A9 DUALLING
PERTH TO INVERNESS

# Appendix A11.1

## Hydromorphology Assessment

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## Tables

# 1. Introduction

1.1.1. This report forms a technical appendix to the A9 Dualling Tomatin to Moy – Stage 3 Environmental Statement, Chapter 11 (Road Drainage and the Water Environment) in Volume 1.

## 1.2. Aims and objectives

1.2.1. The assessment aims to inform the Road Drainage and the Water Environment Assessment about potential hydromorphological impacts of the Proposed Scheme on the receptors (affected fluvial watercourses) during the construction and operational phases.

1.2.2. The assessment will also examine the mitigation measures required to remove and reduce any potential adverse impacts to watercourses.

1.2.3. The specific objectives of this assessment are:

- Assess the baseline characteristics of each watercourse and categorise each with a sensitivity classification.
- Assess the potential impact on each watercourse from the Proposed Scheme.
- Outline measures required to mitigate potential impacts.
- Identify further investigations required.

1.2.4. Direct and indirect impacts are also considered with regards to the cumulative impacts relating to the wider Water Framework Directive (WFD) objectives in the vicinity of the Proposed Scheme.

## 1.3. Study area

1.3.1. The study area for this assessment focuses on the Proposed Scheme within a 250m proximity. The Proposed Scheme begins around NGR NH 829 262 south of the existing A9 crossing over the River Findhorn at Tomatin South Junction (with the main dualling works begins at the Tomatin grade separated junction), passing by Loch Moy around NGR NH 771 339 and ending northwest of Moy at NGR NH 725 835. Figure A11.1.1 provides an overview of the Proposed Scheme extent and study area.

1.3.2. A full description of the Proposed Scheme can be found in Chapter 5 (The Proposed Scheme) in Volume 1 of the ES.

# 2. Approach and Methodology

## 2.1. Introduction

2.1.1. The hydromorphology impacts of the Proposed Scheme were determined by assessing the sensitivity of each watercourse and then the magnitude of the potential impact(s). The following section outlines the approach to the classification criteria and the methodology by which this has been applied to the watercourse assessment.

2.1.2. To some degree, the assessment of sensitivity and impacts relies on the professional judgement of the surveyor and therefore is partially subjective. Consequently, it is important that a wide range of information is considered when assigning values to each watercourse.

2.1.3. The baseline information collected for the Design Manual for Roads and Bridges (DMRB) Stage 2 assessment is deemed sufficient to inform the impact assessment for Stage 3. Therefore, no further walkover has been undertaken and all baseline data is considered still valid.

2.1.4. The impact assessment is based on more detailed information on the size, alignment and connection of the proposed river crossings, plus the potential impacts on the watercourses more broadly.

2.1.5. Sediment entrainment and stream power calculations were also undertaken based on the outputs from the hydraulic models, providing additional context to the impact assessment.

2.1.6. An initial assessment of the magnitude of impact considers the Proposed Scheme design, including embedded mitigation. Embedded mitigation is that which is already built into the design prior to the impact assessment. Standard and specific mitigation are measures considered necessary to protect the environment, prior to construction, during construction and/or during operation of the Proposed Scheme to reduce any identified impact. The initial impact (including embedded mitigation) when combined with the standard and specific mitigation results in the residual magnitude of impact.

2.1.7. The combination of the sensitivity and residual magnitude of impact will produce an overall significance of residual effect.

## 2.2. Desk study

2.2.1. The desk study was undertaken to identify current hydromorphological conditions and trends in river behaviour. Table A2.1 lists the data used during the desk study and the information it provided.

**Table A2.1: Desk Study Data Sources**

| Data source | Description and information provided |
|---|---|
| Contemporary aerial photographs | Aerial photographs provide contextual information about the site and surrounding landscape, including land use and vegetation types. It can also provide some insight into the distribution of fluvial features, such as gravel bars, palaeochannels and wetland features. |
| Contemporary Ordnance Survey (OS) Mapping | Providing basic contextual information, such as elevation, relative relief and an indication of channel gradients. |

| Data source | Description and information provided |
|---|---|
| Geological mapping (solid and drift plus soils) | Indicates the underlying geology and feeds into the understanding of potential response/stability. |
| Historical mapping (where available): National Library of Scotland[i] and Old maps[ii] | Comparison of historical maps to determine channel change over a period of approximately 150 years. Provides important context and understanding to modifications and existing fluvial processes. Provides insight into long-term instability issues. |
| Topographic survey | Understanding the arrangement and topography of existing features and landscapes in the study area. The topographic survey is a combination of flown, aerially captured levels (LiDaR) and ground survey methods. |
| River Basin Management Plan (RBMP) | The RBMPs indicate which water bodies are classified under the WFD as main rivers and their relative status. It will also provide an insight into the proposed mitigation measures and targets which can be built into future designs. |
| The Proposed Scheme | To assess the potential impacts to the watercourses. |

## 2.3. Field study

2.3.1. The field study complements and builds on the findings of the desk study to determine the specific character of the geomorphological forms and processes at each watercourse. The field study comprised a rapid hydromorphological walkover along each watercourse to broadly assess the following:

- landscape and floodplain
- channel modifications
- planform and boundary conditions (bed and banks)
- existing operating fluvial processes and features
- riparian and in-channel vegetation

## 2.4. Impact assessment

2.4.1. The DMRB does not outline a specific methodology or guidance enabling hydromorphological impacts to be evaluated. However, the general guidance contained in DMRB, Volume 11, Section 3, Part 10 Road Drainage and the Water Environment (HD 45/09) has been used as the framework for the assessment method outlined below.

### Watercourse sensitivity

2.4.2. The sensitivity classification criteria for Stage 2 has been superseded following consultation with all design engineering consultants to ensure a consistent approach has been applied to all sections of the A9. The main changes are a more detailed consideration of the specific sediment regime, morphological condition and fluvial processes. Specific reference to the WFD was removed. The sensitivity of the identified watercourses are based on broad classification criteria (Table A2.2), which has been adapted from similar guidance[iii], taking into account research and development programmes of the Environment Agency and Scottish National Heritage (SNH) (as compiled[iv]), as well as professional experience.

**Table A2.2: Watercourse Sensitivity Classification Criteria**

| Sensitivity | Criteria |
|---|---|
| Very High | Sediment Regime: Water feature sediment regime provides a diverse mosaic of habitat types suitable for species sensitive to changes in sediment concentration and turbidity, such as migratory salmon, freshwater pearl mussels. Water feature appears in complete equilibrium with natural erosion and deposition occurring. The water feature has sediment processes reflecting the nature of the catchment and fluvial system.<br>Channel Morphology: Water feature includes varied morphological features (e.g. pools, riffles, bars, natural bank profiles) with no sign of channel modification.<br>Natural Fluvial Processes: Water feature displays natural fluvial processes and natural flow regime, which would be highly vulnerable to change as a result of modification. |
| High | Sediment Regime: Water feature sediment regime provides habitats suitable for species sensitive to changes in sediment concentration and turbidity, such as migratory salmon, freshwater pearl mussels. Water feature appears largely in natural equilibrium with some localised accelerated erosion and/or deposition caused by land use and/or modifications. Primarily the sediment regime reflects the nature of the natural catchment and fluvial system.<br>Channel Morphology: Water feature exhibiting a natural range of morphological features (e.g. pools, riffles, bars, varied natural river bank profiles), with limited signs of artificial modifications or morphological pressures.<br>Natural Fluvial Processes: Predominantly natural water feature with a diverse range of fluvial processes that is highly vulnerable to change as a result of modification. |
| Medium | Sediment Regime: Water feature sediment regime provides some habitat suitable for species sensitive to change in suspended sediment concentrations or turbidity. A water feature with natural processes occurring but modified, which causes notable alteration to the natural sediment transport pathways, sediment sources and areas of deposition.<br>Channel Morphology: Water feature exhibiting some morphological features (e.g. pools, riffles and depositional bars). The channel cross-section is partially modified in places, with obvious signs of modification to the channel morphology. Natural recovery of channel form may be present (e.g. eroding cliffs, depositional bars).<br>Natural Fluvial Processes: Water feature with some natural fluvial processes, including varied flow types. Modifications and anthropogenic influences having an obvious impact on natural flow regime, flow pathways and fluvial processes. |
| Low | Sediment Regime: Water feature sediment regime which provides very limited physical habitat for species sensitive to changes in suspended solids concentration or turbidity. Highly modified sediment regime with limited/no capacity for natural recovery.<br>Channel Morphology: Water feature that has been extensively modified (e.g. by culverting, addition of bank protection or impoundments) and exhibits limited-to-no morphological diversity. The water feature is likely to have uniform flow, uniform banks and absence of bars. Insufficient energy for morphological change.<br>Natural Fluvial Processes: Water feature which shows no or limited evidence of active fluvial processes with unnatural flow regime or/and uniform flow types and minimal secondary currents. |

Table Source: Watercourse Sensitivity Classification Criteria (adapted from Table 14, WebTAG Unit A3, Department for Transport, 2014)

## Impact magnitude

2.4.3. Similarly, to the sensitivity criteria, there is little guidance on the classification of the potential magnitude of hydromorphological impacts. The criteria used in this Stage 3 assessment has been adopted to ensure that a consistent approach to assessing the impacts has been undertaken. The guidance criteria is outlined in Table A2.3 below.

**Table A2.3: Magnitude of Impacts Classification Criteria**

| Magnitude | Criteria |
|---|---|
| Major Adverse | Sediment Regime: Significant impacts on the water feature bed, banks and vegetated riparian corridor resulting in changes to sediment characteristics, transport processes, sediment load and turbidity. This includes extensive input of sediment from the wider catchment due to modifications. Impacts would be at the waterbody scale.<br>Channel Morphology: Significant/extensive alteration to channel planform and/or cross section, including modification to bank profiles or the replacement of a natural bed. This could include: significant channel realignment (negative); extensive loss of lateral connectivity due to new/extended embankments; and/or, significant modifications to channel morphology due to installation of culverts or outfalls. Impacts would be at the waterbody scale.<br>Natural Fluvial Processes: Significant shift away from baseline conditions with potential to alter processes at the catchment scale.<br>Condition Status: Substantial adverse impacts at the water body scale, which causes loss or damage to habitats. Impacts have the potential to cause deterioration in hydromorphology quality elements*. Prevents the water body from achieving Good status. |
| Moderate Adverse | Sediment Regime: Some changes and impacts on the water feature bed, banks and vegetated riparian corridor resulting in some changes to sediment characteristics, transport processes, sediment load and turbidity. Impacts would be at the multiple reach scale.<br>Channel Morphology: Some alteration to channel planform and/or cross section, including modification to bank profiles or the replacement of a natural bed. Activities could include: channel realignment, new/extended embankments, modified bed and/bank profiles, replacement of bed and/or banks with artificial material and/or installation of culverts. Impacts would be at the multiple reach scale.<br>Natural Fluvial Processes: A shift away from baseline conditions with potential to alter processes at the reach or multiple reach scale.<br>Condition Status: Moderate adverse impacts at the reach or multiple reach scale, which causes some loss or damage to habitats. Impacts have the potential to cause failure or deterioration in one or more of the hydromorphological quality elements. May prevent the water body from achieving Good status. |
| Minor Adverse | Sediment Regime: Limited impacts on the water feature bed, banks and vegetated riparian corridor resulting in limited (but notable) changes to sediment characteristics, transport processes, sediment load and turbidity at the reach scale.<br>Channel Morphology: A small change or modification in the channel planform and/or cross section. Includes upgrade to and/or extension of existing watercourse crossing and/or structure with associated minor channel realignment with localised impacts.<br>Natural Fluvial Processes: Minimal shift away from baseline conditions with typically localised impacts up to the reach scale.<br>Condition Status: Minor adverse impacts at the reach scale, which may cause partial loss or damage to habitats. Impacts have the potential to cause failure or deterioration in one of the hydromorphological quality elements. |
| Negligible | Minimal or no measurable change from baseline conditions in terms of sediment transport, channel morphology and natural fluvial processes. Any impacts are likely to be highly localised and not have an effect at the reach scale. |

| Magnitude | Criteria |
|---|---|
| Minor Beneficial | Sediment Regime: Partial improvement to sediment processes at the reach scale, including reduction in siltation and localised recovery of sediment transport processes.<br>Channel Morphology: Partial improvements include enhancements to in-channel habitat, riparian zone and morphological diversity of the bed and/or banks.<br>Natural Fluvial Processes: Slight improvement on baseline conditions with potential to improve flow processes at the reach scale.<br>Condition Status: Slight beneficial impacts at the reach scale, which may cause partial habitat enhancement. Impacts have the potential to improve one of the hydromorphological quality elements. |
| Moderate Beneficial | Sediment Regime: Reduction in siltation and recovery of sediment transport processes at the reach or multiple reach scale.<br>Channel Morphology: Partial creation of both in-channel and vegetated riparian habitat. Improvement in morphological diversity of the bed and/or banks at the reach or multiple reach scale. Includes partial or complete removal of structures and/or artificial materials.<br>Natural Fluvial Processes: Notable improvements on baseline conditions and recovery of fluvial processes at the reach or multiple reach scale.<br>Condition Status: Notable beneficial impacts at the reach to multiple reach scale. Impacts have the potential to improve one or more of the hydromorphological quality elements and/or assist the water body in achieving Good status. |
| Major Beneficial | Sediment Regime: Improvement to sediment processes at the catchment scale, including recovery of sediment supply and transport processes.<br>Channel Morphology: Extensive creation of both in-channel habitat and riparian zone. Morphological diversity of the bed and/or banks is restored, such as natural planform, varied natural cross-sectional profiles, recovery of fluvial features (e.g. cascades, pools, riffles, bars) expected for river type. Removal of modifications, structures, and artificial materials.<br>Natural Fluvial Processes: Substantial improvement on baseline conditions at catchment scale. Recovery of flow and sediment regime.<br>Condition Status: Substantial beneficial impacts at the catchment scale, which result in recovery/restoration of natural habitats suitable for supporting sensitive species. Potential improvement of overall status condition, which could lead to achieving Good status. |

* Hydromorphological quality elements are: quality and quantity of flow; river depth and width variation; structure and substrate of the bed dynamics; river continuity; structure of the riparian zone.

