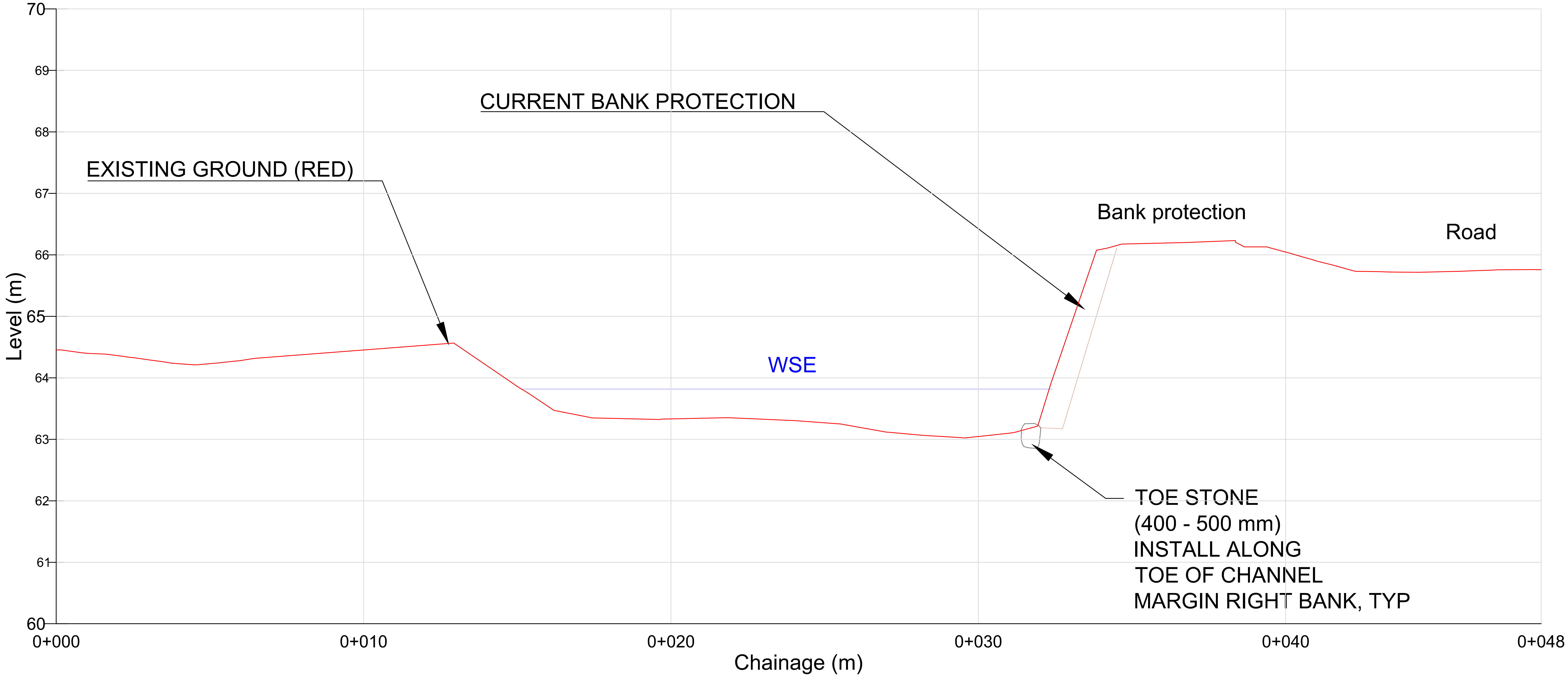
STEP PROFILE DETAIL

FILE NAME Kent Weirs
JOB NUMBER UK17 - 1005
DATE February 2018
SHEET NO. 6 OF 7

