Appendix A11.2

Flood Risk Assessment

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Tables

Event Severity

The severity of the events discussed in this document are defined as Annual Exceedance Probabilities (AEP), the table below provides a summary of AEP and corresponding Return Periods.

The AEP is the probability that there will be an event exceeding a particular severity in any one year. The Return Period is the average duration (in years) between events of a particular severity.

Annual Exceedance Probability	Return Period
50%	1 in 2 years
20%	1 in 5 years
10%	1 in 10 years
4%	1 in 25 years
3.33%	1 in 30 years
2%	1 in 50 years
1.33%	1 in 75 years
1%	1 in 100 years
0.5%	1 in 200 years
0.5% with 20% increase as allowance for climate change	1 in 200 years with 20% increase as allowance for climate change

1. Introduction

1.1 Background

1.1.1 In September 2012, Transport Scotland commissioned the A9 Dualling: Preliminary Engineering Support Services Report (PES)i. The PES undertook an engineering assessment of the A9 route and proposed corridor options and strategies for the improvement works in line with that of a Design Manual for Roads and Bridges (DMRB) Stage 1 Assessment.

1.1.2 Concurrent with the PES, Transport Scotland commissioned the A9 Dualling Strategic Environmental Assessment (SEA). The SEA Environmental Report[ii] identified the key environmental and landscape issues along the length of the A9 route and assessed the potential impacts associated with dualling the A9. Alongside the SEA, a Strategic Flood Risk Assessment (SFRA) was undertaken by CH2MHill[iii] (2014).

1.1.3 The SFRA was a route wide assessment for the A9 between Perth and Inverness that provides information on:

- areas sensitive to flooding along the A9 between Tomatin and Moy,
- the potential constraints; and
- design principles and guidance for the A9 Dualling.

1.1.4 Following the completion of the PES and SEA, the Atkins Mouchel Joint Venture (AMJV) was appointed by Transport Scotland to undertake a DMRB Stage 2 Assessment for the upgrade to dual carriageway of the northern section of the A9 Trunk Road between Dalraddy and Inverness. This included a preliminary flood risk assessment of the Proposed Scheme Options for the upgrade of the A9 between Tomatin and Moy.

1.1.5 The preliminary assessment included a review of all available data, identified potential sources of flooding and sensitive receptors and presented an assessment of the flood risk associated with the route alignment options considered at DMRB Stage 2. A calibrated hydraulic model was used to define the 0.5% Annual Exceedance Probability (AEP) and 0.5% AEP plus climate change flood outlines. One dimensional (1D) hydraulic models were used to calculate the hydraulic capacity of existing water crossings and so to assess the impact of replacing these structures.

1.1.6 The preliminary asessmemt identified the primary source of flooding to the Proposed Scheme as being fluvial, with the Proposed Scheme having the potential to result in a loss of floodplain storage at Allt na Frithe, Dalmagarry and Allt Creag Bheithin and concluded that the DMRB Stage 3 Flood Risk Assessment (hereafter referred to as the FRA) should assess the options available to determine how the impact will be mitigated.

1.1.7 The preliminary assessment defined the following scope for the FRA:

- The baseline model would be refined to improve floodplain definition for key locations of floodplain and the surrounding area where land for floodplain storage may be required. This would include the floodplains at Dalmagarry where all routed options for the Proposed Scheme resulted in a Major impact due to floodplain loss.
- The baseline model would be developed to include the Proposed Scheme alignment allowing the assessment of impacts in the locality of the Proposed Scheme and downstream receptors to be assessed. Where floodplain storage is lost as a direct impact of the scheme the hydraulic model would be used to develop mitigation

measures. This would include identifying locations for compensatory flood storage, and providing floodplain connectivity. Compensatory storage should be provided close to the point of lost floodplain, provide the same volume and be at the same level relative to the design flood level as that lost.

- The assessment should demonstrate that proposed works would not affect sensitive downstream flood receptors (e.g. if structure sizes are increased thus inadvertently increasing peak flows passing downstream).
- Consultation would be undertaken with key stakeholders.

1.1.8 This document is the FRA and provides the detailed modelling and assessment to inform the detailed alignment design and flood mitigation measures referred to in the Stage 3 Environmental Statement.

1.2 Legislation and Policy

1.2.1 The impacts of flooding are well documented and are often devastating with regard to cost of repairs, replacement of damaged property and loss of business. The Scottish Government is working to create a sustainable approach to flood risk management and the impact of climate change, through the implementation of the Flood Risk Management (Scotland) Act 2009[iv].

1.2.2 The Act introduces a sustainable approach to flood risk management taking into consideration the impact of climate change. It creates a joined up and coordinated process to manage flood risk at both national and local level. The Scottish Environment Protection Agency (SEPA) are the overarching authority and have a strategic role for flood risk management. SEPA are working closely with local authorities, Scottish Water, and other responsible authorities to deliver flood risk management planning in Scotland.

1.2.3 The National Flood Risk Assessment (NFRA) was the first step in developing a Flood Risk Management Strategy and Local Flood Risk Management Plans. The assessment increased the understanding of the sources of flooding, allowing areas at the greatest risk to the impact of flooding to be identified. These have been identified as Potentially Vulnerable Areas (PVAs).

1.2.4 In addition to the Act, Scottish Planning Policy (SPP) sets out national policies which reflect the Scottish Minister priorities. Managing Flood Risk and Drainage is included within the National Planning Framework 3 (NPF)[v].

1.2.5 SPP states that planning authorities should promote:

- a precautionary approach to flood risk from all sources of flooding including coastal, watercourse (fluvial), surface water (pluvial), groundwater, reservoirs and drainage systems (sewers and culverts) taking account of the predicted effect of climate change
- flood avoidance; by safeguarding flood storage and conveying capacity, and locating development away from functional flood plains and medium to high risk areas
- flood reduction
- avoidance of increased surface water flooding through requirements of Sustainable Drainage Systems (SuDS) and minimising the area of impermeable surface

1.2.6 The planning system aims to prevent development which would have a significant probability of being affected by flooding or would increase the probability of flooding elsewhere. For coastal and watercourse flooding SPP uses a risk framework that characterises areas for planning purposes by their annual probability of flooding and gives the appropriate planning response:

- Little or no risk area (annual probability of watercourse, tidal or coastal flooding is less than 0.1% AEP
- Low to medium risk area (annual probability of watercourse, tidal or coastal flooding in the range of 0.1% to 0.5% AEP
- Medium to high risk area (annual probability of watercourse, tidal or coastal flooding greater than 0.5% AEP

1.3 Guidance

1.3.1 A complete list of guidance used for the Road Drainage and the Water Environment assessment is given in the main chapter (Chapter 11). The following guidance documents have been used to inform the flood risk assessment:

- A9 Dualling Programme Strategic Flood Risk Assessment (SFRA)[vi].
- Scottish Planning Policy (SPP) (paragraphs 254 – 268)[vii].
- Highways Agency et al., Design Manual for Roads and Bridges (DMRB):
  - Volume 11, Section 3, Part 10 HD 45/09 – Road Drainage and the Water Environment; and
  - DMRB Part 7 HA 107/04 Design of Outfall and Culvert Details[viii].
- The Highland Council - Flood Risk and Drainage Impact Assessment Supplementary Guidance[ix].
- Scottish Environment Protection Agency (SEPA) publications:
  - Technical Flood Risk Guidance for stakeholders V8 – Feb 2015)[x]; and
  - Flood Modelling Guidance for Responsible Authorities version 1.1[xi]
- Construction Industry Research and Information Association (CIRIA) publications:
  - C624 - Development and flood risk – guidance for the construction industry
  - C688 - Flood Resilience for Critical Infrastructure
  - C689 - Culvert design and operation guide[xii]; and
  - C720 - Culvert design and operation guide supplementary technical note on understanding blockage risks[xiii].
- Environment Agency publications:
  - The Fluvial Design Guide[xiv]; and
  - Accounting for residual uncertainty: updating the freeboard guide (Report – SC120014)[xv].

1.4 Design Principles and Standards

1.4.1 A key output from the A9 Dualling SEA was a set of Strategic Environmental Design Principles (SEDP) that were developed in collaboration with SEPA, Scottish Natural Heritage (SNH), Historic Environment Scotland and the Cairngorms National Park Authority. The SEDP are included as Appendix A4.1 in Volume 2; Table A4.6 in the appendix covers water, flooding and SuDS. The SEDPs are summarised as follows:

- SEDP Principle W1 stipulates that the A9 and any associated works should not be located within the functional floodplain. Where this is not possible, the A9 should remain operational and safe for users during times of flood; result in no loss of floodplain storage; and the movement of water should not be impeded and flood risk should not be increased elsewhere. The functional floodplain is defined by the 0.5% AEP flood event.
- The impact of the Proposed Scheme has therefore been assessed for the 0.5% AEP flood event.
- Any mitigation measures, including compensation storage, have been designed to ensure that flood risk does not increase for the 0.5% AEP event.
- In line with SEDP Principle W1 the Proposed Scheme has been designed to ensure that the A9 remains free from floodwater for the 0.5% AEP with a 20% allowance for climate change. A minimum freeboard of 600mm has been allowed for between the maximum water level and road surface in line with guidance from SEPA[x], CIRIA[xii] and DMRB[xvi].
- SEDP Principle W2 directs designers to avoid developing SUDs in the functional floodplain. Where this is unavoidable they should not be inundated up to the 3.33% AEP and compensatory storage should be provided for all loss of capacity up to the 0.5% AEP event.
- The design process for the watercourse crossings is complex, taking account of a range of design criteria and constraints to develop the most appropriate crossing for each watercourse. The primary technical standards driving the design of culverts are DMRB HA107/04 Design of Outfall and Culvert Details (2004) and the CIRIA Culvert design and operation guide (C689) (2010).
- Culverts that pass under the main alignment have been designed to pass the 0.5% AEP plus a 20% allowance for climate change unless an under-sized structure is proposed to protect sensitive flood risk receptors. Culverts that pass under side roads have been designed to comply with the same standard as the main alignment where they are located on the same watercourse and are located immediately upstream or downstream of the main culvert crossing.

1.4.2 It has been assumed that mammal ledges within culverts will be 150 mm above the 4% AEP water level, 500 mm wide and have a 600 mm headroom from ledge to soffit. For the purpose of hydraulic calculations it has been assumed that ledges will be provided along both sides of a culvert and the area below the ledges is not available for flow.

1.4.3 The minimum freeboard allowances adopted for structures, culverts and drains are summarised below:

- 600 mm for culverts or structures with a height greater than 1.2m;
- 300 mm for culverts with a height of 1.2m or less and that pass under the main alignment; and
- Not less than D/4 for drains of 900mm diameter or less (where D is the pipe diameter).

1.5 Study Area

1.5.1 The Study Area is based on the entire River Findhorn Catchment, to allow for the assessment of the impacts on downstream sensitive receptors as well as in the immediate vicinity of the Proposed Scheme. The immediate vicinity is considered to be

5km surrounding the Proposed Scheme. The Proposed Scheme begins south of Tomatin and extends to north of Moy village (Figure A11.2.1 in Volume 3).

1.5.2 Figure A11.2.2 shows the River Findhorn catchment and Figure A11.2.3 shows that the nearest Potentially Vulnerable Area (PVA) that could potentially be impacted by the Proposed Scheme is PVA 05/07, which is located approximately 35km downstream of Tomatin on the River Findhorn. This PVA covers the west of Forres and the mainly rural areas to the south. The known sources of flooding are river (75%) and surface water (25%).

1.5.3 PVA 05/07 and 05/06 together cover Forres. Forres benefits from two flood protection schemes, one on the Burn of Mosset and one on the River Findhorn. The Burn of Mosset is not located in the Study Area. An estimated 1,700 residential and 120 non-residential properties benefit from these two schemes. An estimated 80 non-residential properties are protected (to a 0.5% AEP standard of protection) and 20 non-residential properties remain at risk of flooding in this area.

1.5.4 The Proposed Scheme lies between approximately 10km and 22km southeast of Inverness, skirting the northern extent of the Monadhliath Mountains. The Proposed Scheme follows the lower western slopes of the glaciated river valleys of the River Findhorn, Loch Moy and the Funtack Burn, with higher rolling open moorland to the west of the corridor and gently sloping valley floors to the east.

1.5.5 The southern extent of the study area lies at approximately 300m AOD (above Ordnance Datum), where the existing A9 crosses the River Findhorn at Tomatin. Continuing northwards the elevation of the Proposed Scheme remains at broadly 300m AOD as it wraps around the toe of the valley side, with localised low points in the vicinity of Dalmagarry (270m AOD) and the flat, poorly drained ground to the northwest of Moy (290m AOD). The elevation of the Proposed Scheme rises to approximately 320m AOD at its northern extent, as the road corridor crosses the watershed between the River Findhorn and River Nairn catchments.

1.5.6 There are two main areas of settlement within the study area, the village of Tomatin, close to the southern extent, and village of Moy which follows the western shore of Loch Moy. There are a small number of isolated properties, notably at Invereen, Dalmagarry and Lynebeg.

1.5.7 The Highland Main Line railway lies within much of the Proposed Scheme corridor, running to the west of the existing A9 from Tomatin to north of Dalmagarry, then running in close proximity to the east of the A9 through Moy. North of Moy the Highland Main Line and the Proposed Scheme diverge, as the railway continues north and the Proposed Scheme swings westward.

1.5.8 Land use is predominantly agricultural in the valley floor, with mainly improved and semi-improved grassland. There are also significant areas of conifer plantation on the lower valley slopes, particularly in the northern half of the study area. Around Dalmagarry the hill slopes to the west of the study area are largely open moorland.

2. Methodology

2.1 Approach

2.1.1 The impact of the Proposed Scheme on flood risk has been assessed based on the sensitivity and magnitude matrix shown in Table A2.1.

Table A2.1: Criteria used to Estimate the Significance of Potential Effects

Sensitivity	Magnitude			
	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

2.1.2 Following the screening carried out for the preliminary assessment, the appraisal of flood risk impacts for the FRA considers:

- changes to surface water flows where proposed changes to existing culverts or the introduction of new culverts and associated infrastructure may result in increased flow capacity
- changes to floodplains due to disconnection of the floodplains by the Proposed Scheme and floodplain storage loss or displacement through encroachment by proposed permanent earthworks and land raising

2.1.3 The magnitude and significance of these impacts has been assessed for the 0.5% AEP. The 0.5% AEP plus climate change event has been used to check for sustainability and resilience.

2.1.4 Flooding from coastal, overland flow and groundwater sources were scoped out during the preliminary assessment due to the following reasons:

- Coastal flooding was screened out due to the locality of the Proposed Scheme; there is no risk of coastal flooding.
- Although the Proposed Scheme will result in an increase in impermeable area, a gravity drainage network is being designed which will convey overland flows and surface water to suitable outfall points via sustainable drainage systems. This will maintain overland flow routes and prevent water ponding upstream of the Proposed Scheme. Details of the road drainage design can be found in the A9 Dualling Tomatin to Moy: Stage 3 Environmental Statement Chapter 5 – The Proposed Scheme.
- The surrounding geology is of low permeability and water strike levels from boreholes indicate that there is no significant risk of groundwater flooding. An assessment of the interception of groundwater at cuttings and the potential impact on aquifers is presented in Chapter 10 (Geology, Soils and Groundwater) and Appendix A10.3 Groundwater Assessment.

2.2 Sensitivity Criteria

2.2.1 Receptors of flood risk include anything from property to people and the surrounding environment. Receptors located within the Medium (0.5% AEP) flood outline were identified along the Proposed Scheme and also those within 100m of the Medium flood outline.

2.2.2 The sensitivity of water features in general takes into account their quality, rarity, scale and substitutability. With respect to flood risk, sensitivity is determined by the number and type of receptors that are hydrologically linked with the water feature. The criteria used in determining the sensitivity of each water feature are detailed in Table A2.2.

Table A2.2: Sensitivity Criteria - Flood Risk Examples

Sensitivity	General Criteria	Typical Examples for Flood Risk
Very High	Attribute has a high quality and rarity on regional or national scale.	Water feature with direct flood risk to > 100 residential properties or critical infrastructure (e.g. trunk roads, main line railways, hospitals, schools, safe shelters etc.).
High	Attribute has a high quality and rarity on local scale.	Water feature with direct flood risk to 1 -100 residential properties, > 10 industrial premises, and/or other land use of high value or indirect flood risk to critical infrastructure.
Medium	Attribute has a medium quality and rarity on local scale.	Water feature with direct flood risk to recreational land or high value agriculture (e.g. arable land, pastures, complex cultivation patterns and agro-forestry) and/or affecting < 10 industrial premises.
Low	Attribute has a low quality and rarity on low scale.	Water feature with little or no flood risk, affecting low value agricultural land (e.g. rough grazing land).

Source: DMRB Volume 11 Section 3 (HD 45/09)

2.3 Magnitude Criteria

Watercourse Crossings

2.3.1 Existing watercourse crossings were identified from OS Mastermap data, Transport Scotland's structures database and confirmed from site visit. Peak flows were derived for each watercourse crossing catchment using the methodologies outlined in the Flood Estimation Handbook[xvii] and methods agreed with SEPA. The capacities of each crossing have been calculated using unsteady state one dimensional (1D) hydraulic models.

2.3.2 The one-dimensional models were run in unsteady state as many of the structures became surcharged under design flow conditions such that upstream storage affected the hydrodynamics. Although unsteady runs present more challenges with regards to model stability, they are not less accurate than steady state models.

2.3.3 For the purposes of assessment each watercourse crossing was provided a unique crossing reference ID, this is referenced as TM-WC-xx and is numbered sequential from south to north. In addition to this, each watercourse crossing has a corresponding watershed/catchment reference ID, this is referenced as TM-xx. The Transport Scotland reference ID has been retained, for continuity between the DMRB Stage 2 and Stage 3 reports. In addition, there is a new proposed Transport Scotland Structure ID, which from herein will be referred to.

2.3.4 A matrix was developed using professional judgement to determine the magnitude of an increase in the hydraulic capacity based on the size of the watercourse and the existing capacity of the structure. By applying the matrix set out in Table A2.3, an assessment of the impact of replacing all existing crossings could be determined.

Table A2.3: Watercourse Crossings – Magnitude Criteria

Existing Capacity	0.5% Peak Flows (m^3/s)			
	<1m^3/s	1-5m^3/s	5-25m^3/s	>25m^3/s
Existing Capacity is >0.5% AEP. No flood attenuation potential, upsizing will not have an impact on downstream hydrograph.	Negligible	Negligible	Negligible	Negligible
Existing Capacity 1%-0.5% AEP. Small potential for increasing downstream flows if culvert is upsized.	Negligible	Minor	Moderate	Major
Existing Capacity 10% - 1% AEP. Some potential for increasing downstream flows if culvert is upsized.	Minor	Moderate	Moderate	Major
Existing Capacity <10% AEP. Significant potential for increasing downstream flows if culvert is upsized.	Minor	Moderate	Major	Major

Floodplain Impacts

2.3.5 This assessment uses the DMRB criteria for estimating magnitude of impact from flood risk, as shown in Table A2.4, with the exception that the 0.5% AEP event has been used rather the 1% AEP.

Table A2.4: Floodplain Impact – Magnitude Criteria

Magnitude of Impact	Criteria	Typical Example
Major Adverse	Results in loss of attribute and/or quality and integrity of the attribute.	Increase in peak flood level (0.5% AEP) >100mm.
Moderate Adverse	Results in effect on integrity of attribute, or loss of part of attribute.	Increase in peak flood level (0.5% AEP) of between 50mm and 100mm.
Minor Adverse	Results in some measurable change in attribute quality or vulnerability.	Increase in peak flood level (0.5% AEP) of between 10mm and 50mm.
Negligible	Results in effect on attribute, but of insignificant magnitude to affect the use or integrity.	Negligible change in peak flood level (0.5% AEP) <+/-10mm.
Minor Beneficial	Results in some measurable improvement in attribute quality or vulnerability.	Moderate improvement over baseline conditions involving a reduction in 0.5% AEP peak flood level of between 10mm and 50mm.
Moderate Beneficial	Results in positive effect on integrity of attribute, or gain of part of attribute.	Moderate improvement over baseline conditions involving a reduction in 0.5% AEP peak flood level of between 50mm and 100mm.
Major Beneficial	Results in gain of attribute and/or quality and integrity of the attribute.	Moderate improvement over baseline conditions involving a reduction in 0.5% AEP peak flood level >100mm.

Source: DMRB Volume 11 Section 3 (HD 45/09)

2.3.6 The hydraulic model developed for the preliminary assessment was refined further and used to estimate the magnitude of the impacts and to develop mitigation options when required. The model is described in section 4.2.

2.3.7 For impacts associated with floodplain loss a sequential test has been developed to determine the need for storage compensation. The tests, given in Table A2.5 to Table A2.7 are based on the approach used in Planning Policy Statement 25 (PPS25) relating to flood risk and development.

Table A2.5: Floodplain Loss Sequential Test 1

Test 1	Pass?	Actions
Can the impact on the 0.5% AEP floodplain be avoided?	Yes	No action required.
	No	Can we adjust the alignment? Do we need to improve the accuracy of the floodplain extent? If the floodplain cannot be avoided then go to Test 2.

Table A2.6: Floodplain Loss Sequential Test 2

Test 2	Pass?	Actions
Is there is an overriding need for the development to be located on an area that is floodplain?	Yes	Proceed to Test 3
	No	Consider adjusting the alignment and reapply Test 1.

Table A2.7: Floodplain Loss Sequential Test 3

Test 3	Pass?	Actions
Can direct or indirect full replacement of floodplain volume be provided subject to the following constraints? - Available land take. - No detrimental impact on the environment, landscape or cultural heritage. - No long term issues relating to land ownership. - No increase in flood risk elsewhere. - Other site or scheme specific issues.	Yes	Preference will be given to direct compensatory storage which is located close to the point of impact, provides level for level compensation and is hydraulically linked with the floodplain. If necessary, in-direct compensatory storage will be used which should hydraulically connect the floodplain and storage area and be controlled to ensure level for level compensation.
	No	On the basis of a satisfactorily robust model it should be clearly demonstrated that there would be no increase in flood risk upstream or downstream of the development at sensitive receptors. The criteria to be satisfied should be agreed with SEPA and other stakeholders as necessary.

2.4 Limitations

2.4.1 The accuracy of the 1D hydraulic modelling of the watercourse crossings is limited by the quality of the topographic information. The delineation of the upstream catchment and estimation of the design flows are the most uncertain aspects of the hydraulic analysis. In general a precautionary approach has been taken whereby the method giving the largest design flow estimate has been used.

2.4.2 The accuracy of the 1D/2D linked hydraulic models is primarily constrained by the quality of hydrological and topographical data. Key factors include the resolution of the topographic data, the accuracy of surveys of hydraulic structures, the availability of data on past flooding and the limitations of the modelling software. SEPA and Environment Agency (EA) guidance[x, xiv] was adopted were appropriate to assess the accuracy of models using sensitivity analysis.

2.4.3 Many of the proposed watercourse crossings drain small catchments, which are not accurately defined by the Flood Estimation Handbook (FEH) CD ROM (V3). Catchment boundaries have therefore been defined using topographic data and observations made during site visits. Freeboard allowances and model sensitivity have been used to include allowance for this uncertainty in the culvert design.

2.4.4 Due to the rural nature of the watercourses there are few accurate records of past flooding along the route of the existing A9 that can be used to calibrate the 1D and 1D/2D models. The models make best use of available information but it is a limitation that the calibration has had to focus on data from SEPA gauging stations.

3. Data Collection

3.1 General Data

3.1.1 The key sources of information which were provided by Transport Scotland, SEPA, and The Highland Council; and data that is in the public domain are listed below:

- A9 Dualling Perth to Inverness Strategic Flood Risk Assessment (SFRA)
- Topographical Survey (including aerial imagery) for the A9 Dualling Corridor (Blom)
- SEPA Flood Maps[xviii]
- SEPA river flow and rainfall data
- The SEPA National Flood Risk Assessment[xix]
- OS Mapping
- NextMap DTM
- FEH CD ROM (Version3)[xx]
- Road Drainage Record Drawings
- BGS 1:50,000 superficial and bedrock geology mapping
- BGS Hydrogeological Map of Scotland 1:625,000 scale
- BGS Groundwater Vulnerability Map of Scotland 1:625 000 scale
- A9 Perth to Inverness Dualling Geotechnical Preliminary Sources Study Report
- A9 Dualling Northern Section: Tomatin to Moy Geotechnical Preliminary Sources Study Report

3.1.2 Site visits to consider the flood risk aspects of existing watercourse crossings were undertaken in July 2015, with a further visit to the Dalmagarry area in December 2016. Information and photographs recorded by other AMJV teams have also been available to this study.

3.1.3 The topographic and hydrometric data are key to the accuracy of the FRA and therefore this data is described in more detail in the following sections.

3.2 Topographical Data

3.2.1 Transport Scotland appointed Blom AEROFILMS to undertake topographical survey works to provide information to facilitate outline and detailed design work for the A9 Dualling Programme. Transport Scotland provided the following key information:

- 1:2500 ortho-photo and grid DTM
- topographical survey at 1:500 Scale
- high precision 1:500 survey of the carriageway envelopes
- 3D models, including elevations and information of spans, headroom and clearance for each watercourse crossing and road structure

3.2.2 The topographic survey was available for a 200m wide strip along the existing A9 as MX ground models. The data was converted into points, strings and contours; and elements that were not ground levels were removed. Strings and contours were densified to enable more accurate triangulation to minimise the potential for triangulation through linear features. Finally, the three sets of points were combined to produce a 1m elevation grid.

3.2.3 In addition to the above information, Transport Scotland provided the LiDAR coverage for a 1km wide strip surrounding the A9. The data provides elevations at 10m grid postings and is quoted to have a vertical accuracy of +/- 700mm. Data was provided in two forms: as a 10m grid and as elevations along line features.

3.2.4 Nextmap DTM (5m resolution and a vertical accuracy of 0.7 - 1m and captured between 2002 and 2003) is available for the study area but was only used when no higher accuracy elevation data was available.

3.2.5 AMJV undertook additional topographical survey of the following watercourses in December 2015 and October 2017:

- Moy Burn
- Allt Creag Bheithin
- Dalmagarry Burn
- Funtack Burn
- River Findhorn

3.2.6 Figure A11.2.4a-c shows the coverage of each topographic survey.

3.2.7 Table A3.1 compares the topographical survey data available and the error within the dataset. These values were calculated by AMJV based on a direct comparison of the data sets and using AMJV topographic survey data as reference. They should be treated as being indicative only.

Table A3.1: Available Topographical Survey Data and its Associated Error

	BLOMTopo Survey	LiDAR 1Km - Survey	Nextmap DTM
Average Absolute Error (m)	0.14	0.21	0.18

	BLOMTopo Survey	LiDAR 1Km - Survey	Nextmap DTM
Average Positive Error (m)	0.15	0.24	0.22
Average Negative Error (m)	-0.12	-0.10	-0.15
Maximum Positive Error (m)	0.41	1.47	1.08
Maximum Negative Error (m)	-0.31	-0.66	-0.45

3.2.8 The composite ground model data facilitates hydrological catchment delineation and hydrological flow estimation and can also be utilised for 2D overland flow modelling.

3.3 SEPA Rainfall and Hydrometric Data

3.3.1 SEPA operates gauges on the River Findhorn at Shenachie (7001) and Forres (7002) (Figure A11.2.5). Data from the gauging stations is available from the 1960s to the present.

3.3.2 In 2014 the Forres area of the River Findhorn catchment underwent several modifications due to the Forres (River Findhorn & Pilmuir) Flood Alleviation Scheme. The channel and control at Forres were completely transformed following the flood alleviation works and a high flow event on the 11/08/14. As a result, a new rating curve has been derived for post 2014 gauging using high flows recorded in 2014 and 2015.

3.3.3 Both gauges are suitable for use as QMED donor stations and for pooling in FEH. Annual maxima (AMAX) and flow series for the following five high flow events were received from SEPA:

- 11/08/2014;
- 25/01/2008;
- 15/11/2002;
- 08/11/2000; and
- 01/07/1997.

3.3.4 SEPA provided rainfall data for three gauges located within the study catchments and two gauges some distance outside of the catchments (Figure A11.2.5). Summaries of the rain gauges and their location in relation to the study area is shown in Table A3.2.

Table A3.2: Rain gauges within study catchment

Rain Gauge	NGR	Location	Interval (min)	Records Available 1997	Records Available 2000	Record Available 2002	Record Available 2008	Record Available 2014
Coignafearn	NH 70963 17820	River Findhorn	15	Yes	Yes	Yes	Yes	Yes
Freeburn	NH 79547 30023	Allt na Frithe	15	Yes	Yes	Yes	Yes	Yes
Lochindorb	NH 98500 37310	River Findhorn	15	Yes	Yes	Yes	Yes	Yes

Rain Gauge	NGR	Location	Interval (min)	Records Available 1997	Records Available 2000	Record Available 2002	Record Available 2008	Record Available 2014
Sluggan	NH 86980 21930	Outside of the study area	15	Yes	Yes	Yes	Yes	Yes
Wardend	NJ 03930 55845	Outside of the study area	15	Yes	Yes	Yes	Yes	Yes

3.3.5 Some data quality issues were reported with the 25/01/2008 event at the Wardend and Coignafearn gauges, and SEPA provided 2008 Lochindorb and Sluggan records for the 2008 event for comparison purpose. The data quality issue was believed to be due to snowmelt. Caution was similarly advised for the 1997 event, where the peaks flows were not recorded.

4. Baseline Information

4.1 Existing Watercourse Crossings

4.1.1 For each watercourse crossing the catchments were delineated using the FEH CD Rom Version 3, NextMap, LIDAR, topographical survey, and aerial imagery. Peak flow estimations were derived for each catchment using the FEH standard methodologies including the:

- FEH Rainfall Runoff Method; and
- FEH Statistical Approach (where catchment > 5km^2).

4.1.2 The catchments can be seen in Figure A11.2.6 with Table A4.1 below providing details of each crossing. The catchment and watercourse names are consistent with the system used in Chapter 11 in Volume 1, where a structure already exists its Transport Scotland identification number has been given and in all cases the identification number for the new or replacement structure has been given.

4.1.3 The sensitivity categories are based on Table A2.2 and professional judgment. A precautionary approach has been taken to assigning sensitivities to the watercourses in general. For example, the presence of access tracks has been used to justify increasing the sensitivity to Medium. At Dalmagarry Farm where there is a concentration of receptors the sensitivity has been increased to Very High. Forestry and agricultural land (this includes arable land, pastures, complex cultivation patterns and agro-forestry) has been assigned a Medium sensitivity.

4.1.4 The sensitivities of the watercourses from the Funtack Burn Trib 6 / 7 extending north to the Allt na Loinne Moire are judged to be High rather than Very High as the Highland Main Line railway is substantially above the 0.5%AEP floodplain and the watercourses are judged to represent an indirect flood risk to the railway.

4.1.5 Watercourses have been included in Table A4.1 where a crossing is proposed but no asset currently exists to show the baseline receptors and sensitivities. Whereas only existing assets that could be modelled are included in Table A4.2.

4.1.6 Table A4.2 gives details of the estimated peak flows for each watercourse. The precautionary approach has been applied to the determination of the peak flows for each watercourse crossing at this stage (i.e. the highest value for flow estimation has been adopted, generally from the FEH Rainfall Runoff method).

4.1.7 Where Table A4.2 identifies that the capacity to the road level is <0.5% AEP, the A9 mainline is considered to be sensitive to flooding impacts, and therefore the sensitivity of receptors at that structure is assigned ‘Very High’.

Table A4.1: Delineated Catchment Information between Tomatin and Moy (south to north)

Watercourse	Existing Structure ID	Catchment ID	Area (km^2)	Catchment Description	Downstream Receptor	Sensitivity
River Findhorn Trib 1	A9 1240 C2	TM28	0.61	Drainage Path	Forestry land.	Very High
Allt na Frithe	A9 1250	TM27	5.8	The Allt na Frithe rises in the Beinn Bhreac hills, flows north east to the River Findhorn.	Agricultural land, with classification as land capable of producing a narrow range of crops.	Low
River Findhorn Trib 2	A9 1250 C17	TM26	0.18	Drainage Path	Forestry commission land.	Very High
Allt Dubhag	A9 1250 C25	TM25	2.6	A tributary of the River Findhorn. It rises from the Carn a Bhothain hill.	Forestry commission land.	Medium
River Findhorn Trib 3	A9 1250 C30	TM24	0.05	Drainage Path	<10 Residential properties.	High
Funtack Burn Trib 1	n/a	TM23	0.61	Drainage Path	<10 Non Residential Properties.	Medium
Dalmagarry Burn Trib 1	n/a	TM22	0.81	Drainage Path	< 10 Non Residential Properties.	Medium
Dalmagarry Burn Trib 2	n/a	TM21	0.04	Drainage Path	Unclassified road and agricultural land.	Medium
Dalmagarry Burn Trib 3	n/a	TM20a	0.09	Drainage Path	Unclassified road and agricultural land.	Medium
Dalmagarry Burn	A9 1260	TM20	8.4	The Dalmagarry Burn rises from the Carn nam Bo-airigh hills, and flows in easterly direction crossing under the A9.	Dalmagarry farm (residential and non-residential properties), access road and agricultural land.	Very High
Funtack Burn	n/a		47.17	Funtack Burn including Loch Moy and it inflows.	Unclassified road, scattered residential properties and agricultural land.	High
Funtack Burn Trib 2	A9 1260 C20	TM19	0.09	Drainage Path.	Unclassified road, providing access to Dalmagarry Farm.	Very High

Watercourse	Existing Structure ID	Catchment ID	Area (km^2)	Catchment Description	Downstream Receptor	Sensitivity
Funtack Burn Trib 3	A9 1260 C35	TM18	0.34	Tributary of the Funtack Burn, which raised from Carn na Loinne and flows eastward under the A9.	Unclassified road, providing access to Dalmagarry Farm.	Very High
Funtack Burn Trib 4	A9 1260 C65	TM17	0.24	Tributary of Colls, Flows east under the A9 and B9154 before discharging into Strathdearn downstream of Loch Moy.	B9154 and agricultural land.	High
Funtack Burn Trib 5	A9 1270 C4	TM16	0.08	Tributary of Colls, Flows east under the A9 and B9154 before discharging into Strathdearn downstream of Loch Moy.	Forestry land, and the B9154.	High
Funtack Burn Trib 6 / 7	A9 1270 C7	TM15	0.08	Drainage Path	Forestry land and the Highland Main Line railway.	High
Funtack Burn Trib 8	A9 1270 C9	TM14	0.1	Drainage Path	Forestry land and the Highland Main Line railway.	High
Funtack Burn Trib 9	A9 1270 C10	TM13	0.06	Drainage Path	Forestry land and the Highland Main Line railway.	High
Caochan na h-Eaglais	A9 1270 C14	TM12	0.77	Rises from Carn na Loinne flowing north. It crosses the A9, Railway and B9145 before discharging into Loch Moy.	Forestry land and access road, the Highland Main Line railway is immediately downstream from this.	High
Moy Burn Trib 1	A9 1270 C19	TM11	0.74	Rises from Carn na Loinne flowing north. It crosses the A9, Railway and B9145 before discharging into Loch Moy.	Forestry land and access roads, the Highland Main Line railway is immediately downstream from this.	High
Allt na Loinne Moire	A9 1270 C22	TM10	2.86	Raises from Carn na h-Easgainn and flows north, crosses the A9 and discharges into the Moy Burn upstream of Loch Moy.	Forestry land, and grass lands which are capable of producing a narrow range of crops (Land Capability for Agriculture (LCA) classification). The Highland Main Line railway is immediately downstream.	High
Moy Burn Trib 2	A9 1270 C29	TM9	0.19	Drainage Path	Grasslands, with a number of drainage pathways.	Low
Moy Burn Trib 3	A9 1270 C30	TM8	0.05	Drainage path	Grasslands, with a number of drainage pathways.	Low

Watercourse	Existing Structure ID	Catchment ID	Area (km^2)	Catchment Description	Downstream Receptor	Sensitivity
Allt Creag Bheithin Trib 1	A9 1270 C33	TM7	0.92	Tributary of the Allt Creag Bhethin.	Grasslands, with a number of drainage pathways.	Low
Allt Creag Bheithin Trib 2	A9 1270 C35	TM6	0.08	Small tributary/drain of the Allt Creag Bhethin.	Grasslands, with a number of drainage pathways.	Low
Allt na Slanaich	A9 1270 C39	TM5	2.43	Rises from the Beinn nan Cailleach, it flows North East crosses the A9, the Railway and B9154 before joining the Moy Burn 1.5km downstream of the A9.	Grass lands which are suited to rough grazing. Farm access tracks.	Medium
Allt Creag Bheithin	A9 1270 C41	TM4	2.84	Rises from the Beinn nan Cailleach it flows North East. It crosses the A9, the Railway and B9154 before joining the Moy Burn 1.5km downstream of the A9.	Grass lands which are suited to rough grazing. Farm access tracks.	Medium
Allt Creag Bheithin Trib 3	A9 1270 C48	TM3	0.37	Rises from Maell Mor and flows southeast where it crosses the A9 before joining the Allt Creag Bhethin.	Forestry commission land.	Medium
Allt Creag Bheithin Trib 4	A9 1270 C59	TM2	0.17	Rises from the Maell Mor and flows south, where it crosses the A9 before joining the Allt Craeg Bheithin.	Forestry commission land.	Medium
Allt Creag Bheithin	A9 1270 C43	TM1	0.25	Rises from Maell Mor, and flows southwest, where it crosses the A9 before joining the Allt Creag Bheithin.	Forestry commission land.	Medium
Allt Creag Bheithin Trib 5	n/a	TM30	0.99	Rises from Maell Mor, and flows southwest, where it crosses the A9 before joining the Allt Creag Bheithin.	Forestry commission land.	Medium
Midlairgs Burn	n/a	TM31	0.51	Drains north facing forestry and open moorland.	Forestry commission land.	Medium
Midlairgs Burn 1	n/a	TM32	0.39	Drains north facing forestry and open moorland.	Forestry commission land.	Medium
Midlairgs Burn 2	n/a	TM33	0.19	Drains north facing forestry and open moorland.	Forestry commission land.	Medium