## Impact significance

2.4.4. The overall impact is determined using the impact matrix outlined in Table A2.2, which cross-references the sensitivity and the magnitude of impact ratings. The overall impact uses a significance rating score from neutral to very large as per the DMRB[v].

**Table A2.4: Overall Impact Matrix**

| Magnitude / Sensitivity | Major | Moderate | Minor | Negligible |
|---|---|---|---|---|
| Very High | Very Large | Large/Very Large | Moderate/Large | Neutral |
| High | Large/Very Large | Moderate/Large | Slight/Moderate | Neutral |
| Medium | Large | Moderate | Slight | Neutral |
| Low | Slight/Moderate | Slight | Neutral | Neutral |

## 2.5. Limitations

2.5.1. Limitations to be aware of relating to the findings of this report are as follows:

- The results are based on a rapid fluvial geomorphological walkover rather than a full fluvial audit approach. The findings of the walkover are focused around the immediate vicinity of the proposed crossings and are not broken into reaches, except for those sections upstream and downstream of the A9 crossing. Where possible a minimum of 250m upstream and downstream was surveyed.
- Access was limited in some areas by the relevant permissions and safe/easy access. Where access was not possible, spot checks were undertaken at existing watercourse crossings or via footpaths.
- The features and processes observed may vary over time/seasons and high flow events. The survey was undertaken under relatively dry conditions, and the overall function and stability was inferred through professional judgement and the interpretation of features on site.
- The Proposed Scheme is at preliminary design stage with detailed design to be undertaken by the appointed contractor. Therefore, the precise nature of the impacts on the watercourses are potentially subject to change. In all cases the worst-case scenario has been considered and assessed.
- Sediment entrainment and stream power calculations are semi-empirical equations based on limited (sometimes geographically biased) variables, and arguably over-simplify fluvial processes (and pressures) within the river channel. The equations are considered appropriate for uniform gravel-bed rivers, but do not account for complex channel roughness properties, e.g. mixed particle sizes, sheltering or the presence of vegetation. The results of the calculations have therefore been interpreted in the context of the empirical site observations and measurements.
- Some of the existing channel gradients for the smaller watercourses have been inferred from the topographic survey model in the absence of specific ground measurements. This is considered sufficient for assessing hydromorphological impacts and does not present a significant limitation at the preliminary design stage.

# 3. Baseline

## 3.1. Initial screening

3.1.1. As part of the Stage 2 hydromorphology assessment a long list of watercourses crossed by the Proposed Scheme was initially developed and included over 40 watercourse crossings.

3.1.2. An initial hydrological walkover survey assessed these crossings and identified several watercourse crossings of "hydromorphological interest" (those exhibiting some natural features and processes). The remaining crossings were screened further based on the available site photographs and desk study information (basemaps and aerial imagery) to confirm their elimination or inclusion. The screening aimed to identify those crossings which met a broad set of criteria based on a similar process undertaken for the aquatic ecology assessment (Appendix A11.3 Aquatic Ecology). These are:

- the watercourse is a permanent flowing system with a channel width >1m

  AND

- the watercourse is to be lost/culverted/diverted or potentially experience a substantial change in water quality or quantity[1]

  AND

- is not obviously canalised or heavily managed

  OR

- is hydrologically linked to a designated water-dependent site

3.1.3. This assessment required some interpretation and professional judgement, therefore where it was unclear if the channel met the above criteria the crossing was included for further investigation.

3.1.4. This initial screening exercise identified eight watercourses for further investigation.

3.1.5. The Moy Burn Trib 1 (previously referred to as Unnamed Tributary of Moy Burn at Stage 2) was excluded from further survey following Stage 2 assessment having been considered a minor watercourse (<1.0m) unlikely to be substantially affected by the Proposed Scheme nor form a hazard to the Proposed Scheme. Caochan na h-Eaglais, was initially screened out, but remains in the survey following additional survey downstream of the railway bridge.

3.1.6. An additional crossing across the Midlairgs Burn was not initially considered during Stage 2. The Midlairgs Burn is affected by the extension of the forestry track north of the scheme, but has been screened out due to the size of the watercourse and existing crossing. The forestry track has also resulted in an additional crossing of the Allt Creag Bheithin, close to the SUDS pond reference PY-A.

3.1.7. The final list of watercourses and associated crossings comprising more detailed hydromorphological impact assessment within this appendix are presented below in Table A3.1 and shown on **Error! Reference source not found.**a-f.

3.1.8. Please note that this document is intended to form an impact assessment with regards to the ES. All watercourses which require modification, i.e. realignment, including those

[1] Note - this was difficult to assess at the time as the Proposed Scheme Options were still to be confirmed.

minor watercourses screened out in this assessment, will each require further consideration by a geomorphologist during detailed design.

**Table A3.1: Watercourses Requiring Further Assessment (from south to north)**

| Watercourse Name | Crossing ID |
|---|---|
| Allt na Frithe (Figure A11.1.2c) | A9 1250 and A9 1245 F |
| Allt Dubhag (Figure A11.1.2c) | A9 1250 C25 |
| Dalmagarry Burn (Figure A11.1.2c & Figure A11.1.2d) | A9 1260 ARB1, A9 1260 and A9 1260 SRB1 |
| Caochan na h-Eaglais (Figure A11.1.2d) | A9 1270 C80 and A9 1270 C80 S |
| Allt na Loinne Mòire (Figure A11.1.2e) | A9 1273 C8 |
| Allt na Slànaich (Figure A11.1.2e) | A9 1273 C28 |
| Allt Creag Bheithin (Figure A11.1.2e & Figure A11.1.2f) | A9 1273 C31 S (MC90 C1), A9 1273 C31 and A9 1273 MCY0 C1 |

## 3.2. Desk study results

### Historical mapping analysis

3.2.1. All the watercourses surveyed and affected by the Proposed Scheme have been previously impacted and/or modified by the existing A9, as well as the Highland Main Line railway. There is evidence that some watercourses in this area, such as Dalmagarry Burn and Allt na Frithe, have had their planforms realigned, probably because of the road and rail developments or for land drainage/agricultural purposes. More recent evidence from the late-20th century indicates the planforms have been recovering and regained a naturalised meandering planform again (apart from the Funtack Burn which is considerably constrained). Aerial imagery shows a number of river terraces, gravel bars and mid-channel islands which are indicative of previous planforms.

3.2.2. Another key pressure has been abstraction. The ‘Mill Dam’ is shown along the course of Allt na Loinne Mòire around NGR NH 760 342 in the late-19th/early-20th century. The map shows the Mill Lead connecting with Allt na Slànaich, and a second smaller dam at NGR NH 763 342. More recent maps indicate no further evidence of significant channel change or modifications. The dam is now derelict and the surrounding channels left to recover a natural path through the residual sediments.

3.2.3. Potentially related, late-20th century mapping shows the planform of Allt na Slànaich has remained approximately the same downstream to NGR NH 748 342, after which the main channel then flows north-northeast (rather than east-northeast as previously) and broadly follows the route of a pre-existing track until its confluence with Allt Creag Bheithin at NGR NH 751 349. The original channel is depicted on this map as a “drain”, and both channels are still visible on present day maps with no further notable channel change or modification.

3.2.4. Evidence for the remaining watercourses suggest that Allt Dubhag, Caochan na h’Eaglais and Allt Creag Bheithin have undergone no notable channel change or modification in the past 150 years, except for being culverted underneath the existing road/railway.

## Geology

3.2.5. The geological maps indicate that the southern part of the site (south of NGR NH 795 314) is underlain by metasedimentary psammite (sandstone) and semi-pelite (clay-rich shale) rocks of Dalradian age. North of this, igneous intrusive (granitic) rocks associated with the Findhorn Pluton Formation underlay the area of the site up to NGR NH 795 314. The most northerly section of the site is underlain by further psammite, semi-pelite and quartzite rocks. The superficial geology underlying the site comprises a variation of glaciofluvial (gravel, sand and silt), till and alluvium (clay, silt, sand and gravel) deposits, with localised pockets of Quaternary age peat.

3.2.6. A more comprehensive study of the bedrock geology and superficial deposits can be found in the Geotechnical Preliminary Sources Study Report for the A9 Dualling Perth to Inverness, Slochd to Moy (B1557620/GEO/PSSR/11, Revision 04) prepared in October 2013. This information is summarised and discussed further in Chapter 10 (Geology, Soils and Groundwater) in Volume 1 of the ES.

## Water Framework Directive (WFD)

3.2.7. The WFD underpins the nature of the assessment overall and will drive much of the design for the crossing structures and any channel realignments. The status of each water body is listed within the RBMP[vi]. The reportable WFD water body status applies to designated main water bodies, defined broadly as those watercourses visible on a 1:50,000 scale OS map. However, the water body catchment comprises a network of tributaries, small watercourse and drains. Hydrologically they are linked and therefore modifications to this network can have a direct impact on the main water body status. It is important to consider the impacts within this context.

3.2.8. None of the watercourses assessed in this report are designated main water bodies within the RBMP. Nevertheless, some of the watercourse crossings (regardless of how minor or localised the impacts may be) are <100m upstream of main water bodies. Those water bodies directly linked to the assessed watercourses are listed in Table A3.2, see below (note, lakes and other water bodies have been assessed separately).

3.2.9. The current Morphological Impact Assessment System (MIMAS) total impacts are also included in Table A3.2 which is derived as a proportion of the combined physical impacts along the total length of water body. This percentage provides an indication of how modified the water body is and the likely capacity remaining for further modifications before there is a potential derogation in Water Framework Directive classification.

3.2.10. It is assumed the compliance assessment will be captured as part of a scheme wide assessment under the Controlled Activity Regulations (CAR) applications during detailed design.

**Table A3.2: WFD Water Body Status [as of October 2017]**

| Water Body Name | River Findhorn – Tomatin to Dorback Burn | Funtack Burn | Moy Burn | River Findhorn – Tomatin to Garbole |
|---|---|---|---|---|
| **Water Body ID** | 23004 | 23008 | 23009 | 23012 |
| **National Grid Reference** | 28934 84023 | 27929 83213 | 27878 83664 | 27884 82579 |
| **Catchment** | River Findhorn | River Findhorn | River Findhorn | River Findhorn |
| **Heavily Modified** | No | No | No | No |
| **Water Body Length (MIMAS total Impact %)** | 42.9km (7.9%) | 3.5km (14.2%) | 12.2km (11.3%) | 8.8km (15.1%) |
| **Parameter** | **Status** | **Status** | **Status** | **Status** |
| **Overall status** | **Moderate** | **Good** | **Good** | **Good** |
| Physico-Chem | High | High | Good | - |
| Temperature | High | High | High | - |
| Soluble Reactive Phosphorus | High | High | High | - |
| Dissolved Oxygen | High | High | High | - |
| Acidity | High | High | Good | - |
| Biological Elements | Moderate | High | Good | High |
| Biological Elements | Moderate | High | Good | High |
| Invertebrate Animals | High | - | Good | - |
| Fish | Moderate | High | High | High |
| Specific Pollutants | Pass | Pass | Pass | - |
| Zinc | - | - | - | - |
| Ammonium | Pass | Pass | Pass | - |
| Hydromorphology | Good | Good | Good | Good |
| Morphology | Good | Good | Good | Good |
| Overall Hydrology | High | High | High | High |

## 3.3. Field survey results

3.3.1. A site walkover was undertaken between the 28th September and 1st October 2015. This information set out below for each watercourse (in combination with the desk study) formed the basis of the sensitivity classification.

| | |
|---|---|
| **Watercourse Name** | Allt na Frithe – upstream of existing A9 |
| **Crossing References** | A9 1250 and A9 1245 F |
| **Primary function** | Exchange |
| **Primary process** | Laterally Adjusting (stable) |

**Description**

The surveyed watercourse began adjacent to the Tomatin Distillery immediately downstream of the railway. The active channel was broadly 2-3m wide with a bankfull width of 6-7m. The channel here possessed a moderately steep gradient through a deep, narrow valley. The distillery and access roads were situated adjacent to the upper sections of the channel and the watercourse is crossed several times by the railway, minor access roads and the A9 itself. There was little bank protection except in the immediate vicinity around the crossings.

