24.3 Fluvial Geomorphology

1 Introduction

General Background

1.1 This report is a technical appendix of the Chapter 24 (Water Environment) of the Environmental Impact Assessment for the Southern Leg section of the Aberdeen Western Peripheral Route (AWPR). In addition to supporting Chapter 24 (Water Environment), this report also has links with the Appendix A25.9 (Freshwater Ecology).

1.2 This report focuses specifically on the fluvial geomorphological impacts of the scheme on watercourses that would be crossed by the proposed scheme. This assessment examines potential impacts on the geomorphology of watercourses that may result during the construction and operation of the proposed scheme.

1.3 The main driving force behind the inclusion of geomorphological assessments in Environmental Impact Assessments such as this is the EU Water Framework Directive (WFD). The WFD, which is transposed into Scottish Law by the Water Environment and Water Services Bill, aims to classify rivers according to their ecological and chemical status and sets targets for improvements. Ecological status is split into three elements, namely ecological, hydromorphological and supporting physiochemical factors. For high status waterbodies, the WFD requires that there is no more than very minor human alteration to the hydromorphology elements. This includes a consideration of the:

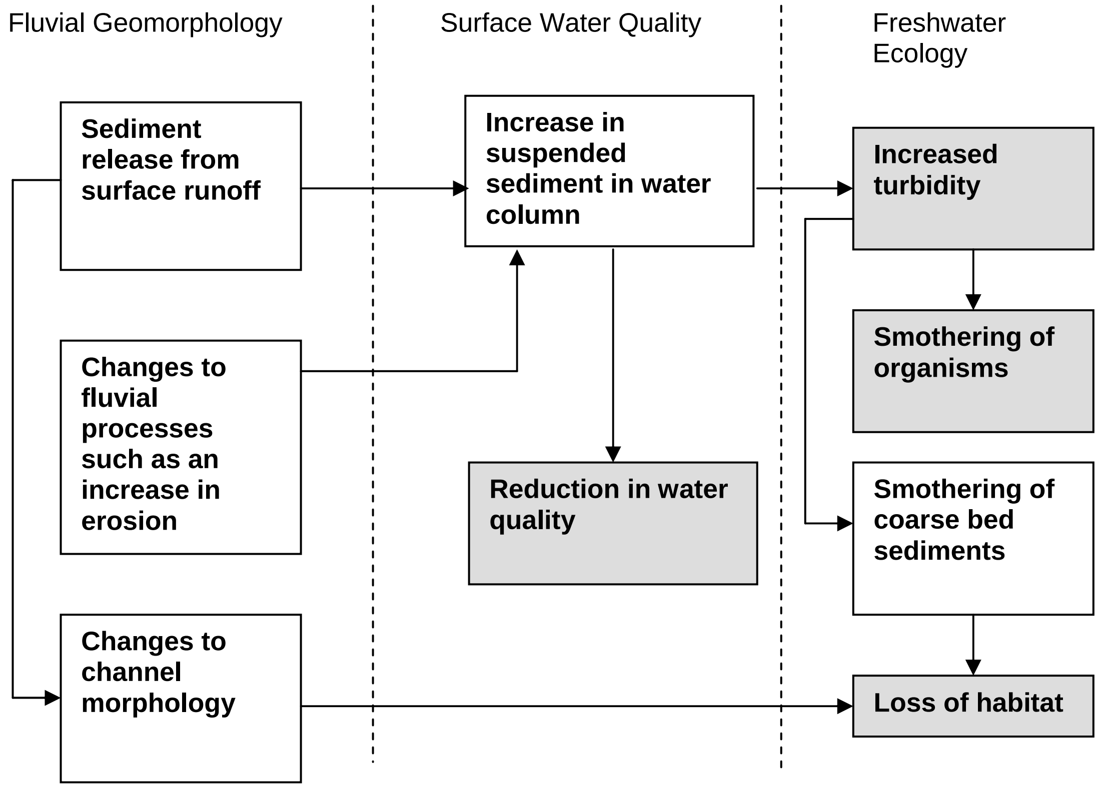
- extent to which flow, sediment regime and the migration of biota are constrained.
- extent to which the morphology of the river channel has been modified.
- degree to which natural fluvial processes are compromised, i.e. the channel's ability to adjust to changes in the flow and sediment regime is reduced

1.4 Fluvial geomorphology is the study of the landforms associated with river channels and the sediment transport processes that form them. The principal focus of fluvial geomorphology is the relationship between sediment regime and erosion, transport and deposition, and channel and floodplain morphology (Appendix A24.5, Annex 22). 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.

The Study Area

1.5 This appraisal focuses on watercourses that would be subject to geomorphological impacts as a result of the operation and construction of the Southern Leg section of the proposed scheme. These watercourses range in size, from small ephemeral field drains to large streams. The study area includes two wetland features, Hare Moss and Moss of Auchlea. These features have been scoped out of the geomorphological assessment however, they are included in the Surface Water Hydrology, Water Quality and Freshwater Ecology assessments.

Figure 1 – Conceptual Diagram Illustrating the Relationships Between Impacts on Fluvial Geomorphology, Water Quality and Ecology (grey denotes an impact on receptor)

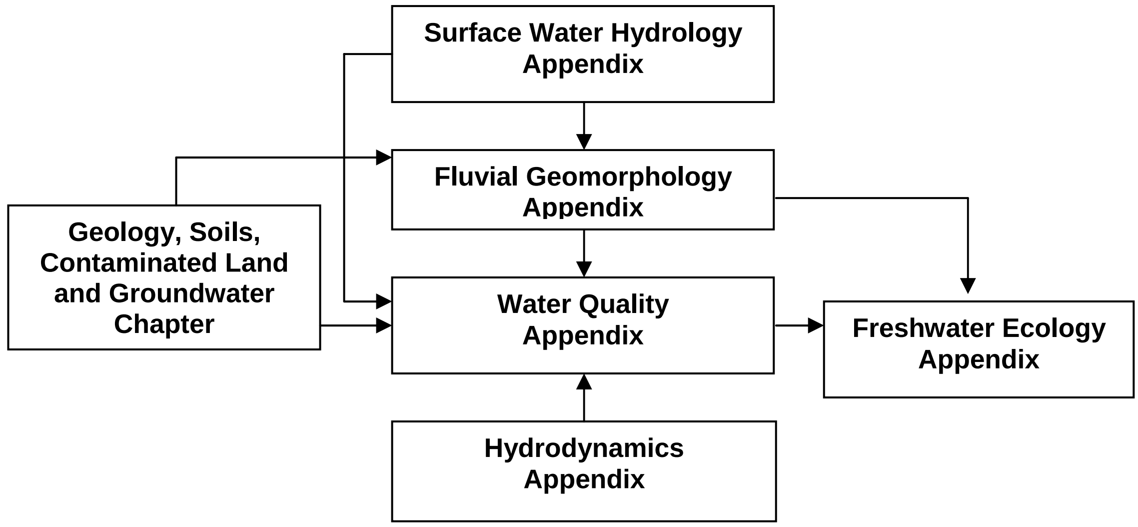


1.6 There are four main potential impacts on the fluvial geomorphology of watercourses (Figure 1). These are:

- increases in fine sediment delivery to watercourses with potentially detrimental impacts on sensitive species. These can 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;
- alteration of the natural functioning of the river channel (natural fluvial processes), for example prevention of channel migration due to bank protection, bridge pier installation or culverting. If this interrupts natural fluvial processes it may have consequences for both for WFD targets and have detrimental effects on habitat diversity; and
- 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 leads to an increase in sediment delivery, which can have a significant impact where sites of importance for freshwater ecology are located downstream.

1.7 This report is one of a number of technical reports and used to inform the Water Quality and Freshwater Ecology appendices (A24.4 and A25.9 respectively). For example, the Surface Water Hydrology Appendix and Geology, Contaminated Land and Groundwater Chapter have provided information for the Geomorphology Appendix, which is then fed into the Water Environment Chapter. The relationship between the Geomorphology Appendix and the other related components of the EIA is summarised in Figure 1.2.

Figure 2 – Flow Chart illustrating the Relationships between the Technical Appendices and Chapters



1.8 The overall aim of this chapter is to inform the water quality and ecological assessments of potential geomorphological impacts, which may affect the receptors considered in the appendices.

1.9 This technical appendix aims to assess the potential impacts of the proposed scheme during both the operation and construction phases. It also outlines possible mitigation measures that will reduce the impact of the road on the fluvial geomorphology of the affected watercourses. Having outlined the mitigation measures, the report then considers the impacts of the proposed scheme with mitigation measures in place (residual impacts). The impact of changes in fluvial geomorphology on specific receptors is considered in the water quality and freshwater ecology appendices (A24.4 and A25.9 respectively).

1.10 The specific objectives of this assessment reflect the WFD water quality and hydromorphological targets, and are to:

- assess the baseline characteristics of each watercourse
- assess potential impacts on each watercourse affected, against the baseline, on the:
  - sediment regime
  - channel morphology
  - natural fluvial processes
- suggest mitigation measures for the potential impacts; and,
- assess the residual impacts as a result of the suggested mitigation measures.

1.11 In addition to identifying potential impacts on watercourses that would be affected by the proposed scheme, impacts are also evaluated in terms of whether they are direct or indirect effects. The duration of impact is also considered, as is the likelihood of cumulative impacts occurring.

2 Approach and Methods

General Approach

2.1 This report concentrates on outlining the potential impacts on the fluvial geomorphology of watercourses that would be crossed by the proposed scheme. The approach adopted in this appendix differs from that followed in the other appendices as fluvial geomorphology does not have any direct receptors (entities such as organisms or ecosystems) that are susceptible to the adverse effects of impacts. Change to the geomorphology is the mechanism (pathway) by which receptors such as water quality and freshwater ecology are affected by the scheme (A24.4 and A25.9 respectively). Therefore no sensitivity scoring has been applied to each watercourse and no significance scoring is calculated for residual impact. However the geomorphological processes and forms associated with each watercourse are vulnerable to change as a result of external influences such as road construction. The vulnerability of each watercourse to undergo change has been evaluated for each watercourse.

2.2 The criteria used to assess the vulnerability of watercourses to undergo change as a result of disturbance is outlined in Table 1.

Table 1 – Criteria to assess the vulnerability of Watercourses

Vulnerability	Criteria
High	**Sediment regime** A watercourse supporting a range of species and habitats, sensitive to a change in suspended sediment concentrations and turbidity, such as migratory salmon or freshwater pearl mussels. This includes sites with International and European nature conservation designations due to water dependent ecosystems e.g. a Special Protection Area, Special Area of Conservation, Ramsar Site, EU designated freshwater fisheries. This also includes all nature conservation sites of national importance designated by statute including Sites of Special Scientific Interest and National Nature Reserves. **Channel morphology** Watercourses exhibiting a range of morphological features such as pools and riffles, active gravel bars and varied river bank types. Such morphological variability is a primary determinant of ecological diversity. **Natural fluvial processes** Dynamic rivers, those which show evidence of channel migration and other morphological changes such as bar evolution. These processes ensure high ecological diversity, but are vulnerable to interventions such as bank protection, culverting, realignment and construction on the surrounding floodplain. In addition, laterally stable rivers can be vulnerable to change as a result of realignment, particularly where this alters gradient, which may lead to increased erosion and deposition within the channel. Boundary conditions such as the presence of bedrock are a key control on the likelihood of such as response. Such a change in river behaviour may be significant where an ecologically sensitive site is located downstream.
Medium	**Sediment regime** A watercourse supporting limited species sensitive to a change in suspended sediment concentrations or turbidity. This includes non-statutory sites of regional or local importance designated for water dependent ecosystems. **Channel morphology** Watercourses exhibiting limited morphological features such as pools and riffles, few active gravel bars and relatively uniform bank types. **Natural fluvial processes** Rivers that are vulnerable to changes in fluvial processes are likely to have a limited impact on habitat quality. This also includes watercourses are vulnerable to localised change in rates of adjustment, but are not located upstream of important ecological sites.

Vulnerability	Criteria
Low	**Sediment regime** A watercourse which does not support any significant species sensitive to changes to suspended solids concentration or turbidity. **Channel morphology** Watercourses exhibiting no morphological diversity; flow is uniform gravel bars absent and bank types uniform and stable. Such watercourses may have been subject to past modification such as bank protection and culverting. **Natural fluvial processes** Watercourse which shows no evidence of active fluvial processes and which is not likely to be affected by modification to boundary conditions.

2.3 The potential impacts are based on evaluating the potential change in baseline conditions (sediment regime, channel morphology and natural fluvial processes) caused by the proposed scheme.

2.4 As the Design Manual for Roads and Bridges (DMRB) (The Highways Agency *et al*., 1993) does not outline a specific methodology to enable the geomorphological impacts to be evaluated, the methodology adopted in this appraisal was developed using the guidelines from Research and Development Programmes of the National Rivers Authority, Environment Agency and Scottish Natural Heritage. These guidelines are outlined in the Defra / Environment Agency R&D Report FD1914 Guide Book of Fluvial Geomorphology (Sear *et al*., 2003).

2.5 In addition, the requirements of the EU Water Framework Directive were also taken into account when developing the methodology using SEPA policy guidance 'The Future for Scotland's Waters, Guiding Principles on the Technical Requirements of the Water Framework Directive' (SEPA, 2002).

2.6 A range of standard geomorphological methodologies are available to fulfil the requirements of a variety of different river management activities which require geomorphological investigations. Typically these studies fall into two categories, those designed to provide information at the catchment-scale, such as a Detailed Catchment Baseline Survey and Fluvial Audit, or reach specific investigations which provide a far greater level of detail such as Geomorphological Dynamics Assessment and Environmental Channel Design (see, Defra / Environment Agency R&D Report FD1914 (Sear *et al*., 2003) for further information). These differing methodologies reflect the trade-off between the spatial scale of an investigation and the level of detail that can be provided.

2.7 This study does not fit readily into this existing framework as it requires geomorphological information for a number of different watercourses each with their own catchments. Adopting a whole catchment approach to the analysis of each watercourse would have been prohibitively time consuming due to the total length of watercourse that would need to have been examined. Similarly the logistics of undertaking detailed Geomorphological Dynamics Assessments of each watercourse would also have been prohibitively time consuming due to the volume of data collection required for this type of analysis. Due to the spatial coverage required, an approach similar in resolution to the catchment-scale fluvial audit was adopted to examine the sediment system, fluvial processes and potentially destabilising phenomena (the proposed scheme) for each watercourse in the study area. This was deemed an appropriate scale of survey for the likely impacts that would result for each crossing point.

Impact Assessment Methodology

2.8 The potential impacts were considered in terms of the likely degree of change to the baseline conditions, for each individual watercourse, as a result of the operation and construction of the proposed scheme. The method used to determine the baseline conditions comprises of two parts, namely a desk study and a field investigation.

2.9 The main potential impacts on the fluvial geomorphology of watercourses as a result of the proposed scheme are:

- increases in fine sediment delivery to watercourses with potentially detrimental impacts on sensitive species;
- reductions in the morphological diversity of river channels, for example due to culverting, bank and bed protection and realignment; and
- change in natural fluvial processes such as a reduction in the ability of the river channel to naturally self-adjust its form. This could be caused by bank protection, bridge pier installation, or culverting. This can have detrimental effects on habitat diversity and consequences for WFD targets. Secondly, accelerated fluvial activity such as an increase in bank erosion may occur in response to engineering, for example as a result of unsympathetic channel realignment. Bank erosion, or channel incision, both can lead to an increase in sediment supply, which can have a significant impact where sites of ecological importance are located downstream.

2.10 The criteria used to assess the magnitude of potential impacts on watercourse are outlined in Table 2. The overall vulnerability is described by the highest risk e.g. if a watercourse had low vulnerability in sediment regime and channel morphology but medium vulnerability in natural fluvial processes then it would be described as being at medium risk overall.