Table A4.2 Existing Watercourse Crossing Structure Details

Watercourse	Existing Structure ID	Structure Description	Size	Flow Estimation Method	Peak Flow (m^3/s)		Capacity to soffit (flow in m^3/s / AEP)	Capacity to road level (flow in m^3/s / AEP)
					0.5%	0.5% plus Climate Change		
River Findhorn Trib 1	A9 1240 C2	Circular, concrete, little/ no bed material. Wide, trash screen covering whole orifice.	0.5m Ø	Rainfall Runoff	2.46	2.95	0.2 / <50%	0.36 / <50%
Allt na Frithe	A9 1250	Circular, corrugated, with concrete low flow channel	4.5m Ø	Statistical	17.1	20.57	48.9 / >0.1%	88 / >0.1%
River Findhorn Trib 2	A9 1250 C17	Circular, concrete. Wide, trash screen covering entire orifice.	0.6m Ø	Rainfall Runoff	0.95	1.14	0.17 / <50%	0.5 / 10%
Allt Dubhag	A9 1250 C25	Circular culvert, concrete, concrete low flow channel	2.5m Ø	Rainfall Runoff	7.65	9.18	10.5 / 0.5%+CC	25.5 / >0.1%
River Findhorn Trib 3	A9 1250 C30	Circular culvert, concrete. Trash screen covering entire orifice.	0.55m Ø	Rainfall Runoff	0.24	0.29	0.26 / 0.5%	0.35 / 0.1%
Dalmagarry Burn	A9 1260	Bridge, split channel, gravel bed.	1.5 x 7m	Statistical	24.6	29.56	16.3 / 10%	30.8 / >0.5%
Funtack Burn		Existing wooden footbridge.		The structure is included here for completeness. It does not constrain flood flows or control flood levels at sensitive receptors.				
Funtack Burn Trib 2	A9 1260 C20	2 circular culverts, concrete moderate amount of bed material, moderate vegetation.	0.6m Ø 0.45m Ø	Rainfall Runoff	0.49	0.59	0.29 / ~10%	0.47 / 1%
Funtack Burn Trib 3	A9 1260 C35	Circular culvert, concrete, moderate amount of bed material and vegetation.	0.9m Ø	Rainfall Runoff	1.79	2.15	0.8 / ~20%	1.65 / 1%
Funtack Burn Trib 4	A9 1260 C65	Circular, concrete.	1.6m Ø	Rainfall Runoff	1.26	1.52	3.7 / >0.1%	12 / >0.1%

Watercourse	Existing Structure ID	Structure Description	Size	Flow Estimation Method	Peak Flow (m^3/s)		Capacity to soffit (flow in m^3/s / AEP)	Capacity to road level (flow in m^3/s / AEP)
					0.5%	0.5% plus Climate Change		
Funtack Burn Trib 5	A9 1270 C4	Circular culvert, corrugated, little/ no bed material.	0.8m Ø	Rainfall Runoff	1.05	1.26	0.68 / >0.1%	1.16 / >0.1%
Funtack Burn Trib 6 / 7	A9 1270 C7	Circular culvert, corrugated, little/ no bed material.	0.9m Ø	Rainfall Runoff	0.42	0.51	0.88 / >0.1%	1.59 / >0.1%
Funtack Burn Trib 8	A9 1270 C9	Circular culvert, corrugated, little/ no bed material.	0.8m Ø	Rainfall Runoff	0.50	0.60	0.81 / >0.1%	1.57 / >0.1%
Funtack Burn Trib 9	A9 1270 C10	Circular culvert, corrugated, moderate amount of bed material.	0.8m Ø	Rainfall Runoff	0.28	0.37	0.65 / >0.1%	1.06 / >0.1%
Caochan na h-Eaglais	A9 1270 C14	Circular Culvert, corrugated, small amount of bed material.	1.8m Ø	Rainfall Runoff	3.57	4.28	5.32 / >0.1%	14.71 / >0.1%
Moy Burn Trib 1	A9 1270 C19	Circular culvert, corrugated, little/ no bed material.	1.2m Ø	Rainfall Runoff	3.19	3.83	1.98/ 4%	4.07 / >0.5%
Allt na Loinne Moire	A9 1270 C22	2 circular culverts, corrugated, little/ no bed material.	2x 2.2m Ø	Rainfall Runoff	9.67	11.60	18.46 / >0.1%	41.46 / >0.1%
Moy Burn Trib 2	A9 1270 C29	Circular culvert, corrugated, small amount of bed material.	1.2m Ø	Rainfall Runoff	0.88	1.06	1.87 / >0.1%	0.92 / 0.1%
Moy Burn Trib 3	A9 1270 C30	Circular culvert, corrugated, moderate/ high bed material and vegetation.	1.0m Ø	Rainfall Runoff	0.24	0.29	1.19 / >0.1%	2.19 / >0.1%
Allt Creag Bheithin Trib 1	A9 1270 C33	Circular culvert, corrugated, small amount of bed material.	1.6m Ø	Rainfall Runoff	4.20	5.04	4.12 /0.5%	7.77 / >0.5%
Allt Creag Bheithin Trib 2	A9 1270 C35	Circular culvert, concrete.	0.8m Ø	Rainfall Runoff	0.35	0.42	14.49 / >0.1%	12.27 / 0.1%

Watercourse	Existing Structure ID	Structure Description	Size	Flow Estimation Method	Peak Flow (m^3/s)		Capacity to soffit (flow in m^3/s / AEP)	Capacity to road level (flow in m^3/s / AEP)
					0.5%	0.5% plus Climate Change		
Allt na Slanaich	A9 1270 C39	2 circular culverts, corrugated. Moderate/ high amount of bed material.	2x 2m Ø	Rainfall Runoff	9.02	10.82	0.73 / >0.1%	1.85 / >0.1%
Allt Creag Bheithin	A9 1270 C41	Circular culvert, corrugated, little/ no bed material.	1.8m Ø	Rainfall Runoff	7.65	9.18	5.13 / 2%	8.10 / 0.1%
Allt Creag Bheithin Trib 3	A9 1270 C48	Circular culvert, corrugated, little/ no bed material.	1.4m Ø	Rainfall Runoff	1.73	2.08	2.65 / >0.1%	4.88 / >0.1%
Allt Creag Bheithin Trib 4	A9 1270 C59	Circular culvert, corrugated, little amount of bed material.	1m Ø	Rainfall Runoff	0.82	0.98	1.22 / >0.1%	2.40 / >0.1%
Allt Creag Bheithin	A9 1270 C43	Circular culvert, corrugated, little amount of bed material.	1.5m Ø	Rainfall Runoff	1.20	1.44	2.89 / >0.1%	4.14 / >0.1%

4.1.8 The existing hydraulic capacities of the watercourse crossings were calculated through the use of unsteady-state one dimensional (1D) hydraulic models. The models were built in either ISIS 3.7 or Floodmodeller software, with cross sectional information extracted from the existing Blom Ortho topographical survey. Each model typically consists of three cross sections upstream of the culvert, with a spacing of approximately 10m between each section, with sufficient cross sections downstream to minimise the potential for downstream boundary impact on the culverts.

4.1.9 From the existing structures nine are identified as having an existing capacity which is less than the 0.5% AEP event:

- A9 1240 C2 (River Findhorn Trib 1)
- A9 1250 C17 (River Findhorn Trib 2)
- A9 1250 C30 (River Findhorn Trib 3)
- A9 1260 (Dalmagarry Bridge)
- A9 1250 C20 (Funtack Burn Trib 2)
- A9 1260 C35 (Funtack Burn Trib 3)
- A9 1270 C19 (Moy Burn Trib 1)
- A9 1270 C33 (Allt Creag Bheithin Trib 1)
- A9 1273 C41 (Allt Creag Bheithin)

4.1.10 The impact of new and replacement structures is assessed in Section 5.2.

4.2 Floodplain Extents

4.2.1 The SEPA Flood Maps have been reviewed as part of the baseline assessment for the Proposed Scheme[1].

4.2.2 The baseline assessment carried out for the preliminary assessment identified three floodplain locations, which would potentially be impacted by the dualling, via either disconnection, displacement and/or encroachment of earthworks onto the floodplain:

- River Findhorn / Allt Na Frithe;
- Funtack Burn / Dalmagarry Burn; and
- Moy Burn / Allt Creag Bheithin.

4.2.3 To improve the floodplain definition a 1D/2D linked hydraulic model was developed. A schematic of the model is given in Figure A11.2.7a-c and a description of the model is given in the following sections. The catchment inflows are also shown in Figure A11.2.7a-c. Annex B gives a detailed description of the model development and calibration. A summary is provided below.

4.2.4 The model includes three watercourses upstream of Loch Moy: the Allt Creag Bheithin, Allt na Slanaich and the Moy Burn. Downstream of Loch Moy there are four watercourses modelled: Dalmagarry Burn, Funtack Burn, River Findhorn and Allt na Frithe.

4.2.5 The model involved detailed catchment delineation, which takes account of the inflows to the river reach, with a total of 16 sub-catchments (represented as 6 direct and 10

[1] http://map.sepa.org.uk/floodmap/map.htm

lateral inflows in the model). The catchments were delineated using the FEH CD Rom version 3, and detailed topographical information.

4.2.6 The downstream model boundary is 0.54km downstream of the Shenachie SEPA gauging station on the River Findhorn (NGR NH 829 339) and there are 13 existing structures included in the 1D model and 6 structures modelled in the 2D domain.

4.2.7 The channel and floodplain roughness coefficients are estimated from site inspection and photographs taken during the survey and are based on Manning's 'n' values. Table A4.3 shows the range used within the 1D/2D Linked Hydraulic model.

Table A4.3: Manning 'n' Roughness Values used in the 1D/2D Hydraulic Model

River Reach	River Channel Manning's 'n' values	Bank / Floodplain Mannings 'n' values
Allt na Frithe	0.035-0.040	0.040-0.060
River Findhorn	0.035-0.040	0.040-0.060
Funtack Burn	0.032-0.035	0.040-0.055
Dalmagarry Burn	0.035-0.040	0.045-0.060
Moy Burn	0.040	0.040-0.050
Allt na Slanaich	0.040	0.045-0.055
Allt Craig Bheithin	0.040	0.035-0.055

4.2.8 Calibration of the model was undertaken based on data made available by SEPA for Shenachie gauging station and rain gauges at Freeburn and Coignafeam for the following three events:

- August 2014 - the peak of this event occurred on the 11th of August at 9:30;
- November 2000 - the peak of this event occurred on the 8th of November at 13:45; and
- November 2002 - the peak of this event occurred on the 15th of November at 10:00.

4.2.9 The time to peak (Tp) calculated using the FEH Rainfall Runoff method was reduced by 30% to achieve the best possible match between the observed and modelled peak water levels at Shenachie gauge for the largest of the three events (August 2014). The calibrated model was then validated for the other two events and shown to be satisfactory.

4.2.10 The design flow hydrographs were calculated for each of the 16 sub-catchment using a combination of Rainfall Runoff and Statistical estimations, with hydrographs derived from the Rainfall Runoff method. The sub-catchment hydrographs were scaled to ensure that the design flows at four locations matched the peak flow estimated using the FEH Statistical method.

4.2.11 The four locations (Table A4.4) referred to here as check catchments, were selected for the downstream boundaries of those reaches where a more detailed understanding of the floodplain was required. This was to ensure that the impact assessment is based on appropriate design flows and critical storm durations.

Table A4.4: 1D/2D Hydraulic Model Check Catchments

Watercourse	Description	NGR	Area (km^2)	0.5% AEP Peak Flow (m^3/s)
Allt Greag Bheithin	Upstream of Moy Burn (south of A9)	NH 761 350	7.2	21.0
Dalmagarry Burn	Upstream of Funtack Bridge (south of A9)	NH 795 320	9.2	28.7
Funtack Burn	Downstream of Dalmagarry Burn	NH 796 320	56.1	64.4
River Findhorn	Upstream of Allt na Frithe confluence	NH 721 301	340.3	456.7

4.2.12 The downstream model boundary was checked using a 20% increase of downstream water levels. This check was carried out to determine the sensitivity of the model to conditions downstream. There was some sensitivity to variations in downstream water level but this sensitivity did not extend significantly into the reach of interest and is not considered significant enough to materially affect model results.

4.2.13 The hydraulic model was also tested by varying the roughness conditions (Manning's 'n') by +/- 20 % to assess model sensitivity. Generally, the variation of Manning's 'n' roughness yielded a sensible and constant variation in water levels.

4.2.14 Following the modelling of selected watercourses and floodplains, the floodplain extents have been refined as discussed in Table A4.5 below. Table A4.5 also provides a summary of receptors sensitive to flood risk for each watercourse/floodplain. Figures A11.2.8a-f, A11.2.9a-f and A11.2.10a-f show the baseline floodplain extents for the 0.5%, 3.33% and 0.5%AEP plus climate change flood events. The Findhorn and Moy Burn floodplains have been included for completeness.

Table A4.5: Floodplain Receptors and Sensitivity

Floodplain	Description	Receptors	NGR	Sensitivity
Allt na Frithe	The floodplain of the Allt na Frithe is generally constrained by the steep topography of the surrounding area. As the Allt na Frithe flows through Tomatin the floodplain extends with the merging of two unnamed tributaries to approximately 100m showing inundation to Residential and Non-Residential properties in Tomatin. As the channel flows towards the A9 the floodplain is again constrained within the valley. Downstream of the A9 crossing the Allt na Frithe flows towards the River Findhorn, with the floodplains remaining contained.	Agricultural Land (upstream face of the road embankment)	NH 796 299	Medium
		Agricultural Land (downstream face of the road embankment)	NH 797 300	Medium
		Non Residential properties in Tomatin (Warehouses)	NH 792 298	Medium
		Residential properties (Moss Villa, Freeburn Cottage and Pinewood)	NH 795 297	High
		Minor Road (C1121) and Watercourse crossing	NH 795 297	Medium
		A9	General	Very High
River Findhorn	The floodplain for the River Findhorn between Tomatin House (NGR NH 811 299) and the Allt Dubhag is generally well contained to both the left and right bank. At the Allt na Frithe the left bank of the River Findhorn is steep with the floodplains extending 50-70m on the right bank, for approximately 600metres. Downstream of the Allt Dubhag the floodplain remains contained until Invereen where both the right and the left bank flatten. At this location, the flood map shows a substantial widening of the floodplain, extending 200-400metres. In this area the AMJV floodplain is similar in extent and shape to the SEPA flood map.	Agricultural Land	General	Medium
		Grasslands	General	Low
		Forestry	General	Medium
		Various tracks	General	Low
		Residential properties (Tomatin House) located outside the 0.5% AEP	NH 811 299	High
		Various non-residential properties located outside the 0.5% AEP	General	Medium
		A9	General	Very High
Funtack Burn	The Funtack Burn flows out of Loch Moy, with the SEPA flood map showing the floodplain extending 50-300m on the right bank (towards the A9). This is due to the steep topography below Meall a Bhreacraibh, creating a	Agricultural Land	General	Medium

Floodplain	Description	Receptors	NGR	Sensitivity
	preferential flow pathway. The slope from the A9 down to the Funtack Burn is shallow with an approximate gradient of 1-2%. The AMJV flood mapping shows the Funtack Burn to remain within channel, with little or no floodplain. This is in contrast to the SEPA flood maps which have the floodplain extending between 50-300 metres to the right bank. The difference most likely reflects the more accurate representation of the embankments in the AMJV model. Downstream of the Dalmagarry confluence the AMJV and SEPA flood maps are consistent with the floodplains extending on both banks up to the 265m contour.			
Dalmagarry Burn	The Dalmagarry Burn runs parallel to the Funtack Burn downstream of the A9, and connects immediately upstream of the minor road bridge (NGR 2797, 8320). The floodplain on the Dalmagarry Burn is wide immediately upstream of the railway and similarly widens upstream of the A9. At this point the AMJV and SEPA flood maps are consistent in extent and general shape. Downstream of the A9 there are two flow pathways, which results in flooding to the agricultural land between the Dalmagarry Burn and Funtack Burn. The flood extents in this area are larger than those shown on the SEPA flood maps and believed to be more accurate being based on additional topographic survey data. The floodplain has been delineated into 3 cells: • Floodplain A is the area between the existing A9 crossing and the confluence with the Funtack Burn • Floodplain B is the area upstream of the existing A9 crossing • Floodplain C is the area north of Dalmagarry Farm between the existing A9 and the Funtack Burn.	Residential and non-residential properties at Dalmagarry	NH 787 323	Very High
		Agricultural land (Floodplain A)	NH 792 321	Medium
		Agricultural land (Floodplain B)	NH 784 323	Medium
		Agricultural land (Floodplain C)	NH 786 326	Medium
		Ruthven Road (U2786) and bridge crossing	NH 797 320	Medium
		Milton of Moy (Residential property)	NH 800 321	High
		Highland Main Line railway	Upstream face of the railway embankment (approx. NH 784 324 to NH 786 322)	Very High
		A9	General	Very High
Moy Burn	The Moy Burn floodplain is confined by the valley slopes of Meall a Bhreacraibh to the south and Beinn Bhreaca to the north. The floodplain begins to widen to the left bank at Moymore (NGR NH 276 836), where the ground level on the left bank is 275m AOD. The floodplain remains on the	B9154	General	High
		Highland Main Line railway	General	Very High
		Agricultural Land	General	Medium

Floodplain	Description	Receptors	NGR	Sensitivity
	left bank and a constant width until the Allt Creag Bheithin joins the Moy Burn at Cnoc Fraing. At this location the floodplain doubles in size and inundates a minor road, which provides access to Moy Hall. Both Limetree Cottage and Moyhall are within 100m of the flood outline. The AMJV floodplains are larger than those shown on the SEPA flood map, with the floodplain immediately upstream of Moy Loch being approximately 400m wide and extending towards Moy Hall. Although the floodplain in this area is greater in extent it does not bring in additional sensitive receptors.	Minor Access Road and watercourse crossing	NH 759 571	Medium
Allt Creag Bheithin	At Moy, the detailed modelling shows the floodplains extend for approximately 300m immediately upstream of the B9154, with floodplains of the Allt na Bheithin tributaries merging to become one large floodplain. This floodplain is being stored behind the railway embankment (NGR NH 759 349). The flood extents at this location are greater than those indicated on the SEPA flood map primarily due to the improved topographical information for the smaller tributaries. Upstream of the railway the Alt Creag Bheithin and the Allt the Slanaich join at approximately NGR NH 752 349. With the floodplains extending between 130 and 70m for each watercourse respectively. These continue to narrow upstream towards the A9. The existing A9 is a barrier to floodplain conveyance, with the Allt Creag Bheithin overtopping the A9 between NGR NH 748 347 and NH 750 347. This flood extent is not shown on the SEPA Flood Map.	Forestry South of A9 between Allt Creag Bheithin and Allt na Slanaich		Low
		Forestry South of A9 between Allt na Slanaich and Tributary of Allt Creag Bheithin 002		Low
		Forestry South of A9 between Tributary of Allt Creag Bheithin 002 and Tributary of Allt Creag Bheithin 001		Low
		Access track at Allt Creag Bheithin crossing point	NH 751 349	Medium
		B9154	Between NH 757 353 and NH 761 348 across the floodplain	High
		Highland Main Line railway	Between NH 758 354 and NH 761 348 across the floodplain	Very High
		A9	General	Very High

5. Proposed Scheme

5.1 General

5.1.1 The Proposed Scheme involves upgrading the existing A9 single carriageway road between Tomatin and Moy (a length of approximately 9.6 km) to dual carriageway standard. A full description is given in Chapter 5 in Volume 1 and the scheme general layout is shown in Figure 5.1a-c with more detailed plans in Figure 5.3a-h.

5.1.2 There will be one grade separated junction (GSJ) at Tomatin at the southern end of the scheme providing access to the village. A new side road adjacent to the southbound carriageway of the dualled A9 will connect into the junction, and this will provide access from the GSJ to an existing road (Ruthven Road) which currently has an at grade junction with the A9.

5.1.3 Three Left In Left Out junctions will be provided, one off the southbound carriageway of the A9 at Moy (close to an existing at grade junction with the A9), one off the northbound carriageway at Lynebeg (also close to an existing at grade junction with the A9) and another on the A9 northbound carriageway at an existing forestry access (within a section of the A9 that is already dualled).

5.2 Watercourse Crossings

5.2.1 As part of the Proposed Scheme all the existing watercourse crossings will be upgraded and/or replaced. Details of the new water crossings are given in Table A5.1. There are 4 new bridge structures, 34 culverts and 4 drains.

Table A5.1: Proposed Watercourse Crossings

Watercourse Name	New Structure ID	NGR	Existing Height (m)	Existing capacity to Soffit	Type	Proposed Height (m)	Proposed Width (m)	Length (m)	Gradient (%)
River Findhorn Trib 1	A9 1240 C2	NH 79991 29660	0.5m Ø	The existing structure is to be extended.					
Allt na Frithe	A9 1250	NH 79657 29974	4.5m Ø	48.9 / >0.1%	Bridge	3.00	4.50	78.00	5.53
River Findhorn Trib 2	D5	NH 79428 30305	0.6m Ø	0.17 / <50%	Drain	2*0.9	2*0.9	61.50	0.14
Allt Dubhag	A9 1250 C25	NH 79350 30492	2.5m Ø	10.5 / 0.5%+CC	Culvert	3.00	2.50	84.00	3.88
River Findhorn Trib 3	D8	NH 79364 30648	0.55m Ø	0.26 / 0.5%	Drain	0.90	0.90	32.90	8.69
Funtack Burn Trib 1	DB	NH 79345 30806	N/A	N/A	Drain	0.75	0.75	0.00	0.00
Dalmagarry Burn Trib 1	DG	NH 79445 31357	N/A	N/A	Drain	2* 0.9	2* 0.9	136.00	0.20
Dalmagarry Burn Trib 2	A9 1250 C85	NH 79031 31977	N/A	N/A	Culvert	2.50	1.20	50.00	4.00
	A9 1250 C85 S	NH 79065 32036	N/A	N/A	Culvert	1.80	1.80	6.00	2.88
Dalmagarry Burn Trib 3	A9 1250 C93	NH 78858 32068	N/A	N/A	Culvert	1.20	1.20	48.00	5.89
Dalmagarry Burn	A9 1260	NH 78759 32184	1.5 x 7m	16.3 /10%	Bridge	3.5m (min. headroom)	23m (span)	30.10	0.00
	A9 1260 ARB1	NH 78440 32160	This new structure will be a clear span bridge located to the west of the railway and crossing the Dalmagarry Burn. It will provide NMU access to the NCN7 and farm vehicle access to land west of the railway line. The soffit will be above the 0.5% AEP plus climate change and the structure will not restrict flow. It has been included in the floodplain impact assessment.						
	A9 1260 SRB1	NH 78720 32237	This new clear span structure will be located to the east of the A9 carrying the proposed Ruthven Moy Link Road over the Dalmagarry Burn. The soffit will be above the 0.5% AEP plus climate change and the structure will not restrict flow. It has been included in the floodplain impact assessment.						
Funtack Burn Trib 2	A9 1260 C25	NH 78441 32426	0.6m & 0.45m	0.29 / ~10%	Culvert	1.20	1.20	46.00	1.89
	A9 1260 C25 S	NH 78481 32454	0.6m & 0.45m	0.29 / ~10%	Culvert	1.20	1.20	18.00	4.19
Funtack Burn Trib 3	A9 1260 C35	NH 78368 32557	0.9m Ø	0.8 / ~20%	Culvert	2.00	2.00	62.00	6.45
	A9 1260 C35 S	NH 78431 32592	0.9m Ø	0.8 / ~20%	Culvert	1.20	2.50	38.00	1.17

Watercourse Name	New Structure ID	NGR	Existing Height (m)	Existing capacity to Soffit	Type	Proposed Height (m)	Proposed Width (m)	Length (m)	Gradient (%)
Funtack Burn Trib 4	A9 1260 C65	NH 78163 32904	1.6m Ø	3.7 / >0.1%	Culvert	2.50	2.50	78.00	5.52
	A9 1260 C65 S	NH 78273 32930	1.6m Ø	3.7 / >0.1%	Culvert	0.75	2.50	12.00	1.42
Funtack Burn Trib 5	A9 1260 C94	NH 78051 33047	N/A	N/A	Culvert	2.00	1.20	98.00	5.86
	A9 1260 CNR1		N/A	N/A	Culvert	1.20	1.80	8.00	0.80
	A9 1260 C94 S		N/A	N/A	Culvert	1.20	1.80	8.00	1.40
	A9 1270 CNR2		N/A	N/A	Culvert	1.20	1.20	18.0	0.70
	A9 1270 C10 S		N/A	N/A	Culvert	1.20	1.20	6.00	6.70
Funtack Burn Trib 6 / 7	A9 1270 C35	NH 77584 33522	0.8m Ø	0.68 / >0.1%	Culvert	1.20	1.20	34.00	0.88
	A9 1270 C35 S	NH 77715 33478	0.8m Ø	0.68 / >0.1%	Culvert	1.20	1.20	10.00	6.98
Funtack Burn Trib 8	A9 1270 C50	NH 77461 33646	0.8m Ø	0.81 / >0.1%	Culvert	1.20	1.20	34.00	4.23
	A9 1270 C50 S	NH 77512 33688	0.8m Ø	0.81 / >0.1%	Culvert	1.20	1.20	10.00	5.99
Funtack Burn Trib 9	A9 1270 C60	NH 77382 33714	0.8m Ø	0.65 / >0.1%	Culvert	1.20	1.20	40.00	2.12
	A9 1270 C60 S	NH 77439 33748	0.8m Ø	0.65 / >0.1%	Culvert	1.20	1.20	10.00	0.64
Caochan na h-Eaglais	A9 1270 C80	NH 77062 33897	1.8m Ø	5.32 / >0.1%	Culvert	2.50	2.50	58.00	7.86
	A9 1270 C80 S	NH 77140 33961	N/A	N/A	Culvert	1.8	2.5	8	4.50
Moy Burn Trib 1	A9 1273 C5	NH 76586 34150	1.2m Ø	1.98/ 4%	Culvert	1.20	1.20	38.00	2.39
Allt na Loinne Moire	A9 1273 C8	NH 76375 34268	2 No. x 2.0m Ø	18.46 / >0.1%	Culvert	2.50	5.00	44.00	4.86
Moy Burn Trib 2 and Moy Burn Trib 3**	A9 1273 C18	NH 75771 34545	1.0m Ø	1.19 / >0.1%	Culvert	1.50	2.00	66.00	3.53
Allt Creag Bheithin Trib 1	A9 1273 C22	NH 75468 34632	1.6m Ø	4.12 /0.5%	Culvert	2.00	2.50	36.00	1.19
Allt Creag Bheithin Trib 2	A9 1273 C24	NH 75301 34670	2 No. x 2m Ø	14.49 / >0.1%	Culvert	1.50	1.50	66.00	2.08
Allt na Slanaich	A9 1273 C28	NH 75026 34718	0.8m Ø	0.73 / >0.1%	Culvert	1.85	1.80	56.00	0.67
Allt Creag Bheithin	A9 1273 C31	NH 74862 34735	1.8m Ø	5.13 / 2%	Culvert	2.00	2.00	38.00	1.39

Watercourse Name	New Structure ID	NGR	Existing Height (m)	Existing capacity to Soffit	Type	Proposed Height (m)	Proposed Width (m)	Length (m)	Gradient (%)
	MC90 C1	NH 74908 34786	0.8m Ø	n/a	Culvert	1.20	4.00	8.00	0.75
Allt Creag Bheithin Trib 3	A9 1273 C40	NH 74198 34745	1.4m Ø	2.65 / >0.1%	Culvert	2.00	2.00	40.00	0.85
Allt Creag Bheithin Trib 4	A9 1273 C43	NH 74002 34720	1m Ø	1.22 / >0.1%	Culvert	2.00	2.00	34.00	1.72
Allt Creag Bheithin 5	A9 1273 MCY0 C1	NH 73904 34596	N/A	N/A	Culvert	2.00	5.00	8.00	0.6
Midlairgs Burn	A9 1273 MCR1 C1	NH 72941 34594	N/A	N/A	Culvert	1.80	2.50	16.00	1.1
Midlairgs Burn Trib 1	A9 1273 MCR0 C2	NH 72640 35009	N/A	N/A	Culvert	1.80	1.80	16.00	1.7
Midlairgs Burn Trib 2	A9 1273 MCR0 C1	NH 72619 35031	N/A	N/A	Culvert	1.80	1.80	16.00	1.8

*Two watercourses have not been included within the FRA as follows:

- River Findhorn Trib 1.1 – identified as a drain and included within the surface water drainage assessment

- Funtack Burn Trib 10 – Flows under the B9154 and therefore not within the scheme boundary

**Moy Burn Trib 2 and Moy Burn Trib 3 previously had independent crossing locations. As part of the FRA, one crossing has been proposed for these two watercourses and therefore, they have been merged into one catchment

5.2.2 New culverts will consist of a reinforced precast concrete box or portal construction thus minimising construction and maintenance costs. Culverts with natural beds will be constructed, where feasible. Where box culverts are being constructed, 300mm of suitable bed material is proposed. Mammal ledges will also be installed where required and will be designed to be above the 4% AEP flood level.

5.2.3 The majority of the culverts will be constructed offline from the existing culverts which will maintain flows of the watercourses during construction. Minor local watercourse diversions at the inlets and outlets will also be necessary to allow offline construction. Cascades and plunge pools have been indicatively identified where required.

5.3 Floodplains

5.3.1 The areas where the Proposed Scheme could potentially impact on the 0.5% AEP floodplain are:

- River Findhorn / Allt Na Frithe
- Funtack Burn / Dalmagarry Burn
- Moy Burn / Allt Creag Bheithin

5.3.2 Details of the Proposed Scheme are given in Chapter 5. A summary is given in the following sections highlighting those elements that are most pertinent to flood risk.

5.3.3 The proposed main alignment crosses the floodplain of the Allt na Frithe watercourse some 120m upstream of where it enters the River Findhorn. The new structure requires the realignment of the Allt na Frithe watercourse and will include mammal passages on either side of the watercourse running through the structure. The proposed bridge will be 78m wide in length and 2.5m high made from reinforced concrete and have a 4.5m single span.

5.3.4 At Dalmagarry, the mainline will diverge offline between the Highland Main Line railway and the existing A9 Dalmagarry Burn crossing, raising the finished road levels moderately relative to the existing A9 and crossing the Dalmagarry Burn via a new bridge. To accommodate the alignment of the dual carriageway and avoid impacting the Highland Main Line railway a section of the Dalmagarry Burn will be realigned. This requires a 640m diversion of the burn downstream of the existing Dalmagarry rail bridge to accommodate the A9 crossing and a SuDS basin adjacent to a low point in the A9.

5.3.5 The proposed mainline crosses the Allt Creag Bheithin close to the existing crossing at NH 7487 3474. The mainline also crosses a tributary of the Allt Creag Bheithin, the Allt na Slanaich (NH 7503 3474) and four unnamed tributaries south of the Allt Creag Bheithin crossing. The baseline modelling indicates that the flood water ponds behind the existing road during the 0.5% AEP event. The Proposed Scheme in the vicinity of Allt Creag Bheithin includes a raised road level, enlarged embankments, replacement water crossings, SuDS ponds and access tracks to SuDS.

6. Flood Risk Impact

6.1 Watercourse Crossings – Impact

6.1.1 The assessment presented in the following sections considers the impact of the proposed water crossings on flow and water levels in the watercourse and the resulting impact on sensitive receptors in the vicinity of the crossing.

6.1.2 The potential impact of the water crossings on the wider floodplain due to changes in peak flood flows, time to peak flow and flood volumes are considered within the floodplain assessment (Section 6.2).

6.1.3 Construction and operational impacts are assessed separately.

Watercourse Crossings - Construction Impacts

6.1.4 The construction of the Proposed Scheme will include the upgrade, replacement, extension and/ or new watercourse crossings. The majority of the culverts will be constructed offline from the existing culverts which will maintain flows of the watercourses during construction. Minor local watercourse diversions at the inlets and outlets will also be necessary to allow offline construction.

6.1.5 Should it be required to construct crossings online then the watercourse will be temporarily diverted through a temporary channel and/or pumped, which could result in flows being:

- conveyed more effectively downstream increasing the flood risk to the site and third parties or
- water backing up due to insufficient capacity resulting in washout to the construction area

6.1.6 Materials and plant equipment stored on site could result in the blockage to existing structure and localised flooding to the site and sensitive receptors.

6.1.7 Excavation and construction works on the site could lead to blockage and or severance of surface water that could lead to localised flooding to the site and sensitive receptors.

6.1.8 During construction, localised ground-raising could result in displacement of floodwater and changes to the surface water runoff pathways increasing the flood risk to the surrounding area.

6.1.9 During construction, movement of materials on site including the creation of stockpiles could alter flow pathways and displace flood water.

6.1.10 The operation of plant may result in compaction of soils, which may reduce the infiltration capacity. This could result in an increase in surface water runoff leading to localised flooding and runoff into the receiving watercourse.

6.1.11 The magnitude of impact of flood risk associated with the construction of the Proposed Scheme will consider the duration, time of year and construction sequencing in addition to the factors give in section 2.3. Any impacts are likely to be temporary and mitigation will be possible. Once construction details are known flood risk impacts should be assessed and any mitigation agreed with SEPA. Table A6.1 provides an overview of the potential construction activities that impact on flood risk and typical mitigation measures.

Table A6.1: Watercourse Crossings - Construction Impacts

Activity	Timing of Measure	Description of Measure	Purpose of Measure
Flood Risk	Pre-Construction & Construction	In relation to flood risk the Contractor will implement the following mitigation measures during construction: • the Flood Response Plan will set out mitigation measures to be implemented when working within the functional floodplain (defined here as the 0.5% AEP (200-year) flood extent); • plant and materials will be stored in areas outside the functional floodplain where practicable, with the aim for temporary construction works to be resistant or resilient to flooding impacts, to minimise/prevent movement or damage during potential flooding events. Where this is not possible, agreement will be required with the EnvCoW; • where practicable, haul routes will be located out of the functional floodplain. When in the floodplain stockpiling of material must be carefully controlled with limits to the extent of stockpiling within an area to prevent compartmentalisation of the floodplain and stockpiles should be away from water feature banks (not within 10m of the water feature banks). This is in order to limit floodplain encroachment, associated increased flood risk and sediment entering the water feature.	To reduce the risk of flooding impacts on construction works.
Runoff and Surface Water Drainage	Pre-Construction & Construction	The Contractor will implement appropriate controls for construction site runoff: • installation of temporary drainage systems/SuDS systems (or equivalent) including pre-earthworks drainage to increase storage capacity potential for surface water runoff; • treatment facilities to be scheduled for construction early in the programme to control the rate of flow before water is discharged into a receiving watercourse; • temporary drainage systems will be implemented to alleviate localised surface water flood risk and prevent obstruction of existing surface runoff pathways	To implement appropriate controls for site runoff and sedimentation and reduce impacts on the water environment and the risk of flooding as a result of increased runoff rates.
In-channel works	Pre-Construction & Construction	In relation to in-channel working the Contractor will implement the following mitigation measures: • compliance with SEPA regulations in relation to in channel works; • undertaking in-channel works during low flow periods (i.e. when flows are at or below the mean average) as far as practicable; • minimise length of channel disturbed and size of working corridor; • limit the amount of removal of the vegetated riparian corridor and woodland area retaining vegetated buffer zone wherever possible; and	To reduce impacts on frequency, depth, extent and duration of flooding.

Activity	Timing of Measure	Description of Measure	Purpose of Measure
		• limit the amount of tracking along the side of watercourses and avoid creation of new flow paths between exposed areas and new or existing channels.	
Channel realignment	Construction	Where channel realignment is proposed the following mitigation measures will be implemented by the Contractor: • once a new channel is constructed, the flow should, where practicable, be diverted from the existing channel to the new course under normal/low flow conditions. In addition, diverting flow to a new channel should be timed to avoid forecast heavy rainfall events at the location and higher up in the catchment. The optimum time for constructing a new channel, where practicable, is in the spring and early summer months to allow vegetation establishment to help stabilise the new channel banks.	To reduce impacts on frequency, depth, extent and duration of flooding.
General site activities	Construction	The placement of site compounds and the storage of construction material and equipment should be outside of natural flow paths to prevent severance of flow pathways and displacement of flood water.	To reduce impacts on frequency, depth, extent and duration of flooding.

6.2 Watercourse crossings - Operational Impacts

6.2.1 The design process for the watercourse crossings is complex, taking account of a range of design criteria and constraints to develop the most appropriate crossing for each watercourse. The primary technical standards driving the design of culverts are DMRB HA107/04 Design of Outfall and Culvert Details (2004) and the CIRIA Culvert design and operation guide (C689) (2010). However, in addition to these technical standards, other drivers that influence the culvert design include:

- **Flood risk** - In the event that a culvert is either extended (based on current geometry) or replaced, the impact on flood sensitive receptors may change by either retaining more water on the upstream side of the A9 or by passing more water through the culvert. Extending a culvert in the absence of any other change may increase flood levels upstream, while replacing an existing culvert with a larger one will increase the flow downstream, possibly reducing water level upstream and increasing water level downstream.
- **Maintenance requirements** - Maintenance of culverts to meet DMRB standards (as defined by HA107/04) requires consideration of a minimum culvert size. This culvert may be larger than the culvert size required from a hydraulic perspective, in which case increasing the culvert size may have an impact on flood sensitive receptors downstream.
- **Ecological considerations** - When designing new culverts, consideration is given to the provision of adequate integrated mammal passage, which if required will influence culvert size. In addition, consideration is given to maintaining a natural bed level within the culvert barrel by burying the culvert invert such that the culvert is sized to carry both flood flow and river bed sediment.
- **Geomorphological considerations** - When increasing the size of a culvert there is the potential for influencing sediment transport which occurs during a flood, thereby impacting on either erosion or sedimentation in the vicinity of the culvert, both upstream and downstream.
- **Highway drainage design** - The culvert design, in terms of both gradient and cross-section, needs to be considered so that it does not conflict with the proposed scheme, i.e. the proposed road structure and drainage system.

