Aberdeen Western Peripheral Route

A9.3 - Fluvial Geomorphology

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Contents

1 Introduction

1.1 General Background

1.1.1 This report is a technical appendix of the Water Environment chapter of the Stage 3 Environmental Impact Assessment (EIA) for the Northern Leg of the Aberdeen Western Peripheral Route (AWPR).

1.1.2 This report focuses specifically on the fluvial geomorphological impacts of the proposed scheme on the watercourses crossed by the road during both the construction and operation phase.

1.1.3 The main driving force behind the inclusion of geomorphological assessments in EIA 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 status and sets targets for improvements. Water quality and hydro-morphology (fluvial geomorphology) are characteristics against which ecological status is to be assessed. For high status water bodies the WFD requires that there is no more than very minor human alteration to hydromorphology elements. This includes a consideration of:

- 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; and
- degree to which natural fluvial processes are compromised, that is the channels ability to adjust to changes in the flow and sediment supply is reduced.

1.1.4 Fluvial geomorphology is the study of the landforms associated with river channels and the sediment transport processes which form them. The principal focus of fluvial geomorphology is the relationship between sediment regime – erosion, transport and deposition – and channel morphology (Appendix A9.5; Annex 22). Fluvial processes create a wide range of morphological forms which provide a variety of habitats within and around river channels. As a result, geomorphology is integral to river management.

1.1.5 This geomorphological appraisal focuses on 14 watercourses which are likely to be subject to geomorphological impacts as a result of the operation and construction of the proposed scheme. These watercourses range in size, from small ephemeral field drains to the River Don, a major river that flows into the North Sea. A further five watercourses (Kepplehill Field Ditch, Walton Field Ditch, Craibstone Ditch, Parkhead Burn and Parkhead Ditch) that would be affected by the proposed scheme were not assessed in detail due to their small size, ephemeral hydrological regime and negligible sediment load.

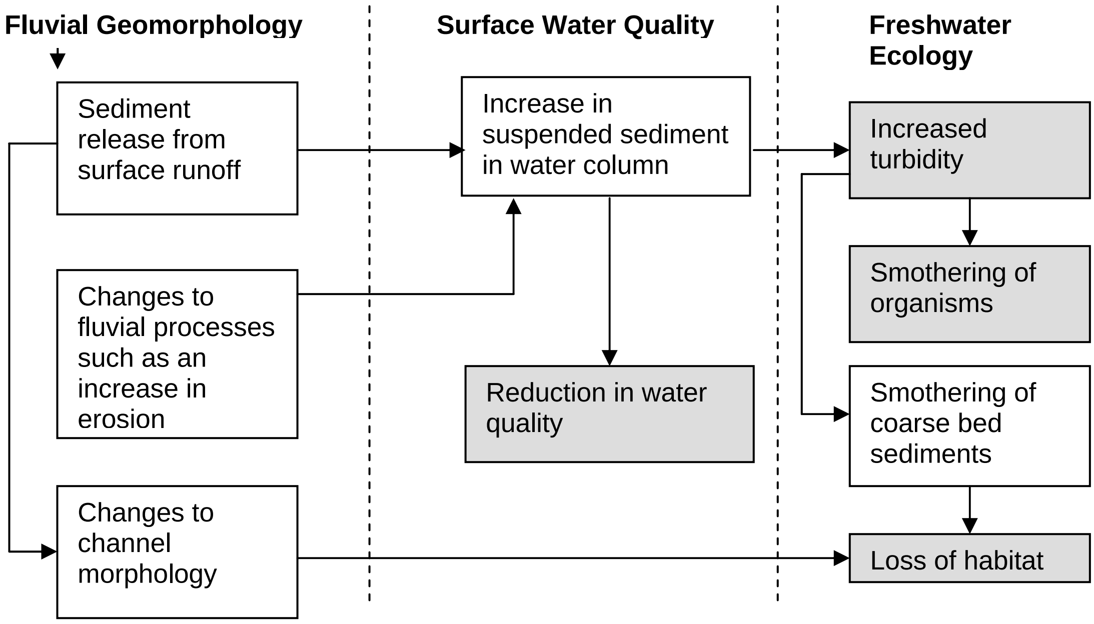

Figure 1.1 – Conceptual diagram illustrating the relationships between impacts on fluvial geomorphology, water quality and ecology. Grey denotes an impact on receptor.

1.1.6 Four main potential impacts on the fluvial geomorphology of the watercourse are anticipated (Figure 1.1), these are:

- Increases in fine sediment delivery to the watercourses with potentially detrimental impacts on sensitive species, this may occur both 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 to the natural functioning of the river channel (natural fluvial processes), for example, prevention of channel migration due to bank protection, bridge pier installation, culverting. Where this interrupts natural fluvial processes this may have consequences both for WFD targets and may also have detrimental effects on habitat diversity.
- Increases in fluvial activity such as bank erosion in response to channel engineering, such as unsympathetic channel realignment. 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.

1.1.7 This report is one of a number of technical reports and chapters used to inform the Water Quality and Freshwater Ecology appendices (A9.4 and A10.16 respectively). For example Appendix A9.1 (Surface Water Hydrology) and Chapter 8 (Geology, Contaminated Land and Groundwater) have provided information for this assessment. The relationship between this assessment and the other related components of the EIA is summarised in Figure 1.2.

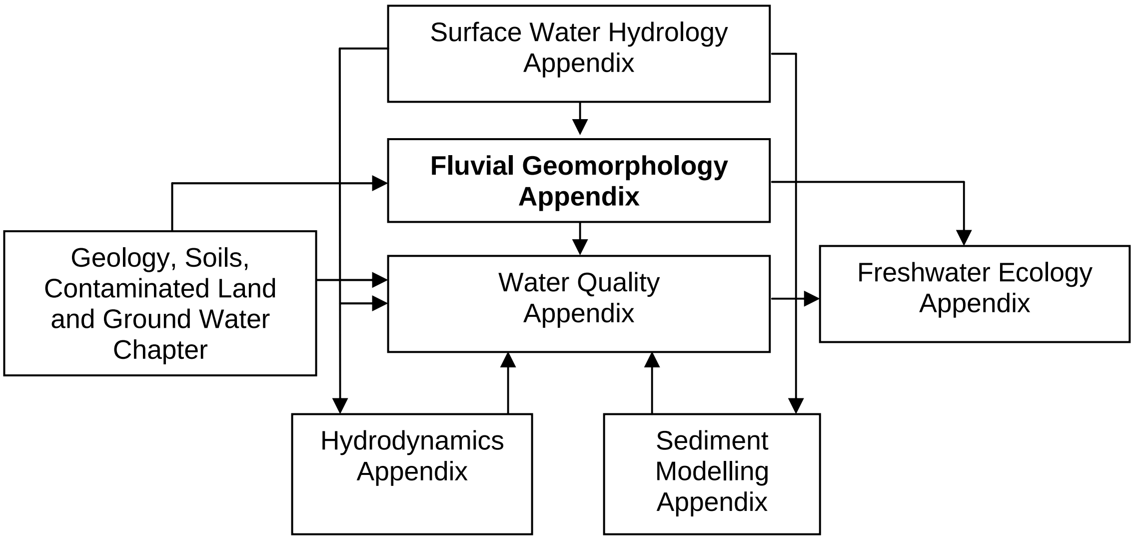

Figure 1.2 – Flow chart illustrating the relationships between the technical appendices and chapters

1.2 Assessment Aims

1.2.1 The overall aim of this chapter is to inform the water quality and ecological chapters about potential geomorphological impacts which affect the receptors considered in the chapters.

1.2.2 Specifically this technical appendix aims to assess the potential impacts of the proposed scheme during both the operation and construction phases and to outline possible mitigation measures that will reduce the impact of the proposed scheme on the fluvial geomorphology of the 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, as a result of the proposed scheme, on specific receptors is considered in the water quality and freshwater ecology appendices (A9.4 and A10.16 respectively).

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

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

1.2.4 In addition to identifying the range of impacts on the watercourses, the 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.

1.2.5 In response to the WFD, The Controlled Activities (Scotland) Regulations 2005 (CAR) have been introduced (hereafter referred to as CAR). The CAR process provides regulatory control, passed by Scottish Parliament on 01 June 2005 (came into force on 01 April 2006). The regulations state that it is an offence to discharge to all wetlands, surface waters and groundwaters without CAR authorisation. There are three different types of authorisation under CAR – General Binding Rules (GBR), Registration and License (both simple and complex). The level of regulation implemented through authorisations increases as the activity poses a progressively deleterious impact on the water environment. The level of authorisation required for the AWPR is dependent on the activity proposed but is likely to range from GBR, covering some construction activities and outfalls, to licences required for outfalls (draining over 1km of road in length), culverting and watercourse realignment. The applications will require baseline environmental information of the watercourse, details of the proposed design and a detailed construction method statement. These would be developed prior to construction and require approval from SEPA before construction can begin. Further information can be found in SEPA (2007), The Water Environment (Controlled Activities) (Scotland) Regulations 2005: A Practical Guide, Version 3.

2 Approach and Methods

2.1 General Approach

2.1.1 This report concentrates on outlining the potential effects of the proposed scheme on the fluvial geomorphology of the watercourses crossed by the proposed road. 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 proposed scheme (Appendix A9.4 and A10.16).

2.1.2 Unlike the other assessments in this ES, impacts have not been considered in terms of sensitivity or significance to lead to an assessment of 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 therefore been evaluated for each watercourse.

2.1.3 The criteria used to assess the vulnerability of watercourses to undergo change as a result of disturbance are outlined in Table 2.1.

Table 2.1 – 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. Includes sites with international and European nature conservation designations due to water dependent ecosystems e.g. Special Protection Area, Special Area of Conservation, Ramsar Site, EU designated freshwater fisheries. 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 re-alignment, 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 very significant where an ecologically sensitive site is located downstream.
Medium	Sediment regime

Vulnerability	Criteria
	A watercourse supporting limited species sensitive to a change in suspended sediment concentrations or turbidity. 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 which may be vulnerable to changes in fluvial processes which is likely to have a limited impact on habitat quality. This also includes watercourses which may be vulnerable to localised change in process rates but which are not located upstream of important ecological sites.
Low	Sediment regime A watercourse which does not support any significant species sensitive to changes in 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.

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

2.1.5 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).

2.1.6 In addition, the requirements of the WFD 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).

2.1.7 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 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). These differing methodologies reflect the trade-off between the spatial scale of an investigation and the level of detail which can be provided.

2.1.8 This study does not fit readily into this existing framework as it requires geomorphological information for a number of different watercourses (14 in total) each with their own catchments (the majority being sub-catchments of the Don). Adopting a whole catchment approach to the analysis of each watercourse would have been prohibitively time consuming due to the total length of watercourse which 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 carriageway) in the vicinity of the proposed scheme for each watercourse.

2.2 Impact Assessment Methodology

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

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

- increases in fine sediment delivery to the watercourses with potentially detrimental impacts on sensitive species, this may occur both during construction and during the operation of the proposed scheme;
- 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 natural functioning of the river channel. For example, prevention of channel migration due to bank protection, bridge pier installation, culverting. This may have consequences both for WFD targets and may also have detrimental effects on habitat diversity. Secondly, an increase in fluvial activity such as bank erosion may occur in response to engineering, for example as a result of unsympathetic channel re-alignment. Bank erosion leads to an increase in sediment delivery which can have a significant impact where sites of ecological importance are located downstream.

2.2.3 The criteria used to assess the magnitude of predicted impacts on watercourse are outlined in Table 2.2.

Table 2.2 – Criteria to Assess the Magnitude of Predicted Impacts on Watercourses

Magnitude	Criteria
High	Major shift away from baseline conditions. **Sediment regime** Major impacts to the river bed over this area due to 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 this area 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 this area 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 or erosion.
Low	Minimal shift away from baseline conditions. **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**

Magnitude	Criteria
	Minimal change in fluvial processes operating in the river; 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 highly localised.

Desk Study

2.2.4 The desk study utilised existing data sources to identify current known geomorphological conditions and trends in river behaviour. The range of data examined during the desk study and information provided during consultation are summarised in Table 2.3.

