Appendix A13.4: Fluvial Geomorphology

1 Introduction

Background

1.1 This technical appendix informs Chapter 13 (Road Drainage and the Water Environment) of the Environmental Impact Assessment Report (EIAR). It focuses on the fluvial geomorphology aspects of the study, providing a detailed understanding of the baseline environment and the assessment of impacts of the A9/A96 Inverness to Smithton scheme (hereafter referred to as 'the proposed scheme').

1.2 Fluvial geomorphology has been included in the assessment primarily as a result of the requirement of the EU Water Framework Directive (WFD, 2000/60/EC), transposed into Scottish law by the Water Environment and Water Services (Scotland) Act 2003 (WEWS Act). The legislation aims to classify rivers according to their ecological and chemical status and sets targets for improvements through River Basin Management Plans (RBMP) (Scottish Government 2015). Ecological status is split into three quality elements: biological; physico-chemical; and hydromorphological quality. Hydromorphology is a WFD legislative term to encompass the hydrology and geomorphology of watercourses. For 'High' status water bodies, the WFD requires that there is no more than very minor human alteration to the hydromorphology quality elements including:

- the quantity, dynamics and velocities of flow;
- the continuity of the river: allowing sediment transport and migration of aquatic organisms; and
- the morphology of the river: channel patterns, width and depth variations, substrate conditions and both the structure and condition of the riparian zone (river corridor).

1.3 The fluvial geomorphology assessment and this appendix are intended to provide an understanding of the baseline hydromorphological condition of the watercourses within the study area of the proposed scheme before providing an assessment of the potential impacts. Geomorphology is inherently related to the hydromorphology quality element of the WFD. Hydromorphology is a supporting element within the assessment of 'Ecological' quality that links the disciplines of geomorphology and hydrology enabling the assessment of both disciplines under the WFD.

Fluvial Geomorphology

1.4 Fluvial geomorphology is the study of the landforms and physical features associated with river systems (including their channels and floodplains); and the sediment supply and transport processes that create them. Fluvial processes create a wide range of morphological forms that provide a variety of habitats within and around river channels. As a result, geomorphology is integral to river management.

1.5 The geomorphological form of a river channel and valley floor is influenced by many different factors and complex inter-related processes. Controls influencing river systems are both external (including catchment geology, topography, soil type, climatic trends and land management practices) and internal (including bed and bank materials, vegetation characteristics, gradient and flow conditions). These variable controls and their interactions determine the character of fluvial processes, which in turn, influence individual channel forms and features.

1.6 As an unmodified system, a river evolves in response to natural influences. However, rivers are often affected by human activities. Channel modifications, including artificial structures, alter flow and sediment movement, typically resulting in changes to river morphology (form), laterally (channel width, floodplain connectivity) and/or longitudinally (planform, bed gradient or depth). Changes in one part of the river catchment either through natural or human activity can result not only in geomorphological adjustment over time at that point, but also in changes upstream and downstream.

1.7 An understanding of fluvial geomorphology adds value to the design of river modifications and structures (such as culverts, scour/bank protection and channel realignment) by identifying areas at risk of erosion, deposition and other morphological changes. This leads to a potential reduction of maintenance costs by embedding mitigation to both protect assets and reduce/eliminate impacts on natural fluvial processes.

1.8 In support of statutory requirements to protect biodiversity, fluvial geomorphology also contributes to the understanding of habitat requirements, their sustainable management and mitigation of impacts resulting from development works.

1.9 Understanding the fluvial geomorphology environment of watercourses enables identification of lengths of channel that are currently in poor condition that can provide opportunity for morphological (and consequently WFD) enhancements. Enhancement can take various forms and range from simple riparian improvements to structure removal and reach restoration.

Assessment Aims

1.10 The specific objectives of this assessment (and those relevant to the hydromorphological elements of the WFD assessment (refer to Appendix 13.6: Water Framework Directive and River Basin Management Plans)) are to:

- understand the baseline characteristics for each water feature;
- assess the potential impacts on each water feature affected by the proposed scheme against the baseline (with consideration of the sediment regime, channel morphology and natural fluvial processes);
- recommend mitigation measures to minimise potential impacts resulting from the proposed scheme; and
- understand and outline any residual impacts following the application of recommended mitigations.

Study Area

1.11 The study area for fluvial geomorphology extends to a reach length of at least 500m centred on the proposed watercourse crossing locations. For some more sensitive watercourses (following the importance criteria established in Table 13.5 in Chapter 13: Road Drainage and Water Environment), the study area was extended to 1km to allow for a more detailed assessment of the baseline characteristics and processes.

2 Methodology

General Approach

2.1 Geomorphological impacts are assessed in terms of potential disturbance to the existing channel morphology, sediment regime and fluvial processes.

2.2 The forms and processes occurring within river systems provide and sustain physical habitat for aquatic species, and may also influence water quality, the stability of infrastructure and flood risk, with implications for local communities and businesses. Potential receptors, sensitive to geomorphological change, are therefore both environmental and socio-economic.

2.3 To inform the impact assessment process, both desk-based data and field data were collected and analysed. The methodology for the fluvial geomorphology assessment follows best practice guidance including:

- The Fluvial Design Guide (Environment Agency 2010);
- Applied Fluvial Geomorphology for River Engineering and Management (Thorne et al. 1997);
- The Scottish Rivers Handbook (Perfect et al., 2013);
- Manual of River Restoration Techniques (RRC 2013);
- Guidebook of Applied Fluvial Geomorphology (Sear et al., 2010); and

- Supporting Guidance (WAT-SG-21) Environmental Standards for River Morphology (SEPA 2012).

2.4 Chapter 13 (Road Drainage and Water Environment) provides a description of how the baseline information has been gathered as well as the criteria for assigning importance, determining the magnitude of potential impacts and the significance of impact.

2.5 Evaluating the importance of watercourses and magnitude of impacts involves several elements. For instance, importance has been determined by assessing the structure of the channel bed and banks, flow and sediment dynamics, connectivity, complexity and structure of the riparian zone, and morphologically valuable features, e.g. bedforms. Magnitude of impacts during both construction and operation takes into consideration the timing, scale, location, duration, type of impact and consideration for the features the impact would be affecting

Limitations to Assessment

2.6 Baseline conditions reported in this study are informed by site walkover information. During the January 2018 site surveys, moderate flow levels were observed following recent rainfall. Where stated, channel widths are based on observations undertaken during these winter site surveys. Channel measurements at ‘normal’ flow conditions (e.g. bankfull/QMED) will be established during surveys to be undertaken during subsequent design stages (e.g. Specimen and Detailed design stages), which is a standard practice in developing the design.

2.7 The assessment of the potential impacts of the construction and operation of the proposed scheme upon the sediment regime for each watercourse is based on the existing baseline conditions. Modelling had been previously scoped out of the assessment due to the relative value the data would provide for the Design Manual for Roads and Bridges (DMRB) Stage 3 design (i.e. the design assessed within this EIAR). Sufficient information related to the sediment regime has been collected for the purposes of this stage of assessment through on-site survey observations and sediment sampling.

2.8 All watercourses potentially impacted by the proposed scheme were surveyed over a minimum 500m reach length as centred on the proposed crossing point. Where watercourses were considered to be more sensitive to potential impacts, the survey length was extended to 1km (refer to paragraph 1.11). Survey extents depended on the availability of land access.

3 Baseline Geomorphology

3.1 The following sections describe the baseline conditions for the fluvial geomorphology attributes of each water feature potentially impacted by the proposed scheme.

Water Feature Descriptions

Inshes Burn (SWF02)

3.2 Inshes Burn has its source south of Balvonie Wood and flows north-west for approximately 2.4km to the Inshes Retail Park. The watercourse then flows north for approximately 620m, under the A9 Perth – Inverness Trunk Road (hereafter referenced as the A9) and then east for 1km to Scretan Burn (SWF04) where it passes in an aqueduct over the Highland Main Line Railway. The catchment land use consists of pastoral fields and conifer woodland plantations upstream of Inshes and urban land downstream.

3.3 Inshes Burn had an asymmetrical two-stage cross section with a low sinuosity planform and variable channel width. Visual estimates of the bankfull width suggest a range of between 1.5m and 2m within the upstream section from Balvonie Wood to Inshes (Photograph 1). The channel banks consisted of fine sediments and soil with low gradient profiles. The bank height was approximately 0.2m but due to an asymmetrical cross section this height varied. The channel lies within a V-shaped valley with a width of approximately 20m to 30m.

3.4 From Inshes downstream the watercourse passes through approximately 12 culverts (according to OS maps). The planform appeared to be artificially straight with a trapezoidal cross section suggesting resectioning. Visual estimates of width suggest the channel was approximately 0.3m wide at the time of survey. The bank top appeared to be 0.8m high and 2m wide and was laterally constrained (Photograph 2).

