Appendix 11.3

Flood Risk Assessment
Part 1

Contents

Tables

Figures

1 Introduction

1.1 A Flood Risk Assessment (FRA) has been carried out by the CH2M/Fairhurst Joint Venture (CFJV) on behalf of Transport Scotland, as part of the Design Manual for Roads and Bridges (DMRB) Stage 3 Environmental Impact Assessment (EIA) for Project 9 - Crubenmore to Kincraig (Central Section) of the A9 Dualling Programme. This FRA report will be included as a supporting appendix to **Chapter 11** (Road Drainage and the Water Environment) of the EIA.

1.2 Project 9 upgrades approximately 16.5km of the A9 to dual carriageway, between Crubenmore and Kincraig, replacing the existing single carriageway and upgrading two sections of 'wide single 2+1' carriageway. Project 9 includes the Spey Crossing where the A9 currently spans the River Spey for approximately 140m.

1.3 The Spey crossing within Project 9 crosses a Special Area of Conservation (SAC) and the Scheme extent is close to several ecologically sensitive areas and watercourses, some of which have specific ecological designations and protections. Project 9 is wholly within the Cairngorms National Park (CNP) and the Badenoch and Strathspey ward of The Highland Council (THC).

1.4 In the context of this report, 'Proposed Scheme' includes all permanent works proposed as part of the Dualling Programme within Project 9. These include the proposed mainline of the A9 itself, access roads, diversion channels and drainage features.

1.5 Project 9 has been progressed through the DMRB scheme assessment processes in accordance with DMRB (Vol. 5, S. 1, Pt. 2 TD37/93). The DMRB Stage 3 assessment considers the proposed alignment in greater detail and involves the assessment of significant environmental effects in accordance with Section 20A and 55A of the Roads (Scotland) Act 1984. Potential impacts on the water environment are reported in Chapter 11, and this FRA (Appendix 11.3) reports specifically on flood risk and describes the measures included in the Proposed Scheme to avoid or effectively mitigate potential flood risk impacts.

Approach

1.6 **Section 2** of this report introduces the scheme extents and surrounding water environment, and lists the survey information acquired for this assessment. Available information on local flood risk has been reviewed and is summarised in **Section 3**; this includes the work done in earlier A9 Dualling studies as well as feedback from stakeholders.

1.7 Aspects of the Proposed Scheme that may affect the water environment with regards to flood risk are outlined in **Section 4**.

1.8 **Section 5** outlines potential sources of flood risk. Consideration of fluvial flood risk is informed by a Hydrological and Hydraulic Modelling (H&HM) study, which has been developed through SEPA consultations and feedback on previous iterations of the modelling study undertaken prior to and early in the DMRB Stage 3 assessment process. The H&HM approach is described in **Section 6** and further details are provided in **Annex A** and **B**.

1.9 Pre- and post-development flood risk is assessed for both the existing A9 and the Proposed Scheme in **Section 7**, and is assessed at key locations outside the Proposed Scheme in **Section 8**. The assessment has been undertaken in accordance with Scottish Environment Protection Agency (SEPA) Technical Flood Risk Guidance for Stakeholders (2015) and DMRB; cognisant of best practice and other planning legislation and design standards where noted. A revision of the Technical Guidance was issued in July 2018 and any material changes to the guidance are highlighted where relevant.

1.10 Until **Section 9** 'Mitigation', the Proposed Scheme is considered as it was presented for initial assessment in September 2017. Assessment findings were then used to inform the developing scheme design and changes incorporated to address potential impacts either by avoidance or through the inclusion of project-specific 'embedded' mitigation. **Section 9** describes the changes made to the Proposed Scheme and reports on the assessment of 'embedded' mitigation including measures such as compensatory flood storage. **Section 9** concludes that all remaining 'residual' impacts to the Proposed Scheme and other receptors will be fully and effectively addressed by the inclusion of the 'additional' mitigation specified.

1.11 Compensatory storage is the preferred mitigation for replacement of lost floodplain volume using a 'like-for-like' replacement and 'volume-slices' approach. Compensatory storage effects are not modelled by default due to the complexity and potential uncertainty associated with representing it effectively in hydraulic models (as per SEPA Technical Guidance 2015, supported by SEPA consultation Nov. 2016).

Legislation & Design Standards

1.12 Scottish Planning Policy (SPP, 2014) sets out national planning policy guidance which reflects Scottish Ministers' priorities for operation of the planning system and for the development and use of land. A precautionary approach to flood risk is promoted. The flood risk hierarchy prioritises flood avoidance, flood reduction and avoidance of increased surface water flooding. This includes locating development away from 'functional flood plain' and 'Medium to High Risk' areas (0.5% [1:200] probability of flooding in any one year). The flood risk framework included in SPP to guide development includes three categories of flood risk.

1.13 For areas at Medium to High Risk, the framework notes that undeveloped and sparsely developed locations may be suitable for development that is essential for transport infrastructure "…*which should be designed and constructed to be operational during floods and not impede water flow''*. The Framework goes on to note that where built development is permitted on Medium to High Risk land *''…measures to protect against or manage flood risk will be required and any loss of flood storage capacity mitigated to achieve a neutral or better outcome"* [built development is not explicitly defined]. SPP also includes a list of factors to consider in applying the Risk Framework, which includes taking account of "*cumulative effects, especially the loss of flood storage capacity''.*

1.14 The Flood Risk Management (Scotland) Act 2009 places specific roles and responsibilities on local authorities and SEPA in relation to flood risk management. The Act also requires that all sources of flooding be considered in the assessment of flood risk including fluvial, coastal, pluvial, sewer and groundwater flooding.

1.15 The Cairngorms National Park (CNP) produced a Flood Management report, issued June 2016. The general strategy within this report is to identify those who have a responsibility for the National Park and aim to restore natural catchments so they are able to deal with flood events and benefit from other social and environmental elements.

1.16 The Highland Council general policy on flood risk requires avoidance of flood risk areas and promotes sustainable flood management measures. THC publishes Supplementary Guidance for the assessment of flood risk (adopted January 2013) outlining suggested FRA content and providing advice in line with SPP.

1.17 The SEPA Technical Flood Risk Guidance for Stakeholders outlines methodologies that may be appropriate for hydrological and hydraulic modelling studies, and sets out what information SEPA requires to be submitted as part of a Flood Risk Assessment report.

1.18 The DMRB contains requirements and advice relating to works on trunk roads for which one of the Overseeing Organisations is the highway authority (in this case Transport Scotland). It is written to reflect Highways England standards; therefore the manual is required to be interpreted with a view to Scottish standards when influencing design in Scotland.

1.19 DMRB Volume 11, Section 3 'Environmental Assessment Techniques' provides guidance for the environmental assessment of projects. Chapter 5 'Procedure for Assessing Impacts' includes guidance on how potential flooding impacts should be assessed in relation to road projects. Chapters 6 and 7 provide additional information on the scope and level of assessment required and reporting of the assessment process and findings.

1.20 Where design decisions have been particularly influenced by legislation, or follow specific design standards in relation to flood risk, it is noted within the body of this report.

2 Existing Conditions

Location and Key local Features

2.1 Project 9 of the A9 Dualling Programme is in the River Truim and River Spey valleys, within the CNP. Project 9 extends approximately 16.5km, from the existing dual carriageway at South Lodge (Crubenmore) to Kincraig.

2.2 The River Spey is located to the west of the A9 until the A9 turns in a north easterly direction and crosses the River Spey at Kingussie, for the remaining stretch of Project 9 (east of Kingussie) the River Spey is located to the south-east of the A9.

2.3 Within the extents of Project 9, the A9 travels in a north-easterly direction from Crubenmore to the southern end of Loch Insh, near Kincraig. The Highland Main Line railway (HML) runs adjacent to the A9 at the southern end of the section with the River Spey further west. Further north the A9 crosses both the River Spey and the HML at Kingussie. Beyond this point, both the river and the HML sit to the east of the road.

2.4 The A86 passes through Newtonmore and Kingussie to the north of the A9 before crossing beneath the A9 to the east of Kingussie at ch.50,760, north of the Spey crossing. The A86 continues for approximately 200m beyond the A9 crossing before turning northward at the junction to the A9 merge. Beyond the junction, the B9152 continues in an easterly direction towards Lynchat, in between the Spey and the A9.

2.5 Significant environmental features include internationally and nationally designated nature conservation sites, particularly the River Spey Special Area of Conservation (SAC).

2.6 The Insh Marshes SAC, east of Kingussie, is a significant environmental feature in the area as well as the internationally important designations of the River Spey-Insh Marshes Special Protection Area (SPA) and Ramsar wetland site.

Watercourses

2.7 Watercourses are classified as 'Major' where they are shown on 1:50,000 Ordnance Survey (OS) mapping; all other watercourses (identified via OS 1:10,000 mapping, topographical survey, site visits and review of Transport Scotland records) are classified as 'Minor'. Watercourse labels and crossing identifications (IDs) are marked on the 'Water Features Survey' figures provided in **Annex D.1**.

2.8 In this report, 'tributaries' is the term used to describe natural watercourses crossing the A9, as described below, whereas 'land drains' is used to describe smaller features that do not have an associated crossing under the A9.

2.9 The River Spey and other significant watercourses are described below.

River Spey

2.10 The Spey flows for 157km from its source in the Monadhliath Mountains to the Moray Firth. Many of its tributaries have sources in the steeper upper catchment within the Cairngorms Mountains. The A9 crosses the Spey at ch.50,200 and in other areas the distance from the A9 to the main river channel of the Spey varies from 95m to 1050m. Upstream of the crossing the Spey runs to the west of the A9. Downstream of the Spey crossing the watercourse is located to the east of the road.

<u>River Truim</u>

2.11 The River Truim flows in a northerly direction and is located to the west of the A9 from the start of Project 9. At ch. 41,400 the River Truim discharges into the River Spey which continues to flow in a north easterly direction to the west of the A9. The distance from the A9 to the main river channel of the River Truim varies from 160m to 740m within the Project 9 extents. The high ground to the east of the A9 drains toward the River Truim: the A9 crosses 6 tributaries of the River Truim within the length of Project 9. The overall catchment draining to the River Truim is $125km^2$ at its confluence with the River Spey.

2.12 The River Truim is discounted from further consideration as a potential source of flood risk to the Proposed Scheme due to it being more than 25m below the level of the A9.

<u>Milton Burn / Burn of Inverton (ID147)</u>

2.13 The Milton Burn is a right bank tributary of the River Spey with headwaters below the summit of Creag nam Bodach at Loch an Dabhaich. It crosses under the A9 mainline at ch.47,350, as the A9 forms an embankment across the burns wide floodplain. With a contributing catchment of $34.8km^2$ at its confluence with the River Spey, the Milton Burn is the largest "tributary" of Project 9.

<u>Gynack Burn</u>

2.14 The Gynack Burn flows through Kingussie before joining the River Spey 700m upstream of the A9 Spey crossing (ch.50,200). The Gynack Burn has a contributing catchment of $21.9km^2$ at its confluence with the River Spey. The A9 itself does not cross the Gynack Burn and any development proposal is remote to this watercourse.

<u>Raitts Burn (ID162)</u>

2.15 The Raitts Burn is a single thread left bank tributary of the River Spey flowing approximately 7km south-eastwards across the north-western flank of Strathspey. It crosses under the A9 mainline at ch.53,450 and has a contributing catchment of $12.4km^2$ as it joins the River Spey.

2.16 The channel planform is straight directly upstream and downstream of the A9 crossing set within a wide valley with gentle slopes. Between the HML railway and the B9152 road, mid-channel deposition of materials ranging from gravel to boulder has led to constriction and subsequent backing up of flow beneath both road and railway bridges and further deposition of fines on the embankments.

Other Water Features

2.17 There are also several land and road earthwork drainage ditches along the route of the existing A9 within Project 9.

2.18 Loch Ericht, Loch Cuaich, Loch Phoines and the Spey Reservoir are subject to impoundment in the vicinity of Project 9, and are registered as Controlled Reservoirs under the Reservoirs (Scotland) Act 2011. The SEPA reservoir maps show parts of the A9 would be inundated if any of the reservoirs were to fail. However SEPA guidance states that, *'Reservoir flooding and flooding from other infrastructure - although unlikely, failure of infrastructure such as dams or canals could result in a large volume of water being released very quickly. Flooding from reservoirs is very unlikely to occur and there has been no loss of life from reservoir failure in the UK since reservoir safety legislation was introduced in 1930s'.* Therefore flooding from failure of impoundment structures at Loch Ericht, Loch Cuaich, Loch Phoines and the Spey Reservoir is considered very unlikely.

Survey Information

2.19 In addition to 1:10,000 scale and 1:25,000 scale OS mapping used under licence, a number of ground information sources have been used to inform this assessment:

- High precision 1:500 topographic mapping of the carriageway envelope, based on LiDAR and ground survey, produced by Blom Land Surveys (BLOM) for the project in 2014
- Photogrammetry and accompanying aerial photographs (BLOM 2014)
- 1m LiDAR DTM of the River Spey valley produced in 2011 as part of Scottish Water/Atkins Phase 1 project
- 5m 'Nextmap' DTM of the River Truim valley

River surveys - October 2015 and June 2016

2.20 A topographical survey was specified to gather information on channel shapes, including cross-sections and levels at key locations along the Rivers Spey and Truim to support the DMRB Stage 3 H&HM study. The survey was targeted to describe key locations in terms of potential impact, based on design information from earlier stages of the DMRB process.

2.21 The river survey includes cross-sections of the river bed and details of potentially influential structures on watercourses (e.g. HML railway crossings). It was carried out in two stages due to access restrictions associated with the fish spawning season.

Other survey and geographical information

2.22 Other survey and geographical information includes:

- Peat survey (incl. probing, coring and other Ground Investigation) information predominantly gathered in 2016, but dating back to 2011 and currently ongoing
- As-built information for the A9 received from THC
- National Vegetation Classification (NVC), as a shapefile in GIS received from SNH
- Walkover surveys conducted in 2016 to support the DMRB Stage 3 assessment – including information gathered to clarify crossing connectivity and size

SNH environmental information

2.23 Environmental survey information is publically available on the SNH website. A number of these GIS shapefiles were used to inform placement of mitigation areas as part of the ongoing design and wider environmental assessment including:

- Ancient Woodland Inventory
- Geological Conservation Review Sites
- Sites of Special Scientific Interest (SSSI)
- Special Areas of Conservation (SAC)
- Special Protection Areas (SPA)
- World Heritage Sites (Natural Heritage)
- Wetlands of International Importance (Ramsar)

3 Flood Risk Information

3.1 Flood risk to the Proposed Scheme is primarily associated with fluvial flooding from the two main rivers and tributaries located within the vicinity of Project 9. Other sources of flooding, such as surface water, ground water and sewer flooding are also addressed within this section.

SEPA Flood Maps

3.2 SEPA Flood Maps provide guidance on the possible extent, depth and velocity for different likelihoods ('High, Medium and Low') of three different sources of flooding (River, Coastal and Surface Water), alongside other associated information. Caveats to the mapping note that "*…they are indicative and of a strategic nature… It is inappropriate for these Flood Maps to be used to assess flood risk to an individual property*."

3.3 The river flood map is based on a two-dimensional flood modelling method applied across Scotland to all catchments greater than $3km^2$ and includes hydraulic structures "*where appropriate information was available*"; thus many of the smaller tributaries are not considered and flood extents may be particularly unrepresentative at watercourse crossings.

3.4 Some of the mapping in the road corridor appears to have been generated using Nextmap digital terrain data with 5m spatial resolution. The dataset provides insufficient topographic detail to represent smaller watercourses – limiting the reliability of the mapped flood extents.

3.5 SEPA Flood Maps indicate that there are areas at risk of fluvial flooding (10yr, 200yr and 1000yr) within Project 9 extent from the surrounding watercourses. The flood extent of the River Spey is shown to come against the A9 embankment at various locations.

3.6 Whilst the SEPA Flood Maps can be a useful tool for initially considering whether a site may be at risk of flooding, more detailed analysis is required to assess flood risk around the A9 corridor.

A9 Strategic Flood Risk Assessment

3.7 The A9 Strategic Flood Risk Assessment (SFRA), published in 2013, considers the entire 177km of the A9 between Perth and Inverness and breaks the road into sections. The SFRA identifies one major catchment area within Project 9, the River Spey, which flows in a north easterly direction.

3.8 The SFRA refers to historic flooding and states that data has been collated from a number of sources. Section 4.2.2 includes a review of historic flood events: "*Review of the flood history indicated that most known flooding issues occurred around residential properties away from A9 route corridor*". Several of these events were located close to the A9, with "*…six flood records recorded within the 200m wide A9 dualling corridor.*" However, precaution should be taken as the area surrounding the A9 is largely rural and flooding incidents may not have been reported.

3.9 The SFRA has used Digital Terrain Model information that is available for the area and has identified a correlation between the locations of frequent flooding and the steep hill sides adjacent to the road: "*Using available Digital Terrain Model information, the locations where road flooding is frequently reported were noted to be along the stretches within cuts adjacent to steep hill sides".*

3.10 The SFRA summarises flood reports into 5 areas which indicate a common issue:

- Heavy rain
- Snow melt from hills

- Runoff from fields/ hills onto road
- Runoff containing sediment (sand, silt)
- Flooding from French drains

3.11 The above descriptions suggest a typical hillside runoff flood mechanism where flooding is caused by issues related to roadside drainage in collection and draining of the surface water runoff from the fields or hillside during heavy rain or snowmelt.

3.12 It is noted that infrastructure failure, such as reservoir failure, could in theory also impact the A9, although it is considered very unlikely.

Findhorn, Nairn and Speyside Local Flood Risk Management Plan (2016)

3.13 The first Local Flood Risk Management (FRM) Plan for Findhorn, Nairn and Speyside was published by Moray Council in June, 2016 in agreement with THC, Scottish Water, SEPA, Forestry Commission Scotland and CNPA. It follows the Draft FRM produced by SEPA in 2014.

3.14 Newtonmore, adjacent to the south of Project 9, is identified within a Potentially Vulnerable Area (PVA 05/13) factsheet for an area of approximately 6km^2 including the town and surrounding rural area and is within the CNP. The River Spey is the main river in this PVA and there are many small burns draining off the steep hillsides. There are approximately 20 residential and 20 non-residential properties at risk of flooding. The Annual Average Damages are approximately £41,000, caused by 27% river flooding and 73% surface water. Two locations on the A9, with a total length of 370m, are noted in the PVA factsheet as being at risk from flooding. There is no further detail about the exact location or flood mechanism.

3.15 Kingussie, adjacent to the north of Project 9, is identified within a Potentially Vulnerable Area (PVA 05/12) factsheet for an area of approximately 24km^2 including the town and surrounding rural area, and is within the CNP. The River Spey is the main river in this PVA and there are many small burns draining off the steep hillsides such as the Gynack Burn which flows through Kingussie. There are approximately 30 residential and 20 non-residential properties at risk of flooding. The Annual Average Damages are approximately £92,000, caused by 91% river flooding and 9% surface water. The Gynack is noted as the main source of river flooding to properties in Kingussie. Three locations on the A9, with a total length of 50m, are noted as being at risk from flooding. There is no further detail about the exact location or flood mechanism.

3.16 The Local FRM Plan also refers to a Flood Protection Study which aims to reduce flood risk to Kingussie from the Gynack Burn. The study will investigate options to improve conveyance and provide natural flood management. Options include upstream storage in Loch Gynack, direct defence through Kingussie and the widening of the railway bridge. The FRM plan states that the study could benefit 36 residential and 16 non-residential properties which are currently at risk of flooding in this location, as well as a reduction in flood risk to the railway and local roads.

Other Studies

Kingussie Flood Study

3.17 The "*Kingussie Flood Study - Stage 1 and 2*" was prepared by URS in 2012 for The Highland Council. It provides a review of the flooding problems in Kingussie, based on a 1D hydraulic model of the Gynack Burn and a short reach of the River Spey, highlighting the combination of undersized crossings and high sediment load within the Gynack Burn as the main flooding driver for the town of Kingussie. Mitigation options are investigated: upstream attenuation storage, flood defences in Kingussie, flood flow management (formalising flood flow paths within the town by adjusting road levels/cambers), and combination of options. The provision of upstream storage is presented as the preferred option.

3.18 Pitmain Estate received planning consent in June 2016 for the construction of a flood alleviation scheme diverting extreme flows from the Allt Mhor watercourse (a tributary of the Gynack Burn) along an open channel approximately 1200m long to discharge into the adjacent Loch Gynack. This work will integrate with the existing hydropower scheme which included the reconstruction of the Dam on the River Gynack at Pitmain Lodge.

Insh Marshes National Nature Reserve: River Restoration Feasibility Study

3.19 In October 2015, 'EnviroCentre' produced the draft *"Insh Marshes National Nature Reserve: River Restoration Feasibility Study"* for RSPB Scotland. Using a refined hydraulic model of the Insh Marshes, the study investigates options to amend flood embankments and bank protection works along the River Spey and its tributaries within the Insh Marshes in view of the restoration of the natural functioning of the floodplain, requiring reduced human intervention to maintain the ecological interests of the site. The study is based on a hydraulic model of the Insh Marshes floodplain and focusses on flooding events of low return periods (5-POT to Q_{med}). The range of options reviewed (do nothing, partial removal or full removal of agricultural embankment) highlight the complexity of the flow mechanisms within the marshes for this type of event.

Balavil Mains Farmhouse Redevelopment

3.20 The planning application and relevant supporting documents (flood risk assessment report and supplementary report) for Balavil Mains Farmhouse redevelopment (permission now granted) were also reviewed. The site is located to the north of the existing A9, approximately 3.6km to the east of Kingussie on the banks of the Raitts Burn, a tributary to the River Spey. The planning documents state that informal bunds upstream of the A9 culvert act as a flood defence for the proposed development. In their planning consultation response SEPA have stated that, '*no alterations are made to raise, strengthen or lengthen/extent the existing informal flood embankments'.* Therefore the existing level of flood risk will remain and the site could be susceptible to flooding should the flood embankments be overtopped or breached. SEPA have also made reference to the A9 Dualling within their response for the Balavil Mains Farmhouse application and state that, '*changes may be made to the A9 culvert as part of those works'.*

River Spey Abstractions

3.21 A report on River Spey abstractions (April 2008) has been prepared by EnviroCentre for the Spey Fishery Board (SFB). This report highlights that the abstractions in the Spey catchment for hydroelectric power generation influence flows in the Spey itself, along with tributary watercourses. A potential deficit of between 10% – 20% in water balance in the Spey is identified.

Previous Stages of the Proposed Scheme Flood Risk Assessment

3.22 This DMRB Stage 3 FRA follows on from Chapter 11 of the CFJV (2015) DMRB Stage 2 Environmental Assessment: Road Drainage and the Water Environment, which is a comparative assessment of the potential environmental impacts, including flood risk, of the proposed road alignment options. DMRB Stage 3 work builds on and hence supersedes the Stage 2 flood risk findings, and follows the approach laid out in the DMRB Stage 3 Hydrology & Hydraulic Modelling Approach report (2016), summarised in **Section 6** of this report.

SEPA and THC Information

3.23 SEPA and THC have provided datasets indicating locations of historical flood events in the vicinity of the Glen Garry to Kincraig A9 route. This data is considered in the A9 Dualling SFRA, which was prepared in support of the Strategic Environmental Assessment (SEA).

3.24 SEPA have also provided information on their flow gauges at Invertruim and Kinrara, and provided feedback on the hydrological and hydraulic modelling approach taken at previous stages of the Proposed Scheme. Hydrology is discussed in more detail in **Section 6** and related **Annex A.**

4 Proposed Scheme Design

4.1 The Proposed Scheme includes measures that change the way the road interacts with the water environment, such as widening the existing road surface for the dual carriageway; the provision of access roads, drainage and watercourse crossings and diversion channels that meet modern design standards; and the introduction of mitigation to alleviate adverse environmental impacts.

Design Development

4.2 Throughout the DMRB Stage 3 design process, several environmentally-led workshops considered each aspect of the developing design.

4.3 The main body of this FRA report is based on the proposals included in a design presented for initial assessment in September 2017. Subsequent design development was carried out to avoid and minimise potential clashes with environmental or physical constraints, and achieve a better balance of engineering and environmental objectives e.g. steepening earthworks slopes locally to avoid floodplain encroachment. Design development is further described in the DMRB Stage 3 EIA, Chapter 4.

4.4 The initial flood risk assessment findings were fed back into the developing design to avoid and minimise impacts where possible. Flood risk mitigation options were then developed and assessed against wider environmental considerations. **Section 9** of this report describes changes made following the September 2017 initial assessment, sets out details of additional hydraulic modelling undertaken to investigate design changes, and recommends measures to address flood risk for the Proposed Scheme in the developed design presented for assessment in July 2018. **Section 9** concludes that potential flood risk impacts to the Proposed Scheme and other receptors will be fully and effectively addressed by avoidance or through the inclusion of appropriate mitigation.

Key Design Features

4.5 A number of features of the design intrinsically affect flood risk to the Proposed Scheme itself, as well as the potential impacts of the Proposed Scheme on flood risk elsewhere, notably:

- Upgrading the **River Spey crossing** structure and associated embankment near Kingussie
- Upsizing **watercourse crossings** to provide capacity for a 200yr design event and freeboard allowance, and setting a minimum crossing size (1200mm) for maintenance access
- Raising **road levels** to accommodate for increased watercourse crossing heights, as well as a minimum of 2m above culvert crowns for road build up, drainage and services, and 600mm freeboard to the 200yr flood levels with climate change allowance
- Providing **Sustainable Drainage Systems** (SuDS) to manage surface water runoff and water quality
- Providing and upgrading **tracks** and other operational assets for local users or maintenance access (depending on end-user requirements and other planning constraints, the defined standard for the Proposed Scheme mainline may not apply)
- Providing **compensatory storage** to mitigate for loss of floodplain volume as a result of encroachments.

4.6 In order to maintain a precautionary approach to the assessment, this FRA considers the Proposed Scheme without compensatory storage until **Section 9**.

Other Pertinent Changes

4.7 The Proposed Scheme will change the road infrastructure within Project 9 extents. Changes likely to impact on the water environment include:

- The **earthworks footprint** of the Proposed Scheme mainline relative to the existing A9 – whilst it will remain online, dualling will increase the road footprint, with potential implications on local watercourse floodplains, channels and road drainage
- The new road footprint and profile will require **diversion of some watercourse channels**, either to relocate outside the earthworks footprint as noted above, or to upgrade channels to meet design standards
- The **existing A9 drainage will be replaced by a new drainage system** and all areas catered for by the existing drainage will be catered for in the Proposed Scheme

4.8 The implications of these changes on flood risk are assessed in **Section 7** and **Section 8** of this report.

Context for Crossing Design Approach

4.9 Within the study area for this project the existing A9 mainline crosses watercourses that range in size from small open channels such as field drains to much larger watercourses such as River Spey which require significant bridge structures. To support the dualling of the A9, the Proposed Scheme will include the extension or replacement of many structures which convey these flows.

4.10 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. DMRB and industry design standards set out the key technical criteria for the design of bridges and culverts. However, in addition to these technical standards, across all project areas there are other drivers that influence the crossing design which include:

- **Flood risk**. In the event that a crossing structure is either extended 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 crossing. Extending a crossing structure in the absence of any other change may increase flood levels upstream, while replacing an existing structure 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 crossings, consideration is given to the provision of adequate integrated mammal passage, which if required will influence opening size. In addition, for culverts 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 opening size of a crossing structure 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 crossing, both upstream and downstream

- **Road drainage design**. The crossing 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

4.11 These factors have been considered on a case-by-case basis to develop the most appropriate design for each crossing. This design process is iterative, such that the final design meets the fundamental design standard, which is that the trunk road will remain 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 road level and the peak water level during the 0.5% AEP (200-year) plus climate change event.

4.12 The design approach for the watercourse crossings, which takes account of the relevant technical design guidance, allows for a degree of flexibility and engineering judgement to be applied to the design, to account for the various influencing factors outlined above.

4.13 Due to its size, the context for the River Spey crossing design includes the above elements together with wider aspects, amongst them landscape and visual impact, habitat issues, environmental designations, engineering, construction, local geology, and costs.

4.14 A range of alternative opening widths for the proposed Spey Bridge was examined with regards to potential flood risk to sensitive receptors upstream and downstream of the crossing. The associated specific assessment, carried out using a hydraulic model developed for this FRA, is presented in **Section 6**.

5 Potential Sources of Flood Risk

5.1 Potential sources of flood risk over the length of Project 9 have been identified as follows:

- **Fluvial flows:** Extreme fluvial flood events have the potential to cause rapid inundation of land whilst posing a threat to the welfare of occupants and potentially preventing emergency access to properties and essential infrastructure. The site may be at risk of direct fluvial flooding from the River Spey and its tributaries. In addition, any change on the hydrological environment brought about by the Proposed Scheme may change the hydrological or hydraulic behaviour of local watercourses, potentially increasing flood risk to parts of the Proposed Scheme or elsewhere. The effect of the Proposed Scheme on flood risk at local and wider scales requires consideration
- **Infrastructure failure:** Flooding due to the failure of man-made water infrastructure. The failure or blockage of conveyance infrastructure, such as culverts or bridges could increase the risk of flooding at the site. Local drainage infrastructure is also a potential source of flood risk, including any locations where SuDS are to impound water. In addition, where there are bodies of water impounded in the wider Spey catchment, such as Loch Ericht and Spey Reservoir, there may be a risk associated with the failure of these structures
- **Overland flow:** Overland flow occurs when the infiltration capacity of the ground is exceeded in a storm event. This could result in water travelling as sheet flow overland or excess water being conveyed from one location to another by local road networks. Overland flow from the hillsides up-slope of the A9 is a potential source of flood risk
- **Groundwater:** Groundwater flooding could occur at low points on any given site, particularly if that site is next to a water feature or below local land features. Groundwater is likely to be a flooding mechanism that contributes to other flooding. It has the potential to extend the duration or extent of flooding in low-lying areas and may be important to consider in flood mitigation strategies
- **Sewer flooding:** If the capacity of surface, combined or foul sewers or the road drainage is exceeded in an extreme event, or a blockage occurs, surcharging of the network can result in surface flooding

5.2 One potential source has been discounted based on the location of the development site:

- **Coastal flooding:** the site is not at risk from tidal inundation or coastal waves due to its elevation; over 220m above sea level

6 Hydrological and Hydraulic Modelling Study

Overview

6.1 A summary of the DMRB Stage 3 hydrology and hydraulic modelling study is provided below. Details are provided in **Annex A** (Hydrology) and **Annex B** (Hydraulic modelling).

6.2 A Hydrological and Hydraulic Modelling (H&HM) study has been undertaken to aid the assessment of aspects of fluvial flood risk potentially affecting the existing A9, the Proposed Scheme mainline and other sensitive receptors.

6.3 The DMRB Stage 3 H&HM methodology has been developed through regular consultations with SEPA and THC. Stakeholder feedback on previous iterations of the modelling study has been used to inform the current approach. SEPA recently confirmed that the consultation process has given good confidence in the work carried out to-date. SEPA also emphasised the importance of documenting processes to demonstrate the extent of the analysis underpinning the assessment. This section summarises the H&HM approach and further details are provided in Annex B.

Scope

6.4 The modelling output is intended to provide the assessor with information on predicted changes in flood level, depth and velocity, as well as define the functional floodplain of key watercourses. These outputs allow for the potential impact of the Proposed Scheme to be assessed at receptors, and are supplied to other disciplines for input to the wider environmental impact assessment (e.g. hydromorphology assessment).

6.5 The H&HM study considers design proposals as they were in the September 2017 Initial Design. In order to maintain a precautionary approach to the assessment, compensatory storage areas (CSAs) are not included in the scope of the general H&HM study. However, additional modelling has been undertaken at discrete locations to investigate mitigation, including some compensatory storage areas.

6.6 Changes made between the Initial Design and the Final Assessment Design are considered in **Section 9**. Where changes introduced by the Assessment Design might be of significance, additional modelling work has been carried out and is reported in **Section 9**.

6.7 Recommended measures to alleviate flood risk are included in **Section 9**. Where these measures include compensatory storage, storage provision has been sized following SEPA's preferred method of like-for-like replacement.

Approach

6.8 The DMRB Stage 3 hydrology and hydraulic modelling approach has been informed by the findings and limitations of the DMRB Stage 2 assessment. The hydrological analysis has been reviewed and refined to reflect wider information on gauged data. The DMRB Stage 2 Enhanced 2D models have also been updated to include targeted ground and watercourse survey data to improve confidence in the understanding of flood risk.

6.9 DMRB Stage 3 models have been developed to consider the reach of the River Spey adjacent Project 9 and cover pertinent tributary crossings. The design information, including Proposed Scheme mainline, access roads, SuDS basins and watercourse diversions has been used to create post-development versions of each model reach in order to analyse the effect of the Proposed Scheme, and the findings have been fed back into the ongoing design process.

6.10 The River Spey model was used to cover the River Spey adjacent to Project 9. Tributaries adjacent to the River Spey have been modelled separately from the main channel where required, using a smaller and more tailored grid.

6.11 The modelling exercise includes pre and post development scenarios to support effective assessment of impact. The modelling output has been used to identify any change in flood level and extent, and has informed the requirement for and subsequent mitigation design.

Hydrological Assessment

<u>River Spey Hydrology</u>

6.12 The River Spey model is fed by the discretised inflows from the upstream catchment (River Spey at Invertruim) and the lateral contribution of the 13 large tributaries of the River Spey between Invertruim and Kinrara, as illustrated by the map in **Figure 6-1** below.

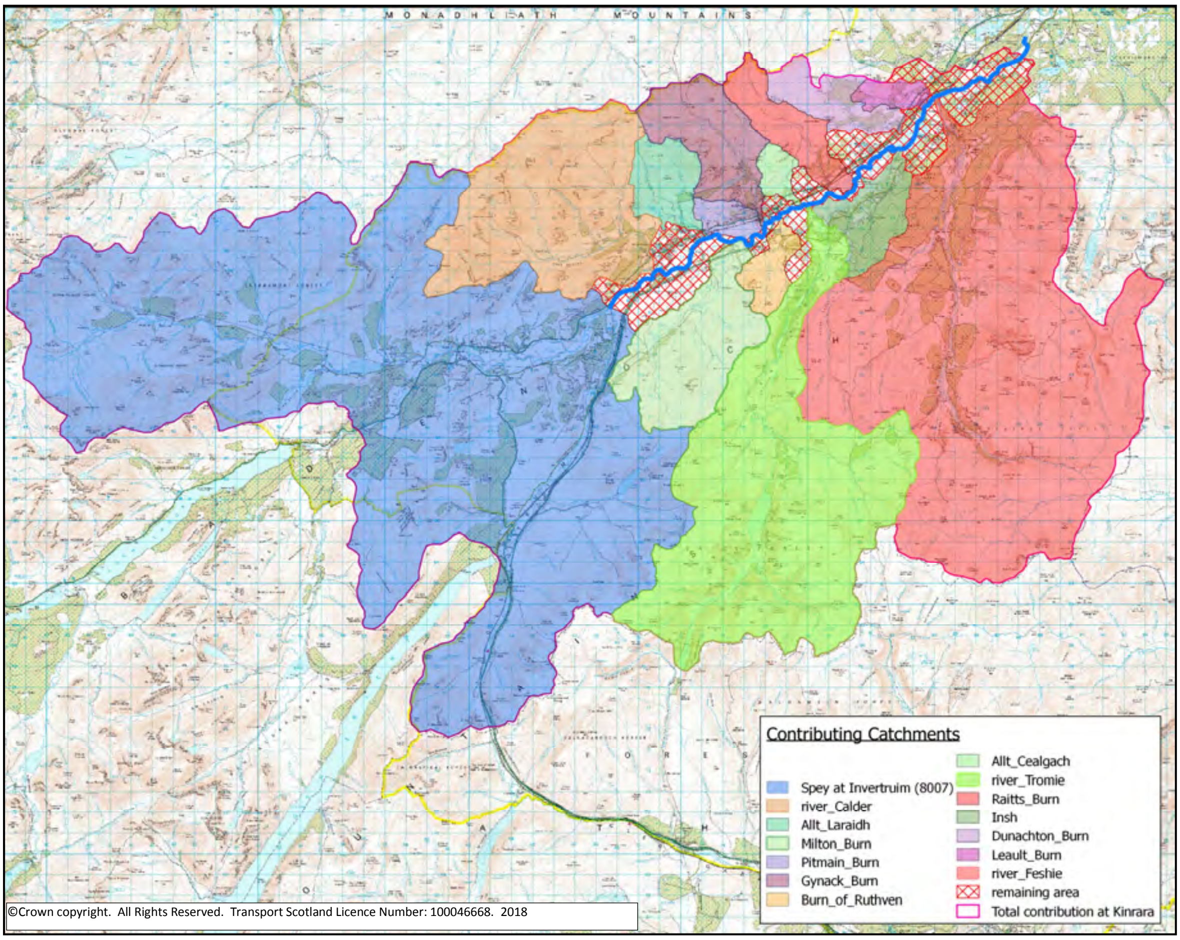


Figure 6-1: Spey – contributing sub-catchments.

6.13 One of the key characteristics of the modelled reach of the River Spey is the influence of floodplain storage to the propagation of the flooding events. The hydrological methods have therefore been developed so events of various durations can be modelled in order to consider the routing effect associated with the storage along the River Spey model. The chosen hydrological models therefore allow for the storm duration to be varied in the hydraulic modelling software so models with various storm durations can be run as batches.

Upper catchment at Invertruim

6.14 The peak flow and hydrograph shape of the upstream Spey at Invertruim are informed by the gauged information at Invertruim gauging station (8007).

6.15 SEPA provided a dataset of updated Annual Maximum flows (AMAX) for this station, using new rating information and including 2015 and 2016 water years, which are the two highest flows recorded at the gauge in the 63 year period of record. The updated AMAX record also accounts for a revised estimate of bypassing at high flows. Q_{med} and growth factors were obtained by single site statistical analysis of the updated AMAX set, enabling the calculation of peak flows for various return periods (see **Annex A.3** and **A.4**).

6.16 15min records at the Invertruim gauge were also used to synthesise a typical hydrograph shape in Invertruim based on 50 events taking place between 1989 and 2016. Various hydrological models were tested against the synthetic hydrograph and the ReFH model provided the best shape fit (see **Annex A.5**)

6.17 Although the ReFH model is superseded, the ReFH rainfall runoff model has been adopted to provide information on the hydrograph shape only. The design hydrograph is derived by fitting the ReFH shape to the peak flow generated from the statistical analysis of the AMAX data.

6.18 The use of a fitted and scaled ReFH model was presented to SEPA and THC flood teams in the Interim H&HM report in 2016 and as part of a consultation meeting on 26/07/2017. In their review of the Interim H&HM report (SEPA Ref. PCS/150629) SEPA accepted this approach, acknowledging the superseded ReFH model is only used to inform the shape of the hydrograph.

Contributing sub-catchments

6.19 A review of the gauged data available on the River Tromie (8008) and the River Feshie (8013) concluded that the data is not reliable enough to provide peak flow values via statistical analysis. There would also be issues in transferring the results to the other 11 sub-catchments contributing to the model as these two gauged catchments are not representative of the ungauged contributing catchments given the large difference in the size of the catchments and the effect that hydro schemes have on the flow regime in the Tromie.

The Flood Estimation Handbook (FEH) Rainfall-Runoff model, based on catchment descriptors, was used to predict the flow contribution (both hydrograph peak and shape) from these sub-catchments.

Key limitations

6.20 Given the size and topography of the whole catchment to the model, storms are likely to be spatially and temporally varied throughout the contributing area. The analysis of storm pattern is beyond the scope of the study. Instead, it is assumed that a global storm of uniform characteristics (in terms of return period and duration) will take place over the whole catchment. Similarly, the timing between every contributing hydrograph was adjusted to provide coincident peaks.

6.21 Adoption of the above assumptions represents a conservative approach to deriving the resulting design event due to the underlying lower joint probability of coincident events.

Tributary Crossing Models

6.22 A review of the hydrological assessment carried out at DMRB Stage 2 for the tributaries crossed by the A9 has been undertaken. ‘Other’ watercourses (i.e. not shown on OS 1:50,000 or OS 1:10,000 scale mapping) were scoped out of the DMRB Stage 2 Assessment and a simplified equal distribution of flows was applied to the group of 'Other' crossings. In contrast, all watercourses crossed by the A9 were initially considered at DMRB Stage 3.

6.23 Design flows for tributaries with catchments greater than 0.5km^2 have been derived using the FEH RR method, with SPR raised to match the SPR applied to the Spey catchments where necessary. Institute of Hydrology (IH) Report No.124 (IH124, 1994) methodology has been adopted for catchments below 0.5km^2.

6.24 Catchment areas draining to these watercourses at the point they are crossed by the A9 were estimated using 1:25,000 scale OS mapping, survey information on the watercourse channel adjacent to the road and, where catchment boundaries are unclear from OS contour lines, aerial photography and site observations. A figure showing the catchments adopted for the study is provided in **Annex D**.

6.25 For the Proposed Scheme modelling, catchment areas were determined in cognisance of the Initial Design proposals for diversions and crossings, with capacity assumptions as noted in the **Section 4** of this report.

6.26 FEH CD-ROMv3 catchment descriptors have been used to inform the parameters within both hydrological methods. For smaller watercourses, values are donated from the nearest appropriate FEH catchment. A new online tool for catchment descriptors (FEH Web Service) became available during the study. Flows were derived using the ReFH2 method for comparison with those derived using the adopted methods. As for other variations in estimation techniques noted above, equivalent flow estimates derived using the newer descriptors and rainfall profiles (FEH13) were found to be lower or well within the bounds of typical sensitivity tests.

6.27 As many of the smaller IH124 catchments are located lower on the hillside than the centroids of the FEH catchments, the donated 1961-90 standard-period average annual rainfall (SAAR) value is likely to be precautionary. Where a flow is estimated using the FEH RR method and the difference between estimated area and catchment descriptor area is significant, other key descriptors such as Drainage Path Length (DPL) have been checked against the estimated area (in the case of DPL, using the alternative FEH calculation) and adjusted to be precautionary.

DMRB Stage 3 River Spey Model

6.28 The DMRB Stage 3 River Spey model is a 1D-2D 'Flood Modeller–TuFLOW' linked model built from an Enhanced 2D model developed for the DMRB Stage 2 assessment. The model extends from approximately 1km upstream of the SEPA gauging station at Invertruim (8007), to around 1km downstream of the gauging station at Kinrara (8002), to account for the substantial floodplain attenuation along this reach of the Spey.

Geometry

6.29 The River Spey channel is described by the Flood Modeller 1D model, based on surveyed cross-sections at key locations (Kingussie and Spey crossing, Kincraig and River Feshie fan, Invertruim and Kinrara gauging stations) surveyed in 2015 and 2016, supplemented by cross-sections extracted from Phase 1 LiDAR elsewhere, where the accuracy of the bed description is less significant.

6.30 The use of a 1D model to describe the River Spey channel within the existing Enhanced 2D model improves channel definition and conveyance description at the key locations, when compared to the 2D approach taken during DMRB Stage2, which relies on an orthogonal grid.

6.31 The River Spey floodplain is described by a 10m orthogonal computational grid. This grid size balances achieving an appropriate representation of the flood mechanisms within the Spey floodplain whilst allowing for reasonable computational run time.

6.32 Ground levels in the 2D grid are informed by Phase 1 LiDAR. The crest of the "thin" elements (relative to the computing grid) likely to affect flood mechanisms during a 200yr flood were enforced within the 2D domain. These include:

- The B970 Ruthven Road embankment and flood relief culverts (based on ground topographical survey)
- The unclassified Road running to the east of Loch Insh (based on ground topographical survey)
- The HML railway embankment running within the River Spey floodplain (based on levels from Phase1 LiDAR)
- Agricultural embankments in the Spey crossing area (based on ground survey for the Ruthven cell, based on Phase1 LiDAR elsewhere)

6.33 The topographical information used for the model is presented in figures in **Annex B**.

6.34 Within the 2D domain smaller culverts through embankments were implemented as 1D ESTRY units.

6.35 The Proposed Scheme is represented in the proposed condition models by amending the DTM of the existing conditions using the proposed earthworks footprint. SUDS basins, access road levels and watercourse diversion channels have also been imposed on the DTM for the proposed condition runs.

6.36 The River Spey model is run for a set of different storm durations (20 to 65hrs, in a 5hr increment) to fully account for the routing effect along the extensive floodplain. The final flood extent is the combined maximum from all the runs.

Model Boundaries

6.37 The inflow hydrographs presented in River Spey Hydrology section were implemented as upstream boundaries. The contributing sub-catchments along the modelled reach are accounted for as inflow hydrographs implemented at their confluence with the River Spey.

6.38 The downstream boundary, located downstream of the extent of the assessment area was set at normal depth conditions for a slope value representative of conditions further downstream. Sensitivity tests to the downstream conditions were carried out.

Model verification

6.39 The River Spey model was calibrated and verified against three flooding events for which flow hydrographs at the gauging stations and flood levels at various locations along the model are available. The calibration exercise is presented in **Annex B.2**.

6.40 Although the model exhibits satisfactory fitting to the calibration data, the limitations of the calibration exercise are recognised, the lack of information from the ungauged contributing catchments being the main issue in this exercise. A sensitivity analysis to flows, roughness and grid size was also carried out and is presented in **Annex B.3**.

River Spey Bridge Option Assessment

6.41 The DMRB Stage 3 River Spey model was used to inform an assessment of the opening width for the proposed River Spey crossing (Hydro ID152). Proposed bridge span lengths of 270m, 310m, 350m, 650m and 950m (i.e. full removal of crossing embankment) were considered. The assessment and findings are presented in **Section 8**.

DMRB Stage 3 Tributary Crossing Models

Screening Exercise

6.42 A screening exercise was undertaken on the tributary crossings to consider whether they have the potential to impact on flood risk. All crossings with 200yr flow greater than $1.1m^3/s$ have been implemented in the DMRB Stage 3 models. $1.1m^3/s$ represents the full bore capacity of a 900mm diameter circular culvert, the original minimum culvert size in the proposed conditions (Note: the minimum crossing size has increased to 1200mm for the Proposed Scheme primarily for maintenance purposes. The implications of this change are discussed in **Section 9.**

6.43 Where the 200yr flows are less than $1.1m^3/s$, the capacity of the existing crossing is compared to the proposed to establish if the Proposed Scheme removes an existing flow constraint. If so, the crossing has been implemented in the existing and proposed models to assess the impact of its removal. Remaining crossings are screened out of the modelling exercise.

6.44 Some crossings originally screened-out by the above selection process have still been included in the hydraulic model, as well as the contributing inflow if there is a hydraulic connection upstream or downstream of the road with a screened-in tributary. The list of modelled tributary crossings is given in Appendix B.5.

Geometry

6.45 Existing crossing geometry has been updated to reflect the findings of the detailed crossing surveys. Crossings themselves are represented as nested 1D elements in the DMRB Stage 3 2D tributary models. For some tributary crossings (Milton Burn, Raitts Burn) a 1D-2D model was developed to describe the watercourse channel upstream and downstream of the crossing structure due to the complexity of the local flood mechanisms.

6.46 The computational grid size of the tributary crossing models vary between 1 to 3m, depending on the extent and size of the modelled watercourse, and to keep runs to reasonable durations.

Model Boundaries

6.47 Tributaries inflows are represented using simplified triangular hydrographs and input to the model upstream of each crossing, except for MW9.6 Milton Burn at ID 147 and MW9.14 Raitts Burn where a FEH Rainfall Runoff hydrograph was used.

Gynack Burn/Spey Interaction

6.48 The influence of the Proposed Scheme to the flooding conditions along the Gynack Burn was investigated using a hydraulic model of the Gynack Burn with a downstream boundary reflecting the flood levels on the River Spey. The modelling exercise demonstrates that the change in levels along the River Spey has no impact on the flooding associated with the Gynack Burn within Kingussie. The influence of the River Spey levels is to a short reach of the downstream end of the Gynack Burn, near the confluence.

6.49 The hydraulic modelling exercise therefore demonstrates that the flooding conditions along the Gynack Burn are effectively independent of the flood levels within the River Spey at its junction with the Gynack Burn. The contribution from the Gynack Burn to the River Spey model is therefore only accounted for as a point inflow at the junction between the Gynack Burn and the River Spey.

Modelling Limitations

6.50 Models have been developed to assess existing flood risk with consideration of the limits of the topographic information, hydrological information, hydraulic modelling methods and computational power available, as appropriate and suitable for a DMRB Stage 3 assessment of flood risk.

6.51 It is important to understand the limitations of any modelling study before interpreting the results of simulations, whether they are presented graphically or otherwise. Where a modelling assumption has a clear bearing on assessment of flood risk it is noted in the relevant section.

6.52 The Spey model grid resolution does not allow for small channels to be represented within the model. The DTM has been checked for potential issues with grid sampling (e.g. false blockages) and is considered to represent the wider River Spey floodplain and potential overland flood routes suitably for the relatively large 200yr return period flows being considered. Where channels have been enforced on the DTM, because they are deemed large enough to carry 200yr flow, the model potentially overestimates channel capacity. This is necessary to maintain a precautionary approach to assessment of potential impacts downstream, but limits the accuracy with which the model can predict the capacity of the proposed diversion channels. Where this could impact on the assessment findings it is noted in the relevant section.

6.53 There are uncertainties in relation to the design flow. The return period approach represents the industry standard approach for planning and design; however, the hydrology of a catchment the size of the Spey, with its many sub-catchments, is complex. The 200yr design event on the River Spey model, based on coinciding peak inflows and global storm duration over the whole catchment was found to be very conservative when compared to the gauged results at Kinrara.

6.54 With the exception of the Milton Burn and Raitts Burn, modelling of each crossing tributary has been focussed within the road corridor. Where desk study review within the corridor suggests that floodwaters could spill out-of-bank upstream to approach the road along different flow routes than otherwise would be considered, an effort has been made to represent this in the model. There is a risk that flood waters in catchments upstream may approach the road in an unexpected manner. Similarly, the characteristics of watercourse channels upstream of the road may change over time. This risk is considered appropriate for the assessment and, as with other modelling assumptions, is highlighted where it may be of note.

6.55 The River Spey model extends beyond the limits of the scheme to allow for calibration. During discussion with SEPA, it was noted that the River Druie, joining the River Spey downstream of the model, is recognised as a significant influence on flood risk in Aviemore and incoming flow from this would help to limit any scheme effects passed downstream of Kinrara. The additional floodplain storage between Kinrara and Aviemore was also acknowledged. The current limits of the assessment were discussed and agreed with SEPA and THC during a consultation meeting in Dingwall on 30st October 2017.

Model Results

6.56 Rasters of the modelling results, combining 1D and 2D output (depth varying output) have been produced and interrogated to inform the FRA. This interrogation of results is recorded in tables provided in **Annex C.1** (describing the sifting exercise used to interpret clashes with the floodplain extent) and **Annex C.2** (recording the impacts predicted by the DMRB Stage 3 models). Flood extent figures showing 200yr flood depths predicted for both the pre- and post-development case are included in **Annex D**. Predicted flood depth, level, velocity, stream power and bed shear stress have been exported as TIF files and provided to other disciplines as part of the wider EIA process.

6.57 The flood extents identified during DMRB Stage 2 are superseded by those of this DMRB Stage 3 Assessment. Notable differences in predictions are primarily linked to the different tributaries being considered due to the refined selection/scoping exercise.

6.58 Model results are discussed in **Section 7** and **Section 8**.

Calibration and Sensitivity Analysis

6.59 The River Spey model has been calibrated against 3 past events of small to medium flood magnitude. Due to the large contribution of ungauged sub-catchments and the limited amount of level information available for each event, the calibration focussed on the model behaviour around the Kingussie area. Details of the calibration procedure are given in **Annex B.2.**

6.60 In the absence of reliable local gauged flow records, no calibration for the tributary models was carried out. Watercourse flows and rainfall have been recorded recently at Raitts Burn and Milton Burn to support water quality assessment and monitoring as part of the A9 project. Preliminary results of the monitoring have been used to provide a comparison between recorded events and the hydrographs produced by the FEH Rainfall Runoff models used to provide tributary design flows. Details of the comparison exercise are presented in **Annex A.9**.

6.61 Proving techniques have been adopted to assess the influence of key model parameters to the River Spey as well as the Tributary models – Manning's 'n' roughness coefficient (+20%) and design flow (+20%). Overall the models behave as expected to changes in key parameters. Details and results of the sensitivity runs are provided in **Annex B.3.**

7 Flood Risk Assessment (Existing A9 and Proposed Scheme)

7.1 Sources of flood risk identified in **Section 5** are assessed in this section by category (Fluvial, Infrastructure Failure, Overland Flow, Groundwater and Sewer Flooding), considering both the existing A9 and the Proposed Scheme without specific flood risk mitigation measures such as compensatory storage.

7.2 Potential impacts on flood risk receptors other than the Proposed Scheme itself are assessed in **Section 8** and all impacts are then summarised along with associated mitigation requirements in **Section 9.** Potential impacts are first assessed without project-specific mitigation and then with inclusion of 'embedded' mitigation and other design changes made following assessment of the initial design as presented in September 2017.

7.3 Project-specific mitigation identified in **Section 9** includes items already 'embedded' in the design presented for assessment and any 'additional' measures identified following further assessment. All measures required to address impacts associated with the Proposed Scheme are then collated and reported in line with DMRB guidance in **Chapter 11** of the ES and carried forward to **Chapter 21** as scheme-wide 'standard' and 'project-specific' mitigation in the Schedule of Environmental Commitments.

7.4 All mitigation items have been reviewed for compatibility with engineering and other environmental disciplines and deliverability in terms of design, construction, and land-take and other spatial constraints.

Fluvial

River Spey and modelled tributaries

7.5 Fluvial flood risk from the River Spey and its larger tributaries has been assessed with the aid of the hydraulic modelling study detailed in the previous chapter of this report. Figures provided in **Annex D** show the predicted flood extents and depths for the design 200yr return period flood both pre- and post-development from both the River Spey and the modelled tributaries.

River Spey

7.6 The 200yr floodplain of the River Spey is predicted to reach the foot of the embankment of the existing A9 and the Proposed Scheme mainline at five locations within Project 9: ch.49,300-ch.50,200, ch.50,675-ch.50,750, ch.51,900, ch.53,000-ch.53,100 and ch.56,500-ch.56,550. The River Spey is not predicted to overtop the existing A9 or Proposed Scheme mainline.

7.7 The first of the five locations reported above (ch.49,300-ch.50,200) is the extent of the A9 embankment for the Spey crossing at Kingussie. Both the existing A9 and the Proposed Scheme mainline are about 5m above the 200yr flood levels predicted along the embankment. In the other four locations, the A9 in both existing and proposed conditions is at least 7m higher than the predicted 200yr flood levels. These differences in elevation allow for uncertainties in the hydraulic modelling process, as well as predicted sensitivity of flood levels to future climate change. The Proposed Scheme mainline has a very low risk of flooding from the River Spey.

7.8 Proposed access tracks running in parallel to the A9 are set back from the River Spey functional floodplain.

7.9 The following SuDS basins proposed in the Initial Design partially or totally encroach into the 200yr floodplain associated with the River Spey: Basin 493 at ch.49,300, basin 507 at ch.50,700 and basin 537 at ch.53,700. The SuDS access track associated with the above basins is also partly within the 200yr flood extent. Basins encroaching onto floodplains associated with modelled tributaries are addressed in the following section (where SuDS basin embankment heights provide a freeboard above 200yr flood levels).

River Spey Crossing option assessment

7.10 The DMRB Stage 3 River Spey model was used to inform selection of a proposed opening width for the proposed River Spey crossing (Hydro ID152), considering alternative bridge spans of 270m, 310m, 350m, 650m and full embankment removal. Results were derived in relation to potential impact at sensitive receptors upstream and downstream of the Spey crossing including infrastructure, residential and non-residential properties, and utilities within the 200yr flood extent. The assessment also considered the effect of opening width on the flow hydrograph passed further downstream, beyond the model boundary.

7.11 Analysis of the Spey Bridge in the Proposed Scheme concluded that reducing the existing embankment length will reduce water levels upstream of the A9 with a slight increase in water levels downstream. Whilst flood risk was a key consideration in the assessment of alternative bridge spans, option appraisal in the wider context considered other material factors including fluvial geomorphology, land-use and other environmental and engineering constraints, visual impact, constructability, and whole life cost.

7.12 Hydrological and hydraulic modelling found that extending the opening width at the crossing results in a measurable improvement in terms of reduced flood risk to sensitive receptors upstream. Whilst larger spans result in a corresponding larger reduction in water levels upstream, flood risk benefits are limited by several factors, including the controlling effects of the B970 embankment upstream and the relatively small number of sensitive receptors in the functional floodplain immediately upstream of the crossing.

7.13 Modelling results also show that extending the opening width results in a small increase in water levels downstream of the crossing. Whilst the impact on flood risk for an extended opening width was shown to be beneficial in terms of overall flood risk management, larger openings show a progressively larger and potentially material increase in the volume and timing of peak flows passing downstream.

7.14 The approach and the findings of the Spey Bridge opening assessment were presented to SEPA and THC flood teams as part of a consultation meeting in Dingwall on 30/10/2017. Further details including presentation material and post meeting information is provided in **Annex B.5**.

MW9.6 – Milton Burn

7.15 The 200yr flood extent associated with the Milton Burn is predicted to reach the existing A9 embankment at the following locations: ch.46,025-ch.46,090 and ch.47,000-ch.47,375. The freeboard of the existing A9 above the 200yr flood levels at that location is greater than 6m.

7.16 The existing access track and crossing structure over the Milton Burn immediately north of the A9 crossing are predicted to be overtopped during the 200yr flood event to a maximum depth of up to 600mm. It was found that the access track level has an impact on the water levels south of the A9 embankment.

7.17 In the September 2017 Initial Design modelled, the proposed access track follows the route of the existing access track at similar levels. Hydraulic modelling therefore predicts the Milton Burn to overtop the proposed access track downstream of crossing ID147 and spill across the road surface the track (ch.47,400) at depths of up to 600mm.

MW9.14 – Raitts Burn

7.18 In existing conditions, The Raitts Burn is predicted to flood the low lying areas alongside the A9 embankment. The freeboard of the existing A9 road above the 200yr flood levels has a minimum value of 350mm at the existing entrance to the Mains of Balavil (ch.53,625). Downstream of the A9, the Raitts Burn overtops its banks and water is predicted to flood the B9152 and the HML. The problem is exacerbated by the reduced capacity of the crossing structures under the B9152 and the HML due to sediment aggregation.

7.19 The modelling outputs from the initial assessment show an increase in flood levels upstream of the A9 due to the reduction in capacity of the crossing structure of the proposed track running at relatively low level along the northbound of the A9. The reduced crossing capacity means water backs up to greater levels over the proposed access track and eventually spills over the proposed A9 embankment.

7.20 Downstream of the A9 the proposed conditions show a decrease in flood levels due to the upstream flow restriction from the low access track crossing. The modelling also shows a change in flow pattern due to proposed access track to SuDS 534 raised above existing ground levels. The modelling tests carried out with the upstream restriction removed indicate that the raised access track to SuDS 534 increases flood levels at the B9152 and the HML due to the deflection of flows.

7.21 Improvements to the flood risk from the Raitts Burn to the proposed A9 and other scheme infrastructure, developed as part of the Proposed Scheme, are presented in **Section 9**.

Other Modelled Tributaries

7.22 Modelling predicts that the existing A9 is at risk of flooding from several tributaries of the River Spey. At many of the tributary crossings, flood waters are predicted to back up from existing structures. In four locations the existing A9 is predicted to be overtopped in the design event:

- Watercourse MW9.11 is predicted to overtop the existing A9 at crossing ID155 and spill across the road surface (ch.51,200) at depths of up to 310mm. The upstream channel and crossing structure ID155 do not have the capacity to carry the flow in-bank. At this location the existing A9 road levels are similar to the surrounding ground.
- A similar mechanism for W9.26 is predicted at ID156, where the existing crossing structure does not have sufficient capacity and water is predicted to spill over the existing A9 (ch.51,450), with flood depths across the road surface up to 80mm.
- Watercourse W9.27 is predicted to overtop the existing A9 (ch.52,700) at ID159 with predicted flood depths across the road surface up to 135mm.
- Watercourse W9.39 is predicted to overtop the existing A9 (ch.55,450–ch.56,200) as the crossing structure ID168 doesn't have sufficient capacity. The predicted flood depths across the road surface reach 320mm.

7.23 In addition to the locations where the road is overtopped, the 200yr flood extent associated with the modelled tributary crossings is predicted to reach the existing A9 embankment at the following locations: ch.46,085-ch.46,080, ch.47,920-ch.48,050, ch.51,675-ch.51,950 and ch.56,175-ch.56,220. Freeboard of the existing A9 road above the 200yr flood levels at these locations is greater than 2.0m.

7.24 The 200yr flood extent associated with the modelled tributary crossings is predicted to reach the Proposed A9 embankment at the following locations: ch.42,060-ch.42,100, ch.43,815-ch.43,825, ch.45,675, ch.46,675-ch.47,375, ch.51,100, ch.51,255, ch.51,705-ch.51,745, ch.51,865-ch.51,900 and ch.56,170-ch.56,220. The freeboard of the proposed A9 road above the 200yr flood levels at these locations is greater than 1.0m in all but one location, upstream of crossing ID159, as noted below.

7.25 The proposed access tracks and roads running along the A9 in the Initial Design are overtopped at the following locations:

- An existing local access road adjacent to Nuide Farm is included within the Assessment Design because passing places are being introduced. The proposed alterations do not change the level of the road and do not introduce encroachment in the flood plain. Watercourse W9.11 is predicted to overtop this local access road at crossing ID146 and flood it to a depth of 300mm however with the proposed mitigation set out in **Section 9** there will be no increase in depth at this location. At this location the proposed levels for the A9 mainline are more than 5m above the 200yr flood levels predicted around the ID146 crossing.
- Watercourse MW9.11 is predicted to overtop the proposed access track at crossing ID155 and flood the proposed access track (ch.51,150-ch.51,250) at depths of up to 170mm. The upstream existing channel does not have the capacity to carry the design flow in-bank. At this location, the proposed levels for the A9 mainline are at least 1.4m above the 200yr flood levels predicted upstream of the proposed crossing at ID155.
- Watercourse W9.27 is predicted to overtop the proposed access track (ch.52,600) at ID159 with predicted flood depths across the road surface up to 90mm. Similarly to the above point, the existing drain does not have the capacity to carry the water to the upstream inlet of ID159 crossing structure. Although water is not predicted to reach the proposed main line road at this location, the proposed main line is potentially at risk of inundation as a result of overland flow. The proposed road design removes a 1.5m high ridge of elevated ground between the A9 main line and the watercourse. Modelling indicates that the track is inundated and that there is approximately <40mm freeboard between the 200yr level and the level at which it would spill down the cut slope onto the northbound carriageway at ch.52,595. Additionally with the removal of the high ground north of the A9, there is the potential for out-of-bank flows to the west of this location to occur which likewise may spill over the track onto the main line.
- Watercourse MW9.14 is predicted to overtop the proposed access track (ch.53,220-ch.53,750)

<u>Minor watercourses (not modelled)</u>

7.26 There are several small watercourses on the hillsides above the A9 where approximately 7.4km of the Proposed Scheme mainline will be in cut. The cut slope is vulnerable to out-of-bank flow from upslope watercourses. In addition, where the road is in cut, there is little or no attenuation volume upstream and the road is the next viable overland flood route. Flood risk from natural catchment runoff is considered within the *Overland Flow* sub-section of this assessment. The existing A9 is at risk of flooding if flows exceed the capacity of minor watercourse channels upslope of the A9 or the culverts carrying these watercourses under the A9.

Extreme flow predictions for small steep catchments carry more uncertainty than those for larger watercourses, though the ceiling for extreme flows is also limited by their small catchment area. Proposed watercourse diversion channels are sized for 200yr design flows with clearance for floating debris and freeboard provided to safeguard sensitive receptors. The Proposed Scheme will thus be at low risk of flooding from the minor watercourses sifted from the detailed modelling study in extreme flood events as risks will be fully and effectively addressed by appropriate drainage design.

Climate change

7.27 Prediction of the possible impact of climate change on extreme weather events is problematic, in part because the processes causing extremes (such as floods and droughts) are complex and their representation is at the limit of the current capability of climate models. SEPA generally recommend a climate change allowance of +20% be applied to the 200yr design flow (SEPA Technical Guidance) in order to assess the impact of climate change on fluvial flood risk. This 20% value was confirmed during Design Guide consultation with SEPA Hydrologists (A9 Dualling Programme Environmental Design Guide CH2M, 2015). The potential impacts of climate change on fluvial flood risk to the Proposed Scheme are assessed in this report using the results of the +20% flow model run undertaken as part of the hydraulic modelling study sensitivity analysis.