Table 2.3 – Potential Data Sources Examined During the Desk Study

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 Bore Hole 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, which in conjunction with field investigations, enables the contemporary and past geomorphological processes to be elucidated.
Land Use Data	Land use data provides 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 bank full 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 series of historical maps allows changes in river channel planform to be determined over periods of up to 150 years. This 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 insight into the impact of changes in flood frequent and magnitude.
Existing Topographic Survey (where available)	Cross-sectional survey provides useful information about channel structure, such as 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 dominant function 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 will be conducted along the River Don and is described in Appendix A9.5 Annex 28.

Data Source	Information Provided
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 A10.16).
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

2.2.5 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 range of geomorphological information collected during the field study is summarised in Table 2.4. This field survey was undertaken in May and June 2005.

Table 2.4 – Information to be Obtained During the 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 to be made.
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 determined.
Space for Time Substitution	This involves examining neighbouring watercourses, with similar geomorphological characteristics, which were subject to past modification such as re-alignment. This will enable the vulnerability of watercourses to modification to be determined and the likely morphological response predicted.

2.2.6 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 determining the impacts of both construction and operation of the proposed scheme.

<u>Additional Study</u>

Red Moss Burn

2.2.7 Due to the proximity of this watercourse to the Corby Loch (forms part of a SSSI) an additional geomorphological assessment was conducted to inform the CAR application process and enable detailed site specific mitigation measures to be developed. The studies combined a Fluvial Audit and a Substrate Mobility Assessment. The site survey was undertaken in August 2006.

2.2.8 The Fluvial Audit combined an additional desk study to that already undertaken to review the land use in the catchment and the hydrology of the watercourse and additional catchment-wide site survey designed to record the sediment sources (erosion) and sinks (deposits).

2.2.9 This assessment was used to determine mobility of the bed sediments along the watercourse. The method involved extracting four bed sediment samples from the Burn during the field survey. The samples were then analysed to determine the particle size distribution of the sediments in each sample (grading) by wet sieving. The likelihood of sediment mobilisation and transport downstream was assessed by using a bed load transport equation to determine the maximum sediment transport rate per unit width for a given grain size (usually D_{50}) at a range of discharges (derived from Flood Estimation Handbook (FEH) calculations (Institute of Hydrology, 1999). This assessment enabled the size of sediments to bed placed in the culvert invert to be determined. Further details of this assessment will be provided to SEPA as part of the Red Moss Burn CAR application.

2.3 Limitations to Assessment

2.3.1 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. However, a separate mathematical model was constructed to examine the potential impact of construction operations of the River Don mainline approach roads, where more data was available; this is described in Appendix A9.2 (Hydrodynamic Modelling).

2.3.2 The paucity of historical data (flow variation, channel morphology measurements, sediment concentrations in flow) and archive maps for many of the watercourses means 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.

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

2.3.4 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 there is less vegetation, the signs of bank erosion are more readily detectible.

2.3.5 The upstream and downstream boundaries were determined by the time (and therefore money) available for field work and access constraints. The extent of field survey varied according to these constraints, however all site investigations considered the channel upstream and downstream of the proposed road over a distance varying from 200m to 1km. The distance of survey was proportional to the size of the watercourse.

2.3.6 Detailed construction information will not be available until contractors have been selected and confirmed a programme of works (e.g. location of temporary access roads, timing of construction etc). Construction impacts are therefore based on estimated activities as described in Chapter 4 of the ES (The Proposed Scheme) and Appendix A4.1 (Typical Construction Methods).

3 Baseline

3.1.1 A brief description of each watercourse is provided below. Additional information about the channel dimensions, substrate, modifications, gradient, geology and ground conditions are provided in Appendix A9.5 (Annex 23). In addition photographs of each watercourse are provided in Appendix A9.5 (Annex 24).

3.1.2 The baseline conditions are used to assign a level of vulnerability to the watercourse (Table 2.1). A low vulnerability implies a relatively low quality watercourse and one that will be relatively unresponsive to potential impacts, that is, a very limited change to baseline will occur. A high vulnerability watercourse indicates good quality (in terms of sediment regime, channel morphology and natural fluvial processes) and one that would be very vulnerable to change and a major change in baseline conditions may occur.

Kepplehill Burn

3.1.3 This watercourse resembles a shallow vegetated field drain. The channel is straight and there is little morphological diversity and the banks are occasionally walled. The bed consists predominantly of coarse gravel although silt lies on the bed where the flow is inadequate. In some locations cattle poaching leads to an increase in fine sediment load. Water seepage from the surrounding slope indicates that the water table is high.

3.1.4 The highly modified nature of the channel and low morphological quality means that the vulnerability of this watercourse is low.

Gough Burn

3.1.5 Gough Burn is a cobble/gravel bed channel with pockets of fine sediments (mainly sand) probably originating from bank erosion upstream. Flow is highly varied. Pools and riffles with protruding boulders and gravel bars provide good morphological diversity. The river corridor is wooded with trees along the channel margins with promote bank stability, although some localised undercutting is evident. The ground vegetation is relatively thin and surface runoff leads to fine sediment supply to the watercourse. Presently, road drainage directly enters the burn supplying fine sediment.

3.1.6 Both upstream and downstream of the proposed road crossing, the watercourse has been modified through straightening and walling. This means that in the context of its small catchment this section of the Gough Burn is an important morphologically diverse section of watercourse.

3.1.7 The presence of road runoff limits the vulnerability of the sediment regime to medium. However, the high morphological diversity and range of natural fluvial processes at the proposed crossing point means each of these elements are highly vulnerable to disturbance. The overall vulnerability of the watercourse is high.

Craibstone Burn

3.1.8 The channel is relatively steep and located in a wooded valley. The channel is predominantly natural with occasional walls and exhibits a highly sinuous course. The channel bed is cobble gravel and together with protruding boulders and the woody debris create a morphologically diverse stream. There are some accumulations of fines and these are likely to have been sourced from the arable land in the vicinity. The banks are stable but locally undercut. Downstream of the proposed road the gradient is lower but the incised channel is of similar size and character to that upstream. The lower reaches towards the River Don display more modification (straightening and walling).

3.1.9 Both upstream and downstream of the proposed road crossing the watercourse has been modified through straightening and walling. This means that in the context of its small catchment this section of the Craibstone Burn is an important morphologically diverse section of watercourse.

3.1.10 The presence of fine sediment on the riverbed, which appears to be sourced from surrounding fields, and the presence of occasional channel modifications means the vulnerability of the sediment regime and fluvial processes is medium. In spite of this, high morphological diversity of the channel means this watercourse is highly vulnerable to disturbance.

Green Burn

3.1.11 Green Burn has been historically straightened. The banks are well vegetated or walled so erosion is limited. Locally embankments are present along the channel and these disconnect the channel from the floodplain. The cobble gravel bed is covered by fine sediment due to the low gradient. Downstream of the road bridge the channel is more confined and exhibits a lower gradient and lower morphological diversity. The made ground on the left bank is a source of coarse material.

3.1.12 The extensive modification of the channel means the vulnerability of the channel morphology and associated fluvial processes to disturbance are both low. However, the channel is of relatively low gradient and therefore an increase in sediment loading as a result of disturbance may lead to detrimental increases in channel siltation, although this will not lead to a drastic reduction in the quality of the watercourse. The sediment regime is therefore of medium vulnerability and the overall vulnerability of this watercourse is medium.

Howemoss Burn

3.1.13 Howemoss Burn is a small watercourse that flows between fields towards the Kirkhill Industrial Estate. In the location of the proposed road the watercourse has been historically straightened and over deepened.

3.1.14 The highly modified nature of the channel and low morphological quality means that the vulnerability of this watercourse is low.

Bogenjoss Burn

3.1.15 The upper Bogenjoss (proposed upper crossing) is a narrow low sinuosity, medium gradient stream located along the margins of a coniferous forest. The ground is uneven and boggy (waterlogged) and the channel banks are peaty. The bed comprises fine gravel and sand with occasional moss covered boulders. The flow velocity is varied displaying glides and some small step-pool sequences.

3.1.16 The lower section of Bogenjoss affected by the proposed scheme is a medium-high gradient, high sinuous stream set within a wooded shallow ‘v’ shaped valley. The channel displays natural processes and features and has a good morphological diversity. Step-pool features are abundant due to the relatively high gradient and protrusion of boulders and woody debris in the channel. The bed consists mainly of cobble/gravels although pockets of sand are also present. The banks comprise cobbles and boulders in a fine matrix and although bank erosion is evident the channel is laterally stable. The channel is free to adjust laterally and vertically to changes in flow as it is not constrained or modified in any way.

3.1.17 The high quality of the lower section of the Bogenjoss Burn and its proximity to the River Don means that each geomorphological element is highly vulnerable to disturbance, giving the watercourse a high overall vulnerability.

River Don

3.1.18 The river is a clean, fast flowing cobble-bed river with high morphologically diversity. Riffles and pools are present and marginal emergent and submerged channel vegetation is common. The floodplain is well connected to the channel, which is inundated during floods.

3.1.19 The high geomorphological and ecological quality of the River Don means it is highly vulnerable to disturbance.

Goval Burn

3.1.20 Goval Burn has been realigned and deepened in the past but has subsequently re-naturalised. Channel walling is still present in parts but bank vegetation and channel vegetation is well established. The channel bed comprises cobbles and gravels and exhibits good morphological diversity. The floodplain is connected to the channel along most of its upper length but embankments and over-deepening prevent floodplain inundation downstream. The bank face and top support vegetation. There is localised erosion and deposition. Downstream towards the confluence of the River Don, the flow diversity is reduced.

3.1.21 Despite historic modification to Goval Burn, the watercourse has good morphological diversity, which will be adversely affected by changes in the sediment regime and natural fluvial processes. As a result the watercourse is highly vulnerable to disturbance.

Mill Lade

3.1.22 This artificial watercourse was constructed to transfer water from a reservoir, located on Goval Burn upstream, to the town of Dyce. The channel is straight and the bed and banks are predominantly artificial. The gradient of the Lade is low, and slow deep flow is observed upstream of the road and sluice gate. Downstream, the channel is much narrower and there is no perceptible flow and vegetation has colonised the channel. There is no flow variation and morphological diversity is very poor.

3.1.23 As the Mill Lade is an entirely artificial channel it has a low geomorphological vulnerability to change.

Corsehill Burn

3.1.24 The Corsehill Burn has been historically straightened and realigned to follow field boundaries. The width and depth of the channel is fairly consistent along the upper reach, then narrows and deepens downstream. The bed is cobble/gravel with few fines and the flow is varied despite the relatively low gradient. The banks are walled but the face is vegetated and there is a riparian buffer strip. In the lower reach, the channel is perched above the field on the right hand side. The adjacent land use is a mixture of grazing and arable. A number of field drain pipes enter the channel.

3.1.25 As the channel has been subject to significant past modification both the morphological diversity and fluvial processes operating along the watercourse are of low vulnerability. However, as this watercourse joins the Goval Burn, which is of high vulnerability, changes to the sediment regime, which can be transmitted downstream, may have some impact on the Goval Burn. This means the vulnerability of the sediment regime is medium, as is the overall vulnerability of the watercourse.

Red Moss Burn

3.1.26 The stream drains an area of waterlogged ground which is very peaty. The channel is straight and over-deepened with limited morphological diversity. The channel is vegetated due to the low gradient and the deposition of silt. Corby Loch located approximately 200 metres downstream of the proposed crossing point is designated as a SSSI. The sediment regime of the burn is an important control on the quality of the marsh habitat at the lake inlet.

3.1.27 The vulnerability of the sediment regime is medium, while the low morphological diversity and walled nature of the channel means the channel morphology and natural fluvial processes are of low vulnerability. The overall vulnerability of the watercourse is medium.

Blackdog Burn and Ditch

3.1.28 The Blackdog Burn is a narrow gravel-bed stream which has been subjected to past modification including localised channel straightening, walling and deepening. The watercourse is narrow and well vegetated. Flow is generally uniform owing to low morphological diversity. The channel is culverted where it flows under the existing alignment of the A90. Blackdog ditch is a very small tributary of this burn.

3.1.29 The highly modified nature of these channels and low morphological quality means that the vulnerability of these watercourses is low.

Middlefield Ditch

3.1.30 Middlefield ditch is straight, narrow and deep and takes road drainage from the A90. Other modifications include a culvert. The watercourse is densely vegetated, both in the channel and on the banks. The channel substrate is predominantly fine gravel, with pockets of fine sediment and flow is minimal.