The adjacent landscape initially was well maintained with large areas of mown grass, although the bank tops and downstream reaches were dominated by rough grassland. There were few trees present (at least on the bank tops) and generally there was good connectivity with the floodplain, with a two-stage channel profile common throughout.

The steep gradient near to the distillery created a slightly straighter planform. As the gradient reduced towards the A9 more defined meanders were formed.

The banks comprised sandy soils with large amounts of gravels and cobbles. The bed substrates were dominated by coarse material from gravels through to boulders, forming step-pools. Sand and other fine gravels were present at the margins and at the bottom of pools. The system also possessed a dynamic and diverse range of flows typical of upland streams, including step-pool sequences. At low flows the system was primarily a stable transfer system, however large gravel bars and regular (albeit not extensive) erosion suggested an exchange process with potential for lateral adjustment at higher flows.

P1030760 – View downstream illustrating gravel/cobble bar opposite bank erosion (NGR NH 793 297)

P1030774 – View upstream on Allt na Frithe. Tomatin distillery on the right hand side of the image (NGR NH 795 298)

| | |
|---|---|
| **Watercourse Name** | Allt na Frithe - downstream of existing A9 |
| **Crossing References** | A9 1250 |
| **Primary function** | Transfer |
| **Primary process** | Stable |

**Description**

A short remaining section of watercourse flowed downstream of the existing A9 crossing and into the River Findhorn. The channel was artificially protected with concrete bed and banks through the culvert and immediately at its exit. There was evidence of some failure of the bed and a sudden drop at the end of the concrete apron. The channel then ran through a narrow wooded valley with an informal, dirt access track situated on the right hand bank. The gradient briefly steepened again at this point and step-pools were still common.

The bed and banks were largely similar to upstream of the A9, comprising a range of material sizes dominated by boulders and cobbles which form the steps. The banks were sandy soils and the bank tops well vegetated with mature trees and rough grassland.

There were few signs of active erosion and only isolated gravel bar features, although there were some larger gravel bars associated with the confluence with the River Findhorn. The flow range continued to be diverse in this downstream section. Overall the channel was geomorphologically stable and was functioning to transfer material through the system.

P1030789 – View downstream through existing A9 culvert showing concrete bed and banks (NGR NH 797 300)

DCSF3950 – View downstream from culvert exit; the concrete apron has failed at the end of the culvert; limited gravel deposits on the left hand bank (NGR NH 797 300)

| | |
|---|---|
| **Watercourse Name** | Allt Dubhag – upstream and downstream of existing A9 |
| **Crossing References** | A9 1250 C25 |
| **Primary function** | Transfer |
| **Primary process** | Stable |

**Description**

Upstream and downstream of the A9, Allt Dubhag is contained within a deep valley surrounded by mature woodland. The watercourse is already crossed by the A9, plus a number of smaller access roads, and the railway further upstream. It eventually joins the River Findhorn approximately 440m downstream.

The surveyed channel initially began with naturalised sandy soiled banks and coarse gravel substrate, the channel was then artificially lined with stone bed and bank protection, through a straightened planform leading into the existing A9 culvert.

Prior to the straightening, gravel bars were present on the margins and some bank erosion hinted at the potential for active morphological processes upstream and some availability of coarse substrate. Overall the flows observed were uniform and the channel had been restrained leading into the culvert. The watercourse (in the vicinity of the crossing) was representative of a stable transfer system.

Downstream of the A9, the channel was slightly less constrained. Access was limited to 50m by dense vegetation and land access, therefore it is difficult to thoroughly assess the channel beyond this. However, the channel was similarly modified and protected on the bed and banks immediately downstream of the culvert. The channel soon naturalised with a slight steepening of the gradient and an increase in coarse substrate encouraging a sinuous planform and the development of step-pools (perhaps partly formed from failed bank protection material). More energetic flows were observed over the steps, but predominantly the energy within the channel was low with smooth gliding flow. The moss on the boulders and lack of notable or persistent bank erosion indicates that this too is a stable transfer reach. OS maps indicate the channel retains a sinuous planform for another 300m through a dense woodland (likely to be providing stability) before joining with the River Findhorn.

P1040023 – View towards the existing A9 culvert (upstream of the A9); the channel has been artificially straightened and bank/bed protected throughout (NGR NH 793 305)

P1040041 – Downstream of the culvert a series of step-pools have developed and the channel returns to a more natural profile and planform (NGR NH 794 305)

| | |
|---|---|
| **Watercourse Name** | Dalmagarry Burn – upstream of existing A9 |
| **Crossing References** | A9 1260 and A9 1260 ARB1 |
| **Primary function** | Transfer |
| **Primary process** | Stable |

**Description**

The surveyed reach began at the confluence with another tributary (Allt a' Chùil) running from the upstream hills. The landscape here is more lowland (grazing pastures) than the upstream rolling moorland hills. A wide open floodplain was present on the left hand bank with a steep valley side on the right. The left bank was artificially embanked and both banks lined with stone protection which effectively cut the channel off from its floodplain. Its planform was largely straightened with some inherent sinuosity with few trees or dense vegetation present along the bank tops. More formal bank protection comprising concrete and stone brickwork was noted around the existing river crossings (railway and A9).

The bed comprised cobble and boulder material, with some sands at the margins and in pools. Although protected, the banks were mainly sandy soils. The channel displayed a good range of flows associated with step-pool sequences. There was little bank erosion present and few notable deposits beyond the scattering of boulders on the bed, suggesting a stable transfer system.

P1030800 – View upstream showing embankment on the left hand bank and stone protection throughout (NGR NH 784 321)

P1030804 – View downstream underneath railway bridge (NGR NH 786 322)

| | |
|---|---|
| **Watercourse Name** | Dalmagarry Burn – downstream of existing A9 |
| **Crossing References** | A9 1260 and A9 1260 SRB1 |
| **Primary function** | Sink |
| **Primary process** | Aggrading/Stable |

**Description**

Much like upstream of the A9, the channel here flowed through a lowland system and displayed signs of previous modification/realignment. Wide open floodplain consisting of grazing pastures were noted on the left hand bank and the A9 embankment on the right, with woodland being more common downstream. The riparian vegetation, comprising tall marginal vegetation and grasses, was denser than upstream, with increased tree cover downstream towards the confluence with the Funtack Burn.

The left hand bank was still embanked, however the stone protection appeared to be absent. Large mobile gravel bars which were situated immediately downstream of the road crossing suggest a lowering of the gradient and there was some limited bank erosion on the right hand bank. Faster and more energetic flows were associated around a number of steps and cascades flowing in between the bar features. Further downstream as the tree cover dominates, there was an increase in fine sediment and algae growth as the gradient and flow energy decreases. There were still some occasional gravel bars and riffles suggesting potential for large sediment movements downstream. Immediately before the confluence with the Funtack Burn the channel was very straight and continued to be embanked and constrained.

The frequency of gravel bars and fine sediment on the bed suggested a tendency for deposition, but the channel was mostly geomorphologically stable.

P1030810 – View downstream of large gravel deposit; Current A9 alignment on the right hand side of image (NGR NH 788 322)

P1030823 – View downstream through wooded section, some evidence of fine sediment and algae growth on bed suggesting low energy flows for long periods (NGR NH 792 320)

| | |
|---|---|
| **Watercourse Name** | Caochan na h-Eaglais – upstream and downstream of existing A9 |
| **Crossing References** | A9 1270 C80 and A9 1270 C80 S |
| **Primary function** | Transfer |
| **Primary process** | Stable |

**Description**

Situated within an active plantation forest, the channel weaves its way steeply towards the existing A9 crossing. For the most part the channel is left to naturally find its way through the dense vegetation. The watercourse was relatively small, c.0.5-1.0m wide, but widens out as you reach the culvert, where it was heavily modified with bed and bank protection leading to the culvert. A little further upstream the channel is forded by heavy plant for forestry access, artificially increasing the amount of fine sediment in the system.

The banks comprised sandy soils with some embedded gravels. The bed comprised fine to coarse gravels, with some fine silt (likely to be exacerbated from the forestry works upstream). There were no signs of erosion or large areas of deposition, and boulders situated within the channel looked stable.

Overall the channel was acting as a stable transfer system.

P1040010 – View upstream of existing crossing; wide boulder bed with regular steps (NGR NH 771 339)

P1040028 – View from downstream towards existing railway bridge with heavily modified bed and banks (NGR NH 772 340)

| | |
|---|---|
| **Watercourse Name** | Allt na Loinne Mòire – upstream of existing A9 |
| **Crossing References** | A9 1273 C8 |
| **Primary function** | Exchange (Sink) |
| **Primary process** | Stable |

**Description**

For simplicity, the watercourse upstream of the A9 can be broadly split into three reaches. The first spanning the upper section where the watercourse was contained within a tight valley, dominated by gorse and heathland vegetation on both banks. There were few signs of channel modifications through this section, although General Wade's Military Road once ran close south of this location. The overall channel gradient was steep and has been naturally regulated by a series of step-pools, resulting in high energy and dynamic flows being common. The banks comprised sandy soils embedded with cobbles and boulders. Due to the combination of this erodible bank material and the steep valley sides, there were several large landslips noted. Overall there was an exchange of material, with most material depositing to form large bars as the burn exits the constraints of the valley.

The second reach began a little further downstream where a historic reservoir once existed. The reach through this section starts with a lowering in gradient and the surrounding landscape becomes dominated by wet grassland species (an indication of its past land use). Most the gravels drop out at the start of the reach and as such the presence of gravels was limited through this section. The watercourse bifurcates through a series of smaller channels likely to have formed because of the drawdown during the decommissioning of the reservoir. These channels were deep and, with little gradient, hardly flowed. Banks here comprised earthy soils, with fine sediment and algae dominating the bed. Overall, the system appeared to be stable.

The third and final reach immediately upstream of the A9 (and downstream of the now derelict dam) saw the return of some flow diversity, coinciding with an increase in gradient, step-pools and boulder formations. Sediment starvation meant there were some signs of minor erosion (scour/undercutting and bank slumping) through this reach. Although the reach was generally stable.

P1030849 – View upstream; large gravel bars present throughout the upper sections (NGR NH 759 341)

P1030869 – Further downstream the channel shows signs of impacts from historic abstraction from a now derelict reservoir (NGR NH 762 342)

| | |
|---|---|
| **Watercourse Name** | Allt na Loinne Mòire – downstream of existing A9 |
| **Crossing References** | A9 1273 C8 |
| **Primary function** | Transfer |
| **Primary process** | Stable |

**Description**

Downstream of the existing A9 crossing, the Allt na Loinne Mòire meanders through a tight corridor with steep valley sides, bordered by improved grassland, although there is a definite increase in tree cover compared with upstream. The channel has been heavily modified over time because of the construction of both the A9 and railway, plus additional access roads approximately 200m further downstream. In total the watercourse is crossed a total of four times over a distance of approximately 300m. The channel was heavily protected in places with stone and concrete bed and bank protection.

The banks again comprised sandy soils, with a cobble and gravel bed (where not artificially lined). Despite the modifications the channel still displays a good degree of flow diversity over some naturally occurring step-pools within a two-stage profile. There were some areas of bank slumping, but overall the channel was stable.

Beyond Moy (>350m downstream of the A9) the channel was inaccessible but appears to flow within a dense woodland for another 200m and into Moy Burn, before quickly joining Loch Moy.

P1030897 - View downstream down Allt na Loinne Mòire showing steep valley sides and step-pools (NGR NH 764 344)

1030905 – View upstream of bank and bed protection underneath railway bridge (NGR NH 765 345)

| | |
|---|---|
| **Watercourse Name** | Allt na Slànaich – upstream of existing A9 |
| **Crossing References** | A9 1273 C28 |
| **Primary function** | Exchange |
| **Primary process** | Lateral migration |

**Description**

The surveyed section of Allt na Slànaich upstream of the A9 was contained within a dense and mature woodland corridor, although the initial 200m was in open grassland. The woodland has historically been subject to traditional forestry practices and General Wade's Military Road once ran through this area (now a Public Right of Way). Some evidence of previous river crossings still exists in derelict form, one of which has formed a weir mid-way through the reach, and the other may form the location of the proposed side road improvement as part of the Proposed Scheme.

The watercourse flowed via an irregularly sinuous planform, through a moderately steep gradient, which on occasion (space allowing) bifurcated into multiple channels and possessed regular step-pools and riffles. The watercourse, although constrained by the adjacent woodland, was actively scouring its banks (comprising sandy soils) and generating large amounts of gravel and cobble material. The channel profile was two-stage, with large gravel bar features common throughout (some of which were vegetated). The bed of the channel comprised coarse gravels and cobbles, and was well sorted with the larger cobbles and boulders situated at the channel margins or forming the bar features.

Flow patterns through the reach were typical of a moderately high energy gravel bed stream, with areas of dynamic flow (rippled and standing waves) and other areas of ponded/pooled water behind boulder features. Some fallen woody material also interacted with the watercourse to create high energy flows.

These observations indicated an exchange of material within the reach and areas of active laterally migration, with erosion on the outer bends mirrored with point bars and side bars.