6.2.2 For all areas, these influencing factors need to be considered together on a case-by-case basis to develop the most appropriate culvert design for each crossing. This design process is iterative, such that the final design meets the fundamental design standard, which is that the proposed scheme remains free from flooding in the 0.5% AEP (200-year) design flood event plus an allowance for climate change (increase in flow of 20%), and freeboard (typically 600mm). In this context freeboard is defined as the difference between the proposed scheme road level and the peak water level during the 0.5% AEP (200-year) plus climate change event.

6.2.3 The design approach for the watercourse crossings, which takes account of the culvert design guidance, allows for a degree of flexibility and engineering judgement to be applied to the culvert design, to take into account the various influencing factors outlined above. The final designs for the watercourse crossings included within this FRA are all compliant with this guidance, with a focus on design considerations set out in CIRIA C689 and DMRB HA107/04.

6.2.4 The results of the 1D hydraulic modelling confirmed that all the proposed structures under the main A9 alignment pass the 0.5% AEP flow with 20% allowance for climate change and an appropriate freeboard. The minimum freeboard allowance is 600mm for structures larger than 1.2m high and 300mm for smaller openings in line with DMRB guidance on freeboard allowance for culverts. Sediment load at each watercourse crossing will be considered by a geomorphologist on a case by case basis at detailed design stage to minimise the risk of deposition and promote sediment transport through the culvert.

6.2.5 The magnitude of the impact is based on the capacity of the existing structure (given in Table A4.2) to reflect the change in downstream flow when the culvert is replaced. For watercourses where no structure currently exists the magnitude has been set as negligible on the basis that all new structures have the capacity to convey the 0.5% AEP plus climate change.

6.2.6 The assessed impacts for each watercourse are given in Table A6.2 below.

Table A6.2: Watercourse Crossings - Operational Impacts

Watercourse	Existing Structure ID	New Structure ID	Catchment ID	Sensitivity	0.5% Peak Flow (m^3/s)	Existing Capacity (m^3/s / AEP)	Preliminary Potential Magnitude	Preliminary Potential Significance
River Findhorn Trib 1	A9 1240 C2	A9 1240 C2	TM28	Very High	2.46	0.2 / <50%	Negligible	Neutral
Allt na Frithe	A9 1250	A9 1250	TM27	Low	17.1	48.9 / >0.1%	Negligible	Neutral
River Findhorn Trib 2	A9 1250 C17	D5	TM26	Very High	0.95	0.17 / <50%	Minor	Large
Allt Dubhag	A9 1250 C25	A9 1250 C25	TM25	Medium	7.65	10.5 / 0.5%+CC	Negligible	Neutral
River Findhorn Trib 3	A9 1250 C30	D8	TM24	High	0.24	0.26 / 0.5%	Negligible	Neutral
Funtack Burn Trib 1	n/a	DB	TM23	Medium	0.53	N/A	Negligible	Neutral
Dalmagarry Burn Trib 1	n/a	DG	TM22	Medium	3.20	N/A	Negligible	Neutral
Dalmagarry Burn Trib 2	n/a	A9 1250 C85	TM21	Medium	1.85	N/A	Negligible	Neutral
		A9 1250 C85 S						
Dalmagarry Burn Trib 3	n/a	A9 1250 C93	TM20a	Medium	0.68	N/A	Negligible	Neutral
Dalmagarry Burn	A9 1260	A9 1260	TM20	Very High	24.15	16.3 / 10%	Major	Very Large
	N/A	A9 1260 ARB1				N/A	Negligible	Neutral
	N/A	A9 1260 SRB1				N/A	Negligible	Neutral
Funtack Burn Trib 2	A9 1260 C20	A9 1260 C25	TM19	Very High	0.71	0.29 / ~10%	Minor	Large
		A9 1260 C25 S					Minor	Moderate
Funtack Burn Trib 3	A9 1260 C35	A9 1260 C35	TM18	Very High	2.55	0.8 / ~20%	Minor	Large
		A9 1260 C35 S					Minor	Large
Funtack Burn Trib 4	A9 1260 C65	A9 1260 C65	TM17	High	0.93	3.7 / >0.1%	Negligible	Neutral
		A9 1260 C65 S					Negligible	Neutral
Funtack Burn Trib 5	A9 1270	A9 1260 C94	TM16	High	1.59	0.68 / >0.1%	Negligible	Neutral
	N/A	A9 1260 CNR1	N/A	High	1.05	N/A	Negligible	Neutral
	N/A	A9 1260 C94 S	N/A	High	0.194	N/A	Negligible	Neutral
	N/A	A9 1270 CNR2	N/A	High	0.064	N/A	Negligible	Neutral
	N/A	A9 1270 C10 S	N/A	High	0.127	N/A	Negligible	Neutral
Funtack Burn Trib 6 / 7	A9 1270 C7	A9 1270 C35	TM15	High	0.22	0.88 / >0.1%	Negligible	Neutral
		A9 1270 C35 S					Negligible	Neutral
Funtack Burn Trib 8	A9 1270 C9	A9 1270 C50	TM14	High	1.00	0.81 / >0.1%	Negligible	Neutral
		A9 1270 C50 S					Negligible	Neutral
Funtack Burn Trib 9	A9 1270 C10	A9 1270 C60	TM13	High	0.28	0.65 / >0.1%	Negligible	Neutral
		A9 1270 C60 S					Negligible	Neutral
Caochan na h-Eaglais	A9 1270 C14	A9 1270 C80	TM12	High	3.57	5.32 / >0.1%	Negligible	Neutral
		A9 1270 C80 S			3.19	N/A	Negligible	Neutral
Moy Burn Trib 1	A9 1270 C19	A9 1273 C5	TM11	High	3.23	1.98/ 4%	Moderate	Large

Watercourse	Existing Structure ID	New Structure ID	Catchment ID	Sensitivity	0.5% Peak Flow (m^3/s)	Existing Capacity (m^3/s / AEP)	Preliminary Potential Magnitude	Preliminary Potential Significance
Allt na Loinne Moire	A9 1270 C22	A9 1273 C8	TM10	Medium	9.65	18.46 / >0.1%	Negligible	Neutral
Moy Burn Trib 2 and Moy Burn Trib 3	A9 1270 C30	A9 1273 C18	TM8	Low	1.10	1.87 / >0.1%	Negligible	Neutral
Allt Creag Bheithin Trib 1	A9 1270 C33	A9 1273 C22	TM7	Low	4.20	4.12 /0.5%	Minor	Neutral
Allt Creag Bheithin Trib 2	A9 1270 C35	A9 1273 C24	TM6	Low	0.35	14.49 / >0.1%	Negligible	Neutral
Allt na Slanaich	A9 1270 C39	A9 1273 C28	TM5	Medium	9.02	0.73 / >0.1%	Negligible	Neutral
Allt Creag Bheithin	A9 1270 C41	MC90 C1	TM4	Medium	7.65	5.13 / 2% 2.65 / >0.1%	Moderate	Moderate
		A9 1273 C31					Moderate	Moderate
Allt Creag Bheithin Trib 3	A9 1270 C48	A9 1273 C40	TM3	Medium	1.73	1.22 / >0.1%	Negligible	Neutral
Allt Creag Bheithin Trib 4	A9 1270 C59	A9 1273 C43	TM2	Medium	0.82	2.89 / >0.1%	Negligible	Neutral
Allt Creag Bheithin 5	A9 1270 C43	A9 1273 C54	TM1	Medium	1.20	5.13 / 2%	Negligible	Neutral
		A91273 MCY0 C1	TM30				Negligible	Neutral
Midlairgs Burn	N/A	A91273 MCY0 C1	TM31	Medium	2.77	N/A	Negligible	Neutral
Midlairgs Burn 1	N/A	A91273 MCY0 C1	TM32	Medium	1.11	N/A	Negligible	Neutral
Midlairgs Burn 2	N/A	A91273 MCY0 C1	TM33	Medium	1.01	N/A	Negligible	Neutral

Drain D5

6.2.7 The proposed drain D5 (which replaces A9 1250 C17) gives a **Large** impact on the River Findhorn Trib 2 due to the fact that the existing drain has a capacity of less than the 0.5% AEP flow and the A9 has been included as a receptor. However, the outlet to the drain is only 220m upstream of the River Findhorn, the land use downstream of the drain is forestry and there are no sensitive receptors. The 1D model indicates that the proposed drain will operate under inlet control during the 0.5% AEP flood indicating that upstream storage is utilised as far as possible. Therefore no mitigation is proposed.

Dalmagarry Watercourse Crossings

6.2.8 The new watercourse crossings in the vicinity of Dalmagarry (A9 1260, A9 1260 SRB1, A9 1260 C25, A9 1260 C25S, A9 1260 C35 and A9 1260 C35 S) have an impact on downstream flows ranging from Moderate to Very Large. The impact of changes in flow on flood risk is complex due to the interactions between the different watercourses and floodplains and has been assessed using the 1D/2D hydraulic model. The impact on flood risk and the need for mitigation has been progressed as a part of the floodplain assessment and is presented in Section 7.3.

6.2.9 The water levels at crossing A9 1260 ARB1 are contained entirely within the channel and do not encroach on the floodplain as can be seen on Figures A11.2.11e. The channel cross section is included within the hydraulic model as DBXS102. It indicates that there is more than a 600mm freeboard allowance above the peak 0.5% AEP water level and the soffit level of the structure.

Moy Burn Tributary 1

6.2.10 The new culvert at Moy Burn Trib 1 (A9 1273 C5) is assessed as having an impact of Large significance if the capacity of the structure was to be increased from the 4% AEP (for the existing culvert) to the 0.5% AEP plus climate change. This is due to the increase in predicted downstream water level and inclusion of the High sensitivity receptor (the HML).

6.2.11 A topographic survey of the watercourse was carried out in October 2017 and a hydraulic model developed in order to assess the impact of the Proposed Scheme on downstream receptors. The downstream receptors being the HML and the B9154. The modelling is described in Appendix C.

6.2.12 The results of the modelling established that the HML railway culvet limits flows that pass downstream to the B9154 and that the capacity of the replacement structure under the A9 should not exceed that of the existing structure.

6.2.13 The new structure has therefore been sized to give the same hydraulic capacity as the existing 1.2m diameter culvert. The proposed culvert is a 1.2m x 1.2m box culvert with 0.25m of bed material. The modelling confirms that flood levels will not increase at the HML railway or B9154 and that the A9 remains free from floodwater for the 0.5% AEP with a 20% allowance for climate change.

6.2.14 The magnitude of the impact can therefore be reduced to Negligible giving a revised impact of **Neutral** and no mitigation is proposed. The reduced capacity culvert is included in the Proposed Scheme as embedded mitigation.

MC90 C1 and A9 1273 C31

6.2.15 The proposed culverts MC90 C1 and A9 1273 C31 have a Moderate impact on the Allt Creag Bheithin. The cumulative impacts of replacing the culverts in this location on flood risk are assessed as a part of the floodplain assessment at Allt Creag Bheithin.

A9 1260 ARB1 Dalmagarry Access Bridge

6.2.16 The water levels at crossing A9 1260 ARB1 are contained entirely within the channel and do not encroach on the floodplain as can be seen on Figure A11.2.11c. The channel cross section is included within the hydraulic model as DBXS102. It indicates that there is more than a 600mm freeboard allowance above the peak 0.5% AEP water level and the soffit level of the structure.

A9 1260 SRB1

6.2.17 This is the new clear span bridge structure located downstream of the new A9 crossing to allow the side road to cross the Dalmagarry Burn. It will be a reinforced concrete bridge with a span of approximately 16 m and a total deck width of 7.3 m. The model results show that it is not located on the 0.5% baseline floodplain and the minimum freeboard between the bridge soffit and 0.5% AEP maximum water level with a 20% allowance for climate change is 600 mm. The bridge is included in the hydraulic model between nodes Div_Chal_85 and Div_Chal_135. The magnitude of the impact is therefore Negligible and significance Neutral. All other proposed crossings have a neutral impact on the water crossings and do not therefore require mitigation.

6.3 Floodplain - Impact

6.3.1 The 1D/2D hydraulic model was used to determine the impact of the Proposed Scheme on the 0.5% AEP floodplain. The modified topography and new watercourse crossings were included in the model and the impact assessed.

6.3.2 The impacts have been assessed separately for the construction and operation phases and are presented in the following sections.

Floodplain – Construction Impact

6.3.3 During construction, localised ground-raising could result in displacement of floodwater and changes to the surface water runoff pathways increasing the flood risk to the surrounding area.

6.3.4 During construction, movement of materials on site including the creation of stockpiles could alter flow pathways and displace flood water.

6.3.5 The operation of plant may result in compaction of soils, which may reduce the infiltration capacity. This could result in an increase in surface water runoff leading to localised flooding and runoff into the receiving watercourse.

6.3.6 The magnitude of impact of flood risk associated with the construction of the Proposed Scheme will consider the duration, time of year and construction sequencing in addition to the factors give in section 2.3. Any impacts are likely to be temporary and mitigation will be possible. Once construction details are known flood risk impacts should be assessed and any mitigation agreed with SEPA.

Floodplain – Operational Impact

6.3.7 The impact in this section is assessed for the Proposed Scheme without any allowance for compensation storage and with culverts designed to satisfy SEDP initially.

6.3.8 The operational impact on floodplains have been assessed using the method set out in Section 2. The hydrology and hydraulic modelling, which were used to determine the magnitude of the impact on the 0.5% AEP floodplain, are described in detail in Annex B.

6.3.9 The 1D/2D hydraulic model results were processed to give the magnitude of the impact for each of the receptors given in Table A4.5. The magnitude and receptor sensitivity are combined to give the impact.

6.3.10 The results are given in Table A6.3 below. Table A6.3 includes the Proposed Scheme as a receptor in addition to those identified in Table A4.5.

Table A6.3: Floodplain Receptor Impact Assessment

Floodplain	Description	Receptors	Location (NGR)	Sensitivity	Magnitude	Impact
Allt na Frithe	The existing watercourse crossing at the Allt na Frithe (A9 1250) is to be replaced with a portal frame structure. The opening of the new structure will be 4.5m wide by 2.5m deep and 78m long. It has sufficient capacity to pass the 0.5% AEP with a freeboard. The existing structure has a hydraulic capacity greater than the 0.5% AEP so there will be no increase in downstream flow. The proposed alignment crosses the 0.5% AEP of the Allt na Frithe but as the proposed structure does not constrain the main channel and the outlet is less than 100m upstream of the confluence with the Findhorn there is no significant impact on modelled water levels. The model results show that there is no increase in water level at nearby sensitive receptors and that the A9 would not be submerged. The A9 road level is above the 0.5% AEP flood level with climate change.	Agricultural Land (upstream face of the road embankment)	NH 797 300	Medium	Negligible	Neutral
		Agricultural Land (downstream face of the road embankment)	NH 797 300	Medium	Negligible	Neutral
		Non Residential properties in Tomatin (Warehouses)	NH 792 298	Medium	Negligible	Neutral
		Residential properties (Moss Villa, Freeburn Cottage and Pinewood)	NH 795 297	High	Negligible	Neutral
		Minor Road (C1121) and Watercourse crossing	NH 795 297	Medium	Negligible	Neutral
		A9 Dualling		Very High	Negligible	Neutral
Dalmagarry Burn	The Proposed Scheme impacts on the hydraulics of the floodplain at Dalmagarry due to the following modifications: - The new enlarged embankment crosses the 0.5% AEP floodplain - A new bridge crossings at the Dalmagarry Burn (A9 1260) - Removal of the old A9 bridge - Removal of existing flood relief culverts - Realignment of the burn for 640m downstream of the new bridge crossing	Residential and non-residential properties at Dalmagarry	NH 787 323	Very High	Negligible	Neutral
		Agricultural land located south of Dalmagarry Farm and between the Funtack Burn and Dalmagarry Burn (floodplain A)	NH 792 321	Medium	Moderate Adverse	Moderate
		Agricultural land located west of the Highland Main Line railway and north of the Dalmagarry Burn (floodplain B)	NH 784 323	Medium	Negligible	Neutral

<table>
<tr><th>Floodplain</th><th>Description</th><th>Receptors</th><th>Location (NGR)</th><th>Sensitivity</th><th>Magnitude</th><th>Impact</th></tr>
<tr><td rowspan="5"></td><td rowspan="5">- New Millennium culvert crossings under the main alignment and side road north of the farm (A9 1260 C25 and A9 1260 C25s) at NGR 785 325
- A SUDS basin will be located between the realigned burn and the new A9.
- 3 existing culverts that allow runoff from land to the west of the railway join the Dalmagarry Burn are to be replaced with 1.2m x 1.2m box culverts
- A side road running between the A9 and Dalmagarry Burn which will also provide access to the SUDS
- A new clear span bridge structure will be located to the west of the railway and crosses the Dalmagarry Burn (A9 1260 ARB1). It will be a reinforced concrete bridge providing NMU access to the NCN7 and farm vehicle access to land west of the railway line. Designed to pass the 0.5% AEP plus climate change and freeboard.
- A new clear span bridge structure (A9 1260 SRB1) will be located 17m downstream of the new A9 crossing to allow the side raod to cross the Dalmagarry Burn. It will be a reinforced concrete bridge with a span of approximately 16 m and a total deck width of 7.3 m
The new bridge crossing A9 1260 has a greater opening than the existing bridge and does not constrain the 0.5% AEP flow (or the 0.5% AEP with climate change flow).
The realigned section of the burn has been sized to replicate the existing flow regime as far as is practicable. A two stage channel is proposed to achieve a more natural hydromorphology.</td><td>Agricultural land located north of Dalmagarry Farm between bounded by the A9 in the west and Funtack Burn in the east (floodplain C)</td><td>NH 786 326</td><td>Medium</td><td>Moderate Adverse</td><td>Moderate</td></tr>
<tr><td>Ruthven Road and Bridge crossing (Funtack Burn)</td><td>NH 797 320</td><td>Medium</td><td>Minor Beneficial</td><td>Slight Beneficial</td></tr>
<tr><td>Milton of Moy (Residential property)</td><td>NH 800 321</td><td>Very High</td><td>Minor Beneficial</td><td>Moderate Beneficial</td></tr>
<tr><td>Highland Main Line railway</td><td>Upstream face of the railway embankment (approx. NH 784 324 to NH 786 322)</td><td>Very High</td><td>Minor Beneficial</td><td>Moderate Beneficial</td></tr>
<tr><td>A9</td><td>General</td><td>Very High</td><td>Negligible</td><td>Neutral</td></tr>
</table>

Floodplain	Description	Receptors	Location (NGR)	Sensitivity	Magnitude	Impact
	Bank heights have been set to control the time and volume of spill from the main channel onto the floodplain to ensure that the loss of floodplain storage is mitigated for and the impact downstream of the confluence with the Funtack Burn is neutral. The impact on the floodplain hydraulics and the approach to mitigating increases in flood risk are described in Section 7.					
Allt Creag Bheithin	The existing A9 is a barrier to floodplain conveyance with the Allt Creag Bheithin, overtopping the A9 between NGR NH 748 347 and NH 750 347. The Proposed Scheme includes new watercourse crossings which have sufficient capacity to pass the 0.5% AEP with climate change and a freeboards allowance. Modelling indicates that flood flow spills from the right bank of the Allt Creag Bheithin (around NGR NH 748 347) and drains towards the A9. The modelling is described in Appendix D. Mitigation is discussed in more detail in Section 7.	Forestry north of A9 between Allt Creag Bheithin and Allt na Slanaich		Low	Major Beneficial	Slight Beneficial
		Forestry north of A9 between Allt na Slanaich and Tributary of Allt Creag Bheithin 002		Low	Major Beneficial	Slight Beneficial
		Forestry north of A9 between Tributary of Allt Creag Bheithin 002 and Tributary of Allt Creag Bheithin 001		Low	Major Beneficial	Slight Beneficial
		B9154	Between NH 7572 3533 and NH 7614 3483 across the floodplain	High	Minor Adverse	Moderate
		Highland Main Line railway	Between NH 7583 3544 and NH 7607 3484 across the floodplain	Very High	Moderate Adverse	Very Large
		A9		Very High	Major Adverse	Very Large

6.3.11 There is no floodplain loss at Allt na Frithe and no impact on flood risk to sensitive receptors. Therefore the Proposed Scheme passes the Sequential Tests 1 and 2 and no further assessment is required

6.3.12 The Proposed Scheme increases flood levels at Dalmagarry and would impact on very high sensitivity receptors. The Proposed Scheme therefore fails Test 2 and Sequential Test 3 has been applied.

6.3.13 The existing A9 is at risk of flooding for the 0.5% AEP event at Allt Creag Bheithin (Figure A11.2.8e) and the floodplain would be impacted by the Proposed Scheme due to the loss of floodplain storage and changes in connectivity. Sequential Test 3 has therefore been applied.

6.3.14 The results of the Sequential Test 3 assessment and the proposed actions are given in Section 7.3 as operational mitigation measures.

7. Mitigation

7.1 Construction Mitigation Measures

7.1.1 A Schedule of Environmental Commitments will be incorporated into the works construction documents and the appointed Contractor will be obliged to adhere to these requirements throughout the contract period. The construction commitments will be addressed through the Construction Environmental Management Plan (CEMP). Details of these commitments are given in Chapter 21. The sections below highlight those that relate to flood risk.

7.1.2 Standard S1 is for the Contractor to prepare a Construction Environmental Management Plan (CEMP) to set out how they intend to operate the construction site, including construction-related mitigation measures. The relevant section(s) of the CEMP will be in place prior to the start of construction work.

7.1.3 The CEMP will include a Flood Response Plan and reference should be made to SEPA's Floodline service. Although the Proposed Scheme is not within a SEPA Flood Warning area, the alignment does fall within the Findhorn, Nairn, Moray and Speyside Flood Alert area. Flood alerts indicate that flooding is possible to a wider geographical area and gives an early indication of potential flooding.

7.1.4 The Flood Response Plan will be prepared and submitted to Transport Scotland for approval before construction work commences and will include the following:

- how information gathered from SEPA's Flood Alert should be provided and disseminated
- what will be done to protect the critical infrastructure of the development and how easily damaged items will be relocated
- the availability of staff and time taken to respond to a flood alert
- the use of high level refuges for staff within the plant
- the time needed to evacuate the site
- provision of safe access to and from the development
- the ability to maintain key operations during a flood event
- expected time taken to re-establish normal operation following a flood event

7.1.5 The Contractor will implement Mitigation Item W2 during construction In relation to flood risk. These measures include:

- in relation to flood risk the Contractor will implement the following mitigation measures during construction:
- the Flood Response Plan (as part of the CEMP) will set out the following mitigation measures to be implemented when working within the functional floodplain (defined here as the 0.5% AEP (200-year) flood extent):
  - routinely check the MET office Weather Warnings and the SEPA Floodline alert service for potential storm events (or snow melt), flood alerts relevant to the area of the construction works
  - during periods of heavy rainfall or extended periods of wet weather (in the immediate locality or wider river catchment) river levels will be monitored using, for example, SEPA Water Level Data when available or visual inspection of water features. The Contractor will assess any change from base flow condition and be familiar with the normal dry weather flow conditions for the water feature, and be familiar with the likely hydrological response of the water feature to heavy rainfall (in terms of time to peak, likely flood extents) and windows of opportunity to respond should river levels rise
  - should flooding be predicted, works close or within the water features should be immediately withdrawn (if practicable) from high risk areas (defined as: within the channel or within the bankfull channel zone - usually the 50% (2-year) AEP flood extent). Works should retreat to above the 10% AEP (10-year) flood extent) with monitoring and alerts for further mobilisation outside the functional floodplain should river levels continue to rise
- plant and materials will be stored in areas outside the functional floodplain where practicable, with the aim for temporary construction works to be resistant or resilient to flooding impacts, to minimise/prevent movement or damage during potential flooding events. Where this is not possible, agreement will be required with the EnvCoW
- temporary drainage systems will be implemented to alleviate localised surface water flood risk and prevent obstruction of existing surface runoff pathways
- where practicable, haul routes will be located out of the functional floodplain. When in the floodplain stockpiling of material must be carefully controlled with limits to the extent of stockpiling within an area to prevent compartmentalisation of the floodplain and stockpiles should be away from water feature banks (not within 10m of the water feature banks). This is in order to limit floodplain encroachment, associated increased flood risk and sediment entering the water feature

7.2 Operational Mitigation Measures - Watercourse Crossings

General

7.2.1 In relation to culverts the Contractor will implement the mitigation measures set out in Mitigation Item W15. In particular, detailed design shall mitigate flood risk impacts through appropriate hydraulic design of culvert structures. Flood risk shall be assessed against the 0.5%AEP (200-year) plus an allowance for climate change design flood event. Widening of the proposed scheme footprint may lead to loss of existing floodplain storage volume. Detailed design shall mitigate this where required by appropriate provision of compensatory storage. Where culvert extension is not practicable or presents adverse impact on the water environment, appropriately designed replacement culverts may be installed.

Dalmagarry and Allt Creag Bheithin

7.2.2 The impact of the new crossings in the vicinity of Dalmagarry and Allt Creag Bheithin are addressed in the floodplain mitigation measures (Section 7.3).

7.2.3 There are no other significant impacts on flood risk resulting from the replacement and new watercourse crossings that require mitigation.

7.3 Operational Mitigation Measures - Floodplain

7.3.1 The Sequential Test 3 has been applied to two floodplain areas: Dalmagarry and Allt Creag Bheithin.

7.3.2 The floodplain for the 0.5% AEP and 0.5% AEP with climate change events are shown in Figures A11.2.11a-f and A11.2.12a-f. The impacts on flood depth (impact magnitude) are shown in Figures A11.2.13a-f and A11.2.14a-f.

7.3.3 Changes in depth at receptors have been rounded to the nearest 10mm to reflect typical model accuracy associated with the underlying ground model, inflows, and model schematisation.

Dalmagarry

7.3.4 The Proposed Scheme at Dalmagarry was developed based on a wide range of constraints including hydromorphology, flood risk, ecology and the interests of the landowner. The process has involved several design iterations and meetings with stakeholders.

7.3.5 The impact of the Proposed Scheme is caused by a combination of a loss of floodplain storage, modifications to the hydraulic links between floodplains and changes in the morphology of the Dalmagarry Burn. Under these circumstances replacing floodplain storage displaced by the scheme does not guarantee that flood risk will not be increased. Modelling has therefore been used to understand the hydraulics and to assess the effectiveness of proposed mitigation.

7.3.6 The following criteria were used to guide the design of flood risk mitigation:

- The impact magnitude at residential and non-residential receptors should not increase.
- The impact magnitude at Ruthven Road should not increase.
- The impact magnitude at the Highland Main Line railway should not increase.
- The impact on the baseline flood hydrograph at a point just downstream of the confluence of the two burns was used to confirm that the loss of floodplain storage had been mitigated.

7.3.7 The proposed watercourse crossings that connect the Dalmagarry and Funtack floodplains (given in Table A6.2) have been included in the model to ensure that the impact of increasing the hydraulic capacity of the structures is included in the assessment. This specifically relates to structures A9 1260, A9 1260 C25, A9 1260 C25S, A9 1260 C25, A9 1260 C25S, A9 1260 C35 and A9 1260 C35S which currently have capacities less than the 0.5% AEP.

Floodplain A and the Realigned Dalmagarry Burn

7.3.8 The 1D/2D hydraulic model has been used to determine 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.

7.3.9 The existing cross sections were initially moved laterally onto the proposed alignment and then adjusted until the channel could conveyed the 50% AEP flow. This is the flow that is currently carried within the main channel without spilling onto the floodplain.

7.3.10 The channel bed widths vary from 10m at the outlet to the railway bridge to 8m some 250m downstream of the railway bridge and 2m at the downstream end of the diversion just upstream of where it returns to its existing alignment.

7.3.11 The left bank of the burn has been raised around the first bend of the diverted burn downstream of the proposed crossing (between NGR NH 787 322 and NH 788 322) to keep the 0.5% AEP in channel at this point. Flood water first leaves the channel at a low point on the left bank at NH 790 321 close to where it does at present. Flood water leaving the main channel flows northwards towards the Funtack as it does at present. Flow eventually overtops the left bank of the Dalmagarry Burn at a second location (NGR NH 789 321) some 180m downstream of the new A9 crossing.

7.3.12 The removal of the flood relief culverts under the existing farm access road removes the existing flood pathway to the south of Dalmagarry Farm and ensures that the new access road is out of the floodplain.

Floodplain B

7.3.13 The extent of Floodplain B remains unchanged. Flood flow leaves the left bank of the Dalmagarry Burn upstream of NH 783 321, flows across the floodplain towards the inlet to the railway culvert at NH 784 324. Excess flow also returns along the toe of the railway embankment to re-enter the Dalmagarry Burn at the inlet to the railway bridge at NH 786 322.

7.3.14 The new access road that gives the farm access to this field will not be raised above existing ground levels allowing water stored on the floodplain to return to the burn unimpeded.

Floodplain C

7.3.15 The floodplain north of Dalmagarry Farm (Floodplain C) remains unchanged. The new culverts under the A9 allow water to flow towards the Funtak Burn and the depth of water and flooded extent remain almost unchanged.

Impacts on Floodplain Extent and Depths

7.3.16 Table A7.1 below summarises the change in flood levels, for different flood return periods, at receptors. The changes are relatively small and are regarded as being less than the accuracy of the 1D/2D model.

Table A7.1: Changes in flood levels at Dalmagarry with Mitigation for different Flood Events

		Change in Average Maximum Water Level (m)					
Receptors	**Sensitivity**	**50%**	**2%**	**3.3%**	**1%**	**0.5%**	**0.5% + CC**
Residential and non-residential properties at Dalmagarry	Very High	0.00	0.00	0.00	0.00	0.00	0.00
Agricultural land located south of Dalmagarry Farm and between the Funtack Burn and Dalmagarry Burn (floodplain A)	Medium	0.03	0.02	0.02	0.01	-0.01	-0.01
Agricultural land located west of the Highland mainline railway and north of the Dalmagarry Burn (floodplain B)	Medium	0.00	0.03	0.00	0.01	0.01	0.01
Agricultural land located north of Dalmagarry Farm bounded by the A9 in the west and Funtack Burn in the east (floodplain C)	Medium	0.00	0.00	0.00	0.02	0.02	0.01
Ruthven Road (U2786) and bridge crossing	Medium	0.00	0.00	0.00	-0.02	0.01	0.02
Milton of Moy (Residential property)	High	0.01	0.01	0.01	0.00	0.01	0.01
Highland Main Line Railway	Very High	-0.02	-0.02	-0.02	0.00	0.00	0.01

7.3.17 The impacts of fhe Proposed Scheme on the 0.5% AEP are shown in Figures A11.2.13c and A11.2.14c together with the location of the receptors listed in Table A7. It should be noted that the water level change for Milton of Moy is calculated over the area between the Findhorn and the outer limit of the floodplain. The buildings in this area all lie outside of the 0.5% AEP and 0.5% AEP plus climate change floodplains (as shown in Figures A11.2.11c and A11.2.12c).

7.3.18 The baseline and impacted peak flows downstream of the confluence are given in Table A7.2. Differences of less than 2% are not significant given the data and modelling uncertainties (e.g. topographic data accuracy, flow estimation errors and roughness values). The model results confirm that the impact of the Proposed Scheme is fully mitigated. The results also confirm that this is the case for more frequent flood events.

Table A7.2 Impact on Peak Flow at the Confluence between the Dalmagarry and Funtack Burns

Event (% AEP)	Baseline (m^3/s)	Proposed Scheme (m^3/s)	Difference (%)
50%	23.96	23.94	-0.1%
20%	26.08	26.02	-0.2%
3.33%	28.69	28.75	+0.2%
1%	40.03	39.43	-1.5%

Event (% AEP)	Baseline (m^3/s)	Proposed Scheme (m^3/s)	Difference (%)
0.5%	41.34	41.85	+1.2%
0.5% plus CC	47.70	47.13	-1.2%

Allt Creag Bheithin

7.3.19 Appendix D gives details of the detailed modelling carried out to assess the potential impact of the Proposed Scheme and the mitigation reuired at this location and described in the following sections.

7.3.20 It is evident from Figure 1 in Appendix D that the Proposed Scheme crosses the 0.5% AEP floodplain of the Alt Creag Bheithin resulting in a potential loss of floodplain. New watercourse crossings will allow the Allt Creag Bheithin, Allt na Slanaich and two tributaries of the Allt Creag Beithin pass under the new road.

7.3.21 The Proposed Scheme was included in the model without any compensation storage and with culverts sized to satisfy SEDP and the impact on flood levels, flows and velocities assessed. The model results confirmed that the Proposed Scheme would lead to an increase in peak 0.5% AEP water level at the railway bridge by +60mm. This is a Moderate Adverse magnitude impact giving a Large/Very Large Significant impact as the HML railway is a Very High Sensitivity receptor.

7.3.22 Measures are therefore required to ensure that the A9 satisfies Strategic Environmental Design Principles (SEDP) Principle W1 at this location (i.e. the A9 should remain operational and safe for users during times of flood; result in no loss of floodplain storage; and the movement of water should not be impeded).

7.3.23 Compensation storage is proposed to compensate for the displacement of floodplain and increase in peak flood levels. Two storage areas are to be located upstream of culverts A9 1273 C31 and A9 1273 C28. The opening area of the proposed culvert A9 1273 C31 has been set to 2m x 2m to control flood flow through the structure and allow water to overtop upstream on Allt Creag Bheithin into the two storage areas. This does mean that there is no freeboard at the upstream extent of culvert A9 1273 C31 during the 0.5% AEP event, however this is necessary to prevent adverse impacts downstream during flood events. At the downstream end of this culvert, there is 534mm freeboard during the 0.5% AEP event.

7.3.24 The area of each bore of the 3 bore culvert at A9 1273 C28 on Allt na Slanaich is proposed to be 1.85m heigh x 1.80m wide. The freeboard through each barrel is 650mm during the 0.5% AEP event satisfying the SEDP.

7.3.25 The magnitude and resulting impact with mitigation is summarised in Table A7.3 and this confirms that the Proposed Scheme addresses the significant impacts identified for at the railway crossing.

Table A7.3 Magnitude of Impact on Peak Water Levels at Allt Creag Bheithin

Receptors	Sensitivity	Change in Average Maximum Water Level (m)					
		50%	2%	3.3%	1%	0.5%	0.5% + CC
Forestry north of A9 between Allt Creag Bheithin and Allt na Slanaich	Low	0.05	0.00	-0.06	-0.12	-0.03	0.11

Receptors	Sensitivity	Change in Average Maximum Water Level (m)					
		50%	2%	3.3%	1%	0.5%	0.5% + CC
Forestry north of A9 between Allt na Slanaich and Tributary of Allt Creag Bheithin 002	Low	0	-0.25	-0.27	-0.28	-0.29	-0.23
Forestry north of A9 between Tributary of Allt Creag Bheithin 002 and Tributary of Allt Creag Bheithin 001	Low	0	-0.28	-0.30	-0.32	-0.34	-0.36
B9154	High	-0.01	0.00	0.01	0.01	0.00	-0.01
Highland Main Line Railway	Very High	-0.01	0.01	0.02	0.02	0.00	-0.02

7.3.26 The resulting flood outline (Figure A11.2.11e) shows that the Proposed Scheme with compensation storage and downsized culverts returns the flow path to the channel morphology of the Allt Creag Bhethin. The baseline was distorted by the existing A9 alignment and crossing locations (specifically crossing Allt Creag Bheithin trib 2).

7.3.27 The 0.5% maximum flood levels on the B9154 and at the railway are predicted to remain unchanged with the compensation storage in place as are levels in and around Loch Moy.