Table 2 – Criteria to Assess the Magnitude of the Potential Impact on Watercourses

Magnitude	Criteria
High	Major shift away from baseline conditions. **Sediment regime** Major impacts to the river bed over the reach due to accelerated deposition or erosion. Major impacts to sensitive species or habitats as a result of changes to suspended sediment load or turbidity. **Channel morphology** Major impacts on channel morphology over the reach leading to a reduction in morphological diversity with consequences for ecological quality. **Natural fluvial processes** Major interruption to fluvial processes such as channel planform evolution or erosion and deposition.
Medium	Moderate shift away from the baseline conditions. **Sediment regime** Moderate impacts to the river bed and sediment patterns over the reach due to either erosion or deposition. Changes to suspended sediment load or turbidity resulting in a moderate impact on sensitive habitats or species. **Channel morphology** Moderate impact on channel morphology. **Natural fluvial processes** Moderate interruption to fluvial processes such as channel planform evolution, deposition or erosion.
Low	**Sediment regime** Minimal changes to sediment transport resulting in minimal impacts on species or habitats as a result of changes to suspended sediment concentration or turbidity. Minor impacts to sediment patterns over this area due to either erosion or deposition. **Channel morphology** Limited impact on channel morphology. **Natural fluvial processes** Minimal change in fluvial processes. Any change is likely to be highly localised.
Negligible	Very slight change to the baseline conditions. **Sediment regime** Negligible changes to sediment transport resulting in negligible impacts on species or habitats as a result of changes to suspended sediment concentration or turbidity. No discernible impact to sediment patterns and behaviour over the development area due to either erosion or deposition. **Channel morphology** No significant impact on channel morphology in the local vicinity of the proposed site. **Natural fluvial processes** No change in fluvial processes operating in the river. Any change is likely to be very localised.

Desk Study

2.11 The desk study is designed to utilise existing data sources to provide an insight into current geomorphological conditions and trends in river behaviour. The range of data sources consulted during the desk study and the information that they can provide is summarised in Table 3.

Table3 – Potential Data Sources

Data Source	Information Provided
Contemporary Ordnance Survey Mapping	This provides basic contextual information, such as elevation, relative relief and an indication of channel gradient.
Geological Maps (solid and drift plus soils)	Solid and drift geological maps provide an understanding of the likely channel boundary conditions. This, in addition to the soils data, provides an indication of the likely quantity and calibre of sediment released.
Geological Borehole Data	Detailed solid and drift geology data derived from bore holes can be used to augment that provided by geological maps.
Aerial Photography	Aerial photography provides basic contextual information about the site such as land use and vegetation types. In addition aerial photography provides information on the distribution of geomorphological features such as channel deposits, palaeochannels and sediment sources. In conjunction with field investigation this enables the contemporary and past geomorphological processes to be elucidated.
Land Use Data	Land use data provide an indication of the likely impact of land management practices on the hydrological and sediment regime of the river.
Hydrological Data (where available)	Hydrological data such as bankfull discharge or mean annual flood can be used as the basis of sediment transport calculations to provide an indication of the likely impact of changes to channel morphology, in particular, gradient. Flood event hydrographs provide an insight into the mechanism of flooding and the response of the river to rainfall events of different magnitudes and duration. The hydrological response of catchments to rainfall events can influence the nature and severity of erosional and depositional response. Long term (~50 years) flow records provide an indication of the variability in the hydrological regime of the catchment and allow an assessment of the likelihood of future morphological adjustments to be made.
Historical Maps	Comparing a series of historical maps allows changes in river channel planform to be determined over periods of up to 150 years. Such information provides an understanding of the nature of fluvial processes and allows trends in channel behaviour to be elucidated. When compared to long-term hydrological information this can allow insights into the impact of changes in flood frequent and magnitude to be determined.
Existing Topographic Survey (where available)	Cross-sectional surveys provide useful information about the channel structure, such as the width depth ratio which can be used, in conjunction with field study, to determine the dominant function of differing sections of channel such as zone of net erosion, transport or deposition. Similarly the long-profile (gradient profile) of the river can also be used to determine the functions (with respect to likely energy levels) of sections of river channel.
Sediment Transport Modelling	Mathematical sediment transport modelling can be used to provide an indication of the likely concentrations of sediment released by engineering activities. Modelling is to be conducted along the River Dee and this will be included in the Addendum.
River Habitat Survey	This provides useful observational information into the nature of channel condition and materials as well as providing an indication of morphological diversity and the nature and importance of ecological communities (Refer to Freshwater Ecology Appendix A25.9).
Previous Geomorphological Studies	Previous geomorphological studies conducted along these or similar neighbouring watercourses (either reports or academic papers) can provide useful insight into the nature of fluvial processes. When compared to contemporary conditions previous studies can provide a useful comparison to enable changes in baseline conditions to be ascertained enabling trends in river behaviour to be determined.

Field Study

2.12 The field study was designed to build on the findings of the desk study to determine the geomorphological forms and processes at each site. The geomorphological information collected during the field study is summarised in Table 4.

2.13 The extent of investigation for each watercourse varied according to site conditions. The reaches that were assessed during field investigations varied from a minimum of 200m (i.e. Bishopton Ditch) up to 1km (River Dee).

Table 4 – Information Obtained During Field Study

Data Source	Information Provided
Geomorphological Mapping	Geomorphological mapping is a well established technique for characterising river channels. This allows: The pattern of existing erosion and deposition to be recorded. The dominant function of differing sections of channel to be determined (sediment source, transfer and sink). The spatial arrangement of morphological forms to be determined allowing inferences to be made about contemporary and past geomorphological processes enabling the identification of trends in channel behaviour. The impact of past management practices can also be examined enabling inferences to be made about the potential consequences of interference.
Boundary Condition Information	Determining the nature of boundary materials (bed and bank) enables an insight to be gained into the intrinsic controls on patterns of erosion and deposition. This allows the likelihood of morphological adjustments to channel interference to be evaluated.
Space for Time Substitution	This involves examining neighbouring watercourses, with similar geomorphological characteristics, which were subject to past modification such as realignment. This enables the vulnerability of watercourses sites to modification to be evaluated and the likely morphological response to be assessed.

2.14 Combining the results of the desk and field study enabled the baseline conditions at the site to be determined in terms of sediment regime and fluvial processes together with an understanding of the morphological structure of the river channel. Establishing detailed baseline conditions provided the basis for evaluating the impacts of construction and operation of the proposed scheme.

Limitations to Assessment

2.15 Mathematical modelling of sediment input, transfer or deposition, during road operation or construction, was beyond the scope of this assessment due to the lack of available data around which to build the models for the majority of watercourses. Due to their small size, little additional information would be gained by modelling these watercourses. However, a separate mathematical model will be constructed to examine the potential impact of construction operations of the River Dee, and will be included in the Addendum.

2.16 The paucity of historical data (flow variation, channel morphology measurements, sediment concentrations in flow) and archive maps for many of the watercourses meant that the baseline conditions were judged on field observations during one site visit, providing an indication of character at a snap-shot of time rather than over a period of time.

2.17 In addition, only one site visit means that watercourses were observed under one flow condition (often low-flow) rather than under several flow conditions. Streams and rivers are less dynamic (active) at low flow.

2.18 Fieldwork was conducted in the summer when riparian and bank vegetation cover was dense. This often inhibited a full evaluation of the extent of bank erosion. The presence of vegetation on the bank face and bank top implies that the channel is not actively eroding. However, during winter months when banks are less vegetated, the signs of bank erosion are more readily detectible.

2.19 The upstream and downstream boundaries were determined by the extent of likely impacts caused by the crossing and access constraints. The extent of field survey conducted also varied according to these constraints. However all site investigations considered the channel upstream and downstream of the proposed scheme over a distance of 200m to 1km. The distance of survey was proportional to the size of the watercourse.

2.20 It is not possible to assess the potential impacts of construction before construction contractors have finalised their programme of works – e.g. the location of temporary access roads, timing of construction etc. However, an assessment was made of the likely potential impacts caused by generic impacts during construction of the watercourse crossings.

3 Baseline Conditions

Loirston Burn and Loch

3.1 The source of Loirston Burn is to the west of Blue Hill in a plantation (predominantly coniferous). The stream is ditch-like, following a straightened course with a series of 90 degree bends. The banks are very high for the size of the watercourse (up to 3m high in some reaches) resulting in an overdeepened channel with no floodplain connectivity. The water width is quite narrow, between 0.5 and 0.8m, and in many places flow is imperceptible due to the low bed gradient. The channel is lined by grasses/rushes and nettles which obscure the banks. Where visible, the bed contains gravel and cobble, with some mosses and liverworts. The proposed crossing location occurs just before the stream emerges from the plantation at a sharp bend, which shows no evidence of erosion. Downstream of this point, the course follows the boundary of the plantation. The shape of the channel remains straight and overdeep but vegetation cover is less complete and areas of the bank reveal bare earth of peaty consistency. Farther downstream, the burn is crossed by the A90 and A956, before draining into Loirston Loch.

3.2 The heavily modified nature of the watercourse and limited flow means that active geomorphological processes are limited. Therefore, the watercourse is of low vulnerability to modification.

Greengate Ditch

3.3 Greengate Ditch is a tributary of Loirston Burn. The watercourse has been straightened and appears to have been subject to historic deepening. The channel has a trapezoidal cross-section and has a relatively low gradient. The banks are well vegetated by grasses and locally trees are also present. The bed is composed of gravel with patches of silt. Overall, the channel has low morphological diversity and shows no evidence of significant erosion or deposition.

3.4 The modified nature of the channel and low morphological diversity means that the watercourse is of low vulnerability to modification.

Burn of Ardoe

3.5 The Burn of Ardoe is a tributary of the River Dee. The proposed road crossing is located in the upper, headwater, reaches of the catchment immediately before the stream enters Hare Moss. In this location, the stream is characterised by a narrow (0.6 m), low gradient channel. The channel is filled with vegetation that obscures the bed and traps fine sediment within the channel. In planform, the stream is relatively straight and appears to have been historically realigned. The stream does not show any evidence of significant natural fluvial processes and this appears to be related to the low channel gradient.

3.6 The modified nature of this watercourse and lack of active fluvial processes means that this watercourse is of low vulnerability.

Jameston Ditch

3.7 This is a boggy, straight ditch (a dug channel), with a low gradient and little perceptible flow. The bed of the channel is covered with vegetation and fine sediment.

3.8 There are no active geomorphological processes and the artificial nature of the watercourse means that it has a low vulnerability to modification.

Bishopston Ditch

3.9 This is a grass-filled straight ditch, with a low gradient and no perceptible flow. It is already culverted under a track.

3.10 There are no active geomorphological processes and the artificial nature of the watercourse means that it has a low vulnerability to modification.

Heathfield Burn

3.11 This burn is part of a field ditch network to the south of Hare Moss and is a tributary of the Burn of Ardoe. Adjacent land use is rough grazing and there are no trees along the bank tops. The channel is narrow (0.3m), straight and artificially deepened. There is no perceptible flow in the channel. Water is ponded by vegetation and the low gradient of the watercourse. There is silt on the bed and the water quality appears poor.

3.12 There are no active geomorphological processes and the artificial nature of the watercourse means that it has a low vulnerability to modification.

Whitestone Burn

3.13 Whitestone Burn is a straight channel that has been realigned to follow the field boundaries. The bed is sandy and silty with some cobbles, and flow is ponded in places. The channel is walled along much of its length.

3.14 The heavily modified nature of the watercourse and limited flow means that active geomorphological processes are very limited and the watercourse is of low vulnerability to modification.

Burnhead Burn

3.15 The Burnhead Burn is a tributary of the Blaikiewell Burn. The source of the stream is to the west of Clochandighter Forest. It starts as a series of straight drain-like channels aligned along field boundaries. Immediately downstream of its confluence with the Swellhead Burn, the stream passes under a minor road between Burnhead and Craigentath. Downstream of this road, the watercourse continues to follow field boundaries in a low gradient trapezoidal ditch-like channel that reflects past deepening and straightening. The stream bed is composed of gravel and occasional moss covered cobbles but is relatively uniform in character.

3.16 After passing under the access road to Blaikiewell, the stream follows a straightened course alongside the access road and descends down a moderate gradient towards Blaikiewell Burn. However, despite being modified, the channel bed exhibits good morphological diversity in this section with a series of steps and pools. This reflects the increase in channel gradient and the presence of large cobbles and boulders in the channel. Reworking of bed sediments during high flows helps to maintain good morphological diversity.

3.17 The upper low gradient section of Burnhead Burn is highly modified. It has a low gradient and exhibits low morphological diversity, and therefore from a geomorphological perspective is of low vulnerability to modification. However the lower section, which is steeper and exhibits good bed morphology, is of medium vulnerability to modification.

Blaikiewell Burn

3.18 Blaikiewell Burn is a tributary of Cyrnoch Burn. The source of the stream is to the northwest of Burnhead, however the majority of the flow is received from Burnhead Burn, which joins approximately 250m downstream. The middle reaches of the watercourse (the location of the proposed road crossing) to the southwest of Cleanhill Wood, are located within a ‘u’ shaped valley which has gently sloping sides and contains a narrow strip of floodplain on both banks. The channel has a moderate gradient and appears to have been subject to straightening at some point. The channel now appears to have begun to re-adjust and is developing a slightly sinuous planform. The bed is composed of gravel with occasional cobbles and moss covered boulders. It exhibits good morphological diversity in the form of pools, riffles and runs with occasional steps where boulders and bedrock outcrops are present. There are occasional small accumulations of fine sediment in the pools. Bank erosion along the watercourse is limited to localised under-cutting, which supplies some fine sediment to the channel. The banks are generally well vegetated. In places patches of organic material are present on the bed of the channel. The burn passes under a minor road (bridge) before entering a narrower gorge-like section of valley. This is densely wooded as the watercourse approaches Cyrnoch Burn. The gradient of the channel is steeper and the channel has a sinuous planform and is wider and shallower than upstream. The bed in the mid-lower reaches has a greater quantity of cobbles and boulders than upstream. These are supplied by bank erosion, which is also greater in this section. The channel is generally natural through this reach and exhibits excellent morphological diversity. Immediately before entering Cyrnoch Burn, the channel descends steeply over bedrock into the valley.

3.19 As the watercourse exhibits good morphological diversity, particularly downstream of the proposed road crossing, the channel is highly vulnerable to modification.

Kingcausie Burn

3.20 Kingcausie Burn is a tributary of Cyrnoch Burn. The source of the stream is to the west of Cleanhill Wood, and follows a broad ‘v’ shaped valley in a northwesterly direction through the woodlands of the Kingcausie Estate. The upper reaches of the watercourse are located along the eastern edge of Cleanhill Wood. At this location, the channel morphology is controlled by the roots and lower branches of thick riparian vegetation, particularly dense rhododendrons, and woody debris. Where the riparian vegetation is thinner, the watercourse is wider (up to 1.5m) and sinuous. The channel has a gravel-bed with occasional patches of sand. The channel exhibits excellent morphological diversity with alternating pools, riffles and side bars. Some small scale bank erosion is also evident supplying sand and some gravel to the channel. Accumulations of woody debris are common along the channel and provide flow variation.

3.21 After being culverted under an access track, the channel flows along the margin of a large field, where it has been extensively realigned. It is extensively walled along the left bank and the bed of the channel has also been modified by paving, using cobbles. The channel has relatively low gradient through much of this section, but begins to increase in the northwest corner of the field in the location of the proposed road. In this location, the channel becomes deeper and more natural in character.

3.22 The channel then enters another section of woodland. At this location, the channel has a more natural form and is locally sinuous in planform. The bed is composed of gravel and occasional moss covered cobbles and boulders. It is morphologically diverse, exhibiting alternating pools and riffles and occasional gravel bars (sediment deposits). The banks are composed of cobbles and gravels set within a matrix of silty sands. Locally however, there is evidence of past straightening, although the channel appears to have readjusted into a more natural form through localised erosion and deposition.

