JBA consulting

Dowie's Mill Weir

Design Report

March 2017

RAFTS

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Contract

This report describes work commissioned by River and Fisheries Trusts Scotland (RAFTS), by a letter dated 7 December 2016. The work was carried out by Amanda Kitchen, David Bassett, Sebastian Bentley, Lynsey MacLeary, Michael McDonald, Jon Whitmore, David Cameron, Rebecca Thrower, Fran Tobin, Nick Allin, Alex Craven, Steven Thomson, James Howard, Steve Hughes, Josh Redpath and Jonathan Summersgill of JBA Consulting, and Nicky Toop of FAS Heritage.

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Purpose

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Abbreviations

BAP .... Biodiversity Action Plan
CAR .... Controlled Activities Regulations
EA .... Environment Agency
FDSFB .... Forth District Salmon Fishery Board
LBS .... Local Biodiversity Site
mAOD .... Metres above Ordnance Datum
RAFTS .... Rivers and Fisheries Trust of Scotland
Q95 .... Flow exceeded 95% of the time
SEPA .... Scottish Environment Protection Agency
SEPA WEF .... Scottish Environment Protection Agency Water Environment Fund
SINC .... Site of Importance for Nature Conservation
SNH .... Scottish Natural Heritage
SPA .... Special Protection Area
SSSI .... Site of Special Scientific Interest
TWIC .... The Wildlife Information Centre

Definitions

Design life .... The life expectancy of an asset; the length of time between placement into service of an item and when an item starts to wear out.

Ramsar .... Wetland site designated of international importance under the Ramsar Convention.

1 Introduction

1.1 Background

Dowie's Mill Weir is located in the lower reaches of the River Almond, west of Cramond; the nearest address is Dowie's Mill Lane, Cramond, Edinburgh, EH4 6DW (OS NGR NT17924 75652). The weir obstructs passage by species such as salmon, sea trout, eel, sea lamprey and brook lamprey, and has been identified as a high-priority barrier for removal to restore fish passage on the Almond. The weir is located approximately 1 km upstream of Fair-A-Far Weir, 180 m downstream of the historic Cramond Brig and 320 m downstream of the A90 Cramond Bridge.

The structure is a broad-crested weir with a variety of downstream face gradients; it is approximately 70 m wide and is predominantly concrete with some rock armour in places. An existing sluice at the right bank is sub-optimal for fish passage, resulting in limited usage.

Options appraisal was carried out as part of a feasibility and optioneering study (Atkins, 2015). Although an easement would have some aesthetic and heritage benefits, this would result in lower confidence in passability for all species, continued risk of poaching, residual risk of weir failure and a need for maintenance to remove debris. Removal would restore full fish passage for all species, restore sediment transport, eliminate poaching opportunities and require minimal maintenance; therefore, this option was taken forward to detailed design.

1.2 Objectives

The Rivers and Fisheries Trust of Scotland (RAFTS) in partnership with the Scottish Environment Protection Agency Water Environment Fund (SEPA WEF) are working to improve fish passage and enhance the local environment for the River Almond and its catchment. The weir owner, City of Edinburgh Council (CEC), has agreed to the preferred option being taken forward to detailed design. Funding has been secured and detailed design is now required.

1.3 Terms of reference

JBA Consulting was appointed to undertake detailed design of works at Fair-a-Far and Dowie's Mill Weir. The deliverables will comprise the following.

- Visualisations
- Drawings
- Design report
- Technical specification
- Designers' hazard inventory as required under the Construction (Design and Management) Regulations 2015
- Bill of Quantities and Engineer's estimate
- Risk register
- Applications for CAR licence, planning permission and (if required) Listed building consent

A screening opinion from CEC has confirmed that an Environmental Impact Assessment is not required.

1.4 About this report

This report sets out the method of approach, environmental baseline information, design criteria, proposed works and construction management information. It also makes recommendations for the next steps. The report has been structured for ease of conversion into a contract document.

2 Methodology

2.1 Introduction

The design adopted a multi-disciplinary approach, involving specialists in geomorphology, fisheries ecology, contaminated sediment and waste management, heritage, landscape and visual amenity, hydrology, hydraulic modelling and civil engineering.

2.2 Stage 1 Data gathering and review

Data gathering and review were carried out to determine the project objectives, constraints and opportunities, drawing on a review of existing data, previous work (Atkins, 2015; Mott MacDonald, 2014), site walkovers, surveys and stakeholder engagement.

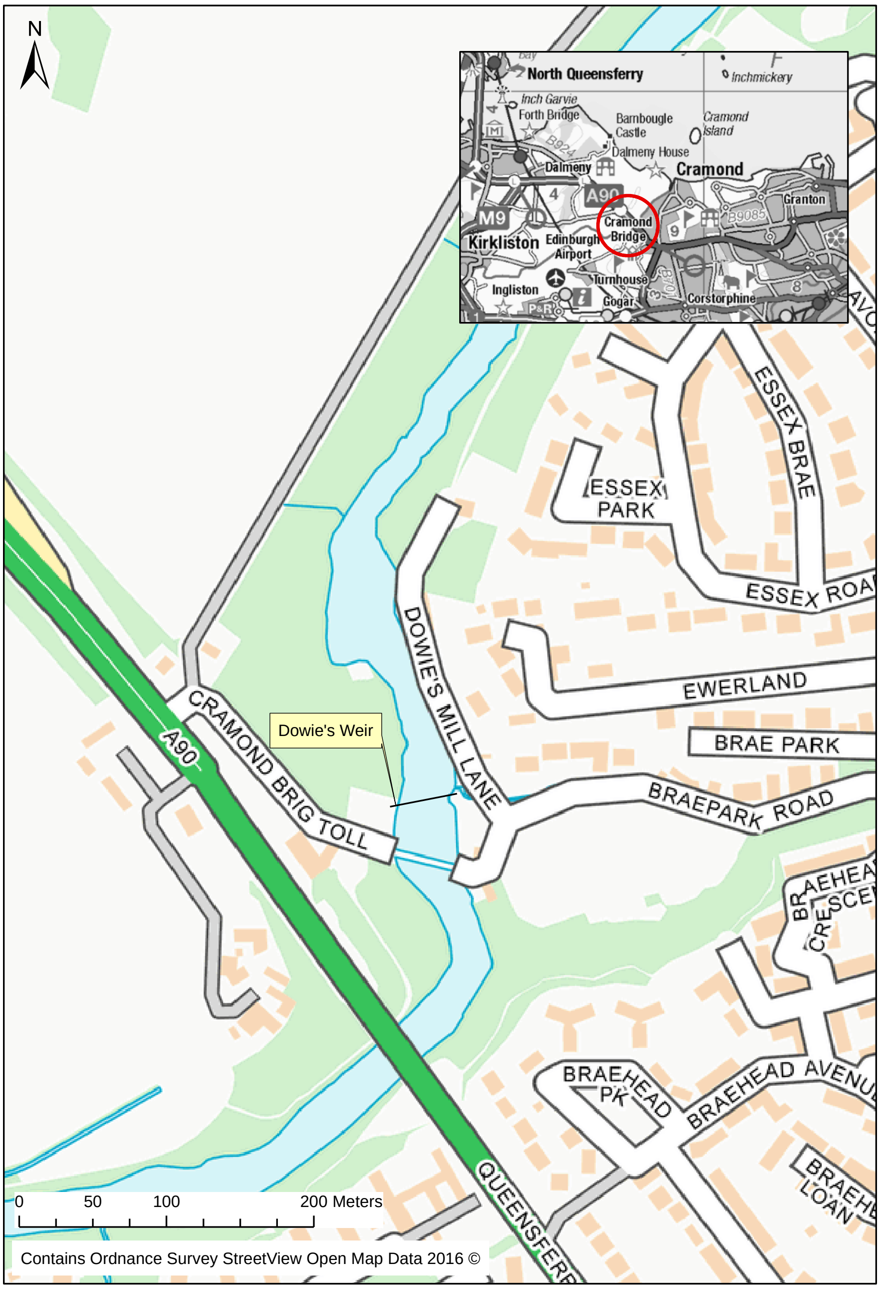

Figure 2-1: Site Location

2.2.1 Data review and site walkover

Existing data were gathered and reviewed to assess their adequacy and identify any gaps. The following data types were considered: Ordnance Survey mapping and aerial photographs; geological mapping; topographic survey; LiDAR; services searches; previous studies (Atkins, 2015; Mott MacDonald, 2014); flood estimation records; and existing hydraulic models.

Additional data relating to services, archaeology and heritage were identified as being required.

The design team met for a site walkover to gain familiarity with the site and identify inter-disciplinary links.

Access routes and possible site compound locations were assessed; both of these factors will influence design and the choice of materials. Methods of transferring plant and materials to and from the site were considered, particularly with regard to impacts on public rights-of-way, access for local residents and businesses, hours of working and vehicle movements.

The provision of safe access for inspection and maintenance was considered. The safety of visitors, whether on land or water, was also considered. The River Almond Walkway is used by walkers and the weir crest is sometimes accessed for recreation and poaching. The River Almond is used by canoeists on occasions.

2.2.2 Pre-application meetings

Pre-application discussions were held with the key stakeholder, CEC, to ensure that objectives and constraints were identified and incorporated into data gathering, surveys and investigations (21 December 2015).

The local authority Access Officer was consulted regarding potential impacts on the adjacent Core Path and the viability of temporary closure and/or diversion during the works.

2.2.3 Topographic survey

Additional detailed cross-section survey of the river and floodplain was undertaken to inform detailed design (JBA Consulting, Jan 2016).

A hydrographic survey of the river at Cramond Brig was undertaken using a remote-controlled boat (Aspect Surveys, 18 January 2016; River Almond at Craigiehall 0.58 m). Further hydrographic survey of the river between the weir and Cramond Brig was carried out using similar equipment, with a probing survey to hard bed level at the same time (JBA Consulting, 13 April).

2.2.4 Underwater survey

An underwater survey of Cramond Brig was carried out by divers to inform a scour risk assessment (GW Marine, 2016). The survey area encompassed all parts of the structure from river bed level to the high flood level. Soundings were taken at 2 m intervals, extending 10 m upstream and downstream of the structure. These were related to a fixed datum point to allow comparison with past and future inspections and identification of any changes to the river bed over time. The survey also checked for scouring or undermining at bed level, open joints and damage to masonry (such as misalignment, bulging, missing blocks or spalling).

2.2.5 Preliminary ecological appraisal

A Preliminary Ecological Appraisal (PEA) was undertaken, involving an Extended Phase 1 Habitat Survey. This included mapping of habitats at the site, recording any evidence of protected and notable species, and an assessment of the potential of each habitat to support such species. The PEA was undertaken by a qualified Ecologist following guidance provided by the Chartered Institute of Ecology and Environmental Management and Joint Nature Conservation Committee. As part of the ecology survey, JBA looked for any structures with bat roost potential and examined these for evidence of bat activity.

Information collected during the PEA survey was recorded and mapped in the field using GISMapp, an iOS-based application developed in-house, which records and geo-locates species and habitat data as well as associated photographs in real time directly onto our servers. This system ensures positional accuracy when sampling on site and removes transposition errors as well as saving time.

The site survey was supplemented by a desk-based assessment, including a data search from the Local Biodiversity Records Centre (LBRC) and The Wildlife Information Centre (TWIC) to determine which species have been recorded within 2 km of the weirs as well as any local site designations.

The results of the PEA, both site survey and desk-based assessment, informed potential appropriate mitigation measures. We liaised with Scottish Natural Heritage regarding non-statutory sites and notable habitats (ancient woodland) mitigation, as required.

A Habitat Regulations Assessment (HRA) Screening Study was undertaken to assess the aspects and the potential impacts of the weir removal schemes on the European sites (Special Area of Conservation (SAC), SPA and Ramsar Sites) that fall within 10 km of the works. As part of the process, SNH were consulted and an Appropriate Assessment was not required.

2.2.6 Hydrology and hydraulic modelling

Flood flow and low flow estimates were prepared using up-to-date gauged flow data, the latter to allow hydraulic assessment of low flow conditions.

The existing hydraulic model and new flood and low flow estimates were used to determine baseline water levels, as well as the impact of the proposed works on flood risk, water levels and velocities.

Central to the effective design of sustainable fish pass measures is an understanding of upstream and downstream water levels and the head difference across the structures at key flow states (as given in Armstrong *et al*., 2010); the hydraulic model was used to produce these critical design levels.

2.2.7 Inspections

Dowie's Mill Weir was inspected from the bank during moderate flow conditions. The weir is constructed from concrete and boulders, with a varying slope (from mild to near-vertical) to the downstream face. In several places, the apron is missing or has been overlaid with concrete. The overall condition of the weir is poor.

2.2.8 Ground investigation

A ground model of the river bed was available from previous studies, based on geophysical survey and verified by boreholes and window sampling on the river bank (Mott MacDonald, 2014). Vertical and horizontal coring were used to determine the foundation depth and construction of the weir.

Two boreholes were drilled on Dowie's Mill Lane at the location of the existing retaining walls (near Dowie's Mill Cottages) to inform slope stability analysis (JBA Consulting, 2016). Material classification tests were carried out to give moisture content, Atterberg limits, particle size distribution, bulk unit weight, shear strength and effective shearing resistance. Environmental testing was carried out for one soil sample.

Five sediment samples were taken upstream of the weir (JBA Consulting, 2016). Analysis of particle size distribution was carried out on one sample. Owing to their coarse particle size, these samples were unsuitable for environmental testing.

2.3 Stage 2 Outline design

Design criteria were developed using the Environment Agency's Fish Pass Manual (Armstrong *et al*., 2010) as the framework for fish passage design. Options for achieving the agreed design criteria were examined and discussed with primary stakeholders.

2.3.1 Hydraulic modelling and flood impact assessment

Reach-scale hydraulic modelling was carried out during design development to assess baseline and with-scheme water levels, velocities and impacts on flooding. This used the 1D-2D model from Atkins (2015) with supplementary cross-sections obtained by JBA (Jan 2016 survey; see also Section 2.2.3).

Detailed hydraulic modelling of the preferred option was carried out to confirm adequate flow depths and velocities for fish passage and to derive sectional velocities for the design of bank protection. This used a 1D HEC-RAS model extending from the upstream limit of the works to downstream of the existing weir to provide suitable design parameters.

Potential impacts on river hydraulics, geomorphology, scour, fish passage (for a range of species), habitat and ecology, heritage, landscape and visual amenity were assessed and either accepted or mitigated by design.

2.3.2 Heritage Impact Assessment

A heritage assessment Appendix H was undertaken to set out the heritage significance of the weirs and their setting, and to establish the likely impact of the proposed work on that significance. This included consideration of both designated and non-designated heritage assets, and involved Sites and Monuments Records (SMR) searches, historic map regression and a site visit. The City of Edinburgh Archaeologist has been consulted regarding requirements for archaeological mitigation.

2.3.3 Landscape Visual Impact Assessment

Landscape and visual appraisal was undertaken to assess the impacts of the proposed works on the above policy designations, alongside key receptors such as the Core Path CEC 11, roads and local residential properties. The report included details of mitigation strategies that will look to limit adverse effects or increase amenity value at both sites.

A site visit was undertaken by a Landscape Architect, with reference photography to allow the production of two visualisations for the site, illustrating the proposed scheme with mitigation for inclusion within stakeholder consultation material.

2.3.4 Geomorphological design

A geomorphological walkover undertaken in 2011 (Atkins), in conjunction with silt sampling and testing of bed sediment, has shown that the bed material comprises predominantly gravels upstream of Dowie's Weir.

A fluvial audit was carried out to help understand the river typology and current forms and processes. Geomorphological assessment was carried out using the results of hydraulic assessment to determine the likely impacts of weir removal on sediment mobilisation, lateral and vertical erosion and deposition risk downstream. The likely impacts of full removal and bed re-grading on existing structures, including Cramond Brig and two pipeline crossings, were examined. The design was refined to minimise or mitigate impacts, with bed re-profiling designed to manage the increase in hydraulic gradient associated with removing the structure.

A contamination assessment was carried out to assess the likelihood and consequences of sediment mobilisation and contaminant release.

2.4 Stage 3 Detailed design

2.4.1 Drawings

The design was developed in consultation with RAFTS, RFFT and SEPA using a three-dimensional CAD model of the river bed.

2.4.2 Design report

Written documents were prepared to accompany the drawings. These included the following:

- technical specification setting out requirements for materials;
- designers' hazard inventory under the Construction (Design and Management) Regulations 2015;
- bill of quantities using the Civil Engineering Standard Method of Measurement (CESMM4);
- Engineer's estimate using experience and recent costs, suppliers' quotations, prices from Spons price book 2013 (where available) or labour, plant and materials and supported using the early contractor involvement);
- quantitative risk register setting out the project risks, consequences, mitigation and owners, with a quantitative estimate of probability, financial consequences and risk budget.

3 Environmental baseline

3.1 Introduction

This chapter covers the site history and knowledge regarding the natural and built environment at Dowie's Mill Weir.

3.2 Site history

A chronology of Dowie's Mill Weir and Cramond Brig is given in Table 3-1.

Dowie's Mill Weir was constructed in the 1600s to impound water for Dowie's Mill. The mill extended downstream from Dowie's Mill Cottages, beyond the existing headwall. The weir breached and was repaired in 1962. Also in the 1960s, a portion of the weir was removed (and presumably replaced) to allow replacement of the A90 bridge.

Cramond Brig was constructed in 1488, 110 years or more before the weir. This implies that the bridge was designed for the more natural flow conditions that existed before the weir, although knowledge of scour was undoubtedly limited and this may have contributed to the flood damage that occurred in 1619.

Table 3-1: Chronology at Dowie's Mill Weir and Cramond Brig

Date	Description	Source
1488	Cramond Brig built	1
1600s	Dowie's Mill Weir constructed	1
1619	Cramond Brig re-constructed after flood damage	1
1687	Repair of Cramond Brig	2
1761	Repair of Cramond Brig	2
1776	Repair of Cramond Brig	2
1781/2	Mill bought by Sir William Cadell	2
	Mill converted to iron-making	2
1854	Repair of Cramond Brig	2
1945	CEC obtained Dowie's Mill Weir	3
1962	Dowie's breached and repaired	1
1960s	Central portion of weir removed to allow replacement of A90 bridge upstream	1

Notes.
1. Atkins (2015)
2. The Cramond Association (date) Walk the Cramond Old Mill Trail
3. Meeting CEC, 22 December 2015

3.3 Existing structures

Dowie's Mill Weir is a diagonal weir with a width of 70 m and a downstream face of varying slope (from mild to near-vertical). Weir height is typically 1.0 to 1.5 m but varies owing to irregularities in the riverbed downstream. Several sections have been repaired by concrete overlay, which is presumed to be mass concrete. A drawdown sluice adjacent to the right-hand headwall provides a low flow route approximately 1.3 m wide. This is sub-optimal for fish passage owing to the turbulent and confused flow and large head drops, resulting in limited usage.