7.3.28 The Proposed Scheme therefore incorporates embedded mitigation for flood risk impacts.

8. Residual Risk

8.1 Watercourse Crossings

8.1.1 The residual risk associated with the new watercourse crossings are given in Table A8.1

Table A8.1: Residual Risk - Watercourse Crossings

Watercourse	Proposed Structure ID	Sensitivity	Potential Impact		Proposed mitigation	Residual Effect	
			Magnitude	Significance		Magnitude	Significance
River Findhorn Trib 1	A9 1240	Medium	Negligible	Neutral	None	Negligible	Neutral
Allt na Frithe	A9 1250	Low	Negligible	Neutral	None	Negligible	Neutral
River Findhorn Trib 2	D5	Medium	Minor	Slight	None	Minor	Slight
Allt Dubhag	A9 1250 C25	Medium	Negligible	Neutral	None	Negligible	Neutral
River Findhorn Trib 3	D8	High	Negligible	Neutral	None	Negligible	Neutral
Funtack Burn Trib 1	DB	Medium	Negligible	Neutral	None	Negligible	Neutral
Dalmagarry Burn Trib 1	DG	Medium	Negligible	Neutral	None	Negligible	Neutral
Dalmagarry Burn Trib 2	A9 1250 C85	Medium	Negligible	Neutral	None	Negligible	Neutral
Dalmagarry Burn Trib 2	A9 1250 C85 S	Medium	Negligible	Neutral	None	Negligible	Neutral
Dalmagarry Burn Trib 3	A9 1250 C93	Medium	Negligible	Neutral	None	Negligible	Neutral
Dalmagarry Burn	A9 1260	Very High	Major	Large / Very Large	See floodplain assessment	See floodplain assessment	Neutral
Dalmagarry Burn	A9 1260 ARB1	Very High	Negligible	Neutral	See floodplain assessment	See floodplain assessment	Neutral
Dalmagarry Burn	A9 1260 SRB1	Very High	Negligible	Neutral	See floodplain assessment	See floodplain assessment	Neutral
Funtack Burn Trib 2	A9 1260 C25	High	Minor	Slight/Moderate	See floodplain assessment	See floodplain assessment	Neutral
Funtack Burn Trib 2	A9 1260 C25 S	High	Minor	Slight/Moderate	See floodplain assessment	See floodplain assessment	Neutral
Funtack Burn Trib 3	A9 1260 C35	High	Minor	Moderate/Large	See floodplain assessment	See floodplain assessment	Neutral
Funtack Burn Trib 3	A9 1260 C35 S	High	Minor	Moderate/Large	See floodplain assessment	See floodplain assessment	Neutral

Watercourse	Proposed Structure ID	Sensitivity	Potential Impact		Proposed mitigation	Residual Effect	
			Magnitude	Significance		Magnitude	Significance
Funtack Burn Trib 4	A9 1260 C65	High	Negligible	Neutral	None	Negligible	Neutral
Funtack Burn Trib 4	A9 1260 C65 S	High	Negligible	Neutral	None	Negligible	Neutral
Funtack Burn Trib 5	A9 1260 C94	High	Negligible	Neutral	None	Negligible	Neutral
Funtack Burn Trib 6 / 7	A9 1270 C35	High	Negligible	Neutral	None	Negligible	Neutral
Funtack Burn Trib 6 / 7	A9 1270 C35 S	High	Negligible	Neutral	None	Negligible	Neutral
Funtack Burn Trib 8	A9 1270 C50	High	Negligible	Neutral	None	Negligible	Neutral
Funtack Burn Trib 8	A9 1270 C50 S	High	Negligible	Neutral	None	Negligible	Neutral
Funtack Burn Trib 9	A9 1270 C60	High	Negligible	Neutral	None	Negligible	Neutral
Funtack Burn Trib 9	A9 1270 C60 S	High	Negligible	Neutral	None	Negligible	Neutral
Caochan na h-Eaglais	A9 1270 C80	High	Negligible	Neutral	None	Negligible	Neutral
Caochan na h-Eaglais	A9 1270 C80 S	High	Negligible	Neutral	None	Negligible	Neutral
Moy Burn Trib 1	A9 1273 C5	Medium	Moderate	Moderate/Large	Maintain existing hydraulic capacity	Negligible	Neutral
Allt na Loinne Moire	A9 1273 C8	Medium	Negligible	Neutral	None	Negligible	Neutral
Moy Burn Trib 2 and Moy Burn Trib 3	A9 1273 C18	Low	Negligible	Neutral	None	Negligible	Neutral
Allt Creag Bheithin Trib 1	A9 1273 C22	Low	Minor	Neutral	None	Minor	Neutral
Allt Creag Bheithin Trib 2	A9 1273 C24	Low	Negligible	Neutral	None	Negligible	Neutral
Allt na Slanaich	A9 1273 C28	Medium	Negligible	Neutral	None	Negligible	Neutral
Allt Creag Bheithin	MC90 C1	Medium	Moderate	Moderate	See floodplain assessment	See floodplain assessment	Neutral
Allt Creag Bheithin	A9 1273 C31	Medium	Moderate	Moderate	See floodplain assessment	See floodplain assessment	Neutral
Allt Creag Bheithin Trib 3	A9 1273 C40	Medium	Negligible	Neutral	None	Negligible	Neutral

Watercourse	Proposed Structure ID	Sensitivity	Potential Impact		Proposed mitigation	Residual Effect	
			Magnitude	Significance		Magnitude	Significance
Allt Creag Bheithin Trib 4	A9 1273 C43	Medium	Negligible	Neutral	None	Negligible	Neutral
Allt Creag Bheithin	A9 1273 C54	Medium	Negligible	Neutral	None	Negligible	Neutral
Allt Creag Bheithin 5	A91273 MCY0 C1	Medium	Negligible	Neutral	None	Negligible	Neutral
Midlairgs Burn	A91273 MCY0 C1	Medium	Negligible	Neutral	None	Negligible	Neutral
Midlairgs Burn 1	A91273 MCY0 C1	Medium	Negligible	Neutral	None	Negligible	Neutral
Midlairgs Burn 2	A91273 MCY0 C1	Medium	Negligible	Neutral	None	Negligible	Neutral

8.2 Floodplain Assessments

8.2.1 The residual risk associated with the Proposed Scheme are given in Table A8.2.

Table A8.2: Residual Risk – Floodplain Assessment

Floodplain	Receptors	Sensitivity	No Mitigation		Proposed Mitigation	With Mitigation	
			Magnitude	Significance		Magnitude	Significance
Allt na Frithe	Agricultural Land (upstream face of the road embankment)	Medium	Negligible	Neutral	None	Negligible	Neutral
	Agricultural Land (downstream face of the road embankment)	Medium	Negligible	Neutral		Negligible	Neutral
	Non Residential properties in Tomatin (Warehouses)	Medium	Negligible	Neutral		Negligible	Neutral
	Residential properties (Moss Villa, Freeburn Cottage and Pinewood)	High	Negligible	Neutral		Negligible	Neutral
	Minor Road (C1121) and Watercourse crossing	Medium	Negligible	Neutral		Negligible	Neutral
Dalmagarry Burn	Residential and non-residential properties at Dalmagarry	Very High	Negligible	Neutral	The realigned section of the burn has been sized to replicate the existing flow regime as far as is practicable. A two stage channel is proposed to achieve a more natural hydromorphology. Bank heights have been set to control the time and volume of spill from the main channel onto the floodplain to ensure that the loss of floodplain storage is mitigated for and the impact downstream of the confluence with the Funtack Burn is neutral.	Negligible	Neutral
	Agricultural land located south of Dalmagarry Farm and between the Funtack Burn and Dalmagarry Burn (floodplain A)	Medium	Moderate	Moderate Adverse		Negligible	Neutral
	Agricultural land located west of the Highland mainline railway and north of the Dalmagarry Burn (floodplain B)	Medium	Negligible	Neutral		Negligible	Neutral
	Agricultural land located north of Dalmagarry Farm between bounded by the A9 in the west and Funtack Burn in the east (floodplain C)	Medium	Moderate	Moderate Adverse		Minor	Slight Adverse
	Ruthven Road and Bridge crossing (Funtack Burn)	Medium	Minor	Slight Beneficial		Negligible	Neutral

Floodplain	Receptors	Sensitivity	No Mitigation		Proposed Mitigation	With Mitigation	
			Magnitude	Significance		Magnitude	Significance
	Milton of Moy (Residential property)	Very High	Minor	Moderate Beneficial		Negligible	Neutral
	Highland Main Line Railway	Very High	Minor	Moderate Beneficial		Negligible	Neutral
	A9	Very High	Negligible	Neutral		Negligible	Neutral
Allt Creag Bheithin	Forestry north of A9 between Allt Creag Bheithin and Allt na Slanaich	Low	Major	Slight Beneficial	Two storage areas are to be located upstream of culverts A9 1273 C31 and A9 1273 C28. The opening area of the proposed culvert A9 1273 C31 has been set to 2m x 2m to control flood flow through the structure and allow water to overtop upstream on Allt Creag Bheithin into the two storage areas. The area of each bore of the 3 bore culvert at A9 1273 C28 on Allt na Slanaich is proposed to be 1.85m height x 1.80m wide.	Major	Slight Beneficial
	Forestry north of A9 between Allt na Slanaich and Tributary of Allt Creag Bheithin 002	Low	Major	Slight Beneficial		Major	Slight Beneficial
	Forestry north of A9 between Tributary of Allt Creag Bheithin 002 and Tributary of Allt Creag Bheithin 001	Low	Major	Slight Beneficial		Major	Slight Beneficial
	B9154	High	Minor	Moderate Adverse		Negligible	Neutral
	Highland Main Line Railway	Very High	Moderate	Very Large Adverse		Negligible	Neutral
	A9	Very High	Major	Very Large Adverse		Negligible	Neutral

9. Conclusion

9.1.1 The focus of the FRA is on the potential impact of new or replacement watercourse crossings and the loss or displacement of floodplain storage on the flood risk of sensitive receptors (including the A9 as a receptor of Very High sensitivity).

9.1.2 A methodology has been developed to classify the sensitivity of a receptor, the magnitude of the impact and so assess the significance of the impact. The method was used in the preliminary assessment to screen for significant impacts which have been assessed in more detail in the FRA.

9.1.3 The results of the impact assessment given in Section 5.3.5 show that the Proposed Scheme will have at least a slight impact on the flood risk associated with 9 watercourses and 3 floodplain locations.

9.1.4 A more detailed assessment of the watercourse crossings established that mitigation measures are not required for the watercrossing at River Findhorn Trib 2. The impacts in the vicinity of Dalmagarry and Allt Creag Bheithin are addressed as a part of the floodplain assessments at those locations.

9.1.5 Moy Burn Trib 1 is to not be increased in hydraulic capacity as hydraulic modelling shows that this would lead to an increase in downstream impact on flood risk.

9.1.6 Modelling is used to demonstrate that will be no increase in flood risk upstream or downstream of the development at Allt na Frithe and therefore no compensation storage is required.

9.1.7 The Proposed Scheme at Dalmagarry minimises the loss of floodplain storage and uses the design of the realigned burn to fully compensate for the effect of lost floodplain storage. Modelling shows that there is no impact on the peak flood flows at the confluence of the Funtack and Dalmagarry Burns for the range of return periods assessed.

9.1.8 The Proposed Scheme crosses the floodplain of the Allt Creag Bhethin leading to a displacement of floodplain storage and significant impact at the downstream railway crossing. Compensation storage and reduced culvert openings are proposed to ensure that the impact of the Proposed Scheme is neutral.

9.1.9 Overall, the Proposed Scheme will have no significant impact on flood risk with the mitigation actions set out in section 7.

10. References

[i] Jacobs (2014); A9 Dualling: Preliminary Engineering Support Services Annex
[ii] Transport Scotland (2013); A9 Dualling Programme Strategic Environmental Assessment (SEA), Transport Scotland.
[iii] CH2MHILL (2014); Strategic Flood Risk Assessment, Transport Scotland
[iv] The Scottish Government (2009); Flood Risk Management Act, The Scottish Government
[v] The Scottish Government (2014); National Planning Framework (3), The Scottish Government
[vi] Transport Scotland (2014); A9 Dualling Programme Strategic Flood Risk Assessment (SFRA).
[vii] The Scottish Government (2014); Scottish Planning Policy (paragraphs 254 – 268).
[viii] The Highways Agency, Scottish Executive, Welsh Assembly Government and The Department Regional Development Northern Ireland (2004); Design Manual for Roads and Bridges, Volume 4, Section 2, Part 7 Design of Outfall and Culvert Details HA107/04.
[ix] The Highland Council (2013); Flood Risk & Drainage Impact Assessment: Supplementary Guidance.
[x] SEPA (2015); Technical Flood Risk Guidance for stakeholders.
[xi] Flood Modelling Guidance for Responsible Authorities version 1.1
[xii] Construction Industry Research and Information Association (CIRIA) (2010); C689 - Culvert design and operation guide.
[xiii] CIRIA (2013); C720 - Culvert design and operation guide supplementary technical note on understanding blockage risks.
[xiv] Environment Agency: The Fluvial Design Guide (http://evidence.environment-agency.gov.uk/FCERM/en/FluvialDesignGuide/Fluvial_Design_Guide_Overview.aspx)
[xv] Environment Agency: Accounting for residual uncertainty: updating the freeboard guide (Report – SC120014)
[xvi] Design Manual for Roads and Bridges. Design of Highway Drainage Systems. HD 33/16 Volume 4, Section 2, Part 3.
[xvii] Institute of Hydrology (1999); Flood Estimation Handbook (five volumes), Centre for Ecology & Hydrology.
[xviii] SEPA, 2015, Flood Risk Management Maps, Available at: http://map.sepa.org.uk/floodmap/map.htm, Accessed December 2015.
[xix] The SEPA National Flood Risk Assessment (https://www.sepa.org.uk/media/99914/nfra_method_v2.pdf).

Annex A. Watercourse Crossings – 1D Hydraulic Modelling

A.1 Hydrology

A.1.1 Catchment boundaries were derived for each watercourse crossing using the FEH CD Rom (Version 3). The boundaries were checked and adjusted based on OS Mapping, Nextmap 5km Digital Terrain Model (DTM), and the Blom Topographical survey information available.

A.1.2 Based on the proposed culverts and depending upon the requirement of additional culverts within a catchment area, the catchment areas were redefined to reflect the catchments draining to each proposed culvert.

A.1.3 Table A.1 provides information on the revised delineated catchment areas which have been determined for use in the Stage 3 assessment.

Table A.1: Details of delineated catchments

Watercourse	Proposed Structure ID	Catchment ID	Catchment Area (km^2)
River Findhorn Trib 1	A9 1240	TM28	0.61
Allt na Frithe	A9 1250	TM27	5.80
River Findhorn Trib 2	D5	TM26	0.18
Allt Dubhag	A9 1250 C25	TM25	2.60
River Findhorn Trib 3	D8	TM24	0.05
Funtack Burn Trib 1	DB	TM23	0.10
Dalmagarry Burn Trib 1	DG	TM22	0.81
Dalmagarry Burn Trib 2	A9 1250 C85	TM21	0.32
Dalmagarry Burn Trib 2	A9 1250 C85 S	TM21	0.32
Dalmagarry Burn Trib 3	A9 1250 C93	TM20a	0.09
Dalmagarry Burn	A9 1260	TM20	8.02
Funtack Burn Trib 2	A9 1260 C25	TM19	0.10
Funtack Burn Trib 2	A9 1260 C25 S	TM19	0.10
Funtack Burn Trib 3	A9 1260 C35	TM18	0.36
Funtack Burn Trib 3	A9 1260 C35 S	TM18	0.36
Funtack Burn Trib 4	A9 1260 C65	TM17	0.16
Funtack Burn Trib 4	A9 1260 C65 S	TM17	0.16
Funtack Burn Trib 5	A9 1260 C94	TM16	0.26
Funtack Burn Trib 6 / 7	A9 1270 C35	TM15	0.04
Funtack Burn Trib 6 / 7	A9 1270 C35 S	TM15	0.04
Funtack Burn Trib 8	A9 1270 C50	TM14	0.14
Funtack Burn Trib 8	A9 1270 C50 S	TM14	0.14
Funtack Burn Trib 9	A9 1270 C60	TM13	0.06

Watercourse	Proposed Structure ID	Catchment ID	Catchment Area (km^2)
Funtack Burn Trib 9	A9 1270 C60 S	TM13	0.06
Caochan na h-Eaglais	A9 1270 C80	TM12	0.78
Caochan na h-Eaglais	A9 1270 C80 S	TM12	0.78
Moy Burn Trib 1	A9 1273 C5	TM11	0.75
Allt na Loinne Moire	A9 1273 C8	TM10	2.86
Moy Burn Trib 2 and Moy Burn Trib 3**	A9 1273 C18	TM08	0.24
Allt Creag Bheithin Trib 1	A9 1273 C22	TM07	0.92
Allt Creag Bheithin Trib 2	A9 1273 C24	TM06	0.08
Allt na Slanaich	A9 1273 C28	TM05	2.43
Allt Creag Bheithin	MC90 C1	TM04	2.84
Allt Creag Bheithin	A9 1273 C31	TM04	2.84
Allt Creag Bheithin Trib 3	A9 1273 C40	TM03	0.37
Allt Creag Bheithin Trib 4	A9 1273 C43	TM02	0.17
Allt Creag Bheithin	A9 1273 C54	TM01	0.25
Allt Creag Bheithin 5	A91273 MCY0 C1	TM30	0.99
Midlairgs Burn	A91273 MCR1 C1	TM31	0.51
Midlairgs Burn Trib 1	A91273 MCR0 C2	TM32	0.19
Midlairgs Burn Trib 2	A91273 MCR0 C1	TM33	0.20

A.1.4 Where the catchments were redefined, the FEH CD-ROM was applied to extract catchment descriptors. Donor catchments have been applied at specific locations where there is no FEH catchment (i.e. where the catchment area is <0.5km^2). The choice of a ‘donor’ catchment was based on a location near the site, and comparison of the catchment steepness (DPSBAR), extent of urbanisation (URBEXT), standard percentage runoff (SPR) and catchment shape. The ‘donor’ catchments were scaled to the delineated inflow catchments.

A.1.5 Donor catchments have been used where:

- the subject catchment area <0.5km^2
- if the subject catchment is a small area within a very large FEH catchment a smaller section of the larger FEH catchment area has been identified with similar characteristics to the subject site and the descriptors scaled as appropriate.

A.1.6 The FEH scaled method has been used where an inflow location is close to but not co-located to the FEH catchment outflow point (e.g. where the inflow to a culvert crossing is required and the FEH catchment is cut by the road alignment). Small modifications have then been made to the descriptors.

A.1.7 The choice of donors and the scaling of FEH catchments involves professional judgment. For example, donor catchments can be a few kilometres from the inflow catchment where the inflow catchment is a small fraction of the FEH catchment.

A.1.8 A summary of the delineated catchments is provided in Table A.23 with a comparison between the FEH CD-ROM catchment area and the delineated catchment area draining to each structure. The delineated catchment areas are considered more accurate than the catchment areas extracted from the FEH CD-ROM. Table A.2 shows the important catchment descriptors at each delineated catchment, incorporating any changes that were made.

A.1.9 The $URBEXT_{1990}$ has been updated using the Council for the Protection of Rural England (CPRE) formula detailed in FEH Volume 5.

$$UEF = 0.8165 + 0.2254 \tan -1\{\frac{year - 1967.5}{21.25}\}$$

A.1.10 The catchment descriptors were checked against the solid and superficial geological map, the land classification for agricultural map, Base Flow Index Scotland Map. There were no adjustments made to the catchment descriptors.

Table A.2: Delineated catchment area and FEH point locations

Watercourse	Proposed Structure ID	Catchment ID*	Grid Reference	Flow Estimation FEH/ FEH Scaled/Donor	Grid Reference	FEH Area (km^2)	Revised Catchment Area (km^2)
River Findhorn Trib 1	A9 1240	TM28	NH 79991 29660	Donor	NH 79400 31150	0.67	0.61
Allt na Frithe	A9 1250	TM27	NH 79657 29974	FEH	NH 79650 29950	5.67	5.80
River Findhorn Trib 2	D5	TM26	NH 79428 30305	Donor	NH 76750 33800	0.52	0.18
Allt Dubhag	A9 1250 C25	TM25	NH 79350 30492	Donor	NH 79600 30700	2.60	2.60
River Findhorn Trib 3	D8	TM24	NH 79364 30648	Donor	NH 76750 33800	0.52	0.05
Funtack Burn Trib 1	DB	TM23	NH 79345 30806	Donor	NH 76750 33800	0.52	0.10
Dalmagarry Burn Trib 1	DG	TM22	NH 79445 31357	Donor	NH 79400 31150	0.67	0.81
Dalmagarry Burn Trib 2	A9 1250 C85	TM21	NH 79031 31977	Donor	NH 76750 33800	0.52	0.32
Dalmagarry Burn Trib 2	A9 1250 C85 S	TM21	NH 79065 32036	Donor	NH 76750 33800	0.52	0.32
Dalmagarry Burn Trib 3	A9 1250 C93	TM20a	NH 78858 32068	Donor	NH 76750 33800	0.52	0.09
Dalmagarry Burn	A9 1260	TM20	NH 78759 32184	FEH	NH 78700 32200	8.09	8.02
Funtack Burn Trib 2	A9 1260 C25	TM19	NH 78441 32426	Donor	NH 76750 33800	0.52	0.10
Funtack Burn Trib 2	A9 1260 C25 S	TM19	NH 78481 32454	Donor	NH 76750 33800	0.52	0.10
Funtack Burn Trib 3	A9 1260 C35	TM18	NH 78368 32557	Donor	NH 76750 33800	0.52	0.36
Funtack Burn Trib 3	A9 1260 C35 S	TM18	NH 78431 32592	Donor	NH 76750 33800	0.52	0.36
Funtack Burn Trib 4	A9 1260 C65	TM17	NH 78163 32904	Donor	NH 76750 33800	0.52	0.16
Funtack Burn Trib 4	A9 1260 C65 S	TM17	NH 78273 32930	Donor	NH 76750 33800	0.52	0.16
Funtack Burn Trib 5	A9 1260 C94	TM16	NH 78051 33047	Donor	NH 76750 33800	0.52	0.26
Funtack Burn Trib 6 / 7	A9 1270 C35	TM15	NH 77584 33522	Donor	NH 76750 33800	0.52	0.04
Funtack Burn Trib 6 / 7	A9 1270 C35 S	TM15	NH 77715 33478	Donor	NH 76750 33800	0.52	0.04
Funtack Burn Trib 8	A9 1270 C50	TM14	NH 77461 33646	Donor	NH 76750 33800	0.52	0.14
Funtack Burn Trib 8	A9 1270 C50 S	TM14	NH 77512 33688	Donor	NH 76750 33800	0.52	0.14
Funtack Burn Trib 9	A9 1270 C60	TM13	NH 77382 33714	Donor	NH 77300 34050	1.11	0.06
Funtack Burn Trib 9	A9 1270 C60 S	TM13	NH 77439 33748	Donor	NH 77300 34050	1.11	0.06
Caochan na h-Eaglais	A9 1270 C80	TM12	NH 77062 33897	Donor	NH 77300 34050	1.11	0.78
Caochan na h-Eaglais	A9 1270 C80 S	TM12	NH 77138 33957	Donor	NH 77300 34050	1.11	0.78
Moy Burn Trib 1	A9 1273 C5	TM11	NH 76586 34150	Donor	NH 76950 34300	0.55	0.75
Allt na Loinne Moire	A9 1273 C8	TM10	NH 76375 34268	Donor	NH 76600 34500	2.87	2.86
Moy Burn Trib 2	A9 1273 C18	TM08	NH 75771 34545	Donor	NH 75450 34600	0.91	0.24
Allt Creag Bheithin Trib 1	A9 1273 C22	TM07	NH 75468 34632	Donor	NH 75450 34600	0.91	0.92
Allt Creag Bheithin Trib 2	A9 1273 C24	TM06	NH 75301 34670	Donor	NH 75450 34600	0.91	0.08
Allt na Slanaich	A9 1273 C28	TM05	NH 75026 34718	Donor	NH 75450 34600	2.36	2.43
Allt Creag Bheithin	MC90 C1	TM04	NH 74908 34786	Donor	NH 74900 34800	2.84	2.84
Allt Creag Bheithin	A9 1273 C31	TM04	NH 74862 34735	Donor	NH 74900 34800	2.84	2.84
Allt Creag Bheithin Trib 3	A9 1273 C40	TM03	NH 74198 34745	Donor	NH 75450 34600	1.61	0.37
Allt Creag Bheithin Trib 4	A9 1273 C43	TM02	NH 74002 34720	Donor	NH 74000 34650	1.26	0.17

Watercourse	Proposed Structure ID	Catchment ID*	Grid Reference	Flow Estimation FEH/ FEH Scaled/Donor	Grid Reference	FEH Area (km^2)	Revised Catchment Area (km^2)
Allt Creag Bheithin	A9 1273 C54	TM01	NH 73216 34777	Donor	NH 74000 34650	1.26	0.25
Allt Creag Bheithin Trib 5	A91273 MCY0 C1	TM30	NH 73904 34596	Donor	NH 74100 34250	0.69	0.99
Midlairgs Burn	A91273 MCY0 C1	TM31	NH 72941 34594	Donor	NH 72950 34550	0.51	0.51
Midlairgs Burn 1	A91273 MCY0 C1	TM32	NH 72640 35009	Donor	NH 72950 34550	0.51	0.19
Midlairgs Burn 2	A91273 MCY0 C1	TM33	NH 72619 35031	Donor	NH 72950 34550	0.51	0.20

Table A.3 Catchment descriptors of delineated catchment areas

Watercourse	Proposed Structure ID	Catchment ID	Flow Estimation FEH/ FEH Scaled/Donor	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST (%)	URBEXT	FPEXT
River Findhorn Trib 1	A9 1240	TM28	Donor	1.000	0.68	0.425	0.89	120.9	951	46.48	0.000	0.0075
Allt na Frithe	A9 1250	TM27	FEH	0.997	0.68	0.472	3.30	100.2	1042	56.23	0.000	0.0163
River Findhorn Trib 2	D5	TM26	Donor	1.000	0.68	0.323	0.78	177.6	1035	53.69	0.000	0.0193
Allt Dubhag	A9 1250 C25	TM25	Donor	1.000	0.68	0.41	2.43	98.8	1007	52.20	0.000	0.0269
River Findhorn Trib 3	D8	TM24	Donor	1.000	0.68	0.323	0.78	177.6	1035	53.69	0.000	0.0193
Funtack Burn Trib 1	DB	TM23	Donor	1.000	0.68	0.323	0.78	177.6	1035	53.69	0.000	0.0193
Dalmagarry Burn Trib 1	DG	TM22	Donor	1.000	0.68	0.425	0.89	120.9	951	46.48	0.000	0.0075
Dalmagarry Burn Trib 2	A9 1250 C85	TM21	Donor	1.000	0.68	0.323	0.53	177.6	1035	53.69	0.000	0.0193
Dalmagarry Burn Trib 2	A9 1250 C85 S	TM21	Donor	1.000	0.68	0.323	0.53	177.6	1035	53.69	0.000	0.0193
Dalmagarry Burn Trib 3	A9 1250 C93	TM21	Donor	1.000	0.68	0.368	0.27	177.6	1035	56.55	0.000	0.0192
Dalmagarry Burn	A9 1260	TM20	FEH	1.000	0.68	0.368	3.13	121.0	1062	56.55	0.000	0.0192
Funtack Burn Trib 2	A9 1260 C25	TM19	Donor	1.000	0.68	0.323	0.28	177.6	1035	53.69	0.000	0.0193
Funtack Burn Trib 2	A9 1260 C25 S	TM19	Donor	1.000	0.68	0.323	0.28	177.6	1035	53.69	0.000	0.0193
Funtack Burn Trib 3	A9 1260 C35	TM18	Donor	1.000	0.68	0.323	0.57	177.6	1035	53.69	0.000	0.0193
Funtack Burn Trib 3	A9 1260 C35 S	TM18	Donor	1.000	0.68	0.323	0.57	177.6	1035	53.69	0.000	0.0193
Funtack Burn Trib 4	A9 1260 C65	TM17	Donor	1.000	0.68	0.323	0.37	177.6	1035	53.69	0.000	0.0193
Funtack Burn Trib 4	A9 1260 C65 S	TM17	Donor	1.000	0.68	0.323	0.37	177.6	1035	53.69	0.000	0.0193
Funtack Burn Trib 5	A9 1260 C94	TM16	Donor	1.000	0.68	0.323	0.48	177.6	1035	53.69	0.000	0.0193
Funtack Burn Trib 6 / 7	A9 1270 C35	TM15	Donor	1.000	0.68	0.323	0.25	177.6	1035	53.69	0.000	0.0193
Funtack Burn Trib 6 / 7	A9 1270 C35 S	TM15	Donor	1.000	0.68	0.323	0.25	177.6	1035	53.69	0.000	0.0193
Funtack Burn Trib 8	A9 1270 C50	TM14	Donor	1.000	0.68	0.323	0.28	177.6	1035	53.69	0.000	0.0193
Funtack Burn Trib 8	A9 1270 C50 S	TM14	Donor	1.000	0.68	0.323	0.28	177.6	1035	53.69	0.000	0.0193
Funtack Burn Trib 9	A9 1270 C60	TM13	Donor	1.000	0.68	0.326	1.11	149.7	1017	53.19	0.000	0.0203

Watercourse	Proposed Structure ID	Catchment ID	Flow Estimation FEH/ FEH Scaled/Donor	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST (%)	URBEXT	FPEXT
Funtack Burn Trib 9	A9 1270 C60 S	TM13	Donor	0.973	0.68	0.326	1.11	149.7	1017	53.19	0.000	0.0203
Caochan na h-Eaglais	A9 1270 C80	TM12	Donor	0.973	0.68	0.326	1.11	149.7	1017	53.19	0.000	0.0203
Caochan na h-Eaglais	A9 1270 C80 S	TM12	Donor	0.973	0.68	0.326	1.11	149.7	1017	53.19	0.000	0.0203
Moy Burn Trib 1	A9 1273 C5	TM11	Donor	1.000	0.68	0.344	1.17	124.5	1027	52.19	0.000	0.0366
Allt na Loinne Moire	A9 1273 C8	TM10	Donor	1.000	0.68	0.484	2.83	116.0	1095	56.97	0.000	0.0236
Moy Burn Trib 2	A9 1273 C18	TM08	Donor	1.000	0.68	0.439	1.21	146.8	1051	54.76	0.000	0.0386
Allt Creag Bheithin Trib 1	A9 1273 C22	TM07	Donor	1.000	0.68	0.439	1.21	147.8	1051	54.75	0.000	0.0386
Allt Creag Bheithin Trib 2	A9 1273 C24	TM06	Donor	1.000	0.68	0.439	1.21	146.8	1051	54.76	0.000	0.0386
Allt na Slanaich	A9 1273 C28	TM05	Donor	1.000	0.68	0.466	2.27	127.8	1091	57.15	0.000	0.0212
Allt Creag Bheithin	MC90 C1	TM04	Donor	1.000	0.68	0.396	1.68	154.5	1020	54.53	0.000	0.0497
Allt Creag Bheithin	A9 1273 C31	TM04	Donor	1.000	0.68	0.396	1.68	154.5	1020	54.53	0.000	0.0497
Allt Creag Bheithin Trib 3	A9 1273 C40	TM03	Donor	1.000	0.68	0.374	1.12	167.5	1012	54.35	0.000	0.042
Allt Creag Bheithin Trib 4	A9 1270 C59	TM02	Donor	1.000	0.68	0.386	1.05	167.4	1016	54.75	0.000	0.0478
Allt Creag Bheithin	A9 1270 C43	TM01	Donor	1.000	0.68	0.386	1.05	167.4	1016	54.77	0.000	0.0478
Allt Creag Bheithin Trib 5	A91273 MCY0 C1	TM30	Scaled	1.000	0.68	0.499	0.74	181.9	1048	57.47	0.000	0.0292
Midlairgs Burn	A91273 MCY0 C1	TM31	Scaled	1.000	0.68	0.484	0.93	150.1	1037	57.67	0.000	0.0146
Midlairgs Burn 1	A91273 MCY0 C1	TM32	Donor	1.000	0.68	0.484	0.93	150.1	1037	57.67	0.000	0.0146
Midlairgs Burn 2	A91273 MCY0 C1	TM33	Donor	1.000	0.68	0.484	0.93	150.1	1037	57.67	0.000	0.0146

A.1.11 Peak flow estimations were derived for each redefined catchment using the same standard FEH methodologies as applied in the Stage 2 DMRB assessment:

- FEH Rainfall Runoff Method
- FEH Statistical Method Approach (where catchment > 5km^2)

A.1.12 ReFH estimates have not been included a part of this assessment as they were discounted at the preliminary assessment as a suitable method of flow estimation. Modifications have only been made to the existing calculations using either the Rainfall Runoff method of the Statistical method.

A.1.13 Table A.4 details the methodology limitations and guidance on appropriate methodologies.

Table A.4: FEH Methodologies and Limits of application

	Return Period Limits	Catchment Area Limits	Urbanisation Limits	Other limits
FEH Statistical Method	50- 0.5% (has been applied up to 0.1%)	Over 0.5km^2 but can be applied to smaller areas	URBEXT$_{1990}$ up to 0.5	Suitable for Permeable catchments
Rainfall Runoff Method	50%-0.5%	0.5 to 1000km^2 but can be applied to smaller areas	URBEXT$_{1990}$ up to 0.5	

Table Source: EA, 2015

A.1.14 Design peak flows were derived from the following return periods; 50%, 20%, 10%, 4%, 3.3%, 2%, 1%, 0.5%, 0.5% including a 20% allowance for climate change and 0.1% Annual Exceedance Probability event.

A.1.15 The Rainfall Runoff method was undertaken for all catchments. The statistical method would only be applied to catchments with an area greater than 5km^2. Two of the catchments were defined to have an area of more than 5km^2. This is consistent with the methodology applied in the preliminary assessment.

A.1.16 The rainfall runoff method uses the FEH DDF (depth duration frequency) model to estimate rainfall totals, these are then distributed according to either a 75% winter or 50% summer profile. They take account of the Catchment Wetness Index (CWI) which is estimated for SAAR (Standard Average Annual Rainfall) and base flow which is calculated using equation 2.19 in the FEH Volume 4. Flows are estimated using the unit hydrograph and losses model. For the design events, the rainfall totals, rainfall profiles, CWI, base flow and unit hydrograph and losses model for each sub-catchment were estimated using FEH boundaries in ISIS 3.7.

A.1.17 Table A.5 details the parameters for the FEH Rainfall Runoff models and Table A.6 details peak flow outputs from the FEH Rainfall Runoff model.

A.1.18 For each of the subject sites the storm duration has been optimised to generate the highest peak flow.

Table A.5: Rainfall Runoff Parameters

Watercourse	Proposed Structure ID	Catchment ID	Rural (R) Urban (U)	Tp (0): Method	Tp Value (hours)	SPR Method	SPR Value (%)	Baseflow Method	Baseflow Value (m^3/s)
River Findhorn Trib 1	A9 1240	TM28	R	CD	2.40	CD	46.48	CD	
Allt na Frithe	A9 1250	TM27	R	CD	5.00	CD	56.23	CD	
River Findhorn Trib 2	D5	TM26	R	CD	1.80	CD	53.69	CD	
Allt Dubhag	A9 1250 C25	TM25	R	CD	4.50	CD	52.20	CD	
River Findhorn Trib 3	D8	TM24	R	CD	1.80	CD	53.69	CD	
Funtack Burn Trib 1	DB	TM23	R	CD	1.80	CD	53.69	CD	
Dalmagarry Burn Trib 1	DG	TM22	R	CD	2.40	CD	46.48	CD	
Dalmagarry Burn Trib 2	A9 1250 C85	TM21	R	CD	1.80	CD	53.69	CD	
Dalmagarry Burn Trib 2	A9 1250 C85 S	TM21	R	CD	1.80	CD	53.69	CD	
Dalmagarry Burn Trib 3	A9 1250 C93	TM21	R	CD	0.57	CD	56.55	CD	
Dalmagarry Burn	A9 1260	TM20	R	CD	1.97	CD	56.55	CD	
Funtack Burn Trib 2	A9 1260 C25	TM19	R	CD	0.81	CD	53.69	CD	
Funtack Burn Trib 2	A9 1260 C25 S	TM19	R	CD	0.81	CD	53.69	CD	
Funtack Burn Trib 3	A9 1260 C35	TM18	R	CD	0.66	CD	53.69	CD	

Watercourse	Proposed Structure ID	Catchment ID	Rural (R) Urban (U)	Tp (0): Method	Tp Value (hours)	SPR Method	SPR Value (%)	Baseflow Method	Baseflow Value (m^3/s)
Funtack Burn Trib 3	A9 1260 C35 S	TM18	R	CD	0.66	CD	53.69	CD	
Funtack Burn Trib 4	A9 1260 C65	TM17	R	CD	0.74	CD	53.69	CD	
Funtack Burn Trib 4	A9 1260 C65 S	TM17	R	CD	0.74	CD	53.69	CD	
Funtack Burn Trib 5	A9 1260 C94	TM16	R	CD	1.80	CD	53.69	CD	
Funtack Burn Trib 6 / 7	A9 1270 C35	TM15	R	CD	1.80	CD	53.69	CD	
Funtack Burn Trib 6 / 7	A9 1270 C35 S	TM15	R	CD	1.80	CD	53.69	CD	
Funtack Burn Trib 8	A9 1270 C50	TM14	R	CD	1.80	CD	53.69	CD	
Funtack Burn Trib 8	A9 1270 C50 S	TM14	R	CD	1.80	CD	53.69	CD	
Funtack Burn Trib 9	A9 1270 C60	TM13	R	CD	1.12	CD	53.19	CD	
Funtack Burn Trib 9	A9 1270 C60 S	TM13	R	CD	1.12	CD	53.19	CD	
Caochan na h-Eaglais	A9 1270 C80	TM12	R	CD	1.12	CD	53.19	CD	
Caochan na h-Eaglais	A9 1270 C80 S	TM12	R	CD	1.12	CD	53.19	CD	
Moy Burn Trib 1	A9 1273 C5	TM11	R	CD	1.22	CD	52.19	CD	
Allt na Loinne Moire	A9 1273 C8	TM10	R	CD	1.98	CD	56.97	CD	
Moy Burn Trib 2	A9 1273 C18	TM08	R	CD	1.17	CD	54.76	CD	

Watercourse	Proposed Structure ID	Catchment ID	Rural (R) Urban (U)	Tp (0): Method	Tp Value (hours)	SPR Method	SPR Value (%)	Baseflow Method	Baseflow Value (m^3/s)
Allt Creag Bheithin Trib 1	A9 1273 C22	TM07	R	CD	1.12	CD	54.76	CD	
Allt Creag Bheithin Trib 2	A9 1273 C24	TM06	R	CD	1.12	CD	54.76	CD	
Allt na Slanaich	A9 1273 C28	TM05	R	CD	1.66	CD	57.17	CD	
Allt Creag Bheithin	MC90 C1	TM04	R	CD	1.32	CD	54.53	CD	
Allt Creag Bheithin	A9 1273 C31	TM04	R	CD	1.32	CD	54.53	CD	
Allt Creag Bheithin Trib 3	A9 1273 C40	TM03	R	CD	1.03	CD	54.36	CD	
Allt Creag Bheithin Trib 4	A9 1270 C59	TM02	R	CD	1.04	CD	54.77	CD	
Allt Creag Bheithin	A9 1270 C43	TM01	R	CD	1.04	CD	54.77	CD	
Allt Creag Bheithin Trib 5	A91273 MCY0 C1	TM30	R	CD	0.85	CD	57.47	CD	
Midlairgs Burn	A91273 MCY0 C1	TM31	R	CD	0.92	CD	57.67	CD	
Midlairgs Burn 1	A91273 MCY0 C1	TM32	R	CD	0.83	CD	57.67	CD	
Midlairgs Burn 2	A91273 MCY0 C1	TM33	R	CD	1.04	CD	57.67	CD	