3.5 After passing through Inshes, the watercourse then flows north and then east under the A9 towards Scretan Burn (SWF04). From upstream of the A9, water is conveyed by separate pipes towards the Raigmore Junction during low flows with little to no water being conveyed under the A9. At average and high flow volumes, the watercourse flows east under the A9 through a pipe culvert and over the Highland Main Line Railway in an aqueduct (some flows still pass to the Raigmore Junction). The pipe system upstream of the A9 described here, was installed in 2005 to alleviate flood risk to the A9 and surrounding areas. It is thought to restrict flow volumes and sediment transport downstream along Inshes Burn. The chamber and aqueduct are likely to restrict sediment transport downstream.

3.6 The flow type appeared to typically consist of turbulent to laminar flow types, with riffle-run bedforms and homogenous reaches. The channel substrate consisted of sand and fine gravels with cobbles found in the faster flowing reaches. Substrate appeared to be mobile, showing no evidence of armouring, and had undergone some sorting. Lateral bars were identified in sinuous reaches and were comprised of well sorted fine gravels and sands.

3.7 The riparian zone and adjacent land use upstream of Inshes was vegetated by a mix of mature deciduous and coniferous trees, providing a dense woodland canopy. The riparian zone in the understory of the woodland consisted of grasses and shrubs. Downstream of Inshes the riparian zone was fragmented by culverts. Where present the riparian zone appeared to be vegetated by shrubs and grasses.

3.8 Based on existing conditions, Inshes Burn currently displays the characteristics of a Plane-riffle Sensitivity C River Type (SEPA 2012, WAT-SG-21).

3.9 Historical map analysis indicated Inshes Burn has been subject to modification to the planform prior to and since 1868. Minor straightening of the tributary upstream of Inshes has been undertaken since 1967. Similar realigning and straightening of the channel immediately downstream of B9006 Culloden Road and through the Inverness Retail and Business Park had also been undertaken during the same period. A large pond had also been removed immediately north of the Raigmore Hospital. Mapping from 1944 to 1967 suggests Inshes Burn was hydrologically connected to Beechwood Burn (SWF03) more significantly than it is presently.

3.10 Land use has also changed significantly since 1868. Upstream of Inshes, Balvonie Wood previously covered a greater area of the catchment and bordered the channel in a more consistent manner from source to Briargrove Drive. Current land use consists of urban residential and commercial properties.

3.11 A 2.4km tributary of Inshes Burn is present upstream of Inshes and 260m to the south-west of the main course. The upstream reaches were affected by collapsed trees and bushes. Where visible, the channel appeared straight with a bankfull width of 1.2m, a depth of 0.15m and a series of cobble step-pools. Substrate resembled the main course, consisting of gravels and larger cobble steps, and woody debris. Backwater areas developed behind woody material providing flow and depth variation. The channel was constrained by embankments on both banks.

3.12 As Inshes Burn is predominantly modified through Inshes and there is only a limited length of the water feature displaying characteristics of an unmodified channel, it has been assessed to have ‘low’ sensitivity to disturbance and is consequently of ‘low’ importance to the assessment.

Photograph 1: Sinuous channel set within the river valley looking upstream (NH 69636 43319)

Photograph 2: Straight section within Inshes Burn upstream of Briargrove Drive (NH 68991 44032

Beechwood Burn (SWF03)

3.13 Beechwood Burn has its source between the A9 and B9006 Culloden Road and flows north-west for 1km where it is met by the historic channel of Inshes Burn (SWF02). The watercourse flows north-east approximately 1km to the confluence with Scretan Burn (SWF04). Catchment land use is predominantly agricultural with areas of urban development.

3.14 Beechwood Burn had a predominantly straightened planform from source to confluence with Scretan Burn (SWF04). Upstream of the Highland Main Line Railway, the burn had a bank top width of approximately 3m which appeared to be narrowing with a sinuous low flow width of approximately 0.4m developing between vegetated berms (Photograph 3). Channel banks were comprised of fine sediments and soil and measured approximately 0.4m high with low bank angles from the berm to the bank top. Downstream of the Highland Main Line Railway, the channel exhibits a more uniform cross section measuring approximately 1.5m to 2m wide with a 0.8m wide low flow channel. The steep channel banks were approximately 0.4m high with an embankment along the left bank of 1.5m (Photograph 4). The burn displays variability in flow types from tranquil to turbulent associated with run and riffle bedforms respectively. Woody material was also observed partially blocking the channel creating a backwater effect.

3.15 Upstream of the Highland Main Line Railway, the channel substrate consisted predominantly of unsorted fine to coarse gravels with small cobbles. Silt substrate was noted downstream of the railway.

3.16 The riparian zone consisted predominantly of grasses and shrubs. The riparian zone was identified to be fragmented by culverts through Inverness Campus. Downstream of the Highland Main Line Railway the left bank was observed to be vegetated by large deciduous trees and a grass understorey.

3.17 Based on existing conditions, Beechwood Burn currently displays the characteristics of a Plane-riffle Sensitivity C River Type (SEPA 2012, WAT-SG-21).

3.18 Historical map analysis indicated the channel planform has been artificially modified prior to and since 1868. A minor realignment has been made to the channel planform at the junction of U1058 Caulfield Road North and B9006 Culloden Road since 1967.

3.19 As Beechwood Burn is predominantly modified and there is limited evidence of natural processes, natural features or of a supply of sediment capable of developing these features, is has been assessed to have a ‘low’ sensitivity to disturbance and is consequently of ‘low’ importance to the assessment.

Photograph 3: Straight low flow channel leaving a road culvert at Inverness Campus (NH 69087 44782)

Photograph 4: Homogenous channel with an embankment on the left bank (NH 69473 45362)

Scretan Burn (SWF04)

3.20 Scretan Burn has its source south of Bogbain. From the source, the channel flows north under B9006 Culloden Road, U1124 Caulfield Road, U1058 Caulfield Road North and through a series of straight channels between agricultural fields to Inverness Retail and Business Park. Scretan Burn discharges into the Inner Moray Firth 700m north-east of Inverness Retail and Business Park. The majority of Scretan Burn flows through grazed agricultural land with woodland reaches of under 500m in length upstream of Inshes, between B9006 Culloden Road and U1058 Caulfield Road North, and downstream of the A96 Aberdeen – Inverness Trunk Road (hereafter referred to as the A96). The channel was observed to contain flows in January 2018 but was dry in August 2018 due to warm and dry antecedent conditions.

3.21 Downstream of U1124 Caulfield Road the channel had been straightened and modified, with the bed and vertical embankments constructed of gabion baskets. During surveys in January 2018, the full width of the 3m channel was wetted, within which mid-channel gravel deposits were observed. Downstream of the modified channel, the low flow channel narrowed to a width of approximately 1m with steep soil banks. A series of cobble steps were identified within the channel providing step-pool bedforms and flow types.

3.22 North, and downstream, of U1058 Caulfield Road North the channel had been artificially straightened and the cross section modified, having steep resectioned banks approximately 0.4m high. The channel at this location was wider than the upstream reaches approaching 1.5m with a homogenous bed and laminar flow type. Substrate consisted of armoured fine to coarse gravels. The section described indicates a plane-bed channel type.

3.23 The channel is culverted under the Highland Main Line Railway within a wide riparian zone of between 10m and 13m and vegetated by grass within which a 5m to 6m floodplain was present. The channel had narrowed and a sinuous low flow channel (1m in width) had formed between alternating stable vegetated berms (Photograph 5) Banks were less than 45° at the bank toe with a two-stage cross section within the riparian zone. Substrate through the sinuous reach appeared poorly sorted, mobile and consisted of cobbles, and fine to coarse gravels.

3.24 After the confluence with Beechwood Burn (SWF03), the channel widened to approximately 2m and flowed to the south of Inverness Retail and Business Park. The banks had steep slope angles and were approximately 0.4m high. An embankment on the left bank separated the channel from Inverness Retail and Business Park. The channel substrate consisted of gravels with finer substrate in the channel margins. Substrate was partly armoured and poorly sorted. At bends in the channel small berms had formed on the inside and scour on the outside of the bend, suggesting adjustment. From the access track to Ashton Farm downstream towards the A96, the channel widened to approximately 2m with 1m high gabion walls with no in-channel features. The flow from the top of the surveyed reach to this point consisted of a series of turbulent and tranquil flows associated with riffle and run bedforms and would be considered a plane-riffle channel.

3.25 The watercourse is culverted under the A96, downstream of which large areas of bank erosion were present on the outside bends of the low sinuosity planform. Bank material within this section predominantly consisted of fine sediments and soil with steep, vertical or undercut bank profiles. Coarse gravel point bars and sand side bars were identified within the reach (Photograph 6). Substrate consisted of coarse gravels and cobbles and appeared to be mobile. Flows downstream of the A96 alternated between tranquil and turbulent flow types typically with run-riffle bedforms, interrupted by backwater areas behind debris dams and fallen trees. The reach downstream of the A96 would be considered to be a meandering channel.