Dowie's Mill Cottages is a Category C-listed building overlooking the weir on the right bank, converted to seven dwellings. On the left bank, the remains of Craigie Mill can be found in the woodland.

Cramond Brig is a Category A-listed bridge spanning the river 180 m upstream of the weir. The three-span masonry arch bridge is constructed from coursed ashlar sandstone masonry. The bridge is closed to vehicles and carries pedestrian traffic. The bridge is maintained by CEC and is in good condition, but is thought to have scour-susceptible shallow foundations and a masonry invert providing scour protection.

The weir is no longer used to supply water to the mill, but provides an impoundment that the local community values for aesthetics and informal boating. The slower velocities also provide a degree of scour protection to Cramond Brig, the pipeline crossings and the left bank at Dowie's Mill Lane.

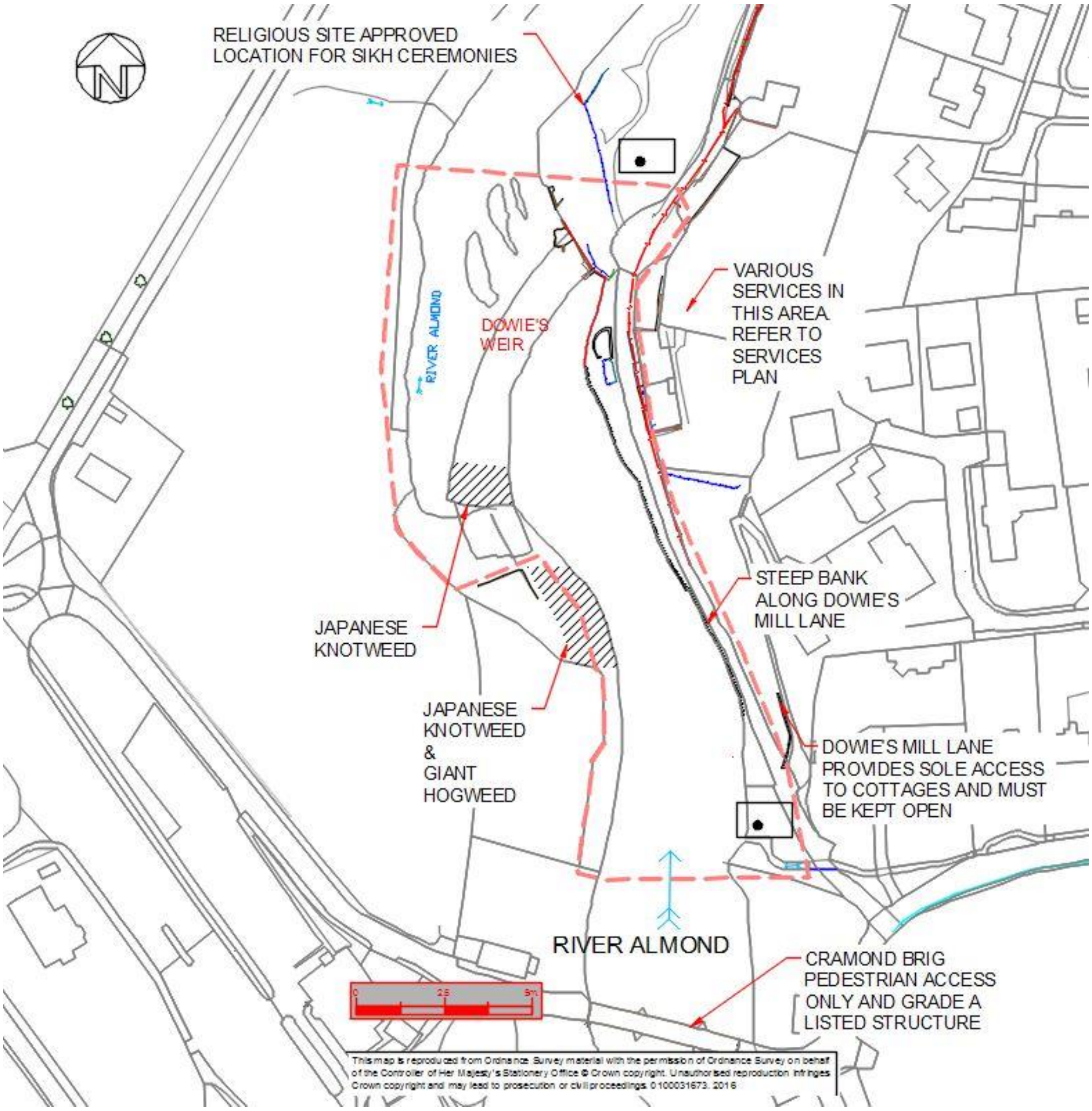

Figure 3-1: Site Layout

3.4 Access

Feasible access routes and possible site compound areas are given in Tables 3-2 and 3-3, respectively, with some additional comments in the sections below. Site access has been confirmed with the third party however, the preferred route will depend on the contractor's chosen method. Site accommodation arrangements will also be made by the successful contractor in their own right.

3.4.1 Left bank

Subject to agreement, vehicular access to the left bank upstream of the weir could be obtained via Cramond Brig Toll and an existing track through private woodland, although tree felling and ground improvement would be needed. Japanese Knotweed and Giant Hogweed are present along the riverbank. This appears the most practical route as it involves minimal environmental impact and negotiation with just one landowner and the fewest number of residents that would reduce impact on public access.

Vehicular access to the left bank upstream of Cramond Brig could be obtained via Cramond Brig Toll and an existing access track through woodland. Again, some tree felling would be required.

3.4.2 Right bank

Vehicular access to the right bank downstream of the weir is available via Dowie's Mill Lane. This route is considered unsafe for heavy vehicle use, owing to its narrow width, the poor condition of the river bank and its proximity to residential properties.

Vehicular access to the right bank downstream of the weir could be obtained from Braepark Road via a private garden, subject to agreement and site clearance.

Access for boat launching is available on the right bank upstream of Cramond Brig, near a footpath to the public car park.

3.4.3 Compounds

On the right bank, a flat area is available immediately downstream of the weir (Site A). This contains buried archaeology and would require an archaeological investigation. Flat areas are also available off Braepark Road (Site B) and at the central horse paddock (Site C).

On the left bank, a private car park is available to the rear of the steakhouse (Site D) and would be ideal for any scour protection works to Cramond Brig. An area of flat agricultural land near Craigiebank, off Cramond Brig Toll (not shown in Figure 3-1), would be suitable if access to the river is taken from the left bank (Route 1). It may be possible to construct a direct pathway through the wood. Either of these left bank locations appear most practical as they minimise environmental impacts and involve negotiation with just one landowner and the fewest number of residents.

Table 3-2: Access routes

Option	Advantages	Disadvantages
Route 1 Left bank via Cramond Brig Toll and private woodland (downstream of 'Willowbank')	Direct access from A90 Existing track through woodland and relatively clear route through trees Single landowner (Dalmeny Estates) Impacts on few residential properties	Some felling of minor trees may be needed Soft ground Japanese Knotweed and Giant Hogweed infested material would need removing and disposal off site, with strict biosecurity
Route 2 Left bank from steakhouse car park	Existing track through woodland to water's edge	Would involve tracking or boating downstream past Cramond Brig, gas pipeline and combined sewer. These would need protection if tracking along riverbed.
Route 3 Right bank via Dowie's Mill Lane	Shortest route from public highway Existing metalled road Trees affected do not have bat roost potential	Lane access unsafe for heavy vehicles/plant Sole access to mill cottages Potential conflict between local residents, walkers and site traffic Tight bend at head of Dowie's Mill Lane Felling of single tree and trimming of others needed
Route 4 Right bank via private garden (20 Braepark Road)	Short route from public highway Single, private landowner	Upstream of gas pipeline and combined sewer crossings, which would need protection if tracking along riverbed Requires negotiation with private landowner May require temporary re-housing of occupiers
Route 5 Right bank from Brae Park car park (by water via River Almond)	Brae Park and playground are public land	Requires trimming of mature trees with good ivy cover near launch point. Trimming of minor branches will have negligible impact on bats. If more extensive de-limbing of trees is needed, trees should be inspected for bats.

Table 3-3: Site compound options

Option	Advantages	Disadvantages
Site A: Right bank near weir	Closest to works Existing metalled	Archaeological investigation required. Impacts on trees. Lane access unsafe for heavy vehicles/plant
Site B: Right bank off Braepark Road (190 m)	Adjacent to public highway Reduces volume of site traffic on Dowie's Mill Lane	Private land Requires negotiation with private landowner
Site C: Right bank horse paddock	Adjacent to public highway Reduces volume of site traffic on Dowie's Mill Lane	Requires temporary surfacing and reinstatement. Requires negotiation with private landowner
Site D: Right bank public car park near playground (360 m)	Existing public open space Cul-de-sac - would not affect access to properties	Distance to works
Site E: Left bank steakhouse lower car park	Used by CEC recently Convenient for existing track to riverside just upstream of Cramond Brig, and down to weir access track on left hand side	Requires negotiation with private landowner (one only)
Site F: Left bank near Craigiebank	Flat agricultural land Avoids tree felling Single landowner	Indirect route to working area Elevated above river level

3.5 Watercourse conditions

3.5.1 Flow gauging

The nearest SEPA gauging station is located on the River Almond at Craigiehall, about 1.8 km upstream of the weir (http://apps.sepa.org.uk/waterlevels/default.aspx?sd=t&lc=14867). This gauging station has 58 years of record. SEPA issues flood alerts for Edinburgh and Lothians, and a flood warning for Cramond based on heavy rainfall or observed and forecast river levels.

3.5.2 Hazardous conditions

The River Almond is flashy. Flows and water levels can rise rapidly according to weather conditions within the catchment.

Dowie's Mill Weir exhibits fast turbulent flow downstream of the weir (Figure 3-2). Neither the weir nor the river should be accessed during these conditions. No structural assessment of the weir has been undertaken, but there are visible defects; therefore, the point at which the weir becomes dangerous cannot be specified and must be determined by appropriate risk assessment of the proposed activity.

High flow conditions on 11 December 2015

River level 1.2 m, Flow 22.5 m3/s, Q5 approx.

Lower flow conditions on 21 January 2016

River level 0.67 m, flow 7.63 m3/s, Q20 approx.

Figure 3-2: Conditions at Dowie's Mill Weir

3.6 Surveys

3.6.1 Topographic survey

Topographic survey was undertaken by Greenhatch (2015), oriented to Ordnance Survey National Grid (OSGB36) via Global National Satellite Systems (GNSS) and OS Active Network (OS Net). Additional cross-section survey was undertaken by JBA Consulting (2016).

3.6.2 Hydrographic survey

Hydrographic survey was carried out to determine bed and invert levels upstream of the weir and in the vicinity of Cramond Brig (Aspect Land and Hydrographic surveys, 2016). This was accompanied by a probing survey to assess the depth of soft sediment accumulation (JBA Consulting, 2016). The findings are available in the following drawings: River Almond Cramond Brig bed levels; River Almond bed levels topo survey.

3.6.3 Underwater survey

Underwater survey was carried out at Cramond Brig and the findings are given in Appendix G1 (GW Marine, 2016). The survey showed that an existing masonry invert is present. The invert comprises a slightly dished hand-pitched stone with dry joints, although the type of stone is unknown. The invert is in fair condition, with local areas of plucking and undermining. The level varies as follows:

- Left-hand arch: 12.69 to 12.85 mAOD;
- Centre arch: 12.61 to 12.98 mAOD;
- Right-hand arch: 12.70 to 12.90 mAOD.

3.6.4 Bathymetry

The bathymetry of the weir pool for the Q95 water level is shown in **Error! Reference source not found.** with levels ranging from 14.00mAOD in pink to 10.2mAOD in yellow. The drawing 2015s3628-S-D413_Bathymetric Survey is based on levels obtained during the topographic and hydrographic surveys (Greenhatch, 2015; Aspect Surveys, 2016; JBA Consulting, 2016).

The main channel features are existing scour holes upstream of Cramond Brig, immediately upstream of the pipeline crossings and near the right bank near Dowie's Mill Cottages.

Figure 3-3: Bathymetry upstream of weir

Elevations Table				
Number	Minimum Elevation	Maximum Elevation	Area	Color
1	10.20	10.40	0.18	
2	10.40	10.60	94.89	
3	10.60	10.80	249.95	
4	10.80	11.00	539.83	
5	11.00	11.20	951.19	
6	11.20	11.40	633.77	
7	11.40	11.60	549.78	
8	11.60	11.80	593.30	
9	11.80	12.00	767.07	
10	12.00	12.20	1024.36	
11	12.20	12.40	1190.58	
12	12.40	12.60	1242.79	
13	12.60	12.80	1488.77	
14	12.80	13.00	1640.31	
15	12.78	13.20	3061.02	
16	12.84	13.40	3733.29	
17	12.91	13.60	4216.01	
18	13.15	13.80	3938.29	
19	13.66	14.00	2301.83	
20	14.00	14.20	832.69	

3.6.5 Bed sediment

Sediment sampling indicates that sediment has accumulated upstream of Dowie's Mill Weir (Mott MacDonald, 2014). The sediment depth is estimated to be 1 to 2 m, decreasing to less than 0.15 m at the banks of the river. The area of sediment is shown in Figure 3-4 below and in the longitudinal section in Figure 3-5.

The total volume of sediment is estimated to about 1,000 m³, based on a bed level of 11.25 mAOD. More recent sampling carried out as part of the 2016 ground investigation indicates that the sediment consists predominantly of gravel and stones with silt in the interstices. Sands and gravels typically have a porosity ranging from 0.23 to 0.38 (http://www.geotechdata.info/parameter/soil-porosity.html). Assuming an average porosity of 0.3, the volume of silt can be estimated to be no more than a maximum of 300 m³ (= 1,000 m³ x 0.3). In the bulk samples taken, it was difficult to find sufficient silt to sample, suggesting that the actual volume may be lower than the above estimate.

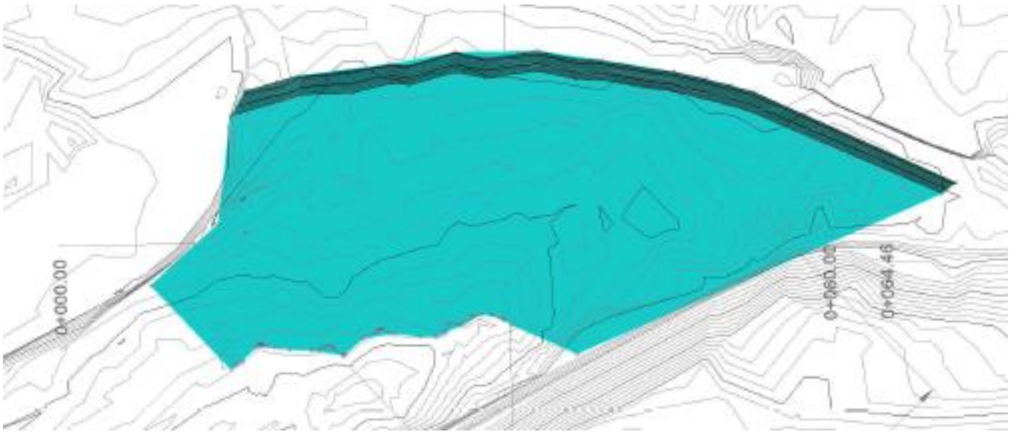

Figure 3-4: Sediment location plan

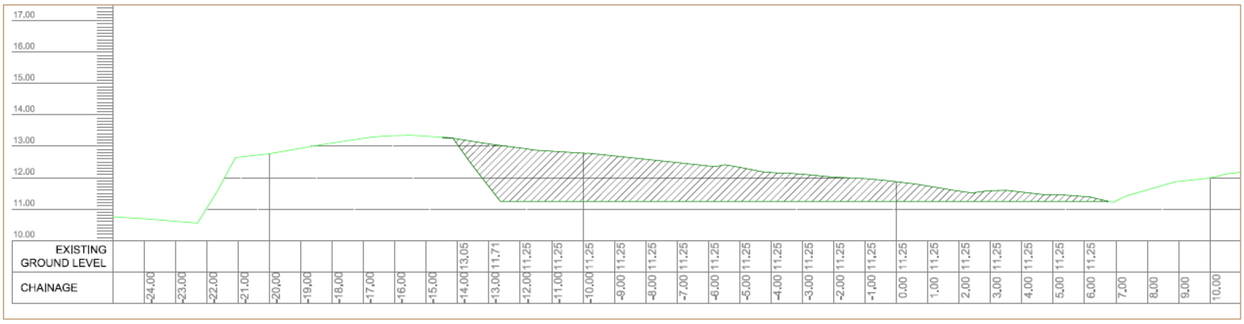

Figure 3-5: Longitudinal section through sediment (weir to left)

3.7 Ground conditions

3.7.1 Geology

The geology of the site includes alluvium of gravel, sand, clay and silt, overlying mudstone, siltstone and sandstone (Mott MacDonald, 2014).

3.7.2 Ground investigation

Three boreholes drilled downstream of the weir (one on the left bank and two on the right) indicate that the ground comprises made ground over alluvium and glacial till. The holes were up to 4.7 m deep and bedrock was not located. The bedrock is known to be more than 10 m below ground level (Mott MacDonald, 2014).

Two 1.5 m deep window samples on the left bank showed made ground over alluvium downstream of the weir and alluvium only upstream of the weir.

Further borehole investigation was carried out on Dowie's Mill Lane (JBA Consulting, 2016). A geotechnical interpretative report is given in Appendix D, with borehole logs and laboratory test results. Two boreholes were drilled to depths of 10.5 and 10.83 m, at the location of the existing retaining walls.

