JACOBS

Appendix A11.3: Flood Risk Assessment

1 Introduction

1.1 Purpose

1.1.1 This Flood Risk Assessment (FRA) provides detailed information on the assessment of all sources of flood risk relevant to the A9 dualling between the Tay Crossing and Ballinluig (Project 03), also referred to as the 'proposed scheme'. It informs Chapter 11: Road Drainage and the Water Environment (RDWE), of the Environmental Statement (ES).

1.1.2 The purpose of this FRA is to:

- investigate existing flood risks;
- identify potential flood risk impacts associated with the proposed scheme; and where necessary,
- provide details of appropriate flood mitigation / flood management measures.

1.1.3 As a result, this FRA demonstrates that the proposed scheme has adequately addressed local flood risk issues, ensuring that the proposed scheme would remain safe and operational during times of flood and that it would have a neutral or better effect on overall flood risk, taking cognisance of environmental, engineering and economic constraints.

1.1.4 This report is to be read in conjunction with the following sections of the Environmental Statement:

- Chapter 11 (Road Drainage and the Water Environment (RDWE));
- Appendix A11.1 (Baseline Conditions);
- Appendix A11.2 (Surface Water Hydrology);
- Appendix A11.4 (Hydraulic Modelling Report);
- Appendix A11.5 (Fluvial Geomorphology); and
- Appendix A11.8 (Watercourse Crossing Reports).

Context

1.1.5 The existing A9 between Perth and Inverness covers a total length of 177km. This consists of approximately 48km of existing dual carriageway and 129km of single carriageway to be upgraded to dual carriageway status as part of the A9 Dualling Programme. Transport Scotland has sub-divided the A9 Dualling Programme into several projects, this FRA pertains to Project 03: Tay Crossing to Ballinluig.

1.1.6 The majority of the A9 road corridor traverses a hilly and mountainous environment and runs alongside and crosses some of the largest rivers in Scotland, with several significant tributaries to the River Tay and numerous smaller watercourses flowing beneath the existing carriageway. Many of these watercourses are of high ecological value, including nature conservation designations at both National and International level.

1.1.7 Parts of the existing A9 are currently located in areas considered to be at risk of flooding. Therefore, without mitigation measures the proposed scheme could alter existing hydraulic regimes and flood mechanisms, which may result in undesirable ecological, social and economic impacts

Flood Risk Policy & Guidance

1.1.8 This FRA has been developed with reference to the following legislation, policy and guidance:

Flood Risk Management (Scotland) Act 2009

1.1.9 The Flood Risk Management (Scotland) Act 2009 sets in place a statutory framework for delivering a sustainable and risk-based approach to the management of flooding, including the preparation of assessments of the likelihood and impacts of flooding and associated catchment focussed plans.

1.1.10 The Act places a duty on responsible authorities (Scottish Ministers, SEPA, Scottish Water and local authorities) to manage and reduce flood risk and promote sustainable flood risk management. The main elements of the Act, which are relevant to the planning system, are the assessment of flood risks and undertaking structural and non-structural flood management measures.

1.1.11 With reference to the proposed scheme, local authorities are required to consider flood risk management plans that are produced under Section 41 of the Act. For proposed developments, applicants must assess flood risk in respect of the development (Section 42 of the Act). This amends the Town and Country Planning Regulations (Scotland) 2009 so that local planning authorities require applicants to provide an assessment of flood risk where a development is likely to result in the material increase in the number of properties at risk of flooding.

Scottish Planning Policy

1.1.12 Through the Flood Risk Management Act, Scottish Planning Policy (Scottish Government, 2014) requires planning authorities to consider all sources of flooding (coastal, fluvial, pluvial, groundwater, sewers and blocked culverts) and their associated risks when preparing development plans and reviewing planning applications. One of the key principles of Scottish Planning Policy (SPP) is to avoid development in areas at risk of flooding.

1.1.13 SPP proposes a flood risk framework to guide development to the appropriate flood risk areas linked to annual probabilities. However, given the scale of the proposed scheme, and the fact that the works involves dualling an existing road, it would be impracticable to develop the proposed scheme completely outwith areas currently at risk of flooding. Further details of some of the alternative options considered can be found in Appendix E of the A9 Dualling Programme Strategic Environmental Assessment (SEA) Environmental Report (Transport Scotland, 2013) and within the Online vs Offline Route Option Comparative Assessment (Transport Scotland, 2016).

1.1.14 SPP therefore recognises that built-up areas considered to be at medium to high risk of flooding (an annual probability of coastal or watercourse flooding greater than 0.5% (200-year) Annual Exceedance Probability (AEP) flood event), may be suitable for “Essential Infrastructure”, such as the proposed scheme. This is under the provision that that they are designed and constructed to remain operational during times of flood and not to impede flood flow.

SEPA Technical Flood Risk Guidance for Stakeholders

1.1.15 The Technical Flood Risk Guidance for Stakeholders document (SEPA, 2015) provides an overview of the risk assessment process; primarily appropriate methodologies and techniques to be adopted to ensure flood risk matters have been addressed in a manner consistent with SPP and the Flood Risk Management Act. This guidance recommends that the 0.5% AEP (200-year) peak flow estimates should be increased by 20% to account for the impacts of climate change. This should be over and above any separate allowance for freeboard, which is recommended as between 500mm and 600mm.

Design Manual for Roads and Bridges

1.1.16 The Design Manual for Roads and Bridges (DMRB) provides a comprehensive system, which accommodates current design standards, advice notes and other published documents, for the design, assessment, operation, maintenance and improvement of trunk roads and motorways. Volume 11: DMRB (Highways Agency et al., 2009) provides guidance on the assessment and management of the impacts that road projects may have on the water environment, including flooding.

1.1.17 In line with SPP, the DMRB states that route alignments should avoid the functional floodplain where possible. The functional floodplain is the flood extent up to and including the area covered by a 0.5%

AEP (200-year) flood event as defined by the SEPA Flood Map. Where this is not possible, and a route alignment encroaches into the functional floodplain, it must be designed and constructed to:

- remain operational and safe for users during times of flood;
- result in no loss of floodplain storage;
- not impede water flows; and
- not increase flood risk elsewhere.

Flood Risk Assessment Approach

1.1.18 In order to ensure that the proposed scheme has considered flood risk at all stages of the design process, the DMRB advocates a staged approach to the evidence-based assessment. Table 1 presents the adopted process of assessing flood risk within the context of DMRB and how this relates to SEPA's technical requirements as a statutory consultee.

1.1.19 In accordance with the DMRB, the development of the proposed scheme is currently at DMRB Stage 3 'Detailed Assessment'. This FRA documents the findings of the assessment undertaken on the latest design only.

Table 1: Flood risk assessment stages

Stage	Assessment Detail	Purpose	Alignment with the requirements of SEPA Technical Guidance
DMRB Stage 1 Scoping Assessment	The 'Scoping Assessment' uses readily available information to: • highlight potential sources of flood risk; and • identify and establish areas and flood sources that require further detailed assessment. This includes high-risk sources of flooding as identified in the route-wide Strategic Flood Risk Assessment including rivers, small watercourses and existing A9 water-crossings.	To scope the DMRB 2 'Simple Assessment'.	Identification of sources and types of flooding.
DMRB Stage 2 Simple Assessment	The 'Simple Assessment' aims to assess and compare flood risks between alternative alignment route options by: • providing a description of the baseline conditions; • identifying receptors sensitive to flooding; • assessing the impacts of the proposed scheme route options; and • assessing the importance of the impact i.e. magnitude of the impact against the sensitivity of the receptor.	To inform the selection of a preferred route option and the Stage 2 assessment Environmental Report.	Assessment of design flows. Identification of the plan extents of flooding. Describe the proposed structure/changes and impacts on predicted water level. Assessment of climate change impacts.
DMRB Stage 3 Detailed Assessment	The 'Detailed Assessment' will focus on potential effects of the preferred alignment route option and where necessary consider appropriate flood mitigation measures to achieve a neutral flood risk.	To inform the scheme design and the Environmental Statement.	Provide details of proposed flood mitigation measures. Provide an assessment of any displaced floodwater on sensitive receptors. Provide reference to any other impact on the river environment.

1.1.20 This FRA has adopted a range of assessment techniques, ranging from preliminary hydraulic calculations to detailed one-dimensional (1D)/two-dimensional (2D) hydraulic modelling, to quantify the existing risk of flooding and potential impact of the proposed scheme on flood risk. Where necessary to aid discussion the FRA includes a brief overview of the adopted techniques.

1.1.21 Further detail of the hydrology and hydraulic modelling techniques adopted are contained within the following documents:

- ES Chapter 11 Appendix A11.2 (Surface Water Hydrology); and
- ES Chapter 11 Appendix A11.4 (Hydraulic Modelling Report)

1.1.22 Generally, as the proposed scheme has progressed from the DMRB Stage 1 assessment through to DMRB Stage 3 assessment, so has the level of supporting flood risk evidence, as outlined in Table 1. As a result, the detailed assessment of flood risk has focused on existing areas of medium to high flood risk or where the proposed scheme is likely to have a potential impact on flood sensitive receptors in line with the impact assessment criteria (Annex A: Impact Assessment Criteria).

1.1.23 Where the FRA has identified potential flood risk impacts, flood mitigation measures (either embedded in design or standalone) have been considered to minimise the overall impact on flood risk. At locations where the proposed scheme may have an impact, a range of measures have been explored with the aim of achieving a neutral effect on overall flood risk.

Sources of Flooding

1.1.24 The assessment of flood risk has considered all sources of flooding, specifically:

- Fluvial (Principal Watercourses): Flooding originating from principal watercourses, including the River Tay, River Tummel, Kindallachan Burn, Sloggan Burn and Dowally Burn, which have the potential to pose the most significant flood risks within the study area (see Section 3: Principal Watercourses).
- Fluvial (Minor Watercourses): Flooding originating from minor watercourses, with localised or less significant flood risk issues (see Section 4: Minor Watercourses).
- Surface Water (Pluvial): Urban or rural flooding resulting from high intensity rainfall saturating the drainage system (either natural or man-made), with excess water travelling overland and ponding in local topographic depressions before the runoff enters any watercourse, drainage systems or sewer (see Section 5: Surface Water).
- Groundwater: Flooding due to a significant rise in the water table, normally as a result of prolonged and heavy rainfall over a sustained period of time (see Section 6: Groundwater).
- Sewers and Water Mains: Flooding due to exceedance of the capacity of man-made drainage systems. A review undertaken as part of the A9 Strategic Flood Risk Assessment (SFRA) indicated that the A9 is within an essentially rural area and that the extent and coverage of the existing sewer network in this area is limited. The proposed scheme would not result in additional flow being discharged into the existing sewer, or affect the water supply networks, therefore it is anticipated that the risk of flooding is unlikely to change and consequently this source of flooding has only been briefly discussed (see Section 7: Failure of Water Retaining Infrastructure).
- Land Drainage and Artificial Drainage: Failure of land drainage infrastructure such as drains, channels and outflow pipes, which is most commonly the result of obstructions, poor maintenance and/or blockages. For the proposed scheme, a like for like replacement would be undertaken where this infrastructure is affected. Therefore, the risk of flooding is unlikely to change and consequently the FRA has not considered this source of flooding further.
- Failure of Water Retaining Infrastructure: Flooding due to the collapse and/or failure of man-made water retaining features such hydropower-dams, water supply reservoirs, canals, flood defences structures, underground conduits, and water treatment tanks or pumping stations (see Section 7: Failure of Water Retaining Infrastructure).
- Coastal: Flooding originating from the sea where water levels exceed the normal tidal range and flood onto the low-lying areas that define the coastline. The proposed scheme does not traverse areas considered to be at risk of coastal flooding and would not increase the risk of coastal flooding. Therefore, the FRA has not considered this source of flooding further.
- Construction Risks: Risk associated with all sources of flooding, which could influence the construction phase (see Section 8: Construction Phase).

1.1.25 Throughout this report flood events are presented as AEP events such as 50%, 20%, 10%, 3.33%, 2%, 1%, 0.5% and 0.1%, which are equivalent to the 2, 5, 10, 30, 50, 100, 200 and 1000-year return period respectively. Annual Exceedance Probability, or AEP, refers to the chance that a flood of a particular magnitude is experienced or exceeded during any one year. For clarity, the notation used in this report, to describe for example the 0.5% AEP flood event, is ‘0.5% AEP (200-year) flood event’.

1.1.26 This FRA uses the SEPA Flood Maps (2014) as one of a number of sources of information used to assess the risk of both fluvial and surface water flooding. For each source of flooding, the maps illustrate flood extents for a Low, Medium and High probability of flooding, which refer to the 0.1% AEP (1,000-year), 0.5% AEP (200-year) and 10% AEP (10-year) flood events respectively. This information has been supplemented by detailed hydraulic modelling where considered necessary for the assessment.

1.1.27 The functional floodplain is defined by the SEPA 0.5% AEP (200-year) flood extent. It should be noted that the SEPA flood mapping can be indicative in nature and does not include an allowance for climate change (CC). Consequently, the 0.5% AEP (200-year) flood extent outline indicates the areas considered to be at flood risk for this flood event at the present time. Where detailed hydraulic modelling has been undertaken on Principal Watercourses for this FRA it will supersede the published SEPA flood map as the assessment of baseline (existing) flood risk.

1.1.28 The hydraulic model developed for this FRA includes survey information obtained for the proposed scheme, including river cross sections, and is more detailed and up to date than the version used to produce the SEPA Flood Map which was published in 2015. For example, the model used to produce the SEPA flood map is unlikely to include all culverts through the Highland Main Line railway embankment or the existing A9. The FRA has considered the potential impact of climate change on fluvial flood depths and extents. In line with current fluvial guidance as published by the Department for Environment, Food and Rural Affairs (Defra) and quoted in SEPA’s Technical Flood Risk Guidance for Stakeholders (SEPA, 2015), peak flow estimates for the 0.5% AEP (200-year) flood event have been increased by 20%, which will be denoted by 0.5% AEP (200-year) plus CC. This has been adopted as the ’design flood event’.

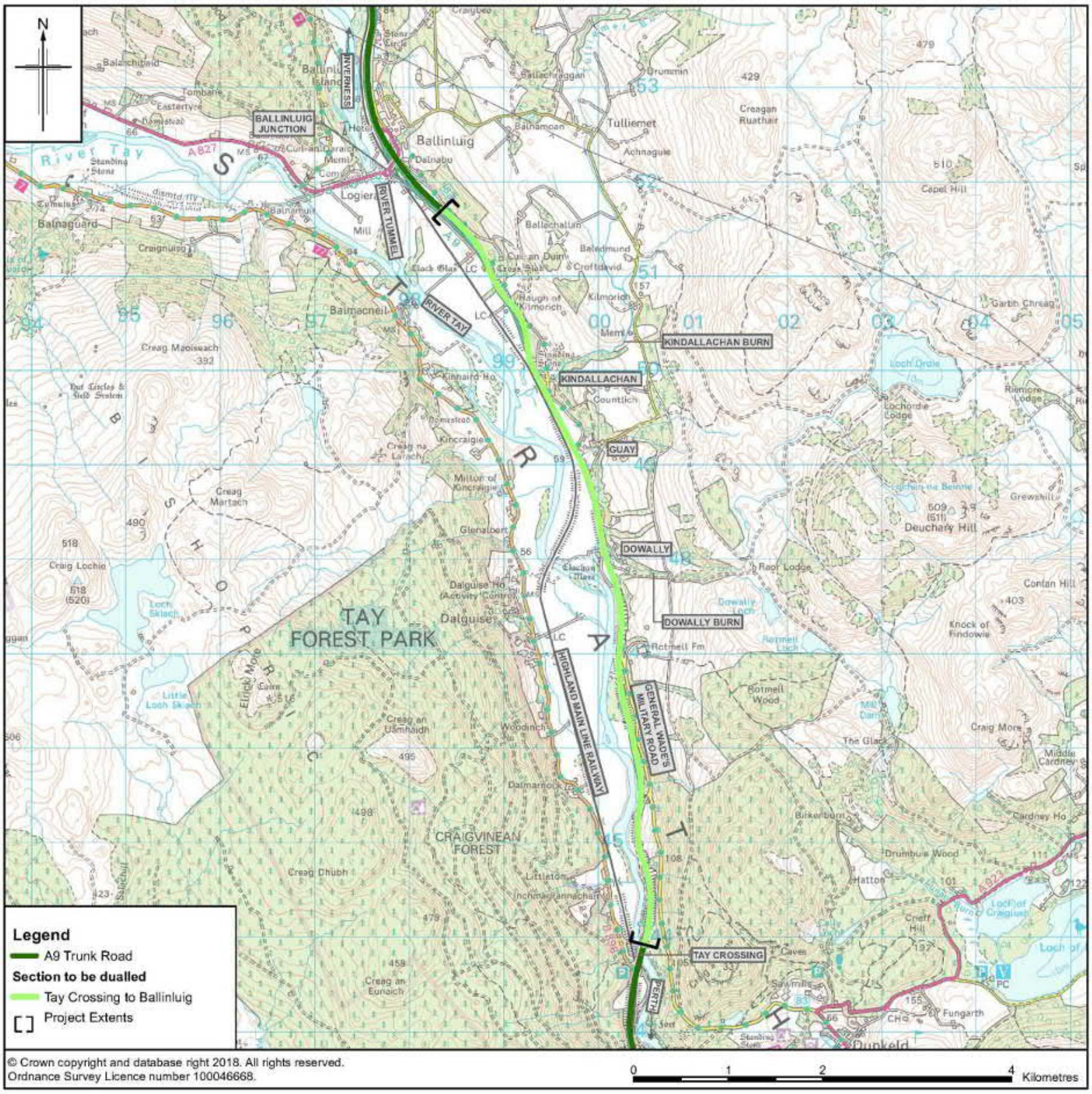
JACOBS

2 A9 Corridor

The Existing A9

2.1.1 This FRA for Project 03 covers the existing A9 between the Tay Crossing and Ballinluig (see Figure 1), which includes the dualling of approximately 7.7km of single carriageway.

Figure 1 : A9 corridor – Tay Crossing to Ballinluig



2.1.2 The existing A9 in this project area runs through the low valley floodplain of the River Tay. The River Tay runs parallel and in close proximity to the road, particularly in the southern extents. The valley floor is generally flat, with ground levels rising gently along the A9 towards the northern end of the proposed scheme. The confluence of the Rivers Tummel and Tay is at the northern end of this section. The A9 does not cross either of these principle watercourses within this project area, with the Tay Crossing approximately 0.1km south of the Project 03 boundary.

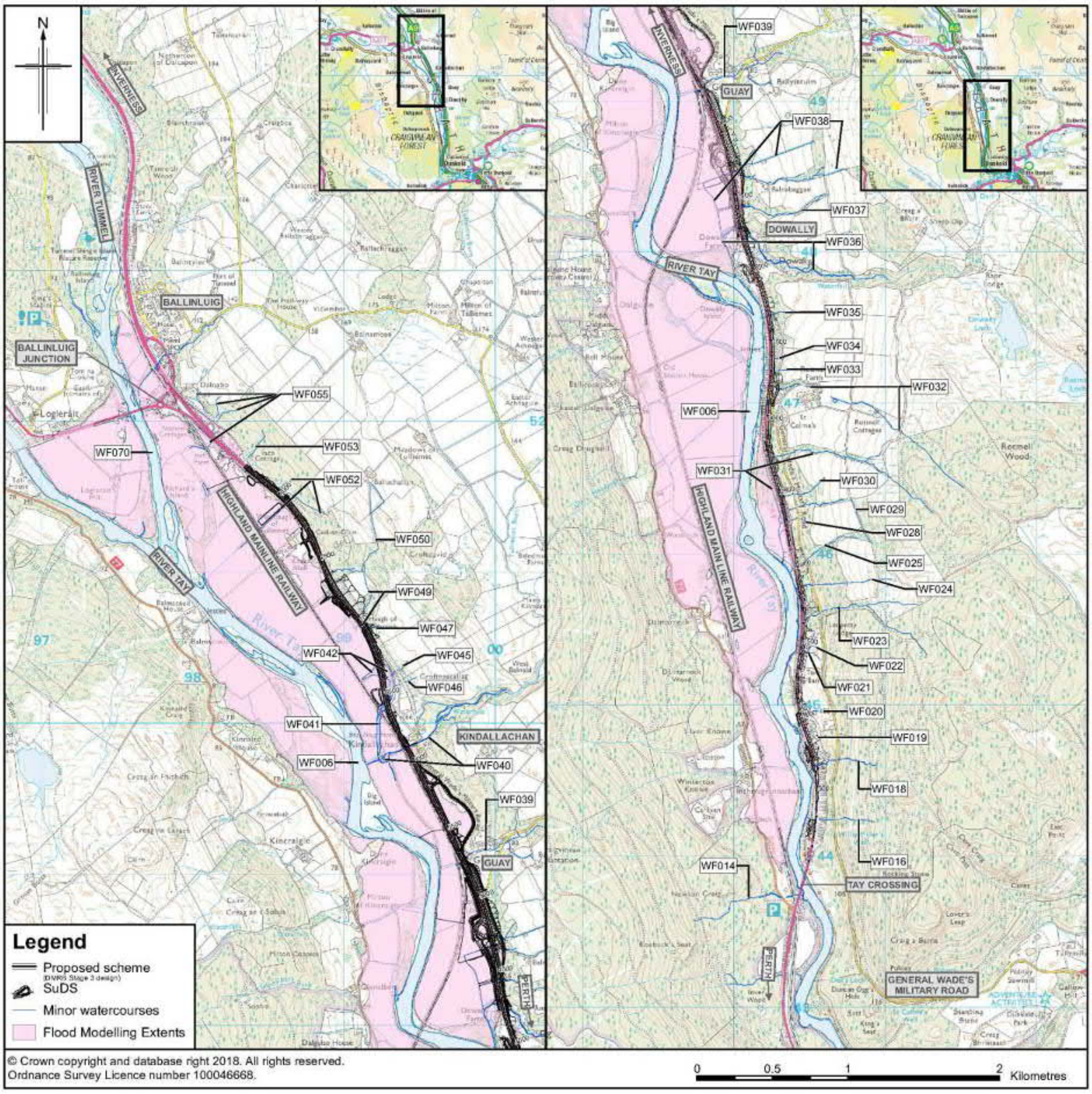
2.1.3 There is a series of cuttings on the eastern side of the road and occasional embankments along the west side. The A9 route is moderately elevated compared to the valley floor (but typically less than 5m higher).

2.1.4 Most residential properties within the Project 03 area are located within the communities of Dowally, Guay and Kindallachan, with the remainder made up of scattered rural dwellings including a number of farmhouses and their associated cottages. These are predominantly located north of Haugh of Kilmorich. The remaining project area is predominantly agricultural land to the west of the A9 on the Tay floodplain, which is typically used for arable farming and grazing. The majority of the land to the east is woodland with the steep topography limiting other land uses.

2.1.5 The Highland Main Line railway runs to the west of, and broadly parallel to, the A9 between Ballinluig and Guay. The railway is on embankment through the floodplain, with several culverts through the embankment maintaining hydraulic connectivity to the floodplain to the west. The area between the railway and the A9 is generally agricultural land. Near to Guay, the railway heads south away from the A9, to cross the River Tay near Dowally, and runs on an embankment on the west side of the Tay floodplain to beyond the southern boundary of the scheme area.

2.1.6 In addition to the two large principal watercourses in the project area (the River Tay and River Tummel), there are three further principal watercourses that flow underneath the A9 (the Dowally Burn, Sloggan Burn and Kindallachan Burn). There are also a number of smaller watercourses typically with catchment areas of less than $0.5km^2$ that drain lateral catchments and flow underneath the A9 towards the River Tay. The A9 crosses 24 of these minor watercourses within the Project 03 extents. The location of the watercourses within the project area can be seen on Figure 2.

Figure 2: Watercourse designations and 2D model domain



The Proposed Scheme

2.1.7 The proposed scheme between the Tay Crossing and Ballinluig is an online option, covering approximately 7.7km of single carriageway to be dualled, and includes widening the existing single carriageways along with junction, access road and drainage improvements.

2.1.8 The subsequent subsections provide an overview of the key features of the proposed scheme pertaining to flood risk. Chapter 5 (The Proposed Scheme) contains a full description of the proposed scheme while Annex D of this Appendix contains a figure illustrating the horizontal alignment of the proposed scheme features.

<u>A9 Dualling, Junctions, Access Roads and Tracks</u>

2.1.9 The proposed scheme generally includes widening of the existing southbound carriageway. This would involve new cuttings into steep hillside and widening of existing embankments. Embankments on the northbound carriageway would also be extended as part of the proposed scheme to provide a widened verge.

2.1.10 The proposed scheme would include the provision of modified or new local surfaced access roads to Kindallachan, Guay and Dowally, including an overbridge crossing the A9 south of Guay (Guay South Overbridge). Other surfaced access roads or unsurfaced access tracks to be modified or provided by the proposed scheme include new access roads for Sustainable Drainage System (SuDS) features and access tracks serving a small number of properties.

Minor Watercourse Crossings

2.1.11 The existing A9 carriageway crosses 24 minor watercourses and three principal watercourses (the Kindallachan Burn, Sloggan Burn and Dowally Burn) within the study area. Many of these crossings include culverts for small open channels such as field drains. The proposed scheme would include the extension, replacement and/or enlargement of these culverts.

2.1.12 The design process for the minor watercourse crossings is complex, taking account of a range of design criteria and constraints to develop the most appropriate crossing for each watercourse. The factors that influence the culvert design include:

- horizontal and vertical alignment of the proposed scheme, specifically the influence on online construction and the level of the road drainage to avoid clashes with the watercourse crossing;
- maintenance requirements to meet DMRB standards;
- ecological considerations, such as the need to provide adequate mammal passage through culverts;
- geomorphological considerations related to potential erosion and sedimentation issues upstream and downstream of the watercourse crossings; and
- existing flood risks and the potential impact on upstream and downstream flood sensitive receptors in the event that a culvert is either extended (based on current geometry) or enlarged.

2.1.13 For all areas, these influencing factors need to be considered collectively on a case-by-case basis to develop the most appropriate culvert design for each crossing. During the design process, the decision-making hierarchy adopted was to retain the existing culvert or to extend the culvert on a 'like-for-like' basis to accommodate the proposed scheme. Only where this was not possible, due to engineering or environmental considerations as listed in Section 2.1.12, would the existing culvert be replaced with a new culvert. There are a number of locations where the proposed scheme will result in earthworks 'cut' into the adjacent hillside or the invert of the new watercourse crossing will be lowered to pass beneath the proposed road drainage system. In both cases this will result in a steepened watercourse requiring a 'cascade' to safely convey the design flood event without compromising the integrity and existing landform of the hillside and/or operation of the proposed scheme.

2.1.14 Appendix A11.8 (Watercourse Crossing Report) contains further detail and justification for the design of each structure.

Surface Water Drainage

2.1.15 The proposed scheme would include the construction of new drainage features to treat and attenuate surface water runoff to ensure no detrimental impact upon flood risk and water quality. This will include Pre-Earthwork Drainage (PED), road drainage networks including SuDS ponds with associated outfall structures and access tracks. The proposed scheme includes geocellular storage within the A9 embankment and SuDS ponds/wetlands to collect, treat and attenuate runoff from the proposed scheme road drainage system prior to discharge to the nearest appropriate watercourse via an outfall.

Proposed Scheme Design Principles and Standards

2.1.16 The design of the proposed scheme has developed over the three DMRB assessment stages and is cognisant of a range of design principles and standards and a full range of locational and environmental issues. Table 2 provides a list of flood risk design principles and standards considered during the development of the proposed scheme to minimise potential flood risk impacts.

JACOBS

Table 2 : Proposed scheme flood risk design principles and standards

Proposed Scheme	Design Principles and Standards	Description
Mainline A9 Dualling, Junctions, Access Roads and Tracks	• 0.5% AEP (200-year) Functional Floodplain • 0.5% AEP (200-year) plus CC flood event plus 600mm freeboard	Avoid locating the proposed scheme and any associated works within the functional floodplain. Set the mainline, junctions and surfaced access roads above the design flood event level. Unsurfaced access tracks would remain unchanged from existing elevations and as a result could have lower flood design standards.
Principal Watercourse Crossings	• 0.5% AEP (200-year) Functional Floodplain • 0.5% AEP (200-year) plus CC flood event plus 600mm freeboard	Avoid locating the proposed scheme and any associated works including bridge piers and abutments within the functional floodplain. Where the proposed scheme intends to replace existing structures, soffit levels are set above the design flood event level.
Minor Watercourse Crossings	<u>New (or replaced) mainline and access road culverts</u> • 1% AEP (100-year) flood event plus appropriate freeboard <u>New (or replaced) unsurfaced track culverts</u> • 2% AEP (50-year) flood event plus appropriate freeboard <u>Freeboard</u> • Culverts up to or equal to 2.4m in diameter or height shall provide a minimum freeboard above the design event peak water level of D/4 where D is the diameter for circular culverts, or the height for non-circular. For culverts with a diameter or height greater than 2.4m, the minimum freeboard shall be 600mm	In line with DMRB, all new (or replaced) mainline and access road culverts are designed to freely pass the 1% AEP (100-year) design flood event (with appropriate freeboard within the culvert barrel). In line with DMRB, all new (or replaced) unsurfaced track culverts are designed to freely pass the 2% AEP (50-year) design flood event (with appropriate freeboard within the culvert barrel). The flood design standard for unsurfaced access track culverts is lower than for mainline culverts as these tracks are mainly unsurfaced, with a low traffic volume, which only serve as access to a few agricultural properties. Unsurfaced access tracks are also to be set at existing ground level (which may be elevated), to avoid changing the local risk of flooding. The impact of the proposed scheme on flooding has been assessed against the design flood event. Within the Project 03 area, all new culverts have been designed to pass the 0.5% AEP (200-year) plus CC event due to their location and proximity to the A9.
Pre-earthwork Drainage (PED)	• 1.3% AEP (75-year) rainfall runoff flood event	In line with DMRB, PED are designed to capture and convey surface water runoff from the catchment they would be intercepting and discharge into the nearest watercourse.
Road drainage system	• 100% AEP (1-year) rainfall flood event, without surcharging • 20% AEP (5-year) rainfall flood event, plus a 20% allowance for climate change, without exceeding the chamber cover	As per DMRB (2016), the design of the road drainage system would accommodate a short duration, high intensity rainfall event, without surcharging.
SuDS Features	• 0.5% AEP (200-year) Functional Floodplain	Avoid developing SuDS in the functional floodplain and provide mitigation for increase in flood risk caused by any loss of floodplain capacity where practicable.
	• 3.33% AEP (30-year) flood event	SuDS features not to be inundated with floodwater during the fluvial event
	• 0.5% AEP (200-year) rainfall flood event, plus an allowance for climate change and appropriate freeboard where practicable and at least the 3.33% AEP (30-year) flood event.	SuDS features to treat and attenuate the peak flow from the proposed road drainage system.
	• 50% AEP (2-year) 'greenfield' runoff rate where practicable and no greater than existing 50% AEP (2-year) runoff where not.	SuDS features to discharge into the nearest watercourse at a controlled rate.
Compensatory Flood Storage	• Same volume to be provided at the same level relative to the design flood event, which is the 0.5% AEP (200-year) flood event.	Compensatory flood storage should be provided close to the point of lost floodplain and provide the same volume at the same level relative to the design flood level as that lost. In designing compensatory flood storage, the

Proposed Scheme	Design Principles and Standards	Description
		impacts of the measure will be tested against a range of flood events up to the design flood event. Where appropriate, the feasibility of providing storage will also be tested up to the 200-year event plus climate change to take account of criteria associated with long-term sustainability detailed in Scottish Planning Policy (2014), although noting that SEPA Technical Guidance only explicitly requires Compensatory Flood Storage to be provided up to the 0.5% AEP (200-year) flood event.

Flood History

2.1.17 A review of the historical flood records provided by SEPA and Perth and Kinross Council indicates that there have been a number of flood events that have occurred within the study area, predominantly identified as within the floodplain of the principal watercourses, or due to surface water flooding of roads.

2.1.18 Significant flooding from the principal watercourses within the project area has been recorded as recently as December 2015, with recent examples within the project area included in Table 3.

Table 3: Historic flood events

Date	Location	Source	Cause and further details (from SEPA/Perth and Kinross Council records)
1990	Logierait to Tay Crossing	Fluvial	B898 impassable near Dalguise
1993	Logierait to Dalguise	Fluvial	Rapid snow melt and heavy rain resulting in widespread flooding within the area.
2005	Guay to Dalguise	Fluvial	Heavy rain resulting in flooding to agricultural land, B898 impassable in places.
2006	Logierait to Tay Crossing	Fluvial	Large flows in the River Tay resulting in flooding to properties and the railway and B898 becoming impassable in places.
2008	Logierait	Not stated	Unknown - A827 impassable
2012	Ballinluig	Not stated	Heavy rain resulted in the A9 being closed just south of the A827 junction.
2015	Logierait to Tay Crossing	Fluvial	Widespread flooding throughout project area.

Strategic Flood Risk Assessment

2.1.19 A route-wide SFRA was undertaken in March 2014 for the A9 route between Perth and Inverness as an addendum to the SEA to provide an overview of flood risk from all sources to the A9.

2.1.20 The SFRA for the A9 Dualling Programme referred to the Potentially Vulnerable Area (PVA 08/08) identified by SEPA as part of the National Flood Risk Assessment under the Flood Risk Management (Scotland) Act 2009. This area includes the project area south of Dowally. The reports of flooding were attributed to river flooding (63%) and surface water flooding (37%), while it was also noted that there is a potential moderate to high contribution from Groundwater Flooding within part of the catchment.

TAYplan Level 1 Strategic Flood Risk Assessment

2.1.21 The Level 1 TAYplan SFRA (The Strategic Development Planning Authority (SDPA), 2014) aims to bring sustainable economic development to the region by ensuring flood risk is taken into account in the planning of new development. The TAYplan Level 1 SFRA (SPDA, 2014) did not highlight any areas of significant flood risk between the Tay Crossing and Ballinluig, but does refer to a flood study at Logierait that will be undertaken once funding is identified.

3 Principal Watercourses

Introduction

3.1.1 This FRA categorises principal watercourses as those having the potential to pose the most significant flood risk impact along the existing A9 corridor. These include the River Tummel and the River Tay plus its largest tributaries in the project area; the Kindallachan Burn, Sloggan Burn and Dowally Burn.

3.1.2 The existing A9 in the project area is located in the floodplain of the River Tay and River Tummel. The SEPA Flood Map indicates that from Ballinluig to north of Kindallachan the floodplain is bounded by the railway embankment to the west of the A9. Approximately 600m of the A9 would be overtopped north of Kindallachan in a 0.5% AEP (200-year) event under existing conditions. Further south, approximately 50m lengths of the A9 are shown to be flooded at the Kindallachan Burn and Sloggan Burn. The SEPA flood map also indicates that the existing A9 is overtopped for approximately 100m between Guay and Dowally and over approximately 50m close to the Dowally Burn. Through much of the southern extent of the proposed scheme (south of Dowally) the A9 embankment marks the edge of the 0.5% AEP (200-year) functional floodplain. Several areas of encroachment onto the embankment and the edge of the road (particularly near to Ledpetty Lodge) indicate the embankment may be restricting the extent of the floodplain, but nowhere is the whole road shown to be overtopped during this event.

3.1.3 Given the proximity of the proposed scheme to the floodplain, an assessment has been undertaken to consider the risk of flooding to it and its impact on flood risk elsewhere.

Assessment Approach

3.1.4 Given the limitations of the SEPA Flood Map, which is based on high level hydraulic modelling, a hydraulic model has been developed for the scheme area. The model adopts a linked one-dimensional (1D)/two-dimensional (2D) technique, where it represents the river channel as a 1D component using Flood Modeller software and it is linked dynamically to the floodplain, which is represented in 2D, using TUFLOW software.

3.1.5 It should be noted that hydraulic modelling software has a tolerance of +/- 10 millimetre (mm) on predicted water levels and that there are further tolerances within the survey data and hydrology used to construct the model. Further details are available within Appendix A11.2 (Surface Water Hydrology) and Appendix A11.4 (Hydraulic Modelling Report). These tolerances are applicable to both the baseline and proposed scheme modelling and therefore are not considered to have an impact on the assessment of flood risk to the scheme. The inherent small uncertainty is addressed via the incorporation of freeboard within the proposed scheme design. Throughout this FRA modelling results are reported to the nearest mm to provide as detailed an indication of model outputs as possible, but it is emphasised that they are subject to these tolerances.

3.1.6 A baseline hydraulic model was developed to reflect the existing situation (pre the proposed development) and included representation of the River Tummel, River Tay and the Kindallachan Burn, Sloggan Burn and Dowally Burn. A further 13 watercourses were added to the model as the assessment process progressed as either the River Tay floodplain was found to reach the downstream outlet of the culvert under the A9, or where hydraulic complexity meant a spreadsheet based assessment was considered insufficiently robust.

3.1.7 To assess existing flood risk and the potential impact of the proposed scheme, the modelling considers a range of flood events for two scenarios: the ‘baseline (existing A9) scenario’ and the ‘proposed scheme (without mitigation) scenario’. A third modelling scenario, the ‘proposed scheme (with mitigation) scenario’ was developed to identify methods of mitigating any adverse impacts. The Environmental Statement (Appendix A11.4: Hydraulic Modelling Report) provides further details of the hydraulic model build process, but in summary, modifications to the baseline model to represent the proposed scheme included:

- horizontal and vertical changes to the existing A9 and embankments to accommodate the new carriageway, which includes embedded mitigation to prevent the carriageway from flooding;

- modifications to existing A9 structures and inclusion of new hydraulic structures (bridges and culverts) in the river channel; and
- inclusion of proposed scheme features within the floodplain, including junctions, access roads and tracks, and road drainage features, such as SuDS features.

3.1.8 Both model scenarios were then simulated for a range of flood events including the design flood event in accordance with SEPA recommendations (SEPA, 2015). Appendix A11.2 (Surface Water Hydrology) provides further detail of the flood hydrology. Peak flows at key locations on each of the principal watercourses are included in Table 4. It should be noted that hydraulic modelling (Transport Scotland 2017b) demonstrates there will be a negligible increase in flows (less than 0.5m^3/s in the 0.5% AEP (200-year) plus CC event) as a result of the proposed A9 dualling scheme from Pitlochry to Killiecrankie, upstream of this model. Therefore, no adjustment of flows within the Project 03 model is considered necessary as a result of the proposed scheme upstream.

Table 4: Peak predicted baseline flows (m^3/s) on key watercourses

Watercourse	50% AEP (2-year)	3.33% AEP (30-year)	2% AEP (50-year)	0.5% AEP (200-year)	0.5% AEP (200-year) plus CC
Tummel at Tay/Tummel confluence	566	1,000	1,050	1,359	1,630
Tay at Tay/Tummel confluence	356	697	770	1,064	1,277
Kindallachan Burn (WF40)	8	16	17	24	29
Sloggan Burn (WF39)	1	2	2	4	4
Dowally Burn (WF36)	3	6	7	9	11
Tay at downstream model extent	769	1,445	1,578	2,136	2,563

3.1.9 Once simulated, 1D and 2D model outputs were extracted and mapped, with specific comparison made to:

- peak flood hydrograph and level within the channel;
- peak flood depth within the floodplain;
- spatial flood extent;
- peak water velocity;
- flood inundation volume; and
- historic flood records for verification purposes.

3.1.10 Annex D contains mapping illustrating the baseline scenario and the proposed scheme (no mitigation) scenario flood depths across the modelled floodplain. The mapping also illustrates the impacts on maximum flood level difference, categorised using Table 5, during the design flood event. Appendix A11.4 (Hydraulic Modelling Report) contains peak water levels for each model cross-section.

Table 5 : Fluvial flood risk impacts

Potential flood impact		Change in Peak Flood Level for the Design Flood Event
	Major Adverse	Increase in peak flood level >100mm
	Moderate Adverse	Increase in peak flood level >50mm
	Minor Adverse	Increase in peak flood level >10mm
	Negligible	Negligible change in peak flood level <+/- 10mm
	Minor Beneficial	Reduction in peak flood level >10 mm

Potential flood impact		Change in Peak Flood Level for the Design Flood Event
	Moderate Beneficial	Reduction in peak flood level >50mm
	Major Beneficial	Reduction in peak flood level >100mm

Baseline Fluvial Flood Risk

3.1.11 This section provides an overview of baseline fluvial flood risk along the existing A9 corridor identified using the hydraulic model. The baseline extents are included on Figure 4 to Figure 16.

Ballinluig to Westhaugh of Tulliemet

Refer to Figure 3 and Figure 4

3.1.12 At the northern end of the scheme area, hydraulic modelling predicts that the River Tummel and River Tay would start to flood as a result of an event more frequent than the 3.33% AEP (30-year) event. In the 3.33% AEP (30-year) event, hydraulic modelling predicts flooding at Mill of Logierait Farm, with existing defences overtopped. However, no flooding is predicted to the A827 in this area. On the east bank of the Tummel, several areas of flooding are predicted by the hydraulic model, with overtopping of the banks and informal flood defences that have been constructed in this area, resulting in inundation of low lying areas of the floodplain beyond. Approximately half of the floodplain between the river and the Highland Main Line railway embankment is predicted to flood. Two areas of the floodplain between the railway and the existing A9 are also flooded due to flows through culverts in the railway embankment.

3.1.13 In the 0.5% AEP (200-year) plus CC flood event, flooding extends north of the A827, including flooding of the A827 over approximately a 270m length. The floodplain on the west bank of the Tummel is more extensively filled by flood water, with the area between the River Tummel and the railway completely inundated with the exception of isolated high spots, some of the Station Cottages and their access road. The area between the existing A9 and the Highland Main Line railway also has a far greater flood extent in this event, although there are still some dry islands.

3.1.14 Modelling predicts flooding in the 0.5% AEP (200-year) plus CC design flood event to the House of Bruar complex at Inch Farm, as well as at Station Cottages. Peak flood depths at Station Cottages vary but a depth in excess of 0.5m is predicted to one of the properties. Flooding to a similar depth is predicted at Inch Farm.

Figure 3: Ballinluig to Westhaugh of Tulliemet, 3.33% (30-year) baseline flood risk

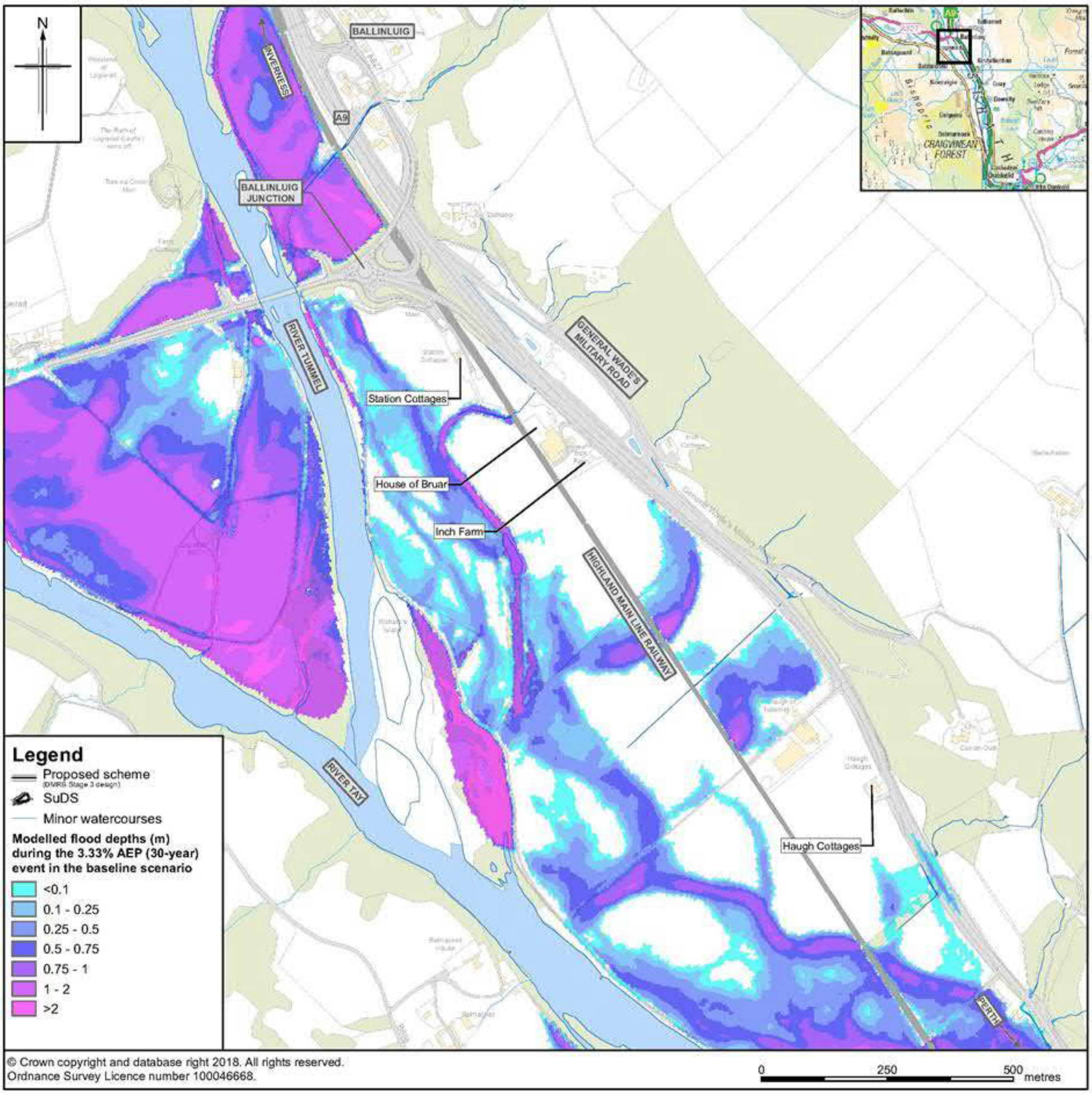
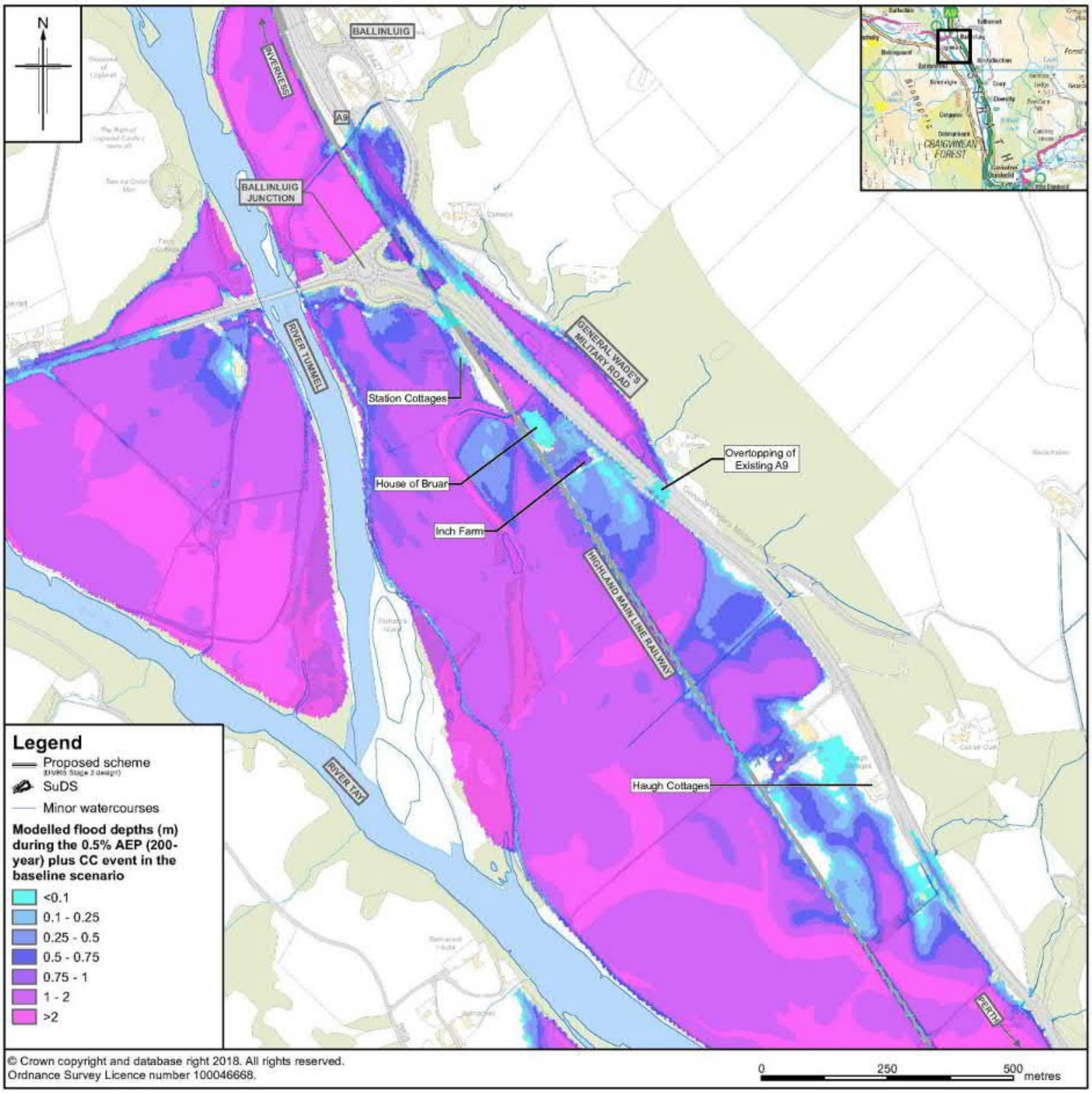


Figure 4: Ballinluig to Westhaugh of Tulliemet, 0.5% (200-year) +CC baseline flood risk



3.1.15 In this event overtopping of the existing A9 over an approximately 400m length of the carriageway is predicted at Ballinluig Junction, north of the scheme extents. This results in flooding to the existing A9, to depths of up to 0.95m, as well as flows from the area of overtopping south towards a field to the north east of the existing A9 where existing road drainage ponds are located.

