A9.4 Fluvial Geomorphology

1 Introduction

1.1.1 This appendix presents additional detail on the assessment of the proposed scheme in terms of fluvial geomorphology. It supports the summarised fluvial geomorphology findings presented in Chapter 9 (Water Environment).

1.1.2 Fluvial geomorphology is the study of landforms associated with river channels and the sediment transport processes that form them. Fluvial processes create a wide range of morphological forms providing a variety of habitats within and around rivers. As a result, geomorphology is integral to river management.

1.1.3 This fluvial geomorphology appendix describes the assessment methodology, including details of the main sources of information that were utilised (Section 2: Approach and Methods). The baseline conditions are described, representing the existing or 'Do-Minimum scenario' which is the situation if the proposed scheme were not to proceed and the Forth Road Bridge and associated road infrastructure continued to be used (Section 3: Baseline Conditions).

1.1.4 Potential impacts, both direct and indirect, that may occur as a consequence of the proposed scheme are considered. Potential impacts to watercourses are assessed separately, and both construction and operational impacts are considered.

1.1.5 Mitigation to avoid, reduce or offset the potential impacts is outlined where possible, based on published guidance, best practice and our current understanding of the proposed scheme (Section 5: Mitigation). Residual impacts are then identified based on the implementation of proposed mitigation.

2 Approach and Methods

2.1 Structure of Assessment

2.1.1 With the implementation of the Water Framework Directive (WFD), fluvial geomorphology (hydromorphology) is considered to be a receptor of potential environmental impacts. The assessment of potential impacts and the development of mitigation measures draw on recommended best practice, such as SEPA (2008).

2.1.2 The approach to the assessment of impacts on fluvial geomorphology was agreed with SEPA.

2.1.3 Geomorphology in the context of solid and drift geology is considered separately in Chapter 8 (Geology, Contaminated Land and Groundwater).

2.2 Legislative Context

2.2.1 The 2000/60/EC 'Water Framework Directive' (WFD) which is transposed into Scottish law by the 'Water Environment and Water Services (Scotland) Act 2003' (WEWS Act) (Scottish Executive, 2003), aims to classify surface waters according to their ecological status and sets targets for restoring/improving the ecological status of waterbodies. Water quality and hydromorphology are characteristics against which ecological status is assessed. Under the WFD, the status of water is assessed using a range of parameters including chemical, ecological, physical, morphological and hydrological measures to give a holistic assessment of aquatic ecological health. Furthermore, there is a requirement under the WFD that natural waterbodies must attain at least 'good ecological status' by 2015. Certain waterbodies may be designated as artificial/heavily modified and will have less stringent targets to meet, however these will still need to demonstrate 'good ecological potential' by 2015 (SEPA, 2002).

2.2.2 In addition to the WEWS Act, the Water Environment (Controlled Activity) (Scotland) Regulations 2005 (Scottish Executive, 2005) (referred to hereafter as CAR) controls engineering works in, or in the vicinity of, inland surface waters, as well as point source discharges, abstractions and impoundments, supporting implementation of the WFD in Scotland. There are three different levels of authorisation under CAR: General Binding Rules (GBR), Registration, and Licence (either simple or complex). The level of authorisation increases as the activity poses a higher risk of impact on the water environment. The level of authorisation under CAR for the proposed scheme will depend on the activities proposed, but is likely to range from GBR covering construction activities, to licences for road drainage discharges (draining over 1km in length), river crossings and river realignment.

2.2.3 Environmental Standards for River Morphology have been established (SEPA, 2007a). These standards are used to determine whether the impact of an engineering activity would result in a deterioration in WFD status by establishing ‘capacity limits’ for future channel modification. These tests are conducted by SEPA during the CAR application process. Although CAR applications are a separate process to EIA, regular consultation has been undertaken with SEPA to ensure that the Stage 3 environmental assessment and the progression of the proposed scheme design take into account the anticipated requirements of CAR. Design and assessment was also informed by the guidance provided in ’The Water Environment (Controlled Activities) (Scotland) Regulations 2005: A Practical Guide’ (SEPA, 2007b).

2.2.4 As there is no standard methodology for undertaking a fluvial geomorphology assessment for an Environmental Impact Assessment, the assessment methodology was developed using relevant DMRB guidance, legislation and regulations including the following:

- Highways Agency et al., 2006a DMRB Volume 4, Section 2: Drainage;
- Highways Agency et al., 2006b DMRB Volume 11, Section 3, Part 10 (HA 216/06): Road Drainage and the Water Environment;
- SEPA WFD policy guidance ‘The Future for Scotland’s Waters, Guiding Principles on the Technical Requirements of the Water Framework Directive’ (SEPA, 2002);
- Haycocks Associates, 2005, Review of Impact Assessment Tools and Post Project Monitoring Guidelines, Report to SEPA, 64pp; and
- Environment Agency (1998) River Geomorphology: A Practical Guide.

2.3 Study Area

2.3.1 The baseline study area for the water environment is shown in Chapter 9 (Water Environment) Figures 9.1 and 9.2.

2.3.2 There are no watercourses to the north of the Firth of Forth that would be crossed/impacted by the proposed scheme. To the south of the Firth of Forth, the following seven watercourses may be affected and are therefore assessed:

- Swine Burn;
- Tributary of Swine Burn;
- Niddry Burn;
- Tributary of Niddry Burn;
- River Almond;
- Dolphington Burn; and
- Ferry Burn.

2.3.3 This report only considers fluvial waterbodies and therefore does not consider the Firth of Forth which is an estuarine (tidal) waterbody.

2.4 Determination of Baseline Conditions

2.4.1 Baseline conditions were identified through a combination of consultation, desk-based assessment and site walkovers. In addition, for the purposes of determining existing flood level conditions along the Swine Burn and Niddry Burn, topographic surveys and hydrodynamic modelling were undertaken along appropriate reaches of these watercourses.

Consultation

2.4.2 Consultations, as described in Chapter 6 (Scoping and Consultation), were undertaken with statutory consultees and key stakeholders such as:

- SEPA (WFD risk designations and agreed assessment methodologies); and
- SNH (key areas for sensitive species, e.g. salmonids).

Baseline Assessment

2.4.3 The baseline assessment combined a desk-based assessment and field survey.

2.4.4 The desk study utilised existing data sources to identify current known geomorphological conditions and trends in river behaviour. A summary description of data sources is provided in Table 2.1 as below.

Table 2.1: Data Sources Examined During the Desk Study

Data Source	Information Provided
Contemporary Ordnance Survey Plans	Basic contextual information, such as elevation, relative relief and an indication of channel gradient.
Geological Maps (solid and drift plus soils)	Enables an understanding of the likely channel boundary conditions. This, in addition to the soils data, helps indicate the likely quantity and calibre of sediment released.
Geological Borehole Data	Augments geological maps.
Aerial Photography	Basic contextual information about the site such as land use and vegetation types. Also provides information on the distribution of geomorphological features which helps the contemporary and past geomorphological processes to be understood.
Hydrological Data (where available)	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 the channel gradient. Flood event hydrographs describe the response of catchments to rainfall events, which can influence the nature and severity of erosional and depositional response.
Historical Maps	Allows changes in river channel planform to be determined over periods of up to 150 years, which provides an understanding of the nature of fluvial processes and allows trends in channel behaviour to be elucidated.
Topographic Survey (where available)	Cross-sectional survey provides useful information about channel structure and gradient 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.