Table A.6: Rainfall Runoff calculated flows

Watercourse	Propsoed Structure ID	Catchment ID	Critical Storm Duration (hours)	50%	20%	10%	4%	3.3%	2%	1%	0.5%	0.5% including CC	0.1%
River Findhorn Trib 1	A9 1240	TM28	2.2	0.67	0.99	1.20	1.50	1.56	1.80	2.10	2.46	2.95	3.63
Allt na Frithe	A9 1250	TM27	4.9	5.06	7.26	8.64	10.99	11.45	12.94	14.86	17.14	20.57	24.46
River Findhorn Trib 2	D5	TM26	1.9	0.25	0.38	0.46	0.58	0.61	0.69	0.81	0.95	1.14	1.41
Allt Dubhag	A9 1250 C25	TM25	4.3	2.21	3.19	3.81	4.83	5.05	5.73	6.60	7.65	9.18	11.02
River Findhorn Trib 3	D8	TM24	1.9	0.07	0.10	0.12	0.15	0.15	0.17	0.21	0.24	0.29	0.36
Funtack Burn Trib 1	DB	TM23	1.9	0.14	0.21	0.26	0.32	0.34	0.38	0.45	0.53	0.63	0.78
Dalmagarry Burn Trib 1	DG	TM22	2.3	0.88	1.30	1.56	1.95	2.03	2.34	2.73	3.20	3.84	4.72
Dalmagarry Burn Trib 2	A9 1250 C85	TM21	1.9	0.50	0.75	0.91	1.14	1.18	1.35	1.58	1.85	2.22	2.73
Dalmagarry Burn Trib 2	A9 1250 C85 S	TM21	1.9	0.50	0.75	0.91	1.14	1.18	1.35	1.58	1.85	2.22	2.73
Dalmagarry Burn Trib 3	A9 1250 C93	TM20a	1.2	0.18	0.27	0.33	0.42	0.44	0.49	0.57	0.68	0.81	1.02
Dalmagarry Burn	A9 1260	TM20	4.1	7.83	11.31	13.50	17.07	17.81	20.18	23.24	26.88	32.25	38.59
Funtack Burn Trib 2	A9 1260 C25	TM19	1.6	0.14	0.28	0.34	0.42	0.44	0.50	0.59	0.69	0.83	1.03
Funtack Burn Trib 2	A9 1260 C25 S	TM19	1.6	0.14	0.28	0.34	0.42	0.44	0.50	0.59	0.69	0.83	1.03
Funtack Burn Trib 3	A9 1260 C35	TM18	1.3	0.57	0.85	1.03	1.30	1.36	1.53	1.80	2.12	2.54	3.15
Funtack Burn Trib 3	A9 1260 C35 S	TM18	1.3	0.57	0.85	1.03	1.30	1.36	1.53	1.80	2.12	2.54	3.15
Funtack Burn Trib 4	A9 1260 C65	TM17	1.5	0.28	0.41	0.50	0.63	0.66	0.75	0.88	1.03	1.24	1.53
Funtack Burn Trib 4	A9 1260 C65 S	TM17	1.5	0.28	0.41	0.50	0.63	0.66	0.75	0.88	1.03	1.24	1.53
Funtack Burn Trib 5	A9 1260 C94	TM16	1.9	0.43	0.64	0.78	0.98	1.02	1.15	1.35	1.59	1.91	2.36
Funtack Burn Trib 6 / 7	A9 1270 C35	TM15	1.9	0.15	0.23	0.28	0.36	0.37	0.42	0.49	0.58	0.69	0.86
Funtack Burn Trib 6 / 7	A9 1270 C35 S	TM15	1.9	0.15	0.23	0.28	0.36	0.37	0.42	0.49	0.58	0.69	0.86
Funtack Burn Trib 8	A9 1270 C50	TM14	1.9	0.18	0.27	0.33	0.41	0.43	0.48	0.57	0.67	0.80	1.00
Funtack Burn Trib 8	A9 1270 C50 S	TM14	1.9	0.18	0.27	0.33	0.41	0.43	0.48	0.57	0.67	0.80	1.00
Funtack Burn Trib 9	A9 1270 C60	TM13	2.5	0.12	0.18	0.22	0.27	0.28	0.32	0.38	0.44	0.33	0.65
Funtack Burn Trib 9	A9 1270 C60 S	TM13	2.5	0.12	0.18	0.22	0.27	0.28	0.32	0.38	0.44	0.33	0.65
Caochan na h-Eaglais	A9 1270 C80	TM12	2.5	0.08	0.11	0.14	0.17	0.18	0.21	0.24	0.28	4.28	0.41
Caochan na h-Eaglais	A9 1270 C80 S	TM12	2.5	0.08	0.11	0.14	0.17	0.18	0.21	0.24	0.28	4.28	0.41
Moy Burn Trib 1	A9 1273 C5	TM11	2.5	0.92	1.36	1.64	2.05	2.14	2.45	2.85	3.34	3.82	4.90
Allt na Loinne Moire	A9 1273 C8	TM10	4.3	2.81	4.05	4.84	6.12	6.38	7.24	8.34	9.65	11.60	13.88
Moy Burn Trib 2	A9 1273 C18	TM08	2.5	0.32	0.45	0.54	0.68	0.71	0.81	0.94	1.10	1.32	1.61
Allt Creag Bheithin Trib 1	A9 1273 C22	TM07	2.5	1.22	1.72	2.07	2.60	2.70	3.09	3.60	4.20	5.04	6.16
Allt Creag Bheithin Trib 2	A9 1273 C24	TM06	2.5	0.10	0.14	0.17	0.21	0.22	0.25	0.30	0.35	0.42	0.51
Allt na Slanaich	A9 1273 C28	TM05	3.7	2.71	3.76	4.51	5.66	5.91	6.73	7.77	9.02	10.82	13.04
Allt Creag Bheithin	MC90 C1	TM04	2.9	2.26	3.16	3.80	4.74	4.93	5.65	6.56	7.65	9.17	11.15
Allt Creag Bheithin	A9 1273 C31	TM04	2.9	2.26	3.16	3.80	4.74	4.93	5.65	6.56	7.65	9.17	11.15
Allt Creag Bheithin Trib 3	A9 1273 C40	TM03	2.3	0.50	0.71	0.86	1.07	1.12	1.27	1.48	1.73	2.08	2.55

Watercourse	Propsoed Structure ID	Catchment ID	Critical Storm Duration (hours)	50%	20%	10%	4%	3.3%	2%	1%	0.5%	0.5% including CC	0.1%
Allt Creag Bheithin Trib 4	A9 1270 C59	TM02	2.1	0.24	0.33	0.40	0.51	0.53	0.60	0.70	0.82	0.98	1.21
Allt Creag Bheithin	A9 1270 C43	TM01	2.1	0.35	0.49	0.59	0.74	0.77	0.87	1.02	1.20	1.43	1.76
Allt Creag Bheithin Trib 5	A91273 MCY0 C1	TM30	1.7	1.63	2.34	2.85	3.60	3.76	4.25	4.94	5.83	6.99	8.70
Midlairgs Burn	A91273 MCY0 C1	TM31	1.9	0.81	1.14	1.37	1.72	1.79	2.04	2.37	2.77	3.32	4.05
Midlairgs Burn 1	A91273 MCY0 C1	TM32	1.7	0.31	0.45	0.54	0.69	0.72	0.81	0.94	1.11	1.33	1.65
Midlairgs Burn 2	A91273 MCY0 C1	TM33	2.1	0.29	0.41	0.49	0.62	0.65	0.73	0.86	1.01	1.21	1.50

A.1.19 The statistical method uses an index flood, the median annual flood (QMED). This is multiplied by a growth curve factor to obtain a flood frequency curve. The flood frequency curve is based on a sample of at least 500 years of data from catchments identified as being similar to the subject site. All calculations were undertaken using WINFAP FEH 3 software and are recorded in a FEH Calculation Record.

A.1.20 The statistical method has been completed for the following watercourse crossings, as these have catchment areas greater than $5km^2$ and the methodology is considered appropriate.

- A9 1250
- A9 1260

A.1.21 Donor catchments were sought to improve the QMED estimates. Table A.7 details the donor catchment which was considered.

Table A.7: Information of donor catchment

NRFA Number	Name	Reason for Choosing or Rejecting	Method for Estimating QMED	QMED from Flow (A)	QMED from Catchment Descriptors (B)	Adjustment Ratio
7001	Findhorn @ Shenachie	Accepted as a donor for A9 1250, and A9 1260. Gauge is located downstream of the subject site.	AM	284.08	151.42	1.64

A.1.22 The initial QMED has been estimated from catchment descriptors using the equation below, as recommended in EA Science Report: SC50050 Improving the FEH statistical procedures for flood estimation.

$$QMED = 8.3062\ xAREA^{0.8510}\ x0.1536^{\frac{1000}{SAAR}}\ x\ FARL^{3.4451}x\ 0.0460^{BFIHOST}$$

A.1.23 Table A.8 details the initial QMED estimate including any adjustments to determine the Final QMED. The URBEXT2000 has been updated based on equation below.

$$UEF = 0.7851 + 0.2124\ tan -1\{\frac{year - 1967.5}{20.32})\}$$

Table A.8: Initial QMED Estimate

Proposed Structure ID	Watercourse	Catchment ID	Initial QMED Estimate	Donor Site	Final Estimate of QMED (m3/s)
A9 1250	Allt na Frithe	TM27	3.06	7001	3.73
A9 1260	Dalmagarry Burn	TM20	5.74	7001	6.92

A.1.24 For each subject site pooling groups were derived using the WINFAP-FEH 3 software, with version 3.3.4 WINFAP files. A target of 500 years was used for each pooling group. Each default pooling group was reviewed and Table A.9 details the changes that were made.

Table A.9: Pooling group details

Proposed Structure ID	Watercourse	Catchment ID	Changes made to the default pooling group	Weighted average L-CV & L-SKEW
A9 1250	Allt na Frithe	TM27	49006 – Station removed: Discordant, negative L-skew and 6 years of data 47002 – Station removed: FARL 0.942 206006 – Station removed: Discordant 91802 – Station removed: SAAR high (2555) 54022 – Station removed: SAAR high (2483) 48009 – Station removed: Discordant and negative L-skew Sites removed to bring length of record to 535 years	L-CV - 0.261 L- Skew – 0.293
A9 1260	Dalmagarry Burn	TM20	49006 – Station removed: Discordant, negative L-skew and 6 years of data 47002 – Station removed: FARL 0.942 206006 – Station removed: Discordant 48009 – Station removed: Discordant and negative L-skew 54022 – Station removed: SAAR high (2483) Sites removed to bring length of record to 500 years	L-CV - 0.266 L- Skew – 0.289

A.1.25 All the sites are essentially rural and no urban adjustments were made. Table shows the distribution applied to generate the growth curve parameters and Table A.1110 shows the peak flow estimated.

Table A.10: Derivation of Flood Growth Curves

Watercourse	Proposed Strucure ID	Catchment ID	Distribution used and reason for choice	Note Permeable or Urban adjustment	Parameters	Growth factor for 100 year return period
Allt na Frithe	A9 1250	TM27	GL – Provides the best fit and is recommended for UK catchments.	N/A	Location: 1.00 Scale:0.255 Shape: --0.301	3.49
Dalmagarry Burn	A9 1260	TM20	GL – Provides the best fit and is recommended for UK catchments.	N/A	Location: 1.00 Scale: 0.0.263 Shape: -0.289	3.53

Table A.11: Peak flows derived from pooling groups

Watercourse	Proposed Structure ID	Catchment ID*	50%	20%	10%	4%	3.3%	2%	1%	0.5%	0.5% including CC
Allt na Frtihe	A9 1250	TM27	3.06	4.40	5.48	7.18	7.57	8.76	10.67	13.00	15.60
Dalmagarry Burn	A9 1260	TM20	5.74	8.31	10.37	13.60	14.34	16.60	20.23	24.64	29.56

A.1.26 The Rainfall Runoff method has been applied to catchments that are <5km^2. This applied to 30 of the delineated catchment areas. Where the catchment area was <0.5km^2, a suitable donor catchment with similar catchment characteristics was identified and scaled to fit the subject catchment. The statistical method was applied to the two catchments identified as being >5km^2 which was considered the most suitable method of flow estimation for these catchments.

A.2 Modelling Approach

A.2.1 Unsteady one-dimensional (1D) hydraulic models were built for each proposed watercourse crossing using the Flood Modeller modelling software. The purpose of the models was to ensure each of the proposed culverts had a 1 in 200 year flow capacity plus a suitable allowance for climate change and freeboard to assess the resultant magnitude of impacts downstream.

A.2.2 Representative channel cross sections were extracted from existing topographic data (BLOM Ortho Topo). Culvert dimensions were designed to consider the existing watercourse dimensions, the requirements for mammal passage, the 1 in 200 year flow conveyance and limitations due to the existing ground levels and proposed carriageway levels.

A.2.3 Mammal passages are required within a number of culverts to meet the requirements of the DMRB criteria.

A.2.4 The surface roughness of bank and bed materials have been represented in the hydraulic model using Manning's 'n' parameter.

A.2.5 The bed of the modelled watercourses is typically characterised by a stony substrate with some instream vegetation. Therefore, a Manning's roughness value of 0.045 has been used for this sub-reach of the model.

A.2.6 The floodplains and top of bank areas associated with the watercourses are typically characterised by long grass / heather, therefore the same Manning's 'n' value of 0.045 has been assigned to them.

A.2.7 For the concrete culverts passing under the A9, a Manning's 'n' roughness value of 0.035 and 0.020 has been used to represent the invert and the soffit respectively.

A.2.8 For the corrugated culverts, a Manning's roughness value of 0.035 and 0.020 has been used to represent the invert and soffit of the culvert respectively.

A.2.9 An unsteady state FEH (FEHBDY) boundary was used as the upstream boundary. This was based on the adjusted catchment descriptors based from Table A.3.

A.2.10 A normal depth boundary was used at the downstream extent of the model reach. This is based on the flow-stage rating relationship generated by the ISIS river sections for the furthest downstream section.

A.2.11 A sensitivity analysis was carried out to assess the possible impact of variation in critical design parameters on the modelled peak flood levels. This is a standard validation exercise in hydraulic modelling as it quantifies the degree to which assumed values can impact on model results. The variables selected for sensitivity testing were:

- Downstream Boundary sensitivity (+20% on stage at downstream boundary).
- Roughness sensitivity (+/- 20% adjustment to roughness within culverts only and +/- % global roughness adjustment).
- Inflow sensitivity (+/- 20% inflow).
- Blockage Sensitivity (up to 50% blockage scenario).

Annex B. Floodplain Assessments - 1D-2D Hydrodynamic Models

B.1 Approach

B.1.1 The open channel river sections were defined from the AMJV topographical survey, which was completed in March 2016 or the Loy Surveys topographical survey completed in September 2016.

B.1.2 The Manning's 'n' roughness coefficient values were based on a visual inspection during site visits and defined in accordance with values depicted in 'Open Channel Hydraulics' (Chow, 1959). Table B.1 details the Manning's range applied.

Table B.1: Manning's values assigned to channel section within the model

River Reach	River Channel Manning's 'n' values
Moy Burn	0.040
Allt Creag Bhethin	0.040
Allt Na Slanaich	0.040
Funtack Burn	0.032 - 0.035
Dalmagarry Burn	0.035 – 0.040
Allt na Frithe	0.035 – 0.040
River Findhorn	0.035 – 0.040

B.2 Floodplains

B.2.1 The floodplains have been defined using the NextMap DTM. Where additional topographical data has been available the ground model has been updated to improve the resolution. A representative 2D domain was generated to represent the floodplains.

B.2.2 The Manning's 'n' roughness coefficient values were based on a visual inspection during site visits and defined in accordance with values depicted in 'Open Channel Hydraulics' (Chow, 1959). Table B.2 details the Manning's range applied.

Table B.2: Manning's values assigned within floodplain areas of the model

River Reach	Bank / Floodplain Manning's 'n' values
Moy Burn	0.040 – 0.050
Allt Creag Bheithin	0.035 – 0.055
Allt Na Slanaich	0.045 – 0.055
Funtack Burn	0.040 – 0.055
Dalmagarry Burn	0.045 – 0.060
Allt na Frithe	0.040 – 0.060
River Findhorn	0.040 – 0.060

B.3 Structures

B.3.1 The culverts were represented using standard conduit units and upstream/ downstream culvert Inlet / Outlet units. Values of Manning's for the culverts were split into an "upper half" and a "lower half",

B.3.2 For the circular and rectangular culverts, the "upper" and "lower" values of the concrete culverts were assigned Manning's roughness values of 0.035 and 0.020 respectively and corrugated culverts were assigned Manning's values of 0.035 and 0.020 respectively. Higher values were used on the lower half of the culverts to represent bed material and any organic growth commonly found within hydraulic structures.

B.3.3 For the symmetrical culverts, the Colebrook White Friction value appropriate for concrete conduits was applied. The upper and lower values assigned to the concrete culverts were 0.15m and 0.0015m.

B.3.4 Bridges were represented using either USBPR1978, arch bridge units or culvert units, depending on the geometry and dimension of the structures. All bridges, regardless of their representation in the model have inline spill units attached to represent overtopping.

B.3.5 The exceptions to this is where a structure is of such a large dimension that the calculated flows, for the 1000 year return period, result in the stage at the structure registering well below the soffit.

B.3.6 The structures included in the hydraulic modelling are presented in the Table B.3.

Table B.3: Details of structures included within floodplain model

Figure reference	Watercourse	Structure	Dimensions (m)	Representation in the model	Photograph
1	Allt Creag Bhethin	A9 1273 C31 Culvert passing under A9	N/A Open Channel	Open channel to represent bridge structure with sufficient capacity to convey the 0.5% Plus CC	
2	Allt na Slanaich	A9 1273 C28 Culvert passing under A9	N/A Open Channel	Open channel to represent bridge structure with sufficient capacity to convey the 0.5% plus CC	
3	Allt Creag Bheithin Trib 2	A9 1273 C24 Culvert passing under A9	1.2 Ø	ESTRY culvert in the 2D model. Overtopping of road was represented in the 2D model.	

Figure reference	Watercourse	Structure	Dimensions (m)	Representation in the model	Photograph
4	Allt Creag Bheithin Trib 1	A9 1273 C22 Culvert passing under A9	2.5 Ø	ESTRY culvert in the 2D model. Overtopping of road was represented in the 2D model.	
5	Allt Creag Bhethin	Bridge passing under the railway	7.5 x 37	Bridge unit in ISIS. Overtopping of road was represented in the 2D model.	
6	Allt Creag Bhethin	Bridge passing under small road	1.4 x 5.0	Bridge unit in ISIS. Overtopping of road was represented in the 2D model.	
7	No water crossing / Underpass	Bridge passing under the railway	4.3 x 5	ESTRY culvert in the 2D model. Overtopping of road was represented in the 2D model.	
8	Moy Burn	Bridge passing under small road	2.3 x 10	Bridge unit in ISIS. Overtopping of road was represented in the 2D model.	
9	Moy Burn	Bridge passing under small road	2.5 x 7	Bridge unit in ISIS. Overtopping of road was represented in the 2D model.	
10	Moy Burn	Bridge passing under small road	2.5 x 7	Bridge unit in ISIS. Overtopping of road was represented in the 2D model.	

Figure reference	Watercourse	Structure	Dimensions (m)	Representation in the model	Photograph
11	Funtack Burn	Bridge passing under small road	2.3 x 8.5	Bridge unit in ISIS. Overtopping of road was represented in the 2D model.	
12	Dalmagarry	Railway Bridge passing under railway	8.5 x 14	Bridge unit in ISIS.	
12	Dalmagarry Burn	A9 1260 Bridge passing under A9	N/A Open Channel	Open channel to represent bridge structure with sufficient capacity to convey the 0.5% Plus CC	
13	Millennium	Culvert passing under the railway	0.5 x 0.7	ESTRY culvert in the 2D model. Overtopping of road was represented in the 2D model.	
17	Millennium Funtack Burn Trib 2	A9 1260 C25 Culvert passing under A9	1.2 x 1.2	ESTRY culvert in the 2D model. Overtopping of road was represented in the 2D model.	
18	Funtack Burn	Arch Bridge passing under small road	2.5 x 10	Bridge unit in ISIS. Overtopping of road was represented in the 2D model.	
19	Allt na Frithe	A9 1250 Culvert passing under A9	N/A Open Channel	Open channel to represent bridge structure with sufficient capacity to convey the 0.5% Plus CC	

B.4 Sensitivity Analysis

B.4.1 A sensitivity analysis was carried out to assess the possible impact of variation in critical design parameters on the modelled peak flood levels. This is a standard validation exercise in hydraulic modelling as it quantifies the degree to which assumed values can impact on model results.

B.4.2 The 1D/2D hydraulic models have been checked in terms of parameter sensitivity to determine the response / stability of the model for changes in roughness and downstream boundary conditions. The variables selected for sensitivity testing were:

- Channel and floodplain roughness coefficients (adjusted - 20%).
- Channel and floodplain roughness coefficients (adjusted + 20%).
- Downstream Boundary stage increased by 20% relative to the depth.

B.4.3 The sensitivity testing was undertaken using the 0.5%AEP event.

B.5 2D Hydrology

B.5.1 Hydrology schematisation was undertaken to delineate catchments for identified inflow boundaries within the model reach. Catchment area delineation was undertaken using FEH CD-ROM (version 3), topographic survey data and Ordnance Survey mapping and is shown in Figure A11.2.2.

B.5.2 The downstream boundary of the model is located approximately 550 m downstream of the Shenachie flow gauge (7001) on the River Findhorn. The identified sub-catchments are summarised in Table B.4.

Table B.4: Hydrological sub catchments

Catchment ID	Watercourse	Description	Grid Reference	Area (km^2)
C1	Moy Burn	Upstream of Allt Greag Bheithin (north of A9)	NH 76150 35050	25
C2	Allt Creag Bheithin	Upstream of Moy Burn (south of A9)	NH 75000 34850	2.8
C3	Allt na Slanaich	Upstream of Allt Greag Bheithin (south of A9)	NH 75050 34800	2.4
C4	Dalmagarry Burn	Upstream of Funtack Bridge (south of A9)	NH 79500 32000	9.2
C5	Allt na Frithe	Upstream of River Findhorn (south of A9)	NH 80700 32500	5.8
C6	River Findhorn	Upstream of Allt na Frithe (south of A9)	NH 80750 32350	339
C6_4	River Findhorn	Forres	NJ 01800 58350	781.7

B.5.3 Any area adjacent to the watercourses that are unaccounted for in the inflow delineation are defined as lateral inflows within the model. The lateral inflow catchments are summarised in Table B.5.

Table B.5: Lateral inflow catchments

Catchment ID	Watercourse	Description	Inflow Grid Reference	Area (km^2)
C1_1	Loch Moy	North of A9	NH 78450 33540	5.3

Catchment ID	Watercourse	Description	Inflow Grid Reference	Area (km²)
C1_2	Loch Moy	South of A9	NH 76370 34290	4.6
C1_3	Funtack Burn	Upstream of Dalmagarry Burn (north of A9)	NH 79670 32020	5.0
C1_4	Funtack Burn	South of A9	NH 78100 32920	0.83
C1_5	Funtack Burn	Upstream of River Findhorn and downstream Dalmagarry junction (north of A9)	NH 80730 32530	1.6
C2_1	Allt Greag Bheithin	Downstream of Allt na Slanaich (north of A9)	NH 76170 35000	0.80
C2_2	Allt Greag Bheithin	Upstream of Moy Burn (south of A9)	NH 75460 34640	1.2
C6_1	River Findhorn	Downstream of Funtack Burn (north of A9)	NH 81050 81810 32420	3.0
C6_2	River Findhorn	Upstream of Funtack Burn (north of A9)	NH 82900 33980	5.6
C6_3	River Findhorn	Between Dalmagarry Burn and Allt na Frithe (south of A9)	NH 79360 30530	2.9

B.5.4 A schematic of the delineated sub-catchments and lateral inflow catchments is provided in Figure A11.2.8a-c.

B.5.5 Check catchments have been identified at key locations for design flow estimation. This allows for a comparison to be made between the estimated flow values at each check catchment and the routed flows within the hydraulic model.

B.5.6 At each of the check catchments, design flows have been estimated using the standard FEH estimation methods. The estimated flow values at each check catchment have been compared to the routed design flows within the hydraulic model.

B.5.7 Four check catchments have been identified within the study catchment and the locations are detailed in Table B.6.

Table B.6: Hydrological check catchments

Watercourse	Description	Grid Reference	Area (km²)
Allt Creag Bheithin	Upstream of Moy Burn (south of A9)	NH 76150 35000	7.2
Dalmagarry Burn	Upstream of Funtack Bridge (south of A9)	NH 79500 32000	9.2
Funtack Burn	Downstream of Dalmagarry Burn	NH 79600 32000	56.1
River Findhorn	Upstream of Allt na Frithe confluence	NH 72140 30100	340.3

B.5.8 At each of the check catchments, design flows have been estimated using the FEH statistical method. The estimated flow values at each check catchment have been compared to the routed flows within the hydraulic model. It is important to ensure the routed flows at those locations are consistent with the independent flow estimates for those same locations.

B.5.9 The Flood Estimation Handbook (FEH) provides the two main approaches to flood frequency estimation in the UK: the rainfall runoff method and statistical analysis. The rainfall runoff method has been used to generate hydrographs for input to the hydraulic model, whilst statistical estimates have been generated at each check catchment in order to check estimates of peak flows for each return period.

B.6 Flow Estimation

FEH Rainfall Runoff

The rainfall runoff method uses the FEH DDF (depth duration frequency) model to estimate rainfall totals, these are then distributed according to either a 75% winter or 50% summer profile. They take account of the Catchment Wetness Index (CWI) which is estimated for SAAR (Standard Average Annual Rainfall) and base flow which is calculated using equation 2.19 in the FEH Volume 4. Flows are estimated using the unit hydrograph and losses model. For the design events, the rainfall totals, rainfall profiles, CWI, base flow and unit hydrograph and losses model for each sub-catchment were estimated using FEH boundaries in ISIS 3.7.

B.6.1 Catchment descriptors for each direct inflow, lateral inflow and POI were entered into ISIS FEH boundary units (FEHBDY) and hydrographs were generated for the 1 in 200 year design flows and in 1 in 200 year design flow plus an allowance for climate change.

B.6.2 Table B.7B.7 provides the peak flow outputs from the FEH Rainfall Runoff model.

B.6.3 For each of the subject sites the storm duration has been optimised to generate the highest peak flow.

Table B.7: Rainfall Runoff peak flows

Inflow ID	Inflow Type	Watercourse	Critical Storm Duration (hours)	0.5%	0.5% including CC
C1	Direct	Moy Burn	6.53	57.15	68.58
C2	Direct	Allt Creag Bheithin	2.85	11.08	13.30
C3	Direct	Allt na Slanaich	3.74	8.66	10.40
C4	Direct	Dalmagarry Burn	4.06	30.90	37.08
C5	Direct	Allt na Frithe	4.52	18.04	21.64
C6	Direct	River Findhorn	13.43	602.11	722.54
C6_4	Direct	River Findhorn	13.43	840.91	1009.10
C2_1	Lateral	Allt Greag Bheithin	2.85	3.30	3.96
C2_2	Lateral	Allt Greag Bheithin	2.81	5.09	6.11
C1_1	Lateral	Loch Moy	4.39	18.69	22.43
C1_2	Lateral	Loch Moy	4.39	16.13	19.35
C1_3	Lateral	Funtack Burn	3.38	15.01	18.02
C1_4	Lateral	Funtack Burn	2.37	4.25	5.09
C1_5	Lateral	Funtack Burn	3.12	5.16	6.19
C6_1	Lateral	River Findhorn	3.15	8.03	9.64
C6_2	Lateral	River Findhorn	2.42	18.04	21.65
C6_3	Lateral	River Findhorn	2.42	9.11	10.93

FEH Statistical Method

The statistical method uses an index flood, the median annual flood (QMED). This is multiplied by a growth curve factor to obtain a flood frequency curve. The flood frequency curve is based on a sample of at least 500 years of data from catchments identified as being similar to the subject site. All calculations were undertaken using WINFAP FEH 3 software and are recorded in a FEH Calculation Record.

B.6.4 The statistical method has been completed for the following watercourse crossings, as these have catchment areas greater than $5km^2$ and the methodology is considered appropriate.

- C1
- C4
- C5
- C6
- C6_4

B.6.5 Donor catchments were sought to improve the QMED estimates. Table B.8 details the donor catchment which was considered.

Table B.8: Donor catchments

NRFA Number	Name	Reason for Choosing or Rejecting	Method for Estimating QMED	QMED from Flow (A)	QMED from Catchment Descriptors (B)	Adjustment Ratio
7001	Findhorn @ Shenachie	Accepted as a donor for all POI's.	AM	284.08	151.42	1.64
7002	Findgorn @ Forres		AM	356.203	211.162	1.687

B.6.6 The initial QMED has been estimated from catchment descriptors using the equation below, as recommended in EA Science Report: SC50050 Improving the FEH statistical procedures for flood estimation.

$$QMED = 8.3062\ x AREA^{0.8510}\ x 0.1536^{\frac{1000}{SAAR}}\ x\ FARL^{3.4451} x\ 0.0460^{BFIHOST}$$

B.6.7 Table B.9 details the initial QMED estimate including any adjustments to determine the Final QMED. The URBEXT2000 has been updated based on equation below.

$$UEF = 0.7851 + 0.2124\ tan\ -1\{\frac{year - 1967.5}{20.32})\}$$

Table B.9: Initial QMED estimates

Inflow ID	Watercourse	Initial QMED Estimate	Donor Site	Final Estimate of QMED (m3/s)
C1	Moy Burn	10.01	7002	12.31
C4	Dalmagarry Burn	6.02	7002	7.48
C5	Allt na Frithe	3.08	7002	3.84
C6	River Findhorn	145.61	7001	200.61

Inflow ID	Watercourse	Initial QMED Estimate	Donor Site	Final Estimate of QMED (m3/s)
C6_4	River Findhorn @ Forres	211.162	7001	254.61

B.6.8 For each subject site pooling groups were derived using the WINFAP-FEH 3 software, with version 3.3.4 WINFAP files. A target of 500 years was used for each pooling group. Each default pooling group was reviewed and Table B.10 details the changes that were made.

Table B.10: Details of changes made to pooling groups

Inflow ID	Watercourse	Changes made to the default pooling group	Weighted average L-CV & L-SKEW
C1	Moy Burn	44008 – Station removed: High growth curve 44013 – Station removed: High growth curve 22003 – Station removed: High growth curve 47021 – Station removed: High discordancy 48009 – Station removed: Negative skew 28058 – Station removed: Negative skew Sites removed to bring length of record to 536 years	L-CV - 0.194 L- Skew – 0.170
C4	Dalmagarry Burn	49006 – Station removed: few years data, negative skew and discordant 47022 – Station removed: FARL = 0.942 26802 – Station removed: High BFIHOST 44008 – Station removed: High BFIHOST 48009 – Station removed: Negative skew and discordant Sites removed to bring length of record to 545 years	L-CV - 0.248 L- Skew – 0.270
C5	Allt na Frithe	49006 – Station removed: few years data, negative skew and discordant 47022 – Station removed: FARL = 0.942 26802 – Station removed: High BFIHOST 44008 – Station removed: High BFIHOST 91802 – Station removed: High SAAR 54022 – Station removed: High SAAR 48009 – Station removed: Negative skew and discordant	L-CV - 0.248 L- Skew – 0.276

Inflow ID	Watercourse	Changes made to the default pooling group	Weighted average L-CV & L-SKEW
		Sites removed to bring length of record to 537 years	
C6	River Findhorn	77003 – Station removed: Negative skew 23006 – Station removed: Low BFIHOST 202001 – Station removed: Low growth curve 15010 – Station removed: Low FARL 83005 – Station removed: High URBEXT Sites removed to bring length of record to 510 years	L-CV - 0.248 L- Skew – 0.276
C6_4	River Findhorn @ Forres	27089 – Station removed: Discordant and High URBEXT Sites removed to bring length of record to 550 years	L-CV - 0.248 L- Skew – 0.276

B.6.9 All the sites are essentially rural and no urban adjustments were made Table B.10 shows the distribution applied to generate the growth curve and the parameters. Table B.11 shows the peak flow estimated.

Table B.11: Peak flow estimates from pooling groups

Inflow ID	Inflow Type	Watercourse	0.5%	0.5% including CC
C1	Direct	Moy Burn	32.94	39.53
C4	Direct	Dalmagarry Burn	29.15	34.98
C5	Direct	Allt na Frithe	15.11	18.14
C6	Direct	River Findhorn	456.73	548.07
C6_4	Direct	River Findhorn @ Forres	828.56	994.28

B.6.10 Hydrological Check Catchments

FEH statistical analysis was undertaken at each of the check catchment locations to determine peak flows for a range of return periods.

B.6.11 Donor catchments were identified to improve the QMED estimates. Table B.12 provides details of the donor catchments which were considered.

Table B.12: Donor catchments

NRFA Number	Name	Reason for Choosing or Rejecting	Method for Estimating QMED	QMED from Flow (A)	QMED from Catchment Descriptors (B)	Adjustment Ratio
7001	Findhorn @ Shenachie	Accepted as a donor for all check catchments	AM	284.08	151.42	1.64
7002	Findgorn @ Forres		AM	356.203	211.162	1.687

B.6.12 The initial QMED has been estimated from catchment descriptors using the equation below, as recommended in EA Science Report: SC50050 Improving the FEH statistical procedures for flood estimation.

$$QMED = 8.3062\ xAREA^{0.8510}\ x0.1536^{\frac{1000}{SAAR}}\ x\ FARL^{3.4451} x\ 0.0460^{BFIHOST}$$

B.6.13 Table B.13 details the initial QMED estimate including any adjustments to determine the Final QMED. The URBEXT2000 has been updated based on equation below.

$$UEF = 0.7851 + 0.2124\ tan\ -1\{\frac{year - 1967.5}{20.32})\}$$

Table B.13: Initial QMED estimates

Watercourse	Initial QMED Estimate	Donor Site	Final Estimate of QMED (m3/s)
Allt Greag Bheithin	4.53	7001	5.16
Dalmagarry Burn	6.02	7001	7.37
Funtack Burn	14.83	7001	17.87
River Findhorn	145.61	7001	200.58

B.6.14 For each subject site pooling groups were derived using the WINFAP-FEH 3 software, with version 3.3.4 WINFAP files. A target of 500 years was used for each pooling group. Each default pooling group was reviewed and Table B.14 details the changes that were made.

Table B.14: Details of pooling groups

Watercourse	Changes made to the default pooling group	Weighted average L-CV & L-SKEW
Allt Creag Bheithin	49006 – Station removed: discordant and 6 years of data 47022 – Station removed: FARL= 0.942 54022 – Station removed: High SAAR 91802 – Station removed: High SAAR Sites removed to bring length of record to 548 years	L-CV - 0.261 L- Skew – 0.272
Dalmagarry Burn	49006 – Station removed: discordant, 6 years of data and negative skew 47022 – Station removed: FARL = 0.942 26802 – Station removed: High BFIHOST 44008 – Station removed: High BFIHOST 48009 – Station removed: Discordant and negative skew Sites removed to bring length of record to 545 years	L-CV - 0.248 L- Skew – 0.27
Funtack Burn	42011 – Station removed: High URBEXT value Sites removed to bring length of record to 513 years	L-CV - 0.241 L- Skew – 0.244
River Findhorn	77003 – Station removed: Negative skew 23006 – Station removed: Low BFIHOST	L-CV - 0.161 L- Skew – 0.141

Watercourse	Changes made to the default pooling group	Weighted average L-CV & L-SKEW
	202001 – Station removed: Low growth curve 55016 – Station removed: Negative skew 15010 – Station removed: Low FARL 83005 – Station removed: High URBEXT Sites removed to bring length of record to 545 years	

B.6.15 All the sites are essentially rural and no urban adjustments were made. Table B.15B.15 shows the distribution applied to generate the growth curve and the parameters..Table B.16 shows the peak flow estimated.

Table B.15: Derivation of Flood Growth Curves

Watercourse	Distribution used and reason for choice	Note Permeable or Urban adjustment	Parameters	Growth factor for 100 year return period
Allt Greag Bheithin	GL – Provides the best fit and is recommended for UK catchments.	N/A	Location: 1.00 Scale:0.255 Shape: --0.301	3.38
Dalmagarry Burn	GL – Provides the best fit and is recommended for UK catchments.	N/A	Location: 1.00 Scale: 0.263 Shape: -0.289	3.24
Funtack Burn	GL – Provides the best fit and is recommended for UK catchments.	N/A	Location: 1.00 Scale:0.255 Shape: -0.301	3.04
River Findhorn	GL – Provides the best fit and is recommended for UK catchments.	N/A	Location: 1.00 Scale:0.255 Shape: -0.301	2.05

Table B.16: Peak flow estimates

Watercourse	50%	20%	10%	4%	2%	1%	0.5%	0.5% including CC
Allt Creag Bheithin	5.16	7.42	9.19	11.93	11.93	14.44	17.43	20.92
Dalmagarry Burn	7.37	10.42	12.81	16.49	19.86	23.88	28.70	34.44
Funtack Burn	17.87	24.96	30.37	38.52	45.81	54.34	64.38	77.26
River Findhorn	200.58	250.41	284.41	331.09	369.37	411.05	456.73	548.08

B.7 Calibration

B.7.1 Calibration of the model was undertaken based on data at Shenachie flow gauge, the only existing flow gauge in the study area. The estimated flows were run through the hydraulic model and peak flow data from the model checked against data recorded from observed events at Shenachie gauge.

B.7.2 Model calibration was carried out with the following three observed events:

- November 2000 - the peak of this event occurred on the 8th of November at 13:45;
- November 2002 - the peak of this event occurred on the 15th of November at 10:00; and
- August 2014 - the peak of this event occurred on the 11th of August at 9:30.

B.7.3 These events were selected as they are the most recent large flood events recorded at Shenachie gauge. Furthermore, water level data derived by SEPA using their rating curve was provided for these events. The November 2000 and November 2002 events were used for verification of the model.