3.26 Riparian vegetation for the length of Scretan Burn predominantly consisted of a narrow border of mature deciduous trees along at least one bank and small shrubs and grasses on both banks. However, along the length of channel from U1058 Caulfield Road North to Inverness Retail and Business Park the channel margin was vegetated by grasses with sparse shrub cover. This vegetation cover continued along the right bank of Scretan Burn to the A96. Downstream of the A96 the understory was minimal and consisted of sparse grasses and bare earth.

3.27 Based on existing conditions, Scretan Burn currently displays the characteristics of a Step-Pool Sensitivity B River Type and a Plane-riffle Sensitivity C River Type (SEPA 2012, WAT-SG-21).

3.28 Historical map analysis indicated the channel planform has been artificially modified prior to and since 1868. The channel had been realigned immediately upstream of the A96, previously passing under the road through a sluice 75m west from the present location and had been straightened downstream between 1967 and the present day. The channel passes under several culverts, including the A96 and the Highland Main Line Railway. Some lateral migration of the channel has occurred immediately upstream of the Inner Moray Firth.

3.29 Whilst Scretan Burn has been significantly modified, there are signs of adjustment both upstream and downstream of the A96. Varying flow types, bedforms, erosional and depositional features and a partly mobile coarse substrate offer morphological diversity and the opportunity for further development of morphological features. Scretan Burn has been assessed to have a ‘medium’ sensitivity to disturbance and is consequently of ‘medium’ importance to the assessment.

Photograph 5 Low sinuosity low flow channel flowing downstream towards Inverness Retail and Business Park (NH 69671 45311)

Photograph 6: Gravel and sand lateral bars (NH 69783 45822)

Tributary of Scretan Burn (SWF05)

3.30 Tributary of Scretan Burn is a small drainage channel forming the boundary of agricultural fields (Photograph 7). The water feature had a straight planform and a trapezoidal cross section. The width of the channel was 0.1m with a depth of <0.05m. The bank top was approximately 0.6m high and 1.5m wide (Photograph 8). The channel was embanked on both sides and had a vegetated riparian zone comprising grasses and shrubs on the right bank only. Through a 200m woodland reach, the banks were observed to have a steep slope angles and were sparsely vegetated. Upstream, and at the confluence with an indirect tributary of Scretan Burn (SWF06), large deciduous trees lined the right bank.

3.31 The predominant flow type was turbulent. Sections of tranquil flow were also observed, notably through the reach vegetated by woodland. The channel substrate consisted of silt, however localised areas of fine gravels were also identified.

3.32 Historical map analysis indicated the channel planform has been artificially modified prior to and since 1868.

3.33 The watercourse is heavily modified and based on existing conditions, currently displays the characteristics of a Plane-bed Sensitivity B River Type (SEPA 2012, WAT-SG-21).

3.34 The channel has been significantly modified and has an artificial planform and cross section. The water feature typically lacks riparian vegetation larger than grasses, with the exception of the woodland section, and in-channel morphological features. As such, the watercourse has been assessed to having a 'low' sensitivity to disturbance and is consequently of 'low' importance to the assessment.

Photograph 7: Agricultural field drain (NH 69916 45181)

Photograph 8: Straightened planform (NH 69819 45384)

SWF06: Indirect Tributary of Scretan Burn

3.35 This indirect tributary of Scretan Burn was a small, artificial watercourse with a low flow width of 0.2m on average and a depth of less than 0.05m to 0.15m. Bankfull width was not clearly identifiable during the site survey. The channel occupies a narrow ditch with steep banks approximately 0.5m high. It was observed to have a small embankment (approximately 0.2m high) that was vegetated by a narrow strip of grasses and shrubs. Mature deciduous trees lined the right bank. The channel substrate was predominantly silt.

3.36 The reach prior to the confluence with Scretan Burn (SWF04) was unfenced. Grasses colonised the channel and narrowed the channel width or blocked the watercourse. Channel banks and bank tops were vegetated by grasses and shrubs. Channel substrate consisted of gravels that appeared to be mobile. Where flow was perceived through the reach it appeared to be of tranquil over a homogenous bed.

3.37 Historical map analysis indicated the channel planform has been artificially modified prior to and since 1868.

3.38 Based on existing conditions, the watercourse currently displays the characteristics of a Plane-bed Sensitivity B River Type (SEPA 2012, WAT-SG-21).

3.39 The indirect tributary of Scretan Burn was identified as an artificial channel with little morphological value. Consequently, the watercourse has been assessed to have a 'low' sensitivity to disturbance and is consequently of 'low' importance to the assessment.

Un-named Drain (SWF07)

3.40 The watercourse consisted of a 0.5m road drain passing from Ashton Farm along an access track and through a field drain. The substrate of the road drain was observed to consist of silt. The banks of the road drain were observed to consist of fine sediments and soil, had a vertical profile and were embanked. The water feature had a continuous tree lining on the left bank and was overgrown with brambles which grew out from the understory of the trees along the left bank (Photograph 9).

3.41 The field drain was a straightened channel 0.5m wide with a water depth of 0.1m with a continuous tree lining on the right bank and an intermittent fence on the left bank. At the time of survey flows were not perceived and substrate consisted of silt.

3.42 The channel is most likely an artificial drainage channel and based on existing conditions, displays the characteristics of a Plane-bed Sensitivity B River Type (SEPA 2012, WAT-SG-21).

3.43 As the channel is likely to be artificial and has no morphological features of value, it has been assessed to have a 'low' sensitivity to disturbance and is consequently of 'low' importance to the assessment.

Photograph 9: Roadside channel (NH 69943 45681)

Cairnlaw Burn (SWF08)

3.44 Cairnlaw Burn has its source south of Muckovie Quarry (disused) where flows issue, however it is likely that the initial source occurs at Upper Muckovie Farm at a small reservoir which flows north to Muckovie Quarry where flows sink. From the quarry the watercourse flows north-west through the urban settlements of Easter Muckovie and Cradlehall. Flowing under U1058 Caulfield Road North and the Highland Main Line Railway the watercourse follows a series of agricultural field boundaries in a north-easterly direction passing beneath C1032 Barn Church Road, the A96, and the Aberdeen to Inverness Railway Line discharging into the Inner Moray Firth. Catchment land use is agricultural with three areas of woodland present, upstream of B9006 Culloden Road, upstream C1032 Barn Church Road and downstream of the A96. Deciduous trees were present within the riparian zone adjacent to these woodlands. Riparian vegetation elsewhere along the water feature typically consisted of shrubs and grasses.

3.45 Between Cradlehall and Ashton Farm, the channel was observed to be embanked on both sides and had very limited connectivity with the floodplain (Photograph 10 and Photograph 11). The channel cross section was trapezoidal and over-deep, with fine sediment and soil banks of 1m to 1.5m in height. No perceivable flow was evident immediately upstream of the Highland Main Line Railway and the low flow channel had been vegetated at the time of the site surveys. Substrate at this location is likely to consist of silts, however these may have smothered gravels as gravels are present both upstream and downstream of this location. Downstream from the meander towards the railway, riffle bedforms were identified. A sinuous channel of approximately 0.4m wide and 0.1m deep formed between alternating berms. Substrate at this location consisted of partly armoured gravels and marginal sands.

3.46 Downstream from Ashton Farm, the channel width remained similar to that upstream for a length of approximately 700m. Following this the bankfull width increased to approximately 1.5m with a low sinuosity and channel width of 0.5m passing between gravel bars and berms (Photograph 12). Average bank height was approximately 0.3m with an asymmetrical cross section due to the embankment present on the steep right bank. A wire fence crossing the channel had become blocked with debris forcing the flows to pass through the debris and causing the channel to aggrade upstream, resulting in a notable difference in bed level between upstream and downstream of the fence.

3.47 The channel passed under C1032 Barn Church Road through a 2m wide culvert (1.3m low flow). Immediately downstream of C1032 Barn Church the channel widened to 2.4m wide downstream with a channel width of 0.7m and less than 0.05m in depth with a mobile cobble and coarse to fine gravel substrate. Banks were steep (between 60° and 90°) and 0.2m high. Immediately downstream of this reach the channel narrowed to a cobble step into a 0.4m deep and 0.6m wide pool with sandy substrate.

3.48 Downstream, the sinuosity increases, and the channel had developed a series of low flow berms, gravel point bars and gravel riffles with an asymmetrical cross section. Evidence of bank failure, predominantly rotational failure, was observed. The channel then passed through a 160m straightened reach, with an armoured cobble and gravel substrate (Photograph 13). Flow types through the reach were turbulent. Channel banks were steep and approximately 0.3m in height. The wetted width was approximately 0.5m wide and bank top width 1m.