This confirmed the stratigraphy within the study area to be around 0.5 m of made ground, over an average thickness of 0.9m of sandy gravelly Silt (alluvium) deposits. Below this, the ground comprised till deposits. The till consists of a stiff to very stiff sandy slightly gravelly Clay with low cobble content. The first 1m of the till is weathered although still stiff and the base of this strata was not proven. The ground investigation did not prove the solid geology, which comprises the sandstone, siltstone, limestone and mudstone of the Calders Formation (BGS data). No groundwater strikes were encountered in the boreholes. This is due to the impermeable nature of the clay and that water was required to advance the boreholes.

Material classification tests were carried out to give moisture content, Atterberg limits, particle size distribution, bulk unit weight, shear strength and effective shearing resistance. The results are given in Appendix D.

Environmental testing was carried out for one soil sample (weathered till deposits). The contamination test results were reviewed against a trigger level for "open space residential" use as documented in the LQM/CIEH S4ULs for Human Health Risk Assessment. No tests exceeded the guideline values and the till deposits can be classed as inert. The made ground and alluvium were not tested as part of these works.

3.7.3 Conclusion

Slope stability modelling was used to assess the destabilisation risk for 2 retaining walls situated on Dowie's Mill Lane. The risk to bank stability is caused by the draining of the impoundment at Dowie’s Weir required for the proposed river restoration. The modelling was undertaken using Slope/W and Seep/W from Geostudio 2015, which uses limit equilibrium equations to assess slope stability in terms of factor of safety (FOS) per time step with varying ground water conditions. The modelling focused on 2 retaining walls owing to concerns of bed erosion potentially undermining wall foundations. The two slope profiles were modelled corresponding to the position and geology of boreholes 1 and 2, undertaken in during the ground investigation.

The results of the modelling show that the retaining walls will remain stable both during construction and in the long term. Although the modelling shows stability during the construction phase, the placement of rock armour should be completed as soon as practicable after draw down to ensure that maximum stability of the retaining walls is maintained throughout.

Although the ground investigation and slope stability analysis was specifically focused on the 2 existing retaining walls it is possible to glean information that can be inferred to inform on the general stability of the right bank.

Given that the geology in both boreholes was very similar it can be assumed that the geology of the rest of the right bank will be comparable, consisting of a stiff clay over bedrock. This is evident as there are small near vertical faces located sporadically along the river bank. This information can be used to inform the temporary works.

The slope stability analysis of the retaining walls indicated that the bank would remain stable after draw down of the impounding water for temporary works. Given the stiff nature of the clay encountered in the ground investigation it is likely that the unsupported bank will remain stable during temporary works. The analysis of the retaining walls did not however indicate how long this temporary condition may last before instability may begin.

In order to construct the right bank protection, the impoundment must be drained which increases the risk of bank instability, the following options are proposed to mitigate the instability risk:

- Lower the impoundment in steps of 300mm, installing bank protection as the water level drops one step at a time. This ensures that the bank is supported for as long as possible particularly at the toe where the largest pore water pressure will be. Temporary cofferdams could be used to create semi dry workable zones in which a panel of bank protection can be constructed. The cofferdam would move downstream as the impoundment drops. Pumps used to maintain a semi dry working zone could be used to refill the site should slope instability be noted and requires immediate support.
- Install temporary riprap throughout the right bank as a temporary measure during draw down. It is possible that the stoney material intended for the construction of the riffle pool sequence could be placed as temporary reinforcement to the tow of the bank. The riprap would be moved in panels to allow the green bank protection to be constructed.

3.7.4 Structure cores

Two structural cores through the weir indicate that the weir construction comprises concrete and boulders over glacial till (Mott MacDonald, 2014). The investigation indicated voids on both sides of the weir, with a foundation depth of 1.55 to 2.0 m towards the left bank and 1.3 to 1.4 m on the east bank.

Structural coring at Cramond Brig indicated that the left-hand (west) abutment was approximately 2.0 m thick with a foundation level of 12.19 mAOD (Mott MacDonald, 2014). The right-hand (east) pier has a 0.7 m sandstone face over a sandstone and lime concrete core and a foundation level of approximately 11.78 mAOD. Note that it should not be assumed that all piers and abutments will have the same foundation depth.

3.7.5 Bed sediment

Two bed sediment samples taken upstream of the weir indicated clay near the left bank (10 m upstream) and silt near the right bank (35 m upstream) (Mott MacDonald, 2014). Particle size distribution testing showed the samples to consist of clay to gravel.

Laboratory testing of sediments upstream of the weir by Mott MacDonald indicated the presence of polyaromatic hydrocarbons, metals (zinc) and certain biological contaminants at levels above generic screening values (described further in Section 5.13). Although land use along the 50 km length of river upstream of the study area is largely agricultural, contamination is thought to have arisen from a variety of historic land uses, including former mills close to the river at several locations, mineral extraction operations (including shale), a gas works near Cramond Brig and upstream contributions from sewage works and industrial use.

Five further bed sediment samples were taken upstream of the weir in 2016 (see Appendix D) but were not subject to laboratory chemical analysis as no silt was recovered. Particle size distribution testing showed the sample to consist entirely of gravel and cobbles, which was not appropriate for environmental testing. The absence of fine material compared with the 2014 samples may have been the result of prolonged floods during winter 2015 to 2016.

3.7.6 Water quality

Water quality in the River Almond is poor, with contamination due to past industrial land uses and runoff and sewage (SEPA, 2015)[1]. Contamination is discussed further in section 5.13.

3.8 Ecology

3.8.1 Designated sites

A number of statutory and non-statutory designated sites are located adjacent to or near the site.

The Firth of Forth 1.6 km downstream of the weir is a multi-designatory site (Special Protection Area (SPA), Ramsar and Site of Special Scientific Interest (SSSI)), which may be affected by any sediment mobilisation.

The River Almond is designated under the Local Development Plan as a Site of Importance for Nature Conservation (SINC) and Local Biodiversity Site (LBS). These designations are non-statutory protection, but the local authority should protect the site in recognition of its local importance.

3.8.2 Habitat

The habitats identified during the desk study and survey are summarised below with full details in Appendix A (Table 4-1):

- broadleaved woodland - semi-natural;
- coniferous woodland - semi-natural;
- improved grassland;
- running water - eutrophic;

1 The 2015-2027 RBMP report was published in December 2015 and details the expected achievements for the period from 2015 to 2027. The information sheet for the SEPA reach 3000 - River Almond (Maitland Bridge to Cramond) noting the current poor water quality is located at http://www.sepa.org.uk/data-visualisation/water-environment-hub/ [accessed 10/02/2017].

- standing water;
- arable;
- buildings;
- bare ground;
- other habitat.

Woodland on the north bank of the River Almond within the study area falls within the Ancient Woodland Inventory. The woodland, which comprises sycamore, *Acer pseudoplanatus*, Ash, *Fraxinus excelsior,* and beech, *Betula* spp., is an ancient woodland of semi-natural origin. This habitat is listed under the UK BAP.

The survey area is situated within a semi-rural environment comprising predominately artificial habitats, including housing and arable land, situated adjacent to the River Almond, which runs south-west to north-east through the area.

3.8.3 Protected species

A data search from The Wildlife Information Centre (TWIC) returned numerous records of protected species and birds (protected and notable) within 2 km of the survey area. These are summarised below, with full details in Appendix A (Tables 4-2 and 4-3).

Terrestrial mammals

- Bat Species *Chrioptera spp*.;
- Pipistrelle Bat *Pipistrellus pipistrellus*;
- Brown Long-eared Bat *Plecotus auritus*;
- Badger *Meles meles*;
- Otter *Lutra lutra*;

Marine mammals

- Common Porpoise *Phocoena phocoena*;
- Grey Seal *Halichoerus grypus*;
- White Beaked Dolphin *Lagenorhynchus albirostris*;

Amphibians

- Common Toad *Bufo bufo*.

Birds

- Kingfisher *Alcedo atthis*;
- Bar-tailed Godwit *Limosa lapponica*;
- Barn Owl *Tyto alba*.

No records of Great Crested Newts were returned from the data search and the only amphibian records within 2 km of the weirs refer to Common Toad. Furthermore, there are no records of reptiles within 2 km of the weirs.

The data search returned a record for Kingfisher approximately 1.1 km from Dowie's Mill Weir, but the banks of the river were not considered to be good nesting habitat for Kingfisher owing to the vegetation cover and substrate. The following bird species were recorded during the site walkover: Dipper, Grey Heron, Goosander, Mallard, Woodpigeon, Black-headed Gull, Wren, Blackbird, Carrion Crow, Grey Wagtail, Great Tit, Blue Tit, Chaffinch, Goldfinch, Greylag Goose and Starling.

No evidence of bats was found during the survey; however, there are several mature trees within the riparian woodland along the River Almond that may offer suitable roosting opportunities for bats. A tree that overhangs Dowie's Mill Weir was considered to be a Category 2 tree (in line with BCT guidance), showing no obvious potential, but it supports some limited potential features for roosting bats. The trees on the left bank are considered to have negligible-low bat roost potential owing to the age of the trees.

No conclusive evidence of badger was recorded during the survey, although several mammal runs were present along the embankment on the right bank.

No evidence of otter was found during the survey, although the River Almond provides excellent foraging and commuting habitat for this species.

3.8.4 Fish

The River Almond is a known salmonid fishing river, and Cramond Angling Club is active along the river reach surveyed as part of this commission, recording Brown Trout, sea trout and occasional Atlantic salmon. No records of fish were returned from the data search from TWIC, but Marine Science Scotland (MSS) catch returns were provided for the five-year period from 2010 to 2014 (inclusive). A total of 792 migratory trout (finnock and sea trout) and 132 Atlantic salmon (wild multi sea winter fish and grilse) were caught in this period.

3.8.5 Non-native invasive species

Non-native invasive species Japanese Knotweed and Giant Hogweed have been found adjacent to the weir, with stands of Japanese Knotweed on the weir structure itself.

3.9 Services

This section should be read in conjunction with the drawing Figure 3-6 and 2015s3628-S-D412_Services Plan.

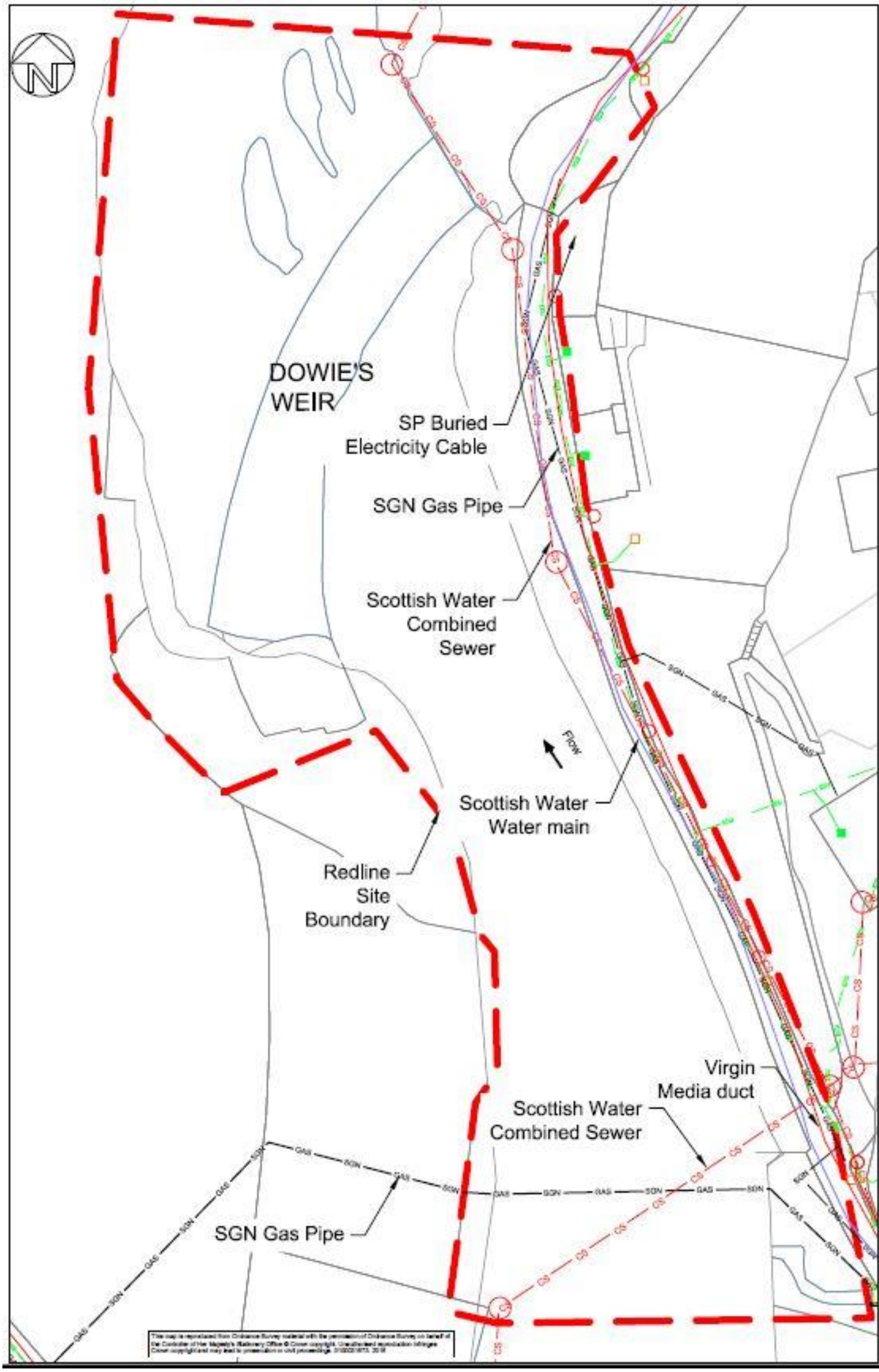

Figure 3-6: Services

3.9.1 Gas pipeline

An SGN (Scotia Gas Networks) medium-pressure gas pipeline (up to 2Bar) crosses the river about 70 m upstream of the weir and 70 m downstream of Cramond Brig. On the left bank, this runs from the site of a former gas works immediately upstream of Cramond Brig (Ordnance Survey 1853-1856 map). On the right bank, the pipe turns to run beneath private land at 2 Dowie's Mill Lane.

The depth of the pipeline is unknown. Under present-day standards, the pipeline would be installed below the riverbed, but the pipeline could be up to 35 years old and these standards may not have applied at the time of installation. The pipeline comprises a plastic pipe, which is cased in a 10" steel sleeve beneath the river. Marker posts show the location of the sleeve on the left bank.

Hydrographic survey found no obvious evidence of the gas pipeline, indicating that this is below bed level (JBA Consulting, 2016).

3.9.2 Combined sewer

A Scottish Water 150 mm combined sewer runs along the left-hand side of the river channel, from upstream of Cramond Brig to the downstream boundary of Willowbank (Manhole 9501). Here, it crosses the river at an angle of 45 degrees, before joining a 600 mm diameter combined sewer along the right bank (at Manhole 9502). The sewer runs along the river bank, with a manhole just downstream of the weir. It then runs along Dowie's Mill Lane to a manhole near the weir headwall, turning sharp left to a riverside manhole before following the riverbank downstream.

The depth of the pipeline is not known precisely. Hydrographic survey indicated that the sewer is partially exposed at the river crossing near the left bank, dropping beneath bed level about halfway across the river.

East of the river (manhole 9502, invert level 11.87 mAOD), the top of the sewer is estimated to be 12.02 mAOD and the surveyed riverbed level is 12.24 mAOD, giving cover of about 0.22 m. West of the river, an estimate of the sewer pipe depth can be made using the known invert level at the eastern, downstream and assuming a sewer pipe gradient of 1:60. This results in a western, upstream (9501) invert level of 12.803 m, with an approximate invert level in the centre of the channel of 12.338 m.

3.9.3 Other services

A gas pipe (90 mm diameter HPPE) runs beneath a trench scar along Dowie's Mill Lane.

A buried electric cable runs along Dowie's Mill Lane to and beyond Dowie's Mill House.

An overhead line (presumed communications) follows Dowie's Mill Lane, crossing it three times before reaching a telegraph pole adjacent to the right-hand headwall of the weir.

A water pipe (60 mm diameter HPPE) runs along the metalled surface of Dowie's Mill Lane, continuing along the unsurfaced track to Dowie's Mill House.

3.10 Other users

The River Almond Walkway provides a scenic route from Cramond Brig to Cramond Village at the Firth of Forth. The route is about a mile long and valued by the community for historic and environmental value. The route is busy with walkers during the summer.

Local anecdotes suggest that the weir pool is used informally for swimming and is an unsupervised attraction for local youths (RAFTS Questionnaire; Steering group, 18 May 2015). Swimming is likely to take place during low flow conditions in the summer months.

The river is used by canoeists in spate conditions. Guidance recommends disembarking at Cramond Brig rather than continuing to the Firth of Forth (www.ukriversguidebook.co.uk, accessed 27 May 2016), owing to dangerous weirs.

The land between Dowie's Mill Lane and the River Almond is owned by various parties, including 17 Ewerlands, and two of Dowie's Mill Cottages.

Dowie's Mill Lane provides sole access to nine residential properties, including a woodturner's workshop that is open to the public. Vehicular access must be maintained for residents and emergency access. Dowie's Mill Cottages, a two-storey Category C listed building overlooking the weir, has been converted to seven apartments (14/15/16/17/18/20 and 21 Dowie's Mill Lane), whilst a house in the woodland downstream contains two dwellings (22 Dowie's Mill Lane and Dowie's Mill House).

4 Design criteria

4.1 Introduction

This chapter sets out the project objectives and design criteria for the removal of Dowie's weir. The design criteria were determined based on input from a range of disciplines, including fisheries, hydromorphology, landscape, environment, cultural heritage, geotechnical, constructability, maintenance and safety. Key stakeholder aspirations were also compiled from the findings of the earlier consultation. The design will provide a varied channel form which will allow fish passage. The new channel has been designed within the constraints of the services which cannot be relocated and to minimise erosion of the newly exposed channel banks.

4.2 Project objectives

The project objectives are as follows:

- restore fish passage by removing the existing weir;
- reinstate natural processes within the impounded zone and natural sediment transport processes to downstream reaches;
- avoid increasing flood risk;
- avoid damage to existing infrastructure.