Westhaugh of Tulliemet to Kindallachan

Refer to Figure 5 *and Figure 6*

3.1.16 South of Westhaugh of Tulliemet, hydraulic modelling predicts that a large proportion of the floodplain between the River Tay and the Highland Main Line railway is flooded in the 3.33% AEP (30-year) event and is completely inundated in the 0.5% AEP (200-year) plus CC design flood event.

Figure 5 : Westhaugh of Tulliemet to Kindallachan 3.33% (30-year) baseline flood risk

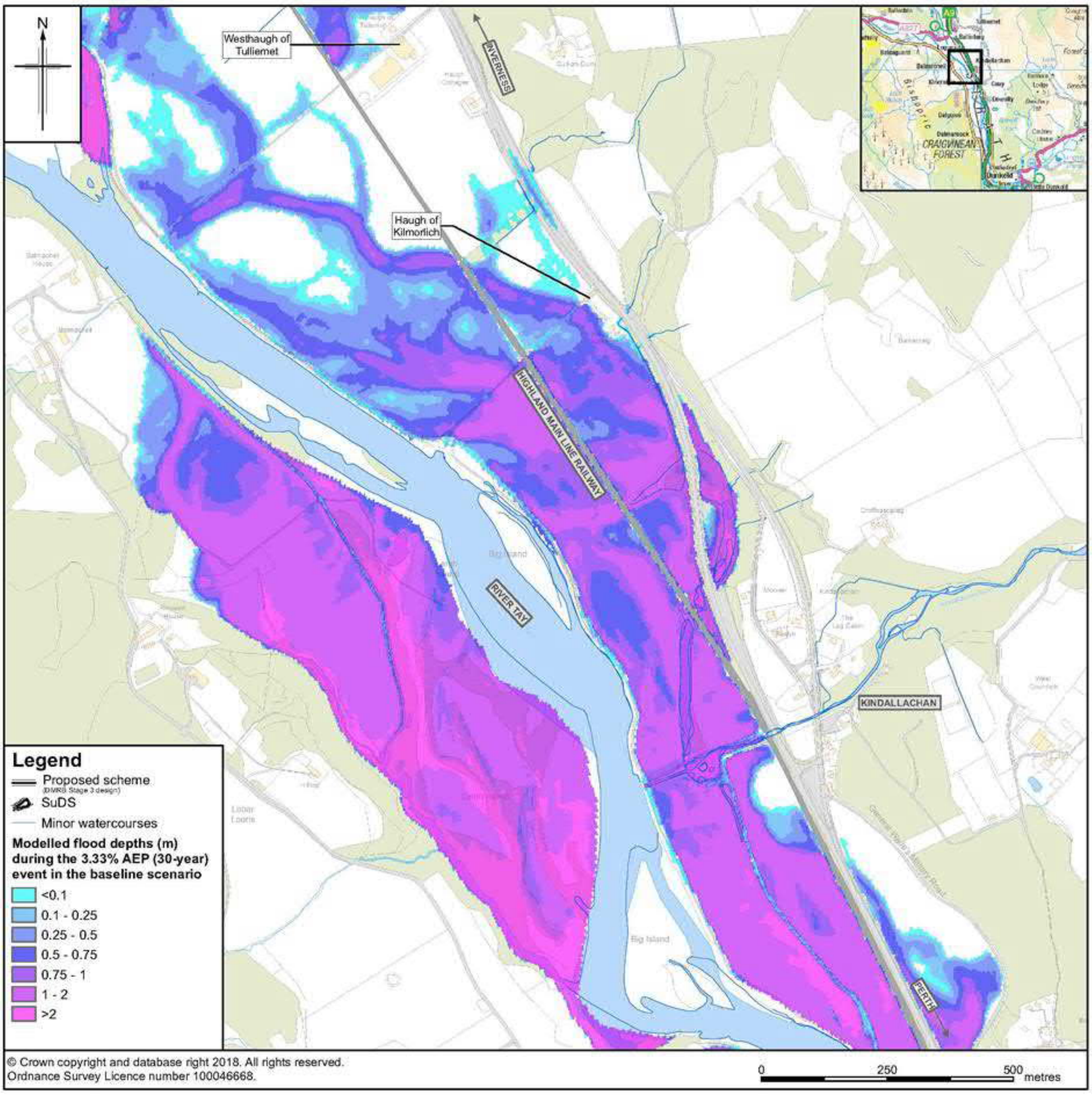
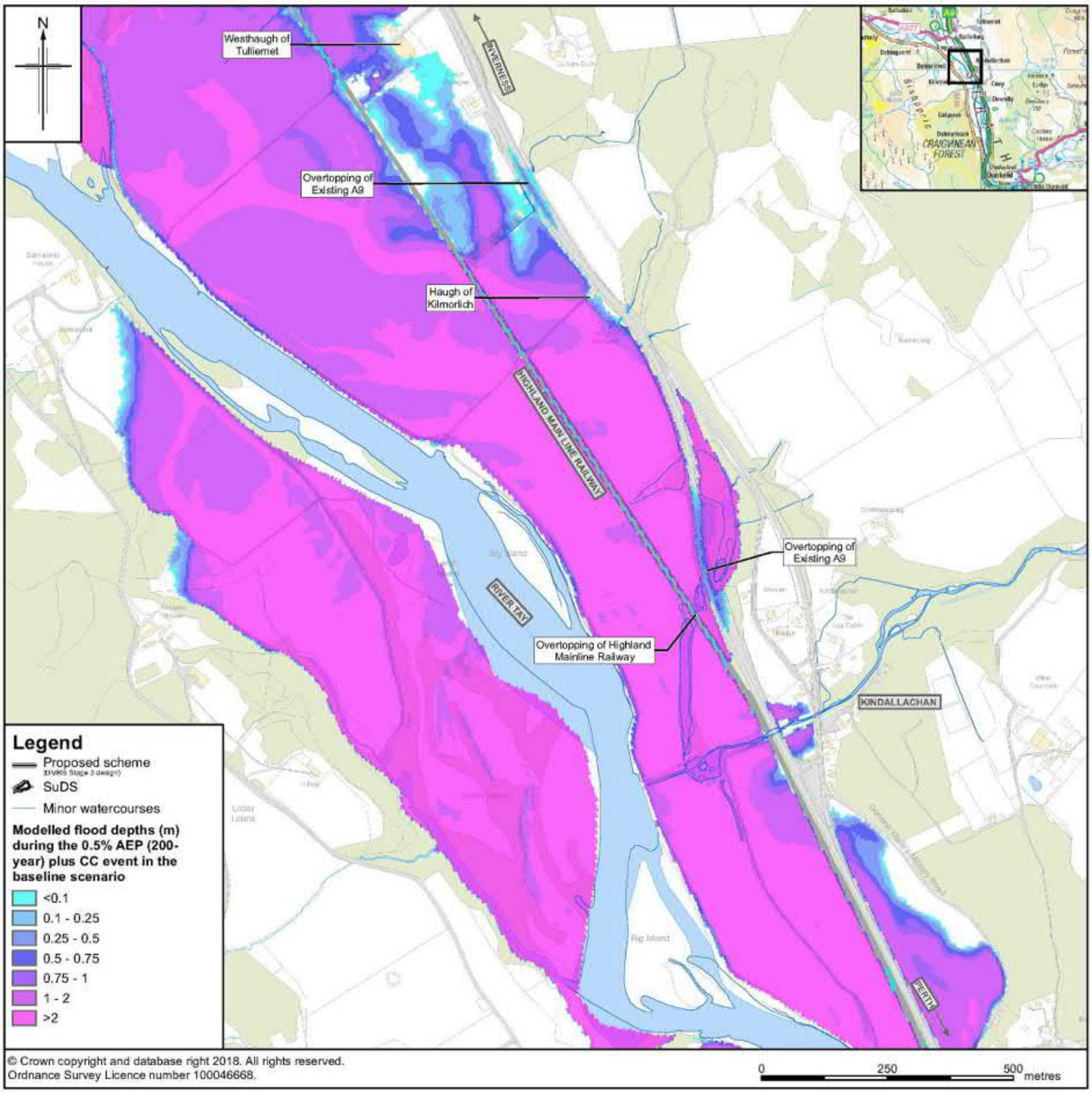


Figure 6 : Westhaugh of Tulliemet to Kindallachan 0.5% (200-year) +CC baseline flood risk



3.1.17 The model indicates that the area between the Highland Main Line railway embankment and the existing A9 south of Westhaugh of Tulliemet and north of Kindallachan also becomes inundated in the 0.5% AEP (200-year) plus CC flood event, with floodwater flowing from the north of Westhaugh of Tulliemet, through culverts in the railway embankment and due to overtopping of the railway embankment, particularly near Kindallachan. In the 3.33% AEP (30-year) flood event, there is no flooding predicted near Haugh Cottages, but flooding is predicted at the southern end of the area.

3.1.18 Flooding to the existing A9 carriageway is predicted in the 0.5% AEP (200-year) plus CC flood event, with areas of overtopping of the existing A9 approximately 150m in length south of Haugh Cottages and 300m in length north of Kindallachan. Where overtopping occurs to the north of Kindallachan, flood levels either side of the road are predicted to equalise via two culverts under the existing A9, which would then drain the area to the east of the existing A9 as the flood event recedes.

3.1.19 Within this area there are no properties predicted to be at risk in the 3.33% (30-year) AEP flood event; however, in the 0.5% AEP (200-year) plus CC flood event flooding is predicted to an outbuilding at Westhaugh of Tulliemet and to Haugh of Kilmorich.

Kindallachan to Guay

Refer to Figure 7 and Figure 8

3.1.20 This section of the existing A9 includes two of the larger tributaries to the River Tay within the project area: Kindallachan Burn and Sloggan Burn, which are culverted under the existing A9. Flood water from the Tay flows through both these culverts, resulting in flooding immediately to the east of the existing A9. This is predicted to cause flooding to Guay Farmhouse, but does not affect properties in Kindallachan. The floodplain on both the east and west of the River Tay is inundated in the 3.33% AEP (30-year) flood event.

Figure 7 : Kindallachan to Guay 3.33% AEP (30-year) baseline flood risk

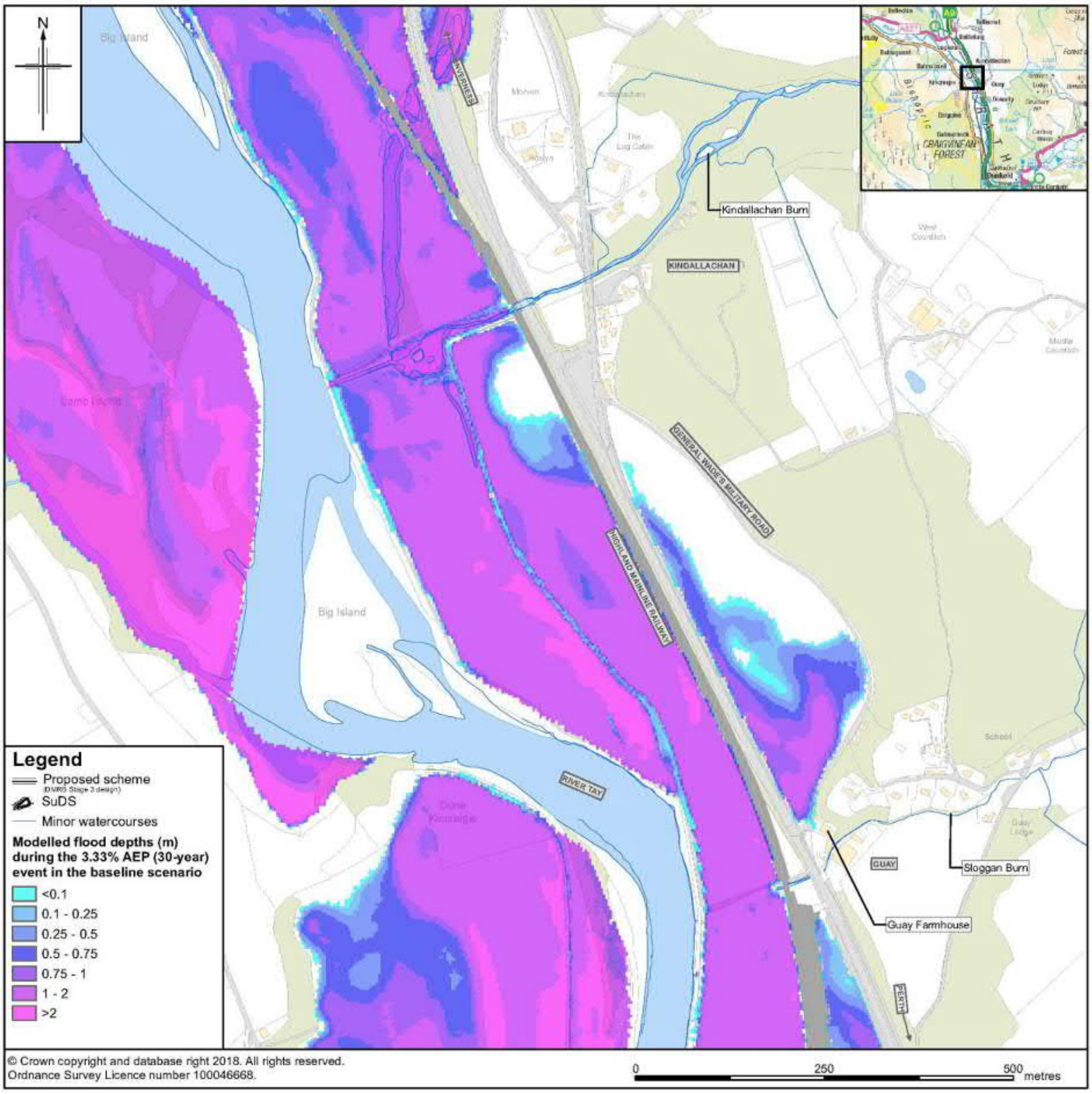
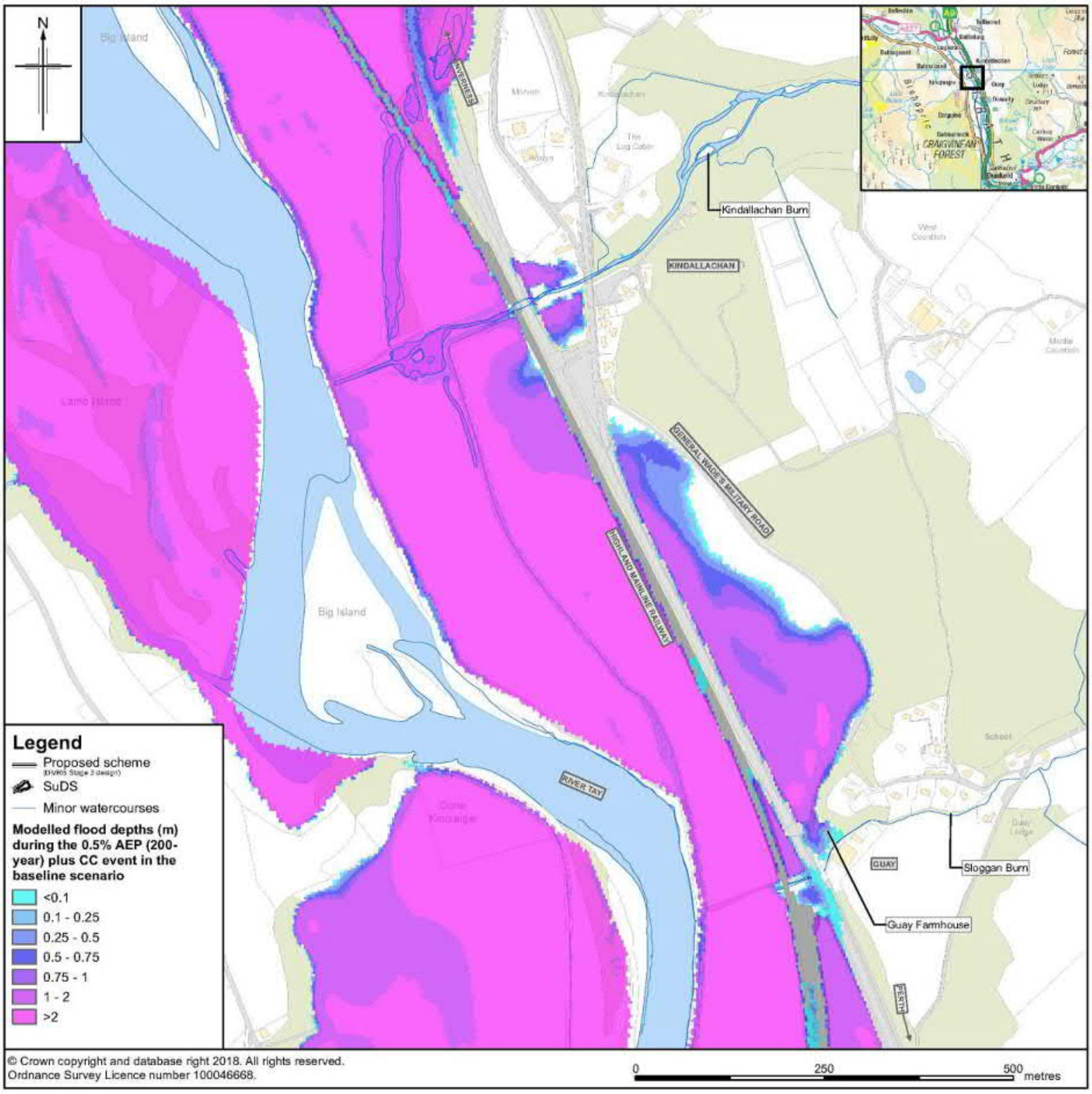


Figure 8 : Kindallachan to Guay 0.5% AEP (200-year) +CC baseline flood risk



3.1.21 Flooding has been observed in photographs and reported by local residents as occurring in the field immediately east of the existing A9 between ch5300 and ch5900, north of Guay. Initial modelling of this area indicated limited flooding, with flooding to the southern end of the field from the Sloggan Burn. Further investigation into potential flood mechanisms in this area has therefore been undertaken. A survey of the field following stakeholder consultation found no evidence of a culvert under the existing A9 that was suggested during consultation. Groundwater flooding has also been considered as a potential source of the flood water, with potential for hydraulic connectivity between the River Tay and east of the existing A9 via superficial gravel deposits. Monitoring has been undertaken with a data-logger to monitor ground water levels within the borehole located in the field. The results of this monitoring have been inconclusive and are discussed in greater detail within Section 6. Surface water flooding from woodlands to the east is also a possibility, with SEPA surface water flood maps indicating that much of the field is at high risk of surface water flooding from a 10% AEP (10-year) flood event.

3.1.22 Flooding in the field has been observed to occur during flood events on the River Tay and wrack marks have been recorded within this area. Photographic evidence provided by SEPA indicates that the flooding in the field occurs simultaneously with the main floodplain. This suggests that should groundwater flooding occur, it is linked to water levels in the River Tay. Groundwater flooding would be likely to have a slower response to flooding than that represented in the baseline model.

3.1.23 Due to uncertainty in the exact detail of the flood mechanism, baseline hydraulic modelling of this area has taken a conservative approach, with connectivity provided between the field and the floodplain west of the A9 through introduction of a culvert under the road embankment. This representation is considered conservative when compared to surface water or groundwater flooding, as the flood event on the River Tay provides maximum flood depths within the project area. The rainfall event resulting in maximum surface water flood depths (short duration event) in this area would be very different from the event resulting in maximum flood depths on the River Tay (longer duration event), indicating that the two events are very unlikely to coincide.

3.1.24 The likely delay in groundwater levels rising within the field would similarly reduce peak water levels in the field when compared to the baseline model representation and therefore the culvert has been added to the baseline model as a conservative approach to estimate peak water levels. Water levels predicted by the model using this method have been verified against flood extents and wrack marks as part of the model calibration. Further information on model calibration can be found in Appendix A11.4 (Hydraulic Modelling Report).

Guay to Dowally

Refer to Figure 9 and Figure 10

3.1.25 Between Guay and Dowally the River Tay floodplain is predicted to become inundated in the 3.33% AEP (30-year) flood event. In this area, the Highland Main Line railway heads in a south-western direction, away from the existing A9. The rail embankment acts as a partial barrier to the passage of flood water, however the areas to the east of the Highland Main Line railway still become flooded due to a culvert through the embankment, and, in more extreme scenarios such as the design event, due to overtopping of the rail embankment and the informal flood defences to the south of Dowally. This results in flooding to the existing A9 near Guay to depths of up to 0.1m over approximately a 75m length of the road in the 0.5% AEP (200-year) plus CC flood event. Further south, near Balnabeggan, flooding of the western edge of the existing A9 carriageway is predicted over approximately 250m. Flooding is also predicted to the access road to Dowally and to Dowally Farm.

Figure 9 : Guay to Dowally 3.33% (30-year) baseline flood risk

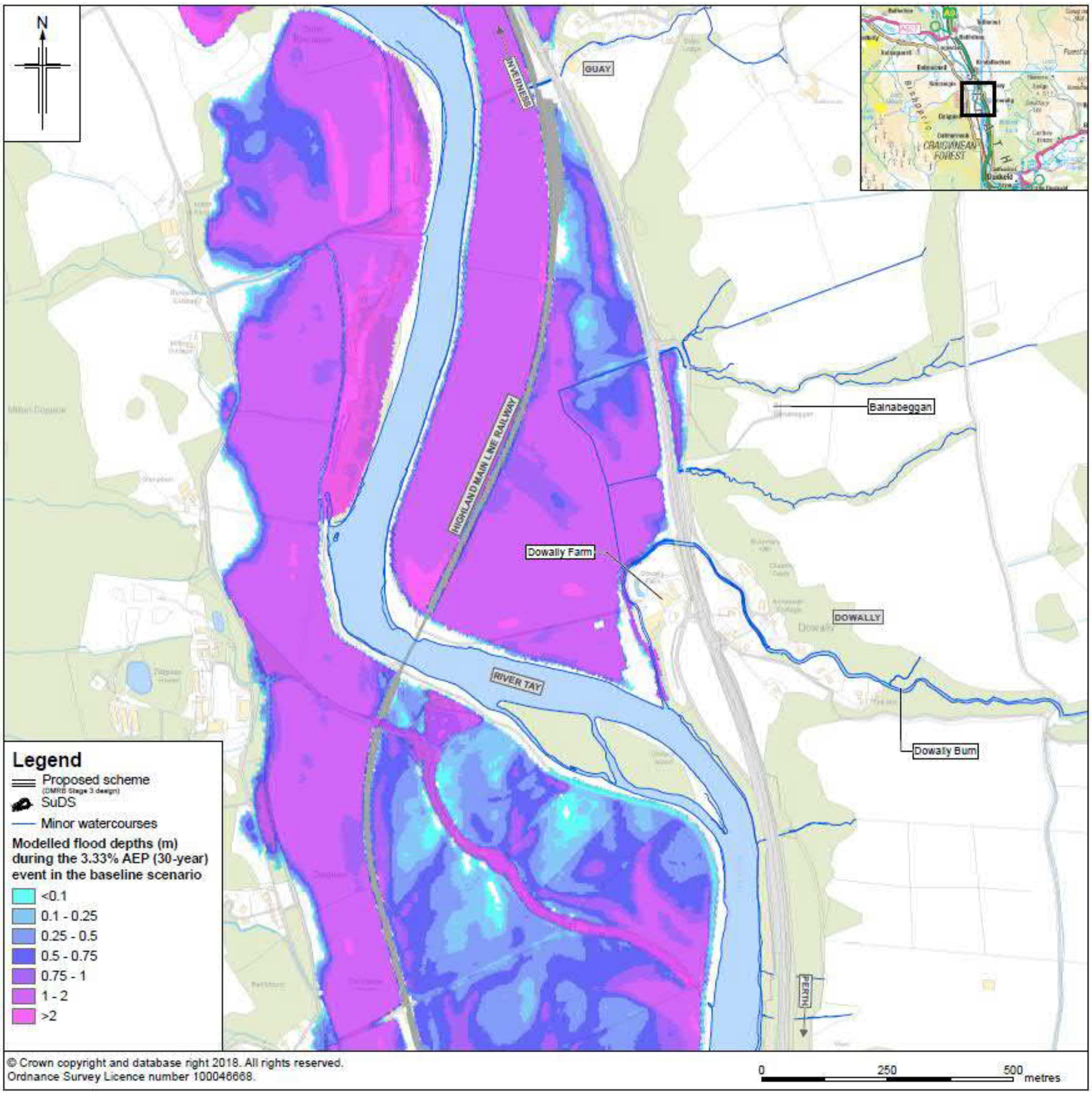
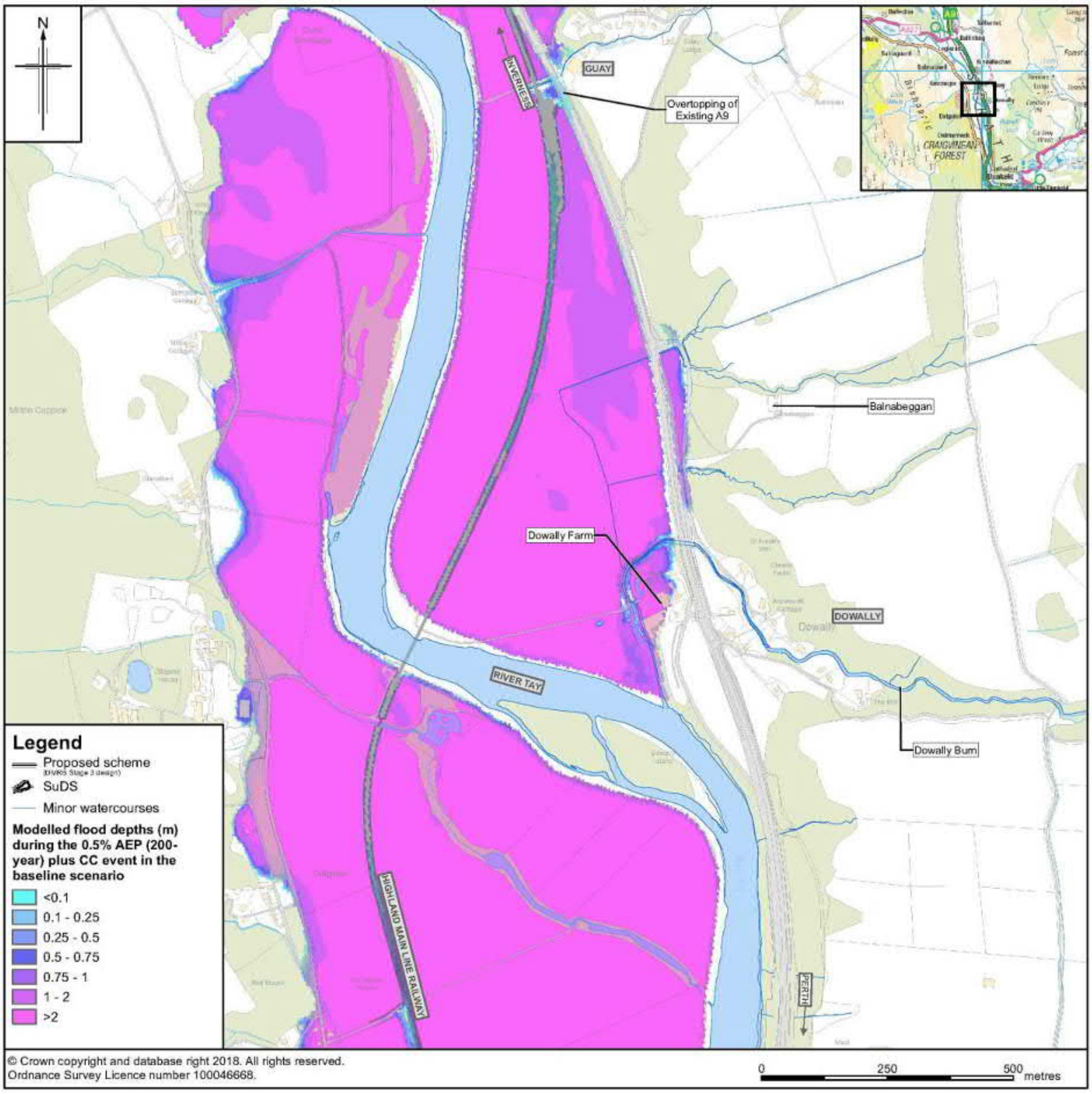


Figure 10 : Guay to Dowally 0.5% (200-year) +CC baseline flood risk



Dowally to Tay Crossing

Refer to Figure 11, Figure 12, Figure 13*, Figure 14, Figure 15 and Figure 16*

3.1.26 South of Dowally the left (east) bank of the River Tay is steeper, resulting in limited flooding within this area. The floodplain on the right (west) bank is predicted to become inundated in the 3.33% AEP (30-year) flood event. The Highland Main Line railway runs on embankment through this area, with hydraulic connectivity provided by culverts through the embankment. The railway is predicted to be overtopped in several locations in a 0.5% AEP (200-year) plus CC flood event. Flooding is predicted to properties including buildings at Dalguise House, Ballicock and Woodinch. There is an area of flood plain on the left bank between Rotmell Farm and Ledpetty Lodge, which results in overtopping of the existing A9 in a 0.5% AEP (200-year) plus CC flood event over approximately 300m, with depths of up to 0.45m on the carriageway.