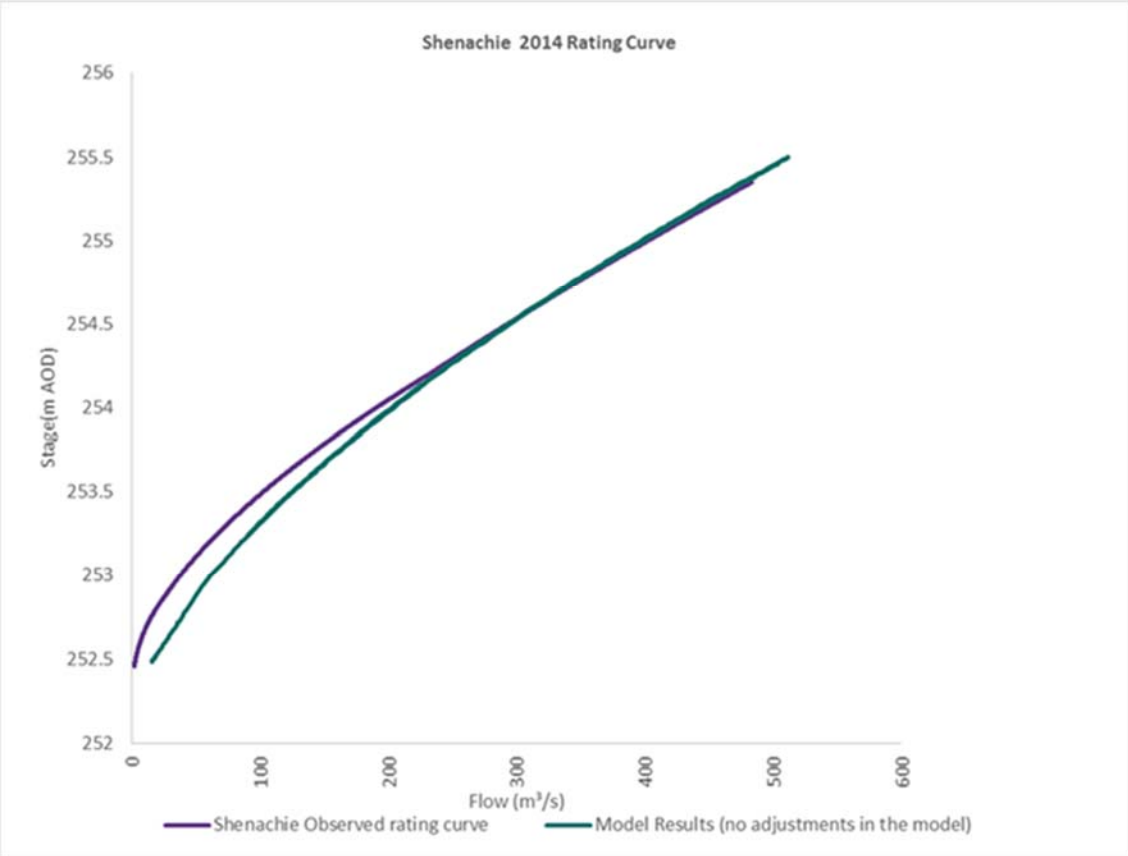
B.7.4 Two SEPA nearby rainfall gauges were identified in the area for model calibration, the Freeburn rain gauge and the Coignafeam rain gauge. These gauges are the only gauges located within the study catchment.

B.8 Hydraulic calibration

B.8.1 A hydraulic calibration was undertaken based on estimated and gauged rating curves. Predicted rating curves have been compared with the gauge rating curve at Shenachie. The results indicate that there is a very good correlation between the rating curves and therefore adjustments to model parameters were not considered necessary.

B.8.2 Figure B.1 shows the predicted and observed ratings curves for the Shenachie gauge location. The model appears to be very accurate for high return period flows and a reasonable observed / predicted correlation has been achieved for lower return period flows. There is a slight under-prediction of water levels as flows decrease, however, as we are interested in the higher flow events for this study, the model is considered sufficiently accurate.

Figure B.1: Predicted and observed rating curves at Shenachie gauge



B.9 Hydrological calibration

B.9.1 The model has been calibrated hydrologically based on recoded events which occurred in November 2000, November 2002 and August 2014.

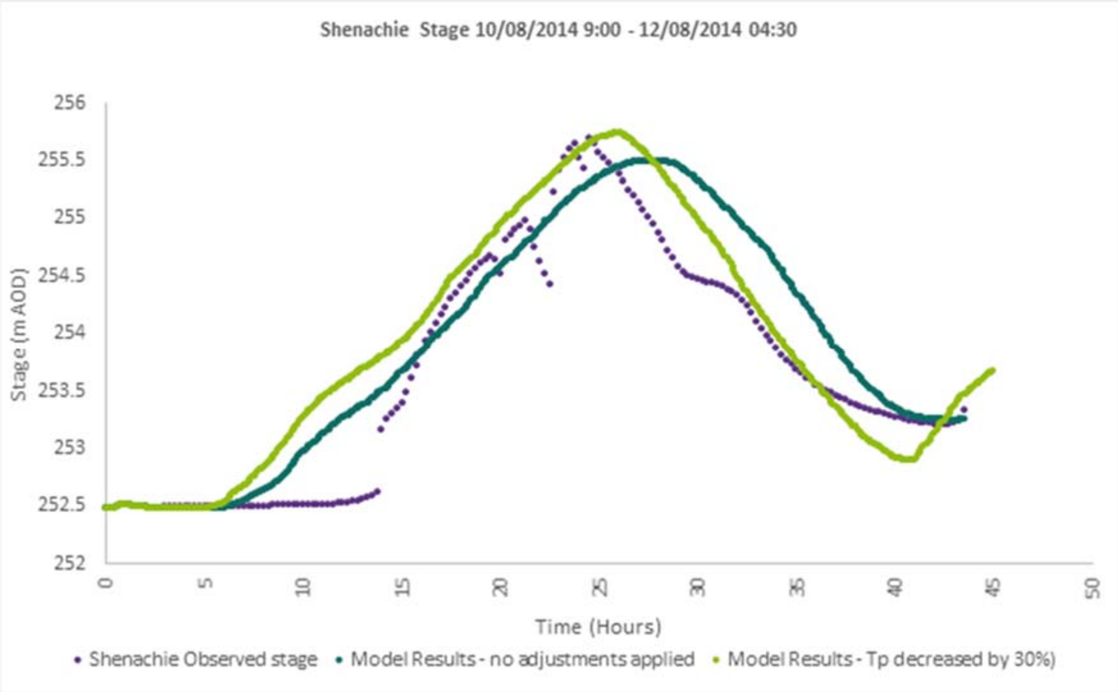
B.9.2 The rainfall data from the Freeburn and Coignafeam gauges for these events was applied as inflows to all sub catchments and routed through the model. This was carried out initially for the most significant event (August 2014). Modelled and recorded water levels and flows taken from the model at Shenachie gauge were then compared for the August 2014 event.

B.9.3 During the initial model run and comparison, the hydraulic model under predicted the peak flow and peak stage in comparison to observed data from Shenachie gauge. The time to peak (Tp) factor was adjusted to improve the representation of catchment response and achieve the best possible match between the observed data and modelled water levels for the August 2014 event.

B.9.4 T(p) was reduced by 30% for all the sub-catchments which improved the correlation between the observed and modelled values.

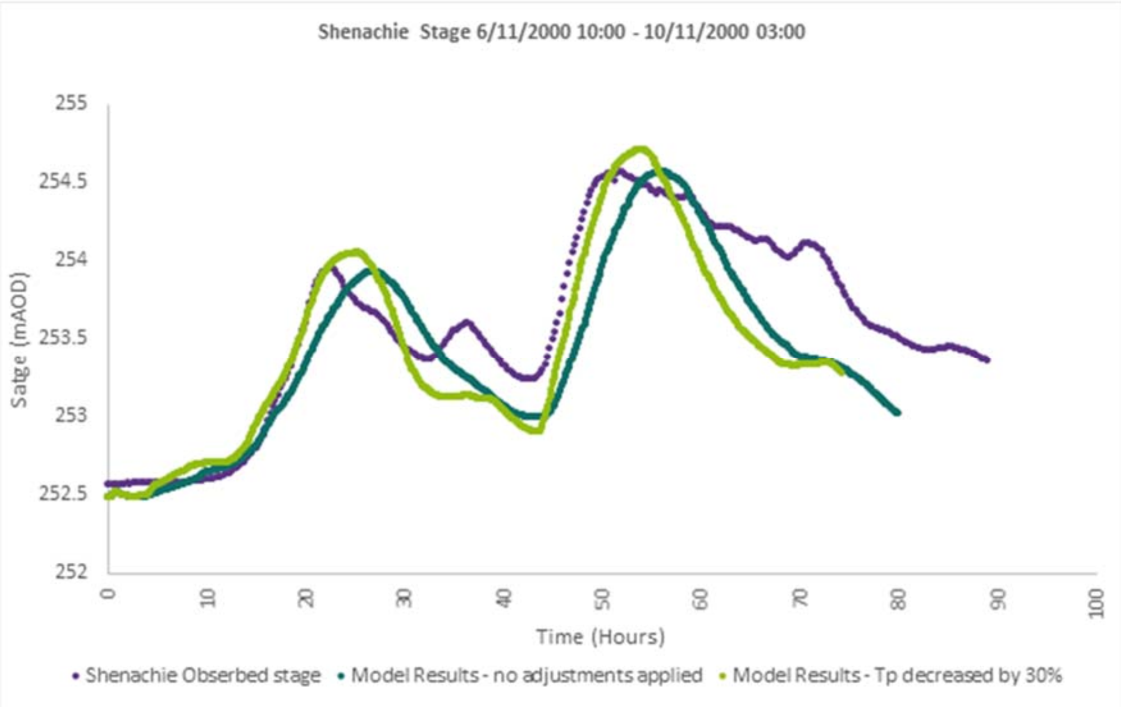
B.9.5 In addition, the rising and receding limbs of the recorded and modelled hydrographs along with the time to peak correlate well following the adjustment of T(p). Graphical representation of the comparisons of the modelled and observed levels are presented in Figure B.2

Figure B.2: Modelled and Observed Stage at Shenachie Gauging Station for 10-12 August 2014



B.9.6 Checks were made against the November 2000 and November 2002 to confirm that the adjustment to T(p) was reasonable. Graphs of the comparison of the modelled and observed levels are presented in Figure B.3.

Figure B.3: Modelled and Observed Stage at Shenachie Gauging Station for 6-10 November 2011



Check catchments

B.9.7 The critical storm duration was determined for each of the check catchments in order to define a suitable storm duration within the hydraulic model for each floodplain area.

These varied depending upon the catchment response and the critical storm duration for each catchment is shown in Table B.17.

Table B.17: Check catchments critical storm durations

Watercourse	Description	Grid Reference	Area (km^2)	Critical Storm Duration (hrs)
Allt Creag Bheithin	Upstream of Moy Burn (south of A9)	NH 76150 35000	7.2	3.1
Dalmagarry Burn	Upstream of Funtack Bridge (south of A9)	NH 79500 32000	9.2	3.1
Funtack Burn	Downstream of Dalmagarry Burn	NH 79600 32000	56.1	5.7
River Findhorn	Upstream of Allt na Frithe confluence	NH 72140 30100	340.3	9.5

B.9.8 Flows at each check catchment have been calculated using different hydrological flow estimation methods. The most suitable and justifiable hydrological flow estimation method and associated design flow estimate has been adopted. These flows have then been compared with the routed flows in the model at these check catchments.

B.9.9 Table B.18 summarises the rainfall runoff routed flows in comparison to the flows from the most suitable / justifiable flow estimation methodology for each check catchment.

Table B.18: Comparison between routed flows and estimated flows at check catchments

Check Catchment Watercourse	Flow Derivation Method	Return Period					
		50%	20%	3.33%	1%	0.5%	0.5% +CC
Allt Creag Bheithin	Routed FEH RR model flows (m^3/s)	8.1	11.9	18.4	24.6	28.6	34.3
	FEH Statistical flows using donor (m^3/s)	5.2	7.4		17.4	21.0	25.3
	Difference (m^3/s)						
	Difference (%)						
Dalmagarry Burn	Routed FEH RR model flows (m^3/s)	9.9	14.6	22.8	30.3	35.2	42.3
	FEH Statistical flows using donor (m^3/s)	7.4	10.4		23.9	28.7	34.4
	Difference (m^3/s)						
	Difference (%)						
Funtack Burn	Routed FEH RR model flows (m^3/s)	42.9	61.1	95.8	124.6	143.8	172.6
	FEH Statistical flows using donor (m^3/s)	17.9	24.9		54.3	64.4	77.3
	Difference (m^3/s)						

Check Catchment Watercourse	Flow Derivation Method	Return Period					
		50%	20%	3.33%	1%	0.5%	0.5% +CC
	Difference (%)						
River Findhorn	Routed FEH RR model flows (m^3/s)	227.6	317.6	499.0	637.7	730.2	876.3
	FEH Statistical flows using donor (m^3/s)	200.6	250.4		411.1	456.7	548.1
	Difference (m^3/s)						
	Difference (%)						

Annex C. Moy Burn Tributary 1 Modelling Note

C.1 Study Area

C.1.1 The Moy Burn Tributary has a catchment area of 0.74km^2 at the A9 crossing. It predominantly drains forestry on the northbound side of the existing A9 carriageway. The watercourse then flows north east around the southern fringe of Moy, before discharging into Loch Moy at NGR 77092 34538.

C.1.2 The Moy Burn Tributary catchment was delineated from FEH CD-ROM (version 3), topographic survey data, Ordnance Survey mapping and 5m NextMAP DTM data of the area (Figure C-1). The catchment area adjusted to reflect the topography.

Figure C-1 Catchment Boundary

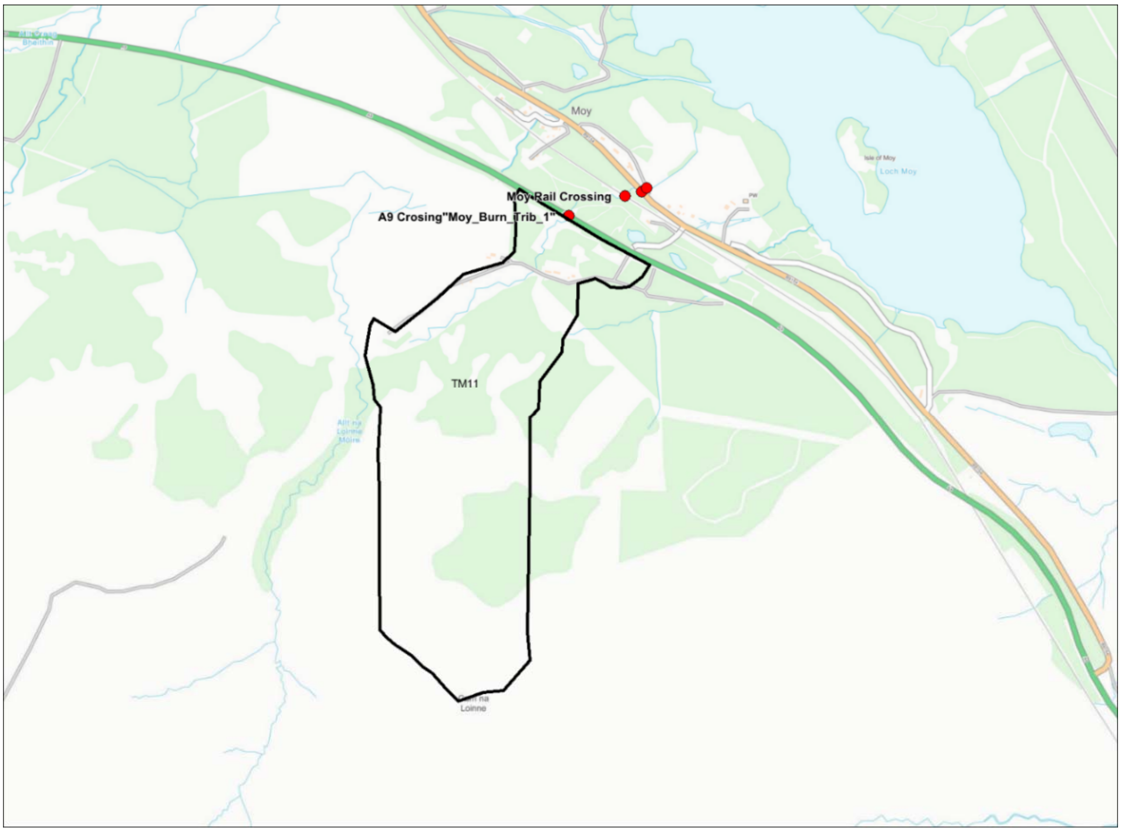


Table C.1: The Moy Burn Tributary Hydrological Parameters

Watercourse	Inflow ID	Inflow Location	Inflow Type	Method	Easting	Northing	Area (km^2)
Moy Burn Tributary	"Moy_XS 013" or "CS1"	Upstream of the A9 Crossing NGR 276556 834124	Direct	FEH Direct	276550	834300	0.77

C.1.3 Peak flows were calculated for each inflow using the FEH Rainfall Runoff methods, an FEH statistical estimate was undertaken at the downstream boundary for comparison.

C.1.4 Critical storm durations vary across the catchment. A catchment wide storm duration provides a more realistic representation of actual rainfall events. The critical storm duration for the Moy Burn Tributary was set as 2.5 hours.

Table C.2: The Moy Burn Tributary Peak Flow Estimates

Watercourse	Inflow ID	Inflow Location	0.5%	0.5+CC
Moy Burn Tributary	"Moy_XS 013" or "CS1"	Upstream of the A9 Crossing NGR 276556, 834124	3.33	4.00

C.1.5 Given the size of the catchment a statistical estimate would not be appropriate. Applying the precautionary approach and considering the size of the catchment the Rainfall Runoff peak flow estimates have been applied and optimised within the hydraulic model.

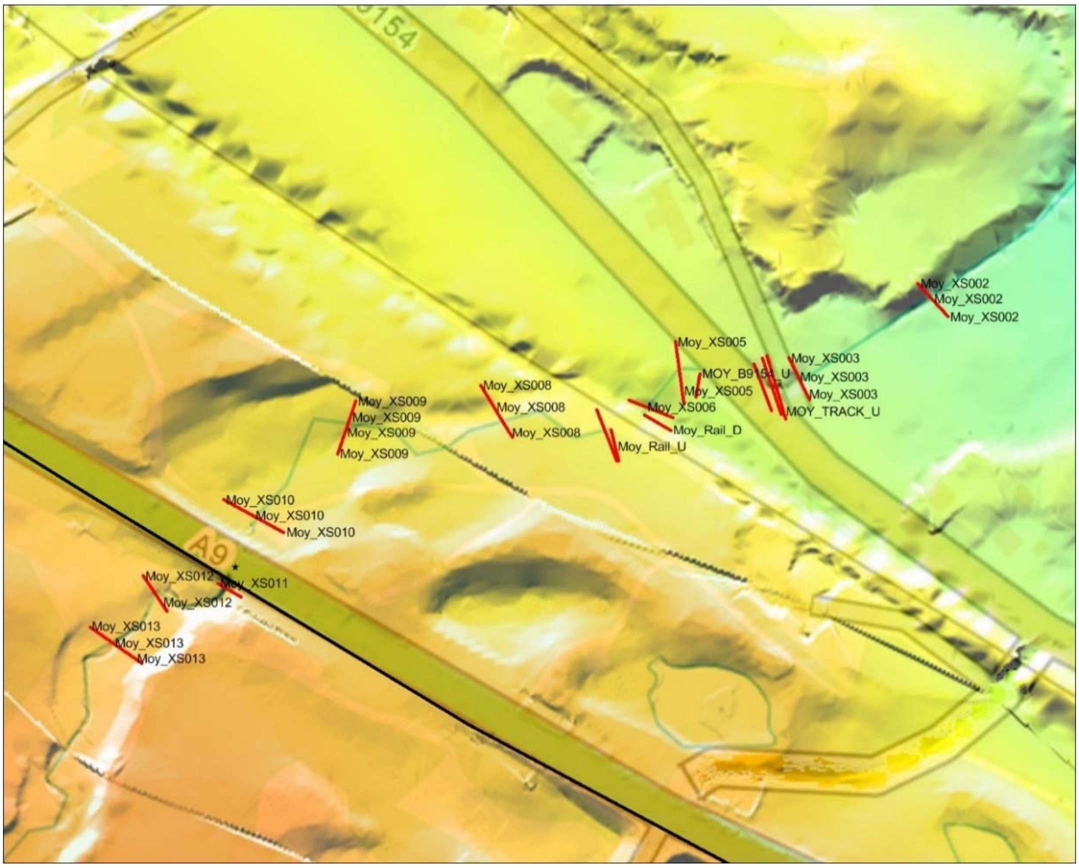
C.1.6 Hydrographs were generated using the FEH Rainfall Runoff method.

C.2 Topographic Survey

C.2.1 A topographic survey was carried out in October 2017 to obtain details of the channel cross sections and long profile for hydraulic modelling and all hydraulic structures.

C.2.2 Locations of all cross sections surveyed are given in Figure C-2.

Figure C-2.The Moy Burn model cross section locations



C.2.3 Locations of all cross sections surveyed are tabulated in Table C.3.

Table C.3: Baseline Model. Section chainages and bed elevations

Cross section Name	Distance to next cross section (m)	Cumulative Chainage (m)	Bed Elevation (m aod)
Moy_XS13	32	0	296.14
Moy_XS12	37.6	32	295.46
A9_Culvert_U/S	28.06	69.6	293.76
A9_Culvert_D/S	6.1	97.66	293.52
Moy_XS10	68.6	103.76	292.33
Moy_XS09	81.4	172.36	289.73
Moy_XS08	53	253.76	286.14
Moy_XS07	2.7	306.76	283.8
Moy_Rail_U	19	309.46	283.56
Moy_Rail_D	3.7	328.46	283.37
Moy_XS06	22	332.16	283.1
Moy_XS05	10	354.16	282.46
Moy_B9154_U	30	364.16	282.15
Moy_B9154_D	4	394.16	281.28
Moy_XS04	2	398.16	281.24
Moy_Track_U	12	400.16	281.19
Moy_Track_D	1	412.16	280.6
Moy_XS03	72.3	413.16	280.6
Moy_XS02	0	485.46	278.46

The hydraulic structures were surveyed in March 2016 and their details are given in section C.3.

C.3 Hydraulic Model

C.3.1 The upstream extent of the Moy Burn Tributary model is located within a cleared woodland area to the north of a small group of houses, it flows downstream in a north easterly direction before crossing the A9 (Structure Code: “A9 1273 C5”) at NGR 276618 834161. The watercourse then flows under the Highland Main Line railway at NGR 276802, 834226, the B9154 at NGR 276849 834521 and a small track at NGR 276876, 834247. The downstream extent of the model is located approximately 200m south west of Loch Moy.

C.3.2 Table C.4 below details the model extents and key features.

Table C.4: Moy Burn Tributary, Key Model Features.

Model Reach	Modelled Reach (m)	Upstream model extent (grid ref)	Downstream model extent (grid ref)	Number of A9 Crossings	Total number of modelled structures
Moy Burn Tributary	Approximately 500m	276557 834124	277023 834353	1	4

C.3.3 A direct inflow hydrograph is applied to the hydraulic model at the upstream extent of the model. A Normal Depth boundary was used at the downstream extent of all the models.

C.3.4 The open channel river sections were defined from the topography survey, with the Manning's 'n' values defined from the site visits, which were undertaken in March 2016 and photographs taken during the 2017 topographic survey. Colebrook White roughness is used for structures. The Table C.5 provides the range of roughness values used and the justification.

Table C.5: Moy Burn tributary, roughness values.

Section Type	Minimum	Maximum	Commentary
River Channel (Mannings)	0.015	0.04	Ranging from finished concrete culvert entrances to Clean winding channels with pools and shoals.
Structures (Colebrook White)	0.0015	0.15	Ranging from smooth concrete, to rough bed material.
Floodplain (Mannings)	0.05	0.06	(Chow, 1959).3.C.2 / 3 = "Light brush and trees in Summer / Winter"

C.3.5 The details of all structures and cross sections were taken from the October 2017 survey data. During this survey is was discovered that the structure that passes under the railway is asymmetrical box culvert that varies in width and height along its length. At the U/S opening of the culvert crossing the railway was modelled with the average dimensions of (w x h) (0.66m x 0.63m) and at the D/S opening (w x h) (0.87m x 0.83m).

C.3.6 A detailed examination of the railway culvert carried out in May 2016 was made available by Network Rail. The report comments on vegetation and notes a partially blocked outlet. The report confirms the culvert is a stone box culvet approximately 0.80m x 0.60m.

C.3.7 Photographs included in the Network Rail report confirm this and illustrate the condition of the structure (Figure C-3) in May 2016 when the depth of standing water was 80 mm and the depth of silt was recorded as 20 mm.

Figure C-3. Photographs of Railway Culvert (Taken from Network Rail Examination Report 11 May 2016)

Interior from Down inlet

Vegtation at inlet

 **Inlet**	 **Outlet covered by timber hatch**

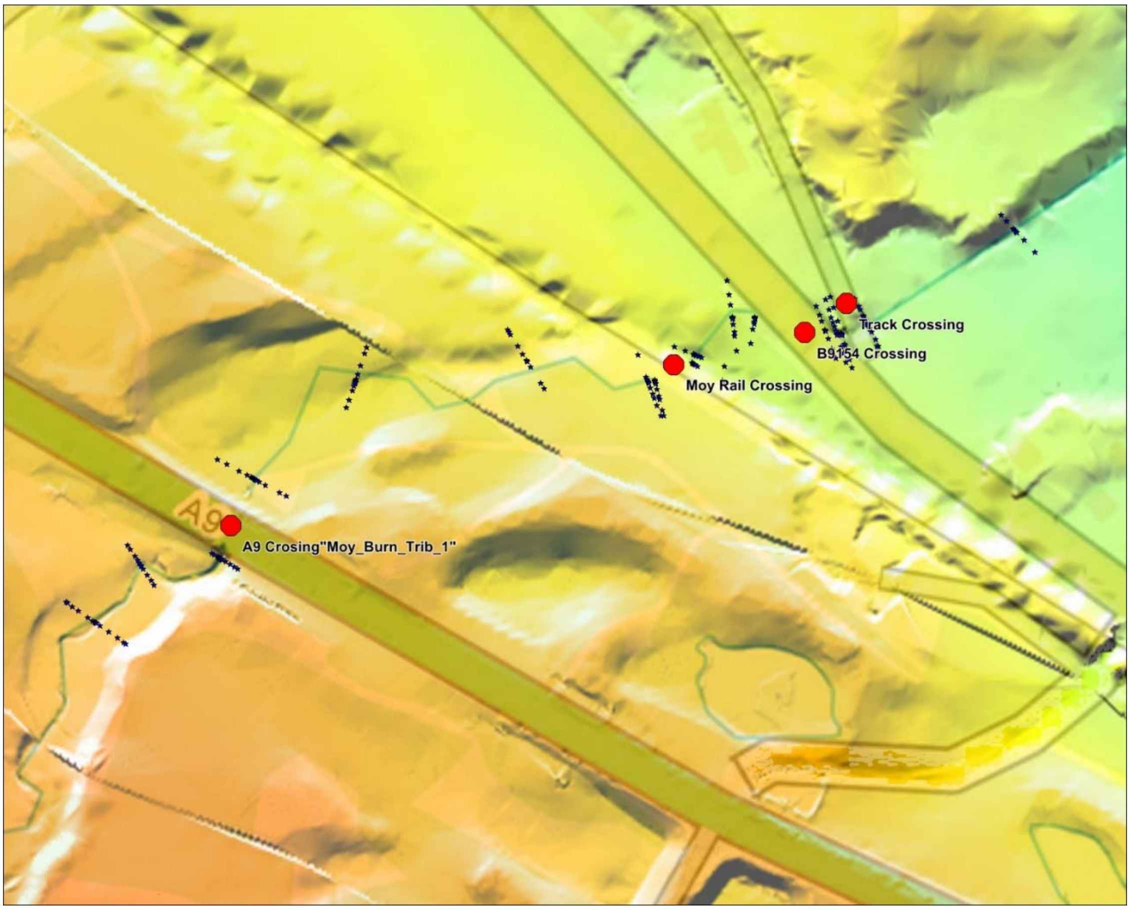
C.3.8 The survey team noted that they could not locate the structure at the U/S end of the model that passes under the track approximately 15m east of the B1954. The assumption that the U/S opening would be the same as the D/S, lowered to the bed level.

C.3.9 The Table C.6 below provides the details of how the structures are represented within the model. Figure C-4 shows the location of these modelled structures.

Table C.6: The Moy Burn Tributary Modelled Structures Details

Water Crossing ID	Structure	Watercourse	Dimensions (m)	Re presentation in the model	Photograph
Moy Burn Trib 1 CH2_ID “825”	A9 1273 C5 Culvert passing under A9	Moy Burn Tributary	1.2m Ø	Represented in a 1D ISIS Model. Circular Conduit	
Moy Burn Trib 1 Rail crossing	Culvert	Moy Burn Tributary	U/S (wxh) (0.66 x 0.63) D/S (wxh) (0.87 x 0.83)	Symmetrical conduit Unit	
Moy Burn Trib 1 B9154 crossing	Culvert	Moy Burn Tributary	0.6m Ø	Circular Conduit	
Moy Burn Trib 1 Track	Culvert	Moy Burn Tributary	(wxh) (0.72 x 0.40)	Symmetrical conduit Unit	

Figure C-4. Location of the structures in the Moy Burn Model



C.4 Proposed Model

C.4.1 Analysis of the baseline results showed that the culvert under the railway is undersized and is unable to convey the Q200 flow. This railway culvert acts as a constriction to the downstream flood threat, as a result it has been decided not to increase flood risk to the railway. It was decided to replace the existing A9 culvert and replace it with structure that is able to convey similar flow. The existing culvert is a 1.2m diameter culvert this give it an effective area of 1.13m^2. The proposed culvert is a standard 1.2m x 1.2m box culvert with 0.25m of bed material. This gives the culvert an effective area of 1.2m * 0.95m = 1.14m^2.

C.4.2 Around the A9 crossing, major earthworks will be being constructed and as a result the channel upstream and downstream of the A9 will be re-graded. In the proposed model, the new regraded sections have been used up to “Moy_XS009” then the sections in the Baseline model used.

C.4.3 The downstream extent of the model was originally located approximately 100m further downstream, however the surveyed sections for “Moy_XS002” and “Moy_XS001” were found to not have the required capacity to convey flows associated with the Q25 event. This lack of capacity is because the sections effectively represent the mouth of the watercourse entering Loch Moy and were extremely wide and flat. It was decided not to use the surveyed sections Moy_XS002 and Moy_XS001, and to use a copy of Moy_XS003 placed in the same location, and lowered to the same bed level as Moy_XS002.

C.4.4 The proposed model cross sectiosn are given in Table C.7 below.

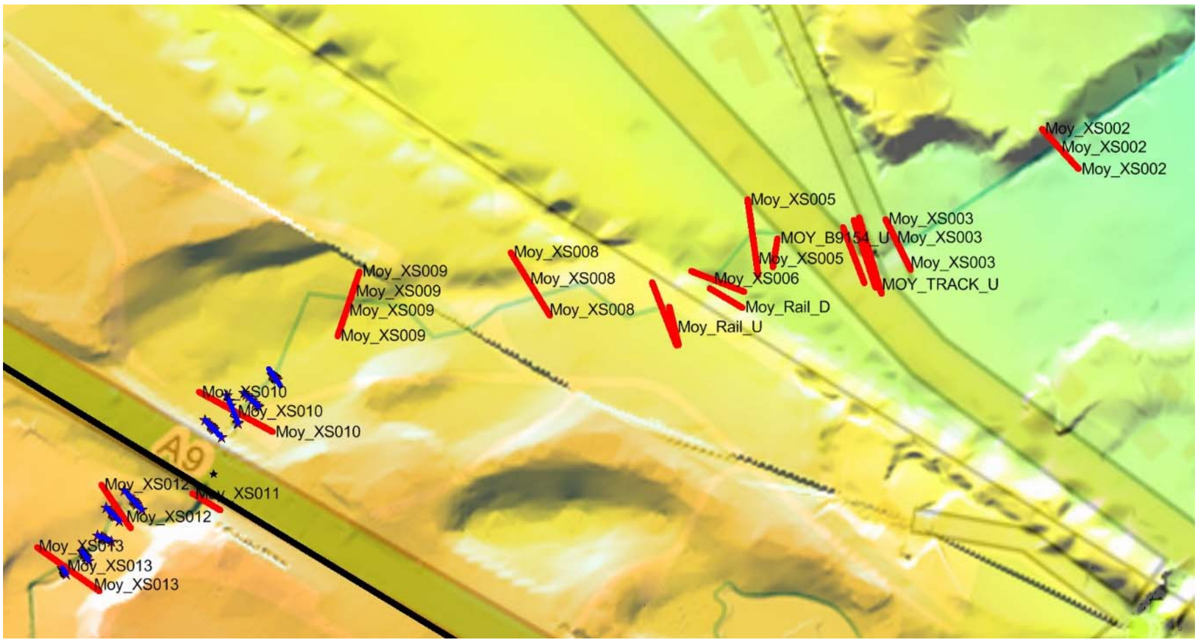
Table C.7: Proposed model. Section chainages and bed elevations.

Cross section Name	Distance to next cross section (m)	Cumulative Chainage (m)	Bed Elevation (m aod)
CS1	10	0	296.7
CS2	10	10	296.09
CS3	9.9	20	295.48
CS4	9.5	29.9	294.877
A9_Culvert_U/S	38	39.4	294.27
A9_Culvert_D/S	10	77.4	293.36
CS7	8.5	87.4	293.135
CS8	12.5	95.9	292.557
CS9	50	108.4	291.7
Moy_XS09	81.4	158.4	289.73
Moy_XS08	53	239.8	286.14
Moy_XS07	2.7	292.8	283.8
Moy_Rail_U	19	295.5	283.56
Moy_Rail_D	3.7	314.5	283.37
Moy_XS06	22	318.2	283.1
Moy_XS05	10	340.2	282.46
Moy_B9154_U	30	350.2	282.15
Moy_B9154_D	4	380.2	281.28
Moy_XS04	2	384.2	281.24
Moy_Track_U	12	386.2	281.19
Moy_Track_D	1	398.2	280.6
Moy_XS03	72	399.2	280.6
Moy_XS02	0	471.2	278.46

C.5 Comparison of Baseline and Proposed results

C.5.1 Comparison of stage at the baseline and proposed scenarios was not possible in areas immediately U/S and D/S of the A9. This was due to the fact that the watercourse, approximately 100m upstream and 70m downstream of the A9, will be realigned to fit the proposed route option. Figure C-5 below shows the baseline model cross sections (Red) and the 9 proposed cross sections (Blue).

Figure C-5. Showing the locations of the Moy Burn Surveyed cross sections (Red) and proposed sections (Blue)



C.5.2 Since cross section profiles and bed levels vary notably between the existing and proposed models around the A9, it was not possible to compare variations in stage until cross section “Moy_XS009” which is approximately 170m downstream from the U/S extent of the model. From this location, continuing downstream, all cross sections are the identical in the baseline and proposed models.

C.5.3 In order to assess impacts of the new A9 crossing, peak flows were compared at non-identical cross sections in the baseline and proposed models however were located in the same approximate locations (see Figure C-4). The comparative sections where peak flow is reported include:

- Moy_XS_013 and CS1
- Moy_XS_012 and CS3
- Moy_XS_010 and CS7

C.5.4 The variation in flow between the baseline and the proposed models is shown below in Table C.8.

Table C.8: Comparison of Baseline and Proposed Flows for comparative model cross sections.

	Baseline (m^3/s)	Proposed (+/-)	Baseline (m^3/s)	Proposed (+/-)	Baseline (m^3/s)	Proposed (+/-)	Baseline (m^3/s)	Proposed (+/-)	Baseline (m^3/s)	Proposed (+/-)
Cross section	**Q200+CC**		**Q200**		**Q100**		**Q30**		**Q2**	
"CS1" and Moy_XS13"	4.00	0.00	3.34	0.00	2.85	0.00	2.14	0.00	0.92	0.00
"CS3" and Moy_XS12"	3.98	0.03	3.34	0.00	2.85	0.00	2.14	0.00	0.92	0.00
"CS7" and Moy_XS10"	3.90	0.09	3.33	0.00	2.84	0.00	2.14	0.00	0.92	0.00
Moy_XS09	3.90	0.09	3.33	0.01	2.85	0.00	2.13	0.00	0.92	0.00
Moy_XS08	3.91	0.09	3.33	0.01	2.84	0.00	2.11	0.00	0.92	0.00
Moy_XS07	3.89	0.09	3.32	0.01	2.83	0.00	2.01	0.00	0.92	0.00
Moy_Rail_U	3.90	0.09	3.32	0.00	2.83	0.00	2.01	0.00	0.92	0.00
Moy_Rail_D	3.90	0.09	3.32	0.00	2.83	0.00	2.01	0.00	0.92	0.00
Moy_XS06	3.90	0.09	3.32	0.00	2.83	0.00	2.01	0.00	0.92	0.00
Moy_XS05	3.89	0.09	3.32	0.00	2.83	0.00	2.02	0.00	0.92	0.00
Moy_B9154_U	3.89	0.08	3.32	0.00	2.83	0.01	2.01	0.00	0.92	0.00
Moy_B9154_D	3.89	0.08	3.32	0.00	2.83	0.01	2.01	0.00	0.92	0.00
Moy_XS04	3.89	0.08	3.32	0.00	2.82	0.01	2.01	0.00	0.92	0.00
Moy_Track_U	3.89	0.08	3.32	0.00	2.83	0.01	2.01	0.00	0.92	0.00
Moy_Track_D	3.89	0.08	3.32	0.00	2.83	0.01	2.01	0.00	0.92	0.00

	Baseline (m^3/s)	Proposed (+/-)	Baseline (m^3/s)	Proposed (+/-)	Baseline (m^3/s)	Proposed (+/-)	Baseline (m^3/s)	Proposed (+/-)	Baseline (m^3/s)	Proposed (+/-)
Cross section	**Q200+CC**		**Q200**		**Q100**		**Q30**		**Q2**	
Moy_XS03	3.89	0.09	3.32	0.00	2.83	0.01	2.01	0.00	0.92	0.00
XS03_i1	3.89	0.09	3.32	0.00	2.82	0.01	2.01	0.00	0.92	0.00
XS03_i2	3.89	0.09	3.32	0.01	2.82	0.01	2.01	0.00	0.92	0.00
Moy_XS02	3.89	0.09	3.32	0.00	2.82	0.01	2.01	0.00	0.92	0.00

C.5.5 The variation in stage between the Baseline and the Proposed model D/S of the A9 beginning at cross section “Moy_XS_09” and continuing the D/S extent of the model “Moy_XS02” are shown below in Table C.9 below.