2.4.5 The field study was designed to build on the findings of the desk study to determine the geomorphological forms and processes at each site. Walkover surveys were undertaken in April and November 2008 in the study area to visually inspect the watercourses.

2.4.6 The range of geomorphological information collected during the field study is summarised in Table 2.2.

Table 2.2: Information Obtained During Field Study

Data Source	Information Provided
Geomorphological Mapping	Geomorphological mapping, which involves producing a map of geological features, 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 would enable the sensitivity of watercourses to modification to be determined and the likely morphological response predicted.

2.4.7 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.

Impact Assessment

2.4.8 As Highways Agency et al., (2006a) 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 SNH such as Environment Agency (1998) and Sear et al. (2003).

2.5 Impact Assessment

2.5.1 The impact assessment has been carried out using the general approach outlined below, where the level of significance of an impact is assessed based on the sensitivity of the surface water feature (receptor) and the magnitude of potential impact, during both construction and operation. Impacts are adverse unless stated otherwise.

2.5.2 Further assessments of the impacts of the proposed scheme on the water environment may be required pre-construction as part of the CAR process, as described in paragraphs 2.2.2 and 2.2.3.

Sensitivity

2.5.3 The sensitivity of the receiving environment was categorised on a scale of ‘low’ to ‘high’, in accordance with the criteria provided in Table 2.3. In defining these criteria, guidance such as The Highways Agency et al., (2006a) DMRB has been consulted.

2.5.4 The sensitivity of each watercourse has been evaluated by a particular set of criteria (separate from the other disciplines) for fluvial geomorphology, as listed in Table 2.3. The sensitivities assigned to each watercourse are relevant to the surveyed reach and not the entire catchment (Section 3: Baseline Conditions).

Table 2.3: Fluvial Geomorphology Criteria to Assess the Sensitivity of Water Features

Sensitivity	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. 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: Watercourses which may be highly vulnerable to changes in fluvial processes as a result of modifications. Watercourse response likely to involve changes to baseline conditions with a high impact on ecology.
Medium	Sediment regime: 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: Watercourses which may be vulnerable to changes in fluvial processes which are 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; uniform flow, gravel bars are 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: Watercourses which show no evidence of active fluvial processes and are not likely to be affected by modification to boundary conditions.

Impact Magnitude

2.5.5 The magnitude of impact is influenced by timing, scale, size and duration of change to the baseline conditions, as defined in Table 2.4.

Table 2.4: Fluvial Geomorphology Criteria to Assess the Magnitude of the Predicted Impact on Water Features

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 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 - Slight shift away from baseline conditions.	Sediment regime: Slight 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: Slight change in fluvial processes operating in the river; any change is likely to be highly localised.
Negligible - Minimal change from 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.

Impact Significance

2.5.6 The significance of impact was determined as a function of the sensitivity of the receiving environment and the magnitude of the impact, as outlined in Table 2.5.

Table 2.5: Matrix for Determination of Impact Significance

Sensitivity \ Magnitude	Negligible	Low	Medium	High
High	Negligible	Moderate	Moderate/ Substantial	Substantial
Medium	Negligible	Slight	Moderate	Moderate/ Substantial
Low	Negligible	Negligible	Slight	Moderate

Interactions with Ecology and with Geology, Contaminated Land and Groundwater

2.5.7 Impacts on the flow and sediment regime, morphological diversity and water quality of watercourses can cause indirect ecological impacts. Geomorphological sensitivities and the overall Water Environment sensitivities assigned to each watercourse were discussed with the project team's ecological specialists to take into consideration the links between physical processes and their dependent habitats.

2.5.8 To avoid repetition, all direct assessments on ecology are reported in Chapter 10 (Terrestrial and Freshwater Ecology) and Chapter 11 (Estuarine Ecology). However, as part of the criteria to assess water environment sensitivity, the ecological designations of the watercourses and the surrounding area have been considered where they indicate potential water environment sensitivities. This provides a comprehensive evaluation of the baseline conditions and creates a close link with the freshwater ecology assessment. Consequently, this appendix focuses on evaluating the sensitivity of the watercourse in terms of the physical attributes and processes encompassed by fluvial geomorphology.

3 Baseline Conditions

3.1 Introduction

3.1.1 In this section, the baseline conditions are described and used to assign a level of sensitivity to waterbodies as defined in Table 2.3.

3.1.2 The paragraphs below describe the baseline situation for all waterbodies in the study area. The baseline conditions reflect the 'Do-Minimum Scenario', which is based on an assumption of no proposed scheme and continued use of the Forth Road Bridge and associated road infrastructure.

3.1.3 For fluvial geomorphology, the overall sensitivity of each watercourse to disturbance defaults to the highest susceptibility to change out of the natural fluvial processes, sediment regime and morphological diversity of the existing channel.

3.1.4 The waterbodies described below (and where applicable the locations and SEPA sampling classifications) are shown on Figure 9.1, catchment areas are shown on Figure 9.2 and areas of flood risk are shown on Figure 9.4.

3.2 Watercourse Descriptions

Swine Burn

3.2.1 Swine Burn has a catchment area of approximately 10km^2 and is a tributary of the River Almond. The burn is approximately 8km in length and flows in a southeasterly direction through a predominantly rural catchment which includes agricultural land (Photograph 3.1), and mixed and broadleaf woodland.

3.2.2 For the majority of its length Swine Burn is a gravel-bed stream with a moderate to low gradient. The channel has been extensively modified by straightening, deepening and resectioning; the watercourse shows little variation in form. The bed is generally smothered by fine sediment and this results in limited flow diversity. The watercourse is interrupted by Humbie Reservoir and a lake to the west of Kirkliston. These lakes act as sinks for fine sediment.

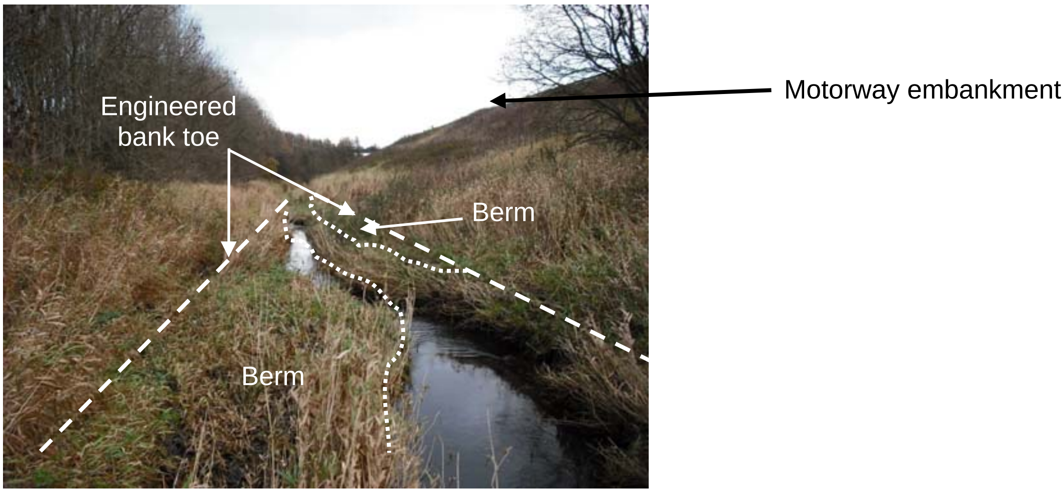
3.2.3 In the vicinity of the M9 however, Swine Burn has a sinuous planform and shallow gravel-bed channel with pools and riffles. These features provide a high degree of morphological diversity. The channel has fragmentary tree lining. There is some large woody debris in the channel, from fallen trees and branches which snags fly tipped material (Photograph 3.2). Downstream of the minor road bridge at NT 1100 7460 there is a significant amount of rubbish tipped on the floodplain and within the channel (Photograph 3.2). The banks of Swine Burn are fairly cohesive and are steep as a result of clay being present in the soil. Remnants of bank protection are present in the form of sections of historic walling which comprises moss covered laid stone (typically the size of cobbles). The bed comprises sand and fine gravels with some silt on the margins. In places the historic walling has failed and the stones have fallen onto the channel bed.