Figure 11: Dowally to Rotmell Farm 3.33% (30-year) baseline flood risk

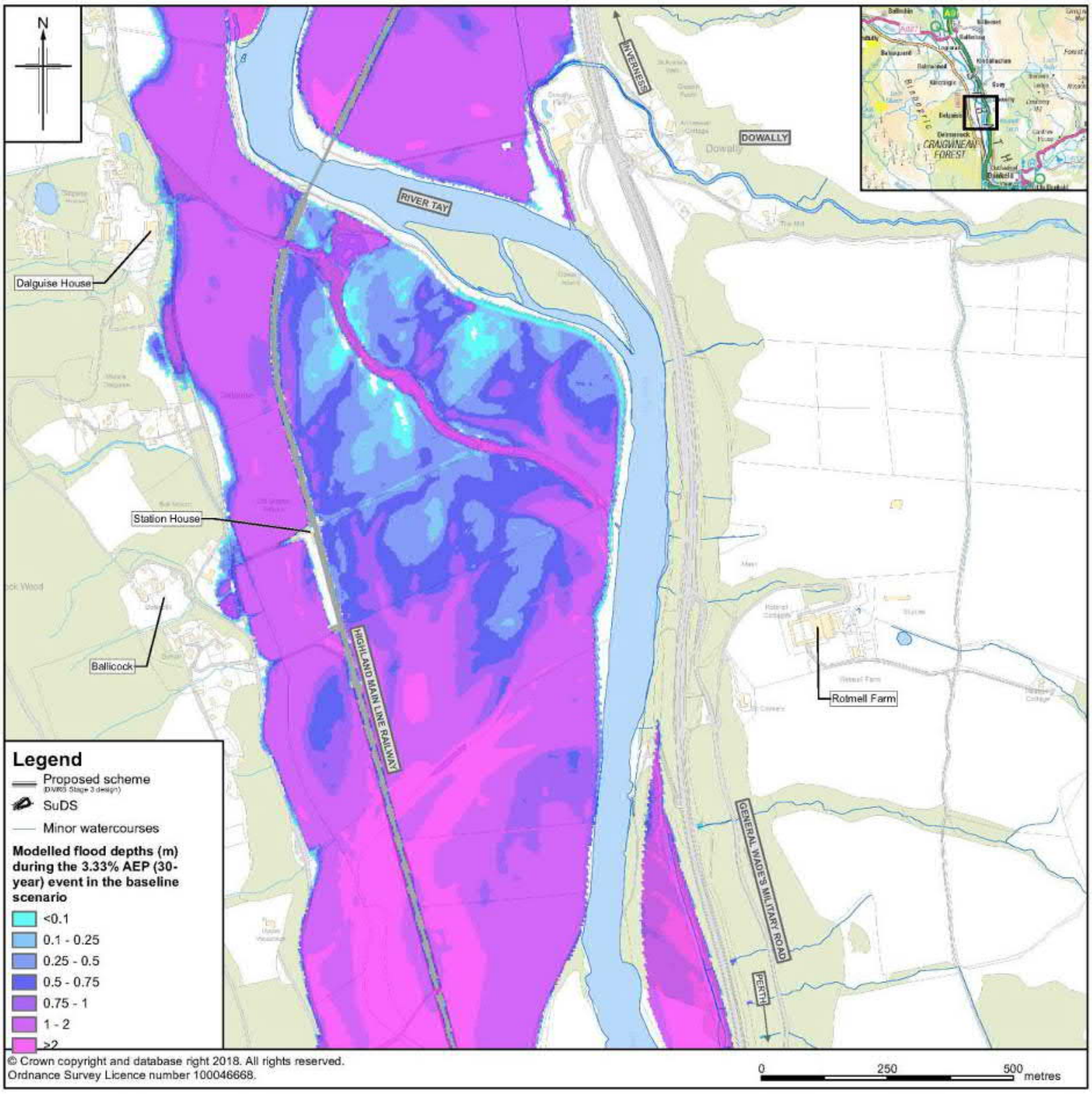


Figure 12: Dowally to Rotmell Farm 0.5% (200-year) +CC baseline flood risk

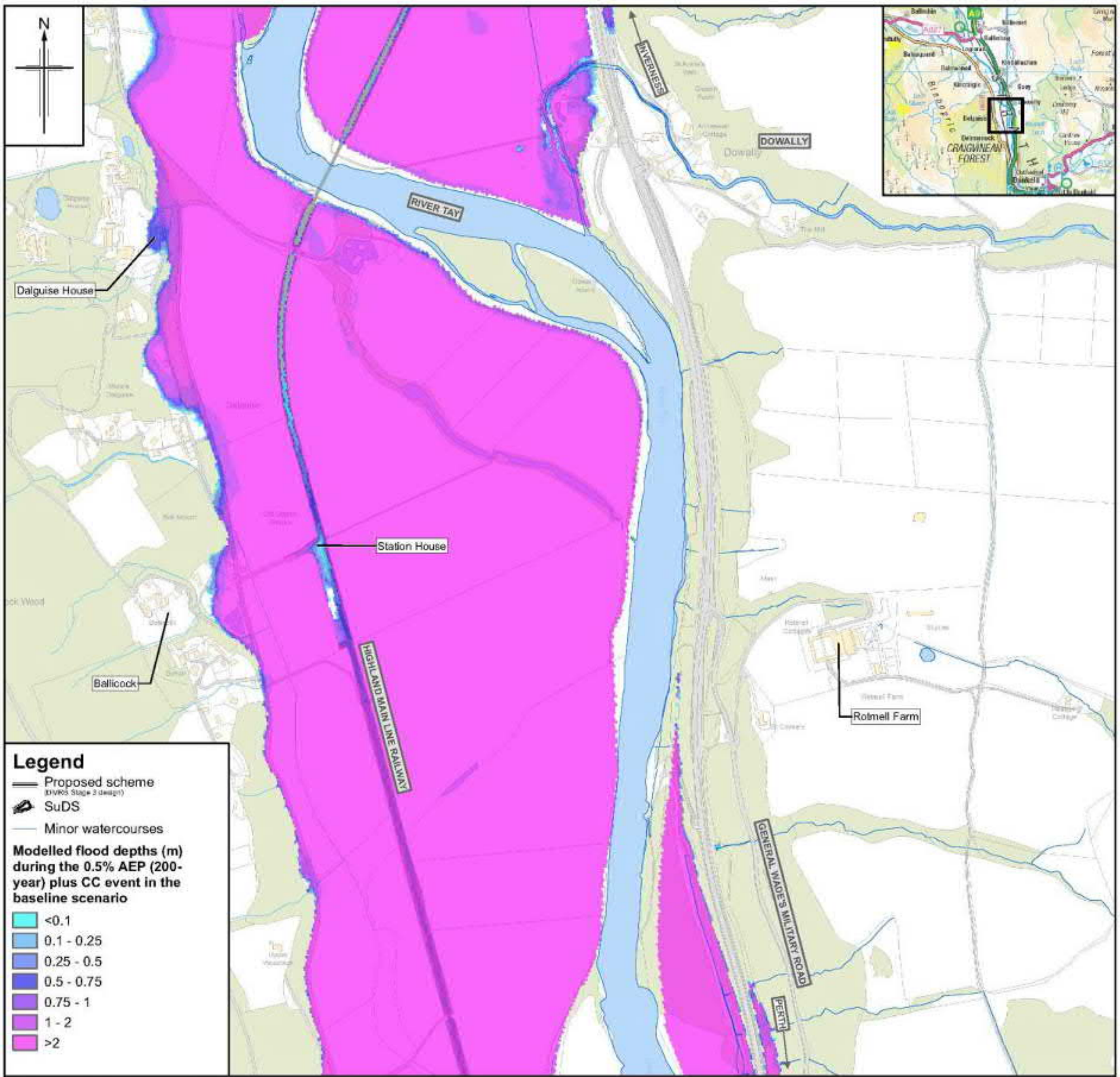


Figure 13: Rotmell Farm to Dalmarnock 3.33% (30-year) baseline flood risk

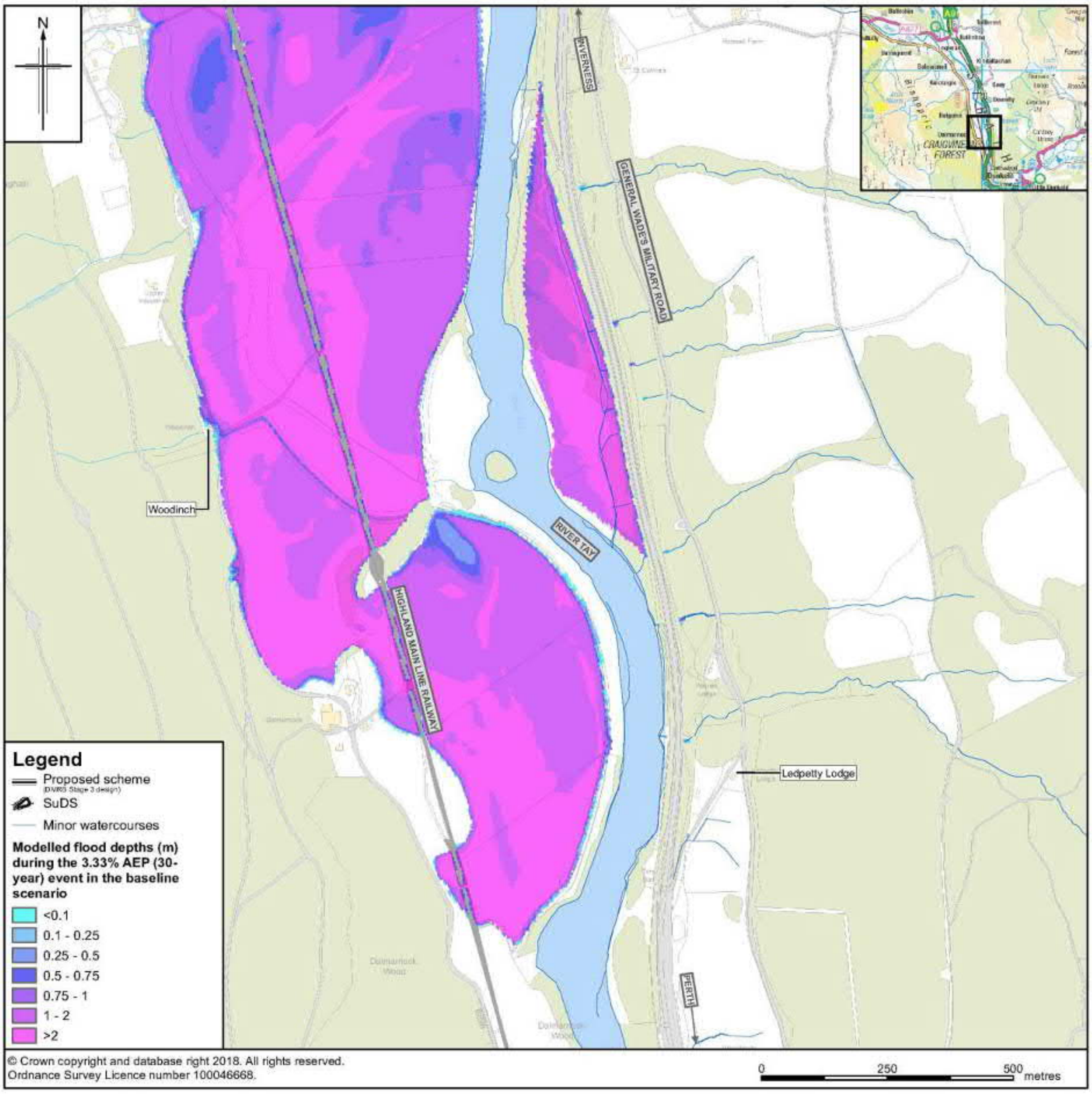


Figure 14: Rotmell Farm to Dalmarnock 0.5% (200-year) +CC baseline flood risk

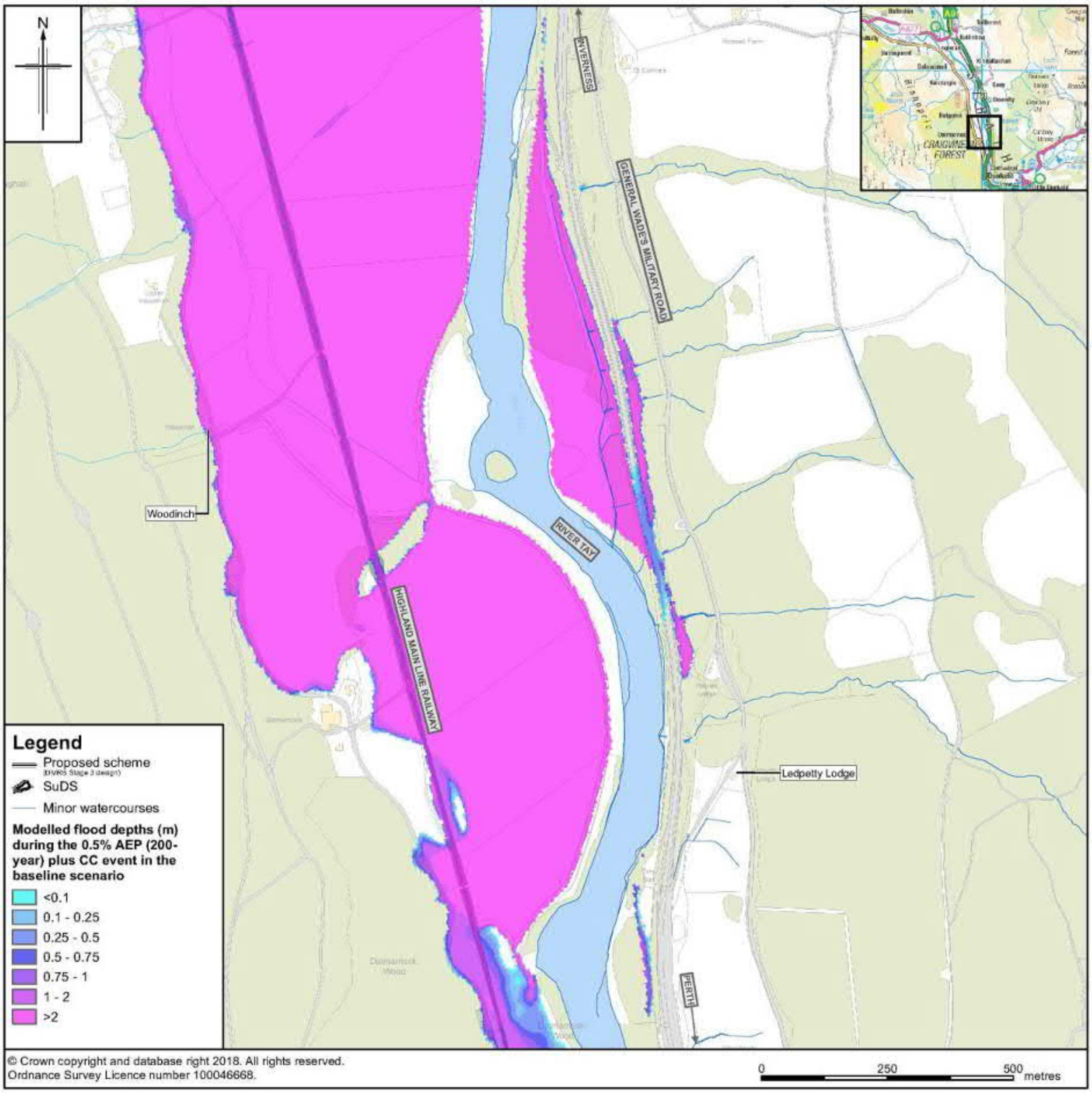


Figure 15: Dalmarnock to Tay Crossing 3.33% (30-year) baseline flood risk

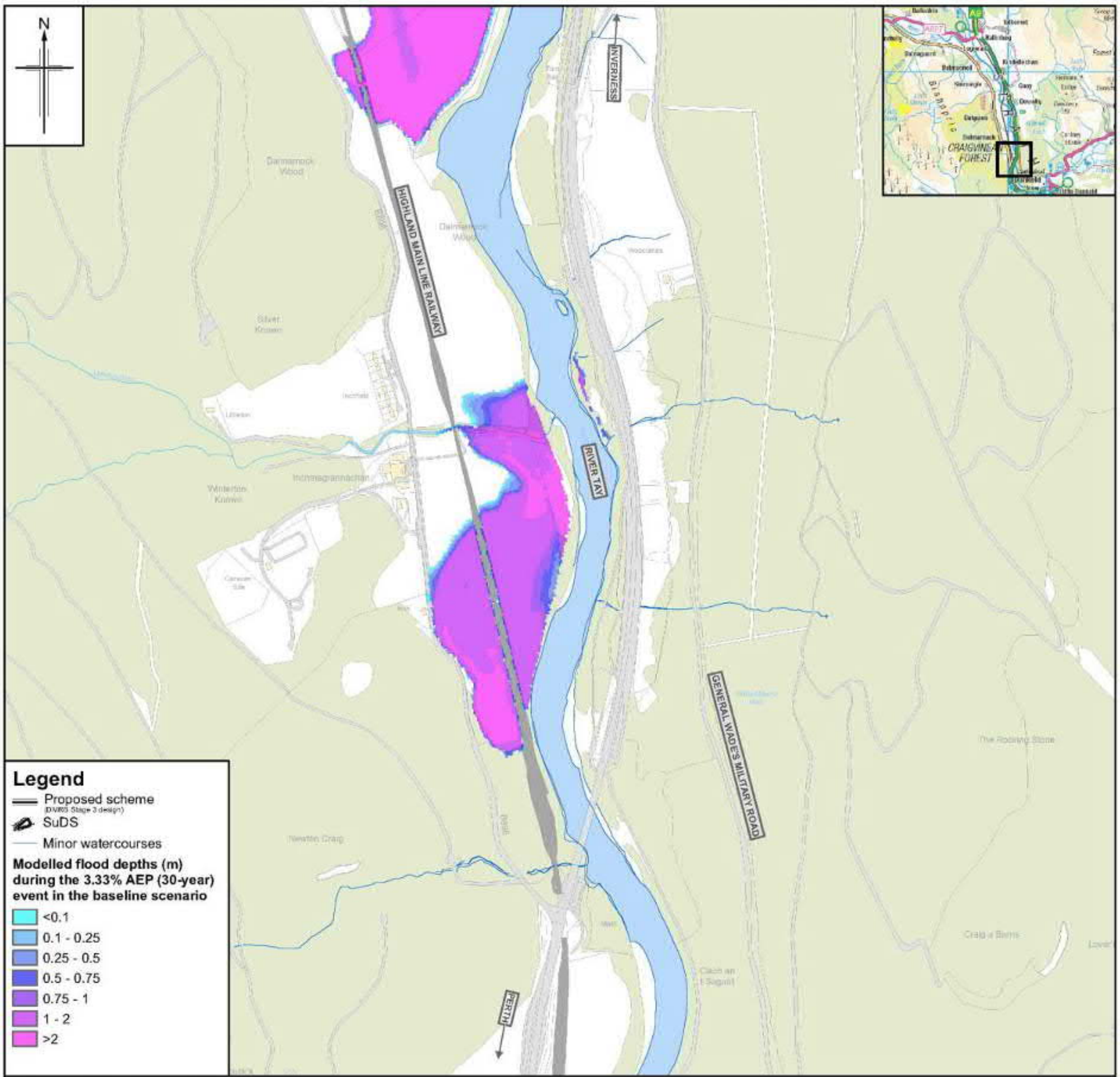
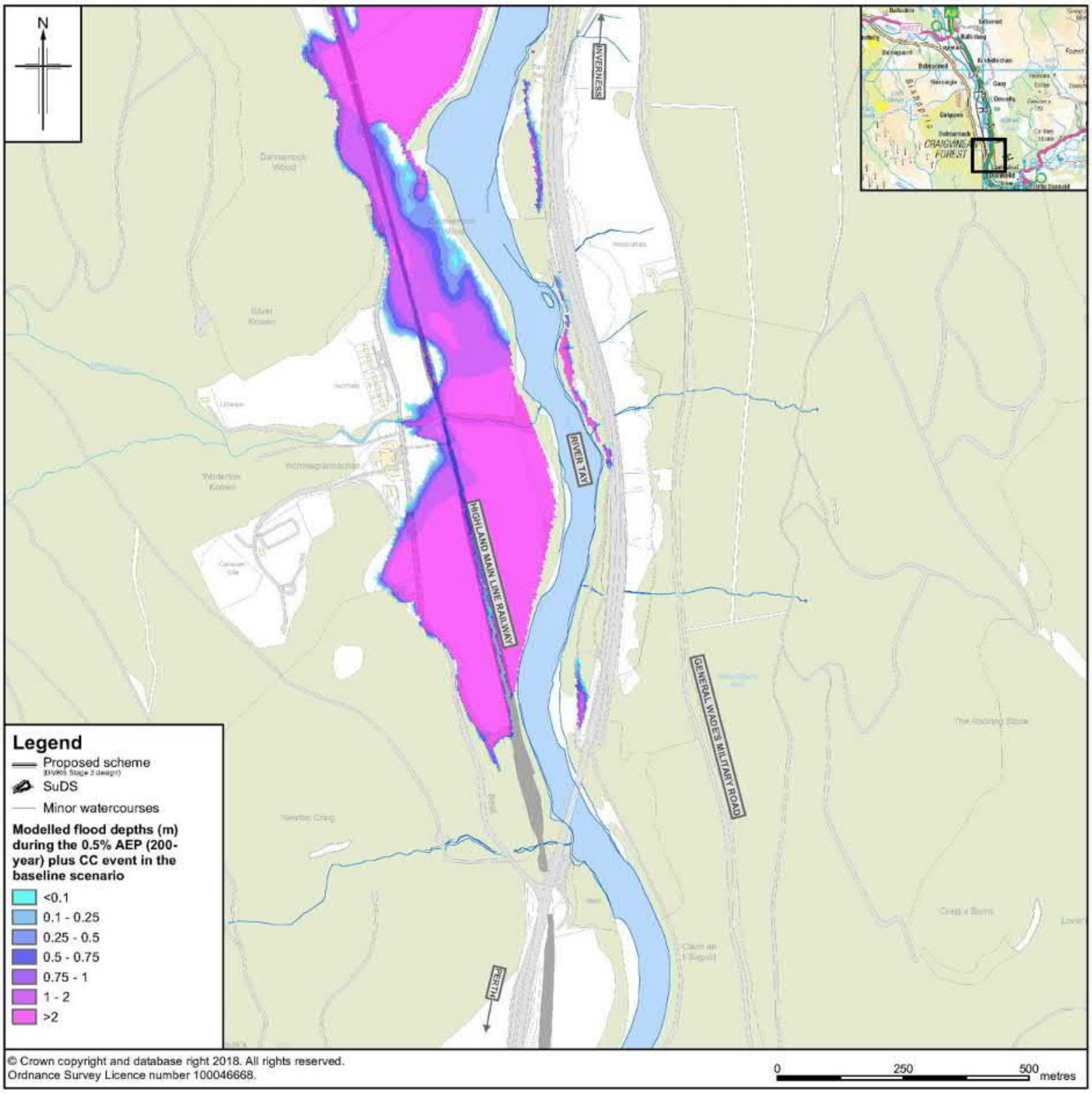


Figure 16: Dalmarnock to Tay Crossing 0.5% (200-year) +CC baseline flood risk



Summary

3.1.27 The predicted baseline flood risk within the project area has been summarised in Table 6.

Table 6: Baseline flood risk

Location	Baseline Flood Risk in 0.5% AEP (200-year) plus CC event
Ballinluig to Westhaugh of Tulliemet	Flooding to A9 north of scheme extents, Mill of Logierait Farm, Station Cottages and Inch Farm. Extensive flooding to agricultural land and on rail embankment.
Westhaugh of Tulliemet to Kindallachan	Flooding to section of the A9 north of Kindallachan, to an outbuilding at Westhaugh of Tulliemet and to Haugh of Kilmorich. Extensive flooding to agricultural land and on rail embankment.
Kindallachan to Guay	Flooding to Guay Farmhouse and A9. Extensive flooding to agricultural land and rail embankment.
Guay to Dowally	Flooding to Dowally Farm and A9. Extensive flooding to agricultural land and rail embankment.

Location	Baseline Flood Risk in 0.5% AEP (200-year) plus CC event
Dowally to Tay Crossing	Flooding to Dalguise House, properties within Ballicock and Woodinch and A9. Extensive flooding to agricultural land and rail embankment.

Potential Impacts

3.1.28 This section provides an overview of the impact of the proposed scheme upon fluvial flood risk without mitigation.

3.1.29 The proposed scheme includes raising the main alignment above the 0.5% AEP (200-year) plus CC peak water level to reduce the risk of flooding to the proposed scheme. Where possible, a minimum freeboard of 600mm has been provided above this level as per SEPA guidance (SEPA 2015a). However, in one location (chainage 5480 to 5590) achieving this would have significant implications on Guay Farmhouse and the constructability of the scheme. A reduced freeboard has therefore been proposed, with a minimum of 470mm, to try to reduce the overall impact of the proposed scheme, whilst still providing sufficient resilience to major flood events. Lifting the main alignment in this area would require the road to be realigned to the east to avoid impacting on the Highland Main Line. This realignment would impact on the side road alignment. As this passes in close proximity to Guay Farmhouse, any realignment of either the side road or the main alignment would be likely to further reduce clearance to the property and is therefore considered undesirable.

<u>Ballinluig to Westhaugh of Tulliemet</u>

3.1.30 The proposed scheme has a limited footprint within the floodplain within this area, with road infrastructure located outside the 0.5% AEP (200-year) plus CC flood extents where possible. However, the proposed scheme impacts on flood risk through the upsizing of the culvert for WF53. This culvert acts as a conduit for flood water that overtops the existing A9 further north of the proposed scheme, allowing it to flow back to the main floodplain to the west of the existing A9. It is proposed to upsize this culvert as a result of the proposed scheme. This upsizing reduces the overtopping of the proposed scheme at this location, reducing flood risk to the proposed scheme and resulting in negligible increase (<10mm) in peak water levels in fields downstream of the proposed scheme.

<u>Westhaugh of Tulliemet to Kindallachan</u>

3.1.31 The proposed scheme footprint encroaches into the 0.5% AEP (200-year) plus CC flood extent on both the west and east sides of the main alignment through this section. To the east, the widened embankment reduces the floodplain available within the area between the main alignment and General Wade's Military Road. This area is an existing wetland, with steep sided slopes. The widening therefore results in an increase in flood risk in this area, with an increase in flood depths in the design event of 0.011m.

3.1.32 On the west side of the main alignment there is an increase in flood risk as a result of access track construction within the floodplain and the raising of the main alignment. The access tracks to Westhaugh of Tulliemet and Haugh Cottages are predominantly outside of the design event flood extents and the loss of floodplain where the embankments do encroach has a negligible impact on flood risk. There is a more significant loss of floodplain as a result of the inclusion of the Haugh of Kilmorich Access, with approximately 1,720m^3 of floodplain storage lost. This, combined with the raising of the main alignment in this section (reducing the flood risk to the main alignment but also requiring works within the floodplain to the west of the existing A9), reduces the available floodplain. The impact of this in the design event is negligible, however in events between the 3.33% AEP (30-year) and 1.33% AEP (75-year) it results in an increase in flood depths of up to 0.009m in the area between the A9 and the railway embankment, impacting on the embankments of both. There is also an increase in flood risk of up to 0.009m adjacent to Haugh of Kilmorich in events greater than the 2% AEP (50-year) event.

Kindallachan to Guay

3.1.33 Between Kindallachan and Guay the main alignment has been raised, reducing available floodplain and cutting off a small area of floodplain to the east of the existing road. There is also a reduction in floodplain within the field between the main alignment and the Dowally to Kindallachan Side Road south of Kindallachan, due to the widening of the road into this field. The raising of the road in the vicinity of the Sloggan Burn also reduces floodplain extents in the area of existing overtopping. These changes result in localised increases in peak flood depth to the Highland Main Line railway of 0.010m north of Guay and up to 0.072m immediately north of the Sloggan Burn.

Guay to Dowally

3.1.34 Between Guay and Dowally, the scheme footprint within the floodplain is significant, predominantly due to the location of the access roads associated with the proposed Guay South Overbridge in this location, although these have been located in the higher part of the existing floodplain where possible. The loss of floodplain in this area results in an increased peak flood depth in the design event of up to 0.010m to the Highland Main Line railway embankment and within the field between the main alignment and the railway.

Dowally to Tay Crossing

3.1.35 South of Dowally, the primary area of lost floodplain is due to the raising of the mainline preventing overtopping of the road between approximate ch1800 and ch2100. This results in a reduction in floodplain volume of approximately 15,700m^3, resulting in an increase in peak flood depth of 0.062m immediately east of the proposed scheme.

3.1.36 A general increase in peak flood depth in the design event can also be seen within the floodplain in this section. This increase is predominantly between 0.005m and 0.006m and impacts the Highland Main Line railway and the B898 as well as agricultural land.

Summary

3.1.37 The impact of the unmitigated scheme on flood risk within the project area has been summarised in Table 7.

Table 7: Impact of proposed scheme upon 0.5% AEP (200-year) fluvial flood risk (unmitigated)

Location	Approximate Volume of Floodplain Lost (m^3)	Impact [1]
Ballinluig to Westhaugh of Tulliemet	60	Negligible
Westhaugh of Tulliemet to Kindallachan	24,130	Increased peak flood depth in wetland east of the proposed scheme of 0.011m. Increased peak flood depth between main alignment and Highland Main Line railway embankment and around Haugh of Kilmorich of up to 0.009m in events between 3.33% AEP (30-year) and 1.33 AEP (75-year).
Kindallachan to Guay	25,600	Increased flood risk to Highland Main Line railway of up to 0.070m north of the Sloggan Burn.
Guay to Dowally	43,100	Increased flood risk to Highland Main Line railway and general floodplain of up to 0.010m.
Dowally to Tay Crossing	15,700	Increased flood risk to Highland Main Line railway, B898 and general floodplain of up to 0.006m. 2,000m^2 area to east of proposed scheme with increase in peak flood depth of 0.062m.
Total	**108,590**	

1: For the 0.5% AEP (200-year) event, unless stated otherwise

Mitigation Measures

3.1.38 The hydraulic model predicts that without mitigation the proposed scheme would increase peak water levels locally within the River Tay floodplain. Mitigation measures to prevent these increases have therefore been considered and are discussed in more detail in the following sections.

Embedded Mitigation

3.1.39 Initially, potential changes in the proposed scheme design to reduce the impact on flood risk were considered. The embedded mitigation options considered and whether they have been incorporated are included in Table 8. It should be noted that the volumes of floodplain lost due to the proposed scheme are included in Table 7.

Table 8: Embedded mitigation measures considered

Measure	Flood Risk Benefit	Incorporation in Proposed Scheme
Relocate scheme outside floodplain	Would prevent loss of floodplain storage on the River Tay.	A multi-disciplinary technical study looking at potential alternative routes was undertaken at DMRB Stage 2. Routes that completely removed the proposed scheme from the floodplain were considered less favourable due to greater potential environmental impacts and considerably greater cost.
Reduce extent of scheme within floodplain	Would reduce loss of floodplain storage on the River Tay.	A multi-disciplinary technical study considering potential scheme layouts was undertaken at DMRB Stage 2. A desire to reduce impact on the floodplain was one of the primary reasons for southbound widening. Where possible, side roads have been relocated to be outside the functional floodplain. When considering options for the location of the overbridge, areas of lower flood risk have been considered in preference to areas of higher risk. Where practicable, embankment slopes within the floodplain, have been steepened to minimise encroachment.
Remove raised elements of SuDS ponds within the flood plain	Would reduce loss of floodplain storage on the River Tay.	Raised SuDS ponds removed from functional floodplain. Where ponds are within the floodplain they are below existing ground level.

Flood Risk Mitigation

3.1.40 Where it has not been possible to prevent the scheme from impacting on the functional floodplain by embedding mitigation within the design, the initial measure considered for standalone mitigation has been the provision of compensatory storage that, in accordance with SEPA guidance, should *'be provided close to the point of lost floodplain, provide the same volume and be at the same level relative to the design flood level as that lost*' (SEPA, 2015). The same SEPA guidance also states that '*the preferred method of like-for-like replacement storage should be followed as standard although there may be exceptions. For example, large-scale, Brownfield, development-plan led proposals for which it has been clearly demonstrated that like-for-like compensatory storage cannot be fully achieved may be progressed with information based on the detailed and robust application of acceptable modelling practices in consultation with SEPA*'.

3.1.41 There are significant geological, ecological, environmental and land constraints to the provision of compensatory storage within the proposed scheme area. These have all been taken into account as part of the assessment of mitigation measures and appropriate levels of mitigation have been proposed that reflect these constraints.

3.1.42 The primary aim in mitigation design and assessment has been to achieve a neutral impact on flood risk as a result of the proposed scheme. Where this has been identified as impracticable due to local constraints, prevention of increase in flood risk to sensitive receptors such as buildings and local infrastructure has been prioritised over increases to agricultural and other undeveloped land within the existing floodplain.

3.1.43 The process for identifying required mitigation has generally been as follows:

- Identify areas of floodplain loss as a result of the proposed scheme;

- Develop a long-list of potential mitigation options, including areas of potential level for level compensation;
- Multi-criteria analysis of the long-list to create a short-list for more detailed consideration; and
- Detailed analysis of shortlisted options, generally including hydraulic modelling.

3.1.44 The following sections set out the mitigation that has been short listed for consideration within the proposed scheme extents. The mitigation options considered have been assessed for their effectiveness both to mitigate changes in flood risk locally and as part of a wider range of measures to consider the wider floodplain. For ease of discussion the proposed scheme extents have been split into five separate areas and are discussed in turn, however the hydrology of the scheme area is such that there are clear links between the flooding in different sections and mitigation proposed in one section may provide benefits in another. Where this is the case it has been included within the discussion in the section where the mitigation is first cited. Additional options that were considered as part of a long-list and not progressed for further consideration are included in Annex C.

Shortlisted Measures

3.1.45 Shortlisted mitigation options located within the proposed scheme area are included in Table 9. It should be noted that the mitigation options within an area are not necessarily required to mitigate an increase in flood risk within the same area. A detailed discussion of the assessment undertaken and the rationale for the selected option can then be found in the following sections.

Table 9: Shortlisted mitigation measures

Location	Mitigation measures shortlisted
Ballinluig to Westhaugh of Tulliemet	• Do-nothing • Compensatory storage in field to the east of the main alignment near Ballinluig Junction (potentially in conjunction with additional culverts through the main alignment to improve connectivity with floodplain to the west). • Compensatory storage within raised areas of fields between the main alignment and the Highland Main Line railway
Westhaugh of Tulliemet to Kindallachan	• Do-nothing • Compensatory storage between the main alignment and Highland Main Line railway • Flood storage within road embankment or below main alignment through use of a structure • Compensatory storage to the east of the main alignment in wetland between the main alignment and Kindallachan North Access Road • Flood bund to protect Haugh of Kilmorich
Kindallachan to Guay	• Do-nothing • Compensatory storage within field between the main alignment and Dowally to Kindallachan Side Road • Flood walls along sections of the Sloggan Burn • Additional culvert for the Sloggan Burn west of the Highland Main Line railway.
Guay to Dowally	• Do-nothing • Compensatory storage south of the Sloggan Burn, between the main alignment and the Highland Main Line railway. • Compensatory storage east of the main alignment • Compensatory storage on edge of floodplain on right (west) bank of River Tay, adjacent to B898.
Dowally to Tay Crossing	• Do-nothing • Compensatory storage areas on right (west) bank of River Tay, at Dalguise, Dalmarnock or Inchmagrannachan • Compensatory storage area adjacent to the main alignment near Ledpetty Lodge

Mitigation Appraisal and Selection

Ballinluig to Westhaugh of Tulliemet

Refer to Figure 17

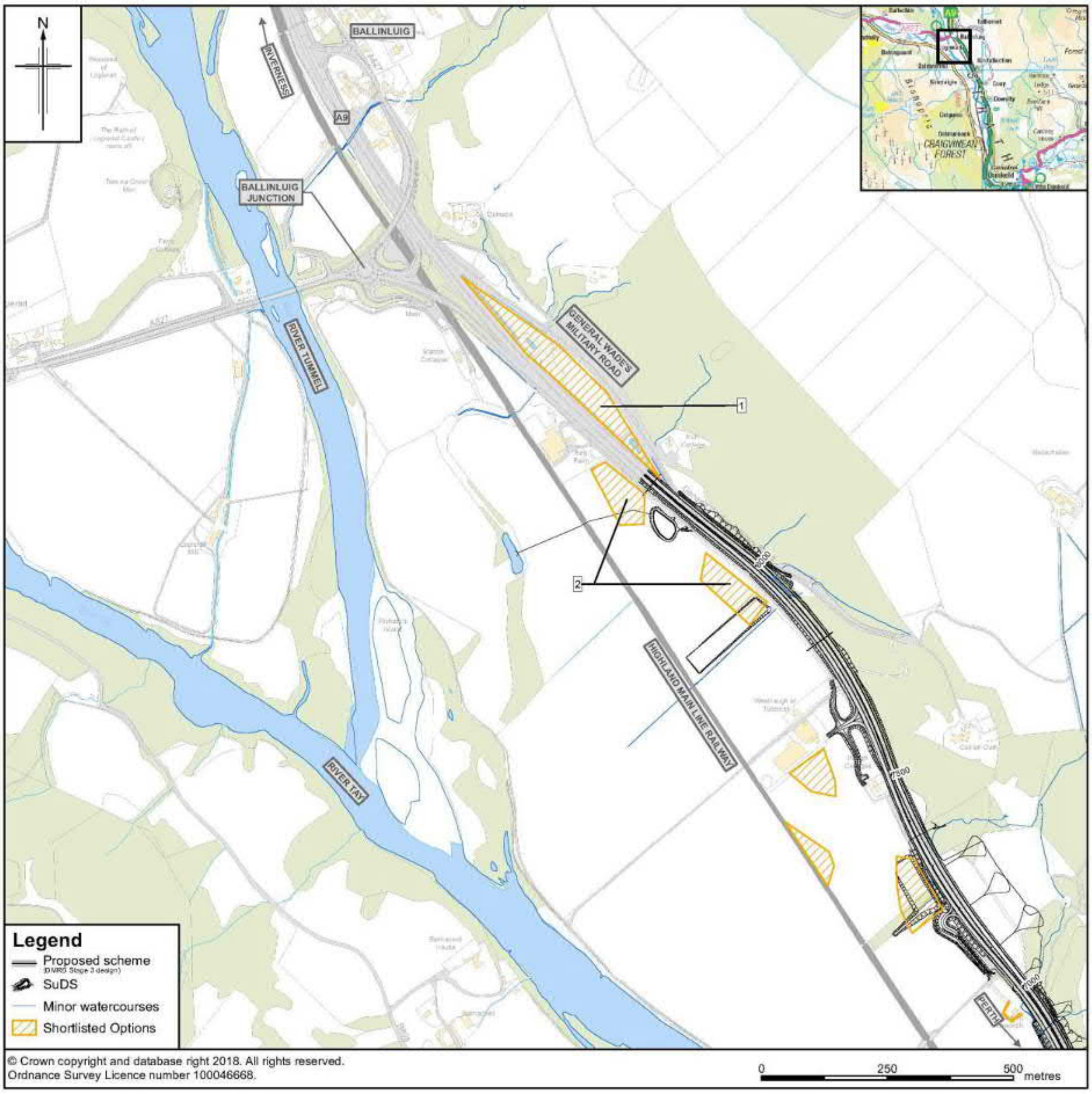
3.1.46 Three potential measures were shortlisted for consideration in this area. Although the volumetric loss of floodplain in this section is small (approximately 60m^3) and has negligible impact on flood risk, potential mitigation options in this area were also considered in conjunction with options for the Westhaugh of Tulliemet to Kindallachan section, to identify if there was sufficient hydraulic connectivity between the two areas for mitigation in this section to have benefits further downstream.

3.1.47 Compensatory storage in the area in the field to the east of the existing A9 at Ballinluig Junction was considered (Area 1 on Figure 17). This area is flooded in the design event as a result of overtopping of the existing A9 north of Ballinluig Junction and a flow path south into the field. The field has two existing SuDS ponds taking road drainage from the junction. The proposed mitigation considered would have lowered levels across the rest of the field, providing additional storage. This would have limited benefit to the west of the proposed scheme as modelling indicates that in the peak of the design flood, the culverts under the proposed scheme have drowned outlets and the water level is lower on the eastern side of the road, indicating there is additional storage available within the field at its current level. The addition of further culverts under the main alignment of the proposed scheme was therefore considered, to identify if this would result in increased storage to the east of the road. This was found to increase storage slightly to the east and gave a few millimetres reduction in peak flood levels west of the proposed scheme, but with negligible impact on downstream flood risk. Significant excavation (approximately 4,500m^3) would be required to obtain benefit downstream. Consequently, as a result of the potential adverse impact on the landowner if the land were used as floodplain compensation and the negligible benefit to an area with negligible impact from the proposed scheme this option was not progressed further.

3.1.48 Compensatory storage was also considered by using areas of higher ground within the fields to the west of the existing A9. Two areas were tested within the hydraulic model (labelled Area 2 on Figure 17). They were found to provide negligible benefits, predominantly due to the small volume of the areas available in comparison to the flows within the area. The impact on landowners would also be potentially significant as the areas considered are generally at higher levels within the field. The higher areas within the fields are more likely to remain dry in major flood events and therefore provide potential refuge areas for livestock and equipment. Lowering land so that it does not drain naturally has not been considered a viable option as there would be a high possibility of storage not being available due to water being retained from previous flood events. Loss of these areas would therefore have a significant adverse impact on the landowner and therefore, given the negligible benefits identified, these storage areas have not been progressed further.

3.1.49 The final option shortlisted in this section was to do-nothing. This option would minimise land take and consequently impact on landowners and reduce the volume of earthworks required. This would therefore have environmental and cost advantages when compared to providing floodplain compensation areas. Given that there are negligible impacts on flood risk as a result of the proposed scheme in this area this option was considered the most practicable and no flood mitigation for Principal Watercourses is therefore proposed in this section of the scheme.

Figure 17: Ballinluig to Westhaugh of Tulliemet mitigation options



<u>Westhaugh of Tulliemet to Kindallachan</u>

<u>*Refer to Figure 18*</u>

3.1.50 Five potential options were shortlisted for consideration in this area. The volumetric loss of floodplain in this area is approximately 24,130m^3 and results in increased flood risk to Haugh of Kilmorich in events of greater magnitude than the 2% AEP (50-year) event. There is also an increase in flood risk to the Highland Main Line railway, including locations where this would be overtopped in the design event, and to agricultural land.

3.1.51 Do-nothing was considered as an option for this section. This would reduce costs, landtake and environmental impact, however, the increase in flood risk, particularly to the Haugh of Kilmorich and the Highland Main Line would not be in accordance with SPP or the scheme design principles and therefore this option has been rejected at this location.

3.1.52 As the primary increase in flood risk is to the Haugh of Kilmorich, consideration was made of methods to protect the property from the increase in flood risk. Provision of a bund around the property was considered, designed to the design event peak water level (indicative outline labelled as option 1 on

Figure 18). This would improve the flood risk for the property when compared to the baseline scenario, by providing protection from flood events that would currently flood the property. However, this option would have resulted in bunds or walls of over 2m height in places, potentially impacting on views, as well as increasing flood risk downstream by reducing floodplain storage (although the impact of this was modelled and found to be negligible). However, this option provides no mitigation to increased flood risk to the Highland Main Line or to the surrounding agricultural land.

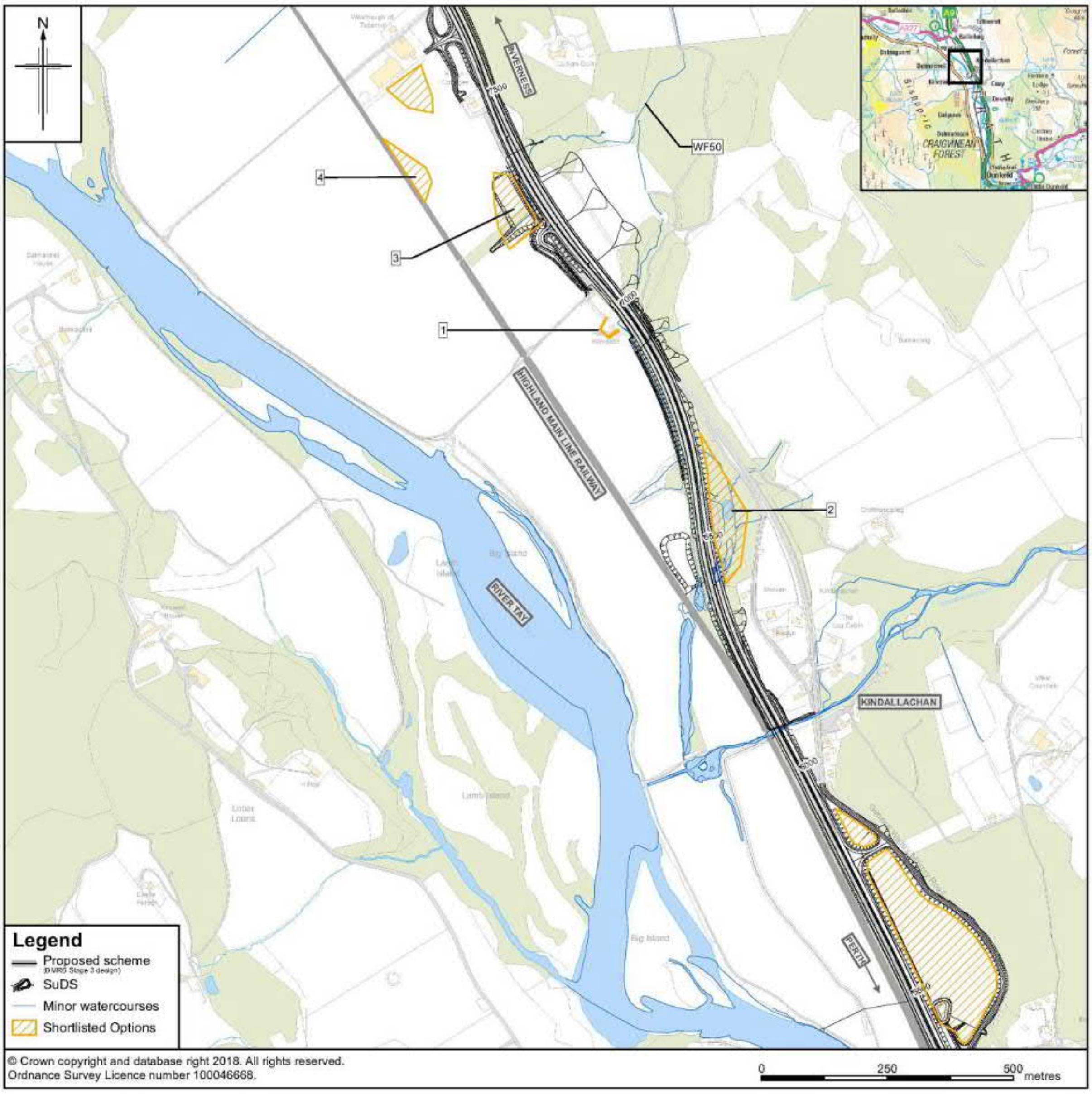
3.1.53 Compensatory storage for the areas of floodplain loss has been considered, with two potential options shortlisted. Initially areas where level for level compensation could be provided were considered. The areas of loss in this section are either due to the construction of earthworks within the floodplain, or due to the raising of the main alignment to prevent overtopping in the design event. As the embankments are generally towards the edge of the floodplain there are limited options available for provision of level for level compensation to the west of the A9, as surrounding land is generally at lower level than the areas lost and already flooded.

3.1.54 The areas of loss due to overtopping or at higher levels within the embankments cannot be provided on the west side of the proposed scheme due to the areas of loss being at higher level than existing ground. To the east of the proposed scheme, the ground generally rises steeply away from the road into woodland, introducing significant constraints to the provision of floodplain compensation, with major engineering works in the form of excavations and retaining walls likely to be required and other environmental impacts to be considered. One area of lower ground to the east of the proposed scheme, in wetlands north of Kindallachan, was considered for compensatory storage (area 2 on Figure 18). This area is connected to the floodplain to the west by two existing culverts (WF41 and WF42) and floods in the design event. Provision of floodplain storage by excavating and steepening the sides of the existing area would provide some compensation at almost all of the levels of floodplain loss and consequently it was tested utilising the hydraulic model. This identified that retaining walls in excess of 15m height would be required in places. These significantly impact on the cost of the proposed storage area, which was calculated to be approximately £1.5M. Given that modelling indicated the impact of the storage was negligible (and within model tolerances), the environmental impact of the works and the cost, this option was not progressed further.

3.1.55 Similar to this option, consideration was made of providing storage within the footprint of the proposed scheme itself, by introducing viaduct sections of the main alignment through the areas of greatest impact on the floodplain. This option was found to mitigate the increases in flood risk, however the cost was calculated to be £45M and considered disproportionate to the benefit given the increase to peak water levels in the design event was less than 10mm.

3.1.56 The small areas of floodplain at higher levels between the Highland Main Line railway and the A9 were considered able to provide some of the required storage levels (labelled 3 and 4 on Figure 18). These areas were modelled and found to provide mitigation, reducing the increase in peak flood depth to negligible levels at Haugh of Kilmorich and across the floodplain between the main alignment and the Highland Main Line railway. The areas considered are also areas used by the landowner as a refuge for livestock during major flood events, as the areas at the highest points within the fields to the west of the A9. Given this and the negligible benefits provided by providing compensation in all of these areas, it is proposed to provide floodplain compensation in one of the areas (area 3), close to WF50. This area has therefore been included in the proposed scheme as Compensatory Flood Storage 6. This reduces the impact on the landowner compared to provision of multiple excavations to construct the storage areas, whilst ensuring negligible change in flood risk due to the scheme in this section.

Figure 18: Westhaugh of Tulliemet to Kindallachan mitigation options



<u>Kindallachan to Guay</u>

<u>Refer to Figure 19</u>

3.1.57 Four options were shortlisted for consideration in this section. Approximately 25,600m^3 of flood storage would be lost as a result of the proposed scheme in this section, predominantly due to raising of the main alignment to prevent overtopping of the road. This results in increased flood risk to receptors including Guay Farmhouse and the Highland Main Line railway.

3.1.58 Do-nothing was one of the options considered for this section. This would minimise cost, land-take and environmental impact, however would result in increased flood risk to Guay Farmhouse, the Highland Main Line and to agricultural land within the River Tay floodplain. Given the increase in flood risk, do-nothing was not considered an acceptable solution for this area.

3.1.59 Compensatory storage was therefore considered. The storage lost is predominantly above existing ground levels in the floodplain to the west of the A9. This limits the options for providing compensatory storage to areas to the east of the proposed scheme. Within this section, ground levels rise steeply away from the east of the proposed scheme, with the exception of the field between the main alignment and Dowally to Kindallachan Side Road.

3.1.60 Excavation into the hillside to provide level for level compensatory storage was considered as part of the longlist of options, however the extent of the excavations and structures required meant that these options were considered impracticable. Therefore, storage within the field between the main alignment and Dowally to Kindallachan Side Road was considered (labelled 1 on Figure 19). Increased storage would be created by lowering ground levels to just above the level on the west side of the main alignment. Connection to the main floodplain would be provided by a culvert through the main alignment and railway embankments. This culvert would both fill and drain the storage area.

3.1.61 As discussed in paragraph 3.1.22, a similar culvert has been included in the baseline model, to provide a connection to the floodplain to the east of the existing A9 which is known to flood in some events. The inclusion of this culvert in the scheme design, means that the with-scheme model used is an accurate representation of the proposed scheme. Inclusion of this storage area in the hydraulic model for the proposed scheme revealed that it contributes to ensuring the change in flood depth downstream of this section is negligible. This option has therefore been included within the proposed scheme as Compensatory Flood Storage Areas 1 and 2. The culvert representation in the baseline model increases water level in the baseline scenario and therefore reduces the volume of compensatory storage provided by the proposed mitigation in this area. If the flooding has surface water or groundwater components, it is anticipated that the proposed compensatory storage area would provide additional storage to that modelled in the proposed scheme scenario, as surface water would be likely to flow out of the culvert prior to the main Tay flood event and groundwater would respond more slowly after the peak on the Tay had passed. The inclusion of the culvert in the baseline is therefore considered a conservative assumption.

3.1.62 Flood protection measures, in the form of a flood wall along the bank of the Sloggan Burn, upstream (east) of the A9 culvert for WF39, were also considered (labelled 2 on Figure 19). This would prevent an increase in flood risk to Guay Farmhouse from the Sloggan Burn. This, in conjunction with the proposed Dowally to Kindallachan Side Road alignment to the north of Guay Farmhouse would also provide a degree of betterment by protecting the property from events up to the design event. This would however result in an increase in flood risk downstream of the main alignment as a result of increased flows through culvert WF39.

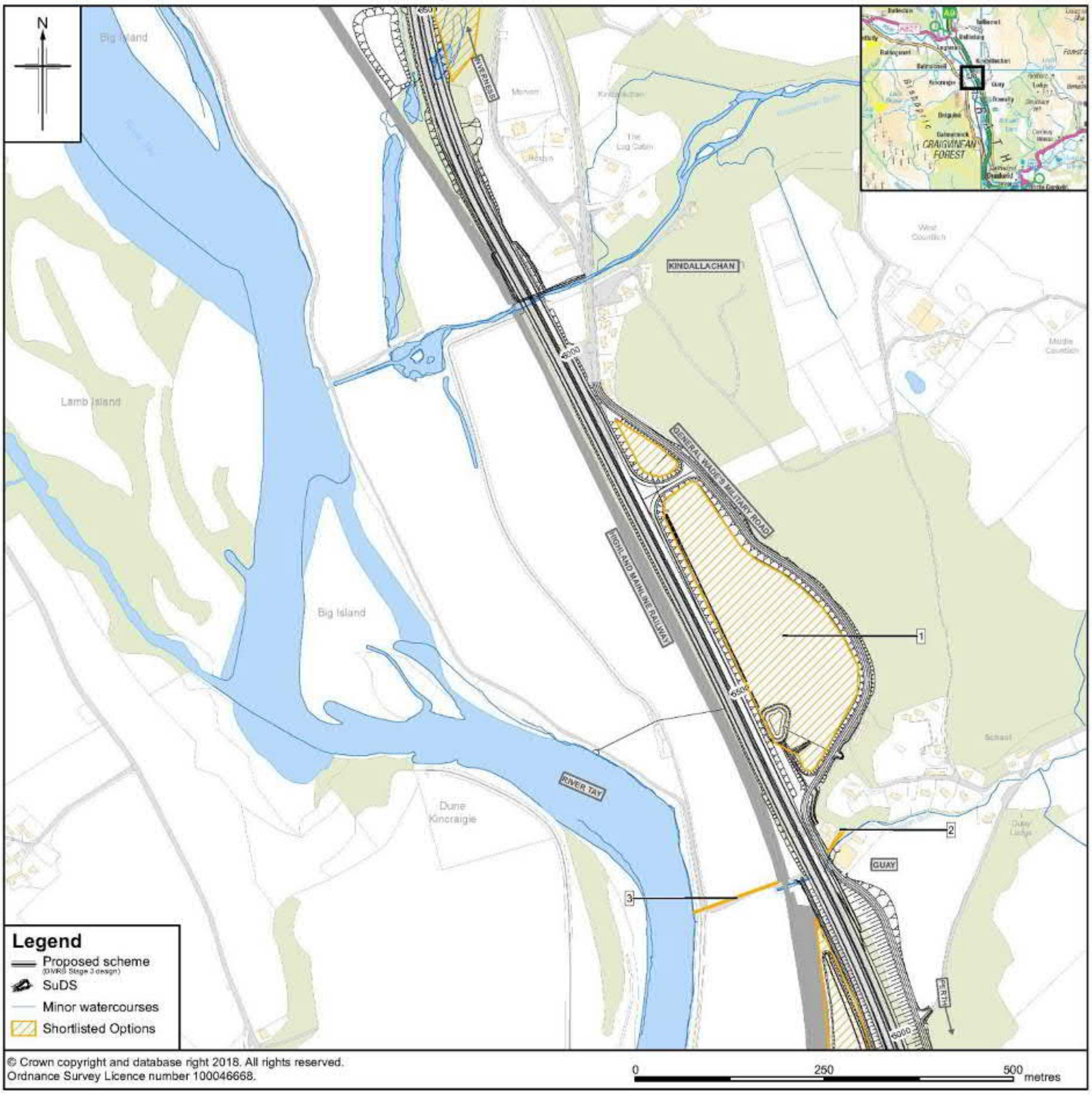
3.1.63 Flood protection measures along the bank of the Sloggan Burn were considered in conjunction with culverting of the watercourse between the main alignment and the Highland Main Line railway and provision of an additional culvert downstream of the railway embankment on the Sloggan Burn (labelled 3 on Figure 19). This culvert would include a flap-valve or similar to prevent flows backing up from a flood event on the River Tay and would run alongside the existing culvert through the field to the west of the Highland Main Line railway.

3.1.64 The existing culvert has insufficient capacity to pass the design event and the baseline hydraulic model indicates that in the design event on the Sloggan Burn there would be flooding to the railway embankment and fields alongside the watercourse. Any increase in flows through the culvert as a result of the proposed scheme would result in an increase in the magnitude and extent of this flooding. Provision of an additional culvert mitigates this increase in flood risk. However, this would increase flows from the Sloggan Burn into the River Tay. The increase ($0.54m^3/s$) is negligible in comparison with peak flows on the River Tay.

3.1.65 However, if the design event on the Sloggan Burn were to coincide with a 50% AEP (2-year) event on the River Tay, hydraulic modelling indicates a small area of increased flood risk downstream on the west bank floodplain approximately 2km south of the Sloggan Burn. This area, of approximately $1,200m^2$ (indicated on Figure 24), would experience an increase in peak flood depth of approximately 0.012m compared to the baseline scenario. This is as a result of the small increase in flows from the River Tay adding to flows in a channel through the floodplain which overtops during this flood event. The depth is slightly greater and the extent of flooding is slightly larger as a result of the increase in flows from the Sloggan Burn. This area is within the floodplain of the Tay and would have a flood depth of over 2.5m in the design event on the River Tay. With the design event on the Sloggan Burn, flood depths in the area effected are generally less than 0.3m, but are as high as 0.8m.

3.1.66 The increase of 0.012m in this area is considered hydraulically insignificant and no physical mitigation is proposed (mitigation would be likely to require a disproportionate volume of compensatory storage and is impracticable to provide locally given the location close to the centre of the floodplain). It is therefore proposed that the area be included within the CPO boundary for the scheme and returned to the landowner with appropriate burden to reflect the increased flood risk (as shown on Figure 24). As this option (the additional culvert for the Sloggan Burn) mitigates increases in flood risk to sensitive receptors, provides significant benefits to Guay Farmhouse and only has a minor adverse impact on a small area downstream, it is proposed to include this mitigation within the proposed scheme.

Figure 19: Kindallachan to Guay Mitigation Options



<u>Guay to Dowally</u>

<u>Refer to Figure 20</u>

3.1.67 Four options were shortlisted for consideration in this section, which has the largest loss of floodplain storage as a result of the scheme (approximately 43,100m^3), predominantly due to embankments associated with the overbridge and its access roads. These embankments have been designed and located to minimise the impact on the floodplain where possible.

3.1.68 Although a do-nothing scenario would be the most cost effective and result in reduced environmental and landowner impact, this option has been rejected for this section as a result of increases in flood risk to the Highland Main Line railway that would be caused by the scheme.

3.1.69 Compensatory storage options have therefore been considered. Floodplain is lost across a range of levels as it is caused by embankments from ground level up to the A9 carriageway. Provision of level for level compensation to the west of the main alignment and east of the railway embankment is therefore not possible as ground levels are generally lower than the levels required to achieve this. Provision of level for level compensation on the east of the main alignment would potentially be possible as ground levels generally rise steeply into the adjacent woodland. Lowering these areas to replace floodplain levels would however require major earthworks and structural works and result in loss of woodland and other environmental impacts.