7.28 The routing exercise of the Spey model was carried out with the inflow hydrographs increased by 20%. Predicted flood levels generally increased as follow:

- 100 to 250mm in the upper end of the model, up to the B970 Ruthven Road,
- 300 to 400mm between the B970 and the A9 embankment at Kingussie,
- 300 to 450mm from the A9 embankment to Kincraig,
- 250 to 700mm between Kincraig and the downstream end of the model where the narrowing valley of River Spey amplifies the impact of increased flows. At that location the A9 is remote from the River Spey.

7.29 The existing A9 level is over 4m above the +20% flow level in the River Spey.

7.30 Several of the tributaries spill over the existing A9 as a result of undersized crossings. At these locations the maximum depths on the road are approximately 4 to 70mm higher in the +20% flow scenario.

7.31 Flooding at minor watercourses not included in the modelling study is also likely to be exacerbated by climate change. Calculations using Haested Methods 'CulvertMaster' software indicate that the flood level for a 900mm diameter crossing (the smallest diameter crossing proposed) could increase by 50mm with a +20% allowance for climate change in the largest design flow for which this size of crossing is proposed. A minimum 0.3m clearance between soffit level and 200yr flood level is allowed for in the sizing of proposed crossings and 600mm minimum freeboard to road surface.

7.32 All proposed watercourse crossings have been checked for free discharge against respective 200yr +20% flows. This allows for over 600mm freeboard to the Proposed Scheme mainline road surface. Proposed watercourse diversion channels have been designed with a 200yr capacity, using precautionary approach to hydrology.

7.33 The Proposed Scheme mainline is at low risk of fluvial flooding when considering the design 200yr event with future climate change.

Key Point summary of fluvial flood risk to the A9 pre- and post-Scheme

7.34 There is a very low risk of flooding from the River Spey to both the existing A9 and Proposed Scheme mainline but the existing A9 is predicted to flood locally in some locations due to undersized tributary crossings.

7.35 With the exception of the proposed access track crossing MW9.11, tributary crossings do not represent a flood risk to the proposed design. Raitts Burn was undersized in the Initial Design, and causes flooding to the Proposed Scheme mainline. This is addressed in the Proposed Scheme as the track will come closer to the A9 mainline and share an extended crossing structure of a same opening section as the existing, as described in **Section 9**. The freeboard to the Proposed Scheme mainline will be greater than under existing conditions.

Infrastructure Failure

7.36 The existing A9 is potentially at risk of flooding from infrastructure failure - existing fluvial flood risk will be exacerbated by any blockage or otherwise failure of conveyance infrastructure on the River Spey, or its tributaries. Measures taken in the proposed Scheme design to address this risk are discussed below.

Crossings under the Proposed Scheme Mainline

7.37 Proposed Scheme watercourse crossings are typically designed to convey the 200yr flow with a minimum 300mm freeboard to structure/ culvert soffit, and the 200yr flow plus climate change allowance allowing for a minimum freeboard of 600mm to the proposed road surface, and as such are typically larger than existing crossings and inherently less likely to block. The risk of a full blockage of any of the crossings considered in the hydraulic modelling study is low as all are 900mm diameter or larger and are expected to be regularly checked and responsibly cleared of debris as part of future maintenance activities.

7.38 Any changes to proposed culverts, such as restricting flows below this 200yr flow standard as part of mitigation measures discussed in **Section 9**, will maintain the minimum culvert size requirement.

7.39 Flow backing up from ID138 being partially blocked could eventually reach the top of the proposed road embankment. Due to the longitudinal slope and camber of the proposed road at this location, any spilling water would flow alongside the eastern edge of the area of sightline, down to ch.42,600 where it will flow into the low-lying area to the south of the mainline and find relief in culverts ID139-1 and ID139-2.

7.40 Flow backing up from ID142 could potentially reach the A9 mainline. The camber and the longitudinal slope of the proposed road means that water reaching the edge of the proposed road would flow westward alongside the southbound sightline until ch.43,600 to find relief through ID141 or in the drainage associated with Ralia underpass.

7.41 Flows backing up from ID145 if blocked would eventually spill onto the A9 mainline. The crossing at ID145 will be a structure, there are no trees or upslope development (2.1km^2 catchment, 200yr flow 6.2m^3/s) and there is a track crossing the watercourse about 80m upstream of the ID145. The blockage potential for ID145 is therefore very low.

7.42 In the event of a blockage at ID146, backing up water could eventually flow into the underpass at ch.46,060. There are no trees or upslope development (0.6km^2 catchment, 200yr flow 1.23m^3/s), limiting blockage potential.

7.43 Due to the size and arrangement of the crossing structure (with the underpass), the likelihood of a significant blockage of the Milton Burn crossing (ID147) is limited. If such an event was to occur, backing up water could eventually spill over the A9 at the localised low point (approx. level 235.3mAOD at ch.47,150).

7.44 Due to the size of the crossing structure, the likelihood of a significant blockage at the Spey crossing (ID152) is negligible.

7.45 A partial blockage of crossing ID155 could potentially result in the proposed A9 to be overtopped. The crossing arrangement in the proposed condition provides a greater freeboard between the crossing soffit and the proposed road level than in the existing.

7.46 In the event of a partial blockage at crossing ID156, backing-up water could eventually flow westward along the embankment of the Proposed Scheme mainline and find relief through the proposed crossing structure at ID155.

7.47 ID 157 and ID158 provide alternative relief if one or other becomes blocked.

7.48 A significant blockage of ID159, ID161, ID166 and ID168 would eventually lead to water spilling over the Proposed Scheme mainline. The underpass located next to ID170 would provide relief in the event of a blockage.

7.49 Due to the size of the crossing structure, the likelihood of a significant blockage of the Raitts Burn crossing (ID162) is small. The proposed structure will keep the same opening size as the existing conditions, therefore the risk of blockage remain as per existing condition. If such an event was to occur, backing up water could the eventually spill over the A9 at the low point along the Proposed Mainline (ch.53,900).

7.50 Significant blockage is generally considered unlikely with appropriate maintenance, due to the size of the crossings relative to catchment size and the lack of vegetation or other source of large mobile debris upstream. The Proposed Scheme earthworks drainage and road drainage would help to mitigate any flooding and disperse floodwaters should floodwaters back up from a blockage and threaten to spill over onto the road surface.

Impoundments

7.51 Loch Ericht, Loch Cuaich, Loch Phoines and the Spey Reservoir are subject to impoundment within the vicinity to Project 9, and are registered as Controlled Reservoirs under the Reservoirs (Scotland) Act 2011. The SEPA reservoir maps show parts of the A9 would be inundated if any of the reservoirs were to fail. However SEPA guidance states that, *'Reservoir flooding and flooding from other infrastructure - although unlikely, failure of infrastructure such as dams or canals could result in a large volume of water being released very quickly. Flooding from reservoirs is very unlikely to occur and there has been no loss of life from reservoir failure in the UK since reservoir safety legislation was introduced in 1930.'* Therefore flooding from Loch Ericht, Loch Cuaich, Loch Phoines and the Spey Reservoir is considered very unlikely.

Summary of risk from Infrastructure Failure

7.52 Any risk of conveyance infrastructure failure exacerbates fluvial flood risk to the existing A9.

7.53 There is generally a low risk of flooding to the Proposed Scheme mainline from infrastructure failure. It is recommended that the risk of blockage is reduced by regular inspection and maintenance of the proposed crossings.

Overland Flow

Direct rainfall - road surface drainage

7.54 SEPA flood maps identify pluvial flooding within the Project 9 scheme extents. Discrete lengths of the existing A9 are marked as potentially at risk in a 200yr event. These are low points in the road surface where water could potentially gather during intense rainfall events. Pluvial flooding incidents reported by Transport Scotland Local Operating Company were mapped in the SFRA. None was shown in the extent of Project 9.

7.55 The drainage design for the Proposed Scheme will comprise several new and independent gravity drainage networks designed to collect and convey surface water runoff from impermeable surfaces, in accordance with DMRB standards. Road surface drainage systems are designed to shed the relatively small volumes of excess floodwater in exceedance events safely from the road to verge areas and earthworks drainage thus avoiding any increase in flood risk to other sensitive receptors.

Natural Catchment Runoff

7.56 In the event that rainfall exceeds the infiltration capacity of the natural ground, excess water will flow overland. This may present a flood risk to the existing A9 where ground levels fall towards the road.

7.57 The SFRA notes that there is a relationship between the areas which have frequent flooding events and the steepness of the surrounding hillsides: *'Using available Digital Terrain Model information, the locations where road flooding is frequently reported were noted to be along the stretches within cuts adjacent to steep hill sides.'*

7.58 The Proposed Scheme will be afforded protection by the provision of new earthworks drainage (designed to 75yr standard and including allowances for climate change and freeboard) intercepting overland flow and diverting it safely to the nearest watercourse.

7.59 Storm events critical for the road drainage networks are shorter and more intense than those producing the lower peak flows generated from the natural catchments. Thus, any overland flows exceeding the capacity of earthworks drainage will be intercepted by the road surface linear drainage systems (i.e. filter drains and swales in roadside verges) effectively managing overland flows without increasing flood risk to other sensitive receptors.

Summary of flood risk from overland flows

7.60 The Proposed Scheme will be designed to appropriate DMRB standards allowing for the management of excess surface water to avoid flood risk to the Proposed Scheme or other sensitive receptors from overland flows in the design event.

Groundwater

7.61 SEPA flood maps provide a guide as to where groundwater could influence the duration and extent of flooding from other sources rather than where groundwater alone could cause flooding. There are no such areas identified within the Project 9 corridor.

7.62 Where the Proposed Scheme mainline is raised above local ground levels and adjacent watercourse levels there is a very low risk of groundwater flooding.

Groundwater Flow

7.63 Approximately 7.2km of the Proposed Scheme mainline will be cut into the adjacent hillside and there is a risk that ground water flow may emerge from the cut embankment, resulting in surface water spilling onto the carriageway if not collected by road/ cut-slope drainage.

7.64 Groundwater flow within the superficial deposits is considered likely to predominantly follow surface topography, towards local surface watercourses. However, shallow flows are also likely to be locally complex, influenced by the presence of peat, local lower permeability deposits, shallow rock and the presence of culverts; while overland flows may also be locally significant.

7.65 Any flooding from this source is likely to be limited and, if present at all, provide a minor contribution to the risk of flooding considered in the *Overland Flow* sub-section above – any flood risk to the Proposed Scheme will be alleviated by the proposed earthworks and drainage system.

Groundwater Table

7.66 Any risk of groundwater flooding could be exacerbated by a high water table. Initial Ground Investigation (GI) carried out Raeburn in 2015 recorded groundwater in several boreholes and trial pits, with water strikes at depths between 0.70m Below Ground Level (BGL) (at TP7-001) and 9.08m BGL (BH7-003) in the superficial deposits. This factor should be considered in the detailed design of drainage systems.

Groundwater Summary

7.67 There is no evidence that the water table exacerbates flood risk to the A9. **Chapter 10** of the Environmental Impact Assessment (A9P07-CFJ-EGN-X_ZZZZZ_ZZ-DO-EN-0004) 'Geology, Soils and Groundwater' provides a detailed review and assessment of the existing geology and hydrogeology of the area.

7.68 It is recommended that the output from DMRB Stage 3 Site Investigation is reviewed at detail design and appropriate measures taken to mitigate any risk from this source.

Sewer Flooding and the Road Drainage Network

7.69 The A9 within Project 9 passes through almost exclusively non-serviced rural land and the flood risk to the existing A9 from sewer flooding is low.

7.70 The drainage design for the Proposed Scheme will comprise several new and independent gravity drainage networks designed to collect and convey surface water runoff from impermeable surfaces, in accordance with DMRB standards. The system is designed to shed any excess floodwater safely from the road surface.

7.71 There is a very low risk of flooding from local sewer networks or the road drainage network to the Proposed Scheme.

8 Impact of the Proposed Scheme (on other receptors)

8.1 In accordance with the requirements of the DMRB (Volume 11, Environmental Assessment), this section identifies the potential impacts of the Proposed Scheme on flood risk elsewhere. To support decision making, this process identifies receptors outwith the Proposed Scheme itself that may be at increased risk due to the impact on the water environment.

8.2 The Proposed Scheme is considered here as presented for assessment as an initial design in September 2017, without project-specific 'embedded' flood risk mitigation measures such as compensatory storage. Further design development, including mitigation, and assessment of residual impacts is discussed in **Section 9.**

Receptors

8.3 Potential flood risk receptors in the watercourse basins adjacent to the Proposed Scheme have been identified using SEPA's Flood Risk Appraisal Baseline Receptor Datasets (GIS shapefile) reviewed and augmented by information from 1:10,000 OS maps and aerial photographs.

8.4 Receptors identified as being at risk of flooding pre-development include the HML railway, local roads, access tracks, residential properties, non-residential properties (including community services) and utilities. Land classifications have been downloaded from The James Hutton Institute website. Cultural heritage sites adjacent to the modelled extent were also identified. Figures showing receptors in relation to the predicted pre-development 200yr floodplain are included in **Annex D**.

8.5 There are environmental designated sites alongside Project 9: River Spey – Insh Marshes Ramsar site, the River Spey – Insh Marshes Special Protection Area (SPA), the River Spey – Insh Marshes Site of Special Scientific Interest (SSSI), the Insh Marshes Special Area of Conservation (SAC), the River Spey SAC, the River Spey SSSI and the Insh Marshes National Nature Reserve (NNR). These designated areas are fundamentally part of the water environment; these are not highlighted on the receptor figures.

Fluvial Flood Risk

8.6 The impacts of the Proposed Scheme on 200yr flood extents of the River Spey and its major tributaries outside the boundary of the Proposed Scheme have been assessed by comparing pre- and post-development results from the Hydraulic Modelling Study. Potential impacts on fluvial flood risk are assessed by comparing model results at and adjacent to receptors.

8.7 Aspects of the Proposed Scheme represented in the post-development hydraulic model include embankments and cuts to reflect the Proposed Scheme mainline, channel diversions, new access roads, junctions and SuDS facilities. The Proposed Scheme does not significantly alter the catchments and hence, design flows are predicted to be the same as in the existing case at all crossings.

8.8 The Proposed Scheme is likely to have an impact on fluvial flood risk in the following cases:

- **Encroachments:** where the footprint of the Proposed Scheme mainline or access track embankments encroaches into the existing 200yr floodplain, floodplain volume is lost and design flood levels may increase locally as less attenuation is available for flood flows. The characteristics particular to each watercourse will determine how far downstream flood levels and flows are impacted. Although access tracks are to be designed to maintain existing ground levels as far as possible, where they encroach on the 200yr floodplain the potential for realignment has been considered as it is more likely that there is scope to reposition these features

- **SuDS:** although SuDS basins have been designed to avoid flood plains where possible, where they encroach on the 200yr floodplain the effect is considered separately to other encroachments by the Proposed Scheme mainline and access tracks as it is more likely there is scope to reposition these features
- **Crossings:** larger flows may be passed downstream in an extreme flood event where proposed crossings provide greater capacity than crossings under the existing A9. Similar to encroachments into the floodplain, there may be an impact on flood levels and flows downstream where floodplain volume upstream of the existing A9 is lost due to the Proposed Scheme design. In addition, where the positions of crossing inlets and outlets have changed, there are local impacts on the floodplain
- **Diversions:** downstream of the tributary crossings flood flow may be impacted by the diversion of watercourses, or otherwise the inclusion of designed channels with larger capacity than existing channels adjacent to the road. As well as having a local impact on the floodplain, diversions have the potential to route water more quickly to the receiving watercourse and impact on downstream flood risk, depending on local flow characteristics. This may also be the case where catchments draining to crossings are larger and / or a greater amount of flow is caught by earthworks drainage and improved channel diversion upstream of the crossing

8.9 Predicted impacts of the Proposed Scheme, based on the proposals included in a design presented for initial assessment in September 2017, (without mitigation) on fluvial flood risk are summarised in **Table 8-1** below. Specific findings are noted alongside comments on floodplain predictions in **Annex C.1**.

8.10 The assessment of the impacts has been extended downstream of the scheme as far as Kinrara by which point any measurable change in water level as a result of the Proposed Scheme are negligible (less than 1mm in the 200yr flood event). The Proposed Scheme is not considered to present a measurable increase in flood risk beyond this point.

8.11 During discussion with SEPA, it was noted that the River Druie, joining the River Spey downstream of the model, is recognised as a significant influence on flood risk in Aviemore. Incoming flow from the River Druie and floodplain storage between Kinrara and Aviemore will help to prevent any scheme effects passing downstream of Kinrara.

Table 8-1: Predicted impacts summary (fluvial flood risk without mitigation) by receptor type.

Receptor type	Potential Impact (initial assessment)	Comment
Residential property	1nr receptor where 200yr flood level is increased by more than 100mm 3nr receptors where 200yr flood level is increased by 10 to 50mm. 14nr receptors with 'negligible impact' (<+/- 10mm), of which 7nr receptors where there is no impact on flood levels. 5nr locations where 200y flood level is decreased by 10 to 50mm. 1nr locations where 200y flood level is decreased by 50 to 100mm. 1nr receptors where 200yr levels has decrease by more than 100mm 2nr receptor will no longer be inundated in the 200y event.	Substantial flood increases are predicted around the Raitts Burn, with a **958mm** increase at the Mains of Balavil, due to the restricted crossing under the proposed access track (as in the September 2017 Initial Design), immediately upstream of the A9. Nuide Farm shows an increase of flood levels of **47mm** linked to the loss of attenuation at ID146. The improved capacity of the watercourse downstream of the A9 on watercourse **ID155** results in higher flows being directed towards two dwellings located north of Kingussie Cemetery (flood level increase of **30 and 16mm**). The opening of the Spey Crossing embankment shows a marginal increase in flood levels on 7 residential receptors located further downstream (1 to 4mm) down to Kinrara. These receptors are all already inundated to depths >200mm in the existing case. The model shows **no impact** for 7 receptors located in the Newtonmore area. Widening of the Spey crossing results in reductions in Spey water levels for 5 receptors immediately upstream of the crossing (**29** to **112mm**). 1 residential receptor is no longer inundated. The proposed A9 reduces the overland flow towards 1 residential property downstream of ID155 **(-11mm).** The restricted flow through ID162 in the proposed conditions also reduces the impact at the Railway Cottage (**-85mm**) The Balavil West Lodge is shown not to flood any longer due to the proposed raised track to SuDS 534 which protects it from the Raitts Burn flood flows. This raised track also limits the flow from the Raitts Burn travelling west towards Lynchat.
Non-residential property	2nr receptor where 200yr flood level is increased by 50 to 100mm 1nr receptors where 200yr flood level is increased by 10 to 50mm. 26nr receptors with 'negligible impact' (<+/- 10mm), of which 24nr receptors where there is no impact on flood levels. 7nr locations where 200y flood level is decreased by 10 to 50mm. 1nr locations where 200y flood level is decreased by 50 to 100mm. 1nr receptors where 200yr levels has decrease by more than 100mm 1nr receptors will no longer be inundated in the 200y event.	Increase in flood levels are seen for 2 receptors located in the area of Kingussie cemetery (**10mm** and **96mm**) due to the concentration of flow downstream of ID155 and 1 receptor at Nuide Farm (**51mm**), due to the loss of attenuation around ID146. The opening of the Spey Crossing embankment shows a marginal increase (**1** to **4mm**) in flood levels on 2 receptors located further downstream around Kincraig down to Kinrara. The model shows **no impact** for 24 receptors located in the Newtonmore area. Widening of the Spey crossing results in significant reductions in Spey water levels for 8 receptors immediately upstream of the crossing (**36** to **112mm**). In the Highland Wildlife Park, 1 receptor shows a reduction in flood levels of **51mm** and 1 receptor is no longer flooded

Receptor type	Potential Impact (initial assessment)	Comment
Roads	1nr location where 200yr flood level at the receptor is increased by more than 100mm 1nr location where 200yr flood level at the receptor is increased by 50 to 100mm 6nr location where 200yr flood level at the receptors shows 'negligible impact' (<+/- 10mm) 2nr locations where 200y flood level at the receptor is decreased by 10 to 50mm 1nr location where 200y flood level at the receptor is decreased by 50 to 100mm	The B9152 road at Balavil is predicted to flood as a result of overland flow from ID162 with predicted water depths of **361mm** on the running lanes. In the existing case the road was not flooded in this area. Flooding of the local road at Nuide Farm is predicted to increase by **54mm** due to the loss of attenuation at ID146. Marginal increases in flood risk due to the Spey crossing opening are noticed at five locations, next to the B970 at Gordon Hall Farm (**+9mm**, but not flooded), at Kingussie Cemetery (**+2mm** but not flooded), B9152 at the Highland Wildlife Park (**+3mm**) and at Dunachton (**+7mm**), and the unclassified road between Kincraig and Insh (**+4mm**). A marginal increase in flood level is also predicted at the unclassified road next to Ralia lodge (**+9mm**). A reduction of **11mm** is predicted along the Road between Lynchat and Balavil West Lodge, due to the impact of the raised access track to SuDS 534. A reduction of **39mm** is predicted on the B970 Ruthven Road at Kingussie, due to the effect of the Spey crossing opening. A reduction of **98mm** is predicted in the currently flooded extent of the B9152 at Balavil due to the restricted flow conditions at ID162.
HML railway	2nr length with 'negligible impact' (<+/- 10mm), of which 1 length with no impact. 1nr length of the HML where the 200year flood level is decreased is decreased by 50 to 100mm	There is a marginal increase in flood levels along the HML within the Insh Marshes (**+4mm**) as a result of the widening of the Spey crossing at Kingussie. There is **no impact** to the flooded section of the HML in the Newtonmore area. The is a **75mm** decrease in 200yr flood levels at the highland main line immediately downstream of the Raitts Burn due to the restricted flow conditions at ID162.
Property Access	2nr receptors where 200yr flood level is increased by 10 to 50mm. 6nr receptors with 'negligible impact' (<+/- 10mm) 1nr receptors where 200yr levels has decrease by more than 100mm	A **49mm** increase in water level is predicted on Nuide Farm property access due to the loss of attenuation at ID146 A **30mm** increase in water level is predicted for Inverton property access A marginal increase in flood levels (**3 to 4mm**) is predicted for 6 property accesses of the unclassified road between Kincraig and Insh and to the south west of Loch Insh (Farleiter). This is associated with the widening of the Spey crossing. The area of Manse Road and the railway underpass in Kingussie sees a decrease in flood levels of **117mm**.
Utilities	4nr receptors with 'negligible impact' (<+/- 10mm), of which 1nr receptors with no impact 1nr receptors where 200yr levels has decrease by more than 100mm	In Kincraig, two utilities see a marginal increase (**+3mm**) in flood levels due to the widening of the Spey crossing. At Lynchat, one utility sees a marginal increase (**+3mm**) in flood levels due to the widening of the Spey crossing. A utility in Newtonmore, flooded in the existing conditions sees **no** impact due to the scheme. Flood levels at the Waste Water Treatment Works in Kingussie are predicted to decrease by **117mm** due the widening of the Spey crossing
Agricultural land	Approx. 5.8ha of mixed Agricultural land is removed from the 200yr flood extent Approx. 1.2ha of Improved Grassland is also taken out of the 200yr flood extent Approx. 0.03ha of rough grazing is removed from the 200yr flood extent	Proposed Scheme design removes wide overland flood routes due to changes around crossings ID155 (capacity increased) and downstream of ID162 (access track cutting off overland flow). Smaller areas of flood extent are reduced throughout Proposed Scheme with increase in crossing culvert size (e.g. ID146) Some mixed agricultural land lost upstream of ID162 due to the increase in flood extent with the restricted crossing

8.12 It is necessary to mitigate local impacts on fluvial flood risk as well as losses of floodplain volume, which potentially impact flood risk downstream. Assessment findings have been used to inform design development and mitigation options have been developed accordingly. **Section 9** discusses changes made to the Proposed Scheme since the initial design was presented for preliminary modelling and assessment in September 2017 and outlines the mitigation measures subsequently identified to address potential flood risk impacts. **Section 9** concludes that potential flood risk impacts to the Proposed Scheme and other receptors will be fully and effectively addressed by avoidance or through the inclusion of appropriate mitigation.

8.13 The Gynack Burn joins the Spey within the reach affected by the drop in levels upstream of the Spey Crossing as a result of its widening. Modelling tests carried out on the Gynack Burn demonstrated that the change in flood levels in the River Spey do not have an impact on the water levels in the Gynack, other than immediately at the interface between the Gynack and the Spey flood plains.

Flood Risk Downstream – Cumulative Impact

8.14 Due to the difference in contributing catchment sizes, critical storm durations for the River Spey along the modelled reach (20 to 70hrs) were found to be of an order of magnitude greater than the modelled crossing tributaries (2 to 7hrs), as shown in **Annex B**.

8.15 The largest impact of the Proposed Scheme at a tributary crossing is evaluated for the tributary's critical storm event. This condition produces the largest design peak flow and result in the largest volume of encroachment and the largest change in water levels at receptors. These conditions at the tributary will not coincide with the worst conditions along the River Spey, predicted for a catchment wide, longer duration storm.

8.16 Storm events, longer by an order of magnitude (critical for the River Spey system) generate less than critical conditions at the tributaries, with lower peak flows, reduced flood extents and reduced impacts from the proposal.

8.17 For Spey-critical storm durations, the River Spey model predicts a marginal increase in flood risk passed downstream, with an increase in water levels of 1 to 4mm, and an increase in peak flow of 0.5%.

8.18 For the range of storm durations critical for the smaller tributaries, increased flows passed downstream of the modelled reaches are assumed to diffuse in a "non-critical condition" Spey System. For the larger Milton Burn and the Raitts Burn crossings, the proposed crossing should be designed to ensure no increase in peak flow will be passed downstream.

8.19 The cumulative impact of marginally larger peak floods from some of the tributaries combined with the River Spey worst conditions was therefore not quantified. The joint probability of timed occurrence for both critical events would be much lower than the design event.

Road Drainage Network

Discharge from the Road Drainage Network

8.20 The Proposed Scheme will increase the proportion of impermeable surfaces in the catchment. This will increase the volume and rate of surface water runoff via the road drainage network. The uncontrolled discharge of surface water runoff from the road drainage network to existing watercourses during storm events could have the potential to cause localised flooding and increase the risk of flooding downstream, although consequential damage or disturbance to non-residential and natural features is considered extremely unlikely.

8.21 The Proposed Scheme employs SuDS to alleviate the potential impacts of increased surface runoff rates and reduce flood risk in the receiving watercourses. Site controls such as extended detention basins – attenuation and treatment of surface water runoff prior to discharge – are to be included in the drainage design, and attenuation basins will generally be designed to provide attenuation to greenfield runoff. Where drainage networks cross catchment watersheds the allowable discharge is based on the greenfield runoff from the receiving catchment. Attenuation calculations consider the road as greenfield land for discharge controls and therefore provide beneficial effect downstream.

<u>Overland Flow Routes from SuDS Basins</u>

8.22 Proposed SuDS basin locations are shown on the flood extents figures provided in **Annex D**. In the event of design capacity exceedance, blockage of the outfall, or otherwise failure of the basins, flood waters would spill onto the surrounding land. SuDS will be designed with emergency spillways to direct excess flood water safely away from nearby receptors to the receiving watercourse, via overland flow routes or through overflow pipes.

<u>Exceedance of Road Drainage Capacity</u>

8.23 Road drainage is designed to current DMRB standards and offers improvement on the existing arrangement. The system is designed to shed any excess floodwater safely from the road surface. Exceedance events should be considered at detail design and new road drainage sized to ensure that flood risk elsewhere will not be increased by the road drainage proposals.

Infrastructure Failure

8.24 For the smaller watercourses the Proposed Scheme reduces or does not increase the likelihood of a blockage at the crossings under the road in an extreme event, due to the size of crossings beneath the A9 being increased or remaining unchanged.

8.25 Associated flood risk is also reduced due to the upgrade of the earthworks and road drainage. In the case of a failure of other local or neighbouring infrastructure (e.g. blockage of bridges or failure of impounded water storage) the Proposed Scheme represents improvement relative to the existing arrangement, helping to alleviate any flooding from these sources.

8.26 The crossing structure on the Milton Burn will be replaced by a structure of a very similar opening size. The opening size is large and the risk of full blockage in an extreme event is limited.

8.27 In the event of partial blockage of crossing during an extreme event the water levels upstream of the road will be increased, however due to the height of the road above the watercourse it is unlikely that the road would be at risk of inundation.

8.28 The Raitts Burn structure will be extended upstream at its existing width therefore there is no increase in the risk of blockage to the A9.

Overland Flow

8.29 The earthworks drainage and watercourse diversion channels upslope of the Proposed Scheme are designed to modern standards, and will better manage design flows with less chance of exceedance and failure. Exceedance events should be considered at detail design stages. The Proposed Scheme will provide betterment to overland flood risk downstream.

8.30 There is an increase in overland flood risk downstream of the A9 mainline crossing of watercourse ID155 (ch.51,250) where the proposed downstream channel directs more flow towards the receptors. Mitigation requirements are discussed in **Section 9**.

8.31 Elsewhere the Proposed Scheme has a negligible effect on overland flood risk to receptors downstream.

Groundwater

8.32 Where the Proposed Scheme is raised above existing levels it is unlikely to have any material impact on the effect that groundwater may have on flood risk elsewhere, and may present a betterment if intercepting floodwaters from groundwater springs or similar. There are no soakaways proposed as part of the roads drainage. The Proposed Scheme will not have an adverse impact on this source of flood risk.

9 Mitigation (and Residual Impacts)

9.1 Due to the scale of the Proposed Scheme and its proximity to, and interaction with, a large number of watercourses along its length, a number of receptors are predicted to experience flood risk impacts. These impacts are attributed to various aspects of the Scheme as discussed in **Section 8.**

9.2 Additional measures to mitigate potential flood risk impacts (including compensatory storage to replace lost floodplain volume) have been included in the Proposed Scheme as outlined in this section. Potential impacts relating to crossing ID's 147, 155, 159 and 162 warranted further updated modelling to account for design development and the results of this work are discussed before residual impacts are summarised in this section.

Approach

9.3 As the Proposed Scheme has progressed from the Initial Design, many of the potential impacts noted above have been designed out, with a preference for removal or reduction of floodplain encroachments. A flood risk alleviation hierarchy of avoidance, then reduction, and finally mitigation has been followed, as described below. Where appropriate additional mitigation is proposed to specifically target local impacts from watercourse diversion channels and alterations to crossings, the details of these have been discussed below.

9.4 Following initial assessment, Compensatory Storage Areas (CSAs) were introduced to replace lost floodplain volume, using the approach detailed below. CSAs were refined alongside the design as encroachments were removed and minimised, and the areas were considered holistically alongside other environmental disciplines. The CSAs proposed as part of the Assessment Design are presented and discussed under *Proposed Mitigation*.

9.5 Natural Flood Risk Management through the removal of flood embankments around the Insh Marshes has been considered as a mitigation approach however it has been found not to be effective in the higher return periods as a result of the embankments being completely submerged. A study of the effects of flood embankment removal commissioned by RSPB highlighted that as a result of the complex connectivity between the various areas behind the embankments flood levels in some locations would decrease and increase in others.

<u>Encroachments</u>

9.6 Encroachments into the functional floodplain have been avoided where possible at all stages of design. Some encroachments that existed in the earlier stages of the design have been removed from the floodplain as the design has been refined. Locations where the Proposed Scheme was found to encroach on the modelled existing 200yr floodplain are noted in **Annex C.1**, with an indicative encroachment volume. **Annex C.1** also records the sifting exercise undertaken to identify encroachments from areas where the Proposed Scheme overlays the 200yr floodplain in plan, but other aspects of the Proposed Scheme – notably upsized diversion channels – act to compensate for lost volume at the same like-for-like levels, or the proposed crossing size and headwall detailing will remove the footprint from the floodplain. In these cases there is no net loss of storage and no further mitigation is proposed.

<u>Crossings</u>

9.7 Upsizing watercourse crossings to design standards may result in loss of floodplain storage upstream, such as upstream of crossing ID146 and ID168. Reducing flood levels upstream also increases the area required for effective compensatory storage measures upstream of a crossing.

9.8 In the case of the loss of storage upstream of ID146, mitigation will be provided in the form of compensatory storage and this is discussed more fully later in this section.

9.9 In the case of the loss of storage upstream of ID168 upsizing the culvert has a beneficial impact on flood risk upstream and downstream receptors are unaffected by flooding. No mitigation is therefore proposed, as discussed in Table 9-1 below.

9.10 A number of non-flood-risk considerations may impact on crossing capacity, such as provision of mammal passage and geomorphological issues.

Compensatory Storage Areas

9.11 Where possible, compensatory storage areas (CSAs) are provided to replace floodplain lost to encroachments. The potential to provide compensatory storage to replace lost volume has been investigated, within the wider constraints on the Proposed Scheme such as land classification, other environmental sensitivities, location of receptors and how CSAs tie-in with local hydrology post-development.

9.12 CSAs have been initially sized based on the plan area of the 200yr floodplain encroachment including an assumption made in lieu of fully detailed landform and earthworks design that compensation storage will over the full area of the 200yr encroachment at the lowest return period level with side slopes projected up at 1:3 to meet existing ground levels. Where applicable the initial plan area has been sized to account for likely differences between return period water depths at the encroachment and potential CSA locations by comparing the existing and proposed hydraulic model results at the relevant locations.

9.13 During detailed design, CSAs will be sized using the SEPA recommended volume-balance approach, on a 'return period slices' basis. 200, 100, 50, 30, 10 and 5 year return period flood levels will be available from the DMRB Stage 3 H&HM study.

9.14 The volume-balance approach provides compensation for floodplain loss on both a volume-for-volume and a level-for-level basis. Level-for-level storage can be provided where CSAs are adjacent to the lost floodplain. Otherwise, where storage is remote to the source of floodplain loss, the return period slices approach enables elevation to be considered relative to the water surface profile of the river and not Ordnance Datum, so that storage effects the flood hydrograph in the same manner pre- and post-development.

9.15 Due to the perched nature of watercourse ID 162, conventional level-for-level flood storage for encroachments related to flooding from this source is not practical. An offline return period slice volume based approach has therefore been adopted in this instance and the practicalities of this are discussed further in the *Proposed Mitigation* sub-section below.

July 2018 Assessment Design (the Proposed Scheme)

9.16 The Proposed Scheme has been developed taking into account comments on flood risk. The resultant design removes and reduces some encroachments, although as a result of other design constraints, some floodplain encroachments have increased locally. Changes have also been made to address potential flood risk increase at watercourse crossings. Locations where a substantial design change could increase potential flood risk have been re-modelled.

9.17 A summary of design developments including flood risk specific mitigation and residual impacts is given in **Table 9-1**. The impact of the design changes onto the floodplain encroachments are also described in **Annex C.1**. Compensatory storage and other flood risk specific mitigation introduced as part of the design development is discussed further under *Embedded Mitigation* and within **Table 9.2**. Additional mitigation required to address residual impacts identified during this assessment is described in **Table 9-3**.

Table 9-1: Design development (Initial Design to the Proposed Scheme Design) and Residual Impacts

Chainage	Initial Design Impact	Design Development (Initial Design to Proposed Scheme)	Residual Impacts (including Embedded Mitigation)
Ch.43,810	Crossing ID142 outlet is located to the east of the existing outlet and watercourse and as a result directs flow towards local road resulting in a 9mm increase in water level at the receptor.	Following dialogue between the flood risk team and the culverts and watercourses team, realignment of the culvert to return it to its existing outfall prevents redirection of flows.	None – The downstream flow route is as existing.
Ch.46,060	At crossing ID 146 the proposed road and access track encroach into the floodplain. The encroachment volume is estimated to be 4138m^3. This loss of floodplain storage results in impacts ranging from 47mm to 55mm at receptors around Nuide farm.	Following dialogue between the flood risk team and the roads team the estimated encroachment has been reduced to 4025m^3 by steepening embankments to the maximum practicably and the access track moved closer to the mainline. The remaining flood plain encroachment is mitigated through the provision of compensatory storage (CSA IDs 1 and 2) at the upstream and downstream side of the crossing.	None – Loss of floodplain storage addressed through provision of compensatory storage.
Ch.46,650	A slightly raised access track encroaches into the floodplain upstream of crossing ID 147 this reduces the storage capacity upstream of the crossing and results in more flow passed downstream.	Following dialogue between the flood risk team and the roads team the access track is lowered to existing ground level removing this encroachment.	None – The encroachment is removed.
Ch.47,300	The widening of the mainline earthworks footprint to accommodate the extra road lanes results in encroachment into the floodplain upstream of crossing ID 147 and the access track to Inverton Cottage is raised and encroaches into the floodplain downstream of crossing ID 147. The total estimated encroachment is 8102m^3. The proposed crossing is also slightly upsized from existing and this in combination with the encroachments results in a higher peak flow passed downstream and an increase of ~30mm at the access track to Inverton cottage.	The access track to the north of the mainline has been realigned resulting in a greater floodplain encroachment- results in an increased loss of floodplain storage downstream of the mainline crossing	Loss of floodplain storage due to encroachments upstream and downstream and the crossing detailed in the Proposed Scheme design passes more flow downstream of the A9 at some return periods. *Requirement for Additional Mitigation – refer to **Table 9-3**.*
Ch.48,000	The proposed mainline earthworks encroach into floodplain on the upstream side of crossing ID 148. The volume of encroachment is estimated to be 1197m^3.	Following dialogue between the flood risk team and the roads team the estimated encroachment is reduced by steepening earthworks slopes. The remaining encroachment is estimated to be 1150m^3.	Hydraulic modelling predicts a 51mm increase water levels in Lochan an Tairbh. As there are no receptors affected this is considered to be an acceptable residual impact. No further action is proposed.

Chainage	Initial Design Impact	Design Development (Initial Design to Proposed Scheme)	Residual Impacts (including Embedded Mitigation)
Ch.49,350 - Ch.50,250	SuDS basin 493 encroaches into the floodplain of the River Spey. The estimated encroachment is 6940m^3. The Spey embankment also encroaches significantly into the floodplain of the River Spey however due to the removal of the unused existing embankment there is only approximately a 7000m^3 net encroachment into the floodplain. The increase in bridge span and the reduction in embankment length result in a larger conveyance capacity and hence a loss of upstream storage and reduction in upstream flood level. This results in an increase of 9mm adjacent to the B970 at Gordon Hall Farm, 7mm increase at the B9152 at Dunachton, and increases of between 1mm and 4mm at a number of receptors downstream. The reduction in upstream flood level is around the town of Kingussie and results in significant reductions in flood level at a large number of receptors within this area ranging from 29mm to 117mm.	The addition of the access track into the design and the reshaping of the SuDS basin result in the estimated encroachment increasing. The addition of a layby within the Spey embankment results in a slight increase in the volume of encroachment however the change is minimal. Through discussion with SEPA it has been decided that the environmental impacts of providing compensatory storage are far more significant that the flood risk impact resulting from the lost floodplain storage therefore compensatory storage will not be provided for these encroachments. The bridge span is increased by 20m to the north, however the area of ground over which the bridge spans is substantially higher than the 200yr flood levels in this area. The proposed location for the south abutment remains as per the Initial Design. Therefore, there is no increase in the conveyance capacity and hence the hydraulics remain the same as per the Initial Design.	There are increases in water level downstream of the Spey crossing and decreases in water level upstream of the Spey crossing however these are primarily attributed to the loss of upstream storage resulting from the increase in the bridge span and the reduction in the embankment length. The Insh marshes downstream largely absorb the negative impacts from the Spey encroachments with the increase in water levels rapidly decreasing to between 1mm and 4mm within and downstream of the Insh marshes. There is a reduction in freeboard of 9mm at the B970 at Gordon Hall Farm. THC Roads Department will be consulted by Transport Scotland with regard to reduced freeboard on section of B970. There is a 7mm increase in water levels at the B9152 at Dunachton which is inundated to a depth of approximately 700mm in the existing case. Given the depth of inundation in the existing case the increase is proportionally negligible and therefore no mitigation is proposed for this negligible impact. The Scottish Water utility site at Lynchat experiences a 3mm increase in water levels (inundated with 19mm water depth in the existing case). Scottish Water will be consulted by Transport Scotland with regard to the 3mm increase in 200yr flood level at the Lynchat utility site. All other receptors impacted by the changes to the Spey crossing in the range of 1 -4mm have significant depths of inundation in the existing case. The change in depth is proportionally negligible and therefore no mitigation is proposed Larger decreases in water level at receptors upstream of the Spey crossing are predicted, representing an overall betterment relative to the existing 'baseline' condition. .

Chainage	Initial Design Impact	Design Development (Initial Design to Proposed Scheme)	Residual Impacts (including Embedded Mitigation)
Ch.50,700	The mainline earthworks encroach into the Spey floodplain along with SuDS basin 507. This has an estimated encroachment volume of 1812m^3.	Following dialogue between the flood risk team, the drainage team and the roads team SuDS basin 507 is removed from the floodplain and a headwall at the A86 is extended to reduce the mainline encroachment. The estimated remaining encroachment volume is 1071m^3. The remaining encroachment is mitigated through the provision of compensatory storage locally to the east of the encroachment (CSA ID 7).	None – The encroachment is fully compensated and therefore there are no residual impacts. .
Ch.51,200	The existing channel upstream of crossing ID 155 does not have capacity for the 200 year flow therefore overland flow runs to the west of the channel and inundates the proposed access track to the north of the A9 mainline. The watercourse diversion downstream of crossing ID 155 directs more flow towards several receptors resulting in increase in flood levels between 10mm and 96mm.	Following dialogue between the flood risk team and the culverts and watercourses team a channel has been introduced to the north of the previously inundated access track to intercept overland flow from the north. Additionally the watercourse diversion downstream of the crossing has been extended to a point downstream of the receptors.	The upstream channel intercepts the majority of the overland flow however it does not extend far enough to the west to intercept all the flow and there is still some slight inundation of the proposed access track. One non-residential receptor still experiences a 12mm increase in water levels as a result of the downstream diversion channel not having sufficient capacity to convey the flow in one short reach. *Requirement for Additional Mitigation – refer to **Table 9-3**.*
Ch.51,800	The A9 mainline earthworks encroach into the floodplain upstream of crossing ID's 157 and 158. The estimated volume of encroachment is 9284m^3.	Through dialogue between the flood risk team and the roads team the encroachment has been reduced by steepening earthworks embankments as much as practicable. The remaining estimated encroachment is 9043m^3. Through discussion with SEPA it has been decided that given the unusual hydraulics of the crossings and the downstream floodplain, along with wider environmental impact considerations, the provision of compensatory storage will not be required as the loss of floodplain storage does not increase water levels at B9152 and the HML and any increase in flow will be absorbed by the Insh Marshes.	No increase in water level downstream of the crossing. There are minor changes to the shape of the hydrograph passed downstream of the B9152 however any impacts of this will dissipate within the Insh Marshes. No further action is proposed.

Chainage	Initial Design Impact	Design Development (Initial Design to Proposed Scheme)	Residual Impacts (including Embedded Mitigation)
Ch.52,950	The watercourse diversions around crossing ID 159 direct the flow slightly differently and as a result there are localised increases and decreases in water level on the Chapelpark farm accesses (+/-2mm). There is some localised inundation of the access track to the north of the A9 mainline upstream of crossing ID 159 which is a result of overland flow from the existing channel. Upstream of watercourse crossing ID 159 the proposed widening of the A9 Mainline to the north results in the removal of a ridge of high ground that in the existing case meant that overland flow from the watercourse could not reach the road. Its removal presents a material increase in the flood risk to the Proposed Scheme mainline road. SuDS basin 530 encroaches into the floodplain of the River Spey and the estimated encroachment volume is 1037m^3.	A new underpass providing access to Balavil has been introduced to the east of Chapelpark and as a result crossing ID161 has been realigned to the east of this underpass. Flows from ID161 now no longer contribute to the flows through the undersized existing culvert under the existing access to Chapelpark farm and as a result this culvert can accept increased flows from the outfall of crossing ID 159. This reduces the overland flow downstream of ID 159 and hence the local increases are mitigated. Following dialogue between the flood risk team and the drainage team SuDS 530 has been reshaped to minimise the encroachment. As a result of the introduction of the underpass the access track has been raised within the floodplain resulting in localised encroachments into the floodplain of the River Spey the combined estimated encroachment resulting from the access tracks and the remaining SuDS basin encroachment is 1385m^3. The encroachments are mitigated through compensatory storage local to the encroachments (CSA ID 9).	The removal of the ridge of high ground to the north of the A9 results in a material increase in flood risk to the Proposed Scheme. *Requirement for Additional Mitigation – refer to **Table 9-3**.*
Ch.53,200 - Ch.53,900	The crossing at ID162 is significantly undersized in the Initial Design resulting in extensive backing up of floodwaters from the crossing which inundates the proposed A9 mainline, B9152 and the residential property at the Mains of Balavil (958mm increase in water levels). Conversely the restriction of the crossing results in decreased levels downstream. The A9 mainline earthworks, access track earthworks, and SuDS basins 534 and 537 all encroach into the floodplain upstream and downstream of crossing ID162. Additionally, SuDS basin 537 encroaches into the floodplain of the River Spey to the east of crossing ID 162. The estimated total volume of encroachment in this area is 9355m^3. The raised access track to SuDS basin 534 alters flow patterns and largely cuts off the overland flow route to the west driving a higher proportion of the flows towards the HML the B9152 and a residential receptor although due to the undersized crossing under the A9 the levels at these receptors sill decrease.	Following dialogue between the flood risk team, the drainage team, the roads team and the structures team, the encroachment from the mainline and access track earthworks on the north side of the mainline has been reduced by realigning the access track closer to the mainline. In addition to this a new "left in – left out" junction has been introduced to the east of crossing ID 162 however the increase in encroachment that this brings is offset by the reduction in the other areas. The crossing structure size has been increased back to its existing opening size. Additionally the access track to SuDS basin 534 has been lowered to near existing ground levels thereby reducing the encroachment and the impact on overland flow. As there is still a portion of the track raised above existing levels there is still some encroachment and impact to the flow patterns however the effect is significantly reduced. SuDS basins 534 and 537 have been reshaped to minimise their encroachments. The estimated remaining encroachment is 7038m^3. This is mitigated through the introduction of compensatory storage on the upstream side of the A9 to the west of the watercourse (CSA ID 10)	Impacts relating to encroachments are mitigated though compensatory storage. Due to the raised portion of access track to SuDS basin 534 altering flow patterns it is expected that there will be small local increases in water level to the east of the watercourse downstream of crossing ID 162. *Requirement for Additional Mitigation – refer to **Table 9-3**.*

Chainage	Initial Design Impact	Design Development (Initial Design to Proposed Scheme)	Residual Impacts (including Embedded Mitigation)
Ch.55,300	Access track earthworks encroach into the floodplain at the upstream end of crossing ID 166. The estimated volume of encroachment is 117m^3. Alterations to the culvert at crossing ID168 result in a loss of storage upstream of the A9 and reductions in water levels at upstream receptors and increases in water level downstream adjacent to the HML and the B9152 although both receptors have significant freeboard above the 1 in 200 year proposed tributary floodplain.	The loss of floodplain storage is mitigated through the introduction of compensatory storage to the west of crossing ID 166 (CSA ID 11).	There is a loss in flood plain storage relating to the changes to the size of the culvert at crossing ID168. This has a beneficial impact on upstream receptors, removing 1 non-residential receptor from the floodplain. Flood levels associated with the tributary are increased downstream but there is a significant freeboard to the HML and B9152. Flooding from the River Spey is also the critical scenario for the road and rail infrastructure at this location. Increased downstream flows would dissipate within the Insh Marshes. Provision of mitigation at this location offers no real downstream benefit and no further action is proposed.
Ch.56,200	The mainline earthworks encroach into the floodplain upstream of crossing ID 170. The estimated encroachment is 1226m^3.	The encroachment is reduced through the introduction of a headwall for the Highland Wildlife Park access road. There is still a residual encroachment volume that is not mitigated in any way in the Assessment Design. The remaining encroachment volume is estimated to be 650m^3.	There is a residual encroachment that is not mitigated this may increase water levels downstream of the crossing and result in more flow passed downstream. *Requirement for Additional Mitigation – refer to **Table 9-3**.*

Crossing culvert design

9.18 The minimum size for culvert size in the Proposed Scheme has been increased to 1200mm (from a 900mm minimum size initially assessed). This updated criterion does not alter the selection of modelled tributary crossings from the screening exercise because any potential impacts of the culvert sizing approach are already considered in the analysis.

9.19 Other design developments have led to changes in culvert size on some tributary crossings as summarised in **Annex B.5**. All culverts in the Proposed Scheme have been reviewed against the previously modelled scheme design and any significant changes have been remodelled.

Embedded Mitigation

Compensatory Storage Areas

9.20 CSAs have been proposed in six locations subject to assessment of wider environmental impacts, along with other measures to mitigate the potential impacts of the Proposed Scheme on local and downstream flood risk. Details of these compensatory storage areas are provided in **Table 9-2** below. Plans of CSAs alongside respective encroachments are shown within the datasheets in **Annex C.4** and in **Annex D.6.**

Table 9-2: CSAs and associated mitigation to replace lost floodplain storage volume

CSA & location (P09 ch. and OS ref.)	Impact mitigated	Comments on assessed design
CSA ID Number: 1 ch.45,970 – ch.46,120 [u/s of ID146] E273180 N798340	ch.46,025 – ch.46,090: Mainline and Access Track encroachment on floodplain where floodwaters back up from crossing ID146. Culvert upsized resulting in loss of upstream floodplain storage. Increased flood levels in the Nuide Farm area (residential, non-residential, access, local road)	Direct replacement of lost volume through excavation upstream of ID146 in conjunction with further CSA proposals downstream of ID146 due to the limited space upstream of the crossing. As much storage as practical to be achieved here at detailed design with the fall back of the downstream area.
CSA ID Number: 2 ch.45,890 – ch.46,060 [d/s of ID146] E273090 N798420		Downstream replacement of lost volume upstream of receptors through excavation downstream of ID146. To be used to accommodate any volume that has not been accommodated in the upstream area.
CSA ID Number: 7 ch.50,720 – ch.50,775 [d/s of Spey Crossing] E276770 N801040	ch.50,675 – ch.50,710: Mainline encroachment into floodplain of the River Spey.	Direct replacement of lost volume through excavation adjacent to the encroachment within the River Spey floodplain.
CSA ID Number: 9 ch.53,025 – ch.53,160 [d/s of ID159] E278650 N801930	ch.52,960 – ch.53,050 SUDS Pond and Access Track encroachment into floodplain of the River Spey along with floodplains of watercourse ID159 and watercourse ID162.	Direct local replacement of lost volume through excavation adjacent to encroachment.
CSA ID Number 10 ch.53,240 – ch.53,500 [u/s of ID162] E278800 N802220	ch.53,260 – ch.53,825 Mainline, Access Track and SUDS Pond encroachment into floodplain upstream and downstream of crossing ID162.	Direct replacement and upstream replacement of lost volume through excavation and design of an offline storage area. Careful design of the inlet and outlet to the area will achieve volume for volume storage on a return period slice basis.
CSA ID Number 11 ch.55,170 – ch.55,260 [u/s of ID166] E280310 N803290	ch.55,270 – ch.55,310 Access Track encroaches into floodplain where flood water backs up from crossing ID166.	Direct replacement of lost volume through excavation adjacent to the watercourse can be provided immediately upstream of the crossing. Changes in the hydraulics of the crossing mean that the area has to be significantly larger than the area of encroachment.

9.21 Additional compensatory storage areas were originally proposed to address encroachments associated with ID147 (CSA3), ID148 (CSA4), SuDS basin 493 (CSA5), The Spey Embankment (CSA6), ID157 and 158 (CSA8 and 13) and ID170 (CSA12). Through the EIA process, the provision of these areas has been identified as impacting on wider environmental features and/or providing no tangible benefit. The additional compensatory storage areas are therefore not promoted as part of the scheme, as summarised below. Reasons for omitting the compensatory storage areas identified during the initial scheme assessment are provided in the datasheets presented in **Annex C.4**.

9.22 Traditional compensatory storage around ID147 through excavation has been removed from the design through discussion with SEPA in favour of compensatory storage through displacement upstream of the A9 crossing. This is discussed further under *CSA3 at ID147 (Milton Burn)*.

9.23 The small increase in flood levels predicted at Loch an Tairbh, the large freeboard to elements of the Proposed Scheme, the absence of sensitive receptors and the nature of Loch an Tairbh system (no known outfall) justified discarding the development of a compensatory storage area to the south of the A9 mainline.

9.24 Due to the context for CSA5 (NNR and designated areas, landscape and cultural heritage), it was proposed, to re-group the compensatory storage with CSA6, further downstream. Through discussion with SEPA the resultant combined CSA6 was ultimately removed as its potential benefits in relation to flood risk were significantly outweighed by the other impacts of providing the compensatory storage area.

9.25 CSA8 was originally proposed upstream of crossings ID157 and ID158, but discounted due to the presence of ancient woodland and steep topography. CSA13 was then investigated as an alternative. Through discussion with SEPA and as a result of the context of CSA13 in relation to the NNR and other designated areas, CSA13 has been removed from the Assessment Design. Modelling results for the Proposed Scheme show no predicted increase in water levels downstream of the A9.

9.26 Through the design development process, the encroachment around ID170 was removed by the introduction of headwalls allowing CSA12 to be removed. However, the length of the headwalls has been reduced and hence the encroachment has been reintroduced into the design. Whilst the potential for effective compensatory storage is limited at this location due to the constrained topography surrounding the crossing, the loss of floodplain storage can be minimised or removed by extending headwalls at both the upstream and downstream ends of the crossing.

CSA3 at ID147 (Milton Burn)

9.27 Modelling of the Milton Burn has shown that in the 200 year flood there is an extensive area of floodplain upstream of the A9 which provides significant attenuation in the baseline case. The level of this storage area is controlled by the combination of the A9 crossing and the crossing and level of a downstream access track. The A9 crossing comprises 3 Armco culverts – two which carry the normal flows within the watercourse and one which under normal flow conditions is an underpass and acts as a flood relief culvert.

9.28 Modelling of the proposed scenario highlighted that the proposed change to rectangular concrete culverts resulted in more flow being passed downstream at lower return periods for the same width of culvert. This is in part a function of the reduction in the roughness within the culverts, however the main change is the wider bases resulting in more flow being passed for a lower upstream flood level.

9.29 Through extensive modelling tests, recommended sizes for the culverts under the A9 have been developed such that they will not pass more flow at any return period or for any storm duration which once included within the scheme design will mitigate the risk of cumulative impacts occurring through additional flow passed downstream.

9.30 As the shape of the proposed recommended culvert does not match the existing culvert, to achieve the result of no additional flow downstream, less flow is passed at some levels. This shape change increases water levels and overall storage upstream of the A9 and for the 200 year event an increase of approximately 250mm compensates for the encroachment through storage displacement. The displaced storage will extend the area of rough grazing land currently inundated in more extreme flood events and no sensitive receptors are affected.

Overland Flow Interception Channel (ID155)

9.31 Overland flow resulting from flood water spilling from the existing watercourse upstream of the A9 was predicted to inundate the access track to the north of the A9 mainline. A channel above the proposed access track has been included in the Proposed Scheme to partially intercept overland flows.

Downstream Diversion Channel (ID155)

9.32 Modelling originally predicted that the proposed watercourse diversion downstream of ID155 would direct higher flow rates towards a number of receptors increasing water levels locally. The channel realignment has been extended downstream to a point beyond the flood risk receptors and the detailed design will ensure sufficient hydraulic capacity.

Residual Impacts & Additional Mitigation

9.33 Residual impacts (i.e. those impacts which are not already addressed in the Proposed Scheme presented for assessment) and appropriate 'additional' mitigation are summarised in **Table 9-3**. Any alternative mitigation measures proposed during later stages of design development will require appropriate assessment and agreement with regulatory authorities (e.g. SEPA and THC).

Table 9-3: Residual impacts and recommendations for Additional Mitigation

Residual Impact (Post Mitigation)	Additional Mitigation to address Residual Impacts
Ch.47,300 Loss of upstream floodplain storage and the form of the Burn of Inverton crossing detailed in the Proposed Scheme (ID147) result in more flow downstream at some return periods and storm durations. The downstream access track encroaches into a deep area of flood plain.	The access track to Inverton Cottage will be realigned to reduce encroachment and the Burn of Inverton crossing will be sized to maintain effective compensatory storage upstream and provide a neutral or better effect on downstream flood risk.
Ch.49,350 - Ch.50,250 SuDS basin 493 encroaches into the floodplain of the River Spey. Compensatory storage has not been provided as described above (CSA 5/6)	Subject to agreement with SEPA and THC, reduce standard of protection for SuDS basins as far as possible to reduce encroachment.
Ch.51,150 – Ch.51,350 The drainage channel upstream of crossing ID 155 intercepts the majority of the overland flow however it does not extend far enough to the west to intercept all the flow and there is still some slight inundation of the access track. Downstream of crossing ID 155, one non-residential receptor still experiences a 12mm increase in water levels as a result of the downstream diversion channel not having sufficient capacity to convey the flow in one short reach.	The channel upstream of crossing ID 155 will be extended to the west to improve capture of overland flows. The channel capacity downstream of crossing ID 155 will be increased to mitigate the impact to the non-residential receptor.
Ch.52,390 – Ch.52,950 Upstream of watercourse crossing ID 159 the proposed widening of the A9 Mainline to the north results in the removal of a ridge of high ground that in the existing case meant that overland flow from the watercourse could not reach the road. Its removal presents a material increase in the flood risk to the Proposed Scheme mainline.	A channel sized to convey peak flows in the upstream watercourse will be provided along the top of the cut slope until it reaches the higher ground to the west.

Residual Impact (Post Mitigation)	Additional Mitigation to address Residual Impacts
Ch.53,325 – Ch.53,420 Due to the raised portion of access track to SuDS basin 534 altering flow patterns it is expected that there will be residual small increases in water level to the east of the watercourse downstream of crossing ID 162, although these have not been explicitly quantified as the modelling combines the effect of increases in water level resulting from lost floodplain storage. Increases (B9152, HML and Railway Cottage) are however considered to be negligible (<10mm) in the 200year.	Lower access track to SuDS basin 534 as far as possible along its full length to mitigate or reduce impacts relating to the changes in flow patterns or provide culverts under the raised of the access track to maintain overland flood route.
Ch.56,175 – Ch.56, 225 Residual encroachment associated with the crossing at ID 170 may increase water levels downstream of the crossing and result in more flow passing downstream.	The headwalls on the upstream and downstream side of the crossing will be extended to remove or minimise the encroachment.

9.34 The following general recommendations for maintaining effective flood risk management during construction and operation of the Proposed Scheme were also highlighted during consultation with SEPA and THC:

- During detailed design, consideration should be given to adopting lower SuDS design criteria where basins and ponds encroach into the functional floodplain
- Also during detailed design, the performance of road drainage systems should be examined for exceedance events to demonstrate that flood risk to the road can be managed without increasing flood risk elsewhere
- During construction and operation, risk of blockage will be reduced by regular inspection and maintenance of proposed crossings
- TS will investigate the feasibility of raising or resurfacing the B970 locally to maintain the existing freeboard (see **Table 9-1** for further explanation).
- TS will also investigate the feasibility of carrying out works to protect an existing Scottish Water utility asset at Lynchat (see **Table 9-1** for further explanation).

10 Conclusion

10.1 Sources of flood risk to the existing A9 and the Proposed Scheme have been assessed. The potential impacts of the Proposed Scheme on fluvial flood risk has been assessed with the aid of a Hydrological and Hydraulic Modelling study, developed with the aid of stakeholder consultations at earlier stages in the DMRB process. Developing design information has been used to create post-development flood models, and the findings have been used to inform further design development.

10.2 The existing A9 is not predicted to be at risk of fluvial flooding from the River Spey. There is a risk of fluvial flooding to the existing A9 in 4 locations from tributaries of the River Spey. The Proposed Scheme mainline is not at risk of flooding from any of the modelled fluvial sources. The 4 locations previously affected are no longer 'at risk'. Flood extents figures showing predicted 200yr flood depths for pre- and post- development conditions are included in **Annex D**.

10.3 The Proposed Scheme represents an overall improvement for flood risk to receptors around Kingussie due to the widening of the Spey crossing. Flood levels downstream of the crossing are marginally increased due to the increased conveyance and associated partial loss of upstream storage. A 1mm increase in peak water level at the downstream end of the model is considered negligible in the context for the River Spey downstream of the area of assessment.

10.4 Interim flood risk assessment findings have been used to inform design development. The Proposed Scheme thus offers an overall reduction in flood risk by addressing existing issues and generally avoiding or minimising loss of floodplain storage.

10.5 In parallel, mitigation options have been developed accounting for the Proposed Scheme. CSA's proposed as part of the Proposed Scheme are shown on the CSA figures provided in **Annex C**.

10.6 Where embedded mitigation fails to fully address potential impacts effectively, additional mitigation has been recommended as described in in **Section 9**. With appropriate mitigation included in the completed scheme, potential local impacts will be addressed and any cumulative impact on flood risk downstream will be negligible.

10.7 All scheme-wide 'standard' and project-specific mitigation requirements identified in this assessment have been reviewed to ensure compatibility with engineering and other environmental disciplines and deliverability in terms of design, construction, and land-take and other spatial constraints.

10.8 Various aspects of the proposed development have been designed against events of set standards based on DMRB recommendations and Scottish Planning Policy. These aspects include watercourse crossings, earthworks drainage, road drainage and SuDS. Exceedance events will be considered at detail design to ensure any residual flood risk to the development is acceptable with no increase in flood risk to nearby receptors.

Appendix 11.3

Flood Risk Assessment

Annex A: Hydrology

Contents

A.1 Watercourse Descriptions

Major Watercourses

River Truim (MW 8.1)

A.1.1 The River Truim is a major right bank tributary of the River Spey draining the western edges of the Cairngorms with a catchment area of 125km^2, as shown in **Figure A2-1**. Its headwaters are situated in the Pass of Drumochter, approximately 8km south of Dalwhinnie. It flows adjacent to Project 9 from south of Bridge of Truim to its confluence with the River Spey approximately 1.8km further downstream.

A.1.2 It has a Water Framework Directive (WFD) classification of 'Moderate ecological potential' – lower catchment (2016). It is designated as part of the River Spey Special Area of Conservation (SAC) for its populations of Atlantic salmon (*Salmo salar*) (the Truim is noted as important for its salmonid smolt production) and otter (*Lutra lutra*). Sea lamprey (*Petromyzon marinus*) and freshwater pearl mussel (*Margaritifera margaritifera*) are also qualifying features of the River Spey SAC; therefore, overall the watercourse has been assessed as having a **Very High** sensitivity value for water quality.

A.1.3 SEPA WFD classification for Upper Spey Sands and Gravel is determined as 'Good'. BGS data for this section of the Truim indicates that the waterbody is within a high groundwater vulnerability zone (Class 4); therefore a **High** sensitivity has been assigned.

A.1.4 The watercourse continues lateral migration, working into the glacial deposits, transporting and depositing materials, exhibited by sinuous meandering and braided planforms. Therefore, a **High** hydromorphological sensitivity value has been assigned.

A.1.5 Flooding of the River Truim impacts on receptors including residential and non-residential properties, though none are located within the Project 9 extent. Along the Project 9 extent, the Truim is located at least 160m away and 25m lower than the existing A9 and does not present any flood risk; therefore a **Low** sensitivity value is assigned.

River Spey (MW 9.1/ Hydro ID 152)

A.1.6 The River Spey is the dominant watercourse within the Project 9 extent, as shown in **Drawings 11.1** to **11.12** in **Volume 3**. The Spey flows for 157km from its source in the Monadhliath Mountains to the Moray Firth.

A.1.7 Many of its tributaries have sources in the steeper upper catchment within the Cairngorms Mountains. These watercourses are capable of generating high energy flows and introduce large volumes of coarse sediment, comprised of bedrock and fluvio-glacial deposits, into the main channel. The gentler gradients of the wider valley floors result in lower energy flows and subsequent deposition of this coarse material; this has been noted by channel narrowing at confluences with the River Spey.

A.1.8 The Spey is a designated SAC for species including Atlantic salmon and freshwater pearl mussel which are susceptible to changes in the sediment regime, channel morphology and fluvial processes of the river. Modifications within the catchment including abstractions, drainage, bridges and culverts etc. have led to changes in flow and sediment dynamics; as well as hydro schemes including which alter the hydrological regime of the river. It is classified as 'Good Ecological Potential' under the WFD River Basin Management Plan (2016) due to the presence of two hydroelectricity schemes operating in the upper catchment; the Tromie/ Truim tributaries and at Spey Dam. Overall, the watercourse has been assessed as having a **Very High** sensitivity value for water quality due to the various factors described above.

A.1.9 The river has an actively meandering planform and is working into a floodplain which is comprised of fluvio-glacial deposits (alluvium - clay, silt and sand and till). Mid-channel and lateral gravel bars are evident throughout the river reaches, many with fully established vegetation cover. The river has retained a gravel-bed channel due to this continued lateral migration working into the glacial deposits, transporting and depositing materials exhibited by sinuous meandering and braided planforms.