4.3 Fish passage

Priority designed-for species are as follows:

- Atlantic salmon *Salmo salar;*
- Sea trout *Salmo trutta*
- European eel *Anguilla anguilla;*
- Sea lamprey *Petromyzon marinus;*
- Brook lamprey *Lampetra planeri;*

The removal of the weir and replacement with a new channel will provide a range of velocities within the channel suitable to allow the priority species above. The concept design is not a technical pass and is designed to result in significant velocity heterogeneity. This in-channel variability will provide conditions that the priority species will find passable. The more natural design is difficult to qualify with any degree of accuracy as it is largely beyond the limits of what is possible with even 2D hydraulic modelling, but the design concept will result in extensive wet, slack margins and higher notch velocities that will be exploitable by such fish. To ensure a greater degree of certainty of fish being able to pass through the newly designed reach, hydraulic modelling at key points (riffle crests and over the boulder bar) has been carried out to ensure the principal fish pass design criteria are achieved for a range of design flow conditions.

The works avoid inadvertently creating a new obstruction to fish at Cramond Brig by maintaining sufficient flow depth over the existing masonry scour protection apron.

The principal documents used to inform the hydraulic design of the works are the Environment Agency (EA) of England's Fish Pass Manual, Armstrong *et al*. (2010) and USBR (2007). The EA document sets out numerous hydraulic design criteria and the reader is referred to this document for full details. The principal design criteria used to inform the design are given in Table 4-1.

Table 4-1 Principal fish pass design criteria (**after Armstrong *et al.*, 2010**)

Criteria	Threshold
Range of exceedence flow over which design criteria to be achieved	Salmon - Q10 to Q90 Sea trout - Q10 to Q95 Eel - Q70 to Q99 Sea lamprey - Q20 to Q50 River lamprey - Q30 to flood flows(1)
Position & alignment of downstream entrance to fishway	As close to barrier to migration as possible. In alignment with main channel flow.
Minimum fishway discharge (% of mean daily flow)	≥5%
Maximum head difference (m)	Migratory salmonids - 1.8 m(2)
Maximum flight length (m)	Migratory salmonids – 12 m Other species – 10 m(2)
Maximum operating head (m)	Migratory salmonids - 0.8(3) Trout 0.5 m
Minimum depth in fishway (m)	Large migratory fish - 0.15(4) Trout - 0.10
Minimum velocity at fishway exit (m/s)	All species - 1.0
Maximum velocity in fishway (m/s)	Salmon - 2.0(5) Sea Trout - 2.0 Brown Trout - 1.6
Discharge (l/s/m)	Migratory salmonids - 250 to 1400 Trout - 150 to 650
Notes 1 - "Flood flows" is not further defined in the manual. 2 - The manual does not differentiate between different life stages of migratory salmonids, neither are differing criteria given for non-migratory salmonids. 3 - The manual does not differentiate between different life stages of migratory salmonids. 4 - The manual does not differentiate between species of migratory fish. 5 - The manual does not differentiate between different life stages of salmon.	

4.4 Hydrology and hydraulics

4.4.1 Design flows

The design must be passable for fish at the Q95 to Q10 range of flows.

The works must avoid increasing flood risk to property or infrastructure at the site or elsewhere as a material requirement of planning permission. The impact of the works on flood risk was assessed for a design flood of 0.5% annual probability (200-year return period) plus an allowance for climate change.

Selected low flows and modelled water levels are given in Table 4-2, with full details of the hydrological assessment in Appendix C. The modelled water levels are immediately upstream of Cramond Brig and downstream of the weir. Selected peak flood flows for geomorphological design and flood risk assessment are given in Table 4-3.

Table 4-2: Selected low flows and modelled water levels

		Baseline (008.dat)			Design (Scenario7_004.dat)		
Percentile	Flow (m^3/s)	Water level Cramond Brig (mAOD) Downstream bridge face (DW_06_0366)	Water level downstream of weir (mAOD) (DW_16_0555)	Difference (metres)	Water level Cramond Brig (mAOD) Downstream bridge face (DW_06_0366)	Water level downstream of removed weir (mAOD) (DW_16_0555)	Difference (metres)
Q99	0.818	13.265	10.952	2.31	12.922	11.481	1.44
Q95	1.044	13.285	10.994	2.29	12.935	11.494	1.44
Q10	13.530	13.604	11.661	1.94	13.287	11.846	1.44

Table 4-3: Selected peak flood flows

Annual Probability (AP)	Return period (years)	Flow (m^3/s)
50	2	137.9
20	5	181.5
10	10	207.3
4	25	236.7
2	50	256.5
1.33	75	267.3
1	100	274.6
0.5	200	291.1
0.5 + 20% CC	200 + 20% CC	349.3

4.4.2 Tidal limit

The tidal limit is located downstream of Fair-a-Far weir and there is no need to design for saline conditions at Dowie's Mill Weir.

4.5 Geomorphology and scour

The works should avoid any adverse material impacts on river morphology/processes that would further downgrade the watercourse (according to the Water Framework Directive).

The works should avoid causing bank instability at Dowie's Mill Lane and protect against unwanted bed and bank erosion.

The works should avoid mobilising potentially contaminated silt, which may smother habitat downstream and could affect water quality, particularly in the River Forth SPA/Ramsar site/SSSI downstream. It may be necessary to remove the finer fractions of sediment to prevent such mobilisation. If so, this sediment should be tested at the time and treated prior to disposal to landfill, under the Landfill Directive. It may be necessary to use temporary silt control measures during temporary works to limit the potential for mobilisation of bed sediment. Improving water quality is outside the scope of the works.

4.6 Ecology

Construction works, including temporary works, should avoid mobilising silt, which may reduce oxygen content in the River Almond and/or River Forth SSSI downstream; this could affect aquatic organisms, the availability of prey species and otter foraging.

The permanent works should maintain or improve the chemical and ecological status of watercourses under the Water Framework Directive.

The works should avoid harming designated sites under the Habitats Directive.

The works should avoid damage to the ancient woodland on the left bank.

The works should avoid disturbing protected species or damaging or blocking access to their habitat under the Habitats Directive. If this is not possible, it will be necessary to implement mitigation measures and obtain a licence.

The works should avoid spreading non-native invasive species in accordance with the Wildlife and Countryside Act 1981 and Infrastructure Act 2015.

4.7 Heritage

Cramond Brig, located 180 m upstream of the weir, is Category A listed. There is a legal duty to avoid affecting the character of listed structures under the Planning (Listed Buildings and Conservation Areas) (Scotland) Act 1997. Listed Building Consent will be required for works to the bridge. A heritage impact assessment is given in Appendix H.

The works should avoid increasing the risk of scour at the bridge.

The works should avoid adverse impacts on buried archaeological material and land drainage on the former mill site on the right bank at the head of the weir, avoiding topsoil stripping or excessive loading of the ground (meeting, CEC, 21 December 2015).

Sections of the weir should be retained on either bank, so that the route of the historic structure can be appreciated.

A scheme of archaeological mitigation will be required, to a brief agreed with the City of Edinburgh archaeologist. This will include a full pre-intervention survey of the weir and other structures to be affected, archaeological monitoring during works, and full excavation and recording of any features encountered during the works.

4.8 Landscape and amenity

Dowie's Mill Weir is located in a designated public open space. The left bank is designated as a Designed Landscape and an Area of Outstanding Landscape Quality in Local Policy. The weir is adjacent to the highly valued River Almond Walkway, an accessible footpath that is busy during summer. The impounded water (known as the 'mill pond') above Dowie's Mill Weir is valued as a tourist spot on the river, enjoyed by both locals and visitors.

Cramond Brig is on UK Cycle Route One which attracts national and international tourists, as well as many locals, on a regular basis.

A landscape and visual impact assessment is given in Appendix I.

The works should avoid adverse impacts on the landscape.

Any temporary works should also minimise impacts on the River Almond Walkway, and this should remain open during the works. Site access is to be confirmed by the contractor but temporary, short-term closures during vehicle movements will be required to avoid conflicts between site traffic and pedestrians. Care will be needed to segregate the two. Any damage to footpaths must be reinstated.

4.9 Geotechnical and structural design

4.9.1 Existing structures

The works should avoid temporary or adverse impacts on existing structures and their occupants, including Dowie's Mill Lane Cottages (20 m away), a medium-pressure gas pipeline (65 m away) and Cramond Brig (130 m away as the crow flies). It will be necessary to consider the impacts of vibration on existing structures and select appropriate methods for demolition and excavation.

The works should protect against scour and undermining of structures in or near the water, including Cramond Brig, pipeline crossings and Dowie's Mill Lane. A geotechnical interpretative report is given in Appendix F. A scour assessment is given in Appendix G. The revised scour assessment which is advised in Appendix G is costed in Appendix M - Bill of Quantities.

4.9.2 Design life

The works do not have a specified design life in their constructed form, as they are intended to change and adapt as the channel morphology changes. Materials used in the design are natural materials such as rock and gravels, and their sizes are calculated on the basis of resistance to forces encountered during the 200 year design flood including an allowance for climate change. Access to the weir is difficult, and the cost of temporary works will form a high proportion of the construction cost. Materials need to be durable and low maintenance, since they will be exposed to permanent moisture and in a 'hard to reach' location. The materials used must be capable of withstanding the exposure conditions and chemical environment of the site.

The works should re-use selected excavated materials where possible (such as boulders) and remove man-made material (such as concrete).

4.10 Operation and maintenance

The design replicates natural processes and will adapt and evolve over time, thus minimising the need for maintenance.

The design should provide safe access for inspection and maintenance, including the removal of debris, under the Construction (Design and Management) Regulations 2015.

4.11 Consultation

Consultation with SEPA confirmed that there is currently a lack of national guidance in relation to assessment of contamination in river sediments in terms of sampling strategies, risk assessment and sediment quality guideline values. It was agreed that Canadian Sediment Quality Guidelines could be used as a frame of reference to assess sediment quality.

Consultation with the local community, including local landowners, identified the following:

- conflicting views regarding the primacy of ecology and heritage (some feel that ecology should override heritage, whilst others hold the opposite view);
- a wish to preserve industrial history;
- a wish to maintain impounded water above the weir;

5 Proposed works

5.1 Introduction

This chapter provides a list of drawings and a description of the proposed works. It sets out the design philosophy, the development of the detailed design and recommendations for monitoring and maintenance. The potential impacts of the works are also given.

5.2 List of drawings

Series 400 General

- Site Location Plan - D410 2015s3628 - Construction Issue
- Site Plan [1of2] Constraints Plan - D411 2015s3628 - Construction Issue
- Site Plan [1of2] Services Plan - D412 2015s3628 - Construction Issue
- Site Bathymetric Survey - D413 2015s3628 - Construction Issue

Series 500 Channel stabilisation

- Existing&Proposed Elev.[1of13] - D510 2015s3628 - Construction Issue
- Existing&Proposed Elev.[2of13] - D511 2015s3628 - Construction Issue
- Existing&Proposed Elev.[3of13]- D512 2015s3628 - Construction Issue
- Existing&Proposed Elev.[4of13] - D513 2015s3628 - Construction Issue
- Existing&Proposed Elev.[5of13] - D514 2015s3628 - Construction Issue
- Existing&Proposed Elev.[6of13] - D515 2015s3628 - Construction Issue
- Existing&Proposed Elev.[7of13] - D516 2015s3628 - Construction Issue
- Existing&Proposed Elev.[8of13] - D517 2015s3628 - Construction Issue
- Existing&Proposed Elev.[9of13] - D518 2015s3628 - Construction Issue
- Existing&Proposed Elev.[10of13] - D519 2015s3628 - Construction Issue
- Existing&Proposed Elev.[11of13] - D520 2015s3628 - Construction Issue
- Existing&Proposed Elev.[12of13] - D521 2015s3628 - Construction Issue
- Existing&Proposed Elev.[13of13] - D522 2015s3628 - Construction Issue

5.3 Description of works

The Option 6 works will comprise the following.

- Construction of temporary access through woodland on left bank using route 1 (see Table 3-2). This will involve some tree felling, a temporary haul road to protect a gas pipeline and removal of Japanese Knotweed and Giant Hogweed contaminated material.
- Removal and separation of up to 300 m^3 silt from bed sediment, with re-use of selected coarse material and de-watering and disposal of fine material, potentially as hazardous waste.
- Provision and placing of 90 m long green bank protection to the right bank (willow spiling).
- Provision and placing of an approximately 35 m long boulder bar consisting of a staggered double row of 1.5 m boulders with erosion protection to services extending for about 10 m upstream of the boulder bar.
- Provision and placing of 17.5 m long rip-rap bank protection (390 tonnes) to the right hand bank.
- Provision and placing of 763 tonnes of imported natural boulders and 426 tonnes gravel and clay to create a 124 m long riffle-pool channel within a boulder rapid for fish passage and boating. The boulders will have a nominal dn_{50} size of 1.5 m.
- Removal of 60 m length of 2 m high concrete and boulder weir, with re-use of selected material within the riverbed downstream and disposal of material unsuitable for re-use.

5.4 Design development

This section describes the weir removal options considered during the design process. Non-removal options such as fish easement were not considered as these had already been rejected following previous studies (Atkins, 2015).

5.4.1 Option 1 Weir failure

The residual life of the existing weir is unknown and failure could occur at any time, most likely during flood conditions. Since uncontrolled failure could lead to damage to infrastructure, necessitating emergency or reactive repairs or scour protection works, as well as the uncontrolled release of sediment, this option was rejected.

5.4.2 Option 2 Weir removal only

Weir removal is preferable to uncontrolled weir failure as it gives greater control over the resulting impacts. Hydraulic modelling showed that weir removal in isolation would reduce water levels and increase flow velocities throughout the impoundment reach.

Hydraulic modelling showed that, for a typical invert level of 12.66 mAOD, the flow depth over the invert of the Brig would be insufficient for fish passage during low flow conditions (<0.15 m) and that the Brig would create a new barrier to fish passage during low flow conditionsTable 5-1

Table 5-1: Modelled water levels and depths at Cramond Brig - weir removal only

Event	Q99	Q95	Q10	2-year	200CC
Water level (mAOD)	12.60	12.62	13.04	14.65	16.09
Water depth (m)	Dry	Dry	0.18	>>0.15	>>0.15

Weir removal would lead to knickpoint recession, potentially leading to slope instability at Dowie's Mill Lane, undermining of two pipeline crossings and undermining of the historic Cramond Brig.

Scour risk at Cramond Brig could be reduced by lowering the invert re-using the existing masonry, but there would be a risk of exposing the foundations at the piers, which are 0.7 m below bed level. The replacement invert could be dished to avoid this. An alternative would involve sheet piling along the downstream edge of the invert to protect against undermining from knickpoint recession. However, there would also be risks associated with piling adjacent to an historic structure, and the piling would encroach on a 150 mm combined sewer that runs from upstream to downstream beneath the left-hand arch (Manhole 9406 to 9501). Furthermore, a rock ramp would be needed downstream of the invert to maintain fish passage up this new 'weir'.

This option was rejected owing to potential impacts on infrastructure and impassability at Cramond Brig.

5.4.3 Option 3 Rock ramp

Option 3 includes removal of the existing weir and the creation of a rock ramp from the site of the existing weir to Cramond Brig. This solution would be more of an artificial feature, and would therefore need some monitoring and maintenance. This option was rejected owing to the need to avoid maintenance and possibly repair the existing structure. Moreover, this option does not adequately address fish passage.

5.4.4 Option 4 Weir removal with impoundment

Weir removal with an engineered impoundment 100 m upstream of the existing weir was examined with the aim of mitigating for the impacts of weir removal. This would slow flow velocities, control bed incision and avoid the need to protect Cramond Brig and the pipeline crossings.

During low flow conditions, the target water level at Cramond Brig was set as the invert level plus the minimum depth of water for salmon passage (12.66 mAOD + 0.15 m = 12.81 mAOD) for Q95 and if achieveable, the Q75. This has to be balanced against the need to avoid an increase in flood risk.

Hydraulic modelling indicated that the target water level at Cramond Brig during low flows could be achieved with an impoundment level of 12.66 mAOD, corresponding to an impoundment 660 mm above the natural bed level of 12.00 mAOD. In order to control the hydraulic gradient and flow velocities following weir removal, this was followed by a 50 m long, 1 in 50 sloping apron at the level of the natural riverbed. It was found that this increased flood water levels (see Table 4-

1) and extent on the floodplain at two locations: on the right bank at Braepark and on the left floodplain upstream of the A90 bridge. Both areas flood because of low spots in the banks/ adjacent floodplain. On Braepark Road, one property was identified where flood risk was increased with the modelled boulder rapids; upstream of Queensferry Road, there is one property that may be at increased risk.

Variations were examined, including a parabolic control structure with a longer crest length and a lower crest level, but these were found to be ineffective at reducing flood risk. This is because, during flood conditions, any impoundment would be drowned out; that is, the downstream water level would rise such that the structure no longer behaves as a weir and conditions in the River Almond upstream of the weir would be controlled by the conditions downstream. This is known as channel control, rather than structure control. The same applies to Dowie's Mill Weir.

This option was rejected owing to the predicted increase in flood risk.

5.4.5 Option 5 Weir removal with boulder rapid

Weir removal with a 124 m long boulder rapid was examined with the aim of reinforcing the bed, reducing flow velocities and avoiding impacts on flood risk. The design would include bank protection at Dowie's Mill Lane, scour protection to two pipeline crossings (retaining a degree of impoundment that may be desirable to mitigate local preferences) and the repair of existing scour protection at Cramond Brig.

Hydraulic modelling shows that the boulder rapid would reduce water levels slightly at Brae Park and Cramond Brig (Table 4-2). The maximum velocity of 3.76 m/s would occur in the reach near Dowie's Mill Cottages, immediately upstream of the weir (Table 4-3).

Option 5 is not a satisfactory solution, because it does not adequately address fish passage over the full range of flows from Q95 to Q10 (Appendix C. Table C-3).

5.4.6 Option 6 Weir removal with riffle-pool-boulder rapid (PREFERRED)

Option 6 would involve removing the weir and reinstating the river bed with a boulder rapid in the reprofiled high energy section, that incorporates a pool-riffle sequence in low flow areas, to allow fish passage at low flows and minimise erosion at higher flows. The design includes bed reinforcement over known services to reduce the risk of erosion to the gas pipeline and sewer. The design will retain water levels that will allow fish passage around Cramond Brig. There will also be localised green bank protection and rip rap to more vulnerable areas.