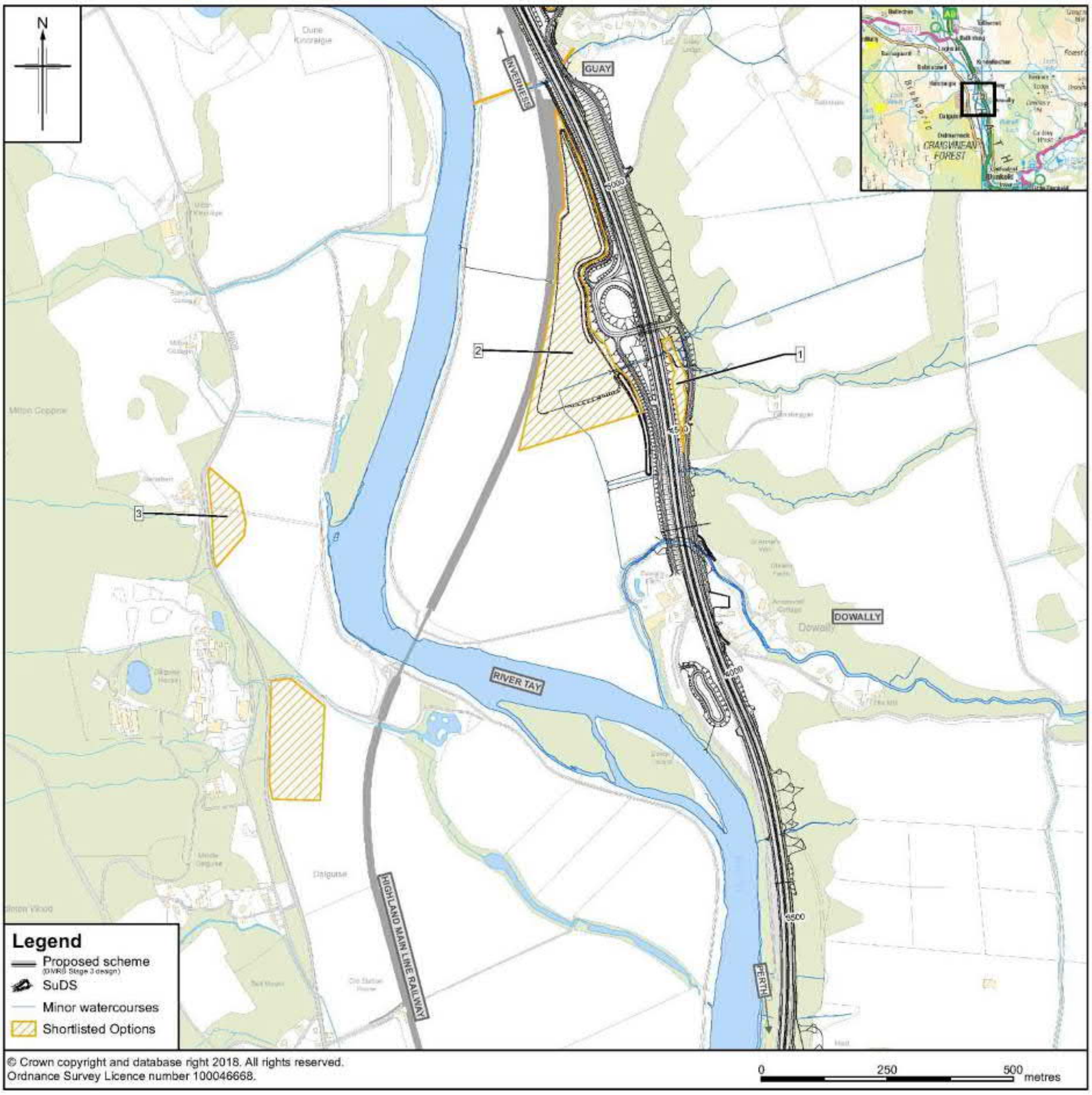
3.1.70 One area where ground levels east of the main alignment are slightly lower than the proposed scheme and therefore could potentially be used for storage with less significant environmental impacts was identified. Even in this area (labelled 1 on Figure 20), significant retaining structures would be required for both the A9 and the access road to Dowally to provide effective storage. This was included within the hydraulic model and found to provide negligible benefits within the main floodplain, predominantly due to the area becoming flooded too early in the design event to reduce peak flood depths. Potential options to provide flow control devices or similar to ensure the storage operates when required were considered but deemed impractical due to local minor watercourses flowing into the area which would have different flow control requirements.

3.1.71 Storage on the west of the proposed scheme was therefore considered. While this would not provide level for level compensation, the northern section of the field in which the Guay South Overbridge and embankments are proposed is at higher level that the south of the field. Storage formed by lowering ground levels to closer to the southern end of the field has therefore been considered (labelled 2 on Figure 20). This area was found to mitigate the increased flood risk as a result of the relocated overbridge and has therefore been included within the proposed scheme as Compensatory Flood Storage 3, 4 and 5.

3.1.72 A further location where additional compensatory storage was considered was on the right (west) bank of the River Tay, at the edge of the floodplain (labelled 3 on Figure 20) formed by lowering the area to similar levels to the surrounding floodplain. When included in the hydraulic model, this was found to have no impact on peak flood levels in the design event, with the additional storage filling too early in the event and full prior to peak flows in the area. During frequent flood events, the option has negligible impact (due to reduced loss of floodplain) and therefore provision of storage is considered unnecessary.

3.1.73 Alternative designs for the compensation area were tested, including leaving higher ground at the edge of the area with a weir to control flows into the area during a major flood event. It was found that this design would provide additional storage, but that it would only address the impact of the design event and not more frequent events and any benefits were deemed negligible. The land is one of the few unflooded areas on the right bank of the River Tay east of the B898 and may therefore be used as a refuge point for livestock during a flood. Construction of any compensation area would require major earthworks and potential structural works to the adjacent road. Consequently, as the measure produced negligible benefits to flood risk it has not been considered further.

Figure 20: Guay to Dowally mitigation options



Dowally to Tay Crossing

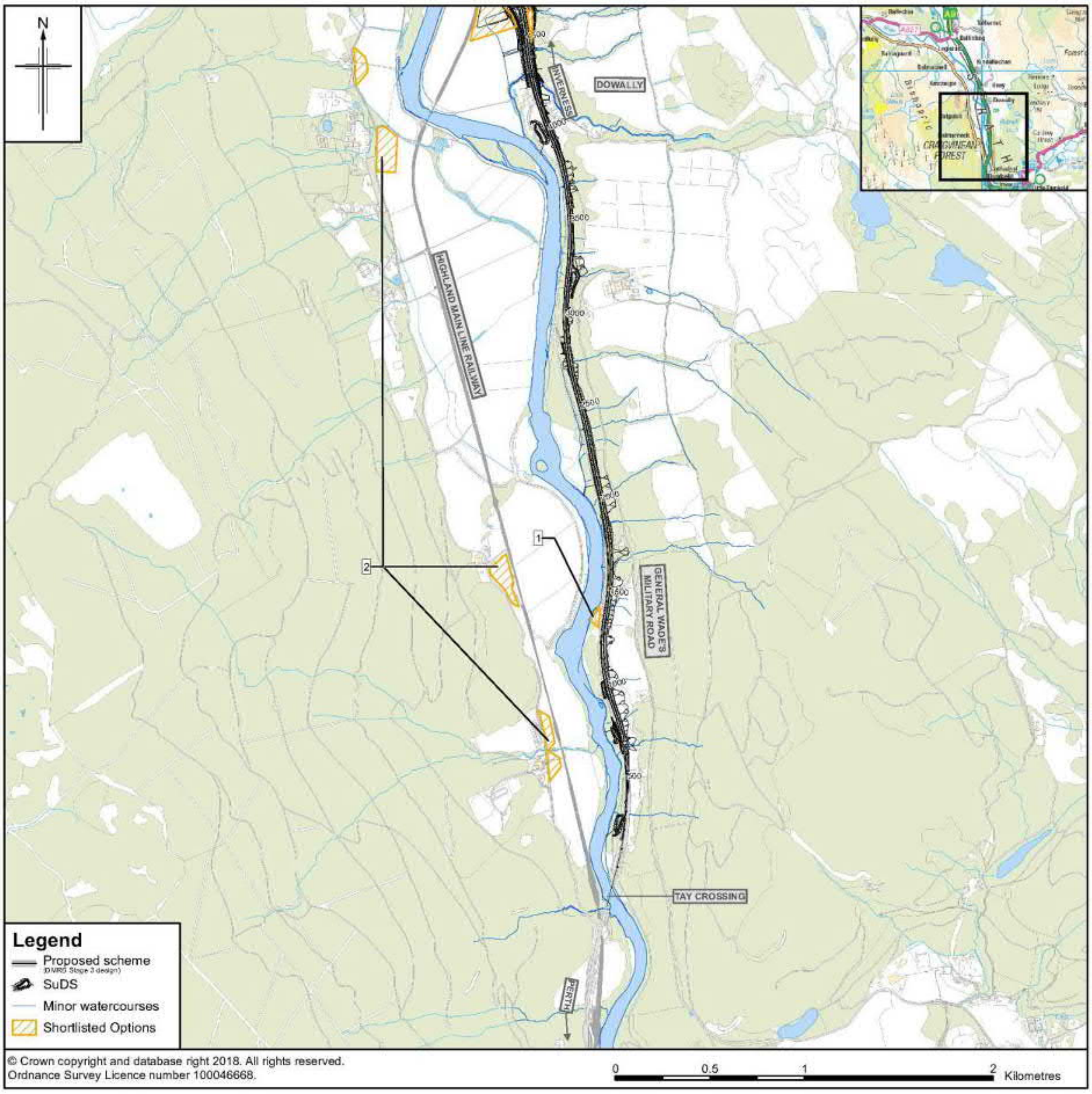
Refer to Figure 21

3.1.74 South of Dowally, the route of the proposed scheme is generally closer to the River Tay and therefore there are very few receptors between the proposed scheme and the river. Loss of floodplain storage in this area is predominantly due to the raising of the main alignment to prevent overtopping.

3.1.75 Within this section the proposed scheme generally marks the eastern extent of the floodplain in the design event and three potential mitigation options have been considered. To the east of the proposed scheme, there are limited areas of ground at similar levels to the main alignment, with much of the land rising away to the east, steeply in places. This restricts the available space for the provision of compensatory storage, with similar constraints as have been previously discussion in other sections. One potential area to the west of the proposed scheme was identified: a small area of high ground almost immediately adjacent to the River Tay (labelled area 1 on Figure 21). Significant excavation would be required to lower this ground and provide additional storage. The option was tested in the hydraulic model, however it resulted in virtually no change in peak water levels, consequently it has not been considered further.

3.1.76 Storage on the right (west) bank of the River Tay was therefore considered. This would have the advantage of potentially providing increased benefits to the receptors on the right bank, which include several residential properties and the Highland Main Line railway. Three potential areas were identified (labelled 2 on Figure 21). These were selected because they were outside the design event flood extents or areas with reduced flood depth. The impact of lowering these areas to match the rest of the floodplain was therefore considered. Hydraulic modelling indicated that compensatory storage at the northern most of the areas considered had the potential to increase flood risk for certain events at Dalguise, due to increased flow into the area between Dalguise and the Highland Main Line railway embankment. The two areas identified further to the south were found to provide negligible benefits. As construction of these areas would require significant land-take (again in areas potentially used as refuges during major flood events) and have cost and environmental impacts, it is not proposed to include these areas within the proposed scheme as the benefits they accrue are considered negligible.

Figure 21: Dowally to Tay Crossing mitigation options



Recommended Mitigation

3.1.77 The assessment set out above demonstrates that multiple mitigation options have been considered and explains the process through which selection of effective mitigation has been made. The proposed mitigation measures adopted are:

- Compensatory Flood Storage 6: Floodplain compensation area north of Haugh of Kilmorich (Area 3 on Figure 18)
- Compensatory Flood Storage 1 and 2: Floodplain compensation area within the field between the A9 and Dowally to Kindallachan Side Road north of Guay (Area 1 on Figure 19)
- Flood wall on the right bank of the Sloggan Burn at Guay (Area 2 on Figure 19)
- Additional culvert for the Sloggan Burn west of the Highland Main Line railway (Area 3 on Figure 19)
- Compensatory Flood Storage 3, 4 and 5: Floodplain compensation south of Guay between the railway and the main alignment (Area 2 on Figure 20).

3.1.78 The volume of compensatory storage provided by the proposed mitigation is summarised in Table 10.

Table 10: Volume of compensatory storage proposed

Storage Area	Compensatory Storage Volume (m^3)
Compensatory Flood Storage 6 (North of Haugh of Kilmorich)	8,300
Compensatory Flood Storage 1 and 2 (Field north of Guay)	33,700
Compensatory Flood Storage 3, 4 and 5 (Between railway and A9 south of Guay)	34,600
Total Storage Provided	76,600(1)
Total Storage Lost	108,590
Change in Storage	-31,990(1)

(1) Figures exclude approximately 3,000m^3 of additional storage provided within the River Tay floodplain as mitigation for flooding on minor watercourses (see paragraphs 4.1.62 and 4.1.67 for details).

Impact of Scheme with Proposed Mitigation

3.1.79 The proposed scheme has been modelled with all the proposed mitigation included to identify any residual impact of the scheme. The impact of the scheme has been investigated over a range of flood events (50% AEP (2-year), 3.33% AEP (30-year), 2% AEP (50-year), 0.5% AEP (200-year) and 0.5% AEP (200-year) plus CC) and the impact of the scheme on peak depths and flows has been considered.

Peak Flood Depth at Receptors

3.1.80 The change in peak flood depth at a range of receptors in an unmitigated scenario is presented in Table 11. Table 12 gives the equivalent change for the mitigated proposed scheme. The receptors included are properties within the flood extents modelled for the design event and a selection of points within the general floodplain. The points selected are identified on Figure 22. The negligible changes in flood depth at these receptors as a result of the proposed scheme (with mitigation) means that there would also be negligible change to the threshold, extent and frequency of flooding as a result of the proposed scheme.

Table 11: Change in Flood Depth with unmitigated scheme

No.	Receptor Name	30yr				50yr				200yr				200yr+CC			
		Baseline		No Mitigation		Baseline		No Mitigation		Baseline		No Mitigation		Baseline		No Mitigation	
		Level	Depth	Level	Change	Level	Depth	Level	Change	Level	Depth	Level	Change	Level	Depth	Level	Change
Key Receptors																	
22	Logierait Mill	61.217	1.081	61.217	0.000	61.406	1.268	61.406	0.000	61.798	1.661	61.798	0.000	62.019	1.882	62.019	0.000
21	Station Cottages	-	-	-	-	-	-	-	-	-	-	-	-	61.678	0.174	61.678	0.000
20	Inch Farm (HoB)	-	-	-	-	-	-	-	-	-	-	-	-	61.548	0.144	61.546	- 0.002
19	Haugh of Kilmorich	-	-	-	-	-	-	-	-	59.521	0.531	59.524	0.003	59.882	0.892	59.882	0.000
17	Guay Farmhouse	-	-	-	-	-	-	-	-	57.450	0.018	-	- *0.018*	57.602	0.161	57.473	- *0.129*
12	Dowally Farm (office)	-	-	-	-	-	-	-	-	-	-	-	-	57.036	2.084	57.039	0.003
11	Dalguise House	-	-	-	-	-	-	-	-	56.909	0.124	56.911	0.002	57.495	0.698	57.498	0.003
6	Ballicock Hall	55.232	0.509	55.234	0.001	55.529	0.806	55.532	0.002	56.373	1.650	56.376	0.003	57.033	2.310	57.038	0.005
10	Cottar House	55.202	0.119	55.204	0.002	55.505	0.393	55.508	0.003	56.359	1.247	56.361	0.003	57.023	1.912	57.028	0.005
7	The Old Post Office	55.141	0.383	55.143	0.002	55.470	0.713	55.472	0.002	56.337	1.579	56.339	0.002	57.015	2.259	57.020	0.005
9	Bellfield Cottage	-	-	-	-	-	-	-	-	-	-	-	-	57.017	0.306	57.022	0.005
8	The Orchard	-	-	-	-	-	-	-	-	-	-	-	-	57.010	0.506	57.015	0.005
4	Old Station House	-	-	-	-	-	-	-	-	-	-	-	-	56.999	0.248	57.004	0.005
2	Woodinch	54.654	1.175	54.656	0.002	55.146	1.667	55.150	0.004	56.051	2.572	56.055	0.004	56.853	3.375	56.858	0.005
Floodplain																	
18	West of Railway near Haugh of Kilmorich	58.529	1.615	58.530	0.001	58.977	2.063	58.978	0.001	59.584	2.670	59.584	0.000	59.934	3.020	59.934	0.000
16	West of Railway near Guay	57.333	1.867	57.336	0.003	57.610	2.143	57.612	0.002	58.182	2.715	58.183	0.001	58.610	3.143	58.612	0.002
15	Between Railway and A9 near Guay	55.843	0.309	55.862	**0.019**	55.956	0.422	55.972	**0.016**	56.391	0.857	56.403	**0.012**	57.021	1.488	57.031	**0.010**
14	West of Railway near Dowally	56.805	1.562	56.806	0.001	56.986	1.743	56.986	0.001	57.552	2.309	57.553	0.002	58.034	2.791	58.036	0.002
13	Between Railway and A9 near Dowally Farm	55.825	1.456	55.826	0.001	55.941	1.572	55.942	0.001	56.383	2.014	56.385	0.002	57.016	2.647	57.021	0.005
5	Dowally Island	54.763	0.770	54.765	0.002	55.142	1.149	55.144	0.002	56.277	2.285	56.281	0.004	57.030	3.037	57.035	0.005
3	West bank, east of railway opposite Rotmell Farm	54.623	0.713	54.625	0.002	55.011	1.101	55.014	0.003	56.133	2.223	56.137	0.004	56.923	3.013	56.928	0.005
1	Inchmagrannachan - main floodplain west bank	53.574	1.792	53.577	0.003	53.976	2.194	53.979	0.003	55.237	3.455	55.241	0.005	56.073	4.291	56.079	0.006
23	West of Railway north of Sloggan Burn	57.624	1.823	57.628	0.004	57.919	2.119	57.921	0.002	58.483	2.683	58.485	0.001	58.883	3.082	58.885	0.002

Negligible	(No change or less than +/- 0.01m)	***Level in mAOD***
Betterment	(Greater than or equal to 0.01m)	***Change in m***
Increase	(Greater than or equal to 0.01m)	***Flood Depths in m***

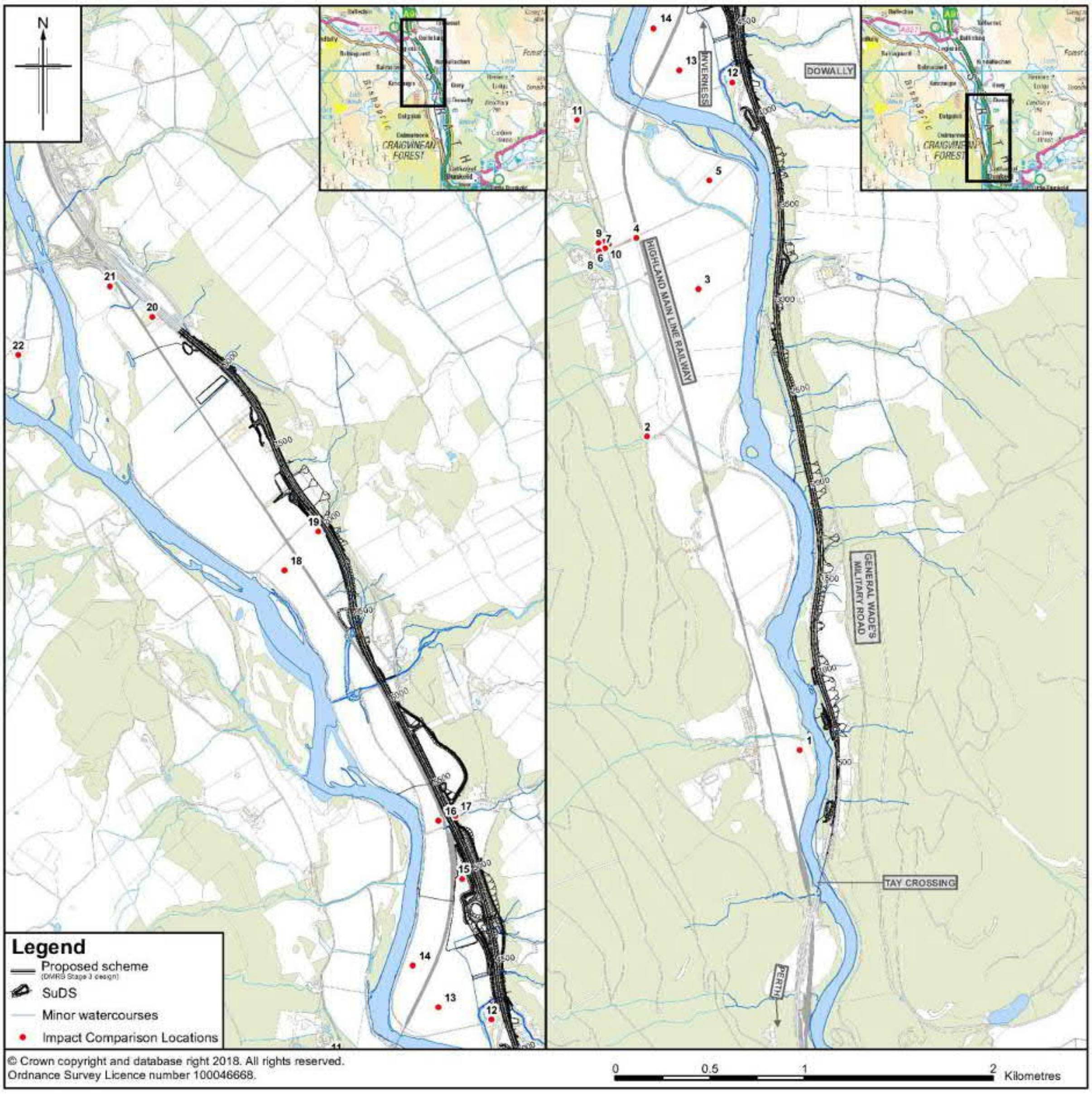
JACOBS

Table 12: Change in Flood Depth with mitigated scheme

No.	Receptor Name	30yr				50yr				200yr				200yr+CC			
		Baseline		With-Scheme		Baseline		With-Scheme		Baseline		With-Scheme		Baseline		With-Scheme	
		Level	Depth	Level	Change	Level	Depth	Level	Change	Level	Depth	Level	Change	Level	Depth	Level	Change
Key Receptors																	
22	Logierait Mill	61.217	1.081	61.217	0.000	61.406	1.268	61.406	0.000	61.798	1.661	61.798	-0.000	62.019	1.882	62.019	0.001
21	Station Cottages	-	-	-	-	-	-	-	-	-	-	-	-	61.678	0.174	61.678	0.000
20	Inch Farm (HoB)	-	-	-	-	-	-	-	-	-	-	-	-	61.548	0.144	61.546	-0.002
19	Haugh of Kilmorich	-	-	-	-	-	-	-	-	59.521	0.531	59.523	0.002	59.882	0.892	59.882	0.000
17	Guay Farmhouse	-	-	-	-	-	-	-	-	57.450	0.018	-	*-0.018*	57.602	0.161	-	*-0.161*
12	Dowally Farm (office)	-	-	-	-	-	-	-	-	-	-	-	-	57.036	2.084	57.037	0.001
11	Dalguise House	-	-	-	-	-	-	-	-	56.909	0.124	56.910	0.001	57.495	0.698	57.497	0.002
6	Ballicock Hall	55.232	0.509	55.233	0.001	55.529	0.806	55.531	0.002	56.373	1.650	56.375	0.002	57.033	2.310	57.036	0.003
10	Cottar House	55.202	0.119	55.204	0.002	55.505	0.393	55.507	0.002	56.359	1.247	56.360	0.002	57.023	1.912	57.026	0.003
7	The Old Post Office	55.141	0.383	55.142	0.002	55.470	0.713	55.472	0.001	56.337	1.579	56.338	0.001	57.015	2.259	57.018	0.003
9	Bellfield Cottage	-	-	-	-	-	-	-	-	-	-	-	-	57.017	0.306	57.020	0.003
8	The Orchard	-	-	-	-	-	-	-	-	-	-	-	-	57.010	0.506	57.013	0.003
4	Old Station House	-	-	-	-	-	-	-	-	-	-	-	-	56.999	0.248	57.002	0.003
2	Woodinch	54.654	1.175	54.656	0.002	55.146	1.667	55.149	0.003	56.051	2.572	56.054	0.003	56.853	3.375	56.856	0.003
Floodplain																	
18	West of Railway near Haugh of Kilmorich	58.529	1.615	58.529	0.000	58.977	2.063	58.978	0.001	59.584	2.670	59.584	-0.000	59.934	3.020	59.934	-0.000
16	West of Railway near Guay	57.333	1.867	57.336	0.003	57.610	2.143	57.611	0.001	58.182	2.715	58.183	0.001	58.610	3.143	58.611	0.001
15	Between Railway and A9 near Guay	55.843	0.309	55.835	-0.008	55.956	0.422	55.951	-0.005	56.391	0.857	56.392	0.001	57.021	1.488	57.024	0.003
14	West of Railway near Dowally	56.805	1.562	56.806	0.001	56.986	1.743	56.986	0.001	57.552	2.309	57.552	0.001	58.034	2.791	58.035	0.001
13	Between Railway and A9 near Dowally Farm	55.825	1.456	55.826	0.001	55.941	1.572	55.942	0.001	56.383	2.014	56.384	0.001	57.016	2.647	57.018	0.002
5	Dowally Island	54.763	0.770	54.764	0.001	55.142	1.149	55.143	0.001	56.277	2.285	56.280	0.003	57.030	3.037	57.033	0.003
3	West bank, east of railway opposite Rotmell Farm	54.623	0.713	54.625	0.002	55.011	1.101	55.013	0.002	56.133	2.223	56.136	0.003	56.923	3.013	56.926	0.003
1	Inchmagrannachan - main floodplain west bank	53.574	1.792	53.576	0.002	53.976	2.194	53.978	0.002	55.237	3.455	55.240	0.003	56.073	4.291	56.076	0.003
23	West of Railway north of Sloggan Burn	57.624	1.823	57.626	0.003	57.919	2.119	57.921	0.002	58.483	2.683	58.484	0.000	58.883	3.082	58.884	0.001

Negligible	(No change or less than +/- 0.01m)	***Level in mAOD***
Betterment	(Greater than or equal to 0.01m)	***Change in m***
Increase	(Greater than or equal to 0.01m)	***Flood Depths in m***

Figure 22: Receptor locations

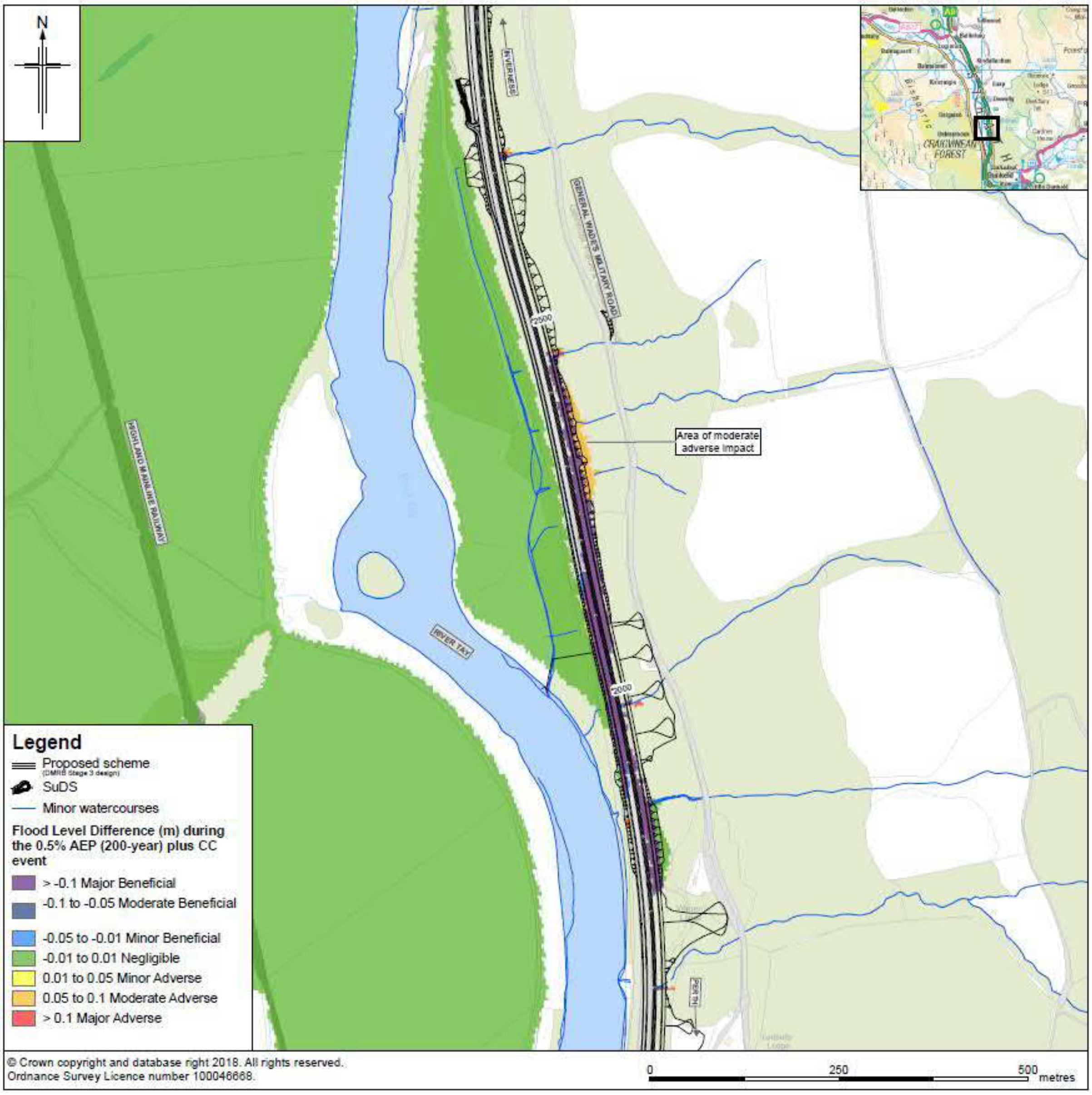


3.1.81 It can be seen from the results presented within Table 12 and within Annex D that any change as a result of the scheme is negligible, with the exception of a beneficial impact to Guay Farmhouse and adverse impacts within areas of floodplain compensation or areas to be purchased as part of the scheme. Land purchased for the scheme and returned to the landowner would include appropriate conditions reflecting the slightly increased flood risk. Two areas outside of the scheme footprint have been identified as having increased flood risk in the design event on the River Tay as a result of the scheme.

3.1.82 The first area is the wetland east of the A9 north of Kindallachan (area 2 on Figure 18). The increase in flood risk here is generally 0.011m in the design event. Given that this area is an existing wetland and that freeboard to the A9 (the lowest lying receptor nearby) remains greater than 0.6m as a result of the scheme, this increase in flood risk is considered to have no impact other than to scheme areas and no mitigation is proposed.

3.1.83 The second area is between ch2200m and ch2400m. Here, the reduction in floodplain as a result of the road being widened results in an increase in flood risk upstream of the A9 culverts in the design event, where floodwater from culverts under the A9 flows into a smaller area than previously. The increase is approximately 0.060m and within an area where the baseline flood depth in the design event is generally over 1.0m. The increase is to the foot of the proposed widened A9 embankment and to woodland immediately adjacent to it. There are no sensitive receptors within the area affected and the area is to be purchased to allow construction of the scheme. Given this and the small increase relative to the baseline flood depths, no mitigation for this increase is proposed.

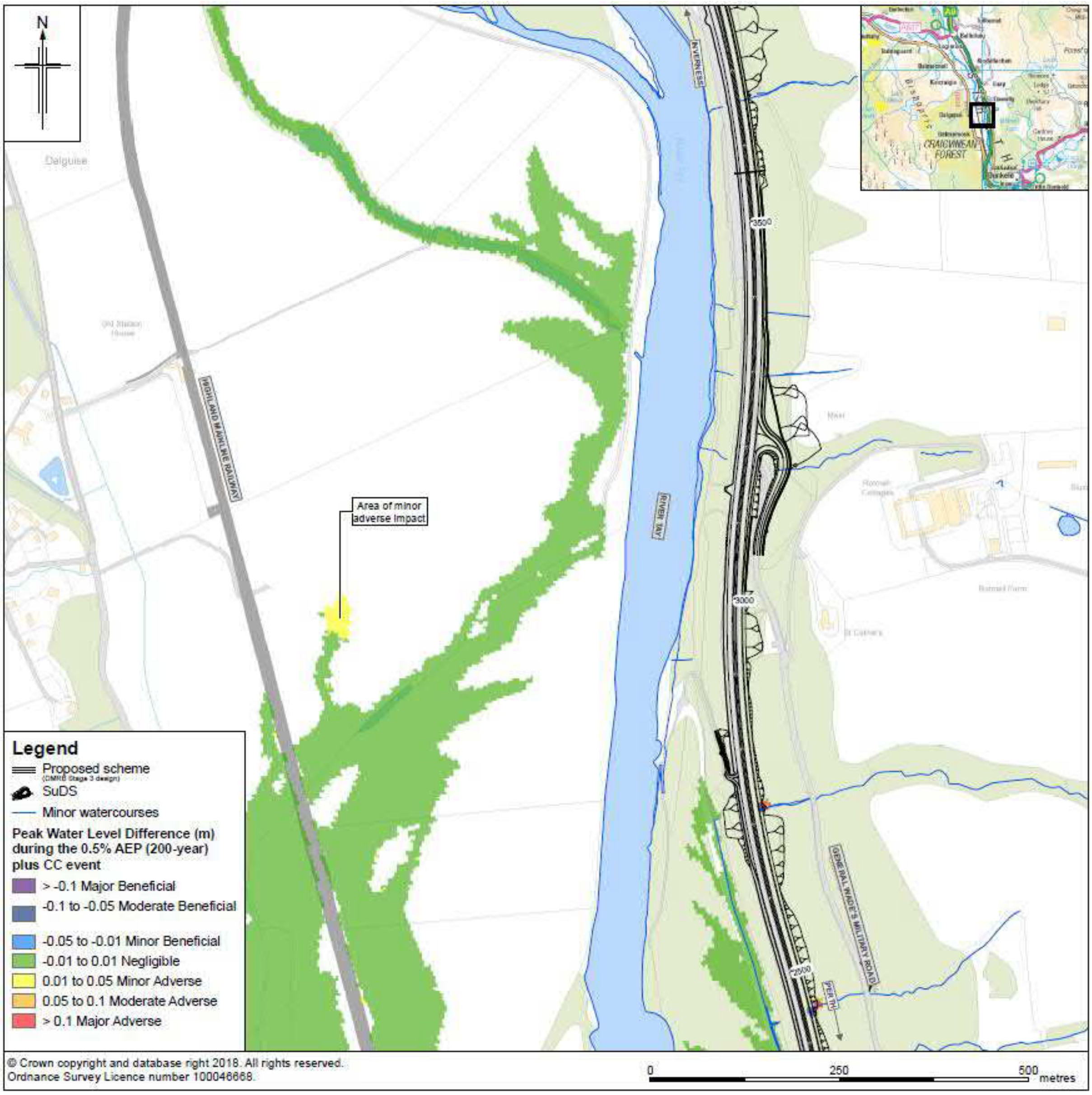
Figure 23: Change in flood risk in 0.5% AEP (200-year) plus CC event



3.1.84 The impact of the scheme on flooding as a result of the 0.5% AEP (200-year) plus CC event on the other watercourses within the scheme area was also considered. The smaller catchment areas mean that the storm events causing the flood events on the Kindallachan Burn, Sloggan Burn and Dowally Burn are of far shorter duration than the equivalent flood event on the River Tay and River Tummel. Therefore, the peak flood on these watercourses would not be anticipated to coincide with a major event on the River Tay or River Tummel.

3.1.85 The proposed scheme has been found to have a negligible impact on flood risk due to these watercourses across the project area, with the exception of one area of increased flood risk. This is on the right (west) bank of the River Tay, within the existing floodplain. The increase in flood risk is observed with the design event on the Sloggan Burn and a 50% AEP (2-year) event on the River Tay. The increase, to an area of approximately 1,200m^2, is approximately 0.013m. The area impacted is indicated on Figure 24. As this area is inundated to a far greater depth in more frequent flood events on the River Tay (2.3m in a 3.33% AEP (30-year) event for example) and negligible change is exhibited in events more frequent than the 0.5% AEP (200-year) event, this change is considered to have minimal impact on the affected land. However, the area will be included within the CPO boundary for the proposed scheme due to the increased flood risk.

Figure 24: Area of peak water level increase in 0.5% (200-year) plus CC event on Sloggan Burn



3.1.86 As has been demonstrated, the proposed mitigation measures result in negligible impact on flood risk across the project area over a broad range of flood events. Any adverse impacts outside proposed scheme areas or areas discussed in earlier sections are within the model tolerance of +/- 10mm.

Impacts Downstream

3.1.87 The impact of the proposed scheme on receptors downstream of the project area has also been assessed by considering any changes in conditions at the downstream end of the hydraulic model. This is to identify any potential cumulative impacts that the proposed scheme may contribute to. The result of this assessment is included in Table 13 and Table 14.

Table 13: Downstream extent of model –River Tay peak flow rates (m^3/s)

Model	50% AEP (2-year)	3.33% AEP (30-year)	2% AEP (50-year)	0.5% AEP (200-year)	0.5% AEP (200-year) +CC
Baseline (Existing)	782.7	1,420.5	1,579.0	2,116.1	2,507.8
With-Scheme (mitigated)	782.8	1,421.3	1,579.7	2,117.5	2,509.1
Change	0.1	0.7	0.8	1.4	1.3
% Change	0.01	0.05	0.05	0.07	0.05

Table 14: Downstream extent of model – River Tay water level (mAOD)

Model	50% AEP (2-year)	3.33% AEP (30-year)	2% AEP (50-year)	0.5% AEP (200-year)	0.5% AEP (200-year) +CC
Baseline (Existing)	51.164	53.017	53.425	54.699	55.515
With-Scheme (mitigated)	51.164	53.019	53.427	54.702	55.517
Change (mm)	0	2	2	3	2

3.1.88 Table 13 demonstrates very small changes in peak flow across all the return periods considered in comparison to the total flow within the River Tay at this point. The increase in flow is less than 0.1% in all return periods. Table 14 demonstrates a similarly small increase in water level when compared to the baseline (less than 3mm for all events), with the change well within model tolerances. This is also demonstrated in the flow hydrographs for the River Tay presented on Figure 25 to Figure 29.

Figure 25: River Tay flow hydrograph for 0.5% (200-year) AEP plus CC event – downstream extent of hydraulic model

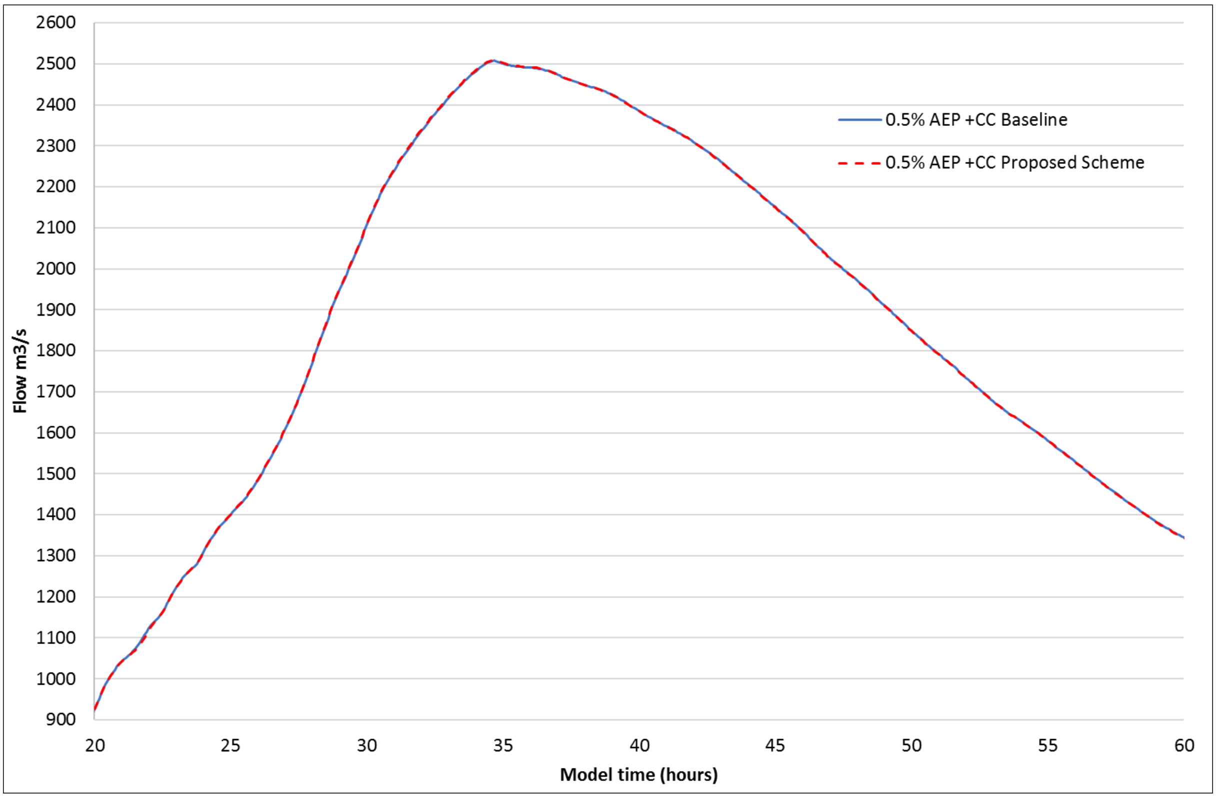


Figure 26: River Tay flow hydrograph for 0.5% (200-year) AEP event – downstream extent of hydraulic model

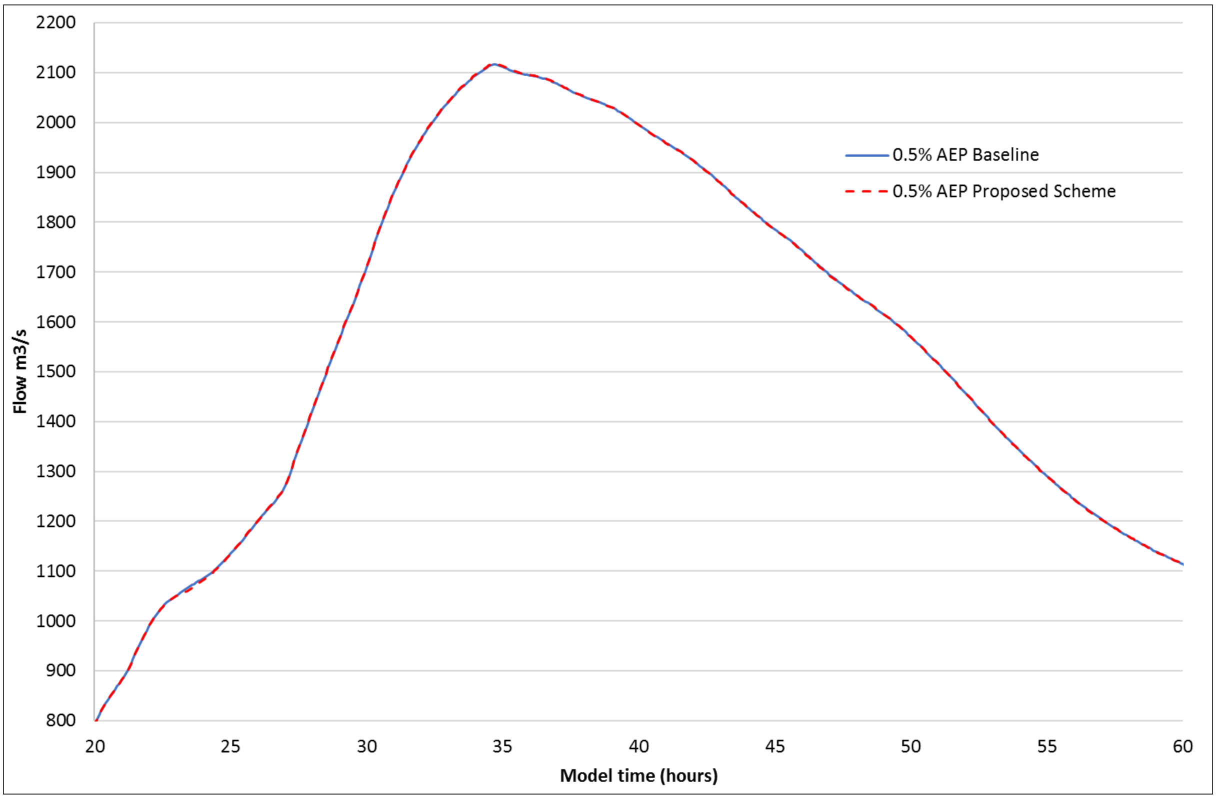


Figure 27: River Tay flow hydrograph for 2% (50-year) AEP event – downstream extent of hydraulic model

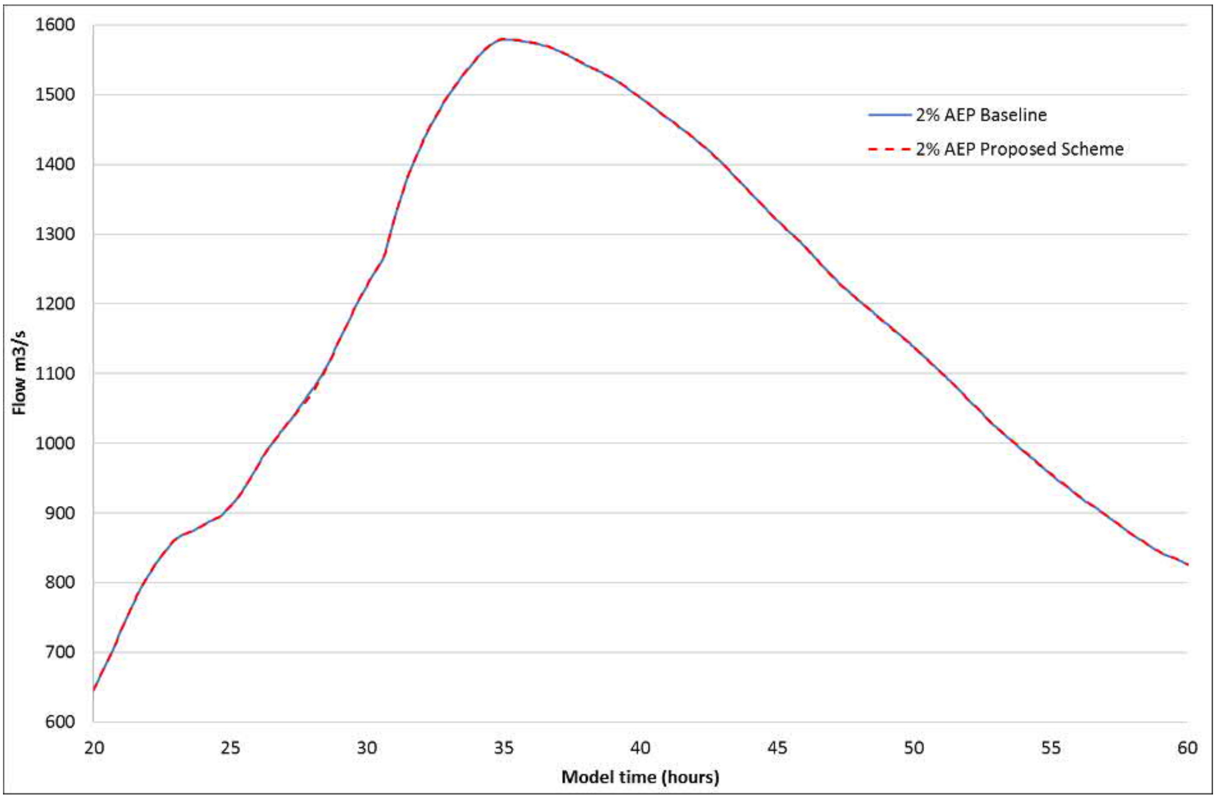


Figure 28: River Tay flow hydrograph for 3.33% (30-year) AEP event – downstream extent of hydraulic model

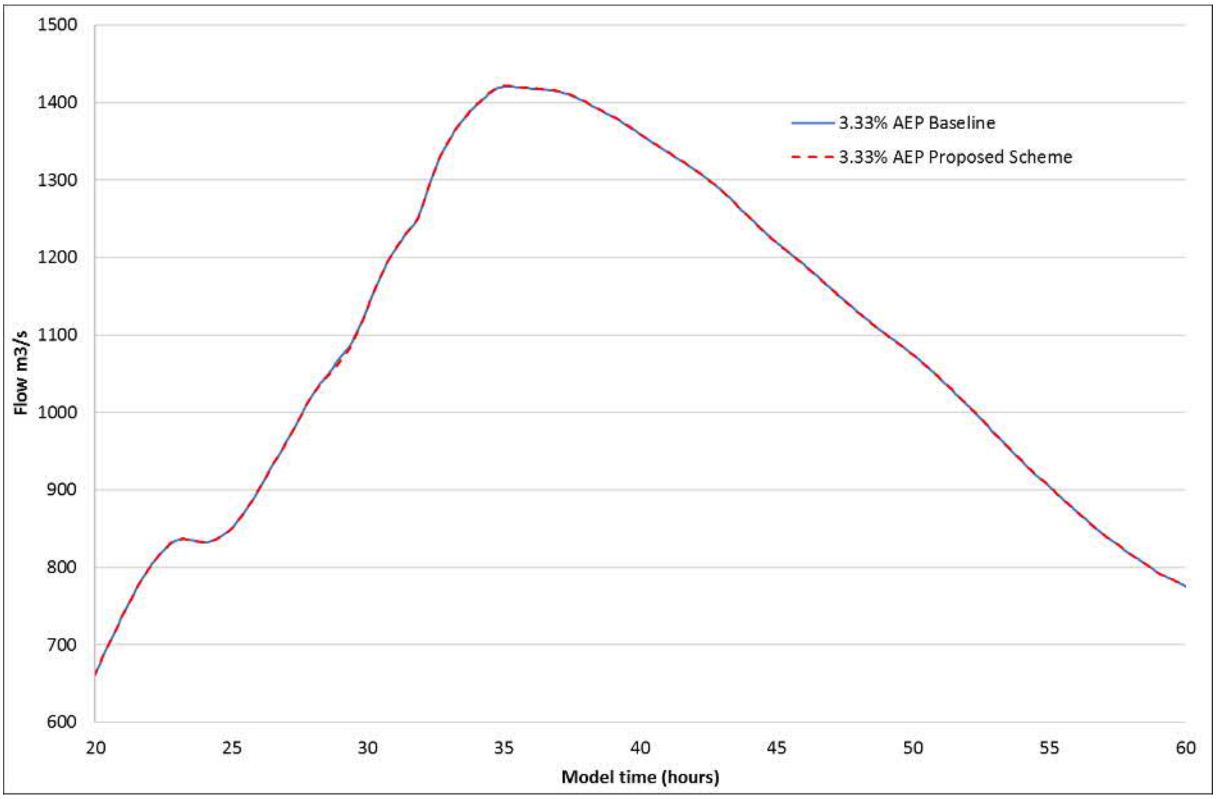
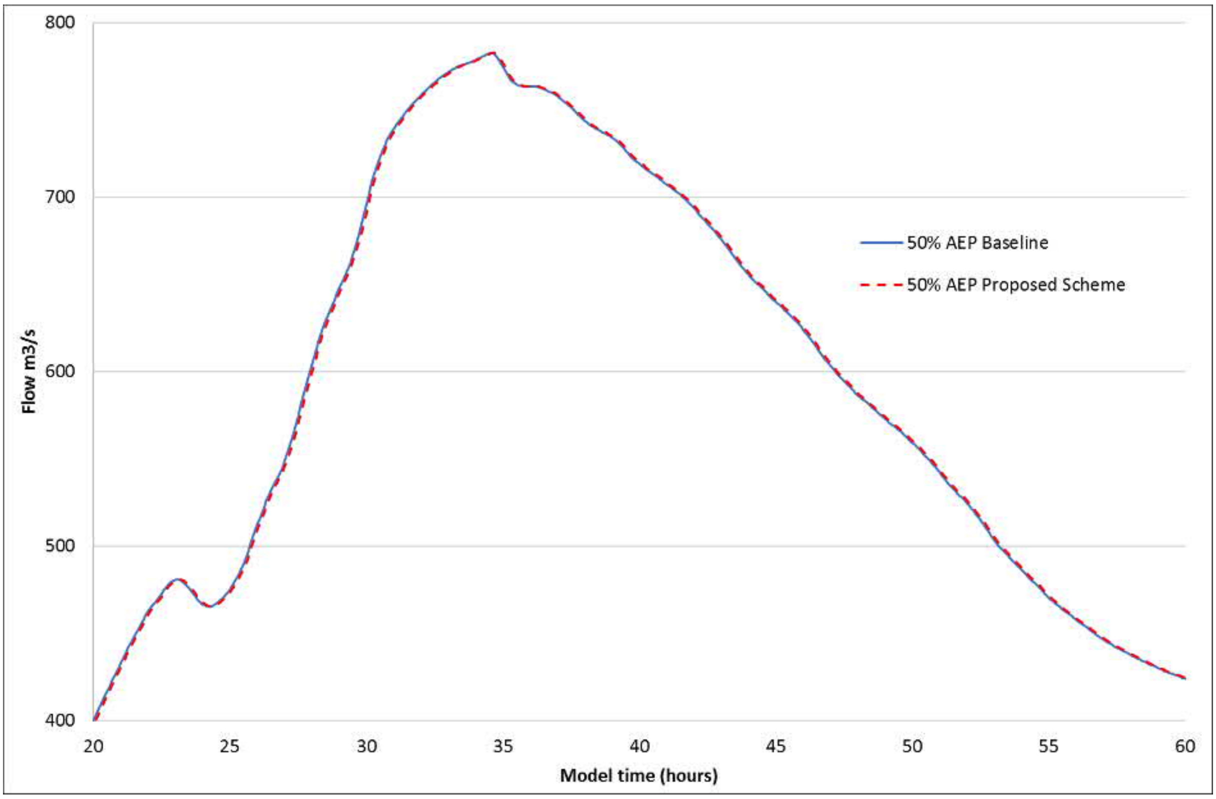


Figure 29: River Tay flow hydrograph for 50% (2-year) AEP event – downstream extent of hydraulic model



3.1.89 These results indicate that despite the net loss of floodplain storage, the proposals do not substantially affect the flood mechanisms in terms of conveyance or in terms of flow rates and volumes into and out of the floodplain. It is noted that the volume of floodplain lost as a result of the proposed scheme represents approximately 0.25% of the total floodplain storage during the baseline design event within the Project 03 modelled reach.