3.49 Downstream of the A96 and the Aberdeen to Inverness Railway Line, Cairnlaw Burn had artificially reinforced banks (wing walls) and natural but armoured bed passing flows under and beyond the A96 and railway culvert. The banks were reinforced with brickwork viaduct piers under a private access road (U1144 Milton of Culloden Road). The channel dimensions from this point downstream do not vary significantly. The approximate channel width was 1.5m with a depth of less than 0.1m. Substrate resembled the reach upstream of the culvert. Downstream of the confluence bedforms varied between runs and riffles. Occasional pools typically formed behind woody material and at meander bends. Immediately upstream of the Inner Moray Firth, sand dune bedforms were identified with tranquil flow types. Channel banks at the outside of meander bends show evidence of scour and undercutting, exposing tree roots. Inside meander bends gravel and sand point and side bars and small berms were identified.

3.50 Upstream of the confluence with Tower Burn (SWF10), based on existing conditions, Cairnlaw Burn displays the characteristics of a Plane-bed Sensitivity B River Type and a Plane-riffle Sensitivity C River Type. Downstream of the confluence with Tower Burn (SWF10), based on existing conditions, Cairnlaw Burn displays the characteristics of an Active Meandering Sensitivity D River Type and Plane-riffle Sensitivity C River Type (SEPA 2012, WAT-SG-21).

3.51 Historical map analysis shows the channel planform was straightened and realigned to its present course between Cradlehall and the confluence with Tower Burn (SWF10) before 1868. With further straightening adjacent to Caulfield Gardens occurring since 1967. The channel planform has also been realigned and straightened downstream from Kenneth’s Black Well (SWF12) as the it flows through Milton. Cairnlaw Burn is now culverted under the A96, which is not depicted in historical maps prior to 1967.

3.52 Cairnlaw Burn is designated as a WFD water body and consultation undertaken with SEPA in June 2018 indicated that it is currently achieving 'Bad' physical condition (Table 1); however, this status change has not yet been reflected on the SEPA's Water Classification Hub (SEPA 2018). The watercourse is currently under pressure due to extensive modification of the bed and banks of the channel. Consultation with SEPA has noted that there is currently an error with the SEPA water body line for Cairnlaw Burn (as used in this EIAR). This means that the reach currently shown on SEPA's Water Environment Hub (SEPA 2016) and Water Classification Hub (SEPA 2018) within the study area and crossed by the proposed scheme may be subject to change. However, at the time of writing, the water body line remains the same, therefore the assessment has been completed on this basis.

3.53 Due to the presence of varying flow types, morphological features and bedforms, as well as evidence of active morphological processes within a modified water feature, Cairnlaw Burn has been assessed to have a 'medium' sensitivity to disturbance and is consequently of 'medium' importance to the assessment.

Table 1: WFD Quality Status of Cairnlaw Burn

WFD Quality Element	
Water body Name	Cairnlaw Burn
Water body ID	20241
Overall classification	Moderate
Designation as Artificial or Heavily Modified Water Body (A/HMWB)	Not Designated
Pressures on water body	Modifications to bed, banks and shores
Overall Hydromorphology status	Bad
Morphology status	Bad
Overall hydrology status	High

Photograph 10: Small embankments on both banks (NH 70281 45138)

Photograph 11: Straightened and overdeep channel with embankments (NH 70173 45535)

Photograph 12: Gravel deposits (NH 70368 46042)

Photograph 13: Narrowed channel (NH 70586 46456)

<u>Indirect tributary of Cairnlaw Burn (SWF09)</u>

3.54 The indirect tributary of the Cairnlaw Burn is a straightened drainage ditch, which forms the boundary between several agricultural fields. The source begins 110m north of U1058 Caulfield Road North and flows along agricultural field boundaries in a northerly direction, crossing under Ashton Farm before the confluence with Tower Burn (SWF10).

3.55 The channel is likely to have been artificially created and has a trapezoidal cross section. The riparian zone was narrow, approximately 2m over both banks, with vegetation typically consisting of grasses. Sparse clumps of trees were noted along a field boundary at Ashton Farm and a woodland stand present 130m upstream of the confluence with Tower Burn (SWF10). The water feature appeared to have a narrow low sinuosity channel within the confines of the engineered alignment.

3.56 The indirect tributary of Cairnlaw Burn (SWF09) displays the characteristics of a Plane-bed Sensitivity B River Type (SEPA 2012, WAT-SG-21).

3.57 Due to the artificial nature of the watercourse and absence of morphological features and riparian vegetation, the indirect tributary of Cairnlaw Burn (SWF 09) has been assessed to have a ‘low’ sensitivity to disturbance and is consequently of ‘low’ importance to the assessment.

<u>Tower Burn (SWF10)</u>

3.58 The source of Tower Burn begins immediately north of Easter Bogbain and flows north along a straightened length of channel. Tower Burn has undergone high impact realignment upstream of B9006 Culloden Road where the planform is straight, presumably to accommodate drainage for the adjacent agricultural and forestry land. Downstream of B9006 Culloden Road, the river flows through Westhill and Smithton and is culverted by six structures; including at the B9006 Culloden Road. The planform of the channel was noted as being unmodified. The watercourse flows under U1058 Caulfield Road North and continues north through straight agricultural field boundaries to a wooded area, where the channel is more sinuous.

3.59 Upstream of its confluence with Cairnlaw Burn (SWF08), the channel had a wetted width of approximately 2m and sinuous planform. The channel banks consisted of fine sediments and soil and were typically planar to vertical in profile and 0.2m to 0.3m high. The exception to this was identified at the upstream end of the woodland where the banks consisted of soil and gravels and were higher, with the left bank reaching 0.5m in height. Channel substrates became finer closer to the confluence with Cairnlaw Burn (SWF08), ranging from cobbles to fine gravels, and were poorly sorted. Flows were turbulent with run-riffle bedforms. Mid-channel and marginal deposits of gravels and sands were typical. (Photograph 14 and Photograph 15).

3.60 The riparian zone typically consisted of grasses and shrubs both upstream and downstream of Westhill and Smithton, between which there was a fragmentary, narrow deciduous woodland. The riparian zone upstream of the confluence with Cairnlaw Burn (SWF08) was defined by a shallow valley with low gradient slopes reaching a height of 3m above the channel. The riparian zone was vegetated by large deciduous trees with an understory comprised of grasses and shrubs.

3.61 Historical map analysis shows evidence of straightening of the channel planform upstream of Smithton and Westhill since 1914 with the expansion of urban areas. Immediately upstream of the confluence with Cairnlaw Burn (SWF08) the channel appears to have undergone some lateral migration.

3.62 Tower Burn displays the characteristics of a Plane-riffle Sensitivity C River Type (SEPA 2012, WAT-SG-21).

3.63 Due to the presence of a morphologically diverse reach immediately upstream of the A96, which is predominantly unmodified and exhibits a diverse array of features depositional features and coarse substrate, Tower Burn has been assessed to have a 'medium' sensitivity to disturbance and is consequently of 'medium' importance to the assessment.

Photograph 14: Marginal deposits (NH 70502 45944)

Photograph 15: Mid channel and marginal deposits (NH 70451 46065)

Summary

3.64 Following the assessment of the baseline condition for each water feature, an importance level has been assigned based on the methodology outlined in Section 13.2 (Approach and Methods) of Chapter 13 (Road Drainage and the Water Environment). Table 2 below provides a summary of the watercourses. No very high sensitivity watercourses are present within the study area.

Table 2: Overview of Fluvial Geomorphology Sensitivities

Water Feature ID and Name	Qualifying criteria for sensitivity of watercourses	Sensitivity
SWF02 (Inshes Burn)	Water feature has limited physical habitat and has been extensively modified with little morphological diversity and evidence of active morphological processes.	Low
SWF03 (Beechwood Burn)	Water feature has limited physical habitat and has been extensively modified with little morphological diversity and evidence of active morphological processes.	Low
SWF04 (Scretan Burn)	Provides some habitat for species. Water feature has some natural features (pools, riffles, bars and berms) and diverse natural processes including flow types, regime and sediment transport, but has been obviously modified with anthropogenic influences visible.	Medium

Water Feature ID and Name	Qualifying criteria for sensitivity of watercourses	Sensitivity
SWF05 (Tributary of Scretan Burn)	Water feature has limited physical habitat and has been extensively modified with little morphological diversity and evidence of active morphological processes.	Low
SWF06 (Indirect Tributary of Scretan Burn)	Water feature has limited physical habitat and has been extensively modified with little morphological diversity and evidence of active morphological processes.	Low
SWF07 (Un-named Drain)	Water feature has limited physical habitat and has been extensively modified with little morphological diversity and evidence of active morphological processes.	Low
SWF08 (Cairnlaw Burn)	Is classified as having Moderate overall WFD status. Provides some habitat for species. Water feature has some natural features (pools, riffles, bars and berms) and natural processes including flow types, regime and sediment transport, but has been obviously modified with anthropogenic influences visible.	Medium
SWF09 (Indirect Tributary of Cairnlaw Burn)	Water feature has limited physical habitat and has been extensively modified with little morphological diversity and evidence of active morphological processes.	Low
SWF10 (Tower Burn)	Provides some habitat for species. Water feature has some natural features (pools, riffles, bars and berms) and natural processes including flow types, regime and sediment transport, but has been obviously modified with anthropogenic influences visible.	Medium

4 Potential Impacts

4.1 The potential impacts of the proposed scheme on fluvial geomorphology have been divided into construction and operational impacts. The construction impacts are those associated with activities undertaken during the construction phase and are therefore considered to have shorter-term effects. The operational impacts are considered to have longer-term impacts.