Photograph 3.1: Swine Burn flowing through agricultural land

Photograph 3.2: Large woody debris snagging tipped waste forming a debris jam in Swine Burn

3.2.4 Where Swine Burn runs parallel to the M9 embankment, which forms an artificial valley side (Photograph 3.3), there is evidence of past channel straightening. In addition to this, the left hand bank appears to have been modified by past quarrying and rock waste material (spoil) present on the valley side. However, the watercourse has subsequently re-adjusted its morphology towards a more natural form. At this location, the watercourse has a two-stage cross-sectional form. Field evidence and historical maps indicate that historical channel modifications involving channel straightening, widening and deepening occurred prior to 1856 and were designed to improve flow conveyance. Subsequent readjustment involved the deposition of sediment within the channel, forming alternate side bars, which were subsequently colonised by vegetation forming berms, which provide a degree of sinuosity.

3.2.5 The section of Swine Burn upstream of the culvert under the M9 spur has a relatively high morphological diversity with a more natural planform (as a result of the development of berms); natural cross-section for a cobble stream; varied flow types; varied bank top vegetation. This high morphological diversity is maintained by active sediment transport on the bed of the channel. The relatively high morphological diversity of the watercourse and evidence of historic adjustment to engineering means the watercourse has a medium sensitivity to disturbance.



Photograph 3.3: Downstream view of Swine Burn, including berms and motorway embankment

Tributary of Swine Burn

3.2.6 This short watercourse originates in Ross's Plantation to the west of the M9 near Charles Bridge. The tributary is crossed by the M9 motorway at Charles Bridge culvert and discharges into the main stem of the Swine Burn approximately 50m north of this culvert.

3.2.7 This gravel-bed stream has been extensively modified by straightening and culverting (Photograph 3.4). Immediately downstream of the culvert the banks are concrete lined for approximately 25m. After this reach there is a short section of scour protection. The banks of the tributary are clay rich earth and are generally covered by vegetation. The bed consists of silt, sand and gravel. There is some woody debris within the channel.

3.2.8 The channel has been extensively modified through culverting and realignment giving an artificial channel form. This watercourse has low sensitivity to disturbance.

Photograph 3.4: Upstream view of the tributary of Swine Burn culvert under M9

Niddry Burn

3.2.9 Niddry Burn, located to the west of Kirkliston, is a tributary of the River Almond. It is approximately 7km in length and has a catchment area of approximately 20.6km^2. The catchment has a predominantly rural land use.

3.2.10 This gravel-bed stream has been subject to localised modifications in the form of localised realignment and culverting (Photograph 3.5). Immediately upstream of the M9 culvert, both banks of the channel have full bank protection for approximately 30m. Despite the localised modifications, the watercourse has good morphological diversity and evidence of active bed sediment movement. The channel bed is characterised by pools and riffles and occasional exposed gravel bars are also present. Although the channel appears to have been modified in the past, by straightening, the watercourse is re-naturalising towards a more natural morphology through sediment deposition and erosion. This is driving localised channel migration and an increase in sinuosity. This adjustment has lead to the formation of a low river terrace on the left hand bank of the channel (Photograph 3.6).

3.2.11 Despite localised modification, Niddry Burn shows evidence of active morphological adjustment through sediment transport, erosion and deposition which has allowed the development of diverse channel morphology. The watercourse is therefore considered to be of medium sensitivity to geomorphological disturbance.

Photograph 3.5: Existing culvert on Niddry Burn

Photograph 3.6: Upstream view of Niddry Burn illustrating local erosion and protection

Tributary of Niddry Burn

3.2.12 The tributary of Niddry Burn originates at NGR NT 0980 7350 and is approximately 2.5km in length, draining a small catchment. The watercourse flows in an easterly direction past Newliston, through two online ponds impounded by weirs before finally discharging into Niddry Burn approximately 180m upstream of Niddry Burn and River Almond confluence. The ponds are associated with Newliston House and appear to be ornamental features.

3.2.13 The watercourse has a straight planform due to human modifications, presumably to improve land drainage adjacent to the channel. The watercourse now has the characteristics of a drainage ditch. The majority of land use is arable farmland, with pockets of improved grassland. Bank top vegetation is predominantly long grasses, with occasional clumps of trees.

3.2.14 Due to the highly modified nature of this watercourse, relatively small catchment and flow regulation by upstream ponds, which reduce downstream sediment supply, the burn is considered to be of low sensitivity to geomorphological disturbance.

River Almond

3.2.15 The River Almond is the largest watercourse in the study area (excluding the Firth of Forth), at approximately 50km long. The River Almond rises in the Cant Hills above Harthill (approx NGR NS 8740 6280) and flows into the Firth of Forth at Cramond. It has a catchment area of approximately 388km² and receives flow from the Niddry Burn and Swine Burn.

3.2.16 In the location of the M9 motorway, the River Almond is a moderate to low gradient gravel-bed river with an irregularly sinuous planform, which has been historically realigned and re-sectioned in places. The bankfull width is approximately 30m and channel depth is approximately 3m. The channel banks have been engineered and re-profiled, giving the channel a trapezoidal cross section (Photograph 3.7). The dominant flow type at the site of survey is smooth glide reflecting the engineered channel form and relatively deep water. The banks are protected by boulders placed along the bank toe. The bank faces are well vegetated and young trees are growing on the river bank face on both sides of the channel. There is one bridge pier in the channel and an existing outflow. There is also an existing outfall at this location. This river is crossed by the M9.

Photograph 3.7: Downstream view of the River Almond channel cross section

3.2.17 The relatively large size of this watercourse, and therefore relatively large increases in flow energy and water levels during flood events, means that modifications to channel form could trigger localised morphological adjustment. However, as the existing channel has been modified and for a watercourse of its size, it shows limited morphological diversity. The watercourse is considered to be of medium sensitivity to geomorphological disturbance.

Dolphington Burn

3.2.18 Dolphington Burn is located south of South Queensferry. The watercourse originates within the Dundas Estate and flows in an easterly direction to the south of Dalmeny. It has a catchment area of approximately 3.7km².

3.2.19 Dolphington Burn is a low lying stream with no visible valley sides. Downstream of the A90 trunk road, to the east of Dalmeny, the burn becomes Cockle Burn, which flows directly into the Outer Firth of Forth. The watercourse flows through a mixture of mixed woodland and agricultural land and has several tributaries, primarily field drains. It is a gravel-bed stream, with earthy banks (Photograph 3.8).