3.1.31 The highly modified nature of the channel and low morphological quality means that the vulnerability of this watercourse is low.

Summary

3.1.32 Table 3.1 outlines the vulnerability assigned on the basis of the baseline conditions for each of the watercourses.

Table 3.1 – Summary of the Vulnerability of Watercourses to Disturbance.

Watercourse	Sediment Regime	Channel Morphology	Natural Fluvial Processes	Overall vulnerability
Kepplehill Burn	Low	Low	Low	Low
Gough Burn	Medium	High	High	High
Craibstone Burn	Medium	High	Medium	High
Green Burn	Medium	Low	Low	Medium
Howemoss Burn	Low	Low	Low	Low
Bogenjoss Burn	High	High	High	High
River Don	High	High	High	High
Mill Lade	Low	Low	Low	Low
Goval Burn	High	High	High	High
Corsehill Burn	Medium	Low	Low	Medium
Red Moss Burn	Medium	Low	Low	Medium
Blackdog Burn	Low	Low	Low	Low
Blackdog Ditch	Low	Low	Low	Low
Middlefield Ditch	Low	Low	Low	Low

4 Potential Impacts

4.1 Generic Impacts

4.1.1 There would be a number of generic impacts associated with the proposed scheme which would affect all the watercourses. These are divided into operation impacts and construction impacts. The operation impacts are those that are long-term and would influence the watercourses after the proposed scheme is complete. The construction impacts are shorter-term and would affect the watercourse during the construction phase.

4.1.2 The potential impact assessment for the operation and construction phase is presented with the assumption of no mitigation. Residual impacts taking into account proposed mitigation are provided in Section 6.

4.1.3 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 2.2.

4.1.4 The impacts are predominantly direct impacts. Those that are indirect include increased discharge and realignment within the operation impacts. This is discussed further in Chapter 9 and Appendices A9.1 (Surface Water Hydrology) and A9.4 (Water Quality).

Operational Impacts

4.1.5 Table 4.1 outlines potential generic effects on the geomorphology during the operation of the proposed scheme.

Table 4.1 – Potential Impacts on Geomorphology during Operation

Source of Impact	Potential Effect
Suspended Solids Direct Impact Increased fine sediment supply from road runoff. The actual volume of sediment generated by the operation of the proposed scheme will vary between watercourse depending on the length of road from which runoff will be directed into the through drains watercourse.	**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. This may increase the activity of geomorphological processes within the channel and also increase flood risk. Flood risk will also be increased where embankments constructed across floodplains or where crossing structures constrict the channel, reducing flow conveyance. In both cases flood risk increased by backing-up.	**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 is likely to 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 will 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.
Culverts Direct Impact Many of the watercourse crossings are likely to involve culverting the watercourse. This section assumes a culvert sized to convey a range of flows will be installed level with the existing watercourse bed, effectively providing artificial bed and banks. Figures 9.4a-g.	**Sediment Regime** The 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 is likely to reduce stream powers leading to sedimentation within the culvert, reducing capacity. This may increase both 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 the culvert is greatly reduced due to artificial bed and banks. Interruption of morphological continuity will also segment the watercourse. **Natural Fluvial Processes** Culverts will 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.

Source of Impact	Potential Effect
Realignments Indirect Impact The proposed road alignment may result in the diversion (realignment) of watercourses. This may lead to a change in the geomorphological behaviour of the watercourse over time. This represents an indirect impact of the proposed scheme. Figures 9.4a-g.	**Sediment Regime** A major change in sediment regime may occur. A new course may result in a change in sediment supply, rate of sediment transfer downstream and deposition zones. Changes in boundary materials through realignment to more erodable types are likely to increase the volume of sediment supplied to the channel. Increases in channel gradient as a result of realignment will 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, is 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 which can lead to a reduction in channel stability, increasing lateral migration for example. An increase in the rate of channel processes may lead to an increase in morphological quality; however sediment transfer downstream may have negative consequences.
Outfalls Direct Impact Road drainage outfalls will be required on many of the watercourses. In addition to contributing sediment to the watercourse from road runoff (discussed above) the outfall structures themselves may also be vulnerable to scour from flow in the watercourse into which they discharge.	**Sediment Regime** Scour around outfalls will lead to local increases in sediment supply to the watercourse. The magnitude of this is likely to be limited and would be proportional to the size of the watercourse. **Channel Morphology** Scour around outfalls will lead to localised changes in channel morphology. **Natural Fluvial Processes** Outfalls provide fixed points along river banks which can alter fluvial process through increases in scour or changes in rates of bank erosion. In addition, where erosion around an outfall causes the structure to project into the river channel they may lead to localised alterations to flow and patterns of sediment deposition. These impacts are likely to be highly localised and proportional to the size of the watercourse.

Construction Impacts

4.1.6 The impacts (and potential effects) during the construction phase would be similar to those of the operation phase except they are short-term and generally more intense. There are a higher number of sources of impacts relating to suspended solids, and include runoff from plant and vehicle washing, excavations, blasting and excavation of road drains. Vegetation near the watercourse will also have to be cleared for construction works which will influence bank stability.

4.1.7 The magnitude of impact is dependent on the schedule of works. The scale of excavations and need for blasting will be site specific. Blasting for example is only likely to be used near Bogenjoss Burn. A Blasting Assessment is provided as Appendix A8.2 of the ES.

4.1.8 In addition, weather conditions will also influence the severity of impacts. The majority of the impacts would be worsened if there are intense or prolonged rainfall events during the construction phase.

4.1.9 Table 4.2 outlines potential generic impacts on the geomorphology during the construction of the proposed scheme.

Table 4.2– Potential Impacts on Geomorphology during the Construction Phase

Source of Impact	Potential Effect
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 likely. The ecology of gravel bed rivers will also be severely affected. **Natural Fluvial Processes** Loss of dynamic activity due to 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 will 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 likely. 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 The majority of the watercourse crossings will involve culverting. Culvert installation will cause major disturbance to the river bed.	**Sediment Regime** Installation will 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, 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 will occur during cutting a new course. A subsequent increase in channel erosion is likely if the channel is straightened and gradient increased. **Channel Morphology** Bedforms that have developed over a long period of time may be disturbed. The new channel will lack morphological diversity. **Natural Fluvial Processes** Channel instability may be induced due to the new course. Fluvial processes are likely to be exacerbated by realignment, especially in high flows.
Outfalls Direct Impact The construction of outfalls within the banks of watercourses may lead to sediment release.	**Sediment Regime** Installation could increase the volume of sediment directly entering the channel and consequently cause an increase in turbidity. **Channel Morphology** Construction activities may lead to localised modifications to the channel morphology although this is likely to be highly site specific. **Natural Fluvial Processes** The stability of the river banks may be reduced during installation leading to the potential for higher rates of erosion. This is likely to be highly site specific.

4.2 Site Specific Impacts

Operation Impacts

4.2.1 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.

4.2.2 Table 4.3 describes the potential impacts in more detail with specific reference to the individual watercourse.

Table 4.3 – Summary of Site Specific Impacts during Operation.

Watercourse	Potential Effect of Impact	Magnitude of Impact
Kepplehill Burn	**Release of Suspended Solids** n/a as no direct drainage outfall is proposed to this watercourse.	n/a
	Increased Discharge n/a as no direct drainage outfall is proposed to this watercourse.	n/a
	Culvert A long culvert will disrupt the bed morphology. As the channel has previously been walled and straightened this will not represent an adverse change in the geomorphology of the watercourse. In order to ensure satisfactory flow conveyance through the new culvert it may be necessary to alter the channel gradient. This will result in a change in stream power. Where this increases, scour and erosion may increase both within and immediately downstream from the culvert. Conversely where stream power is reduced there may be an increase in the potential for siltation within the culvert.	Low
	Realignment In order to install the culvert the channel will need to be realigned. Channel length would be maintained so there would be no change to the gradient. Therefore, there would be little impact on the watercourse.	Low
Gough Burn	**Release of Suspended Solids** n/a as no direct drainage outfall is proposed to this watercourse.	n/a
	Increased Discharge n/a as no direct drainage outfall is proposed to this watercourse.	n/a
	Two Culverts Culverting will interrupt sediment transfer and significantly alter the channel morphology. Indeed the channel morphology downstream of this existing minor road culvert is extremely good and given the extent of channel modifications elsewhere in the catchment this should be conserved. The loss of morphologically diverse channels in this area is extremely undesirable due to the widespread occurrence of highly modified channels in this area.	High
	Realignment Due to its current form the channel would need to be realigned, reducing channel sinuosity and length. Channel gradient would be increased, causing stream power to rise and thereby increasing the potential for channel erosion/channel instability and, increasing the volume of sediment transferred downstream. The realignment may also lead to decline in the morphological quality of the watercourse.	High
Craibstone Burn	**Release of Suspended Solids** n/a as no direct drainage outfall is proposed to this watercourse.	n/a
	Increased Discharge n/a as no direct drainage outfall is proposed to this watercourse.	n/a
	Culvert A long culvert under the main carriageway and adjoining access road with an artificial bed will reduce the bed morphology with associated detrimental impacts on the channel ecology. In addition, routing the channel through a culvert will lead to a reduction in channel sinuosity, which will add to the reduction in morphological quality, and also lead to	High

Watercourse	Potential Effect of Impact	Magnitude of Impact
	an increase in gradient and an associated rise in stream power which may lead to erosion (scour) downstream. The loss of morphologically diverse channels in this area is extremely undesirable due to the widespread occurrence of highly modified channels in this area.	
	Realignment Due to its current form the channel would need to be realigned, reducing channel sinuosity and length. Channel gradient would be increased, causing stream power to rise and thereby increasing the potential for channel erosion/channel instability and, increasing the volume of sediment transferred downstream. The realignment may also lead to decline in the morphological quality of the watercourse.	High
Green Burn	**Release of Suspended Solids** Due to the low gradient, fine material will accumulate on the bed and potentially lead to channel siltation, leading to a lack of morphological diversity.	Medium
	Increased Discharge The channel is walled so bank erosion will be limited, but an increase in discharge or flashiness may lead to a greater risk of flooding.	Medium
	Three Culverts It will be necessary to install three culverts. This will reduce the morphological diversity of the river channel. However as this channel is already highly modified this will be of low magnitude.	Low
	Realignment The channel will need to be extensively realigned. This realignment would lead to a minor change in channel length, resulting in a medium impact on channel morphology.	Medium
	Outfall Potential sediment release as a result of scour around the outfalls may lead to an increase in sedimentation further downstream, which could cause a reduction in morphological diversity. As the watercourse has a low gradient, any sediment supplied is likely to accumulate on the bed. However, the low gradient of the channel means that flow energy is unlikely to be sufficient to lead to significant scour around the outfall. The past modification to this watercourse means that there will be a limited impact on the morphology.	Low
Howemoss Burn	**Release of Suspended Solids** n/a as no direct drainage outfall is proposed to this watercourse.	n/a
	Increased Discharge No direct drainage outfall is proposed to this watercourse. However, the hydrological regime of the catchment is affected by the road (Appendix A9.1) Given the small size of the watercourse, and the previous modification, this is not expected to have an impact on the geomorphology of the watercourse. As such, this watercourse is not considered further in this Appendix.	n/a
	Culvert n/a	n/a
	Realignment n/a	n/a