4.2 The following assessment of potential impacts is based on the proposed scheme without considering additional mitigation. Where embedded mitigation has been included within the design, this is accounted for in the potential impacts assessment. This includes (but is not limited to):

- geomorphology design input to the positioning of outfall locations;
- geomorphology input to the positioning of the proposed scheme alignment to minimise the length of new culverts on watercourses and ensure appropriate channel gradients and continuity (upstream and downstream); and
- flood risk input to sizing of culverts.

4.3 The locations of proposed culverts and outfalls are shown in Figures 13.1 and 13.4 respectively, which form part of Chapter 13 (Road Drainage and the Water Environment).

4.4 The most significant risks of potential impacts on the fluvial geomorphology of watercourses are associated with:

- Increases in fine sediment delivery to watercourses with potentially detrimental effects to the channel substrate. These could result during construction and operation of the proposed scheme.
- Reductions in the morphological diversity of river channels, for example due to culverting, bank and bed protection and realignment works.
- Alteration of the natural functioning of the river channel (natural fluvial processes), for example prevention of channel migration due to bank protection or culverting. The interruption of natural fluvial processes may have negative consequences upon WFD targets due to detrimental effects on habitat diversity.
- Accelerated fluvial activity such as an increase in the rate of bank erosion in response to channel engineering, such as unsympathetic channel realignment. Accelerated bank erosion leading to an increase in fine sediment delivery can have impacts where sites of importance for freshwater ecology are located downstream.

General Impacts

4.5 An outline of the potential general impacts on the fluvial geomorphology elements (sediment regime, channel morphology and natural fluvial processes) of the watercourses during both construction and operation is provided in Chapter 13 (Road Drainage and the Water Environment). The activities likely to impact fluvial geomorphology are summarised here for convenience:

<u>Construction</u>

- vegetation clearance and topsoil stripping;
- in-channel construction (including structures such as culverts and outfalls); and,
- construction within the floodplain (including drainage and embankments).

<u>Operation</u>

- culverting;
- outfall structures and associated discharges; and,
- changes to flow paths and catchment areas.

Site Specific Impacts

4.6 An impact assessment for both the construction and operation of the proposed scheme on the fluvial geomorphology of the watercourses identified above has been undertaken and is presented in Table 3.

4.7 The assessment has considered the existing baseline and the key fluvial geomorphology elements (sediment regime, channel morphology and natural fluvial processes). No impacts during construction and operation were assessed for Inshes Burn (SWF02), Indirect Tributary of Scretan Burn (SWF06), Un-named Drain (SWF07), Indirect Tributary of Cairnlaw Burn (SWF09) and Tower Burn (SWF10).

4.8 The assessment of impacts on geomorphological receptors and the significance of the impacts is inherently relevant to the hydromorphological element status of Cairnlaw Burn WFD water body and the assessment of the proposed scheme contained in Appendix 13.6 (Water Framework Directive (WFD) and River Basin Management Planning (RBMP). Impacts identified as having a minor magnitude of effect would naturally relate to small adverse effects upon hydromorphological status, whereas impacts that are identified as having a moderate magnitude of effect would relate to more significant adverse effects on hydromorphological status, and these are likely to result in a more detrimental impact on hydromorphological status. Adverse impacts would be anticipated to prevent the improvement of the hydromorphological status of Cairnlaw Burn WFD water body. The assessment of whether the impacts of the proposed scheme result in a deterioration in the hydromorphological element condition is contained within Appendix 13.6 (WFD and RBMP).

Table 3: Specific Impact Assessment for Construction and Operation on Fluvial Geomorphology

Source of Impact	Construction impacts *(for locations of proposed culverts and outfalls please refer to Figures 13.1 and Figure 13.4)*	Overall Impact Magnitude	Operational impacts *(for locations of proposed culverts and outfalls please refer to Figures 13.1 and Figure 13.4)*	Overall Impact Magnitude
SWF03 (Beechwood Burn)	**Release of Suspended Sediments** Potential increased fine sediment delivery to Beechwood Burn from direct construction activities, e.g. vegetation removal and surrounding earthworks activities (including construction of embankments). Impacts include changes to the morphological features present, including the channel bed. Due to the limited extent of morphological features there is unlikely to be notable detriment to features of value. Increased sediment loading could cause aggradation or narrowing of the channel, forming fine sediment features such as berms and altering the dimensions of the watercourse during low flow; thereby reducing channel capacity. Downstream impacts on Scretan Burn (SWF04) are also possible. The impacts described above are considered to result in an impact of minor magnitude. **Construction within the Floodplain** Works within the vicinity and along the banks of Beechwood Burn could reduce the floodplain area and alter the lateral connectivity of the water feature. Beechwood Burn is embanked and over-wide and is poorly connected to the floodplain. The localised reduction in floodplain area and reduction in connectivity is therefore likely to have an impact of minor magnitude. Although removal of vegetation could destabilise the banks, no significant impacts are expected because the vegetation currently comprises grasses. Results in an impact of negligible magnitude. **In-channel Construction** In-channel works would consist of the construction of new / replacement culverts and outfalls: • Culvert C05 – approximate 16m new culvert • Culvert C09 – approximate 35m replacement culvert • Culvert C10 – approximate 5m extension to existing culvert • Outfall to the south of Inverness Campus, approximately 300m downstream of culvert C09. • Outfall approximately 50m downstream of culvert C05 In-channel construction would likely disturb silt substrate and bank sediment, thereby mobilising fine sediment. The channel could begin to erode bed and bank material, altering the channel dimensions locally and supplying increased fine sediment downstream. Increased sediment load	moderate	**Changes to Flow Paths** As no notable changes are expected to the topography of Beechwood Burn catchment and the area of catchment being made impermeable is minimal, changes to flow paths should be minimal; results in an impact of negligible magnitude. **New Culvert C05** A new culvert with a length of approximately 16m would require the permanent removal of channel bed, banks and vegetated riparian zone. In addition, further modification upstream and downstream of the culvert would be required to tie-in the new structure with the existing banks and provide any necessary bed and bank reinforcement. The bed and banks of the channel at the proposed crossing location are of limited value, consisting of silt and soil respectively. Removal of bed and banks is therefore expected to result in an impact of minor magnitude. As the riparian vegetation at the new culvert location consists of grasses and shrubs, the impact of vegetation removal on morphology should be negligible in magnitude. The culvert design is currently an overwide twin box culvert to mitigate flood risk, the culvert and possible associated changes to flow processes could cause an increase in deposition in the vicinity of the crossing location. This results in an impact of moderate magnitude. **Culvert Replacement C09** The replacement of the existing culvert with an approximate 35m long culvert adjacent to B9006 Culloden Road would require the permanent removal of greater length of channel bed, banks and vegetated riparian corridor than existing. The removal of silt bed and steep banks over the increased length would result in an impact of minor magnitude. As the riparian vegetation at the culvert location consists of grasses and shrubs, the impact of vegetation removal on morphology should be negligible in magnitude. Depending on the design, the culvert and possible associated changes to flow processes could cause or increase erosion. The unconsolidated banks are poorly vegetated and relatively steep and could be prone to erosion, especially during higher flows. This results in an impact of minor magnitude. **Culvert Extension C10** The extension of the existing culvert (approximately 5m) from the southbound side of A9, discharging into the Beechwood Burn, would require the permanent	moderate