Construction of a boulder bar across the channel minimises the increase in bed level velocities. This will reduce the risk of scour in the vicinity of existing buried services and the invert of Cramond Brig. The downstream pool and riffle sequence provides greater confidence in the passage of fish upstream over the range of design flows. As flows gradually increase over Q95, more of the channel section is utilised until, at Q10, the full channel width is utilised with a typical water depth of about 550 mm. The boulder rapid consists of perturbation boulders spaced to reduce the channel flow velocities to levels that permit fish passage and that also produce refuges for smaller fish in higher flows. There will also be localised green bank protection and short sections of rock armourstone to more vulnerable areas.

Along with fish passage, the final design ensures that the character of the water profile upstream of the boulder bar is altered as little as possible, ensuring that views to and from Cramond Brig remain unchanged and the millpond can still be seen, or is reflected, as a feature in the landscape.

5.5 Hydraulic assessment

5.5.1 Hydraulic modelling

The impacts of the options on water levels, flood risk, flow velocities and shear stresses were assessed by re-scale hydraulic modelling. Modelled water levels, velocities and shear stresses are given in Appendix D. Flood outlines are also given in Appendix D.

In determining the method of hydraulic modelling, we assessed the advantages and likely outputs from 1D and 2D modelling, and how this would be used to inform the design.

2D hydraulic modelling is a good tool for predicting post construction flow depth, velocities and lateral dynamics in river restoration and re-sectioning works. However, to be representative the terrain model and grid mesh need to be sufficiently detailed to allow the model to predict flow patterns. The preferred option is for a complex boulder rapid and the resource needed to build and run a 2D model at a sufficient resolution would be significant for a river reach of this size. The effort needed to develop a model of this size also needed to be balanced against the accuracy of the achievable results. The mesh needed model flows was equal or smaller than the construction tolerance, and the detailed microscale results attained from the model are unlikely to be truly representative. 2D modelling is also more susceptible to instability in shallow flow conditions and a primary concern of the design is fish passage at low flow conditions.

1D modelling is also a good tool for predicting post construction flow depth and velocities in re-sectioning works, but only provides results through a specific cross-section in the channel. A 1D model will not provide lateral dynamic results, but the model does provide near bank velocity and shear stress to inform the design. To overcome these limitations a large number of cross-sections are required at the critical locations. However, the effort required to build and run a 1D model is significantly less and can be quickly revised to assess design iterations. 1D modelling is also more stable in low flow shallow conditions and a single model can be used for design purposes.

When balancing the requirements of hydraulic modelling to inform the design and predict morphological response, 1D modelling provided the most pragmatic solution, particularly in a relatively uniform, but complex design. Due to practical modelling constraints and construction tolerance, 2D modelling would not improve the confidence in the detailed design, particularly to unexpected morphological response as the design is based on an analogue approach from measurements on other stable reaches in the watercourse.

The riffle-pool sequence was assessed using a detailed 1D hydraulic model. This comprised 18 cross-sections, including upstream and downstream boundaries, sections upstream and downstream of each riffle formation and a section though each pool. Appendix D, file note 2015s3628-E-N006-2 provides a detailed summary of the 1D modelling outputs.

5.5.2 Flood risk

The River Almond upstream of Dowie's Mill Weir is relatively confined; existing flood risk areas that may be affected by the works are Brae Park Road on the right bank (94 m upstream of the weir) and a single property on the left bank immediately upstream of the A90 (298 m upstream of the weir).

Option 6's proposed works would reduce flood water levels upstream of the weir, reducing flood storage on Brae Park for both 2 year event and the 200 year event including an allowance for climate change, as follows.

- For the 2-year event, the water level would decrease by 0.22 m at Brae Park and 0.18 m at the A90; flooding would be negligible and limited to low-lying riverside areas, with or without the weir.
- For the 200 year event including climate change, the water level would decrease by 0.14 m at Brae Park and 0.13 m at the A90; flood risk would be decreased slightly along Brae Park. This would reduce the volume of flood storage at Brae Park.

The work would not increase flood risk downstream of the weir, at riverside properties on Caddell's Row (downstream of Fair-a-Far Weir) or on the River Almond Walkway downstream of the former Peggy's Mill, as evidenced by the absence of any change in water levels downstream of the weir.

5.5.3 Low flow water levels

Detailed low flow hydraulic modelling of the pool-riffle sequence and boulder rapid was undertaken using HEC-RAS 5.0 to determine water depth and sectional velocities for 18 sections across the river channel.

The depth of water over the pool-riffle sequence was also modelled to ensure the critical design parameters were achieved. The critical section was at the new boulder bar with the Q95 depth over the boulder bar estimated to be 150 mm. The other critical sections occurred at the crest of the riffle formations and the depth of flow exceeded the critical parameter of 150 mm in each of these transition points. Drawing 2016s3628-S-D512 provides a long section though the reach showing the Q95 and Q10 water profile.

For low flow conditions (Q95 to Q10), the critical location through Cramond Brig is estimated to be 150 mm above the masonry invert and meets the requirements for fish passage. The minimum invert level in the central arch is around 12.66 mAOD. The modelled water levels at Cramond Brig are 12.83 mAOD for Q95 and 13.28 mAOD for Q10, giving water depths 0.17 m and 0.62 m, respectively, which are sufficient for fish passage (Appendix D).

5.5.4 Velocities

The works will reduce water levels, increase hydraulic gradient and increase flow velocities in the River Almond over the reach. The most significant change in velocity will occur immediately upstream of the removed weir crest, with increases of up to 2.03 m/s. Further upstream, from the pipeline crossings to Cramond Brig, the increase will be around 0.2 m/s owing to the smaller reduction in water level.

Flow velocity is an important variable for the design of bank protection and the sizing of boulders in the boulder rapid. Critical locations at risk of bed and bank erosion are as follows.

- Immediately upstream of the weir, particularly on the right bank, flow velocity would increase significantly as a result of weir removal, with increases of 2.01 and 2.03 m/s for the 2-year and 200-year with climate change events, respectively.
- At Brae Park (pipeline crossings), the flow velocity would increase to a similar extent, with increases of 0.22 and 0.27 m/s for the respective events.
- At Cramond Brig, flow velocity would increase to a lesser extent, with respective increases of 0.17 and 0.15 m/s.
- At the A90, the impact is even smaller, with respective increases of 0.09 and 0.06 m/s on the upstream face of the bridge.

The HEC RAS model was used for detailed hydraulic modelling of the pool-riffle sequence and boulder rapid. The model was used to determine sectional velocities for 18 sections across the river channel. This allowed detailed assessment of near-bank velocities to inform bank erosion protection, riffle velocities and notch velocities between the placed boulders. As expected, the model indicated that that bankside velocities were lower than the mid-stream velocities. The Q95 design velocity for the riffle section varied from 0.23 to 1.2 m/s, while the Q95 design velocities for the pool section varied between 0.11 and 0.37 m/s. The Q10 design velocity for the riffle section varied from 2.08 to 1.04 m/s, while those for the pool section varied between 0.12 and 0.39 m/s. The velocity range between the boulders was found to be in the region of 0.12 to 1.27 m/s for Q10 flows.

The modelling also indicated that estimated bankside velocities for the 200 flow range from 1.07 to 3.21 m/s; this is within the design parameters for green bank protection. The sectional velocity calculations are provided in Appendix E.

5.5.5 Shear stresses

Shear stresses are given in the geomorphological report.

5.6 Geomorphological assessment

5.6.1 Lateral erosion

Geomorphological study has indicated that there is little need for concern about any lateral erosion risk owing to the presence of bedrock, the confined valley setting and analogue information from elsewhere in the watercourse. In particular, historic maps show that no lateral erosion occurred as a result of the removal or failure of an historic weir downstream of Dowie's Mill Weir (Peggy's Mill Weir).

5.6.2 Bed incision

Despite the inferred lateral stability, the modelled increases in velocity will mobilise fine material that has been deposited on the bed owing to the presence of the weir (unless this sediment is removed pro-actively; see Section 5.12). Left unchecked, bed incision will restore the river to its historic level and gradient. A rapid-type feature is likely to return to the formerly impounded zone (and indeed may be uncovered following water level lowering).

If no controls are put in place, weir removal would lead to the upstream migration of the knickpoint.

The worst-case magnitude of bed incision was estimated by assuming that the knickpoint moved upstream from the lowest point upstream of the weir to Cramond Brig, which was classed as a fixed point. The bed incision was estimated to be 800 mm at the pipeline crossings and 240 mm at Cramond Brig (Figure 5-1).

Only a minor increase in the delivery of gravel-sized material downstream during smaller flood events is likely, as material is currently transported over the weir during elevated flow conditions. The release of sediment from behind the weir is likely to be assimilated into the normal flow regime quickly, travelling to the next downstream pinch point, which is Fair-A-Far weir. However, the bed level at this weir is close to the weir crest, resulting in minimal storage capacity. Accordingly, sediment will, over time, be transported over this weir and out to sea.

Potential contamination within fine sediment behind the weir is discussed in Section 5.13.

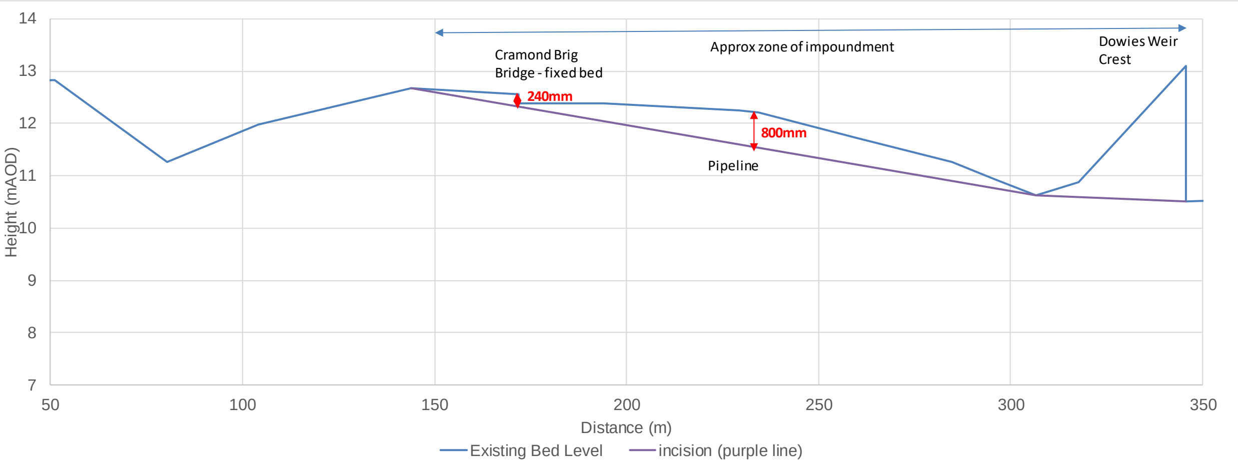

Figure 5-1: Predicted bed incision

5.6.3 Bank stability post Weir Removal

Without mitigation, both banks may be susceptible to bank slips after weir removal as water levels reduce as discussed in Section 3.7.

The left bank is on the inside of the bend and bank slips are predicted to stabilise over time. The impacts would be low, with land use nearby being undeveloped woodland. It is unlikely that the slips will affect the mill remains, which are 11 m from the bank.

The right bank supports property and infrastructure, and is more susceptible to short term geotechnical instability and water erosion, being located on the outside of a slight bend where velocities will be higher. The right bank between the river and Dowie's Mill Lane is steep, with a crude stone toe and a covering of patchy grass, well-established shrubs and small trees. There are two short lengths of pre-cast concrete retaining wall and signs of slippage near the cottages. The potential instability arises from two sources: slip arising from rapid drawdown when the impoundment is removed, and erosion due to higher velocities after the impoundment is removed. The most vulnerable reach is the highest point near Dowie's Mill Lane Cottages, which is close to the weir, where the water level will drop the most. The lane provides the sole access to nine residential properties, as well as carrying numerous services.

Slope stability analysis was carried out for the existing retaining walls. Although slope stability analysis was not carried out for the natural bank reaches, it can be inferred that there is a short-term risk of instability to the right bank after the impoundment is removed. During the construction phase temporary bank reinforcement may be needed prior to the permanent works being completed. This will be subject to the method of working employed by the contractor and should be a material consideration as part of the temporary works design.

In the longer term, the permanent works will allow pore pressures to dissipate and stabilise the banks.

5.7 Weir removal

A 60 m length of the weir will be removed down to natural bed level. It is possible that the weir is located on an existing hard point on the riverbed; if so, the bed will not be excavated beyond this.

A 12 m length of the weir will be retained at the right-hand bank. The river is thought to be artificially over-widened at this point and this will restore the river to its former condition. It will also reduce the risk of bank slips adjacent to Dowie's Mill Cottages, where the bank is steep. The abandoned channel immediately upstream and a scour hole immediately downstream will be filled with selected excavated material from the riverbed (from a predicted surplus). The end of the weir will be protected with imported riprap.

The works have been designed to provide a diverse morphology both in plan and longitudinal form, taking account of analogue reaches both upstream and downstream of the section. The low flow channel with pools and riffles has been designed along the existing thalweg of the channel and hence ties in with the reaches upstream and downstream. Velocities will vary across the reach, with local hydraulic features forming around the boulders. It would be expected that the low flow channel will be continually submerged (as per the hydraulic modelling (e.g. Q95 flow)), allowing sediments to continually pass through the system with an equilibrium being reached; sediment deposition would be expected towards the banks of the river, where water levels and hence velocities are lower causing sediments to drop out.

5.8 Boulder bar structure

A boulder bar structure will be constructed 5 m downstream of the pipeline crossings. This will control bed incision and limit flood flow velocities, thereby protecting the pipeline crossings and Cramond Brig against undermining. Unsupported, the pipeline would fail, leading to sewerage spills and water quality impacts. Re-location of the pipeline crossings was rejected as disproportionately costly.

The boulder bar will be curved in plan to improve stability, to focus flows towards the centre of the channel and for a visually pleasing appearance. The structure will have a typical crest level of 12.95 mAOD, with a low flow notch at 12.75 mAOD to direct flow towards a pool and riffle sequence. Hydraulic modelling of the 200 year event demonstrates that the structure will not adversely affect flood risk. For Q95, the depth of flow will be 0.2 m at the low flow notch in the boulder bar and 0.29 m at the Cramond Brig invert; both of these are sufficient for fish passage. The boulders are aimed to be fixed but other sizes of sediment will be transported. The average Q95 flow velocity in the pools is 0.2 - 0.4 m^3/s which would result in transport of fine (0.001 - 0.04 mm) sediments such as clay and silt, while larger particles ranging from sand (0.05 mm) to boulders (1000mm) will be deposited.

The boulder bar will comprise two staggered rows of 1.5 m nominal diameter boulders, two-thirds embedded to resist mobilising forces during flood conditions. The boulder bar will be up to 2.5 m wide in the flow direction, and will extend into either bank by a distance of at least 1 m to resist outflanking.

Immediately upstream, a line of flat rocks will be placed against the boulders to resist scour due to downflow and turbulence generated by the boulders.

An erosion-resistant substrate will extend 10 m upstream of the re-sectioning structure to provide scour protection to the pipeline crossings. The 0.5 m thick substrate will comprise nominal 180 mm diameter material. The leading edge of the substrate will be toed into the bed to protect against transition scour with a 200 mm gravel bed.

The alignment and level of the gas main and sewer crossings are to be confirmed on site at the start of construction (see Section 6.4).

5.9 Pool and riffle sequence

A pool and riffle sequence will be constructed between the boulder bar and existing weir. This will convey low flows and recreate natural conditions suitable for fish passage. A more natural-type pass should provide better opportunities for lamprey and eels (and indeed smaller salmonid juveniles).

Although a non-technical solution, the sequence is based on observed characteristics of the natural channel and has been designed to key design parameters in the Environment Agency Fish Pass Manual. Achievement of these design criteria is summarised in Table 5-2.

The concept design is not a technical pass and is designed to result in significant velocity heterogeneity. This in-channel variability will provide conditions that the priority species will find passable. The more natural design is difficult to qualify with any degree of accuracy as it is largely beyond the limits of what is possible with even 2D hydraulic modelling, but the design concept will result in extensive wet, slack margins and higher notch velocities that will be exploitable by such fish. To ensure a greater degree of certainty of fish being able to pass through the newly designed reach, hydraulic modelling at key points (riffle crests and over the boulder bar) has been carried out to ensure the principal fish pass design criteria are achieved for a range of design flow conditions. The use of the analogous features and boulder sizes similar to those existing in the channel permits a tie-in that will be indistinguishable from the existing natural channel at the tie in point.

Table 5-2 Achievement of hydraulic design criteria in riffle-pool

Criteria	Threshold	Designed performance	Criteria achieved (across whole of flow range, where relevant)?
Alignment of fishway	Aligned with main channel flow.		Yes
Flow type	Streaming flow, avoid plunging flow	Yes	Yes
Maximum head difference (m)	Rock ramp 1m	≤1m	0.35m
Maximum flight length (m)	-	≤15m	≤15m
Slope	Rock ramp 1 to 5% (can be up to 10%)	≤5%	3.33%
Minimum flow depth over riffles (m)	200mm	Q95 200mm Q10 550mm	150-220mm 530-620mm
Maximum velocity over riffles or riffle/boulder rapid (m/s)	Q95 1.17m/s (median sustained speed for trout EA FPM Table 2) Q10 1.5m/s (maximum swimming speed for 0.4m long fish at 2 degrees Celsius EA FPM Figure 4)		0.84-1.2 m/s 1.04-2.08 m/s
Attraction flow			100% channel flow over all ranges

The pool and riffle sequence will follow the existing thalweg along river right (see Figure 3-3) before moving out to the centreline. The 114 m long sequence will fall of 1.65 m, giving a mean gradient of 1 in 70. Scour holes along the sequence will be filled, as the retention of scour holes would result in a gradient that is too steep for fish to swim up the channel without construction of a fish pass.

The sequence will comprise four pools and five riffles.

The riffles will have an even gradient of 1 in 30 and will vary in length from 8 to 15 m. They will be constructed with random 550 mm nominal diameter boulders embedded in a 200 mm thick substrate of river gravel. Local excavation and fill of the existing bed will be carried out as required, with a stony cohesive fill where needed to bring the bed to formation level.

The pools will vary in length from 10 to 27 m, with a naturalised rounded planform and variable water depth to provide a resting facility for fish.

At the downstream end of the sequence, the downstream-most riffle formation will tie into the existing river bed. The tie-in will be created by having the downstream lip of the last pool in the pool and riffle sequence coincide with the existing channel bed level at the upstream end of the existing natural riffle. This construction ensures that water flows out of the last constructed pool and onto the upstream end of an existing natural riffle.