Photograph 3.8: The straight channel of the Dolphington Burn

3.2.20 The burn has a straight channel as a result of extensive channel modifications (Photograph 3.8). These modifications are principally in the form of historic channel straightening and realignments to follow tracks and field boundaries. The burn is culverted in several locations as it passes beneath roads, railways and the Oil Storage Depot at Dalmeny. The watercourse was culverted and realigned during the construction of the M9 Spur (Photograph 3.9). There is also evidence that the watercourse is periodically dredged to improve flow conveyance. As a result of this extensive modification, the watercourse has a very uniform morphology with little evidence of active fluvial processes. However, there is evidence of localised active adjustment in response to the channel engineering, such as beneath the recently completed M9 Spur.

3.2.21 Underneath the M9 road bridge the burn has been straightened, deepened and reprofiled. The banks are steep and free from vegetation. As a consequence of this modification the toe of the bank (lower 0.3m) has been eroded by recent high flows releasing sediment downstream, which has created localised areas of deposition.

Photograph 3.9: Recent culverting of the Dolphington Burn

3.2.22 As this watercourse has been extensively modified through realignment, re-sectioning and crossing structures it is considered to be of low sensitivity to geomorphological disturbance.

Ferry Burn

3.2.23 Ferry Burn is located to the south of South Queensferry. It originates in Ferry Muir and drains a heavily urbanised catchment. The watercourse is approximately 1km long and has a catchment area of approximately 1.3km^2. Ferry Burn is heavily modified, and flows through sections of both open and culverted channel towards the Firth of Forth. Where the channel is open it comprises a gravel and sandy bed with earthy and vegetated banks (Photograph 3.10). Ferry Burn discharges into the Firth of Forth through a sewer pipe which extends out into the estuary (Photograph 3.11). Ferry Burn is fed by local drainage ditches, ditches and receives drainage from agricultural ditches and the motorway embankment.

Photograph 3.10: An open channel section of Ferry Burn

3.2.24 The burn has a low sinuosity as a result of extensive channel modifications. These modifications are principally in the form of historic channel straightening and realignments to drain the periphery of residential areas. The extensive modification and culverting means the burn has a low sensitivity.

Photograph 3.11: The Ferry Burn outfall discharging into the Firth of Forth

3.3 Summary of Watercourse Sensitivities

3.3.1 Table 3.1 summarises the sensitivities assigned to each watercourse, for fluvial geomorphology, using the criteria outlined in Table 2.3.

Table 3.1: Sensitivity of watercourses affected by the proposed scheme for Fluvial Geomorphology

Watercourse	Sensitivity
Swine Burn	Medium
Tributary of Swine Burn	Low
Niddry Burn	Medium
Tributary of Niddry Burn	Low
River Almond	Medium
Dolphington Burn	Low
Ferry Burn	Low

4 Potential Impacts

4.1 Introduction

4.1.1 This section describes the potential impacts on the fluvial geomorphology that could arise in the absence of mitigation, during both the construction and operational phases of the proposed scheme. Residual impacts taking into account proposed mitigation are then provided in Section 6 (Residual Impacts).

4.1.2 Generic potential impacts are described, followed by specific impacts on water features, firstly during the construction and then the operational phases of the proposed scheme. Specific impacts are summarised in Table 4.2.

4.2 Generic Construction Impacts

4.2.1 The construction impact assessment was carried out qualitatively. For the purposes of this assessment, the combination of different engineering activities (construction of water crossings and associated works) that would be carried within the vicinity of a watercourse, as well as the extent of the proposed works, was taken into consideration.

4.2.2 The impacts during the construction phase mostly relate to suspended solids. In addition, weather conditions would also influence the severity of impacts. The majority of the impacts would worsen during intense or prolonged rainfall events throughout the construction phase.

4.2.3 Table 4.1 outlines potential generic impacts on the geomorphology during the construction of the proposed scheme. The main potential impacts relate to an increase in fine sediment delivery, a reduction in morphological diversity and a change in natural fluvial processes of river channels.

Table 4.1: Potential Impacts on Geomorphology during the Construction Phase

Source of Impact	Potential Impacts
Suspended Solids Direct Impact: increased fine sediment supply to watercourses is likely to occur during construction operations. This may result from: • runoff from vegetation free surfaces; • construction and operation of temporary roads; • plant and vehicle washing; • excavations; • earthworks; and • excavation of road drainage.	**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 could also be 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 would be particularly significant where woodland clearance is required.	**Sediment Regime** An increase in supply of fine sediment through bank instability, especially during the winter months is likely. **Channel Morphology** Reduced morphological diversity due to bank collapse and sediment deposition may occur. **Natural Fluvial Processes** Bank instability due to bank erosion may increase. Increased sediment delivery may impact on any sites of ecological importance located downstream.
Culvert Installation Direct Impact: the majority of the watercourse crossings would involve culverting.	**Sediment Regime** Installation would increase the volume of sediment directly entering the channel and consequently increase turbidity. **Channel Morphology** Channel bed would be disturbed in the vicinity of the installation. **Natural Fluvial Processes** Localised erosion and deposition may occur, planform change may be constrained. A prevention of channel migration may have consequences both for WFD targets and detrimental effects on habitat diversity.
Channel realignment	**Sediment Regime** An increase in sediment supply would occur during cutting a new course. A subsequent increase in channel erosion is likely if the channel is straightened and gradient is increased. **Channel Morphology** Bedforms that have developed over a long period of time may be disturbed. The new channel would lack morphological diversity. **Natural Fluvial Processes** Channel instability may be induced due to the new courses. Fluvial processes are likely to be exacerbated by realignment, especially in high flows.

Source of Impact	Potential Impacts
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.

4.3 Specific Construction Impacts

4.3.1 The proposed scheme has been considered in the context of the general discussion of potential construction impacts above. The following components of the proposals could affect specific watercourses as described below and as summarised in Table 4.2.

Swine Burn

4.3.2 Channel realignment, the installation of a new culvert, an extension to the existing culvert and outfall construction would require in-channel works. This process can release suspended sediment which may then be transported downstream. The construction of embankments on the floodplain of the watercourse in this location may also increase the supply of sediment. Downstream, sediment deposition would lead to reductions in morphological quality by smothering the gravel-bed. In addition, clearing trees and shrubs may lead to bank instability which could also increase fine sediment supply with detrimental effects on channel morphology. The extensive nature of the works would, if unmitigated, lead to a potential impact of high magnitude on Swine Burn, resulting in an impact of Moderate/Substantial significance.

Tributary of Swine Burn

4.3.3 Construction of a new outfall may lead to a release of sediment into the watercourse as this would involve disturbance to a section of river bank. Downstream, sediment deposition would lead to localised reductions in morphological quality. However, due to the limited extent of the works required, the potential impact of this would be of low magnitude, resulting in an impact of Negligible significance.

Niddry Burn

4.3.4 Extending the existing culvert would disturb the bed and release plumes of fine sediment. Construction works would provide a high sediment supply which may enter the channel. Downstream, sediment deposition would lead to reductions in morphological quality. Construction of an outfall may lead to a release of sediment into the watercourse as this would involve disturbance to a section of river bank. Downstream, sediment deposition would lead to reductions in morphological quality. However, the limited extent of the works required and modified nature of the watercourse means the potential impact of this would be of low magnitude, resulting in an impact of Slight significance.