Source of Impact	Construction impacts *(for locations of proposed culverts and outfalls please refer to Figures 13.1 and Figure 13.4)*	Overall Impact Magnitude	Operational impacts *(for locations of proposed culverts and outfalls please refer to Figures 13.1 and Figure 13.4)*	Overall Impact Magnitude
	could result in increased deposition of sediment downstream of culvert C05 in this watercourse or within the Scretan Burn (SWF04). The impacts above result in an impact of moderate magnitude.		removal of greater length of channel bed, banks and vegetated riparian corridor. This results in an impact of negligible magnitude. The removal of silt bed and steep banks over the increased length would result in an impact of minor magnitude. **Discharge from Outfalls** Increased discharge from the outfalls as a point source of additional flows and sediment could increase deposition downstream of the outfall and cause erosion. As the channel substrate is predominantly silt increased deposition is expected to result in an impact of negligible magnitude. Localised scour of the silt substrate and of the opposing bank could result in an impact of minor magnitude. Depending on rates or erosion, future bank failure could be a risk.	
SWF04 (Scretan Burn)	**Release of Suspended Sediments** Potential increased fine sediment delivery to Scretan Burn from direct construction activities, e.g. vegetation removal and surrounding earthworks activities (including construction of embankments). Increased fine sediment delivery could potentially smother the cobble and gravel substrate. Marginal gravels are likely to be buried as the channel deposits fines at the margins. Gravel deposits downstream of the A96 are also likely to be smothered reducing the availability of coarse sediment. This results in an impact of minor magnitude. **Construction within the Floodplain** The construction of new outfalls and culverts: • Outfall immediately downstream of Culvert C01 • Outfall 135m south of Highland Main Line Railway • Culvert C01 - approximate 48m new culvert • Culvert C04 – approximate 28m new culvert • Culvert C08 - approximate 6m new culvert Construction of outfalls and culverts are expected to have minimal impact upon the floodplain. The watercourse is poorly connected to the floodplain and is of low geomorphological value. This results in an impact of minor magnitude. Permanent removal of riparian vegetation would have an impact of minor magnitude at culvert C04 and culvert C08. At culvert C01 and the outfall immediately downstream, deciduous trees would be removed which provide bank stability. This also results in an impact of minor magnitude. **In-channel Construction**	major	**Changes to Flow Paths** Changes to flow paths are expected to be minimal due to the following: no notable changes to the topography of the Scretan Burn catchment, no overland flow paths are being intercepted by the proposed scheme and the design includes drainage of impermeable areas. Results in an impact of negligible magnitude. **Outfalls** Lateral connectivity with the floodplain is anticipated to be reduced due to new headwalls. This impact is expected to be negligible in magnitude at both outfalls as the channel is poorly connected to the area outside of the channel. **New Culverts** Culverts would require the permanent removal of channel bed and banks all of which are bounded by unconsolidated banks, totalling approximately 82m in length. In addition, further modification upstream and downstream of each culvert would be required to tie-in the new structure with the existing banks and provide any necessary bed and bank reinforcement. At culvert C01 and culvert C04 and both outfalls, silt substrate would be removed and replaced with imported material. At culvert C08, berms and coarse gravel and cobble substrate would be removed from the channel. The installation of the three culverts in combination results in an impact of major magnitude. Deciduous trees would be lost from the riparian zone at culvert C01. Removal of vegetation could result in erosion of the watercourse downstream of the culvert due to the reduction in bank stability, resulting in an impact of minor magnitude. Loss of riparian vegetation at the remaining culverts would result in an impact of negligible magnitude as vegetation consists of grasses. Construction in the riparian zone at culvert C04 upstream of the confluence with Beechwood Burn (SWF03) would locally remove the riparian zone which	major

Source of Impact	Construction impacts *(for locations of proposed culverts and outfalls please refer to Figures 13.1 and Figure 13.4)*	Overall Impact Magnitude	Operational impacts *(for locations of proposed culverts and outfalls please refer to Figures 13.1 and Figure 13.4)*	Overall Impact Magnitude
	Permanent removal of a length of natural bank and bed at culvert and outfall locations would disturb channel substrate. Culvert C01, the outfall immediately downstream, and culvert C04, would not remove or disturb morphological features of value. Steep unconsolidated banks and the channel bed would be disturbed leading to supply of sediment downstream. At culvert C08, berms, coarse substrate and banks would be lost. The impact the construction of the three culverts and two outfalls in combination would result in an overall impact of major magnitude.		the channel occupies during higher flows, reducing both the lateral and longitudinal connectivity of the watercourse. This results in an impact of moderate magnitude. **Discharge from Outfalls** Increased discharge from the outfalls as a point source of additional flows and sediment. This could result in potential aggradation of the channel, burial and smothering of coarse sediment which results in a moderate magnitude of impact. Localised scour of the bed and of the opposite bank could result in an impact of minor magnitude, particularly at each outfall location where the banks are steep and vertical with little bank stability and could be undermined causing bank failure. This results in an overall impact of moderate magnitude from the operational outfalls.	
SWF05 (Tributary of Scretan Burn)	**Release of Suspended Sediments** Potential fine sediment input to the tributary of Scretan Burn from direct construction activities, e.g. vegetation removal and surrounding earthworks activities (including construction of embankments). As the channel banks consist of fine sediments and soil, and the channel substrate is silt, potential for increased sediment delivery during construction is high. This is unlikely to have a notable impact. However, small areas of gravel substrate are likely to be smothered. This results in an impact of minor magnitude. **Construction within the Floodplain** The construction of new culverts: • Culvert C02 – approximate 54m new culvert • Culvert C03 – approximate 35m new culvert The channel has poor connectivity to the floodplain. Any connectivity that is present is likely to be restricted local to culvert locations. Loss of riparian vegetation would be required at culvert locations. However, as this only consists of sparse individual trees there is likely to be limited impacts upon sediment delivery or bank stability, resulting in an impact of negligible magnitude. **In-channel Construction** Permanent removal of a length of natural bank and bed at each culvert. This is likely to have a limited impact on the watercourse as the bed and banks consist of silt and soil and there are no noted morphological features at the locations affected. Steep banks and the channel bed would be disturbed leading to supply of sediment downstream. This results in an impact of minor magnitude.	minor	**Changes to Flow Paths** Changes to flow paths are expected to be minimal due to the following: no notable changes to the topography of the catchment, the area of catchment being made impermeable is minimal and the design includes drainage of impermeable areas. However, water that would typically drain to the watercourse from an adjacent field would be diverted to Cairnlaw Burn (SWF08). The volume of this water is likely low. Results in an impact of negligible magnitude. **New Culverts** Culverts would require the permanent removal of channel bed and banks. The channel at both culvert locations was bounded by steep banks with a silt substrate. As the substrate is of low value and no morphological features were present, impacts relating to direct morphological change are of minor magnitude. The channel is poorly connected to the floodplain and has a limited riparian zone, any further disconnection as a result of the culvert operation is likely to have an impact of minor magnitude. Removal of the vegetation within the riparian zone is unlikely to have a notable impact upon the morphology of the watercourse. Vegetation is typically shrubs with sparse, individual trees, removal of which should not adversely affect bank stability and consequently any increased rates of erosion and vegetation removal are likely to result in an impact of minor magnitude.	minor
SWF08 (Cairnlaw Burn)	**Release of Suspended Sediments**	major	**Changes to Flow Paths**	major

Source of Impact	Construction impacts *(for locations of proposed culverts and outfalls please refer to Figures 13.1 and Figure 13.4)*	Overall Impact Magnitude	Operational impacts *(for locations of proposed culverts and outfalls please refer to Figures 13.1 and Figure 13.4)*	Overall Impact Magnitude
	Potential fine sediment input to Cairnlaw Burn from direct construction activities, e.g. vegetation removal and surrounding earthworks activities (including construction of embankments). Channel banks are comprised of unconsolidated sediment which could release fine sediment into the channel when disturbed. Sediment release from vegetation clearance is expected to be low in volume and this result in an impact of minor magnitude. **Construction within the Floodplain** The construction of new outfalls and culverts: • Outfall immediately downstream of culvert C06 • Outfall immediately downstream culvert C07 • Culvert C06 - approximate 27m new culvert • Culvert C07 - approximate 39m new culvert At culvert C06 and the outfall immediately downstream, the channel has poor connectivity to the floodplain and is embanked, consequently any construction is unlikely to have a significant impact. At culvert C07 and the outfall immediately downstream, the watercourse appears to be connected to the floodplain over the left bank of the channel. Consequently, construction is likely to disconnect the channel. This would result in an impact of moderate magnitude. Riparian vegetation at both locations comprises individual trees. Consequently, any removal of riparian vegetation is unlikely to affect bank stability or impact upon channel morphology and would therefore result in an impact of negligible magnitude. **In-channel Construction** Removal of bed and bank material during construction could result in erosion of the bed and banks as bed material and bank material is disturbed, especially following the removal of gravels from the channel. Permanent removal of bed and banks at the location of culvert C06 would have an impact of minor magnitude. Permanent removal of bed and banks at culvert C07 would remove coarse sediment and morphologically valuable features, such as side bars and berms. This would result in an impact of major magnitude. The impact the construction of the culverts and outfalls in combination would result in an overall impact of major magnitude.		As there should be no notable changes to the topography of the catchment, the area of catchment being made impermeable is minimal, no obvious overland flow paths are being intercepted by the proposed scheme and the design includes drainage of impermeable areas, it is expected that any changes to flow paths should be minimal, resulting in an impact of negligible magnitude. **New Culverts** The construction of culvert C07 would require the permanent removal of coarse channel substrate, unconsolidated banks and morphologically valuable features, such as berms and gravel bars. The structure would also alter and restrict the connectivity of the channel with the riparian zone and floodplain and could alter flow patterns in areas sensitive to changes in process where the channel is morphologically active. In addition, further modification upstream and downstream of the culvert would be required to tie-in the new structure with the existing banks and provide any necessary bed and bank reinforcement. This would result in an impact of major magnitude. Removal of riparian vegetation would have limited impact as mature deciduous trees are sparse and do not affect in-channel processes. Impacts upon bank stability would be of negligible magnitude. Due to the presence of existing patterns of erosion and deposition at the location of culvert C07 there is potential for the culvert to exacerbate issues. This is further heightened because the downstream channel forms a right angle to the culvert. Further erosion could result in delivery of fine sediment downstream, damaging morphological features. Potential to alter downstream processes, encouraging erosion and deposition would result in an impact of moderate magnitude. Impacts at culvert C06 would be similar to those at culvert C07, but due to the limited morphological features, silt substrate (which may have smothered gravels), and absence of a complex riparian zone, impacts local to the culvert crossing would be of minor magnitude. **Outfalls** Permanent removal of a length of natural bank and bed at each outfall. At both outfall locations the impact should be minimal as riparian vegetation was limited and the channel bank was vertical with no notable features. Only a limited area of channel bed and coarse substrate is likely to be removed. Lateral connectivity with the floodplain would be reduced, however, the channel is over-deep and poorly connected to the floodplain and the riparian zone is limited. This results in an impact of minor magnitude. **Discharge from Outfalls** Increased discharge from the outfalls as a point source of additional flows and sediment. Changes could increase deposition downstream of the outfall and	