5.10 Boulder rapid

The boulder rapid will be extended on either side of the pool and riffle sequence (where space permits) to provide heterogeneous flow conditions suitable for fish passage during higher flow conditions. This will also increase roughness and reduce flow velocity, thereby reducing the risk of significant bed or bank instability. Individual boulders will create turbulence and provide refuges for fish and diversification of habitat.

The boulder rapid design reflects analogue features on the River Almond, as seen upstream and downstream of the site, as well as USBR rock ramp design guidance (USBR, 2007) and recent successful river restoration projects.

The boulder rapid will have a similar gradient to the pool-riffle sequence and a 25% degree of obstruction. The rapid will be constructed using predominantly single boulders, with occasional clusters of three boulders to add diversity. In plan, centre-to-centre spacing of the boulders (or clusters) will be about 6 m across the channel and about 3.9 m longitudinally.

The boulders have been designed to resist the maximum velocity from the full range of modelled design events (typically the 200-year event with climate change) and to reflect boulders seen in the river elsewhere. These will comprise 1.5 m nominal diameter boulders, two-thirds embedded to resist mobilising forces. The boulders will protrude above bed level to Q10 water level. The rapid will retain the existing boulders downstream of the weir, thought to be a mixture of natural and placed, unless fish passage is an issue. The boulders in the designed section are fixed, while gravels and finer sediments will be subject to transport and deposition processes, including the natural influx of sediment from upstream.

During very low flow conditions, the boulder rapid will be dry, and flow will be conveyed through the pool and riffle sequence. As flow increases, an increasing proportion of the rapid will be wetted, until the full channel width conveys water. The boundary between the boulder rapid and riffle-pool sequence will not be formally defined in order to allow free movement of fish between the two and minimise the risk of fish reaching a dead end in the boulder rapid.

The influence of the boulders on river dynamics was assessed by modelling them as discrete obstructions, rather than a blanket roughness coefficient, which should provide a more realistic output.

Between the boulders, the channel lining will comprise an erosion-resistant substrate of river gravel overlying stony cohesive fill. This will retain water and keep the flow above ground during low flow conditions. The infill material has been chosen based on a qualitative assessment of the existing bed material, which is glacial till. It will not be possible to reproduce the existing glacial till, which is likely to have been consolidated over a period of time. However, the grading provided in the design is a close representation of natural deposits and will be self-sustaining as the watercourse evolves.

5.11 Bank erosion protection

Dowie's Mill Lane provides sole access to a collection of residential properties and also carries multiple services which must be protected both during and after construction. At its most vulnerable sections the road is already supported by retaining walls which will in turn be protected by rip-rap bank protection as part of the scheme. The remaining bank is steep in places consisting of large stones, mixed vegetation and areas of bare earth. As part of the works this area will be reworked to provide a stable slope and better protection for the road.

A 120 m length of bank protection is proposed, extending along the right bank from the weir to the re-sectioning structure to address the issues raised in the geotechnical investigation and as a result of the velocities identified in the hydraulic modelling. Slope stability analysis showed that there is a risk of temporary instability on the right bank immediately after drawdown due to high pore water pressure in the ground material, although the right bank will be stable in the long term (see Appendix F). There are two short lengths of existing retaining wall to the right bank extending over a combined length of about 18 m; their ongoing stability will be addressed by use of riprap support. There is also a risk of erosion due to an increase in flow velocity.

Two ways of mitigating the risk of bank instability and bank erosion have been identified. These are; grey bank protection in the form of rip-rap; or greenbank reinforcement in the form of willow spiling or mattress protection.

Grey Bank Protection has the advantage of being relatively easy to construct and could be placed prior to the weir being breached and the water level being reduced. This provides immediate bank stability and erosion protection. The drawback of this option is that it is relatively more expensive (around £80,000 for raw materials) than greenbank protection. Also around 120m of bank would need to be stripped of vegetation to Dowie's Mill Lane and rip-rap placed on a geo-synthetic liner.

This would have a significant impact on the character of the river bank and would require regular maintenance to ensure the protection of the rip-rap is retained.

The river modelling has shown that the maximum bank velocity during the 200 year event is expected to be in the region of 2-3m/s. Green bank protection has been selected as it can protect against the required flows whilst maintaining a cost effective, less environmentally intrusive and naturally sustaining option. It allows the retention of vegetation along the bank of the river and retains the green characteristics of the river reach, whilst providing long-term bank stability and erosion protection. The disadvantages of green bank protection are; construction is more complicated as it cannot be constructed in deep water prior to breaching the weir; it is suitable for a lower velocity range than rip-rap; it takes a period of time to establish and provide full erosion protection and a velocity of 2-3m/s is towards the top end of the operational limits of green bank protection. Hence, it is necessary to provide robust protection which will naturally integrate into the slope whilst providing immediate protection.

To inform the decision process, detailed 1D hydraulic modelling for the 0.5 AP design flow was undertaken to assess the near bank velocities. A conservative approach was taken using the detailed model developed for the design of the in-channel morphological features. This model is limited to in-channel flows and 'glass-wall's' flows that exceed bank full conditions. This provides a conservative approach to assessing near bank velocities. The calculations estimate that during the design conditions near bank velocities range from 1.07m/s to 3.21m/s with an average velocity of 1.68 m/s. Appendix E graphically shows the velocity distribution across the channel sections.

Guidance on the selection and application of Greenbank protection methods are provided in the CIRIA publication Protection of River and Canal Banks (R W Hemphill and M E Bramley, 1989). Other guidance is available from the Manual of River Restoration Techniques (The River Restoration Centre, 2014)[2] and in-house observations from the application of techniques applied on other projects.

The prevailing design considerations are; to provide bank stability by reducing the bank slope to a self-sustaining gradient (1 in 2), using a suitably permeable material that will allow long-term dissipation of pore water pressures from the original bank material; and provide erosion resistance to near bank flows, which is assessed as level of attack based on flow velocity. The level of attack along this reach for the design flow is conservatively assessed to be in the medium to heavy category. Based on these design parameters two greenbank reinforcement methods have been identified; willow fascine mattress; and willow spiling.

Willow spilling is a well-used method of green bank protection, which can be readily installed and maintained. It is possible to use other woods such as ash and alder, however these stakes will not regenerate resulting in the long-term erosion protection being dependant on the natural succession of bank vegetation to stabilise the banks. Whilst this will offer the same level of protection as willow initially, over a period of 2-3 years the stakes will start to deteriorate and the level of protection will fail, and without the spilling structure local slumps may occur making the banks more susceptible to progressive erosion failure. Willow spilling creates secure root systems to help bind the bank together. From a geotechnical perspective the stepped geometry provides a stable profile while the root systems become established and the slope is re-naturalised. The willow spilling steps are filled with class 4 material which is a free draining granular material. This will prevent pore water pressure from building in the slope hence increasing slope stability.

5.12 Proposed Bank Protection

No bank protection is proposed for the left bank as any bank slips are predicted to stabilise over time and the impacts on the woodland would be low.

The right bank protection will largely comprise willow spiling with coir rolls as shown on the drawings. The main features are as follows:

- bank slope of 1 in 2;
- toe protection formed from 1.8 m long full round chestnut posts driven vertically into the bank, with coir rolls over rock roll placed between them;
- 2.0 m long willow posts will be driven vertically into the bank at 500 mm intervals centre-to-centre in both the longitudinal and transverse directions;
- willow spiling woven between the 250 mm high exposed sections of the posts.

2 The River Restoration Centre, 2014. http://www.therrc.co.uk/manual-river-restoration-techniques

JBA have used this type of greenbank protection in many high energy watercourse environments. Most recently this was using in stabilisations work in inverness and have been tested under high flow conditions and found to be quick to establish and highly resistant to erosion. The photos below show the method in practice.

Channel erosion

Willow spiling stabilisation

Willow spiling ten months after construction

Rip-rap will be placed to two short sections of the right bank, one approximately 10 m long and the other approximately 8 m long, in front of the existing two retaining walls to provide additional stability at locations where there is a history of bank instability, as evidenced by the presence of the retaining walls. Of the grey options, rip-rap is environmentally the most favourable and visually congruent with the boulder rapid. It is also flexible and able to adapt to changes in bed level.

The rip-rap was designed in accordance with the CIRIA *Manual on scour at bridges and other hydraulic structures* (Kirby *et al*., 2015; May *et al*., 2003). Design details are as follows:

- 550 mm nominal diameter riprap laid to 1 in 2 slope;
- horizontal crest level corresponding to 200-year with climate change flood level plus 300 mm freeboard (or top of bank, whichever is the lower), to allow rip-rap to tie in with the existing retaining walls and provide a platform for inspection;
- toe detail 1.5 m deep below bed level to restrain the sloping revetment;
- geotextile filter layer beneath rip-rap to prevent washout of fines;
- gaps in rip-rap to be filled, topsoiled and overlaid with pre-seeded coir matting.

The alignment and level of the 600 mm diameter sewer running along the riverbank is to be confirmed by hand excavation before construction of the bank protection to ensure the sewer is adequately protected during the works.

5.13 Cramond Brig

The preferred solution retains an impounded depth of water over the Cramond Brig invert; therefore, the works do not impact Cramond Brig.

Some damage to the invert was identified during the bathymetric survey and, for the benefit of the asset owner, repair of the masonry invert is suggested. This will require listed building consent.

Scour risk assessment for the existing and with-scheme scenarios was carried out in accordance with BD97/12, part of the Design Manual for Roads and Bridges (The Stationery Office, 2012).

Cramond Brig would have a high risk of scour failure owing to its shallow foundations, were it not for the presence of an existing masonry invert at the bridge. This invert protects the foundations from undermining, reducing the risk from high to low. The presence of a sound invert of sufficient extent is critical to satisfactory scour protection.

Hydraulic modelling shows that weir removal with the re-sectioning structure will reduce water level at the bridge by 0.13 m and increase velocity by 0.29 m/s for the 200-year with climate change event. The increase in velocity is marginal and will not increase the scour risk to the bridge invert. The impoundment upstream of the re-sectioning structure will limit changes in flow depth and velocity at the bridge. Re-assessment of scour risk showed that the resultant conditions would have no impact on scour risk.

5.14 Sediment removal

5.14.1 Review of sediment quality analysis

Previous analysis of the weir in 2014 by Mott MacDonald has identified the presence of river bed sediment deposits upstream of the weir structure; these deposits are described as comprising a layer of up to 1 m of dark brown sandy gravelly clay and clayey sandy silt. PSD analysis of the samples also indicated the presence of clay and gravel sized materials, as summarised in Section 3.7.4. Two samples of sediment at locations approximately 10 m and 35 m upstream of the weir were subject to laboratory analysis by Mott MacDonald for a broad range of potential biological, metallic, inorganic and hydrocarbon based contaminants. During the geotechnical investigation undertaken by JBA in 2016, it was not possible to recover samples of sediment upstream of the weir for chemical testing owing to the coarse-grained nature of the materials encountered. This could be as the sediment has been moved during floods between the two sample date or indicate the variability in the sediment. It suggests that the issue of contaminated sediment may be less than was anticipated when looking at the samples taken by Mott Macdonald but should be factored into any works.

In the UK, there are currently no statutory sediment quality criteria or guideline values against which to assess the significance of contaminants in river sediments. Sediment quality data for the two samples recovered from the Dowie's Weir site in 2014 by Mott MacDonald are presented in Table 5.3 below, which shows the range of concentrations for a selected range of metallic and organic based contaminants. Also included within the table are existing Canadian Sediment Guideline expressed as the Probable Effect Level (where a current Canadian quality guideline value exists). The Canadian Guideline values were originally adopted in 2014 by Mott MacDonald (in agreement with SEPA) in order to evaluate baseline sediment quality in the river. Canadian Environmental Quality guidelines for sediments define two key concentration thresholds: a threshold effect level (TEL), below which the presence of sediment-derived contaminants are not thought to serve as a threat to aquatic organisms; and a probable effect level (PEL), representing the lower limit of the range of contaminants associated with adverse biological impacts. It should be noted that these guidelines were originally designed as triggers for further assessment rather than strict environmental quality standards; furthermore, for many of the potential contaminants tested, there are no equivalent TELs or PELs.

In order to evaluate the significance of the Dowie's sediment data, also presented in the table are the calculated 95th percentile concentration values for sediment quality for all of the baseline sediment analyses carried out along the River Almond by Mott MacDonald in 2014. These data include 5 upstream locations and 1 downstream location relative to the Dowie's site.

In addition, historic data have been obtained for sediment quality; these were gathered by the Scottish Fisheries Research Services and presented in a 2005 report[3]. This included baseline quality analysis of sediments from dredge disposal and wastewater sludge disposal sites along the east coast of Scotland, including 3 sites in the Firth of Forth. For the heavy metallic contaminants, the data presented in the table provide historic maximum values recorded within the Firth of Forth sites; conversely, for the PAH contaminants, the dataset includes wider sample sites across the wider east coast of Scotland.

Based on review of the information presented in the table, the following conclusions can be drawn.

1. For the Dowie's Mill Weir samples, the Canadian PEL is exceeded for arsenic only at the upper end range. However, while levels of various other contaminants were not found to be above analysis detection limits, it should be noted that the PEL is in some cases below the detection limit, particularly for pesticide-based compounds (e.g. Chlordane, DDD, DDE, DDT, Dieldrin, Endrin, Heptachor epoxide, Lindane) and mercury. It is also noted that pesticides were not detected above analysis detection limits in any of the River Almond samples. '
2. A number of heavy metallic and PAH-based contaminants in the Dowie's Mill Weir samples exceed the calculated US95 values for all of the River Almond samples, though this was often only within the higher end sample, with the exception of arsenic and copper. This may be indicative of a localised source of contamination within the sediment.

3 http://www.gov.scot/Uploads/Documents/IR0805.pdf; Hayes, P, Russell, M, Packer G. Surveys of Dredged Material and Wastewater Sludge Sea Disposal Sites for the East Coast of Scotland, Fisheries Research Services Internal Report No 08/05, May 2005.

3. For the contaminants assessed, with the exception of arsenic, the maximum contaminant levels identified within the Dowie's Mill Weir samples was less than the historic maximum values reported in the 2005 paper.

Table 5-3: Sediment quality analysis

Determinand (Limit's of Detection)	Existing Canadian PEL	Dowies Weir 2014 sediment analysis range of concentrations	95th percentile concentration for all 2014 baseline sediment samples at River Almond sites	Historic (2005) Fisheries Research Services maximum sediment concentrations
Arsenic µg/kg	17000	15000 - 31000	7912	30600
Cadmium µg/kg	3500	<1000	nc	500
Chlordane µg/kg	8.87	<10 - <50	nc	nd
Chromium µg/kg	90000	14000 - 19000	16156	76700
Copper µg/kg	197000	41000 - 65000	29228	105000
DDD µg/kg	8.51	<10 - <50	nc	nd
DDE µg/kg	6.75	<10 - <50	nc	nd
DDT µg/kg	4.77	<10 - <50	nc	nd
Dieldrin µg/kg	6.67	<10 - <50	nc	nd
Endrin µg/kg	62.4	<10 - <50	nc	nd
Heptachlor epoxide µg/kg	2.74	<10 - <50	nc	nd
Lead µg/kg	91300	35000 - 75000	37242	218300
Lindane µg/kg	1.38	<10 - <50	nc	nd
Mercury µg/kg	486	<1000	nc	2200
Acenaphthene µg/kg	88.9	<10 - 20	nc	102.1
Acenaphthylene µg/kg	128	<10 - 10	nc	7.4
Anthracene µg/kg	245	20 - 30	27	204.8
Benzo(a)anthracene µg/kg	385	70 - 80	70	639.9
Benzo(a)pyrene µg/kg	782	60 - 70	61	474.9
Chrysene µg/kg	862	50 - 80	67	nd
Dibenzo(a,h)anthracene µg/kg	135	10	12	118.8
Fluoranthene µg/kg	2355	90 - 160	161	1086.8
Fluorene µg/kg	144	20 - 30	23	143.9
Naphthalene µg/kg	391	10 - 50	22	364.1
Phenanthrene µg/kg	515	70 - 100	107	865.8
Pyrene µg/kg	875	130 - 150	142	794.4
tPCB µg/kg	277	<0.35	2	nd
Zinc µg/kg	315000	150000 - 210000	130830	178000

nc Not calculated as all samples analysed returned concentrations less than analysis detection limits.

nd No data available from historic analyses. It should be noted that for the heavy metals the historic dataset relates to samples recovered from the Firth of Forth only. For remaining analysis (PAHs) the datasets also includes additional sample datasets from the east coast of Scotland.

<10 - <50 Different samples tested to different levels of detection.

On the basis of the above, it can be concluded that, for certain contaminants, the Dowie's Mill Weir samples indicate slightly higher concentrations of certain metallic and PAH contaminants relative to other sample sites along the River Almond. However, with the exception of arsenic, contaminant concentrations from Dowie's Mill Weir are less than existing PELs (notwithstanding the issue in relation to higher detection limits against PEL for the pesticides and mercury, though it is noted that, based on the testing undertaken, there is no evidence of a particular pesticide contamination issue within the Almond in terms of sediment quality). With the exception of arsenic, the maximum contaminant levels identified at Dowie's Mill Weir are less than the corresponding maximum levels recorded for the Firth of Forth (heavy metals) and wider (PAHs) sample sites in the 2005 sediment quality survey.

It should be noted that the existing sediment quality sample dataset for Dowie's Mill Weir is limited to two samples. Collection and analysis of additional samples would improve the existing level of sediment characterisation and would allow for further assessment of potential contamination issues.[4]

The presence of potentially contaminated sediment behind the existing weir (i.e. levels of certain contaminants above Canadian Guideline Values) does not under current circumstances necessarily present a risk to the aquatic environment. The actual impact of contaminants that might currently be entrained within the sediment would be dependent upon a number of factors, including the relative solubility and bioavailability of the contaminants should they partition into the water column. However, removal of the weir could potentially alter the risk status at the site through the following mechanisms:

- short-term exposure of the construction workforce to contaminants (including potential biological contaminants and pathogens) present in the sediment during in channel works;
- short-term mobilisation of sediment and transport downstream during the weir removal works; or
- long-term changes in sediment transport due to weir removal, resulting in transport and deposition of contaminated sediments further downstream and/or increased contaminant loading around and downstream of the weir during erosion and transport.
- Mitigation measures to deal with sediments during construction work are described in Section 5.13.4.