Tributary of Niddry Burn

4.3.5 Extending the existing culvert would disturb the bed and release plumes of fine sediment. Construction works would provide a high sediment supply which may enter the channel. Downstream, sediment deposition would lead to reductions in morphological quality. However, due to the limited extent of the works required and the small size of the watercourse, which would limit the dispersal of sediment, the potential impact of this would be of low magnitude, resulting in an impact of Negligible significance.

River Almond

4.3.6 Construction of the outfall structure may lead to a release of sediment into the watercourse. An increase in sediment supply through earthworks and vehicle access and runoff would have a detrimental impact on channel morphology. The channel has a medium morphological quality and smothering of the bed with fine sediment may lead to a reduction in morphological diversity. However, the highly localised nature of the construction activities would lead to a potential impact of low magnitude, resulting in an impact of Slight significance.

Dolphington Burn

4.3.7 Road drainage will be routed into the existing drainage system and utilise existing treatment systems (Sustainable Drainage Systems; SUDS). This would lead to a potential impact of negligible magnitude, resulting in an impact of Negligible significance.

Ferry Burn

4.3.8 Construction of an outfall may lead to a release of sediment into the watercourse as this would involve disturbance to a section of river bank. Downstream, sediment deposition would lead to reductions in morphological quality. However, due to the limited extent of the works required, this would lead to a potential impact of low magnitude, resulting in an impact of Negligible significance.

4.4 Generic Operational Impacts – Watercourses

Road Drainage Impacts

4.4.1 An increase in road drainage discharging to a watercourse may lead to an increase in fine sediment supply. The actual volume of sediment generated by the operation of the proposed scheme would vary between watercourses depending on the length of road from which runoff would drain into them. Impacts on the geomorphology of watercourses could include:

- Sediment Regime: an increase in transportation (turbidity) and deposition of fine sediment (sediment deposition).
- 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 sediment deposition. 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.

4.4.2 Road drainage outfalls would be required on several watercourses (Table 4.2). 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. The following impacts could result:

- Sediment Regime: scour around outfalls would 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 would lead to localised changes in channel morphology.
- Natural Fluvial Processes: outfalls provide fixed points along river banks which can alter fluvial processes 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 it 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.

4.4.3 An increase in discharge (flow) in the watercourse during rainfall events may occur as a result of increased surface runoff due to the low infiltration potential of the road surface. This may increase the activity of geomorphological processes within the channel. The following impacts may result:

- 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 could increase. Morphological diversity could be reduced, or improved, depending on sediment supply.
- Natural Fluvial Processes: adjustment to different flow and sediment regime, for example, a flashier regime would provide more energy for erosion leading to increased lateral migration. This could be a beneficial impact where there is an improvement to morphological diversity or, alternatively, an adverse impact where an increase in fine sediment supply occurs.

Watercourse Crossing Impacts

4.4.4 Culverting watercourses can have a range of impacts:

- 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 sediment deposition 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 reduced due to artificial bed and banks. Interruption of morphological continuity segments the watercourse.
- Natural Fluvial Processes: Culverts would constrain the channel preventing lateral and vertical adjustment.

Watercourse Realignment Impacts

4.4.5 Watercourse realignments may result in the following impacts:

- Sediment regime: A major change in sediment regime may occur. Channel realignment may result in a change in sediment supply, rate of sediment transfer downstream and depositional zones. Changes in boundary materials through realignment into materials more prone to erosion are likely to increase the volume of sediment supplied to the channel. Increases in channel gradient as a result of realignment would result in an increase in stream power leading to greater erosion rates reducing channel stability and promoting sediment downstream. A reduction in channel gradient however, would be likely to lead to increased deposition within the channel, leading to adverse impacts on morphological diversity.
- Channel Morphology: Disruption to the channel bed may be short lived and realignment may lead to an improvement in channel morphology. In poor quality streams, realignment provides an opportunity to restore/rehabilitate the watercourse.
- Natural Fluvial Processes: As described above, realignments can alter the nature of fluvial processes operating within a reach. An increase in erosion and/or deposition can have feedback effects that can lead to a reduction in channel stability, increasing lateral migration for example. An increase in the rate of channel processes can lead to an improvement in morphological quality. However, sediment transfer can result in adverse impacts downstream.

4.5 Specific Operational Impacts

4.5.1 The following components of the proposals could affect specific watercourses as described below and as summarised in Table 4.2.

Swine Burn

Realignment

4.5.2 A 451m realignment of Swine Burn is proposed. The channel realignment will, where practicable, maintain existing channel dimensions (width and depth) and the overall length and gradient. Any existing flood storage areas within the realigned area will also be replaced to maintain the capacity of the watercourse, prevent an increase in flood risk and sustain connectivity to downstream areas.

4.5.3 The realignment, shown on Figure 9.5, will have a two-stage channel form comprising:

- sinuous low flow channel (1.5m wide at bed, 2.5m wide at bank top and 0.5m deep) to match the upstream channel;
- 10m floodplain (width to vary between 7m and 3m on either side) to provide flood flow attenuation and separate the low flow channel from the side slopes to limit the potential for erosion of these slopes;
- on bends in the low flow channel a minimum of 3m of floodplain will be provided between the bank top and the side slope;
- 1 in 3 side slopes; and
- cobble/gravel bed with appropriately sited pools and riffles.

4.5.4 The outline design proposed will enable some improvements to channel morphology, as compared to the existing straightened channel. However, both immediately upstream of the new culvert and in the section between the new culvert and the existing culvert, the toe of the right side slope of the new alignment will form the right bank of the channel (no floodplain is provided). The toe of the side slope in this location may therefore be vulnerable to erosion, especially during flood events. Erosion at the toe of the slope may trigger instability of the lower side slope due to over-steepening. This would be considered during detailed design (refer to Section 5: Mitigation).

4.5.5 The channel realignment would have an impact on Swine Burn of low magnitude and Slight significance.

Culverts

4.5.6 The extension of an existing culvert and the provision of a new culvert along Swine Burn would lead to localised reductions in the morphological diversity of the river channel at this location and potentially also interruptions to sediment transport. However as the watercourse is already modified by straightening this will have a potential impact of low magnitude and therefore an impact of Slight significance.

Outfalls

4.5.7 Two new SUDS outfalls are proposed for road drainage. One outfall is to be located on the right bank immediately upstream of the existing Overton Road bridge. This is located on the inside of a bend in the channel where flow energies are relatively low. This will limit the potential for scour around the outfall structure. The other outfall is to be located within the proposed channel realignment on the left bank immediately upstream of the new culvert. Here the outfall will be located on the outside of a bend in the realignment, where flow is concentrated along the bank toe and face. Locating the outfall in this position means there is a risk of scour around the outfall structure leading to a localised increase in channel erosion and therefore sediment supply.

4.5.8 Sediment supplied by untreated road drainage may increase water turbidity (sediment loading) and may also be deposited on the channel bed downstream leading to localised smothering of the bed and reductions in channel morphological diversity (filling voids in riffles and covering the bed of pools. However, the quantity of sediment supplied to the channel from road drainage is likely to be relatively low and concentrated into periods of high rainfall, when river flows would be high. This would increase dilution of suspended sediment and increase dispersal and therefore reduce the potential impact of increased sediment supply.