P1030958 – View downstream from start of surveyed section in open grassland, active erosion was observed throughout (NGR NH 747 342)

P1030977 – View through wooded section with large gravel bars forming a multiple stage channel profile (NGR NH 749 345)

| | |
|---|---|
| **Watercourse Name** | Allt na Slànaich – downstream of existing A9 |
| **Crossing References** | A9 1273 C28 |
| **Primary function** | Transfer |
| **Primary process** | Stable |

**Description**

Allt na Slànaich only exists for a short length downstream of the A9 before it joins with Allt Creag Bheithin after approximately 150m downstream. The channel is no longer contained within the woodland (upstream A9). The watercourse, which is already crossed by the A9, is likely to have been historically modified for land-use purposes. There is some evidence of this on P1030909 (below) showing regularly (and unnaturally) placed boulders on the outside of the bend

The watercourse planform was sinuous with a two-stage profile. The banks (as upstream) comprised sandy soils and the bed substrate was dominated by coarse sediment (gravels and cobbles), with some fine sediment present in the shallow margins and deeper areas.

There were some isolated areas of bank erosion occurring, but overall the channel was more stable than upstream. The gravel bars were smaller in extent than upstream and, on the whole, the channel was primarily a stable transfer system, moving sediment through the reach downstream.

P1030909 – View immediately downstream of existing A9 culvert with unnaturally placed boulders on the outside bend (NGR NH 751 348)

P1030915 – View of confluence with Allt Creag Bheithin; note the macrophytes situated within the channel (NGR NH 751 349)

| | |
|---|---|
| **Watercourse Name** | Allt Creag Bheithin – upstream of existing A9 |
| **Crossing References** | A9 1273 C31 and A9 1273 MCY0 C1 |
| **Primary function** | Sink |
| **Primary process** | Aggrading |

**Description**

The survey upstream of the watercourse was hindered by limited access therefore we are not able to confidently characterise the channel upstream. However, OS maps and aerial imagery indicate the channel flows through dense woodland. Observations close to the crossing indicates the channel is likely to have been modified upstream from forestry practices, although the planform on the OS maps shows an irregularly sinuous meandering. The size of the channel also suggests it is likely to be a low energy system.

The banks, although tree lined further upstream, were mainly grass covered comprising sandy soils. Closer to the culvert the banks were protected with stone and concrete. The bed was mainly fine material over coarse gravel and cobbles. Ponded flow leading up to the culvert has led to the preferential deposition fine material over the coarse substrate, exacerbated by a low level obstruction (weir) across the channel.

The channel showed few signs of erosion, but with the deposition of fine sediment it is likely to be a sink, which is nominally aggrading, although it is primarily stable.

P1030991 – View upstream towards woodland; channel in this location is ponded and fines deposited on top of gravels (NGR NH 749 347)

P1030994 – View of culvert underneath existing A9 (NGR NH 749 347)

| | |
|---|---|
| **Watercourse Name** | Allt Creag Bheithin – downstream of existing A9 |
| **Crossing References** | A9 1273 C31 and A9 1273 C31 S (MC90 C1) |
| **Primary function** | Sink |
| **Primary process** | Stable |

**Description**

Downstream of the A9 the landscape opens out into a wide floodplain. The adjacent vegetation was a mixture of emergent vegetation and wet grassland/bog, with the occasional tree. The channel has been previously modified by the existing A9 crossing, railway and minor crossings for land management access. The watercourse has also been embanked along some of its course immediately downstream of the A9 crossing.

The watercourse possessed a characteristic lowland meandering planform before straightening underneath the railway to the northeast and is then further constrained as it joins the Moy Burn.

The banks comprised sandy soils in the upper sections, but is largely peat and bog leading up to the railway bridge. The bed substrate was predominantly gravel and cobble, with some large scattered boulders. Although the flow was initially quite slow moving as it exits the existing A9 culvert (ponded and smooth), increasingly dynamic flows emerge downstream of the confluence with Allt na Slànaich, including rippled flow and some unbroken standing waves over bedform features.

The high energy flows and reduction in gradient have resulted in the transportation and formation of large gravel bars, suggesting a reliable supply of gravels from upstream and the surrounding landscape. As the planform straightened out into the wetter, boggier area the gravel bars were less common (as the gravels having dropped out earlier) and the flow was more uniform. Fine sediment arriving from upstream and adjacent floodplain has been deposited over the gravel substrate.

Although there was evidence supporting the transfer and deposition of large gravel material through the Creag Bheithin, it coincides with the Allt na Slànaich confluence. The channel immediately around the existing crossing was a very stable, low energy system and primarily a sink for fine sediment.

P1030940 – View downstream just after the confluence with Allt na Slànaich demonstrating the large gravel bar deposits and dynamic flows (NGR NH 755 351)

P1030950 – View downstream towards the railway bridge through the boggier area downstream of the A9; there are fewer gravel deposits through this section (NGR NH 759 350)

## 3.4. Watercourse sensitivity classification

3.4.1. Based on the classification criteria outlined above (see Table A2.2) the sensitivity classifications and justification for each watercourse is summarised in Table A3.3, below.

**Table A3.3: Watercourse Sensitivity Summary Classifications**

| Watercourse name | Sensitivity | Justification |
|---|---|---|
| Allt na Frithe | High | Watercourse exhibiting a good range of morphological features and active fluvial processes, with a diverse and dynamic range of flows. The observed features suggest potential for large sediment movements through the system. However, it has been modified/constrained by the adjacent land use and existing road and rail crossings. |
| Allt Dubhag | Low | Watercourse near the existing crossing is already extensively modified with bed and bank protection and long culvert. The flows were uniform, despite some discrete areas of step-pools. |
| Dalmagarry Burn | High | Watercourse has historically been realigned and the existing channel is in part constrained by embankments and crossed several times. There were, however, signs of renaturalisation and evidence of very active sediment transport processes occurring, with step-pool sequences and large gravel bars around the existing A9 crossing. |
| Caochan na h-Eaglais | Low | Minor watercourse with some dynamic fluvial features (step-pools, gravel bars) encouraging diverse flows. However, it has been extensively modified upstream and downstream of the existing crossing, and the upstream catchment is significantly affected by forestry. |
| Allt na Loinne Mòire | Medium* | Watercourse exhibiting highly dynamic gravel bed features in the upstream section, but has been significantly modified by a now derelict reservoir, road and rail crossings. There are some signs of recovery, but the channel is still constrained. |
| Allt na Slànaich | Medium | Watercourse displays a wide range of morphological features and dynamic fluvial processes. It has been historically modified albeit limited to existing and old crossings. |
| Allt Creag Bheithin | Medium | Upstream survey limited by access, however downstream displayed a range of flows and morphological features, with large gravel bars. There were some sections of uniform flows and straightened planform. |

* Please note Allt na Loinne Mòire was classified as High sensitivity during Stage 2, but further amended following updated criteria.

# 4. The Proposed Scheme

4.1.1. For each proposed crossing Table A4.1 (below) outlines broadly the following impacts:

- **realignment** – SEPA requires a simple CAR licence application for "*All diversions, realignment, flood by-pass channels and culverting for land gain on rivers ≲3m wide*" and a complex licence for those >3m wide
- **new crossing** – a completely new crossing over a river
- **extended crossing** – an extension (or replacement) of an existing crossing on the A9 or existing minor roads
- **modification** – changes to an existing structure which may affect flow and sediment conditions, e.g. addition of bank protection at the inlet/outlet, installation of mammal passes or any other modification which does not fundamentally change the position or size of the crossing.
- **no impact** – no obvious impact likely as a result of the Proposed Scheme

4.1.2. An assessment of the overall potential impact on the loss or gain of 'open watercourse' has also been estimated by comparing the length of the existing and proposed watercourse (from the cut-off and tie-in locations) and the lengths of the existing and proposed structures, with a net loss or gain identified.

4.1.3. Please note other activities across the water environment will also require a CAR licence application[vii]. As stated in SEPA's guidance documents, the following activities require a CAR authorisation:

- Any activity liable to cause pollution of the water environment, including discharges of polluting matter and disposal of waste sheep dip and waste pesticides.
- Abstraction of water from the water environment.
- Construction, alteration or operation of impounding works (e.g. dams and weirs) in surface water or wetlands.
- Carrying out building or engineering works (a) in inland water (other than groundwater) or wetlands; or (b) in the vicinity of inland water or wetlands and having or likely to have a significant adverse effect on the water environment.
- Artificial recharge or augmentation of groundwater.
- The direct or indirect discharge, and any activity likely to cause a direct or indirect discharge, into groundwater of any hazardous substance or other pollutant.
- Any other activity which directly or indirectly has or is likely to have a significant adverse impact on the water environment.

4.1.4. These include the installation of 'grey' and 'green' bank reinforcement, bed reinforcement, sediment removal, culvert installation and channel diversions on main watercourses (i.e. those shown on 1:50k OS maps).

**Table A4.1: Summary of Proposed Works**

| Watercourse Name | Crossing Ref | Realignment | New Crossing | Extended/ | Modified | No impact | Description of proposed works |
|---|---|---|---|---|---|---|---|
| Allt na Frithe (Figure A11.1.2c) | A9 1250 | ü | | ü | | | Single extended (replacement) 4.5m wide x 3.0m high portal frame culvert totalling a length of 78m, replacing the existing 42m culvert. The proposed culvert gradient would be set at approx. 5.4%.<br>Upstream of the culvert the watercourse would be realigned over 20m with a similar gradient to existing, i.e. approx. 3.4%. The watercourse downstream would require a realignment of approx. 48m with a gradient of 3.3%. The existing gradient downstream varies between 3 and 7%, as the existing channel is initially steep downstream of the culvert before lowering leading into the confluence with the Findhorn.<br>The realignments would result in a loss of 41m of open watercourse compared to existing. |
| | A9 1245 F | | | ü | | | Existing footbridge will be replaced with a 1.5m wide footbridge. No realignments will be necessary.<br>It is assumed there will be no loss of open watercourse compared to existing. |
| Allt Dubhag (Figure A11.1.2c) | A9 1250 C25 | ü | | ü | | | Single extended (replacement) 2.5m wide x 3.0m high portal frame culvert totalling a length of 78m (the proposed culvert gradient is approx. 3.6%), resulting in a loss of open watercourse (the existing culvert is approx. 40m).<br>The upstream realignment would be set at 3.7% over 30m and downstream 7.8% over 26m. The existing gradient upstream is approx. 4 to 5% and 4 to 7% downstream.<br>The total open watercourse lost would be approx. 40m compared to existing. |
| Dalmagarry Burn (Figure A11.1.2c & Figure A11.1.2d) | A9 1260 ARB1 | | ü | | | | Access road bridge situated approximately 200m upstream of the existing railway bridge and proposed A9 crossing. The structure (in-situ portal frame) would affect a 6.5m length of watercourse (not including any bank protection works which may be required). It is anticipated that there will be no permanent in-channel impact as it will be a clear span structure. |
| | A9 1260 | ü | | ü | | | Replacement bridge structure (28m span and 3.5m minimum headroom) across 32m of the watercourse, approx. 4m longer than the existing. The amended alignment of the bridge and footprint of the embanked mainline to the south would require the realignment of the Burn.<br>The realignment would result in a net gain of 30m of open watercourse. This includes the proposed watercourse length of 680m, compared with the existing channel at 640m, and the three structures combined (A9 1260, A9 1260 ARB1 and A9 1260 SRB1) affecting 47m of channel, compared with the existing structures at 37m. |

| Watercourse Name | Crossing Ref | Realignment | New Crossing | Extended/ | Modified | No impact | Description of proposed works |
|---|---|---|---|---|---|---|---|
| | | | | | | | The channel upstream (already impacted by A9 1260 ARB1, see above) and downstream would require some bank protection to tie-in with the bridge structure, this is assumed to be kept to a minimum. There may be minor (localised) impacts on the channel gradient, but the intention would be to keep the gradients similar to the existing channel. The channel would encompass a wide (between 12-20m) two-stage profile and a narrower low flow channel (approx. 4m).<br>See section 4.2 for more details on the proposed realignment. |
| | A9 1260 SRB1 | ü | ü | | | | New bridge about 25m downstream of the proposed main A9 road bridge (A9 1260). The proposed side road bridge will have an 18m span and a length of 8.5m along the realigned watercourse.<br>The bridge will form part of the proposed channel realignment as described above. The left bank downstream will require a retaining wall along a length of 60m. |
| Caochan na h-Eaglais (Figure A11.1.2d) | A9 1270 C80 | ü | | ü | | | The proposed 58m long culvert would replace the existing structure (56m long) offset to the west by 5m requiring a diversion of the watercourse approx. 20m upstream and 25m downstream. The 2.5m x 2.5m portal frame culvert would be set at an approx. gradient of 7.9%.<br>The channel is already culverted over a similar length, but it is assumed that the culvert inlet and outlet would tie-in with the existing bed. The watercourse upstream would require a realignment of 28m set at a maximum gradient of 10.6% leading into the culvert. A 35m long realignment would be required downstream of the culvert at a gradient of 8.5%.<br>The existing gradients vary between 3% and 15% immediately upstream of the existing A9 culvert and 6-7% downstream leading towards the proposed A9 1270 C80 S.<br>A total loss of approx. 7m of open watercourse would result from both A9 1270 C80 and A9 1270 C80 S combined compared to existing. |
| | A9 1270 C80 S | | ü | | | | A new 8m long, minor culvert leading to a total loss of open watercourse along its length. The 2.5m x 1.8m portal frame culvert would be set at approx. 4.5% gradient through the structure. The culvert would require an 11m realignment upstream and 21m downstream, with a proposed gradient of 8.7% upstream and 7.0% downstream.<br>The existing gradient upstream varies between 7% and 6%, whilst downstream they vary between 5% and 7% |
| Allt na Loinne Mòire (Figure A11.1.2e) | A9 1273 C8 | ü | | ü | | | 44m long culvert to replace existing 30m long structure. The 5.0m wide x 2.5m high portal frame culvert would be set at a gradient of 4.9%. |