Source of Impact	Construction impacts *(for locations of proposed culverts and outfalls please refer to Figures 13.1 and Figure 13.4)*	Overall Impact Magnitude	Operational impacts *(for locations of proposed culverts and outfalls please refer to Figures 13.1 and Figure 13.4)*	Overall Impact Magnitude
			cause scour on the opposite bank. This could potentially result in aggradation, and burial and smothering of coarse sediment and gravel deposits resulting in an impact of moderate magnitude. Localised scour of the channel bed and opposite bank could result in an impact of minor magnitude at both outfalls, in particular at the outfall immediately downstream of culvert C07 where the banks are steep and vertical with little bank stability and there is evidence of bank scour downstream. This results in an impact of minor magnitude.	

Significant Impacts

4.9 The specific impact assessment has identified that there would likely be significant potential impacts (i.e. Moderate or above), without considering mitigation, on the following watercourses:

Construction

4.10 SWF04 (Scretan Burn) – major magnitude and Large significance as a result of the construction of the three culverts and two outfalls in combination, requiring permanent removal of lengths of natural bank and bed at culvert and outfall locations which would disturb channel substrate. At culvert C08 in particular, berms, coarse substrate and banks would be lost.

4.11 SWF08 (Cairnlaw Burn) – major magnitude and Large significance as a result of the construction of two culverts and two outfalls in combination, requiring permanent removal of lengths of natural bed and banks at culvert and outfall locations. Permanent removal of bed and banks at culvert C07 in particular, would remove coarse sediment and morphologically valuable features, such as side bars and berms. Removal of bed and bank material during construction could result in erosion of the bed and banks as bed material and bank material is disturbed, especially following the removal of gravels from the channel.

Operation

4.12 SWF04 (Scretan Burn) - major magnitude and Large significance as a result of the operation of culverts, outfall structures and any bed or bank reinforcement which would require the removal of, and cause changes to, geomorphological features and processes; including sand/gravel bars and berms, natural and morphologically valuable coarse gravel bed substrate and riffle and run bedform types. Discharge from outfalls has also been assessed to be significant and could potentially cause erosion or burial of coarse substrate, depending on its proximity to the outfall and the dominant morphological processes.

4.13 SWF08 (Cairnlaw Burn) – major magnitude and Large significance as a result of the operation of culverts, outfall structures and any bed or bank reinforcement which would require the removal of, and cause changes to, geomorphological features and processes; including sand/gravel bars and berms, natural and morphologically valuable coarse gravel bed substrate and riffle and run bedform types. Structures would also alter and restrict the connectivity of the channel with the riparian zone and floodplain and could alter flow patterns in areas sensitive to changes in process where the channel is morphologically active. It is anticipated that the impact of major magnitude on Cairnlaw Burn pre-mitigation during the operational phase would prevent improvement of the hydromorphological status of the Cairnlaw Burn WFD water body.

5 Mitigation

5.1 Mitigation measures in relation to reducing the adverse impacts of the proposed scheme on fluvial geomorphology are detailed below. Where relevant, cross reference to the mitigation items within Chapter 13 (Road Drainage and the Water Environment) is provided (refer to Table 13.14 for construction mitigation Table 13.15 for operational mitigation)

Culverts (refer to Mitigation Item WO2)

5.2 Culverts will be designed to maintain the river bed level and bed level gradient that are currently present. The culvert inverts will be buried below bed level and natural channel bed material with a minimum thickness of 300mm where applicable. Culvert C05 on Beechwood Burn (SWF03) requires a widening of the existing channel profile to distribute flood flows between the two barrels of the proposed structure. Consideration will be given at the later design stages (e.g. Specimen and Detailed design stages) as to the maintenance of appropriate conveyance of water and sediment for a range of flows (including at low flow conditions). Culvert C09 on Beechwood Burn (SWF03) is an exception to this stipulation which is restricted in height and can only be buried to minimum depth of 150mm. Generally, it is anticipated the burying of culverts will maintain the continuity of the river bed and existing morphological processes.

5.3 Culvert barrels have been hydraulically designed in accordance with DMRB requirements to be free-flowing with a freeboard of 600mm during the 0.5% AEP (200-year) event including allowance for climate change. One exception to this freeboard design occurs at culvert C05 on Beechwood Burn (SWF03) (due to the need to tie into an existing road level).

5.4 The channel cross section through culverts will replicate the existing channel shape up to the predicted QMED water level where appropriate, maintaining the channel dimensions and gradient of the watercourse, and therefore allowing for the appropriate conveyance of water and sediment for a range of flows (including during low flow conditions) and preserving existing morphological processes.

5.5 The implementation of the above measures would mitigate the adverse impact of culverts on the hydromorphological status of the Cairnlaw Burn (SWF08) WFD water body and maintain morphological continuity and hydrological connectivity on all watercourses with proposed culvert crossings.

Outfalls (refer to Mitigation Item WO1)

5.6 SuDS will be incorporated into the drainage design at outfalls to provide attenuation and treatment. It is anticipated that attenuation, provided by the use of a swales, filter drains and wetlands in the drainage design, would encourage siltation of road run-off reducing fine sediment delivery to the receiving watercourses.

5.7 The velocity of flow discharged from outfalls into the watercourse will be restricted to greenfield runoff rates. This should limit erosion of the bed and opposing bank. Outfalls should be directed to discharge downstream in order to minimise risk of causing erosion on the opposite bank. Should erosion risk be identified, scour protection should be provided in the area at risk of erosion. Where possible, scour protection should use green bank protection methods, such as willow spiling, as opposed to grey bank protection.

5.8 The implementation of the above measures would mitigate the adverse impact of outfalls on the hydromorphological status of all watercourses by maintaining channel morphology and limiting the increase in hydrological connectivity of the catchment with the watercourse. In the case of the Cairnlaw Burn (SWF08), which is the only WFD classified watercourses within the study area of the proposed scheme, mitigation proposed for outfalls will mean it's WFD hydromorphological status will not be adversely affected as a result of the proposed scheme.

Morphological Improvement (refer to Mitigation Item WO3)

5.9 Cairnlaw Burn (SWF08) is currently assigned a 'Bad' status for morphology (based on consultation with SEPA in June 2018). To offset the impact of the proposed scheme, mitigation in the form of morphological improvements are proposed to a 40m reach upstream and 60m downstream of culvert C06 and a reach extending 200m upstream and 50m downstream of culvert C07. The design of these morphological improvements will be developed during the Specimen and Detailed design phases in conjunction with the watercourse crossing designs due to the interdependencies between these two design elements. However, indicative proposals are outlined in the following text.

5.10 Historical analysis shows the channel planform was straightened between Cradlehall and Stratton prior to 1868 and has generally remained relatively unchanged since. Upstream of the confluence with Tower Burn (SWF10), the Cairnlaw Burn channel was noted to have shown signs of natural recovery, developing a low sinuosity low-flow channel between alternating berms.

5.11 Based on the observations upstream of the confluence with Tower Burn (SWF10), it is recommended that this reach is used as a reference for improvements downstream in order to maintain the characteristics of the river type were the channel to continue to recover. Bankfull (QMED) channel dimensions would be obtained from this reference reach to inform appropriate bankfull cross section dimensions to allow the watercourse to continue evolving towards the natural stable regime state (see **Mitigation Item WO2**).

5.12 Along the 40m reach upstream and 60m downstream of culvert C06 and the 200m reach upstream and 50m reach downstream of culvert C07, it is proposed that alternate berms will be created along the reach. The berms will be spaced to mimic natural riffle-pool spacing and formed to a height equivalent to bankfull depth. The berm width will be designed to maintain the formation of a two-stage channel. The dimensions of the channel and features will encourage the watercourse along a recovery pathway and allow for natural adjustment.