3.23 After leaving this wooded section, the channel turns sharply to the west and follows the boundary of a large field. At this location, the channel is extensively walled along the left bank and locally along the right. The channel has a gravel bed, but this is relatively uniform and shows little morphological diversity. The channel course is entirely artificial.

3.24 After approximately 100m, the channel gradient increases and the watercourse enters a further section of woodland. The channel descends steeply over bedrock into the gorge of Cyrnoch Burn. At this location, the channel is filled with numerous large cobbles and boulders and shows evidence of recent bed disturbance which is likely to have been due to flooding. Immediately before the channel drops down into the gorge a dry channel diverges off Kingcausie Burn. This cuts through the woodland running parallel to the gorge for a short distance. It then turns and descends towards the gorge edge. This channel appears to have been cut by a recent flood event.

3.25 Although Kingcausie Burn has been modified in a number of locations, primarily through realignment, the majority of the watercourse exhibits excellent morphological diversity and evidence of active fluvial processes. The watercourse is highly vulnerable to future modification, which threatens the morphological diversity and natural fluvial processes in the wooded sections.

Crynoch Burn

3.26 Crynoch Burn is a tributary of the River Dee. The burn is formed by the confluence of two streams, Cairnie Burn and the Burn of Monquich, both of which have catchments draining the hilly ground to the west of the B979 road. In the upper reaches of the catchments, the headwater streams have relatively steep gradients, while the gradients of the central valleys decline progressively downstream. The majority of the headwater streams in these catchments show evidence of past modification and follow field boundaries. Downstream of the confluence of Cairnie Burn and the Burn of Monquich, near the Mill of Monquich, the watercourse is located in a broad flat bottomed valley. At this location, the stream follows field boundaries and is surrounded by a well developed floodplain composed of alluvial sediments (sands and gravels). In some locations the channel has been straightened, particularly downstream from Westside. Downstream from Invercrynoch, the channel has a more natural sinuous planform and shows a range of morphological features such as pools and riffles and evidence of active erosion and deposition.

3.27 Downstream of Polston, the channel gradient increases as the stream enters a more confined gorge with frequent exposures of bedrock. This section of watercourse falls within the River Dee Special Area of Conservation due to the wide range of ecological communities supported by the watercourse. The channel exhibits excellent morphological diversity and evidence of active fluvial processes including erosion of both the stream banks, and locally the valley side and areas of sediment deposition within the channel. The channel has a coarse gravel bed with frequent cobble and boulders and has a well defined pool and riffle sequence. Fine sediments are generally absent from the bed surface. Locally, bedrock outcrops lead to steep waterfalls and associated deep pools. This gorge is thought to have originated as a glacial meltwater channel (British Geological Survey, 1980). The lower kilometre of Crynoch Burn has been subject to minor modification in the form of a weir, designed to supply water to a pond associated with a former mill. The watercourse is also crossed by two bridges. Despite this, the river bed exhibits excellent morphological diversity at this location with alternating pools and riffles.

3.28 The watercourse exhibits excellent morphological diversity. It is characterised by a wide range of features indicative of active natural fluvial processes. The sediment regime is dominated by coarse sediment. Fine sediment does not make up a significant proportion of the bed surface. The watercourse is highly vulnerable to disturbance.

River Dee

3.29 The River Dee is a large, fast flowing, cobble-bed river. The channel is characterised by high morphological diversity. It has a well defined large-scale pool and riffle sequence and numerous channel deposits including side bars and islands, covered by a range of vegetation types. The river has been designated as a Special Area of Conservation on the basis of the ecological communities that the river supports. The channel has a low gradient. However, flood flows that exceed 1000 m^3s^{-1} occur and these can move a range of sediment sizes. Fine sediment is generally absent from the bed of the river as this is moved by frequent high flows. The channel is in dynamic equilibrium with localised, slow, bank erosion on alternating banks. The channel is partially connected to its floodplain which is inundated during large floods, although some areas are protected by embankments. The channel has been subject to small-scale modifications such as bridges and local bank protection works involving rip-rap. Historic map evidence suggests the river channel has changed in several locations over the last 200 years. A comparison of the 1869 maps with the present maps reveals evidence of the following channel changes (downstream of the B979 road bridge):

- lateral channel migration (between the B979 and of Murtle Estate) since the mid-nineteenth century;
- two bend cut-offs in the mid nineteenth century (reducing channel sinuosity); and
- bend growth (increasing amplitude) upstream of Murtle Estate and the destruction of Morrison's Bridge at Cults and associated sediment deposition and channel division.

3.30 The cause of these changes is not known but it is likely that channel changes were driven, at least in part, by floods. The largest flood on record on the River Dee occurred in 1829. This may have caused the reduction in channel sinuosity through chute cut-off of bends in the river. This is a common mechanism of change in gravel-bed rivers. Support for this is provided by the large expanses of bare gravel within the river during the mid-nineteenth century. However, human-induced channel realignment cannot be ruled out as a contributing factor.

3.31 The destruction of Morrison's Bridge is likely to have been caused by the flood of 1894. Associated channel division in this location is also likely to have been triggered by this event. The 1894 flood in addition to more regular smaller-scale high flow (flood) events are likely to have driven bend growth upstream of Murtle Estate. It is possible this bend growth occurred in response to past reductions in channel sinuosity.

3.32 The high morphological diversity of the watercourse and absence of fine sediment on the riverbed means the River Dee is highly vulnerable to disturbance. In addition, the evidence of past channel changes, which appear to have been associated with floods, indicates that the river can alter its morphology significantly during large flood events.

3.33 Addition baseline information for the River Dee is provided in Annex 25.

Milltimber Burn

3.34 Culverted through Milltimber, the burn emerges at the old railway line to flow alongside the B979, and then across the River Dee's floodplain. The channel is straight and ditch-like. The flow is very low. Tall herb and grass vegetation is extensive along the banks, obscuring the channel in places. In upper reaches, the bed is sandy and gravely, but silt becomes obvious further downstream due to some bank poaching by livestock. The low gradient section acts as a silt trap, preventing large amounts of fine sediment from being transported through to the River Dee during normal flows.

3.35 Past modification and the low gradient means that the watercourse has a low vulnerability to modification.

Culterhouse Burn

3.36 This watercourse is a narrow and ephemeral channel, with a moderate gradient. This has been straightened, culverted under a road, and walled along one bank. The channel was obscured by vegetation at the time of the survey.

3.37 The heavily modified nature of the watercourse and limited flow means that active geomorphological processes are very limited and the watercourse is of low vulnerability to modification.

Beans Burn

3.38 The channel is straight and ditch-like. It is walled in several locations along the right bank. There was very little flow at the time of the survey. The channel is mostly filled by vegetation.

3.39 There are no active geomorphological processes and the artificial nature of the watercourse means that it has a low vulnerability to modification.

Upper Beanshill Burn

3.40 The channel is straight and ditch-like. There is very little flow: the channel is mostly filled by vegetation including scrub and gorse.

3.41 There are no active geomorphological processes and the artificial nature of the watercourse means it has a low vulnerability to modification.

Gairn Burn

3.42 Gairn Burn is a short, narrow (0.4m), gravel bed stream. It is a tributary of Silver Burn. In the upper reaches, the channel is steep and relatively natural, with varied flow and step-pool sequences over coarse block substrate. There are occasional patches of silt. The banks are well vegetated and trees obscure the channel in some places. The channel is bridged by the Broomfold to Blacktop road, along which the lower reach of the stream has been realigned and walled.

3.43 The burn will be crossed by an upgrade to the side road, in a location that is already modified. The upper reaches are in close proximity to the proposed main route. At this location, the stream is relatively natural and has a medium vulnerability to modification.

Westholme Burn

3.44 Westholme Burn is a tributary of Brodiach Burn – which is a tributary of Ord Burn – located to the west of Kingswells. The watercourse is characterised by a straight ditch-like channel with a relatively low gradient. The morphology of the watercourse appears to owe its origin to past straightening and deepening. Locally the banks tops are raised and composed of boulders and cobbles that appear to have been dredged out of the channel. The banks are well vegetated and the channel shows no evidence of active erosion or deposition.

3.45 The modified nature of the watercourse and lack of active fluvial processes means that this watercourse is of low vulnerability to modification.

Summary

3.46 Table 5 outlines the vulnerability of each watercourse on the basis of the baseline conditions for each watercourse.

Table 5 – Summary of the Vulnerability of Watercourses

Watercourse	Sediment Regime	Channel Morphology	Natural Fluvial Processes	Overall Vulnerability
Loirston Burn and Loch	Low	Low	Low	**Low**
Greengate Ditch	Low	Low	Low	**Low**
Burn of Ardoe	Low	Low	Low	**Low**
Jameston Ditch	Low	Low	Low	**Low**
Bishopston Ditch	Low	Low	Low	**Low**
Heathfield Burn	Low	Low	Low	**Low**
Whitestone Burn	Low	Low	Low	**Low**
Burnhead Burn	High	High	High	**High**
Blaikiewell Burn	High	High	High	**High**
Kingcausie Burn	High	High	High	**High**
Crynoch Burn	High	High	High	**High**
River Dee	High	High	High	**High**
Milltimber Burn	Low	Low	Low	**Low**
Culterhouse Burn	Low	Low	Low	**Low**
Beans Burn	Low	Low	Low	**Low**
Upper Beans Hill Burn	Low	Low	Low	**Low**
Gairn Burn	Medium	Medium	Medium	**Medium**
Westholme Burn	Low	Low	Low	**Low**

4 Potential Impacts

4.1 Potential impacts that could affect watercourses are divided into operational impacts and construction impacts. The operation impacts are those that are long-term and would influence watercourses after the scheme is complete. The construction impacts are shorter-term and would affect the watercourse during the construction phase.

4.2 The impact assessment for the operation and construction phase is presented with the assumption of no mitigation.

4.3 Unless otherwise stated, the impacts considered are adverse impacts, having an adverse impact on the sediment regime, channel morphology or natural fluvial processes, and are assigned based on the criteria set out in Table 2.

4.4 The impacts are predominantly direct impacts. Those that are indirect include increased discharge and realignment within the operational impacts. This is discussed further in Chapter 9 (Water

Environment: Northern Leg) and Appendices A24.1 (Surface Water Hydrology) and A24.4 (Water Quality).

4.5 Burnhead Burn and Crynoch Burn would be affected by both the Southern Leg and Fastlink sections of the proposed scheme. For the purposes of reporting, the assessment of these burns is covered in this chapter.

Generic Impacts

<u>Operation Impacts</u>

4.6 Table 6 outlines potential generic effects on the geomorphology during the operation of the road.

Table 6 – Potential Impacts on Geomorphology During Operation

Source of Impact	Potential Impact
Suspended Solids **Direct Impact** Increased fine sediment supply from road runoff where road drainage outfalls into a watercourse. The actual volume of sediment generated by the operation of the road would vary between watercourse depending on the length of road from which runoff would be directed into the watercourse through drains.	**Sediment Regime** An increased in transportation (turbidity) and deposition of fine sediment (sedimentation). **Channel Morphology** A reduction of morphological and consequently ecological diversity due to fine sediment deposition. **Natural Fluvial Processes** A reduction in dynamic processes due to channel sedimentation. For example, the smothering of gravel surfaces, such as bars, by fine sediment can encourage vegetation colonisation increasing the stability of the feature and changing the nature of associated habitats.
Increased Discharge **Indirect Impact** An increase in discharge (flow) along the watercourse during rainfall events may occur as a result of increased surface run-off, due to the low infiltration potential of the road surface where road drainage outfalls into a watercourse. This can accelerate the rate of geomorphological processes within the channel and also increase flood risk. Flood risk would also be increased where embankments are constructed across floodplains or where crossing structures constrict the channel reducing flow conveyance. In both cases flood risk is increased by the backing-up of water.	**Sediment Regime** An increase in turbidity and a greater competence to entrain and transport sediment (fine and coarse material) downstream may occur. **Channel Morphology** Erosion of the channel bed and banks would likely increase. Morphological diversity could be reduced or improved depending on sediment supply. **Natural Fluvial Processes** Adjustment to different flow and sediment regime, for example, a flashier regime would provide more energy for erosion leading to increased lateral migration. This could be a beneficial impact where improvement to morphological diversity results or an adverse impact where an increase in fine sediment supply occurs.

Source of Impact	Potential Impact
Culverts **Direct Impact** Many of the watercourse crossings are likely to involve culverting the watercourse (Figure 24.5. a-f). This section assumes a culvert sized to convey a range of flows would be installed level with the existing watercourse bed, effectively providing artificial bed and banks.	**Sediment Regime** An artificial culvert bed can enhance sediment transfer at high flows. Under normal flows however, sediment could accumulate within the culvert particularly where the culvert has a low gradient. Where culverts are designed to convey flood events with high return periods they may have a greater width than the natural channel. This would be likely to reduce stream powers leading to sedimentation within the culvert, reducing capacity. This can lead to increases in flood risk and lead to sediment starvation downstream. Where culverting increases channel gradient, scour of the bed and banks at culvert outlets often occurs, leading to an increase in the supply of sediment to the watercourse. **Channel Morphology** The morphological diversity within a culvert is greatly reduced due to artificial bed and banks. Interruption of morphological continuity would also segment the watercourse. **Natural Fluvial Processes** Culverts constrain the channel preventing lateral and vertical adjustment. A lack of river corridor (e.g. banks and berms) and in-channel vegetation due to light deficiency is also a detrimental impact.
Realignments **Direct Impact** The proposed road alignment may result in the diversion (realignment) of watercourses (Figure 24.5 a-h). This can lead to a change in the geomorphological behaviour of the watercourse over time.	**Sediment Regime** A major change in sediment regime can occur. A new course may result in a change in sediment supply, rate of sediment transfer downstream and depositional zones. Changes in boundary materials through realignment into materials more prone to erosion are likely to increase the volume of sediment supplied to the channel. Increases in channel gradient as a result of realignment would result in an increase in stream power leading to greater erosion rates reducing channel stability and promoting sedimentation downstream. A reduction in channel gradient however, would be likely to lead to increased deposition within the channel, leading to adverse impacts on morphological diversity. **Channel Morphology** Disruption to the channel bed may be short lived and realignment may lead to an improvement in channel morphology. In poor quality streams, realignment provides an opportunity to restore/rehabilitate the watercourse. **Natural Fluvial Processes** As described above, realignments can alter the nature of fluvial processes operating within the reach. An increase in erosion and/or deposition can have feedback effects that can lead to a reduction in channel stability, increasing lateral migration for example. An increase in the rate of channel processes can lead to an increase in morphological quality. However, sediment transfer downstream result in adverse consequences.

Construction Impacts

4.7 Potential impacts during construction are similar to those that may result during operation, except that they are short-term and generally more severe. There are a higher number of sources of impacts relating to suspended solids, which includes runoff from plant and vehicle washing, excavations, and blasting and excavation of road drains, for example. Any requirement for the removal of riparian vegetation for construction may also influence bank stability.

4.8 The magnitude of impact during construction is dependent on the nature and schedule of the works. Weather conditions would also influence the severity of impacts. The majority of the impacts would be far more severe if there were intense or prolonged rainfall events during the construction phase.

4.9 Table 7 outlines potential generic impacts on geomorphology that could result during the construction of the proposed scheme.