4.5.9 Although the channel realignment will enable an improvement in channel morphology to be provided, there remains a risk of erosion at the downstream end of the realignment. In addition, the new culvert increases the extent of artificial enclosed watercourse. The outfall to be located on the left bank immediately upstream of the new culvert maybe subject to scour. In addition, sediment supplied from untreated road drainage may lead to some limited smothering of the channel bed. However, the localised nature of these adverse impacts will limit the potential impact on Swine Burn to a low magnitude, resulting in an impact of Slight significance.

Tributary of Swine Burn

Outfalls

4.5.10 One new road drainage outfall is proposed. The new outfall may be subject to scour, however the position of the outfall and low stream powers (due to small catchment area) will limit the likelihood of this.

4.5.11 Sediment released by untreated road drainage would have highly localised impacts which, given the highly modified nature of the watercourse and existing low morphological diversity, would have a potential impact of low magnitude and of Negligible significance.

Niddry Burn

Culverts

4.5.12 The proposed increase in the length of the existing culvert would lead to a localised reduction in morphological diversity of the watercourse. However, the relatively short length of these modifications would limit this impact.

Outfalls

4.5.13 A new outfall will be constructed approximately 110m upstream of the existing culvert under the M9. The position of the outfall on the inside of a bend in the channel, where flow energies are low, will reduce the risk of scour.

4.5.14 Sediment supplied by untreated road drainage may be deposited on the channel bed downstream and could lead to localised smothering of the bed and reductions in channel morphological diversity (filling voids in riffles and covering the bed of pools). However, the quantity of sediment supplied to the channel from road drainage is likely to be relatively low and concentrated into periods of high rainfall, when river flows would be high. This would increase dilution of suspended sediment and increase dispersal and therefore reduce the potential impact of increased sediment supply.

4.5.15 Given the modified nature of the watercourse, low morphological diversity and relatively significant dilution potential, due to the size of the watercourse, the release of suspended sediment and potential deposition on the bed would have a potential impact of low magnitude and an impact of Slight significance.

Tributary of Niddry Burn

Culverts

4.5.16 The proposed increase in the length of the existing culvert would lead to a localised reduction in morphological diversity of the watercourse. However, the relatively short length of these modifications would limit this impact.

4.5.17 Given the modified nature of the watercourse, the low existing morphological diversity mean this would have a potential impact of low magnitude and Negligible significance.

River Almond

Outfalls

4.5.18 A new outfall may be subject to scour and depending on its type and location may encourage increases in either channel erosion or deposition.

4.5.19 Sediment supplied by untreated road drainage may lead to an increase water turbidity (sediment loading) and may also be deposited on the channel bed downstream which could lead to smothering of the bed and reductions in channel morphological diversity (filling voids in riffles and covering the bed of pools). However, the quantity of sediment supplied to the channel from road drainage is likely to be relatively low and concentrated into periods of high rainfall, when river flows would be high. This would increase dilution of suspended sediment and increase dispersal and therefore reduce the potential impact of increased sediment supply.

4.5.20 Given the modified nature of the watercourse, low existing morphological diversity and significant dilution potential, due to the size of the watercourse, the release of suspended sediment and potential deposition on the bed would have low magnitude impact of Slight significance.

Dolphington Burn

Outfalls

4.5.21 Road drainage will be routed into the existing drainage system and utilise existing treatment systems (SUDS). This will result in a negligible magnitude impact of Negligible significance.

Ferry Burn

Outfalls

4.5.22 A new outfall may be subject to scour and depending on its type and location may encourage increases in either channel erosion or deposition.

4.5.23 Sediment supplied by untreated road drainage may lead to an increase water turbidity (sediment loading) and may also be deposited on the channel bed downstream and could lead to smothering of the bed and reductions in channel morphological diversity (filling voids in riffles and covering the bed of pools). While the quantity of sediment supplied to the channel from road drainage is likely to be relatively low and concentrated into periods of high rainfall, the small size of the burn means that the potential for dilution and downstream dispersal of sediment may be limited.

4.5.24 Given the modified nature of the watercourse and low existing morphological diversity, the release of suspended sediment and potential deposition on the bed would have negligible magnitude impact of Negligible significance.

4.6 Summary of Potential Impacts

4.6.1 Table 4.2 provides a summary of the potential impacts to each of the watercourses, during both the construction and operational phases of the proposed scheme.

Table 4.2: Summary of Potential Impacts on Fluvial Geomorphology

Water Feature	Sensitivity	Assessed Impact	Phase	Potential Impact (unmitigated)	
				Magnitude	**Significance**
Swine Burn	Medium	New culvert Culvert extension 2 new outfalls Channel realignment	Construction	High	Moderate/ Substantial
			Operation	Low	Slight
Trib of Swine Burn	Low	Outfall	Construction	Low	Negligible
			Operation	Low	Negligible
Niddry Burn	Medium	Culvert extension Outfall	Construction	Low	Slight
			Operation	Low	Slight
Trib of Niddry Burn	Low	Culvert extension	Construction	Low	Negligible
			Operation	Low	Negligible
River Almond	Medium	Outfall	Construction	Negligible	Negligible
			Operation	Low	Slight
Dolphington Burn	Low	Outfall	Construction	Negligible	Negligible
			Operation	Negligible	Negligible
Ferry Burn	Low	Outfall	Construction	Low	Negligible
			Operation	Negligible	Negligible

5 Mitigation

5.1 Introduction

5.1.1 The objectives of the mitigation measures outlined in this section are to prevent, reduce or offset the potential impacts described in Section 4 (Potential Impacts).

5.1.2 Detailed design and mitigation will continue to develop through the CAR application process and ongoing liaison with SEPA.

Guiding Principles

5.1.3 Mitigation is proposed to address adverse impacts where practicable, in particular all impacts assessed as being of Moderate significance or greater and is intended to prevent, reduce or where practicable, offset any significant adverse impacts.

5.1.4 The implications of the WFD have also been taken into account in the formulation of mitigation, i.e. measures aimed to achieve and preserve ‘good’ ecological status of all watercourses by 2015. SEPA requires construction activities near most watercourses or waterbodies, as well as road outfalls draining over 1km of road, to be licensed under the terms of CAR.

Approach to Mitigation

5.1.5 The mitigation measures proposed to address specific potential impacts to waterbodies are summarised in Table 5.1.

5.2 Generic Construction Mitigation

Runoff from the Working Area

5.2.1 During construction of the roadway and associated works, temporary drainage systems will alleviate localised flood risk and prevent obstruction of surface runoff pathways. This will be achieved through the use of geotextile matting, ditches, or other methods detailed in CIRIA C648 and C697. A number of these temporary SUDS will be incorporated into the operational drainage network when the road is completed, but additional site-specific SUDS may be required during construction and will be removed once construction is complete.

Watercourse Crossings

5.2.2 During the installation of new culverts, watercourse flows will be diverted around the works in a temporary channel. The diversion channel will be of similar size and gradient to the existing channel.