CROSS SECTION EXAMPLE
UPSTREAM SECTION



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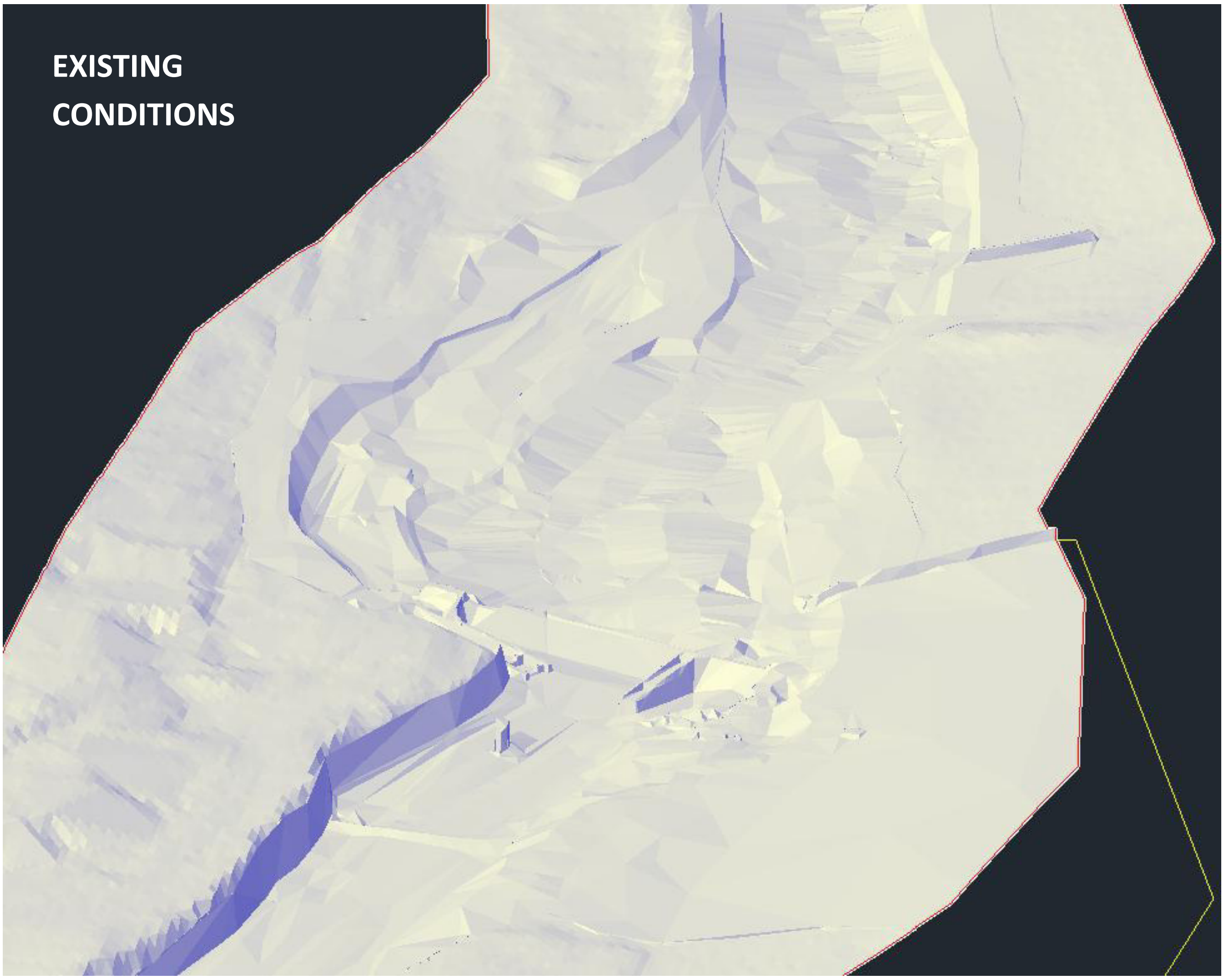
UPSTREAM SECTION DETAIL