3.1.90 The negligible changes to all events from the 50% AEP up to the 0.5% AEP plus CC events further indicates no impacts on flood frequency, as also demonstrated by the flood extents and level differences shown on Figure A11.3.6 in Annex D. This is due to there being fundamentally no change in the timing of the flow through this reach, no substantial change in peak flows and levels experienced and no increase in the extent of flooding, despite the loss of floodplain storage. Consequently, it is concluded that there will be no areas within the modelled reach and downstream which will experience a measurable change in the frequency of flooding.

3.1.91 The flows and levels at the downstream model boundary have been shown to be virtually unaffected, with any minor impacts remaining close to the source and dissipating within the modelled reach. It is concluded that the proposed scheme development will not result in a cumulative impact downstream along the River Tay beyond the model boundary.

Impact of Other Development on the Assessment

3.1.92 This assessment has been undertaken based on existing conditions in the project area and upstream. There is therefore a risk that any significant development upstream could impact on the hydrology of the area and alter the assessment undertaken. Key development planned upstream of the proposed scheme that could have a material impact on the assessment undertaken has therefore been considered:

- A9 Dualling, Project 7 (Glen Garry to Dalwhinnie): The Environmental Statement for this scheme states that the 'results of the Enhanced 2D models do not indicate a material change in flood risk passed downstream' (Transport Scotland, 2017a).
- A9 Dualling Project 5: (Killiecrankie to Glen Garry): Section 3.1.45 of the Flood Risk Assessment for this scheme (Transport Scotland, 2017b) demonstrates that the total impact on peak flow at the downstream point of the modelled reach is an additional $0.52m^3/s$ during the 0.5% AEP + CC event. This represents a 0.04% increase in peak flow on the River Garry. This negligible additional flow would flow into Loch Faskally and would be likely to be attenuated here and therefore have no impact downstream.
- A9 Dualling Project 4: (Pitlochry to Killiecrankie): Flows at the downstream end of the hydraulic model developed for this scheme have been assessed to identify any changes in flow conditions to those considered as part of this FRA. The change in peak flow at the downstream end of the River Tummel hydraulic model developed for Project 4 during the design event is $0.63m^3/s$, which represents an increase of 0.04%. This negligible change results in a maximum increase in peak water level in this location of 1mm.

3.1.93 The changes upstream are therefore considered negligible and would have no impact on the assessment undertaken for the proposed scheme.

Erosion Risk

3.1.94 The scheme has the potential to impact on velocities within the affected watercourses and the floodplain. Any increase in velocity has the potential to increase the risk of erosion whilst any decrease could potentially lead to an increase in sediment deposition. The geomorphology of the area is covered in more detail in Appendix A11.5 (Fluvial Geomorphology).

3.1.95 The hydraulic model has been used to assess the impact of the proposed scheme on peak flow velocities within the floodplain. Across the majority of the floodplain the change in velocity as a result of the scheme would be +/-0.1m/s, which is considered negligible. The locations where the change in velocity is greater than 0.1m/s are within or in close proximity to compensatory flood storage areas or diverted minor watercourses. The change in velocity at these locations is a result of the changes in flows associated with the storage areas. North of Guay, localised increases in velocity of up to 0.5m/s would be between the Highland Main Line railway embankment and the A9, where baseline peak flow velocities are less than 0.5m/s. The small changes in flood velocity are on areas of agricultural land and would not be anticipated to result in additional erosion or sediment deposition. South of Guay the changes in velocity are also localised and up to approximately 0.8m/s, in areas with a baseline velocity of approximately 0.7m/s. This increase (in the 0.5% AEP (200-year) plus CC event) is associated with water draining from the flood storage area on to agricultural land east of the Highland Main Line railway. It is anticipated that these changes would not result in additional erosion or sediment deposition.

Residual Risks

3.1.96 Whilst the proposed scheme has been designed to ensure the proposed scheme is not at risk of flooding during the design flood event, a residual risk remains that it could flood from a more extreme event.

3.1.97 There is a residual risk to side roads and drainage infrastructure within the floodplain which has been designed to a lower design standard to ensure functionality. For example, side roads to properties that are within the floodplain cannot be designed to the same design flood event as the main alignment as this would result in access routes at higher levels than the properties or infrastructure they serve.

4 Minor Watercourses

Introduction

4.1.1 Between the Tay Crossing and Ballinluig the A9 crosses 24 minor watercourses. These are typically smaller unnamed streams, confined to narrow, often deep channels with relatively small catchment areas (less than $0.5km^2$). The majority of these watercourses flow beneath the existing A9 through circular culverts ranging in size from 450mm diameter to 1.3m in diameter. During the 0.5% AEP (200-year) plus CC design flood event, the peak flow estimates for these watercourses range from $0.23m^3/s$ up to $2.31m^3/s$.

4.1.2 The risk of flooding from these watercourses is considered to be low as they typically flow through rural areas away from flood sensitive receptors. The greatest risks are usually associated with the watercourse crossings, especially in those cases where the existing capacity of the culvert impedes flood flow, combined with limited upstream storage for floodwater, which could place neighbouring receptors (including the existing A9) at risk of more significant flooding.

4.1.3 The proposed scheme would include modifications to existing watercourse crossings where the main alignment embankments would be widened to accommodate the dual carriageway. The proposed scheme would also include new watercourse crossings where localised offline realignment is required and where new access roads and access tracks are proposed.

4.1.4 It is generally considered that the proposed scheme would have a negligible impact on flooding at these watercourse crossings and in fact could have a beneficial impact where culverts are to be replaced based on DMRB design criteria to pass the design flood event. This results in increased flow through the culvert, reducing flood risk upstream and increasing pass forward flows. Where these flows are directly into the River Tay, the flood risk downstream is not considered to be increased as the size of the flows is negligible when compared to the flows in the River Tay and the peak of the flood event on the minor watercourse is unlikely to coincide with the peak flood event on the River Tay. However, there is also potential for the proposed scheme to have an adverse impact. For example, changing the culvert geometry and building within the floodplain could increase water levels upstream of the proposed scheme, reduce floodplain storage volume or pass additional flood flow downstream, increasing the risk of flooding. This has the potential to be a significant issue if there are flood sensitive receptors nearby.

<u>Assessment Approach</u>

4.1.5 The FRA Flood Maps (Annex D) illustrate the distribution of minor watercourses and the location of existing A9 watercourse crossings (e.g. bridges, culverts, pipes etc.). Each watercourse has been given a unique water feature reference number (e.g. WF42) as many of the watercourses are unnamed.

4.1.6 The SEPA Flood Map may not include all of these watercourses or ditches as their drainage catchment areas are less than $3km^2$. Whilst it might be possible to infer their flood flow paths and extent using the SEPA Surface Water Map, there is a lack of baseline information available to assess the risk of flooding from these watercourses and structures, in the level of detail suitable for this FRA. This FRA has therefore adopted a staged approach to the assessment of flood risk on such watercourses. The assessment was risk-based considering those watercourses of highest risk of consequence, in greatest detail.

4.1.7 Firstly, the Flood Estimation Handbook (FEH) Statistical method for ungauged catchments and the FEH Rainfall-Runoff method were adopted to estimate the peak design flow for each minor watercourse, with the design flow adopting the highest value predicted by the two methods. Appendix A11.2 (Surface Water Hydrology) provides further details of this approach and results.

4.1.8 Secondly, following the methodology presented in CIRIA's Culvert Design and Operation Guide (CIRIA, 2010), a preliminary assessment was adopted for each of the watercourse crossing structures, the aim of which was to assess for both the baseline and the proposed scheme scenario the:

- flow condition of the existing watercourse crossing structures (i.e. free-flow or surcharged); and
- upstream headwater level (HWL) required to pass the steady-state design flow through the structure.

4.1.9 At this stage, the preliminary assessment assumed the structure conveying the minor watercourse would be extended to accommodate the mainline of the proposed scheme. Whilst the CIRIA approach is likely to estimate a conservative upstream HWL (e.g. it does not take into account flood hydrograph shape, flood volume, local topography and attenuation provided by adjacent floodplain), by comparing results, it does provide a useful initial tool in which to assess existing flood risks and the potential flood impacts of the proposed scheme.

4.1.10 Following completion of the preliminary assessment, its findings, along with a wide range of design criteria and environmental and ecological constraints were used to inform the initial design of the watercourse crossing including the like-for-like extension or replacement of the structure.

4.1.11 Where the preliminary assessment suggested a low risk of flooding or low impact, that watercourse crossing was not considered further, as the approach is sufficiently robust so as not to require a more detailed hydraulic assessment.

4.1.12 Where the preliminary assessment suggested that the initial design could have an adverse flood impact, either by increasing upstream HWL or by passing additional flow downstream, the hydraulic analysis of these watercourse crossings was considered in further detail. This included further GIS analysis of potential flow paths or hydraulic modelling to better define baseline flood risks and potential impacts.

4.1.13 The findings of the detailed assessment were then use to refine the final design of the watercourse crossing and to assess the need for additional mitigation measures, if required.

Preliminary Assessment

4.1.14 An overview of the baseline assessment, when tested against the design flood event, is included in Table 15. The results of the assessment and more detail on each watercourse, can be found in Appendix A11.8 (Minor Watercourse Crossings Report).

Table 15 : Baseline hydraulic performance - mainline

Minor Watercourse Crossing	Total	Culvert Free Flow (no impact on flow)	Culvert Surcharged		
			HWL less than Bank Level	HWL greater than Bank Level	Road at risk*
Mainline	24	16	4	4	2
*Road considered at risk when out of bank flow is predicted and the HWL exceeds or is within 600mm of the road level					

4.1.15 The assessment identifies that approximately 70% of the existing A9 watercourse crossings have adequate capacity, albeit that some have limited culvert freeboard. Approximately 10% of the crossings are under capacity and potentially pose a risk of flooding to the existing A9. These are the crossings associated with WF's 38 and 50. It should be noted that while the estimated upstream HWL is conservative, due to local topography which generally slopes down towards the existing A9, any out of bank flow originating from the culvert inlet could potentially place the existing A9 at risk of flooding.

<u>Proposed Scheme Hydraulic Performance - Mainline</u>

4.1.16 From a flood management perspective, the aim was to retain the flow regime of the existing culvert to maintain the balance between flood risk locally to the watercourse crossing and downstream receptors. For that reason, like-for-like culvert extension or replacement was the preferred option for the proposed scheme. However, this was not always applicable or achievable due to a range of wider environmental and road design considerations. Taking these into account, the proposed scheme includes:

- fifteen replaced culverts designed under DMRB;

- six like-for-like culvert extensions (i.e. same dimensions and gradient); and
- one culvert crossing removed with the watercourse diverted to an adjacent watercourse

There are also two crossings which are not affected by the proposed scheme (the upstream end of the culvert is outside of the proposed earthworks for the scheme). A further watercourse (WF21) is believed to flow into existing road drainage as no outfall to the River Tay has been located. As part of the proposed scheme, flows from the watercourse will be diverted into WF23.

Change in Hydraulic Performance

4.1.17 All of the replaced or proposed scheme crossings are designed to freely pass (i.e. without surcharging) the peak flow during the 0.5% AEP (200-year) plus climate change flood event plus appropriate freeboard, with the exception of WF42. New access track crossings have also been designed to freely pass the peak flow during the 0.5% AEP (200-year) flood event.

4.1.18 To assess the potential impacts on flooding, the hydraulic performance of each crossing was tested against the design flood event. Table 16 provides an overview of the proposed scheme assessment, indicating that generally the proposed scheme has a beneficial impact upstream of the proposed scheme with free-flow conditions in 21 of the 23 culverts. The two culverts that are surcharged in the design event are WF41 and WF42. These are to be extended as part of the proposed scheme. It is not proposed to increase the sizes of these culverts to freely pass the peak flow in the design event, as this would have a negative impact on flood risk in a flood event on the River Tay. In a design event on WF41 or WF42, the culvert would surcharge, however the area in which flooding would occur upstream of the proposed scheme is existing wetland that is to be included within the scheme CPO boundary. As there are no sensitive receptors within this area and the freeboard to the proposed scheme is at least 4m, no additional mitigation is proposed.

Table 16 : Proposed scheme hydraulic performance – mainline

Minor Watercourse Crossing	Total	Culvert Free Flow	Head Water Level (0.5%AEP (200-year) + CC flood event)		
			HWL < Bank Level	HWL > Bank Level	Road at risk*
Mainline	23**	21	21	2	0
*Road at risk when out of bank flow is predicted and the HWL exceeds or is within 600mm of the road level **One watercourse is being diverted (WF49) and the existing watercourse crossing removed					

Change in Head Water Level

4.1.19 Although the proposed scheme reduces the risk of flooding to the A9, 8 of the 23 watercourse crossings would result in an increase in upstream head water level (HWL). Table 17 summarises the impacts of the proposed scheme on upstream HWL for the design flood event.

Table 17: Impacts of the proposed scheme mainline on upstream HWLs

Potential flood impact		Change in upstream Head Water Level	Number of Watercourse crossings	Watercourses
	Major Adverse	Increase in HWL > 100mm	4	WF25, WF30, WF37, WF42
	Moderate Adverse	Increase in HWL >50mm	0	-
	Minor Adverse	Increase in HWL >10mm	4	WF16, WF31, WF35, WF47
	Negligible	Negligible change in HWL <+/- 10mm	3	WF28, WF29, WF41
	Minor Beneficial	Reduction in HWL >10 mm	4	WF19, WF33, WF34, WF53
	Moderate Beneficial	Reduction in HWL >50mm	1	WF24
	Major Beneficial	Reduction in HWL > 100mm	7	WF18, WF20, WF23, WF32, WF38, WF50, WF52

4.1.20 The nine crossings with an adverse impact required more detailed hydraulic assessment and are considered further below. It should be noted that in the majority of cases, the Major Adverse impacts are due to the culvert being extended further upstream, resulting in increased HWL when comparing peak water level at the culvert inlet. This goes up because the location has changed with the extension upstream, but at that new inlet location depth does not change compared to that point in the existing case and consequently there is no increase in flood risk as a result of the proposed scheme. Major Beneficial impacts are generally as a result of improved conveyance due to culvert replacement works.

Change in Pass Forward Flow

4.1.21 Downstream of the watercourse crossings, the proposed scheme has the potential to increase flows as a result of enlarging an existing culvert that may have been inhibiting flows during the baseline scenario.

4.1.22 The preliminary assessment identifies seven watercourse crossings where peak flow may increase downstream when compared to the baseline scenario (i.e. the culvert now conveys the design flood event). However, no downstream flood sensitive receptors were identified near these watercourses and therefore the impact of the proposed scheme is considered to be low. However, all seven of these watercourse crossings have been examined through more detailed hydraulic assessments. The results of these assessments are included in the following sections.

Proposed Scheme Hydraulic Performance – Access Roads

4.1.23 There are eleven locations where proposed access roads or side roads require crossings of minor watercourses. Six of these crossings are located directly adjacent to the proposed A9 main alignment and therefore the mainline culvert would be extended beneath the access/side road. The remaining five watercourse crossings are new formal structures and are designed under DMRB to freely pass the 0.5% AEP (200-year) plus climate change flood event plus appropriate freeboard. The risk of flooding from these watercourse crossings is therefore low and the proposed scheme is shown to have a negligible flood impact. This FRA does not consider these watercourse crossings further, other than where they are extensions to mainline crossings considered in the detailed assessment below, but they are reported in Appendix A11.8 Watercourse Crossings Report.

Detailed Assessment

Adverse Impacts on Upstream Flooding

4.1.24 Table 18 provides an overview of the eight watercourse crossings where the preliminary assessment identifies a potential increase (greater than 10mm for the design event) in upstream HWL and consequently a reduction in the freeboard to the proposed scheme carriageway level.

4.1.25 At seven of the eight crossings, the preliminary assessment estimates that the peak flow would remain in bank and the crossing would be in free flow conditions. There is also greater than 600mm freeboard available between the HWL and the proposed scheme mainline level. Whilst there is an adverse impact predicted on HWL at these watercourse crossings, the impact upon flood risk is considered to be low, as there is sufficient freeboard to the proposed scheme and there are no other sensitive receptors within the areas with increased risk no further mitigation is proposed.

Table 18 : Minor watercourses - adverse impacts on upstream HWL (0.5% AEP (200-year) + CC flood event)

Watercourse	Proposed Scheme Increase on HWL (mm)	HWL Impact	Peak flow in-bank and culvert in free flow?	Remaining Freeboard to Proposed Scheme Mainline Level (m)
WF25	160	Major adverse	Yes	1.95
WF30	100	Major adverse	Yes	1.95
WF31	20	Minor adverse	Yes	3.41
WF35	10	Minor adverse	Yes	3.33
WF37	220	Major adverse	Yes	3.69
WF42	133	Major adverse	No	2.12

Watercourse	Proposed Scheme Increase on HWL (mm)	HWL Impact	Peak flow in-bank and culvert in free flow?	Remaining Freeboard to Proposed Scheme Mainline Level (m)
WF47	20	Minor adverse	Yes	2.42
WF53	30	Minor adverse	Yes	2.29

WF25

4.1.26 WF25 flows through woodland upstream of the existing A9, before flowing under General Wade's Military Road and then under the existing A9 through a 1.05m diameter culvert. It has a catchment area of $0.14km^2$ and a peak flow of $0.46m^3/s$ during the design flood event.

4.1.27 The baseline preliminary assessment estimated the full-bore capacity of the culvert to be $1.51m^3/s$, indicating that the culvert would be free flowing during the design flood event on the watercourse. However, hydraulic modelling indicates that the culvert outlet is below the design peak water level from the River Tay and therefore the outlet would be flooded in some events.

4.1.28 It is proposed to extend the culvert as part of the scheme, with the extension to be of the same dimensions as the existing culvert. As the extension is on the upstream side, the preliminary assessment indicates that this results in an increase in HWL of 0.16m.

4.1.29 The culvert has been included within the detailed hydraulic model for the proposed scheme, to assess the impact of the flooded outlet and the increased HWL. Modelling indicates that in the design flood event on the River Tay, there is flooding both of the existing A9 and upstream of the existing A9 in the baseline scenario. In the WF25 design flood event the hydraulic model predicts a small area of flooding (approximately $75m^2$) upstream of the A9 in the baseline scenario. Flood depths reach 0.3m in the design flood event. Similar to the assessment of WF24, the flooding shown is as a result of the lack of upstream channel representation within the model. Given that modelling does not indicate interaction with flood waters from the River Tay in a design event on WF25, the preliminary hydraulic assessment that the watercourse would remain in bank is considered accurate. The increase in HWL of 0.16m does not alter this assessment and therefore no mitigation measures are proposed.

WF30

4.1.30 WF30 is a small watercourse that flows through agricultural land and rough pasture upstream of the existing A9 and flows under the existing A9 in a 1.0m diameter culvert. It has a catchment area of $0.14km^2$ and a peak flow of $0.47m^3/s$ during the design flood event.

4.1.31 The baseline preliminary assessment estimated the full-bore capacity of the culvert to be $1.30m^3/s$, indicating that the culvert would be free flowing during the design flood event on the minor watercourse.

4.1.32 It is proposed to replace the culvert as part of the proposed scheme and to incorporate a mammal passage at this location, while extending the culvert under the widened main alignment. The replacement would be a 1.5m wide by 1.5m high box culvert. Due to the extension of this culvert, the HWL is increased by 0.1m as the culvert inlet is relocated further upstream on the minor watercourse. At this HWL the flows are in bank and there is 1.95m freeboard to the main alignment and therefore flood risk is considered to be low.

WF31

4.1.33 WF31 flows through woodland upstream of the existing A9 and flows under the existing A9 in a 1.0m diameter culvert. It has a catchment area of $0.37km^2$ and a peak flow of $1.03m^3/s$ during the design flood event.

4.1.34 The baseline preliminary assessment estimated the full-bore capacity of the culvert to be $1.41m^3/s$, indicating that the culvert would be free flowing during the design flood event.

4.1.35 It is proposed to extend the culvert as part of the proposed scheme. This extension results in an increased HWL at the culvert inlet of 0.02m because it is located further upstream on the minor watercourse. As the increased HWL is in bank and there is 3.41m freeboard to the main alignment, flood risk is considered to be low and no further mitigation is proposed.

WF35

4.1.36 WF35 flows through woodland upstream of the existing A9 and flows under the existing A9 in a 1.2m diameter culvert. It has a catchment area of $0.26km^2$ and a peak flow of $0.77m^3/s$ during the design flood event.

4.1.37 The baseline preliminary assessment estimated the full-bore capacity of the culvert to be $2.02m^3/s$ indicating that the culvert would be free flowing during the design flood event.

4.1.38 It is proposed to extend the existing culvert as part of the scheme. This extension results in an increase in HWL of 0.01m upstream of the culvert as a result of the culvert inlet being further up the channel as a result of the extension. As the increased HWL is below bank level and there is a 3.33m freeboard to the proposed main alignment, no mitigation is proposed.

WF37

4.1.39 WF37 flows through woodland upstream of the existing A9 and has a catchment area of $0.30km^2$. The existing A9 crossing is a 1.07m diameter culvert with a full-bore capacity of $1.57m^3/s$ and is a short distance downstream of the crossing of General Wade's Military Road. The peak flow on the watercourse during the design event is $0.76m^3/s$ and therefore the culvert would be free flowing in the design event.

4.1.40 Hydraulic modelling of the River Tay indicates that the existing culvert would be flooded at both the inlet and outlet during the design flood event. It is proposed to extend both ends of the existing culvert as part of the scheme to accommodate widening of the road embankment. A 1D representation of this culvert was therefore included in the hydraulic model of the proposed scheme.

4.1.41 The hydraulic model indicates that in the baseline scenario, flooding from the River Tay results in the culvert outlet being flooded and water passing through the culvert to flood the area between the existing A9 and the Dowally to Kindallachan Side Road, with some flooding to the latter predicted. This is also contributed to by a similar flood mechanism from WF38. Hydraulic modelling indicates that the proposed scheme will increase flood risk locally in an area that already experiences flooding between the existing A9 and General Wade's Military Road, however this is predominantly due to changes to the culvert for WF38 and is discussed further in 4.1.54. As there are no sensitive receptors within the area of increased flood risk and the area is remote and inaccessible, no mitigation measures are proposed. The area will be included within the Compulsory Purchase Order for the scheme.

WF42

4.1.42 WF42 is hydraulically linked to WF41, with the inlet to the existing A9 culvert located in the same area of wetland to the west of the existing A9. Modelling indicates that the existing A9 culvert act as a flood relief culvert rather than for conveying normal flows in the watercourse. The culvert is 0.6m in diameter and has a full-bore capacity of $0.35m^3/s$.

4.1.43 Hydraulic modelling of the River Tay indicates that in the design flood event both the inlet and outlet of the culvert are inundated by the River Tay. A 1D representation of this culvert was therefore included in the hydraulic model for the proposed scheme.

4.1.44 As part of the proposed scheme the culvert is to be extended on both sides of the main alignment.

4.1.45 The hydraulic model predicts that in the design event on WF42, there is flooding both upstream and downstream of the existing A9 in the baseline scenario. East of the existing A9 the flooding is within an existing wetland area, with flood depths estimated at over 0.65m. West of the existing A9 flooding is within agricultural land, with flood depths of up to 0.53m. With the proposed culvert extensions, there is an increase in peak flood depth to the east of the proposed scheme of up to 0.14m. Given the areas of increase in flood risk are existing wetland areas and would be flooded to a depth between 1-3.6m for a 0.5% AEP (200-year) flood event on the Tay, no mitigation for these increases is proposed.

The area will be included within the Compulsory Purchase Order as it is required to construct the scheme. Should it be returned to the landowner it will be with an appropriate burden to reflect the increase in flood risk.

WF47

4.1.46 WF47 flows through woodland upstream of the A9 and has a catchment area of $0.16km^2$ resulting in a peak flow of $0.47m^3/s$. The existing A9 crossing is a 0.9m diameter culvert and the baseline preliminary assessment estimates the full-bore capacity to be $1.06m^3/s$.

4.1.47 As part of the proposed scheme the culvert is to be replaced by a 1.8m wide by 1.2m high box culvert. The increased length of this culvert will result in the upstream end being located further upstream than the existing culvert inlet and this, combined with additional flows from WF49, result in an increase in HWL of 0.02m. Given that the culvert is free flowing, the increased HWL is below bank level upstream of the culvert and the 2.42m freeboard to the proposed level of the main alignment, there is no increase in flood risk and no mitigation is proposed.

WF53

4.1.48 Upstream of the A9 WF53 flows through agricultural land and woodland. The total catchment area is $0.20km^2$ resulting in a peak flow of $0.49m^3/s$ for the design event. The existing A9 crossing is a 1.15m diameter culvert and the baseline preliminary assessment estimates the full-bore capacity to be $1.81m^3/s$, therefore the culvert would be free flowing in the design flood event.

4.1.49 As part of the proposed scheme the culvert is to be extended upstream. This will increase the HWL by up to 0.03m in the WF53 design flood event. Given the proximity of Inch Cottage to this watercourse and the interaction of flood waters from the Tay on both sides of the culvert under the main alignment, this watercourse has been included within detailed hydraulic modelling of the proposed scheme.

4.1.50 The hydraulic model indicates in the design event on WF53, there is flooding between the existing A9 and the rail embankment, with depths of up to 0.7m, although this is lower than the depths predicted due to the design event on the River Tay (generally 1.1m or greater). There is also a small area (approximately $120m^2$) of flooding upstream of the existing A9. The existing A9 itself is not shown to be at risk.

4.1.51 The with-scheme model indicates negligible change in flood risk upstream or downstream of the proposed scheme in the design event on WF53 as a result of the extension to the existing culvert.

Increase in Downstream Flows

4.1.52 The preliminary assessment identified 15 culverts that are being replaced as a result of the proposed scheme. Of these, seven were surcharged in the existing scenario design flood event and therefore the replacement culvert has the potential to pass increased flows, potentially increasing flood risk downstream of the proposed scheme.

4.1.53 Where the watercourse discharges directly into the River Tay downstream of the proposed scheme, no further assessment has been completed because the increase in flows from the minor watercourse is considered to be negligible when compared to the flow on the River Tay (range approximately $344m^3/s$ to $2,540m^3/s$). The rainfall events that would produce the peak flood event on the River Tay and minor watercourses are different and therefore are unlikely to occur simultaneously on the different watercourses. Further information is included in Appendix A11.4 – the Hydrology Report. A summary of the watercourses with an increase in downstream flows is included in Table 19.

Table 19: Culverts with increased downstream flows (all figures for design event)

Watercourse	Water Feature baseline flow (m^3/s)	A9 crossing baseline capacity (m^3/s)	Increase in flows with scheme (m^3/s)	Downstream receptors	Proposed Action
WF18	0.99	0.43	0.55	River Tay	None – increase in flows negligible compared to flows in River Tay
WF20	0.90	1.12	0.10	River Tay	None – increase in flows negligible compared to flows in River Tay
WF23	2.56 [1]	1.35	1.21	River Tay	None – increase in flows negligible compared to flows in River Tay
WF32	1.60	1.07	0.53	River Tay	None – increase in flows negligible compared to flows in River Tay
WF38	1.51	0.37	1.14	Dowally Burn, River Tay and Highland Main Line	Further assessment
WF50	1.04	0.13	0.47	River Tay and Highland Main Line	Further assessment
WF52	0.69	0.32	0.37	River Tay and Highland Main Line	Further assessment

1: Includes flows from WF21 and WF22 proposed to be diverted into WF23 as part of the scheme)

WF38

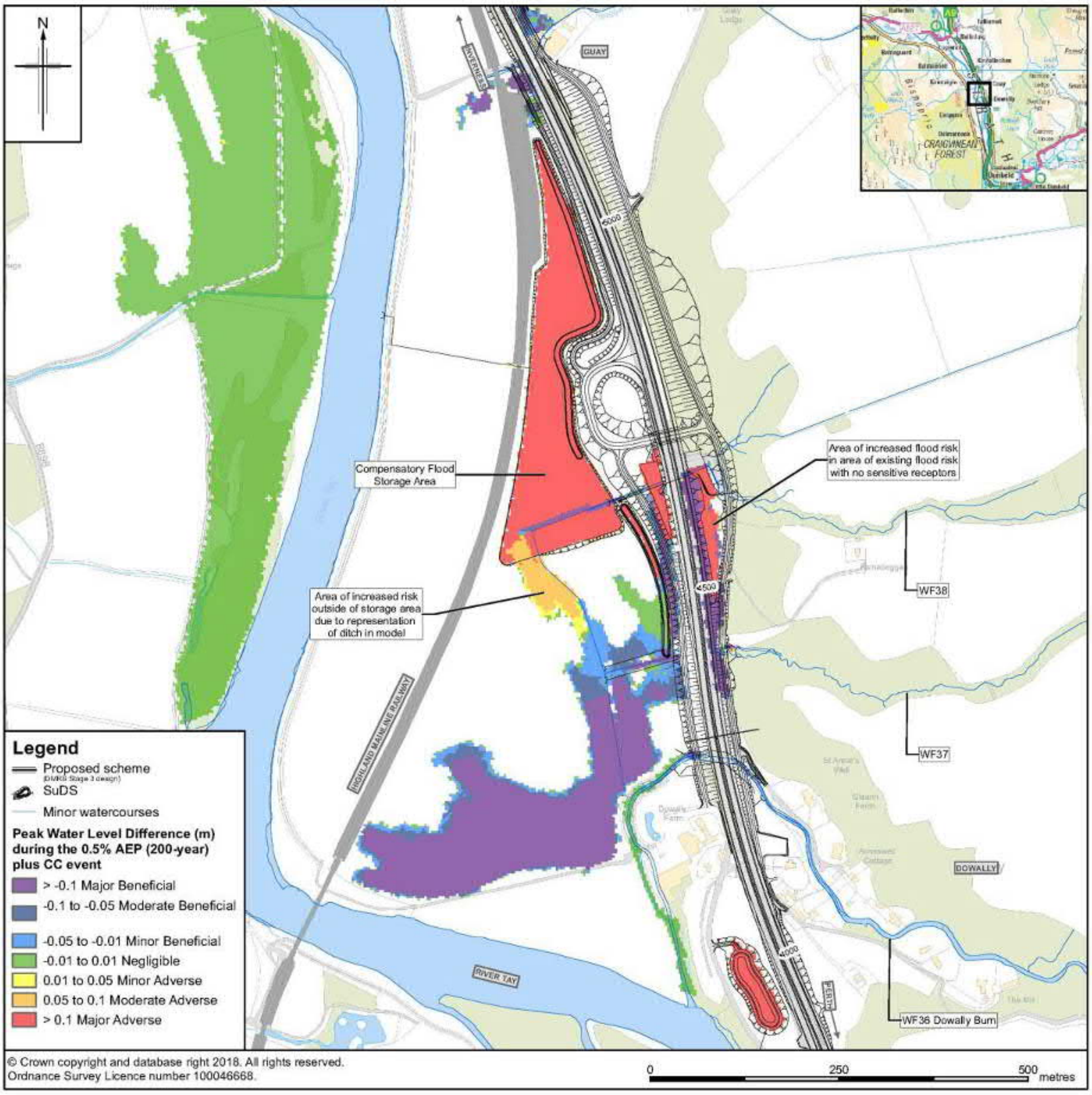
4.1.54 WF38 flows through agricultural land and areas of native woodland and has a catchment area of $0.68km^2$, resulting in a peak flow of $1.51m^3/s$. The existing A9 crossing is a 0.6m diameter culvert. Downstream of the existing A9 the watercourse flows through agricultural land and discharges into the Dowally Burn (WF36).

4.1.55 The baseline preliminary assessment estimated the maximum capacity of the culvert to be $0.37m^3/s$, so the culvert would be surcharged in the design flood event. The HWL is estimated to be approximately 1.52m above the level of the existing A9, suggesting the carriageway is at risk of flooding in this location.

4.1.56 As part of the proposed scheme the culvert will be replaced with a 2m wide by 1.5m high box culvert. This has a capacity of $1.53m^3/s$ and will therefore allow free flow through the culvert during the design flood event, mitigating the flood risk to the proposed scheme. This will result in an increase in flows through the culvert. Given the potential flood risk to the A9 and the interaction of the River Tay flood levels which are predicted to be above culvert inlet levels (resulting in backflow through the culvert), this watercourse has been included within the detailed hydraulic model for the proposed scheme.

4.1.57 The hydraulic modelling indicates that the increased capacity of the culvert will result in increased flows downstream of the proposed scheme. However, the flows would be directed into the flood mitigation area immediately downstream in the design flood event and therefore any out of bank flows will be stored in that compensation area (see Figure 30). The model predicts that there will be an increase in flows from the compensation area towards the Dowally Burn and flooding to the surrounding agricultural field. This increase is due to the grid resolution of the hydraulic model ($6m^2$ grid size) being too large to fully represent the existing drainage ditch from WF38 towards the Dowally Burn. The capacity of this ditch has been estimated using Manning's equation and is sufficient for the peak WF38 0.5% (200-year) plus CC flood event flows out of the storage area, therefore it is considered that flows would remain in-bank and flow towards the Dowally Burn. The increase in flows downstream is small in comparison to the receiving watercourse (Dowally Burn) and any exceedance will result in shallow depths of flooding within the existing floodplain, at far lower depths than the (greater than) 1.5m predicted during a 3.33% AEP (30-year) flood event on the River Tay in the vicinity of this watercourse. The Dowally Burn discharges into the River Tay and any increase in flows is negligible compared to the flows on the River Tay, therefore the increase in flood risk is considered negligible.

Figure 30: Scheme impact on flood risk from WF38



4.1.58 An increase in flood risk upstream of the proposed scheme is also predicted by the model. This is predominantly due to the scheme footprint reducing existing floodplain storage between the main alignment and the Dowally to Kindallachan Side Road. This results in an increase in flood depth in the design event of 0.2m to the remaining area between the main alignment and the side road. Given that this is an area of existing flood risk, is to be purchased as part of the proposed scheme and contains no sensitive receptors, no mitigation for this increase is proposed.

WF50

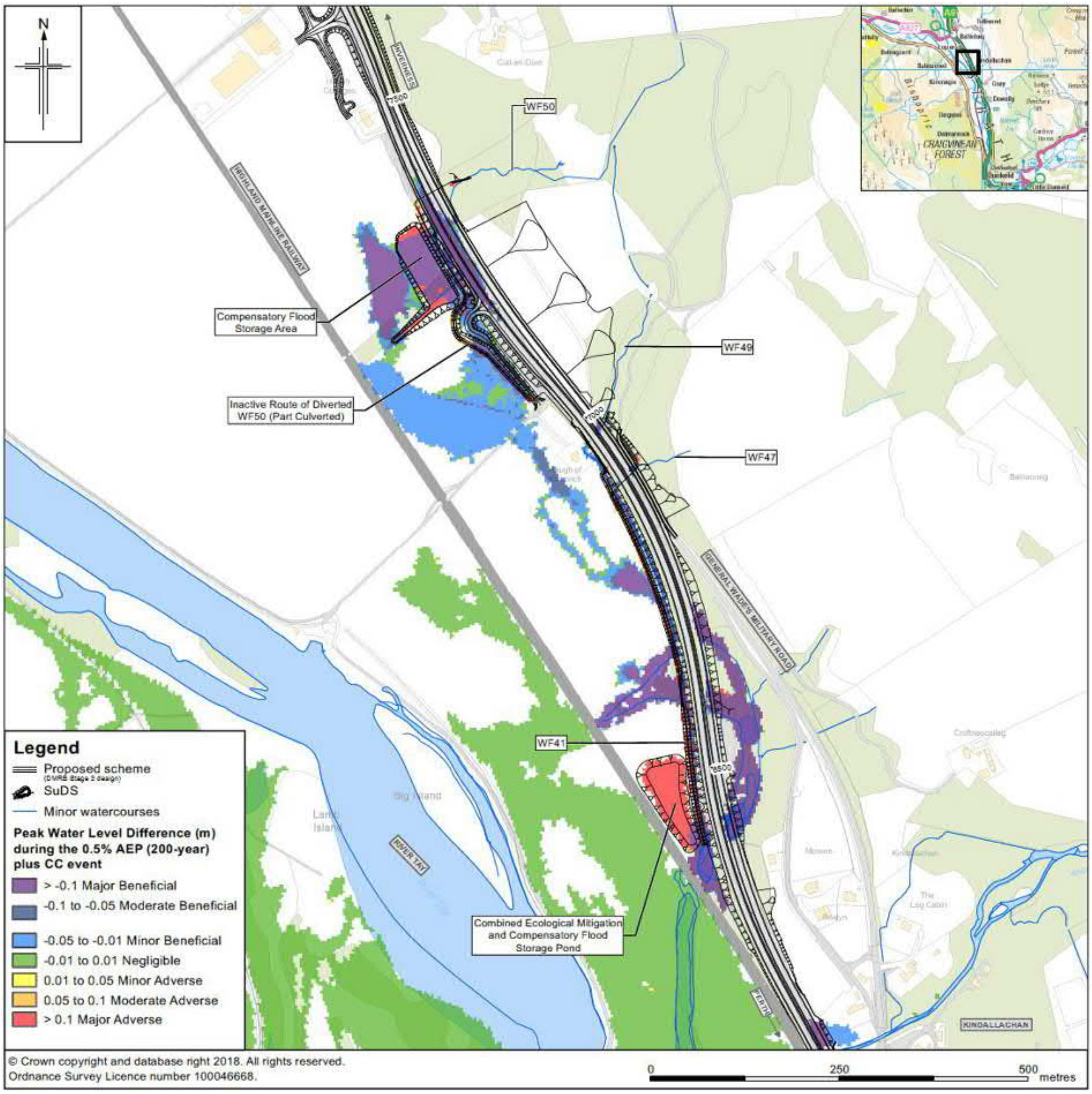
4.1.59 WF50 flows through woodland upstream of the existing A9 and has a catchment area of 0.21km^2 resulting in peak flows of 0.6m^3/s in the design event. The existing crossing of the existing A9 is a 0.45m diameter culvert with a full-bore capacity of 0.131m^3/s. The culvert is therefore surcharged in the design event, with the baseline assessment predicting a HWL 1.74m above existing A9 carriageway level. The existing A9 is therefore at risk of flooding and the culvert is proposed to be replaced with a 1.4m diameter culvert. This culvert will have a change in gradient at a manhole located in the verge alongside the A9 southbound carriageway. The upstream section will run from the existing watercourse approximately 16m upstream of the proposed retaining wall east of the main alignment to a manhole between the road and the retaining wall. The culvert will then run under the widened main alignment. This arrangement will permit free flow conditions in the design flood event, resulting in an increase in peak flows through the culvert of 0.47m^3/s.

4.1.60 Downstream of the existing A9, WF50 flows towards the rail embankment, before sinking approximately 100m west of the existing A9. Given the potential for the increased flows to result in increased flood risk to the rail embankment downstream, this watercourse has been included within the hydraulic model of the proposed scheme.

4.1.61 Hydraulic modelling indicates that in the baseline scenario there is extensive flooding to the existing A9 and the fields downstream in the design flood event on WF50. The flooding is generally in the same areas and at a reduced depth on the River Tay floodplain downstream of the existing A9 when compared to flood depths from the design event on the River Tay. In the design event on either the River Tay or WF50 there is flooding to approximately 200m of the existing A9 carriageway with depths of up to 0.3m. Ponding in the floodplain between the A9 and the rail embankment reaches up to 0.5m depth in places.

4.1.62 Hydraulic modelling indicates that the proposed scheme will result in increased flows through the culvert in the design flood event. To avoid an increase in flood risk downstream of the proposed scheme, it is proposed to divert the watercourse so that it runs parallel with the proposed scheme towards WF41 (see Figure 31). The spill level into the floodplain compensation area immediately adjacent to the culvert crossing downstream of the proposed scheme, will be set to ensure excess flows into this area do not result in an increase in flood risk downstream. The watercourse extension beyond the floodplain compensation area will be directed towards WF41 and WF42. This will result in increased flows into this area, however a combined ecological mitigation and floodplain compensation area is proposed in this area to mitigate any significant increase in flood risk as a result.

Figure 31: Scheme impact on flood risk from WF50



WF52

4.1.63 WF52 flows as two tributaries upstream of the existing A9, with one splitting into two to pass under the access road to Cuil-an-Duin. Downstream of the access road, the three tributaries combine into a single watercourse that passes under the existing A9 in a 0.59m diameter culvert. WF52 has a catchment area of 0.30km^2 resulting in peak flows of 0.69m^3/s in the design flood event. The existing culvert has a full-bore capacity of 0.32m^3/s, indicating that the culvert will be surcharged in the design flood event. The baseline assessment indicates that this will result in a HWL with a freeboard of 1.21m to the A9.