5.14.2 Sediment volume

The total volume of sediments entrained behind the weir has been estimated to be of the order of 1,000 m^3 and it is currently anticipated that excavation of sediments will initially be required in order to form a stable base for construction purposes.

Finer and medium grained river sediment fractions can act as effective sinks for contaminants and as such are likely to show higher contamination levels than coarser grained fractions. Analysis of a Particle Size Distribution curve for a sample of sediment collected from behind the weir in April 2016 indicates that the finest fraction of the sediment comprises fine gravel, with no sand or silt sized fractions. Previous samples indicated some silt and there could be silt in the interstital spaces between the gravel. Therefore, a conservative approach assumes the presence of silt between the gravels. However, applying a conservative approach assuming a porosity for gravel-based sediments of 0.3 gives an estimated upper bound volume of 300 m^3 (0.3 x 1,000 m^3) for potentially finer grained sediment (silt fraction) that could potentially contain contaminants.

5.14.3 Release of contaminants

A basic mass balance calculation was carried out for the metals As and Cu, which were found in slightly higher concentrations than other Almond sites in the 2014 samples. The calculation was completed on the basis that there could potentially be up to 300 m^3 of silt-sized sediment present behind the weir, as presented in the preceding section. The concentration data used in the calculations were taken from the Mott MacDonald 2014 sediment analysis data.

Mass of silts potentially behind weir: 300 m^3 x 1800 kg/m^3 = 540,000 kg

Mass of As in silt based on max measured level = 31 mg/kg x 10^{-5} kg x 540,000 kg = 16.74 kg

Mass of Cu in silt based on max measured level = 65 mg/kg x 10^{-5} kg x 540,000 kg = 35.09 kg

Potential increased contaminant loading assuming the release of all entrained sediment in one day (highly pessimistic) during the two-year return period flood.

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4 In April 2016 additional investigations were undertaken behind the weir. However, owing to the course grained nature of the materials encountered it was not possible to recover sufficient additional samples of sediment for laboratory analysis to provide additional information on contamination levels.

Flow in river = 137.9 m^3/s = 11.9 x 10^6 m^3/day = 11.9 x 10^{10} l/day

As 16.74/11.9 x 10^{10} = 1.41 x 10^{-3} kg/l = 0.001 mg/l < Freshwater AA EQS 0.05 mg/l, OK

Cu 35.1/11.9 x 10^{10} = 2.94 x 10^{-3} kg/l = 0.0029 mg/l > Freshwater AA EQS 0.001 mg/l [bioavailable], hence not OK.

Thus, using some extremely conservative assumptions (i.e. all of the contamination is released into the river over a 24-hour period in a 2-year return period flood and all contamination is partitioned into the water column from all of the entrained sediment) results in exceedance of EQSs for these two contaminants. It is considered highly unlikely that these conditions would be realised. If release occurred over a greater timescale (for example, over a year), the effects would be almost negligible.

5.14.4 Sediment management

Three broad options were identified to mitigate the risks highlighted above, as follows.

Option 1 Do minimum: No specific measures adopted for sediments following construction and undertake long-term monitoring to evaluate any residual impacts. The sediment would mobilise naturally and accumulate upstream of the next obstruction, believed to be Fair-a-Far weir. Turbidity and gravel smothering would harm habitat and aquatic life.

Option 2 Source removal: Excavate and remove sediments, and dispose off-site prior to weir removal. Any arisings would almost certainly need to be treated to reduce their moisture content prior to disposal. It would also be necessary to undertake additional testing as part of the Waste Acceptance Criteria of sediments if they were to be disposed of at a licenced waste facility in order to establish whether or not they would be classified as hazardous or non-hazardous wastes.

Option 3 Source isolation: Cap sediments as part of weir removal works if risks are deemed to be unacceptable. However, this type of solution is also likely to be technically challenging.

While risks associated with short-term exposure to potentially contaminated river sediments and the risks of short-term mobilisation can be adequately mitigated, predicting the long-term impact associated with sediment movement following construction is less certain based upon the existing level of information. Applying a conservative approach, source removal (i.e. excavation and disposal of accumulated sediments) could be implemented to address potential future long-term impacts on downstream water quality, or potential impacts on downstream receptors such as the SAC, which may result from changed conditions in the river channel leading to future contaminant/sediment mobilisation. However, it should also be noted that excavation and off-site removal of sediments would almost certainly attract premium disposal rates and that the sediments would require pre-treating to reduce their moisture content prior to off-site transport. In addition, removal and disposal of sediments per se is not considered to be a particularly viable option from an environmental sustainability viewpoint.

Although there is the absence of a clear driver for the removal of sediments (e.g. evidence of a particular contamination source in the vicinity of the weir, SNH have required the removal of any contaminated sediments. The approach within the design option 2 has been to quantify the risk i.e. that although large quantities of fine sediment were not present during JBA's sampling there may be silt between some of the coarse sediment. During the construction phase all the sediment will be removed and fine sediment isolated and disposed of appropriately after testing.

5.14.5 Proposed strategy

Based upon the preceding section, the overarching recommended approach to management of sediments is based on retention within the newly formed channel following construction. However, a watching brief should be maintained during construction works, such that any finer grained sediments that are suspected as being potentially contaminated can be separated and analysed for a range of potential contaminants.

In addition, samples should be taken of the newly formed interface between the sediment and the overlying water column to verify that levels of contamination are within the range previously detected during earlier baseline assessments. This could be undertaken during construction activities in the river channel upstream of the weir. Monitoring just upstream and downstream of the weir could also be implemented at the same time to evaluate any changes in water quality/chemistry.

5.15 Monitoring and maintenance

The creation of a boulder rapid would be a natural approach, working with natural processes and mimicking the natural morphology seen elsewhere. These are self-sustaining and frequent maintenance requirements would not be anticipated, barring some immediate post-works monitoring to check stability whilst bedding in or the removal of man-made debris that accumulates on boulders.

Routine inspection and maintenance of scour protection works is recommended annually and after significant flood events. An inspection should be scheduled after the first 2-year flood, then after the first 5-year flood, and so on, to record the morphological changes to the works after these floods. Maintenance need only be considered if the morphological changes in the restored reach differ from the changes in the adjoining upstream and downstream undisturbed reaches.

5.15.1 Design life

The river re-naturalisation is a dynamic environment that is designed to change and adapt to prevailing conditions over time. Applying a specific design life to such systems is not appropriate, although they should be designed to be effective with minimal maintenance. Periodic inspection to confirm that the resectioned channel is developing as predicted and is providing fish passage is recommended. Materials for which a design life can be attributed are given in Table 5-4.

Table 5-4 Design life of materials

Material	Design life
Riprap	Well-designed riprap should have a design life 60 years or more, but can damaged by flows in excess of the design event and may be supplemented if necessary should flood damage occur.
Erosion-resistant substrate	It is intended this will become part of the natural river system, slowly moving and changing, depending on the river 'dynamics' so apart from immediate post contract monitoring no further works should be required in the foreseeable future.
Willow spiling	Willow spiling provides a solution which grows and as trees become more established the roots secure the bank. Willow should be allowed to establish over a number of years.

6 Construction management

6.1 Introduction

This chapter covers construction access, water management, environmental and heritage mitigation measures required during the implementation of the works, health and safety, programme, cost estimate and project risks. A likely construction sequence is given, but a detailed construction method statement should be developed by the appointed works contractor prior to works commencing.

6.2 Construction access

The recommended vehicular access route for construction is the left bank via Cramond Brig Toll and an existing track through private woodland (Route 1 in Section 3.4). The existing track through the woodland on the left hand bank will require some widening, removal of large rocks and building up so as to prevent damage to underground services. From the existing track, a temporary access track through the woodland to the river channel may be constructed for plant and launching of a pontoon and plant. This will require some tree removal which will require landowner permission and planning permission. A temporary access through the woodland track to the left hand edge of the existing weir may be constructed for removal.

Japanese Knotweed and Giant Hogweed are present on the riverbank on, adjacent to and upstream of the weir. Removal and offsite disposal of non-native invasive species contaminated material will be required, unless a lead time of three years is available for spraying before the works commence. The seedbank for Giant Hogweed is relatively long-lived: seeds remain viable for about seven years. Therefore, all soil in that area is potentially a concern if machinery uses this route for access. Strict biosecurity must be in place during the works to ensure no fragments or contaminated soil are spread downstream.

Light vehicle or pedestrian access may be obtained via the right bank, along the River Almond Walkway. This is busy during the summer and valued by the community. The walkway must be kept open during the works, although temporary, short-term closures during vehicle movements will be permitted to avoid conflicts between site traffic and pedestrians. Care will be needed to segregate the two. Footpaths must be reinstated.

6.3 Water management

Flow to the River Almond downstream must be maintained.

Flow should be maintained over at least half of the channel at any one time.

Suitable and sufficient pipes should be provided in any access ramps.

The river upstream of the weir should ideally be de-watered for construction of the pipeline protection and river restoration, and the Contractor is free to choose his own method. A suitable method might involve partial demolition of a short length of weir to allow flow diversion. Flow from upstream may be diverted past the works in a temporary bypass channel along one side of the river, operating under gravity flow. If lined with polythene, this will prevent mobilisation of any fine fractions of silt.

Flood risk should not be increased.

6.4 Utilities

6.4.1 Gas pipeline crossing

A medium-pressure gas pipeline (up to 2Bar) runs beneath the river 70 m upstream of the weir (Drawing D402). Marker posts should show the location of the sleeve on either side of the river. Beneath the river, the plastic pipe is cased in a 10” steel sleeve.

Hydrographic survey indicates that the pipeline is buried, although its depth is unknown. Pipelines would normally be installed below the riverbed under present-day standards, but these may not have applied at the time of installation. The pipeline is an older installation, probably up to 35 years old.

It is recommended that the alignment and depth of the gas pipeline be confirmed at the start of construction, ideally using electromagnetic CAT and Genny (Cable Avoidance Tool and Signal generator) tracing of the steel sleeve and a hand-dug trial hole in the river.

SGN (Scotia Gas Networks) are willing to attend site during this investigation (contact Gordon McLeod, mobile 07747 758 399, gordon.mcleod@sgn.co.uk).

General constraints on working near the pipeline are as follows:

- no explosives within 30 m of plant;
- no piling or boring within 15 m of plant without prior consultation and agreement;
- hand excavation only within 3 m of plant.

6.4.2 Sewer crossing

A Scottish Water 150 mm combined sewer crosses the river at an angle of 45 degrees, before joining a 600 mm diameter combined sewer along the right bank (at Manhole 9502).

Hydrographic survey indicates that the sewer is partially exposed at the river crossing near the left bank, dropping beneath bed level about halfway across the river. The depth of the pipeline is not known precisely due to the nature of records supplied by SW.

It is recommended that the alignment and depth of the sewer should be confirmed at the start of construction by hand excavation.

Contact Brian Robertson (brian.robertson@scottishwater.co.uk, 0131 445 6625).

6.4.3 Sewer on right bank

A Scottish Water 600 mm combined sewer runs along the right river bank with a manhole just downstream of the weir (Manhole 9603 to 9701). It then runs along Dowie's Mill Lane to a manhole near the weir headwall, turning sharp left to a riverside manhole before following the riverbank downstream.

There is a risk of bank protection works affecting this sewer, especially in the infill area just upstream of the weir. It is recommended that the alignment and depth of the sewer along the right bank should be confirmed at the start of construction by hand excavation and adequate protection provided to the sewer before works commence.

There is a risk of weir removal works disturbing the 600 mm diameter combined sewer to the rear of the headwall, although the sewer is about 2 m deep at this location (Manhole 9602 to 9603). The headwall should be retained or dismantled with care.

6.5 Environmental mitigation

6.5.1 General requirements

Statutory Designated Nature Conservation Sites

A Habitat Regulation Appraisal Screening Assessment was undertaken to identify any potential adverse and/or uncertain impacts on the Firth of Forth designated site (Ramsar, SPA and SSSI) 0.8 km downstream. SNH advised that an Appropriate Assessment would not be required.

Non-statutory Designated Nature Conservation Sites

Mitigation measures and working methodologies were discussed with SNH to ensure that there are no residual adverse impacts on LBS and SINC sites.

6.5.2 Fish

The River Almond is a salmonid river and as such it is important that the works are scheduled outside the spawning season for salmonid species. For trout, spawning takes place in mid-October and continues through to early January. For salmon, spawning occurs between November and December but, in some localities, particularly in larger rivers, this may extend from October to late February. Therefore, it is recommended that no in-channel works are undertaken between October and April inclusive and the timing of works is discussed in detail with the local district salmon fishery board.

6.5.3 Trees

Woodland on the left bank falls outside the Ancient Woodland Inventory but within Cramond Conservation Area. Access via Cramond Brig Toll and the left bank woodland (Route 1) will require some tree removal to facilitate the works. Access for light vehicles only via Dowie's Mill Lane would be unlikely to require tree removal.

Liaison with the local authority regarding Tree Preservation Orders (TPO) is undertaken prior to any arboriculture works. The works fall within Cramond Conservation Area and, as such, changes to the character of the area, including removal of trees (particularly those designated as TPOs), will need to be agreed by the council.

In view of the large number of trees forming woodland habitat within the immediate vicinity of the weirs, and given the uncertainty of the location(s) and extent of tree removal, individual trees were not subjected to a bat roost potential assessment. If trees with potential to support bat roosts (particularly sub-mature and mature trees, i.e. with a stem diameter exceeding 300 mm) are scheduled for significant arboricultural works, such as de-limbing and felling, further inspections must be undertaken.

6.5.4 Bats

Trees on the left bank that are potentially affected by access were considered to have low bat roost potential and, as such, further surveys (dawn/dusk bat surveys) are not required according to the Bat Conservation Trust (BCT) guidelines.

Roosting

If sub-mature and mature trees require felling as part of the works, they should first be visually inspected by an experienced ecologist for any evidence of roosting bats.

Trees with moderate to high potential to support bat roosts may require further activity surveys.

When felling any trees with negligible to low roosting potential for bats, guidance in *Bat Habitat Assessment prior to Arboricultural Operations* (Natural England, 2010) should be followed.

- Work should be carried out between late August and early October or between March and April, wherever possible.
- Shortly prior to felling or removing timber with bat potential, an ecologist or tree climber should conduct a visual inspection for signs of bats, ideally when the trees aren't in leaf for ease of visual inspection. Inspections and surveys may be conducted without a licence until a roost is identified.
- If bats or roosts are discovered, prior to or during operations, works should stop immediately and a suitably qualified ecologist and/or SNH contacted to advise the way forward.
- Work should be conducted in a sensitive manner and, where reasonably practicable, timber with bat potential should not be directly sawn through. If such timber is removed, it should be left at the base of the tree for at least 48 hours.

Foraging and commuting

If works are scheduled for the period between April and September, when bats are most active, any night-time working should use directional lighting rather than floodlights to avoid causing unnecessary disturbance to foraging and commuting bats during the works. Lights should be fitted with a directional cowl to avoid unnecessary light spill and should be directed away from any potential foraging/commuting habitats (e.g. treelines).

6.5.5 Breeding birds

Vegetation clearance should be conducted outside the bird breeding season, which runs between March and September inclusive.

If works are undertaken within the bird breeding season, the works area should be checked for Dipper nests. If nests are found within close proximity to the weirs, and are thus likely to be disturbed by works, the works will need to be postponed until the chicks have successfully fledged. Dippers tend to have two broods each year; thus, it is unlikely to be able to determine whether the brood is the first breeding attempt or the second one in the year, unless nests are identified early in the season.

If any tree removal is required within the bird breeding season, a pre-works nesting bird survey should be carried out to identify the location of any nests within the works footprint. Any nests found will need to be safeguarded until the chicks have successfully fledged.

6.5.6 Badger

No confirmed field signs of badger were recorded during the survey although several mammal runs were present along the embankment on the right bank; however, this is inconclusive evidence of badger activity.

In order to limit disturbance to commuting and foraging badger within the area, it is advised that works are undertaken during daylight hours where possible and any night time working is done under spotlights and away from woodland areas. Any excavation left overnight should be covered to prevent exploration by badger.

6.5.7 Otter

No evidence of otter was made during the survey and the weir does not provide suitable habitat for holt sites.

It is considered an appropriate precaution to undertake a pre-works survey prior to in-channel and bankside construction works along the river banks within the works footprint.

If an otter holt is identified within the works area, a license will be required from SNH and mitigation measures such as installation of artificial otter holts may be required. If no holts are identified, mitigation measures to reduce disturbance to foraging and commuting otter should be implemented. Such measures should include covering of all excavations overnight to prevent exploration by otter.

6.5.8 Non-native invasive species

Japanese Knotweed and Giant Hogweed are present on the left bank directly adjacent to the weir (the location of these infestations are shown as Target Note 4 in Figure 4-3, Appendix A). Japanese Knotweed is also growing on part of the weir structure. Himalayan Balsam was noted within the Atkins (2015) report to be present within proximity to the weirs. No Himalayan Balsam was identified within the works area, but survey was conducted at a suboptimal time to survey for flowing plants.

The works are to be undertaken within the area of Japanese Knotweed infestation, and an Invasive Non-native Species Management Plan should be produced following guidance from Scottish Natural Heritage (SNH) and the UK Government to ensure that the spread of Japanese Knotweed and other invasive species does not occur as a result of completing the works.

Almond Angling Club undertakes annual spraying along the Almond, but none has been undertaken on the left bank at Dowie's Mill Weir Weir yet. RFFT are undertaking a catchment-based approach to this effort, commencing upstream and working downstream.

Appropriate measures are likely to include application or cutting and injection of glyphosate herbicide. Alternatively, if low-impact works are required, it may be appropriate to instate a cleaning area to ensure that contaminated soils are not unintentionally moved off the site during the works. Further advice from SEPA should be sought in relation to conducting such works by a watercourse.

Herbicide application must be undertaken by contractors with appropriate certification, and use of herbicide near water must be approved by SEPA. Spraying of the herbicide may not be suitable on the water's edge, so direct application of herbicide to the leaves may be needed. Another method would be to use a scythe (absolutely no flailing permitted) to cut the stems in spring and treat the remaining stumps in late summer with the herbicide.