A.1.10 Aerial photography and historic mapping indicates numerous meander cut-offs and abandoned channels; within Project 9 this is notable around Ballochbuie Island east of the A9 Spey crossing at Kingussie. Right-hand bank undercutting into agricultural land is noted west of the Spey crossing as the river approaches the existing bridge. Deposition of material ranging from pebble to boulder is evident on the floodplain beneath the crossing. Bank protection has been implemented with stone gabions on the left bank below the bridge. The existing crossing restricts natural geomorphological processes, fixing the position of the existing banks. This has also resulted in scouring of existing bridge piers. Overall, a **Very High** sensitivity value has been assigned for hydromorphology.

A.1.11 The baseline hydraulic modelling highlights flooding at sensitive receptor locations throughout the Project 9 extent at the 1 in 200 year return period, including; residential and non-residential properties (Newtonmore, Nuide, Kingussie and Balavil); roads (B9150/ Perth Road, B970/ Ruthven Road, A86, B9152); the HML railway, cultural heritage (Ruthven Barracks); recreational areas, agricultural land. The 200yr floodplain of the River Spey is predicted to reach the foot of the existing A9 at three locations within Project 9 (ch.49,300 to ch.50,200, ch.50,675 to ch.50,750 and ch.53,000 to ch.53,100), though not predicted to overtop the road. Overall, a **Very High** sensitivity value has been assigned.

Photograph A1-1: River Spey

A) River Spey looking upstream from north embankment by Kingussie. The existing Spey crossing is seen to the left of photograph.

B) River Spey looking downstream. Confluence with the Gynack Burn to the left of photograph

C) River Spey looking upstream from south embankment opposite to Kingussie.

D) River Spey looking downstream from north embankment opposite Kingussie.

Allt Torr an Daimh (MW 9.2/ Hydro ID 138_2) and Unnamed Tributary (MW 9.2a)

A.1.12 The Allt Torr an Daimh is a 570m single channel right bank tributary to the River Spey flowing through a wide valley with gently sloping sides both upstream and downstream of the A9. It flows through an area of wet and riparian woodland/ scrub upstream of the road and blanket bog/ fens downstream. It crosses the A9 through a 1200mm concrete pipe before joining with a floodplain tributary (MW9.2a) and discharging to the Spey (**Drawing 11.2** in **Volume 3**).

A.1.13 The watercourse is not classified by SEPA and no water quality information was available. It is not known to support any designated freshwater-dependent ecosystems and it will receive a degree of road runoff; therefore, a **Low** sensitivity has been assigned for water quality.

A.1.14 Licenced discharge DISC 9.4 (STE to soakaway) is located approximately 130m to the west of the A9 by Ralia Centre. BGS data indicates that the waterbody is within a high groundwater vulnerability zone (Class 4); therefore a **High** sensitivity has been assigned.

A.1.15 To the east of the A9, the watercourse has incised into hummocky glacial deposits and peat; to the west the channel flows along a flat gradient of the Spey floodplain comprised of glacio-fluvial terraced deposits before joining the main watercourse. The channels are straight and narrow (c. <1m) and heavily vegetated with concrete headwalls at the culvert. Upstream, in-channel material sizes range from boulder to gravel; downstream material sizes range from boulders to fine; and varied sediment size accumulation is noted within the culvert. Overall, a **Medium** sensitivity value has been assigned for hydromorphology.

A.1.16 No flooding issues have been identified for this watercourse; therefore a **Low** sensitivity has been assigned.

Photograph A1-2: Allt Torr an Daimh (MW 9.2/ Hydro ID 138_1)

A) Metal sluice upstream of A9 B) Upstream of A9 looking towards inlet C) Downstream outlet under A9 looking east

Caochan Riabhach (MW 9.3/ Hydro ID 142)

A.1.17 Caochan Riabhach is a right bank tributary to the River Spey which flows for 610m from headwaters at approximately 250mAOD to the River Spey at approximately 245mAOD. Upstream of the A9 crossing W9.5 flows for 150m before joining the Caochan Riabhach and continuing on a narrow and relatively straight, shallow channel through a wooded area (**Drawing 11.3** in **Volume 3**).

A.1.18 Both watercourses are unclassified by SEPA and no water quality information was available. They have a combined catchment area of 0.71km^2. The watercourses will receive a degree of road runoff and three STE to soakaway discharges (DISC 9.10, DISC 9.11 and DISC 9.12) are located within the Ralia Lodge site; however, these are approximately 100m to the east of the watercourses, therefore, they been assigned a **Low** sensitivity value.

A.1.19 Although classed as a 'Major' watercourse (shown on OS 1:50K mapping), Caochan Riabhach (MW9.3) is a small channel draining a boggy area upstream of the existing road cutting. The channel downstream of the crossing has been realigned, likely during railway construction to take flow from this and other channels through a single point in the railway embankment. The channel is vegetated indicating a level of stability with limited morphological activity in the catchment overall; therefore, a **Low** sensitivity value for hydromorphology has been assigned.

A.1.20 Hydraulic modelling indicates Caochan Riabhach (MW9.3) overtops and floods the access road to the west of Ralia Lodge in a 200 year event as well as impacting on the HML railway embankments. As the railway is classed as essential infrastructure, but it not directly overtopped and access / egress to / from Ralia Lodge can also be made from the east, a **High** sensitivity value has been assigned.

Photograph A1-3: Caochan Riabhach (MW9.3/ Hydro ID 142)

A) Upstream looking towards A9 B) Looking upstream from A9 inlet C) Downstream of A9 looking towards outlet

Allt Eoghainn (MW 9.4/ Hydro ID 145)

A.1.21 The Allt Eoghainn is a stable right bank tributary of the River Spey (catchment area approximately 2.2km^2) with its headwaters, southwest of the summit of Ordan Shios, in Nuide Moss at an elevation of approximately 325mAOD. It crosses the existing A9 through an 1800mm culvert, downstream of which, it becomes part of a field drainage system and flows for another 2.2km through straightened field-edge boundary channels before reaching the Spey (**Drawing 11.4** in **Volume 3**). It is likely to be affected by acidification due to the land cover and receive a degree of road runoff, though it is not classified by SEPA and no water quality information was available; therefore it has been assigned a **Low** sensitivity.

A.1.22 BGS data indicates that the waterbody is within a high groundwater vulnerability zone (Class 4); therefore a **High** sensitivity value has been assigned.

A.1.23 Downstream of the existing A9 crossing, the channel flows through a relatively low gradient, confined valley bottom with little evidence of recent erosion of the valley sides through to substrate. Upstream of the crossing, it has a meandering planform in the upland section, incising into glacio-fluvial sheet deposits (sand, gravel and boulders) as it flows in a north-easterly direction for 2.8km across a relatively flat heather and grass summit, down to the A9 crossing at 250mAOD. On the hillsides surrounding the Nuide Moss, there is evidence of shallow failure exposing substrate, a possible supply of sediment to the channel ranging in size from gravel to boulder evident upstream of the crossing trash screen. Due to length of modified channel downstream of the crossing, a **Medium** sensitivity value has been assigned.

A.1.24 Hydraulic modelling indicates the watercourse overtops and floods the access road to Nuide in a 1 in 200 year event; therefore, a **High** sensitivity value has been assigned.

Photograph A1-4: Allt Eoghainn (MW9.4/ Hydro ID 145)

A) Upstream of A9 B) Downstream of A9 outlet C) Downstream of A9

Milton Burn/ Inverton Burn (MW 9.6/ Hydro ID 147)

A.1.25 Milton Burn is a right bank tributary of the River Spey (catchment area approximately 34.22km^2) with headwaters below the summit of Creag nam Bodach at Loch an Dabhaich where it flows through moorland, cutting into alluvium and glacio-fluvial sheet deposits (sand, gravel and boulders) before entering the main channel south of Kingussie (**Drawing 11.5** in **Volume 3**). It has a WFD classification of 'Good' (2016) and is designated as part of the River Spey SAC for species including; Atlantic salmon, otter, sea lamprey and freshwater pearl mussel. Further detail on the particular species present is provided in **Chapter 12**.

A.1.26 BGS data indicates that the waterbody is within a high groundwater vulnerability zone (Class 4); therefore a **High** sensitivity value has been assigned. Abstraction (ABS 9.4) is noted approximately 75m to the west of the watercourse.

A.1.27 Upstream of the crossing the channel is narrow, confined by right-side glacial terrace with exposed cobbles and boulders in a matrix of coarser sand. Downstream is a wide valley with gently sloping sides and sections of unprotected earth banks. In the straighter sections there is evidence of riffle flow indicating variance of bed profile and material size; the lower reaches are noted as an important spawning area for both salmon and trout. The channel is stable, well vegetated upstream with transport of material noted throughout and deposition and gravel bed formation noted within the culvert. Overall, a **High** sensitivity value has been assigned for hydromorphology.

A.1.28 Hydraulic modelling indicates the watercourse is out of bank in a 200 year event, flooding agricultural land for much of its length upstream of the A9, also impacting the embankments of the road itself. Downstream of the A9 it floods the access road to Inverton therefore, a **High** sensitivity value has been assigned.

Photograph A1-5: Milton Burn/ Inverton Burn (MW 9.6/ Hydro ID 147)

A) Crossing at A9 under two bridging culverts (third is underpass) B) Downstream of A9 looking toward access crossing

Unnamed (MW 9.11/ Hydro ID 155)

A.1.29 This unnamed watercourse is a left bank tributary of the River Spey (catchment area approximately 0.7km^2) entering the main channel east of Kingussie. It crosses the A9 via a 1200mm culvert and continues a further 1.2km before discharging into the Spey. It is likely to be affected by acidification due to the land cover and receive a degree of road runoff, though it is not classified by SEPA and no water quality information was available; therefore it has been assigned a **Low** sensitivity value.

A.1.30 BGS data indicates that the waterbody is within a high groundwater vulnerability zone (Class 4); therefore, a **High** sensitivity value has been assigned. The Kerrow Farm, STE to land discharge (DISC 9.28) is approximately 200m to the south-west of the watercourse at approximately ch. 51,050 (**Drawing 11.8** in **Volume 3**).

A.1.31 It is comprised of straightened ditches (including several ninety-degree turns around field boundaries) in a wide valley with gently sloping sides flowing over till formation alluvial fan deposits and peat. There are sections lined with concrete banks and it is vegetated along much of its length. Fine sediment size and plane bed morphology is noted throughout with the channel appearing stable. Most of the channel in the upper catchment has a natural planform although the dams and straightening through the golf course will have altered the flow and sediment transport regime. However, within the natural sections of channel there will be varied form and flow conditions and a range of sediment sizes. In the vicinity of the A9 the channel has been realigned and re-sectioned; therefore, a **Medium** sensitivity value has been assigned.

A.1.32 Hydraulic modelling indicates the watercourse is out of bank in a 200 year event upstream of the A9, overtopping the road and flooding residential properties further downstream at Laggan. The B9152 road and the HML railway are also affected by flooding at this location; therefore, a **Very High** sensitivity value has been assigned.

Photograph A1-6: Unnamed watercourse (MW 9.11/ Hydro ID 155)

A) Upstream of A9 crossing B) Downstream of A9 outlet

Allt Cealgach (MW 9.12/ Hydro ID 157)

A.1.33 The Allt Cealgach is a left bank tributary of the River Spey with a catchment area of approximately 3.1km^2, flowing 5.3km from headwaters at 380mAOD. It flows through a wooded area on the upstream side of the existing A9 and crosses the existing road through a 1500mm bridge structure. Downstream of the road the channel has been incorporated into field a drainage system and the watercourse flows into a pond (P9.20) approximately 350m downstream of the road (**Drawing 11.8** in **Volume 3**). It is likely to be affected by acidification due to the land cover and receive a degree of road runoff, though it is not classified by SEPA and no water quality information was available; therefore, it has been assigned a **Low** sensitivity value.

A.1.34 BGS data indicates that the waterbody is within a high groundwater vulnerability zone (Class 4); therefore a **High** sensitivity value has been assigned.

A.1.35 It has several smaller tributaries in the upper reaches and has a meandering planform following the contours of the higher ground. Its confluence with the Spey is located 1km to the east of Kingussie at 224mAOD. In the upper reaches the channel has incised into till formations and alluvial fan deposits in the vicinity of the A9. Upstream of the A9 the channel is single thread with step-pool morphology and formation of a large mid-channel bar comprised of boulders to fines. In-channel scour down to bedrock and bank erosion is also evident upstream.

A.1.36 Downstream there is evidence of avulsion; large scale deposition on both banks has resulted in flow path change shown by overland flow routes across fields, gravels on floodplain from out-of-bank events and a dry channel previously evident on mapping and aerial photography. This has resulted in a multi-thread downstream channel with fan and braided features. The gravels on floodplain now exhibit vegetation establishment indicating a period of stability. Overall a **High** sensitivity value has been assigned for hydromorphology.

A.1.37 Hydraulic modelling indicates the watercourse is out of bank in a 200 year event upstream of the A9, overtopping the road and flooding agricultural land further downstream. The B9152 road and the HML railway are also affected by flooding at this location though the direct source of this is unclear; therefore, a **Very High** sensitivity value has been assigned.

Photograph A1-7: Allt Cealgach (MW 9.12/ Hydro ID 157)

A) Large volume of deposited materials upstream of A9 crossing B) Out-of-bank flow and deposition of material downstream of A9

Raitts Burn (MW 9.14/ Hydro ID 162)

A.1.38 Raitts Burn is a single thread left bank tributary of the River Spey flowing approximately 7km south-eastwards across the north-western flank of Strathspey, draining an ice-scoured hollow (c. 1.5km^2 in diameter), to join the valley of the River Spey 3km downstream of Kingussie (**Drawing 11.10** in **Volume 3**). It has a WFD classification of 'Moderate' (2016) and the lower reaches of the watercourse are designated as part of the 'Insh Marshes' and 'River Spey' SACs and the 'River Spey-Insh Marshes' SSSI, SPA and Ramsar site. Overall, a **High** sensitivity value has been assigned for water quality.

A.1.39 BGS data indicates that the waterbody is within a high groundwater vulnerability zone (Class 4); therefore a **High** sensitivity value has been assigned.

A.1.40 It has a meandering planform, cutting into till, diamicton and alluvium bordered by areas of talus, following natural gradient of the hillslopes and passing over a waterfall in the upper reaches. The channel planform is straight directly upstream and downstream of the crossing set within a wide valley with gentle slopes. Between the HML railway and the B9152 road, mid-channel deposition of materials ranging from gravel to boulder has led to constriction and subsequent backing up of flow beneath both road and railway bridges and further deposition of fines on the embankments. Overall, a **High** sensitivity value has been assigned for hydromorphology.

Photograph A1-8: Raitts Burn (MW 9.14/ Hydro ID 162)

A) Upstream of A9 crossing (looking south) B) Upstream of B9152 – large volume of sediment constricting flow

Unnamed (MW 9.17/ Hydro ID 170)

A.1.41 This small unnamed watercourse (catchment area approximately 1.4km^2) is denoted as a 'Drain' on OS mapping and flows through the eastern edges of the Highland Wildlife Park north of the existing A9. It crosses the road through a 1200mm culvert at Hydro ID 170 (**Drawing 11.12** in **Volume 3**. It is not classified by SEPA and no water quality information was available. As it flows through wooded areas and will likely receive a degree of road runoff, it has been a **Low** sensitivity value.

A.1.42 BGS data indicates that the waterbody is within a high groundwater vulnerability zone (Class 4); therefore a **High** sensitivity value has been assigned.

A.1.43 This watercourse is a single thread channel that appears to be stable. The catchment is well vegetated and there appears to be little sediment supply to the channel. There is limited geomorphic diversity around the existing A9 crossing; however, a **Medium** hydromorphology sensitivity value has been assigned as much of the channel and flow is unmodified.

A.1.44 Hydraulic modelling indicates the watercourse is out of bank in a 200 year event upstream of the A9, impacting the road embankment. The B9152 road and the HML railway are also affected by flooding at this location; therefore a **Very High** sensitivity value has been assigned.

Photograph A1-9: Unnamed watercourse (MW 9.17/ Hydro ID 170)

A) Upstream of A9 crossing (looking south) **B) Upstream of A9 crossing (looking north)**

A.2 River Spey and contributing sub-catchments

Catchment Descriptors

Table A2-1: River Spey and contributing sub-catchments to the River Spey model

LABEL	River Spey at Invertruim (8007)	River Calder	Allt Laraidh	Milton Burn	Pittmain Burn	Gynack Burn	Burn of Ruthven	Allt Cealgach	River Tromie	Raitts Burn	Insh Main Drain	Dunachton Burn	Leault Burn	River Feshie	River Spey at Kinrara (8002)
Easting	268700	270800	273300	275100	275950	275950	276750	277700	278050	278950	282450	282500	283700	284150	288150
Northing	796300	798000	799650	799200	800100	800150	800450	801100	801150	801950	803800	804500	805950	806250	808250
AREA	401.74	68.34	11.83	34.77	4.6	21.88	7.14	3.88	133.6	12.43	13.73	11.97	4.22	230.54	1008.94
ALTBAR	518	608	465	382	279	565	325	341	616	481	286	425	330	616	534
ASPBAR	311	138	168	336	156	136	355	166	5	151	325	146	142	324	10
ASPVAR	0.03	0.3	0.67	0.34	0.57	0.4	0.53	0.61	0.11	0.4	0.58	0.54	0.62	0.12	0.02
BFIHOST	0.411	0.367	0.439	0.547	0.598	0.414	0.433	0.403	0.452	0.362	0.509	0.495	0.635	0.483	0.452
DPLBAR	21.65	9.59	4.31	8.73	2.35	6.67	3.23	2.63	20.44	5.72	4.79	5.64	2.32	20.7	37.13
DPSBAR	181.3	223.5	150.3	100.4	103.6	180.5	93.4	121.1	209.2	134.1	69.4	114	129.7	180.3	175.2
FARL	0.945	0.993	0.996	0.945	1	0.955	1	1	0.9	1	0.97	1	1	0.993	0.927
FPEXT	0.0539	0.0257	0.0327	0.0503	0.3159	0.0221	0.0724	0.0496	0.0346	0.0169	0.1686	0.0249	0.035	0.0422	0.0565
FPDBAR	0.807	0.35	0.395	0.626	5.765	0.26	0.726	0.486	0.552	0.195	3.62	0.289	0.498	0.598	0.966
FPLOC	0.804	0.687	0.682	0.769	0.66	0.701	0.437	0.426	0.738	0.779	0.82	0.765	0.525	0.757	0.825
LDP	41.25	15.98	7.87	14.74	4.82	10.89	5.68	4.95	31.54	10.75	8.82	9.99	5.23	41.86	70.89
PROPWET	0.75	0.68	0.68	0.72	0.68	0.68	0.71	0.68	0.72	0.68	0.68	0.68	0.68	0.7	0.71
RMED-1H	10	9.5	8.5	8.7	7.8	8.9	8.2	7.9	10.1	8.6	8	8.2	7.9	9.4	9.6
RMED-1D	39.5	35.7	32.3	30.1	29.4	32	28.6	29.4	37.9	30.9	28.6	30.1	29.2	35.4	36.5
RMED-2D	55.6	52	47.5	43.6	43.8	48	42.2	43.8	56.5	45.8	41.4	43.7	41.3	52.1	52.6
SAAR	1430	1383	1168	987	923	1230	872	943	1427	1091	824	1014	885	1285	1316
SAAR 4170	1445	1446	1122	962	903	1206	876	914	1441	1064	844	1003	894	1349	1340
SPRHOST	51.15	55.26	50.51	41.01	37.61	56.91	45.2	48.18	53.07	55.55	40.7	46.22	35	49.04	49.67
URBEXT90	0.0001	0	0	0	0.0068	0.0004	0	0	0	0	0.0011	0	0.0009	0	0.0003
URBEXT00	0	0	0	0	0.0274	0.0017	0	0	0	0	0	0	0	0	0.0006

River Spey sub-catchments map

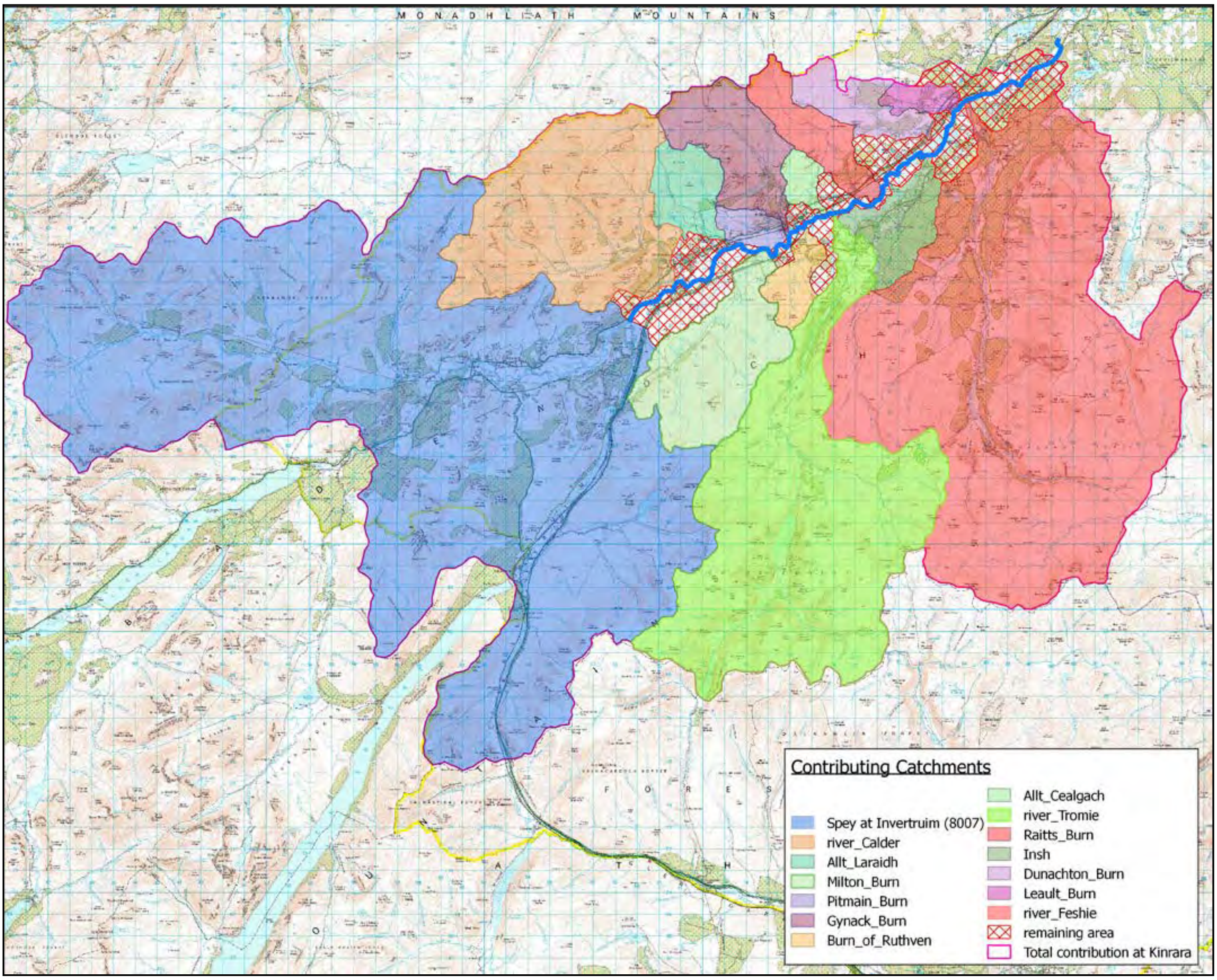


Figure A2-1: River Spey and contributing sub-catchments to the River Spey model

A.3 River Spey Gauged records

8007 River Spey at Invertruim

A.3.1 A new rating equation for the gauging station was received from SEPA in June 2015, along with a reworked AMAX dataset backdated through the entire period of record. The 2016 water year AMAX was added to this record using the rating equation provided, after a 0.05m stage adjustment based on the drawdown reported in SEPA advice.

A.3.2 SEPA advised about the flows bypassing the gauging station in larger flooding event. SEPA recommended adding ten percent to the flow greater for any stage level greater than 2m. The modified AMAX values accounting for bypassing are shown in Table A3-1 below.

A.3.3 The station description in WinFAPv5 dataset for Station 8007 notes the following for FLOW RECORDS:

> *"Unrepresentative period from 01/01/95 to 28/10/98 as inlet pipes broken due to deteriorating data quality, then missing period caused by further deterioration of data quality (28/10/98 and 24/02/00) and station rebuild (24/02/00 to 09/05/00)"*

A.3.4 The AMAX values for the water years 1994 to 1999 are ignored in the analysis (highlighted in red in **Table A3-1)**.

A.3.5 Values used for DMRB2 stage 2 were based on data provided by SEPA in 2014, relying on an older rating. The dataset is given in **Table A3-1** below for reference.

Table A3-1: Current AMAX values alongside historic for 8007@Invertruim and corresponding Q_{med} values.

2014 AMAX		SEPA June 2015 AMAX		Final dataset	
Used in DMRB2 for reference only		- Updated rating - Adjusted for drawdown - Includes WY2015 value (15min gauged records)		- Updated Rating - No adjustment for drawdown - Includes WY 2015 value (from 15min gauged records) - Account for 10% flow bypass - Discard 1994-1999 values	
DATE	FLOW	DATE	FLOW	DATE	FLOW
02-Sep-53	67.070	02-Sep-53	57.798	02-Sep-53	57.80
07-Nov-53	84.050	07-Nov-53	73.636	07-Nov-53	73.64
04-Dec-54	111.500	04-Dec-54	99.389	04-Dec-54	99.39
28-Dec-55	118.000	28-Dec-55	103.249	28-Dec-55	103.25
15-Dec-56	107.000	15-Dec-56	94.310	15-Dec-56	94.31
20-Dec-57	84.620	20-Dec-57	73.636	20-Dec-57	73.64
19-Jan-59	53.490	19-Jan-59	41.167	19-Jan-59	45.17
17-Oct-59	66.790	17-Oct-59	71.305	17-Oct-59	71.31
28-Sep-61	91.410	28-Sep-61	80.760	28-Sep-61	80.76
11-Feb-62	198.200	11-Feb-62	170.486	11-Feb-62	173.12
15-Dec-62	82.920	15-Dec-62	72.467	15-Dec-62	72.47
21-Oct-63	37.640	21-Oct-63	38.918	21-Oct-63	38.92
11-Jan-65	79.520	11-Jan-65	73.636	11-Jan-65	73.64
01-Nov-65	60.280	01-Nov-65	57.798	01-Nov-65	57.80
17-Dec-66	259.500	18-Dec-66	190.317	18-Dec-66	194.94
27-Mar-68	131.900	27-Mar-68	111.098	27-Mar-68	111.10
30-Oct-68	63.210	31-Oct-68	59.990	31-Oct-68	59.99
02-Nov-69	91.080	17-Mar-70	83.177	17-Mar-70	83.18
09-Jan-71	89.070	09-Jan-71	86.842	09-Jan-71	86.84
22-Oct-71	88.330	22-Oct-71	85.615	22-Oct-71	85.62
13-Dec-72	53.990	13-Dec-72	55.630	13-Dec-72	55.63
18-Jan-74	153.700	18-Jan-74	135.351	18-Jan-74	135.35

2014 AMAX		SEPA June 2015 AMAX		Final dataset	
Used in DMRB2 for reference only		- Updated rating - Adjusted for drawdown - Includes WY2015 value (15min gauged records)		- Updated Rating - No adjustment for drawdown - Includes WY 2015 value (from 15min gauged records) - Account for 10% flow bypass - Discard 1994-1999 values	
DATE	FLOW	DATE	FLOW	DATE	FLOW
20-Dec-74	120.600	20-Dec-74	102.732	20-Dec-74	102.73
07-Jan-76	81.720	07-Jan-76	76.225	07-Jan-76	76.22
27-Nov-76	52.170	27-Nov-76	52.742	27-Nov-76	52.74
30-Oct-77	72.660	30-Oct-77	70.032	30-Oct-77	70.03
02-Mar-79	274.500	02-Mar-79	176.822	02-Mar-79	180.09
04-Dec-79	75.250	27-Jul-80	78.483	27-Jul-80	78.48
20-Sep-81	108.000	20-Sep-81	112.158	20-Sep-81	112.16
03-Mar-82	82.650	20-Nov-81	82.934	20-Nov-81	82.93
05-Jan-83	133.200	05-Jan-83	109.383	05-Jan-83	109.38
31-Dec-83	254.000	31-Dec-83	172.741	31-Dec-83	175.60
27-Nov-84	122.100	27-Nov-84	106.760	27-Nov-84	106.76
22-Mar-86	128.700	22-Mar-86	114.019	22-Mar-86	114.02
07-Dec-86	114.800	07-Dec-86	104.416	07-Dec-86	104.42
19-Apr-88	62.222	18-Apr-88	62.876	18-Apr-88	62.88
15-Jan-89	267.901	15-Jan-89	188.769	15-Jan-89	193.23
05-Feb-90	272.638	04-Feb-90	191.869	04-Feb-90	196.64
02-Jan-91	94.165	01-Jan-91	88.692	01-Jan-91	88.69
02-Jan-92	228.334	02-Jan-92	168.389	02-Jan-92	170.82
17-Jan-93	270.940	16-Jan-93	188.614	16-Jan-93	193.06
08-Mar-94	165.706	08-Mar-94	135.070	08-Mar-94	135.07
11-Dec-94	146.982	10-Dec-94	124.003	10-Dec-94	124.003
24-Oct-95	114.662	24-Oct-95	103.249	24-Oct-95	103.249
02-Mar-97	204.453	01-Mar-97	156.263	01-Mar-97	156.263
18-Nov-97	112.020	18-Nov-97	101.442	18-Nov-97	101.442
27-Dec-98	51.641	27-Dec-98	51.473	27-Dec-98	51.473
30-Nov-99	100.813	30-Nov-99	93.555	30-Nov-99	93.555
20-Dec-00	52.056	20-Dec-00	51.684	20-Dec-00	51.68
06-Mar-02	133.069	06-Mar-02	115.353	06-Mar-02	115.35
22-Nov-02	47.249	21-Nov-02	46.798	21-Nov-02	46.80
08-Jan-04	97.536	08-Jan-04	91.177	08-Jan-04	91.18
10-Jan-05	181.015	09-Jan-05	143.694	09-Jan-05	143.69
12-Nov-05	118.507	11-Nov-05	105.847	11-Nov-05	105.85
14-Dec-06	209.544	13-Dec-06	158.902	13-Dec-06	160.38
26-Jan-08	220.484	26-Jan-08	171.988	26-Jan-08	174.77
11-Jan-09	127.363	11-Jan-09	120.061	11-Jan-09	120.06
26-Nov-09	119.235	26-Nov-09	114.685	26-Nov-09	114.69
16-Jan-11	126.740	16-Jan-11	119.655	16-Jan-11	119.66
27-Nov-11	163.663	27-Nov-11	142.128	27-Nov-11	142.13
12-Dec-12	135.231	12-Oct-12	125.097	12-Oct-12	125.10
23-Feb-14	114.542	23-Feb-14	111.495	23-Feb-14	111.50
Median	**113.281**	08-Mar-15	202.678	08-Mar-15	208.53
		05-Dec-15	203.468	05-Dec-15	201.01
		Median	**103.249**	**Median**	**103.835**

8002 River Spey at Kinrara

A.3.6 Previous analysis at 8002 was based on AMAX data received from the SEPA hydrometry team in March 2015.

A.3.7 The WinFAP v5 dataset, available since May 2017, includes the water year 2014 dataset. Small changes in AMAX values are also noted. Additionally, an AMAX value for WY 2015 value was extracted from the 15min record and added to the WinFAP v5 dataset to form the current AMAX dataset shown in **Table A3-2** below.

Table A3-2: Current AMAX values alongside historic for 8002@Kinrara and corresponding Q_{med} values.

DMRB2 AMAX		DMRB3 AMAX*	
DATE	FLOW	DATE	FLOW
02-Sep-53	67.070	05-Nov-51	99.25
07-Nov-53	84.050	02-Sep-53	95.79
04-Dec-54	111.500	07-Nov-53	110.1
28-Dec-55	118.000	04-Dec-54	200.4
15-Dec-56	107.000	28-Dec-55	147.1
20-Dec-57	84.620	16-Dec-56	209.6
19-Jan-59	53.490	28-Jan-58	110.1
17-Oct-59	66.790	19-Jan-59	77.64
28-Sep-61	91.410	23-Jan-60	123
11-Feb-62	198.200	28-Sep-61	128.5
15-Dec-62	82.920	12-Feb-62	273.4
21-Oct-63	37.640	16-Dec-62	135.4
11-Jan-65	79.520	21-Oct-63	77.64
01-Nov-65	60.280	11-Jan-65	119
17-Dec-66	259.500	24-Jun-66	123
27-Mar-68	131.900	18-Dec-66	361.5
30-Oct-68	63.210	28-Mar-68	165.9
02-Nov-69	91.080	30-Oct-68	101.6
09-Jan-71	89.070	17-Aug-70	135.4
22-Oct-71	88.330	09-Jan-71	132.6
13-Dec-72	53.990	22-Oct-71	128.5
18-Jan-74	153.700	14-Dec-72	103.1
20-Dec-74	120.600	19-Jan-74	280.1
07-Jan-76	81.720	21-Dec-74	237.1
27-Nov-76	52.170	07-Jan-76	145.5
30-Oct-77	72.660	27-Nov-76	102
02-Mar-79	274.500	11-Nov-77	115.2
04-Dec-79	75.250	03-Mar-79	278.1
20-Sep-81	108.000	04-Dec-79	103.6
03-Mar-82	82.650	27-Sep-81	154.8
05-Jan-83	133.200	04-Oct-81	194.9
31-Dec-83	254.000	11-Jan-83	232.4
27-Nov-84	122.100	01-Jan-84	282.4
22-Mar-86	128.700	28-Nov-84	202.2
07-Dec-86	114.800	03-Dec-85	161.1
19-Apr-88	62.222	07-Dec-86	151.4
15-Jan-89	267.901	13-Jan-88	98.3
05-Feb-90	272.638	15-Jan-89	238.3
02-Jan-91	94.165	05-Feb-90	265.7
02-Jan-92	228.334	06-Oct-90	125.5
17-Jan-93	270.940	03-Jan-92	226.1
08-Mar-94	165.706	17-Jan-93	253.5
11-Dec-94	146.982	09-Mar-94	210.1
24-Oct-95	114.662	12-Dec-94	201.0
Qmed	**155.5**	08-Mar-15	224.4
		06-Dec-15	247.3
		Qmed	**161.1**

*WinFAP v5 AMAX dataset completed with WY 2015 from 15min gauged record dataset

A.3.8 Since the Interim H&HM report, no further analysis was carried out on the AMAX datasets for 8002 River Spey at Kinrara, 8008 River Tromie at Tromie Bridge and 8013 River Feshie at Feshie Bridge. The Qmed values for these stations are given in **Table A3-3** below.

Table A3-3: Q_{med} values for other 8008 and 8013 gauging stations (from 2015 Interim H&HM Report)

Gauging Station	Contributing Area (km^2)	Qmed – based on observed data (m^3/s)
8008 – River Tromie at Tromie Bridge	131.51	57.2
8013 – River Feshie at Feshie Bridge	229.91	102.3

A.4 Peak Flow Estimates at River Spey gauging stations

8007 River Spey at Invertruim

Updated statistical analysis

A.4.1 Peak flow estimates carried out as part of DMRB2 assessment and presented in the Interim H&HM report, are revised in view of the updated information available for 8007 River Spey at Invertruim.

A.4.2 Revised statistical analyses are presented in this section, using the updated AMAX dataset (presented in **sub-section A.3**) as well as WinFAP 4 software and the WinFAP-FEH v5 dataset.

Rainfall-Runoff model based analysis

A.4.3 Peak flow analyses based FEH Rainfall-Runoff and ReFH2 models were not further progressed since DMRB2. The methods and findings are detailed in the Interim H&HM report. The results are summarised in this report for comparison.

PROJECT	A9 Dualling	JOB No	97318	Calculated by	LG
		PAGE	1 of 4		
TITLE	River Spey at Invertruim - 8007 Enhanced Single Site & Single Site Analysis	DATE	20/09/2017	Checked by	VF

Pooling group generated using WINFAP-FEH v5 dataset

Updated AMAX dataset - Updated Rating
- No adjustment for drawdown
- Includes 2016 value (from 15min gauged records)
- Account for 10% flow bypass
- Discard 1994-1999 values

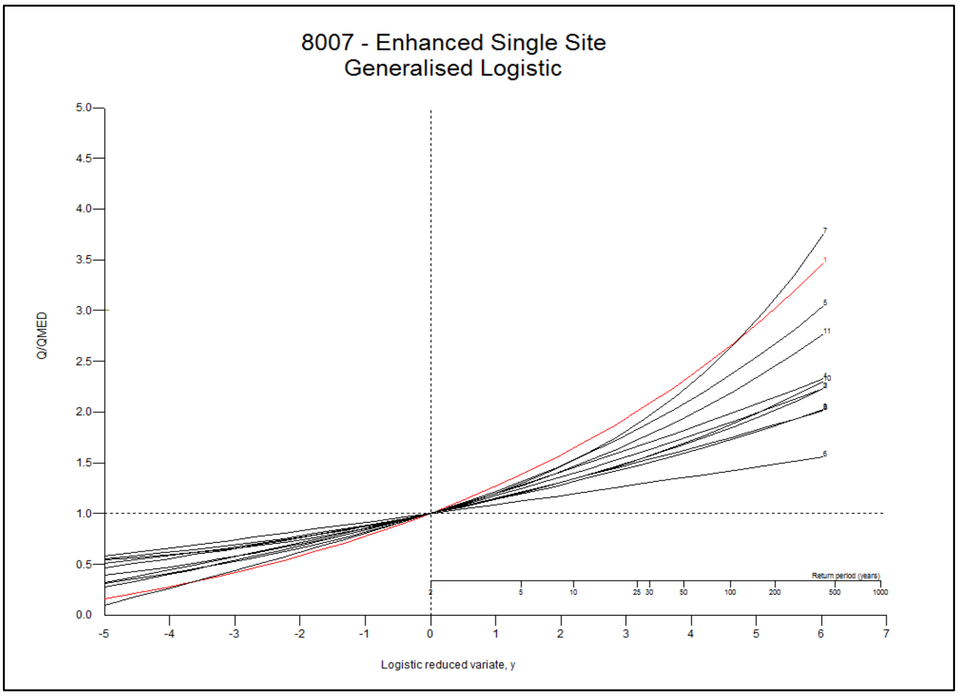
Pooling Group Details

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
8007 (Spey @ Invertruim)	0	58	103.835	0.239	0.159	1.291
27043 (Wharfe @ Addingham)	0.306	41	262.267	0.167	0.062	0.783
79006 (Nith @ Drumlanrig)	0.393	39	336.556	0.133	0.132	0.464
21007 (Ettrick Water @ Lindean)	0.411	45	241.075	0.195	0.036	2.01
7001 (Findhorn @ Shenachie)	0.423	47	248.084	0.198	0.162	0.481
202001 (Roe @ Ardnargle)	0.424	39	149.642	0.088	0.017	1.304
45002 (Exe @ Stoodleigh)	0.436	54	140.766	0.18	0.286	2.325
81002 (Cree @ Newton Stewart)	0.458	43	226.806	0.148	0.038	0.381
27034 (Ure @ Kilgram Bridge)	0.468	47	243.408	0.129	0.084	0.866
77002 (Esk @ Canonbie)	0.476	44	354.566	0.13	0.16	0.54
25008 (Tees @ Barnard Castle)	0.48	47	261.3	0.175	0.156	0.555
Total		504				
Weighted means				0.220	0.129	

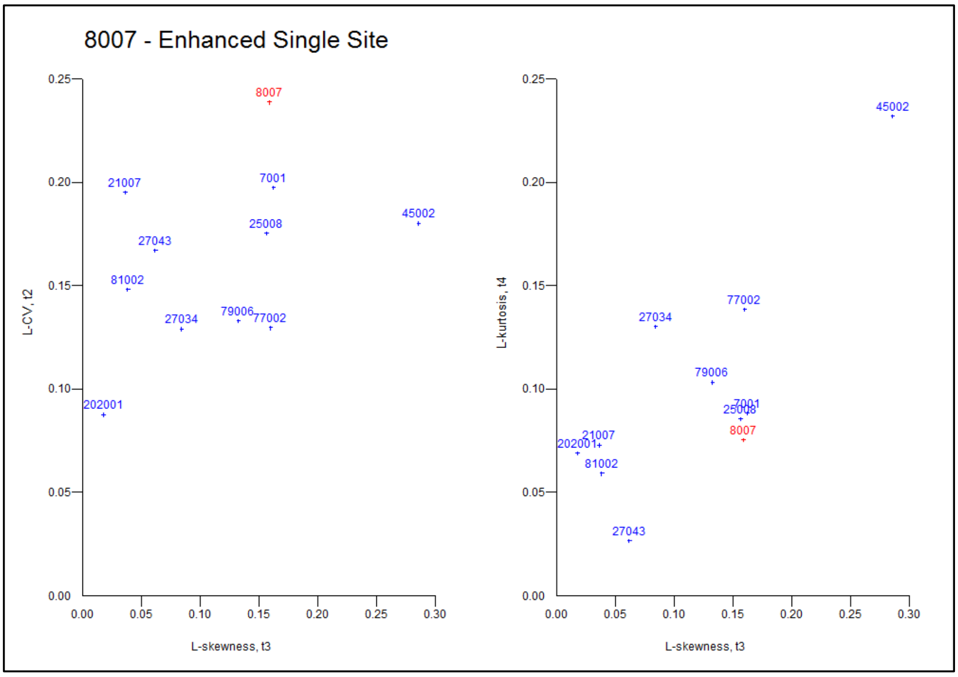
Station	Distance	AREA	SAAR	FPEXT	FARL	URBEXT 2000
8007 (Spey @ Invertruim)	0	401.74	1430	0.054	0.945	0
27043 (Wharfe @ Addingham)	0.306	429.98	1385	0.035	0.975	0.004
79006 (Nith @ Drumlanrig)	0.393	468.87	1485	0.041	0.99	0.002
21007 (Ettrick Water @ Lindean)	0.411	502.73	1306	0.039	0.928	0.002
7001 (Findhorn @ Shenachie)	0.423	415.59	1217	0.039	0.982	0
202001 (Roe @ Ardnargle)	0.424	365.69	1250	0.059	0.993	0.006
45002 (Exe @ Stoodleigh)	0.436	420.71	1361	0.022	0.979	0.002
81002 (Cree @ Newton Stewart)	0.458	366.25	1757	0.07	0.932	0.002
27034 (Ure @ Kilgram Bridge)	0.468	510.9	1338	0.045	0.99	0.004
77002 (Esk @ Canonbie)	0.476	495.37	1423	0.035	0.994	0.001
25008 (Tees @ Barnard Castle)	0.48	510.17	1310	0.035	0.912	0.00

PROJECT	A9 Dualling	JOB No	97318	Calculated by	LG
		PAGE	2 of 4		
TITLE	River Spey at Invertruim - 8007 Enhanced Single Site & Single Site Analysis	DATE	20/09/2017	Checked by	VF

Pooling Groupd details - Site growth curves



Pooling Groupd details - L-moments



PROJECT	A9 Dualling	JOB No	97318	Calculated by	LG
		PAGE	3 of 4		
TITLE	River Spey at Invertruim - 8007 Enhanced Single Site & Single Site Analysis	DATE	20/09/2017	Checked by	VF

Heterogeneity Test

H2= 2.4263
H1= 8.0838
Heterogeneous and review undertaken; none removed

Distributions	Goodness-of-fit Z value
Generalised Logistic (GL)	5.5476
Generalised Extreme Value (GEV)	2.3235

Growth Curve Fitting

Enhanced Single Site

Return Period	GL	GEV
2	1.00	1.00
5	1.34	1.38
10	1.57	1.62
25	1.88	1.90
30	1.95	1.95
50	2.14	2.10
100	2.41	2.28
200	2.71	2.46
500	3.14	2.69
1000	3.51	2.85

Single Site

Return Period	GL - LMED	GEV - LMED
2	1.00	1.00
5	1.38	1.42
10	1.64	1.69
25	2.01	2.03
30	2.09	2.10
50	2.31	2.28
100	2.65	2.52
200	3.02	2.76
500	3.58	3.07
1000	4.06	3.31

Flood Frequency Curve Fitting

Qmed= 103.835 m^3/s (from 8007 AMAX)

Enhanced Single Site

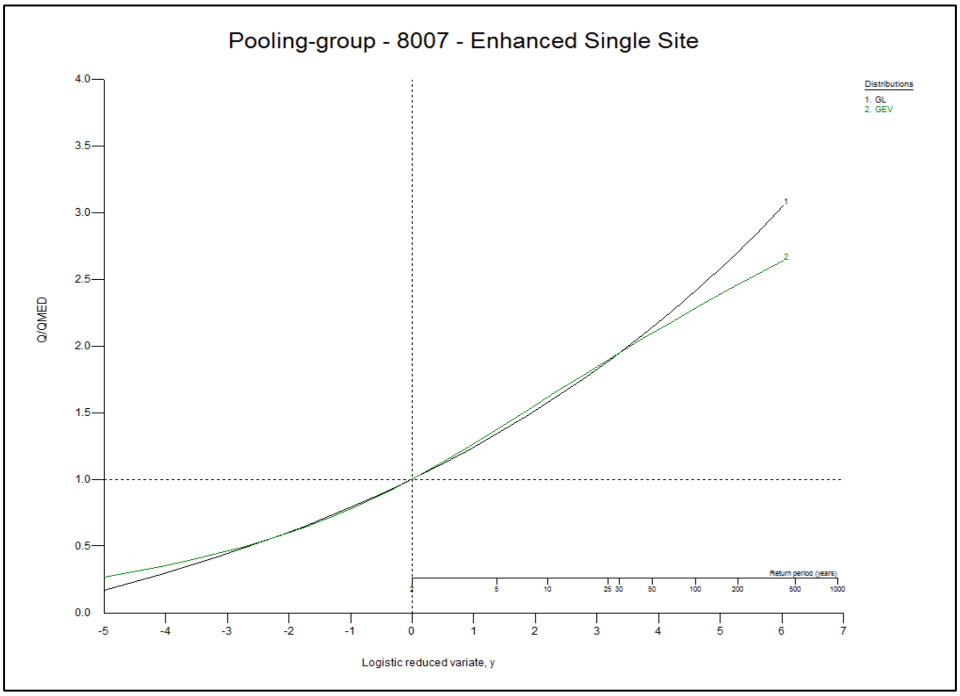
Return Period	GL	GEV
2	103.8	103.8
5	139.2	143.2
10	163.1	167.7
25	195.5	197.0
30	202.3	202.5
50	221.8	217.5
100	250.2	237.1
200	281.1	255.6
500	326.1	278.9
1000	363.9	295.6

Single Site

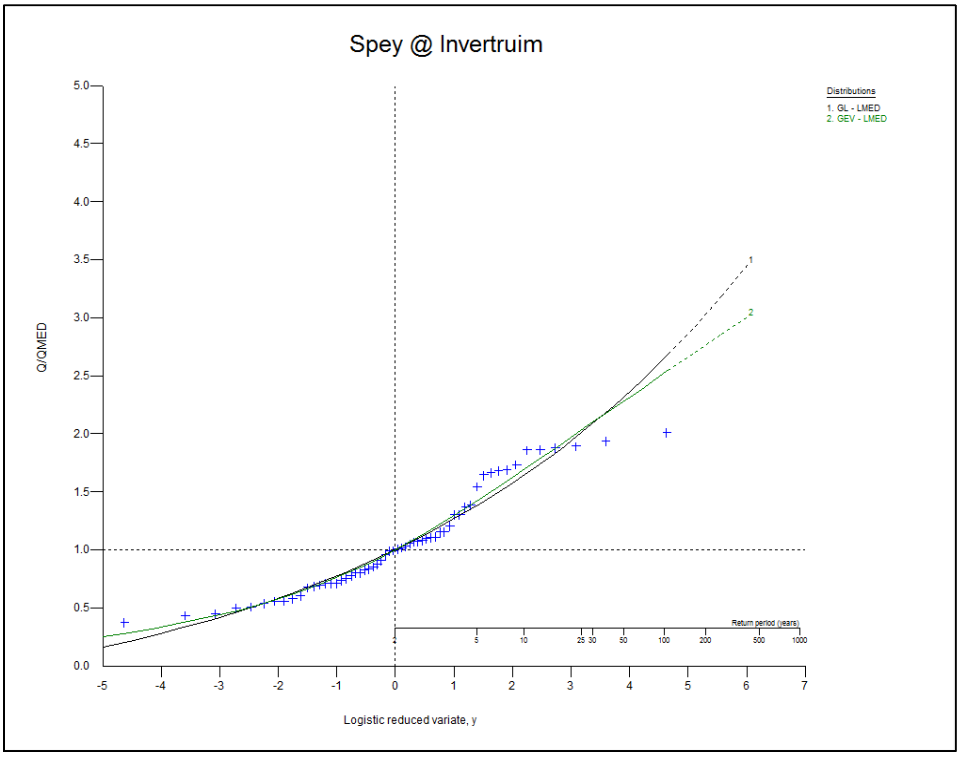
Return Period	GL - LMED	GEV - LMED
2	103.8	103.8
5	143.1	147.3
10	170.5	175.7
25	208.5	210.9
30	216.6	217.7
50	240.3	236.6
100	275.2	261.9
200	314.0	286.8
500	372.0	319.1
1000	421.8	343.2

PROJECT	A9 Dualling	JOB No	97318	Calculated by	LG
		PAGE	4 of 4		
TITLE	River Spey at Invertruim - 8007 Enhanced Single Site & Single Site Analysis	DATE	20/09/2017	Checked by	VF

Growth Curves - Enhanced Single Site



Growth Curves - Single Site



8007 Peak Flow Estimate Summary

A.4.4 **Table A4-1** below shows the updated peak flow estimates for statistical and rainfall runoff analyses for various return periods.

Table A4-1: Flow estimates (m3/s) for River Spey at Invertruim

RP (yr)	Statistical Analysis		Rainfall Runoff Methods*	
	Single Site	Enhanced Single Site	FEH-RR	ReFH2
Qmed/2.34	103.84	103.84	168.99	174.77
5	143.08	139.24	234.95	222.89
10	170.50	163.12	283.62	263.41
30	216.60	202.27	367.27	342.11
100	240.27	250.24	469.84	458.43
200	**314.00**	281.08	538.62	545.25
500	372.04	326.15	645.90	690.27

*Values communicated in the Nov16-H&HM

A.4.5 The single site analysis is the adopted method for estimating peak flows.

Statistical Peak Flow Estimates at other gauging stations within the modelled reach

A.4.6 Since the Interim H&HM report, no further analysis on peak flow estimates for 8002 River Spey at Kinrara, 8008 River Tromie at Tromie Bridge and 8013 River Feshie at Feshie Bridge was carried out. Peak flow values for these stations are given in **Table A4-2** below.

Table A4-2: Flow estimates (m^3/s) for the other gauging stations within the modelled reach (single site analysis)

RP (yr)	8002	8008	8013
Qmed/2.34	159.16	57.18	102.26
5	208.35	77.31	128.13
10	241.61	90.52	150.94
30	287.29	108.07	189.59
100	324.54	122.02	228.35
200	364.96	136.83	278.25
500	409.05	152.67	342.78

A.4.7 As detailed in the Interim H&HM report, the preferred method for peak flow estimate was single site statistical analysis.

A.5 8007 Hydrograph Shape Analysis

Background and preliminary work

A.5.1 SEPA correspondence (Ref PCS/140712, 25 June 2015) provides comments on Fairhurst's Interim Hydrology and Hydraulic Modelling Report (June 2015). Point five of SEPA's letter states:

"In section 4.1.5 we are not entirely clear but it seems that a rainfall runoff design hydrograph is being used for the boundary input to the model, scaled to match the peak flow from the FEH statistical analysis. Further information would be useful to confirm why this approach is better than using a hydrograph synthesised from observed data at the station. Our initial thought would be that given the importance of floodplain storage in the catchment, overall hydrograph volume would be an important factor as well as the peak flow. Maybe this is an area where more detail would be recommended at Stage 3."

A.5.2 An exercise has therefore been undertaken to synthesise a hydrograph from data observed at the Spey at Invertruim gauging station.

A.5.3 A synthesised hydrograph has been generated using 15min gauged records at Invertruim gauging station (8007). The synthesised hydrograph is used to select and adjust a hydrological model which will provide a good fit.

A.5.4 The use of a fitted hydrological model rather than the synthesised hydrograph shape is due to the requirement to vary the storm duration to account for the change in critical durations along the modelled reach.

A.5.5 Preliminary work on a synthesised hydrograph shape for 8007 gauging station was presented in the Nov 2016 DMRB3 H&HM Approach. The work was based on ten noticeable events. The updated analysis includes more events and clarifies rating inconsistencies for some parts of the gauged records used for the preliminary work. The final hydrograph shape presented in this section isn't substantially different from the shape presented in the Nov 16-H&HM.

Updated analysis

15min gauged record at Invertruim – Events selection

A.5.6 The original 15min gauged records showed inconsistencies in the rating used with an old rating applied to the 1988 to 2009 period whereas the 2010 to 2017 period is covered by the current rating. After consultation with SEPA hydrometric team, a new dataset was obtained with a consistent rating for the whole period of records. It consists of two ratings merged (one rating for low flows, one for higher flows), with a merging threshold of 54m^3/s (=POT).

A.5.7 There is no account for bypassing in the 15min records with the merged rating. For the hydrograph shape analysis, this is considered to be conservative giving "wider" standardised hydrograph shapes. No further adjustment was carried out.

A.5.8 Based on WinFAPv5 station description, records from 01/01/1995 to 09/05/2000 were discarded.

A.5.9 The flow hydrographs for 48 relevant events with a peak in the greater than 103m^3/s were extracted from the dataset, as shown in **Figure A5-1** and **Table A5-1** overleaf.

A.5.10 The hydrographs were extracted from -72hrs to +72hrs around the time of peak. Events with multiple peaks happening during this 6-day timeframe are included as separate events (for each peak above 100m^3/s) when the hydrograph recedes substantially between the peaks (less 20percent of peak flow).

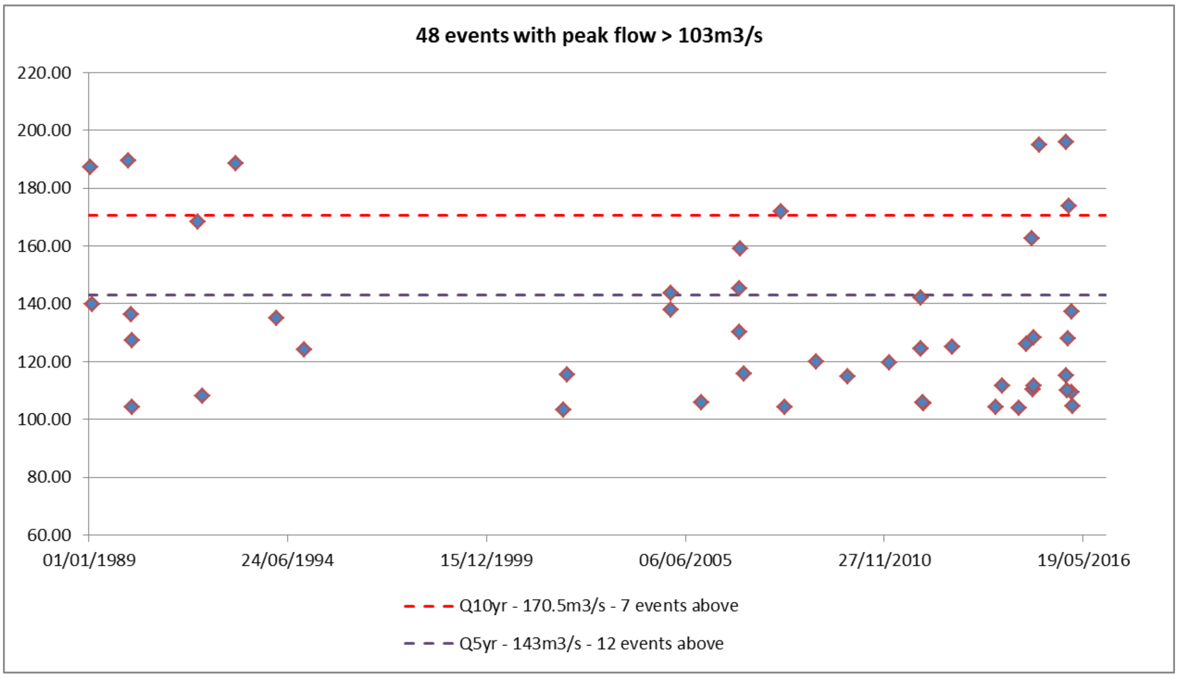


Figure A5-1: Flooding events selected for Synthesised shape hydrograph at Invertruim

Table A5-1: Flooding events selected for the synthesised hydrograph at Invertruim

Event (peak time)	Peak flow* (m3/s)	Event (peak time)	Peak flow* (m3/s)
05/12/2015 14:15	195.84	01/12/2011 03:15	124.41
08/03/2015 06:45	194.98	01/12/2011 03:15	124.41
05/02/1990 00:45	189.39	11/12/1994 08:45	124.00
17/01/1993 04:30	188.61	11/01/2009 22:45	120.06
15/01/1989 10:45	187.22	16/01/2011 11:00	119.66
30/12/2015 12:30	173.70	15/01/2007 11:45	115.62
26/01/2008 05:45	171.99	06/03/2002 13:00	115.35
02/01/1992 19:30	168.39	02/12/2015 09:00	115.26
22/12/2014 00:45	162.74	26/11/2009 12:00	114.69
14/12/2006 00:00	158.90	12/01/2015 10:15	111.63
01/12/2006 06:30	145.41	23/02/2014 20:00	111.50
10/01/2005 07:15	143.69	02/01/2015 04:00	110.44
27/11/2011 04:45	142.13	09/12/2015 21:15	109.97
06/02/1989 23:15	139.72	26/01/2016 15:15	109.52
07/01/2005 09:30	138.02	23/02/1992 04:15	107.94
29/01/2016 09:30	137.32	12/11/2005 02:00	105.85
06/03/1990 08:00	136.19	23/12/2011 05:15	105.78
08/03/1994 18:15	135.07	27/12/2011 04:00	105.64
04/12/2006 15:30	130.33	01/02/2016 12:00	104.42
10/01/2015 10:45	128.40	21/12/2013 00:00	104.29
24/12/2015 06:15	127.97	11/03/1990 10:30	104.29
16/03/1990 03:45	127.29	27/02/2008 02:15	104.16
28/10/2014 14:15	125.92	11/08/2014 12:45	103.77
12/10/2012 12:30	125.10	28/01/2002 22:30	103.25

*Peak flow may differ from corresponding AMAX shown in **sub-section A.3** as no allowance for bypassing flow is made here

Synthesised Hydrograph Shape Generation Method

A.5.11 The synthesised hydrograph was built using the method set out in the Environment Agency Flood Estimation Guidelines (2015), as follow:

- Centre each hydrograph with their peak at 0 hours
- Standardize each hydrograph by its peak such that the peak of each is one
- Average the standardised hydrographs to give a design shape
- Smooth the hydrograph to remove anomalous spikes and jumps resulting from the averaging process

Standardised Synthesised Hydrograph

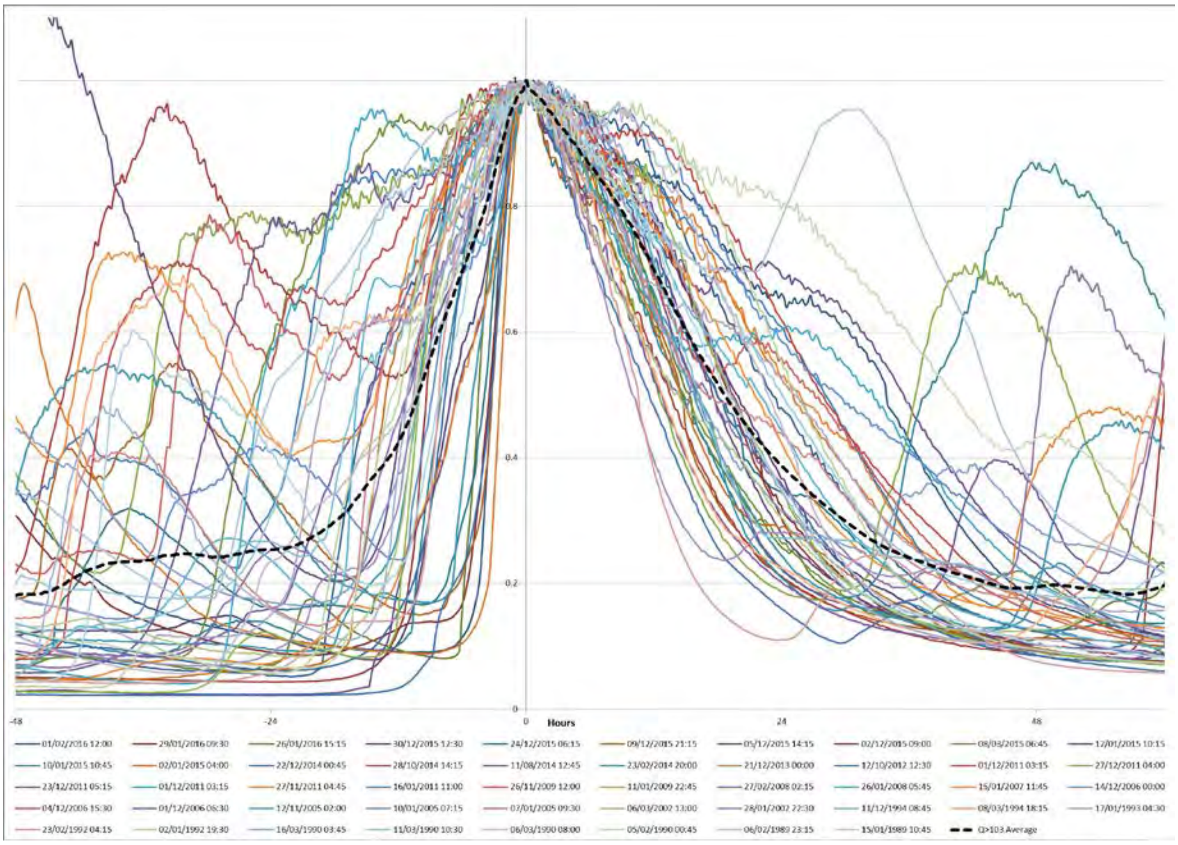


Figure A5-2: Standardised synthesised hydrograph for 8007 River Spey@ Invertruim

Influence of the larger flooding events

A.5.12 The influence of the larger events to the shape of the synthesised hydrograph was investigated by considering only the events with a peak flow greater than $143m^3/s$ (5yr RP, 12 events) and $170.5m^3/s$ (10yr RP, seven events). These thresholds are indicated by the dotted lines in both **Figure A5-1** and **Table A5-1**. The corresponding synthesised hydrographs are presented in **Figure A5-3** below.

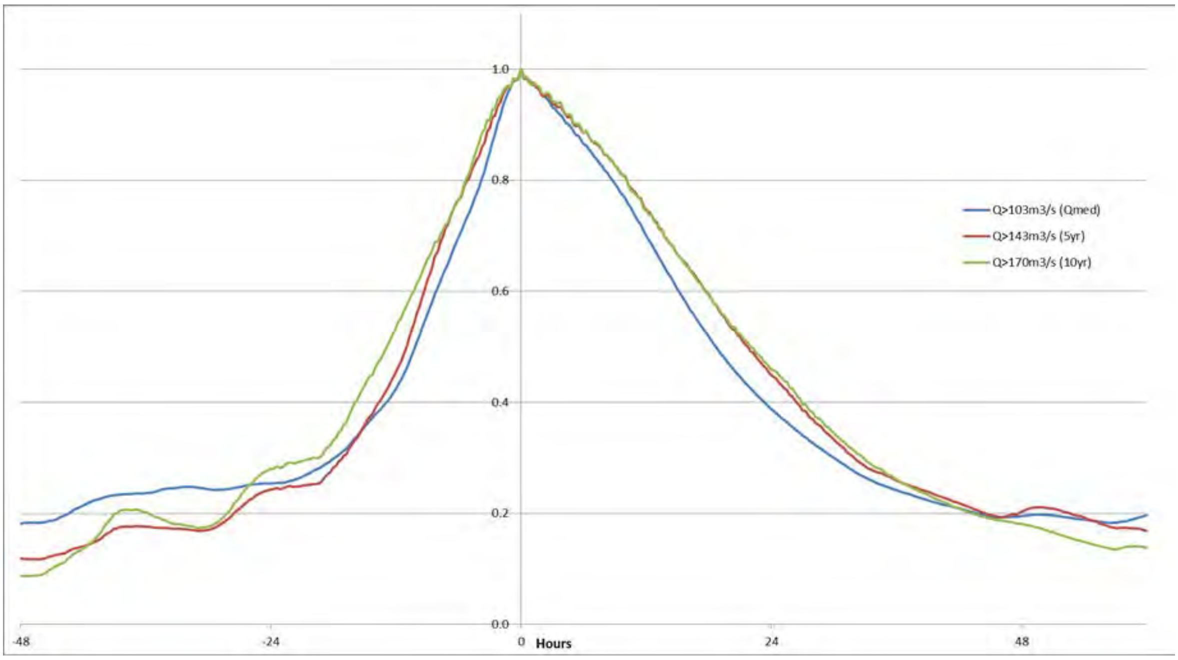


Figure A5-3: Synthesised hydrographs for Invertruim gauging station (8007), various event selection thresholds

A.5.13 The use of a higher threshold has a limited impact on the resulting hydrograph shape, with some increase in the hydrograph width.