Table 7 – Potential Impacts on Geomorphology during Construction

Source of Impact	Potential Impacts
Suspended Solids **Direct Impact** Increased fine sediment supply to watercourses is likely to occur during construction operations. This may result from: • Run-off from vegetation free surfaces • The construction and operation of temporary roads • Plant and vehicle washing • Excavations and blasting • Embankment construction • Excavation of road drains	**Sediment Regime** A possible increase in turbidity and siltation may occur. **Channel Morphology** A reduction in diversity due to increased fine sediment supply and deposition is possible. The ecology of gravel bed rivers would also be severely affected. **Natural Fluvial Processes** An increase in siltation may result.
Vegetation Clearance **Direct Impact** Vegetation clearance during construction may reduce the stability of the river channels, increasing the potential for erosion and associated sediment release. Sediment release is likely to be greatest where vegetation clearance is required on slopes and would be particularly significant where woodland clearance is required.	**Sediment Regime** An increase in supply of fine sediment through bank instability, especially during the winter months, is possible. **Channel Morphology** Reduced morphological diversity due to bank collapse and sedimentation may occur. **Natural Fluvial Processes** Bank instability due to bank erosion may increase.
Culvert Installation **Direct Impact** Culvert installation could cause a major disturbance to the river bed. The majority of the watercourse crossings would involve culverting.	**Sediment Regime** Installation could increase the volume of sediment directly entering the channel and consequently increase turbidity. **Channel Morphology** The channel bed would be severely disturbed in the vicinity of the installation. **Natural Fluvial Processes** Localised erosion and deposition may occur and planform change may be constrained.
Realignments **Direct Impact** The proposed road alignment may result in the diversion (realignment) of watercourses. Construction operations may lead to a range of geomorphological impacts.	**Sediment Regime** An increase in sediment supply would occur during cutting a new course. **Channel Morphology** Bedforms that have developed over a long period of time may be disturbed. The new channel would lack morphological diversity. **Natural Fluvial Processes** Channel instability may be induced due to the new course. Fluvial processes would probably be exacerbated by realignment, especially in high flows.

Site Specific Impacts

Operation Impacts

4.10 The impacts of the proposed scheme on each watercourse would arise from four key changes: the release of suspended sediments, an increase in discharge, culvert installation and realignment. The impact of these changes on the geomorphology of the watercourse is determined by assessing the likely impact of these changes on the sediment regime, the existing channel morphology and the nature of contemporary fluvial processes operating.

4.11 Table 8 describes the impacts in more detail with specific reference to the individual watercourse.

Table 8 – Summary of Site Specific Impacts During Operation

Watercourse	Potential Impact	Magnitude of Impact
Loirston Burn and Loch	**Release of Suspended Solids** An increase in fine sediment could have an adverse effect on water quality and geomorphology. The watercourse has a low gradient therefore any sediment supplied is likely to accumulate on the bed, particularly where the channel bends sharply. **Increased Discharge** An increase in discharge may result in channel erosion, increasing fluvial process rates that could cause changes in the sediment regime and channel morphology. The stable banks will limit this, but erosion may occur on the outer bank of tight bends. Increased flooding is a possibility, although the channel is currently over-sized for prevailing flow. Downstream impacts on Loirston Loch are likely to be limited. **Two New Culverts and Two Existing Extensions** New culverts are proposed for the main crossing and a side road crossing downstream. Existing culverts would need to be extended under the A90 and A956. Due to existing modifications to the channel these alterations would have a low impact. The presence of artificial beds will likely lower morphological diversity and alter the existing fine gravel composition. **Realignment** As the channel is already straight and realigned, it is unlikely that further major realignments would be needed to culvert the stream so there would be only very minor change to the length of the watercourse. However, the bed would need to be regraded in the culvert locations. This could cause localised bed scour.	**Low** **Low** **Low** **Low**
Greengate Ditch	**Release of Suspended Solids** n/a as watercourse would enter earthworks drainage. **Increased Discharge** n/a as watercourse would enter earthworks drainage. **Culvert** n/a as watercourse would enter earthworks drainage. **Realignment** n/a as watercourse would enter earthworks drainage.	**n/a** **n/a** **n/a** **n/a**
Burn of Ardoe	**Release of Suspended Solids** n/a as road drainage would not outfall into the watercourse. **Increased Discharge** n/a as road drainage would not outfall into the watercourse. **Culvert** One culvert is required close to the source of the burn, which could disrupt river continuity and bed morphology. As there is little flow and low sediment transfer this far upstream in the watercourse, it is anticipated that there would be minimal impact. **Realignment** As the channel is already straight and realigned in this location, further realignments would cause no change in stream length or planform. However some extent of bed grading would need to take place to culvert the stream.	**n/a** **n/a** **Low** **Low**
Jameston Ditch	**Release of Suspended Solids** An increase in fine sediment would have an adverse effect on water quality and geomorphology. The watercourse has a low gradient and therefore any sediment supplied is likely to accumulate on the bed. **Increased Discharge** The channel has capacity for an increase in discharge as a result of road drainage input. As it is straight and low of low gradient, erosion is not likely to occur. **Culvert** n/a – watercourse would receive road runoff. **Realignment** **n/a**	**Low** **Low** **n/a** **n/a**

Watercourse	Potential Impact	Magnitude of Impact
Bishopston Ditch	**Release of Suspended Solids** n/a as road drainage would not outfall into the watercourse.	**n/a**
	Increased Discharge n/a as road drainage would not outfall into the watercourse.	**n/a**
	Culvert The stream is already culverted and shows little impact. One additional culvert is required which could disrupt river continuity and bed morphology. As there is little flow and a low sediment transfer rate in this watercourse, it is anticipated that there would be minimal impact. It may be necessary to locally alter the gradient of the channel, in which case stream power may be increased, possibly causing scour within or downstream of the culvert. If stream power is lowered, the culvert may be vulnerable to siltation.	**Low**
	Realignment As the channel is already straight and realigned in this location, further realignments would cause no change in stream length or planform. However some extent of bed grading would need to take place to culvert the stream.	**Low**
Heathfield Burn	**Release of Suspended Solids** n/a as road drainage would not outfall into the watercourse.	**n/a**
	Increased Discharge n/a as road drainage would not outfall into the watercourse.	**n/a**
	Culvert One relatively short culvert is required which could disrupt river continuity and bed morphology. There is good flow leading to some sediment transfer in this watercourse currently. It may be necessary to locally alter the gradient of the channel, in which case stream power may be increased, possibly causing scour within or downstream of the culvert. Alternatively, if stream power is lowered, the culvert may be vulnerable to siltation.	**Medium**
	Realignment As the channel is already straight and realigned in this location, further realignments would cause no change in stream length or planform. However some extent of bed grading would need to take place to culvert the stream.	**Low**
Whitestone Burn	**Release of Suspended Solids** n/a as road drainage would not outfall into the watercourse.	**n/a**
	Increased Discharge n/a as road drainage would not outfall into the watercourse.	**n/a**
	Culvert One culvert would be required, which could disrupt river continuity and bed morphology. As there is little flow and low sediment transfer in this watercourse, it is anticipated that there would be minimal impact. It may be necessary to locally alter the gradient of the channel, in which case stream power may be increased, possibly causing scour within or downstream of the culvert. Alternatively, if stream power is lowered, the culvert may be vulnerable to siltation.	**Medium**
	Realignment As the channel is already straight and realigned in this location, further realignments would cause no change in stream length or planform. However some extent of bed grading would need to take place to culvert the stream.	**Low**

Watercourse	Potential Impact	Magnitude of Impact
Burnhead Burn	**Release of Suspended Solids** An increase in fine sediment may lead to channel siltation in the narrow and relatively low gradient section downstream of the side road crossing. In the higher gradient reach, which is crossed by the southern route to the east of the roundabout, fine sediment may accumulate in slack areas behind cobbles and boulders. This could affect the quality of the bed morphology. Sediment may also reach Blaikiewell Burn and have similar impacts there.	**High**
	Increased Discharge Increased discharge is unlikely to cause significant erosion problems to the banks, due to the straight nature of the channel. However, some erosion of finer bed sediments could occur. Flooding could potentially occur at the existing Blaikiewell access road bridge if the capacity is not enlarged.	**Medium**
	Culvert A culvert is proposed approximately 100m upstream of the confluence with Blaikiewell Burn. In this location the gradient is moderate and the bed material is a mixture of gravel and cobble, with occasional boulders structured into a step-pool sequence. A culvert with an artificial bed would reduce the quality of the channel substrate and be an interruption to continuity of water and sediment flow. Local change in gradient could cause either scour of the bed downstream, or cause siltation if the gradient is reduced.	**High**
	Realignment As the channel is already straight and realigned in this location, further realignments would cause no change in stream length or planform. However some extent of bed grading would need to take place to culvert the stream. This would occur in a location where the channel has a diverse bed consisting of steps and pools, therefore modification could affect the quality of bed morphology.	**Medium**
Blaikiewell Burn	**Release of Suspended Solids** Road drainage would outfall into Burnhead Burn, upstream of this watercourse crossing. As the local bed gradient of the burn is variable, some reaches where the gradient is lower, and flow slower, may be susceptible to siltation. Fine sediments could smother the gravel material currently present in the bed. If this material is transported downstream, it may wash into Cyrnoch Burn, which is designated as a salmonid river and is highly sensitive to increases in fine sediment that can reduces the quality of spawning gravels.	**High**
	Increased Discharge Road drainage would outfall into Burnhead Burn, upstream of this watercourse crossing. The watercourse has quite a limited capacity to contain high discharges, with the valley floor acting as wetland storage in times of high flow. Any disconnection of the channel with the floodplain could affect this natural process and therefore increase flood risk. Natural fluvial processes may also be accelerated, with some bank erosion and bed scour likely to occur through sections with steeper gradients.	**High**
	Culvert Not applicable as it is assumed a bridge would be constructed.	**n/a**
	Realignment Not applicable as it is assumed a bridge would be constructed.	**n/a**

Watercourse	Potential Impact	Magnitude of Impact
Kingcausie Burn	**Release of Suspended Solids** n/a as road drainage would not outfall into the watercourse. **Increased Discharge** n/a as road drainage would not outfall into the watercourse. **Culvert** One culvert is proposed approximately 100-200m upstream of the burn's confluence with Crynoch Burn. The area to be affected is currently of high morphological diversity including deposits, undercut banks, sinuous channel and woody debris features. Artificial bed and banks would remove the characteristics of this reach, which currently possesses a high geomorphological and habitat diversity. The changes in gradient may result in problems of scour or sedimentation. **Realignment** Due to its sinuosity, the channel would be extensively realigned. This would lead to a reduction in channel sinuosity, reducing the channel length and increasing the channel gradient. As a result, stream power would increase, along with the potential for channel erosion and/or incision. This could lead to channel instability, increasing the volume of sediment transferred downstream with potentially widespread reductions in channel morphology. The realignment may also lead to decline in the morphological quality of the watercourse. Instability resulting from realignment could lead to an increase in the sediment load of the burn. This leads to a potential risk of increased sediment supply to Crynoch Burn.	**n/a** **n/a** **High** **High**
Crynoch Burn	**Release of Suspended Solids** Road drainage would outfall into Burnhead Burn, which is a tributary of this watercourse. Crynoch Burn is also downstream of several watercourses that would be affected by the proposed scheme. The burn is part of a SAC and is a salmonid river. An increase in fine sediment inputs from tributaries could result in an increased risk of spawning gravels being infiltrated by fine material and consequently cause a decline in the morphological quality of habitat. **Increased Discharge** Road drainage would outfall into Burnhead Burn, which is a tributary of this watercourse. Crynoch Burn is also downstream of several watercourses that would be altered by the proposed scheme. Some areas of channel instability are present in the form of accelerated bank and cliff erosion. Increased discharge could increase the rate of these natural processes. Sediment is predominantly coarse and therefore it is anticipated that there would be minimal impact on bed sediment mobility, as these sediments would only move at high flows. **Culverts** Not applicable as not crossed by the road. **Realignment** Not applicable as not to be realigned.	**Medium** **Medium** **n/a** **n/a**
River Dee	**Release of Suspended Solids** Fine sediment would be transferred to the River Dee from the tributaries affected by the road scheme and directly from road drainage. An increase in turbidity (high sediment loading) would have an adverse impact of bed morphology, such as affecting the large scale riffle-run sequences which are currently evident. **Increased Discharge** Limited impact due to the size of the river. **Culvert** Not applicable as a bridge would be constructed for the River Dee. **Realignment** n/a	**High** **Low** **n/a** **n/a**

Watercourse	Potential Impact	Magnitude of Impact
Milltimber Burn	**Release of Suspended Solids** n/a as road drainage would not outfall into the watercourse. **Increased Discharge** n/a as road drainage would not outfall into the watercourse. **Culvert** A culvert is required a short distance downstream of the exit from an existing culvert. The low gradient and straight nature of the watercourse mean that an additional culvert is not likely to affect the morphology of the stream significantly, but an artificial bed could lead to a reduction in bed morphology due to loss of the gravel and sand bed. **Realignment** As the channel is already straight and realigned in this location, further realignments would cause no change in stream length or planform. Some extent of bed grading would be required to culvert the stream, although it is anticipated that there would be little change from baseline conditions.	**n/a** **n/a** **Medium** **Low**
Culterhouse Burn	**Release of Suspended Solids** n/a as watercourse would be diverted into earthworks drainage. **Increased Discharge** n/a as watercourse would be diverted into earthworks drainage. **Culvert** n/a as watercourse would be diverted into earthworks drainage. **Realignment** n/a as watercourse would be diverted into earthworks drainage.	**n/a** **n/a** **n/a** **n/a**
Beans Burn	**Release of Suspended Solids** n/a as watercourse would be diverted into earthworks drainage. **Increased Discharge** n/a as watercourse would be diverted into earthworks drainage. **Culvert** n/a as watercourse would be diverted into earthworks drainage. **Realignment** n/a as watercourse would be diverted into earthworks drainage.	**n/a** **n/a** **n/a** **n/a**
Upper Beanshill Burn	**Release of Suspended Solids** n/a as watercourse would be diverted into earthworks drainage. **Increased Discharge** n/a as watercourse would be diverted into earthworks drainage. **Culvert** n/a as watercourse would be diverted into earthworks drainage. **Realignment** n/a as watercourse would be diverted into earthworks drainage.	**n/a** **n/a** **n/a** **n/a**

Watercourse	Potential Impact	Magnitude of Impact
Gairn Burn	**Release of Suspended Solids** The section above the side road crossing is relatively steep, but does not appear to be a significant sediment source. Fine sediment inputs from the area around the culvert may settle in the lower gradient section downstream where the channel has been realigned along the road, or wash through to Silver Burn.	**Medium**
	Increased Discharge An increase in discharge may increase the rate of fluvial activity, although the channel is quite stable and is walled in lower reaches so the channel is unlikely to erode. However, flood risk could be increased due to the steep gradient in the upper reaches.	**Medium**
	Culvert An upgrade/extension to the current road culvert would be required where the side road is being widened. As this is in the same location as an existing culvert, the impact on the watercourse would be minor. If the stream is culverted for a greater length and if the bed gradient has to be altered, there would be potential for either scour if the gradient is increased, or siltation if it is decreased.	**Medium**
	Realignment The watercourse may need to be realigned to install the new culvert. The gradient of the stream above the road crossing is quite high, therefore there is potential for the bed and banks to scour if the course and gradient are changed approaching the culvert. Straightening the channel may also reduce morphological diversity of the watercourse.	**Medium**
Westholme Burn	**Release of Suspended Solids** An increase in fine sediment from road runoff or outfall could have an adverse effect on water quality and geomorphology. The watercourse has a low gradient and therefore any increase in the amount of sediment supplied to the channel is likely to accumulate on the bed.	**Low**
	Increased Discharge An increase in discharge may lead to channel erosion increasing fluvial process rates that would cause changes in the sediment regime and channel morphology. The straight and stable nature of Westholme Burn would likely limit this impact.	**Low**
	Culvert Not applicable – outfall location only	**n/a**
	Realignment Not applicable – outfall location only	**n/a**

Construction Impacts

4.12 The impacts during road construction could generally arise from the release of suspended sediments, vegetation clearance, culvert installation and the activities associated with the construction of the realigned channel. The impact of these changes on the geomorphology of the watercourse is evaluated by assessing the likely impact of these changes on the sediment regime, the existing channel morphology and the nature of contemporary fluvial processes operating.