5.13 To aid the recovery of riffle-pool bedforms, coarse bed material will be introduced to the channel downstream from berms. Sediment will be sized to reflect the existing bed material as obtained from sediment samples. It is anticipated that pools will develop adjacent to berms at the apex of the bend and will be reinstated as such with bed material introduced to reflect those obtained from pool samples. Channel cross sections will vary between bedforms with sections adjacent to berms being wider and deeper to characterise pools, and adjacent reaches being shallower and narrower to characterise riffles, runs and glides.

5.14 Where bank stabilisation is required, green bank protection (willow spiling or similar) will be considered in preference to grey bank protection (e.g. rip-rap).

5.15 The improvements to of the Cairnlaw Burn (SWF08) will remove a significant length of high impact realignment in favour of low impact realignment. This will also provide morphological variability and encourage the channel to adjust to maintain a low sinuosity planform and help it achieve a more natural alignment. Whilst, it is not anticipated that this will result in a direct improvement in the status of Cairnlaw Burn (SWF08) WFD water body, the anticipated improvement to channel morphology and fluvial processes will release additional capacity of the water body, offsetting the impacts of the proposed scheme and contributing towards the improvement of the hydromorphological status of Cairnlaw Burn (SWF08).

5.16 A similar approach is also proposed for Beechwood Burn (SWF03) (an approximate 60m reach downstream of culvert C05, Scretan Burn (SWF 04) (an approximate 60m reach upstream and 190m reach downstream of culvert C01 and an approximate 45m reach upstream and 35m reach downstream of culvert C04) and Tributary of Scretan Burn (SWF 05) (an approximate 95m reach upstream and 30m reach downstream of culvert C02 and an approximate 20m upstream and 65m downstream of culvert C03).

Table 4 Summary of Mitigation for Construction and Operation for Watercourses with Culverts and Outfalls

Water feature	Mitigation details
Construction	
All Watercourses	• Implement Construction Environmental Management Plan (CEMP) **(Mitigation Item SM-01**) (or similar) to minimise impacts to the channel and surrounding riparian area. Fine sediment control methods recommended to minimise delivery of silt to watercourse and minimise sediment delivery downstream (refer to **Mitigation Item WC3).** • Limit the removal of vegetation from the riparian corridor and retain trees on banks and bank top as far as practicable during construction. Retain fallen trees and large wood on banks and in channel margins where practicable (refer to **Mitigation Item WC4**). • Where bank stabilisation is required, green bank protection (willow spiling or similar) will be considered in preference to grey bank protection (e.g. rip-rap) (refer to **Mitigation Item WC4**). • Where morphological improvements are proposed the contractor will follow good practice guidance (refer to **Mitigation Item WC5**).
Operation	
SWF03, SWF04, SWF05, SWF08	• As part of the subsequent design stages (e.g. Specimen and Detailed design), an experienced fluvial geomorphologist will input to the design of all watercourse crossings and associated engineering activities where appropriate (See **Mitigation Item WO2)** • Culverts will be designed to maintain the existing bed gradient, flow velocity and channel width where practical (refer to **Mitigation Item WO2**). • Culvert invert will be designed to be set below bed level with a minimum of 300mm of natural bed material where applicable, to maintain a natural bed through the culvert. Culvert C09 (Beechwood Burn (SWF03)) is an exception to this stipulation which is restricted in height and can only be buried to minimum depth of 150mm (refer to **Mitigation Item WO2**).

Water feature	Mitigation details
	Attenuation for road runoff prior to discharge to reduce flow rates to greenfield runoff rates and to encourage siltation reducing fine sediment delivery to the receiving watercourse (See **mitigation item WO1**).
SWF03, SWF04, SWF05, SWF08	• Additional sediment or flow calculations may be required during the subsequent design stages of channel realignments, culverts or channel re-grading. This will be determined as the designs progress. • Design of culverts and outfalls to guidance and standard practice is required. Design of culverts and outfalls should also incorporate good practice measures e.g. roughening of the bed/banks, allowing the deposition of natural sediment material in culvert invert (refer to **Mitigation Items WO1 and WO2**). • The channel cross section through culverts will be profiled to replicate the existing channel shape up to the predicted QMED water level where appropriate, thereby allowing for the appropriate conveyance of water and sediment for a range of flows (including during low flow conditions) and preserving existing morphological processes (refer to **Mitigation Item WO2**). • Geomorphological input into detailed design of culverts and outfall headwalls, and location of outfalls to minimise risk of erosion / scour. (refer to **Mitigation Items WO1 and WO2**). • Outfalls should be angled in the downstream direction of flow. Avoid outfall placement in zones of erosion or deposition where practicable. (refer to **Mitigation Item WO1**). • Re-planting of vegetation around outfall structures, tying in with natural vegetation. Emphasis on the replacement of trees, if removed, in locations close to the original removal will be required (refer to **Mitigation Item WO1**).
SWF03, SWF04, SWF05, SWF08	Morphological improvements are proposed for the following watercourses (refer to **Mitigation Item WO3**): • Beechwood Burn (SWF03) - an approximate 60m reach downstream of culvert C05. • Tributary of Scretan Burn (SWF05) – an approximate 95m reach upstream and 30m reach downstream of culvert C02 and an approximate 30m upstream and 65m downstream of culvert C03. • Scretan Burn (SWF04) - an approximate 60m reach upstream and 190m reach downstream of culvert C01, an approximate 45m reach upstream and 35m reach downstream of culvert C04. • Cairnlaw Burn (SWF08) - an approximate 40m reach upstream and 60m downstream of culvert C06, and an approximate 200m reach upstream and 50m reach downstream of culvert C07. Mitigation will include the creation of berms and provision of suitable bed material to encourage process-based recovery and encourage maintenance of a sinuous low flow channel with riffle-pool bedforms (where possible). The above improvements will offset / mitigate for adverse impacts from the operation of culverts and / or outfalls and improve the geomorphological characteristics of these watercourses. The design of the morphological improvements will be developed further during the Specimen and Detailed design phases in conjunction with the watercourse crossing designs due to the interdependencies between these two design elements.

6 Residual Impacts

6.1 The significant residual impacts on the geomorphology (and inherently the hydromorphology) of watercourses that are likely to occur during either the construction and/or operational phases following the application of mitigation measures are set out in the following paragraphs.

Construction Residual Impacts

6.2 Following the assessment of all construction activities likely to impact the watercourses along the proposed scheme, it has been concluded that there are no residual impacts of Moderate significance or above expected provided all mitigation is adhered to.

Operational Residual Impacts

6.3 Following the assessment of all operation activities likely to impact the watercourses along the proposed scheme, it has been concluded that there are no residual impacts of Moderate significance or above expected provided all mitigation is adhered to.

7 References

Environment Agency (2010). The Fluvial Design Guide. Available online at: http://evidence.environment-agency.gov.uk/FCERM/en/FluvialDesignGuide.aspx.

European Commission (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy. Off. J. Eur. Communities, 2000 (2000).

Perfect, C.; Addy, S.; Gilvear, D. (2013). The Scottish Rivers Handbook: A guide to the physical character of Scotland's rivers, CREW (Centre of Expertise for Waters) project number C203002. Available online at: https://www.crew.ac.uk/sites/www.crew.ac.uk/files/sites/default/files/publication/scottish%20rivers%20handbook%20web.pdf

Scottish Government (2003). Water Environment Water Services (WEWS) Act 2003. Available online at: http://www.legislation.gov.uk/asp/2003/3/contents.

Scottish Government (2015). The River Basin Management Plan for the Scotland River Basin District: 2015–2027. Available online at: http://www.sepa.org.uk/media/163445/the-river-basin-management-plan-for-the-scotland-river-basin-district-2015-2027.pdf

Sear, D.A., Newson, M.D. and Thorne, C.R. (2010) Guide Book of Applied Fluvial Geomorphology. Defra/Environment Agency R&D Technical Report FD1914, pp. 233

SEPA (2012) SEPA Supporting Guidance (WAT-SG-21) Environmental Standards for River Morphology, v2.1, https://www.sepa.org.uk/media/152194/wat_sg_21.pdf [Accessed 25 May 2016]

SEPA (2016). SEPA Water Environment Hub. Available at: http://www.sepa.org.uk/data-visualisation/water-environment-hub/ [Accessed 02 April 2018]

SEPA (2018). SEPA Water Classification Hub. Available at: https://www.sepa.org.uk/data-visualisation/water-classification-hub/ [Accessed 02 April 2018]

The River Restoration Centre (RRC) (2013). Manual of River Restoration Techniques. Available online at: https://www.therrc.co.uk/manual-river-restoration-techniques

Thorne, C.R.; Hey, R.D.; Newson, M.A. (1997). Applied Fluvial Geomorphology for River Engineering and Management, vi 376p, John Wiley, Chichester, New York