5.2.3 The construction of new culverts would require extensive in-channel works. During culvert installation, flow will be diverted around the channel works, either in a lined open channel or through a pipe. This would allow channel works to be conducted in dry conditions reducing the risk of sediment release during construction. Flow will only be re-routed into the new culvert once channel works are completed, and, if practicable, during low flow conditions.

5.2.4 The extension of existing culverts will require in-channel works. In order to minimise the potential for sediment release it is recommended that works are conducted at low flow. Where possible flow should be temporarily routed through the site within a pipe.

5.2.5 Bare channel banks created during culvert installation will be covered by geotextile matting following completion to limit the potential for erosion. Geotextile matting will limit the potential for fluvial scour, geotechnical failure and rainfall-induced runoff erosion of the exposed banks. The geotextile matting will be seeded to promote vegetation colonisation and to encourage rapid stabilisation.

Outfalls

5.2.6 Effective mitigation for impacts associated with outfalls will be based on the following principles:

- Construction of the outfall will not be conducted during periods of high flow as the disturbed river bank will be vulnerable to erosion.
- Where practicable, provide sediment fences to prevent sediment being washed into the watercourses.
- Where practicable, avoid excavating into the watercourse and limit the extent of disturbance.

Programme of Works

5.2.7 The impact of the proposed scheme can be reduced through timely implementation of certain aspects of the construction works. The programme is also important to facilitate the implementation of mitigation measures at the stage where their application will be most effective. Appropriate timing of the implementation of mitigation measures is critical.

5.2.8 Treatment basins proposed to be included as part of proposed scheme design will be scheduled for construction early in the programme, to allow settlement and treatment of any pollutants contained in site runoff and to control the rate of flow before water is discharged into a receiving watercourse. Additional temporary settlement ponds may also be required during construction, particularly in the vicinity of sensitive waterbodies.

5.2.9 For all watercourses, in-channel works will be avoided during periods of low flow to reduce the risk of a pollution event such as a sediment release and occurrence of dissolved oxygen sags. Additionally, in-channel works and works within the floodplain will be avoided during periods of high flow and increased flood risk for health and safety reasons. In-channel works will avoid spawning periods in salmonid watercourses, i.e. Niddry Burn and River Almond (between October and May). More detailed information on this can be found in Chapter 10 (Terrestrial and Freshwater Ecology) and Chapter 11 (Estuarine Ecology) along with specific figures on work timing for particular species.

5.2.10 Prior to commencing construction, a detailed method statement for the layout and management of each part of the working area subject to a CAR licence will be agreed with SEPA and provided to the Competent Authority and SEPA for approval a minimum of two weeks prior to start of construction. The method statement will identify, where appropriate, the location of drainage ditches, settling ponds and sediment fences throughout the site to reduce the effects of turbid runoff whilst maintaining efficient operation of the site. This will involve a combined site visit and consultation between Environmental Clerk of Works, design engineer, construction site manager, and representatives of the relevant Competent Authority; SEPA or SNH. Where practicable, mitigation methods will be in situ prior to the start of any construction work.

Monitoring

5.2.11 Any monitoring requirements before, during or after construction will be agreed with SEPA in advance of the construction programme.

Table 5.1: Summary of relevant Generic Mitigation Measures during Construction

Source of Impact	Mitigation
Suspended Solids	• Runoff and erosion control measures will include perimeter cut-off ditches; ditches at the base of embankments (where the adjacent ground slopes towards the embankment); settlement lagoons; the installation of sediment fences on cut slopes in the proximity of watercourses, around drainage inlets and any drainage path; placement of hay bales; mulching; erosion control blankets; sediment fencing and hydro-seeding. Should chemical flocculants be proposed for settlement, SEPA will be consulted to obtain the necessary approvals. • Stockpiles will not be located near watercourses and will be covered when not in use, and silt fencing/ bunds must be provided around the perimeter of all stockpiles. Vehicles or vehicle wheels will not be washed near watercourses. • Where practicable, adequate space (exclusion zone) will be allocated between earthworks (embankments and cuttings) and watercourses, to limit the transfer of sediment into them. • Use of temporary culverts will be limited. Where practicable, temporary bridges should be used to cross watercourses rather than temporary culverts and fording watercourses with plant or machinery will be avoided. • Adequate barriers (sediment fences) will be provided along the sides of bridges to prevent sediment being washed into watercourse from road surface. • Access roads will not be created next to channels unless unavoidable. • Drains will be connected to watercourses only on completion. • When drilling boreholes for blasting, dust release will be reduced by damping with water or through providing barriers such as dust boxes.
Culvert Installation or Extension	• The length of channel disturbed will be restricted to that required. • Where practicable flow will be diverted through a pipe or lined channel to bypass the channel works to enable the culvert to be installed into a dry channel. • Where depressed invert culverts are to be installed, appropriately sourced and sized sediments will be used to form the bed of the new culvert.
Vegetation Clearance	• The clearing of vegetation on the channel banks and riparian zone will be limited to only that which is necessary. • Seeded geotextile mats will be used to encourage re-vegetation after works on or near the banks.
Watercourse/ Drain Crossings and Diversions	• Installation of culverts will be undertaken in the dry to reduce potential contamination of the watercourse. Temporary diversions will be put in place before culvert construction is undertaken. Temporary culverts (like permanent ones) will be appropriately sized to allow adequate passage of water during high flow conditions (designed to the 0.5% AEP) and will be designed to allow fish and mammal passage. • Where land drains are interrupted they will be incorporated into the pre-earthworks drainage ditches. • Undertake minimal disturbance to the banks and beds of watercourses and minimal disturbance to existing land drainage systems. If the new road blocks existing drainage, the existing land drainage will be culverted or diverted as appropriate.

Source of Impact	Mitigation
Outfall Construction	• Construction of outfalls will not be conducted during periods of high flow as the disturbed and exposed river banks will be vulnerable to erosion. • Sediment control measures (sediment fences) will be used to prevent sediment being washed into the watercourse. • Excavation into the river banks to be avoided where practicable and the extent of disturbance will be limited.
Potentially Contaminated Land and Sediment	• In areas where ground contains elevated concentrations of contaminants, appropriate measures will be implemented to substantially reduce the risk of pollutants entering watercourses (Chapter 8: Geology, Contaminated Land and Groundwater).

5.3 Specific Construction Mitigation

Swine Burn

5.3.1 The construction of the new culvert will require extensive in-channel works. Effective mitigation for impacts associated with channel realignment, described in Chapter 9 (Water Environment), includes:

- Constructing and completing the realignment off-line by diverting flow around the channel works.
- Covering exposed banks with geotextile matting to limit the potential for erosion.
- Bed sediments will be appropriately sized (and shaped) gravels derived from a local source, rather than being sourced from the existing channel.
- Monitoring the completed realignment to detect adverse morphological adjustments and where these are detected, such as erosion or incision, implementing remediation measures.
- Placing sediment control measures at the downstream end of the realignment to intercept sediment released during the connection of the new alignment.
- Managing site activity in the vicinity of the realignment to reduce the risk of accidental spillage into the watercourse.
- Conducting channel works during periods of low flow conditions (e.g. summer months) to reduce the risk of flood events disrupting the construction site or filling the incomplete realignment with water.

Niddry Burn

5.3.2 The construction process will follow the generic mitigation measures for culvert extensions and outfall construction.

5.4 Generic Operational Mitigation

5.4.1 In order to prevent an increase in sediment supply or discharge during road operation SUDS will be provided for discharges to watercourses. This is described in Chapter 9 (Water Environment).