Watercourse	Potential Effect of Impact	Magnitude of Impact
Bogenjoss Burn	**Release of Suspended Solids** An increase in fine sediment may lead to channel siltation in the narrow, and relatively low gradient, section of channel at the upper crossing point. At the downstream crossing point, fine sediment will accumulate on the bed and have serious implications on the morphology and aquatic life.	High
	Increased Discharge Higher flows will promote fluvial activity in the form of channel incision, bank erosion and sediment entrainment and transport downstream to the River Don.	High
	Six Culverts Culverting will lead to an artificial bed at crossing point, disrupting channel bed morphology and fish migration (especially at the downstream location). Channel instability is likely if the high gradient and high sinuosity channel is culverted. The loss of morphologically diverse channels in this area is extremely undesirable due to the widespread occurrence of highly modified channels in this area.	High
	Realignment Extensive re-alignment of the burn would involve significant alterations and the gradient of the watercourse will lead to changes in stream power with impacts on sediment transfer. A reduction in channel length would cause an increase in channel gradient which would increase stream power and erosion. This would lead to an increase in the volume of sediment transported by the watercourse and may lead to increased sedimentation downstream, which could reduce morphological diversity.	High
	Outfall The locally high gradient of this watercourse would lead to high flow velocities which may lead to scour around the outfall structure. This could potentially lead to an increase in the rate of bank erosion. This sediment release would increase the potential for downstream sedimentation which may cause some reduction in morphological diversity through the smothering the gravel bed with fine sediment.	High
River Don	**Release of Suspended Solids** Fine sediment will be mainly sourced to the Don by the tributaries. Some fine material will settle out before reaching the river due to the wide buffer zone, but this will be more effective in the summer than the winter. Road drainage is also likely to deliver fine sediment to the River Don. An increase in turbidity (high sediment loading) will have an adverse impact on bed morphology.	High
	Increased Discharge Limited impact due to the size of the river.	High
	Culvert n/a - bridge will be constructed.	n/a
	Realignment n/a	
	Outfall The large size of this river and associated high discharges would be likely to encourage scour around the outfall structure and potentially lead to an increase in the rate of bank erosion. This sediment release would increase the potential for localised sedimentation further downstream which may cause some reduction in morphological diversity by the smothering of the gravel bed with fine sediment. Should significant bank retreat occur as a result of scour around the outfall structure, leading it to project out into the channel, then localised changes in flow patterns and sediment deposition may also occur.	High

Watercourse	Potential Effect of Impact	Magnitude of Impact
Goval Burn	**Release of Suspended Solids** An increase in fine sediment supplied from within the burn or tributaries such as Mill Lade will have a detrimental effect as deposition will damage the bed morphology by blocking the voids and reducing the opportunities for spawning fish.	High
	Increased Discharge This may increase the rate of fluvial processes, exacerbating bank erosion. This could cause detrimental changes in channel morphology as a result of this erosion and also due to deposition of the sediment released by erosion.	High
	Culverts n/a - bridges will be constructed.	n/a
	Realignment n/a - bridges will be constructed.	n/a
	Outfall Potential sediment release as a result of scour around the outfalls may lead to an increase in sedimentation further downstream which could cause a reduction in morphological diversity.	High
Mill Lade	**Release of Suspended Solids** Sediment will accumulate on the bed of this low gradient, artificial channel. The high sediment loaded flow will have a more serious impact on the Goval Burn (below).	Low
	Increased Discharge An increase in discharge will have minimal impact in terms of erosion because of the predominantly walled channel; however flooding may be an issue.	Medium
	Culvert n/a as bridge and replacement aqueduct will be constructed.	n/a
	Realignment n/a	n/a
Corsehill Burn	**Release of Suspended Solids** Fine sediment is likely to accumulate on the bed of the channel, especially behind obstacles such as boulders which are evident in the channel.	Medium
	Increased Discharge Increased discharge may cause lateral erosion and incision although this will be limited by the presence of walls and bed armour.	Low
	Three Culverts As the channel is already straightened and walled the construction of a culvert is unlikely to have a significant impact on the overall quality of the channel. However, the presence of an artificial bed will lower morphological quality with detrimental impacts on the channel ecology, particularly fish.	Medium

Watercourse	Potential Effect of Impact	Magnitude of Impact
	Realignment As the existing channel is walled currently bank erosion rates are low. However the new channel will be excavated into less resistant drift deposits. The new channel may therefore experience higher erosion rates than the existing channel leading to a decrease in water quality and a reduction in channel morphology downstream. A realignment of the channel is also likely to alter its gradient and as a result stream power. An increase in channel length would reduce stream power which may cause an increase in the potential for siltation, causing an impact on channel morphology.	Medium
	Outfall Potential sediment release as a result of scour around the outfalls may lead to an increase in sedimentation further downstream which could cause a reduction in morphological diversity.	Medium
Red Moss Burn	**Release of Suspended Solids** An increase in fine sediment will both exacerbate the current problem of siltation and lead to a vegetation choked channel.	Medium
	Increased Discharge An increase in bank erosion will be limited as the channel is walled.	Low
	Culvert A culvert currently exists upstream of the proposed crossing. A long culvert will be required which will affect the river continuity and bed morphology. In order to ensure satisfactory flow conveyance through the new culvert it may be necessary to alter the channel gradient. This will result in a change in stream power. Where this increases, scour and erosion may increase both within and immediately downstream from the culvert. Conversely where stream power is reduced there may be an increase in the potential for siltation within the culvert.	Low
	Realignment The channel will need to be realigned in order to route it through the culvert. As the watercourse has previously been realigned and is highly modified, this will not represent a significant change to natural processes or lead to an appreciable reduction in morphological diversity.	Low
	Outfall Potential sediment release as a result of scour around the outfalls may lead to an increase in sedimentation further downstream which could cause a reduction in morphological diversity. An increase in sedimentation is likely to affect Corby Loch which forms part of a SSSI downstream of Red Moss Burn.	High
Blackdog Burn	**Release of Suspended Solids** Due to the low gradient fine material will accumulate on the bed and potentially lead to channel siltation, leading to a lack of morphological diversity.	Medium
	Increased Discharge The channel is walled so bank erosion will be limited, but an increase in discharge or flashiness may lead to a greater risk of flooding.	Low
	Two Culverts Two culverts are required, and potential impacts may include sedimentation and reduced capacity and consequent flood risk. As the watercourse is already culverted under the A90 and has been extensively realigned (straightened) culverting will lead to relatively limited reductions in morphological quality. In order to ensure satisfactory flow conveyance through the new culverts it may be necessary to alter the channel gradient. This will result in a change in stream power. Where this increases, scour and erosion may increase both within and immediately downstream from the culvert. Conversely where stream power is reduced there may be an increase in the potential for siltation within the culvert.	Low

Watercourse	Potential Effect of Impact	Magnitude of Impact
	Realignment Channel will need to be realigned in two locations in order to route it through the culverts under the mainline of the route and the slip road at Blackdog. As the watercourse has previously been realigned and is highly modified, this will not represent a significant change to natural processes or lead to an appreciable reduction in morphological diversity.	Low
	Two Outfalls Potential sediment release as a result of scour around the outfalls may lead to an increase in sedimentation further downstream which could cause a reduction in morphological diversity. However, the low morphological diversity and the highly modified nature of the watercourse mean that there will be little impact on the morphology.	Low
Blackdog Ditch	**Release of Suspended Solids** n/a as no direct drainage outfall is proposed to this watercourse.	n/a
	Increased Discharge n/a as no direct drainage outfall is proposed to this watercourse.	n/a
	Culvert One culvert is required, and potential impacts may include sedimentation and reduced capacity and consequent flood risk.	Low
	Realignment The channel will need to be realigned in order to route it through the culvert. As the watercourse has previously been realigned and is highly modified, this will not represent a significant change to natural processes or lead to an appreciable reduction in morphological diversity.	Low
Middlefield Burn	**Release of Suspended Solids** Due to the low gradient of the channel it is likely that fine material will accumulate on the bed and potentially lead to channel siltation, reducing morphological diversity. As the channel has a relatively limited morphological diversity at present this is unlikely to lead to an appreciable decline in the quality of the watercourse.	Medium
	Increased Discharge The channel is walled so bank erosion will be limited, but an increase in discharge or flashiness may lead to a greater risk of flooding.	Low
	Three Culverts Three culverts are required, and potential impacts may include sedimentation and reduced capacity and consequent flood risk. As the watercourse is already culverted under the A90 and has been extensively realigned (straightened) culverting will lead to relatively limited reductions in morphological quality. In order to ensure satisfactory flow conveyance through the new culverts it may be necessary to alter the channel gradient, resulting in a change in stream power. Where this increases, scour and erosion may increase within and immediately downstream from the culvert. Conversely where stream power is reduced there may be an increase in siltation potential within the culvert.	Low
	Realignment The channel will need to be realigned in order to route it through the new culverts. As the watercourse has previously been realigned and is highly modified, this will not represent a significant change to natural processes or lead to an appreciable reduction in morphological diversity.	Low
	Outfall Potential sediment release as a result of scour around the outfalls may lead to an increase in sedimentation further downstream which could cause a reduction in morphological diversity. However, the low morphological diversity and the highly modified nature of the watercourse mean that there would be a limited impact on the watercourse from outfalls.	Low

Construction Impacts

4.2.3 The impacts of road construction on each watercourse would arise from four key changes: the release of suspended sediments, vegetation clearance, culvert installation and watercourse 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.

4.2.4 Table 4.4 outlines the potential impacts of the construction of the proposed scheme on the watercourses.

Table 4.4– Summary of Site Specific Impacts during Construction

Watercourse	Potential Effect of Impact	Magnitude of Impact
Kepplehill Burn	**Release of Suspended Solids** Major construction works will provide a high sediment supply which may enter the channel. Downstream, sedimentation will lead to reductions in morphological quality.	Medium
	Vegetation Clearance The gorse and shrubs alongside the channel provide bank stability and filter surface runoff trapping fine sediment. If this vegetation is removed, more sediment is likely to enter the channel directly.	Medium
	Culvert Installation A relatively long length of channel will be disturbed to install the culvert.	Medium
	Realignment Excavating both the new course and temporary realignment will lead to a temporarily 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.	Medium
Gough Burn	**Release of Suspended Solids** Construction will lead to greater surface runoff and an increase in sediment load. An existing pipe draining the minor road is contributing a high fine sediment volume.	High
	Vegetation Clearance Clearing trees and shrubs may lead to bank instability and increased fine sediment input particularly as ground vegetation cover is thin.	High
	Culvert Installation Installation will disturb the bed and release plumes of fine sediment.	High
	Realignment Excavating both the new course and temporary realignment will lead to a temporarily 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
Craibstone Burn	**Release of Suspended Solids** A high volume of sediment will enter the watercourse during construction which will be deposited on the channel bed to the detriment of channel morphology and ecology.	High
	Vegetation Clearance Removal of trees and shrubs may lead to slope instability.	High
	Culvert Installation Installation of culverts on this relatively steep channel will lead to major disturbance to the bed and banks. This is likely to increase the volume of sediment transported downstream increasing the potential for downstream reductions in morphological quality due to sedimentation.	High
	Realignment Excavating both the new course and temporary realignment will lead to a temporarily 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

Watercourse	Potential Effect of Impact	Magnitude of Impact
Green Burn	**Release of Suspended Solids** The high sediment supply will lead to fine sediment deposition and channel vegetation growth, due to the low gradient of the watercourse. The major construction works required to the north will deliver a high sediment loading.	Medium
	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.	Low
	Culvert Installation A considerable length of culvert will have to be installed which will disturb the bed morphology and promote high turbidity.	Medium
	Realignment Excavating both the new course and temporary realignment will lead to a temporarily high sediment supply during construction operations. The resulting increase in sediment delivery is likely to lead to channel sedimentation downstream, reducing morphological quality downstream with potential adverse effects on aquatic ecology and channel morphology. However the low channel gradient in this reach will reduce the extent of this impact.	Medium
	Outfall Construction of the outfall structure may lead to a release of sediment into the watercourse. However, the low morphological quality of this watercourse and the highly localised nature of the impact will limit the impact of this.	Low
Howemoss Burn	**Release of Suspended Solids** n/a	n/a
	Vegetation Clearance n/a	n/a
	Culvert Installation n/a	n/a
	Realignment n/a	n/a
Bogenjoss Burn	**Release of Suspended Solids** Construction operations in this location will involve extensive earthworks. The upper crossing point will involve excavation of a road cutting, involving rock blasting. The lower crossing point will involve the construction of a high embankment. The scale of the earthworks required in this location means construction is likely to lead to a significant increase in the sediment load of the watercourse. The supply and subsequent deposition of fine sediment will be particularly problematic in this location as this is a gravel-bed stream with good morphological diversity. The deposition of fine sediment on this coarse bed will have a detrimental effect on morphology and ecology. The water quality may be adversely affected when the peaty soils are disturbed in the upper reaches.	High
	Vegetation Clearance Clearance of the vegetation (predominantly coniferous woodland upstream, and broadleaved woodland downstream) will lead to bank instability and an increase in sediment supply.	High