Japanese Knotweed is likely to need annual herbicide treatment for three years, preferably in the optimal time (August to October). If a shorter period of treatment is undertaken, the growth on the weir itself is unlikely to be dead by the time the weir is removed, and offsite disposal of Japanese Knotweed infested material will be required.

Giant Hogweed contains a toxic chemical which sensitises the skin and causes severe, long-term blistering when exposed to sunlight. Management should be considered as a biodiversity enhancement following guidance from The Giant Hogweed Best Practice Manual (Nielsen *et al*., 2005).

Our recommendation is that the INNS are treated in advance of works.

6.5.9 Heritage

Given the heritage significance attached to the mills along the River Almond, and the potential for impact on the setting of the Listed workers' housing and Cramond Brig, the ideal scenario in heritage terms would have been preservation of Dowie's Mill Weir in situ. However, retention of the weir which is not currently maintained, is not considered practicable, or consistent with the ecological aims of the project, and so a scheme of archaeological mitigation will be required, to preserve by record any remains to be affected

In order that the weir structure remains legible, sections of the weir should be retained on either bank, to allow its historic layout to be appreciated and this is achieved within the design.

A full pre-intervention record should be made of the weir structure and associated features prior to removal or alteration. Archaeological monitoring will be required during works to ensure that the historic fabric of the weir and any preceding structures, and any hitherto unrecorded archaeological features, can be excavated and preserved by record. An archaeology watching brief has been costed and included within the Bill of Quantities in Appendix M,

Provision should be made for public engagement (in the form of interpretation to the public) during the works, to a brief provided by the City of Edinburgh archaeologist.

Buried archaeological material is thought to be present along the riverside, particularly on the right bank near the weir headwall. Care should be taken to ensure that harm to below-ground remains is avoided as far as possible. Any groundworks that are required should be undertaken with a scheme of archaeological mitigation in place, to be agreed in advance with the City of Edinburgh archaeologist.

6.5.10 Control of sediment

The works will involve in-river removal of sediment from upstream of the weir. This will mobilise plumes of contaminated bed sediment currently stored upstream of the weir, with potential impacts on water quality and downstream habitat. The impact can be greatly minimised by careful excavation of loose deposits; slowing the rate of excavation will minimise the amount of spill from each bucketful and, in addition, minimise the concentration of silt in the flow.

The workforce should use appropriate control measures and PPE during in-channel works to avoid direct contact with contaminated sediments, and should develop methods of working that avoid disturbance of sediments during weir removal works.

Contaminated land sampling strategies should be applied. This should include testing of the upper surface of any residual sediments that may be left in the river following weir modification works, which would most likely be in contact with surface water in the future.

High river levels may inundate working areas upstream of the weir. Heavy rainfall may wash bankside silts and fines into the watercourse.

The contractor should develop an Environmental Management Plan and Construction Phase Management Plan prior to commencement of construction activities at the site in order to document the range of measures that will need to be adopted to mitigate potential impacts. The following measures should be adopted:

- minimise in-river work;
- work in the dry as much as possible;
- minimise plant movements within the silt;
- access the weir crest from downstream if possible (which is less silty);
- isolate the working area from the main river flow, e.g. using dumpy bags (straw bales would probably be washed away);
- install a stilling basin downstream of the weir to settle out suspended sediment;
- store excavated materials in dedicated contained areas, away from the watercourse and above flood levels;
- undertake workforce training to raise awareness of the requirement to prevent contamination of the watercourse;
- water quality or turbidity monitoring during the works.

Further guidance is available in SEPA's *Engineering in the water environment: good practice guides*, including *Sediment management* (SEPA, 2010) and *Temporary construction methods* (SEPA, 2009).

6.5.11 Pollution Prevention Guidelines (PPG)

Appropriate mitigation measures should be implemented to ensure that habitats within proximity of the works are not degraded as a result of pollution events during the construction phase. This mitigation should include the following.

- Abide by relevant PPG produced jointly by the Scottish Environment Protection Agency (SEPA), Environment Agency and the Environment and Heritage Service of Northern Ireland.
- Any chemical, fuel and oil stores should be located on impervious bases 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 10 m).
- 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.
- 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 they can be removed.
- Concrete pouring should be avoided during periods of heavy rainfall and placement of cementitious material in water should be avoided.

6.6 Health and safety

6.6.1 Construction (Design and Management) Regulations 2015

The Construction (Design and Management) Regulations 2015 apply to the design and construction phases of the work.

The work at Dowie's Mill Weir will be notifiable to the Health and Safety Executive as the construction work is likely to exceed 500 person days (based on an estimated five-month programme involving five people).

6.6.2 Designer's hazard inventory

A designer's hazard inventory is given in Appendix J. The top five hazards are presented in the table below.

Table 6-1: Top 5 hazards

Nr	Hazard	Notes
1	Flooding of the works	Work during low flow conditions only. Monitor rainfall and river levels. Register for SEPA flood warnings.
2	Deep, fast flowing water in river, and recirculating flow downstream of weir	Work in the watercourse cannot be avoided. Work must be limited to low flow conditions. Access routes should avoid enter the river immediately downstream of the weir during higher flows. The Contractor should monitor rainfall and river levels, and register for SEPA flood warnings.
3	Install scour protection near buried services	Confirm location and depth by CAT and genny scan, followed by hand-dig with care to 1m depth. Agree working methods with SGN. Hand excavation only within 3.0m of plant. No piling or boring within 15m of plant without prior consultation and agreement. No explosives within 30m of plant.
4	Excavation at toe of slopes to install revetment	Excavate short lengths and re-fill during same shift; hit and miss construction; liaise with residents to avoid heavy traffic during excavation; monitor.
5	Plant oversailing onto Dowie's Mill Lane	Mark shared boundaries and use short-term temporary stoppages during right bank protection works.

6.6.3 Contaminated sediment

During works within the river channel, there is the potential for encountering contaminated materials, such as sediments that have been deposited upstream of the weir.

COSHH Assessments, task-specific method statements and Health and Safety Plans must be completed and issued prior to commencement of site operations.

Control measures should be implemented to protect the health and safety of site personnel and prevent visitors, residents and members of the public from coming into contact with potentially contaminated materials. Measures may include the following:

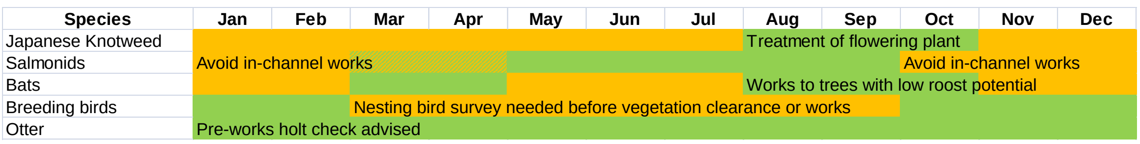
- limiting public access to the works;
- safe working practices during any in-channel works to prevent direct exposure;
- use of Personal Protective Equipment (including eye protection and gloves);
- adopting good practices in relation to personal hygiene, including hand washing and boot cleaning;
- placing excavated soils in a dedicated secure "quarantine" area, pending the results of additional inspection/testing;
- use of sheeting or covering as appropriate to prevent generation of airborne dusts, odours, etc.

General guidance is available in the HSE Document HS(G)66 *Protection of Workers and the General Public during the Redevelopment of Contaminated Land*.

6.7 Programme

The construction programme should minimise impacts on protected species. Any vegetation clearance should be carried out outside the bird breeding season and pre-works surveys should be undertaken shortly before site set-up. Work in the river channel is permitted from the end of May to the end of September (at the discretion of the Forth District Salmon Fishery Board (FDSFB)). Programme constraints are summarised in Figure 6-1.

Figure 6-1: Programme constraints



An outline construction sequence is given below. This may be developed by a future appointed works contractor, although it should be noted that the contractor remains free to choose his own working methods within the programme and environmental constraints.

- site clearance;
- construct access road and working areas;
- remove and de-water sediment;
- breach existing weir near left bank and lower water levels, with fish rescue;
- set up river diversion near left bank;
- protect pipeline crossings;
- construct right bank protection;
- construct riffle-pool and boulder rapid to right-hand side;
- relocate river diversion to riffle-pool;
- construct boulder rapid to left-hand side;
- remove remainder of weir;
- construct lower boulder rapid, tying in to existing river downstream;
- remove accesses;
- reinstatement and landscaping.

Recommended construction programmes are summarised below with full details in Appendix I.

• Treat invasive species	2016 to 2018;
• Site set-up	February to March;
• Remove and de-water sediment	April to May;
• Breach weir and lower water levels	Mid-May;
• Works - river right	May to July;
• Works - river left	July to August;
• Remove remainder of weir	September;
• Reinstatement	October.

6.8 Cost estimate

6.8.1 Methodology

An initial cost estimate was prepared using the Civil Engineering Standard Method of Measurement (CESSM4), with rates from the CESSM4 Carbon and price book 2014, supplier quotations, labour, plant and materials or rates from similar work on other projects. The cost estimate was subsequently submitted for checking by Bailey Construction Limited.

A risk budget was estimated using a quantitative risk register.

6.8.2 Cost estimate

The outline cost estimate for the work is £521,072, with a risk budget of £122,920, giving a total of £643,992.

6.8.3 Assumptions

Part 1 General items

- An area of Japanese Knotweed and Giant Hogweed on the weir crest and left bank will be treated annually over a period of three years prior to the works.
- The site compound will be located off Cramond Brig Toll.
- A temporary haul road will be constructed from Cramond Brig Toll to the left riverbank using ground protection mats (105 m long).
- A temporary silt trap will be constructed across the river downstream of the works to contain any turbidity (30 m long).

- Water levels in the River Almond will be managed during the works by breaking through a section of the weir near the left bank.
- A temporary plastic liner will be installed to allow the conveyance of clean river water through the works without silt mobilisation.
- Drawdown will be slow and controlled to avoid the risk of bank failure of the adjacent riverbanks.
- A rock revetment will be placed along the toe of Dowie's Mill Lane before de-watering to control the risk of instability during drawdown.
- Drawdown will take up to 4 weeks.
- Work in the watercourse will last 19 weeks.
- The construction period will be 32 weeks.
- Daily road cleaning will be undertaken.

Part 2 Weir removal and channel stabilisation

- A 60 m length of weir will be removed in full and disposed of off-site, including parts of the exposed concrete slab near the right bank.
- 740 m^3 of weir materials will be exported off site.
- Construction of an erosion-resistant control section will avoid the need for scour protection work at the pipeline crossings and Cramond Brig.
- A 90 m long riffle-pool and boulder rapid will be constructed in its place.
- 940 tonnes of boulders, cobbles and gravel will be imported via the left bank.
- Armourstone will be sourced within Edinburgh district.
- Dowie's Mill Lane will require some right bank stabilisation using rip-rap at the location of the retaining walls and willow spiling elsewhere along the right bank as shown on the drawings.

Part 3 Sediment

- 1000 m^3 of sediment upstream of the weir will be separated, with 700 m^3 of coarse fractions double-handled for re-use in the works and 300 m^3 of fine sediment de-watered.
- Fine sediment will be de-watered prior to transport in accordance with the EU Waste Directive (e.g. by pumping into geotextile bags on the riverbank).
- Fine sediment will be classed as hazardous waste.
- The nearest disposal site for hazardous waste is Teesside. This has been taken into account as additional costing shown in appendix M as unforeseen ground conditions.

6.9 Risk register

The risk register sets out the project risks, consequences, mitigation and owner, with a quantitative estimate of probability, financial consequences and risk budget (see Appendix K). The top five project risk items are as follows:

- Dowie's Mill Lane embankment slips during or after weir removal;
- high river flows mobilise silt during works;
- volume of sediment exceeds estimate (by, for example, 20%);
- invasive non-native species on the weir crest cannot be treated in advance of the works, for example, if project lead time is less than three years;
- high river flows prevent in-river working;
- high river flows damage work in progress.

6.10 Value engineering

Given the constraints on site, there may be limited opportunities for value engineering and savings unless the original scope of works is revisited.

7 Next steps

7.1 Pre-construction

7.1.1 Non-native invasive species

Produce a non-native invasive species management plan to ensure that the spread of Japanese Knotweed, Giant Hogweed and other invasive species does not occur as a result of the works.

Treat Japanese Knotweed with herbicide annually from August to October, ideally for three years before starting construction.

Treat Giant Hogweed following guidance from The Giant Hogweed Best Practice Manual (Nielsen *et al*, 2005).

7.1.2 Consents and notifications

The work will require a number of consents, and application forms are given in Appendix L.

Obtain landowner consent from CEC (owner of weir and right bank) and Dalmeny Estates (owner of left riverbank, recommended access routes and site compound).

Obtain landowner consent from SGN (owner of gas pipeline) and Scottish Water (owner of combined sewer) for works in close proximity to their assets.

Undertake a tree survey at the appropriate time of year to identify trees for felling or works, assess the significance of their loss and specify re-planting, in partial fulfilment of planning requirements.

Apply for planning permission from CEC.

Apply for **conservation area consent** from CEC.

Apply for SEPA CAR licence (complex). A licence will be required for impounding works for weir removal and temporary access ramps in the riverbed (Form D), and engineering works for sediment management, green bank reinforcement and river restoration (Form E).

Notify the owners of salmon fishing rights (Crown Estates Commissioners and Rosebery Estates) and leaseholders (Cramond Angling Club) of a potential impact on their enjoyment of the right during the works.

7.1.3 Contract preparation and tender stage

Prepare contract document and health and safety plan.

Develop a procurement strategy, with particular regard to the choice of contract, the use of specialist sub-contractors for masonry works and the allocation of risk between the client and contractor. It is important to specify the thresholds for compensation events (e.g. river levels, prolonged high river levels).

Prepare and issue tender documents, undertake tender appraisal and appoint principal contractor.

7.2 Construction

7.2.1 Prepare plans

The principal contractor should develop the following plans: construction phase health and safety plan, environmental management plan, site traffic management plan. The principal contractor should register for flood warnings during construction.

7.2.2 Ecological surveys

Follow-up ecological surveys should be undertaken shortly before site start, as follows:

- breeding bird survey;
- otter survey one month or less before;
- if works are undertaken within the bird breeding season, check the works area for Dipper nests;
- non-native invasive species.

7.2.3 Site clearance

Tree and vegetation clearance should be undertaken outside the bird breeding season (avoid March and September inclusive).

Site clearance should be undertaken along the proposed access routes.

If Himalayan balsam is found, this should be cut back before seeding. The remains of the plant may be disposed of by burning or composting, provided no seeds are present.

Prepare notices and/or site information boards to explain the aims, scope and programme of the works to walkers, tourists and locals.

7.2.4 Surveys and inspections

A pre-construction condition (or dilapidation) survey should be undertaken by the principal contractor and client's representative, to obtain a shared photographic record of the site and access routes. This will protect both parties in the event of any claims for damage during or after the works.

A pre-intervention historic building surveys of the weir should be undertaken, timed to suit each element of the work. This should be a descriptive record including a drawn record, photographs and written record.

7.3 Post-construction

Prepare as-built drawings and other details for health and safety file (by principal contractor).

Complete Health & Safety File.

8 Recommendations

8.1 Additional works

Recommendations are made for items that fall outwith the remit.

8.1.1 Repair of Cramond Brig scour protection

It is recommended that remedial repairs to the existing masonry invert at Cramond Brig be undertaken to ensure satisfactory scour protection. Without this invert, the structure would be Scour Risk Rating 1 (the highest risk) (JBA Consulting, 2016). This work is not required as part of this scheme but the recommendation is included for the benefit of the asset owner.

The work should be undertaken as follows:

1. Masonry/stone sett invert to be exposed in bays by removal of bed material, where applicable;
2. Areas of missing setts to be identified by divers;
3. A masonry unit to be removed or cored to determine the type of stone;
4. Specification of imported stonework to be agreed in consultation with Historic Scotland due to Ancient Monument status;
5. Any voids below formation level of existing invert to be filled with hand-placed concrete bagwork;
6. Invert to be repaired to existing finished level using imported blocks to match existing stonework.

This work can be undertaken underwater by divers. Listed building consent will be required from CEC.

Series 600 Cramond Brig

- 600 Cramond Brig existing plan
- 601 Cramond Brig proposed plan
- 602 Cramond Brig sections and detail

Appendices

A Preliminary ecological appraisal

B Services information

B.1 Contents

Linesearch

Scottish Water wastewater plan and legend

Scottish Water water plan and legend

BT Openreach

SP Energy Networks

Edinburgh City Council street lighting

Virgin Media

C Hydrological Assessment

C.1 Introduction

C.2 Site details and location

C.3 Flood estimation

C.4 Low flow estimation

C.5 Hydrographs

D Hydraulic Assessment

D.1 Modelled water levels

D.2 Modelled velocities

D.3 Modelled shear stresses

E Geomorphological assessment

F Geotechnical interpretative report

G Underwater survey and scour assessment

H Heritage Impact Assessment

I Landscape Visual Impact Assessment

J Technical Specification

K Hazard Inventory

L Programme

M Cost Estimate

N Risk Register

O Consent Application Forms

P Visualisations

References

Armstrong *et al* (2010) Environment Agency Fish pass manual

Atkins (2015) River Almond feasibility and optioneering study to improve fish passage, report for RAFTS.

Greenhatch (2014) River Almond Peggies (sic) Weir, Topographical survey

Greenhatch (2014) River Almond Dowie's Mill, Topographical survey

JBA Consulting (2016) survey

Mott Macdonald (2014) River Almond structural examinations and silt surveys

- Summary Report
- Geo-Environmental Desk Study
- Level 3 Flood Risk Assessment - Hydrological analysis
- Level 3 Flood Risk Assessment - Cramond Weirs

Mott Macdonald (2014) Dowies Mill Weir Structural Examination and Silt Survey

Mott Macdonald (2014) Peggies Mill Weir Structural Examination and Silt Survey

SEPA (2009) Engineering in the water environment: good practice guides, Temporary construction methods

SEPA (2010) Engineering in the water environment: good practice guides, Sediment management

The Cramond Association (undated) *Walk the Cramond Old Mill Trail (www.thecramondassociation).*

The Stationery Office (2012) The assessment of scour and other hydraulic actions at highway bridges, BD97/12, Design manual for roads and bridges

USBR (2007) Rock ramp design guidelines

Minutes of public meeting (11 May 2015);

Minutes of steering group meeting (18 May 2015);

Minutes of public meeting (26 August 2015);

RAFTS Consultation questionnaire;

Public correspondence;

JBA consulting

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