4.13 Table 9 outlines the potential impacts on watercourses that could result during construction of the proposed scheme.

Table 9 – Summary of Site Specific Impacts During Construction

Watercourse	Potential Impact	Magnitude of Impact
Loirston Burn and Loch	**Release of Suspended Solids** The high sediment supply could lead to fine sediment deposition in the channel and potentially to an increase in vegetation growth, due to the low gradient of the watercourse.	**Medium**
	Vegetation Clearance The trees in the plantation alongside the channel filter surface runoff, trapping fine sediment. If this vegetation were removed, more sediment would be likely to enter the channel directly.	**Medium**
	Culvert Installation The channel and adjacent land would be disturbed in four locations to install or enlarge culverts. This would likely lead to a release of fine sediment which may be transferred downstream to the loch, where it would settle on the bed.	**Medium**
	Realignment Excavating channels for temporary realignment would be likely to lead to channel sedimentation downstream, including potential impacts on Loirston Loch. However, the short lengths of the culverts may reduce the magnitude of this impact.	**Low**
Greengate Ditch	**Release of Suspended Solids** The high sediment supply could lead to fine sediment deposition and increased channel vegetation growth although the low morphological quality of this watercourse at present would mean the decline in condition from baseline would be limited.	**Low**
	Vegetation Clearance Removal of the riparian vegetation may lead to localised bank instability and an increase in fine sediment supply with detrimental effects on channel morphology. Only grasses and tall herbs are present at the site.	**Low**
	Routing into Pre-Earthworks Drainage Rerouting the watercourse into pre-earthworks drainage would lead to a considerable disturbance to the channel during construction. However, as the existing channel is characterised by low morphological diversity this would be of limited significance.	**Low**
	Realignment n/a	**n/a**
Burn of Ardoe	**Release of Suspended Solids** The high sediment supply would lead to fine sediment deposition and channel vegetation growth. The watercourse would be crossed at its source, therefore the impact is likely to be very localised.	**Low**
	Vegetation Clearance Removal of the riparian vegetation can lead to localised bank instability and an increase in fine sediment supply with detrimental effects on channel morphology. Only grasses and tall herbs are present at the site of the crossing.	**Low**
	Culvert Installation This would disturb the bed morphology and promote high turbidity, possibly leading to siltation downstream. Due to the low gradient at the source of the watercourse, silt removal may be required to maintain flow.	**Low**
	Realignment Excavating a temporary realignment during culverting would lead to a temporary high sediment supply during construction operations. The resulting increase in sediment delivery would be likely to lead to channel sedimentation downstream.	**Low**

Watercourse	Potential Impact	Magnitude of Impact
Jameston Ditch	**Release of Suspended Solids** The high sediment supply could lead to fine sediment deposition and channel vegetation growth although the low morphological quality of this watercourse at present would mean that the decline in condition from baseline would be limited. **Vegetation Clearance** Removal of the riparian vegetation can lead to localised bank instability and an increase in fine sediment supply with detrimental effects on channel morphology. Only grasses and tall herbs are present at the site. **Culvert Installation** n/a **Realignment** n/a	**Low** **Low** **n/a** **n/a**
Bishopston Ditch	**Release of Suspended Solids** The high sediment supply could lead to fine sediment deposition and channel vegetation growth although the low morphological quality of this watercourse at present would mean that the decline in condition from baseline would be limited. **Vegetation Clearance** Removal of the riparian vegetation can lead to localised bank instability and an increase in fine sediment supply with detrimental effects on channel morphology. Only grasses and tall herbs are present at the site. **Culvert Installation** This would disturb the bed morphology and promote high turbidity, possibly leading to siltation downstream. Due to the low gradient, silt removal may be required to maintain flow. **Realignment** Excavating a temporary realignment during culverting could lead to a temporary high sediment supply during construction operations. The resulting increase in sediment delivery is likely to lead to channel sedimentation downstream.	**Low** **Low** **Low** **Low**
Heathfield Burn	**Release of Suspended Solids** The high sediment supply could lead to fine sediment deposition and channel vegetation growth although the low morphological quality of this watercourse at present would mean the decline in condition from baseline would be limited. **Vegetation Clearance** Removal of the riparian vegetation can lead to localised bank instability and an increase in fine sediment supply, with detrimental effects on channel morphology. Only grasses and tall herbs are present at the site. **Culvert Installation** This would disturb the bed morphology and promote high turbidity, possibly leading to siltation downstream. Due to the low gradient silt, removal may be required to maintain flow. **Realignment** Excavating a temporary realignment during culverting could lead to a temporary high sediment supply during construction operations. The resulting increase in sediment delivery is likely to lead to channel sedimentation downstream.	**Low** **Low** **Low** **Low**
Whitestone Burn	**Release of Suspended Solids** The high sediment supply could lead to fine sediment deposition and channel vegetation growth, although the low morphological quality of this watercourse at present would mean the decline in condition from baseline would be limited. **Vegetation Clearance** Removal of the riparian vegetation, including trees, can lead to localised bank instability and an increase in fine sediment supply with detrimental effects on channel morphology. **Culvert Installation** This would disturb the bed morphology and promote high turbidity, possibly leading to siltation downstream. The burn has moderately steep gradient, so any local change in bed gradient could promote scour and erosion. **Realignment** Excavating a temporary realignment during culverting would lead to a temporary high sediment supply during construction operations. The resulting increase in sediment delivery would be likely to lead to channel sedimentation downstream.	**Low** **Medium** **Medium** **Low**

Watercourse	Potential Impact	Magnitude of Impact
Burnhead Burn	**Release of Suspended Solids** A high volume of sediment could enter the watercourse during construction that could be deposited on the channel bed to the detriment of channel morphology and ecology. There is potentially a downstream impact on Blaikiewell Burn.	**High**
	Vegetation Clearance Removal of the riparian vegetation, including shrubs, can lead to localised bank instability and an increase in fine sediment supply with detrimental effects on channel morphology.	**Medium**
	Culvert Installation Installing culverts would lead to major disturbance of the channel, especially in the downstream location, where the channel is fairly steep and has varied bed morphology. Sediment released by in-channel works would be likely to enter the Blaikiewell Burn due to the close proximity of the confluence.	**High**
	Realignment The burn may have to be realigned for culverting and also to alter its course along a side road. Excavating both the new course and any temporary realignment could lead to a temporary high sediment supply during construction operations. The resulting increase in sediment delivery is likely to lead to channel sedimentation downstream, reducing morphological quality with potential adverse effects on aquatic ecology.	**High**
Blaikiewell Burn	**Release of Suspended Solids** Increased sediment supply through earth works, vehicle access and runoff could have a detrimental impact on channel morphology, especially if fine sediment enters the channel to be deposited on top of the fine gravels currently forming the bed.	**High**
	Vegetation Clearance Removal of the vegetation some distance from the channel would not be likely to affect its stability. However, this would increase volume of fine sediment entering the channel.	**Medium**
	Culvert Installation n/a (a bridge would be constructed).	**n/a**
	Realignment n/a	**n/a**
Kingcausie Burn	**Release of Suspended Solids** A high volume of sediment could enter the watercourse during construction that could be deposited on the channel bed to the detriment of channel morphology and ecology. There is potential for downstream impacts on Cyrnoch Burn, which is a designated fisheries river.	**High**
	Vegetation Clearance The burn runs through a section of broad-leaved woodland, which coincides with the morphological diverse and high quality reach of the burn. Vegetation removal can lead to bank instability and an increase in sediment input to the watercourse, particularly as ground vegetation cover is thin.	**High**
	Culvert Installation A substantial length of culvert would be installed, which would require disruption to the river bed and banks and severely affect the morphological quality of the channel. The diversion of the channel would likely result in the release of large amounts of sediment and change the character of flow.	**High**
	Realignment The channel currently shows evidence of re-adjustment after being realigned historically. Realigning the channel again would change the gradient, which has the potential to cause localised scour and instability and the overall morphological diversity would be reduced.	**High**

Watercourse	Potential Impact	Magnitude of Impact
Crynoch Burn	**Release of Suspended Solids** Construction works on some of the upstream tributaries of Crynoch Burn could result in the introduction of sediment downstream. This would lead to reductions in morphological quality, such as smothering of the gravel and cobble bed. Increased level of suspended sediment may affect local water quality in Crynoch Burn, which is a designated fisheries river.	**High**
	Vegetation Clearance n/a	**n/a**
	Culvert Installation n/a	**n/a**
	Realignment n/a	**n/a**
River Dee	**Release of Suspended Solids** An increase in sediment supply through earth works for bridge construction, vehicle access and runoff would have a detrimental impact on channel morphology, potentially affecting the quality of sediment in the large riffles and resulting in fine sediment deposition around bar features.	**High**
	Vegetation Clearance Removal of the vegetation is not likely to affect stability of channel but would increase the volume of fine sediment entering the channel. Runoff could increase, which could affect the water quality.	**Medium**
	Culvert Installation n/a as a bridge would be constructed.	**n/a**
	Realignment n/a	**n/a**
Milltimber Burn	**Release of Suspended Solids** The high sediment supply could lead to fine sediment deposition and channel vegetation growth, although the low morphological quality of this watercourse at present would mean the decline in condition from baseline would be limited. Flushes of fine sediment may travel downstream to the River Dee, which would be more sensitive to its impact.	**Medium**
	Vegetation Clearance Removal of the riparian vegetation (mainly tall herbs) can increase fine sediment supply.	**Low**
	Culvert Installation This would disturb the bed morphology and promote high turbidity, possibly leading to siltation downstream. Due to the low gradient, silt removal may be required to maintain flow.	**Medium**
	Realignment Excavating a temporary realignment during culverting would lead to a temporary high sediment supply during construction operations. The resulting increase in sediment delivery is likely to lead to channel sedimentation downstream.	**Low**
Culterhouse Burn	**Release of Suspended Solids** The watercourse has a moderate gradient therefore most fine sediment supplied is likely to be washed through at high flows, although during construction it may accumulate on the bed.	**Low**
	Vegetation Clearance Removal of the riparian vegetation (tall herbs and shrubs) can increase fine sediment supply.	**Low**
	Routing into Pre-Earthworks Drainage Rerouting the watercourse into pre-earthworks drainage would lead to a considerable disturbance to the channel during construction. This would result in a temporary release of fine sediment into the water column, which may be transported downstream. However, as the existing channel is characterised by low morphological diversity this would be of limited significance.	**Low**
	Realignment n/a as watercourse would enter earthworks drainage	**n/a**

Watercourse	Potential Impact	Magnitude of Impact
Beans Burn	**Release of Suspended Solids** The high sediment supply could lead to fine sediment deposition and channel vegetation growth although the low morphological quality of this watercourse at present would means that the decline in condition from baseline would be limited.	**Low**
	Vegetation Clearance The gorse and herb vegetation alongside the channel filter surface runoff from the surrounding mixed arable and pasture land. If this vegetation were removed, more sediment iwould be likely to enter the channel directly.	**Low**
	Routing into Pre-Earthworks Drainage Rerouting the watercourse into pre-earthworks drainage would lead to a considerable disturbance to the channel during construction. This would cause a temporary release of fine sediment into the water column, which may be transported downstream. However, as the existing channel is characterised by low morphological diversity this would be of limited significance.	**Low**
	Realignment n/a as watercourse would enter earthworks drainage.	**n/a**
Upper Beanshill Burn	**Release of Suspended Solids** The high sediment supply could lead to fine sediment deposition and channel vegetation growth, although the low morphological quality of this watercourse at present would mean that the decline in condition from baseline would be limited.	**Low**
	Vegetation Clearance The gorse and herb vegetation alongside the channel filter surface runoff from surrounding land. If this vegetation were removed, more sediment would be likely to enter the channel directly.	**Low**
	Routing into Pre-Earthworks Drainage Diverting the watercourse into pre-earthworks drainage would lead to a considerable disturbance to the channel during construction. This would cause a temporary release of fine sediment into the water column, which may be transported downstream. However, as the existing channel is characterised by low morphological diversity this would be of limited significance.	**Low**
	Realignment n/a as watercourse would be diverted into earthworks drainage.	**n/a**
Gairn Burn	**Release of Suspended Solids** The watercourse has a moderate gradient and therefore most fine sediment supplied is likely to be washed through at high flows, although during construction it may locally accumulate on the bed.	**Low**
	Vegetation Clearance The burn runs through a variety of grassland, shrubs and clumps of trees. The more vegetated areas coincide with more morphologically diverse and high quality reaches of the Burn. Clearing trees and shrubs could lead to bank instability and increased fine sediment input. If this vegetation were removed, more sediment would be likely to enter the channel directly, and riparian habitats would be lost.	**Medium**
	Culvert Installation A culvert would need to be installed, causing disruption to the river bed and banks and impacting the morphological quality of the channel. The channel would need to be diverted while the culvert is installed, possibly releasing amounts of sediment, possibly leading to siltation downstream.	**Medium**
	Realignment The burn may have to be realigned for culverting and also to alter its course along a side road. Excavating both the new course and any temporary realignment would lead to a temporarily high sediment supply during construction operations. The resulting increase in sediment delivery is likely to lead to channel sedimentation downstream.	**Medium**

Watercourse	Potential Impact	Magnitude of Impact
Westholme Burn	**Release of Suspended Solids** A high sediment supply could lead to fine sediment deposition and channel vegetation growth, although the low morphological quality of this watercourse at present would mean the decline in condition from baseline would be limited.	**Low**
	Vegetation Clearance Removal of the riparian vegetation can lead to localised bank instability and an increase in fine sediment supply with detrimental effects on channel morphology. Only grasses and tall herbs are present at the site.	**Low**
	Culvert Installation Not applicable – outfall location only.	**n/a**
	Realignment Not applicable – outfall location only.	**n/a**

Impact Summary

Operational Impacts

4.14 Potential impacts have been described in terms of sediment regime, channel morphology and natural fluvial processes (Table 6). The main issues identified relate to potential impacts resulting from increased discharge and increased fine sediment supply, as well as impacts resulting from the use of culverts and realignments.

4.15 An increase in discharge from road surface runoff is often associated with an increase in fine sediment supply to the watercourse due to accelerated bank erosion and channel instability. An increase in fine sediment supply (from road runoff and exacerbated bank erosion rates) accumulates on the bed when the flow velocity subsides and acts to reduce the morphological diversity. Fine sediment deposition is particularly detrimental in gravel-bed watercourses, which are used by migratory fish for spawning.

4.16 An increase in discharge may also lead to a greater risk of flooding. Some of the watercourses currently exhibit flashy hydrological regimes; greater surface runoff and less infiltration could exacerbate this flood risk. An increase in the frequency and magnitude of flood flows would increase the rate of geomorphological processes of both erosion and deposition. This is likely to have significant impacts along Burnhead Burn, Blaikiewell Burn, Kingcausie Burn and Crynoch Burn.

4.17 The majority of watercourses would require either a single culvert or a number of culverts. In cases where the channel is artificial and/or has been historically straightened and displays a poor morphology, the significance of operational impacts would be minimal. Watercourses that exhibit more natural fluvial processes such as erosion and deposition, and features such as pool and riffle sequences, would be subject to more adverse impacts because the bed is replaced by an artificial substrate. The channel through a culvert also lacks bank and riparian features (and all vegetation due to lack of light) which has direct implications for the ability of the river to laterally migrate and maintain sinuosity. This would also have an effect on wildlife that uses the river corridor. Culverts interrupt the river continuity (e.g. the bed morphology and riparian zone), often prohibiting fish and wildlife migration. Watercourses where the introduction of culverts would have a high impact include Burnhead Burn and Kingcausie Burn. Bridges would be constructed over Blaikiewell Burn and the River Dee.