Table C.9: Comparison of Baseline and Proposed Stage (m) for the Moy Burn model

	Baseline	Proposed	Baseline	Proposed	Baseline	Proposed	Baseline	Proposed	Baseline	Proposed
Cross section	**Q200+CC**		**Q200**		**Q100**		**Q30**		**Q2**	
Moy_XS_09	290.37	0.00	290.33	-0.01	290.29	0.00	290.22	0.00	290.19	0.00
Moy_XS08	287.65	0.01	287.60	0.00	287.55	0.00	287.12	0.01	286.61	-0.01
Moy_XS07	287.63	0.01	287.59	0.00	287.54	0.00	287.02	0.00	284.68	0.00
Moy_Rail_U	287.63	0.01	287.59	0.00	287.54	0.00	287.02	0.00	284.68	0.00
Moy_Rail_D	284.04	0.00	283.99	0.00	283.95	0.00	283.86	0.00	283.70	0.00
Moy_XS06	283.93	0.01	283.89	0.00	283.85	0.00	283.77	0.00	283.60	0.00
Moy_XS05	283.70	0.00	283.68	0.00	283.66	0.00	283.62	0.00	283.56	0.00
Moy_B9154_U	283.69	0.00	283.67	0.00	283.65	0.00	283.62	0.00	283.56	0.00
Moy_B9154_D	282.68	0.00	282.66	0.00	282.64	0.00	282.59	0.00	282.50	0.00
Moy_XS04	282.71	0.00	282.68	0.00	282.66	0.00	282.61	0.00	282.50	0.00
Moy_Track_U	282.71	0.00	282.68	0.00	282.65	0.00	282.60	0.00	282.50	0.00
Moy_Track_D	281.32	0.00	281.28	0.00	281.25	0.00	281.18	0.00	281.02	0.00

	Baseline	Proposed	Baseline	Proposed	Baseline	Proposed	Baseline	Proposed	Baseline	Proposed
Cross section	**Q200+CC**		**Q200**		**Q100**		**Q30**		**Q2**	
Moy_XS03	281.29	0.01	281.25	0.00	281.22	0.00	281.15	0.00	280.99	0.00
XS03_i1	280.58	0.00	280.54	0.00	280.51	0.00	280.44	0.00	280.28	0.00
XS03_i2	279.86	0.00	279.82	0.00	279.79	0.00	279.72	0.00	279.57	0.00
Moy_XS02	279.16	0.01	279.12	0.00	279.09	0.00	279.01	0.00	278.86	0.00

C.5.6 As can be seen in the above tables the variation in flow and stage between the baseline and proposed models is extremely low. The 1D model of the proposed design for the A9 crossing on the Moy Burn tributary has shown that there is negligible impact on stage and flows downstream of the crossing.

C.6 Sensitivity Analysis

C.6.1 To analyse the sensitivity of the proposed hydraulic model, 9 sensitivity tests have been run on the Proposed (Baseline) model. These aim to test how sensitive the models are to variable parameters and scenarios. The following tests were run on the Proposed (Baseline) model.

- Global roughness + / - 20%
- Structure roughness + / - 20%
- Flow + / - 20%
- 50% blockage scenario
- Downstream Boundary +/ - 20%

C.6.2 Table C.10 below shows the variation in flow between the Proposed (baseline) model and each of the sensitivity results for the Q200 event. Variation is given in m^3/s.

Table C.10: Variation in flow for sensitivity tests

	Sensitivity tests Q200 Variation in Flow (m3/s)									
	Baseline	Man +20% Global	Man -20% Global	Man +20% Culvert	Man -20% Culvert	Q +20 %	Q - 20%	50% Blockage	DSB + 20% XSO 2	DSB - 20% XSO 2
	Q200	Q200	Q200	Q200	Q200	Q200	Q200	Q200	Q200	Q200
CS1	**3.34**	0.00	0.00	0.00	0.00	0.66	-0.67	0.00	0.00	0.00
CS3	**3.34**	0.00	0.00	0.00	0.00	0.66	-0.67	-0.04	0.00	0.00
Moy_XS_011	**3.33**	0.00	0.00	0.00	0.00	0.66	-0.67	-0.07	0.00	0.00
X088	**3.33**	0.00	0.00	0.00	0.00	0.66	-0.67	-0.07	0.00	0.00
CS7	**3.33**	0.00	0.00	0.00	0.00	0.66	-0.67	-0.07	0.00	0.00
Moy_XS_09	**3.33**	0.00	0.00	0.00	0.00	0.66	-0.67	-0.07	0.00	0.00
Moy_XS_08	**3.33**	-0.02	-0.01	-0.01	-0.01	0.65	-0.70	-0.08	0.00	-0.01
Moy_XS_07	**3.32**	0.00	0.00	0.00	0.00	0.66	-0.70	-0.07	0.00	0.00
Moy_Rail_U	**3.32**	0.00	0.00	0.00	0.00	0.66	-0.70	-0.07	0.00	0.00
Moy_Rail_D	**3.32**	0.00	0.00	0.00	0.00	0.66	-0.70	-0.07	0.00	0.00
Moy_XS_06	**3.32**	0.00	0.00	0.00	0.00	0.66	-0.70	-0.07	0.00	0.00
Moy_XS_05	**3.32**	0.01	0.00	0.00	0.00	0.67	-0.70	-0.07	0.00	0.00
Moy_B9154_U	**3.32**	0.01	0.00	0.00	0.00	0.66	-0.70	-0.07	0.00	0.00
MoyB9D_CPY	**3.32**	0.01	0.00	0.00	0.00	0.66	-0.70	-0.07	0.00	0.00
Moy_XS_04	**3.32**	0.01	0.00	0.00	0.00	0.66	-0.70	-0.07	0.00	0.00
Moy_TRK_XSU	**3.32**	0.01	0.00	0.00	0.00	0.66	-0.70	-0.07	0.00	0.00
Moy_TrkD_Cpy	**3.32**	0.01	0.00	0.00	0.00	0.66	-0.70	-0.07	0.00	0.00
Moy_XS03	**3.32**	0.01	0.00	0.00	0.00	0.66	-0.70	-0.07	0.00	0.00
XS03_i1	**3.32**	0.00	0.00	0.00	0.00	0.66	-0.70	-0.07	0.00	0.00

XS03_i2	**3.32**	0.00	0.00	0.00	0.00	0.66	-0.70	-0.07	0.00	-0.01
Moy_XS02	**3.32**	0.00	0.00	0.00	0.00	0.66	-0.70	-0.07	0.00	-0.01

C.6.3 Table C.11 below shows the variation in stage between the Proposed (baseline) model and each of the sensitivity tests for the Q200 event. Variation is given in meters. Long sections displaying the variation in stage verses longitudinal chainage are shown below.

Table C.11: Variation in flow for sensitivity tests

	Sensitivity tests Q200 Variation in stage (m)									
	Proposed "Baseline"	**Man +20% Global**	**Man-20% Global**	**Man +20% Culvert**	**Man-20% Culvert**	**Q +20 %**	**Q - 20%**	**50% Blockage**	**DSB + 20% XSO 2**	**DSB - 20% XSO2**
Cross section	**Q200**	**Q200**	**Q200**	**Q200**	**Q200**	**Q20 0**	**Q200**	**Q200**	**Q20 0**	**Q200**
CS1	**297.276**	0.04	-0.06	0.00	0.00	0.04	-0.06	1.05	0.00	0.04
CS3	**296.099**	0.04	-0.04	0.00	0.00	0.04	-0.04	2.26	0.00	0.04
Moy_XS_01 1	**295.975**	0.00	0.00	0.00	0.00	0.00	0.00	2.38	0.00	0.00
X088	**293.934**	0.04	-0.05	0.00	0.00	0.04	-0.05	-0.01	0.00	0.04
CS7	**293.454**	0.03	-0.04	0.00	0.00	0.03	-0.04	0.00	0.00	0.03
Moy_XS_09	**290.324**	0.04	-0.04	0.00	0.00	0.04	-0.04	0.00	0.00	0.04
Moy_XS08	**287.617**	0.01	-0.01	0.00	0.00	0.05	-0.08	-0.01	0.00	0.00
Moy_XS07	**287.604**	0.00	0.00	0.00	0.00	0.05	-0.08	-0.01	0.00	0.00
Moy_Rail_U	**287.604**	0.00	0.00	0.00	0.00	0.05	-0.08	-0.01	0.00	0.00
Moy_Rail_D	**284.015**	0.05	-0.05	0.00	0.00	0.05	-0.06	-0.01	0.00	0.00
Moy_XS06	**283.934**	0.04	-0.04	0.00	0.00	0.05	-0.06	0.00	0.00	0.00
Moy_XS05	**283.773**	0.01	0.00	0.00	0.00	0.02	-0.03	0.00	0.00	0.00
Moy_B9154 _U	**283.77**	0.00	0.00	0.00	0.00	0.02	-0.03	0.00	0.00	0.00
Moy_B9154 _D	**282.661**	0.00	0.00	0.00	0.00	0.03	-0.03	0.00	0.00	0.00
Moy_XS04	**282.684**	0.00	0.00	0.00	0.00	0.03	-0.04	0.00	0.00	0.00
Moy_Track_ U	**282.681**	0.00	0.00	0.00	0.00	0.03	-0.04	0.00	0.00	0.00
Moy_Track_ D	**281.28**	0.04	-0.05	0.00	0.00	0.04	-0.05	0.00	0.00	0.00
Moy_XS03	**281.252**	0.04	-0.05	0.00	0.00	0.04	-0.05	0.00	-0.01	0.00
XS03_i1	**280.54**	0.04	-0.05	0.00	0.00	0.04	-0.05	0.00	0.01	0.00
XS03_i2	**279.823**	0.04	-0.05	0.00	0.00	0.04	-0.05	0.00	-0.02	0.35
Moy_XS02	**279.117**	0.04	-0.05	0.00	0.00	0.04	-0.05	0.00	0.13	-0.13

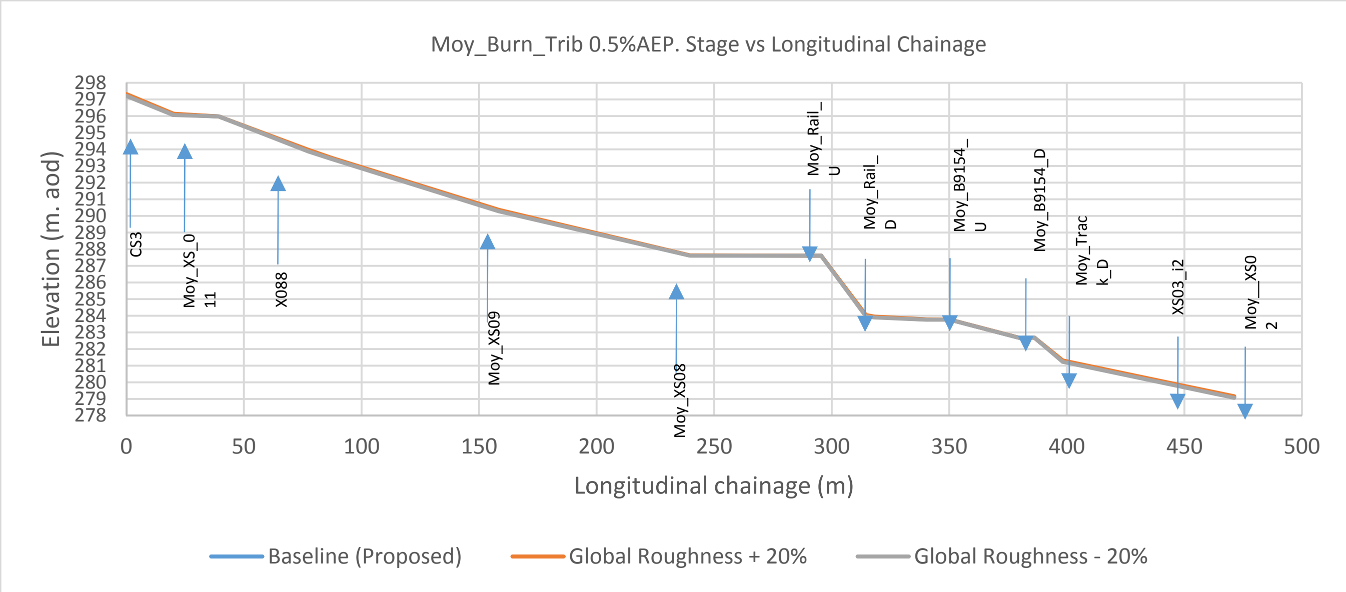


Figure C-6.1 Moy Burn tributary Modelled Long Section Sensitivity Results (Global Roughness)

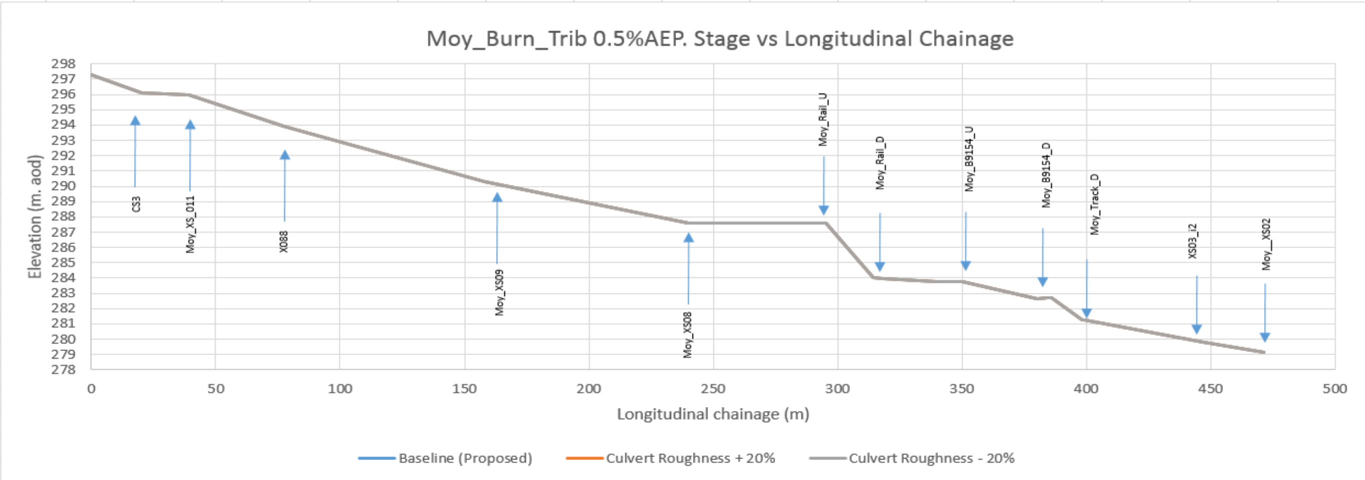


Figure C-7.2 Moy Burn tributary Modelled Long Section Sensitivity Results (Structure Roughness)

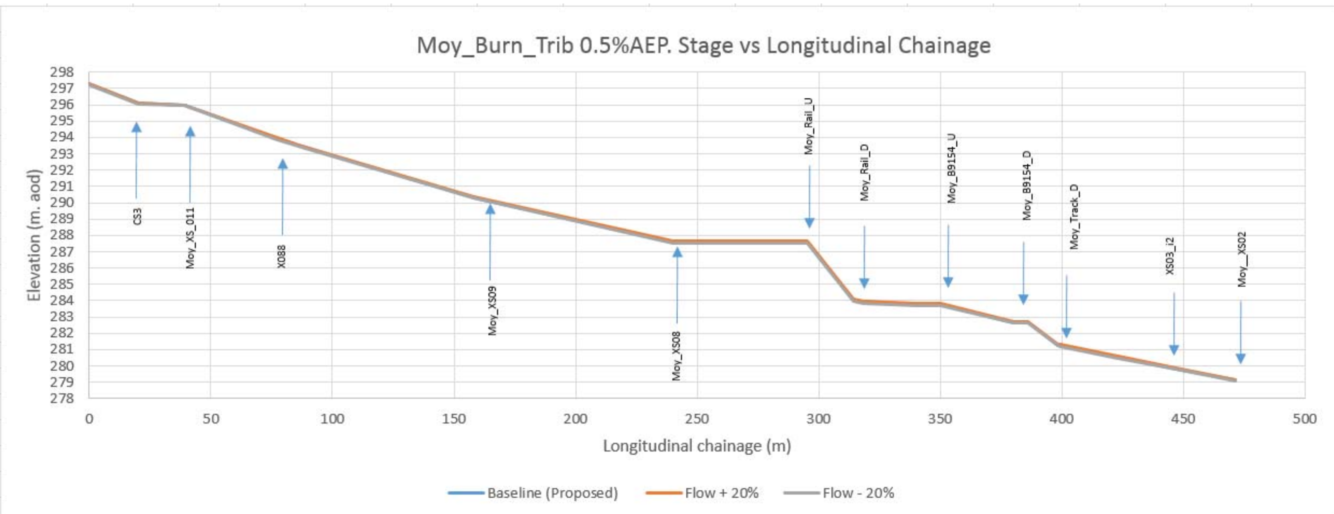


Figure C-1.3 Moy Burn tributary Modelled Long Section Sensitivity Results (Flow Variation

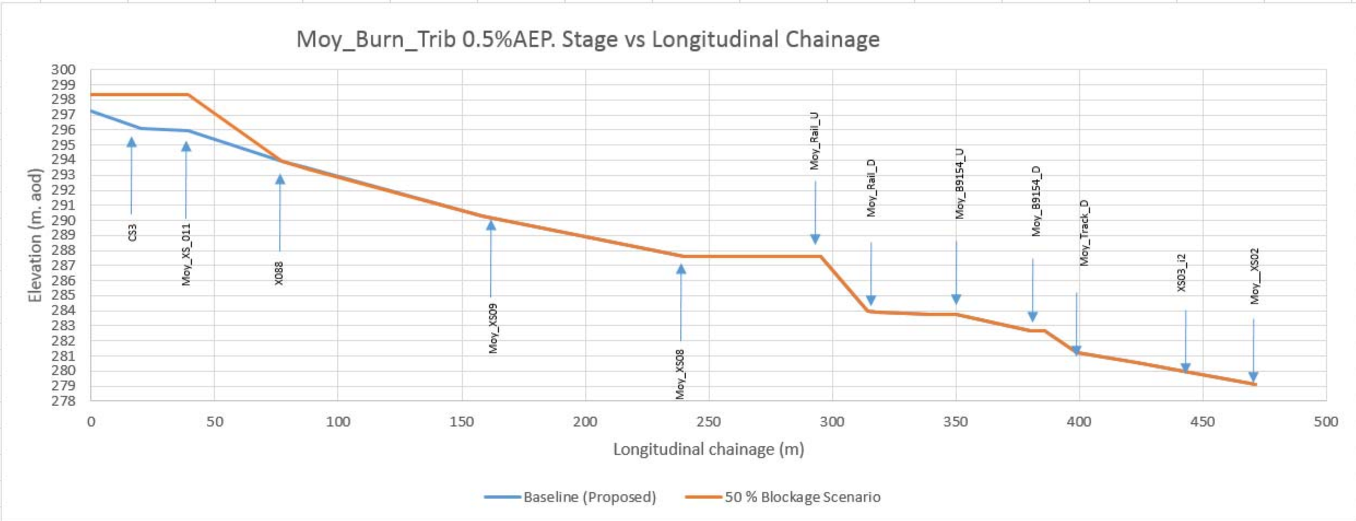


Figure C-8.4 Moy Burn tributary Modelled Long Section Sensitivity Results (Blockage Scenario)

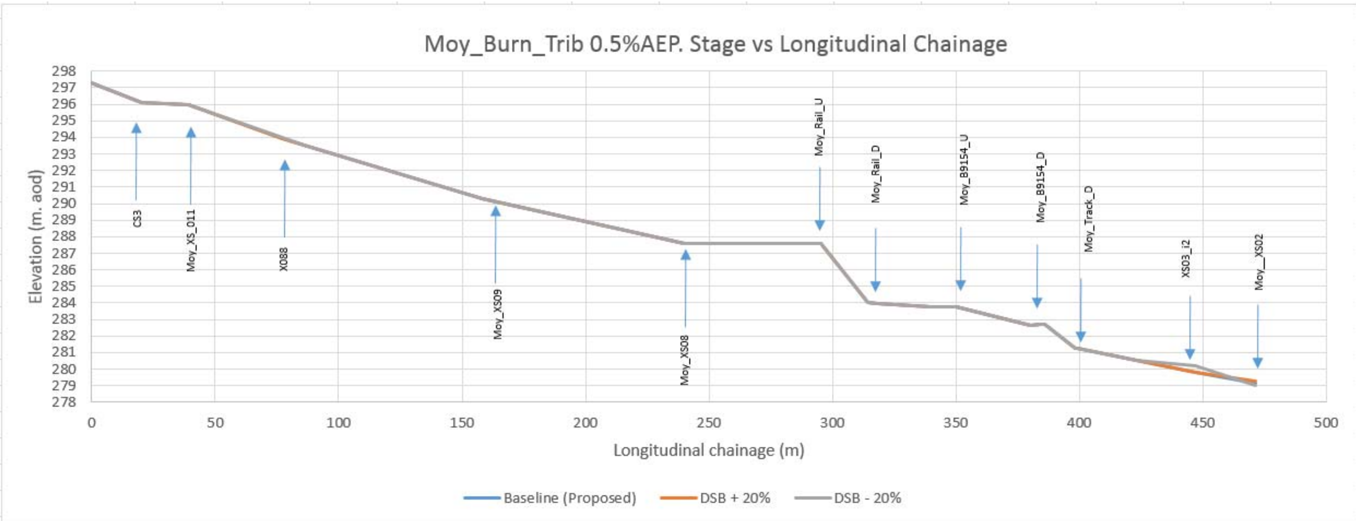


Figure C-9.5 Moy Burn tributary Modelled Long Section Sensitivity Results (DSB variation)

C.7 Conclusions

C.7.1 The modelling has confirmed that the HML railway culvert limits the flow passes downstream and is the main factor in determining the capacityof the new structure under the A9.

C.7.2 The new structure has thefeore been sized to give the same hydraulic capacity as the existing 1.2m diameter culvert. The proposed culvert is a 1.2m x 1.2m box culvert with 0.25m of bed material.

C.7.3 The model results show that the water levels either remain at or are less than the baseline water levels at all return periods tested up to the 200 years. The model results indicate that there is one cross section, Moy_XS08 where the level inceases by 10 mm for the 200 year plus climate change and 30 year return period runs.

C.7.4 The results of the sensitivity runs indicate that the 10 mm increase at Moy_XS08 noted in the previous point is not significant when uncertainty in Manning’s ‘n’ or flow are considered.

C.7.5 The main concludion from the sensitivity results is that the the replacemet structure under the A9 is sensitive to blockage being under-sized (see Figure C-8). A 50% blockage will cause water levels to increase at the inlet by 2.38m for the 200 year flow.

Annex D. Allt Creag Bheithin Hydraulic Modelling Update

D.1 Introduction

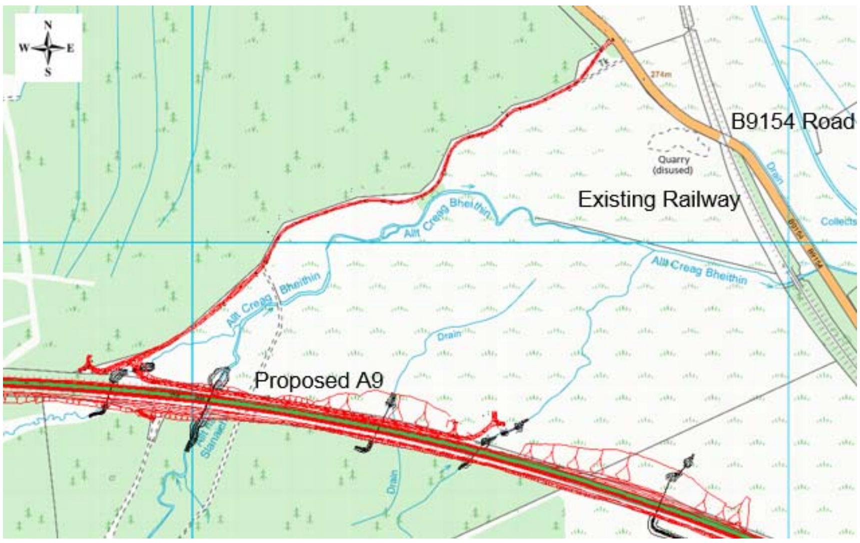
D.1.1 This Appendix provides detailed information on the hydraulic modelling relevant to Allt Creag Bheithin. The Appendix details the methodology and the results of the hydraulic modelling carried out for the A9 1273 C31 and A9 1273 C28 crossings, for the baseline, 'with-scheme' and 'with-scheme and mitigation measures" situation.

D.1.2 This Appendix reports on a trimmed version of the larger T-M model representing only the watercourses upstream of Loch Moy. The larger T-M model is described in Appendix B. The baseline version of the larger T-M model was calibrated using data at Shenachie flow gauge. There are no gauges within the catchment upstream of Loch Moy, therefore it has not been possible to calibrate the trimmed model reported in this note. However, outputs from the larger T-M calibrated baseline model have been used to define the downstream boundary condition in the trimmed model.

D.1.3 The hydraulic model was built using a linked one-dimensional/two-dimensional (1D/2D) schematisation, where the river channel is represented as a 1D component and is linked to the flood plain, which is represented by a 2D domain. The 1D component was constructed using the river modelling package Flood Modeller (version 4.3), and the 2D component was constructed using TUFLOW (version 2016-03-AE).

D.1.4 The area to be modelled is shown in Figure D.1. Approximately 2km west of Loch Moy, the A9 crosses Allt Creag Bheithin and one of its tributaries Allt na Slanaich. The Allt Creag Bheithin rises from the Beinn nan Cailleach and flows in a North East direction. It crosses the A9, the Highland Mainline Railway and B9154 before joining the Moy Burn 1.5km downstream of the A9. The Allt na Slanaich rises from the Beinn nan Cailleach and flows in a North East direction underneath the A9 before flowing into the Allt Creag Bheithin approximately 125m downstream of the A9.

Figure D.1 Allt Creag Bheithin Study Area



D.2 Input Data

D.2.1 The data used to construct the baseline hydraulic model of the Allt Creag Bheithin and Allt na Slanaich is summarised in Table D.1.

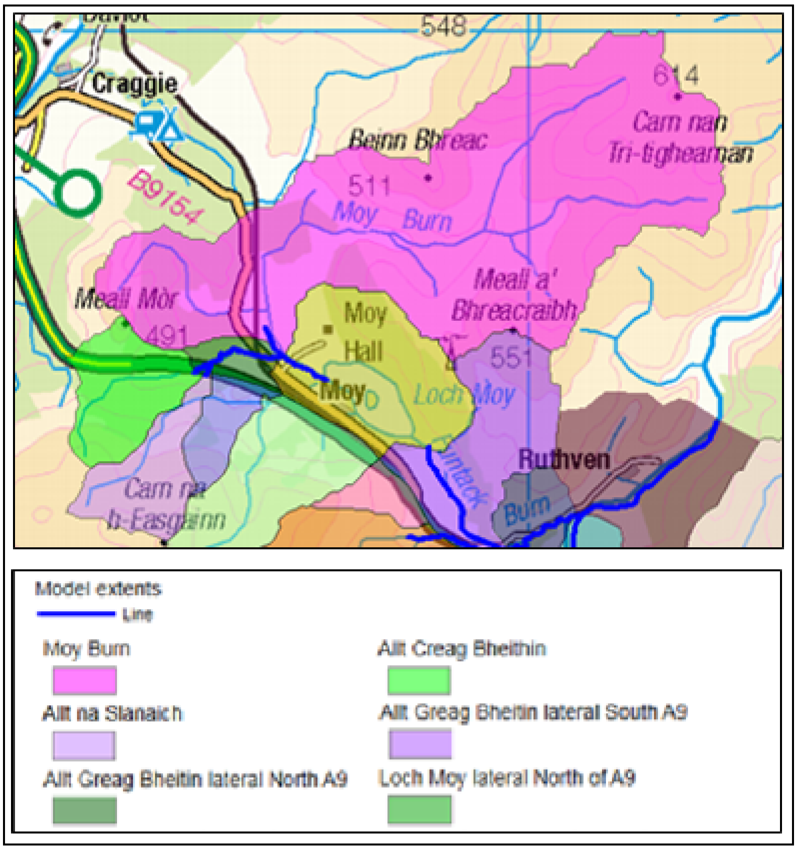
Table D.1 Data used to build the baseline hydraulic model

Data	Description	Source
Topographic Survey November 2015	River cross-section data collected as part of A9 project	WSP (formerly Mouchel)
Topographic Survey October 2017	Additional river cross-section data taken on Allt Creag Bheithin	WSP (formerly Mouchel)
5m NEXTMAP	DTM covering entire study area	Transport Scotland
10m BLOM LiDAR	DTM covering part of study area only	Transport Scotland
BLOM topo	Surveyed contours and points covering part of study area only	Transport Scotland

D.3 Hydrology

D.3.1 Hydrological analysis has been undertaken to derive design flow estimates as inputs to the hydraulic model developed for assessment. The Allt Creag Bheithin and Allt na Slanaich catchments were delineated from the FEH CD-ROM (version 3), topographic survey data, Ordnance Survey mapping and 5m NextMAP DTM data of the area. Figure D,2 shows the delineated catchment areas.

Figure D.2 Catchment Areas



D.3.2 The catchment areas extracted from the FEH CD-ROM were altered to reflect the surrounding topography. Details can be found in Table D.2. Catchment descriptors were extracted from the FEH CD-ROM for all of the delineated catchments. An appropriate method for estimating peak flows for each catchment was chosen as shown in Table D.2. There are three main inflows to the model, these catchments represent the main watercourse inflows (upstream boundaries) to the hydraulic model. In addition to the three main inflows, two lateral inflows have been identified which have been applied to the model to represent additional flows generated over the catchment areas downstream of the main inflow locations. The lateral inflows have been uniformly distributed along the Allt Creag Bheithin and Moy Burn. As only a small reach of the Allt na Slanaich is represented in the model, it was not deemed necessary to add a lateral inflow on this watercourse within the model.

Table D.2. Hydrological Parameters

Watercourse	Inflow ID	Inflow Location	Inflow Type	Method	Easting	Northing	Area (km^2)
Moy Burn	C1	Upstream modelled extent of Moy Burn	FEH Boundary	FEH Statistical	275933	835424	24.91
Allt Creag Bheithin	C2	Upstream modelled extent of Allt Creag Bheithin	FEH Boundary	Rainfall Runoff	274630	834658	2.83
Allt na Slanaich	C3	Upstream modelled extent of Allt na Slanaich	FEH Boundary	Rainfall Runoff	275002	834676	2.41

D.3.3 Peak flows were calculated for the Allt Creag Bheithin and Allt na Slanaich inflows using the FEH rainfall runoff method. Due to the size of the Moy Burn catchment, the FEH Statistical method was used to calculate peak flows on this watercourse, an FEH statistical estimate was also undertaken at the downstream boundary of the model (where Moy Burn flows into Loch Moy) for comparison. Version 3 of WINFAP software was used to undertake the statistical analysis for this assessment.

D.3.4 Critical storm durations vary across the catchment. A catchment wide storm duration provides a more realistic representation of actual rainfall events. The critical storm duration for each inflow in the model was set as 3.1 hours. Table D.3 shows the peak flows. Hydrographs were generated using the rainfall runoff method and for the Moy Burn, the hydrographs generated have been scaled to the statistical peak flow estimates.

Table D.3. Peak Flow Estimates

Watercourse	Inflow ID	Inflow Location	0.5% m^3/s	0.5+CC m^3/s
Moy Burn	C1	Upstream modelled extent of Moy Burn	32.94	39.53
Allt Creag Bheithin	C2	Upstream modelled extent of Allt Creag Bheithin	13.59	16.31
Allt na Slanaich	C3	Upstream modelled extent of Allt na Slanaich	10.87	13.04

D.3.5 The flood events modelled are sumareised in Table D.4.

Table D.4 Modelled Flood Events

Scenario	AEP					
	50%	3.33%	2%	1%	0.5%	0.5%+CC
Baseline	x	x	x	x	x	x
Roughness sensitivity					x	
Hydrological inflow sensitivity					x	
Downstream boundary sensitivity					x	
Model ‘with – scheme’	x	x	x	x	x	x
With-scheme and mitigation				x	x	

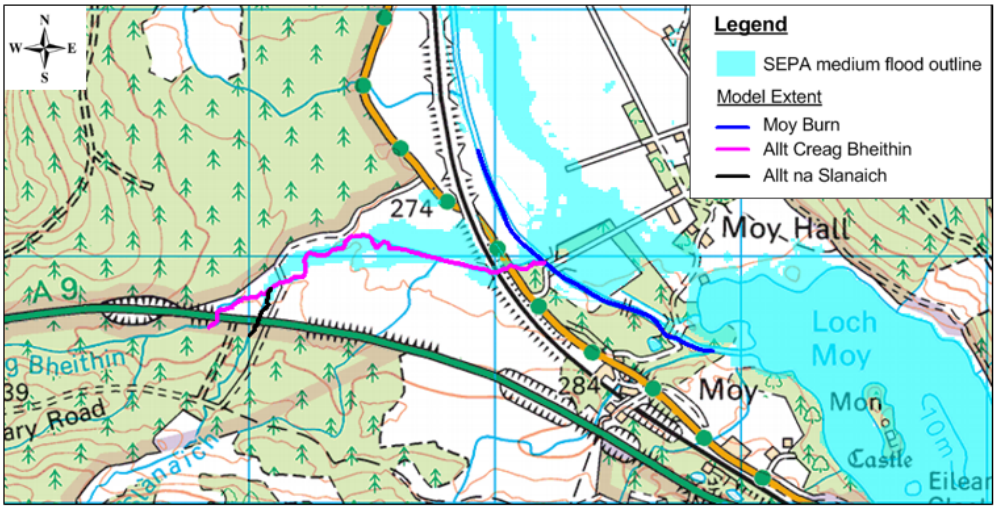
D.4 Baseline Hydraulic Model

D.4.1 Model assumptions and limitations:

- The original model for this area was larger and covered the entire Tomatin to Moy area. The larger model was trimmed for this assessment in order to accurately assess the impact of changes in the Allt Creag Bheithin area. Therefore, the model reported here only extends as far as Loch Moy and does not include representation of any of the watercourses downstream of this.
- The downstream boundary of the trimmed model is Loch Moy and it has been assumed that levels taken from the original larger model in Loch Moy are acceptable as a downstream boundary condition in the model used for this assessment.
- It has been assumed that it is appropriate to include lateral inflows within the model on the Moy Burn and Allt Creag Bheithin but a lateral inflow has not been applied on the Allt na Slanaich. This is deemed appropriate given the short section of the Allt na Slanaich represented within the model.
- It has been assumed that the existing structures within the baseline model are free-flowing and no blockages have been included in the model.
- It is assumed that the topographic survey used to define the river channels within the model accurately represents the geometry of the watercourses and that the interpolation between river cross-sections within the 1D model is acceptable.

D.4.2 In- channel geometry (1D): The 1D model is based on topographic survey of river cross-sections collected on the Allt Creag Bheithin, Allt na Slanaich and Moy Burn. The extent of each watercourse represented in the 1D model is shown in Figure D.3. The existing SEPA medium flood outline is also shown on Figure D.3.

Figure D.3 1D Model Domain



D.4.3 Following the issue of the draft FRA, additional topographic survey was carried out in October 2017 to improve the accuracy of the hydraulic modelling before confirming the magnitude of the impact of the Preferred Scheme. The additional topographic data was used in the hydraulic model that is described in this report. The improved model has been used to update the baseline 0.5% AEP flood outline, re-calculate the magnitude at flood risk receptors and determine the impact significance.

D.4.4 Table D.5 below details the model extents and key features.

Table D.5 Key model features

Model Reach	Modelled Reach (m)	Upstream model extent (grid ref)	Downstream model extent (grid ref)	Number of A9 Crossings	Total number of modelled structures
Allt Creag Bheithin	1800	274630, 834658	276198, 834968	1	4
Allt na Slanaich	210	275002, 834676	275097, 834853	1	1
Moy Burn	1300	275933, 835424	276881, 834617	0	3

D.4.5 Direct inflow hydrographs are applied at the upstream extents of each watercourse in the model. Lateral inflows are used on the Allt Creag Bheithin and Moy Burn to represent the flows generated in the intervening catchment area between the upstream and downstream modelled extents of each watercourse. As only a small reach of the Allt na Slanaich is represented in the model, it was not deemed necessary to apply a lateral inflow on this watercourse. The downstream boundary of the model is a Head-Time (HT) boundary representing levels within Loch Moy. The levels within Loch Moy were taken from the larger, calibrated T-M model (as described in Annex B of the Stage 3 FRA).

D.4.6 The open channel river sections were defined from the topographic survey, with the Manning's 'n' values defined from the site visits, which were undertaken in July 2015. Table C.5: Moy Burn tributary, roughness values. D.6 provides the Manning's 'n' value ranges within the 1D model and justification of the values used.

Table D.6. Manning's n roughness values in 1D model

Section Type	Minimum	Maximum	Commentary
River Channel	0.04	0.04	Representing rough bed material. A consistent value has been used throughout the model to aid stability.
Structures	0.015	0.04	Ranging from smooth concrete, to rough bed material.
Floodplain	0.045	0.05	(Chow, 1959).3.C.2 / 3 = "Light brush and trees in Summer / Winter"

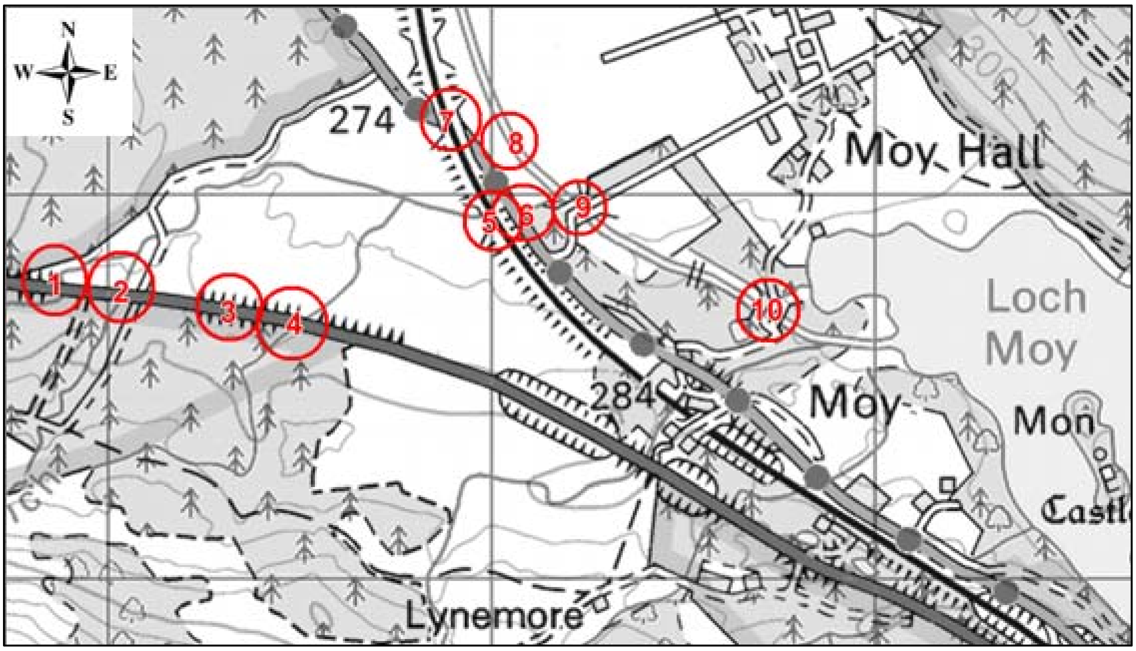
D.4.7 In channel's hydraulic structures: All the structures and cross sections were taken from survey data. Table D.7 provides the details of how the structures are represented within the model. Figure D.4 shows the location of these modelled structures. In total there are 7 structures modelled in the 1D model and 3 structures modelled only in the 2D domain as simple ESTRY 1D links.