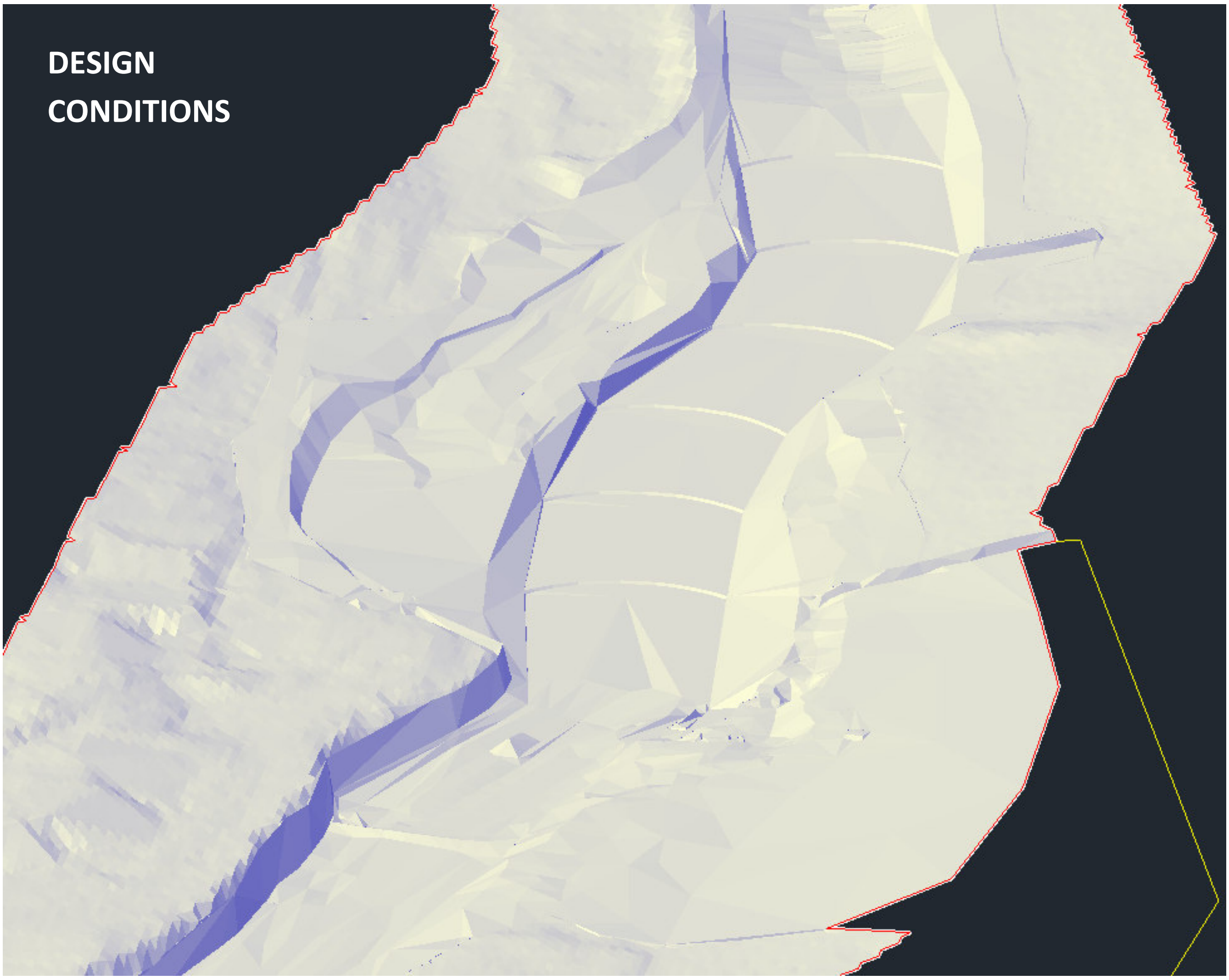
FILE NAME: Kent Weirs

JOB NUMBER: UK17 - 1005

DATE: February 2018

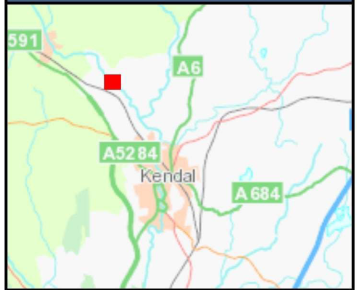
SHEET NO. 7 OF 7


EXISTING
CONDITIONS


DESIGN
CONDITIONS

Project Number	**UK17 - 1005**
Project Title	**Kent weirs**
Drawing Title	**BOWSTON WEIR - CUT / FILL**
Drawing Number	**201802070002**

CUMBRIA (England)



Legend

DEM difference
Existing - Design conditions

- < - 1 m [CUT]
- -1 m - -0.5 m [CUT]
- -0.5 m - 0 m [CUT]
- No difference
- 0 m - 0.5 m [FILL]
- 0.5 m - 1 m [FILL]
- > 1 m [FILL]

Volume calculations (m3)

CUT: 4,141 m3
FILL: 336 m3

NET: 3,805 m3 [CUT]

Client

0 25 50 m

Scale @ A4 - 1: 1,500
N
British National Grid / GCS OSGB 1936

Designed	*Drawn*	*Reviewed*	*Approved*
LC	*JI*	*AW*	

Date	**February 2018**

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Restoration Specialists for Freshwater and Coastal Environments

The Green House,
Beechwood Business Park North,
Inverness, IV2 3BL
(01463) 718831
info@cbecoeng.co.uk
www.cbecoeng.co.uk