4.18 Culverts straighten the channel, constraining lateral migration and increasing the gradient, which may lead to instability. The impact of culverts would be greatest where the existing channel gradient is relatively steep, such as Burnhead Burn.

4.19 A number of watercourse would need to be realigned in order to install a culvert. If the channel geometry, gradient and sinuosity of the new alignments are not appropriate, it can take a long period of time for a channel to adjust to its new course. The impacts of this would include bank erosion, bed incision and channel deposition downstream. The realignment of Kingcausie Burn may potentially lead to high adverse impacts on this watercourse and downstream on Crynoch Burn, into which it flows.

<u>Construction Impacts</u>

4.20 As with operational impacts, many of the impacts associated with construction would be generic to every site, although the severity of the impact would differ according to the individual baseline conditions and the scale of works in the vicinity of the watercourse.

4.21 One major impact on watercourses would be the increased availability of fine sediment associated with activities such as embankment construction, cutting excavation, temporary access roads, vehicle washing. The installation of culverts would also have a direct impact by disturbing the morphology of the channel bed, destabilising the banks and releasing more fine sediment.

4.22 The high fine sediment volume entering the channel during construction can result in channel siltation and the possibility of excessive channel vegetation growth if there is a sustained period of low flow. Fine sediment would have a detrimental effect on the gravel bed streams through the smothering of gravels used for spawning. In addition, sediment that enters the channel may be stored within the watercourse for a long period of time if it cannot be flushed downstream due to channel vegetation. This may prolong the impact on aquatic ecology (refer to Appendix A25.9). The turbidity of the water would also likely be high, with adverse effects on water quality.

4.23 Culvert installation would likely result in short-lived, but potentially severe impacts on watercourses. Long lengths of channel would be disturbed releasing sediment downstream. The banks and surrounding floodplain could also be destabilised. The sediment loading could be greatly increased and the morphological diversity greatly reduced during and after installation. The recovery time of the channel would depend on how dynamic the watercourse is (how much energy it has), which partly depends on flow velocity.

5 Mitigation

Generic Mitigation

<u>Operation Mitigation</u>

5.1 A number of generic mitigation measures can be implemented to reduce the potential impacts that may be associated with the operation of the proposed scheme. These are described in Table 10.

Table 10 – Mitigation Measures for Watercourses During Operation

Source of Impact	Mitigation Measure	Type of Mitigation
Suspended Solids	Avoid direct drain outlets from road into watercourse.	Prevention (avoidance)
	Where road drainage will be routed into watercourses this will be treated using: filter drains; treatment ponds and detention basins. Further details about these options are included in the Water Quality Chapter (section A24.4).	Reduction
Increased discharge (and flooding)	Avoid direct drain outlets from road into watercourse.	Prevention
	Detention basins will be provided where road drainage is to be routed into watercourses. These store road runoff and release it gradually into watercourse to prevent an increase in discharge. The detailed designs for these detention basins vary according to location and are described further in the Water Quality Chapter (section A24.4).	Reduction
	Avoid building structures (e.g. embankments) on the floodplain as these may constrict flow during floods and lead to a backing-up of flow, potentially increasing flooding upstream.	Prevention

Source of Impact	Mitigation Measure	Type of Mitigation
Crossing Structures (Culverts)	A number of options are available for watercourse crossing structures, these are:	
	Build a bridge across the watercourse.	Prevention
	Divert the watercourse.	Offset
	Culvert the watercourse.	Reduction
	The DMRB gives a number of “cases” for water crossings requiring culverts:	
	Case 1: Culvert barrel with dimensions derived for flood flow conditions.	Reduction
	Case 2: Culvert with depressed invert to allow for inclusion of stream bed material within the barrel.	Reduction
	Case 3: Bottomless arch culvert to retain natural stream bed.	Reduction
	Case 4: Provision of a low flow channel within the culvert invert.	Reduction
	Case 5: Provision of baffles within the culvert to increase roughness.	Reduction
Realignments	Ensure the realignment (planform, geometry, sinuosity and morphological features) is appropriate by including input from a geomorphologist.	Reduction (this also represents an opportunity to improve the morphological status of watercourses in the immediate vicinity of the road)

Crossing Structures

5.2 A series of different culvert types has been outlined in Table 10. These represent cost effective alternatives to bridges, although the level of reduction in impacts on watercourses offered by culverts, as crossing structures, is generally less than that provided by bridges.

5.3 The culvert structure cases 1-3 offer progressively increasing levels of mitigation, with Case 3 offering the greatest level, while Cases 4 and 5 provide additional measures that are appropriate in addition to Case 2. Further details of the mitigation provided by these differing designs are provided in Table 11.

5.4 The type of culvert required for each watercourse is determined on the basis of a combination of hydrological (Appendix A24.1), geomorphological and ecological (Appendix A25.9) criteria. Flood flow culverts are only acceptable where the channel is heavily modified and the geomorphological processes are heavily constrained. In these circumstances, the hydrological characteristics of the catchment are maintained (Appendix A24.1). Depressed invert culverts are generally appropriate where channel morphology is already influenced by past modifications but bed morphology is of good quality. Where the majority of the section of watercourse affected by the road is natural, the provision of bridges is recommended, where possible. In addition, bridges are most appropriate where the channel is steep and has a sinuous planform as channel straightening associated with culverting may increase stream powers and lead to scour problems.

5.5 Existing culverts that would be located close to the proposed scheme can have an impact on the effectiveness of mitigation. Inappropriately designed culverts currently in place can act as a barrier to sediment or wildlife movement. Where appropriate, it may be possible to upgrade these structures to maximise the values achieved by the mitigation measures associated with the proposed scheme.

Table 11 – Culvert Types and Mitigation Provided

Culvert Type	Mitigation Provided
Case 1: Culvert barrel with dimensions derived for flood flow conditions	This represents the most basic type of culvert design and only provides mitigation against the impact of flood flows. The sizing of the culvert is designed to contain a 1:200 year flood event to prevent an increase in flood risk upstream which could be caused by the backing-up of flow. These culverts lead to a loss in morphological and process continuity through their entirely artificial structure. Such culverts are only acceptable where existing geomorphological conditions are extremely poor, such as locations where culverts are already present or where the channel is artificial. However, these culverts inhibit lateral channel changes (erosion) and also lead to the artificial straightening of the river channel (increased channel gradient), which may lead to increases in stream power, leading to scour and instability at the culvert outlet. The installation of these culverts requires in-channel works.
Case 2: Culvert with depressed invert to allow for inclusion of stream bed material within the barrel.	In addition to being sized to convey 1:200 year flood flows, the inverts of these culverts are installed at an elevation below the existing watercourse bed to allow a natural bed structure to reform. This reduces the impact of the culvert on morphological structure and continuity and reduces the impact of the culvert on sediment transport processes. However, these culverts inhibit lateral channel changes (erosion) and also lead to the artificial straightening of the river channel (increased channel gradient), which may lead to increases in stream power, leading to scour both within the culvert and at the culvert outlet. Bench features will be installed either side of the wetted channel and be sized relative to the current channel dimensions to provide wildlife access (refer to Freshwater Ecology Appendix A25.9). The installation of these culverts requires in-channel works.
Case 3: Bottomless arch	In addition to being sufficiently large to convey the 1:200 year flood flows, these culverts can provide an opportunity, where local conditions allow, to retain the natural stream bed. This means the continuity of bed morphology is preserved and sediment transport processes can continue without interruption. In such circumstances these culverts will avoid the need for in-channel works during installation so preventing bed disturbance and fine sediment release. In spite of this, these culverts inhibit lateral channel changes. However, where the channel is sinuous it could also be necessary to straighten the channel to fit it through the culvert. This will require extensive channel works during construction and the complete alteration of the channel morphology. Artificial straightening of the channel (increased channel gradient), may lead to increases in stream power, leading to scour both within the culvert and at the culvert outlet.
Case 4: Provision of a low flow channel within the culvert invert.	This option allows a Case 1 or Case 2 culvert to be constructed with a low flow channel set within the culvert. Such a design is desirable where the flood flow capacity requirement of the culvert means the culvert is wider than the channel upstream and downstream. The low flow channel is constructed to a width consistent with the natural channel width to allow sediment transport to continue uninterrupted (if the culvert bed is too wide sedimentation can occur). A low flow channel is not required in Case 3 culverts as the natural channel is retained.
Case 5: Provision of baffles within the culvert to increase roughness.	This option allows a Case 1 or Case 2 culvert to be constructed with baffles on the invert (Case 1) and walls (Case 1 and 2) of the culvert to increase roughness. This allows a limited improvement in bed morphology (Case 1) allowing flow aeration and a reduction in stream power. The provision of baffles is particularly useful where the gradient of the culvert is relatively high as this can reduce flow velocities limiting the potential for downstream scour. This could also have a beneficial effect for fish passage.

Realignments

5.6 Further detailed site specific investigations/assessments are recommended for each watercourse realignment, but designs will be based upon the following principles:

- In general the new alignments will have similar channel dimensions (width and depth) as the existing channels that they are replacing. Where necessary, changes in gradient will be compensated for by varying the channel sinuosity (planform), width and depth.
- The bed of the new channel will be formed using sediment sized to match the existing bed. Where possible an alternating sequence of pools, riffles and runs will be sited appropriately. These features are represented in natural watercourses and will help provide optimum habitat conditions for salmonids.

- Where possible additional morphological elements such as secondary channels, oxbow lakes and ponds will be created to provide morphological diversity and provide a full range of aquatic and riparian habitats.
- Where appropriate, providing secondary channels consisting of strips of bare gravels set within shallow channels set just above mean flow level will provide habitat for invertebrates such as beetles as well as the birds and mammals which feed upon them. Significantly, these channels will also provide flood flow channels, which will alleviate pressure on the channel during flood events. Secondary channels such as these are common features of gravel-bed rivers and streams.
- It is essential that a detailed geomorphological assessment (geo-dynamics assessment) is conducted for each watercourse to be realigned. This will be used to inform the design of the new alignment.
- Site specific recommendations for each realignment, based on further analysis, will be outlined in the addendum.

Construction Mitigation and Recommendations

5.7 A number of generic mitigation measures can be implemented to reduce the impact of the operation of the road scheme. These are described in Table 12 and several of these points are further elaborated upon in the subsequent text.

Table 12 – Mitigation Measures for Watercourses During Construction

Source of Impact	Mitigation Measure	Type of Mitigation
Suspended Solids	Provide barriers between earth working and watercourses to prevent sediment washing into the watercourse.	Reduction
	Avoid positioning stockpiles near the channel bank	Prevention
	Cover the stockpiles when not in use.	Reduction
	Contain the stockpiles with bunds or sediment fences.	Reduction
	Use a sediment trap (settling lagoons) to treat surface runoff.	Reduction
	Do not wash vehicles near watercourses.	Prevention
	Avoid creating access roads adjacent to the channel.	Prevention
	Plant and machinery not to ford any channels.	Prevention
	Limit the use of temporary culverts.	Prevention
	Where possible use temporary bridges rather than culverts to cross watercourses.	Prevention
	Provide adequate barriers (sediment fences) along the sides of bridges to prevent sediment from being washed into the watercourse from the road surface.	Prevention
	Connect drains to watercourses only on completion	Reduction
	Ensure there is an adequate space (exclusion zone) between earthworks (embankments and cuttings) and watercourses, to limit the transfer of sediment into them.	Reduction
	When drilling boreholes for blasting, ensure that dust release is limited by damping with water or through providing dust boxes or other barriers.	Reduction
	During blasting operations ground conditions must be carefully examined to determine the quantity of explosives required to fracture the rock. This will help to minimise the risk of fly rock.	Reduction
Vegetation Clearance	Limit the clearing of vegetation on the channel banks and riparian zone.	Reduction
	Use seeded geotextile mats to encourage re-vegetation after works on or near the banks.	Prevention
Culvert Installation (including upgrades)	Use temporary realignment to reduce the impact on installation on watercourses.	Reduction

Source of Impact	Mitigation Measure	Type of Mitigation
Culvert Installation (including upgrades)	Use temporary bridges rather than culverts to cross watercourses.	Prevention
	Use bottomless arch culverts to avoid disturbance to the channel bed.	Prevention
	Minimise the length of channel disturbed.	Reduction
	Divert flow through a pipe or lined channel to bypass the channel works to enable the culvert to be installed into a dry channel.	Reduction
	Where depressed invert culverts are to be installed, use new, appropriately sourced and sized sediments to form the bed of the new culvert.	Reduction
Pre-earthworks drainage	Construction mitigation measures for the construction of pre-earthworks drainage systems are described in the Water Quality Appendix.	Reduction
Realignments	Limit the use of temporary realignment channels.	Prevention
	Ensure the realignment and length (course, geometry, sinuosity, and morphological features) is appropriate by including input from a geomorphologist.	Reduction
	Use new appropriately sourced and sized sediments to form the bed of the new sections of channel.	Reduction
	Do not allow flow in the new channel until construction is complete.	Reduction

Crossing Structures

5.8 The construction of depressed new invert culverts (Case 2), including culvert upgrading, will require extensive in-channel works. During culvert installation, flow must be diverted around the channel works, either in a lined open channel or through a pipe. This will allow channel works to be conducted in conditions that will assist the minimisation of sediment release during construction. Flow must only be rerouted into the new culvert once channel works are completed and during low flow conditions, to reduce erosion risk.

5.9 To ensure morphological continuity and prevent localised changes in bed elevation, such as the evolution of knickpoints, the river bed in depressed invert culverts will be formed prior to the routing of flow through the culvert. Bed sediments will not be transferred from the existing channel as transferring river bed sediment may release fine sediments and pollutants stored beneath the bed armour (coarse sediments forming the top layer of the bed sediments). The new bed will be formed of locally sourced material (perhaps from excavation works elsewhere along the route) of the same size as the dominant particle size (excluding silt accumulations) in the pre-existing gravel channel. No fine sediment will be placed in the new channels.

5.10 The long-term stability of the bed sediments in depressed invert culverts will depend upon stream power within the culvert. Where the gradient of the culvert is high, stream powers may lead to scouring within the culverts and the loss of these bed sediments to downstream depositional areas. Problems associated with stream power are most likely to occur where culverting has involved the straightening of previously sinuous watercourses. To minimise the risk of scour, baffles will be installed within the culvert to dissipate flow energy and to stabilise the bed sediments. In addition, it may be necessary to install scour protection on the bed of the channel at the culvert outlet, to dissipate energy and prevent scour.

5.11 Clear span bridges are advantageous as these do not require in-channel work during installation and will help preserve the morphology and materials of the existing watercourse. However where sinuous watercourses are to be culverted some channel realignment may be required, involving a reduction in sinuosity. This reduction in sinuosity will increase stream powers and may lead to an increase in erosion, and/or incision, potentially leading to increases in sediment conveyance and deposition downstream. Where possible, watercourse realignment will be avoided through wide culverts or the use of bridges.

5.12 Bare riverbank created during culvert installation will be covered by geotextile matting, where appropriate, to limit the potential for erosion. This is important because these new banks will be vulnerable to scour, particularly at the culvert outlet. Geotextile matting will limit the potential for both fluvial scour, geotechnical failure and rainfall induced runoff erosion of the exposed banks. The geotextile matting will be seeded to promote vegetation colonisation and to ensure rapid stabilisation.

<u>Temporary Realignments</u>

5.13 Temporary watercourse realignments will be constructed with a great deal of care to prevent them from becoming sources of sediment. The temporary channel will be fully lined using geotextiles to prevent erosion of the bed and banks. Where possible, the realignment will have approximately the same channel length as the exiting watercourse in order not to increase the channel gradient. An increase in channel gradient can promote an increase in stream power that could lead to scour downstream.