Table D.7. Modelled Structures Details

Water Crossing ID	Structure	Watercourse	Dimensions (m)	Representation in the model	Photograph
1	A9 1270 C41 Culvert passing under A9	Allt Creag Bheithin	1.8Ø	Circular conduit unit in Flood Modeller. Overtopping of road was represented in the 2D model.	
2	A9 1270 C39 Culvert passing under A9	Allt na Slanaich	Two 2.0Ø culverts	Two circular conduit units in Flood Modeller. Overtopping of road was represented in the 2D model.	
3	A9 1270 C35 Culvert passing under A9	Drain	0.8Ø	ESTRY culvert in the 2D model. Overtopping of road was represented in the 2D model.	
4	A9 1270 C33 Culvert passing under A9	Drain	1.6Ø	ESTRY culvert in the 2D model. Overtopping of road was represented in the 2D model.	

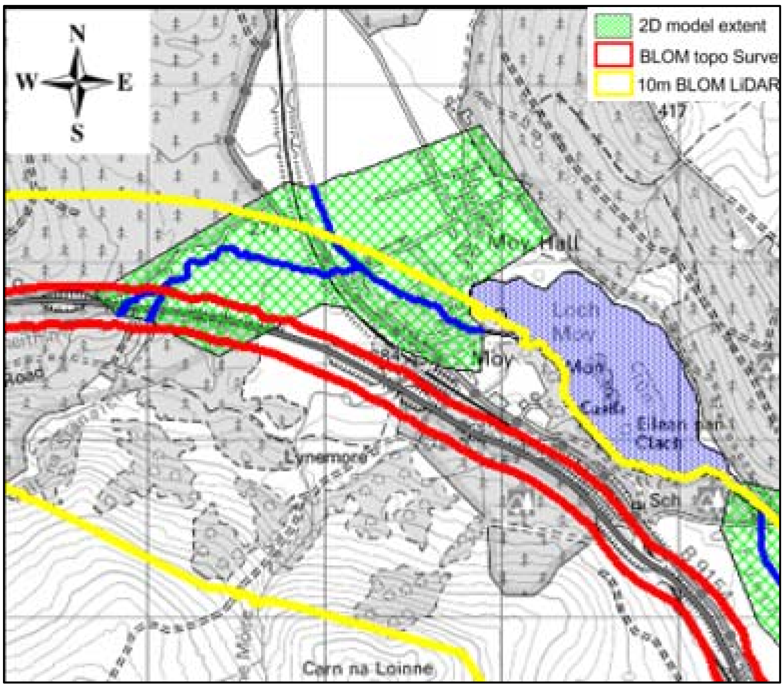
Water Crossing ID	Structure	Watercourse	Dimensions (m)	Representation in the model	Photograph
5	Bridge passing under the railway	Allt Creag Bheithin	7.5x37.0	Bridge unit in Flood Modeller. Overtopping of road was represented in the 2D model.	
6	Bridge passing under small road	Allt Creag Bheithin	1.4x5.0	Bridge unit in Flood Modeller. Overtopping of road was represented in the 2D model.	
7	Bridge passing under the railway	No water crossing / Underpass	4.3x5	ESTRY culvert in the 2D model. Overtopping of road was represented in the 2D model.	
8	Bridge passing under small road	Moy Burn	2.3x10	Bridge unit in Flood Modeller. Overtopping of road was represented in the 2D model.	
9	Bridge passing under small road	Moy Burn	2.5x7	Bridge unit in Flood Modeller. Overtopping of road was represented in the 2D model.	
10	Bridge passing under small road	Moy Burn	2.5x7	Bridge unit in Flood Modeller. Overtopping of road was represented in the 2D model.	

Figure D.4 Location of the structures in the model



D.4.8 A key component of any 2D model is the detailed ground model. The data used for the model were the Nextmap 5m DTM, 10m BLOM Lidar and the BLOMTopo Survey data for the A9 Dualling Corridor. The 2D component of the TUFLOW model was constructed mainly using a mosaic of these three terrains. The 5m DTM is extended enough to cover the whole area of interest, but the accuracy doesn't cover small watercourses and drains. The two sets of BLOM data include more detail but they don't cover all the area of interest. Figure D.5 shows the extents of each dataset in the Tomatin to Moy section as well as the 2D domain extent within the model.

Figure D.5 Terrain data coverage



D.4.9 Floodplain hydraulic structures: Structures 3, 4 and 7 in Table D.7 and on Figure D.4 are floodplain structures that are not represented in the 1D Flood Modeller component but are modelled in ESTRY, the 1D component of TUFLOW. This means that they can represent potential flow routes underneath structures such as roads and the railway within the 2D model domain.

D.4.10 Floodplain hydraulic friction: Differing land use types across the floodplain have been represented in the 2D model domain by varying Manning's 'n' roughness values across the domain depending on the features represented. Table D.8 shows the Manning's 'n' roughness values that have been applied within the 2D domain to represent different land use types on the floodplain.

Table D.8 Floodplain Manning's 'n' roughness values

Land Use	Manning's 'n' value	Commentary
General natural land	0.05	Used to represent undeveloped land including areas of short grass/scrub
Trees	0.07	Used to represent forested areas
Buildings	2	Used to slow flow through buildings as would occur in reality
Roads	0.02	Used to represent smoothness of tarmac

D.4.11 Boundary conditions: The 2D model domain has been sized to be large enough to contain the largest flood extent modelled (0.5% plus climate change), therefore across the majority of the model domain 2D boundaries are not required. However, at the downstream extent of the 1D model where Moy Burn flows into Loch Moy, it has been necessary to apply a 2D downstream boundary either side of the downstream extent of the 1D model to represent the loch levels. This does lead to some inundation of the 2D domain from the loch as would be expected during flood events.

D.4.12 The 1D and 2D components of the model have been linked using the HX approach where the water levels in the 1D model are applied along the banks of the channel represented in 1D. When water levels are high enough to overtop the bank top level in 1D, water is transferred to the 2D domain. The HX boundaries are two-way meaning that water from the 2D floodplain model can flow into the 1D channel model as well. The whole extent of 1D watercourses represented in the model is linked to the 2D domain using this method.

D.4.13 The Flood Modeller anfd TUFLOW runtime information is given in Figures D.6 and D.7.

Figure D.6 Flood Modeller runtime information – baseline model

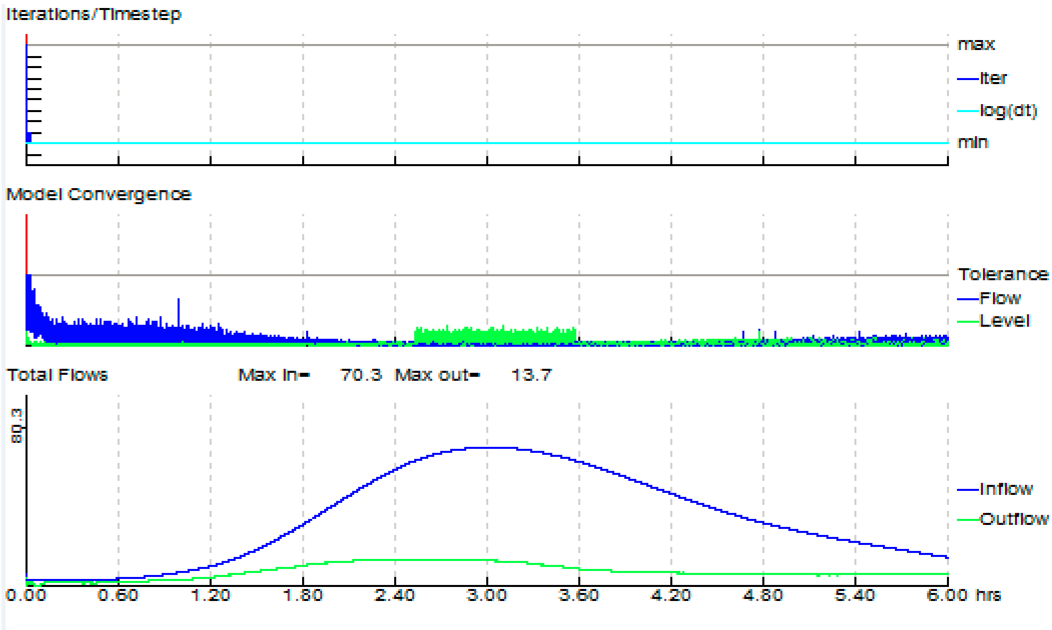
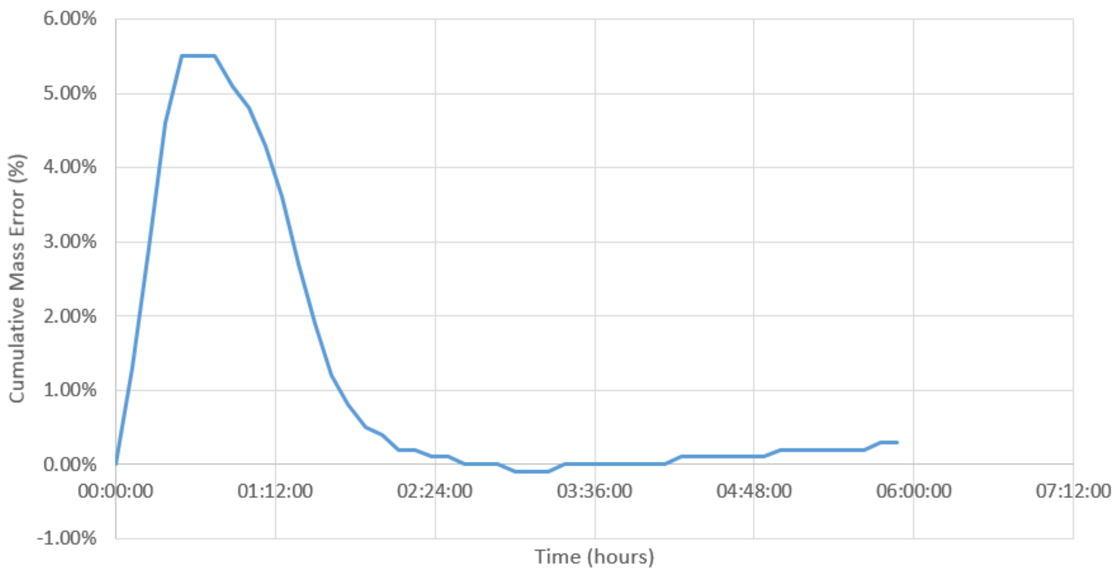


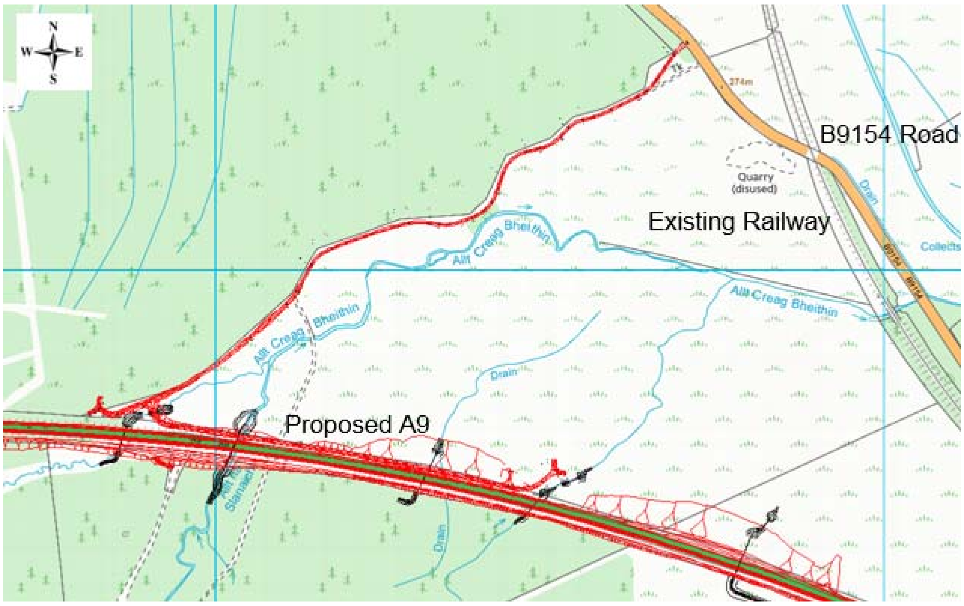
Figure D.7 TUFLOW cumulative mass balance error – baseline model



D.5 Proposed Model ('with-scheme' modelling)

D.5.1 The proposed A9 alignment in the vicinity of the Allt Creag Bheithin model includes a wider highway and a side road north of the A9, which crosses Allt Creag Bheithin and runs alongside the watercourse connecting the A9 with the B9154. Figure D.8 shows the proposed alignment. Around the A9 crossings on the Allt Creag Bheithin and Allt na Slanaich, major earthworks will be constructed and as a result the channels upstream and downstream of the A9 will be re-graded. In the proposed (with-scheme) model, the new regraded sections have been used where the channels will be changed from the baseline.

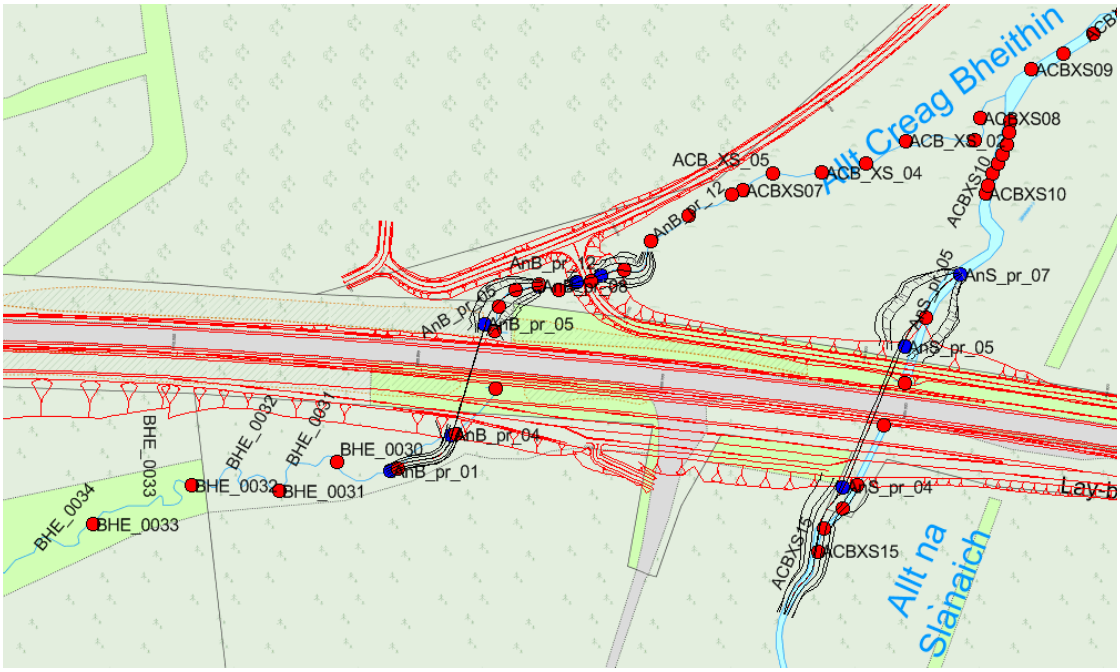
Figure D.8 Proposed Alignment Plan



D.5.2 In order to create the proposed (with-scheme) version of the 1D model, the existing culverts underneath the A9 on the Allt Creag Bheithin and Allt na Slanaich were changed to represent the proposed culverts. On the Allt Creag Bheithin, the existing A9 culvert (1.8m diameter circular culvert) was replaced by a 5m wide by 2m high rectangular culvert in the proposed model. The existing A9 culverts (twin 2m diameter circular culverts) under the Allt na Slanaich were replaced with three parallel 2.5m wide by 1.85m high rectangular culverts.

D.5.3 The watercourses will be realigned near the new crossings to fit the proposed route option. Figure D.9 below shows the baseline model cross sections (Red) and the proposed (with-scheme) cross sections (Blue). To represent the proposed (with-scheme) scenario in the 1D model, the proposed cross-sections have been added to the model and the existing cross-sections they replace have been removed. This means that the cross-section geometry around the A9 has changed in the proposed (with-scheme) model and the gradient of the Allt Creag Bheithin and Allt na Slanaich channels is also different to the baseline model.

Figure D.9 Baseline and proposed watercourse cross-section locations



D.5.4 The location and arrangement of the 1D river channels in the 2D domain has changed in the proposed (with-scheme) model compared to the baseline model due to the widening of the A9 to reflect the realignment of the watercourses as part of the scheme. The new A9 alignment and new side road have been represented in the 2D domain of the proposed (with-scheme) model by adjusting the levels of the base grid using z shapes and z lines. The levels of the proposed A9 and side road were supplied by the design team.

D.5.5 The model is stable in both 1D and 2D. Figure D.10 is the runtime output from Flood Modeller for the 0.5% AEP proposed (with-scheme) model and shows that there is no poor convergence during the run. Figure D.11 shows the cumulative mass balance error in the 2D domain throughout the 0.5% AEP proposed (with scheme) model run, for an hour at the beginning of the model run the mass balance error is outside of the acceptable range (+/- 1%) but this can be attributed to the large volume of water entering the 2D domain from the 1D channels. The cumulative mass balance error is within the acceptable range from 1 hour 40 minutes into the model run until the end of the run meaning that the peak of the event is not affected by high mass balance error.

Figure D.10 Flood Modeller runtime information – proposed (with-scheme)

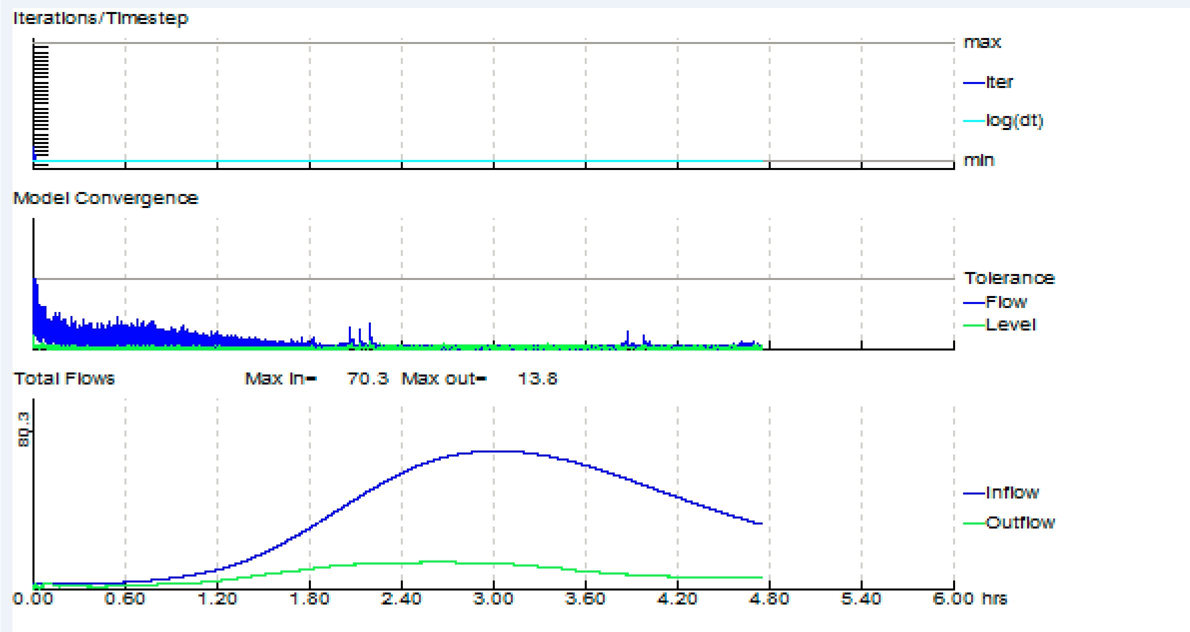
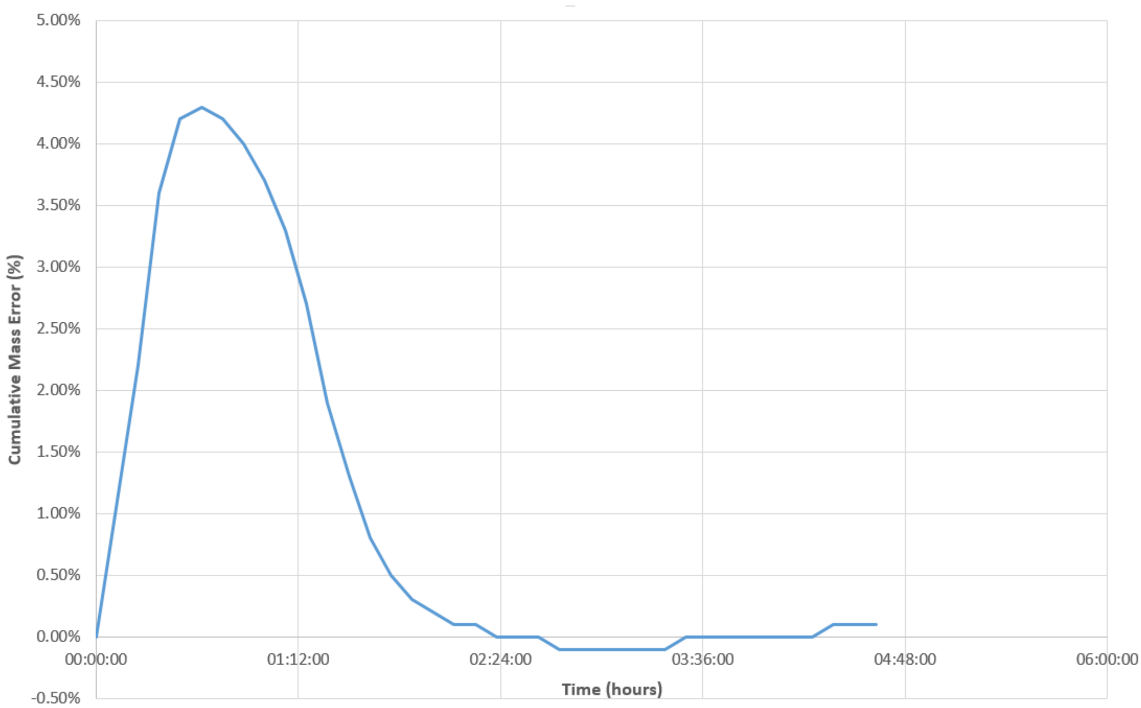


Figure D.11 TUFLOW cumulative mass balance error – proposed (with-scheme)

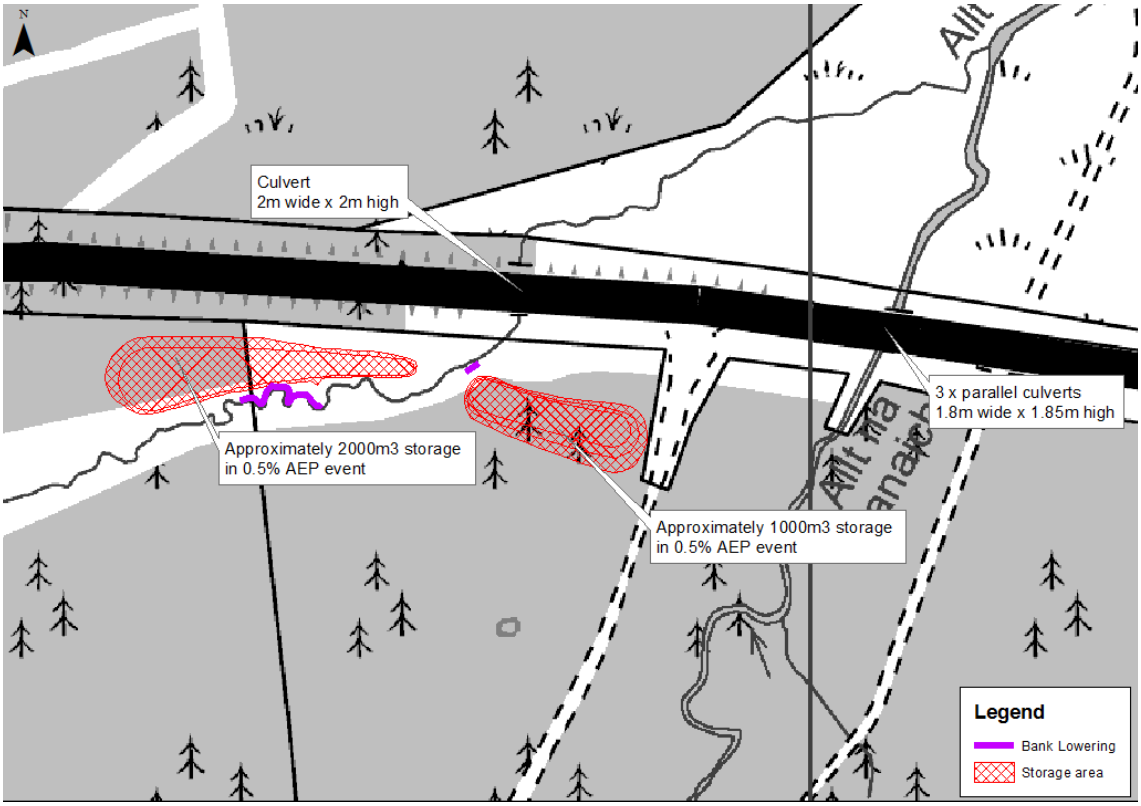


D.6 Proposed Model + mitigation measures ('with-scheme + mitigation measure' modelling)

D.6.1 As the proposed (with-scheme) arrangement improves conveyance on the Allt Creag Bheithin and Allt na Slanaich channels through the upsizing of the culverts under the A9, there is an increase in flood risk from the baseline scenario downstream of the A9 with the scheme in place. This has a negative impact on key receptors within the catchment such as the Highland Mainline Railway and the B9154. The impact of the proposed (with-scheme) scenario compared to the baseline is discussed in Section D5.

D.6.2 Mitigation is required as part of the scheme in order to prevent an increase in flood risk elsewhere in the catchment. Mitigation in the Allt Creag Bheithin catchment is provided in the form of flood storage upstream of the A9. In order to utilise the storage areas fully, it has been necessary to reduce the size of the proposed culverts under the A9 to hold back water in the Allt Creag Bheithin and Allt na Slanaich channels enabling water to overtop the channel banks upstream of the A9 and flow into the proposed storage areas. In order to encourage further storage upstream of the A9, the proposed bank heights in two locations have been lowered. Figure D.12 shows a schematic of the proposed mitigation measures.

Figure D.12 Mitigation Measures Schematic



D.6.3 In the proposed (with-scheme + mitigation measure) 1D model, the proposed A9 culvert A9 1273 C31 was reduced in size from the original proposed size (5m x 2m), the revised dimensions are 2m wide by 2m high. The culvert size in the proposed (with-scheme + mitigation measure) was set to reduce conveyance through the culvert and encourage water into the flood storage areas (discussed below). The A9 1273 C28 crossing on the Allt na Slanaich was also reduced in size from the proposed 2.5m wide by 1.85m high to 1.8m wide by 1.8m high, this was not to encourage water into a storage area upstream of the A9 but was found to be necessary to reduce conveyance along the watercourse.

D.6.4 Within the 1D model, a section of the right bank upstream of the A9 has been lowered to allow more water to overtop the Allt Creag Bheithin during flood events and maximise flood storage upstream of the A9 in order to negate the impact of the proposed scheme on flood risk downstream of the A9. A section of the left bank immediately upstream of the A9 on the Allt na Slanaich has also been lowered to allow more water into a proposed flood storage area.

D.6.5 2D model updates: Within the 2D model, two z shapes were used to represent the storage areas either side of the Allt Creag Bheithin channel, levels in the areas covered by the z shapes have been lowered compared to the existing ground levels. The storage area to the west of the Allt Creag Bheithin provides approximately 1000m^3 of storage and the storage area to the east of the channel provide approximately 2000m^3 of storage.

D.6.6 Where bank heights have been lowered on the Allt Creag Bheithin and Allt na Slanaich, the bank heights read into the 2D model along the HX lines have been adjusted accordingly to represent the new bank levels.

D.6.7 Model Proving: There are no gauges within the modelled extent, therefore it has not been possible to calibrate the model developed for this area. In order to determine how robust the model is and to understand the uncertainty in the model results, a suite of sensitivity tests have been undertaken. The sensitivity tests undertaken are as follows:

- Global roughness +20%
- Culvert roughness +/-20%
- Flows +/- 20%

D.6.8 The sensitivity tests have been carried out using the proposed model (with-scheme + mitigation) as the model is uncalibrated. Tables D.9 and D.10 show the variation in flow and level respectiveky between the proposed model (with-scheme + mitigation) and each of the sensitivity tests for the 0.5% AEP event.

Table D.9 Variation in flow for sensitivity tests

Cross-section	Proposed (with-scheme + mitigation) 0.5% AEP flow (m3/s)	N +20% global	N +20% culverts	N -20% culverts	Flow +20%	Flow -20%
AnB_pr_04	11.53	-0.01	-0.34	+0.96	+1.52	-1.45
AnB_pr_11	11.52	0.00	-0.34	+0.94	+1.50	-1.45
AnS_pr_04	10.85	+0.01	-0.01	+0.04	+2.19	-2.16
ACBXS27	24.71	-0.96	-0.32	+0.69	+3.58	-2.56
MBXS17	38.03	-2.96	+0.17	+0.39	+2.72	-2.28

Table D.10 Variation in water level (m) for sensitivity tests

Cross-section	Proposed (with-scheme + mitigation) 0.5% AEP water level (mAOD)	N +20% global	N +20% culverts	N -20% culverts	Flow +20%	Flow -20%
AnB_pr_04	293.05	-0.02	+0.18	-0.25	+0.37	-0.43
AnB_pr_11	291.37	0.00	-0.03	+0.09	+0.15	-0.15
AnS_pr_04	290.16	-0.14	+0.04	-0.04	+0.19	-0.18
ACBXS27	273.10	+0.04	-0.01	+0.01	+0.07	-0.07
MBXS17	271.08	0.00	0.00	0.00	0.00	0.00

D.6.9 Figures D.13 to D.15 show the variations in water level between the proposed model (with-scheme) and the sensitivity tests undertaken.

D.6.10 The sensitivity tests show that the model is most sensitive to changes in flow, which is as expected and it is worth recognising that hydrology is often the most uncertain part of a hydraulic model. The flows used in this assessment were calculated using the standard FEH methods and a conservative approach has been adopted. Where there are culverts in the model, changing the roughness through the structures has a moderate impact on the flows and water levels predicted. Roughness values for the structures in the model have been applied based on observations made during the topographic survey and site visits and are deemed appropriate. Increasing global roughness in the model by 20% has a marked influence on the flows predicted towards the downstream extent of the model on Moy Burn (MBXS17) but is not shown to affect the predicted water levels in this area. This is because the water levels at the downstream extent of the model are controlled by the levels in Loch Moy.

D.6.11 The downstream boundary condition has not been tested as part of the sensitivity testing because the culverts under the A9 that are the focus of this assessment are much higher than the loch level as both the Allt Creag Bheithin and Allt na Slanaich are steep watercourses.

Figure D.13 Comparison of water levels between proposed (with-scheme + mitigation) 0.5% AEP event and global roughness +20% sensitivity test along Allt Creag Bheithin

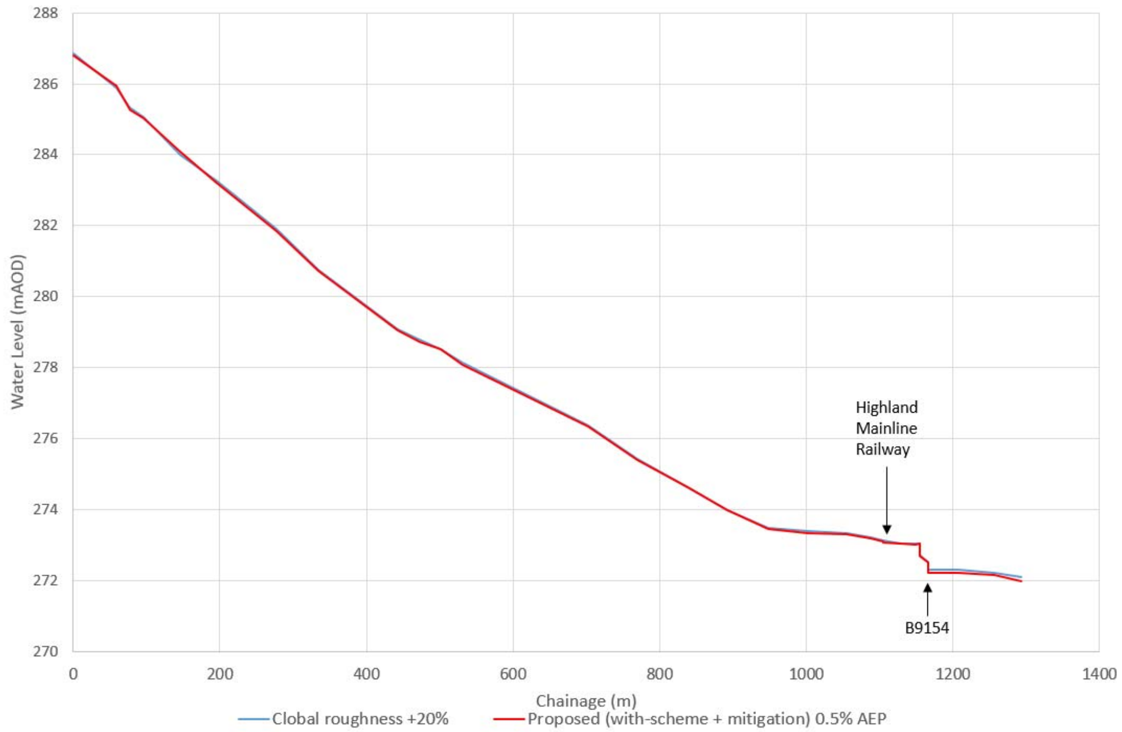


Figure D.14 Comparison of water levels between proposed (with-scheme + mitigation) 0.5% AEP event and culvert roughness sensitivity tests along Allt Creag Bheithin

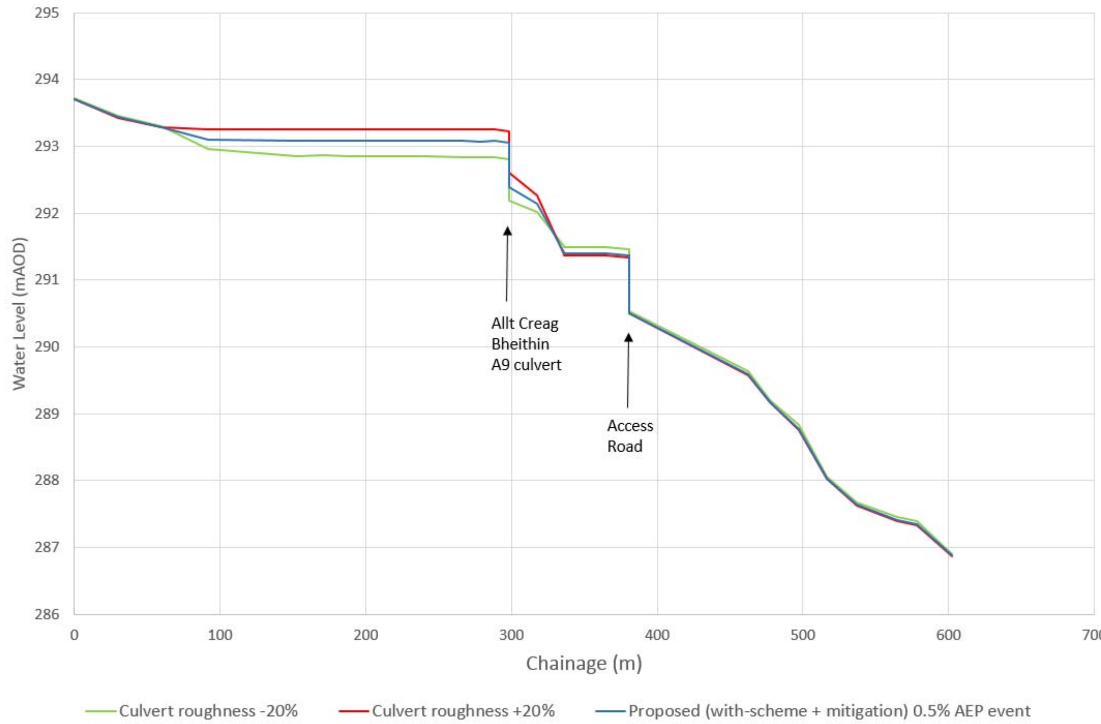


Figure D.15 Comparison of water levels between proposed (with-scheme + mitigation) 0.5% AEP event and flow sensitivity tests along Allt Creag Bheithin