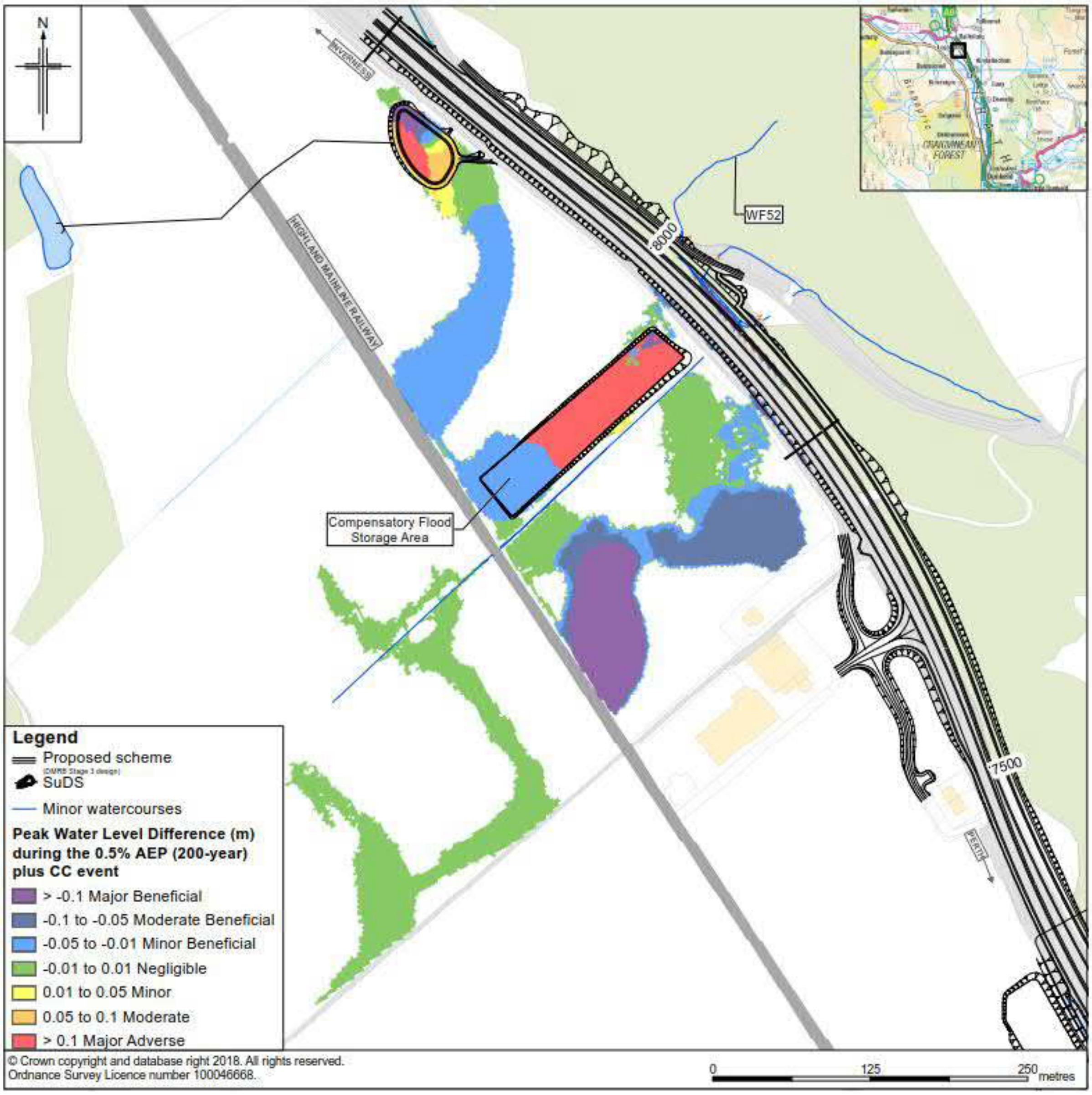
4.1.64 Downstream of the existing A9, WF52 flows towards the Highland Main Line railway embankment, passing under it through a culvert and then infiltrating to groundwater within the River Tay floodplain to the west of the rail embankment.

4.1.65 It is proposed to replace the existing crossing of the A9 as part of the scheme, with a 1.05m diameter culvert proposed. Due to the complexities of the watercourse and the changes required as part of the proposed scheme and the presence of the railway embankment downstream, WF52 was included within the scheme hydraulic model.

4.1.66 Hydraulic modelling indicates that in the baseline scenario there is extensive flooding to the fields downstream of the existing A9 in the design flood event on WF52, as well as flooding between the existing A9 and the access road. The flooding downstream is however generally in the same areas and at a reduced depth when compared to flood depths from the design event on the River Tay. Ponding does however reach over 0.6m in places in close proximity to the Highland Main Line railway embankment.

4.1.67 Downstream of the main alignment, the proposed scheme would result in increased flood risk to fields between it and the Highland Main Line railway and against the railway embankment as a result of the increased flows through the culvert. This increase in flood risk is up to 0.035m against the railway embankment and on the fields either side of the watercourse. To mitigate this increase in flood risk, mitigation in the form of an offline flood storage area is proposed on the right bank of the watercourse (see Figure 32).

Figure 32: Scheme impact on flood risk from WF52



Residual Risks

4.1.68 The residual flood risks from minor watercourses will include:

- Blockages of culverts by large debris that reduce its capacity to convey flows. This FRA confirms that the scheme is robust to reduced flows, but flooding of sensitive receptors including the proposed scheme could occur if a blockage is excessive; and
- Severe flood events which exceed the design capacity of the culverts. It has been confirmed that all minor watercourse culverts in the proposed scheme will not cause flooding of the main alignment for floods up to the 0.5% AEP (200-year) plus CC design event, but some flooding from minor watercourses could occur for exceedance events.

4.1.69 It will be important that the relevant operating company carry out routine inspection and ongoing maintenance of the culverts. The information contained in this FRA will be used to identify the sensitive locations and prioritise any inspection schedule within the A9 operation and maintenance plan.

JACOBS

5 Surface Water

Introduction

5.1.1 Surface water (pluvial) flooding results from rainfall-generated overland flow before the runoff enters any watercourse, drainage system or sewer or when the infiltration capacity of the ground surface is exceeded during extreme rainfall events. Excessive surface water runoff itself may pose a flood risk especially if flowing at high velocity. Localised depressions in the ground topography may result in the ponding of water, sometimes to a significant depth.

5.1.2 The antecedent conditions, permeability of the soil type or geology can affect the volume of runoff, whist the capacity and condition of the drainage network can affect how much water remains on the surface. The topography of the land and location of urban features such as buildings and road networks would also influence surface water flood risk by increasing the velocity of overland flow and depth of ponding.

Baseline Risks

5.1.3 The existing A9 follows the valley of the River Tay, which generally has steep hillsides sloping down towards the road. As a result, the hillsides are likely to generate significant volumes of runoff during high intensity rainfall events that would flow towards the existing A9.

5.1.4 As part of a typical carriageway design, roadside filter drains or Pre-Earthworks Drainage (open ditches) adjacent to earthworks or the mainline collect surface water runoff from hillsides. Therefore, incidences of surface water flooding on the existing A9 tie in closely with existing road drainage efficiency (associated with capacity exceedance and blockages). The existing A9 would also form an obstruction to natural overland flow routes where raised embankments would prevent surface water runoff draining through the usual routes and into nearby watercourses.

5.1.5 Anecdotal evidence has been provided of flooding to land downstream of the existing A9 towards the north of the proposed scheme, near Westhaugh of Tulliemet and Haugh Cottages, potentially as a result of exceedance or failure of the existing drainage network for the Ballinluig Junction immediately north of the proposed scheme. It has not been possible to confirm the source of this existing flood risk. However, the proposed scheme will not change the operation of the road drainage for the Ballinluig Junction and will not result in any increase in flood risk from this source.

5.1.6 This FRA has adopted a preliminary assessment to identify areas along the existing A9 at risk of surface water flooding using the following information and methodology:

- **SEPA Surface Water Flood Map** – the mapping identifies areas with a high (10% AEP (10-year)), medium (0.5% AEP (200-year)) or low (0.1% AEP (1,000-year)) probability of surface water flooding.
- **Overland Flowpath Analysis** – the analysis has used a ‘rolling ball’ technique based on topographic data from a Digital Terrain Model (DTM) to produce a series of theoretical surface water flowpaths. Essentially, the flowpath generated represents the path of ‘low spots’ over the ground along which water would flow if the ground was impermeable. The analysis identifies areas at particularly high surface water flood sensitivity based upon the catchment area and the gradient of the flowpaths within that location, with those flowpaths associated with large catchments and/or steep gradients resulting in high flowpath significance.
- **Historical Flood Incidents** – records provided by Transport Scotland indicate that surface water flooding has occurred on the existing A9 in areas close to Ballinluig

5.1.7 The preliminary assessment concludes that the majority of the existing A9 between the Tay Crossing and Ballinluig is on a raised embankment, which reduces the risk of the road becoming flooded by surface water. In these cases, the SEPA Surface Water Flood Map and the overland flowpath analysis identifies surface water ponding against the embankment, or the embankment directing overland flow routes to the nearest minor watercourse, as listed in Table 20.

5.1.8 The areas of surface water flooding listed in Table 20 are mainly associated with flooding along minor watercourses rather than direct surface water runoff. Since both the SEPA Surface Water Flood Map and the overland flowpath analysis do not take into account existing drainage features such as the existing A9 road drainage or culverts running underneath the existing A9, the flood mapping is likely to provide a conservative estimate of risk. Based upon the information presented above, this FRA concludes that there is an existing low risk of surface water flooding along the A9 corridor.

Table 20: Locations of potential surface water flooding (baseline scenario)

A9 Chainage	Description
ch1000 – ch1100	The SEPA Flood Map identifies surface water ponding on the upstream side of the existing A9 embankment and on the western side of the carriageway. No sensitive receptors have been identified immediately upstream of the A9, but the existing A9 does appear to be at risk. As pre-earthworks drainage upstream of the A9 is not represented within SEPA's surface water model, it is likely that the flooding predicted along the existing A9 in this location is overestimated.
ch2600 – ch2700	The SEPA Flood Map identifies surface water ponding on the existing A9 carriageway, in an area of cutting on the east side of the road. The predicted flooding is immediately up against the cutting and is likely to be due to ponding of water against the cutting slopes. The extent of flooding is small and just to the edge of the carriageway and is likely to be overestimated as the influence of road drainage in the location will not have been taken into account in SEPA's model.
ch3800 – ch3900	The SEPA Flood Map identifies a potential area of surface water flood risk running along the existing A9 at a location with steep hillside sloping down to the existing A9 from the east. As the pre-earthworks drainage upstream of the existing A9 is not represented within SEPA's surface water model, it is likely that the flooding predicted along the existing A9 in this location is overestimated.
ch4200 – ch4300	The SEPA Flood Map identifies areas of surface water ponding on the upstream side of the existing A9 embankment. This is within an area of low ground adjacent to the Dowally Burn and well below the level of the existing A9 and therefore is considered to be a low risk of flooding to the road.
ch4200 – ch4500	The SEPA Flood Map identifies some surface water flooding on the west side of the existing A9, between the road embankment and the railway embankment. The area of flooding is extensive, but as the existing A9 is on embankment at this location and there are large areas of surrounding fields at lower levels that are not predicted to flood and therefore flood risk to the road is considered low.
ch4800 – ch5000	The SEPA Flood Map identifies surface water ponding on the downstream side of the existing A9 with a small area of flooding to the carriageway. The existing A9 is on a very low embankment at this location and so the risk to the road is possible, however as pre-earthworks drainage is not represented within SEPA's surface water model and the road is raised above the area of flooding in the field, the risk of flooding to the existing A9 is considered to be low.
ch5200 – ch5800	The SEPA Flood Map identifies surface water ponding on the upstream side of the existing A9 embankment within the field east of the existing A9 north of Guay, which has a steep hillside sloping up away from it to the east. Guay farmhouse and other properties appear to be just outside of the area at risk. The existing A9 is not identified as being at risk and is on embankment at this location.
ch6200 – ch6700	The SEPA Flood Map identifies surface water ponding on the existing A9 and in fields downstream of the road, in an area downstream of steep sided hillside. Between the hillside and the A9 is an existing wetland area at lower level than the existing A9. This area is not shown to be at risk in the SEPA mapping and it is possible that the digital terrain model (DTM) used for the SEPA mapping did not pick up on the low lying area due to heavy vegetation in this area. Pre-earthworks drainage upstream of the existing A9 and the presence of the culverts for WF41 and will also reduce the risk from that shown by the SEPA maps. Flood risk to the existing A9 in this location is therefore considered low.
ch7600 – ch8000	The SEPA Flood Map identifies surface water ponding on the existing A9 and downstream of the existing A9 embankment. The land to the east of the existing A9 rises sharply up away from the road and therefore run-off is likely to be directed onto the road which is in cutting on the east side. The culvert for WF52, which has been assessed to freely pass the design flood event (see 4.1.63), is located a short distance to the north. The watercourse runs parallel to the road upstream of the existing A9 and would be likely to intercept some of the surface water flows. This, and pre earthworks drainage not included within the SEPA model, are likely to reduce the surface water flood risk from that shown in the mapping.
ch8100 – ch8200	The SEPA Flood Map identifies surface water ponding on the downstream side of the existing A9 and across the existing A9 carriageway. The topography to the east of the existing A9 is steep hillside sloping down to the road, while to the west, field levels are below road level. Buildings at Westhaugh of Tulliemet are shown to be just outside of the identified risk area. As pre-earthworks drainage upstream of the existing A9 and the culvert for WF53, which has been assessed to freely pass the design flood event (see 4.1.49), are not included within the SEPA model, the predicted risk of surface water flooding is therefore considered to be an overestimate.

Potential Impacts

5.1.9 The proposed scheme has the potential to impact existing surface water flood risk, by:

- constructing new features over existing overland flow paths, which could impede the movement of water causing local changes to catchment drainage patterns and consequently flood risk; and
- altering run-off rates from areas impacted by the proposed scheme, with potential for compaction of ground, altering existing gradients and changes in vegetation levels. These could increase or decrease run-off rates locally, however the impact on any receiving watercourse is anticipated to be low and would be expected to be negligible in the context of flows from a significant storm event.

Surface Water Drainage

5.1.10 There is potential for an increase in flood risk as a result of dualling existing single carriageways and the construction of new roads and junctions, which would result in a greater area of paved surface. Without storage and attenuation of the additional runoff it could increase the rate at which runoff reaches receiving watercourses. While the increase from one drainage outfall alone may not make a significant difference to the receiving watercourse, the cumulative effect of all the outfalls in the proposed scheme, or the effects of its construction, may affect flood risk elsewhere in the catchment, increasing fluvial flood risk. Surface water flood risk could also be increased locally by the increase in impermeable surfacing and potential for new surface water flow paths to be formed as a result of the works. The proposed scheme therefore includes surface water drainage features used to manage the risk of surface water flooding along the proposed scheme carriageway and the impact of the proposed scheme on flood risk elsewhere. These features are summarised below.

Pre-Earthworks Drainage

5.1.11 Pre-Earthworks Drainage (PED) is permanent drainage infrastructure located where there is a risk of surface water runoff affecting the earthworks or adjacent land. It is designed to collect hillside runoff at the toe of road embankments where the adjacent land falls towards the earthworks and where there would be a risk of ponding around the scheme footprint. PED is also located at the top of cut slopes where the adjacent land falls towards the slope to prevent runoff flowing down the cut and compromising its structural integrity.

5.1.12 In both cases, PED is usually located in catchments without defined watercourses, where the proposed scheme would intercept overland flow prior to it making its way to a nearby watercourse. The PED would then ensure drainage towards an open watercourse, which would help minimise alterations to local hydrological regimes.

5.1.13 In accordance with DMRB, the design of PED would convey the 1.3% AEP (75-year) rainfall runoff event from the intercepted catchment, which is usually adopted for catchments without defined watercourses. Whilst this is not the case along large stretches of the proposed scheme and large numbers of minor watercourses are present, it would be used along the length of the A9 Dualling Programme for consistency. PED would be designed to ensure flows would not be transferred to another catchment.

5.1.14 Where PED is located at the top of cut slopes, there is the potential for water to overspill down the earthworks towards the proposed scheme during events greater than the 1.3% AEP (75-year) event. However, where practicable, the sizing of PED at the top of the cuttings should be increased to accommodate the design flood event to minimise the risk of overtopping and flood risk to the road. Furthermore, the design of these slopes would ensure that there would be a degree of infiltration into the slope and verge to minimise the volume running onto the mainline of the proposed scheme and into the proposed scheme road drainage network. Measures to encourage infiltration on the cut slope would also limit the potential for erosion. Potential catchment areas flowing into the PED are generally small and therefore any exceedance flows are likely to be small. Any areas where flows could present a risk to the A9 will be considered further at detailed design. As a result, the risk of flooding to the proposed scheme from rainfall runoff is considered low.

Road Drainage

5.1.15 In accordance with DMRB, the design of the road drainage system would accommodate a short duration, high intensity 100% AEP[1] (1-year) rainfall event, without surcharging. The design would also ensure the 20% AEP (5-year) rainfall event would not flood the carriageway. This would include a 20% uplift allowance for predicted impact of climate change.

5.1.16 Hydraulic modelling using MicroDrainage software has been used to identify the impact of a 0.5% AEP (200-year) plus CC rainfall event on the road drainage. The modelling predicts flooding to the carriageway due to exceedance flows, but that these would be shallow (less than 0.25m) and slow moving (maximum of 0.16m/s) and therefore represent a low flood hazard and would then generally flow off the road and down the road embankment, into embankment drainage.

Sustainable Drainage Systems

5.1.17 All runoff from the proposed scheme carriageways would be collected and treated via SuDS features, which are likely to include filter drains, swales and wetlands, as well as under road storage, prior to discharging to a watercourse via an outfall. The location of SuDS features is indicated in Annex D. These SuDS features have been designed to provide an improvement when compared to the existing drainage network, with discharge rates from storms up to the 0.5% AEP (200-year) plus climate change event restricted to the 50% AEP (2-year) greenfield runoff rate where possible and to at least below the 50% AEP (2-year) pre-development discharge rate where it has not been possible to achieve the 50% AEP (2-year) greenfield runoff rate.

5.1.18 Where the proposed scheme includes SuDS, they have been designed with the following design principles in mind:

- As a minimum, all SuDS features are designed to treat and attenuate the peak flow from the new road drainage system for a range of floods up to a 3.33% AEP (30-year) rainfall event, including an allowance for climate change. Where practicable (without increasing footprint of the scheme within the floodplain), features have been designed to attenuate peak flows up to the 0.5% AEP (200-year) rainfall event, including an allowance for climate change;
- Where practicable, SuDS features have been located outwith the functional floodplain (0.5% AEP (200-year) flood extent;
- Where practicable, SuDS features located within the functional floodplain are located outside of the 3.33% AEP (30-year) fluvial flood extent;
- A 300mm freeboard depth over and above the design peak water level has been used to set the attenuation basin spill level height for the features designed to the 0.5% AEP (200-year) event. Where features are within the functional floodplain, spill levels have been set at existing ground levels so as not to reduce floodplain storage;
- If practicable, outfall levels from the SuDS ponds have been set above the 3.33% AEP (30-year) peak water level in the receiving watercourse. Where it has not been possible to achieve this, they have been kept as high as possible; and
- In order to provide sufficient attenuation, the outfall peak flow rate is controlled to the 50% AEP (2-year) 'greenfield' runoff rate where practicable. Where it has not been possible to achieve this without increased impact on the floodplain, outfall peak flow rate is controlled to the 50% AEP (2-year) pre-development runoff rate.

5.1.19 There are conflicting design priorities between sizing the SuDS and under road storage features, sizing the embankment to prevent overtopping and minimising (if possible) the flood impact of the feature whilst considering a wider range of spatial and environmental constraints. The SuDS design process has therefore been an iterative one.

[1] the AEP convention here is used for convenience. The actual AEP for the 1-year event is approximately 63%.

5.1.20 This FRA has informed the SuDS design process by providing modelled baseline flood extents and peak water levels for the design flood event.

5.1.21 Table 21 contains a full list of SuDS features and outfall levels along with associated peak fluvial flood levels (extracted from hydraulic model results).

5.1.22 Whilst it has been possible to locate the majority of the SuDS features outwith the fluvial functional floodplain, three wetland features are to be located within this zone due to other overriding design considerations. During the design event on the River Tay these three SuDS features would become inundated with flood water. Given the volume of flood water within the floodplain in the design flood event, the impact of the SuDS features becoming inundated on flood risk is considered negligible.

Downstream Impacts

5.1.23 The proposed scheme includes online dualling with existing road levels largely retained or increased and is therefore unlikely to increase surface water flows downstream of the road embankment.

5.1.24 The proposed scheme also interacts with a considerable number of minor watercourses. Where possible, PED and road drainage catchments would discharge to the nearest watercourses to mirror natural flow routes and would therefore not be likely to alter existing surface water catchments.

5.1.25 The attenuation volumes provided in the form of SuDS features would also ensure that there is no increase in flood risk downstream along the receiving watercourse because of an increase in runoff rates and volumes due to the extended area of impermeable surfaces.

5.1.26 By following the overarching design principles where possible and ensuring flood risk has been considered at all stages of the design process, the impact of the proposed scheme on surface water flooding is considered negligible.

Table 21 : SuDS basins and outfall levels

Drainage Catchment	Chainage	Attenuation Storage	Discharge Location	Attenuation Proposed (PD – Pre-development or GF – Greenfield)	Pre-development or Greenfield Discharge Rate (QMED) at outfall (l/s)	Outfall Level (mAOD)	SuDS within 3.33% AEP (30-year) Floodplain	Peak 3.33% AEP (30-year) Floodplain Water Level (mAOD)	SuDS within 0.5% AEP (200-year) plus CC Floodplain	Peak 0.5% AEP (200-year) plus CC Floodplain Water Level (mAOD)	Mean River Water Level (mAOD) within Receiving Watercourse
Run A1	150	SuDS wetland	River Tay	0.5% AEP (200-Year) + CC (GF)	26.0	52.86	No	N/A	No	N/A	48.286
Run A2	750	SuDS wetland	River Tay	0.5% AEP (200-Year) + CC (GF)	10.3	56.09	No	N/A	No	N/A	48.598
Run B	2010	Geocellular	River Tay	3.33% AEP (30-Year) + CC (PD)	50.9	53.82	No	N//A	No	N/A	49.854
Run C	3860	Detention basin	River Tay	0.5% AEP (200-Year) + CC (GF)	16.2	58.87	No	N/A	No	N/A	51.853
Run D1	4270	Swale	WF38	3.33% AEP (30-Year) + CC (PD)	8.3	54.17	Yes	55.826	Yes	57.018	53.183
Run D2	4990	Swale	River Tay	3.33% AEP (30-Year) + CC (PD)	18.8	54.00	Yes	55.834	Yes	57.019	53.595
Run E	5490	SuDS wetland	River Tay	3.33% AEP (30-Year) + CC (PD)	12.1	54.64	Yes (bunded)	56.111	Yes	57.593	54.029
Run F1	6415	Geocellular	WF42	3.33% AEP (30-Year) + CC (PD)	9.3	57.27	No	N/A	No	N/A	56.3
Run F2	6575	Geocellular	WF42	3.33% AEP (30-Year) + CC (PD)	3.8	58.28	No	N/A	No	N/A	56.2
Run G1	7300	Geocellular	WF50	3.33% AEP (30-Year) + CC (PD)	12.0	58.49	No	N/A	No	N/A	56.866
Run G2	7320	Geocellular	WF50	3.33% AEP (30-Year) + CC (PD)	6.0	59.50	No	N/A	No	N/A	56.866
Run H	8280	SuDS wetland	WF55	3.33% AEP (30-Year) + CC (BF)	6.6	58.50	Yes	59.813	Yes	60.952	58.475

Mitigation Measures

5.1.27 This FRA considers that, with the surface water drainage systems in place as part of the proposed scheme, no additional mitigation measures are required. Since no additional mitigation measures are proposed, the surface water risks and impacts would remain unchanged from that described under Potential Impacts.

Residual Risks

5.1.28 In the context of the proposed scheme, the residual surface water risks would include:

- severe runoff events as a result of intense rainfall or rapid snow melt, which exceed the design capacity of the PED (greater than 1.33% AEP (75-year)), road drainage (greater than 20% AEP (5-year)) or SuDS features (greater than 3.33% AEP (30-year) or 0.5% AEP (200-year) plus climate change);
- blockages within the drainage infrastructure that reduce its capacity to convey flows from adjacent land and the carriageway or from SuDS features into receiving watercourses; and
- the failure of proposed SuDS features (embankment failure), which could result in a sudden release of water and flooding of receptors downstream.

5.1.29 In the event of extreme events or blockages causing the drainage system to surcharge, the geometry of the mainline of the proposed scheme has been designed in such a way as to shed runoff from the edges of the road and to avoid ponding on the mainline itself ensuring that disruption to traffic is minimised.

5.1.30 The design of SuDS features outwith the functional floodplain also includes a 300mm freeboard of additional storage above the peak attenuated water level to manage the residual risk of blockages and to provide additional storage capacity should it be required. There is also an overflow facility provided in each of the outlet controls, again to provide resilience to the design should any blockages occur. The residual risk posed by these two scenarios is therefore considered to be low.

5.1.31 A high-level assessment of the impact of failure or overtopping of the SuDS ponds has been undertaken, the results of which are included in Table 22. In the vast majority of cases, SuDS features are located in close proximity to watercourses or within the Tay floodplain, with no sensitive receptors between the two. In these cases, should the SuDS feature embankment fail, the water would flow on to the floodplain or directly into the watercourse. The volume of water flowing into large watercourses, such as the River Tay, would be insignificant in comparison to average flows and would have a negligible impact on flood risk downstream.

Table 22 : SuDS Ponds – impact of failure of overtopping

SuDS Feature	Impact of failure/overtopping	Residual Risk
SuDS pond (chainage 200)	The pond would be located downstream of the main alignment in close proximity to the River Tay. The pond would generally be formed by excavating existing ground. An approximately 6m length of raised embankment of up to 660mm height could potentially fail resulting in fast flowing flood water, however this would be likely to flow directly into watercourse 16 and then into the River Tay approximately 35m downstream. In the event of exceedance of pond capacity, water would flow over woodland and an access track and towards the River Tay.	Low – additional flows into River Tay negligible in comparison to flows in the river and unlikely to coincide with peak flood event. Access track usage is low and any flooding would be visible to potential users. No other sensitive receptors downstream.
SuDS pond (chainage 700)	The pond would be located downstream of the main alignment in close proximity to the River Tay. The majority of the pond would be formed by excavation of existing ground, but a section towards the south west would require a raised bund up to 3m high. Failure of this bund would result in flood waters flowing down towards the River Tay, located approximately 10m away through woodland/shrub land. Exceedance of pond capacity would also result in overland flow towards the River Tay.	Low – additional flows into River Tay negligible in comparison to flows in the river and unlikely to coincide with peak flood event. No other sensitive receptors downstream.
SuDS pond	The pond would be located downstream of the main alignment in close proximity to the River Tay. The pond would be formed by excavating existing ground and	Low – additional flows into River Tay negligible in

SuDS Feature	Impact of failure/overtopping	Residual Risk
(chainage 3900)	there are no raised bunds proposed that could fail resulting in fast flowing flood water. In the event of exceedance of pond capacity, water would flow over woodland and towards the River Tay.	comparison to flows in the river and unlikely to coincide with peak flood event.
SuDS pond (chainage 5450)	The proposed pond would be formed with raised bunding within the floodplain compensation area just north of Guay. Failure of any part of the bund or exceedance of pond capacity would result in water flowing into the compensation area.	Low – any exceedance/failure would result in flows into the floodplain compensation area.
SuDS pond (chainage 8200)	The pond would be located downstream of the main alignment. The pond would be formed by excavating existing ground and there are no raised bunds proposed that could fail resulting in fast flowing flood water. In the event of exceedance of pond capacity, water would flow over farmland and towards culverts through the rail embankment.	Low – exceedance of capacity would result in flow towards existing culverts. Any flooding would be within floodplain and at far shallower depth than that caused by flood event on the River Tay.

6 Groundwater

Introduction

6.1.1 Groundwater flooding occurs where water levels, beneath the ground, rise above the ground surface. In some instances, groundwater can emerge at surface level following heavy rainfall events, and contribute to existing flooding from other sources. Alternatively, a greater risk can be presented if construction works or long-term, large-scale developments, such as road schemes, intersect areas with shallow groundwater levels or create pathways for deeper confined artesian pressures, which can be released at ground level and cause widespread flooding.

6.1.2 In order to develop a conceptual understanding of groundwater flooding associated with the proposed scheme, hand-dipped groundwater level data from 49 borehole-monitoring installations along the proposed scheme corridor has been collated and reviewed, as well as continuous data-logger records at three of these locations. The length of the data record varies between boreholes as they were installed during two distinctive phases of ground investigation: the first between August 2015 and December 2015 and the second between October 2016 and April 2017. Monitoring was conducted between September 2015 and January 2016 in 26 boreholes and between October 2016 and May 2017 in 23 boreholes (the monitoring range for individual boreholes varies within these dates). Logger data was collected between April 2016 and September 2016 in three boreholes.

6.1.3 By assessing recorded groundwater levels along the scheme corridor, a screening assessment was carried out to identify those areas at greatest risk of groundwater flooding, potential scheme impacts and to identify where potential mitigation may be required. This included a detailed review of all parts of the proposed scheme that would involve excavations below existing ground level, including cuttings and the locations of proposed detention basins. Chapter 10 (Geology, Soils and Groundwater) undertakes this screening and fully assesses groundwater issues in relation to the proposed scheme.

Baseline Risks

6.1.4 Throughout the proposed scheme area, superficial deposits recorded in ground investigations range in thickness from 0.3m to at least 80m. Superficial deposits comprise glacial till underlying the hillsides of the River Tay valley, with alluvium and glaciofluvial deposits in the valley bottoms. Generally, the existing A9 corridor lies to the east of the River Tay, at the boundary of the alluvium and glaciofluvial deposits. The bedrock in the existing A9 corridor comprises metamorphic psammite and semipellite belonging to the Southern Highland Group.

Groundwater in the Superficial Deposits

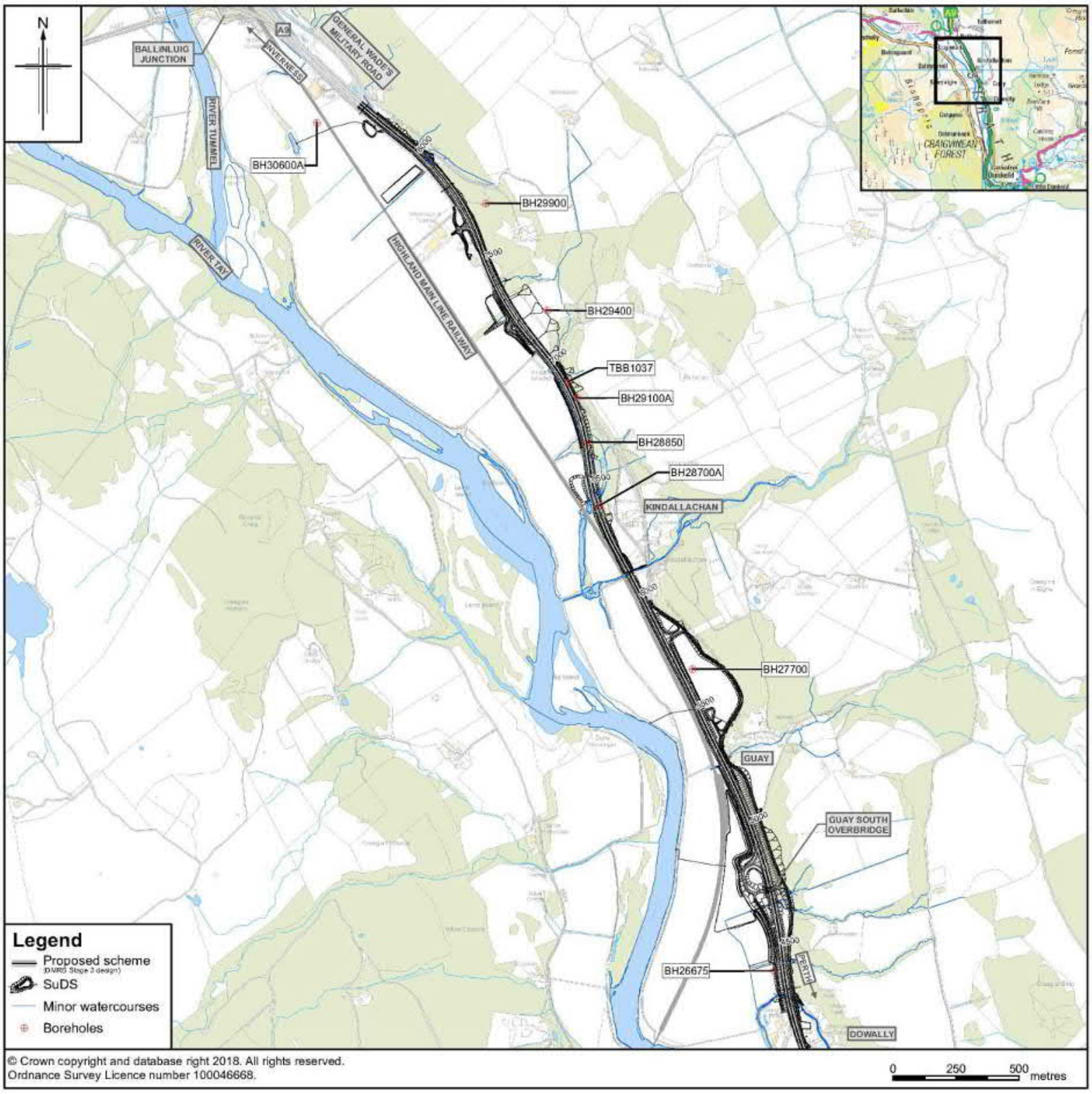
6.1.5 The glacial till is typically composed of poorly sorted sands and gravels within a clay matrix, and is generally considered to have low permeability. As a result, recharge rates into the underlying bedrock aquifer in these locations are likely to be low. After periods of intense or prolonged rainfall, this is likely to contribute to significant waterlogging and surface water ponding in low lying areas and enhanced run-off in other areas.

6.1.6 In valley floor areas, underlain by alluvium and river terrace deposits, groundwater levels may emerge at ground level because of rising groundwater levels in the superficial deposits. In the vicinity of watercourses, there may also be a connection between surface water and groundwater and rising surface water levels may contribute to locally increasing groundwater levels, and vice versa.

6.1.7 The A9 development corridor is linear and consequently the ground investigations cannot fully define groundwater flow directions across the surrounding area. However, the general groundwater flow direction throughout the project area is expected to broadly follow the topography and, at the shallow, local scale, this would be to the west and towards the River Tay. This topographically controlled flow could also contribute to the development of elevated groundwater levels in low-lying areas.

6.1.8 Ground investigation data, obtained from the 49 monitoring installations along the A9 corridor, identifies three locations (ch4400, ch6800 and ch7700) where maximum groundwater levels are less than 0.4m below ground level (bgl). All of the monitoring installations in these areas (BH26675, BH29100A and BH29900) are screened within the superficial deposits, which in all instances comprise shallow sands and gravels overlying low permeability bedrock. All three locations are in close proximity to a small burn or field drain. BH26675 lies within and BH29100A lies in proximity to the SEPA 0.5% AEP ((200-year) Flood Zone. The location of the boreholes is shown on Figure 33.

Figure 33: Ground Investigation Locations



6.1.9 In addition, TBB1037 (ch6880) recorded a shallow maximum groundwater level, at 1.28m below ground level in the superficial deposits in this area. However, BH28850 (ch6600) and BH29400 (ch7100), also installed within the superficial deposits, lie at a similar distance from the River Tay, adjacent to a series of small burns or field drains, but record maximum groundwater levels of 3.3m bgl and 9.7m bgl, respectively. Groundwater conditions are therefore expected to be locally variable.

6.1.10 Elsewhere in the proposed scheme area, BH30600A (ch8300) recorded relatively shallow groundwater in the superficial deposits at a maximum of 0.74m below ground level based. This is located in a low-lying area just outside the 0.5% AEP (200-year) floodplain and within the 0.5% AEP (200-year) + CC flooding outline and in the vicinity of a small burn or field drain.

6.1.11 Data logger information is available for boreholes BH27700, BH28700A and BH28850 between April and September 2016. Groundwater levels in the superficial deposits at these locations are shown to reach a maximum of 2.5m bgl. However, towards the late summer months, groundwater recharge rates, and hence groundwater levels, are typically at their lowest, and winter water levels are anticipated to be closer to ground level than the values quoted in Table 23 below.

Table 23 : Summary of logger groundwater levels recorded in the superficial deposits

Borehole Reference	Chainage	Minimum Recorded Groundwater Level	Maximum Recorded Groundwater Level	Range
BH27700	ch5600	8.5m bgl	8.2m bgl	0.3m
BH28700A	ch6050	3.9m bgl	2.5m bgl	1.4m
BH28850	ch6600	4.4m bgl	3.2m bgl	1.2m

6.1.12 The data generally shows variable water levels in BH28700A and BH28850 throughout the monitoring period. This could be representative of rapid recharge of the superficial deposits following rainfall events, and, or their proximity to local watercourses, where groundwater levels are more likely to be in continuity with river level fluctuations.

6.1.13 Boreholes BH27700 and BH28700A lie within the 0.5% AEP (200-year) floodplain, with BH28850 shown to lie within the 0.5% AEP (200-year) plus CC envelope, as predicted by the Jacobs hydraulic model. However, BH27700 differs from the other two installations in that, whilst it is located within the 0.5% AEP floodplain, it lies >250m from the River Tay and >300m from the nearest burn. The other two boreholes lie within 30m of a watercourse and are more likely to be directly influenced by surface water levels. The data recorded at the three installations supports this as groundwater levels in BH27700 show a very limited range of variation over the monitored period, whilst boreholes BH28700A and BH28850 show much more variation in water levels.

Groundwater in the River Tay floodplain areas

6.1.14 There is no information available on levels in the River Tay within the study area. Due to the location of relevant monitoring boreholes and the limited data range available only a limited evaluation of groundwater-river level response patterns has been possible. The nearest available SEPA river level gauges are on the River Tay, at Pitnacree, upstream of the study area, and Caputh, downstream of the study area. A number of tributaries, including the River Tummel, join between these two gauges, however the response pattern of both gauges is very similar. The Pitnacree gauge has been used primarily to compare river-groundwater response patterns, as the topography in the Pitnacree area is more similar to that around P3 than at Caputh and therefore the rainfall-runoff response for this gauge may be more representative.

6.1.15 No conclusive river level-groundwater correlations have been identified. It is nevertheless considered likely that shallow groundwater within the floodplain area is likely to be in continuity with the River Tay.

6.1.16 There are limited data with which to evaluate likely groundwater levels within the River Tay floodplain areas to the east of the A9, with most of the available boreholes located along the proposed A9 alignment. It should also be noted that the period of groundwater level monitoring available, particularly for the Preliminary GI boreholes, does not cover a full winter period (when groundwater levels would be expected to be higher).

6.1.17 The majority of the areas in proximity to the River Tay appear to lie between the OS 50mAOD and 60mAOD contours and are generally flat, grassed or cropped areas between the A9 and river. These areas do not appear to be marshy and available information does not indicate that they are likely to be frequently waterlogged. There are a number of streams and/or drains crossing this area, although in many cases these appear to connect to drainage systems from the higher ground to the east of the A9 and it is not clear to what extent these may be draining this higher ground rather than primarily acting as field drains.

6.1.18 Overall, based on information available, the water table is anticipated to be in the range 53-57mAOD and may be relatively close to the ground surface in places. However, a high degree of uncertainty remains over the detail of the groundwater situation in these areas.

6.1.19 Encountering shallow groundwater levels in the valley alluvium and river terrace deposits is therefore considered likely and groundwater could contribute to, and extend the duration of other sources of flooding, such as fluvial flooding, in the low-lying areas adjacent to watercourses. However, the data available at this stage does not provide any evidence of shallow groundwater currently significantly contributing to flooding in the area of interest.

Bedrock Groundwater

6.1.20 Groundwater flow in the bedrock metamorphic rocks will occur primarily through fractures. Permeability is expected to be low and variable, dependent on the density and interconnection of fracture networks. Recharge rates into the bedrock may also be low and variable, due to the low bedrock permeability and may contribute to the development of waterlogging and surface water ponding in low lying areas and enhanced run-off in other areas.

6.1.21 Of the 49 monitoring installations along the proposed scheme, there are three boreholes screened within the bedrock as well as the overlying superficial cover. At all three locations (ch800, ch1700 and ch8200), the maximum recorded groundwater level was greater than 10m below ground level throughout the monitoring period. Based on this information, there is no evidence of any areas of existing artesian or sub-artesian bedrock groundwater conditions and existing groundwater flood risk from the bedrock aquifer is low.

Limitations

6.1.22 It should be noted that the groundwater-monitoring data used to inform this baseline assessment predominantly comprises manual dips, rather than continuous logger data, that has been collected over two finite periods (four months from September 2015 to January 2016 and seven months from October 2016 to May 2017). In addition, a limited set of continuous logged data was collected between April 2016 and September 2016. While these periods provide an indication of annual seasonal variation it does not necessarily indicate the maximum groundwater levels that may develop from year to year. Consequently, there may be potential for groundwater related flooding beyond the current conceptual understanding of groundwater flood risk.

Potential Impacts

6.1.23 As the proposed scheme is located at, or below ground level (cuttings) in several locations, there is a risk that groundwater flooding could affect the proposed scheme during both its construction and operational phases, if not managed. The key element of the design of relevance to groundwater flooding is the deep excavations required where new road cuttings are proposed.

6.1.24 A separate road cutting screening exercise has been undertaken in Chapter 10 (Geology, Soils, and Groundwater), which has identified eight cuttings which are likely to intercept groundwater. Of particular relevance are the four areas where shallow groundwater conditions have been recorded. These areas are summarised in Table 24.

Table 24 Summary of shallow groundwater levels recorded

Borehole Reference	Chainage	Maximum Recorded Groundwater Level (m bgl)	Comments
BH26675	Ch4400	0	Shallow groundwater recorded in superficial deposits. Lies in low lying area, at edge of floodplain and within SEPA 0.5% AEP (200-year) Flood Zone. Small burn/drain in vicinity. No significant cuttings in the vicinity.
BH29100A, TBB1037	Ch6800	0	Shallow groundwater recorded in superficial deposits. Lie in low lying area, at edge of floodplain and within 0.5% AEP (200-year) Flood Zone. Small burn/drain in vicinity. Widening 18 is located in this area and expected to intercept groundwater, but will be only 2.6m deep. Some groundwater drainage into this cutting is expected to occur.
BH29900	Ch7700	0.2	Shallow groundwater recorded in superficial deposits. Lies above floodplain. Small burn/drain in vicinity. Widening 11 is located in this area and expected to intercept groundwater, but will be only 1.9m

Borehole Reference	Chainage	Maximum Recorded Groundwater Level (m bgl)	Comments
			deep. Some limited groundwater drainage into this cutting may occur.
BH30600A	Ch8300	0.74	Shallow groundwater recorded in superficial deposits. Lies in low lying area, at edge of flood plain and just outside SEPA 0.5% AEP (200-year) Flood Zone, but within 0.5% AEP (200-year) plus climate change Flood Zone. Small burn/drain in vicinity. No significant cuttings in the vicinity.

6.1.25 Cuttings associated with large-scale road schemes have the potential to create pathways for deeper confined artesian pressures in the bedrock to be released at ground level and cause widespread flooding. Two of the proposed cuttings (W6 and SP3) would require excavation down to bedrock, but in both locations (approximate ch200 and ch7000), there are no known areas of existing confined artesian or sub-artesian bedrock groundwater pressures and hence groundwater flood risk from the bedrock aquifer, even after development, is low.

6.1.26 The cuttings likely to intercept the groundwater table in the superficial deposits will need to comply with the dewatering requirements as identified in Chapter 10 (Geology, Soils and Groundwater). Of particular significance is Widening 6, where an excavation depth of 20.5m is proposed, and in an area where maximum recorded groundwater levels reached 4m bgl.

Mitigation Measures

It is considered that groundwater flood risk can be mostly managed through mitigation embedded into the design of the proposed scheme. Table 25 details the embedded mitigation measures likely to be incorporated into the proposed scheme. With these in place, the impact of the proposed scheme on groundwater flood risk is considered low.

Table 25: Groundwater mitigation measures

Embedded Mitigation Measures	Description
Dewatering of cuttings	During the construction phase, the proposed scheme would include standard excavation dewatering practices involving passive and/or active dewatering, as required. It would protect construction personnel, works, plant and machinery associated with the new cuttings.
Drainage of cuttings	To protect flood sensitive receptors from groundwater flooding during the operational phase, groundwater seepage would be collected by the proposed road drainage system.
Pre-earthworks drainage	Pre-earthworks drainage should be sized appropriately to intercept and accommodate all shallow groundwater flows entering the works area to protect flood sensitive receptors.
Foundation design to permit groundwater flow	All foundations expected to intercept high groundwater levels should be designed to allow existing groundwater flow paths to function. This would prevent an increase in groundwater flood risk to flood sensitive receptors elsewhere.

6.1.27 Other than at cuttings, it is considered unlikely that groundwater flooding will pose a significant issue along the proposed scheme. Although it may contribute to surface water flooding in some areas, as noted above. It is considered that embedded mitigation proposed as part of the proposed scheme would be sufficient to manage the groundwater flooding issues identified above.

6.1.28 However, due to the presence of deep cuttings and the remaining uncertainties associated with the existing ground investigation data to date, it is recommended that a groundwater level monitoring programme is implemented before and during construction to identify any potential future groundwater flood risk issues.

Residual Risks

6.1.29 There is a low, residual groundwater flood risk that temporary drainage systems would be unable to cope with the groundwater flows that could emerge as a result of localised drainage of groundwater at deep cuttings, in particular Widening 6. It is assumed that the contractor is aware of these possible groundwater releases, and as such, would design any future drainage systems to accommodate any potential groundwater flows.

7 Failure of Water Retaining Infrastructure

Introduction

7.1.1 Flooding due to the collapse and/or failure of man-made water-retaining infrastructure such as a dam, water supply reservoirs, canals, flood defences, underground conduits (e.g. sewers), and water treatment tanks or pumping station is considered to be a residual risk.

7.1.2 It is not possible to attach a probability of collapse and/or failure to water-retaining infrastructure, as it would be dependent on the combined effect of a number of factors such as their condition, existing maintenance regimes and other outside influences. However, it would be significantly lower than the design flood event, which is used to assess the risk of fluvial and pluvial flooding.

7.1.3 However, a collapse and/or failure could potentially result in a large volume of water suddenly being released at potentially extremely high velocities, resulting in potentially catastrophic consequences. Released water would follow local topography towards low-lying areas or into nearby watercourses. As the existing A9 crosses the valley floodplain and spans a number of watercourses, the proposed scheme is potentially at risk from this source of flooding and could potentially alter these flow paths.

7.1.4 A preliminary assessment has been undertaken to identify the location of water-retaining infrastructure and assess the potential for the proposed scheme to affect residual risks associated with infrastructure failure.

Baseline Risks

Reservoirs

7.1.5 The project area is downstream of a number of reservoirs, failure of which could result in flood risk to the existing A9 and other receptors within the project area. These include Loch Tummel, Loch Rannoch, Errochty Reservoir, Loch Garry, Loch Faskally, Glen Lyon, Loch Ericht and Loch an Daimh. These reservoirs are located upstream along the River Tummel or River Tay and failure of any of these reservoirs could result in flooding to the existing A9 within the project area.

7.1.6 Loch Ordie is located to the east of the proposed scheme, upstream of the Dowally Burn and Sloggan Burn sections within the project area. Failure of this reservoir could also result in flooding to the A9 and other receptors within the project area.