5.14 Site activity in the vicinity of temporary realignment will be carefully managed to avoid the risk of accidental spillage into the watercourse. All pump generators or fuel tanks will have drip trays to avoid accidents, and be set away from the river. Site road crossings will consist of piped section sufficiently long to provide a road together with strips of ground either side to provide a barrier between the road and open channel sections.

5.15 Sediment control measures will be placed at the downstream end of the temporary realignment to intercept sediment delivered to the temporary realignment as a result of construction activities.

Watercourse Realignments

5.16 Further detailed site specific assessments are recommended for each watercourse realignment once the construction methods have been finalised, but the approach should be based upon the following principles:

- In order to limit the potential for bank erosion, new banks of the realignments will be appropriately graded.
- Covering newly formed banks along the new alignment with geotextile matting (where deemed necessary) will also reduce the potential for erosion by physically holding the newly exposed river bank sediments together. This will limit the potential for both fluvial erosion and runoff induced erosion on the exposed banks during rainfall. The geotextile matting will be seeded to promote vegetation colonisation to ensure rapid stabilisation of this new section of watercourse.
- It is essential that no flow is routed through the new, realigned channel during construction. The channel will be complete, including the new culverts prior to the rerouting of water and no further in-channel works will be conducted. The new channel will be constructed by moving progressively upstream to minimise the risk of flow switching into the new channel during high flow events prior to completion.
- Bed sediments will not be transferred from the existing channel as this will necessitate a temporary realignment during sediment transfer. Bed sediments will not be taken from the existing channel as transferring river bed sediment may release fine sediments and pollutants stored beneath the bed armour (coarse sediments forming the top layer of the bed sediments). Bed sediments will be appropriately sized (and shaped) gravels derived from a local source. The use of gravel sized sediments will provide voids within the riverbed which will act as a sediment sink to fine material allowing a reduction in sediment transfer downstream where any localised readjustment (erosion) occurs following the diversion of flow.
- It is likely that when flow is diverted through the new channel alignment, there would be a period of adjustment during which some sediment release can be expected. The new channel will be monitored regularly and where signs of instability are observed, such as erosion or incision, appropriate remediation measures will be undertaken.
- It is recommended that works be carried out in early spring in lower flow conditions, enabling vegetation to establish over the summer.

Site Specific Mitigation

Operation Mitigation

5.17 In addition to these generic mitigation measures, site specific operation and construction phase mitigation measures will be required as a result of local conditions and site specific factors. These site specific mitigation measures focus on watercourse crossings and realignments. Watercourses that will be routed into pre-earthworks drainage are not considered in this section.

Crossing Structure

5.18 The varied geomorphology of watercourses means that the minimum requirements of each watercourse crossing design vary (Table 10). As such, a range of different crossing structures are required (Table 13). Refer to Table 11 for details of the mitigation provided by the differing culvert types.

Table 13 – Crossing Structures for Watercourses, where required

Watercourse	Crossing Structure
Loirston Burn	Four Case 2 Depressed Invert Box Culverts
Burn of Ardoe	Case 2 Depressed Invert Box Culvert
Bishopston Ditch	Case 2 Depressed Invert Box Culvert
Heathfield Burn	Case 2 Depressed Invert Box Culvert
Whitestone Burn	Case 2 Depressed Invert Box Culvert
Burnhead Burn	Case 2 Depressed Invert Box Culvert
Blaikiewell Burn	Bridge
Kingcausie Burn	Case 2 Depressed Invert Box Culvert
River Dee	Bridge
Milltimber Burn	Case 2 Depressed Invert Box Culvert
Gairn Burn	Case 2 Depressed Invert Box Culvert

Realignments

5.19 A number of watercourse realignments are required, which are listed in Table 14.

Table 14 – Watercourse Realignments Required

Watercourse	Realignment
Loirston Burn	Four Realignments totalling 858 m required, with a 5m increase in channel length.
Burn of Ardoe	Realignment of 171m required with no change in channel length.
Bishopston Ditch	Realignment of 95m required with no change in channel length.

Watercourse	Realignment
Heathfield Burn	Realignment of 137m required with no change in channel length.
Whitestone Burn	Realignment of 178m required with no change in channel length.
Burnhead Burn	Realignment of 177m required with no change in channel length.
Kingcausie Burn	Realignment of 107m required, with a 28m decrease in channel length.
Milltimber Burn	Realignment of 67m required with no change in channel length.
Gairn Burn	Realignment of 156m required, with a 20m decrease in channel length.

Mitigation Summary

5.20 The mitigation measures suggested for the operation phase will be incorporated into the design of the road. The mitigation recommended for the construction phase will be planned and implemented prior to the works.

Operation Mitigation and Recommendations

5.21 The application of the mitigation measures that have been recommended at all crossing points will reduce the impacts of the operation of the road (Table 10).

5.22 The crossing structures that are proposed reflect the differing sensitivities of each watercourse and are summarised in Table 13. Realignments will be required on ten different watercourses (Table 14). Four realignments are proposed for Loirston Burn.

5.23 Open channel realignments will be carefully designed using geomorphological guidance. Following completion it is essential that the morphological response of all watercourse realignments is monitored for a period of at least one year. This is essential because the realigned channels will undergo some morphological readjustment following realignment. This will be monitored to ensure this does not have an adverse effect on the ecology and geomorphology of the channel. A monitoring plan would need to be detailed once the design for the works has been determined.

Construction Mitigation and Recommendations

5.24 A range of generic mitigation measures has been recommended which can be applied at all crossing points to reduce the impact of the construction of the road (Table 12).

5.25 In addition, a series of site specific guidance has been provided for the construction phase at each crossing point. This guidance varies according to the type of crossing structure recommended.

5.26 During in-channel works, flow will be diverted around the construction operations within an appropriately sized temporary realignment (diversion channel) lined with geotextiles to prevent bank erosion (if appropriate).

5.27 A number of watercourse alignments are required. These will be constructed and completed prior to the switching of flow through the new course. This will prevent fine sediment release into watercourses during construction. However, it is likely that when flow is routed through the new channel alignment there will be a period of adjustment during which some sediment release can be expected. It is essential that the new channel is monitored regularly and where signs of excessive instability are observed, such as erosion or incision, appropriate remediation measures are undertaken.

5.28 Prior to construction of these realignments, further geomorphological investigations are recommended to determine the:

- sinuosity and channel cross-sectional dimensions required to minimise subsequent re-adjustments (these may vary along the watercourse); and
- specific requirements for bank and bed protection measures.

6 Residual Impacts

Generic Operational Residual Impacts

6.1 A series of mitigation measures have been recommended, which would reduce the impact of the operation of the proposed scheme on watercourses (Table 10). The residual impacts of these recommendations are applicable to all watercourses in the study area and are summarised in Table 15. Residual impacts are likely to be long-term impacts. With the effective implementation and maintenance of appropriate mitigation, the anticipated impacts are predominantly negligible.

Table 15 –Residual Impacts for Operation

Source of Impact	Residual Impact with Mitigation
Suspended Solids **Direct Impact**	**Sediment Regime** Treatment of the road drainage using filter drains, detention basins and treatment ponds would prevent significant quantities of suspended sediment from being released into watercourses. Sediment removal efficiencies are variable; filter drains remove 80%-90% of suspended solids and treatment ponds have removal efficiencies of between 65% and 90%. Removal efficiency is partly dependant on discharge. During flood events for example, efficiencies would be towards the lower end of the range while during periods of low flows removal efficiency would be greatest. During high flows the suspended sediment is naturally high. The residual impact would be negligible. **Channel Morphology** Overall, the proposed scheme would have a negligible impact resulting in limited fine sediment release. It would also have a negligible impact on channel morphology. **Natural Fluvial Processes** Overall, changes to the sediment regime would be negligible. They would be insufficient to produce any noticeable change in the nature of fluvial processes operating on watercourses in the study area and the residual impact would be negligible for most watercourses.
Increased Discharge **Indirect Impact**	**Sediment Regime** The storage of road discharge in detention basins prior to gradual release into the watercourse would prevent the proposed scheme resulting in significant impacts on the hydrological regime of watercourses in the study area. Overall, the residual impacts on the sediment regime through changes in erosion or deposition rates of watercourses in the study area would be negligible. **Channel Morphology** Overall, the proposed scheme would nave no appreciable impact on the hydrological regime of most of the affected watercourses in the study area and changes in channel morphology would be negligible. **Natural Fluvial Processes** Similarly as the provision of detention basins would limit changes in the discharge and sediment regimes of most of the watercourses in the study area, the changes in natural fluvial processes would be also be negligible.

6.2 A range of site specific mitigation measures has been outlined for each road crossing point and channel realignment. The residual impacts following the implementation of these measures are considered on a site by site basis in subsequent sections.

Generic Construction Residual Impacts

6.3 A series of mitigation measures have been recommended, which would reduce the impact of the construction phase of the proposed scheme on watercourses (Table 10). The residual impact of these recommendations are applicable to all watercourses are summarised in Table 16. The predicted residual impacts are likely to be temporary in nature and most would be negligible.

Table 16 – Residual Impacts for Construction

Impact	Residual Impact with Mitigation
Suspended Sediment **Direct Impact**	**Sediment Regime** Assuming the range of mitigation measures are implemented at each crossing point (in particular treatment of site runoff), the potential for fine sediment delivery to watercourses would be significantly reduced giving a negligible impact. **Channel Morphology** As the road scheme would have a negligible effect on fine sediment release, it is also predicted to have an impact on channel morphology. **Natural Fluvial Processes** As changes to the sediment regime would low be or negligible they would be insufficient to produce any noticeable change in the nature of fluvial processes operating on the watercourse and the residual impact would be negligible for all watercourses.
Vegetation clearance **Direct Impact**	**Sediment Regime** The range of mitigation measures required at each crossing point would reduce the potential for vegetation clearance to lead to an increase in sediment supply. Vegetation clearance would generally have a negligible effect on the sediment regime of the channel. **Channel Morphology** As changes to the sediment regime resulting from construction and vegetation clearance would be low or negligible they would be insufficient to produce any noticeable change in the channel morphology operating on the watercourse and the residual impact would be negligible for all watercourses. **Natural Fluvial Processes** As changes to the sediment regime resulting from construction and vegetation clearance would be low or negligible they would be insufficient to produce any noticeable change in the nature of fluvial processes operating on the watercourse and the residual impact would be negligible for all watercourses.
Loss of watercourse to pre-earthworks drainage **Direct Impact**	Generic residual impacts following mitigation measures for the construction of pre-earthworks drainage systems are described in the Water Quality Appendix.

6.4 A range of site specific mitigation measures have been outlined for each road crossing point and channel realignment. The residual impacts following the implementation of these measures are considered on a site by site basis in subsequent sections.

Site Specific Residual Impact Assessment

Operational Impacts

6.5 The residual operational impacts of the scheme on each watercourse following the application of mitigation measures are outlined below in Table 17. Those watercourses that would be diverted into pre-earthworks drainage are not considered in this section.

Table 17 – Summary of Site Specific Residual Impacts for Operation

Watercourse	Source of Impact	Residual Impact Magnitude
Loirston Burn and Loch	**Four Depressed Invert Box Culverts and realignments** As this watercourse is already modified, straightened and locally culverted, the installation of depressed invert culverts, and upgrading of existing structures if required, would not lead to detrimental impacts on the sediment regime or morphological structure of this watercourse. Although the length of culverted channel would be greater, the preservation of bed continuity would limit the effect of this on morphological diversity. A total length of 853m of channel would be realigned, but this would predominantly be of vertical/bed realignment and unlikely to cause change in an already straightened channel.	**Negligible**
Burn of Ardoe	**Depressed Invert Box Culvert and realignment** The watercourse in the location of the proposed culvert is of low morphological diversity, being right at the source of the watercourse. Culverting this section of the watercourse would have a negligible impact on the morphological diversity and the new culvert would ensure continuity of bed morphology. A length of 171m of channel would be realigned, but this would predominantly be of vertical/bed realignment and unlikely to cause change in an already straightened channel with a low gradient.	**Negligible**
Bishopston Ditch	**Depressed Invert Box Culvert and realignment** The watercourse in the location of the proposed culvert is straight and of low morphological diversity. Culverting this section of watercourse would have a negligible impact on the morphological diversity and the new culvert would ensure continuity of bed morphology. A 95m length of channel would be realigned, but without a change in length and therefore it would be unlikely to cause change in a straight channel with a low gradient.	**Negligible**
Heathfield Burn	**Depressed Invert Box Culvert and realignment** The watercourse in the location of the proposed culvert is already straight, culverted in a number of places, and of low morphological diversity. Culverting a further section of this watercourse would have a negligible impact on the morphological quality and the new culvert would ensure continuity of bed morphology. A 137m length of channel would be realigned, but without a change in length and therefore it would be unlikely to cause change in a straight channel with a low gradient.	**Negligible**
Whitestone Burn	**Depressed Invert Box Culvert and realignment** As this watercourse is already modified, walled, and straightened, the installation of a depressed invert culvert would not lead to detrimental impacts on the sediment regime or morphological structure of this watercourse. The preservation of bed continuity would limit the effect of this on morphological diversity. 178m of channel would be realigned, but without a change in length, and therefore it would be unlikely to cause change in a straight channel with a low gradient.	**Negligible**
Burnhead Burn	**Depressed Invert Box Culvert** This watercourse is already modified, straightened and locally culverted further upstream. However, the installation of a depressed invert culvert in the proposed location, together with a major realignment, would lead to detrimental impacts on the morphological structure of the watercourse. This could be limited by the continuity of bed material provided by a natural bed in the culvert. **Realignment** This watercourse would be subject to an extensive realignment. Sympathetic watercourse design using hydrological, ecological and geomorphological design principles would limit reductions in morphological diversity and continuing long term alterations to geomorphological processes such as sediment transfer. There could be an opportunity for enhancement at this location.	**Medium**
Blaikiewell Burn	**Bridge** The use of a bridge across the surrounding valley means that disruption to morphological processes and the character of the bed and banks of the burn would be limited.	**Low**

Watercourse	Source of Impact	Residual Impact Magnitude
Kingcausie Burn	**Depressed Invert Box Culvert** The provision of a depressed invert culvert allows the bed to be formed from appropriately sourced natural sediments and ensures that the continuity of sediment transfer is maintained. The existing channel in the location of the proposed culvert possesses a natural character with good morphological diversity, which would be affected as a result of the culvert installation. The loss of this morphologically diverse section of channel is undesirable due to the channel modifications on other parts of the watercourse, the high quality of geomorphology and associated habitats and the proximity of the crossing to Crynoch Burn. **Realignment** The gradient of the burn is locally variable. Therefore, it may be difficult to ensure that changes induced by the realignment (28m reduction in length by straightening) encourages neither scour upstream or downstream, or results in the siltation of the bed. Both these scenarios would require additional management and have further impacts on morphology.	**Medium**
Crynoch Burn	**Impacts caused by Changes to Tributary Streams** The adjustment of tributary channels (Burnhead, Blaikiewell, Kingcausie Burn) to changes initiated by the road scheme may lead to residual impacts on this watercourse. In particular, the readjustment of Kingcausie Burn through erosion and deposition in response to realignment and regrading will require monitoring in order to minimise the risk of sediment inputs to Crynoch Burn.	**Low**
River Dee	**Bridge** The construction of a bridge with no in-channel footings would mean the road would have no direct impact on the River Dee in this location.	**Negligible**
Milltimber Burn	**Depressed Invert Box Culvert and Realignment** As this watercourse is already modified, straightened and locally culverted, the installation of a depressed invert culvert would not lead to detrimental impacts on the sediment regime or morphological structure of this watercourse. Although the length of culverted channel would be greater, the preservation of bed continuity would limit the effect of this on morphological diversity. A short (67m) length of channel would be realigned, but with no change in length, and therefore the realignment would be unlikely to cause change in a straight channel with a low gradient.	**Negligible**
Gairn Burn	**Depressed Invert Box Culvert and Realignment** The provision of a depressed invert culvert would allow the bed to be formed from appropriately sourced natural sediments, and ensures that the continuity of sediment transfer is maintained. The existing channel has a relatively natural character and moderate gradient, which would be increased by the planned realignment (20 m shortening of realigned reach). There is currently good morphological diversity, which could be affected as a result of realignment and culvert installation. The loss of this morphologically diverse section of channel is undesirable due to the channel modifications farther downstream.	**Low**

<u>Construction Phase Impacts</u>

6.6 The residual impacts of the proposed scheme on each watercourse following the application of mitigation measures during construction are outlined below in Table 18. Residual impacts associated with the routing of watercourses into pre-earthworks drainage are outline in the Water Quality Appendix.