| Watercourse Name | Crossing Ref | Realignment | New Crossing | Extended/ | Modified | No impact | Description of proposed works |
|---|---|---|---|---|---|---|---|
| | | | | | | | Despite the proposed culvert situated along the same alignment as the existing watercourse realignments are required to ensure a smooth transition. The upstream realignment is approx. 15m long and would require a reduction of the gradient from approx. 3 to 4% to 1.7%. The watercourse downstream would require a 50m realignment with a gradient of 4.4% compared to the existing gradient which varies between 2% and 6%.<br>The total loss of open watercourse would be approx. 8m compared to existing. |
| Allt na Slànaich (Figure A11.1.2e) | A9 1273 C28 | ü | | ü | | | Extended culvert at a length of 56m compared with an approximate length of 20m for the existing culvert. The single culvert will be replaced by three 1.85m high and 1.8m wide portal frame culverts set at a gradient of 0.7%.<br>The proposed culverts would be situated along a similar alignment to the current watercourse, however the inlet and outlet invert levels would be much lower than the existing bed to create enough gradient through the culvert.<br>The upstream watercourse would be realigned over a length of 32m and the downstream watercourse would also be realigned over a length of 32m. The upstream gradient would be increased from approx. 5% to 6.6%. The downstream gradient would decrease from approx. 3% to 1%.<br>The total loss of open watercourse would be approx. 36m compared to existing. |
| Allt Creag Bheithin (Figure A11.1.2e & Figure A11.1.2f) | A9 1273 C31 S (MC90 C1) | ü | ü | | | | Two 1.5m high and 2.0m wide box culverts, 8m long, set at approx. 0.8% gradient. The culvert would be installed underneath the MCX0 SUDS access track, resulting in a loss of open watercourse across this length. The existing gradient upstream is 2% and downstream is <1%. The proposed gradient upstream is 0.8% and 0.5% downstream. |
| | A9 1273 C31 | ü | | ü | | | Extended and repositioned culvert approx. 38m in length compared to the existing culvert at 23m. The proposed portal frame culvert would be sized 2.0m high x 2.0m wide, set at a gradient of 0.6%.<br>The inlet has been offset 5-10m to the west requiring a realignment of the channel course to tie-in with the culvert. The proposed inlet would be lowered by 830mm and outlet by 300mm, requiring a vertical realignment of the channel, steepening the upstream gradient and lowering the downstream. The upstream watercourse would be realigned over a distance of 35m and downstream the realignment would be 22m.<br>The upstream gradient will reduce from between 1% and 3% to a steady 1%, whilst downstream the gradient would remain similar to existing from approx. 0.8% to 0.6%. Two floodplain storage areas |

| Watercourse Name | Crossing Ref | Realignment | New Crossing | Extended/ | Modified | No impact | Description of proposed works |
|---|---|---|---|---|---|---|---|
| | | | | | | | are proposed either side of the watercourse providing a combined storage of 3,000m$^3$ in a 200-year event.<br>The proposed combined culverts (A9 1273 C31 and A9 1273 C31 S (MC90 C1)) would result in a loss of 12m of open watercourse compared to existing. |
| | A9 1273 MCY0 C1 | ü | ü | | | | A new 8m long, 5.0m wide x 2.0m high portal frame culvert, set at approx. 2.5% underneath the MCY0 SUDS Access track. Existing gradients upstream are estimated between 1% and 2%, with a locally steep section of between 3% and 7% immediately upstream of the crossing. Downstream the gradients are approx. 1-3%, with a proposed gradient of 1.2% over a distance of 24m.<br>This would result in a loss of 6m of open watercourse compared to existing. |

4.1.5. There are many minor watercourses previously screened out from further assessment, but will still require minor realignment(s) or modification(s) to the bed level to enable the Proposed Scheme to be constructed. The risks from these structures are considered much lower and environmentally less sensitive.

4.1.6. Whilst these minor watercourses do not warrant further assessment as part of the ES, geomorphological input into the detailed design will still be required to ensure the construction of any realignment are suitable and do not result in instability, such as bank erosion or bed scour (incision) which may undermine the crossing structures. Geomorphological guidance on the size and retention of substrate through the culverts where they are particularly steep may also be required.

## 4.2. Embedded mitigation

### Dalmagarry Burn

4.2.1. The Proposed Scheme design has considered the potential impact on the Dalmagarry Burn. The widened A9 mainline (A9 1260) and side road (A9 1260 SRB1) have required a 680m realignment of the Burn. A plan of the proposed Dalmagarry Burn realignment is shown in Figure A11.1.3a.

4.2.2. The realigned channel will reflect a natural length and size to accommodate the existing flow and sediment regime. This will promote natural functioning of the channel and floodplain and therefore morphological and habitat diversity.

4.2.3. The existing length of the burn to be realigned (historically straightened) is approximately 640m, with the proposed realignment length being approximately 680m (6% longer). This is dictated to a certain degree by the A9 crossing point and the road embankment pushing the river c.40m to the north east, but the realignment will also include a natural sinuosity to encourage natural processes (erosion and deposition) which more closely reflects the pre-straightened length.

4.2.4. Some bank protection is necessary upstream and downstream of the bridge structure, but especially on the left-hand bank immediately downstream of the bridge where the channel turns sharply and flow velocities are high (Figure A11.1.3a). It is currently proposed to construct a reinforced concrete retaining wall along the left-hand bank for approx. 60m. It is assumed all other bank protection can be formed of ‘rough’ or ‘green’ bank protection (refer to SEPA bank protection guidance in Section 4.3.16 and description in Section 4.3) which will also be beneficial to fish habitat. However, the exact extent and type of bank protection works will be confirmed as part of detailed design.

4.2.5. A SUDS pond will be located between the realigned burn and the A9 alignment towards the lower end which will be landscaped and planted to form a wetland area. An access track will also constrain the channel on right-hand bank and crosses the proposed channel downstream of the new A9 crossing.

4.2.6. There is a natural floodplain to the north east of the Dalmagarry Burn, but it is currently embanked on the left bank. The realignment will be located within this floodplain, but the top of bank would need to be raised to ensure that the flood risk to the land to the north of the channel is not increased. The proposed realignment currently comprises a wide corridor (12-20m) within which a low flow channel (4m) will be cut and allowed to adjust naturally. This will reduce the risk of the river migrating laterally across the floodplain either side. Further iterations of the design have recommended a wider corridor up to 20m (see specific mitigation below).

4.2.7. The bed levels are varied in the existing channel due to the gravel deposition in the upper section. The gradient varies between 0.5% and 2.4%, with the gradient generally decreasing downstream (see Figure A11.1.3b). The long profile of the realignment will reflect the existing gradients, varying between 2.7% at the upstream end and decreasing to 0.4% downstream, and it is anticipated this will become more varied over time as it adjusts to its average flow and sediment regime.

4.2.8. The 1D-2D hydraulic model described in the preliminary flood risk assessment reported at Stage 2 has been used to inform the size of the diverted channel. The guiding principle being that the new channel should have the same hydraulic characteristics as the existing channel. The flow capacity of the channel, average velocity and flood characteristics should be replicated as far as is practicable.

4.2.9. The existing cross sections were initially moved laterally onto the proposed alignment and then adjusted until the channel could convey the 2-year return period flow. This is the flow that is carried within the main channel without spilling onto the floodplain.

4.2.10. The resulting channel widths will be between 12 and 20m, before narrowing slightly at the downstream end of the diversion just upstream of where it returns to its existing alignment. The wider channel upstream will accommodate the large gravel deposits immediately downstream of the existing A9.

4.2.11. The existing channel will also be utilised as a backwater at downstream tie-in, creating a slow deep pond suitable as a refuge area for fish at high flows. The SUDS ponds will also discharge through the wet flush into the backwater.

## 4.3. Standard mitigation

4.3.1. Standard design mitigation recommendations (and guidance) were outlined within the hydromorphology assessment at Stage 2 and are expected to be implemented in all cases. These recommendations are outlined below and also align to the Schedule of Environmental Commitments, Chapter 21, Table 21.5.

4.3.2. Exceptions (where known) will be explicitly identified within the magnitude of impacts table (Table A6.1, below).

### Watercourse crossings

*Bridges*

4.3.3. Single span bridges are the preferred type of crossing (see SEPA's guidance on river crossings[viii]). This type of crossing has the least impact on the natural fluvial regime, maintaining existing in-stream and bank side habitats, sediment transport and migration of aquatic species.

4.3.4. Structures with in-stream supports may be appropriate, but only for very wide rivers. Similarly to single span structures, most of the in-stream and bank side habitats can be maintained, although careful consideration is required to the effect that bridge supports may have on the river bed (e.g. scour) and in trapping debris.

*Culverts (extended and new)*

4.3.5. If a clear span structure is not technically feasible nor economically viable, a closed culvert is likely to be required. Culverts are common along many of the UK's road and rail networks, as well as forming large parts of the river networks underneath urban environments. Depending on their age they often have artificial hard beds, may be oversized to allow flood flows and extend for long lengths. Vegetation growth through the culvert is limited to only the hardiest of species and culverts broadly prevent natural fluvial/sedimentary processes (including sediment transport) and create a barrier for the movement of fish and other wildlife. They can also block debris and create flood risk if not properly designed.

4.3.6. Good practice culvert design should consider the following:

- **Natural bed substrate**: for box culverts (i.e. with an artificial bed) a depressed invert set slightly below the existing bed level is required. This will allow space for natural bed substrates to be imported to form the bed level. For culverts less than 1.2 m diameter or height (internal height) the invert should be buried at least 15 cm below the natural bed level. For culverts 1.2 - 1.8 m diameter or height (internal height) the invert should be buried at least 20 cm below the natural bed level. For culverts greater than 1.8 m diameter or height (internal height) the invert should be buried at least 30 cm below the natural bed level[ix]. Baffles (precast or otherwise) may be required if there is a risk of the natural sediment flushing through at high flows. The culvert design should reflect the natural bed profile including bank to bank channel width, channel gradients and substrates where possible. Portal frames which do not possess an artificial bed do not require specific bed mitigation, but do still need an appropriate bed substrate.
- **Low flow channel**: a low flow channel (sized appropriately to each watercourse) should be constructed within the culvert to maintain sufficient water depths and sediment transport through the culvert during normal flow conditions.
- **Fish passage**: a ‘buffer’ zone will be created up and downstream of culverts to allow for the creation of habitats which will both enhance the watercourse, and incorporate features such as pools which will allow fish to rest before entering the culvert. The overall culvert design should not in any way impede fish passage up and downstream, and the gradient should reflect the surrounding landscape, overly steep or shallow gradient should be avoided where possible.
- **Bank protection**: although each culvert should be considered separately, it is likely that some bed and bank protection will be required upstream at transition between the watercourse and culvert. Hard (grey) bank and bed protection should be avoided where possible. Rip-rap and boulders (or ‘greener’ solutions where possible) and planted stone and coir rolls are preferable to gabions.
- **Transition**: appropriate inlet and outlet structures should be provided to ensure smooth hydraulic transition and avoid erosion. Headwall arrangements at the upstream and downstream ends of a culvert should be suitably keyed into the bed and banks of the watercourse, should be the shortest length possible, and should be appropriate to the local environment.
- **Scour pool**: scour pools at the outlet of the culvert should be constructed to dissipate energy and provide resting areas for fish. This is especially important for steeper culverts (>3%) and/or where stream powers are high.
- **Outfalls**: it is also important that the alignment of outfalls are designed to reduce scour around the structure and erosion of the adjacent river bed and banks. Discharge from the outfalls should be similar to the adjoining watercourse (see SEPA guidelines for more information[x]).

4.3.7. SEPA’s Good Practice Guidelines provide further information, as does the DMRB’s own guidance[xi], as does CIRIA[xii].

4.3.8. Culverts are likely to lead to a loss of open river channel. It may be appropriate to compensate for this loss by extending the length of the watercourse elsewhere (if unnaturally straight) or alternatively, providing other wetland features, such as scrapes, meander cut-offs and backwaters. These features positively add to the biodiversity value of the watercourse.

### River realignments/diversions

4.3.9. Many of the new or extended crossings may require some adjustment of the river planform to align the existing watercourse through the proposed culvert or bridge. These realignments may be relatively short, however it is still important to ensure they are properly designed by a suitably qualified and experienced fluvial geomorphologist to safeguard their long-term stability. Badly designed realignments can increase or decrease sediment movements, resulting in instability through incision, bank erosion or excessive sediment deposition.

4.3.10. This is even more important for major realignments where the functioning of the watercourse needs to be maintained over a longer distance and potential instability can have much greater impacts to the structures and the river system as a whole.