7.1.7 The normal operation of these dams poses a negligible risk to the existing A9. The failure of dams associated with these reservoirs is likely to result in the inundation of large extents of the existing A9 as illustrated by SEPA’s Reservoir Flood Maps (2015). It should be noted that the reservoirs listed are regulated under the Reservoirs (Scotland) Act 2011 and therefore the risk of failure is considered low as a result of the monitoring regime the owners have to comply with.

Sewers

7.1.8 Scottish Water records indicate that a short length of combined sewer within Guay is the only sewer within the project area. The risk of flooding to the existing A9 from this sewer is considered low, as in the event of surcharge or failure, flows would be expected to be directed towards the Sloggan Burn. Many properties along the existing A9 corridor are known to use septic tank systems, however it is likely that additional small networks of foul sewerage are present along the route of the existing A9. Given the small catchment areas of the sewer systems it is unlikely that volumes of water sufficient to pose a risk to the existing A9 would be released in the event of sewers surcharging.

7.1.9 There is a more extensive sewer network in Ballinluig, approximately 850m from the proposed scheme’s northern extent. Any flows from this sewer network would be expected to pond in local low areas between the sewer and the proposed scheme and therefore the risk of flooding from this source is considered low and has not been considered further.

Other

7.1.10 There are no formal flood defences indicated on the SEPA Flood Maps (2015) within the project area, however a number of raised embankments have been constructed on the banks of the River Tay to protect farmland. The materials and method of construction of these embankments appears variable and it is not known if they have been designed to provide a particular standard of protection. In past flood events on the River Tay, it has been reported that the defences have failed in places, although the mechanism for this failure is unknown.

7.1.11 In the design event, all of the informal embankments are overtopped and provide no real benefit. Hydraulic modelling undertaken to inform this FRA has included the embankments within the baseline scenario. A sensitivity test has been carried out by removing the embankments from the baseline model to quantify their impact. The assessment concluded that they provided some protection in more frequent flood events such as the 50% AEP (2-year) event through protection of farmland. However, in the 3.33% (30-year) event and greater, the defences are overtopped in places and have limited impact on the flood risk to the existing A9.

7.1.12 Failure of these defences would result in inundation of the floodplain; however, the defences overtop at a lower flood level than would be required to result in flooding to the existing A9 and therefore failure of these defences does not result in additional flood risk to the road.

Potential Impacts

7.1.13 The proposed scheme will not alter or affect any of the infrastructure described above. The flood risk to the proposed scheme from this source of flooding is therefore considered to be low and no mitigation is proposed.

7.1.14 The impact of the proposed scheme on flood risk from these sources has also been considered. The raising of the main alignment, increased embankment footprint and new side roads has the potential to alter flows from any of these sources, potentially increasing flood risk, however the risk is considered to be negligible and therefore no mitigation is proposed.

8 Construction Phase

Introduction

8.1.1 Detailed construction plans and method statements were not available at the time of preparing this FRA and the appointed Contractor would develop these at a later stage. The assessment of flood risk is therefore not site specific. It is the Contractor's responsibility to assess the flood risk to work areas, to assess the flood risk resulting both to and from temporary works, and to provide appropriate mitigation measures where necessary.

8.1.2 This section of the FRA therefore provides an overview of potential flood risks for the Contractor to consider during the construction phase, to set out high-level requirements with respect to managing flood risk, and to provide general guidance to assist the Contractor in doing this.

Potential Short-term Impacts

8.1.3 Temporary works can themselves be at risk of flooding and have the potential to impact flood risks both to work areas and to receptors beyond the work site. Critically, there is a risk to life from flooding to those working on site, and the construction works also have the potential to affect the existing risk to life from flooding beyond the construction site. The design of the temporary works therefore needs to consider these factors.

8.1.4 Table 26 outlines the broad categories of temporary works required during the construction phase and highlights the key potential impacts of the temporary works with respect to flooding.

Table 26: Typical construction elements

Temporary Works	Description	Potential Short-Term Impacts
Temporary earthworks	Including excavation for access road cuttings, pre-earthworks drainage, trenches; and filling for access roads, site compound areas and temporary spoil storage	Excavation works could result in the pooling of pluvial runoff, the emergence of groundwater, the creation of an impounded body of water or a water mains strike. Works associated with filling could result in the diversion of overland flow routes, a reduction in floodplain storage, impacts on floodplain conveyance, and increased volumes of surface water runoff.
Temporary drainage	Including site compound drainage, temporary road drainage, pre-earthworks drainage	Temporary drainage could increase both the rate and volume of pluvial runoff to a receiving watercourse or sewer, and has the potential to transfer sediment to the receiving watercourse or sewer (potentially affecting the flooding mechanisms of the watercourse).
Works within or adjacent to watercourses	Including temporary river works, such as over-pumping, diversions, damming; and temporary access crossings, requiring culverting or bridging of watercourses	Temporary work located within or adjacent to watercourses could affect the frequency, depth, extent and duration of fluvial flooding.
General site activities	Including site compounds and the storage of construction materials and equipment; and works traffic	The location of site compounds and the storage of construction materials and equipment on site could potentially reduce floodplain storage and divert flood flow routes. Placing working sites within the floodplain could also place human life at risk. Works traffic could also damage existing sewers or land drains, and could also compact ground, which could increase pluvial runoff.

8.1.5 The Contractor should ensure that the temporary works are protected from flooding during a high-risk event undertaken during the construction phase and that the temporary works do not increase the risk of flooding beyond the site during a similar event.

8.1.6 The overall guiding principle should be to avoid any temporary works within the functional floodplain: the 0.5% AEP (200-year) extent, where possible. The SEPA Flood Maps provide an excellent starting point as they help illustrate the extent of flooding from fluvial and surface water sources during low, medium and high likelihood events. The SEPA Flood Maps should then be supplement by information contained in this report, including locations at high risk of groundwater flooding, which may not be covered by the SEPA Flood Maps.

8.1.7 Where it is not practical to avoid temporary works in areas at risk of flooding, the Contractor should take into account the depth of flooding, potential floodplain flows and local site conditions to place more vulnerable works in lower risk areas. The Contractor must also provide measures to mitigate the risk of flooding using the below mitigation principles as a starting point.

Mitigation Principles

General Guidance

8.1.8 The Contractor should follow the following general guidance concerning the management of flood risk during the construction period of the proposed scheme:

- Prepare a Flood Response Plan. This should include due consideration of the requirements of businesses, residents and livestock within the project area;
- Sign up to the Floodline, Scotland's flood warning service provided by SEPA, and also be responsible for monitoring forecasts and weather conditions on site (it is recommended the contractor signs up to all three Flood Warning Areas within the proposed scheme extents. These are Ballinluig to Logierait, Logierait to Victoria Bridge and Dalguise);
- Consult with SEPA when working within a river or within 50m of bank top is proposed and ensure the activities are licensed under the Water Environment (Controlled Activities) Regulations (CAR), if applicable;
- Monitor water levels when working within or near rivers;
- Prepare emergency evacuation plans for each construction area given issue of a Flood Warning or following rapid rises in river level or continuous heavy rainfall, identifying safe access and egress routes and refuge points;
- Provide standby pumping equipment to remove any surface water runoff that enters the working area;
- Ensure site drainage is not discharged to a local sewer; and
- Contact SEPA during a flooding event greater in magnitude than the temporary works are designed to, particularly where receptors could be at increased risk of flooding.

Temporary Work Guidance

8.1.9 The Contractor should also follow the following guidance regarding to temporary works and flood risk:

Temporary Earthworks

- Review local groundwater data prior to extensive excavations;
- Where dewatering of excavations is undertaken, discharge overland or to a watercourse (with appropriate treatment where necessary) at the relevant greenfield runoff rate;
- Undertake initial desk-based services searches before digging on site. The Contractor should also undertake appropriate survey (CAT scans, GPR survey, etc.) on site to verify the location or presence of underground services before digging;
- Avoid trafficking areas with known vulnerable services. Assess ground loading in these areas and provide additional cover protection if necessary. Plan abnormal load routes;
- Locate stockpiles outside of areas susceptible to prominent surface water flows. Where this is not possible, stockpiles should be constructed with regular spaces between heaps (with each stockpile not exceeding 25m in length) to preserve existing low points and flow paths, and to prevent surface water backing up behind the structure and being re-directed elsewhere;
- Store excavated materials outside of the floodplain. Excavated material should only be placed in 'at risk areas' when required for use;
- Construct haul roads and access roads as close to ground level as possible when crossing the floodplain; and

- Construct temporary drainage measures along access road / temporary diversion edges to collect runoff and direct to treatment facilities.

Temporary Drainage

- Assess requirements for discharge rate control and treatment as part of the construction works; and
- Drainage receiving runoff, which is expected to contain sediment, should be directed towards a suitable sized temporary settlement pond that provides sufficient treatment before being discharged to a watercourse.

Works within or adjacent to Watercourses

- Design temporary river works, which involve the diversion of a watercourse (e.g. fluming or over-pumping), to convey the design flood event to be agreed with SEPA. A lower standard may be acceptable if the works would be in place for a shorter period than the overall construction phase;
- Design cofferdams and other in-river temporary works to minimise the impact on river conveyance, and prevented from flooding internally;
- Where temporary access crossings include the use of a culvert, design to convey the peak flow during the design flood event, to be agreed with SEPA. Multiple pipes should not be used, where reasonably practicable, to reduce the risk of blockage; and
- Where temporary access crossings include the use of bridges, design the soffit above the peak water level during the design flood event plus 600mm freeboard to be agreed with SEPA. Bridge piers should not be located within the watercourse.

General Site Activities

- Minimise trafficking and loading of unprotected site areas. Consider protecting large site areas subject to heavy traffic loads and methods to alleviate soil compaction post works, as soil compaction may lead to an increased runoff rate;
- Avoid trafficking areas with known vulnerable services. Assess ground loading in these areas and provide additional cover protection if necessary. Plan abnormal load routes;
- Store construction materials outside of the floodplain. Construction material should only be placed in 'at risk areas' when required for use; and
- Raise offices and other site facilities outwith the functional floodplain. Where not suitable, raise offices above the peak water level for the chosen design flood event to be agreed with SEPA. Facilities could be elevated on stilts, or in some cases, located on the higher areas of the compound.

Residual Risks

8.1.10 Given that the Contractor follows and correctly implements the principles outlined in this section of the report, the main residual flood risks during the construction phase of the proposed scheme are considered to be:

- fluvial or surface water events, which exceed the design standard of the temporary works or general site work;
- blockages within temporary surface water drainage; and
- failure (including blockage) of temporary works within watercourses.

8.1.11 In the event of flood events of greater magnitude than the design standard, or blockages causing temporary drainage systems to surcharge, flooding within construction areas could occur. The main risk is likely to be to the site operatives in this event; however, assuming that conditions on site, weather forecasts, flood warnings and river levels are monitored appropriately, and site evacuation plans are in place, the residual risk is considered low.

8.1.12 In the majority of cases, failure of temporary works within watercourses is unlikely to result in a significant detrimental impact to the flood risk on the watercourse affected, as flows are unlikely to be impacted. Again, the main risk is likely to be to site operatives in this event; however, assuming that the Contractor has emergency plans in place given failure of works where operatives are at significant risk, then the residual risk is considered low.

9 Conclusions

Summary

9.1.1 This FRA has been produced to support the Environmental Statement for the dualling of the A9 between the Tay Crossing and Ballinluig (the proposed scheme). The proposed scheme has been developed over a number of assessment stages in broad accordance with the requirements of the DMRB, Scottish Planning Policy and SEPA's Technical Guidance for Flood Risk Assessments. The proposed scheme is currently at DMRB Stage 3 'Detailed Assessment'.

9.1.2 This FRA demonstrates that the proposed scheme design has adequately addressed any local flood risk issues, ensuring that the mainline would remain safe and operational during times of flood. Where achievable, the proposed scheme has a neutral or better effect on overall flood risk. However, where this has not been possible taking cognisance of environmental, engineering and economic constraints, additional mitigation measures have been proposed, or justification as to why potential flood impacts are acceptable when considering the potential consequence of that impact.

9.1.3 Consideration has been given to any change as a result of proposed development upstream of the proposed scheme. This has been assessed to be negligible and therefore does not impact on the findings of this FRA.

9.1.4 Table 27 to Table 31 provides a summary of the FRA findings.

Table 27: Principal watercourses summary

Risk	Summary
Baseline	There is a very high risk of fluvial flooding to the existing A9 from the River Tay and River Tummel. During the design flood event, specific locations at risk of flooding include: • The existing A9, including at Ballinluig Junction, Kindallachan, Guay, north of Dowally and north of Ledpetty Lodge. • The Highland Main Line railway and the B898, • Residential properties, including; Inch Farm (House of Bruar), Mill of Logierait, Station Cottages, Haugh of Kilmorich, Guay Farmhouse, Dowally Farm & Farmhouse, Dalguise House, Ballicock Hall, Cottar House, The Old Post Office, Bellfield Cottage, The Orchard, Old Station House and Woodinch; and • Agricultural land located within the River Tay and River Tummel floodplain.
Potential Impacts	The proposed scheme has been shown to have both beneficial and potentially adverse flood impacts during the design flood event. **Beneficial flood impacts:** • The proposed scheme mainline has been raised above the design flood event and as a result, the proposed scheme would remain safe and operational during times of flood. • Guay farmhouse would be protected from flood risk in events up to a 0.5% (200-year) plus CC event. **Negligible flood impacts:** • Local loss of floodplain storage throughout this project area has been shown to have negligible flood impacts across the wider floodplain within the scheme area and at the downstream end of the project area at the Tay Crossing. **Adverse flood impacts:** • The proposed scheme results in a loss of floodplain storage to the east of the A9 north of Kindallachan, resulting in increased flood levels within an existing wetland area. This area is to be included within the Compulsory Purchase Order as it is required for constructing the proposed scheme. As it is an existing wetland, the small (approximately 0.011m) increase in flood depth is considered negligible. • Unmitigated, the proposed scheme would increase the risk of flooding to flood sensitive receptors including Haugh of Kilmorich and the Highland Main Line railway. • Unmitigated the proposed scheme would also have an adverse impact on flood risk on and near to the Sloggan Burn, including increased flood risk to Guay Farmhouse and the Highland Main Line, as a result of reduction in floodplain capacity and the proposed access road altering flow paths.
Mitigation Measures	Compensatory flood storage has been proposed in several locations within the project area, to mitigate the loss of floodplain storage due to the proposed scheme. Level for level storage was considered, but significant constraints were identified due to the topography of the area. Areas that were identified that would provide level for level compensation were shown to have a negligible impact on flood depth during the design event. Areas that did have a positive impact on mitigating increases in flood depths and have therefore been proposed for inclusion within the scheme include: • Area north of Haugh of Kilmorich within relatively high area of agricultural land;

Risk	Summary
	• Area in field between the main alignment and the Dowally to Kindallachan Side Road north of Guay; and • Area south of Guay between the main alignment and the Highland Main Line railway.
Residual Risks	The residual fluvial flood risks remaining are associated with flood events of greater magnitude than the design standard of the proposed scheme or blockage of any of the culverts that connect floodplain areas on the east of the A9 with the main floodplain. A freeboard allowance has been included in the design to reduce these risks to the A9. The risk of blockage of the culverts is reduced by the flow generally being in the opposite direction during a major flood event to what occurs in general day to day flows from minor watercourses. This risk will be further managed by the maintenance regime for the culverts.

Table 28: Minor watercourses summary

Risk	Summary
Baseline	According to the preliminary assessment carried out for all existing A9 mainline crossings of minor watercourses, during the design flood event: • 22 of the 24 existing A9 mainline watercourse crossings have adequate capacity or surcharge at levels that do not pose a potential risk to the A9; and • 2 of the 24 existing A9 mainline watercourse crossings are under capacity and pose a potential risk of flooding to the existing A9.
Potential Impacts	The proposed scheme has been shown to have both beneficial and adverse flood impacts during the design flood event. **Beneficial flood impacts:** • The proposed scheme has beneficial impacts upstream of 12 minor watercourses where culvert replacement is being undertaken to improve capacity and as a result, the proposed scheme is not at risk of flooding from any of the minor watercourses assessed. • The proposed scheme provides beneficial impacts up and downstream of the main alignment on the Sloggan Burn due to works to the watercourse that improve conveyance of flood water to the River Tay. This includes a major beneficial impact on the flood risk to Guay Farmhouse. **Adverse flood impacts:** • Eight watercourses have an increased HWL as a result of the proposed scheme. At seven of these watercourses the HWL is below bank level in the design event and the culvert has sufficient capacity and therefore there is no increase in flood risk. One watercourse (WF42) culvert has insufficient capacity for the design event. However, the increase in head water level results in increased flood depth within an existing wetland area. As mitigation measures would result in increased flood risk elsewhere, or require extensive works, no mitigation is proposed. • An adverse impact to flooding has been identified between the main alignment and the Highland Main Line railway on WF42. This is due to loss of floodplain storage locally due to the proposed scheme and the diversion of WF50 towards this area. This increase would impact on the rail embankment at this location. • An adverse impact to flooding downstream of the main alignment has been identified on WF52 as a result of increased flows through the culvert and a loss of downstream floodplain due to the scheme.
Mitigation Measures	Mitigation measures proposed for minor watercourses are: • WF42 downstream of the main alignment where an increase in flood risk has been identified on the Highland Main Line railway embankment. To mitigate this increase, an area of compensatory flood storage has been identified close to an existing pond area. The pond that is proposed would provide ecological mitigation in addition to compensatory flood storage. • WF 52 downstream of the main alignment where a compensatory flood storage area is provided adjacent to the watercourse to reduce flood risk to the Highland Main Line railway embankment and the surrounding fields.
Residual Risks	Residual flood risks along minor watercourses are primarily associated with: • Culvert blockage; and • Flood events greater than the design capacity of the watercourse crossing.

Table 29: Surface water summary

Risk	Summary
Baseline	Generally, the preliminary assessment identifies a low risk of flooding to the existing A9. The SEPA Flood Map shows several locations where direct runoff ponds against the existing A9 embankment, ponds on the surface of the A9, or flows across the A9. However, the mapping is likely to be conservative as it does not take into account the road drainage or minor watercourse crossings.
Potential Impacts	As the proposed scheme is an online dualling option, existing surface water flow paths and areas of ponding within fields either side of the main alignment are likely to remain unchanged in most locations. **Beneficial flood impacts:** The proposed scheme would include new surface water drainage features including PED, road drainage and SuDS, to manage the risk of surface water flooding along the proposed scheme carriageway and the impact of the proposed scheme on flood risk elsewhere. These would provide a beneficial impact on surface water

Risk	Summary
	flooding when compared to the baseline scenario.
Mitigation Measures	Additional mitigation measures beyond that provided within the proposed scheme are not recommended.
Residual Risks	Generally, residual surface water risks are considered low and include: • Severe rainfall events, which exceed the capacity of the PED, road drainage or SuDS features; and • Blockages within the drainage infrastructure or SuDS features. In the event of extreme events or blockages, the geometry of the proposed road surface has been designed in such a way as to shed runoff from the edges of the road and to avoid ponding on the carriageway itself ensuring that disruption to traffic is minimised. Where SuDS features are outside the functional floodplain, the design includes a 300mm freeboard above the peak attenuated water level to manage the residual risk of blockages and to provide some additional storage capacity should it be required. Where in the functional floodplain, any exceedance or blockage would result in flooding within the floodplain and eventually flow into local watercourses. If this occurs during a River Tay flood event the impact would be negligible and outside of flood events the depth of flooding would be anticipated to be significantly lower than in a Tay flood. Therefore, there would be no increase in flood risk to sensitive receptors. There is also an overflow facility provided in each of the outlet controls, again to provide resilience to the design should any blockages occur. Ongoing routine inspection and maintenance of the SuDS features would reduce the likelihood of failure.

Table 30: Groundwater summary

Risk	Summary
Baseline	Along the existing A9 corridor, there is a risk of groundwater flooding from valley alluvium and river terrace deposits, which could contribute to, and extend the duration of other sources of flooding, such as surface water or fluvial flooding in low-lying areas. However, data collected at this stage does not provide any evidence of shallow groundwater flooding significantly contributing to flooding in the area of interest.
Potential Impacts	The proposed scheme has the potential to be at risk of groundwater flooding during both construction and operation phase, especially where excavations are proposed for new road cuttings. Where excavations are proposed to bedrock there are no known confined artesian or sub-artesian bedrock groundwater pressures and therefore groundwater flood risk from the bedrock is considered low. However, eight cuttings are likely to intercept groundwater within superficial deposits. **Negligible flood impacts:** It is anticipated that groundwater flood risk can be mostly managed through typical best practice road design and mitigation embedded into the design. As a result, the proposed scheme is considered to have a negligible impact on groundwater flooding.
Mitigation Measures	It is recommended that a groundwater level-monitoring programme be implemented before and during construction, allowing potential impacts to be eliminated through additional mitigation if they arise.
Residual Risks	There is a low residual groundwater flood risk that temporary drainage systems would be unable to cope with the groundwater flows that could emerge as a result of localised drainage of groundwater at deep cuttings. It is assumed that these risks will be managed by the contractor.

Table 31: Failure of water-retaining infrastructure summary

Risk	Summary
Baseline	The risk of flooding to the existing A9 from reservoirs and sewers is considered to be low.
Potential Impacts	**Negligible flood impacts:** The proposed scheme would not include any works that would alter or affect water-retaining infrastructure and as a result the impact of the proposed scheme is considered to be negligible.
Mitigation Measures	No additional mitigation measures are proposed.
Residual Risks	The residual risk of flooding from water-retaining infrastructure would remain unchanged from the baseline scenario and no additional mitigation measures are proposed.

9.1.5 There are also likely to be a number of activities during the construction phase of the proposed scheme that could affect flood risks and potential mitigation measures have been identified. However, the detailed assessment of the risks and appropriate mitigation measures would be best identified and managed by the Contractor on a case-by-case basis depending upon the construction techniques to be used and the location.

9.1.6 The potential impacts as a result of multiple sources of flooding occurring simultaneously has been considered. The most significant event in terms of flood depth and risk to receptors is the design event on the River Tay. The rainfall event that would cause this is very different from the storm event that would result in peak surface water or minor watercourse flooding. The risk of these events coinciding is therefore considered to be low. Groundwater levels would often be expected to respond more slowly to rainfall events than river or surface water flooding, however the response may vary with antecedent conditions. Localised flooding through alluvial deposits hydraulically linked to the River Tay is possible and could occur in a similar timeframe to flooding on the River Tay. Given the hydraulic connectivity, this would not be anticipated to significantly alter peak flood levels in comparison to an event on the River Tay and therefore would not result in increased flood risk to the proposed scheme. The proposed scheme would not be expected to cause a change from the existing risk of groundwater emergence in combination with a fluvial flood event and therefore would not cause an increase in flood risk to other sensitive receptors. Combined flood events that do not include the design event on the River Tay result in reduced flood depths in comparison to Tay flood events. The proposed scheme is therefore considered to have a negligible impact on flood risk from combined events.

9.1.7 The potential for cumulative impacts as a result of multiple A9 proposed schemes has been considered. The assessment shows that there is negligible impact on the Project 03 scheme area from upstream proposed schemes, and negligible impact downstream of Project 03. The assessment shows that across a range of flood events from the 50% AEP (2-year) to the 0.5% AEP (200-year) plus CC event, the increase in peak flow at the downstream limit of the reach is a maximum of 0.07% compared to the baseline, and the increase in water level is a maximum of 3mm compared to the baseline. It is concluded that the cumulative impact is therefore negligible.

9.1.8 In summary, a comprehensive assessment of the risk to and from the proposed scheme has been undertaken. Mitigation measures to manage any identified flood risks have been assessed such that flood risk is managed appropriately up to the design flood event. It is concluded that the proposed scheme would meet relevant planning and design standards in terms of flood risk.

JACOBS

10 References

Centre for Ecology and Hydrology (1999). Flood Estimation Handbook (FEH).

Chow, V.T. (1959). Open-channel hydraulics.

Construction Industry Research and Information Association (2010). Culvert Design and Operation Guide, CIRIA C689.

Level 1 TAYplan SFRA. The Strategic Development Planning Authority (SDPA), (2014).

Reservoirs (Scotland) Act 2011. Scottish Parliament (2011).

SEPA (2015a). Technical Flood Risk Guidance for Stakeholders (SS-NFR-P-002).

SEPA (2015). Reservoir Flood Maps.

SEPA (2015). Flood Maps. Available at: http://map.sepa.org.uk/floodmap/map.htm.

The Highways Agency et al. (2004). Design Manual for Roads and Bridges: Volume 4, Section 2, Part 1 (HA106/04) Drainage of Runoff from Natural Catchments.

The Highways Agency et al. (2004). Design Manual for Roads and Bridges, Volume 4, Section 2, Part 7 (HA 107/04): Design of Outfall and Culvert Details.

The Highways Agency et al. (2009). Design Manual for Roads and Bridges, Volume 11 Section 3, Part 10 (HD 45/09): Road Drainage and the Water environment.

The Highways Agency et al. (2016). Design Manual for Roads and Bridges: Volume 4, Section 2, Part 3 HA33/16 Design of Highway Drainage Systems.

Scottish Government (2014). Scottish Planning Policy

Scottish Government (2009b). Flood Risk Management (Scotland) Act 2009

Transport Scotland (2013). A9 Dualling Programme SEA Strategic Flood Risk Assessment

Transport Scotland (2016). A9 Dualling Programme: Tay Crossing to Ballinluig – Online v Offline Route Option Comparative Assessment

Transport Scotland (2017a). A9 Dualling: Glen Garry to Dalwhinnie - DMRB Environmental Statement

Transport Scotland (2017b). A9 Dually: Killiecrankie to Glen Garry – Flood Risk Assessment

Annex A: Impact Assessment Criteria

Sensitivity

The sensitivity of water features associated with the existing risk of flooding or its hydrological importance.

This FRA considers the existing A9 as a flood sensitive receptor. This approach differs from that approach presented in the EIA, which considers the impact of the proposed scheme on other sensitive flood receptors, assuming that the proposed scheme is not a sensitive flood receptor, as it would ultimately be designed to be operational during the design flood event.

This is important because it allows the focus of the EIA to be on the surrounding area rather than considering the impact of the proposed scheme on the A9 itself. However, from a flood risk perspective, the mainline of the proposed scheme must be considered as a sensitive receptor so that it can be designed to remain operational and safe for users during times of flood.

Table 32: Hydrology and flood risk sensitivity criteria

Sensitivity	Criteria
Very High	Water feature with direct flood risk to the adjacent populated areas, with greater than 100 residential properties at risk or critical social infrastructure units such as the existing A9, hospitals, schools, safe shelters or other land use of great value at risk. Water feature with hydrological importance to: i) sensitive and protected ecosystems of international status; ii) critical economic and social uses (e.g. water supply, navigation, recreation, amenity).
High	A water feature with direct flood risk to the adjacent populated areas, with between 1 and 100 residential properties and/or more than 10 industrial premises at risk from flooding. Water feature with hydrological importance to: i) national designation sensitive and protected ecosystems; ii) locally important economic and social uses (e.g. water supply, navigation, recreation, amenity).
Medium	A water feature with a possibility of direct flood risk to less populated areas without any critical social infrastructure units such as hospitals, schools, safe shelters and/or utilisable agricultural fields. A water feature with some but limited hydrological importance to: i) sensitive or protected ecosystems; ii) economic and social uses; iii) the flooding of 10 or fewer industrial properties.
Low	A water feature passing through uncultivated agricultural land. A water feature with minimal hydrological importance to: i) sensitive or protected ecosystems; ii) economic and social uses; iii) with a low probability of flooding of residential and industrial properties.

Magnitude of Impact

The impact magnitude influenced by the timing, scale, size and duration of change to the baseline conditions, as well as likelihood of occurrence of the potential impact. For flood risk, this is assessed based on the increase in flood level during the design flood event.

Table 33: Hydrology and flood risk magnitude of impact criteria

Sensitivity		Criteria
	Major Adverse	Increase in peak flood level 0.5% AEP (200-year) greater than 100 mm
	Moderate Adverse	Increase in peak flood level 0.5% AEP (200-year) 50 - 100 mm
	Minor Adverse	Increase in peak flood level 0.5% AEP (200-year) 10 - 50mm
	Negligible	Negligible change in peak flood level 0.5% AEP (200-year) less than +/- 10 mm
	Minor Beneficial	Reduction in peak flood level 0.5% AEP (200-year) 10 - 50mm
	Moderate Beneficial	Reduction in peak flood level 0.5% AEP (200-year) 50 - 100mm
	Major Beneficial	Reduction in peak flood level 0.5% AEP (200-year) greater than100mm

Impact Significance

The significance of impact is determined as a function of the sensitivity of the water feature and the magnitude of impact.

Table 34: Hydrology and flood risk impact significance matrix

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

Note that even though the resulting impact significance may not be considered significant in the context of the EIA Regulations mitigation may still be proposed to address any increase in water levels.

Annex B: Hydraulic Performance Assessment

Approach

The culvert capacity and stage/discharge relationship for all minor watercourses (not identified for detailed numerical modelling) were derived using the culvert analysis methodology presented within CIRIA C689.

The methodology calculates the upstream headwater level (HWL) at the culvert for a range of discharges up to the design flood event and involved the following steps:

- computation of average channel gradient and the culvert inlet/outlet levels using the topographic survey data;
- computation of average channel geometry downstream of the culvert, e.g., bottom width (b), top width (B), side slope using at least three channel cross sections downstream of the culvert using the topographic survey sections;
- manning roughness 'n' for channel and culvert sections is based on the photographs taken by the surveyor from the site, information gathered during site visits and using CIRIA guidelines; and
- culvert inlet/outlet and minor loss coefficients from CIRIA C689 guidelines

The results of the minor watercourse crossing hydraulic performance assessment for both the baseline and proposed scheme (no mitigation) scenarios are contained within a spreadsheet provided outside of this FRA report. The spreadsheet includes the crossing location, diameter, soffit level, invert level, upstream bank level and existing and proposed A9 level, peak flow during the 0.5% AEP (200-year) plus climate change event (the design flood event) and derived HWL. When compared, the data helps identify:

- free-flow or surcharged conditions;
- in-bank or out-of-bank flow;
- locations where the A9 is at risk of overtopping (HWL > A9 level – 600mm freeboard); and
- impacts of the proposed scheme.

Assumptions & Limitations

The preliminary assessment is based on the following assumptions:

- the methodology adopted to estimate HWLs is presented in CIRIA's Culvert Design and Operation Guide.
- both upstream and downstream channel cross-sections are identical based on a simplified trapezoidal representation of the observed geometry.
- all structures are considered free of debris, straight, in good operational order and culvert inlets and outlets are designed appropriately to minimise hydraulic head loss.
- the Manning's roughness coefficients for the culvert and channel section are based on available guidance in Chow, 1959.
- the assessment assumes that the tailwater level (TWL) immediately downstream of the culvert is determined by the downstream channel using 'normal' water depth calculated using Manning's equation. The impact of any other downstream structure exerting a hydraulic control on the culvert has not been considered; and
- where the predicted HWL exceeds the channel level or structure diameter/height, in particular for small diameter culverts, the predicted HWL is likely to be conservative estimate as the upstream channel cross sectional area is confined to the channel width. No account is taken regarding the shape of the design hydrograph and consequently the flood volume, or the attenuation afforded by flood storage on adjacent floodplain or overtopping of the carriageway. These assumptions make the preliminary assessment a conservative estimate of water levels.

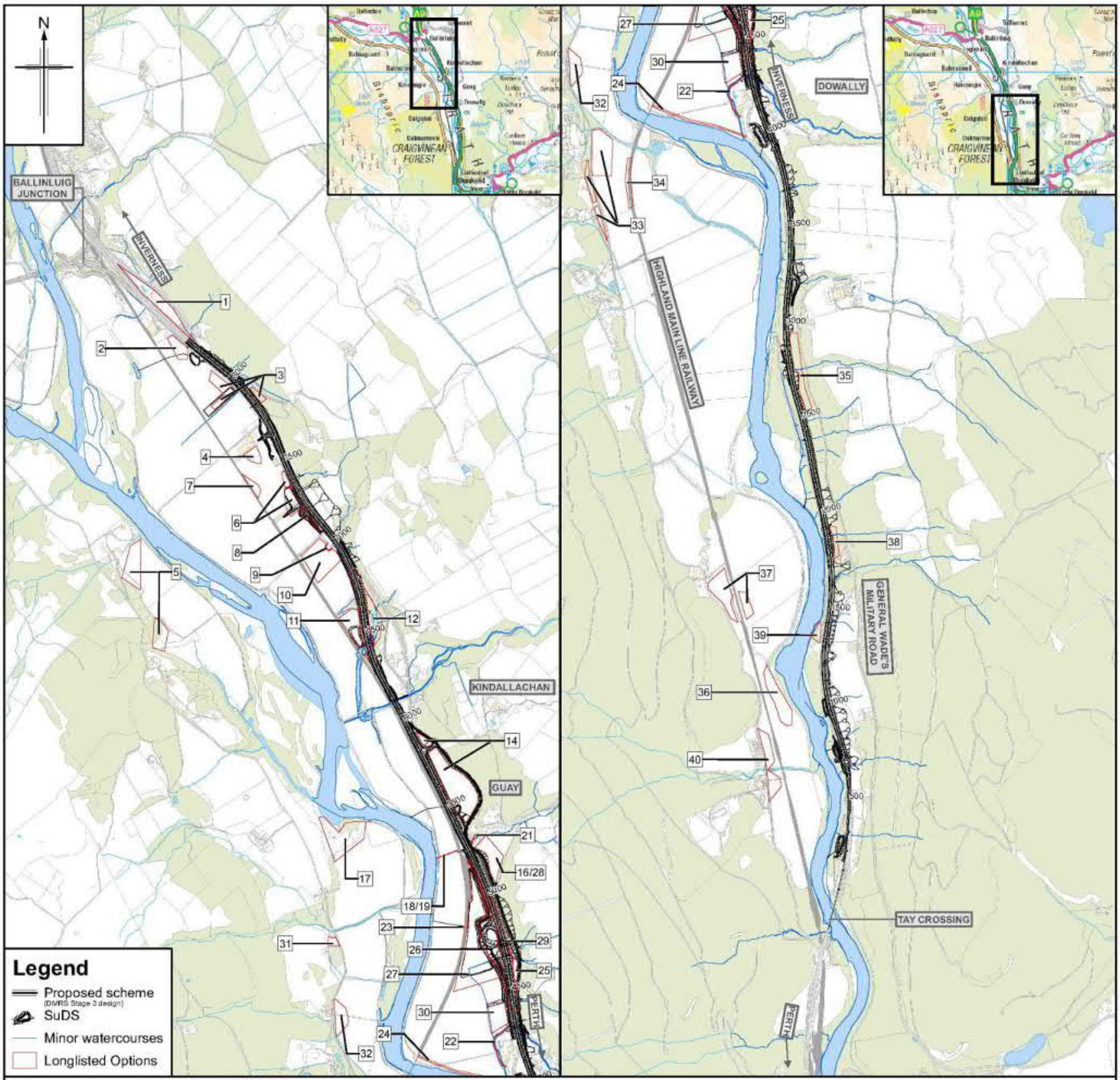
Annex C: Long List of Options Considered

Longlist of options

Location	Mitigation Measure	Number on plan	Shortlisted?
Ballinluig to Westhaugh of Tulliemet	Do-nothing	N/A	Yes
	Compensatory storage east of the A9 near Ballinluig Junction	1	Yes
	Increased connectivity between the A9 and fields east of the A9	N/A (location same as 1)	No
	Compensatory storage within the fields between the A9 and the Highland Main Line (Highland Main Line) railway	2	Yes
	Compensatory storage in existing higher ground east of the A9	3	No
Westhaugh of Tulliemet to Kindallachan	Do-nothing	N/A	Yes
	Access roads within the floodplain constructed on viaduct rather than embankment	6	No
	Compensatory storage on right (west) bank of the River Tay	5	No
	Viaduct section of the A9 between Kindallachan and Haugh of Kilmorich / storage below the road footprint.	8	Yes
	Compensatory storage within the fields south of Westhaugh of Tulliemet between the A9 and Highland Main Line	4	Yes
	Compensatory storage within the fields downstream of WF50	7	No
	Compensatory storage within the field around Haugh of Kilmorich	10	No
	Compensatory storage within the field immediately north of WF41 downstream of the A9	11	No
	Compensatory storage within the wetland to the east of the A9 north of Kindallachan	12	Yes
	Flood bund around Haugh of Kilmorich	9	Yes
	Additional or reduced culvert capacity through Highland Main Line embankment	13	No
Kindallachan to Guay	Do-nothing	N/A	Yes
	Compensatory storage area in field between the A9 and General Wade's Military Road north of Guay	14	Yes
	Compensatory Storage on left bank of the Sloggan Burn downstream of the Highland Main Line	15	No
	Compensatory Storage on right or left bank of the Sloggan Burn upstream of the A9	16	No
	Compensatory Storage on the right (west) bank of the Sloggan Burn near Kincraigie.	17	No
	Open channel replacement of the existing culvert from Sloggan Burn to the River Tay	18	No
	Additional culvert parallel to the existing culvert from Sloggan Burn to the River Tay	19	Yes
	Culverts under the road between Sloggan Burn and the fields between the A9 and General Wade's Military Road north of Guay.	20	No
	Flood wall along the right bank of Sloggan Burn.	21	Yes
Guay to Dowally	Do-nothing	N/A	Yes
	Raised defences along Dowally Burn downstream of the A9	22	No
	Changes to culvert under the Highland Main Line north of Dowally	23	No
	Formal flood defences along banks of River Tay	24	No
	Viaduct section of A9 between Balnabeggan and Dowally	25	No

Location	Mitigation Measure	Number on plan	Shortlisted?
Guay to Dowally	Provision of side roads on viaduct rather than embankment	26	No
	Floodplain compensation area in field between the A9 and Highland Main Line	27	Yes
	Floodplain compensation area east of the A9 south of the Sloggan Burn	28	No
	Floodplain compensation area east of the A9 near Balnabeggan	29	Yes
	Floodplain compensation areas in fields close to Dowally Farm	30	No
	Floodplain compensation area west of the B898 road near Glenalbert (offline storage)	31	No
	Floodplain compensation area east of the B898 road near Glenalbert (both online and offline option considered)	32	Yes
Dowally to Tay Crossing	Do-nothing	N/A	Yes
	Compensatory storage area west of Highland Main Line near Dalguise	33	Yes
	Compensatory storage area on right (west) bank of River Tay near Dalmarnock	36	No
	Compensatory storage area west of Highland Main Line near Dalmarnock	37	Yes
	Compensatory storage area west of Highland Main Line near Inchmagrannachan	40	Yes
	Storage east of A9 near Ledpetty Lodge	38	No
	Compensatory storage area west of the A9 near Ledpetty Lodge	39	Yes
	Compensatory storage area east of the A9 near Rotmell Farm	35	No
	Additional culverts through Highland Main Line railway embankment near Dalguise	34	No

JACOBS

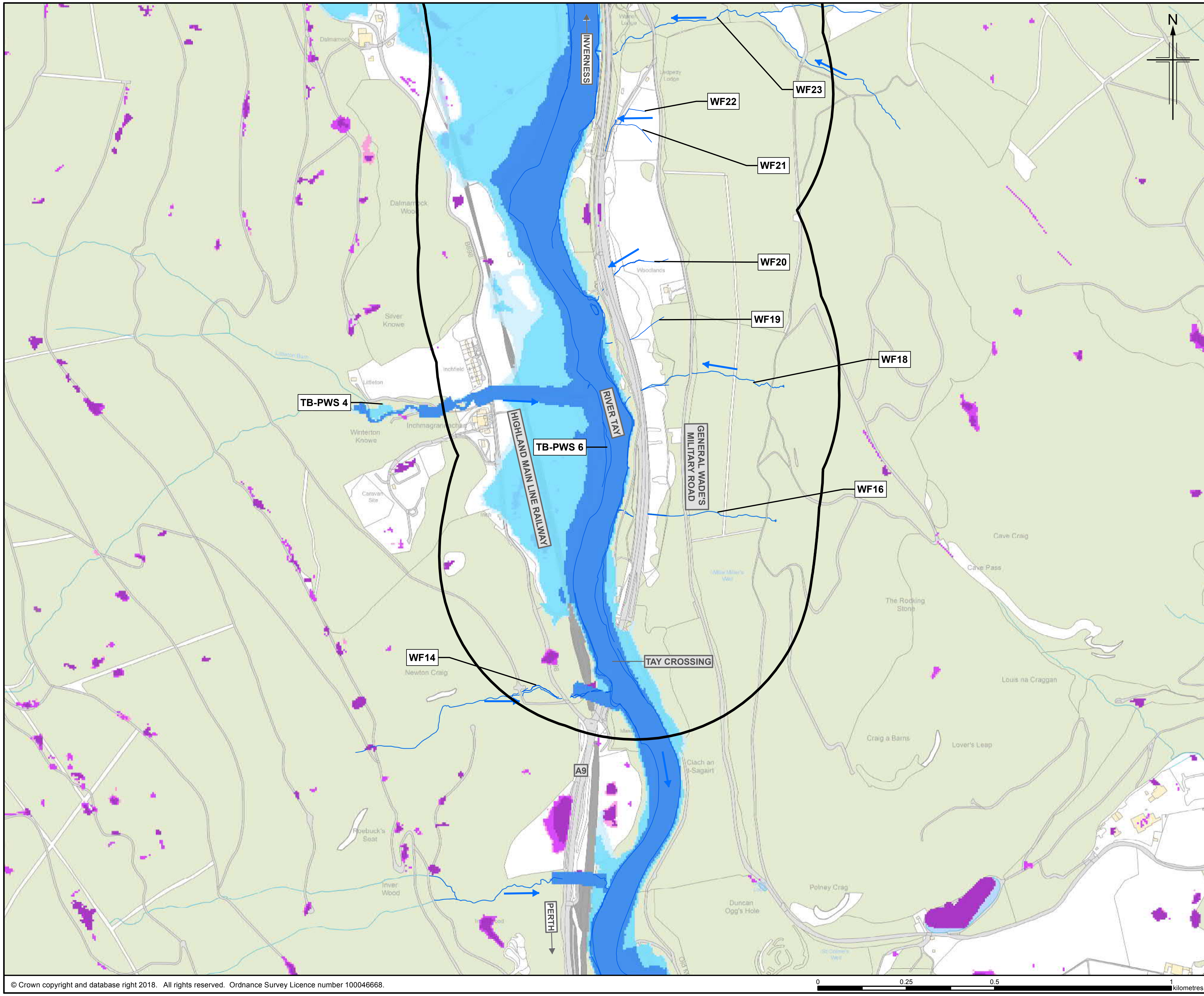

N
BALLINLUIG JUNCTION
INVERNESS
KINDALLACHAN
GUAY
DOWALLY
HIGHLAND MAIN LINE RAILWAY
GENERAL WADE'S MILITARY ROAD
TAY CROSSING
PERTH
Legend
Proposed scheme (DMRB Stage 3 design)
SuDS
Minor watercourses
Longlisted Options
0
0.5
1
2
Kilometres

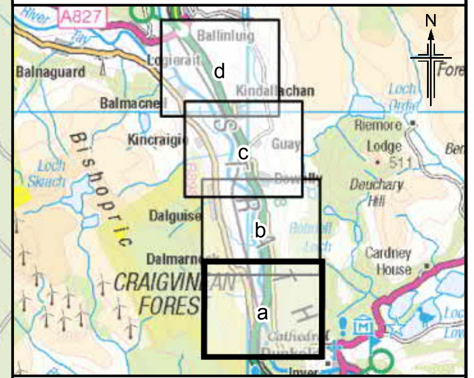
Annex D: Flood Risk Assessment Figures

- Figure A11.3.1a-d: SEPA Flood Map Baseline Scenario
- Figure A11.3.2a-d: Fluvial Flood Depth Map Baseline Scenario
- Figure A11.3.3a-d: Fluvial Flood Depth Map with Scheme (No Mitigation)
- Figure A11.3.4a-d: Fluvial Flood Depth Impact Map with Scheme (No Mitigation)
- Figure A11.3.5a-d: Fluvial Flood Depth Map with Scheme (with Mitigation)
- Figure A11.3.6a-d: Fluvial Flood Depth Impact Map with Scheme (with Mitigation)

[Page intentionally left blank]

Figure 11.3.1a





Legend

- 500m Study area
- Minor watercourses
- Water flow direction

SEPA Fluvial Flood Extent

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability

SEPA Surface Water Flood Extent

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability Plus Climate Change Allowance

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK.
Tel: +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
COMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

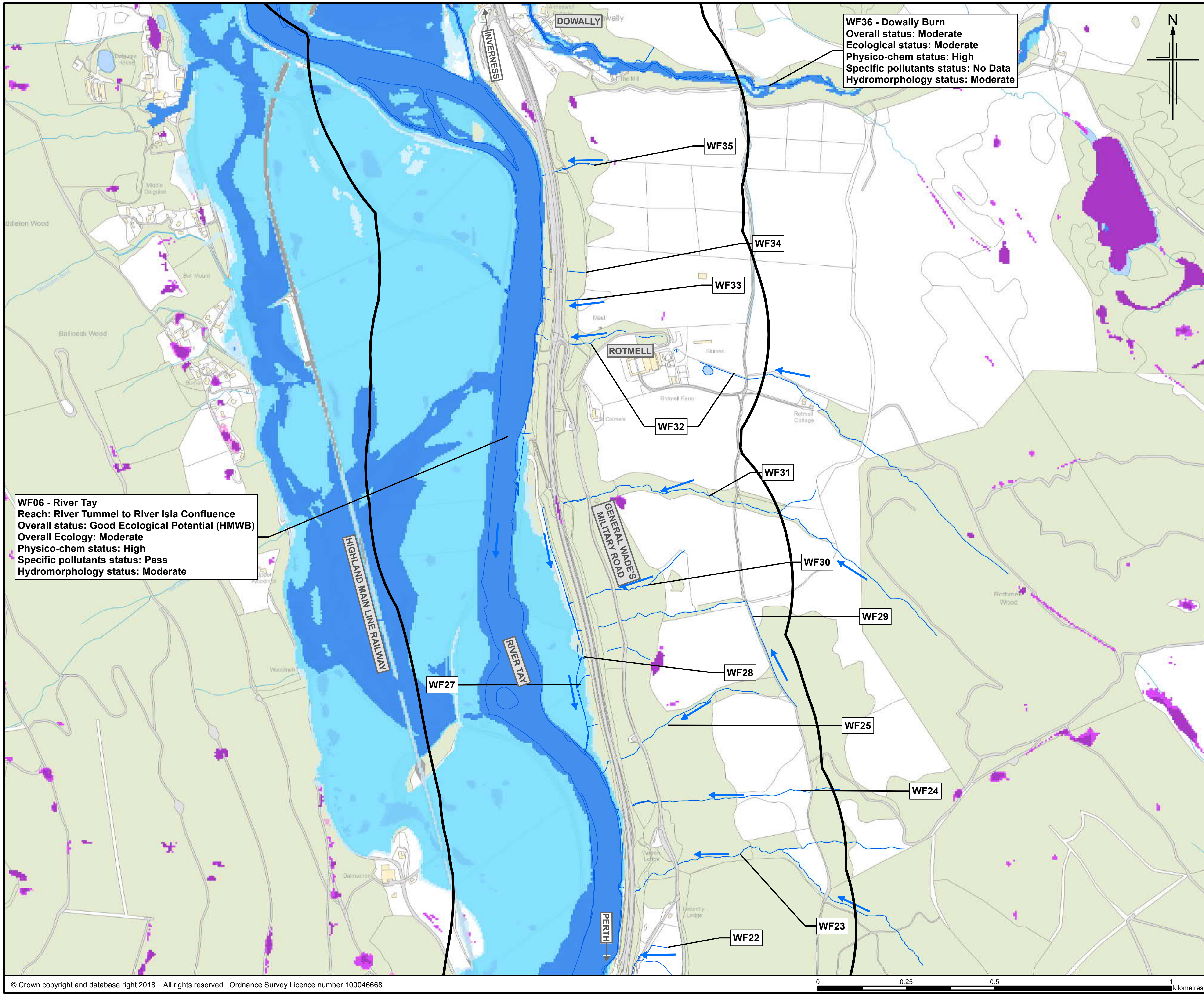
Drawing title

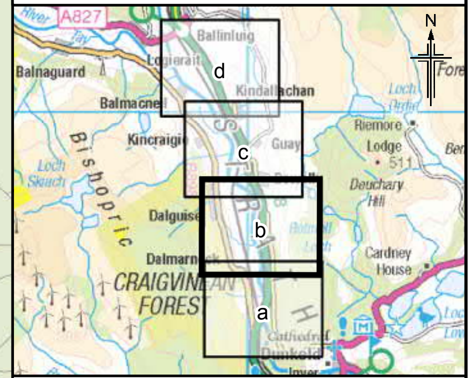
Environmental Statement
SEPA Flood Map
Baseline Scenario