A.5.14 It should be noted that the contribution from the flow by-passing the gauging stations in larger events (not accounted for in this analysis) is likely to “stretch-up” the synthesised hydrographs generated with higher thresholds.

Comparison with hydrological models

A.5.15 The synthesised hydrograph shape informs the choice of hydrological model used in the flood modelling study.

A.5.16 Flow hydrographs generated by different hydrological models are centred and standardised for their shape to be compared with the synthesised hydrograph.

FEH Rainfall Runoff model

A.5.17 The shape of the FEH Rainfall Runoff model is symmetrical and rather narrow with default values of time to peak (Tp) and storm duration (D), as shown in **Figure A5-4**. Different values for Tp and D were tested but none provide a satisfactory fitting.

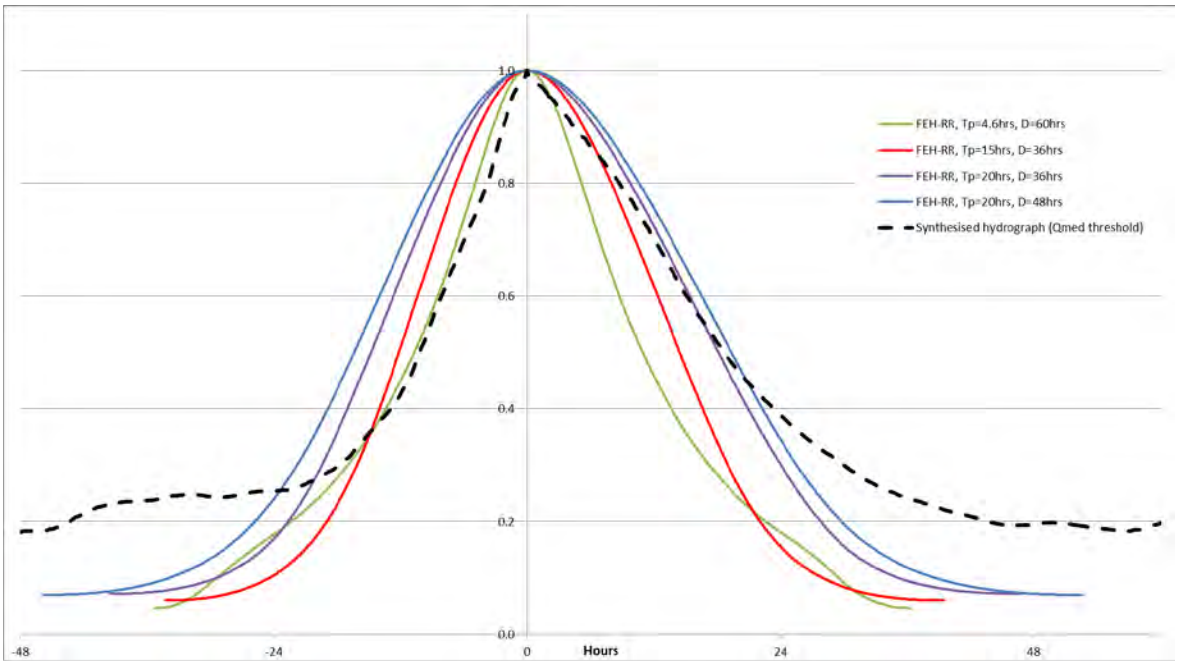


Figure A5-4: Synthesised hydrograph against the FEH-Rainfall Runoff Model

A.5.18 The synthesised hydrograph has a significant duration, which is far in excess of the hydrographs derived using the critical duration storm from the FEH Rainfall Runoff method.

A.5.19 Guidance indicates that the rainfall runoff method does not represent catchment processes well when:

- Snowmelt is a significant contributory factor in flood events; or
- Lakes or reservoirs have a significant influence on the catchment.

A.5.20 The SEPA correspondence (Ref PCS/140712, 25 June 2015) notes that:

> *"The March 2015 event was driven by a rapid increase in temperature leading to significant snowmelt in the Cairngorms, accompanied by further rainfall and high winds."*

A.5.21 Given the nature of the catchment it is considered that snowmelt could be a significant contributory factor to other flood events.

A.5.22 The FARL value for the catchment at the Invertruim gauge is 0.945, reflecting the influence of lochs and reservoirs upstream. This indicates a significant attenuation affect, which would be expected to lead to longer flood events.

ReFH2 model

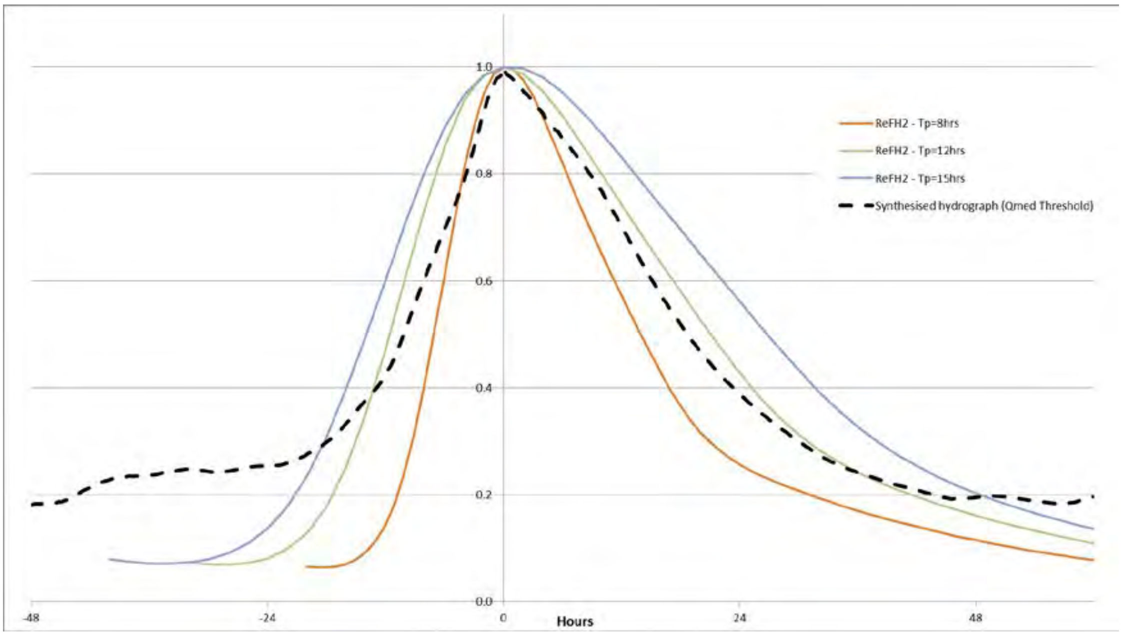


Figure A5-5: Synthesised hydrograph against the ReFH2 model

A.5.23 Comparison between the synthesised shape and the ReFH2 model is shown in **Figure A5-5.** The ReFH2 model offers a better fitting than the FEH-RR as the resulting hydrograph is asymmetrical.

A.5.24 The implementation of the ReFH2 method in Flood Modeller software has limitations: it is not possible to uncouple the storm duration parameter (D) from the Time to Peak (Tp). The flood modeller unit does therefore not allow the use of this method to investigate routing in longer duration events, discarding its use for this project.

ReFH model

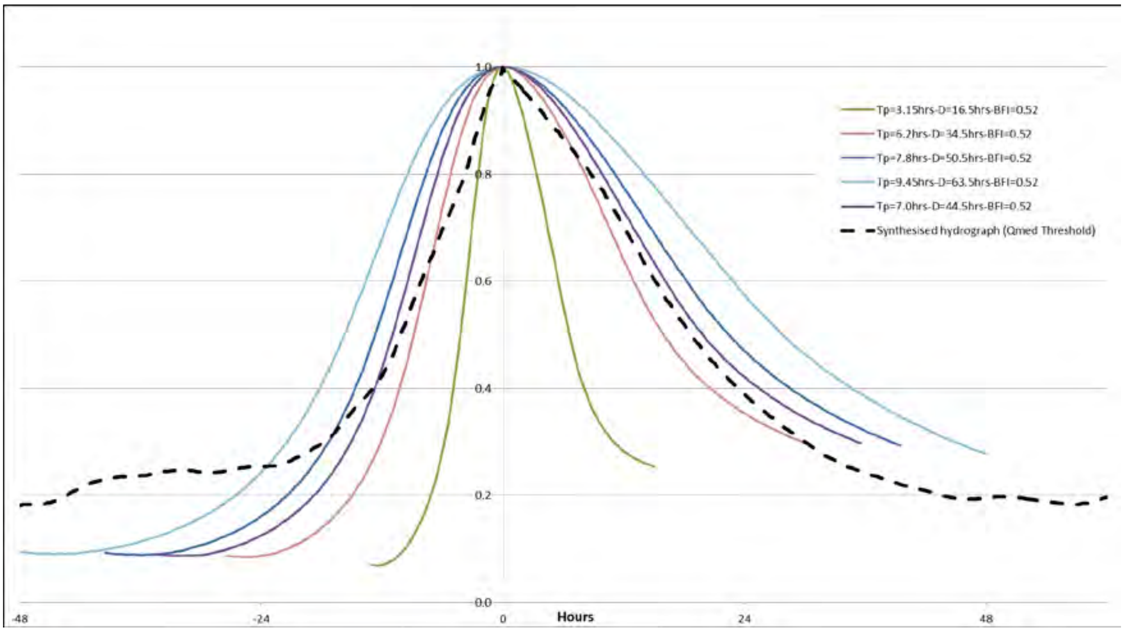


Figure A5-6: Synthesised hydrograph against the ReFH2 model

A.5.25 The ReFH model provides a satisfactory fit with a time to peak of 7.0hrs and storm duration of 44.5hrs. The Base flow index was also adjusted to the value at Invertruim gauging station (BFI=0.52) based on IH108 report.

A.5.26 Choosing the ReFH model has several advantages when it comes to combining the model in hydraulic model of the River Spey: The ReFH model implemented in Flood Modeller Pro software is versatile enough to allow its use in a routing exercise where various storm durations can be tested.

A.5.27 The ReFH model is not an accepted method to predict peak flows in Scotland. But in this specific study and as recognised by SEPA during consultation meeting, using this model to inform the hydrograph shape only, would be acceptable.

A.6 Hydrograph Shape Analysis for Other Gauging Stations

A.6.1 The gauged records at the other river stations along the modelled reach have been used to carry a similar exercise, to confirm the adequacy of the hydrological model used to represent the tributaries inflows in the River Spey model.

8008 – River Tromie at Tromie Bridge

A.6.2 A review of the 15min flow records for the River Tromie at Tromie Bridge gauging station, together with discussion with SEPA on the quality of the rating suggested that the interest in generating a synthetic hydrograph shape for this station is limited. No further work was carried out.

8013 – River Feshie at Feshie Bridge

A.6.3 The River Feshie at Feshie Bridge has 24yr of 15min records. In total, 56 events with a peak flow greater than the statistical Qmed were used, as shown in **Figure A6-1** below and **Table A6-1** overleaf.

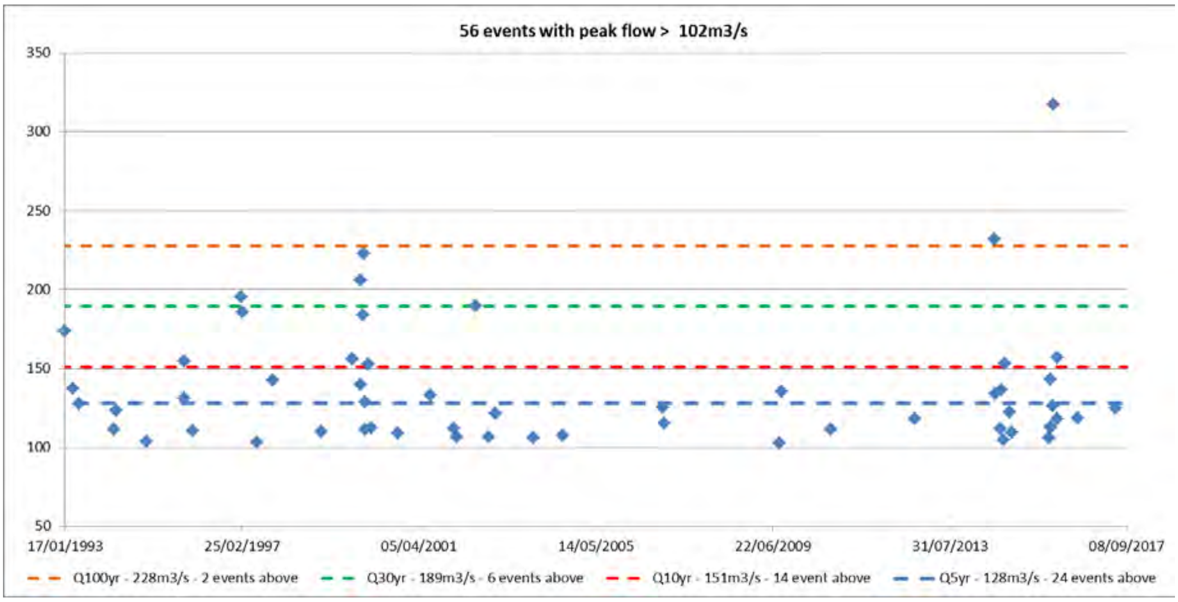


Figure A6-1: Flooding events selected for the synthesised hydrograph for 8013 River Feshie @ Feshie Bridge

Table A6-1: Flooding events selected for the synthesised hydrograph for 8013 River Feshie @ Feshie Bridge

Event (peak time)	Peak flow* (m3/s)	Event (peak time)	Peak flow* (m3/s)
30/12/2015 12:15	317.67	01/12/2006 01:00	125.27
11/08/2014 04:30	231.71	07/06/2017 02:45	124.64
24/12/1999 00:00	222.64	30/03/1994 23:30	123.46
28/11/1999 02:30	205.89	21/12/2014 22:15	122.35
17/02/1997 20:45	195.60	17/01/2003 06:15	121.34
30/07/2002 21:15	189.68	20/07/2016 13:45	118.56
01/03/1997 23:15	185.73	12/10/2012 14:00	117.98
22/12/1999 16:45	183.71	26/01/2016 14:30	117.85
17/01/1993 08:45	173.58	13/12/2006 18:00	115.21
29/01/2016 09:15	156.79	02/12/2015 10:45	112.84
21/09/1999 01:45	155.89	09/12/2015 20:45	112.84
26/10/1995 07:00	154.73	27/02/2000 07:45	112.45
14/11/2014 18:00	153.05	28/01/2002 17:45	112.05
30/01/2000 22:45	152.67	06/10/2014 13:45	111.63
05/12/2015 06:00	142.98	08/03/1994 15:15	111.55
18/11/1997 10:00	142.40	07/01/2000 17:45	111.46
30/11/1999 11:15	139.51	29/10/2010 23:15	111.21
30/03/1993 12:45	137.44	09/01/1996 01:15	110.34
08/10/2014 06:30	136.12	30/12/1998 13:00	109.71
04/09/2009 05:30	135.24	10/01/2015 06:15	109.39
17/08/2014 21:45	133.76	12/10/2000 15:15	108.91
11/07/2001 13:00	132.80	12/08/2004 00:00	107.43
24/10/1995 23:15	130.93	22/11/2002 00:15	106.69
05/01/2000 23:15	128.86	22/02/2002 02:30	106.59
17/05/1993 17:30	127.72	16/11/2015 04:45	106.18
24/12/2015 05:45	126.26	29/11/2003 17:45	106.10

A.6.4 The resulting synthesised hydrograph shape is shown in **Figure A6-2** overleaf. It is compared to the standardised shape of the FEH-Rainfall-Runoff hydrograph in **Figure A6-3**

A.6.5 The FEH-Rainfall Runoff model with the FEH default storm duration provides a satisfactory fitting to the synthesised hydrograph.

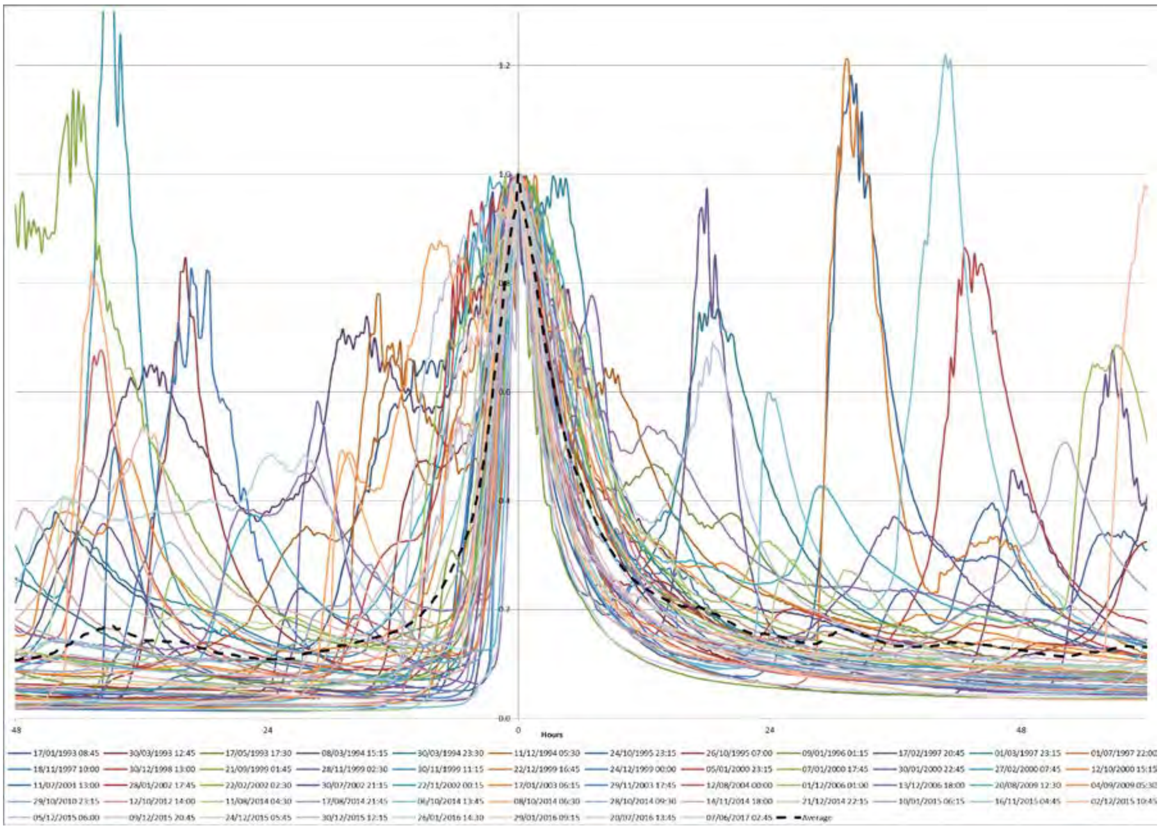


Figure A6-2: Standardised synthesised hydrograph for 8013 River Feshie @ Feshie Bridge

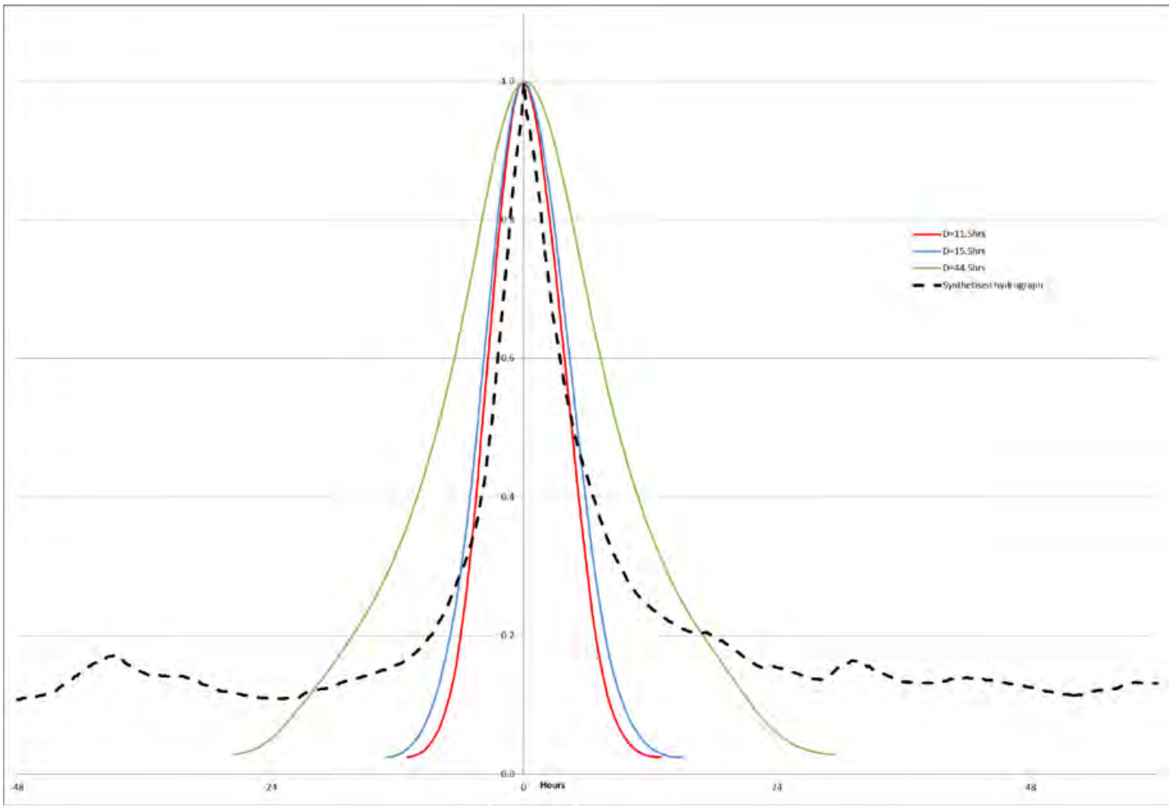


Figure A6-3: 8013 Synthesised hydrograph against the FEH-Rainfall Runoff Model

8002 – River Spey at Kinrara

A.6.6 A similar exercise was carried out for the gauging station at Kinrara, based on 29 events greater than Q_{med}. The results were originally presented during a SEPA/THC consultation meeting (30/10/2017) and is given here for information. The resulting hydrograph is not used to inform the modelling exercise.

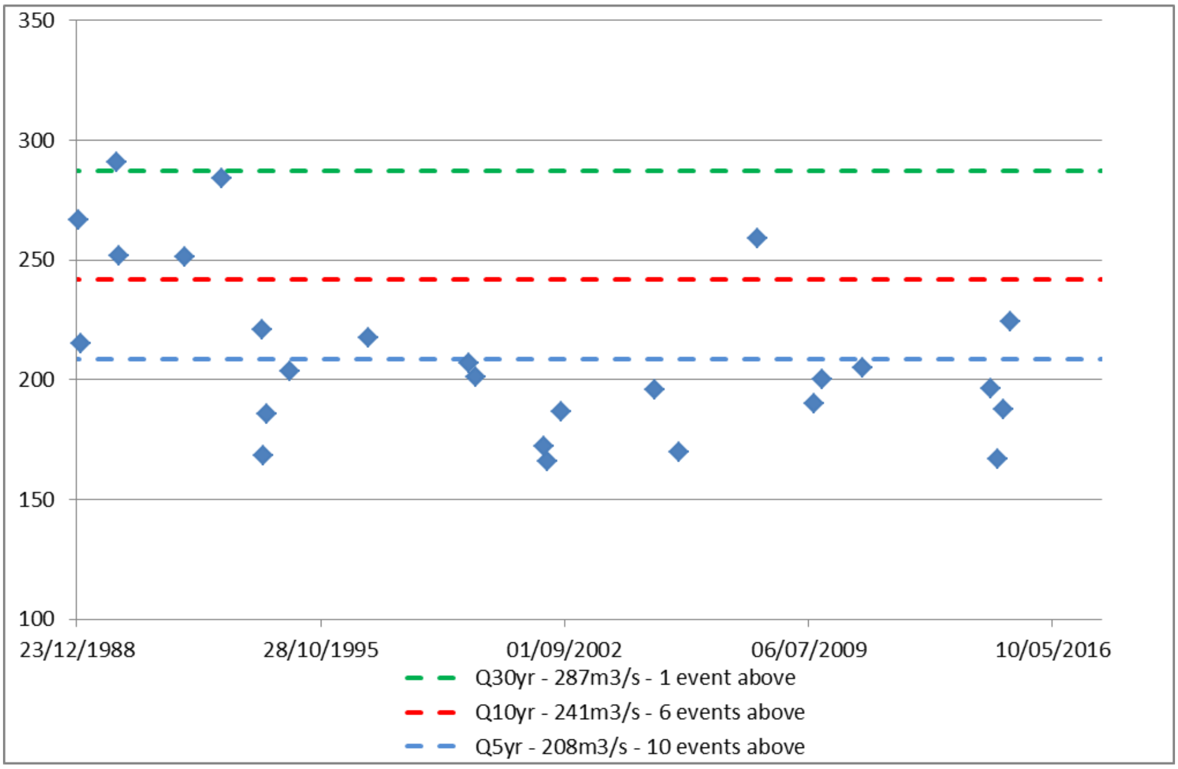


Figure A6-4: Flooding events selected for the synthesised hydrograph for 8002 River Spey @ Kinrara

Table A6-2: Flooding events selected for the synthesised hydrograph for 8002 River Spey @ Kinrara

Event (peak time)	Peak flow* (m3/s)	Event (peak time)	Peak flow* (m3/s)
05/02/1990	290.969	08/03/2000	201.303
17/01/1993	284.22	27/11/2009	200.092
15/01/1989	266.805	12/08/2014	196.272
26/01/2008	259.131	17/03/2005	195.569
06/03/1990	251.908	04/09/2009	189.794
03/01/1992	251.174	22/12/2014	187.732
08/03/2015	224.407	31/07/2002	186.677
09/03/1994	220.78	29/04/1994	185.829
02/03/1997	217.486	28/01/2002	172.039
07/02/1989	215.121	12/11/2005	169.577
25/12/1999	207.057	24/03/1994	168.327
16/01/2011	205.057	28/10/2014	166.929
12/12/1994	203.636	07/03/2002	165.822

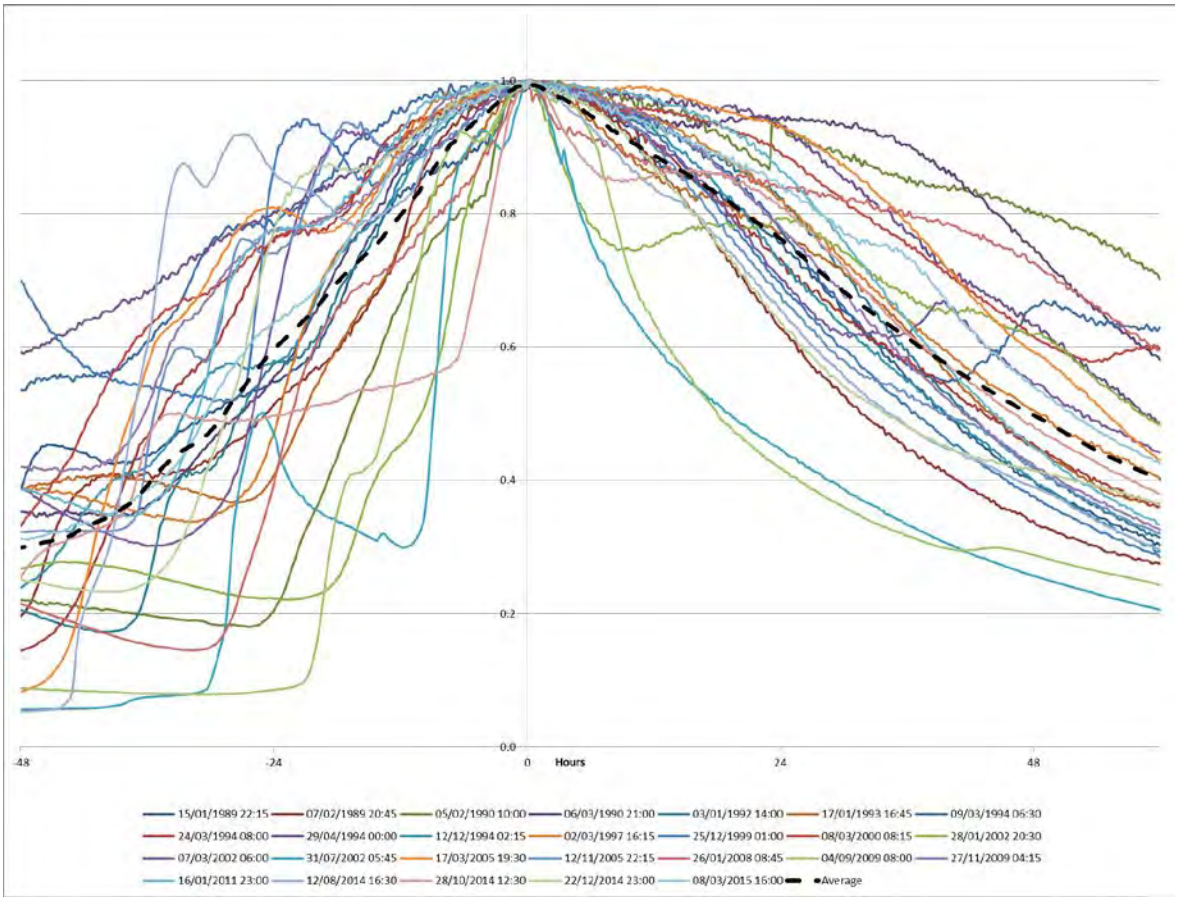


Figure A6-5: Flooding events selected for the synthesised hydrograph for 8002 River Spey @ Kinrara

A.7 Summary of hydrological methods used in the River Spey Model

A.7.1 **Table A7-1** below summarises the hydrological methods used to describe contributing flows from the River Spey model sub-catchments.

Table A7-1: Hydrological methods used for the River Spey model contributing catchments

Sub-catchment	Contributing Area (adjusted)	Hydrological Method
8007 – River Spey at Invertruim	421.2	ReFH fitted to Single site analysis peak
Other contributing Sub-catchments	587.7	FEH Rainfall Runoff hydrograph and peak

8007 – Fitting the ReFH model to the Statistical Peak Flow Estimates

A.7.2 The peak of the ReFH model (Storm duration of 44.5hrs and a time to peak of 7hrs) is fitted to the corresponding statistical value using the ratio shown in **Table A7-2** below. The use of a ratio to fit the peak ensures that the peak value will vary with the storm duration, allowing for a routing exercise to be carried out.

Table A7-2: Peak flow adjustment ratio to fit ReFH peak hydrograph

RP (yr)	Single Site Analysis	ReFH Peak flow[1]	Adjustment Ratio
Qmed/2.34	103.84	201.07	0.516
5yr	143.08	248.63	0.575
10yr	170.50	283.23	0.602
30yr	216.60	337.11	0.643
50yr	240.27	367.06	0.655
100yr	275.16	410.03	0.671
200yr	314.00	463.99	0.677

Storm Duration and Timing

A.7.3 As in DMRB2 analysis, a unique storm duration is imposed to every contributing catchment.

A.7.4 Peak flows from each contributing catchment are assumed to be concurrent, by introducing the required delay at the beginning of the storm hydrograph.

A.8 Catchments at A9 crossings

Catchment Descriptors

Table 8-1: Catchments at A9 crossings: donor FEH catchment descriptors

LABEL	NN69409630	NN70209690	NN72859830	NN74409885	NH76850155	NH77300175	NH78450180	NH78950215	NH80000310	NH81250375
Easting	269400	270200	272850	274400	276850	277300	278450	278950	280000	281250
Northing	796300	796900	798300	798850	801550	801750	801800	802150	803100	803750
AREA	0.56	0.53	2.12	34.01	1.44	2.02	0.51	12.12	0.71	1.39
ALTBAR	295	291	288	386	370	343	296	487	349	299
ASPBAR	303	326	33	336	176	166	168	151	124	118
ASPVAR	0.7	0.69	0.27	0.34	0.59	0.64	0.74	0.39	0.72	0.54
BFIHOST	0.667	0.773	0.75	0.544	0.402	0.328	0.579	0.353	0.44	0.62
DPLBAR	0.82	0.78	2.12	7.77	2.08	1.7	1.06	5.63	1.13	1.53
DPSBAR	101.4	67.3	80.5	100.7	101.1	149.1	106.2	135	148.9	112.6
FARL	1.0	1.0	1.0	0.945	1.0	1.0	1.0	1.0	1.0	1.0
LDP	1.47	1.75	4.1	13.58	3.71	3.17	1.89	10.53	2.05	3.03
PROPWET	0.72	0.72	0.72	0.72	0.68	0.68	0.68	0.68	0.68	0.68
SAAR	928	923	903	990	973	939	867	1097	887	875
SPRHOST	29.98	22.16	23.8	41.29	48.46	52.45	38.2	56.16	48.02	37.85
URBEXT1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0074	0.0	0.0	0.0
URBEXT2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Flow Estimates

Table A8-2: Design flow estimates at crossings – Baseline

Crossing ID	Watercourse Category	Donor catchment	FEH area (km2)	Estimated area	5yr (m3/s)	10yr (m3/s)	30yr (m3/s)	50yr (m3/s)	200yr (m3/s)	1000yr (m3/s)
133	Minor	NN69409630		0.029	0.04	0.04	0.06	0.06	0.09	0.11
134	Minor	NN69409630		0.197	0.20	0.24	0.31	0.36	0.47	0.61
135	*earthworks drainage crossing*	NN69409630		0.218	0.22	0.27	0.34	0.39	0.52	0.67
136	Minor	NN69409630		0.200	0.20	0.25	0.32	0.36	0.48	0.62
138_1	*earthworks drainage crossing*	NN69409630		0.221	0.22	0.27	0.35	0.39	0.52	0.67
138_2	Minor	NN69409630	0.56	1.087	1.80	2.16	2.80	3.14	4.21	6.12
139_1	*earthworks drainage crossing*	NN70209690		0.060	0.07	0.08	0.11	0.12	0.16	0.21
139_2	Minor	NN70209690		0.420	0.39	0.47	0.61	0.69	0.92	1.19
140	Minor	NN70209690		0.292	0.28	0.34	0.44	0.50	0.66	0.86
142	Minor	NN70209690		0.328	0.31	0.38	0.49	0.56	0.74	0.95
143	Minor	NN70209690		0.311	0.30	0.36	0.47	0.53	0.70	0.91
144_1	Minor	NN70209690		0.162	0.17	0.20	0.26	0.30	0.39	0.51
144_3	*earthworks drainage crossing*	NN70209690		0.090	0.10	0.12	0.15	0.18	0.23	0.30
145_1	Major	NN72859830	2.12	2.161	2.66	3.19	4.10	4.59	6.20	8.93
145_3	*earthworks drainage crossing*	NN72859830		0.020	0.03	0.03	0.04	0.04	0.06	0.08
146_1	Minor	NN72859830	2.12	0.603	1.05	1.27	1.66	1.86	2.51	3.68
147	Major	NN74409885	34.01	34.451	29.35	34.80	45.12	50.93	67.12	95.07
148	Minor	NN72859830		0.337	0.31	0.38	0.49	0.56	0.74	0.95
149	Minor	NN72859830		0.115	0.12	0.15	0.19	0.21	0.28	0.36
154	*road*	NH76850155		0.218	0.23	0.28	0.36	0.41	0.55	0.70
154_2	Minor	NH76850155		0.175	0.15	0.18	0.24	0.27	0.36	0.46
155	Major	NH76850155	1.44	0.587	1.04	1.26	1.66	1.87	2.53	3.76
156	Minor	NH76850155		0.118	0.11	0.13	0.17	0.19	0.25	0.32
157	Major	NH77300175	2.02	3.043	4.28	5.17	6.72	7.56	10.26	15.04
158	Minor	NH77300175		0.150	0.13	0.15	0.20	0.23	0.30	0.39
159	Minor	NH78450180	0.51	0.719	1.25	1.52	2.00	2.26	3.06	4.57
160	*agricultural underpass*	NH78950215		0.018	0.02	0.03	0.04	0.04	0.05	0.07
161	Minor	NH78950215		0.145	0.15	0.18	0.23	0.26	0.35	0.45
162	Major	NH78950215	12.12	12.639	12.80	15.25	19.83	22.46	29.82	42.61
163	*earthworks drainage crossing*	NH78950215		0.114	0.12	0.14	0.19	0.21	0.28	0.36
164	*earthworks drainage crossing*	NH80000310		0.148	0.12	0.14	0.18	0.21	0.28	0.36
165	Minor	NH80000310		0.195	0.15	0.18	0.23	0.27	0.35	0.45
166	Minor	NH80000310		0.422	0.30	0.36	0.47	0.53	0.70	0.91
168	Minor	NH80000310	0.71	0.881	1.48	1.80	2.36	2.67	3.63	5.40
170	Major	NH81250375	1.39	1.424	2.00	2.42	3.16	3.56	4.84	7.13

IH124 parameters: SOIL 0.5.

FEH RR parameters: SPR adjusted to 57.37 where otherwise lower.

Table A8-3: 200yr flow estimates at crossings – Stage 3 Initial Design

Crossing ID	Watercourse Category	Donor catchment	FEH area (km2)	Estimated area	5yr (m3/s)	10yr (m3/s)	30yr (m3/s)	50yr (m3/s)	200yr (m3/s)	1000yr (m3/s)
133	Minor	NN69409630		0.029	0.04	0.04	0.06	0.06	0.09	0.11
134	Minor	NN69409630		0.197	0.20	0.24	0.31	0.36	0.47	0.61
135	*earthworks drainage crossing*	NN69409630		0.218	0.22	0.27	0.34	0.39	0.52	0.67
136	Minor	NN69409630		0.200	0.20	0.25	0.32	0.36	0.48	0.62
138_1	*earthworks drainage crossing*	NN69409630		0.221	0.22	0.27	0.35	0.39	0.52	0.67
138_2	Minor	NN69409630	0.56	1.087	1.80	2.16	2.80	3.14	4.21	6.12
139_1	*earthworks drainage crossing*	NN70209690		0.060	0.07	0.08	0.11	0.12	0.16	0.21
139_2	Minor	NN70209690		0.420	0.39	0.47	0.61	0.69	0.92	1.19
140	Minor	NN70209690		0.292	0.28	0.34	0.44	0.50	0.66	0.86
142	Minor	NN70209690		0.328	0.31	0.38	0.49	0.56	0.74	0.95
143	Minor	NN70209690		0.311	0.30	0.36	0.47	0.53	0.70	0.91
144_1	Minor	NN70209690		0.162	0.17	0.20	0.26	0.30	0.39	0.51
144_3	earthworks drainage crossing	NN70209690		0.090	0.10	0.12	0.15	0.18	0.23	0.30
145_1	Major	NN72859830	2.12	2.161	2.66	3.19	4.10	4.59	6.20	8.93
145_3	earthworks drainage crossing	NN72859830		0.020	0.03	0.03	0.04	0.04	0.06	0.08
146_1	Minor	NN72859830	2.12	0.603	1.05	1.27	1.66	1.86	2.51	3.68
147	Major	NN74409885	34.01	34.451	29.35	34.80	45.12	50.93	67.12	95.07
148	Minor	NN72859830		0.337	0.31	0.38	0.49	0.56	0.74	0.95
149	Minor	NN72859830		0.115	0.12	0.15	0.19	0.21	0.28	0.36
154	*road*	NH76850155		0.218	0.23	0.28	0.36	0.41	0.55	0.70
154_2	Minor	NH76850155		0.175	0.15	0.18	0.24	0.27	0.36	0.46
155	Major	NH76850155	1.44	0.587	1.04	1.26	1.66	1.87	2.53	3.76
156	Minor	NH76850155		0.118	0.11	0.13	0.17	0.19	0.25	0.32
157	Major	NH77300175	2.02	3.043	4.28	5.17	6.72	7.56	10.26	15.04
158	Minor	NH77300175		0.150	0.13	0.15	0.20	0.23	0.30	0.39
159	Minor	NH78450180	0.51	0.719	1.25	1.52	2.00	2.26	3.06	4.57
160	*agricultural underpass*	NH78950215		0.018	0.02	0.03	0.04	0.04	0.05	0.07
161	Minor	NH78950215		0.145	0.15	0.18	0.23	0.26	0.35	0.45
162	Major	NH78950215	12.12	12.639	12.80	15.25	19.83	22.46	29.82	42.61
163	earthworks drainage crossing	NH78950215		0.114	0.12	0.14	0.19	0.21	0.28	0.36
164	earthworks drainage crossing	NH80000310		0.148	0.12	0.14	0.18	0.21	0.28	0.36
165	Minor	NH80000310		0.195	0.15	0.18	0.23	0.27	0.35	0.45
166	Minor	NH80000310		0.422	0.30	0.36	0.47	0.53	0.70	0.91
168	Minor	NH80000310	0.71	0.881	1.48	1.80	2.36	2.67	3.63	5.40
170	Major	NH81250375	1.39	1.424	2.00	2.42	3.16	3.56	4.84	7.13

A.8.1 The IH124 method was chosen for catchments smaller than 0.5km^2 in accordance with DMRB guidance for runoff from smaller natural catchments, as FEH RR is not applicable for catchments of this size. The ReFH2.2 method became available during the study and equivalent flow estimates were derived using this method (with the FEH13 rainfall profile) for catchments both larger and smaller than 0.5km^2 in area. The ReFH2.2 estimates are lower or within the bounds of typical sensitivity tests in comparison to the IH124 and FEH RR results.

A.9 FEH Rainfall Runoff Comparison with Gauged Data

Introduction

A.9.1 Design flows for tributary watercourses within the A9 corridor (for catchments exceeding 0.5km^2) have been estimated using the Flood Estimation Handbook Rainfall Runoff (FEH RR) model. A comparison exercise between the FEH RR models and preliminary gauged data was undertaken to confirm that the use of the FEH RR models was appropriate for the A9 watercourses. The validity of the FEH RR models as a tool for estimating design flow for these catchments was assessed using methodology developed from the FEH 'Volume 4' method for simulating a notable event for return period assessment.

Data

Rainfall and River Flow Data

A.9.2 Assessment of the rainfall runoff models requires use of recorded rainfall and river flow data that is representative of the catchment response to a notable rainfall event. River flow and rainfall gauging has been undertaken by Bam Ritchie as part of continued water quality monitoring within the A9 corridor. These gauges are located in the catchments of the Milton Burn and the Raitts Burn and record rainfall at 15 minute intervals and flow rates at hourly intervals. Preliminary data is available from late November, 2017 to March 2018. Parameters which give a description of the data set are provided in **Table A9-1** below.

Table A9-1: Key flow and rainfall dataset information.

Catchment	Hydro ID	Mean Flow (m3/s)	Average Rainfall (mm/day)	Max Flow (m3/s)	Max Daily Rainfall (mm)	Max Hourly Rainfall (mm)
Milton Burn	147	0.908	1.82	8.313 (Occurred 23/01/18)	21.8 (Occurred 24/12/17)	4.6 (Occurred 28/01/18)
Raitts Burn	162	0.561	1.36	4.314 (Occurred 29/01/18)	14.4 (Occurred 22/01/18)	3.6 (Occurred 28/01/18)

A.9.3 The average flows indicate that flow rates were consistently low across the period of record. No significant flood flows were gauged as indicated by the max flow for each watercourse. The average daily rainfall is lower than the standard averages for the period, which is around 3.24mm/day according to climatic information provided by the Met Office weather station in Aviemore.

A.9.4 The data record was processed to identify rainfall events which resulted in a notable response in river flows. Three rainfall events were selected based on the period of record, two occurring in December 2017 and one in January 2018. The selected rainfall events produced clear isolated peaks in both the Milton Burn and the Raitts Burn.

Assessment Parameters

A.9.5 Soil Moisture Deficit (SMD) data was extracted from the NRFA monthly hydrological summaries for December 2017 and January 2018. The monthly summary provides SMD values extracted from MORECS data sets at a 40km^2 spatial resolution. For both December and January the SMD estimate ranged from 0-10mm indicating a high degree of soil saturation.

A.9.6 Catchment descriptors for both the Milton and Raitts Burn were obtained from the FEH CD-ROM (Version 3). The FEH CD-ROM was used to derive the design flows at DMRB stage 2, prior to the establishment of the FEH Web Service. This method has therefore been adopted for the purpose of this assessment. The average drainage path length was not adjusted from the catchment descriptor value for either watercourse reflecting the design approach.

A.9.7 Standard Percentage Runoff (SPR) for both catchments was set at 57.37 percent. This was the value used in the design flow estimation, having been derived from the BFI Scotland Map and deemed to provide a more conservative estimate of flows compared to the catchment descriptors.

Results

A.9.8 The hydrograph outputs from the FEH units were compared to the recorded flows within the watercourses. The simulated hydrographs provided a conservative estimate of peak flows in all events for the Milton Burn. Peak flow estimates were on average 180 percent greater than the peak gauged flows when antecedent conditions were represented by an SMD of 0mm. This has been accepted as appropriately conservative at this stage. The large difference in peak flow estimates can largely be attributed to the difference in the time to peak. The gauge flow record indicates the catchment has a longer duration to peak when compared with the FEH hydrograph. On average the recorded time to peak for the Milton Burn catchment is twice as long as estimated within the FEH unit.

A.9.9 Within the Raitts Burn catchment conservative estimates occurred for two of the three rainfall events. For the two events which exceed the gauged flows the peak flows were on average 106 percent greater than those recorded at the gauge when antecedent conditions were estimated for a SMD of 0mm. As with the Milton Burn, the time to peak for the FEH hydrograph was considerably shorter than the time to peak of the recorded river flow. The recorded time to peak was around 1.9 times longer than the time to peak estimated by the FEH unit.

A.9.10 For the third event the peak flow estimate was 27 percent lower than the recorded flow at the gauge. Reasons for this have been discussed in detail in the section below.

A.9.11 Overall the FEH RR unit has been deemed to produce potentially conservative estimates of peak flows for a given rainfall event. This offers confidence that more extreme flood flow estimates have been derived conservatively. Every precaution has been made to ensure this is the case, including using an increased SPR value derived from the BFI Scotland maps.

Limitations

A.9.12 The gauged data set has been identified as a particular limitation for several reasons. There were a number of negative flows recorded in across the time series. This could be due to an incorrect datum which would mean the gauged flows are underestimated. It could also highlight a fault with the gauge which could potentially explain why flows did not respond to rainfall events throughout June, with the flow gauge recording at a near constant rate of 0.145cumecs.

A.9.13 The gauges were installed to support water quality analysis and not explicitly to support derivation of design flows. The location of the rainfall gauges therefore represents another limitation of the calibration data.

A.9.14 To properly assess catchment rainfall conditions and subsequent flow response there would ideally be multiple rainfall gauges located across the catchment. In this instance the rainfall data was limited to a single gauge per catchment located approximately adjacent to the flow gauge in the lower reach of the watercourse. This is not necessarily representative of rainfall in the upper reaches of the catchment, which could be as far as 9km away. Rainfall data recorded at the Tromie Bridge gauging station was requested in an attempt to better assess the spatial variability of the selected rainfall events, in terms of total rainfall volume and rainfall intensity.

A.9.15 The hyetographs for the three rainfall events at the Tromie gauge were compared to the hyetographs recorded at the Milton and Raitts gauges. The Tromie rainfall data correlated with two of the three rainfall events suggesting there was little spatial variation during these events. For the third event the Tromie gauge recorded the rainfall event as sustained rainfall and less ‘peaky’, similar to the record at the Raitts gauge. This differed from the Milton Burn which showed a brief rainfall event with a higher intensity, suggesting a greater degree of spatial variability during this rainfall event.

A.9.16 Available soil moisture data was limited to $40km^2$ obtained from MORECS data via the NRFA. The percentage difference between the FEH estimated flows and the gauged flows suggests that the soil moisture deficit may have been much greater than those used in the study and that conditions were perhaps drier at the time of the rainfall events than the monthly averages show.

A.9.17 The standard percentage runoff used in the derivation of design flows (57.37 percent) is greater than the estimate provided by the catchment descriptors. This is particularly significant in the case of the Milton burn, where the catchment descriptors provide an SPR of 41.29 percent. A sensitivity check of the FEH RR model was undertaken using the catchment descriptors SPR estimate. Results showed that the average percentage increase was reduced to 104 percent and in one case was as low as 10.6 percent.

A.9.18 The presence of snow within the catchment and potential impacts of snowmelt have not been considered. This may explain why the gauged river flows on the Raitts burn on the 24/12/17 are higher than the FEH estimates for the equivalent rainfall event. Snowmelt within the catchment prior to or during the rainfall event would contribute increased flow which is otherwise not accounted for within the FEH unit.

A.9.19 Validation data for the gauged flows was requested in the form of spot gauging records. However, at the time of writing this had not been received. A record of quality assurance procedures was also not provided with the data at the time of writing.

Appendix 11.3

Flood Risk Assessment

Annex B: Hydraulic Modelling Supporting Information

Contents

B.1 DMRB Stage 3 River Spey Model Details

River Spey Model Development Documentation

B.1.1 Approach and methodology has been developed through DMRB2 and in consultation with SEPA.

B.1.2 Relevant CFJV publications documenting the process and associated feedback letters from SEPA are listed below:

- DMRB2 Interim Hydrology and Hydraulic Modelling Report (June 2015)
- SEPA feedback letter (SEPA Ref. PCS/140712, received 25/06/2015)
- DMRB Stage 3 Hydrology and Hydraulic Modelling Approach (November 2016)
- SEPA review letter (SEPA Ref. PCS/150629, received 08/02/2017)

B.1.3 Consultation meetings with SEPA and THC flood teams:

- 26/07/2017, SEPA offices in Dingwall
- 30/10/2017, SEPA offices in Dingwall
- 12/03/2018, Fairhurst office, Inverness
- 15/06/2018, Fairhurst office, Inverness

River Spey Model Geometry Details

B.1.4 The River Spey model is a 1D/2D Flood modeller/TuFLOW linked model, where the River Spey channel is represented by a 1D element and the floodplain by a 2D grid (10m resolution).

Model extent

The River Spey model extent is shown in **Figure B1-1** below. As for the DMRB Stage 2 model, it extends approx. 1km upstream of the gauging station 8007 River Spey @ Invertruim to 1km downstream of the gauging station 8002 River Spey at Kinrara.

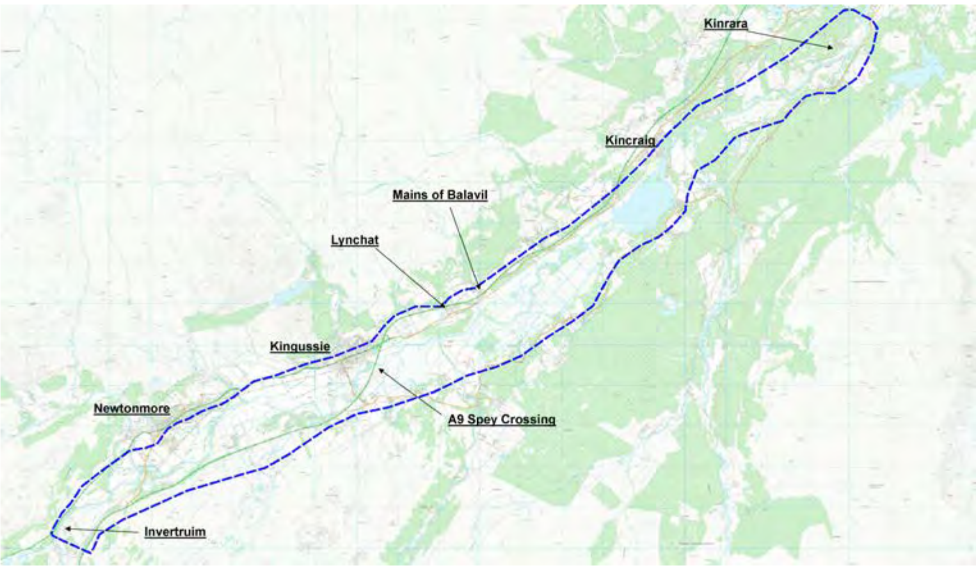


Figure B1-1: River Spey model extent

1D river Sections

B.1.5 Surveyed cross-sections at the following locations and are shown in **Figures B1-2 – B1-9**:

- Around Invertruim Gauging station (10 surveyed sections, over a1.04km long reach)
- Around Kingussie area (33 surveyed sections covering a 8.88km long reach)
- Kincraig and Feshie fan (12 surveyed sections, over a 2.35km long reach)
- Kinrara gauging station (8 surveyed sections, over a 900m long reach)

B.1.6 Between these areas, the 47 cross-sections were extracted from the LiDAR DTM. These cross-sections could potentially misrepresent the bathymetry in the deeper parts of the River Spey channel. Due to their locations, this is not critical for the flood risk assessment.

Loch Insh

B.1.7 1D cross-sections are also specified within Loch Insh to provide continuity between the 1D channel upstream and downstream of Loch Insh. These sections have a rectangular geometry with top of bank level equal to the level of Loch Insh in the DTM (218.9mAOD). The true bathymetry of Loch Insh isn't described by the LiDAR dataset. During a 200yr flooding event, water level in Loch Insh is greater than 222.6mAOD, some 3.8m above the virtual bottom of Loch Insh.

Enforced items and embedded 1D elements within the 2D domain

B.1.8 The crest levels of the following have been enforced using "thick" zsh lines in TUFLOW:

- The B970 Ruthven Road embankment and flood relief culverts (based on ground topographical survey)
- The unclassified Road running to the east of Loch Insh (based on ground topographical survey)
- The HML railway embankment running within the River Spey floodplain (based on levels from Phase1 LiDAR)
- Agricultural embankments in the Spey crossing area (based on ground survey for the Ruthven cell, based on Phase1 LiDAR elsewhere)

B.1.9 The enforced items and 1D embedded elements, mostly culverts, are shown in **Figures B1-2 – B1-9**. Further details on 1D embedded elements are given in **Table B1-1**.

B.1.10 1D/2D boundary location was reviewed based on the available surveyed points (the river top of banks were surveyed in the Kingussie area), LiDAR DTM and site visit observations to ensure the link between the 1D and 2D domains are set at adequate position and level.

Table B1-1: 1D embedded elements details

Location Reference ID	Shape	Length (m)	Manning's	Upstream Invert (mAOD)	Downstream Invert (mAOD)	Diameter/Width (m)	Height (m)	No. Barrels
1	R	20.0	0.022	235.2	235.0	2.5	2.5	1
2	C	20.0	0.022	233.5	233.4	0.9		1
3	C	20.0	0.020	230.6	230.6	0.9		1
4	R	6.0	0.020	229.8	229.8	7.8	1.9	1
5	C	19.0	0.020	225.5	225.4	0.4		1
6	C	19.0	0.020	225.4	225.3	0.5		3
7	R	19.0	0.020	223.0	223.0	1.1	0.4	2
8	R	19.0	0.020	222.2	222.2	0.9	0.6	2
9	C	19.0	0.020	221.5	221.5	1.4		1
10	R	19.0	0.020	222.2	222.2	5.6	3.6	1
11	R	7.3	0.022	220.3	220.6	3.0	1.5	1
12	R	6.6	0.022	221.3	221.2	3.0	3.1	5
13	R	6.6	0.022	221.4	221.4	3.0	3.1	5
14	R	6.6	0.022	222.0	222.0	3.0	2.5	5
15	R	6.5	0.022	222.3	222.2	3.0	2.2	1
16	C	20.0	0.022	221.1	221.1	0.9		1
17	C	20.0	0.020	221.3	221.3	0.3		1
18	R	29.0	0.027	219.9	219.8	3.1	1.7	1
19	R	5.6	0.027	222.5	222.1	1.8	1.3	1
20	R	5.5	0.027	220.9	220.9	3.1	3.1	1
21	C	20.0	0.022	221.3	220.4	0.9		1
22	C	20.0	0.022	220.7	220.0	0.9		1
23	R	23.0	0.027	220.3	220.3	0.1	0.2	1
24	C	29.0	0.027	221.0	220.3	0.8		1

Location Reference ID	Shape	Length (m)	Manning's	Upstream Invert (mAOD)	Downstream Invert (mAOD)	Diameter/Width (m)	Height (m)	No. Barrels
25	R	18.0	0.027	222.4	222.2	3.7	3.3	1
26	C	80.0	0.027	220.0	219.8	0.8		1
27	R	30.5	0.027	220.5	220.7	6.0	5.5	1
28	R	10.7	0.027	219.2	218.8	3.9	1.6	1

Roughness conditions

B.1.12 Roughness values in the hydraulic model are summarised in Table B1-2 below.