4.3.11. As a minimum, realignments should be designed on a like-for-like basis. The following key considerations should be accounted for in any design:

- **Bed gradient**: maintaining the existing bed gradient will ensure the continuity of the existing sediment regime. Too low and excessive substrate may begin to deposit, blocking culvert entrances and/or reducing flood flow capacity, this also reduces sediment supply downstream. Too steep and excessive bank erosion and/or bed incision may begin to occur increasing sediment supply downstream (potentially depositing within culverts). If the design of the road requires a change of the bed gradient, mitigation such as step-pools, bed-checks or sediment traps may be necessary.
- **Cross-section**: the design of an appropriate low flow channel will also ensure the continuity of the existing sediment transport regime. A two-stage or multiple-stage cross-section can provide a wide range of benefits and preserve the existing low flow processes, allowing for natural adjustment and improve system resilience to low flow events. The multiple stage cross-section also encourages a range of habitats to form and accommodates flood flow capacity whilst ensuring a low flow channel is maintained.
- **Planform**: the planform should reflect the existing channel where possible or restore historical planforms where the existing channel has been artificially modified.
- **Boundary conditions**: existing substrates should be collected, stored (without contamination) and reinstated. Where re-use of is not possible, substrates should be matched to local material. The suitability of substrates should be considered using empirical observations made by a qualified geomorphologist, as well sediment transport calculations (where deemed appropriate) and local sources[vii].

4.3.12. Other mitigation features such as woody material, gravel features (bars), vegetation and riffle-pools can also further enhance and restore habitats and natural processes to the watercourse in appropriate locations.

4.3.13. The design of any realignments, especially including features such as steps or bed checks will need to ensure they are suitable (i.e. passable) for any potential migratory fish species present. Consultation with freshwater aquatic ecologists is essential at the outset.

4.3.14. The need for a realignment in all cases should be avoided (or minimised) where possible. Unnecessary modification to a river channel may initiate instability as the channel attempts to recover to a natural course.

### Bank protection

4.3.15. Bank protection may be required as part of the Proposed Scheme in addition to the culvert inlets and outlets, e.g. at tight meander bends or vulnerable areas. Where possible this should be formed of naturally occurring or biodegradable materials, geotextiles, stone (e.g. rip-rap along the bank toe) and/or locally sourced hardwood timber. If the channel requires more engineered solutions it should be sympathetic to the local landscape and habitats, and used in combination with a planting scheme to improve the aesthetics and long-term stability of the banks.

4.3.16. SEPA's guidance on bank protection provides further information[xiii/xiv]. The role of vegetation for channel stability should also not be underestimated and consultation with the landscape architect should be undertaken at the earliest opportunity[xv].

### Bed protection

4.3.17. In some cases it may be necessary to protect the bed from bed scour (incision). In all cases natural materials (boulders, ideally buried) should be used as opposed to smooth concrete to increase roughness, maintain flow diversity and reduce the risk of transferring the erosion downstream.

### Temporary works

4.3.18. Temporary works should also be considered from the outset to minimise any direct or indirect impact on the watercourse.

4.3.19. Temporary bypass channels should be constructed to maintain flow continuity and allow unimpeded fish migration through the watercourse. Crucially, the design of any bypass diversion should also consider all the items listed above, especially if intended to be in-situ for a long period of time. Instability within a temporary channel can affect the channel upstream and downstream.

4.3.20. Temporary channel can have lasting impacts on the watercourse environment, such as the increase in fine sediment supply downstream and/or incision leading to instability migrating upstream. During construction the potential for fine sediment to enter the channel is a key risk. Silt fencing or filtration systems should be installed as standard.

4.3.21. Other temporary works such as pipes or over-pumping should be used where a temporary bypass channel cannot be constructed. In some cases, culverts will be constructed "offline" (Table A4.2) and reconnected to the existing channel upstream and downstream when the crossing works are complete. This minimises the construction impact and duration of impact.

**Table A4.2: Construction Method**

| Watercourse Name | Crossing Ref | Method | Duration |
|---|---|---|---|
| Allt na Frithe | A9 1250 | Offline | TBC |
| | A9 1245 F | Online | 2-3 months |
| Allt Dubhag | A9 1250 C25 | Offline | TBC |
| Dalmagarry Burn | A9 1260 | Online | 2-3 months |
| | A9 1260 SRB1 | Online | 2-3 months |
| | A9 1260 ARB1 | Online | 2-3 months |

| Watercourse Name | Crossing Ref | Method | Duration |
|---|---|---|---|
| Caochan na h-Eaglais | A9 1270 C80 | Offline | TBC |
| | A9 1270 C80 S | Online | 2-3 months |
| Allt na Loinne Mòire | A9 1273 C8 | Offline | TBC |
| Allt na Slànaich | A9 1273 C28 | Offline | TBC |
| Allt Creag Bheithin | A9 1273 C31 S | Online | 2-3 months |
| | A9 1273 C31 | Offline | TBC |
| | A9 1273 | Online | 2-3 months |

# 5. Stream Power and Sediment Entrainment Assessments

5.1.1. A series of sediment transport equations have been used to gain a better understanding of the character and behaviour of the watercourses in response to the Proposed Scheme.

5.1.2. Stream power is essentially based on the relationship between discharge and slope. The specific equations used are presented in Annex AA. The discharges have been provided as part of the hydraulic modelling assessment for both the existing and proposed conditions.

5.1.3. Note, these are semi-empirical equations based on a limited (sometimes geographically biased) datasets. The stability of sediment also relies on several other (often complex) forces, but for the purposes of crude assessments of the likelihood of sediment entrainment these equations are useful, but should be logic checked with direct site observations and measurements.

## Hydrology

5.1.4. A series of return period flows were provided using a rainfall runoff model. Low flows ($Q_{95}$) were calculated using LFE and bankfull flows ($Q_{bkf}$) were also calculated using a 1D hydraulic model. The results are presented in Table A5.1 (below). The limitations of these results are outlined in the flood risk chapter, but are useful for providing an indication of stream power and sediment entrainment thresholds.

**Table A5.1: Baseline modelled discharge results**

| Watercourse Name | Discharge ($m^3/s$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $Q_{95}$ | $Q_{bkf}$ | $Q_2$ | $Q_5$ | $Q_{10}$ | $Q_{30}$ | $Q_{50}$ | $Q_{100}$ | $Q_{200}$ | $Q_{200+CC}$ |
| Allt na Frithe | 0.02 | 5.52 | 5.06 | 7.26 | 8.64 | 11.45 | 12.94 | 14.86 | 17.14 | 20.57 |
| Allt Dubhag | 0.01 | 1.35 | 2.21 | 3.19 | 3.81 | 5.05 | 5.73 | 6.60 | 7.65 | 9.18 |
| Dalmagarry Burn | 0.04 | 17.97 | 7.84 | 11.33 | 13.53 | 17.83 | 20.20 | 23.26 | 26.91 | 32.29 |
| Caochan na h-Eaglais | <0.01 | 9.28 | 0.99 | 1.46 | 1.76 | 2.29 | 2.62 | 3.06 | 3.57 | 4.28 |
| Allt na Loinne Mòire | 0.01 | 7.59 | 2.81 | 4.05 | 4.84 | 6.38 | 7.24 | 8.34 | 9.65 | 11.60 |
| Allt na Slànaich | 0.01 | 10.90 | 2.71 | 3.76 | 4.51 | 5.91 | 6.73 | 7.77 | 9.02 | 10.82 |
| Allt Creag Bheithin | <0.01 | 5.25 | 3.36 | 4.70 | 5.66 | 7.33 | 8.41 | 9.76 | 11.38 | 13.65 |

Red values indicate estimated flows greater than bankfull.

5.1.5. The discharge values above indicate that for most of the watercourses they overtop their banks much sooner than at $Q_{200+CC}$ flow. Allt na Frithe, Allt Dubhag and Allt Creag Bhethin appear to be relatively well connected to their floodplains, whereas Dalmagarry and Allt na Loinne Moire overtop during much higher return periods, i.e. between $Q_{50}$ and $Q_{100}$ flows. Caochan na h-Eaglais and Allt na Slànaich are extremely disconnected from their floodplains.

5.1.6. How the flows have been calculated may not allow a direct comparison, and the return flows may be underestimated[2], however they do give a good indication of floodplain connectivity and therefore the likely functioning of the channel.

5.1.7. Where $Q_{200+CC}$ flows do not exceed bankfull these flows have been used in the stream power calculations, otherwise the bankfull flows have been used.

## Stream power

5.1.8. Stream power (Ω) is a conceptual measure of the available rate of energy at a channel bed relating to sediment transport. Specific stream power (ω) is a derivative of the actual stream power divided by channel width. The units are expressed as watts per square metre, $Wm^{-2}$.

5.1.9. Peer-reviewed scientific work over the past 50 years has proven it to be a valuable measure of river stability. Research[xvi/xvii] has provided some thresholds which can be used to indicate potential behaviour[3]. These are as follows:

- **Low energy streams** ($\omega$ < 10 $Wm^{-2}$) likely to experience sedimentation
- **High energy streams** ($\omega$ > 35 $Wm^{-2}$) likely to experience localised erosion
- **Very high energy streams** ($\omega$ > 100 $Wm^{-2}$) likely to experience significant erosion leading to an increase in sinuosity after straightening. Where lateral erosion is inhibited vertical erosion is likely to occur.

5.1.10. Estimated stream powers have been calculated based on the available information for the upstream cross-sections, gradients and discharge values for both the baseline and the proposed conditions (see Table A5.2 and Table A5.3). Discussion of the results for each watercourse are presented in Table A6.1.

5.1.11. For simplicity, the cross-section dimensions for the proposed design are assumed to be the same (or similar) to the existing and so the changes in stream powers are primarily driven by gradient.

[2] The rain runoff model is a simple catchment model using a hydrograph, whereas the 1D models includes the existing culvert as a constraint on flow.
[3] Please note these thresholds were primarily established for channelised watercourses based on research in the UK and Denmark.

**Table A5.2: Specific stream power (ω) (Wm$^{-2}$) results – upstream baseline**

| Watercourse Name | Crossing Ref | Gradient (m/m) | $Q_{bkf}$ (m$^3$/s) | $Q_{200+CC}$ (m$^3$/s) | Water depth (m) | Water width (m) | Specific stream power (Wm$^{-2}$) |
|---|---|---|---|---|---|---|---|
| Allt na Frithe | A9 1250 | 0.03 | 5.5 | 20.6 | 1.4 | 5.0 | 368 |
| | A9 1245 F | n/a* | n/a* | n/a* | n/a* | n/a* | n/a* |
| Allt Dubhag | A9 1250 C25 | 0.04 | 1.4 | 9.2 | 1.0 | 4.0 | 132 |
| Dalmagarry Burn | A9 1260 | 0.02 | 18.0 | 32.3 | 0.9 | 10.0 | 353 |
| | A9 1260 SRB1 | | | | | | |
| | A9 1260 ARB1 | 0.02 | 18.0 | 32.3 | 0.9 | 10.0 | 353 |
| Caochan na h-Eaglais | A9 1270 C80 | 0.08 | 9.3 | 4.3 | 1.0 | 2.5 | 1360 |
| | A9 1270 C80 S | 0.02 | 9.3 | 4.3 | 1.0 | 2.5 | 269 |
| Allt na Loinne Mòire | A9 1273 C8 | 0.04 | 7.6 | 11.6 | 0.5 | 10.0 | 313 |
| Allt na Slànaich | A9 1273 C28 | 0.05 | 10.9 | 10.8 | 1.8 | 10.0 | 539 |
| Allt Creag Bheithin | A9 1273 C31 S (MC90 C1) | 0.02 | 5.3 | 13.7 | 1.7 | 8.0 | 103 |
| | A9 1273 C31 | 0.01 | 5.3 | 13.7 | 1.7 | 8.0 | 77 |
| | A9 1273 MCY0 C1 | 0.02 | 5.3 | 13.7 | 1.7 | 8.0 | 122 |

* footbridge appended to existing structure

**Table A5.3: Specific stream power (ω) (Wm$^{-2}$) results – upstream proposed for $Q_{bkf}$**

| Watercourse Name | Crossing Ref | Gradient (m/m) | $Q_{bkf}$ (m$^3$/s) | $Q_{200+CC}$ (m$^3$/s) | Bankfull water depth (m) | Bankfull water width (m) | Specific stream power (Wm$^{-2}$) |
|---|---|---|---|---|---|---|---|
| Allt na Frithe | A9 1250 | 0.03 | 2.9 | 20.6 | 0.56 | 4.5 | 212 |
| | A9 1245F | n/a | n/a | n/a | n/a | n/a | n/a |
| Allt Dubhag | A9 1250 C25 | 0.04 | 0.9 | 9.2 | 0.50 | 13.5 | 24 |
| Dalmagarry Burn | A9 1260 | 0.03 | Does not spill | 27.3* | 0.94 | 10.0 | 722 |
| | A9 1260 SRB1 | 0.03 | 5.2 | 25.9* | 0.57 | 5.0 | 426 |

| Watercourse Name | Crossing Ref | Gradient (m/m) | $Q_{bkf}$ ($m^3/s$) | $Q_{200+CC}$ ($m^3/s$) | Bankfull water depth (m) | Bankfull water width (m) | Specific stream power ($Wm^{-2}$) |
|---|---|---|---|---|---|---|---|
| | A9 1260 ARB1 | 0.02 | 8.0 | 27.3* | 0.69 | 4.5 | 226 |
| Caochan na h-Eaglais | A9 1270 C80 | 0.11 | Does not spill | 4.3 | 1.39 | 6.5 | 683 |
| | A9 1270 C80 S | 0.09 | Does not spill | 4.3 | 1.03 | 6.0 | 609 |
| Allt na Loinne Mòire | A9 1273 C8 | 0.02 | Does not spill | 11.6 | 1.47 | 9.0 | 210 |
| Allt na Slànaich | A9 1273 C28 | 0.07 | Does not spill | 13.0 | 1.80 | 13.5 | 624 |
| Allt Creag Bheithin | A9 1273 C31 S (MC90 C1) | 0.08 | 6.3 | 13.0 | 0.82 | 6.0 | 83 |
| | A9 1273 C31 | 0.01 | 5.7 | 13.0 | 0.94 | 7.0 | 88 |
| | A9 1273 MCY0 C1 | TBC | | | | | |

* Q200 return event, Q200+CC not modelled

## Sediment entrainment

5.1.12. The potential maximum sediment size which could theoretically become entrained can be estimated using a critical discharge theory. The critical discharge ($Q_{cr}$) simply calculates the flow required to move a given sediment size. In addition, a critical water depth can also be established and together can form the basis for estimating sediment entrainment (see Annex AA).