Watercourse	Potential Effect of Impact	Magnitude of Impact
	Culvert Installation Installing culverts will lead to major disturbance of the channel, especially in the downstream location, where the channel is steep and fairly sinuous. Sediment released by in-channel works is likely to reach the River Don.	High
	Realignment Excavating both the new course and temporary realignment will lead to a temporarily high sediment supply during construction operations. The resulting increase in sediment delivery is likely to lead to channel sedimentation downstream, reducing morphological quality downstream with potential adverse effects on aquatic ecology. In addition the scale of the realignment required is likely to mean some temporary channel instability (exacerbated erosion and sedimentation) until the channel adjusts its morphology to the flow and sediment regime.	High
	Outfall Construction of the outfall structure may lead to a release of sediment into the watercourse. As the channel has high morphological quality, smothering of this bed with fine sediment may lead to a reduction in morphological diversity.	High
River Don	**Release of Suspended Solids** Increase in sediment supply through earthworks and vehicle access and runoff will have a detrimental impact on channel morphology. A more detailed assessment of the potential for this impact is provided in the Sediment Modelling Annex (A9.5 Annex 29).	High
	Vegetation Clearance Removal of the vegetation is not likely to affect stability of channel but will increase volume of fine sediment entering the channel.	High
	Culvert Installation n/a	n/a
	Realignment n/a	n/a
	Outfall Construction of the outfall structure may lead to a release of sediment into the watercourse. As the channel has high morphological quality, smothering of the bed with fine sediment may lead to a reduction in morphological diversity.	High
Goval Burn	**Release of Suspended Solids** Extensive works in the vicinity will lead to a high volume of sediment entering the channel which is likely to accumulate on the bed reducing morphological quality to the detriment of aquatic ecology, particularly fish.	High
	Vegetation Clearance A greater volume of sediment will enter the channel as a result of a lack of buffering/filtering if the riparian vegetation is removed. Bank instability may also occur in reaches where there is little or no bank protection.	Medium
	Culvert Installation n/a as bridges will be constructed.	n/a

Watercourse	Potential Effect of Impact	Magnitude of Impact
	Realignment n/a as bridges will be constructed.	n/a
	Outfall Construction of the outfall structure may lead to a release of sediment into the watercourse. As the channel has high morphological quality, smothering of the bed with fine sediment may lead to a reduction in morphological diversity.	High
Mill Lade	**Release of Suspended Solids** Fine sediment from increased surface runoff and excavation works may lead to sedimentation in the channel; however the impact of this will be low due to the low morphological diversity of this watercourse. However, sediment released during construction activity may be transferred to the Goval Burn where it may have a detrimental impact on channel morphology.	Medium
	Vegetation Clearance Removal of surrounding vegetation will encourage a greater sediment input through surface runoff due to a lack of interception and trapping of sediment by this vegetation.	Low
	Culvert Installation n/a as bridge and aqueduct replacement will be constructed.	n/a
	Realignment n/a	n/a
Corsehill Burn	**Release of Suspended Solids** Major construction works in the vicinity will provide a high sediment source to the channel.	Medium
	Vegetation Clearance The gorse and shrubs alongside the channel filter surface runoff from the mixed arable and pasture land surrounding the channel which traps fine sediment. If this vegetation is removed, more sediment is likely to enter the channel directly. The lower part of the watercourse is embanked which will minimise the sediment input.	Medium
	Culvert Installation Culvert installation will disturb long lengths of channel bed releasing fine sediment which may then be deposited downstream with negative consequences for morphological diversity.	Medium
	Realignment Excavating both the new course and temporary realignment will lead to a temporarily high sediment supply during construction operations. The resulting increase in sediment delivery is likely to lead to channel sedimentation downstream, reducing morphological quality downstream with potential adverse effects on aquatic ecology and channel morphology. Some fine sediment may be transported downstream to the Goval Burn which may have an adverse impact on fish.	Medium
	Outfall Construction of the outfall structure may lead to a release of sediment into the watercourse. However, the low morphological quality of this watercourse and the highly localised nature of the impact will limit the impact of this.	Low

Watercourse	Potential Effect of Impact	Magnitude of Impact
Red Moss Burn	**Release of Suspended Solids** Construction will lead to greater surface runoff and an increase in sediment load. An existing pipe draining the minor road is contributing a high fine sediment volume to the channel. An increase in fine sediment supply to this watercourse may have adverse impacts on Corby Loch which is designated as a SSSI.	Medium
	Vegetation Clearance Clearing trees and shrubs may lead to bank instability and an increase in fine sediment input, although this effect will be limited by the walled banks of the channel.	Low
	Culvert Installation Installation will disturb the bed and release fine sediment which may be transported downstream and have adverse impacts on Corby Loch which is designated as a SSSI. The flow may also have to be diverted which will impact on morphology and channel ecology.	High
	Realignment Excavating both the new course and temporary realignment will lead to a temporarily high sediment supply during construction operations. The resulting release of fine sediment may be transported downstream and have an adverse impacts on Corby Loch which is designated as a SSSI. The flow may also have to be diverted which will impact on morphology and channel ecology.	High
	Outfall Construction of the outfall structure may lead to a release of sediment into the watercourse. However, the low morphological quality of this watercourse and the highly localised nature of the impact would limit the impact of this.	Low
Blackdog Burn	**Release of Suspended Solids** A high volume of sediment will enter the watercourse during construction which will be deposited on the channel bed to the detriment of channel morphology and ecology.	Medium
	Vegetation Clearance Removal of vegetation (gorse and shrubs) will increase the potential for fine sediment from surface runoff.	Medium
	Culvert Installation Culvert installation will disturb the banks and bed morphology and promote a release of fine sediment downstream.	Medium
	Realignment Excavating both the new course and temporary realignment will lead to a temporarily 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.	Medium
	Outfalls Construction of the outfall structure may lead to a release of sediment into the watercourse. However, the low morphological quality of this watercourse and the highly localised nature of the impact would limit the impact of this.	Low
Blackdog Ditch	**Release of Suspended Solids** A high volume of sediment will enter the watercourse during construction which will be deposited on the channel bed to the detriment of channel morphology and ecology.	Medium
	Vegetation Clearance Removal of vegetation (gorse and shrubs) will increase the potential for fine sediment from surface runoff.	Medium

Watercourse	Potential Effect of Impact	Magnitude of Impact
	Culvert Installation Culvert installation will disturb the banks and bed morphology and promote a release of fine sediment downstream.	Medium
	Realignment Excavating both the new course and temporary realignment will lead to a temporarily 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.	Medium
Middlefield Drain	**Release of Suspended Solids** A high volume of sediment will enter the watercourse during construction which will be deposited on the channel bed to the detriment of channel morphology and ecology. However the limited morphological diversity of the watercourse means this is unlikely to have a significant detrimental impact on the geomorphology of the watercourse.	Medium
	Vegetation Clearance Removal of vegetation will increase the potential for fine sediment from surface runoff. However the limited morphological diversity of the watercourse means this is unlikely to have a significant detrimental impact on the geomorphology of the watercourse.	Medium
	Culvert Installation Culvert installation will disturb the banks and bed morphology and promote a release of fine sediment downstream. However the limited morphological diversity of the watercourse means this is unlikely to have a significant detrimental impact on the geomorphology of the watercourse.	Medium
	Realignment Excavating both the new course and temporary realignment will lead to a temporarily 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.	Medium
	Outfall Construction of the outfall structure may lead to a release of sediment into the watercourse. However, the low morphological quality of this watercourse and the highly localised nature of the impact would limit the impact of this.	Low

4.3 Summary of Potential Impacts

Operational Impacts

4.3.1 There are many generic operational impacts which have been described in terms of sediment regime, channel morphology and natural fluvial processes (Table 4.1). The main issues of concern are increased discharge and high fine sediment supply, the use of culverts, realignment and outfalls.

4.3.2 An increase in discharge from road surface runoff is often associated with an increase in fine sediment supply to the watercourse due to 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.

4.3.3 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 the flood risk. In addition, structures such as embankments on floodplains could lead to a back up of water and flooding upstream, and is designed out. It is also important to highlight that there is the potential for scour (undermining) of the piers/embankments if the river frequently experiences high flows.

4.3.4 The majority of the watercourses require a culvert or culverts. In cases where the channel is artificial and/or has been historically straightened and displays a poor morphology, operational impacts would be minimal. There are many more adverse impacts on watercourses which exhibit natural fluvial processes such as erosion and deposition and features such as pool and riffle sequences because the bed is replaced by an artificial substrate. The channel throughout the culvert also lacks bank and riparian features (and all vegetation due to lack of light) which has direct implications on lateral migration to maintain the sinuosity and wildlife which use the river corridor. Culverts therefore interrupt the river continuity (e.g. bed morphology and riparian zone) often prohibiting fish and wildlife migration. The watercourses where culverts would have a high impact include the Gough Burn, Craibstone Burn, and Bogenjoss Burn. Bridges will be constructed over the River Don, Goval Burn and Goval Mill Lade.

4.3.5 The culverts will 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 steep, such as lower Bogenjoss Burn and Craibstone Burn.

4.3.6 A number of realignments are required, and are designed with appropriate channel geometry, gradient and sinuosity of the new alignments. The impacts of which will include bank erosion and channel sedimentation downstream.

4.3.7 Outfall structures would be installed on a number of watercourses. Depending on the type of outfall structure constructed, these may be vulnerable to scour from flow in the watercourse into which they discharge.

Construction Impacts

4.3.8 As with the operational impacts, many of the impacts associated with the construction phase are generic to each site, although the severity of the impact differs according to the individual baseline conditions and the scale of works in the vicinity of the watercourse.

4.3.9 The main impact on the watercourses is the high fine sediment availability through embankment construction, cutting excavation, temporary access roads, vehicle washing, etc. Culvert installation also has a direct impact on the channel by disturbing the morphology of the channel bed, destabilising the banks and releasing more fine sediment.

4.3.10 The high fine sediment volume entering the channel during construction may lead to channel siltation and the possibility of excessive channel vegetation growth if there is a sustained period of low flow. Fine sediment may block the gravel bed streams and have a detrimental effect on the aquatic life. In addition, the 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 (Appendix A10.16). The turbidity of the water would also likely to be significant with adverse effects on water quality.

4.3.11 Culvert installation would lead to a short-lived adverse impacts on watercourses. Long lengths of channel would be disturbed releasing sediment downstream. The banks and surrounding floodplain will also be destabilised. The sediment loading would be greatly increased and the morphological diversity greatly reduced during, and after, installation. The recovery time of the channel would depend on how dynamic (how much energy) the watercourse has, and this partly depends on the flow velocity.

4.3.12 The construction of outfall structures on watercourses may lead to the localised modifications to the channel morphology, although this is likely to be highly site specific. The stability of the river banks may be reduced during installation leading to the potential for higher rates of erosion. Sediment release during the installation of outfalls could lead to increased sedimentation further downstream.

5 Mitigation

5.1 Generic Mitigation

Operation Mitigation

5.1.1 A number of generic mitigation measures are proposed to reduce the impact of the operation of the proposed scheme; these are described in Table 5.1.

Table 5.1 – 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 must be treated using: filter drains; treatment ponds and attenuation basins. Further details about these options are included in Appendix A9.4 (Water Quality).	Reduction
Increased discharge (and flooding)	Avoid direct drain outlets from road into watercourse.	Prevention
	Attenuation ponds 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 design of these attenuation ponds vary according to location and is described further in Appendix A9.4 (Water Quality).	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
Crossing structures (Culverts)	Build a bridge across the watercourse.	Prevention
	Divert the watercourse.	Offset
	Culvert the watercourse.	Reduction

Source of Impact	Mitigation Measure	Type of Mitigation
	DMRB gives a number of 'cases' for water crossings requiring culverts: Case 1: Culvert barrel with dimensions derived for flood flow conditions. Case 2: Culvert with depressed invert to allow for inclusion of stream bed material within the barrel. Case 3: Bottomless arch culvert to retain natural stream bed. Case 4: Provision of a low flow channel within the culvert invert. Case 5: Provision of baffles within the culvert to increase roughness.	Reduction
Realignments	Realignment (course, geometry, sinuosity and morphological features) designed following input from geomorphological specialists.	Offset – this represents an opportunity to improve the morphological status of watercourses in the immediate vicinity of the proposed scheme.
Outfalls	Ensure that the outfall is correctly positioned to limit the potential for scour around the culvert. It is important that the position of the outfall does not cause a significant alteration to flow patterns which may lead to turbulence and/or excessive deflection of flow towards the bed or banks of the channel. The outfall must not project out into the channel and should not be located where flow converges with river banks, which would cause high shear stresses or, where active bank erosion is occurring.	Reduction
	Ensure that adequate scour protection measures are provided around the outfall. Details of best practice are identified in CIRIA C697.	Reduction

<u>Crossing structures</u>

5.1.2 Where culverts are to be installed they will consist of depressed invert culverts designed to convey flows of up to 1 in 200 year return flow. Depressed invert culverts are culverts where the invert (base) is 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. The installation of these culverts requires in-channel works.