Table B1-2: Manning's values for the River Spey model

Zone	Manning's Value
Flood Plain	0.08
2D Over open water (*e.g.* Loch Insh)	0.02
1D River Spey Bed	0.035

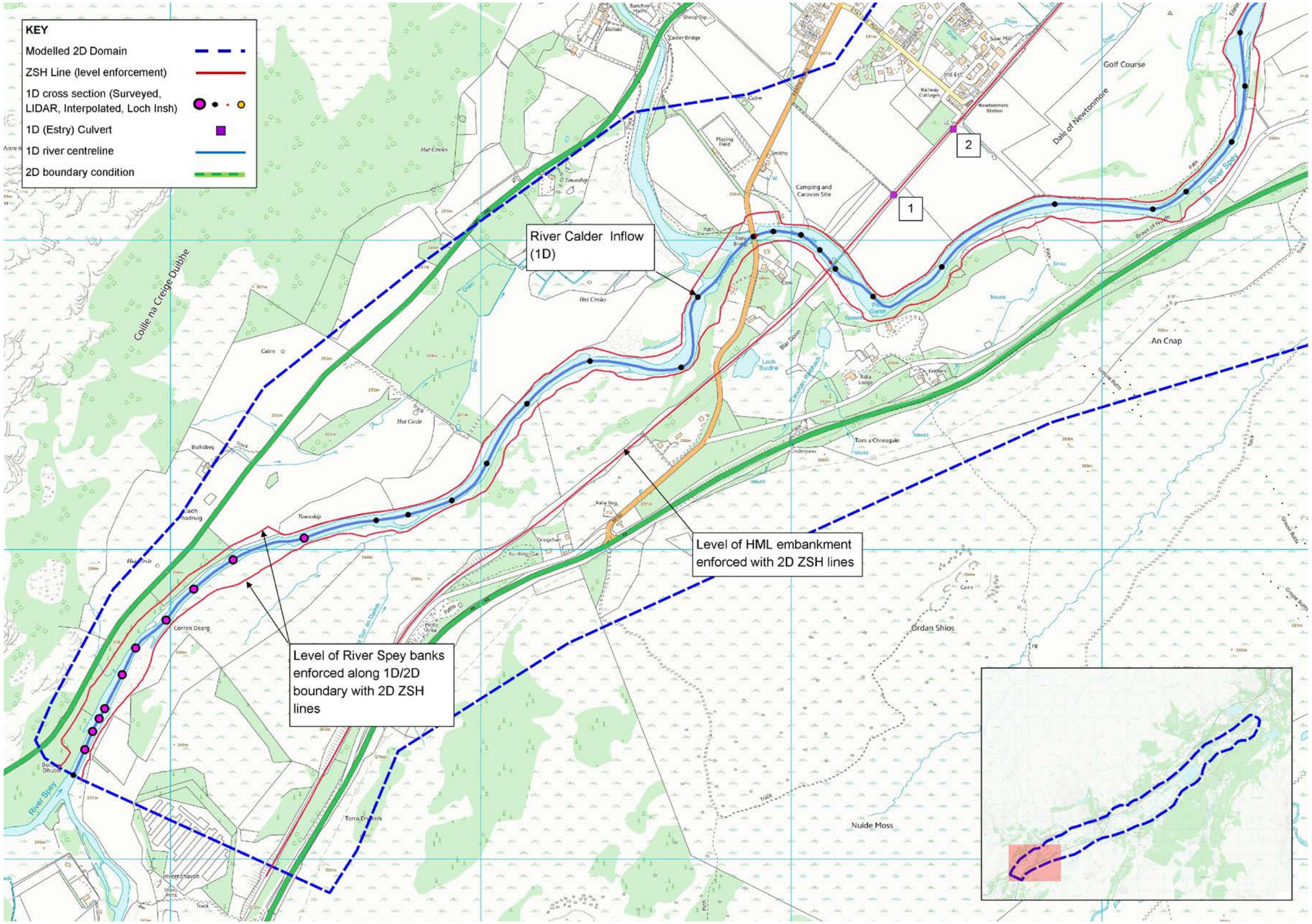


Figure B1-2: River Spey model construction

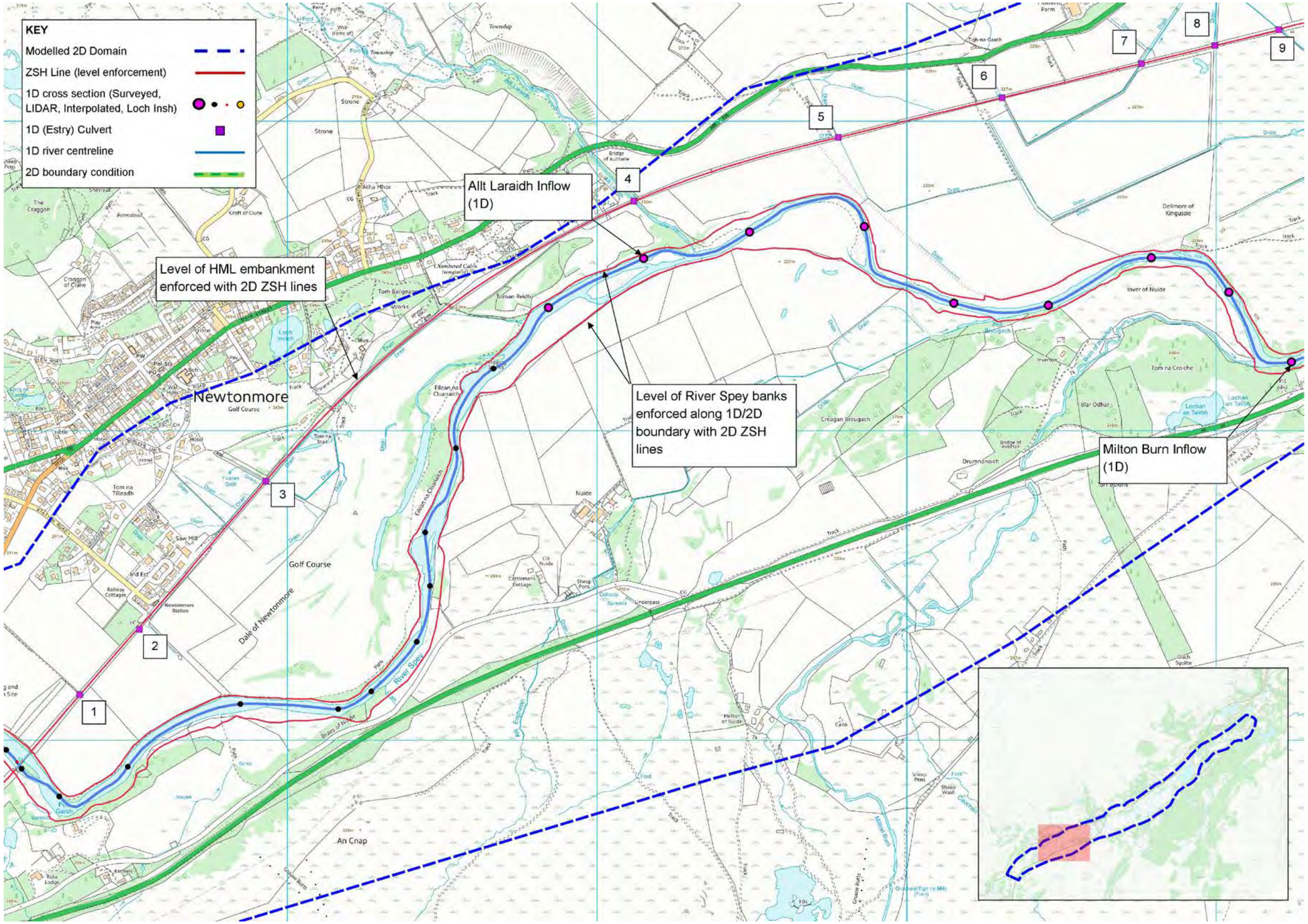


Figure B1-3: River Spey model construction

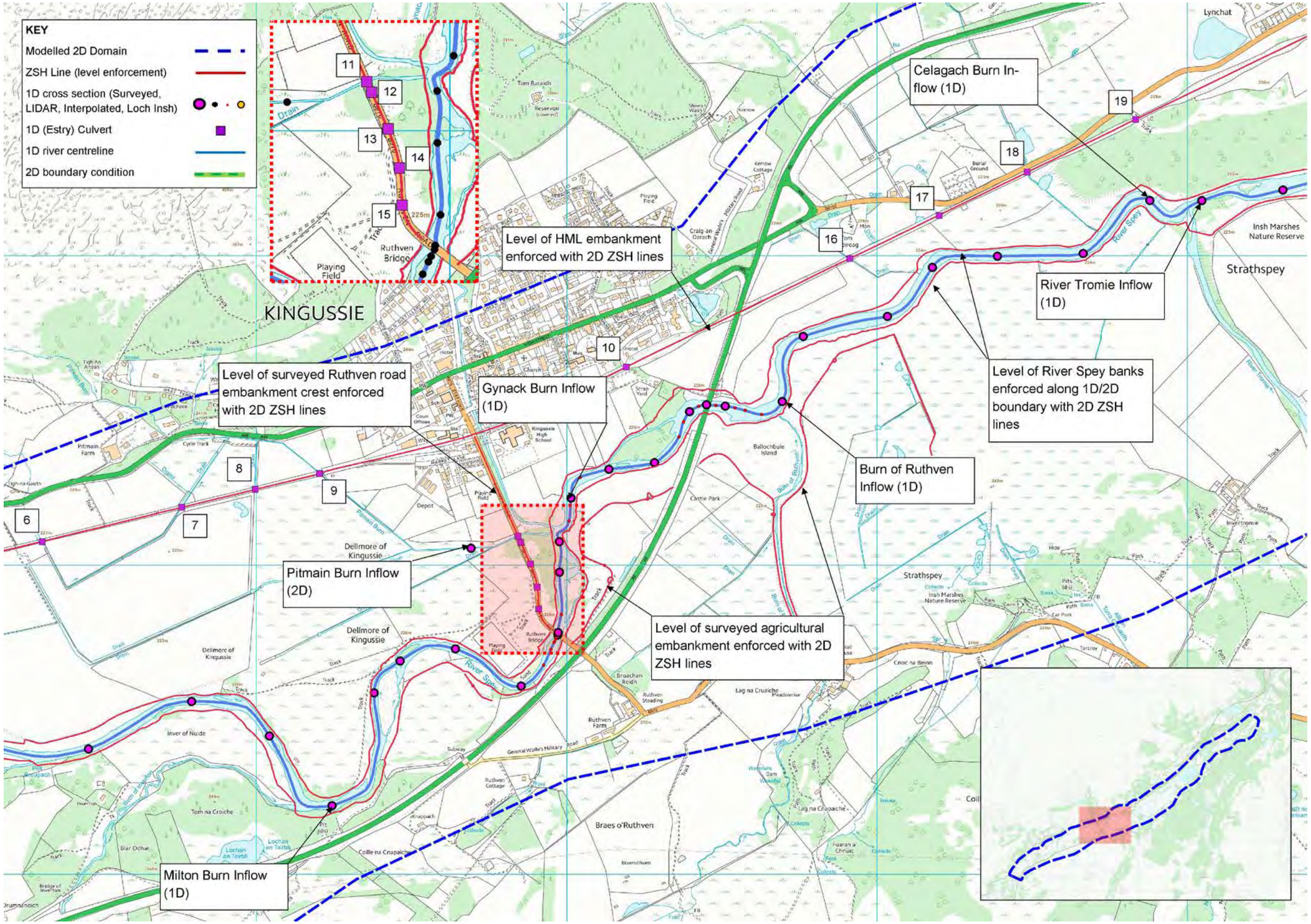


Figure B1-4: River Spey model construction

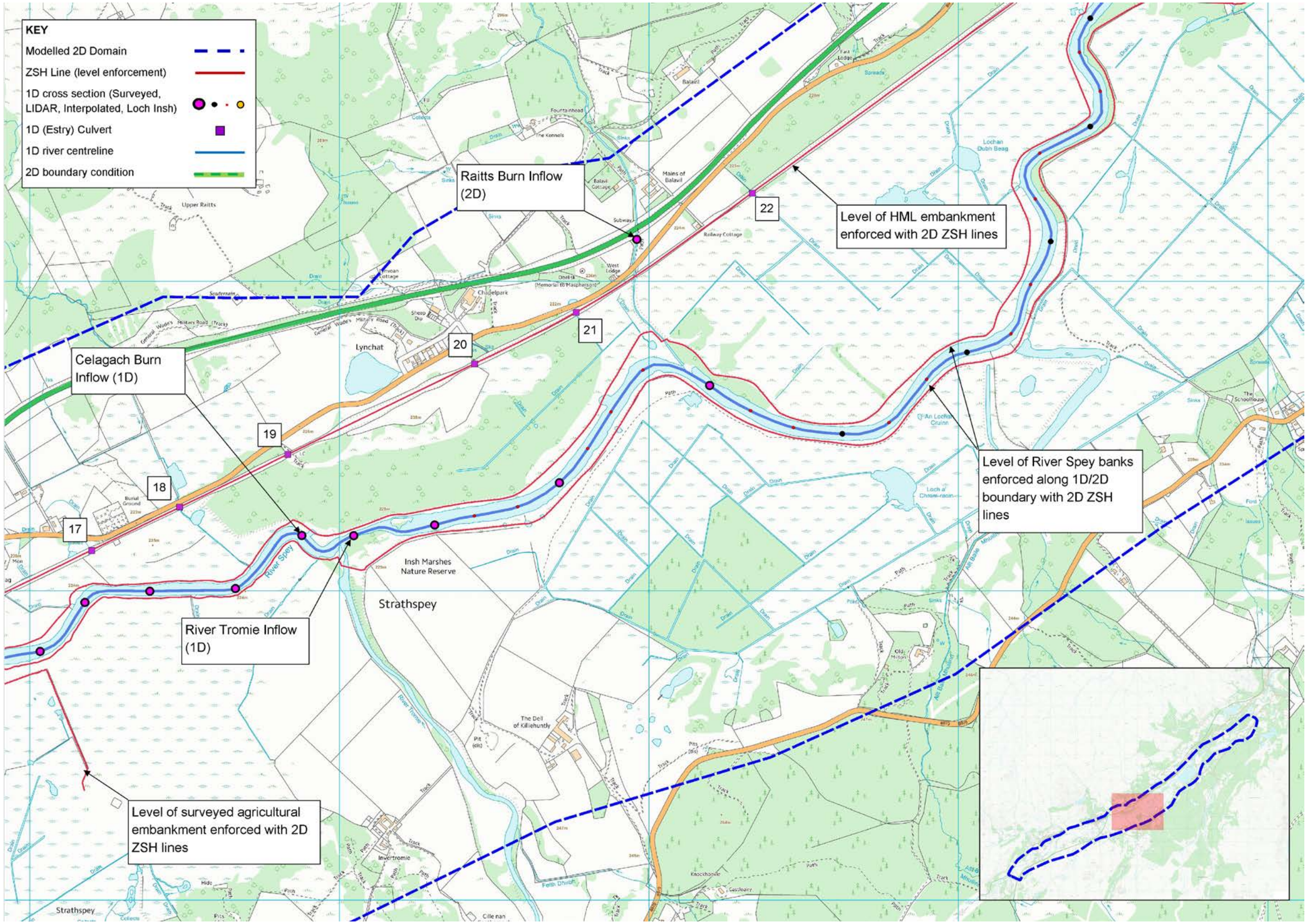


Figure B1-5: River Spey model construction

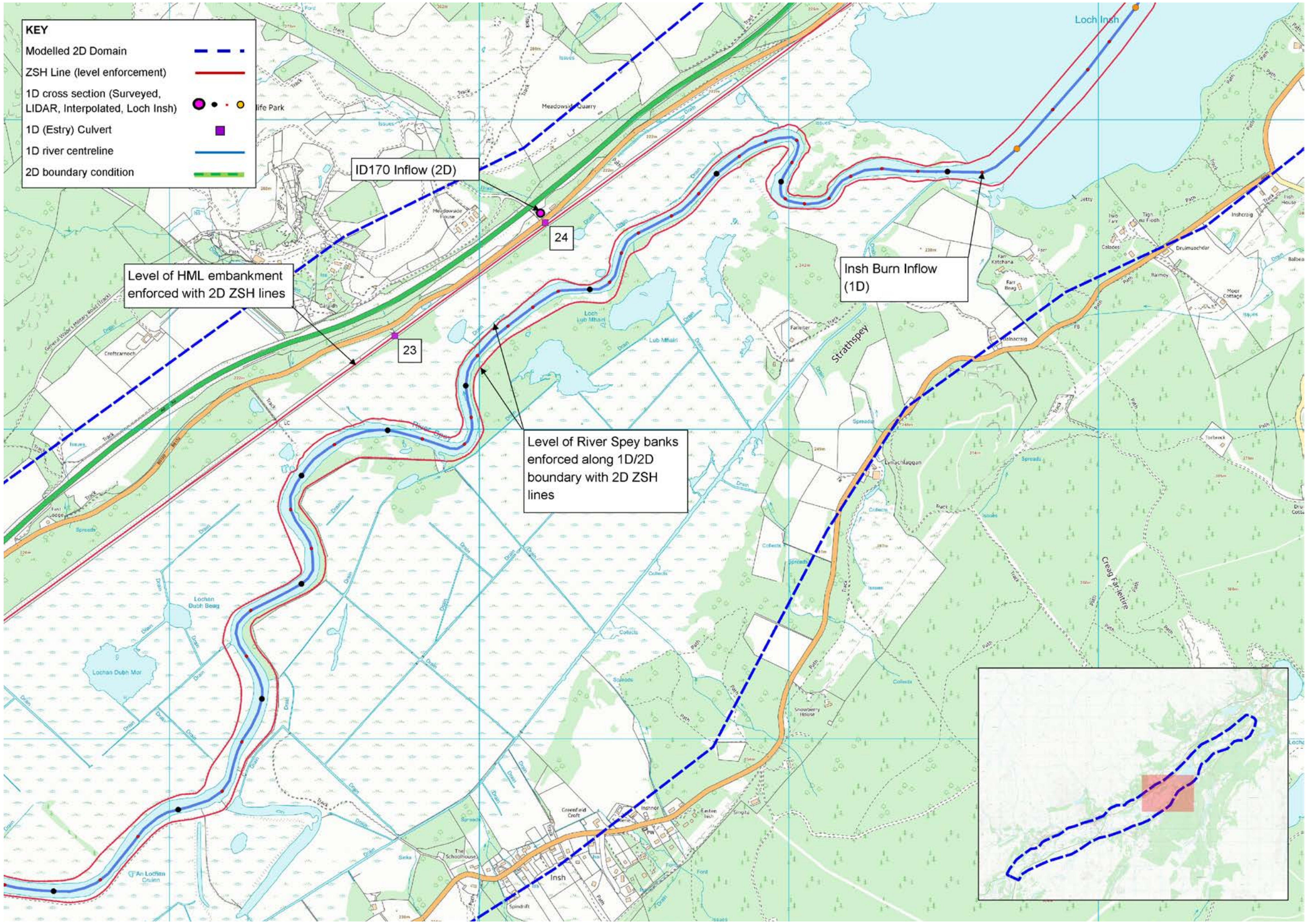


Figure B1-6: River Spey model construction

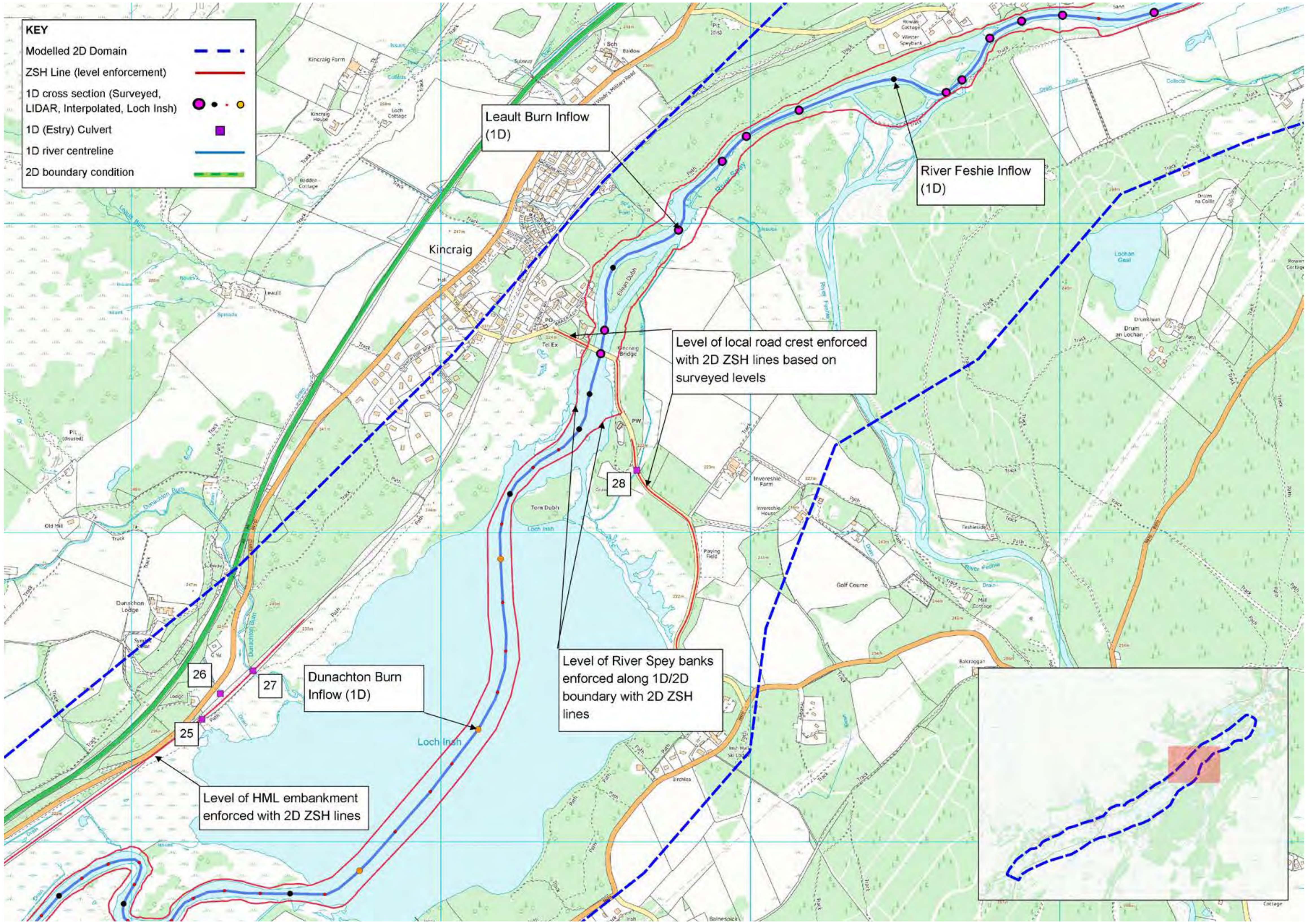


Figure B1-7: River Spey model construction

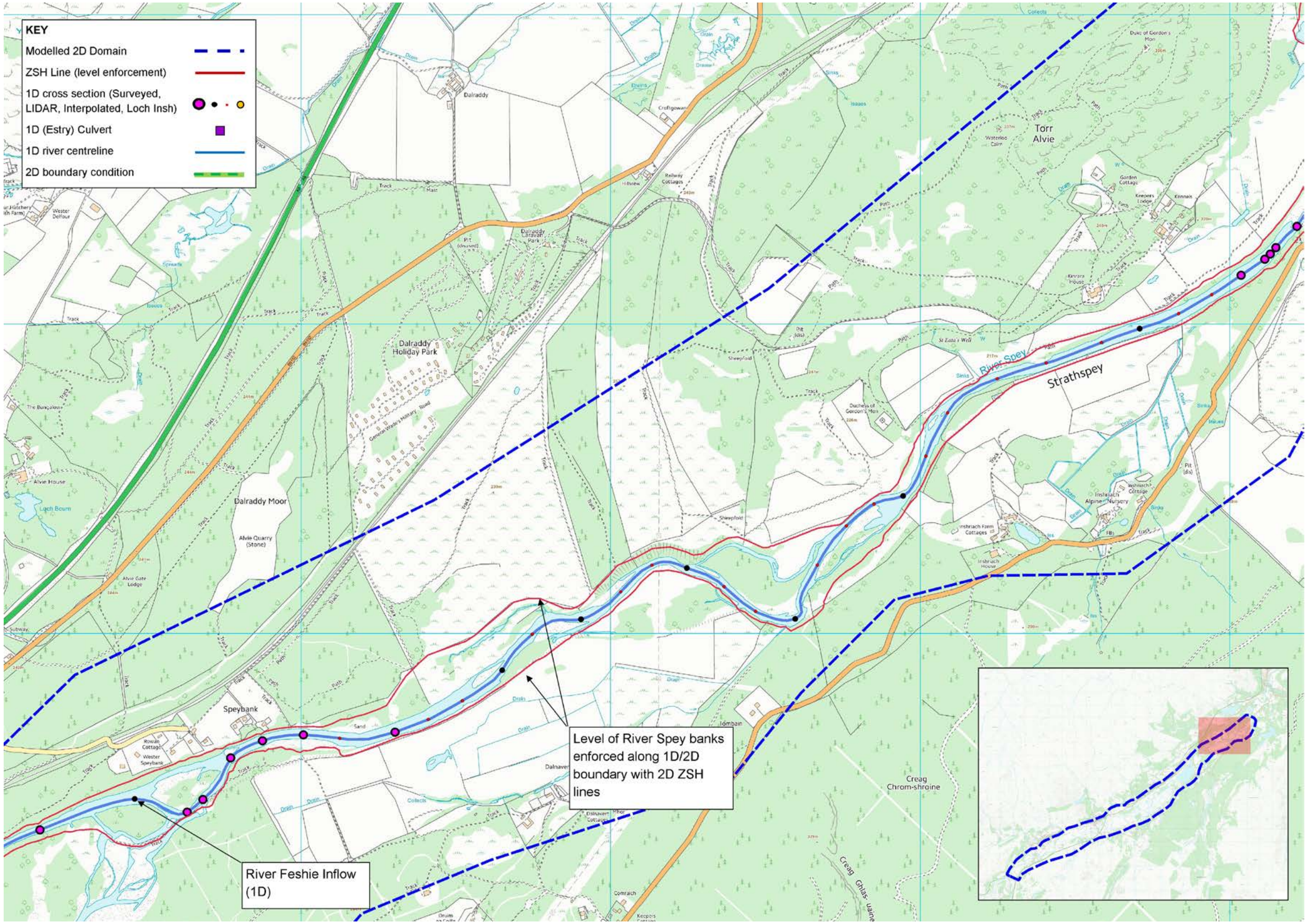


Figure B1-8: River Spey model construction

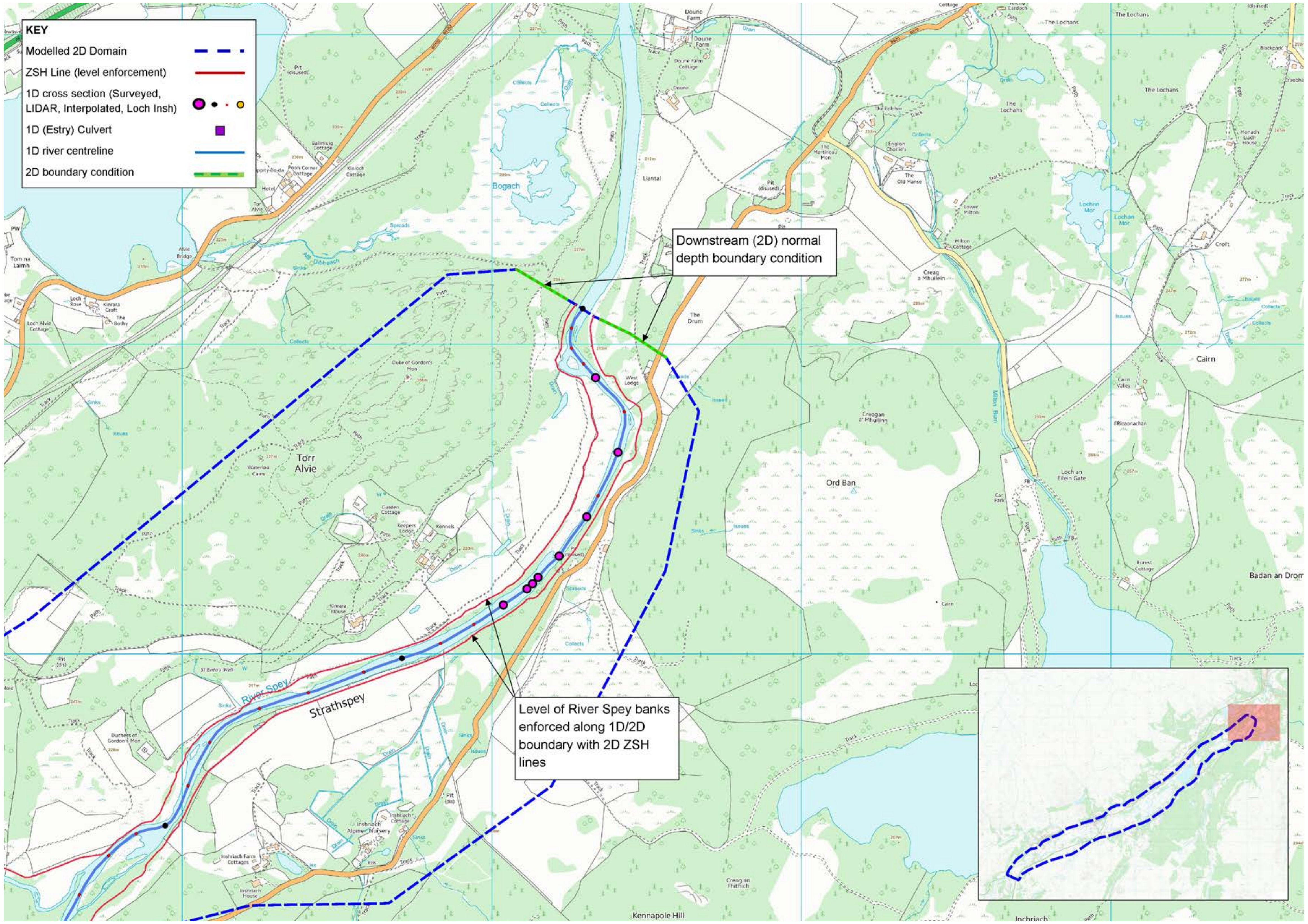


Figure B1-9: River Spey model construction

B.2 DMRB Stage 3 River Spey Model Calibration

Introduction

B.2.1 A calibration exercise was carried out based on three past flooding events which took place in October 2014 (C01), August 2014 (C02) and February 1990 (C03)

B.2.2 Although the events of 2014 are of relatively small magnitude, photographs of the flood in the area of Kingussie give valuable information in an area critical for this study. The February 1990 event is of relatively large magnitude and post flooding survey of wreck marks was carried out. Details of the events and outputs of the calibration are presented below.

B.2.3 The calibration exercise generally indicates that the model gives satisfactory results, given the large unknown associated with the ungauged portion of the contributing catchment.

Event 1 – October 2014

Available information and event characteristics

B.2.4 The 15min records at 8007 River Spey at Invertruim show that the October 2014 is relatively small event with two distinct peaks flood approx. 34hr apart. The records at 8002 River Spey at Kinrara also show a relatively small flooding event. The peak recorded at Kinrara happened before the second peak at Invertruim. 15min record flow hydrographs for the different gauging stations are shown in **Figure B2-1**. The Peak flow values, times and corresponding return periods are given in **Table B2-1**.

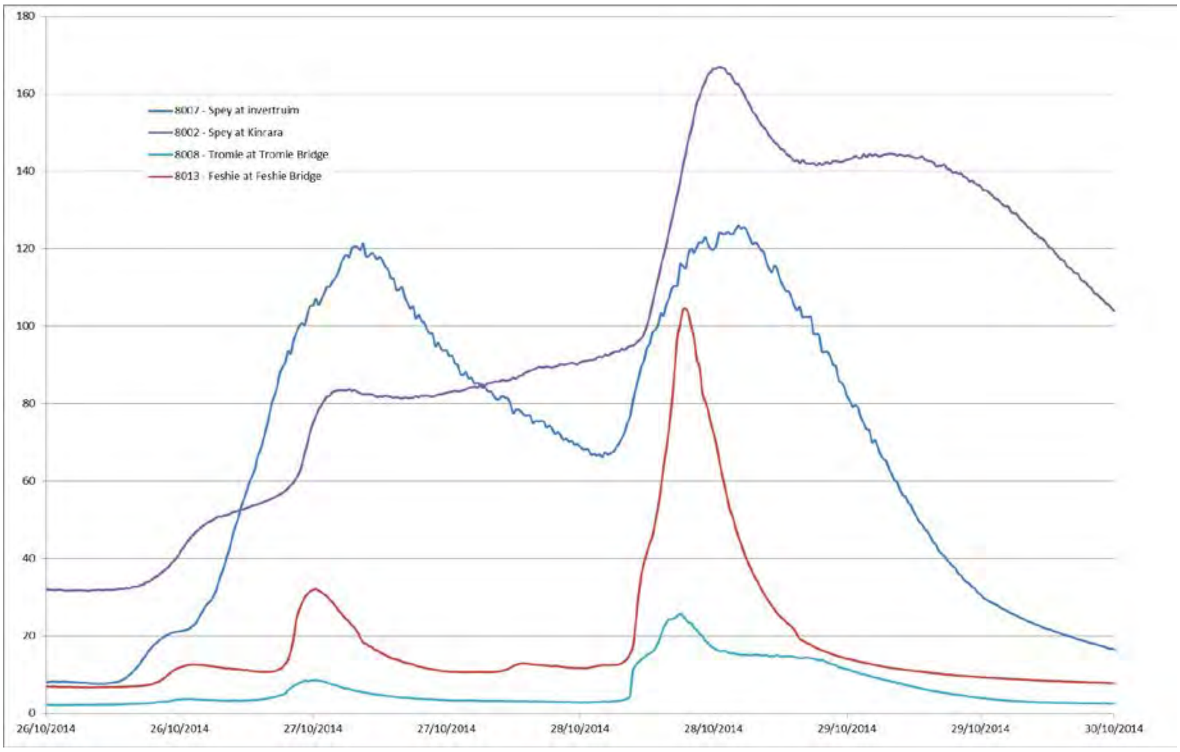


Figure B2-1: October 2014 - Flow hydrographs at gauging stations

Table B2-1: Oct 2014 Event, peak flow, time of occurrence and corresponding Return Period

Station	Peak flow (m^3/s)	Occurrence	Equiv. RP*	Comments
8007	121.28	27/10/2014 04:30	3.5	Stage below 2m – bypassing is not an issue
8007	125.51	28/10/2014 14:45	3.8	Stage below 2m – bypassing is not an issue
8002	166.93	28/10/2014 12:30	2.3	One peak event.
8008	*25.72*	28/10/2014 09:00	*<2yr*	
8013	*104.51*	*28/10/2014 09:30*	*~2yr*	Small peak of 32.1m^3/s on 27/10 at 00:15

* When compared to single site analysis for the relevant gauging station

B.2.5 Photographs taken by the CFJV staff during a site visit are available for this event. The photographs, covering the area of the Spey crossing at Kingussie, were taken at a time close to the second peak. A selection of these photographs is used to estimate flood levels around the Spey crossing embankment by comparison of the flood levels to the topographical survey available in the corresponding area.

Photograph B2-1: October 2014 – B970 Ruthven Road at Kingussie, taken 28/10/2014 13:56

*Photograph B2-2: Zoomed up area from **Photograph 1** and location of calibration level*

B.2.6 The flood level upstream of the B970 Ruthven Road embankment was estimated **Photograph B2-1**, compared to the topographical survey information available along the southernmost flood relief culvert. The flood level at the time the photograph was taken was estimated to 223.0mAOD.

Photograph B2-3: October 2014 – A9 Spey crossing embankment, looking towards Kingussie

*Photograph B2-4: Zoomed up area from **Photograph B2-3** and location of calibration level*

B.2.7 From the LiDAR DTM, the ground level at western corner of the gate is 222.45maOD and looks above the flood level on **Photograph B2-4**, whereas ground immediately west of the gate is 222.3mOAD and is flooded. The flood level at this location was therefore estimated to be 222.35mAOD.

Photograph B2-5: October 2014 – A9 Spey crossing embankment, looking towards the Insh Marshes

B.2.8 A third calibration point was taken along the 1.2m stockproof fence running along the toe of the Spey crossing embankment. **Photograph B2-5** above suggests a 300mm flood depth at the fence (with water reaching the first fence line). Ground level along the fence at the location of the strainer post is about 221.69mAOD (from the Bloom Survey). The flood level was therefore assumed to be 222.0mAOD.

Inflow Hydrographs

B.2.9 The 15min gauged record hydrograph is used as inflow for the River Spey at the upstream end of the model, and for the River Tromie and the River Feshie.

B.2.10 Contributions from ungauged tributaries are modelled using the FEH Rainfall Runoff model: twin peak hydrographs are generated using two FEH-RR hydrographs of 3.5yr and 3.8yr return period (default FEH RR Storm duration) which peaks are coinciding with Invertruim gauged records.

Results

B.2.11 Predicted levels at the calibration points around Kingussie and full hydrographs at Kinrara and Kincraig stations show an acceptable fit of the model's results to the observed conditions.

Table B2-2: Oct 2014 Event, Observed vs Modelled flood levels in the Kingussie area

Easting	Northing	Description	Observation Time	Observed level (mAOD)	Model
275900.4	799850.5	Flood relief culvert u/s A9 embankment	28/10/2014 13:56	223.0	223.03
276053	800318	Wooden Gate u/s A9 embankment	28/10/2014 14:36	222.35	222.53
276268	799990	1.2m stockproof fence d/s A9 embankment	28/10/2014 14:44	222.0	221.81

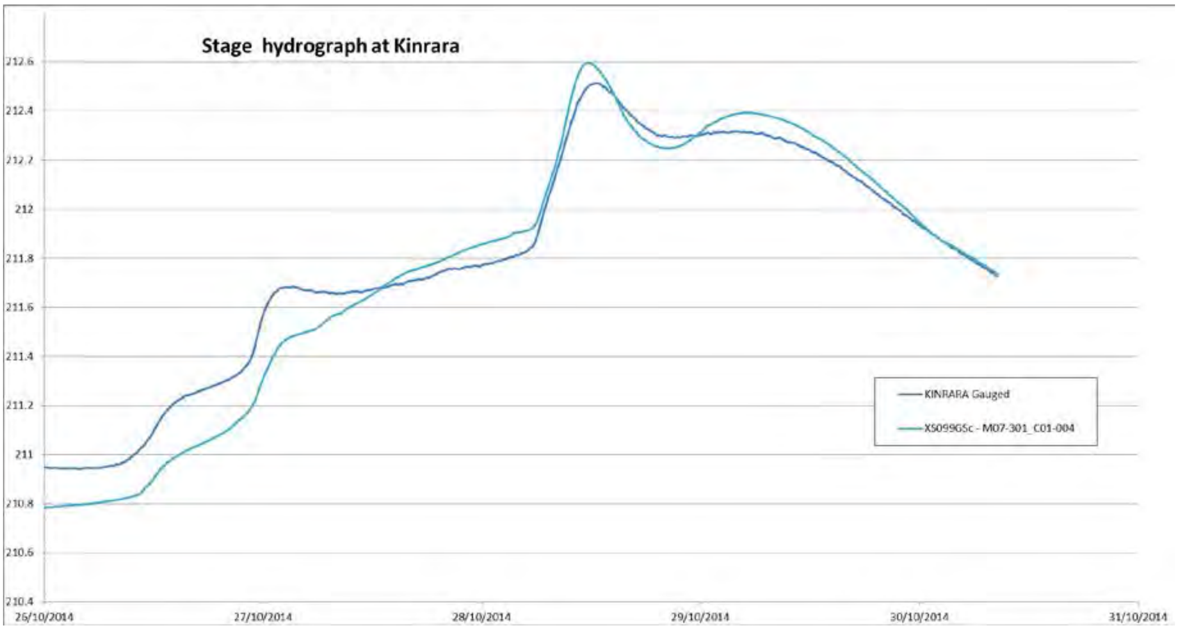


Figure B2-2: October 2014 – Stage hydrograph at Kinrara gauging station

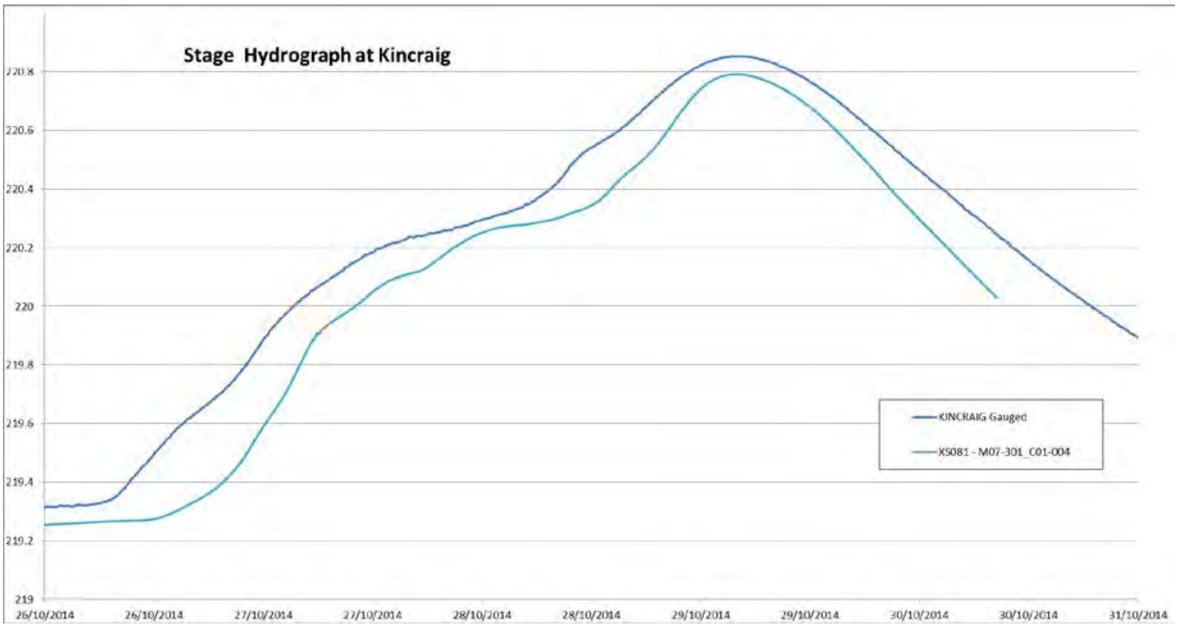


Figure B2-3: October 2014 – Stage hydrograph at Kincraig level station

Event 2 – August 2014

Available information and event characteristics

B.2.12 The August 2014 event is characterised by the dry antecedent condition, unusual for Spey flooding events. In terms of peak flows, the event is of relatively small magnitude along the River Spey (2 and 4yr RP events at 8007 and 8002 respectively).

B.2.13 The flow hydrograph is substantial at 8013 River Feshie at Feshie Bridge, with a succession of two peaks of noticeable magnitude (52yr and 22yr RP) both occurring before the peak flow at 8007. Although no information is available to quantify it, substantial sediment activity on the River Feshie fan is likely to have happened during this event.

B.2.14 In the technical report supporting the Pitmain Flood Alleviation Scheme, rainfall values from a private rain gauge at Kingussie are quoted, suggesting the rainfall in this area was extremely high (with a quoted 100yr RP). The same report also states that the peak flow on the River Gynack in Kingussie reached 43m^3/s, quoting an equivalent RP of 150yr. No further review of this data was carried out.

B.2.15 The levels recorded at 8008 River Tromie at Tromie Bridge (level only at the time of the event) were converted onto a flow hydrograph based on a stage/flow relationship built from previous records and the resulting hydrograph is also printed in **Figure B2-4** for information. Although the precision of the rating is questionable, the exercise indicates that the August 2014 event is of very low magnitude in this catchment. Given the reliability of the station and the unconfirmed rating used, information for this gauging station is ignored when defining model inflows.

Table B2-3: August 2014 Event, peak flow, time of occurrence and corresponding Return Period

Station	Peak flow (m^3/s)	Occurrence	Equiv. RP* (year)	Comments
8007	103.77	11/08/2014 12:45	2	Stage below 2m – bypassing is not an issue
8002	196.27	12/08/2014 16:30	4	
8008	45.58	11/08/2014 10:15	<2	Level only station – approximate, in-house rating
8013	231.71	11/08/2014 04:30	52	
8013	163.59	11/08/2014 10:45	22	

* When compared to single site analysis for the relevant gauging station

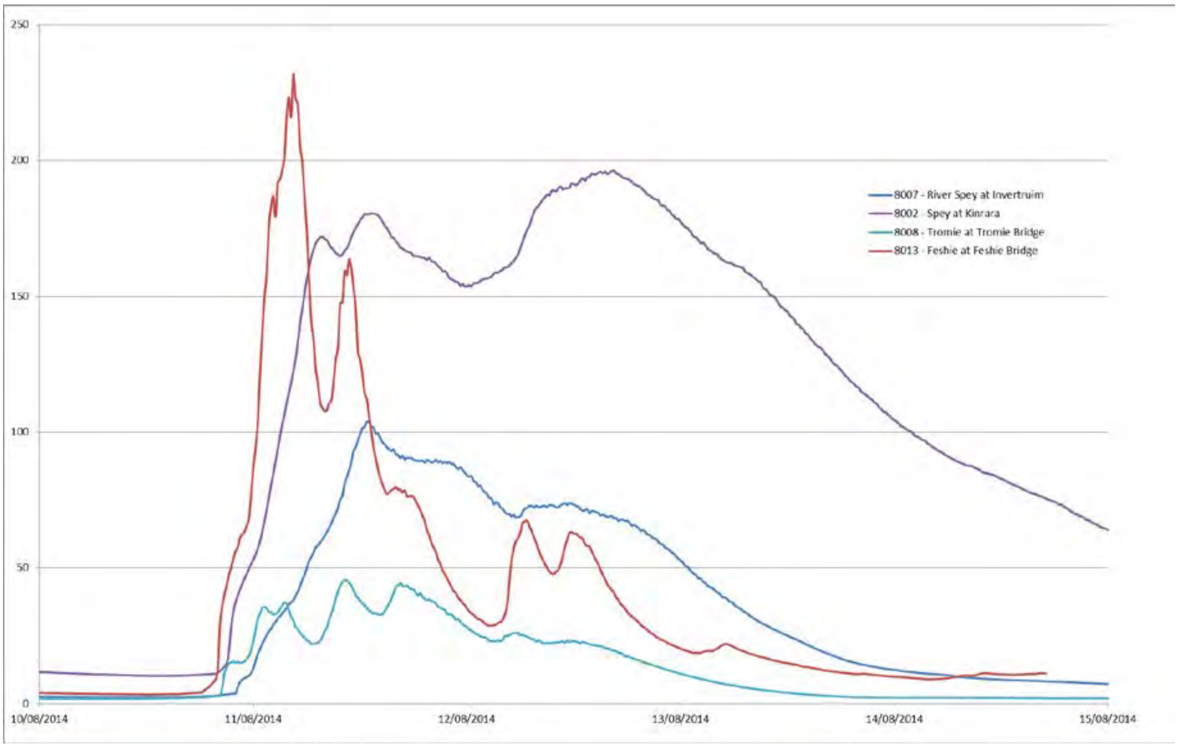


Figure B2-4: August 2014 – Flow hydrographs at gauging stations

B.2.16 Photographs were taken by CFJV staff during a site visit along the Spey Crossing at Kingussie on the 11 August 2014, at around 16:30. The pictures were taken during the rising limb of the flood in the Kingussie area.

B.2.17 The first calibration point is taken along the 1.2m stock-proof fence running along the toe of the Spey crossing embankment. **Photograph B2-6** overleaf suggests a 700mm flood depth at the fence. Ground level along the fence at the location of the strainer post is about 221.69mAOD (from the Bloom Survey). The flood level was therefore assumed to be 222.4mAOD.

B.2.18 The second calibration point is taken at the northern end of the gate found upstream the embankment (see **Photograph B2-7** where flood water is just reaching the bottom of the gate. Based on the Blom survey at this location, the flood level was assumed to be 222.44mAOD.

Photograph B2-6: August 2014 – From A9 Spey crossing embankment, looking downstream, taken 11/08/2014 16:30

Photograph B2-7: August 2014 – From A9 Spey crossing structure, looking upstream, taken 11/08/2014 16:38

Inflow hydrographs

B.2.19 The 15min gauged record hydrograph at 8007 River Spey @ Invertruim is used as inflow at the upstream end of the river model. Similarly, the 15min Hydrograph recorded at the 8013 River Feshie at Feshie Bridge is used as inflow for the River Feshie.

B.2.20 The All the other contributions are modelled the FEH RR method, based on a fitting exercise for the River Feshie at Feshie Bridge, shown in **Figure B2-5**. The FEH-RR models will be set to 50yr return period flooding event with a storm duration of 20hr.

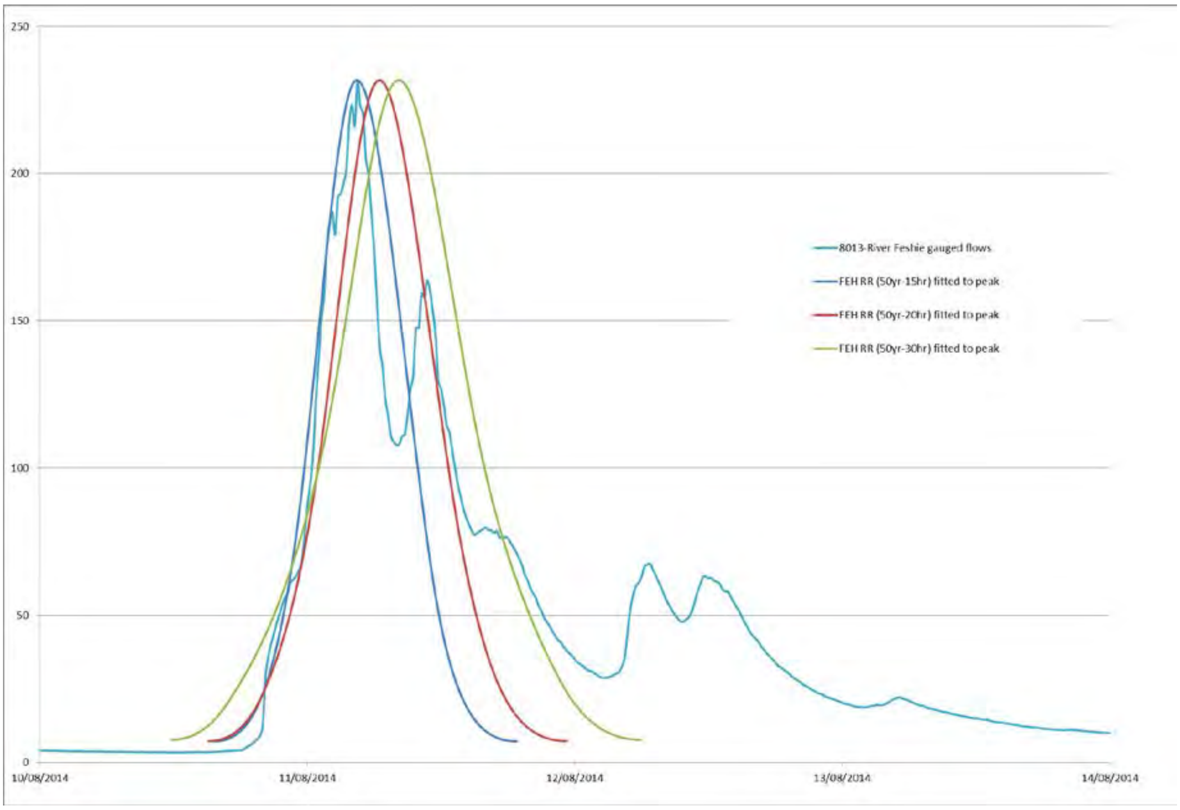


Figure B2-5: August 2014, River Feshie hydrograph fitting exercise

Antecedent conditions

B.2.21 In their consultation response dated 25/06/2015, SEPA flood team highlighted the fact that the August 2014 antecedent conditions were unusually dry. This was replicated in the model by setting low initial water levels in the Insh Marshes (219.25mAOD).

Results

B.2.22 At the calibration points based on the photographs in the Kingussie area, the predicted flood levels are lower than the estimated values, but within acceptable range, as shown in **Table B2-4**.

Table B2-4: August 2014 Event, Observed vs Modelled flood levels in the Kingussie area

Easting	Northing	Description	Observation Time	Observed level (mAOD)	Model
276268	799990	1.2m stock-proof fence running at the toe (d/s) of the A9 embankment	11/08/2014 16:30	222.40	222.11
276396	800422	Eastern side of the fence gate immediately u/s A9 crossing	11/08/2014 16:38	222.44	222.26

B.2.23 Predicted flood levels at Kinrara and Kincraig are shown in **Figure B2-6** and **Figure B2-7**. The difference the rising limb of the hydrograph at Kinrara shows shape and value at peak suggests that the model inflows under-predict the contribution volume for this event.

B.2.24 In Kincraig, the predicted level is 270mm lower than the measured peak, also confirming the under-estimation of the contribution volume.

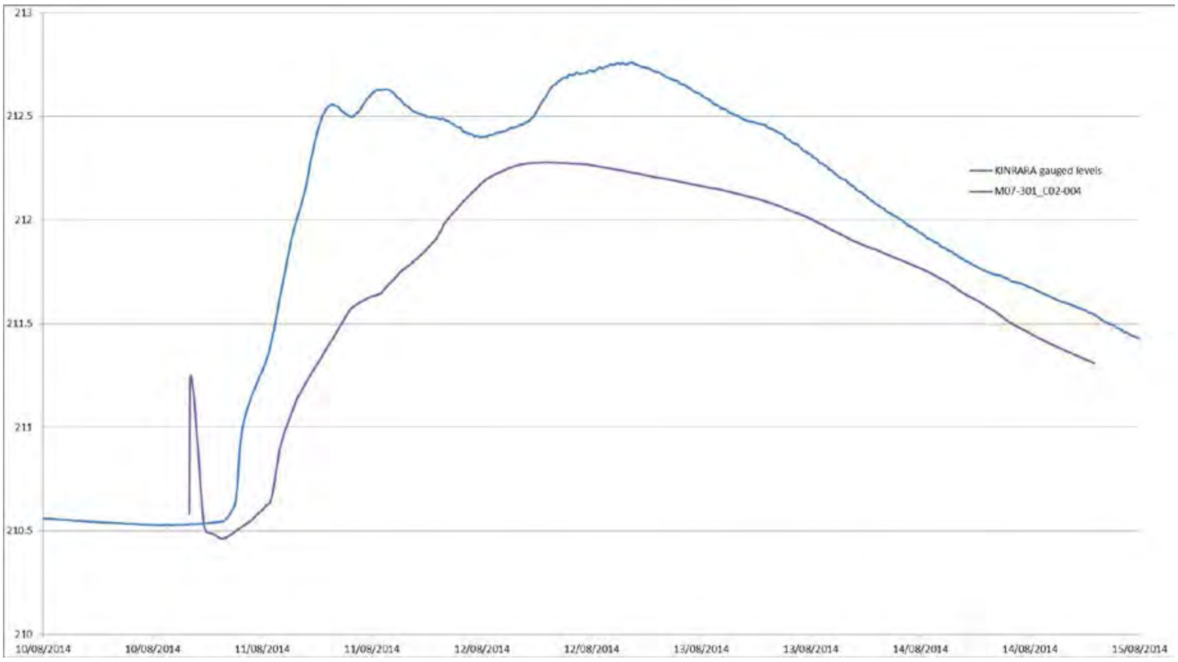


Figure B2-6: August 2014, predicted peak levels at Kinrara gauging station

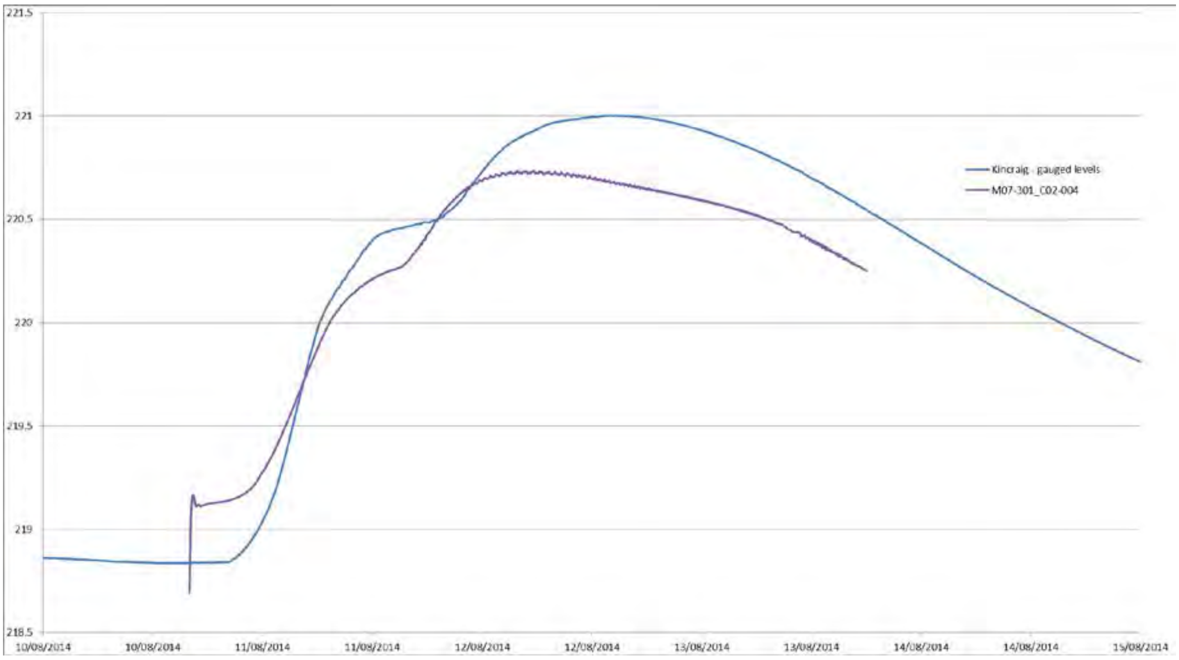


Figure B2-7: August 2014, predicted peak levels at Kincriag level station

Event 3 - February 1990

Available information and event characteristics

B.2.25 The February 1990 flooding event is a relatively large flooding event. With a peak flow ranking as third largest AMAX at Invertruim Gauging station and sixth largest at Kinrara gauging station. The gauging station 8008 River Tromie @ Tromie Bridge failed during the event. No record is available for the River Feshie @ Feshie Bridge. The level only gauging station at Kincraig failed during this event.

B.2.26 Of the georeferenced flood records provided by SEPA (csv file received 05/12/2014) seven records with a quoted level are within the modelled reach, understood to be surveyed levels of wrack marks. The locations and levels are given in **Table B2-6** of the results sub-section.

B.2.27 Peak flow values and 15min gauged hydrographs at Invertruim, Tromie Bridge and Kinrara are shown in **Table B2-5** below.

Table B2-5: Feb 1990 Event, peak flow, time of occurrence and corresponding Return Period

Station	Peak flow	Occurrence	Equiv. RP*	Comments
8007	196.64	05/02/1990 01:15	18yr	Up-to-date rating used
8002	265.70	05/02/1990 10:00	20yr	
8008	77.35	03/02/1990 21:30	7yr	Station failed – Peak value not relevant

* When compared to single site analysis for the relevant gauging station

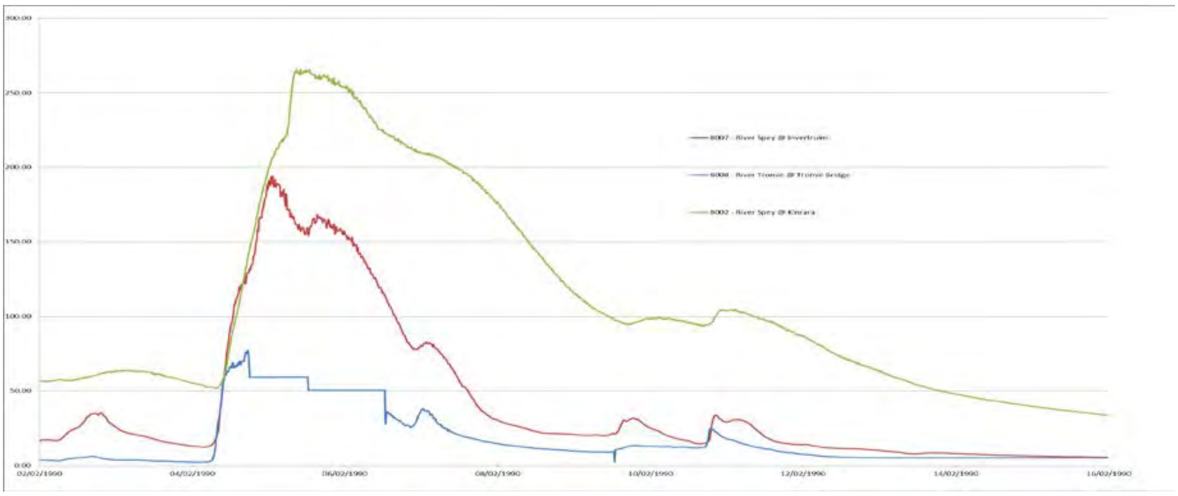


Figure B2-8: Flow hydrographs at gauging stations

Inflow hydrographs

B.2.28 The 15min gauged record hydrograph is used as inflow at the upstream end of the river model. All the other contributions are modelled the FEH RR method. Based on the return periods at Invertruim and Kinrara, the FEH-RR models will be set to 20yr return period flooding event.

B.2.29 The 15min flow hydrographs at 8002, 8007 and 8008 suggest that it was a long duration event. Preliminary runs with FEH-RR set to their critical storm duration highlight a shortage of flood volume.

B.2.30 The hydrograph for 8007 River Spey at Invertruim shows two peaks: a first large peak followed by a second smaller one approx. 24hr later, in the receding limb of the first peak.

B.2.31 The standardised shape of the first peak is well approximated by the ReFH model with a storm duration of 44.5HR.

B.2.32 The relative importance of the second peak was assessed by subtracting the standardised ReFH model from the recorded data, as shown in **Figure B2-8**. As the secondary peak is only 35 percent of the main peak, there was no attempt to reproduce a secondary peak in the inflow hydrograph of the ungauged catchments. The storm duration associated with the ReFH modelling of the main peak (44hrs) was used to inform the storm durations of all the other contributing catchments.

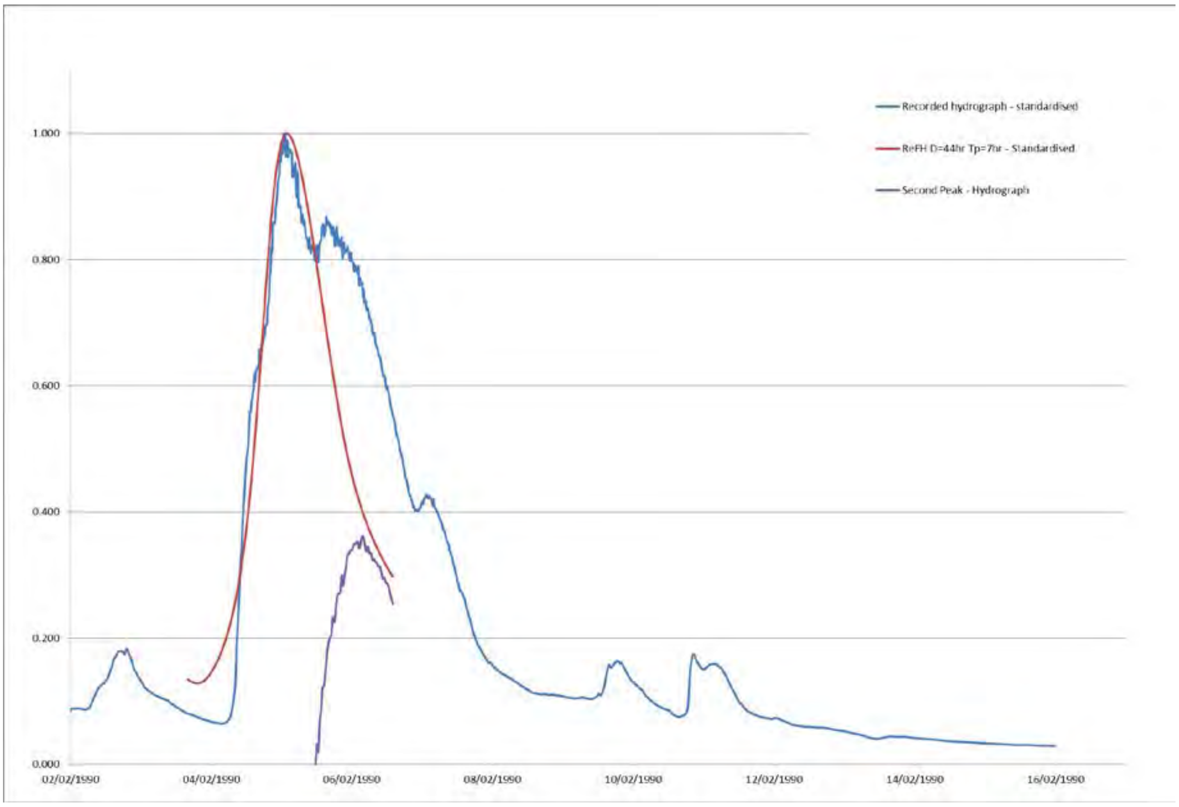


Figure B2-8: Feb 1990 event, 8007 River Spey at Invertruim, standardised hydrograph and standardised ReFH model output

Antecedent conditions

B.2.33 Although the analysis of the 15m gauged record at Invertruim gauging station does not show any major flooding event taking place in the weeks before the 05/02/1990, the gauged levels at Kincraig gauging station are relatively high throughout the second half of January 1990 (220.7mAOD on 23/01/1990 up to the start of the event (Approx. 220.0mAOD on 04/02/1990). Antecedent conditions were therefore taken into account by setting initial water levels along the Insh Marshes to 220.0mAOD.

Results

B.2.34 Predicted flood levels at Kinrara are shown in **Figure B2-9**. The results are generally satisfactory, with the model overestimating the peak level at Kinrara gauging station by 260mm, within the expected range of prediction for this type of model. The modelled hydrograph is narrower than the recorded data, suggesting the contribution volume from the ungauged catchment is underestimated.

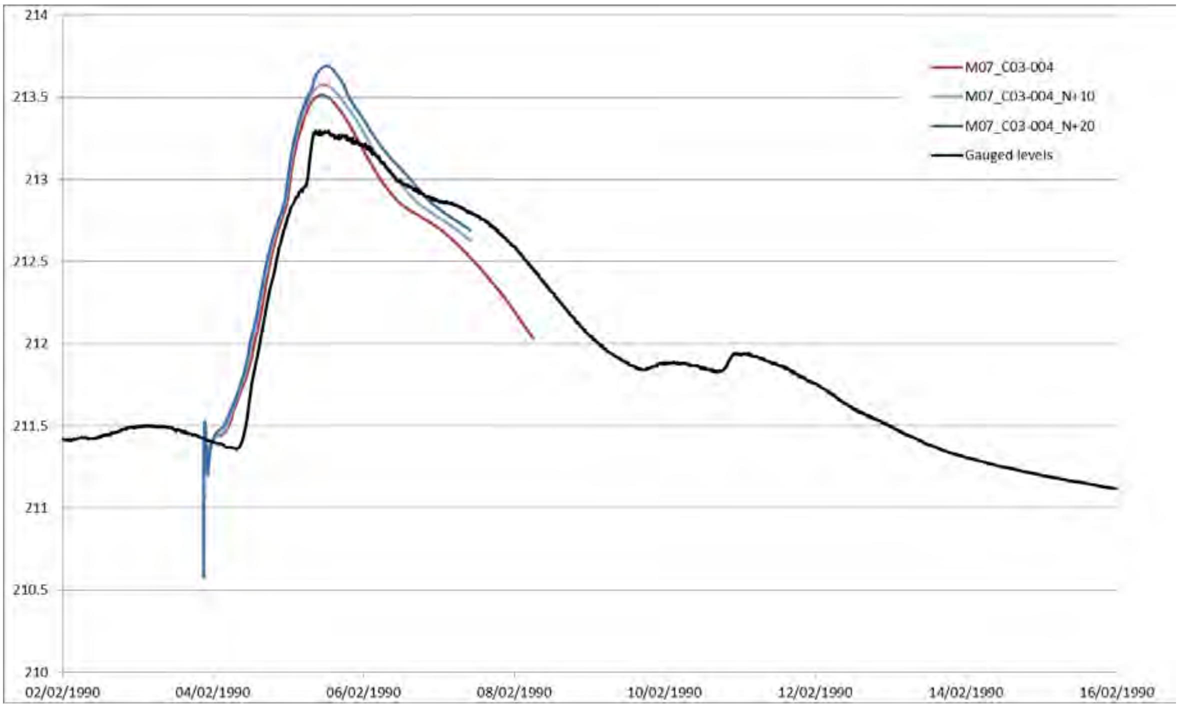


Figure B2-9: Feb 1990, Predicted Peak levels at Kinrara Gauging Station

B.2.35 Predicted results at the locations of selected SEPA flood records show the predicted levels are within an acceptable range from the surveyed data

Table B2-6: Feb 1990 Event, Predicted flood levels at SEPA flood record locations

Description	Flood Level recorded	Flood Levels Predicted
Newtonmore bridge upstream	238.02	230.28
Newtonmore bridge downstream	237.58	237.71
Newtonmore STW	230.49	230.3
Kingussie Market Street	224.27	224.44
Kingussie STW	223.78	223.37
Insh STW	222.11	222.20
Kincraig village	222.38	222.05

B.3 DMRB Stage 3 River Spey Model Sensitivity Analysis

Tested parameters

B.3.1 The model sensitivity to the following parameters was assessed (200yr baseline conditions):

- Manning's roughness: 10 and 20 percent increase of the values presented in **Table B1-2**, both for the 1D and 2D domains
- Peak flows: 20 percent increase in the peak inflow values

B.3.2 In the above cases, the routing procedure (running various storm durations to generate a combined maximum extent) was required to fully capture the influence of these parameters to the modelling outputs.

B.3.3 Additional tests were also carried out on the following parameters:

- Grid size: a run with a 5m grid spacing was carried out
- Downstream boundary condition: the slope of the normal depth downstream boundary (1:100 in the baseline model) is slacken to 1:200 and 1:2000

B.3.4 The second set of tests were carried out only on test run of specific storm durations and directly compared to the corresponding storm duration run from the baseline conditions. No routing exercise was carried out on the smaller grid size, due to the computing time required to run smaller grid size models (8 times longer than the baseline model). The impact of the downstream boundary is limited to the lower part of the model, where a single storm duration value (60hrs) predicts the largest flood extent.

Findings

Manning's roughness

B.3.5 With the exception of the downstream end of the model (Kinrara and beyond) an increase in ten percent in Manning's value transfers as an increase in 40 to 80mm across most of the predicted flood extent. Raising the roughness value bring the increase water level range up to 170mm.

B.3.6 Generally, the model shows a limited sensitivity to roughness coefficient.

Peak flow

B.3.7 Increasing the value of the peak inflows shows some impact to the predicted flood levels along the model: the range of water level variation is +20 to +100mm upstream of the B970 Ruthven, increasing to +300 to +400mm downstream of the A9 crossing embankment to beyond the Feshie fan and 500 to 600mm in Kinrara to the end of the model.

B.3.8 This "growing" impact of the 20percent increase in peak inflow is simply due to the multiple inflows contributing along the modelled reach, and their accumulation along the modelled reach captured by the routing approach taken to calculate the maximum flood extent along the model.

B.3.9 The approach taken to define the 200yr design event is conservative in many aspects (FEH-RR for ungauged catchments, global storm duration and coincidental peaks). The comparison of the design peak flow predicted at Kinrara with the statistical 200yr value (presented in post meeting information in **sub-section B.4**) tend to confirm this. The relative sensitivity of the model to the peak flow

Grid size

B.3.10 The sensitivity test on the grid size shows localised discrepancies around items like embankments, drains, etc. as their description in the model and the hydraulics around is influenced by the grid size.

B.3.11 Between these items showing discrepancies, the difference in peak flood levels between the smaller and the larger grid show smaller but uniform discrepancies over large areas, (-20 to +40mm).

B.3.12 The impact in reducing the grid size to the predicted flood levels is therefore small. The 10m grid can be seen as acceptable size.

Downstream boundary

B.3.13 Modelling tests show that slackening the downstream boundary normal depth slope from 1:100 to 1:200 has an impact on the predicted flood levels at the downstream end of the model, up to Inshriach House (upstream of 8002 Spey @ Kinrara gauging station). The impact at the gauging station is in the region of 100mm.