5.1.13. However, such equations have some limitations, primarily due to the over-simplification of the fluvial processes (and pressures) occurring within the river channel. The equations are considered appropriate for uniform gravel-bed rivers and do not account for channel roughness, e.g. mixed particle sizes or vegetation.

5.1.14. Due to these limitations, the results should be treated as a guide and should be used in conjunction with empirical observations on site and professional judgement.

5.1.15. The critical discharges and water depths for particular sediment sizes (based on standard sediment size thresholds) have been estimated for the proposed discharges and gradients listed above in Table A5.3

5.1.16. The results are shown in Table A5.4 and discussion of the results for each watercourse are presented in Table A6.1.

**Table A5.4: Critical Discharge**

| Watercourse Name | Crossing Ref | Theoretical max sediment size ($D_{50}$) entrained (mm)* | |
|---|---|---|---|
| | | Based on critical discharge | Based on critical water depth |
| Allt na Frithe | A9 1250 | 300 | 250 |
| | A9 1245 F | n/a | n/a |
| Allt Dubhag | A9 1250 C25 | 150 | 250 |
| Dalmagarry Burn | A9 1260 | >1000 | 400 |
| | A9 1260 SRB1 | 500 | 200 |
| | A9 1260 ARB1 | 300 | 200 |
| Caochan na h-Eaglais | A9 1270 C80 | 900 | >1000 |
| | A9 1270 C80 S | 800 | >1000 |
| Allt na Loinne Mòire | A9 1273 C8 | 400 | 400 |
| Allt na Slànaich | A9 1273 C28 | >1000 | >1000 |
| Allt Creag Bheithin | A9 1273 C31 S (MC90 C1) | 200 | 100 |
| | A9 1273 C31 | 200 | 150 |
| | A9 1273 MCY0 C1 | TBC | TBC |

* Based on the dominant flow, i.e. either Q200+cc or $Q_{bkf}$ flows (see Table A5.1).Likely to be an over estimation as equations assume unconsolidated sediment. Designs should consider these figures combined with empirical, field-based observations to select appropriate sediment sizes.

# 6. Impact Assessment

6.1.1. The initial and residual magnitude of impacts for the Proposed Scheme are summarised in Table A6.1, below. The table lists each watercourse and its sensitivity from Table A3.3.

6.1.2. The Proposed Scheme is then assessed in terms of type of impact, i.e. whether they result in an adverse or beneficial impact. Any impact which may result from a new or extended culvert is considered to be adverse, all other impacts are considered on a case-by-case basis.

6.1.3. The initial impact magnitude is assessed taking into consideration the embedded mitigation, but without any standard or additional specific mitigations. The residual magnitude takes all proposed mitigations into account.

**Table A6.1: Summary of Impacts**

| Watercourse Name | Crossing Ref | Summary of initial impact | Stream power/ sediment entrainment comments | Initial Magnitude | Additional Specific Mitigation | Residual Magnitude |
|---|---|---|---|---|---|---|
| Allt na Frithe | A9 1250 | The additional length of culvert (almost twice the length) and realignment would result in a significant loss of open watercourse, approx. 41m. The impact on the functioning of the watercourse itself would likely be minimal with gradients remaining similar upstream and decreasing from 5% to 3% downstream.<br>The proposed culvert would be an improvement on the existing structure which currently possesses an overwide, concrete bed. | Stream power, although still high shows signs of decreasing as the average gradients upstream and downstream are lower than the maximum gradients.<br>Existing channel possesses small to medium boulders and evidence of mobile cobble material, sediment transport competency likely to be unaffected. | Moderate (Adverse) | Assumes application of standard mitigation measures specified in Section 4.2. No further specific mitigation is likely to be required, however the transition between the existing and proposed watercourse may still need appropriate bed checks and step-pool features along the realignment and bank protection around the entrance and exit to the culvert.<br>Hydraulic modelling specifies the need for a cascade or similar feature to manage the flows entering the culvert (to be confirmed at detailed design). The existing realignment should be extended upstream to reduce the impact of the gradient and potential impact on fisheries. The LMA has been extended upstream to allow for this.<br>Boulders approx. 200-300mm in diameter to be used to form bed features. | Minor (Adverse) |
| | A9 1245 F | It is assumed there will be no loss of open watercourse compared to existing. | No change | Negligible | No mitigation required | Negligible |
| Allt Dubhag | A9 1250 C25 | The additional length of culvert (over twice the current length) and realignment would result in a significant loss of open watercourse, approx. 40m. The proposed gradients are moderately | The existing channel is currently stable, any increase in stream powers resulting from the steepening of the gradient could initiate potential channel change (instability). | Moderate (Adverse) | Assumes application of standard mitigation measures specified in Section 4.2. No further specific mitigation is likely to be required, however the likely increase in gradients further heightens the need | Minor (Adverse) |

| Watercourse Name | Crossing Ref | Summary of initial impact | Stream power/ sediment entrainment comments | Initial Magnitude | Additional Specific Mitigation | Residual Magnitude |
|---|---|---|---|---|---|---|
| | | steep, approx. 3.7% upstream and 7.8% downstream, compared to an estimated 4% and 5% respectively. | Observations on site indicate cobble material is readily transported through the system, but larger boulder material (approx. 200-300mm) appears stable.<br>Allt Dubhag is a low energy system and as such the stream powers are amongst the lowest. The stream power upstream further decreases from 132 $W/m^{-2}$ to 24 $W/m^{-2}$. Downstream the stream powers are likely to increase primarily because the gradient increases from 5% to 7.8%. | | for appropriate step-pool/bed check features along the realignment and bank protection around the entrance and exit to the culvert.<br>The upstream reach is modified and any improvements on the channel structure may provide additional benefits to the watercourse locally leading into the culvert. Hydraulic modelling specifies the need for a cascade or similar feature to manage the flows entering the culvert (to be confirmed at detailed design). The existing realignment should be extended upstream to reduce the impact of the gradient and potential impact on fisheries. The LMA has been extended upstream to allow for this.<br>Boulders approx. 200-300mm in diameter to be used to form bed features. | |
| Dalmagarry Burn | A9 1260 | Significant realignment of a moderate river channel, however consultation with SEPA and the design team has already addressed many of the potential impacts and are embedded with the Proposed Scheme.<br>Assumes application of embedded mitigation in Section 4.2. | There will be a general increase in stream power upstream as the average gradient would increase from 2% to 2.7%. However, the channel immediately downstream of the bridge will be wider (up to 20m) and therefore this may mitigate any potential increase in stream power, with average downstream gradients around 1 %<br>Observations on site indicate a channel in equilibrium, but readily able to transport coarse substrate. Large boulders do appear stable. Critical discharge calculations | Moderate (Adverse) | Assumes application of standard mitigation measures specified in Section 4.2. Given the significance of the realignment further mitigation is required to minimise/nullify any potential impacts. These include appropriate bankside planting, installation of instream channel features to support the fish populations (i.e. undercut banks, woody material etc.) and a wetland backwater utilising the downstream tie-in with the existing channel. Maximising connectivity with the adjacent floodplain will improve the | Minor (Adverse) |

| Watercourse Name | Crossing Ref | Summary of initial impact | Stream power/ sediment entrainment comments | Initial Magnitude | Additional Specific Mitigation | Residual Magnitude |
|---|---|---|---|---|---|---|
| | | | suggest 1000mm, but likely to be an overestimation and as the gradient decreases downstream smaller boulders may be used to form bed checks. | | natural functioning of the river system. Channel to possess a two-stage channel profile, with an appropriate low flow channel intended to connect with the second stage every year or two.<br>Bed checks will be needed at appropriate locations (e.g. changes in bed gradient) to reduce the likelihood of incision occurring.<br>Boulders 300-600mm to be used to form bed features. | |
| | A9 1260 SRB1 | Loss of open watercourse length (approx. 8.5m) and requires the realignment of the Dalmagarry Burn (along with A9 1260). | As above, likely to be similar to A9 1260 overall. | Moderate (Adverse) | As above. | Minor (Adverse) |
| | A9 1260 ARB1 | The new footbridge will be a clear span structure or a portal framed culvert structure and will not require any realignment or impact on the river bed. There will be a loss of open watercourse of approx. 6.5m. | Assume no change in stream power through structure. | Minor (Adverse) | Assumes application of standard mitigation measures specified in Section 4.2. No further specific mitigation is assumed necessary given the information available. | Minor (Adverse) |
| Caochan na h-Eaglais | A9 1270 C80 | The proposed length of culvert is 2m longer than existing, but combined with the offset watercourse realignment it would result in a loss of open watercourse, approx. 7m. The proposed gradients are very steep (11% and 8%). However, the topographic survey and site observations suggest the existing upstream gradient is between 8% and 15%. | Steep stable system with existing high stream powers based on steep gradient leading into culvert, unlikely to experience a change from existing conditions, but will be vulnerable in the short-term.<br>Sediment transport unlikely to change because of the proposed realignment. Observations on site show moss covered, stable boulders approx. 300-400mm, suggesting the critical discharge | Moderate (Adverse) | Assumes application of standard mitigation measures specified in Section 4.2. No further specific mitigation is likely to be required, however the increase in gradients further heightens the need for appropriate step-pool/bed check features along the realignment and bank protection around the entrance and exit to the culvert. Boulders 300-400mm to be used to form bed | Minor (Adverse) |

| Watercourse Name | Crossing Ref | Summary of initial impact | Stream power/ sediment entrainment comments | Initial Magnitude | Additional Specific Mitigation | Residual Magnitude |
|---|---|---|---|---|---|---|
| | | The existing channel is currently stable, any increase in stream powers resulting from the steepening of the gradient could initiate potential channel change (instability). The confinement of the channel laterally may result in incision (rather than lateral adjustment) as the channel tries to recover a more naturalised gradient. | calculations are an overestimation. There are signs of cobble material readily being transported through the system.<br>Critical discharge calculations suggest 700-800mm, but likely to be an overestimation and as the gradient decreases downstream smaller boulders may be used to form bed checks. | | features given existing conditions support similar sized boulders. | |
| | A9 1270 C80 S | New culvert and watercourse realignment would result in a loss of open watercourse, approx. 8m. The proposed gradients are very steep (9% and 7%). Based on the structural design this assessment assumes a portal framed culvert structure requiring minimal horizontal or vertical realignment of the watercourse. | Gradients similar to existing, therefore unlikely to experience a change from existing conditions, but will be vulnerable in the short-term. | Moderate (Adverse) | Assumes application of standard mitigation measures specified in Section 4.2. No further specific mitigation is likely to be required, however the increase in gradients further heightens the need for appropriate step-pool/bed check features along the realignment and bank protection around the entrance and exit to the culvert.<br>As above, boulders 300-400mm to be used to form bed features (see above). | Minor (Adverse) |
| Allt na Loinne Mòire | A9 1273 C8 | The additional length of culvert (50% longer than existing) and realignment would result in a loss of open watercourse, approx. 8m. The proposed channel gradient upstream and downstream will be reduced from 4.2% to 1.7%, and 6.4% (max) to 4.4% respectively. | Upstream there is likely to be no change in sediment transport as gradients remain similar and stream powers are likely to remain unchanged.<br>Downstream a slight increase in the gradient is likely to result in an increase in stream power and in turn, sediment transport competency.<br>There was no evidence of significant sediment movement | Moderate (Adverse) | Assumes application of standard mitigation measures specified in Section 4.2. No further specific mitigation is likely to be required, however standard mitigation measures (bed checks and bank protection) should be sufficient.<br>Boulders 200-300mm to be used to form bed features. | Minor (Adverse) |