5.1.3 Depressed invert culverts are generally most 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.

<u>Realignments</u>

5.1.4 Realignment designs are 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 new channels will have gravel beds consisting of appropriately sized particles with occasional boulders and an alternating sequence of pools, riffles and runs sited appropriately. These features are represented in natural watercourses and will help provide optimum habitat conditions for salmonids.

5.1.5 Prior to construction of these realignments, further geomorphological investigations are recommended where watercourse have a medium to high vulnerability to assess:

- 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.

5.1.6 Additional geomorphological assessments will be provided to SEPA, as required, within the CAR application for each realignment.

Construction Mitigation

5.1.7 A number of generic mitigation measures will be implemented to reduce the impact of the operation of the proposed scheme; these are described in Table 5.3 below.

Table 5.2 – 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 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

Source of Impact	Mitigation Measure	Type of Mitigation
	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
	Realignment (course, length, geometry, sinuosity, and morphological features)designed with input from a geomorphological specialists.	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
Outfalls	Ensure that construction of the outfall is not conducted during periods of high flow as the disturbed river banks will be more vulnerable to erosion.	Reduction
	Where possible, provide sediment fences to prevent sediment being washed into the watercourse.	Reduction
	Where possible, avoid excavating into the river banks and limit the extent of disturbance.	Reduction

Crossing Structures

5.1.8 The construction of depressed new invert culverts and the upgrading of any existing culverts, will require extensive in-channel works. During culvert installation operations 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 dry conditions ensuring minimal sediment release during construction. Flow must only be re-routed into the new culvert once channel works are completed, and during low flow conditions where possible.

5.1.9 To ensure morphological continuity and prevent localised changes in bed elevation, such as steps, the channel bed in depressed invert culverts will be formed prior to the routing of flow through the culvert. Bed sediments should not be transferred from the existing channel as transferring 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 proposed scheme) 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.

5.1.10 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. In order to minimise the risk of scour, baffles will be installed within the culvert to dissipate flow energy and to stabilise the bed sediments.

5.1.11 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 potentially leading to increases in sediment conveyance and deposition downstream. Where possible, watercourse realignment should be avoided through wide culverts or the use of bridges.

5.1.12 Bare channel banks created during culvert installation must be covered by geotextile matting 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 should be seeded to promote vegetation colonisation and to ensure rapid stabilisation.

<u>Temporary Realignments</u>

5.1.13 Temporary watercourse realignments will be constructed with care to prevent these from becoming sources of sediment. The temporary channel will be fully lined using geotextiles to prevent erosion of the bed and banks. Where possible realignment should have approximately the same channel length as the exiting watercourse so as not to increase the channel gradient and promote an increase in stream power which could lead to scour downstream.

5.1.14 Site activity in the vicinity of temporary realignment will be carefully managed to avoid the risk of accidental spillage into the watercourse. 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 proposed scheme and open channel sections.

<u>Watercourse Realignments</u>

5.1.15 The approach to watercourse realignments during construction will be confirmed through the CAR process, and will follow the following principles:

- In order to limit the potential for bank erosion, new realignments will be appropriately graded according to channel sinuosity.
- Covering newly formed banks along the new alignment with geotextile matting 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 should be seeded to promote vegetation colonisation to ensure rapid stabilisation of this new section of watercourse.
- No flow will be routed through the realignment during construction. The channel will be completed, 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 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 rerouting of flow.
- 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. The new channel will be monitored regularly and where signs of instability are observed, such as erosion, appropriate remediation measures undertaken.

5.2 Site-Specific Mitigation

5.2.1 In addition to the above 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 re-alignments.

Operational Mitigation

Crossing Structures

5.2.2 The varied geomorphology of the watercourses means that the minimum requirements of each watercourse crossing design varies (Table 5.1), as such a range of different crossing structures are required (Table 5.3).

Table 5.3– Crossing structures for Watercourses (where required)

Watercourse	Culvert
Kepplehill Burn	Depressed Invert Box Culvert
Gough Burn	Two Depressed Invert Box Culverts
Craibstone Burn	Depressed Invert Box Culvert
Green Burn	Three Depressed Invert Box Culverts
Bogenjoss Burn	Six Depressed Invert Box Culverts
River Don	One Bridge
Goval Burn	Three Bridges
Mill Lade	One Aqueduct (extension of existing)
Corsehill Burn	Three Depressed Invert Box Culverts
Red Moss Burn	Depressed Invert Box Culvert
Blackdog Burn	Two Depressed Invert Box Culverts under main carriageway
Blackdog Ditch	Depressed Invert Box Culvert
Middlefield Burn	Three Depressed Invert Box Culverts

Realignments

5.2.3 A number of watercourse realignments are proposed, as listed in Table 5.4.

Table 5.4 – Watercourse Realignments

Watercourse	Culvert
Kepplehill Burn	200m realignment required but no change in channel length
Gough Burn	Two realignments required of 183m and 25m but no change in channel length
Craibstone Burn	196m realignment required with 11m reduction in channel length
Green Burn	Two realignments required of 160m (reducing channel length by 4m) and 435m (increasing channel length by 6m) would involve the construction of new sections of open channel
Bogenjoss Burn	Two realignments of 948m and 240m are required that would reduce the channel length by 156m and 21m, respectively.
Corsehill Burn	Extensive realignment of 585m which would increase the channel length by 15m. This would also involve the construction of new sections of open channel.
Red Moss Burn	A 81m realignment would be required but there would be no change in channel length.
Blackdog Burn	Two realignments (101m and 45m) would be required but this would not involve a change in channel length.
Blackdog Ditch	A 96m realignment would be required which would lead to a decrease in channel length by 2m.
Middlefield Burn	An extensive realignment of 460m would be required which would lead to a reduction in channel length of 65m.

Gough Burn

5.2.4 The existing channel of Gough Burn is already steep where realignment would be required, and this gradient would remain high as no change is anticipated to channel length or gradient as result of realignment. The channel would therefore continue to have high stream power and high potential for both bed erosion in the culvert and bed/bank erosion downstream. To mitigate the potential for bed erosion, baffles will be installed in the culvert, and bank protection will also be required downstream to limit bed/bank erosion. Further information regarding the detailed design of this watercourse will be provided within the CAR application.

5.2.5 In addition, the potential for erosion is also increased in these locations by the relatively tight curves in the channel as these, concentrate flow around the outer bank of bends and lead to higher shear stresses. The potential for bank erosion is further increased along the section of realignment downstream of the culvert because of the high banks. Bank protection measures will be provided in these locations. It is recommended that where possible green bank protection is used.

Craibstone Burn

5.2.6 The realignment of Craibstone Burn would increase the channel gradient to 3.8%. As a result, the potential for erosion of both bed and bank up and downstream of the culvert. Baffles will be installed in the culvert to reduce the potential for bed erosion. Bank protection will be required downstream to limit bank erosion. It is recommended that where possible green bank protection is used. Further detailed geomorphological assessment of the potential for erosion will be conducted prior to the selection of appropriate bank protection measures for sections of the realigned channel.

Bogenjoss Burn

5.2.7 The upper section of the Bogenjoss Burn would follow the valley side, alongside the new access road, and would have a relatively low channel gradient. Restoring a sinuous channel in this location would likely lead to an increase in the potential for sedimentation. As such, the diversion channel will be straight in this section. Having to provide a straight channel would reduce the morphological diversity compared with the existing channel.

5.2.8 Downstream of culvert 2 (Kirkhill Access Track) the channel gradient becomes moderate (1.5%) through culvert 3 (Kirkhill Access Track) and increases substantially to high (9.3%) through culvert 4 and remains high through Culvert 6 (7.2%). The gradient of this section of realignment is likely to increase stream power and as a result the potential for bed and bank erosion will increase the amount of sediment transported downstream. To reduce the potential for bed scour within the culverts 3, 4 and 6, baffles must be provided on the culvert invert to ensure the sediments are not entrained and transported downstream. It may also be necessary to provide a coarse bed substrate within the culvert to limit the potential for scour during high flows. The nature and size of the bed sediment to be installed within the culvert will need to be determined by further analysis. In addition, the steep section of channel upstream and downstream of the culvert will also require erosion protection. It is recommended that where possible green bank protection is used.

5.2.9 As the new channel would be excavated into glacial sediments it will be vulnerable to erosion. The use of hard engineering to protect the banks will be minimised in order to provide optimal ecological conditions, but it is essential that the new alignment does not experience significant bank erosion. The middle and lower sections of the realignment (Culverts 2 to 6) will be most vulnerable to erosion. Bank erosion would increase the quantities of suspended sediment transferred downstream. Bank protection measures will be provided in these sections. It is recommended that where possible green bank protection is used.

5.2.10 The newly created river banks will be covered by seeded geotextile to reduce fluvial erosion and to encourage rapid vegetation development, and river banks slopes will be appropriately specified following any further detailed geomorphological channel design work necessary. Some minor readjustment of the bank profile is likely to occur including steepening through localised erosion and reductions in slope through deposition elsewhere. This readjustment should be monitored to ensure it does not have any adverse impacts on the freshwater ecology.

5.2.11 The bed of the existing stream is composed of fine and coarse gravels with cobbles, the majority of which is covered by moss and algae indicating that the bed is largely stable. As a result it will be necessary to ensure that the bed of the new channel is composed of similar sediments. As it is necessary to ensure the new channel is complete before flow is re-routed away from the existing channel, transplanting of the river bed sediments will not be possible. New sediments, from an appropriate source, will be placed in the bed of the new channel, consisting of sub-angular gravels. The sub-angular nature of these sediments will facilitate the interlocking of particles, reducing the potential for bed erosion. The size of the bed sediment and precise nature of the bed morphology will be determined by further, more detailed, geomorphological analysis under taken as part of the CAR application process.

Mill Lade

5.2.12 An aqueduct would be required to carry the flow of Mill Lade across the proposed scheme. This will have the same channel form as the existing channel; a uniform concrete channel with a trapezoidal cross-section. No further mitigation is considered necessary.

Corsehill Burn

5.2.13 The existing channel of the Corsehill Burn has been resectioned and walled in the past. The new channel however would be realigned and excavated into glacial till, fluvio-glacial sands and gravels. This means that the new channel would have banks that are more prone to erosion than the existing channel. Green bank protection will therefore be provided along the length of the realignment.

Red Moss Burn

5.2.14 On the basis of geomorphological investigations, the depressed invert culvert will be filled with a mix of coarse gravel and cobbles, equal to or greater than 60mm, to ensure the bed of the culvert remains stable under all flow conditions. The uneven surface of the coarse bed will also trap some of the finer sediment and provide a bed morphology similar to the existing channel. However, as no vegetation would be present the quantity of finer sediment deposited on the bed is likely to be less than in the open channel sections.

Middlefield Burn

5.2.15 The shortening of the channel by 65m due to the realignment would increase the channel gradient, and lead to higher stream powers and increase the potential for channel erosion. This is likely to involve both bed and bank erosion upstream and downstream of the culvert. Baffles should be installed in the culverts to reduce the potential for bed erosion. Further detailed geomorphological assessment of the potential for erosion will be conducted prior to the selection of appropriate bank protection measures for sections of the realigned channel. Bank protection measures will be provided along the realignment and it is recommended that where possible green bank protection is used.

Construction Mitigation

<u>Crossing Structures</u>

Gough Burn

5.2.16 Realignment construction and culvert installation will be conducted off-line to limit the potential for sediment release into the watercourse. This may require the construction of a temporary realignment where the culvert is to be installed on, or close to, the line of the existing channel. Where a temporary realignment is required the generic mitigation outlined above.

Craibstone Burn

5.2.17 Realignment construction and culvert installation will be conducted off-line to limit the potential for sediment release into the watercourse. As the new channel and culvert alignment is to be located to right of the existing channel, the new alignment and culvert will be constructed while flow continues to be routed through the existing channel. Following completion of the new alignment, flow can then be re-routed along the new alignment and through the culvert.