B.3.14 A further slackening of the downstream boundary to 1:2000 has greater impact, potentially up to Dalnavert Cottages. Stability issues were encountered when running this test, which could exaggerate the extent of impact.

B.3.15 For the two test cases the impact is limited to the downstream end of the model, away from the development. The influence at the gauging station at Kinrara (8002) is relatively limited (1:200 slope), suggesting comparison with gauged levels at this location is acceptable. .

B.4 River Spey Bridge (ID152) Option Assessment

B.4.1 The DMRB Stage 3 River Spey model was used to inform the opening width for the proposed River Spey crossing (Hydro ID152).

B.4.2 Different bridge spans were considered: 270m, 310m, 350m, 650m and full removal. Results were presented in relation to potential impact at sensitive receptors located upstream and downstream of the Spey crossing. The sensitive receptors included infrastructure, residential and non-residential properties and utilities within the 200yr flood extent of the River Spey. The assessment also considered the effect in the opening width to the flow hydrograph passed further downstream, beyond the model boundary.

B.4.3 The approach and the findings of this assessment were presented to SEPA and THC flood teams on 30/10/2017. Presentation material (PowerPoint slides) is presented overleaf.

B.4.4 Additional information requested during the meeting is also provided as “post meeting information” slides embedded at relevant locations within the presentation.

B.4.5 This assessment was carried out with an earlier version of the model used for the flood risk assessment. Additionally, the River Spey only was considered, ignoring the crossing tributaries which are presented in the rest of this FRA. The set of sensitive receptors and results included in the presentation will therefore differ to the results reported in the flood risk assessment section.

A9P09 – Spey Crossing Options & Flood Risk

Spey Crossing Options from a Flood Risk Perspective

- Spey Crossing Options Assessment
- DMRB3 H&HM – current conditions
- DMRB3 Spey 200yr Flood Envelope and Sensitive Receptors
- Bridge Spans Considered
- Impact Assessment:
  - Flood Extent and Flood Levels
  - Impact at the Sensitive Receptors
  - Floodplain Storage
  - Magnitude of the Flood passed Downstream

Spey Bridge (Grid NH765005), upstream, view south

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A9P09 – Spey Crossing Options & Flood Risk

Relevant Criteria	Comments on selection of embankment and bridge length
Fluvial Geomorphology	All combinations likely to require some bank/embankment protection over the life of the structure and some protection to piers. Erosion to left bank under bridge and downstream erosion will continue but should reduce. Existing embankment offers some protection during construction Increasing span over existing partially restores natural conditions Flooding of retained embankment likely River velocity in flood reduces with increasing bridge span reducing potential for scour
Local soils and construction.	Long piles required for all options. Approx 2 years required for bridge construction (longer bridges need longer construction periods)
Flood mechanism	Greater upstream benefits with longer spans, very long spans and complete embankment removal likely to pass flood risk downstream. Overall benefit in terms of flood risk is commendable and is what would be acceptable to the regulatory authority where there is a negligible increase in downstream flood risk.
Natura designations (SAC, SPA, Ramsar),	Principle of avoidance adopted at Stage 2 – bridge lengths chosen to avoid embankment encroachment in the Natura Sites
National Nature Reserve (NNR)	Developed preferred alignment (4h) results in the smallest footprint in the NNR. The presence of the A9 results in the creation of an avoidance zone for breeding birds which remains irrespective of the bridge/embankment length
Engineering	Longest the bridge on the straight gradient is 312m , Longer bridges would extend over the sag curve on the south approach

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A9P09 – Spey Crossing Options & Flood Risk

Relevant Criteria	Comments on selection of embankment and bridge length
Habitat issues (otter/FWPM)	All the options increase the span from the existing opening and therefore improve connectivity. Habitat benefits by ensuring the river reflects natural conditions
Visual impact	Difficult to quantify – increasing the span of the bridge will make it more visible in the landscape – A very long structure would compete with Ruthven Barracks Only HES have raised concerns in relation to this point
Whole Life Cost	Marginally more expensive (the longer the bridge)
Construction Cost	A 270m long D2 bridge could cost between £19M to £25M depending on bridge type and span length Increasing the span from 270m to 310m adds approximately £2.7M. Increasing the span from 270m to 650m adds approximately £26M. Complete removal adds approximately £43M Assuming £2500/m2 deck area as a guide.

CFJV recommend the Stage 3 assessment proceeds on the basis of a 270m long span over the River Spey.

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A9P09 – Spey Crossing Options & Flood Risk

DMRB3 Hydrology and Hydraulic Modelling

- Updated hydrology
  - Account for DMRB2 feedback
  - Inflow hydrographs
  - Inflow peaks
- Refined hydraulic model
  - 1D/2D model
  - Based on surveyed river sections
  - Calibrated against past events
  - Sensitivity tests
- Model fit for purpose

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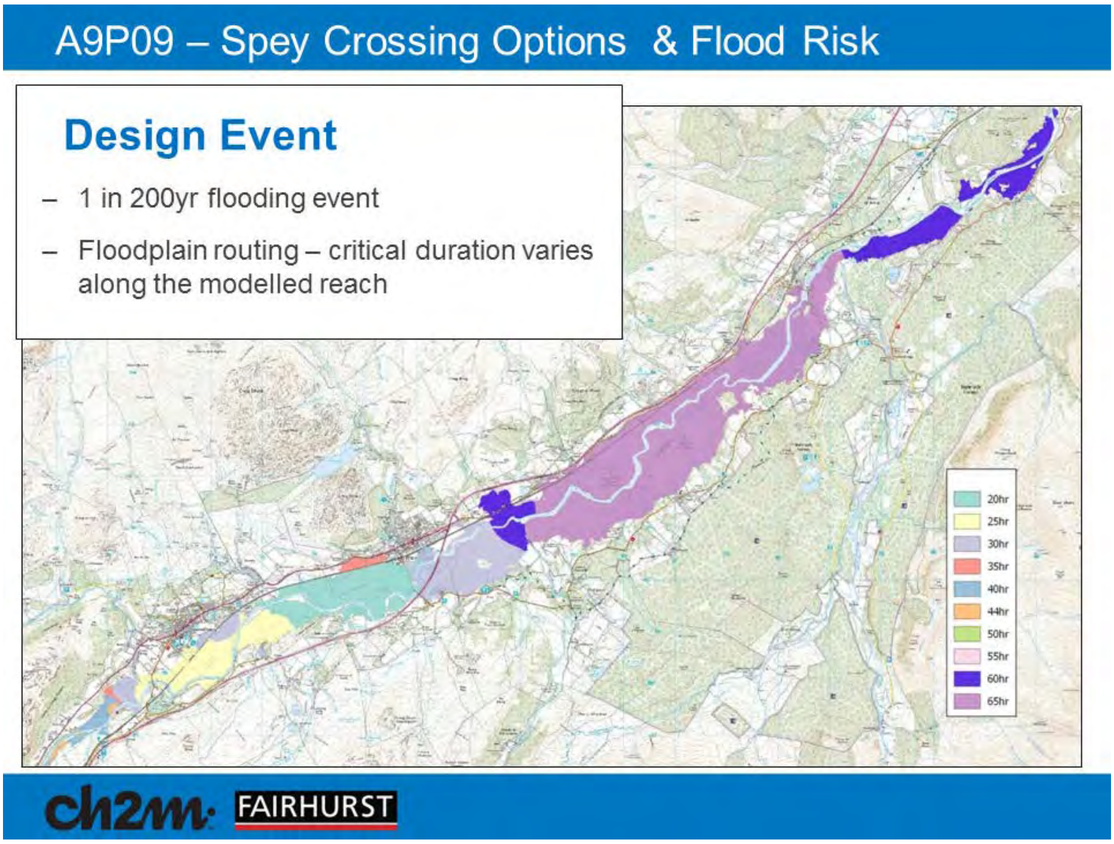
A9P09 – Spey Crossing Options & Flood Risk
Design Event
– 1 in 200yr flooding event
– Floodplain routing – critical duration varies along the modelled reach
20hr
25hr
30hr
35hr
40hr
44hr
50hr
55hr
60hr
65hr
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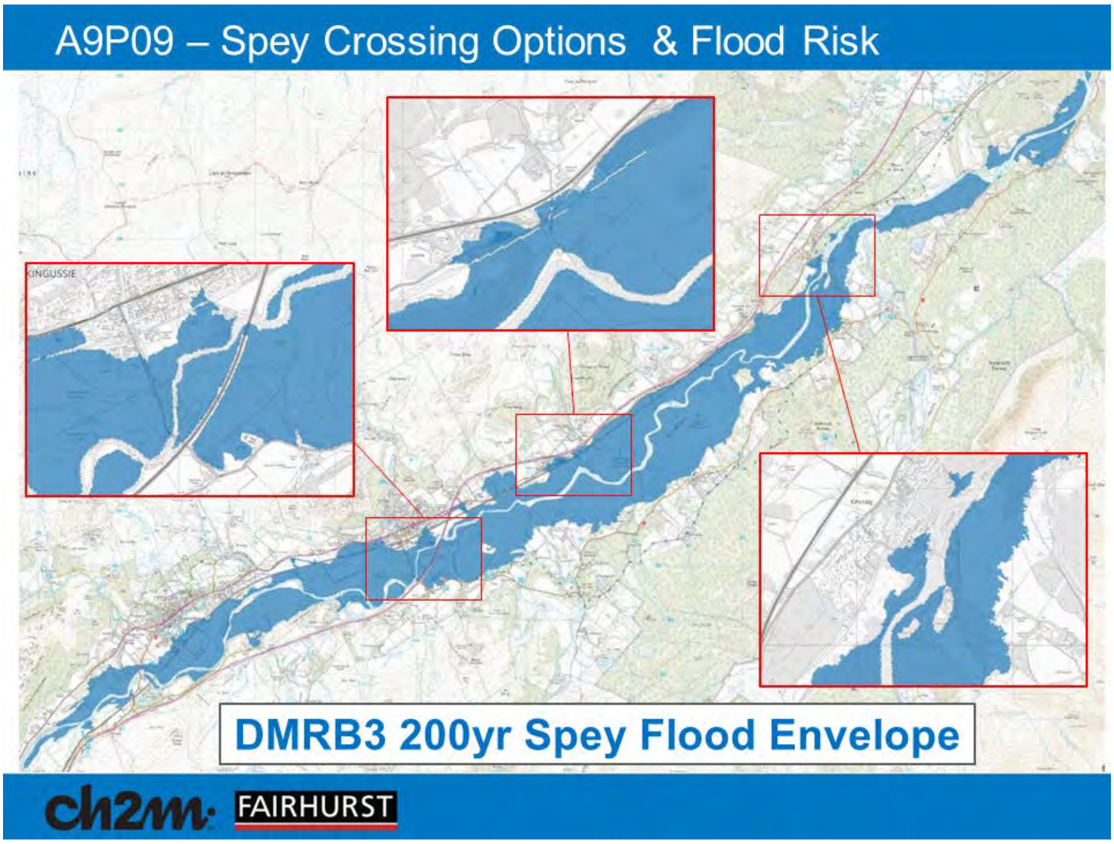
A9P09 – Spey Crossing Options & Flood Risk
KINGUSSIE
DMRB3 200yr Spey Flood Envelope
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A9P09 – Spey Crossing Options & Flood Risk

Sensitive Receptors

- Based on DMRB3 200yr Spey Flood Envelope
  - Upstream of B970 (Ruthven Road)
  - B970 (Ruthven Road) to A9 crossing
  - A9 crossing to Kincraig Bridge
  - Downstream of Kincraig
- Receptor types
  - Residential / Non-residential / Utility
  - Road and Rail
  - Agricultural land

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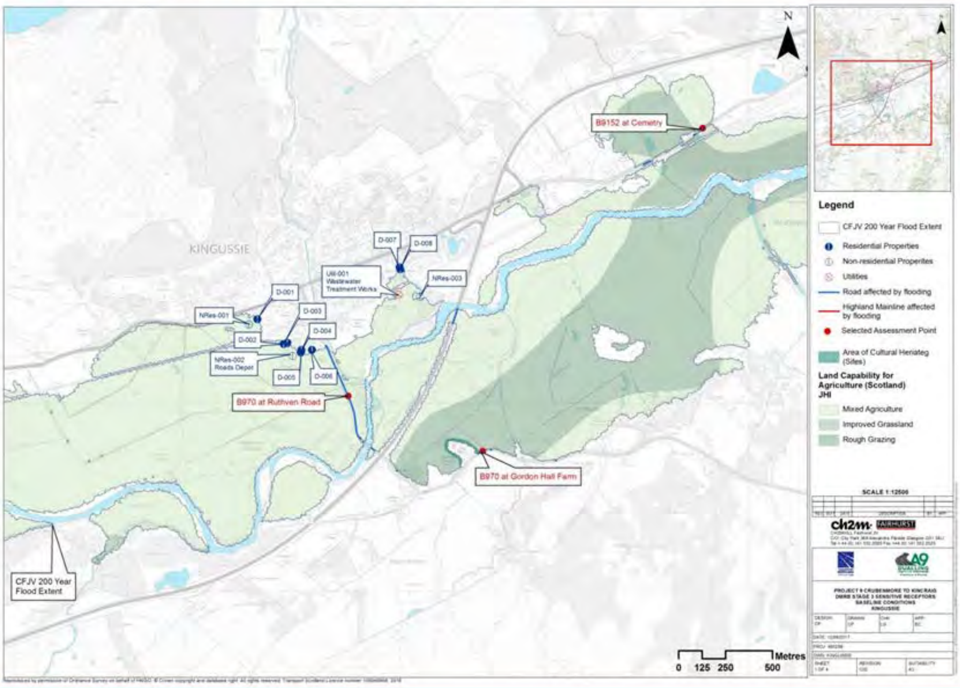
A9P09 – Spey Crossing Options & Flood Risk



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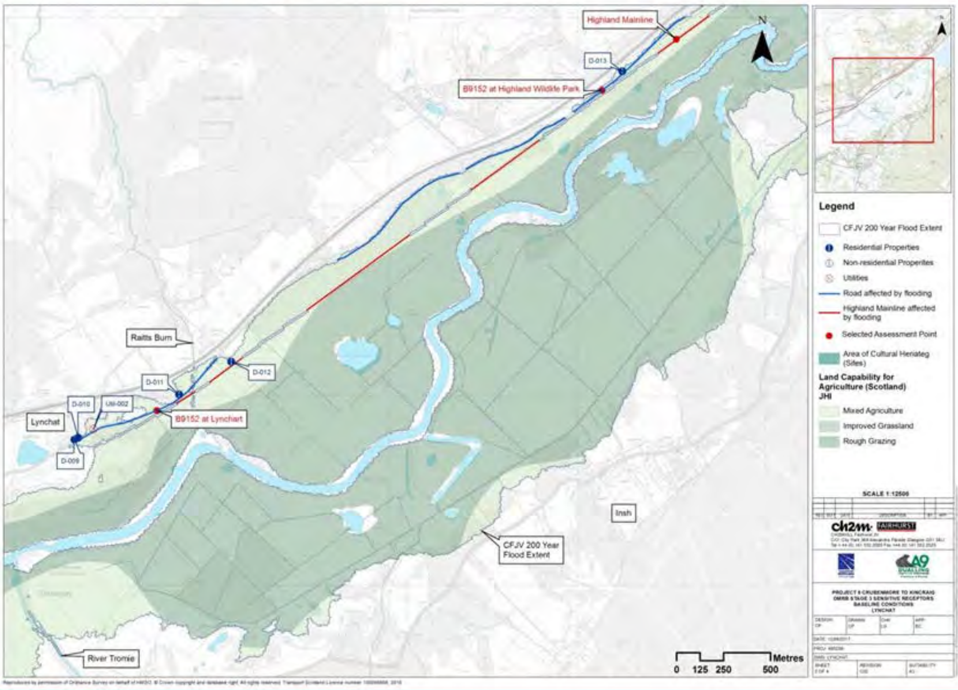
A9P09 – Spey Crossing Options & Flood Risk



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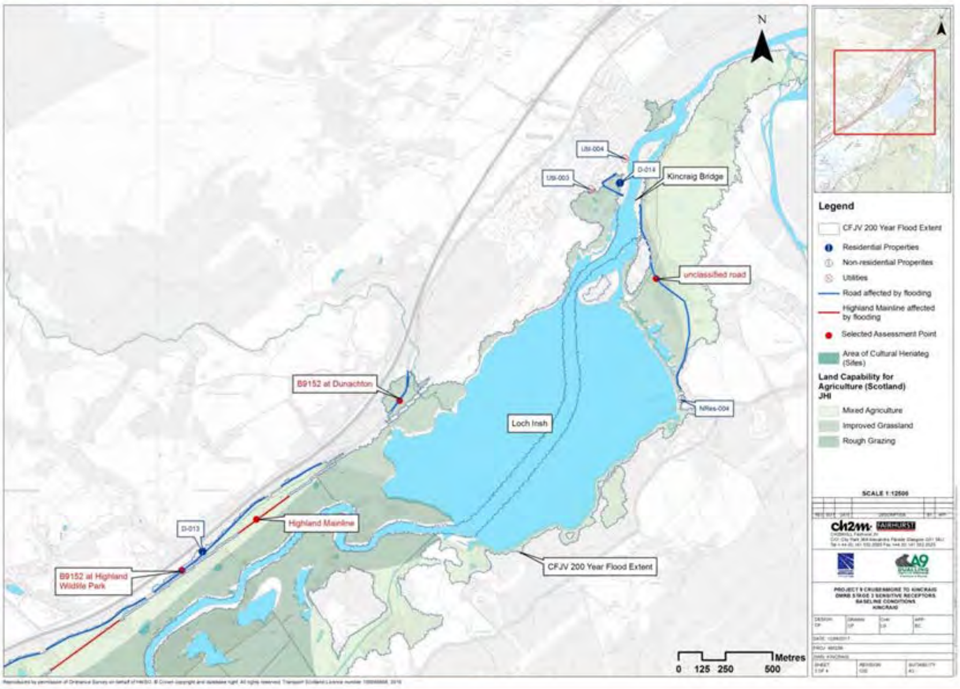
A9P09 – Spey Crossing Options & Flood Risk



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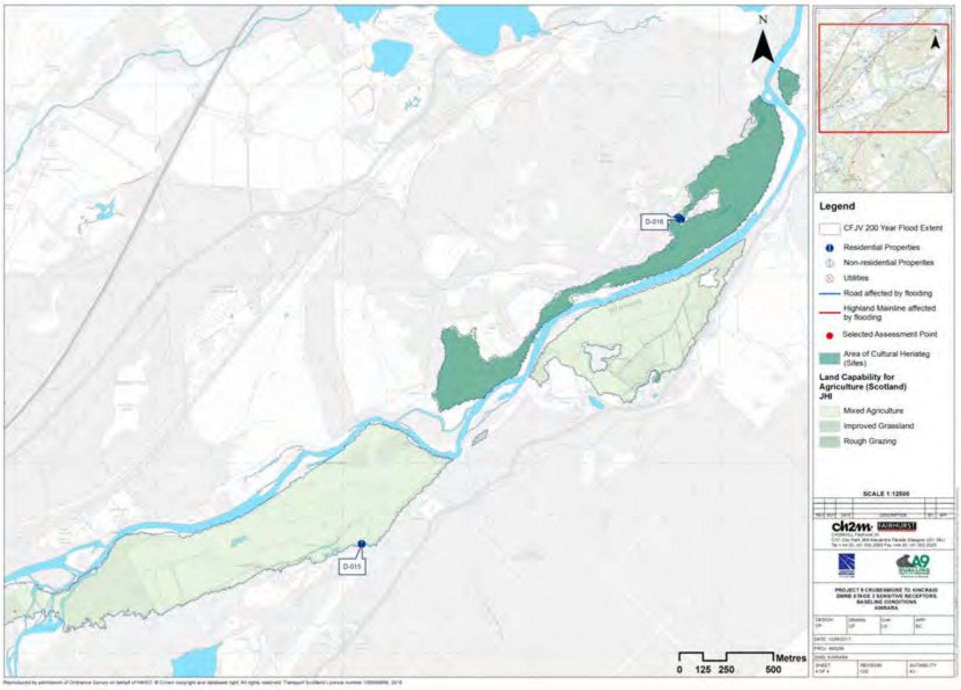
A9P09 – Spey Crossing Options & Flood Risk

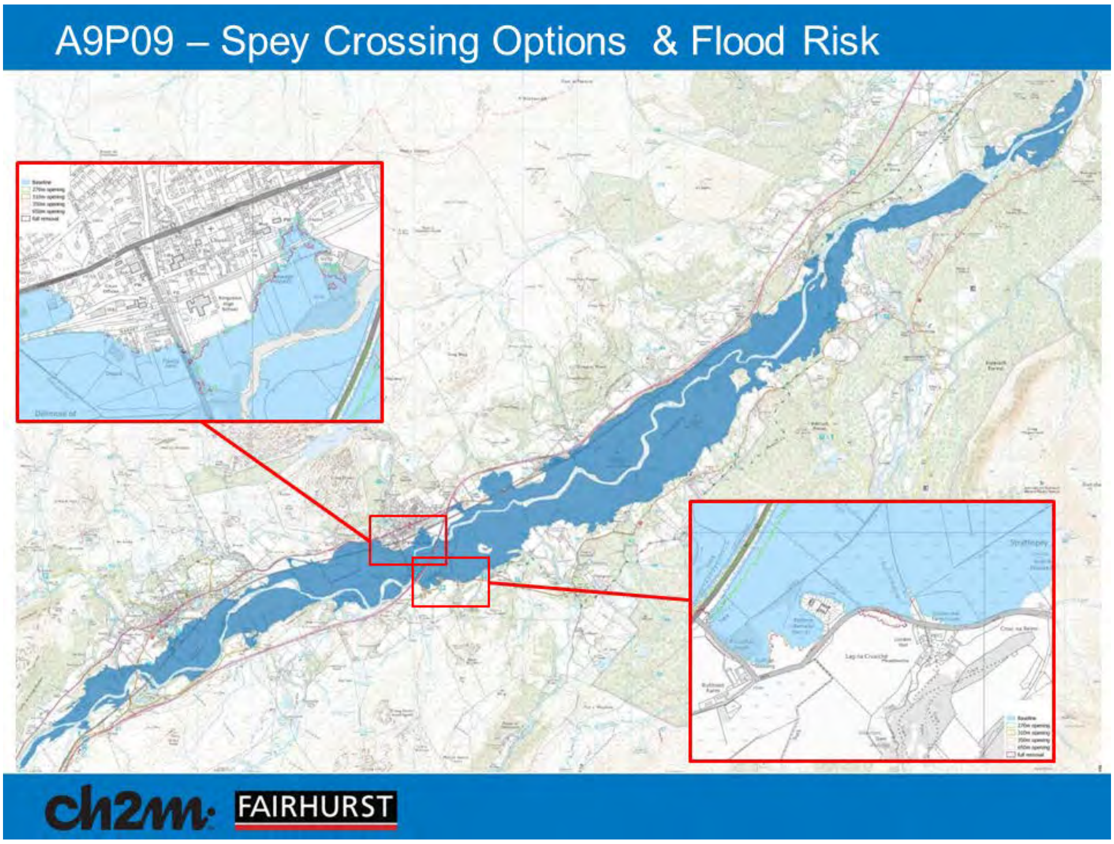


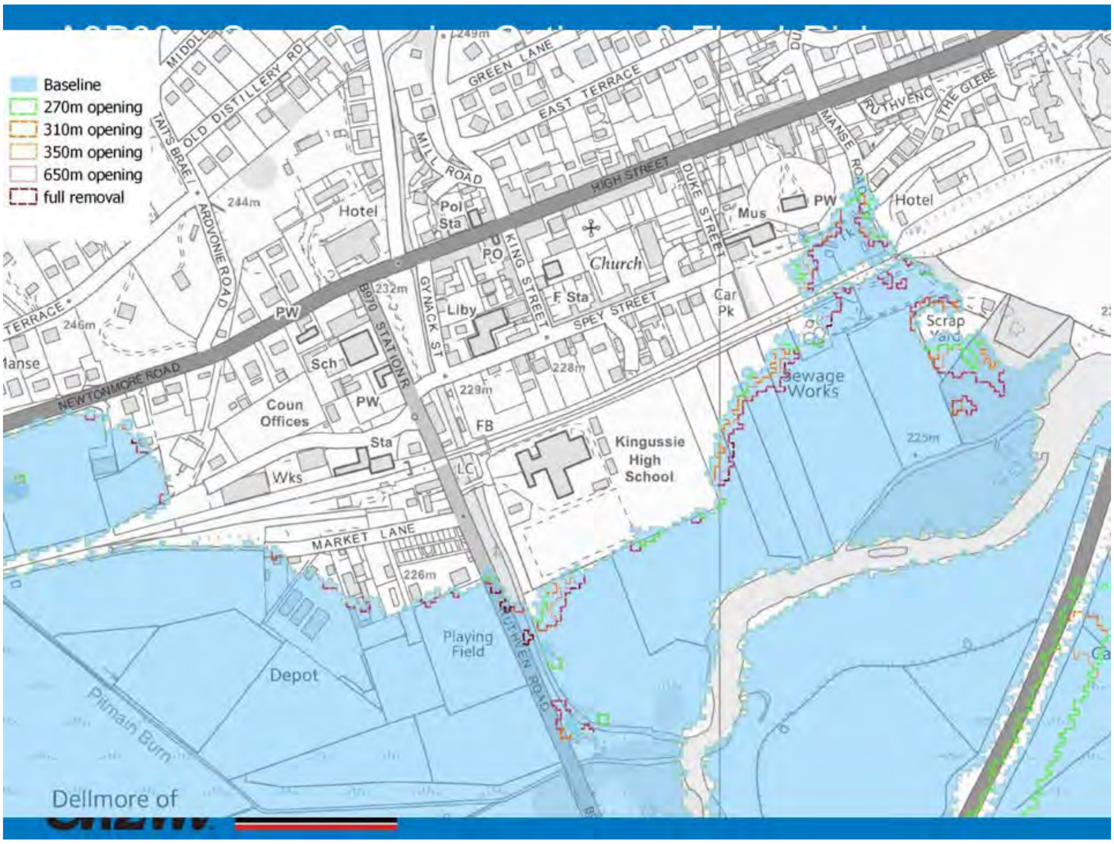
A9P09 – Spey Crossing Options & Flood Risk

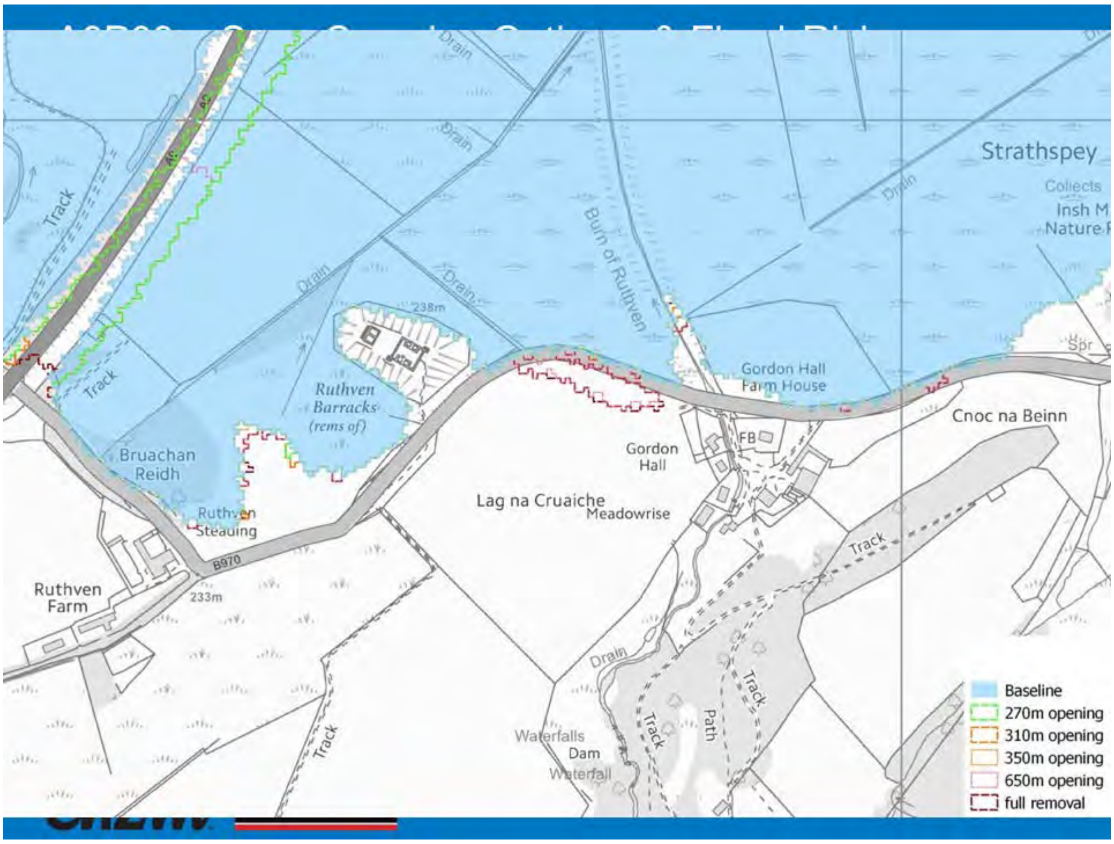
Scenarios

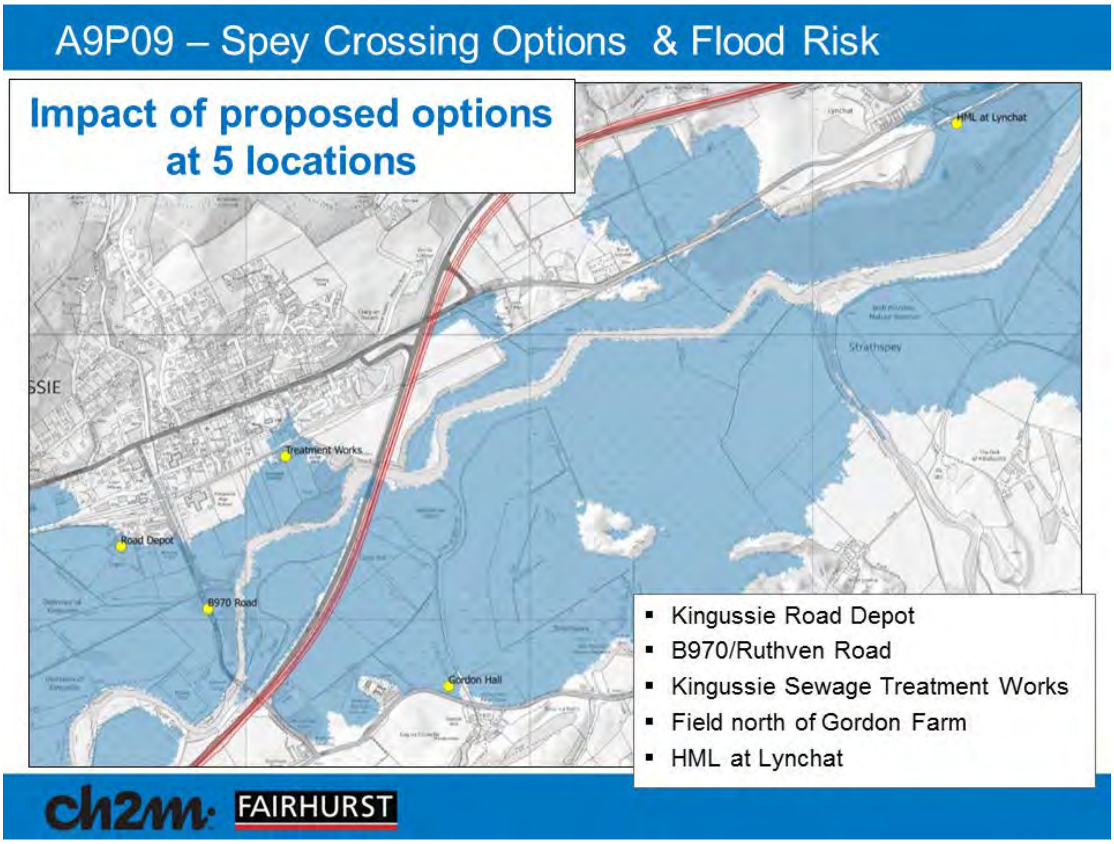
- Existing Condition - 138m span (baseline)
- Preferred alignment – various span lengths:
  - 270m (avoiding SAC)
  - 310m, 350m (incremental increase)
  - 650m (RSPB suggested minimum span)
- Full Embankment Removal (circa 950m span)

All new-build scenarios assume that existing embankment is removed.


A9P09 – Spey Crossing Options & Flood Risk
ch2m. FAIRHURST


Baseline
270m opening
310m opening
350m opening
650m opening
full removal
HIGH STREET
Kingussie High School
Sewage Works
Scrap Yard
Playing Field
Depot
Dellmore of


Strathspey
Ruthven Barracks (rems of)
Bruachan Reidh
Ruthven Steading
Ruthven Farm
B970
233m
238m
Burn of Ruthven
Gordon Hall Farm House
Gordon Hall
Lag na Cruaiche
Meadowrise
Cnoc na Beinn
Waterfalls
Dam
Waterfall
Track
Path
Drain
FB
Baseline
270m opening
310m opening
350m opening
650m opening
full removal


A9P09 – Spey Crossing Options & Flood Risk
Impact of proposed options at 5 locations
HML at Lynchat
Treatment Works
Road Depot
B970 Road
Gordon Hall
Strathspey
Kingussie Road Depot
B970/Ruthven Road
Kingussie Sewage Treatment Works
Field north of Gordon Farm
HML at Lynchat
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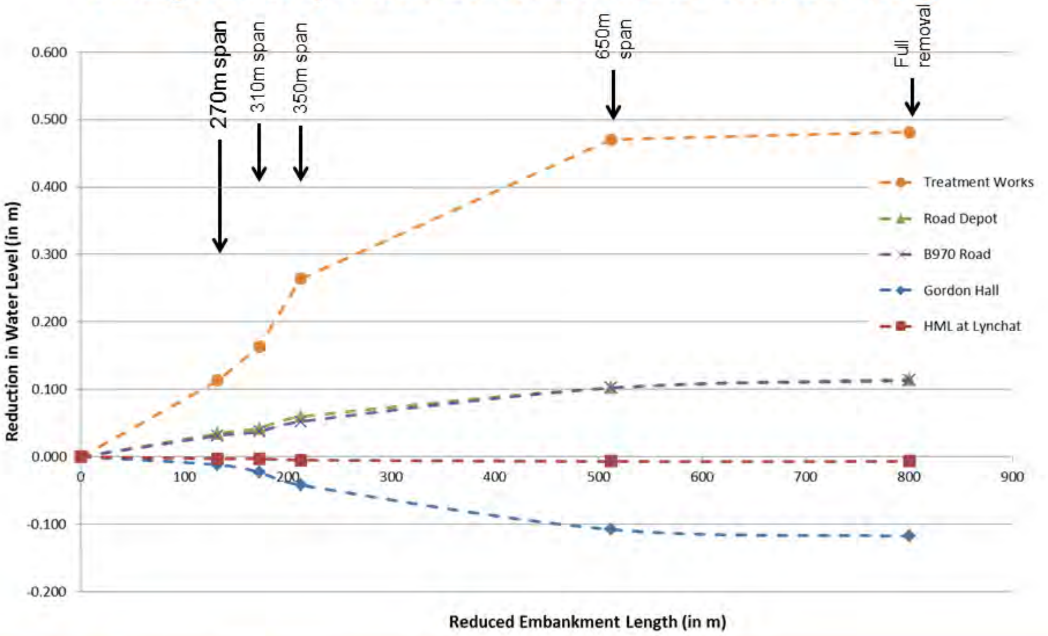
A9P09 – Spey Crossing Options & Flood Risk

Changes in 200yr Flood Levels u/s and d/s of A9 Crossing



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A9P09 – Spey Crossing Options & Flood Risk

Assessment criteria

(SFRA table 6-2 – from DMRB HD45/09 Table A4.4 adapted to SPP)

Importance	Criteria	Flood Risk
Major Adverse	Results in loss of attribute and/or quality and integrity of the attribute	Increase in peak flood level (0.5% annual probability) > 100mm
Moderate Adverse	Results in effect on integrity of attribute, or loss of part of attribute	Increase in peak flood level (0.5% annual probability) > 50mm
Minor Adverse	Results in some measurable change in attribute quality or vulnerability	Increase in peak flood level (0.5% annual probability) > 10mm
Negligible	Results in effect on attribute, but of insufficient magnitude to affect the use or integrity	Negligible change in peak flood level (0.5% annual probability) <+/- 10mm
Minor Beneficial	Results in some beneficial effect on attribute or a reduced risk of negative effect occuring	Reduction in peak flood level (0.5% annual probability) > 10mm
Moderate Beneficial	Results in moderate improvement of attribute quality	Reduction in peak flood level (0.5% annual probability) > 50mm
Major Beneficial	Results in major improvement of attribute quality	Reduction in peak flood level (0.5% annual probability) > 100mm

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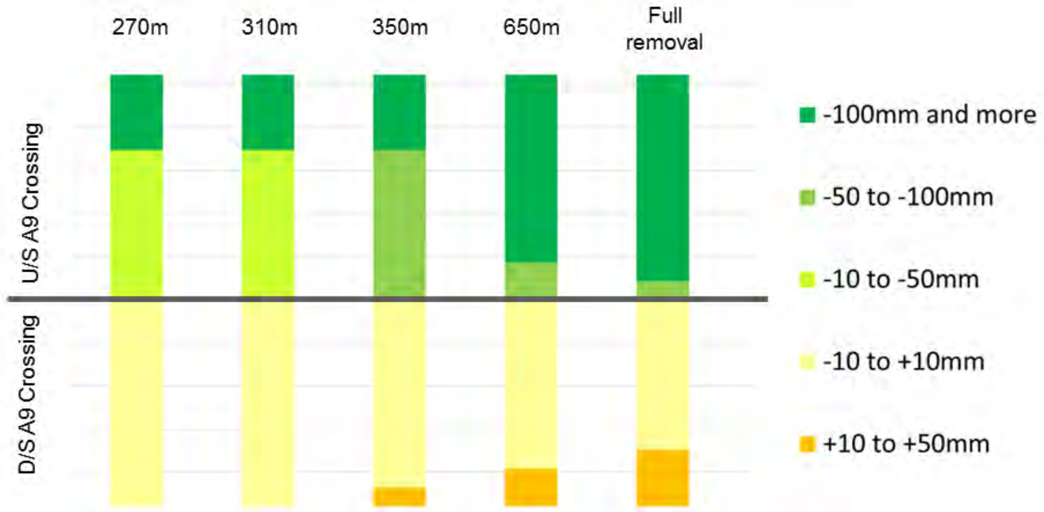
A9P09 – Spey Crossing Options & Flood Risk

Magnitude of Impact on Sensitive Receptors

Residential / Non-Residential Properties and Utilities



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A9P09 – Spey Crossing Options & Flood Risk

Magnitude of Impact on Sensitive Receptors

Residential / Non-Residential Properties and Utilities

TYPE	Label	Existing 200yr water level (mAOD)	270m opening		310m opening		350m opening		650m opening		Embankment fully removed	
			Water Level mAOD	change (mm)	Water Level mAOD	change (mm)	Water Level mAOD	change (mm)	Water Level mAOD	change (mm)	Water Level mAOD	change (mm)
RP	D-002	224.834	224.801	-33	224.792	-42	224.775	-59	224.735	-99	224.723	-111
RP	D-003	224.834	224.801	-33	224.792	-42	224.775	-59	224.734	-100	224.723	-111
NRP	NRes-001	224.815	224.783	-32	224.776	-39	224.760	-55	224.727	-88	224.717	-98
RP	D-001	224.815	224.783	-32	224.776	-39	224.760	-55	dry		dry	
NRP	NRes-002	224.819	224.783	-36	224.777	-42	224.759	-60	224.716	-103	224.703	-116
NRP	D-004	224.817	224.783	-34	224.773	-44	224.754	-63	224.704	-113	224.691	-126
NRP	D-005	224.812	224.778	-34	224.768	-44	224.751	-61	224.706	-106	224.693	-119
B970 RP	D-006	224.809	224.777	-32	224.768	-41	224.748	-61	224.700	-109	224.687	-122
B970 UTIL	Util-001	223.809	223.696	-113	223.646	-163	223.546	-263	223.339	-470	223.328	-481
RP	D-007	223.805	223.694	-111	dry		dry		dry		dry	
RP	D-008	223.805	dry		dry		dry		dry		dry	
A9 NRP	NRes-003	223.760	223.653	-107	223.608	-152	223.516	-244	dry		dry	
A9 RP	D-009	222.819	222.822	3	222.823	4	222.825	6	222.827	8	222.827	8
RP	D-010	222.819	222.822	3	222.823	4	222.825	6	222.827	8	222.827	8
UTIL	Util-002	222.819	222.822	3	222.823	4	222.825	6	222.8270	8	222.827	8
RP	D-013	222.689	222.694	5	222.695	6	222.699	10	222.701	12	222.702	13
NRP	NRes-004	222.648	222.650	2	222.651	3	222.653	5	222.654	6	222.654	6
UTIL	Util-003	222.578	222.581	3	222.581	3	222.583	5	222.585	7	222.585	7
RP	D-014	222.571	222.574	3	222.574	3	222.576	5	222.578	7	222.578	7
UTIL	Util-004	222.495	222.498	3	222.498	3	222.500	5	222.501	6	222.502	7
RP	D-015	217.432	217.434	2	217.435	3	217.438	6	217.441	9	217.442	10
RP	D-016	214.458	214.462	4	214.463	5	214.466	8	214.470	12	214.471	13

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A9P09 – Spey Crossing Options & Flood Risk

- Post Meeting information -

Magnitude of Impact on Sensitive Receptors in context of predicted flood depth

TYPE	Label	Flooding Threshold		Existing 200yr conditions		270m opening	310m opening	350m opening	650m opening	Embankment fully removed
		Value	Source	WL (mAOD)	Flood Depth (mm)	change (mm)	change (mm)	change (mm)	change (mm)	change (mm)
RP	D-002	224.650	LiDAR DTM	224.834	184	-33	-42	-59	-99	-111
RP	D-003	224.700	LiDAR DTM	224.834	134	-33	-42	-59	-100	-111
NRP	NRes-001	224.500	LiDAR DTM	224.815	315	-32	-39	-55	-88	-98
RP	D-001	224.750	LiDAR DTM	224.815	65	-32	-39	-55	Dry	Dry
NRP	NRes-002	224.200	LiDAR DTM	224.819	619	-36	-42	-60	-103	-116
NRP	D-004	224.350	LiDAR DTM	224.817	467	-34	-44	-63	-113	-126
NRP	D-005	224.500	LiDAR DTM	224.812	312	-34	-44	-61	-106	-119
B970 RP	D-006	224.610	LiDAR DTM	224.809	199	-32	-41	-61	-109	-122
B970 UTIL	Util-001	223.000	LiDAR DTM	223.809	809	-113	-163	-263	-470	-481
RP	D-007	223.600	LiDAR DTM	223.805	205	-111	Dry	Dry	Dry	Dry
RP	D-008	223.700	LiDAR DTM	223.805	105	Dry	Dry	Dry	Dry	Dry
A9 NRP	NRes-003	223.400	LiDAR DTM	223.760	360	-107	-152	-244	Dry	Dry
A9 RP	D-009	222.460	Ground survey	222.819	359	3	4	6	8	8
RP	D-010	222.220	Ground survey	222.819	599	3	4	6	8	8
UTIL	Util-002	222.800	Ground survey	222.819	19	3	4	6	8	8
RP	D-013	221.640	Ground survey	222.689	1049	5	6	10	12	13
NRP	NRes-004	221.700	Ground survey	222.648	948	2	3	5	6	6
UTIL	Util-003	223.010	Ground survey	222.578	-432	3	3	5	7	7
RP	D-014	222.700	Ground survey	222.571	-129	3	3	5	7	7
UTIL	Util-004	222.250	Ground survey	222.495	245	3	3	5	6	7
RP	D-015	216.600	LiDAR DTM	217.432	832	2	3	6	9	10
RP	D-016	212.200	LiDAR DTM	214.458	2258	4	5	8	12	13

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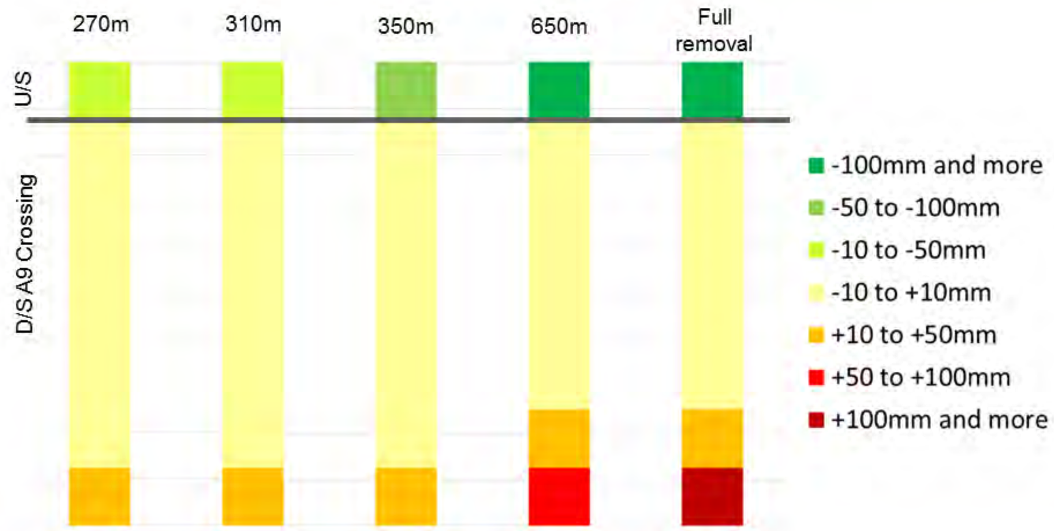
A9P09 – Spey Crossing Options & Flood Risk

Magnitude of Impact on Sensitive Receptors

Roads and Rail



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A9P09 – Spey Crossing Options & Flood Risk

Magnitude of Impact on Sensitive Receptors

Roads and Rail

Location	Existing 200yr water level (mAOD)	Lowest Existing Ground Level (mAOD)	270m opening		310m opening		350m opening		650m opening		Embankment fully removed	
			Water Level (mAOD)	change (mm)	Water Level (mAOD)	change (mm)	Water Level (mAOD)	change (mm)	Water Level (mAOD)	change (mm)	Water Level (mAOD)	change (mm)
B970 at Ruthven Road	224.652	224.340	224.613	-39	224.605	-47	224.585	-67	224.528	-124	224.513	-139
B970 at Gordon Hall Farm	223.127	223.200	223.139	12	223.148	21	223.164	37	223.225	98	223.235	108
B9152 at Cemetery	223.022	223.140	223.023	1	223.025	3	223.026	4	223.027	5	223.028	6
B9152 at Lynchart	222.820	221.960	222.822	2	222.824	4	222.826	6	222.827	7	222.828	8
B9152 at Highland Wildlife Park	222.690	221.820	222.695	5	222.696	6	222.699	9	222.702	12	222.702	12
B9152 at Dunachton	222.667	221.870	222.669	2	222.669	2	222.671	4	222.671	4	222.673	6
unclassified Road (Kincraig)	222.613	221.320	222.615	2	222.616	3	222.618	5	222.619	6	222.620	7
Highland Main Line	222.760	222.510	222.762	2	222.763	3	222.765	5	222.766	6	222.766	6

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A9P09 – Spey Crossing Options & Flood Risk

- Post Meeting information -

Magnitude of Impact on Sensitive Receptors in context of predicted flood depth

Roads and Rail

Location	Flooding Threshold		Existing 200yr conditions		270m opening	310m opening	350m opening	650m opening	Embankment fully removed
	Value	Source	WL (mAOD)	Flood Depth (mm)	change (mm)	change (mm)	change (mm)	change (mm)	change (mm)
B970 at Ruthven Road	224.340	Ground survey	224.652	**312**	-39	-47	-67	-124	-139
B970 at Gordon Hall Farm	223.200	Ground survey	223.127	-73	12	21	37	98	108
B9152 at Cemetery	223.140	Ground survey	223.022	-118	1	3	4	5	6
B9152 at Lynchart	221.960	Ground survey	222.820	**860**	2	4	6	7	8
B9152 at Highland Wildlife Park	221.820	Ground survey	222.690	**870**	5	6	9	12	12
B9152 at Dunachton	221.870	Ground survey	222.667	**797**	2	2	4	4	6
unclassified Road (Kincraig)	221.320	Ground survey	222.613	**1293**	2	3	5	6	7
Highland Main Line	222.510	LiDAR	222.760	**250**	2	3	5	6	6

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A9P09 – Spey Crossing Options & Flood Risk

Magnitude of Impact on Sensitive Receptors

Agricultural Land

Change in flooded land (in hectares)

Land Capability Type	270m opening	310m opening	350m opening	650m opening	Full Removal
Mixed Agriculture	-0.33	-0.47	-0.67	-1.30	-1.36
Rough Grazing	+0.10	+0.15	+0.18	+0.66	+0.74

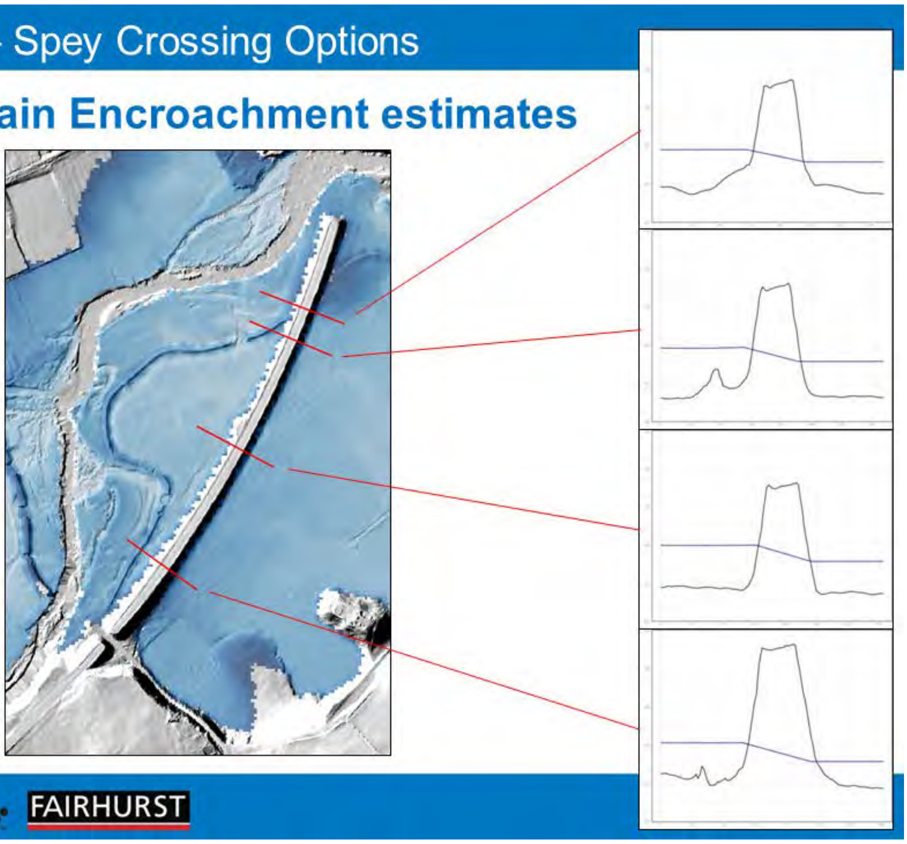
Change is change in flooded area *i.e.*:

- negative value = net decrease in flooded area (= gain of land use)
- positive value = net increase in flooded area (= loss of land use)

Change in flooded land does not account for land gain/loss around the embankment

A9P09 – Spey Crossing Options

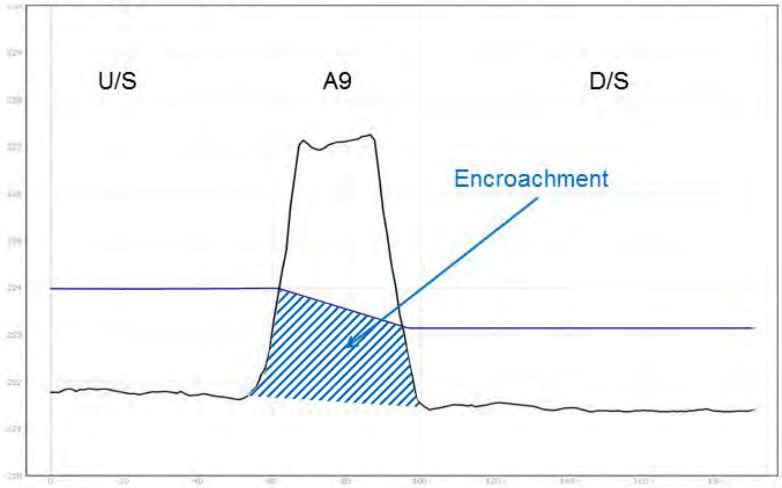
Floodplain Encroachment estimates



A9P09 – Spey Crossing Options & Flood Risk

Floodplain Encroachment Estimates

In existing conditions



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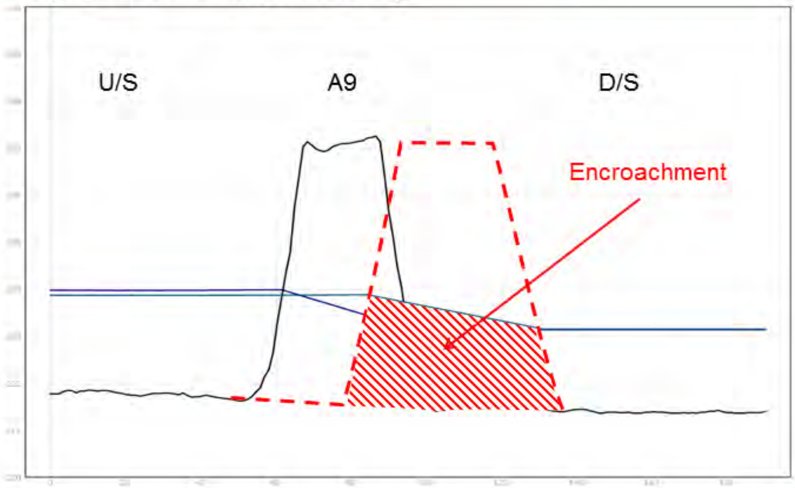
A9P09 – Spey Crossing Options & Flood Risk

Floodplain Encroachment Estimates

In proposed conditions (270m opening)



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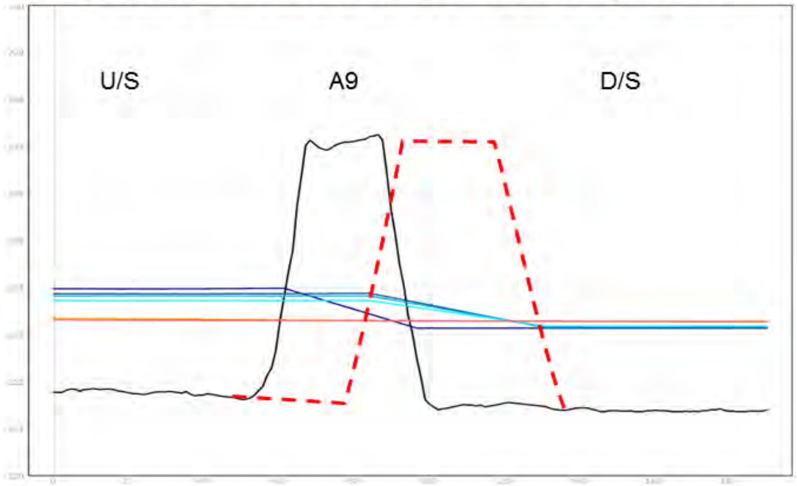
A9P09 – Spey Crossing Options & Flood Risk

Floodplain Encroachment Estimates

Changes in U/S and d/s water levels for the different opening scenarios



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A9P09 – Spey Crossing Options & Flood Risk

Floodplain Encroachment Estimates

Volume of encroached FP (*i.e.* land raising in m3)

	Existing (baseline)	270m opening	310m opening	350m opening	650m opening	Full Removal
Encroached volume	50500	57500	56500	53000	21300	0
Difference	–	+7000	+6000	+2500	-29200	-50500

- **"No increase"** in encroachment volume is **potentially achievable** with opening of ~400m, **BUT…**

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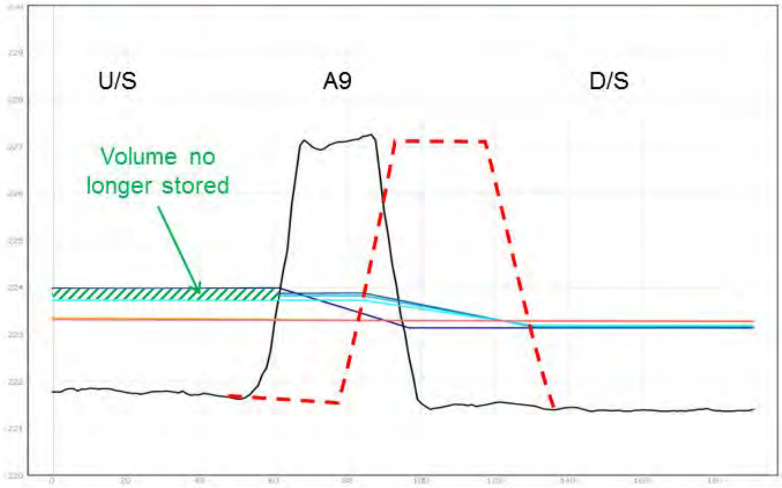
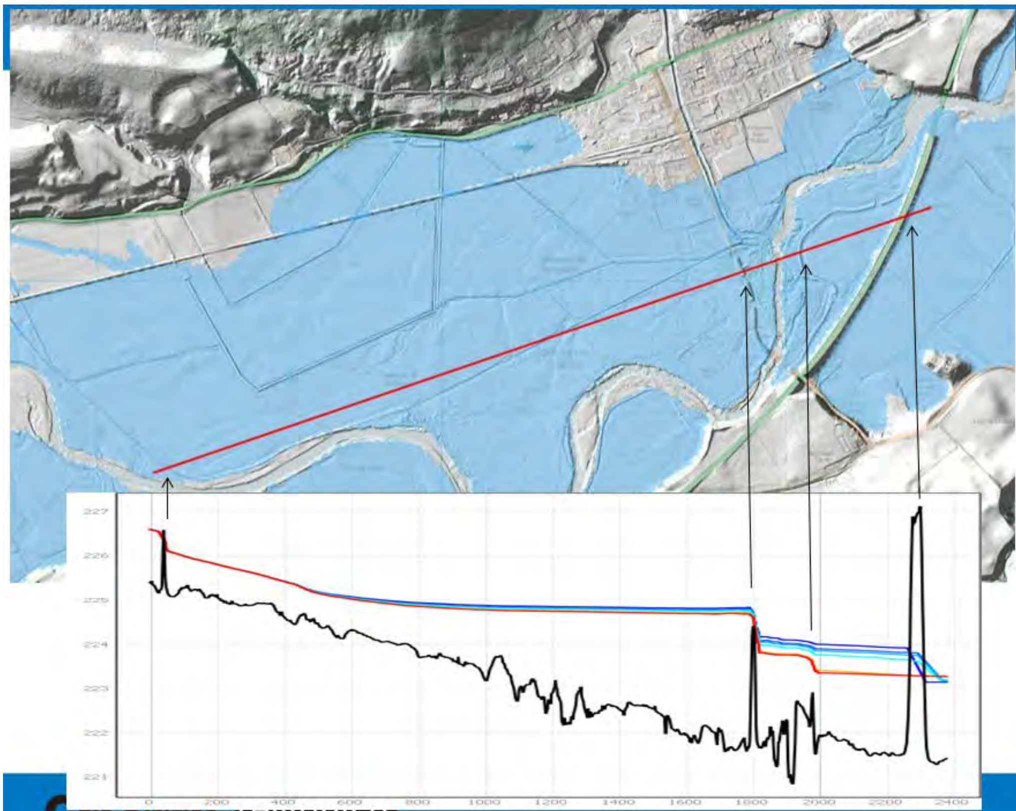
A9P09 – Spey Crossing Options & Flood Risk

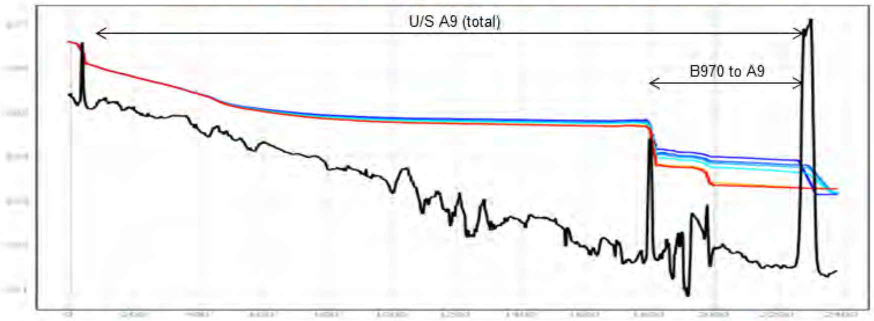
Flood Storage Loss Estimates





A9P09 – Spey Crossing Options & Flood Risk

Flood Storage Loss Estimates



Change in Floodplain volume (from baseline)	270m opening	310m opening	350m opening	650m opening	Full Removal	
B970 to A9	-24500	-36500	-60000	-116000	-124000	5 to 27% of total FP within the reach
U/S of A9 (total)	-60000	-80000	-120000	-220000	-240000	2 to 9% of total FP within the reach

- Negative value = loss of volume
- Combined maximum values

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A9P09 – Spey Crossing Options & Flood Risk

Flood Storage loss – Estimates

	270m opening	310m opening	350m opening	650m opening	Full Removal
Encroachments – Change in FP volume	7000	6000	2500	(+29200)	(+50500)
U/S storage – Change in Flood levels	60000	80000	120000	220000	240000
Net loss	67000	86000	122500	190800	189500

- 270m opening minimises the loss of floodplain storage
- Resulting impact in flood levels presented in previous sections

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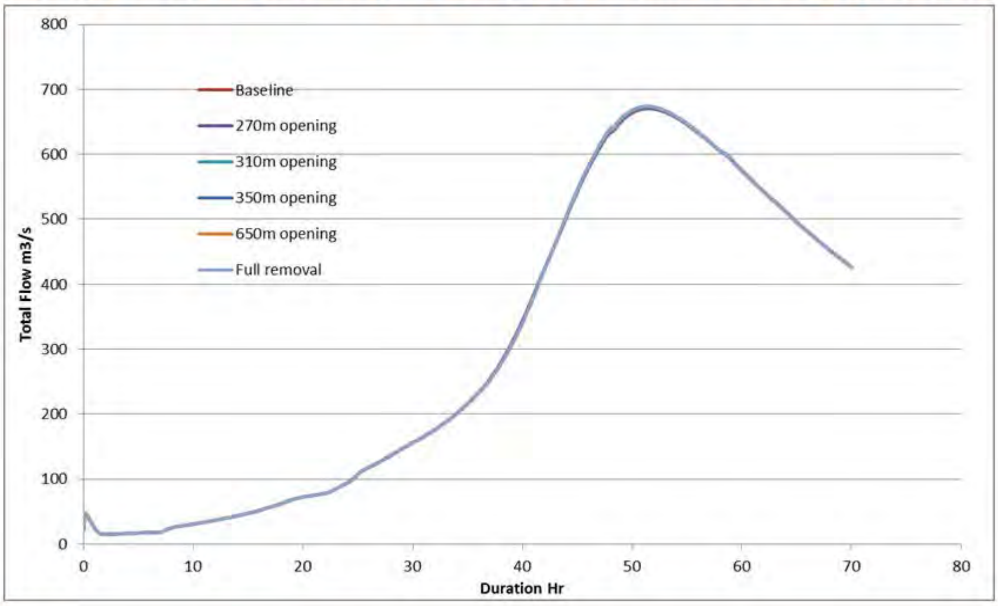
A9P09 – Spey Crossing Options & Flood Risk

Change in Flood Intensity – Peak Flow at Kinrara Gauging Station



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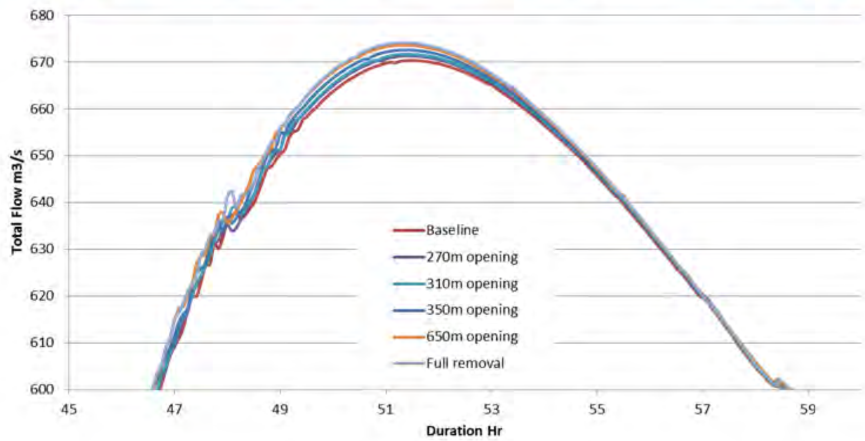
A9P09 – Spey Crossing Options & Flood Risk

Change in Flood Intensity – Peak Flow at Kinrara Gauging Station



Sccenario	Baseline	270m	310m	350m	650m	full removal
Peak Flow m3/s	670.4	671.4	671.7	672.6	673.7	674.2
relative change	0.00%	0.14%	0.20%	0.33%	0.49%	0.57%
Occurrence	51h30'	51h25'	51h25'	51h25'	51h20'	51h20'

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A9P09 – Spey Crossing Options & Flood Risk

- Post Meeting information -

Comparing predicted peak flows at Kinrara GS

The Spey Crossing design event is much larger than 200yr statistical peak flow at Kinrara GS due to concordant event intensity and duration throughout the contributing catchment.