| Watercourse Name | Crossing Ref | Summary of initial impact | Stream power/ sediment entrainment comments | Initial Magnitude | Additional Specific Mitigation | Residual Magnitude |
|---|---|---|---|---|---|---|
| | | | upstream or downstream of the existing culvert and moss-covered boulders immediately downstream suggest a very stable system. Boulder sizes in line with critical discharge calculations are likely to be appropriate. | | | |
| Allt na Slànaich | A9 1273 C28 | The additional length of culvert (almost three times the length of existing) and realignment would result in a significant loss of open watercourse, approx. 36m. The upstream gradients will increase from 5% to 6.6%, whilst the downstream gradients will decrease from 3% to 1%. | Evidence of significant sediment transport upstream, although stabilised towards culvert. Significant increase in stream power likely to result in increased competency for sediment movement and erosion.<br>The stream power assessment upstream indicates a slight increase from the existing conditions. Downstream there is expected to be reduced stream powers (due to reduction in gradients) which could result in increased sediment deposition.<br>Sediment entrainment calculations indicate material >1000mm required, but this is likely to be a significantly over estimate given the conditions observed on site. | Moderate (Adverse) | Assumes application of standard mitigation measures specified in Section 4.2. The increase in gradients further heightens the need for appropriate step-pool/bed check features and bank protection around the entrance and exit to the culvert.<br>The existing realignment should be extended upstream to reduce the impact of the gradient and potential impact on fisheries. The LMA has been extended upstream to allow for this. To be confirmed during detailed design.<br>Boulders 300-600mm are likely to be more appropriate to be used to form bed features (based on site observations). | Minor (Adverse) |
| Allt Creag Bheithin | A9 1273 C31 S (MC90 C1) | New crossing requiring a new culvert resulting in a loss of open watercourse (approx. 8m), requiring minimal horizontal or vertical realignment of the watercourse. The existing and proposed gradients are very low, approx. <1% to 2%. The proposed design will result in a slight | Some decrease in stream power, but unlikely to result in significant changes in channel behaviour. | Minor (Adverse) | Assumes application of standard mitigation measures specified in Section 4.2. The low gradient would mean no further specific mitigation is likely to be required, however standard mitigation measures (bed checks and bank protection) should be sufficient. | Minor (Adverse) |

| Watercourse Name | Crossing Ref | Summary of initial impact | Stream power/ sediment entrainment comments | Initial Magnitude | Additional Specific Mitigation | Residual Magnitude |
|---|---|---|---|---|---|---|
| | | decrease in upstream gradient from 1.9% to 0.8%. Downstream the gradients remain similar. This is unlikely to result in any significant impact on channel behaviour. | | | Boulders 100-200mm to be used to form bed features. | |
| | A9 1273 C31 | The additional length of culvert (almost twice as long) and realignment would result in a significant loss of open watercourse, approx. 12m. The upstream gradient will reduce from between 3% and 1% to an average of 1%.and downstream gradients will remain similar to existing (approx. 1%). | Stream powers are lower than elsewhere along the scheme. There is expected to be no change downstream. The decrease in gradient upstream may result in deposition. Some coarse gravels are transported through the culvert and downstream, but there were few signs of any significant erosion or larger material. | Moderate (Adverse) | Assumes application of standard mitigation measures specified in Section 4.2. The low gradient and increased potential for deposition may lead to the channel narrowing. No further specific mitigation is likely to be required, however standard mitigation measures (bed checks and bank protection) should be sufficient.<br>Boulders 100-200mm to be used to form bed features. | Minor (Adverse) |
| | A9 1273 MCY0 C1 | Overall a minor crossing, but will require a new 6m long crossing requiring a new culvert resulting in a loss of open watercourse.<br>The channel upstream will be similar to existing, and shallowed downstream from 2.3% to 1.2%. It is unlikely any significant horizontal realignment will be necessary. | The overall stream power upstream is likely to decrease by almost half. Downstream the stream power will also decrease but only marginally. | Minor (Adverse) | Assumes application of standard mitigation measures specified in Section 4.2. | Minor (Adverse) |

## 6.2. Residual significance of impact

6.2.1. Table A6.2 summarises the overall significance of impact for each crossing.

**Table A6.2: Overall Significance of Impact**

| Watercourse Name | Crossing Ref | Sensitivity | Initial Magnitude | Residual Magnitude | Residual Significance |
|---|---|---|---|---|---|
| Allt na Frithe | A9 1250 | High | Moderate (Adverse) | Minor (Adverse) | Slight |
| | A9 1245 F | High | Negligible | Negligible | Neutral |
| Allt Dubhag | A9 1250 C25 | Low | Moderate (Adverse) | Minor (Adverse) | Neutral |
| Dalmagarry Burn | A9 1260 | High | Moderate (Adverse) | Minor (Adverse) | Slight |
| | A9 1260 SRB1 | High | Moderate (Adverse) | Minor (Adverse) | Slight |
| | A9 1260 ARB1 | High | Minor (Adverse) | Minor (Adverse) | Slight |
| Caochan na h-Eaglais | A9 1270 C80 | Low | Moderate (Adverse) | Minor (Adverse) | Neutral |
| | A9 1270 C80 S | Low | Moderate (Adverse) | Minor (Adverse) | Neutral |
| Allt na Loinne Mòire | A9 1273 C8 | Medium | Moderate (Adverse) | Minor (Adverse) | Slight |
| Allt na Slànaich | A9 1273 C28 | Medium | Moderate (Adverse) | Minor (Adverse) | Slight |
| Allt Creag Bheithin | A9 1273 C31 S (MC90 C1) | Medium | Minor (Adverse) | Minor (Adverse) | Slight |
| | A9 1273 C31 | Medium | Moderate (Adverse) | Minor (Adverse) | Slight |
| | A9 1273 MCY0 C1 | Medium | Minor (Adverse) | Minor (Adverse) | Slight |

6.2.2. With the additional specific mitigation included, the residual impact magnitudes are all Minor (Adverse), primarily because the watercourses have already been significantly impacted by the existing A9 and the impacts are localised. These impacts also assume the standard and embedded mitigations are applied as stated in Sections 4.2 and 4.3.

6.2.3. The majority of the watercourses have a **Neutral or Slight** overall significance of impact. Due to the High sensitivities of Allt na Frithe and Dalmagarry Burn they initially receive a **Slight/Moderate** impact. In accordance to HD 45/09[xviii] a single description of significance should be decided using reasoned judgement. In both cases, it was decided they warranted a **Slight** overall significance due to their existing modified nature.

6.2.4. Specific mitigation on the Dalmagarry Burn includes bank side planting (for shelter and shading for fish as well as bank stability), some undercut banks through placement of woody material for example and the positioning of the backwater. Implementation of these measures aim to further enhance the realignment and improve the morphological and ecological diversity of the impacted reach.

6.2.5. Whilst the majority of those watercourses assessed within this report individually result in a relatively small loss of open watercourse as a result of the widening of the A9 mainline carriageway and new side roads, cumulatively this is over 200m or roughly twice the existing culverted watercourse length. Dalmagarry Burn does provide some compensation with an additional 40m of channel. However, replacing the concrete box culverts (with artificial beds) with portal frames which allow for natural substrates through the structures is an important benefit. Overall this impact is considered to have a neutral impact overall.

## 6.3. Controlled Activities Regulations Impact

6.3.1. The Proposed Scheme does not directly affect any main stem (reportable) baseline water bodies and therefore will not increase the MIMAS scores. It is unlikely that there will be a significant impact resulting from the scheme due to the existing modifications associated with the A9 and the proposed mitigation to alleviate any further impacts.

# 7. Recommendations and Conclusion

## 7.1. Further investigations

7.1.1. Further consideration of watercourse realignments will be necessary at the detailed design stage to ensure the appropriate location and construction of bed check and step-pool features to reduce and mitigate any potential increase in stream powers. This will reduce the likelihood of erosion occurring either on the bed or the banks and outflanking the crossing.

7.1.2. Updated sediment entrainment calculations are required as the design progresses and more detailed information obtained (hydraulic modelling, channel dimensions, bed gradients etc.) to ensure the geomorphological mitigation features are appropriate and sustainable.

7.1.3. Following consultation, SEPA has requested consideration of a morpho-dynamic model to be developed and used to inform detailed design for Dalmagarry Burn to assess how proposed changes in gradient, planform and surrounding constraints affect the sediment transport and stability of the channel.

7.1.4. The effect of geomorphological features on aquatic species, e.g. migration upstream should be intrinsically linked during detailed design.

7.1.5. Guidance on appropriate substrate should be considered during detailed design to ensure the stability and continuity of the bed. This is particularly important through the culverts themselves.

7.1.6. The geomorphological input in the detailed design should not be limited by this environmental assessment. All modifications to the form and function of the watercourses should consider the same geomorphological principles to ensure the stability of the watercourse in relation to the surrounding assets. This applies to all (and not limited to) watercourse realignments, box culvert or portal frame crossings, piped culverts, cascades and outfalls.

7.1.7. Consultation with SEPA and other stakeholders (local authority and community, fisheries groups etc.) will be essential to ensure the proposals are compliant with the legislation and mitigate the impacts (or enhance) as far as is practicable.

7.1.8. A cumulative WFD assessment and CAR licence applications should be carried out to ensure there will be no deterioration or prevention on attaining GES to those impacted or downstream water bodies.

## 7.2. Conclusions

7.2.1. This Stage 3 DMRB hydromorphology assessment has built on previous work during the Stage 2 assessment. The remaining watercourses (screened in from Stage 2) have been examined in more detail in relation to the Proposed Scheme, including their overall impact on the geomorphological stability, loss of open watercourse length, constructability and sediment transport competence (e.g. stream power assessment and sediment entrainment calculations).

7.2.2. The assessment has also outlined a series of standard mitigation and geomorphological principles to be considered during detailed design, including the installation of bed checks and step-pools to mitigate for particularly steep gradients (typically over >4%), substrate composition through culvert structures, bank protection and temporary works.

7.2.3. Embedded mitigation which has already considered some aspects of the Proposed Scheme include the significant diversion of Dalmagarry Burn and input into the standard culvert design.

7.2.4. An initial assessment of impact was undertaken and specific mitigation was identified to further reduce the potential impacts on the watercourses. These included recommendations for boulder sizes for bed check and step-pool features based on sediment entrainment calculations.

7.2.5. The residual impacts for all the watercourse crossings were deemed to be Minor (Adverse) magnitude, primarily because of the existing modifications on the watercourses (having been already affected by the existing A9) and/or the impacts considered to be very localised. In addition, the standard mitigation and embedded mitigation, plus additional specific mitigation recommendation were considered adequate to minimise impacts on the environment.

7.2.6. Cumulatively the loss of open watercourse throughout the scheme is offset by the proposed improvements to the crossing structures which enable the installation of natural bed substrate, maintaining sediment transport continuity through the A9.

7.2.7. Dalmagarry Burn does provide a slight additional length of watercourse, however further opportunities should be sought to mitigate for the overall loss of open watercourse, including utilising the existing watercourses as backwaters close to the tie-in locations or an extension of realignments where gradients are particularly high and space is available.

7.2.8. As a result, the significance of impact(s) were considered no more than **Slight**. Therefore, the Proposed Scheme is unlikely to have direct significant impact on the watercourses considered as part of this assessment.

# 8. References


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xvi Brookes, A. (1983). River channelisation in England and Wales: downstream consequences for the channel morphology and aquatic vegetation, Southampton: University of Southampton.

xvii Brookes, A. (1987). The distribution and management of channelised streams in Denmark. Regulated Rivers, Issue 1, pp. 3-16.

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# Annex A. Sediment transport equations

## A.1. Stream power

Stream power (W) can be calculated using the following equation:

$$W = \rho\, g\, Q\, s \quad Watts\ per\ metre\ (Wm-1)$$

Where $\rho$ is the specific weight of water, $g$ is acceleration due to gravity, $Q$ is the discharge and $s$ is the slope.

For comparison stream power can be calculated relative to a unit width (specific stream power) by dividing the unit stream power W by channel width $w$:

$$\omega = W/w \quad (in\ units\ of\ Watts\ per\ square\ metre, Wm-2)$$

## A.2. Critical discharge and water depth

The critical discharge ($Q_{cr}$) equation was developed by Schoklitsch[xix], later adapted by Bathurst *et al*[xx]. The equation is simply:

$$Q_{cr} = 0.15\ g^{0.5}\ D^{1.5}\ s^{-1.12}$$

Where $Q_{cr}$ is the critical water discharge per unit width, $D$ is the sediment size and $s$ is the slope. This equation was developed for steeper slopes (0.25 to 20% grade) and coarse gravels (3 to 44mm).

An estimation of the critical water depth can be calculated by using the boundary shear stress calculation, which reads:

$\tau_0 = \rho g d s$ or $\tau_0 = \gamma d s$

Where $\tau_0$ is the actual boundary shear stress and $d$ is depth (m) $\tau_0$ and $\gamma$ is the specific weight of water. The equation can be rearranged to work out the depth:

$$d = \frac{\tau_0}{\rho g s}$$

By substituting actual shear stress ($\tau_0$) with critical shear stress ($\tau_{cr}$) it is possible to calculate $d$. For example for a normal gravel bed river channel, with $D_{50}$ of 1cm and a slope of 0.005 the critical shear stress would be:

$$\tau_{cr} = 730D = (730)(0.01) = 7.3Nm^{-2}$$

And for the shear stress:

$$\tau_0 = \rho g d s = (1000)(9.81)(d)(0.005) = 49.05d$$

Therefore:

$$49.05d = 7.3$$

$$d = 0.15\, m$$

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