Bogenjoss Burn

5.2.18 The location of the realignment incorporating culverts 1-5 away from the existing watercourse means that it can be constructed off-line relatively simply. However, the installation of culvert 6 and the associated channel realignment works will be more complex as the stream is located in a relatively tight valley. Channel realignment and culvert installation will be conducted off-line and in dry conditions.

5.2.19 The proposed realignment would cross the existing sinuous watercourse at two points, and in some locations would be located extremely close to the existing watercourse. These construction works will therefore be carefully phased to ensure that they do not result in sediment release into the watercourse. As such, sections of temporary realignment are likely to be required to divert flow away from the construction area.

River Don

5.2.20 When constructing the central piers for the bridge over the River Don, care will be taken to avoid sediment release into the river. Floodplain works will be timed to avoid periods of heavy rainfall (in particular times when flood watches or warnings have been issued), and where possible undertaken in dry conditions. Construction material will not be stored on the floodplain and vehicle movements will be kept to a minimum. This will help to minimise the amount of sediment which can be entrained if the floodplain is inundated.

5.2.21 Floodplain access roads for the construction of the River Don crossing will be kept to a minimum and it is essential that barriers are provided to prevent untreated road runoff from entering the River Don.

Goval Burn

5.2.22 Due to the importance of this watercourse for migratory salmonids it is essential that no in-channel works are conducted, as this will lead to an increase in suspended sediment and localised disturbance to the channel morphology. Construction work in the riparian zone will be timed to avoid periods of heavy rainfall, which could increase the potential for sediment to be transferred into the watercourse. Where vegetation clearance is to be undertaken on the valley side slope of the channel, sediment fences and surface runoff interception measures must be provided to prevent sediment transfer from the slope into the watercourse.

Mill Lade

5.2.23 During construction of the Mill Lade Aqueduct it will be necessary to stop the flow through Mill Lade, and drain the lower section where construction works will take place. This could be achieved by closing the sluice gate in the middle section of the Lade by the A947. Ponded water will be retained in the upper section of the Lade, but no additional flow allowed to enter the Lade from Goval Burn upstream. Flow that would normally be routed through Mill Lade will be retained in Goval Burn by closing the dam intake.

5.3 Mitigation Summary

Operational Mitigation

5.3.1 Generic mitigation measures have been identified, to be applied as appropriate at all crossing points to reduce the impact of the operation of the proposed scheme (Table 5.1).

5.3.2 Bridge or depressed invert culverts have been proposed on a site by site basis. These reflect the differing sensitivities of watercourses, and are summarised in Table 5.4).

5.3.3 In order to install the culverts 14 watercourse realignments will be required (Table 5.5). Open channel realignments (Green Burn, Bogenjoss Burn, Corsehill Burn, and Middlefield Burn) will be carefully designed using geomorphological guidance. Following completion, the realigned channels will undergo some morphological readjustment following realignment which should ideally be monitored for at least one year to ensure this does not have a negative effect on the ecology and geomorphology of the channel.

5.3.4 Correct positioning of outfalls will limit the potential for scour around the culvert. This involves ensuring that the outfall does not cause a significant alteration to flow patterns which may lead to turbulence and/or excessive defection of flow towards the bed or banks of the channel. The outfall will not project out into the channel and will not be located where flow converges with river banks, which would cause high shear stresses, or where active bank erosion is occurring. Adequate scour protection measures will be provided around the outfall. Details of best practice are identified in CIRIA C697.

Construction Mitigation

5.3.5 A range of generic mitigation measures have been identified, to be applied at all crossing points as appropriate to reduce the impact of the construction of the proposed scheme (Table 5.3).

5.3.6 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 proposed, and the existing conditions at the site.

5.3.7 During in-channel works flow must be diverted around the construction operations within an appropriately sized temporary realignment (division channel) lined with geotextiles to prevent bank erosion.

5.3.8 Watercourse realignments will be constructed and completed prior to the switching of flow through the new course. This will prevent fine sediment release into the 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, appropriate remediation measures are undertaken.

5.3.9 Some of the watercourses will have outfalls installed. The construction of outfalls during periods of low flow will limit the amount of sediment release and erosion from the vulnerable river banks. The use of sediment fences will prevent sediment being washed into the watercourse. Avoiding excavation into the river banks and reducing the extent of disturbance, will limit the extent of sediment release into the watercourses.

5.3.10 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.

5.3.11 Additional geomorphological assessments will be provided, as required, within the CAR application for each proposed realignment.

5.3.12 In order to satisfy the CAR process, a detailed method statement for construction activities in the vicinity of each watercourse will be produced. This will detail the measures which will be taken to further limit the impact of construction.

6 Residual Impacts

6.1 Generic Residual Impacts

Generic Operational Residual Impacts

6.1.1 A series of mitigation measures are outlined in Section 5.1 which limit the impact of the operational phase on watercourses (Table 5.1). The residual impacts of these generic recommendations which are applicable to all the watercourses are summarised in Table 6.1. The residual impacts are likely to be long term impacts, but providing the mitigation measures are properly implemented and maintained, the residual impacts are predominantly of Negligible magnitude.

Table 6.1 – Generic Residual Impacts during Operation

Source of Impact	Residual Impact with Mitigation
Suspended Solids Direct Impact	**Sediment Regime** Treatment of the road drainage using filter drains, attenuation basins and treatment ponds will prevent significant quantities of suspended sediment from being released into the 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 will be towards the lower end of the range while during periods of low flows removal efficiency will be greatest. During high flows the suspended sediment is naturally high. The residual impact will be negligible. **Channel Morphology** As the proposed scheme will only have a negligible effect on fine sediment release, it will also have a negligible impact on channel morphology. **Natural Fluvial Processes** As changes to the sediment regime will be negligible or low they will be insufficient to produce any noticeable change in the nature of fluvial processes operating on the watercourse and the residual impact will be negligible for all watercourses.
Increased discharge Indirect Impact	**Sediment Regime** The storage of road discharge in attenuation basins prior to gradual release into the watercourse will prevent the proposed scheme from having a significant impact on the hydrological regime of the watercourse. For each watercourse the residual impact on the sediment regime through changes in erosion or deposition rates will be negligible. **Channel Morphology** As the proposed scheme will nave no appreciable impact on the hydrological regime of the watercourses changes in channel morphology will be negligible. **Natural Fluvial Processes** Similarly as the provision of attenuation ponds will limit changes in the discharge and sediment regimes of the watercourses, the changes in natural fluvial processes will be also be negligible.
Outfall	**Sediment Regime** Ensuring that each outfall is appropriately located and that best practice design guidance is adhered to (CIRIA C697) will limit the potential for scour around the structure. This will reduce the likelihood that associated increases in sediment supply will result in a negligible impact on each watercourse affected. **Channel Morphology** Ensuring that each outfall is designed and located in accordance with best practice will limit the impact of the outfall on channel morphology. This highly localised change would have a negligible impact on the morphology of each watercourse as a whole. **Natural Fluvial Processes** Ensuring that each outfall is designed and located in accordance with best practice will prevent interference with flow which may lead to changes in erosion and deposition rates. This will ensure this there is a negligible impact on each watercourse.

6.1.2 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.

Generic Construction Residual Impacts

6.1.3 A series of mitigation measures are outlined in Section 5.1 which will limit the impact of the construction phase on the watercourses (Table 5.3). The residual impacts taking into account implementation of proposed mitigation are summarised in Table 6.2. The residual impacts are likely to be temporary in nature and most will be of Negligible magnitude.

Table 6.2 – Generic Residual Impacts during 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 the watercourses will be significantly reduced giving a negligible impact. **Channel Morphology** As the proposed scheme will only have a negligible effect on fine sediment release, it will also have a negligible impact on channel morphology. **Natural Fluvial Processes** As changes to the sediment regime will low be or negligible they will be insufficient to produce any noticeable change in the nature of fluvial processes operating on the watercourse and the residual impact will be negligible for all watercourses.
Vegetation clearance Direct Impact	**Sediment Regime** The range of mitigation measures required at each crossing point will reduce the potential for vegetation clearance to lead to an increase in sediment supply. Vegetation clearance will 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 will be low or negligible they will be insufficient to produce any noticeable change in the channel morphology operating on the watercourse and the residual impact will be negligible for all watercourses. **Natural Fluvial Processes** As changes to the sediment regime resulting from construction and vegetation clearance will be low or negligible they will be insufficient to produce any noticeable change in the nature of fluvial processes operating on the watercourse and the residual impact will be negligible for all watercourses.
Outfall installation	Ensuring that construction of the outfall is appropriately timed and that barriers, such as sediment fences, are provided to prevent sediment being transferred into the watercourse will ensure that impacts on the watercourse would be negligible.

6.1.4 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.

6.2 Site-Specific Residual Impact Assessment

Operational Impacts

6.2.1 The residual site-specific operational impacts of the proposed scheme on each watercourse following the application of mitigation measures are outlined in Table 6.3.

Table 6.3 – Site-Specific Residual Impacts during Operation

Watercourse	Magnitude of Impact Without Mitigation	Source of Impact	Residual Impact Magnitude
Kepplehill Burn	Low	**Depressed Invert Box Culvert** Culverting this watercourse will have a negligible impact on the morphological quality and sediment regime of the watercourse as it is already highly modified. Realigning this watercourse would have negligible impact as channel length will be maintained.	Negligible
Gough Burn	High	**Two Depressed Invert Box Culvert** The provision of a depressed invert culvert allows the bed to be formed from appropriately sourced natural sediments, and ensures the continuity of sediment transfer is maintained. However, the channel will have to be straightened and this may lead to high stream powers. The existing channel has a sinuous planform which provides excellent morphological diversity which will be lost as a result of culvert installation. The loss of this morphologically diverse section of channel is extremely undesirable due to widespread channel modifications elsewhere along the watercourse. In addition the extensive nature of past channel modification of minor watercourses in the Aberdeen area means that natural, morphologically diverse, channels should be conserved. **Realignment** The use of baffles in the culvert and scour and bank protection in the new sections of open channel would help to limit the amount of incision and erosion that occurs as a result of the realignment. This will help to promote bed and bank stability and limit sediment release downstream. However, this would further increase the degree of artificial modification to the watercourse reducing natural morphological diversity.	High
Craibstone Burn	High	**Depressed Invert Box Culvert** The provision of a depressed invert culvert allows the bed to be formed from appropriately sourced natural sediments, and ensures the continuity of sediment transfer is maintained. However although the existing channel is relatively straight in this section, it exhibits a high degree of morphological diversity which will be lost as a result of culvert installation. The loss of this morphologically diverse section of channel is extremely undesirable due to widespread channel modifications elsewhere along the watercourse. In addition the extensive nature of past channel modification of minor watercourses in the Aberdeen area means that natural, morphologically diverse, channels should be conserved. **Realignment** The use of baffles in the culvert and scour and bank protection in the new sections of open channel will help to limit the amount of incision and erosion that occurs as a result of the realignment. This will help to promote bed and bank stability and limit sediment release downstream. However, this would further increase the degree of artificial modification to the watercourse reducing natural morphological diversity.	High
Green Burn	Medium	**Three Depressed Invert Box Culverts** The provision of depressed invert culverts will provide an improvement flow and sediment conveyance and will also ensure bed morphological continuity. As the watercourse is already highly modified, straightened and walled, these culverts will not lead to a significant reduction in morphological quality or change in fluvial processes.	Low