Kinrara Gauging Station Statistical peak flow[(1)]	Spey Crossing assessment design flow			
200yr	200yr	20yr	**15yr**	10yr
409m^3/s	670m^3/s	432m^3/s	**405m^3/s**	366m^3/s

[(1)] Single Site analysis, WinFAP-FEH_v5 dataset + 2016 value

=> 200yr Statistical Peak flow at Kinrara GS equivalent to 15yr Spey Crossing design event.

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A9P09 – Spey Crossing Options & Flood Risk

- Post Meeting information -

Impact of proposed crossing for 15yr design event

(equivalent to 200yr Statistical peak flow at Kinrara GS)

Residential / Non-Residential Properties and Utilities

TYPE		Label	Flooding Threshold		Existing 15yr Conditions		270m opening	
			Value (mAOD)	Source	Water Level (mAOD)	Flood depth (mm)	Water Level mAOD	change (mm)
	RP	D-002	224.650	LiDAR DTM	*dry*	*dry*	*dry*	*n.a.*
	RP	D-003	224.700	LiDAR DTM	*dry*	*dry*	*dry*	*n.a.*
	NRP	NRes-001	224.500	LiDAR DTM	*dry*	*dry*	*dry*	*n.a.*
	RP	D-001	224.750	LiDAR DTM	*dry*	*dry*	*dry*	*n.a.*
	NRP	NRes-002	224.200	LiDAR DTM	224.171	-29	224.161	-10
	NRP	D-004	224.350	LiDAR DTM	*dry*	*dry*	*dry*	*n.a.*
	NRP	D-005	224.500	LiDAR DTM	*dry*	*dry*	*dry*	*n.a.*
B970	RP	D-006	224.610	LiDAR DTM	*dry*	*dry*	*dry*	*n.a.*
B970	UTIL	Util-001	223.000	LiDAR DTM	223.107	**107**	223.084	-23
	RP	D-007	223.600	LiDAR DTM	*dry*	*dry*	*dry*	*n.a.*
	RP	D-008	223.700	LiDAR DTM	*dry*	*dry*	*dry*	*n.a.*
A9	NRP	NRes-003	223.400	LiDAR DTM	*dry*	*dry*	*dry*	*n.a.*
A9	RP	D-009	222.460	Ground survey	222.210	-250	222.211	1
	RP	D-010	222.220	Ground survey	222.210	-10	222.211	1
	UTIL	Util-002	222.800	Ground survey	222.304	-496	222.304	0
	RP	D-013	221.640	Ground survey	222.012	**372**	222.012	0
	NRP	NRes-004	221.700	Ground survey	221.913	**213**	221.913	0
	UTIL	Util-003	223.010	Ground survey	221.858	-1152	221.859	1
	RP	D-014	222.700	Ground survey	221.777	-923	221.778	1
	UTIL	Util-004	222.250	Ground survey	221.771	-479	221.772	1
	RP	D-015	216.600	LiDAR DTM	216.663	**63**	216.663	0
	RP	D-016	212.200	LiDAR DTM	213.594	**1394**	213.594	0

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A9P09 – Spey Crossing Options & Flood Risk

- Post Meeting information -

Impact of proposed crossing for 15yr design event
(equivalent to 200yr Statistical peak flow at Kinrara GS)

Roads and Rail

Location	Flooding Threshold		Existing 15yr conditions		270m opening
	Value	Source	WL (mAOD)	Flood Depth (mm)	change (mm)
B970 at Ruthven Road	224.340	Ground survey	224.259	-81	-11
B970 at Gordon Hall Farm	223.200	Ground survey	222.675	-525	6
B9152 at Cemetery	223.140	Ground survey	222.533	-607	2
B9152 at Lynchart	221.960	Ground survey	222.225	265	1
B9152 at Highland Wildlife Park	221.820	Ground survey	221.908	88	0
B9152 at Dunachton	221.870	Ground survey	221.919	49	1
unclassified Road (Kincraig)	221.320	Ground survey	221.861	541	1
Highland Main Line	222.510	LiDAR	221.998	-512	0

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B.5 DMRB Stage 3 Tributary Crossing Models

B.5.1 Hydraulic modelling of certain tributaries to the River Spey was carried out to allow a quantitative assessment of flood risk resulting from high flows within these watercourses. The process as detailed below followed a systematic approach to the selection and modelling of tributaries of the River Spey to develop representative hydraulic models of each of the selected watercourses.

Screening Exercise

B.5.2 The hydrological assessment carried out identified 34 catchments draining to crossings under the A9 Mainline based on the existing situation. Of these 34 catchments, 16 were included within the hydraulic modelling. The basis for this selection is discussed in **Section 6** within the main body of the report.

B.5.3 The details of the “scoped in” crossings are included in **Table B5-1** below.

Table B5-1: Watercourse crossing ID138 model details (existing and proposed)

Crossing ID	Peak 200 year flow (m^3/s)	Reason for scoping in
ID138	4.21	>1.1m^3/s
ID142	0.74	Existing culvert is a constraint to the 200 year peak flow.
ID145	6.20	>1.1m^3/s
ID146	2.51	>1.1m^3/s
ID147	67.12	>1.1m^3/s
ID148	0.74	Existing culvert is a constraint to the 200 year peak flow.
ID155	2.53	>1.1m^3/s
ID156	0.25	Impacts model results for ID155 and ID157.
ID157	10.26	>1.1m^3/s
ID158	0.30	Impacts model results for ID155 and ID157.
ID159	3.06	>1.1m^3/s
ID160	0.05	Impacts model results for ID159 therefore has been included in ID159 flow.
ID161	0.35	Impacts model results for ID159.
ID162	29.82	>1.1m^3/s
ID166	0.70	Impacts model results for ID168.
ID168	3.63	>1.1m^3/s
ID170	4.84	>1.1m^3/s

Hydraulic Model Construction

B.5.4 The existing and proposed hydraulic models were built using industry standard 1D and 2D modelling packages. In all cases TUFLOW was used to represent the watercourse floodplains and overland flow routes in 2D and were applicable the channels were also modelled using 2D. Where representation of structures and/or channels was considered to be best carried out in 1D, Estry 1D and Floodmodeller 1D were used based on their strengths and weaknesses for given situations.

B.5.5 Two separate TUFLOW 2D solvers were used. The “Classic” solver was used were the gradients within the model were low and hence fast shallow flows were limited or unlikely to occur. The

"HPC" solver was used were gradients within the model were high and hence there was likely to be significant fast shallow flows which often cause instabilities when the "Classic" solver is used.

B.5.6 The base DTM for all of the models was Atkins/Scottish Water Phase 1 LiDAR. This has a 1m cell size and therefore picks up the topography well. For proposed model runs DTMs were produced using the proposed road, access track, SUDS and watercourse diversion CAD models which were read onto the base DTM to represent the effects of the proposed earthworks.

B.5.7 Appropriate Manning's roughness values were applied to both 1D and 2D components of the models based on values from literature.

B.5.8 The reaches modelled extend from an appropriate location upstream of the point the watercourse crosses the A9 Mainline to an appropriate location downstream of the crossing where changes in flood risk will be absorbed by the River Spey and will therefore have no further measurable impacts downstream.

B.5.9 2D model domains were extended such that "glass walling" would not occur. 2D grid sizes were selected based on the variation in topography with the DTM such that they would reasonably represent the topography within the model.

B.5.10 In general inflows were simplified to a triangular hydrograph with the same overall volume and peak flow as the FEH rainfall runoff method hydrograph used to establish the critical storm duration and peak flows for the watercourse. This simplification of the hydrograph is considered acceptable as due to the watercourses having limited floodplain storage the shape of the hydrograph has a negligible effect relative to the peak flow and total volume. The exceptions to this are the inflows for the two largest tributaries, MW 9.6 Inverton Burn and MW 9.14 Raitts Burn, draining to crossing IDs 147 and 162 respectively and for which the full hydrographs were applied to better represent the effect of the significant floodplain storage within these models.

B.5.11 For each model a table has been produced outlining the key aspects of the model in the existing and proposed cases and these are included below. The "Location Reference ID" relates to **Figures B5-1 to B5-20**.

Table B5-2: Watercourse crossing ID138 model details (existing and proposed)

Model Name	T138 (Existing)							
Build Type	2D with 1D (Estry) culverts			2D Solver | Time Step (s)		"Classic" | 0.5		
Catchment Inflows (Peak 200y Flow | Catchment Area)	ID138_2 (2.98m^3/s | 0.705km^2)			Grid Size		2m		
General 2D domain Manning's	0.08			Channel 2D domain Manning's		N/A		
1D Crossings Details								
Location Reference ID	Shape	Length (m)	Manning's	Upstream Invert (mAOD)	Downstream Invert (mAOD)	Diameter/Width (m)	Height (m)	No. Barrels
1a	C	56.0	0.013	259.30	254.80	1.200	N/A	1
1b	R	56.0	0.023	254.80	250.80	1.000	0.500	1
1c	R	56.0	0.023	254.80	250.80	0.800	0.500	1

Model Name	T138 (Proposed)							
Build Type	2D with 1D (Estry) culverts			2D Solver | Time Step (s)		"Classic" | 0.5		
Catchment Inflows (Peak 200y Flow | Catchment Area)	ID138_2 (2.98m^3/s | 0.705km^2)			Grid Size		2m		
General 2D domain Manning's	0.08			Channel 2D domain Manning's		N/A		
1D Crossings Details								
Location Reference ID	Shape	Length (m)	Manning's	Upstream Invert (mAOD)	Downstream Invert (mAOD)	Diameter/Width (m)	Height (m)	No. Barrels
1a	R	56.0	0.013	262.15	254.80	1.375	1.000	1
1b	R	56.0	0.023	254.80	250.80	1.000	0.500	1
1c	R	56.0	0.023	254.80	250.80	0.800	0.500	1

Other Notes	Assumptions have been made about the culvert in the existing and proposed cases. It is not known how the culvert under the A9 Mainline ties in with the culvert under the Highland Mainline therefore it has been assumed that they meet and connect half way along the total length between the inlet upstream of the A9 and the outlet downstream of the Highland Mainline.

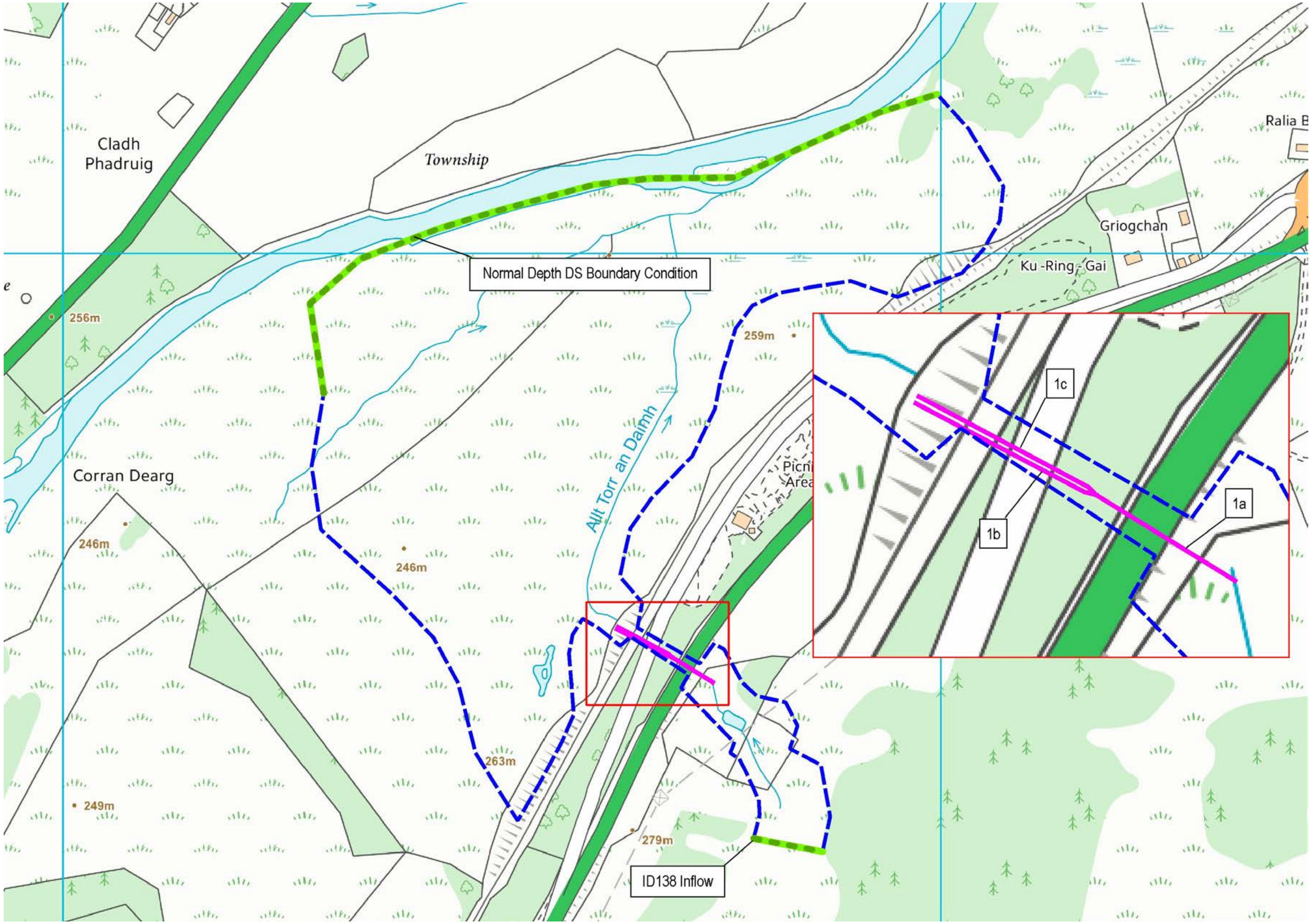

Figure B5-1: Existing Model Layout, ID138

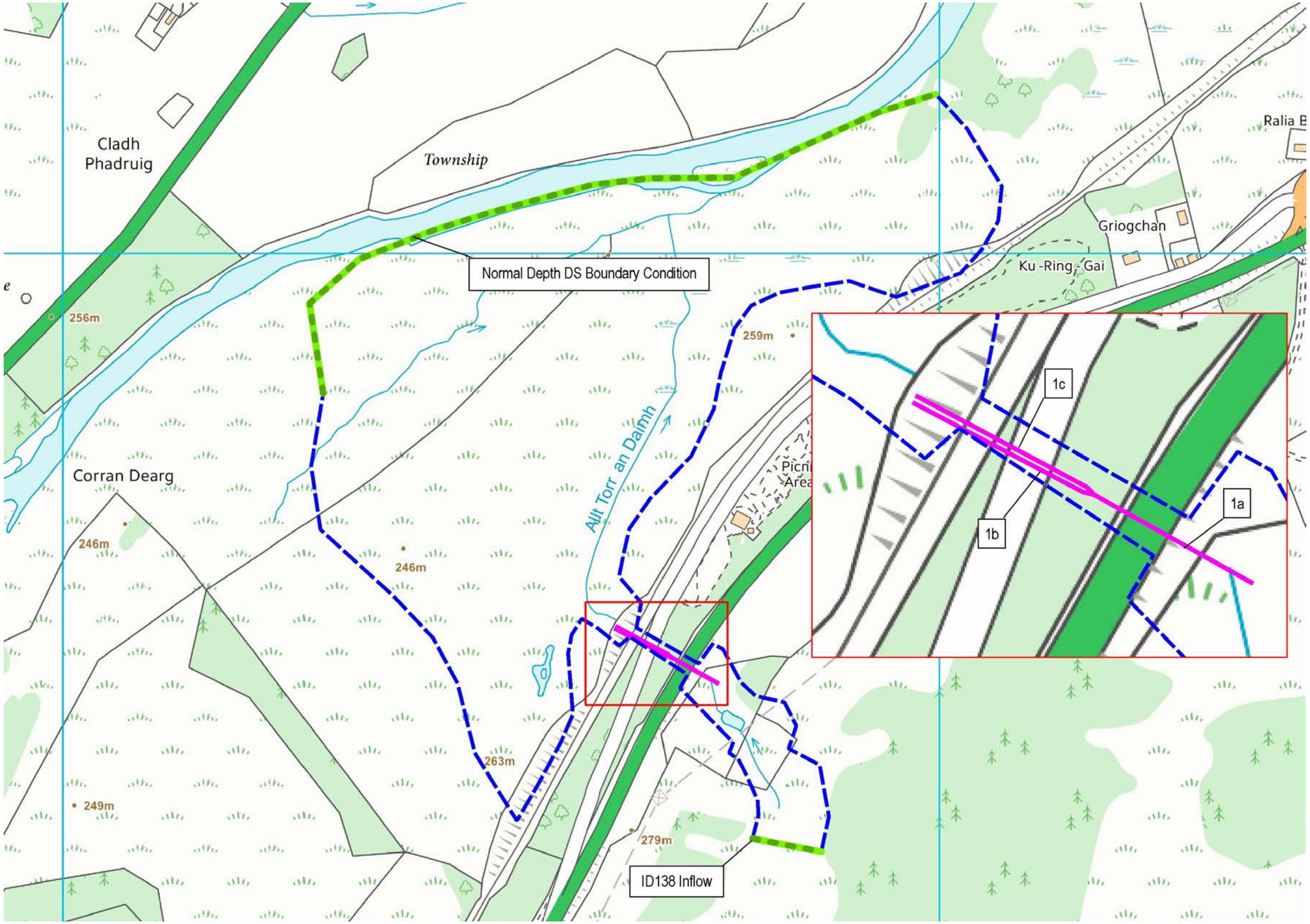

Figure B5-2: Proposed Model Layout, ID138

Table B5-3: Watercourse crossing ID142 model details (existing and proposed)

Model Name	**T142 (Existing)**							
Build Type	**2D with 1D (Estry) culverts**			**2D Solver | Time Step (s)**		**"Classic" | 0.5**		
Catchment Inflows (Peak 200y Flow | Catchment Area)	**ID142 (0.74m^3/s | 0.328km^2)**			**Grid Size**		**1m**		
General 2D domain Manning's	**0.08**			**Channel 2D domain Manning's**		**N/A**		
1D Crossings Details								
Location Reference ID	**Shape**	**Length (m)**	**Manning's**	**Upstream Invert (mAOD)**	**Downstream Invert (mAOD)**	**Diameter/Width (m)**	**Height (m)**	**No. Barrels**
2	**C**	**35.0**	**0.040**	**264.70**	**259.02**	**0.675**	**N/A**	**1**
3	**C**	**15.0**	**0.040**	**253.87**	**253.18**	**0.400**	**N/A**	**1**

Model Name	**T142 (Proposed)**							
Build Type	**2D with 1D (Estry) culverts**			**2D Solver | Time Step (s)**		**"Classic" | 0.5**		
Catchment Inflows (Peak 200y Flow | Catchment Area)	**ID142 (0.74m^3/s | 0.328km^2)**			**Grid Size**		**1m**		
General 2D domain Manning's	**0.08**			**Channel 2D domain Manning's**		**N/A**		
1D Crossings Details								
Location Reference ID	**Shape**	**Length (m)**	**Manning's**	**Upstream Invert (mAOD)**	**Downstream Invert (mAOD)**	**Diameter/Width (m)**	**Height (m)**	**No. Barrels**
2	**C**	**52.1**	**0.022**	**258.88**	**258.37**	**1.200**	**N/A**	**1**
3	**C**	**15.0**	**0.040**	**253.87**	**253.18**	**0.400**	**N/A**	**1**

Other Notes	**N/A**

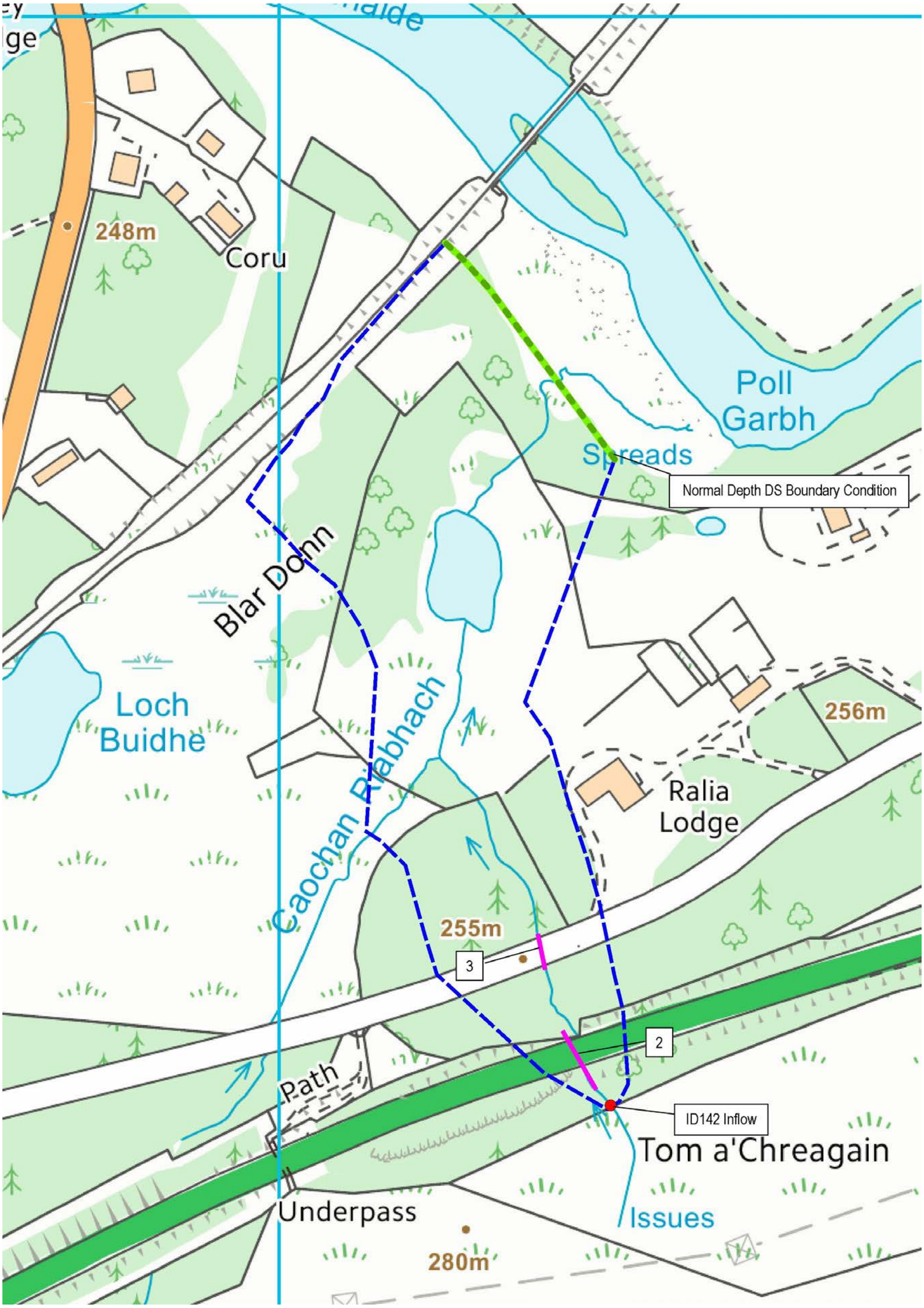

Figure B5-3: Existing Model Layout, ID142

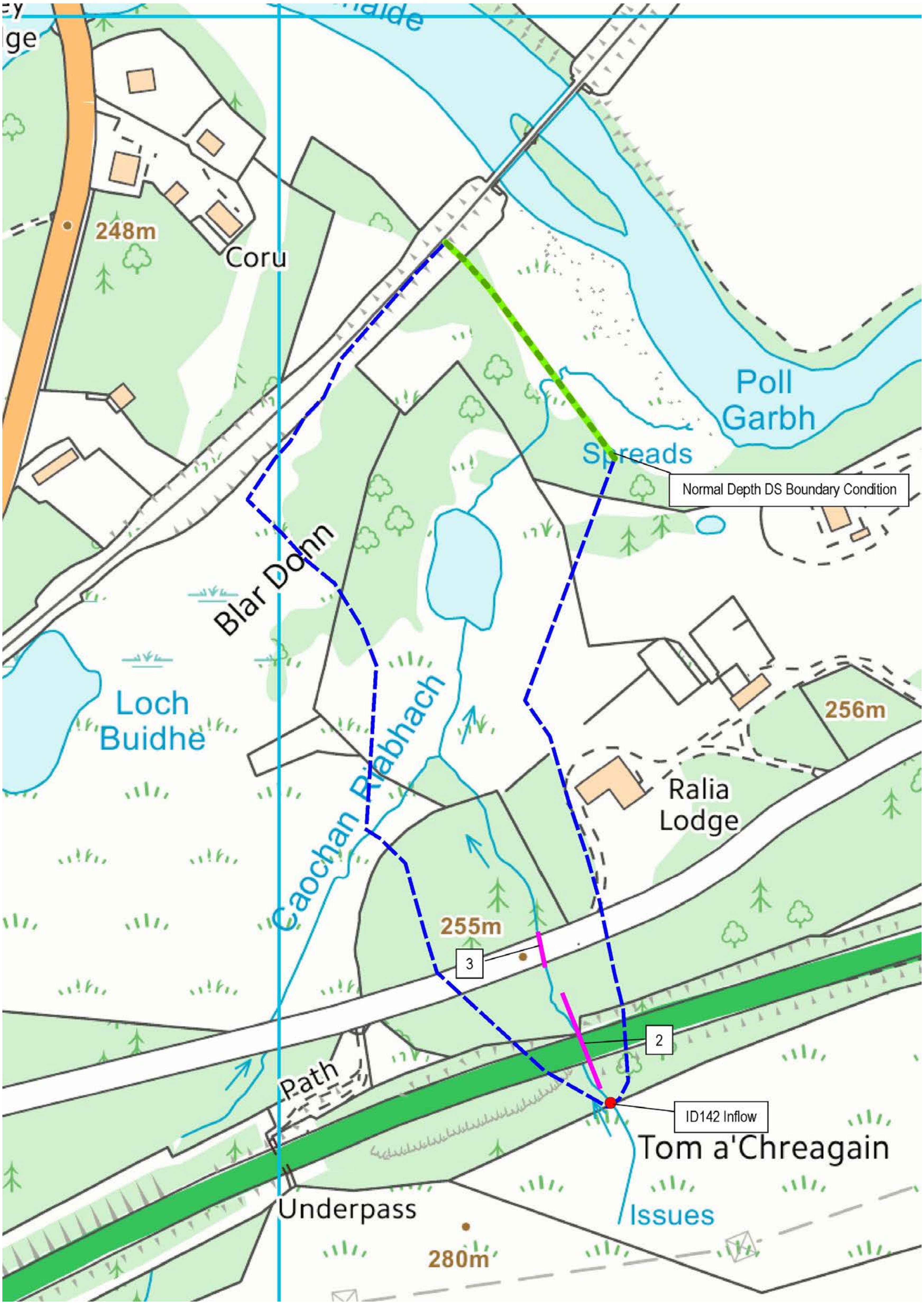

Figure B5-4: Proposed Model Layout, ID142

Table B5-4: Watercourse crossings ID145 and ID146 model details (existing and proposed)

Model Name	**T145 (Existing)**							
Build Type	**2D with 1D (Estry) culverts**				**2D Solver | Time Step (s)**		**"Classic" | 0.5**	
Catchment Inflows (Peak 200y Flow | Catchment Area)	**ID145 (6.20m^3/s | 2.161km^2) ID146 (2.51m^3/s | 0.603km^2)**				**Grid Size**		**2m**	
General 2D domain Manning's	**0.08**				**Channel 2D domain Manning's**		**N/A**	
1D Crossings Details								
Location Reference ID	**Shape**	**Length (m)**	**Manning's**	**Upstream Invert (mAOD)**	**Downstream Invert (mAOD)**	**Diameter/Width (m)**	**Height (m)**	**No. Barrels**
4a	**C**	**46.0**	**0.025**	**243.21**	**240.67**	**1.700**	**N/A**	**1**
5	**R**	**10.0**	**0.040**	**233.75**	**233.40**	**2.950**	**1.350**	**1**
6	**C**	**74.0**	**0.011**	**233.61**	**230.86**	**0.500**	**N/A**	**1**
7	**C**	**25.0**	**0.027**	**237.80**	**237.80**	**2.000**	**N/A**	**1**
8	**C**	**14.0**	**0.011**	**229.05**	**228.93**	**0.450**	**N/A**	**1**
9	**C**	**10.0**	**0.011**	**227.89**	**227.82**	**0.900**	**N/A**	**1**
10	**R**	**7.5**	**0.100**	**227.75**	**227.68**	**1.500**	**1.000**	**1**

Model Name	**T145 (Proposed)**							
Build Type	**2D with 1D (Estry) culverts**				**2D Solver | Time Step (s)**		**"Classic" | 0.5**	
Catchment Inflows (Peak 200y Flow | Catchment Area)	**ID145 (6.20m^3/s | 2.161km^2) ID146 (2.51m^3/s | 0.603km^2)**				**Grid Size**		**2m**	
General 2D domain Manning's	**0.08**				**Channel 2D domain Manning's**		**N/A**	
1D Crossings Details								
Location Reference ID	**Shape**	**Length (m)**	**Manning's**	**Upstream Invert (mAOD)**	**Downstream Invert (mAOD)**	**Diameter/Width (m)**	**Height (m)**	**No. Barrels**
4a	**R**	**37.0**	**0.022**	**246.10**	**245.73**	**3.300**	**1.500**	**1**
4b	**R**	**16.5**	**0.022**	**248.79**	**248.50**	**3.300**	**1.500**	**1**
5	**R**	**10.0**	**0.040**	**233.75**	**233.40**	**2.950**	**1.350**	**1**
6	**R**	**72.6**	**0.022**	**236.27**	**233.37**	**1.500**	**1.500**	**1**
8	**C**	**14.0**	**0.011**	**229.05**	**228.93**	**0.450**	**N/A**	**1**
9	**C**	**10.0**	**0.011**	**227.89**	**227.82**	**0.900**	**N/A**	**1**
10	**R**	**7.5**	**0.100**	**227.75**	**227.68**	**1.500**	**1.000**	**1**

Other Notes	**In the 100 and 200 year return periods there is an inflow from the River Spey floodplain where it flows overland round the farm buildings at Nuide. At lower return periods this does not exist. It has been included as a constant inflow to provide a conservative approach to the modelling.**

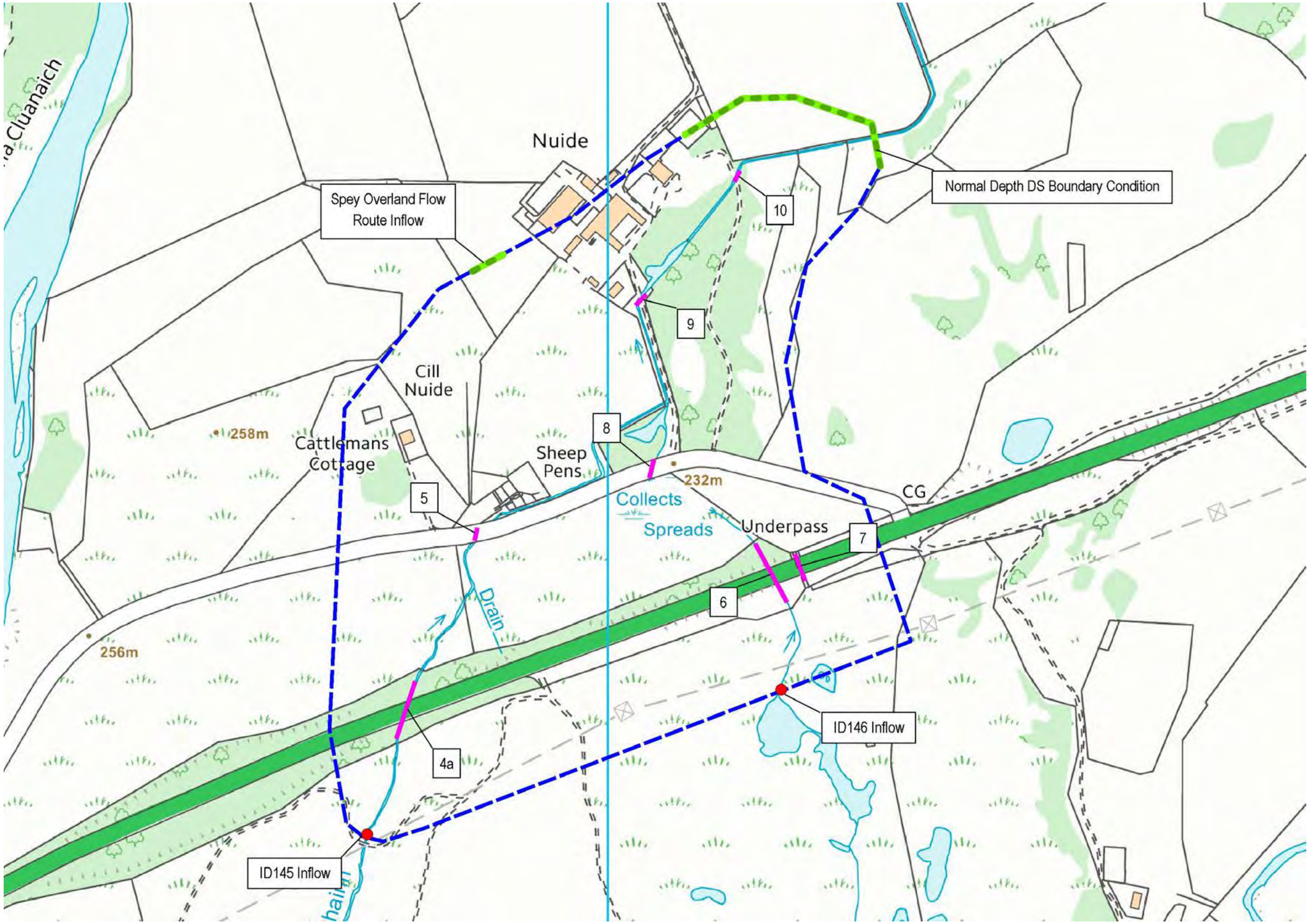

Figure B5-5: Existing Model Layout, ID145 and ID146

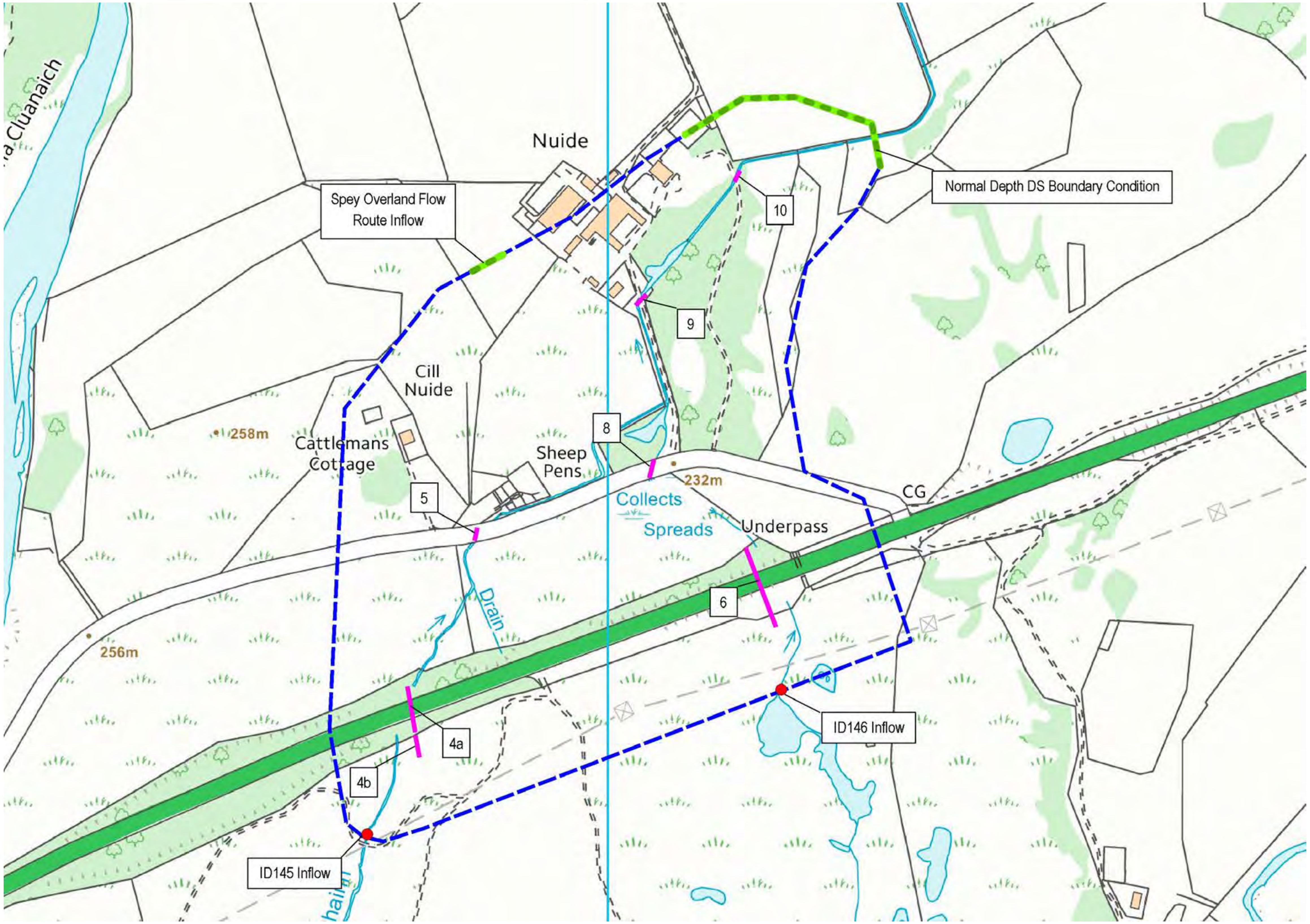

Figure B5-6: Proposed Model Layout, ID145 and ID146

Table B5-5: Watercourse crossing ID147 model details (existing and proposed)

Model Name	**T147 (Existing)**							
Build Type	**2D with 1D (Estry) culverts**				**2D Solver | Time Step (s)**		**"HPC" | N/A**	
Catchment Inflows (Peak 200y Flow | Catchment Area)	**ID147 (67.17m³/s | 34.451km²)**				**Grid Size**		**1.5m**	
General 2D domain Manning's	**0.08**				**Channel 2D domain Manning's**		**0.045**	
1D Crossings Details								
Location Reference ID	**Shape**	**Length (m)**	**Manning's**	**Upstream Invert (mAOD)**	**Downstream Invert (mAOD)**	**Diameter/Width (m)**	**Height (m)**	**No. Barrels**
11a	**I**	**53.1**	**Varies**	**226.04**	**225.98**	**Varies**	**Varies**	**1**
11b	**I**	**53.1**	**Varies**	**226.04**	**225.99**	**Varies**	**Varies**	**1**
11c	**I**	**53.1**	**Varies**	**226.99**	**227.12**	**Varies**	**Varies**	**1**
12	**R**	**7.7**	**0.022**	**225.23**	**225.23**	**5.000**	**2.000**	**1**

Model Name	**T147 (Proposed)**							
Build Type	**2D with 1D (Estry) culverts**				**2D Solver | Time Step (s)**		**"HPC" | N/A**	
Catchment Inflows (Peak 200y Flow | Catchment Area)	**ID147 (67.17m³/s | 34.451km²)**				**Grid Size**		**1.5m**	
General 2D domain Manning's	**0.08**				**Channel 2D domain Manning's**		**0.045**	
1D Crossings Details								
Location Reference ID	**Shape**	**Length (m)**	**Manning's**	**Upstream Invert (mAOD)**	**Downstream Invert (mAOD)**	**Diameter/Width (m)**	**Height (m)**	**No. Barrels**
11a	**R**	**56.0**	**0.022**	**226.01**	**225.91**	**4.200**	**3.600**	**1**
11c	**R**	**56.0**	**0.022**	**226.01**	**225.91**	**4.200**	**3.600**	**1**
12	**R**	**7.7**	**0.022**	**225.23**	**225.23**	**5.000**	**2.000**	**1**

Other Notes	**The DTM within the river channel has been "cleaned" with a ZSH line to remove artificial blockages.**

Note: Extensive modelling tests were carried out to inform the final recommended crossing size. Details of this are presented in **sub section B.6** below.

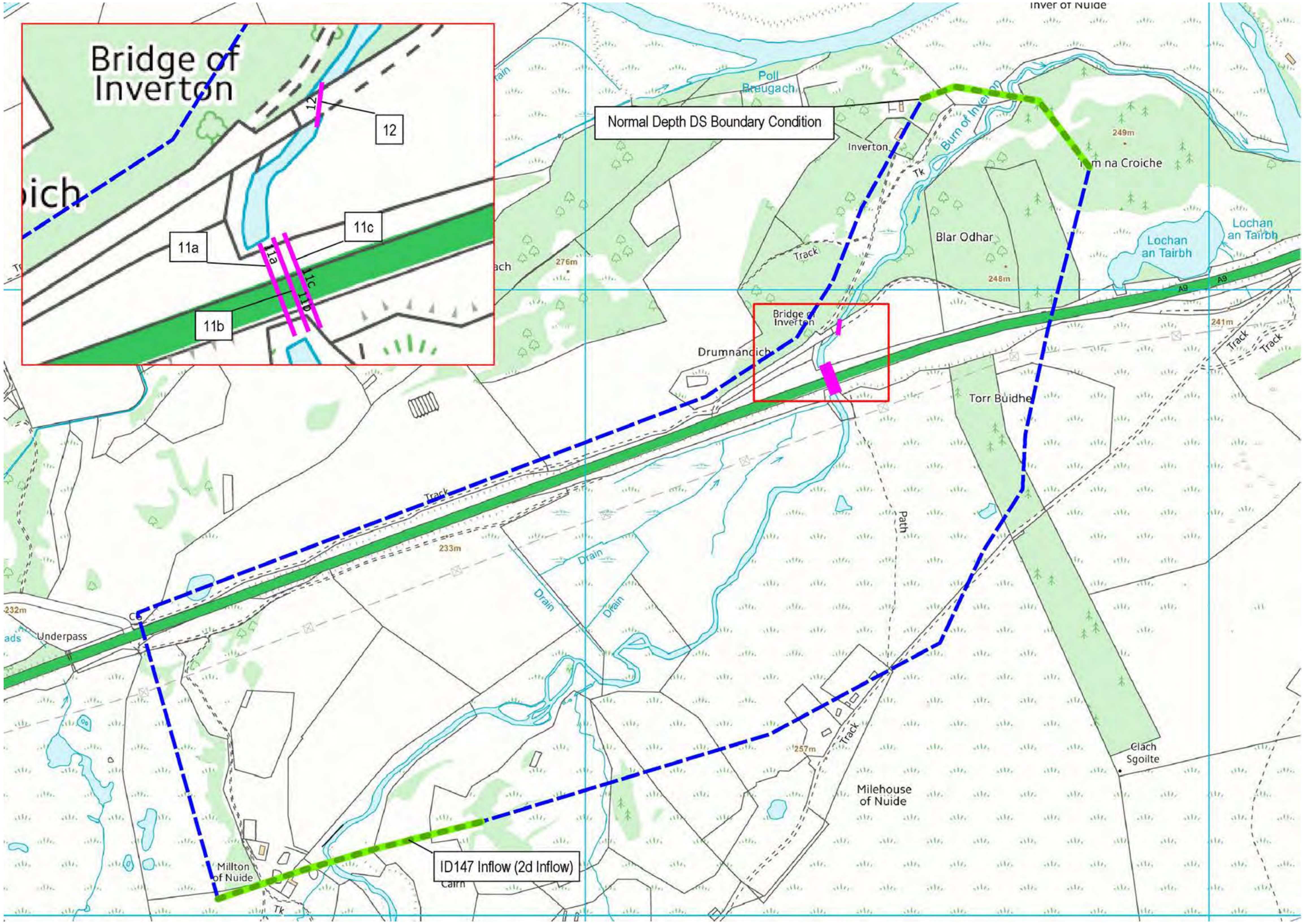

Figure B5-7: Existing Model Layout, ID147

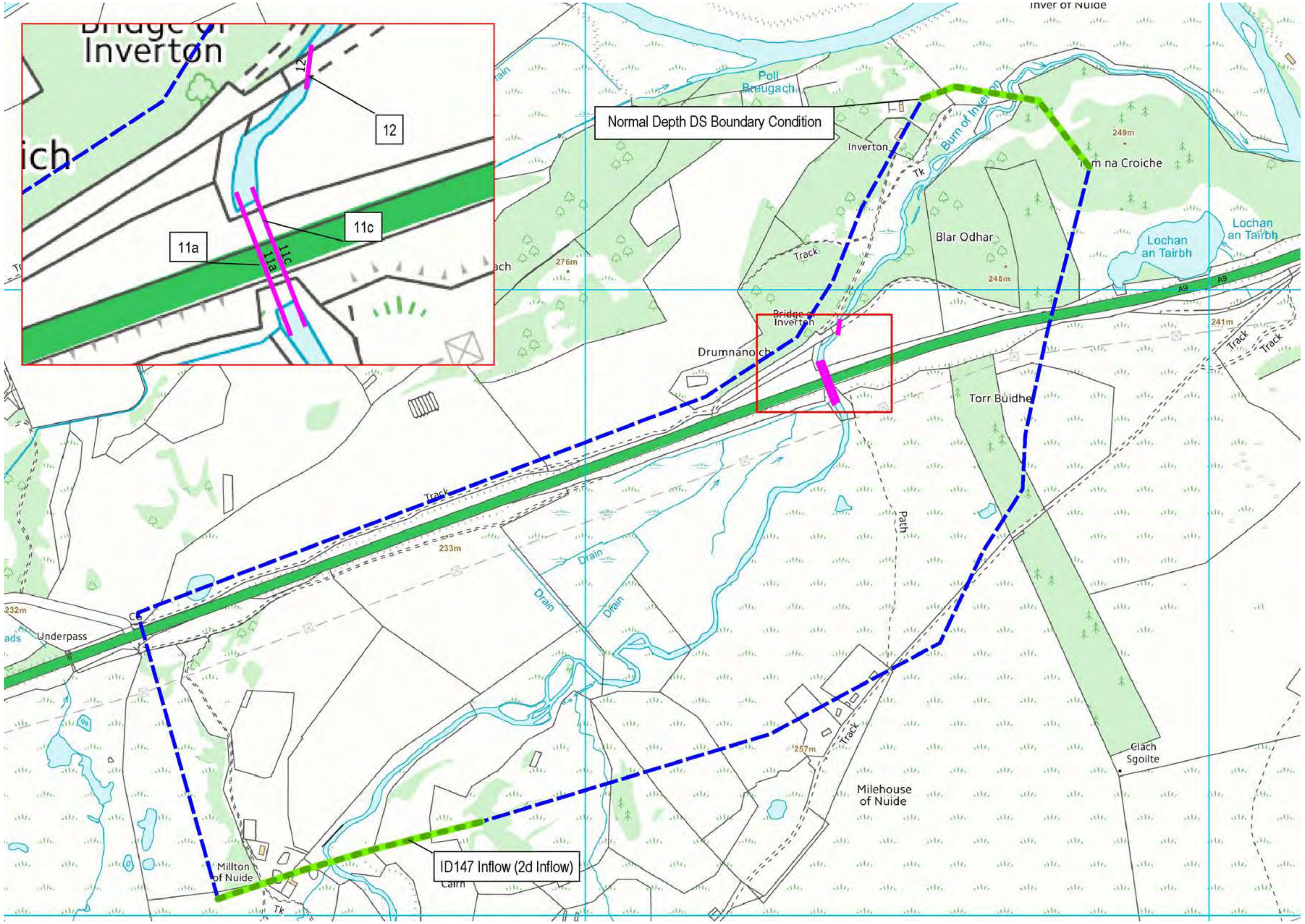

Figure B5-8: Proposed Model Layout, ID147

Table B5-6: Watercourse crossing ID148 model details (existing and proposed)

Model Name	T148 (Existing)							
Build Type	2D with 1D (Estry) culverts			2D Solver | Time Step (s)		“Classic” | 0.5		
Catchment Inflows (Peak 200y Flow | Catchment Area)	ID148 (67.17m³/s | 34.451km²)			Grid Size		2m		
General 2D domain Manning’s	0.08			Channel 2D domain Manning’s		N/A		
1D Crossings Details								
Location Reference ID	Shape	Length (m)	Manning’s	Upstream Invert (mAOD)	Downstream Invert (mAOD)	Diameter/Width (m)	Height (m)	No. Barrels
13	C	35.3	0.022	237.55	235.14	0.400	N/A	1

Model Name	T148 (Proposed)							
Build Type	2D with 1D (Estry) culverts			2D Solver | Time Step (s)		“Classic” | 0.5		
Catchment Inflows (Peak 200y Flow | Catchment Area)	ID148 (67.17m³/s | 34.451km²)			Grid Size		2m		
General 2D domain Manning’s	0.08			Channel 2D domain Manning’s		N/A		
1D Crossings Details								
Location Reference ID	Shape	Length (m)	Manning’s	Upstream Invert (mAOD)	Downstream Invert (mAOD)	Diameter/Width (m)	Height (m)	No. Barrels
13	C	39.7	0.022	238.48	237.04	1.200	N/A	1

Other Notes	The loch (Lochan an Tairbh) has no formal outflow therefore it is assumed to have no outflow for the purpose of the modelling to provide a conservative approach to the assessment.

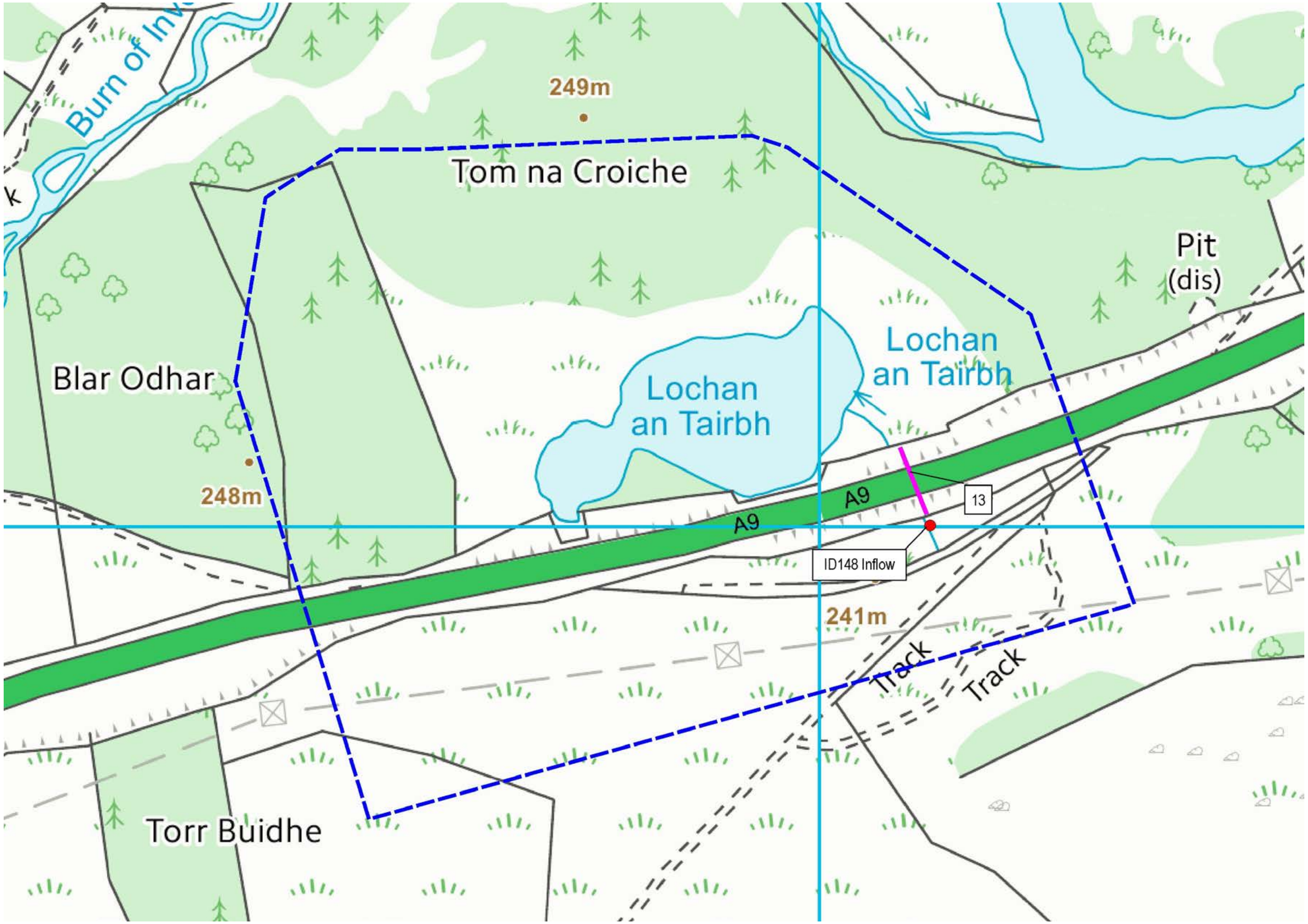

Figure B5-9: Existing Model Layout, ID148

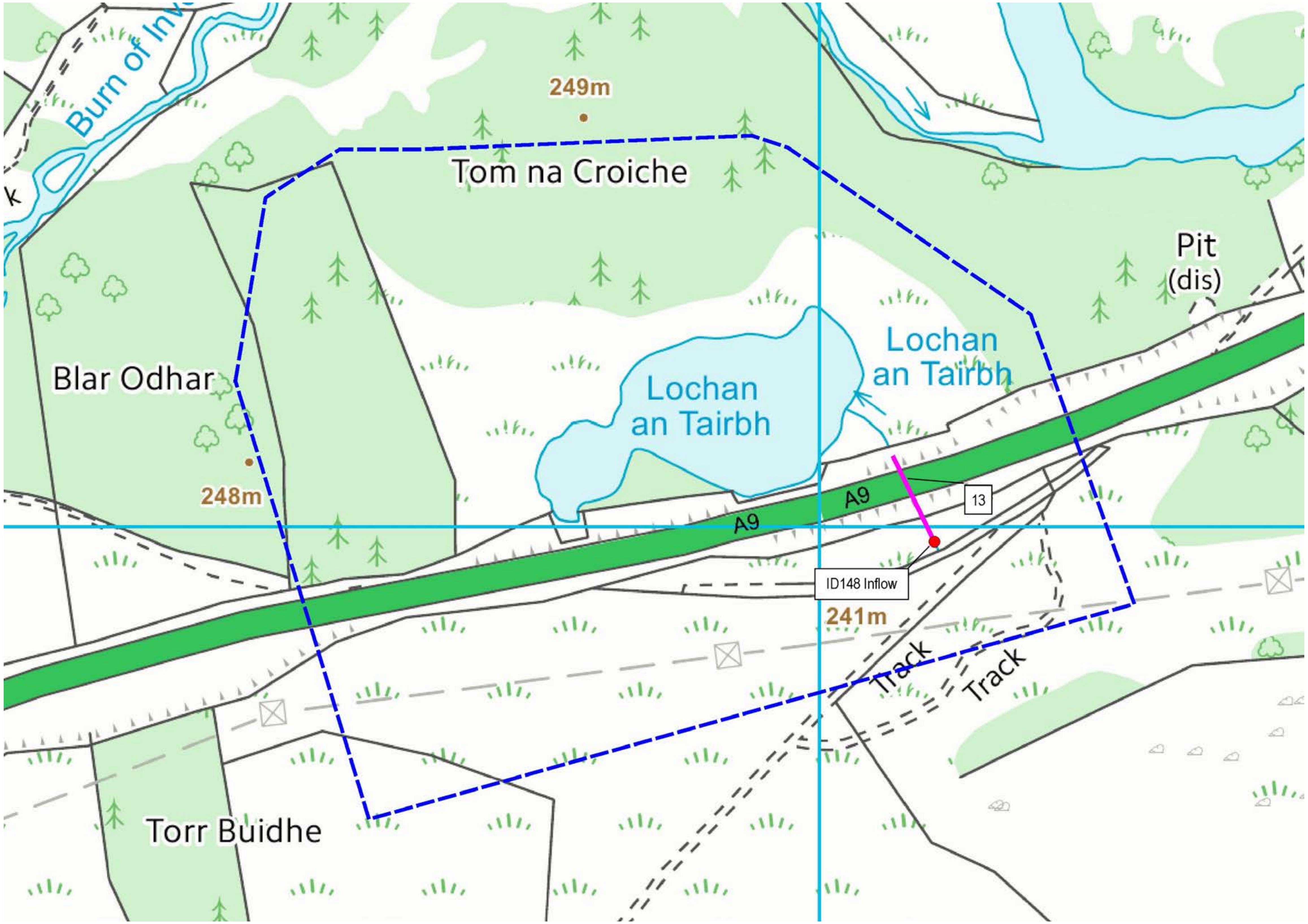

Figure B5-10: Proposed Model Layout, ID148

Table B5-7: Watercourse crossings ID155, ID156, ID157 and ID158 model details (existing and proposed)

Model Name	T155 (Existing)		
Build Type	2D with 1D (Estry) culverts	2D Solver | Time Step (s)	"Classic" | 0.2
Catchment Inflows (Peak 200y Flow | Catchment Area)	ID155 (2.53m^3/s | 0.587km^2) ID156 (0.25m^3/s | 0.118km^2) ID156 (10.26m^3/s | 3.043km^2) ID156 (0.30m^3/s | 0.150km^2)	Grid Size	2m
General 2D domain Manning's	0.08	Channel 2D domain Manning's	N/A

1D Crossings Details

Location Reference ID	Shape	Length (m)	Manning's	Upstream Invert (mAOD)	Downstream Invert (mAOD)	Diameter/Width (m)	Height (m)	No. Barrels
14	C	6.5	0.014	230.50	230.38	0.400	N/A	1
16	C	25.0	0.011	227.04	226.96	1.200	N/A	1
17	C	21.8	0.011	223.50	223.10	0.900	N/A	1
18	R	22.8	0.070	222.20	221.90	1.500	0.500	1
19	C	22.0	0.011	221.40	221.30	0.400	N/A	1
20a	C	9.0	0.019	228.67	228.55	0.900	N/A	1
20b	C	9.0	0.016	228.55	228.43	0.700	N/A	1
21	C	7.0	0.019	227.40	227.21	0.800	N/A	1
22	C	36.0	0.020	227.60	226.00	1.200	N/A	1
23	R	29.0	0.027	219.92	219.78	3.130	1.740	1
24	C	59.0	0.019	225.54	222.92	0.900	N/A	1

Model Name	T155 (Proposed)		
Build Type	2D with 1D (Estry) culverts	2D Solver | Time Step (s)	"Classic" | 0.2
Catchment Inflows (Peak 200y Flow | Catchment Area)	ID155 (2.53m^3/s | 0.587km^2) ID156 (0.25m^3/s | 0.118km^2) ID156 (10.26m^3/s | 3.043km^2) ID156 (0.30m^3/s | 0.150km^2)	Grid Size	2m
General 2D domain Manning's	0.08	Channel 2D domain Manning's	N/A

1D Crossings Details

Location Reference ID	Shape	Length (m)	Manning's	Upstream Invert (mAOD)	Downstream Invert (mAOD)	Diameter/Width (m)	Height (m)	No. Barrels
15	R	7.0	0.014	227.10	227.09	2.4	1.500	1
16	R	46.7	0.011	227.08	226.63	2.4	1.500	1
16a	C	18.0	0.011	225.47	225.18	0.9	N/A	3
17	C	21.8	0.011	223.50	223.10	0.9	N/A	1
18	R	22.8	0.070	222.20	221.90	1.5	0.500	1
19	C	22.0	0.011	221.40	221.30	0.4	N/A	1
20a	C	46.2	0.016	227.99	226.76	1.076	N/A	1
22	R	60.6	0.020	227.90	225.47	3.3	2.100	1
23	R	29.0	0.027	219.92	219.78	3.13	1.740	1
24	C	65.4	0.019	227.69	226.81	1.076	N/A	1

Other Notes	Two additional inflows with catchments smaller than 0.5 km^2 were added as they directly affect the flood risk relating to the larger watercourses.