Table 18 – Summary of Site Specific Residual Impacts During Construction

Watercourse	Source of Impact	Residual Impact Magnitude
Loirston Burn and Loch	**Four Depressed Invert Box Culverts and Realignments** The channel would be disturbed in four locations. Providing a temporary flow diversions and ensuring that channel works are completed before flow is routed along the watercourse would minimise the risk of temporary increases in sediment supply occurring. Any sediment releases that occur as a result of accidental spillage or failure of mitigation measures would likely be of short duration and would have a negligible impact on this watercourse.	**Negligible**
Burn of Ardoe	**Depressed Invert Box Culvert and Realignment** Providing a temporary flow diversion and ensuring that channel works are completed before flow is routed along the watercourse will minimise the risk of any temporary increase in sediment supply. Any sediment releases that occur as a result of accidental spillage or failure of mitigation measures would likely be of short duration and would have a negligible impact.	**Negligible**
Bishopston Ditch	**Depressed Invert Box Culvert and Realignment** Ensuring that the realignment for culverting does not convey flow prior to the completion of the culverts would limit the impact of construction to a negligible level.	**Negligible**
Heathfield Burn	**Depressed Invert Box Culvert and Realignment** Ensuring that the realignment for culverting does not convey flow prior to the completion of the culverts would limit the impact of construction to a negligible level.	**Negligible**
Whitestone Burn	**Depressed Invert Box Culvert and Realignment** Ensuring that the realignment for culverting does not convey flow prior to the completion of the culverts would limit the impact of construction to a negligible level.	**Negligible**
Burnhead Burn	**Depressed Invert Box Culvert and Realignment** Road construction and culvert installation would require temporary watercourse realignment and ultimately permanent watercourse realignments. This would lead to disturbance along the watercourse corridor, involving vegetation clearance and vehicle movements. This activity would have an impact on the morphology of the watercourse, which is currently diverse compared to other nearby watercourses. Ensuring that no flow is routed along the culverted and realigned section during construction would limit the quantity of fine sediments released.	**Low**
Blaikiewell Burn	**Bridge** The construction of a major bridging structure would have some impact on the surrounding valley, but little on the actual watercourse. Due to the difficult access, steep valley sides and wet ground, the movement of plant during construction would be likely to involve vegetation clearance and ground stabilisation, potentially mobilising sediment; however sediment fencing would prevent this sediment from entering the watercourse.	**Negligible**
Kingcausie Burn	**Depressed Invert Box Culvert and Realignment** Road construction would require culverting and realignment along a long stretch of channel. This would lead to disturbance along the riparian corridor, involving vegetation clearance, tree felling and vehicle movements. This activity would have a particularly significant impact on the morphology of the lower section of the watercourse, which is morphologically diverse (bars, sinuosity, undercutting banks, woody debris) and has local, significant changes in gradient. In addition to the impacts on this diverse section of channel, increases in channel erosion or deposition downstream may result due to channel slope changes. Careful management of these activities is required to minimise the risk to Crynoch Burn, as its confluence is in close proximity to the crossing point.	**Medium**
Crynoch Burn	**Impacts Caused by Works on Tributary Streams** Construction works along tributaries of Crynoch Burn (Burnhead, Blaikiewell, Kingcausie Burn) may lead to residual impacts on this watercourse. In particular, the realignment and regrading of Kingcausie Burn will require the strict application of best practice construction methods and monitoring in order to minimise the risk of inputs of sediment into Crynoch Burn.	**Low**

Watercourse	Source of Impact	Residual Impact Magnitude
River Dee	**Bridge** The construction of a bridge would not involve any in-channel works in this location, which would ensure that the road has no direct impact on the River Dee. The surrounding floodplain sediments are sandy in places, therefore some fine sediment may enter the river during digging/construction.	**Low**
Milltimber Burn	**Depressed Invert Box Culvert and Realignment** Ensuring that the realignment for culverting does not convey flow prior to the completion of the culverts would limit the impact of construction to a negligible level.	**Negligible**
Gairn Burn	**Depressed Invert Box Culvert and Realignment** Road construction and culvert installation would require temporary watercourse realignment and ultimately permanent watercourse realignments. This would lead to some disturbance along the watercourse corridor, involving vegetation clearance and vehicle movements. This activity would have an impact on the morphology of the watercourse, which is natural and has a diverse morphology. Ensuring that no flow is routed along the new course during construction would limit the quantity of fine sediments released.	**Low**

Residual Impact Summary

Table 19 – Residual Impacts for Operation

Watercourse	Magnitude of Impact Without Mitigation	Residual Impact with Mitigation
Loirston Burn and Loch	**Medium**	**Negligible**
Burn of Ardoe	**Low**	**Negligible**
Bishopston Ditch	**Medium**	**Negligible**
Heathfield Burn	**Medium**	**Negligible**
Whitestone Burn	**Medium**	**Negligible**
Burnhead Burn	**High**	**Medium**
Blaikiewell Burn	**High**	**Low**
Kingcausie Burn	**High**	**Medium**
Crynoch Burn	**High**	**Low**
River Dee	**High**	**Negligible**
Milltimber Burn	**Medium**	**Negligible**
Gairn Burn	**Medium**	**Low**

Table 20 – Residual Impacts for Construction

Watercourse	Magnitude of Impact Without Mitigation	Residual Impact with Mitigation
Loirston Burn and Loch	**Medium**	**Negligible**
Burn of Ardoe	**Low**	**Negligible**
Bishopston Ditch	**Low**	**Negligible**
Heathfield Burn	**Low**	**Negligible**
Whitestone Burn	**Medium**	**Negligible**
Burnhead Burn	**High**	**Low**
Blaikiewell Burn	**High**	**Negligible**
Kingcausie Burn	**High**	**Medium**
Crynoch Burn	**High**	**Low**
River Dee	**High**	**Low**
Milltimber Burn	**Medium**	**Negligible**
Gairn Burn	**Medium**	**Low**

7 Summary

7.1 This technical appendix has focused on the degree to which the operation and construction of the AWPR would affect the fluvial geomorphology of the watercourses that would be crossed by the proposed scheme.

7.2 The road would cross watercourses that range in size from small ephemeral watercourses, such as field drains, for example Bishopston Ditch, through to large alluvial rivers, such as the River Dee.

7.3 The baseline geomorphological characteristics of watercourses vary considerably, according to the size of the watercourse, its topography and the degree of anthropogenic modification.

7.4 During operation, impacts would include changes to sediment load (primarily increases in suspended solids), increases in discharge, and changes to channel morphology and fluvial processes as a result of crossing structures (mainly culverts) and realignments. During construction, common impacts are changes to sediment load, vegetation clearance, culvert installation and channel realignment.

7.5 Operational impacts would be long-term (permanent) impacts, while those resulting from construction would be short term (temporary impacts) limited to the period of construction.

7.6 The magnitude of impacts has been determined by comparing the range of potential consequences associated with operation and construction of the road with baseline conditions of each watercourse, primarily its geomorphological status (morphological diversity and range of fluvial processes), and the physical proximity of the watercourse to the proposed road.

7.7 Although fluvial geomorphology does not include any receptors, changes to the fluvial geomorphology have consequences for water quality and ecological receptors and these are considered in Appendix A24.4 and A25.9 respectively.

7.8 The effective implementation of appropriate mitigation measures will limit the impact of the proposed scheme on the fluvial geomorphology of watercourses.

7.9 For the operational phase, settling ponds would be used to treat road drainage by trapping fine sediment, while detention basins would limit the impact of the road on the hydrological regime of watercourses. Crossing structures have been designed to reflect the quality of watercourses with bridges over watercourses exhibiting good morphological diversity while depressed invert culverts are to be utilised where lesser quality watercourses are crossed.

7.10 In a number of instances, watercourse realignments have been included in the design to ensure that the proposed scheme would result in a limited impact at locations where watercourse crossings may otherwise be highly damaging to the fluvial geomorphology and dependant receptors. Channel realignment also provides an opportunity to improve the geomorphological quality of modified watercourses, primarily through improvements in morphological diversity. Such improvements would also be beneficial for the water quality and ecology of watercourses (Appendix A24.4 and A25.9).

7.11 During construction, the application of construction site best practice will limit the potential for sediment release into watercourses. Mitigation measures have also been described to limit the impact of channel works required during culvert installation and watercourse realignment.

7.12 The adoption of these mitigation measures during the design and construction phases will ensure that the road scheme generally has a negligible or low impact on the fluvial geomorphology of most of the affected watercourses. As a result of the extent of the activities proposed for Kingcausie Burn and Burnhead Burn, the assessment of residual impact magnitude is predicted to be medium.

8 References

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9 Glossary

Adjustment	the modification of river channel morphology, both vertically and in platform, through erosion and deposition, which occurs in response to a modification to a channel caused by external factors such as human interference, climate or land use.
Bar	a general term referring to a depositional feature, usually formed of gravel deposited in a river.
Berm	permanent deposits that have developed on the margin of the channel consisting of bench like features which effectively create a two-stage channel.
Boulder	particle of diameter > 256 mm "human head" size and above.
Buffer Strip	an area of land between the river channel and cultivated land that is uncultivated and often fenced off.
Channel Capacity	the volume of water that can be contained within a given section of river channel.
Catchment	the total area of land that drains into any given river.
Channel	the course of a river including the bed and banks.
Clay	particle of diameter < 0.002mm.
Coarse sediment	sediment of grain diameter greater than 2 mm.
Cobble	particle of diameter 64mm to 256mm, approximately "fist" sized.
Competence	the ability of a river to transport sediment. Generally competence will increase as flows and velocities increase.
Continuity	relates to how continuous the flow or sediment transfer is within a particular watercourse. Culverts often break the continuity through promoting deposition.
Conveyance	how water is transported downstream (e.g. volume, speed).
Culvert	artificial structure, often concrete, for carrying water underground or under bridges.
Debris dam	coarse woody debris blocking the channel and causing water to pond back.
Discharge	the volume of water flow per unit time usually expressed in cubic metres per second (m3 s-1)
Dynamic rivers	rivers with high energy levels; which are prone to change their channel characteristics relatively rapidly.
Embankment	artificial flood bank built for flood defence purposes, which can be flush with the channel or set back on the floodplain.
Entrainment	the point at which the sediment is picked up before being transported downstream.
Ephemeral stream	usually low order, water only during and immediately after heavy rainfall.

Erosion	the process by which sediments are mobilised and transported by rivers.
Equilibrium	where erosion and deposition are balanced. This is achieved through morphological adjustment which maintains sediment transport continuity.
EUWater Framework Directive:	Under this Directive, Member States must achieve “good ecological potential” in modified systems and prevent deterioration in the status of surface waters. Ecological status is to be assessed using a number of parameters, including hydromorphological (or fluvial geomorphological and hydrological) quality elements: • Hydrological regime – the quality and connection to groundwater reflect totally or neat totally undisturbed conditions. • River continuity – the continuity of the river is not disturbed by human activities and allows the undisturbed migration of aquatic organisms and sediment transport. • Morphological conditions – channel patterns and dimensions, flow velocities, substrate conditions and the structure and condition of the riparian zone correspond totally or nearly totally to undisturbed conditions. (Source: EU Directive 2000/60/EC – The Water Framework Directive).
Exclusion zone	an area of land beside the river which is out of bounds during construction operations. In the AWPR case, the zone includes the 5 m width from the river bank which forms the SAC and a further 4 m totalling 9 m.
Feedback	the linkage between elements of a system.
Fine sediment	sediment of grain diameter finer than 2 mm.
Flood	a high river flow following rainfall or snowmelt where a river flows out of its channel, sometimes affecting human activity.
Floodplain	area of the valley bottom inundated by water when a river floods.
Flow regime	description of how the flow in a river varies over time and how frequently and for how long high flows (floods) and low flows (during droughts) occur.
Fluvial erosion	erosion carried out by a river, including toe scour and cliff erosion.
Fluvial	the branch of geomorphology that describes the characteristics of river systems and examines the processes sustaining geomorphology them.
Geomorphology	the study of features and processes operating upon the surface of the Earth.
Geotextile	fabric membrane used for bank stabilisation, usually to aid re-vegetation.
Gravel	particle of diameter between 2 mm and 64 mm.
Hydraulic	the force exerted by flowing water.
Hydrological	referring to the flow of water, specfically its routeing and speed.
Incised channel	where the riverbed is well below the floodplain due to downwards erosion (incision).
In-stream	that part of the channel covered by water in normal flow conditions.
Internal controls	controls which are components of the river system such as bed and bank materials, gradient and channel morphology.
Load	the amount of sediment that is being carried by the river.
Meander	a bend in the river formed by natural river processes e.g. erosion and deposition.
Mid-channel bars	gravel or other shallow deposits in the middle of straight sections of watercourse.
Migration	lateral movement of channel across floodplain through bank erosion and deposition.
Modification	channel features that have been created by management interventions and often involve river engineering.
Poaching	trampling by livestock.

Point bar	gravel or other shallow sediment deposition on the inside of bends.
Pool	discrete areas of deep water, typically formed on the outside of meanders.
Reach	a length of an individual river which shows broadly similar physical characteristics.
Realignment	alteration of the planform channel (often by straightening) to speed up flows and reduce flood risk.
Re-naturalising	a formally modified channel that is adjusting to represent a more natural channel in terms of geometry and vegetation.
Reprofiling	reshaping a bank to improve its stability and potential habitat value (usually by reducing the angle of the slope).
Resectioning	alteration of the cross-sectional profile of a channel, often to speed up flows and reduce flood risk.
Riffle	a shallow, fast flowing section of water with a distinctly disturbed surface forming upstream-facing unbroken standing waves, usually over a gravel substrate.
Riparian	land on the side of the river channel.
River corridor	land to either side of the main river channel, including associated floodplain(s),
Rock armour	angular stone placed to protect eroding banks.
Run-off	surface flow after rain which entrains and transports fine sediment from the slope to the channel.
Salmonid	the family of fish species that includes the salmon, trout and char
Sedimentation	the accumulation of sediment (fine or/and coarse) which was formerly being transported.
Scour	erosion caused resulting from hydraulic action.
Side bars	gravel or other shallow deposits along the edges of straight sections of river channels.
Siltation	deposition of fine sediment (comprising mainly silt) on the channel bed often promoting vegetation growth if it is not flushed downstream regularly.
Sink	a deposit of sediment in the channel – the location where sedimentation is occurring.
Sinuous	a channel displaying a meandering course. High sinuosity relates to a channel with many bends over a short distance; low sinuosity is often used to describe a fairly straight channel.
Source	where sediment is supplied to a river channel.
Suspended solids	typically fine sediment which is transported in suspension.
Toe (of the riverbank)	where the riverbed meets the bank.
Turbidity	a density flow of water and sediment (suspended solids).
Two stage channel	a channel containing a bench like feature or features (berms) which create a low flow channel within a wider high flow channel.
Woody Debris	accumulations of woody material derived from trees, usually fragments of the branches, trunk and roots.