Outfalls

5.4.2 The detailed positioning of outfalls will be designed to limit the potential for scour around the culvert. The outfall should ideally be oriented in a downstream direction at approximately 45° to flow. The base of the outfall should be level with the bed to prevent bed scour along the edge of the outfall. The outfall should not project out into the channel but should be set into the bank face. Where practicable, outfalls should not be positioned in locations where flow converges with river banks causing higher shear stresses or where active bank erosion is occurring.

5.5 Specific Operational Mitigation

Swine Burn

5.5.1 To limit the risk of erosion along the side slope which forms the right bank at the downstream end of the realignment, bank protection will need to be provided. The specific nature of this bank protection will be considered further during the preparation of the CAR application for the realignment.

5.5.2 The floodplain of the realignment will be encouraged to vegetate with a simple cover of grasses and tall (rank) herbs. In addition, occasional clumps of broadleaf (deciduous) trees will be planted on the floodplain. This vegetation will both replicate the existing conditions and also provide protection against surface scouring during floods.

5.5.3 Clumps of broadleaf (deciduous) trees will also be planted on the floodplain along the outside of bends in the low flow channel. These trees will be set-back from the channel margin by 2m. This will allow for a degree of bank erosion during the immediate post construction phase when vegetation is becoming established. Setting the trees back allows for bank erosion without risking removal of the trees, by erosion, before they become established.

5.5.4 Further design work will continue during the preparation of the CAR application for the realignment. This will be informed by a Sediment Dynamics Assessment. Design refinements emerging from this assessment are likely to include:

- minor amendments to the position of the low flow channel;
- localised variations in the cross-section form of the low flow channel;
- bed sediment sizing;
- determination of the position and dimensions of pools and riffles;
- identification of requirements for bank protection; and
- refined recommendations for floodplain riparian vegetation provision.

5.5.5 A period of monitoring will be undertaken after construction to reassess the effects on sediment transport.

Niddry Burn

5.5.6 To reduce the impact on the watercourse, generic mitigation required for outfall structures will be followed.

5.6 Summary of Mitigation Measures

5.6.1 Table 5.2 summarises the mitigation proposed for the activities which may have an impact on each watercourse during the construction and operational phases of the proposed scheme.

Table 5.2: Summary of Mitigation Measures

Water Feature	Potential Impact	Mitigation Measures
Swine Burn	Road drainage	SUDS.
	Realignment	Further refinement of channel design including provision of bank protection.
	Two outfalls	Ensure correct positioning.
	Construction	Adherence to generic mitigation.
Trib of Swine Burn	Road drainage	SUDS.
	Construction	Adherence to generic mitigation.

Water Feature	Potential Impact	Mitigation Measures
Niddry Burn	Road drainage	SUDS.
	Construction	Adherence to generic mitigation.
River Almond	Road drainage	SUDS.
	Construction	Adherence to generic mitigation.
Dolphington Burn	Road drainage	SUDS.
	Construction	Adherence to generic mitigation.
Ferry Burn	Road drainage	SUDS.
	Construction	Adherence to generic mitigation.

6 Residual Impacts

6.1 Introduction

6.1.1 Following successful implementation of the mitigation outlined in Section 5 (Mitigation), the potential for impacts on the water environment will be avoided, reduced or offset. Residual impacts are detailed below, and summarised for each watercourse in Table 6.1.

6.2 Construction Residual Impacts

Swine Burn

6.2.1 Careful construction using the mitigation measures outlined earlier will result in a residual impact of low magnitude and Slight significance on the geomorphology of the watercourse.

Tributary of Swine Burn

6.2.2 Careful construction using the mitigation measures outlined earlier will result in a residual impact of negligible magnitude and a residual impact of Negligible significance on the geomorphology of the watercourse.

Niddry Burn

6.2.3 Careful construction using the mitigation measures outlined earlier will result in a residual impact of low magnitude and Slight significance on the geomorphology of the watercourse.

Tributary of Niddry Burn

6.2.4 Careful construction using the mitigation measures outlined earlier will result in a residual impact of negligible magnitude and Negligible significance on the geomorphology of the watercourse.

River Almond

6.2.5 Careful construction using the mitigation measures outlined earlier will result in a residual impact of negligible magnitude and Negligible significance on the geomorphology of the watercourse.

Dolphington Burn

6.2.6 Routing runoff into existing drainage will result in a residual impact of negligible magnitude and Negligible significance on the geomorphology of the watercourse.

Ferry Burn

6.2.7 Careful construction using the mitigation measures outlined earlier will result in a residual impact of negligible magnitude and Negligible significance on the geomorphology of the watercourse.

6.3 Operational Residual Impacts

Swine Burn

6.3.1 Although the addition of a new culvert would increase the extent of artificial enclosed watercourse, the realignment will be designed to provide improvements in channel morphology in the open channel section of the realignment. This and the correct siting of outfalls, treatment of road drainage and provision of erosion protection measures where necessary, will limit the overall residual impact on Swine Burn to low magnitude and Slight significance.

Tributary of Swine Burn

6.3.2 Using SUDS will result in an impact of Negligible significance on the geomorphology of the watercourse. Installation of the outfall in line with the mitigation measures recommended will result in a residual impact of negligible magnitude and Negligible significance on the geomorphology of the watercourse.

Niddry Burn

6.3.3 Providing a culvert extension that matches the existing structure will limit the residual impact to a residual impact of low magnitude and Slight significance on the geomorphology of the watercourse.

Tributary of Niddry Burn

6.3.4 Providing a culvert extension that matches the existing structure will limit the residual impact to a residual impact of low magnitude and Negligible significance on the geomorphology of the watercourse.

River Almond

6.3.5 Installation of the outfall in line with the mitigation measures recommended will result in a residual impact of negligible magnitude and Negligible significance on the geomorphology of the watercourse.

Dolphington Burn

6.3.6 Routing runoff into existing drainage will result in a residual impact of negligible magnitude and Negligible significance on the geomorphology of the watercourse.

Ferry Burn

6.3.7 Installation of the outfall in line with the mitigation measures will result in a residual impact of negligible magnitude and Negligible significance on the geomorphology of the watercourse.

6.4 Summary of Residual Impacts

6.4.1 Table 6.1 provides a summary of the residual impacts to the Firth of Forth and each of the waterbodies, after the implementation of mitigation as described in Section 5 (Mitigation), during both the construction and operational phases of the proposed scheme.

Table 6.1: Summary of Residual Impacts on Fluvial Geomorphology

Water Feature	Sensitivity	Phase	Residual Impact Magnitude	Residual Impact Significance
Swine Burn	medium	Construction	low	Slight
		Operation	low	Slight
Trib of Swine Burn	low	Construction	negligible	Negligible
		Operation	negligible	Negligible
Niddry Burn	medium	Construction	low	Slight
		Operation	low	Slight
Trib of Niddry Burn	low	Construction	negligible	Negligible
		Operation	low	Negligible
River Almond	medium	Construction	negligible	Negligible
		Operation	negligible	Negligible
Dolphington Burn	low	Construction	negligible	Negligible
		Operation	negligible	Negligible
Ferry Burn	low	Construction	negligible	Negligible
		Operation	negligible	Negligible

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