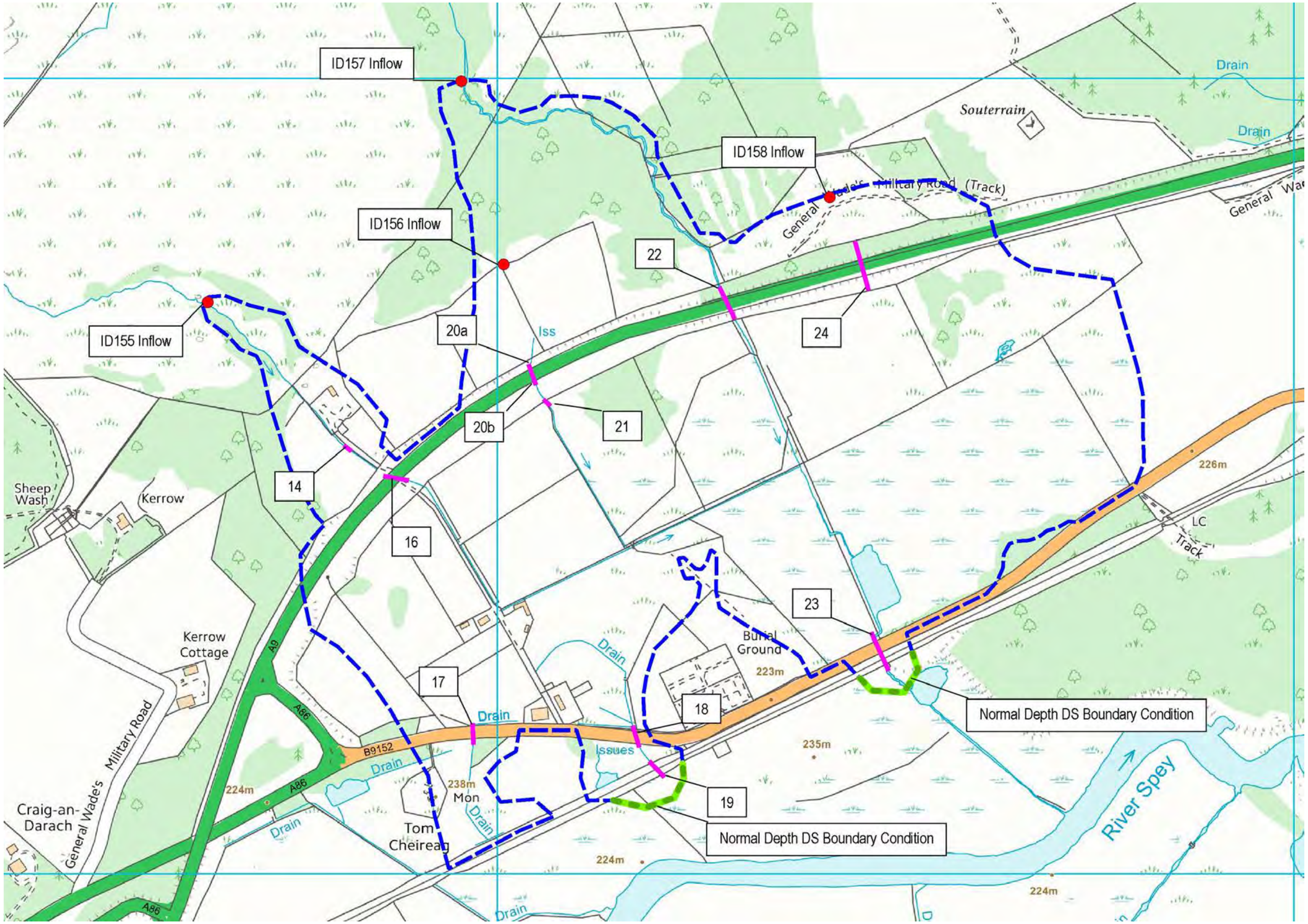

Figure B5-11: Existing Model Layout, ID155 and ID156

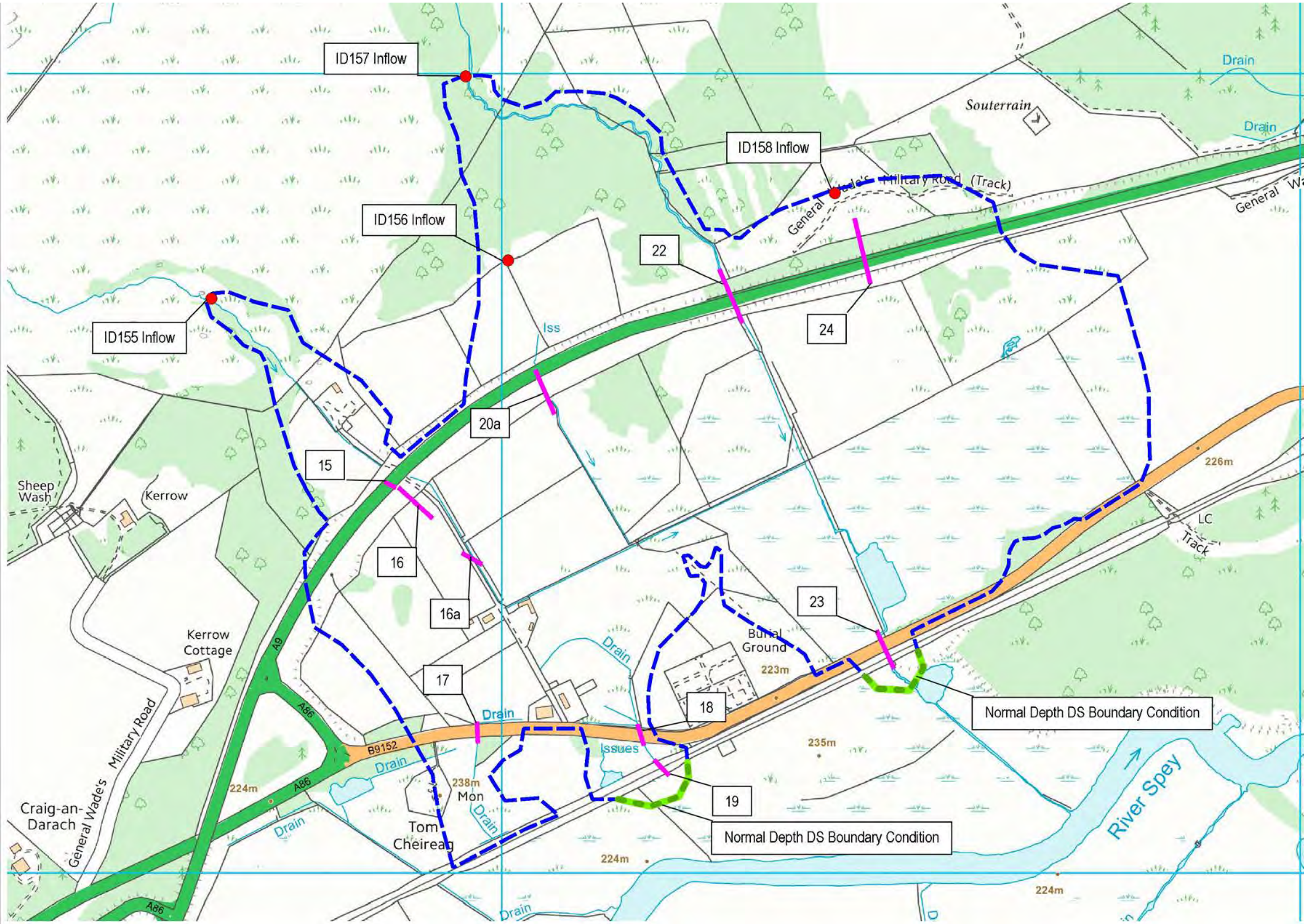

Figure B5-12: Proposed Model Layout, ID155 and ID156

Table B5-8: Watercourse crossings ID159 and ID161 model details (existing and proposed)

Model Name	**T159 (Existing)**							
Build Type	**2D with 1D (Estry) culverts**				**2D Solver | Time Step (s)**		**"HPC" | N/A**	
Catchment Inflows (Peak 200y Flow | Catchment Area)	**ID159 ($3.11m^3/s$ | $0.737km^2$) ID161 ($0.35m^3/s$ | $0.145km^2$)**				**Grid Size**		**1m**	
General 2D domain Manning's	**0.08**				**Channel 2D domain Manning's**		**N/A**	
1D Crossings Details								
Location Reference ID	**Shape**	**Length (m)**	**Manning's**	**Upstream Invert (mAOD)**	**Downstream Invert (mAOD)**	**Diameter/Width (m)**	**Height (m)**	**No. Barrels**
25	**C**	**13.2**	**0.022**	**235.60**	**235.17**	**0.600**	**N/A**	**1**
26	**C**	**70.6**	**0.022**	**233.28**	**227.59**	**1.100**	**N/A**	**1**
27	**R**	**28.0**	**0.022**	**228.04**	**226.40**	**3.000**	**3.000**	**1**
28	**C**	**76.1**	**0.022**	**225.78**	**222.77**	**0.700**	**N/A**	**1**
29	**C**	**137.6**	**0.022**	**227.98**	**222.77**	**0.900**	**N/A**	**1**
30	**C**	**108.9**	**0.022**	**222.77**	**221.00**	**0.600**	**N/A**	**2**
31	**R**	**5.5**	**0.027**	**220.88**	**220.90**	**3.090**	**3.050**	**1**

Model Name	**T159 (Proposed)**							
Build Type	**2D with 1D (Estry) culverts**				**2D Solver | Time Step (s)**		**"HPC" | N/A**	
Catchment Inflows (Peak 200y Flow | Catchment Area)	**ID159 ($3.11m^3/s$ | $0.737km^2$) ID161 ($0.35m^3/s$ | $0.145km^2$)**				**Grid Size**		**1m**	
General 2D domain Manning's	**0.08**				**Channel 2D domain Manning's**		**N/A**	
1D Crossings Details								
Location Reference ID	**Shape**	**Length (m)**	**Manning's**	**Upstream Invert (mAOD)**	**Downstream Invert (mAOD)**	**Diameter/Width (m)**	**Height (m)**	**No. Barrels**
26	**R**	**51.2**	**0.022**	**231.44**	**229.40**	**2.400**	**1.500**	**1**
26a	**R**	**9.3**	**0.022**	**236.45**	**236.15**	**2.400**	**1.500**	**1**
28	**C**	**76.1**	**0.022**	**225.78**	**222.77**	**0.700**	**N/A**	**1**
30	**C**	**108.9**	**0.022**	**222.77**	**221.00**	**0.600**	**N/A**	**2**
29a	**C**	**16.1**	**0.022**	**226.54**	**226.41**	**1.389**	**N/A**	**1**
29	**C**	**50.9**	**0.022**	**224.97**	**224.46**	**1.389**	**N/A**	**1**
29b	**C**	**8.5**	**0.022**	**222.10**	**222.02**	**1.389**	**N/A**	**1**
29c	**C**	**9.3**	**0.022**	**220.15**	**220.06**	**0.900**	**N/A**	**1**
29d	**C**	**25.3**	**0.022**	**219.70**	**221.00**	**0.900**	**N/A**	**1**
31	**R**	**5.5**	**0.027**	**220.88**	**220.90**	**3.090**	**3.050**	**1**

Other Notes	**One additional inflow with a catchment smaller than 0.5 km^2 were added as it directly affects the flood risk relating to the larger watercourse. The catchment for ID160 was amalgamated with the catchment from ID159 rather having a discrete inflow.**

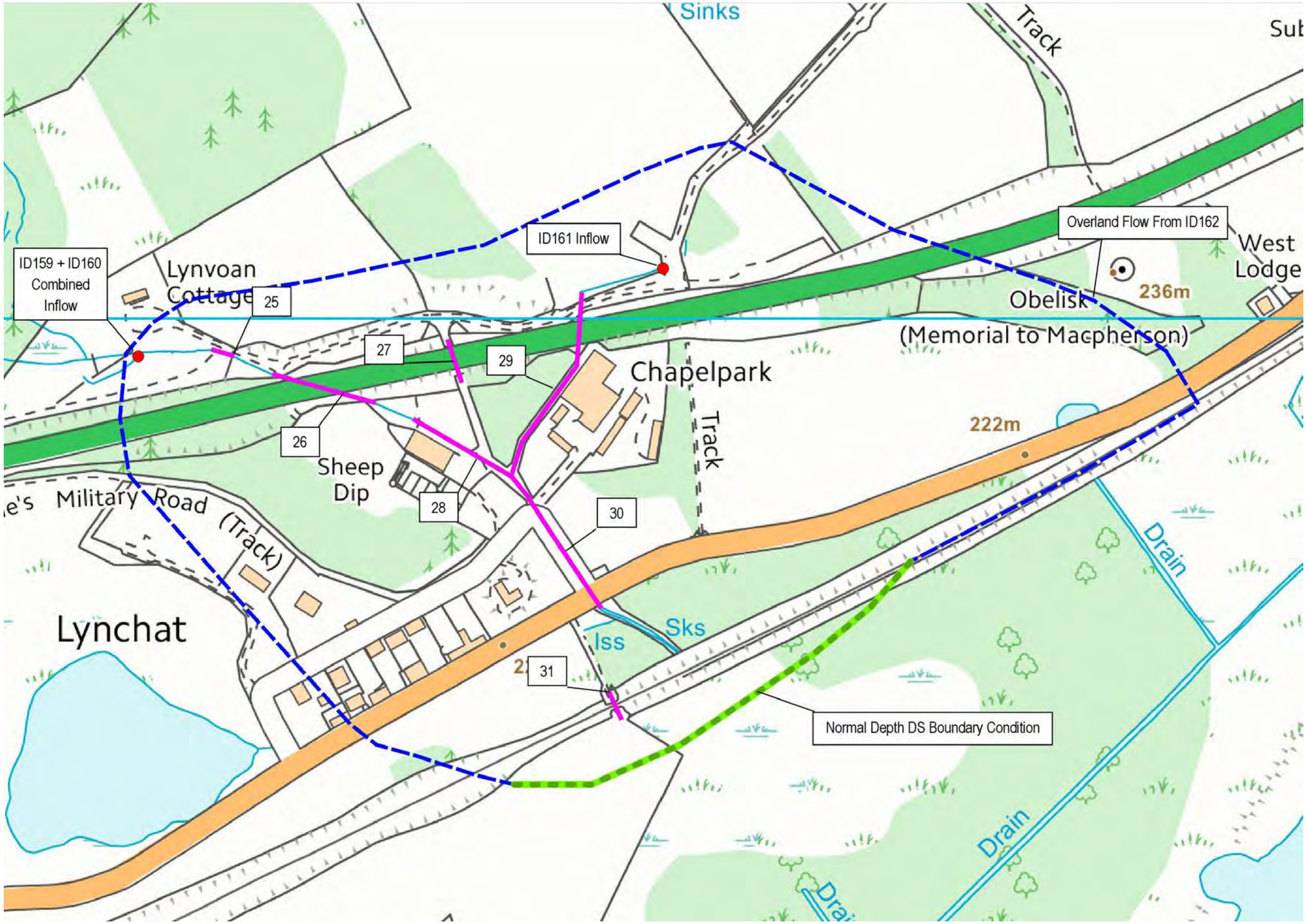

Figure B5-13: Existing Model Layout, ID159 and ID161

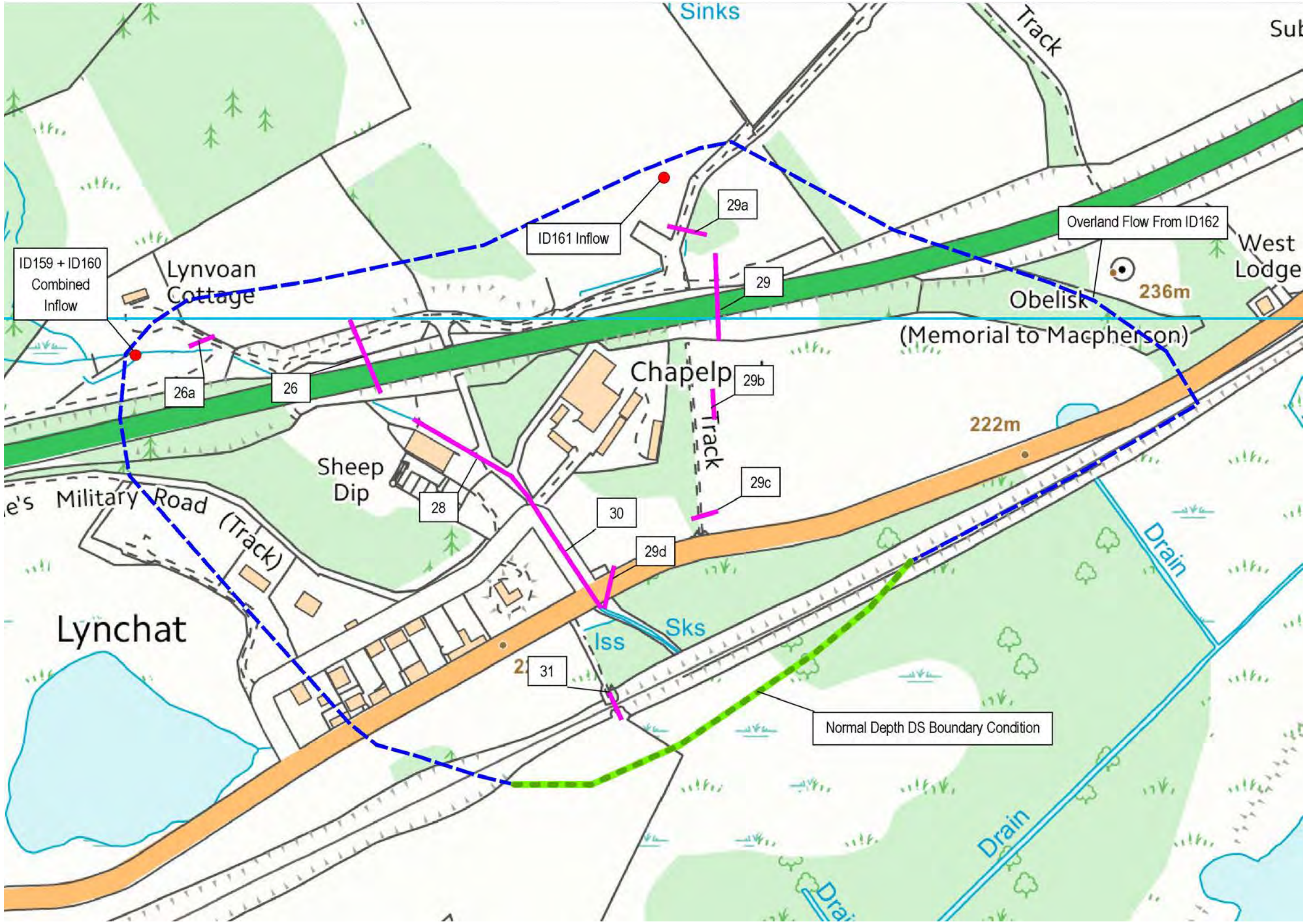

Figure B5-14: Proposed Model Layout, ID159 and ID161

Table B5-9: Watercourse crossing ID162 model details (existing and proposed)

Model Name	T162 (Existing)							
Build Type	2D with 1D (Floodmodeller) Channels and Structures			2D Solver | Time Step (s)		"Classic" | 0.5		
Catchment Inflows (Peak 200y Flow | Catchment Area)	ID162 (29.82m^3/s | 12.639km^2)			Grid Size		1m		
General 2D domain Manning's	0.08			Channel 2D domain Manning's		N/A		
1D Crossings Details								
Location Reference ID	Shape	Length (m)	Manning's	Upstream Invert (mAOD)	Downstream Invert (mAOD)	Diameter/Width (m)	Height (m)	No. Barrels
32	FM Bridge	15.2	Varies	225.01	224.80	8.000	2.180	1
33	FM Bridge	10.7	Varies	223.09	222.70	8.540	0.760	1
34	FM Bridge	15.8	Varies	222.52	222.62	6.460	1.090	1
31	R	5.5	0.027	220.88	220.90	3.090	3.050	1

Model Name	T162 (Proposed)							
Build Type	2D with 1D (Floodmodeller) Channels and Structures			2D Solver | Time Step (s)		"Classic" | 0.5		
Catchment Inflows (Peak 200y Flow | Catchment Area)	ID162 (29.82m^3/s | 12.639km^2)			Grid Size		1m		
General 2D domain Manning's	0.08			Channel 2D domain Manning's		N/A		
1D Crossings Details								
Location Reference ID	Shape	Length (m)	Manning's	Upstream Invert (mAOD)	Downstream Invert (mAOD)	Diameter/Width (m)	Height (m)	No. Barrels
32	FM Bridge	43.8	Varies	225.2	224.80	8.000	2.530	1
33	FM Bridge	10.7	Varies	223.09	222.70	8.540	0.760	1
34	FM Bridge	15.8	Varies	222.52	222.62	6.460	1.090	1
29b	C	8.5	0.022	222.10	222.02	1.389	N/A	1
29c	C	9.3	0.022	220.15	220.06	0.900	N/A	1
29d	C	25.3	0.022	219.70	221.00	0.900	N/A	1
31	R	5.5	0.027	220.88	220.90	3.090	3.050	1

Other Notes	1D Floodmodeller channel and structures linked to 2D TUFLOW floodplain. 1D cross sections are based on a mixture of surveyed cross sections and cross sections extracted from LiDAR.

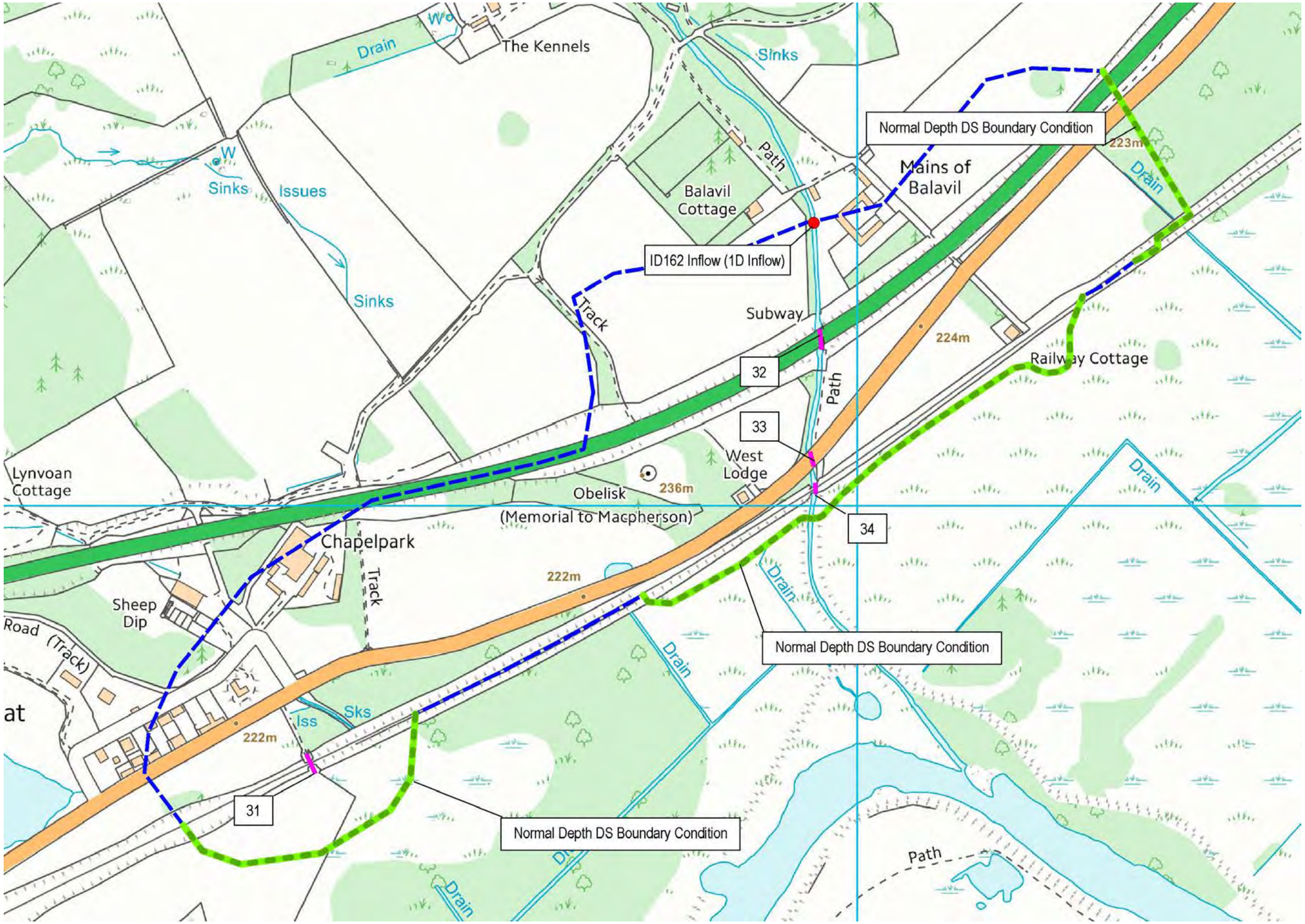

Figure B5-15: Existing Model Layout, ID162

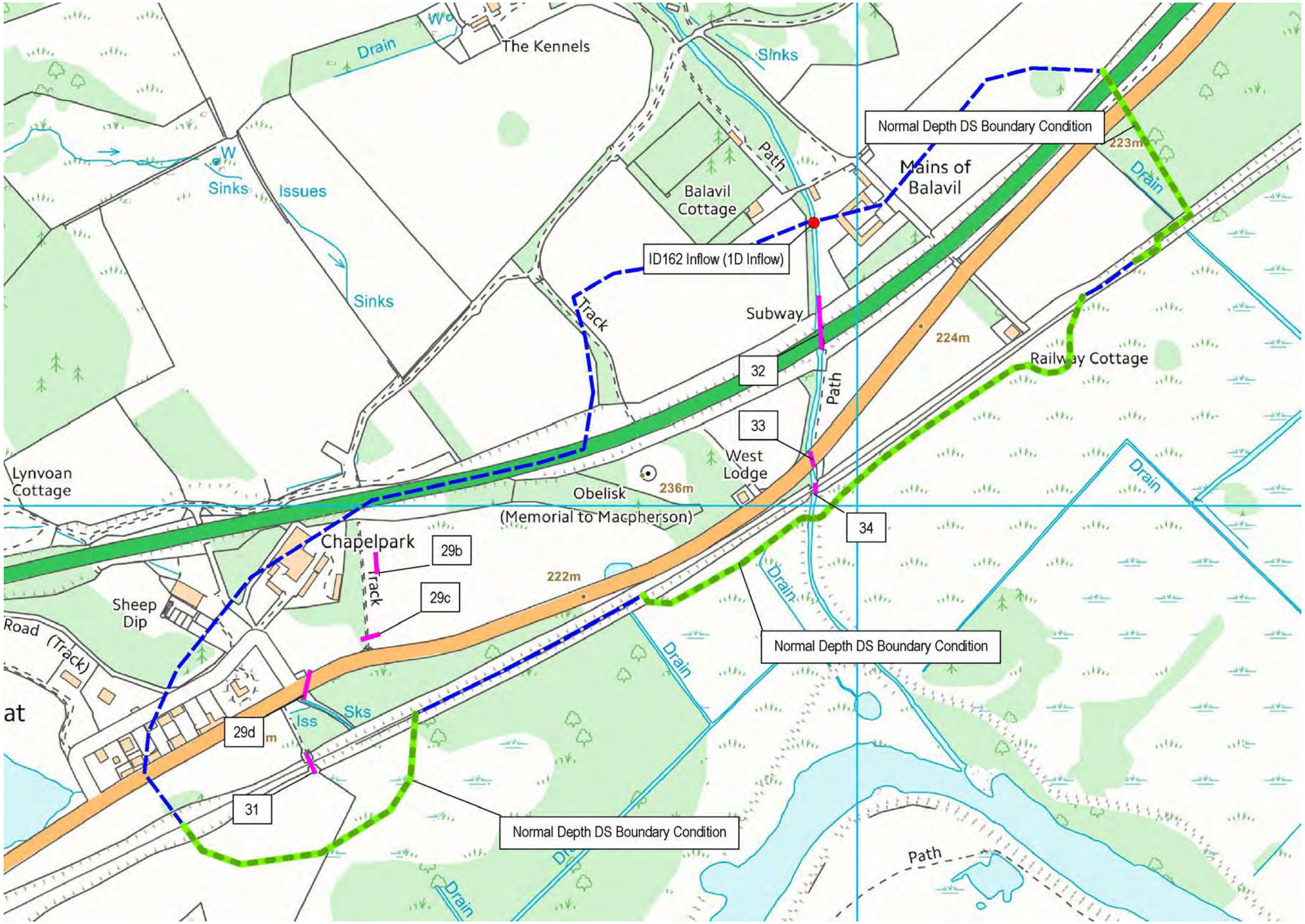

Figure B5-16: Proposed Model Layout, ID162

Table B5-10: Watercourse crossings ID166 and ID168 model details (existing and proposed)

Model Name	T168 (Existing)		
Build Type	2D with 1D (Estry) culverts	2D Solver | Time Step (s)	"HPC" | N/A
Catchment Inflows (Peak 200y Flow | Catchment Area)	ID166 (0.70m^3/s | 0.422km^2) ID168 (3.63m^3/s | 0.881km^2)	Grid Size	1m
General 2D domain Manning's	0.08	Channel 2D domain Manning's	N/A

1D Crossings Details

Location Reference ID	Shape	Length (m)	Manning's	Upstream Invert (mAOD)	Downstream Invert (mAOD)	Diameter/Width (m)	Height (m)	No. Barrels
36	C	49.5	0.022	243.43	240.19	0.900	N/A	1
37	C	12.0	0.022	222.86	221.87	0.600	N/A	1
38	C	22.6	0.022	247.20	247.05	0.600	N/A	1
39	C	25.1	0.022	245.88	244.92	0.900	N/A	1
40	C	53.3	0.022	242.04	228.12	0.900	N/A	1
41	C	13.5	0.022	221.81	220.81	0.159	N/A	2
42	C	7.2	0.022	220.49	220.48	0.380	N/A	2

Model Name	T168 (Proposed)		
Build Type	2D with 1D (Estry) culverts	2D Solver | Time Step (s)	"HPC" | N/A
Catchment Inflows (Peak 200y Flow | Catchment Area)	ID166 (0.70m^3/s | 0.422km^2) ID168 (3.63m^3/s | 0.881km^2)	Grid Size	1m
General 2D domain Manning's	0.08	Channel 2D domain Manning's	N/A

1D Crossings Details

Location Reference ID	Shape	Length (m)	Manning's	Upstream Invert (mAOD)	Downstream Invert (mAOD)	Diameter/Width (m)	Height (m)	No. Barrels
35	R	22.5	0.022	244.57	244.53	1.200	1.200	1
36	R	38.4	0.022	244.32	242.79	1.200	1.200	1
37	C	12.0	0.022	223.97	221.87	0.600	N/A	1
38	C	22.6	0.022	247.20	247.05	0.600	N/A	1
40	R	51.2	0.022	240.81	240.22	2.400	1.500	1
41	R	17.5	0.022	220.51	219.75	2.400	1.500	1
42	C	7.2	0.022	220.49	220.48	0.380	N/A	2

Other Notes	One additional inflow with a catchment smaller than 0.5km^2 were added as it directly affects the flood risk relating to the larger watercourse.

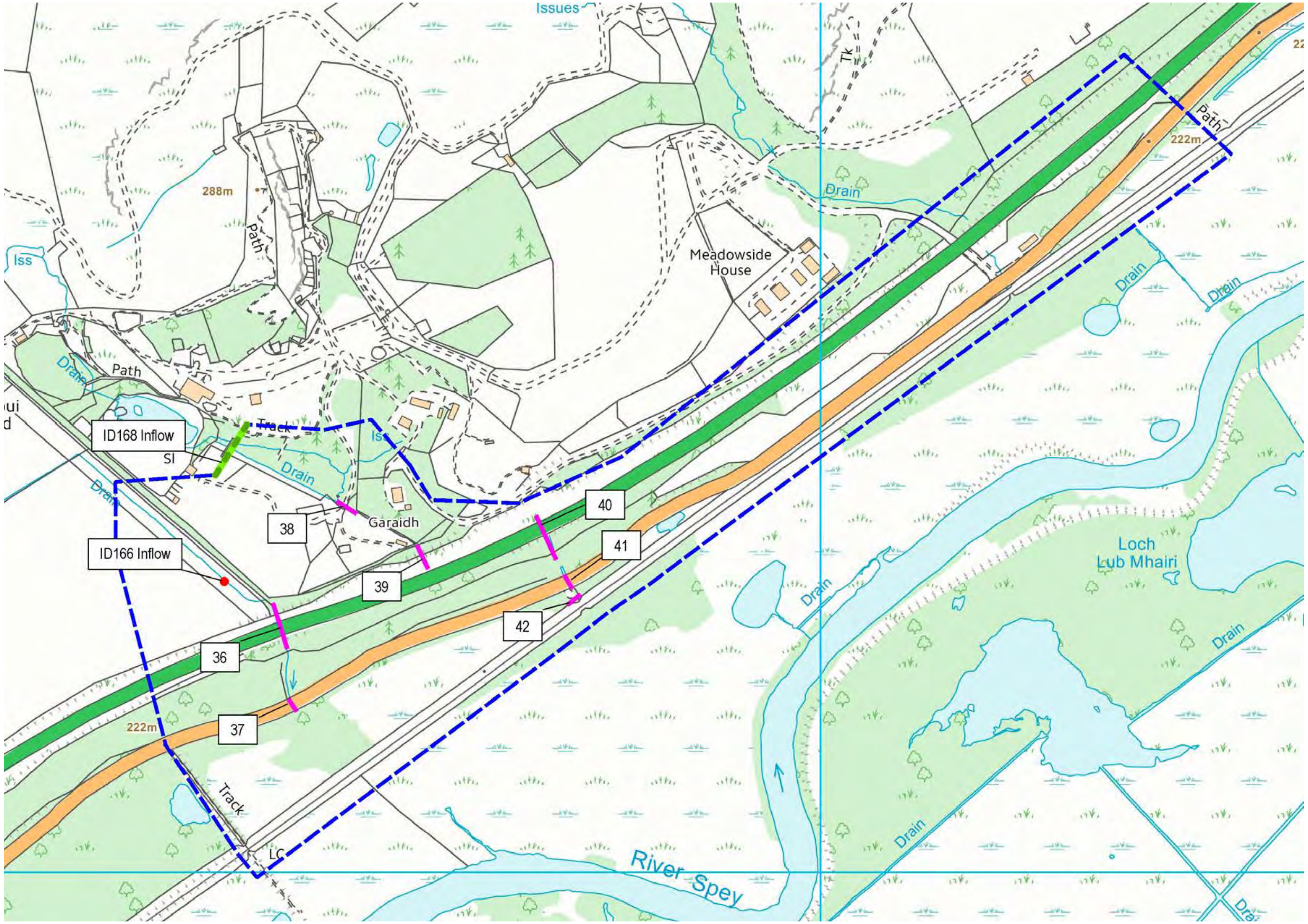

Figure B5-17: Existing Model Layout, ID166 and ID168

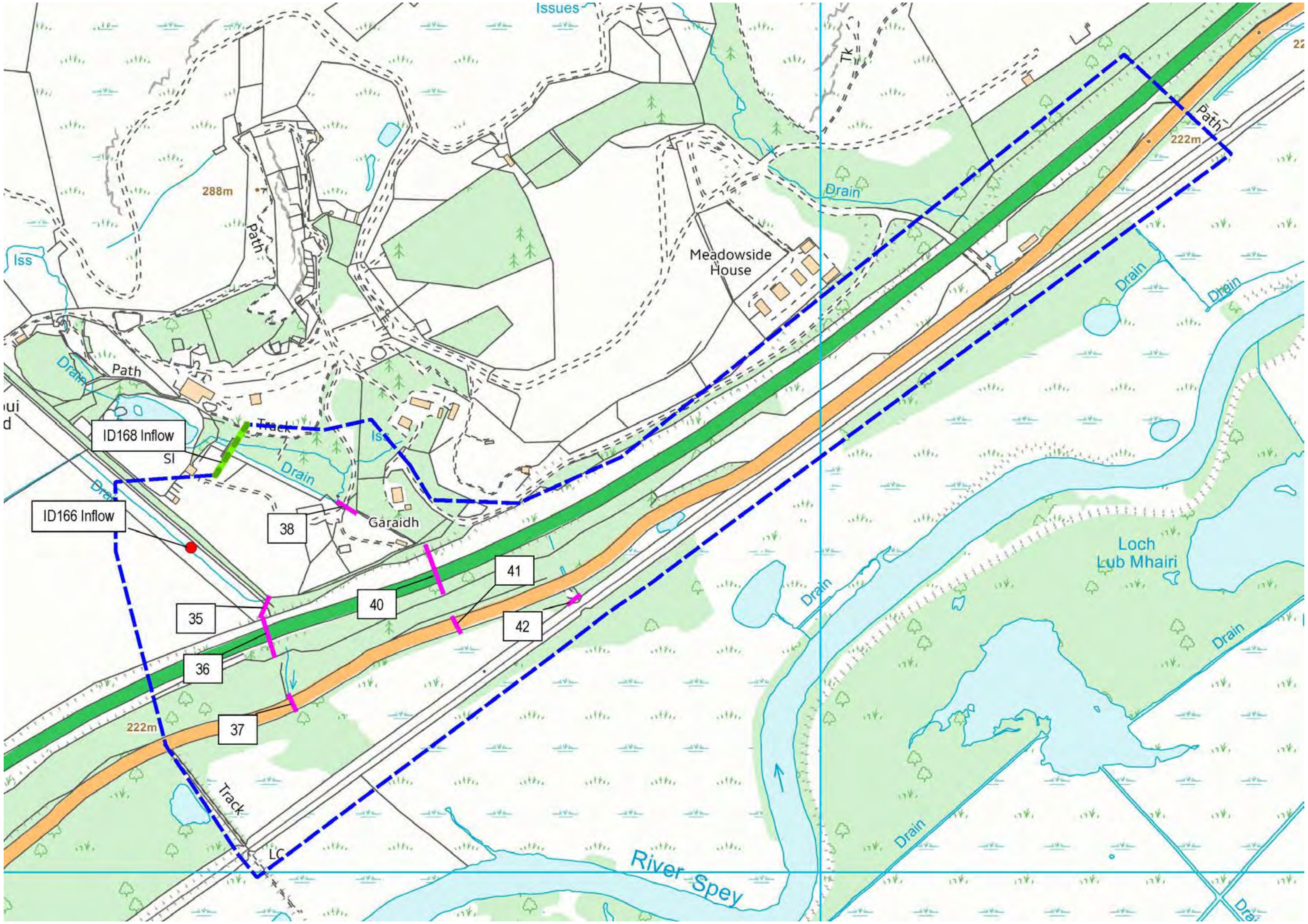

Figure B5-18: Proposed Model Layout, ID166 and ID168

Table B5-11: Watercourse crossings ID170 model details (existing and proposed)

Model Name	T170 (Existing)							
Build Type	2D with 1D (Estry) culverts			2D Solver | Time Step (s)		"HPC" | N/A		
Catchment Inflows (Peak 200y Flow | Catchment Area)	ID170 (4.84m³/s | 1.424km²)			Grid Size		1m		
General 2D domain Manning's	0.08			Channel 2D domain Manning's		N/A		
1D Crossings Details								
Location Reference ID	Shape	Length (m)	Manning's	Upstream Invert (mAOD)	Downstream Invert (mAOD)	Diameter/Width (m)	Height (m)	No. Barrels
43	C	45.0	0.011	224.75	222.75	1.200	N/A	1
44a	R	7.0	0.036	221.25	221.00	1.100	0.300	2
44b	C	7.0	0.011	221.00	220.75	0.450	N/A	2
45	C	15.0	0.011	220.75	220.70	0.750	N/A	1

Model Name	T170 (Proposed)							
Build Type	2D with 1D (Estry) culverts			2D Solver | Time Step (s)		"HPC" | N/A		
Catchment Inflows (Peak 200y Flow | Catchment Area)	ID170 (4.84m³/s | 1.424km²)			Grid Size		1m		
General 2D domain Manning's	0.08			Channel 2D domain Manning's		N/A		
1D Crossings Details								
Location Reference ID	Shape	Length (m)	Manning's	Upstream Invert (mAOD)	Downstream Invert (mAOD)	Diameter/Width (m)	Height (m)	No. Barrels
43	C	70.1	0.022	224.64	223.99	1.327	N/A	1
44a	R	7.0	0.036	221.25	221.00	1.100	0.300	2
44b	C	7.0	0.011	221.00	220.75	0.450	N/A	2
45	C	15.0	0.011	220.75	220.70	0.750	N/A	1

Other Notes	An overland flow route from crossing ID168 is implemented based on the hydrograph from a PO line in the T168 model. Upstream and downstream of crossing ID170 the channel is poorly picked up by LiDAR therefore it has been cleaned up using a ZSH line and ZSH points.

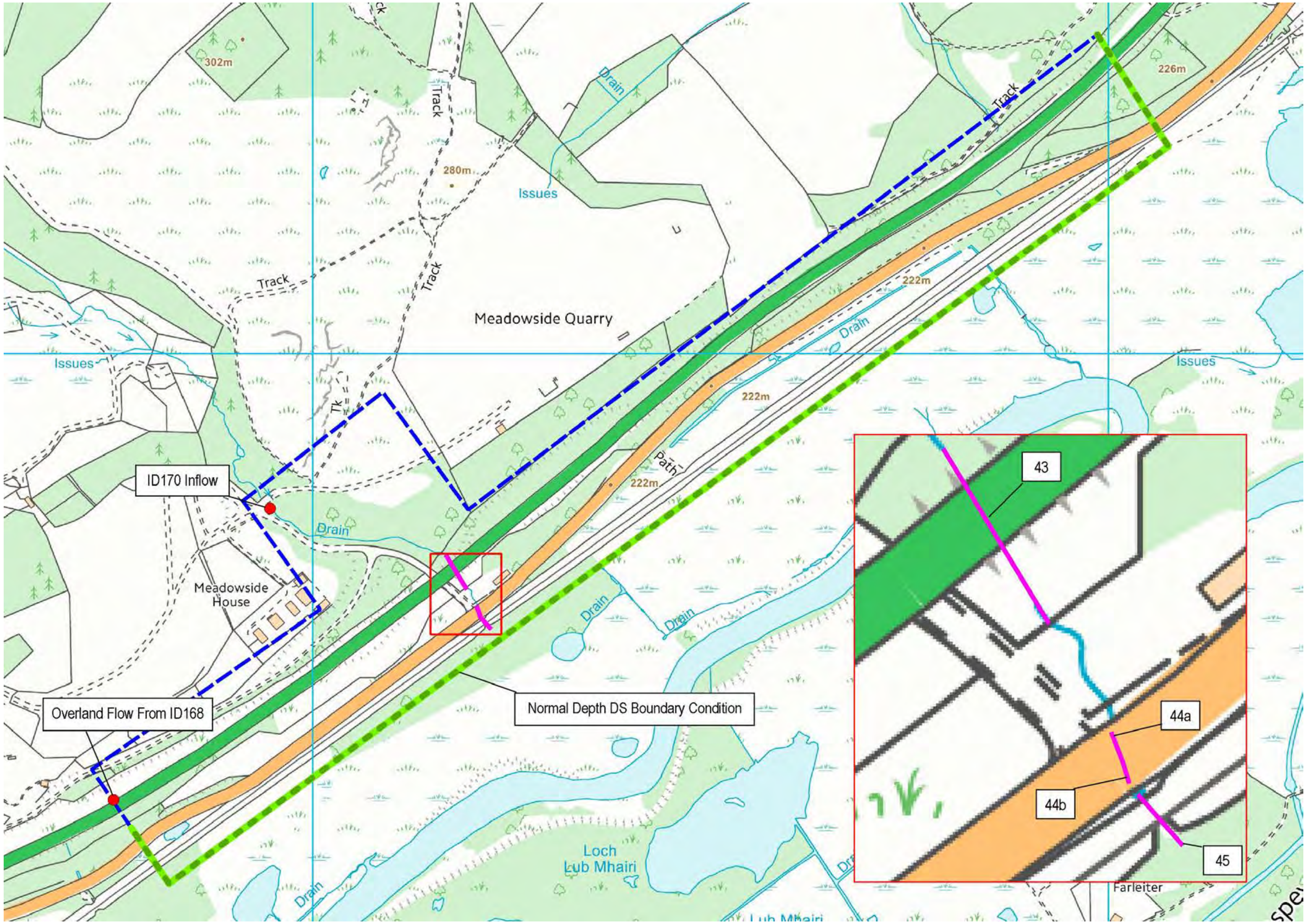

Figure B5-19: Existing Model Layout; ID170

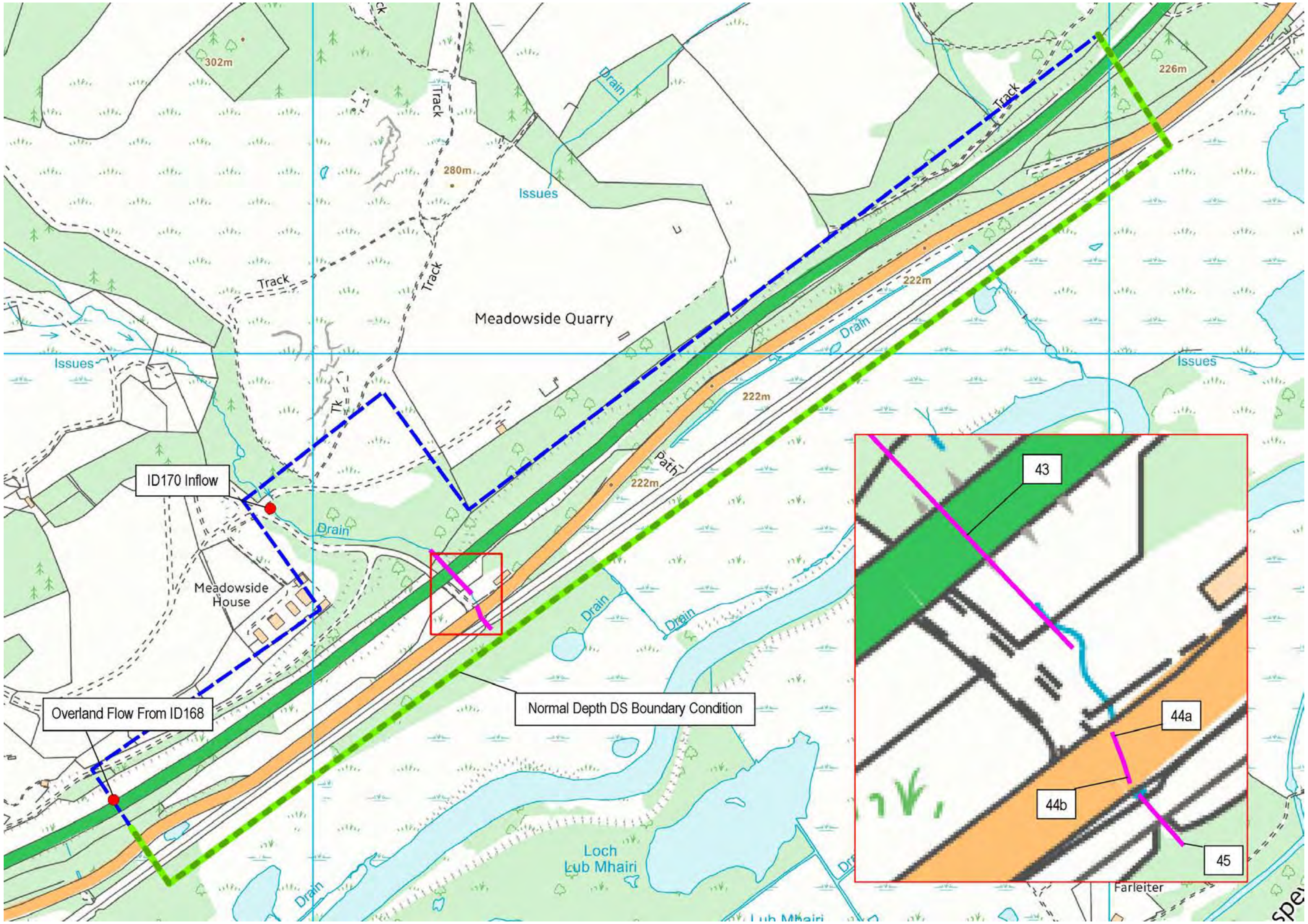

Figure B5-20: Proposed Model Layout, ID170

B.5.12 The design of the culverts under the A9 has evolved since the Initial Design, which was originally used to inform the hydraulic modelling exercise. The updated sizes were checked against the model and the models were updated where the difference could have a significant impact on the flooding conditions. Table B5-12 provides a comparison between the modelled sizes and the Proposed Scheme Design, and discusses any discrepancies in relation to the flood risk assessment.

Table B5-12: Tributary crossing sizes, Proposed Scheme Design vs modelled

Hydro ID	Crossing #	Proposed sizes - Proposed Scheme Design			Modelled sizes (based Initial Design, otherwise stated in comments)			Comments
		W (mm)	H (mm)	Shape[1]	W (mm)	H (mm)	Shape[1]	
ID138	1A	1500	1500	C	1375	1375	C	Negligible upstream attenuation in existing case and no downstream receptors. Change in design culvert size is therefore not considered to affect the conclusions from this model.
ID142	2	1500	1500	C	1200	1200	C	Negligible upstream attenuation in existing case. Change in design culvert size is also small and therefore it is not considered to affect the conclusions from this model.
ID145	4A	2700	2100	R	3300	1500	R	Modelled and design culverts both convey the 200 year flow and present negligible restriction to the passage of water. It is therefore considered that the change in the design culvert size will not alter the conclusions from this model.
ID146	6	1500	1500	R	1500	1500	R	Modelled work has been used to inform the design of CSA1. Modelled size of 1500x1500 is therefore used in the Proposed Scheme Design to ensure the CSA1 design is still functional.
ID147	11A	Twin 4200	3600	R	Twin 4200	3600	R	Modelling work has been used to inform design of crossing structure and is fed back into the Proposed Scheme Design.
ID148	13	1350	1350	C	1200	1200	C	Modelled and design culverts both convey the 200 year flow and present negligible restriction to the passage of water. It is therefore considered that the change in the design culvert size will not alter the conclusions from this model.
ID155	16	2100	1800	R	2100	1800	R	Proposed Scheme Design has been modelled
ID156	20A	1200	1200	C	1200	1200	C	Proposed Scheme Design has been modelled
ID157	22	4200	2100	R	4200	2100	R	Proposed Scheme Design has been modelled
ID158	24	1200	1200	C	1200	1200	C	Proposed Scheme Design has been modelled
ID159/ID160	26	2400	1800	R	2400	1800	R	Proposed Scheme Design has been modelled
ID161	29	900	900	C	900	900	C	Proposed Scheme Design has been modelled
ID162	32	BRIDGE	BRIDGE	B	8000	2.53	R	Modelling work has been used to inform design of crossing structure recommended in the Proposed Scheme Design (Existing structure extended upstream to the same dimensions)
ID166	36	1500	1500	R	1200	1200	R	Negligible upstream attenuation in existing case. Change in design culvert size is not considered to affect the conclusions from this model.
ID168	40	2400	1800	R	2400	1500	R	Design crossing size with 300mm embedment is the same dimensions as was modelled.
ID170	43	1500	1500	C	1327	1327	C	Crossing is modelled using the bore area of a 1500mm circular culvert with 300mm embedment.

(1) R=Rectangular; C=Circular; B=Bridge

Existing and proposed hydrological conditions

B.5.13 The existing and proposed models have both been run using the same flows based on the existing catchments as any changes to the catchments as a result of the proposed scheme are negligible. Where there are multiple catchments within each model the critical storm duration for each catchment may differ. To maintain a conservative approach the peak flows for each catchment are based on their critical storm duration and the peaks of the hydrographs are aligned.

B.5.14 Multiple return periods for each catchments critical storm duration have been run through the model to better understand the flooding mechanisms, improve estimates from required compensatory storage and provide design levels for the roads, access tracks, SUDS and watercourse crossings.

B.5.15 The following return periods have been run for each model:

- 1 in 5 year
- 1 in 10 year
- 1 in 30 year
- 1 in 50 year
- 1 in 100 year
- 1 in 200 year

B.5.16 In addition to this the 1 in 200 year flow with an additional 20percent added to it to accommodate estimated increases in flow resulting from climate change has been run.

Sensitivity testing

B.5.17 Sensitivity testing has been carried out to provide confidence that variation of certain parameters within the modelling does not alter the conclusions or significantly increase the risk to the road or any affected receptors.

B.5.18 200 year flows with 20 percent additional flow were applied to each of the models. As should be expected water levels across the models were higher than with the 200 year flows. There were however no instances of water level increases that significantly change the conclusions detailed within the flood risk assessment.

B.5.19 In addition to flow, manning's values were increased by 20% in both the 1D and 2D domains for the 200 year flow. The decreased conveyance in channels, culverts and across the floodplain resulted in water levels which were locally higher and lower than the 200 year runs with no change to manning's. As with the increased flow there were no locations where the increase or decrease in water level changes the conclusions within the flood risk assessment.

B.5.20 The depth and extent of floodplain in some areas upstream of the A9 at crossing ID162 is sensitive to the depth and manning's. This does not impact on the conclusions within the flood risk assessment as there is still sufficient freeboard to the road and compensatory storage designs in this area have taken into account this sensitivity.

B.5.21 The effect of culvert blockage has been discussed qualitatively within the flood risk assessment and based on this qualitative assessment it was not deemed necessary to carry out a quantitative assessment of the effect of culvert blockage.

B.6 Detailed modelling of Milton Burn crossing (ID147)

B.6.1 Further detailed modelling is carried out at ID147 to better understand the hydraulics around the A9 structure and the influence of the Access track downstream. This is done with a view to inform the opening size of the proposed crossing arrangement under the A9.

B.6.2 The proposed arrangement should ensure that the flow passed downstream of the A9 mainline in the proposed case must not exceed the existing flow in any return period or storm duration. The methodology for carrying out this detailed modelling is discussed below.

B.6.3 Additionally, in the proposed conditions, the underpass will be set above the 200yr flood levels.

B.6.4 A detailed 1D/2D model of crossing ID147 was built and a slowly increasing flow was applied to obtain a flow rating (flow through the structure vs upstream water level) for the existing arrangement and a number of different proposed culvert arrangements.

B.6.5 The existing ARMCO structures were modelled using the surveyed cross-sections from the 2016 river survey, with a Manning's value of 0.036 along the corrugated part and 0.035 in the bottom (embedded) part. The bottom part of the existing underpass being a rough concrete slab, the Manning's value for the bed of the underpass was set to 0.017. Manning's values in the proposed concrete structures were set to 0.013 for walls and soffits and 0.035 for the bed.

B.6.6 To ensure that there was no more flow passed downstream in the proposed case for all return periods the ratings were compared. If for any given upstream water level the flow was greater in the proposed case than the exiting case the proposed culvert arrangement was not considered suitable.

B.6.7 Three proposed arrangements were investigated:

- A twin 3.6m x 3.6m box culvert arrangement resulted in slightly lower flows than the existing case even with the downstream bridge removed
- A single 6.0m x 3.6m box culvert arrangement resulted in significantly lower flows than in the existing case even with the downstream bridge removed
- A further twin 4.2m x 3.6m box culvert arrangement passed slightly lower flows downstream

B.6.8 The comparison of rating curves is shown on **Figure B6-1** below. For the three cases the proposed conditions will pass less flow downstream than in the existing conditions for any given upstream level.

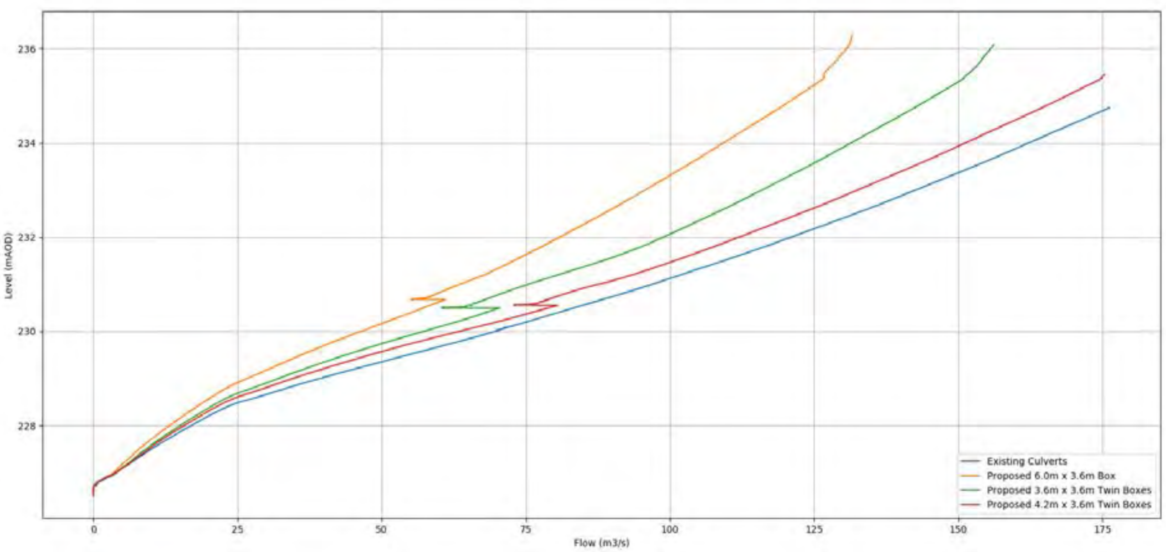

Figure B6-1: ID147 and downstream access track – Upstream flood level as a function of the flow downstream of the access track, Existing conditions and four proposed A9 crossing arrangements.

B.6.9 The peak 200 year flows and upstream water levels existing case along with the 3no. proposed cases discussed above are presented in **Table B6-1** below.

Table B6-1: Existing and proposed flows passed downstream of the A9 mainline and levels upstream of the A9

Crossing arrangement	Existing Case	Twin 4.2m x 3.6m box	Twin 3.6m x 3.6m box	Single 6.0m x 3.6m box
Peak Flow passed downstream (m^3/s)	64.89	64.81	63.96	63.16
Peak Water Level (mAOD)	229.86	229.96	230.17	230.35
Extra volume stored upstream of A9 by displacement (m^3)	0	470	14420	28360

B.6.10 The “extra volume stored by displacement” is calculated by comparing the maximum depth raster outputs from the 2D models, using Zonal Statistics tools in QGIS. The calculation is limited to the two areas where there is a noticeable difference between existing and proposed conditions, as shown in **Figure B6-2** below.

B.6.11 From the two areas in **Figure B6-2** the change in volume in the area to the west is due to the small encroachment with the proposed access track (volume balance is indeed negative) whereas the second, much larger area to the east reflect the extent of flood lift due to the crossing arrangement and include the larger area of encroachment from the mainline (volume balance is positive).

Figure B6-2: ID147 Flood extent and upstream areas where there is a noticeable difference in flood levels between extending and proposed conditions (existing depths shown).

B.6.12 The twin 4.2x3.6m culverts provide the 200yr peak flow closest to the existing conditions. The extra storage by displacement for this combination is 470m^3. Because the proposed embankment is included into the model, difference in volume between existing and proposed condition takes into account the loss from encroachments in the balance of volumes.

B.6.13 Going for next size down and the throttling effect has a greater impact, especially in terms of extra storage provided upstream. In all cases the upstream volume balance is positive: the loss of volume due to encroachment is compensated by the extra flood lift.

B.6.14 If the final structure is to be different to the three options presented here, it is recommended that a rating is obtained for the final proposed crossing design and this is compared to the existing rating curve to ensure the proposed structure passed no more flow than the existing arrangement for any upstream level. Additionally, the impact of the proposed underpass not accounted in this study as it plays no role for the design event. Exceedance events should be tested with the underpass included at detailed design.

B.6.15 The values in **Table B6-1** are derived from model runs for the typical FEH Rainfall Runoff 200yr flood with the default storm duration. A routing exercise has been carried out with a simplified 1D reservoir model using the existing and proposed ratings (shown in **Figure B6-1**) as control and describing the upstream storage (in existing and proposed conditions). The model indicates that although the extra flood lift brought by the proposed crossing arrangements tends to reduce with the longer storm durations, it remains positive.

B.6.16 Greater provision of extra storage to provide scheme wide compensation has not been progressed further as storage provided on one part of the catchment contributing to the A9 crossing would not be efficient for events taking place on other parts of the contributing catchment.

B.7 Detailed modelling of Allt Cealgach crossing (ID157)

B.7.1 When the existing and proposed results from model "T155" were compared it was noticed that despite losing upstream storage between the existing and proposed cases water levels immediately upstream of the B9152 were slightly lower in the proposed case. Additional detailed modelling was therefore carried out in order to determine if this effect was real and sensible.

Methodology

B.7.2 Initially it was hypothesised that the timings and interactions of the peak flows coming from crossing ID155 were the cause of the unusual results. A model was therefore run omitting the inflow at this crossing. It was found that this did not significantly alter the difference in water levels upstream of the B9152. This meant that the effect had to be a function of the changes made to the crossing at ID157.

B.7.3 Time varying 2D outputs from the model omitting the flow from ID155 were therefore examined in detail. This identified a change in the way the flow from ID157 was routed to the crossing under the B9152 and this is discussed in the results section.

Results and Discussion

B.7.4 Through detailed review of the time varying 2D outputs from the model omitting the flow from ID155 the reason behind the unusual change in water levels was identified.

B.7.5 In the existing case water backs up from the undersized ID157 crossing and spills over a low ridge of ground to crossing ID158 to the north east. This splits the flow between the two culverts with the flow through crossing ID157 entering a more canalised route to the crossing under the B9152 and the flow through crossing ID158 discharging to a marshy area to the north east of the crossing under the B9152. This flow takes significantly longer to reach the crossing under the B9152 than the flow from crossing ID157 and fills up storage in this area early in the hydrograph.

B.7.6 In the proposed case the crossing at ID157 is sized to convey the 200 year flow and the downstream diversion channel further canalises the route to the crossing under the B9152. As the crossing under the B9152 does not present a restriction to the low flows at the start of the model increase in proposed flow early in the hydrograph reaching the B9152 crossing does not back up from the crossing. The flow that previously passed through crossing ID158 no longer reaches the marshy area to the north east early in the model therefore, as the flow from ID157 approaches the peak and starts to back up from the crossing under the B9152 this area has additional storage available in it and therefore the peak flow is attenuated in this area to a greater extent.

B.7.7 It is this difference in the routing of flows causing a difference in potential for attenuation of the peak flow that results in the lowering of the water level upstream of the B9152 between the existing and proposed models. The difference is therefore considered to be a real and sensible effect of the proposed scheme on the water levels downstream of the A9 mainline.

B.7.8 **Figure B7-1** shows a comparison of the flow hydrographs passing through the culvert under the B9152 in reference to existing and proposed frames which show how the water is routed in both cases. **Table B7-1** provides comments in reference to **Figure B7-1**.

*Table B7-1: Comments relating to **Figure B7-1***

Frame Number	Existing Comments	Proposed Comments
Frame 1	Existing A9 crossing ID157 has sufficient capacity for flows early in the hydrograph therefore all flow is passed through this culvert to the area downstream of the A9. The crossing under the B9152 is of greater capacity than the A9 culvert therefore all water reaching it is conveyed downstream of the B9152 rather than being attenuated.	The A9 crossing ID157 in the proposed case has 200 year capacity. All flows throughout the full hydrograph are passed downstream of the A9 through this culvert with limited backing up. Early in the hydrograph these flows passed downstream are similar to the existing flows and are conveyed to and through the B9152 crossing with limited attenuation.
Frame 2	Once flows exceed the existing capacity of crossing ID157 they flow overland upstream of the A9 to crossing ID158 to the north east. Compared to the proposed case this limits the flow passed directly downstream to the B9152 crossing as some of the flow is discharged via crossing ID158 to a marshy area to the north east of the B9152 crossing. This water begins spreading to the east and north east and is attenuated.	As the proposed A9 crossings capacity is not exceeded all the flow is conveyed straight to the B9152 crossing and the additional flow reaching the crossing generates a higher head and hence more flow is passed under the B9152. At this stage the marshy area to the north east of the crossing does not attenuate any water.
Frame 3	As the flows approach the peak the B9152 crossing begins to back up and water begins to spill towards the marshy area to the north east. As this area already contains significant volumes of water from the discharge from crossing ID158, the potential storage available is less relative to the proposed case. This ultimately results in a slightly higher peak water level in this area when compared with the proposed results.	As with the existing case as the flows approach the peak the B9152 crossing begins to back up and water begins to spill towards the marshy area to the north east. A this area is still empty at this stage the available storage is greater than in the existing case therefore the slightly more of the peak flow is attenuated resulting in slightly lower levels in this area when compared with the existing results.

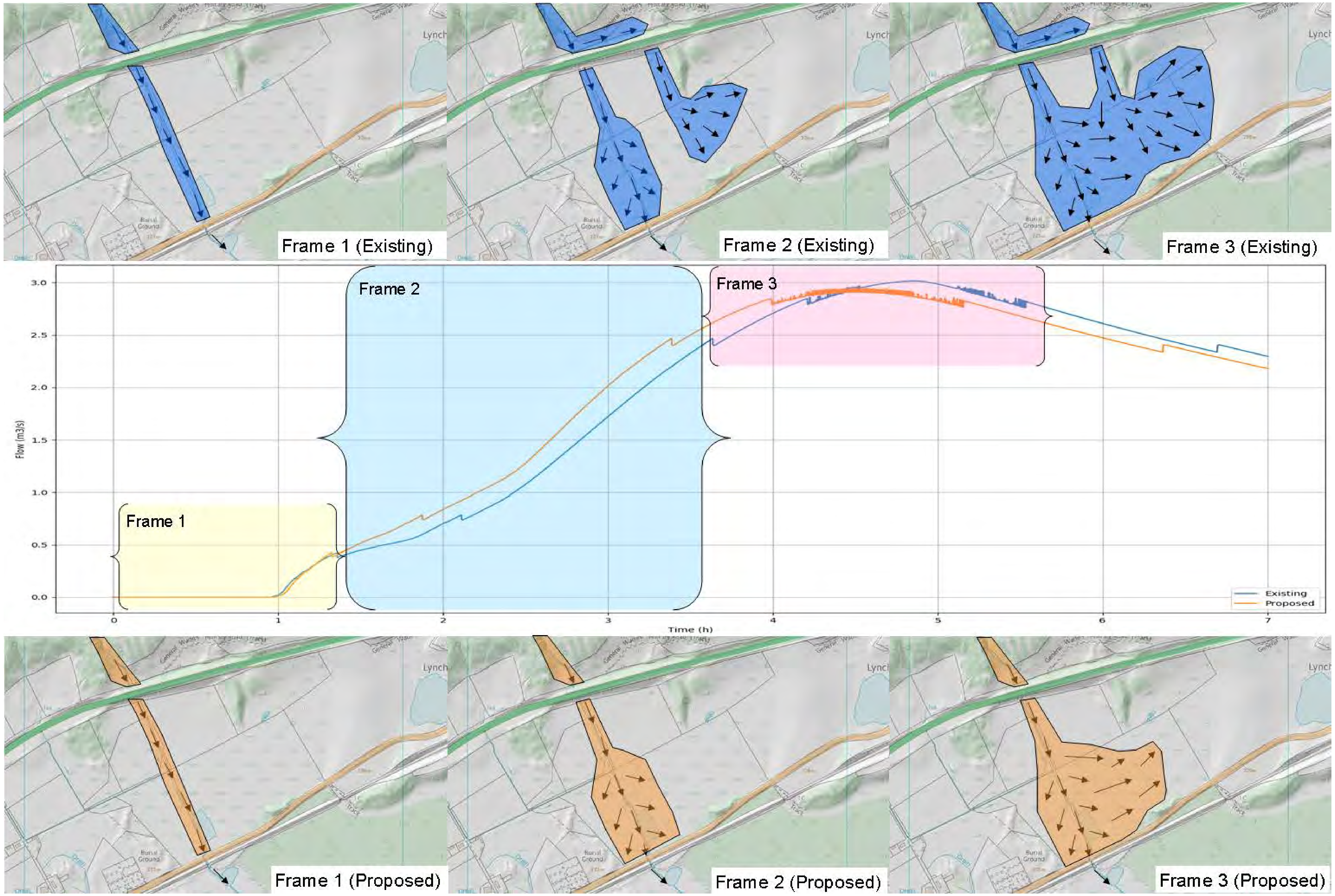

Figure B7-1: Comparison of the flow routing around ID157 in the existing and proposed cases.