Watercourse	Magnitude of Impact Without Mitigation	Source of Impact	Residual Impact Magnitude
		Realignment Although the realignment of the watercourse will lead to a slight decrease in channel gradient along this section of the watercourse, the reach would still have a low gradient. While this low gradient would limit the potential for erosion within the channel, the low stream power may promote the deposition of fine sediments along this reach (siltation) which may reduce channel capacity and morphological diversity. However, as the existing morphological diversity is low the impact of these changes is also likely to be relatively low.	
Bogenjoss Burn	High	**Six Depressed Invert Box Culverts (includes culvert on former watercourse)** The use of depressed invert culverts will allow the preservation of bed continuity reducing the impact of the culverts on the channel morphology. However, culverts result in complete channel modification and enclosure which limits the natural geomorphological functioning of the watercourse and results in reductions in morphological quality. In this case, the lower section of the watercourse which currently exhibits high morphological diversity would be severely affected. To counteract the steep gradients of culverts 4 and 6, baffles will be placed into the culvert invert in order to reduce the potential for bed scour. Culvert (Number 6) will be installed along a section which currently exhibits excellent morphological diversity. The loss of this morphologically diverse section of channel is extremely undesirable due to widespread channel modifications elsewhere along the watercourse. In addition the extensive nature of past channel modification of minor watercourses in the Aberdeen area means that natural, morphologically diverse, channels such as this should be conserved. **Realignment** The upper section of this watercourse will be subject to an extensive realignment. Sympathetic watercourse design using hydrological, ecological and geomorphological design principles will limit reductions in morphological diversity and alterations to geomorphological processes such as sediment transfer. The steep gradients around culverts 4 and 6 will require erosion control measures to prevent destabilisation of sections of open channel which would result in sediment release. This erosion protection would reduce natural morphological diversity where natural sections are retained and limiting the potential for natural morphological readjustment to realignment. The use of baffles in the culvert and scour and bank protection in the new sections of open channel will help to limit the amount of incision and erosion that occurs as a result of the realignment. This would help to promote bed and bank stability and limit sediment release downstream. However, this would further increase the degree of artificial modification to the watercourse reducing natural morphological diversity.	High
River Don	High	**Bridge** The construction of a bridge will mean the proposed scheme will have no direct impact on the River Don in this location.	Negligible
Mill Lade	Medium	**Bridge** The construction of a bridge will mean the proposed scheme will have no direct impact on the Mill Lade in this location. **Aqueduct** As the Mill Lade is an artificial watercourse with no natural geomorphological processes and an extremely limited influence on the sediment regime of the Goval Burn, changes to the structure of the Mill Lade channel will have no adverse geomorphological impacts.	Negligible
Goval Burn	High	**Three Bridges** The use of bridges will ensure the proposed scheme has no impact on the watercourse during operation.	Negligible

Watercourse	Magnitude of Impact Without Mitigation	Source of Impact	Residual Impact Magnitude
Corsehill Burn	Medium	**Three Depressed Invert Box Culverts** As this watercourse is already modified, walled straightened and locally culverted, the installation of a depressed invert culverts will not lead to any detrimental impacts on the sediment regime or morphological structure of this watercourse. Although the length of culverted channel will be greater, the preservation of bed continuity will limit the effect of this on morphological diversity. **Realignment** The provision of a realignment will not lead to any significant deviation from baseline conditions as the channel is already heavily modified, walled and straightened.	Negligible
Red Moss Burn	High	**Depressed Invert Box Culvert** The watercourse in the location of the proposed culvert is already straight and of low morphological diversity. Culverting this section of watercourse will have a negligible impact on the morphological diversity of the watercourse and the new culvert will ensure continuity of bed morphology. The use of sediments sized at no smaller than 60mm in the depressed invert box culvert will ensure that the new channel remains stable and limits the potential for incision to occur. Likewise, if the correct size sediment is used then sedimentation would not occur and the new channel would not compromise flood risk.	Negligible
Blackdog Burn	Medium	**Three Depressed Invert Box Culverts** The watercourse in the location of the proposed culverts is straight and relatively low gradient the culvert is unlikely to lead to any appreciable change in the geomorphology of this watercourse. As the culverts will have a depressed invert the morphological continuity of the bed will be conserved watercourse.	Negligible
Blackdog Ditch	Low	**Depressed Invert Box Culvert** The watercourse in the location of the proposed culvert is already straight and of low morphological diversity. Culverting this section of watercourse will have a negligible impact on the morphological diversity of the watercourse and the new culvert will ensure continuity of bed morphology.	Negligible
Middlefield Burn	Medium	**Three Depressed Invert Box Culverts** As this small watercourse is already highly modified (realigned and culverted) and is of low gradient culverting is unlikely to lead to any adverse change in geomorphological process. As the culvert will have a depressed invert the morphological continuity of the bed will be conserved. **Realignment** The provision of a realignment will not lead to any significant deviation from baseline conditions as the channel is already heavily modified, walled and straightened. The use of baffles in the culvert and scour and bank protection in the new sections of open channel will help to limit the amount of incision and erosion that occurs as a result of the realignment. This would help to promote bed and bank stability and limit sediment release downstream. However, this would further increase the degree of artificial modification to the watercourse reducing natural morphological diversity.	Negligible

Construction Impacts

6.2.2 The residual impacts of the proposed scheme on each watercourse, following the application of mitigation measures during construction, are outlined in Table 6.4.

Table 6.4 – Site-Specific Residual Impacts during Construction

Watercourse	Magnitude of Impact Without Mitigation	Source of Impact	Residual Impact Magnitude
Kepplehill Burn	Medium	**Culvert Installation 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 temporary increases in sediment supply occurring. Any sediment releases that do occur as a result of accidental spillage or failure of mitigation measures are likely to be of short duration and will have a negligible impact on this watercourse.	Negligible
Gough Burn	High	**Culvert Installation and realignment** Realignment construction and culvert installation would be conducted off-line using a temporary realignment which would limit the potential for sediment release into the watercourse. However, construction activities in this location would require widespread disturbance along the relatively narrow watercourse corridor, involving tree felling and vehicle movements. This activity is likely to have an impact on the morphology of this watercourse through sediment release with increases in deposition further downstream.	Low
Craibstone Burn	High	**Culvert Installation and realignment** Realignment construction and culvert installation will be conducted off-line using a temporary realignment which will limit the potential for sediment release into the watercourse. However, construction activities in this location would require widespread disturbance along the relatively narrow watercourse corridor, involving tree felling and vehicle movements. This activity is likely to have an impact on the morphology of this watercourse through sediment release with increases in deposition downstream..	Low
Green Burn	Medium	**Culvert Installation** Providing a temporary flow diversion and ensuring that channel works are completed before flow is routed along the watercourse will minimise the risk of temporary increases in sediment supply occurring. Any sediment releases that do occur as a result of accidental spillage or failure of mitigation measures are likely to be of short duration and will have a negligible impact on this watercourse. **Realignment** As with culvert installation the channel will require extensive realignment. Ensuring that no flow is routed along the new watercourse during construction will limit the quantity of fine sediments released during construction	Negligible
Bogenjoss Burn	High	**Culvert Installation and realignment** Road construction and culvert installation will require temporary watercourse realignment and ultimately permanent watercourse realignments. This will lead to widespread disturbance along the watercourse corridor, involving tree felling and vehicle movements. This activity will have a particularly significant impact on the morphology of the lower section of the watercourse which is both morphologically diverse and relatively steep. In addition to the complete loss of this naturally diverse section of channel increases in channel erosion with increases in deposition downstream are also likely due to channel slope. These activities will have a major impact on this watercourse. To counteract the locally high gradient of the new channel realignment, the use of baffles, geotextiles and appropriately sourced sediment will all help to reduce the potential for bed scour and to promote bed stability.	Medium
River Don	High	**Bridge construction** The construction of a bridge will not involve any channel works in this location which will ensure that the proposed scheme has no direct impact on the River Don.	Negligible
Mill Lade	Medium	**Bridge construction** The construction of a bridge will not involve any channel works in this location which will ensure that the proposed scheme has no direct	Negligible

Watercourse	Magnitude of Impact Without Mitigation	Source of Impact	Residual Impact Magnitude
		impact on the watercourse. **Aqueduct Construction** Ensuring the Mill Lade does not contain any flow during aqueduct construction by closing sluice gates upstream will mean construction has no impact on the Mill Lade itself or the sediment regime of the Goval Burn with which it joins.	
Goval Burn	High	**Bridge construction** The construction of a bridge will not involve any channel works in this location which will ensure that the proposed scheme has no direct impact on the Goval Burn.	Negligible
Corsehill Burn	Medium	**Culvert Installation and realignment** Ensuring that the realignment, along which all the culverts are located, does not convey flow prior to the completion of the culverts will limit the impact of construction to a negligible level. Constructing the realignment prior to the rerouting of flow will limit the impact of the realignment to small scale readjustments with a negligible impact on the sediment regime of the watercourse.	Negligible
Red Moss Burn	High	**Culvert Installation and realignment** Ensuring that the realignment, along with all the culverts, does not convey flow prior to the completion of the culverts will limit the impact of construction to a negligible level.	Negligible
Blackdog Burn	Medium	**Culvert Installation and realignment** Ensuring that the realignment, along with all the culverts, does not convey flow prior to the completion of the culverts will limit the impact of construction to a negligible level.	Negligible
Blackdog Ditch	Medium	**Culvert Installation and realignment** Ensuring that the realignment, along with all the culverts, does not convey flow prior to the completion of the culverts will limit the impact of construction to a negligible level.	Negligible
Middlefield Burn	Medium	**Culvert Installation and realignment** Ensuring that the realignment, along with all the culverts, does not convey flow prior to the completion of the culverts will limit the impact of construction to a negligible level.	Negligible

7 Summary

7.1.1 This technical appendix has focused on the degree to which the operation and construction of the Aberdeen Western Peripheral Route will affect the fluvial geomorphology of the watercourses crossed by the proposed scheme.

7.1.2 The proposed scheme will cross a number of watercourses which range in size from small watercourses, akin to field drains, such as the Middlefield Burn, through to large alluvial rivers such as the River Don.

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

7.1.4 A range of potential impacts have been identified. During operation, potential 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, potential impacts would range from changes to sediment load (primarily increases in suspended solids) as a result of construction site works and vegetation clearance, culvert installation and channel realignment.

7.1.5 Changes in the fluvial geomorphology during operation, resulting from increases in sediment load and culvert installation represent direct impacts, whereas changes resulting from increased discharge or channel realignment represent indirect impacts. Changes in fluvial geomorphology resulting from construction operations, including an increase in sediment loading, vegetation clearance, culvert and realignment installation, all represent direct impacts.

7.1.6 The timescale of the impacts on fluvial geomorphology reflects the duration of disturbances. 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.

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

7.1.8 Although fluvial geomorphology does not include any receptors, changes to the fluvial geomorphology have consequences for water quality and ecological receptors, these are considered in Appendix A9.4 and A10.16 respectively.

7.1.9 A range of mitigation measures have been outlined to limit the impact of the proposed scheme on the fluvial geomorphology of the watercourses.

7.1.10 For the operational phase, settling ponds will be used to treat road drainage by trapping fine sediment while attenuation ponds will limit the impact of the proposed scheme on the hydrological regime of the watercourses.

7.1.11 In a number of instances, watercourse realignments have been included in the design to ensure the proposed scheme has a limited impact in locations, where watercourse crossings might otherwise be highly damaging to the fluvial geomorphology and dependant receptors. Channel realignment also provides an opportunity to improve the geomorphological quality of watercourses, primarily through improvements in morphological diversity. This will also be beneficial for the water quality and ecology of the watercourses (Appendix A9.4 and A10.16) and represents an opportunity to offset the impact of the proposed scheme.

7.1.12 During construction of the proposed scheme, guidance has been provided on construction site practices to limit the potential for sediment release into the watercourses. Mitigation measures have also been described to limit the impact of channel works required during culvert installation and watercourse realignment.

7.1.13 The adoption of these mitigation measures, during the design and construction phases will ensure that the proposed scheme generally has only a negligible or low impact on the fluvial geomorphology of the watercourses.

7.1.14 The majority of the watercourses that would be affected by the proposed scheme join other watercourses also affected. This means that potential impacts such as changes to the sediment regime or flow regime may propagate downstream and exacerbate the impacts of the watercourse, thereby increasing the overall impact of the proposed scheme.

7.1.15 Kepplehill Burn, Gough Burn, Craibstone Burn, Green Burn, Bogenjoss Burn, Goval Burn, Corsehill Burn all join the River Don, either directly or by joining other watercourses first. In the absence of mitigation, this will result in combined impacts that will be particularly acute on the River Don. However, with proposed mitigation, the impact of the proposed scheme on each watercourse will be limited and as a result, any combined impacts will have a negligible impact.

8 References

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9 Glossary

Adjustment	the modification of river channel morphology, both vertically and in planform, 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	the volume of water flow per unit time usually expressed in cubic metres per second ($m^3 s^{-1}$).
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.

EU Water 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 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, specifically its routing 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	are those 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 river bank)	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.