Sheet 1 of 4

Drawing Status	FINAL	
Scale	1:10,000 @ A3	DO NOT SCALE
Jacobs No.	B2140003	
BIM No.		
Drawing number	Figure 11.3.1a	Rev 0

Figure 11.3.1b





Legend

- 500m Study area
- Minor watercourses
- Water flow direction

SEPA Fluvial Flood Extent

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability

SEPA Surface Water Flood Extent

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability Plus Climate Change Allowance

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK.
Tel: +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
COMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

Drawing title

Environmental Statement
SEPA Flood Map
Baseline Scenario

Sheet 2 of 4

Drawing Status	FINAL		
Scale	1:10,000	@ A3	DO NOT SCALE
Jacobs No.	B2140003		
BIM No.			
Drawing number	Figure 11.3.1b	Rev	0

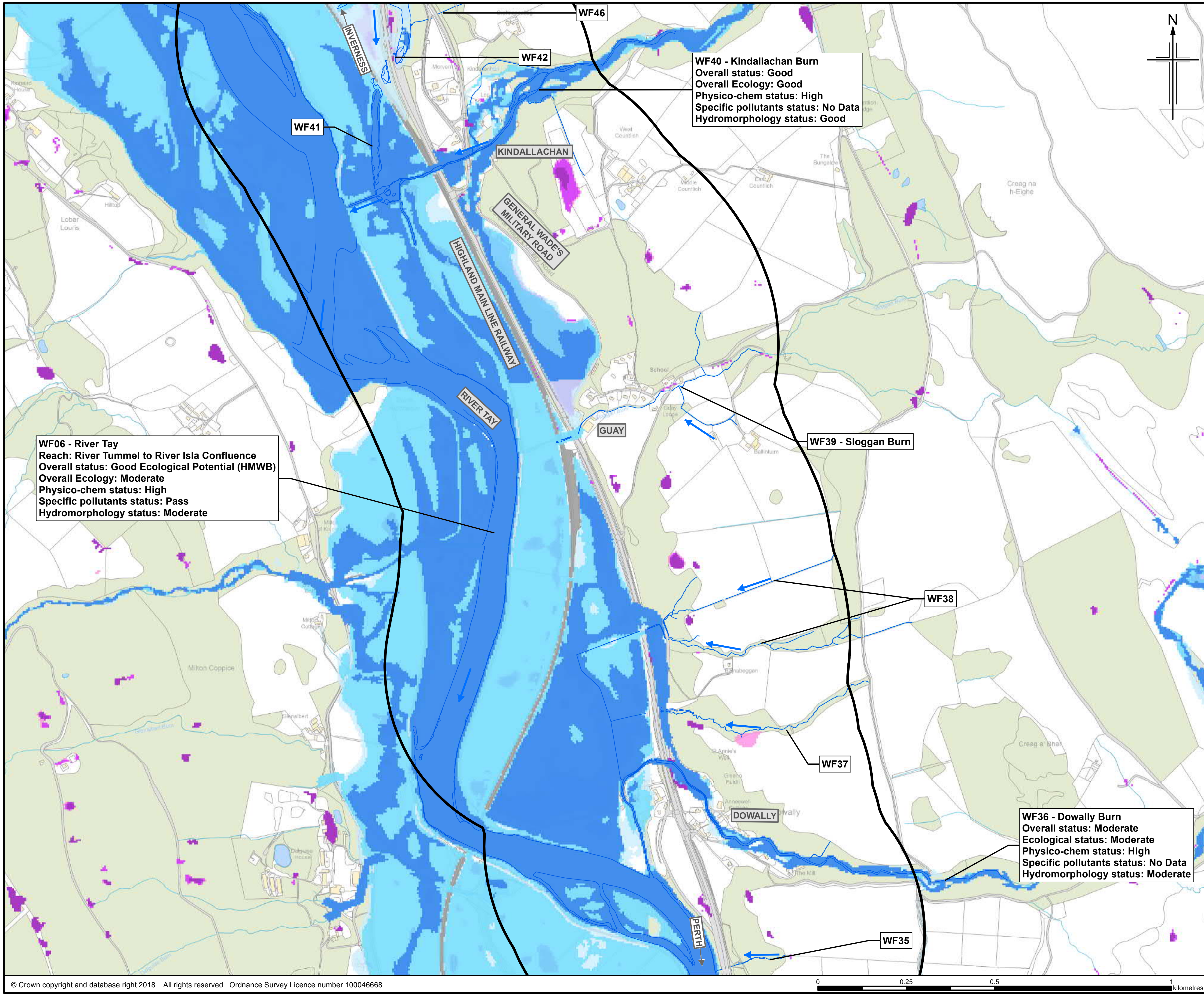
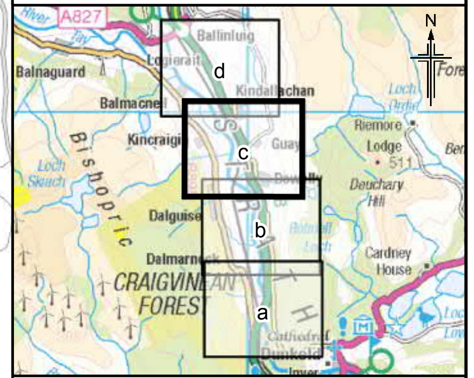


Figure 11.3.1c



Legend

- 500m Study area
- Minor watercourses
- Water flow direction

SEPA Fluvial Flood Extent

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability

SEPA Surface Water Flood Extent

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability Plus Climate Change Allowance

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK.
Tel: +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
COMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

Drawing title

Environmental Statement
SEPA Flood Map
Baseline Scenario

Sheet 3 of 4

Drawing Status	FINAL		
Scale	1:10,000	@ A3	DO NOT SCALE
Jacobs No.	B2140003		
BIM No.			
Drawing number	Figure 11.3.1c		Rev 0

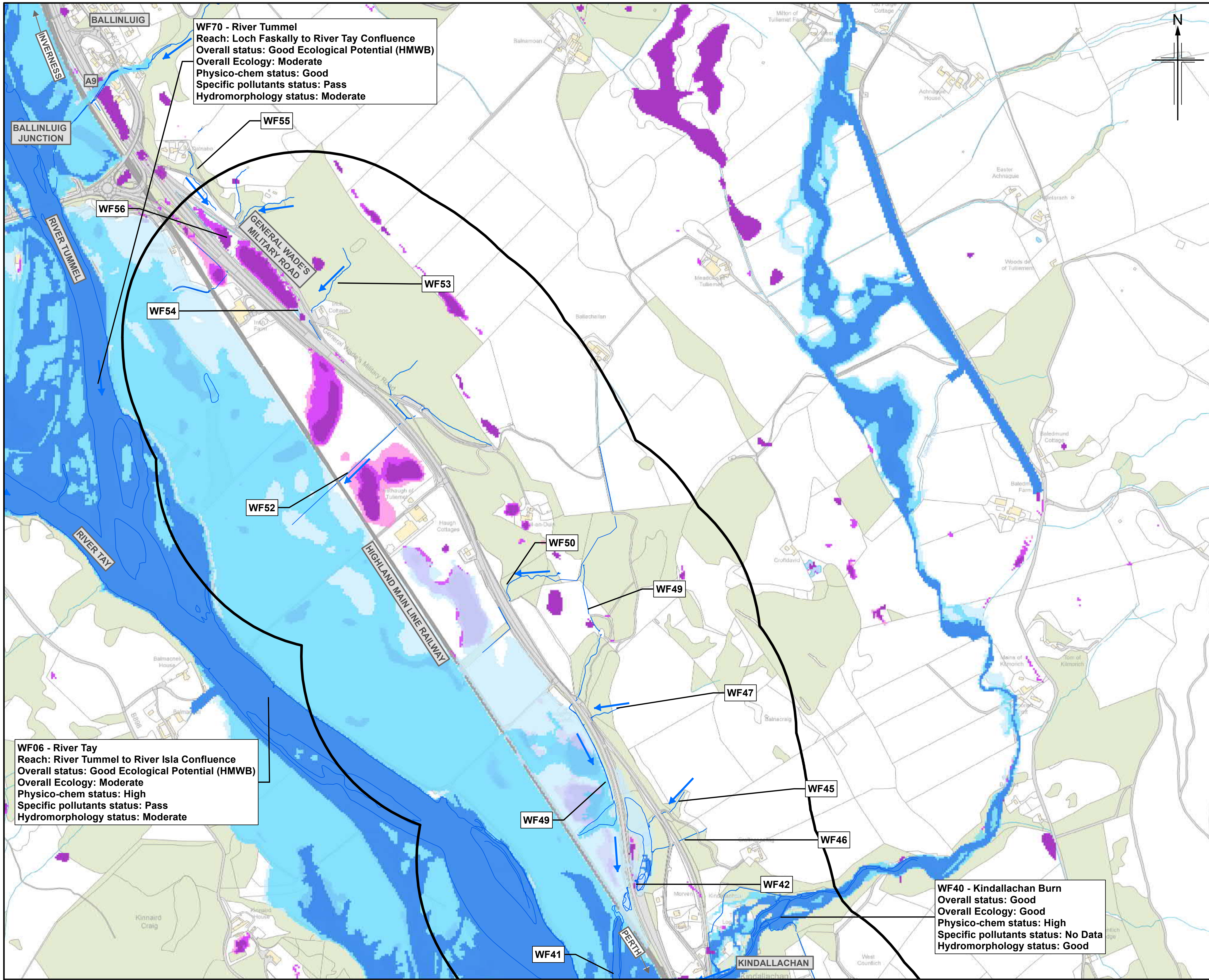
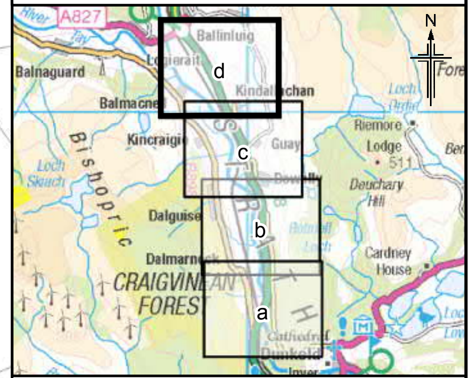


Figure 11.3.1d



Legend

- 500m Study area
- Minor watercourses
- Water flow direction

SEPA Fluvial Flood Extent

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability

SEPA Surface Water Flood Extent

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability Plus Climate Change Allowance

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK.
Tel: +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
COMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

Drawing title

Environmental Statement
SEPA Flood Map
Baseline Scenario

Sheet 4 of 4

Drawing Status	FINAL	
Scale	1:10,000 @ A3	DO NOT SCALE
Jacobs No.	B2140003	
BIM No.		
Drawing number	Figure 11.3.1d	Rev 0

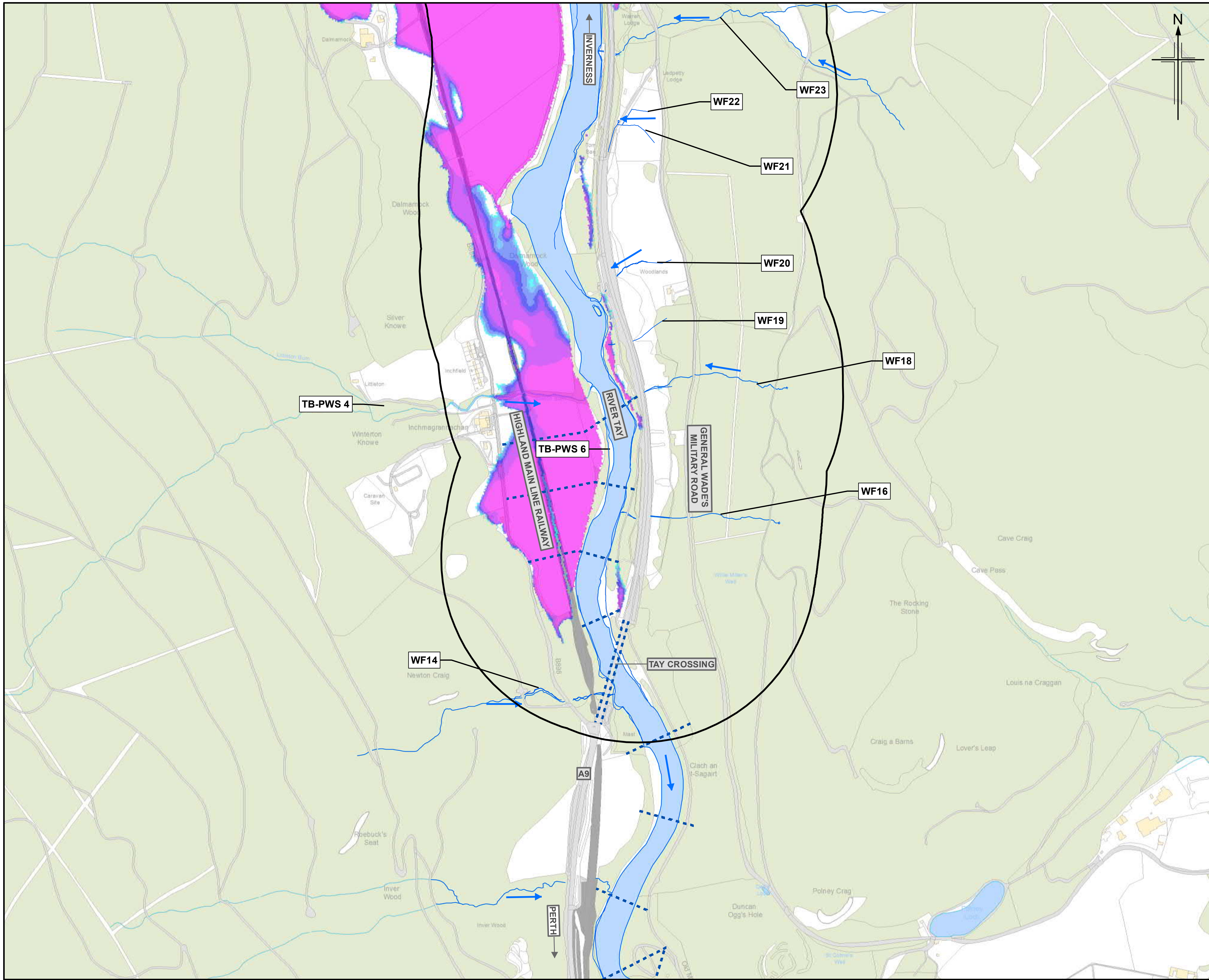
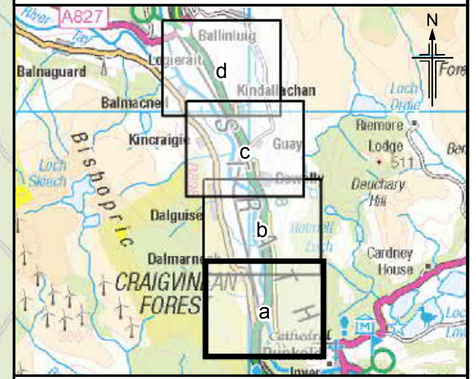


Figure 11.3.2a



Legend

- 500m Study area
- Minor watercourses
- Water flow direction
- Flood model cross section

Modelled flood depths (m) during the 0.5% AEP (200-year) plus CC event in the baseline scenario

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK.
Tel: +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
COMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

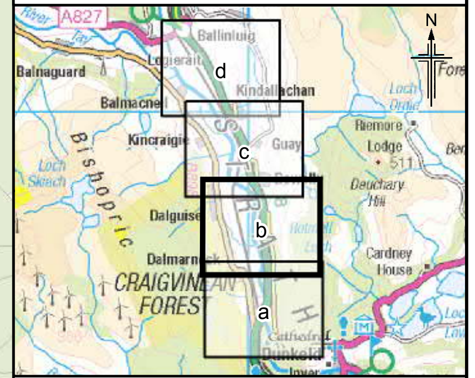
Drawing title

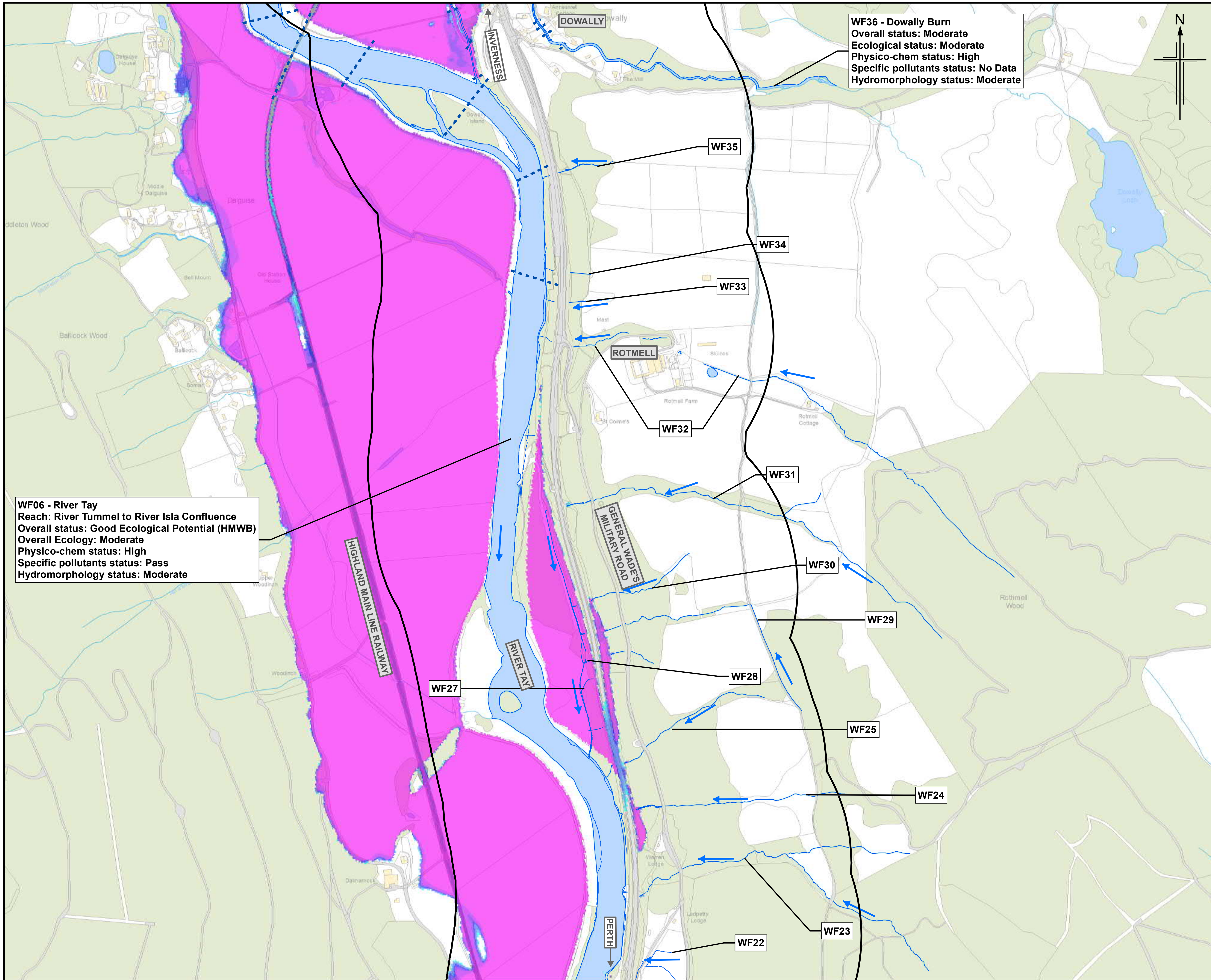
Environmental Statement
Fluvial Flood Depth Map
Baseline Scenario

Sheet 1 of 4

Drawing Status	FINAL		
Scale	1:10,000	@ A3	DO NOT SCALE
Jacobs No.	B2140003		
BIM No.			
Drawing number	Figure 11.3.2a	Rev	0

Figure 11.3.2b





0 0.25 0.5 1 kilometres

Legend

- 500m Study area
- Minor watercourses
- Water flow direction
- Flood model cross section

Modelled flood depths (m) during the 0.5% AEP (200-year) plus CC event in the baseline scenario

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS

95 Bothwell Street, Glasgow, G2 7HX, UK.
Tel: +44(0)141 243 8000
www.jacobs.com

Client

TRANSPORT SCOTLAND
COMHDHAIL ALBA

Project

A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

Drawing title

Environmental Statement
Fluvial Flood Depth Map
Baseline Scenario

Sheet 2 of 4

Drawing Status	FINAL		
Scale	1:10,000	@ A3	DO NOT SCALE
Jacobs No.	B2140003		
BIM No.			
Drawing number	Figure 11.3.2b		Rev 0

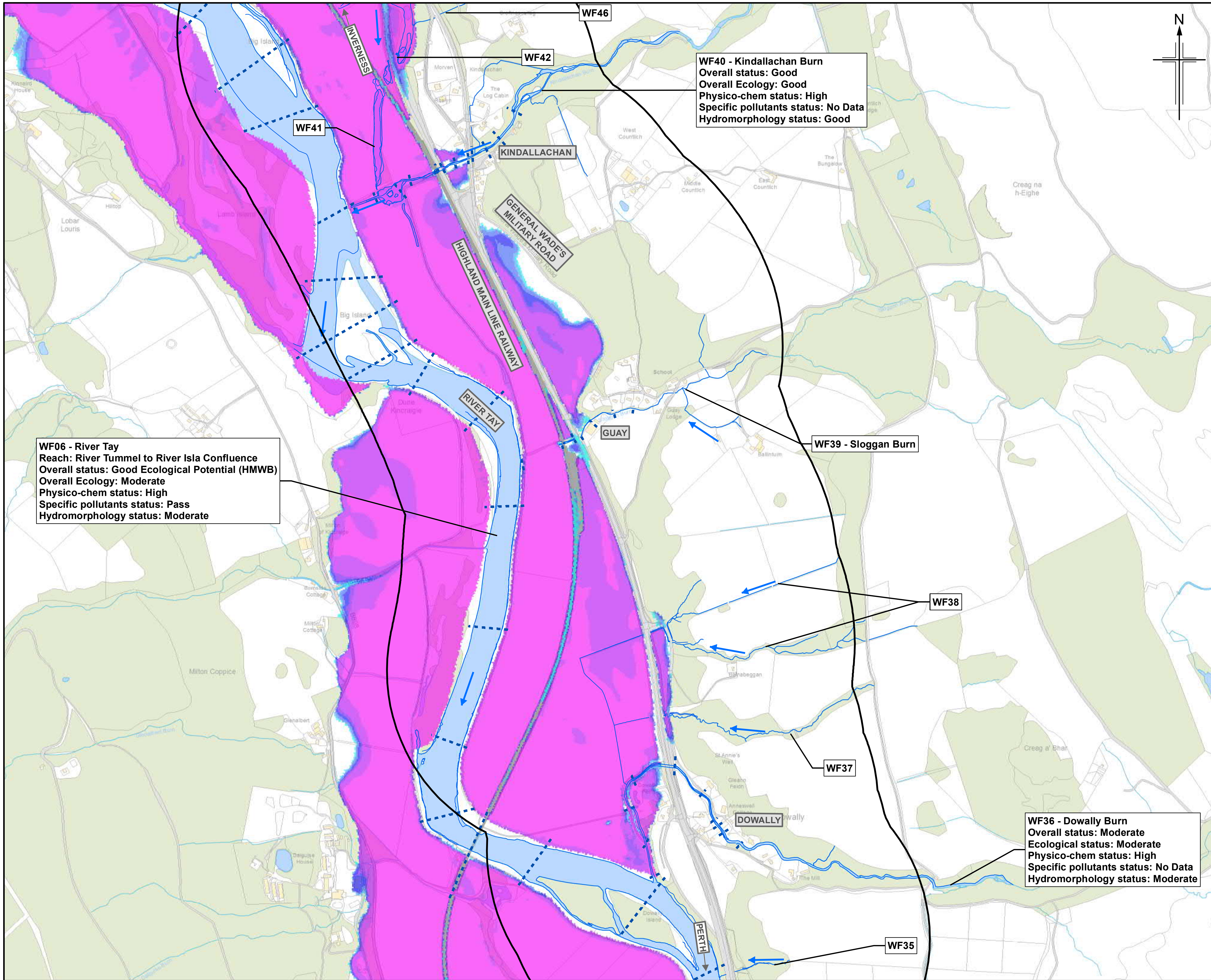
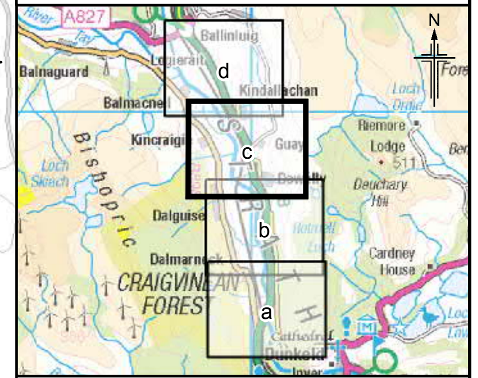


Figure 11.3.2c



Legend

- 500m Study area
- Minor watercourses
- Water flow direction
- Flood model cross section

Modelled flood depths (m) during the 0.5% AEP (200-year) plus CC event in the baseline scenario

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK.
Tel: +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
COMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

Drawing title
Environmental Statement
Fluvial Flood Depth Map
Baseline Scenario

Sheet 3 of 4

Drawing Status	FINAL	
Scale	1:10,000 @ A3	DO NOT SCALE
Jacobs No.	B2140003	
BIM No.		
Drawing number	Figure 11.3.2c	Rev 0

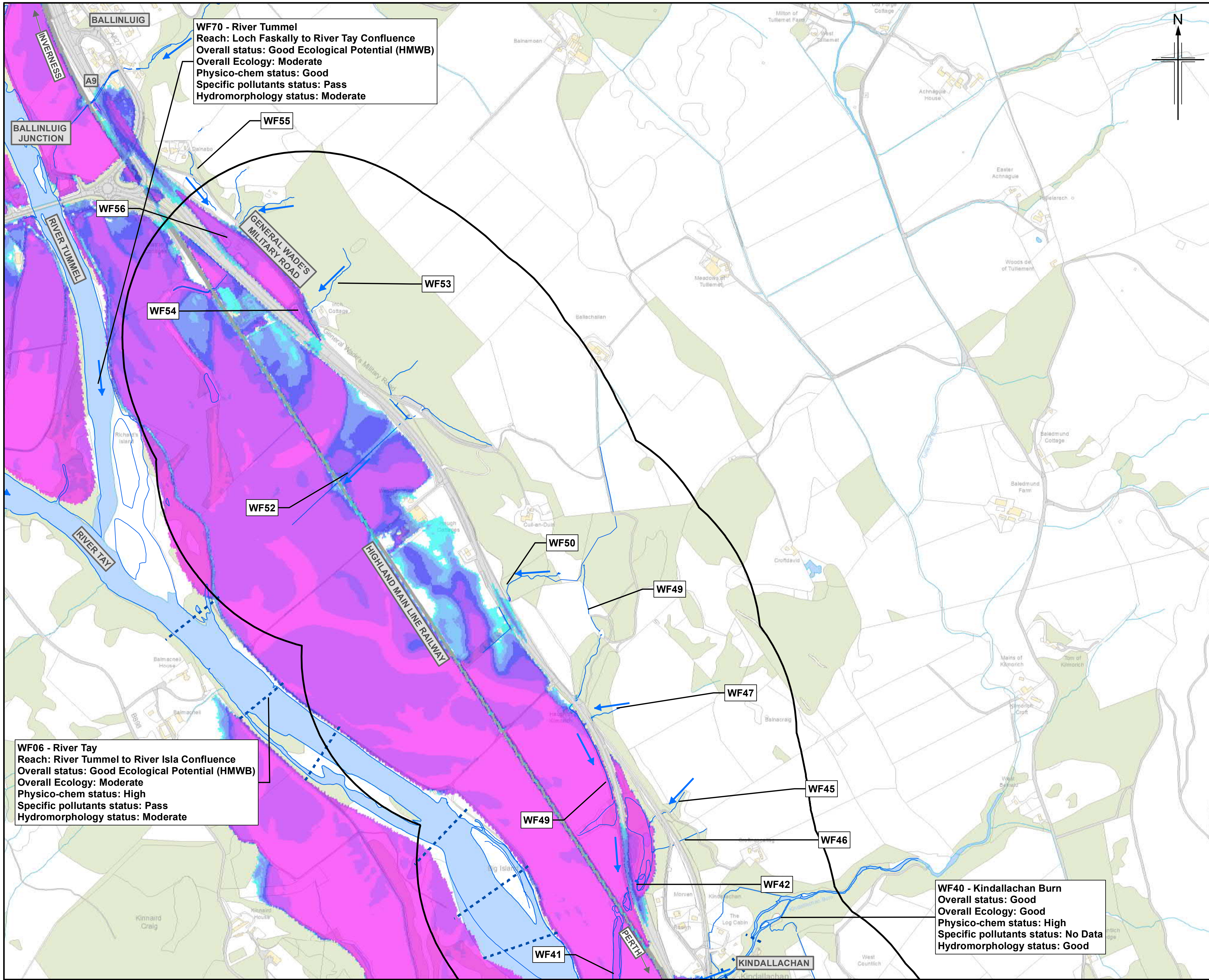
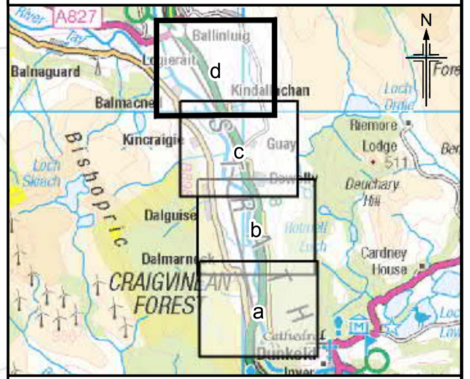


Figure 11.3.2d



Legend

- 500m Study area
- Minor watercourses
- Water flow direction
- Flood model cross section

Modelled flood depths (m) during the 0.5% AEP (200-year) plus CC event in the baseline scenario

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK.
Tel: +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

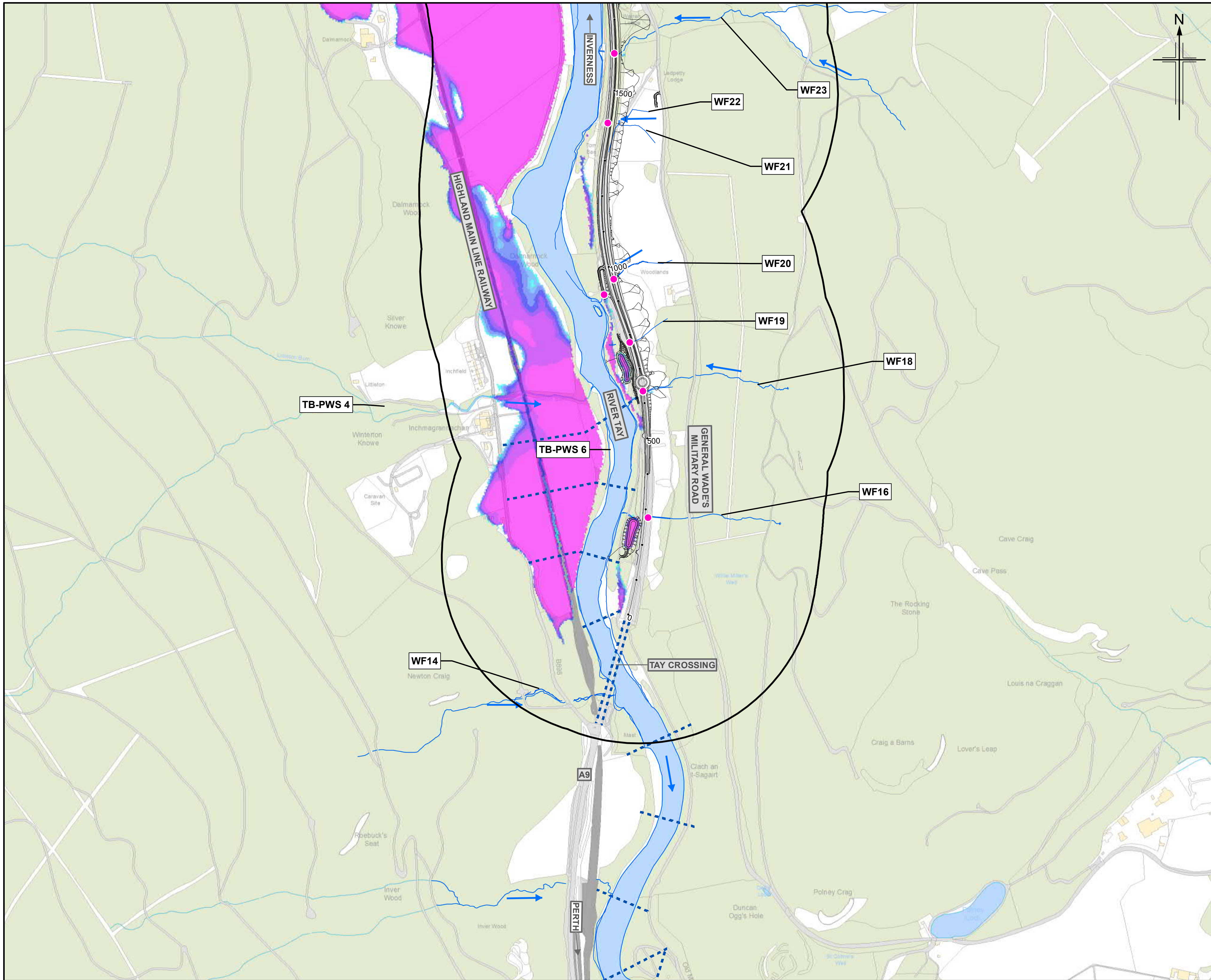
Drawing title

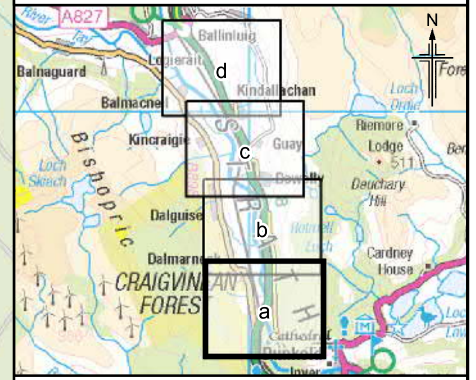
Environmental Statement
Fluvial Flood Depth Map
Baseline Scenario

Sheet 4 of 4

Drawing Status	FINAL	
Scale	1:10,000 @ A3	DO NOT SCALE
Jacobs No.	B2140003	
BIM No.		
Drawing number	Figure 11.3.2d	Rev 0

Figure 11.3.3a





Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- Flood model cross section

Modelled flood depths (m) during the 0.5% AEP (200-year) plus CC event in the proposed scheme (no mitigation) scenario

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK.
Tel: +44(0)141 243 8000
www.jacobs.com

Client: TRANSPORT SCOTLAND COMHDHAIL ALBA

Project: A9 DUALLING PERTH TO INVERNESS Tay Crossing to Ballinluig

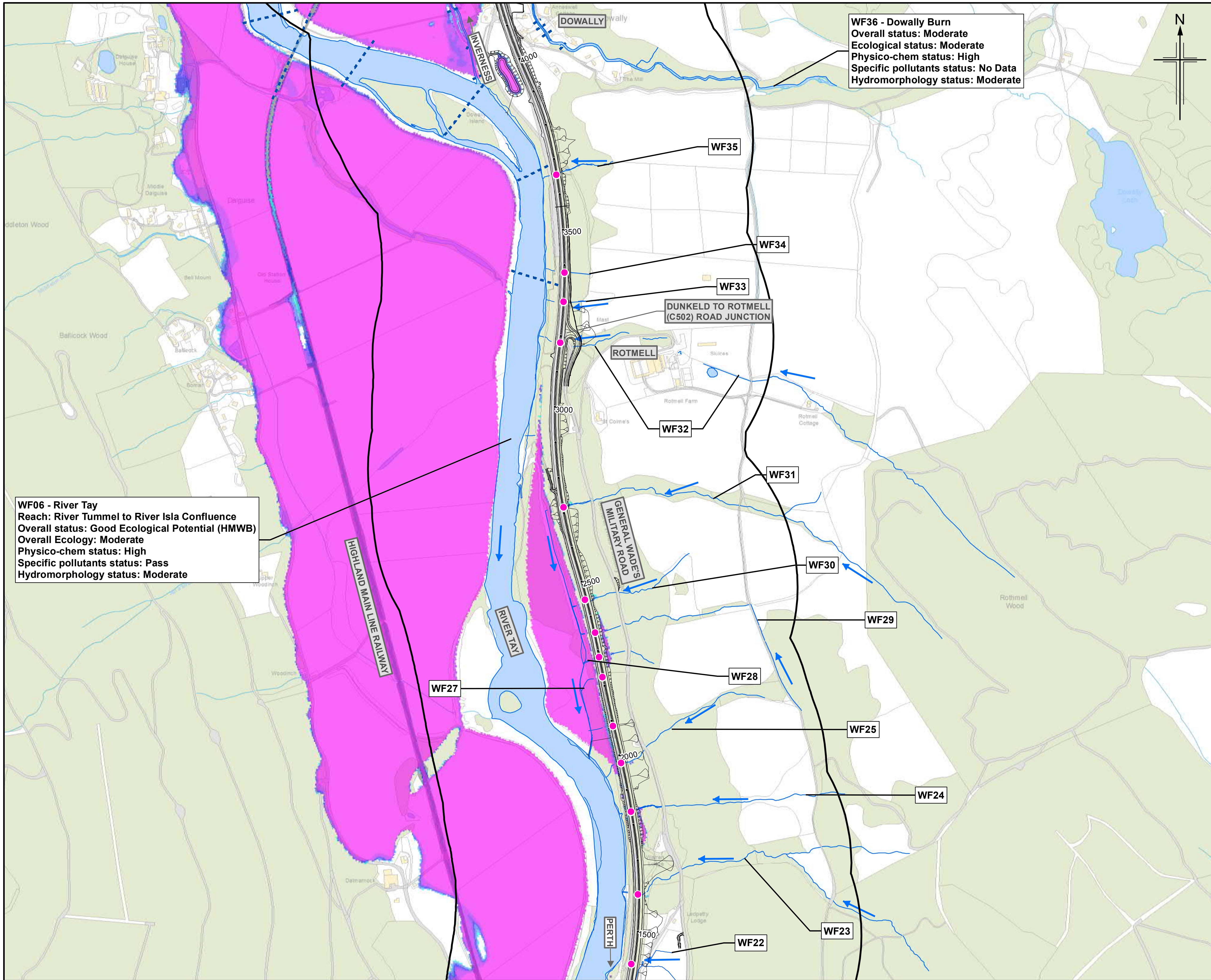
Drawing title

Environmental Statement
Fluvial Flood Depth Map
With Scheme (No Mitigation)

Sheet 1 of 4

Drawing Status	FINAL	
Scale	1:10,000 @ A3	DO NOT SCALE
Jacobs No.	B2140003	
BIM No.		
Drawing number	Figure 11.3.3a	Rev 0

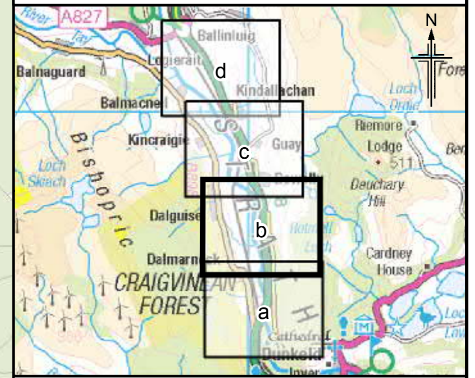
0 0.25 0.5 1 kilometres



© Crown copyright and database right 2018. All rights reserved. Ordnance Survey Licence number 100046668.

0 0.25 0.5 1 kilometres

Figure 11.3.3b



Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- Flood model cross section

Modelled flood depths (m) during the 0.5% AEP (200-year) plus CC event in the proposed scheme (no mitigation) scenario

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK.
Tel: +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
COMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

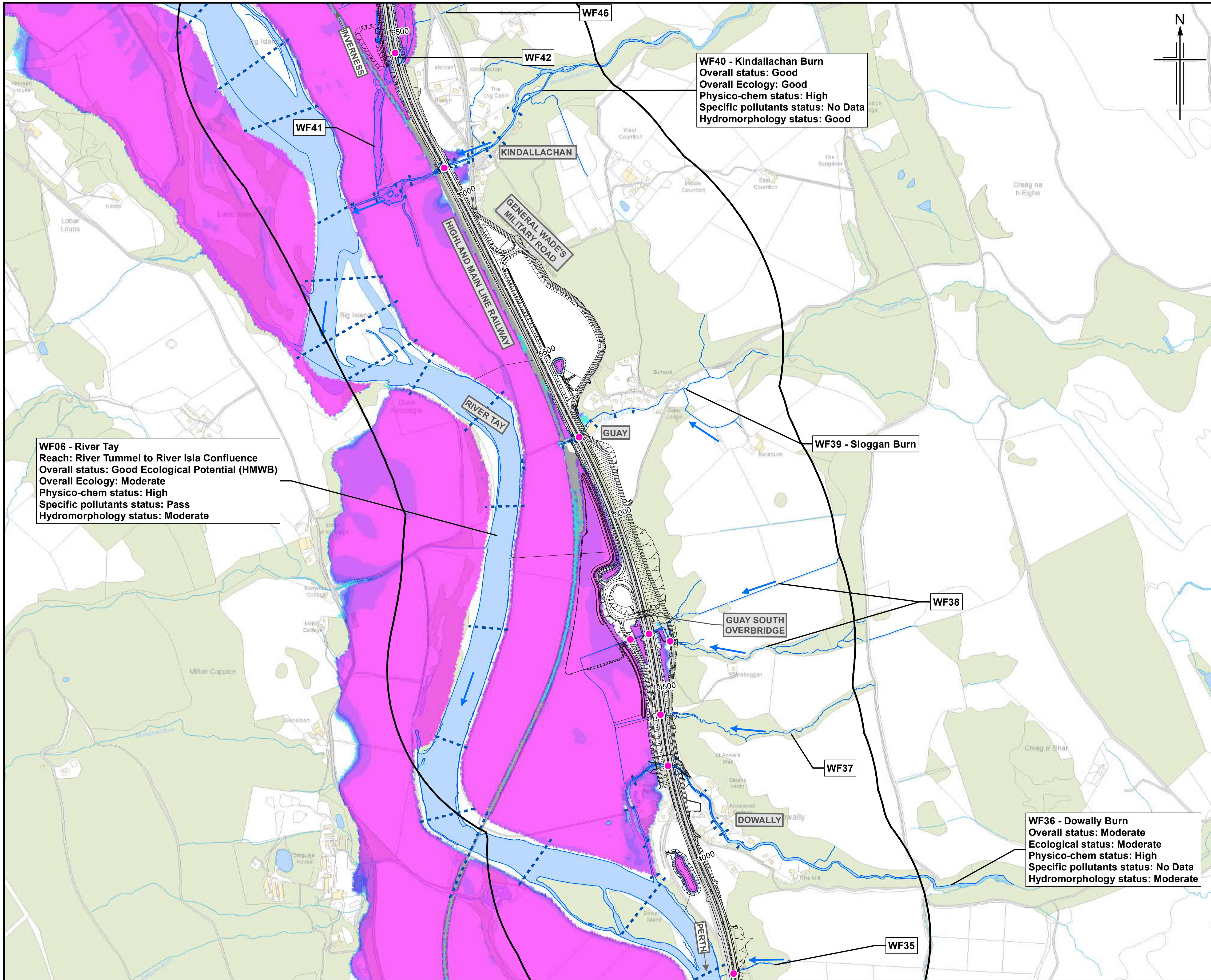
Drawing title

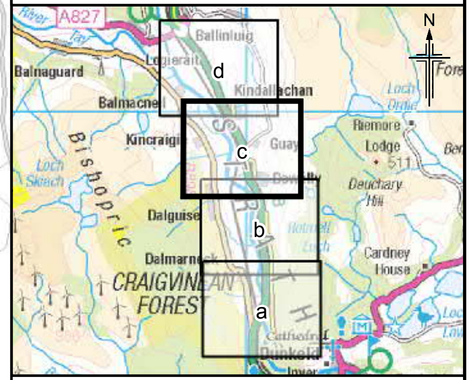
Environmental Statement
Fluvial Flood Depth Map
With Scheme (No Mitigation)

Sheet 2 of 4

Drawing Status	FINAL		
Scale	1:10,000	@ A3	DO NOT SCALE
Jacobs No.	B2140003		
BIM No.			
Drawing number	Figure 11.3.3b	Rev	0

Figure 11.3.3c





Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- Flood model cross section

Modelled flood depths (m) during the 0.5% AEP (200-year) plus CC event in the proposed scheme (no mitigation) scenario

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK.
Tel: +44(0)141 243 8000
www.jacobs.com

Client: Transport Scotland / Comhdhail Alba

Project: A9 Dualling Perth to Inverness — Tay Crossing to Ballinluig

Drawing title

Environmental Statement
Fluvial Flood Depth Map
With Scheme (No Mitigation)

Sheet 3 of 4

Drawing Status	FINAL	
Scale	1:10,000 @ A3	DO NOT SCALE
Jacobs No.	B2140003	
BIM No.		
Drawing number	Figure 11.3.3c	Rev 0

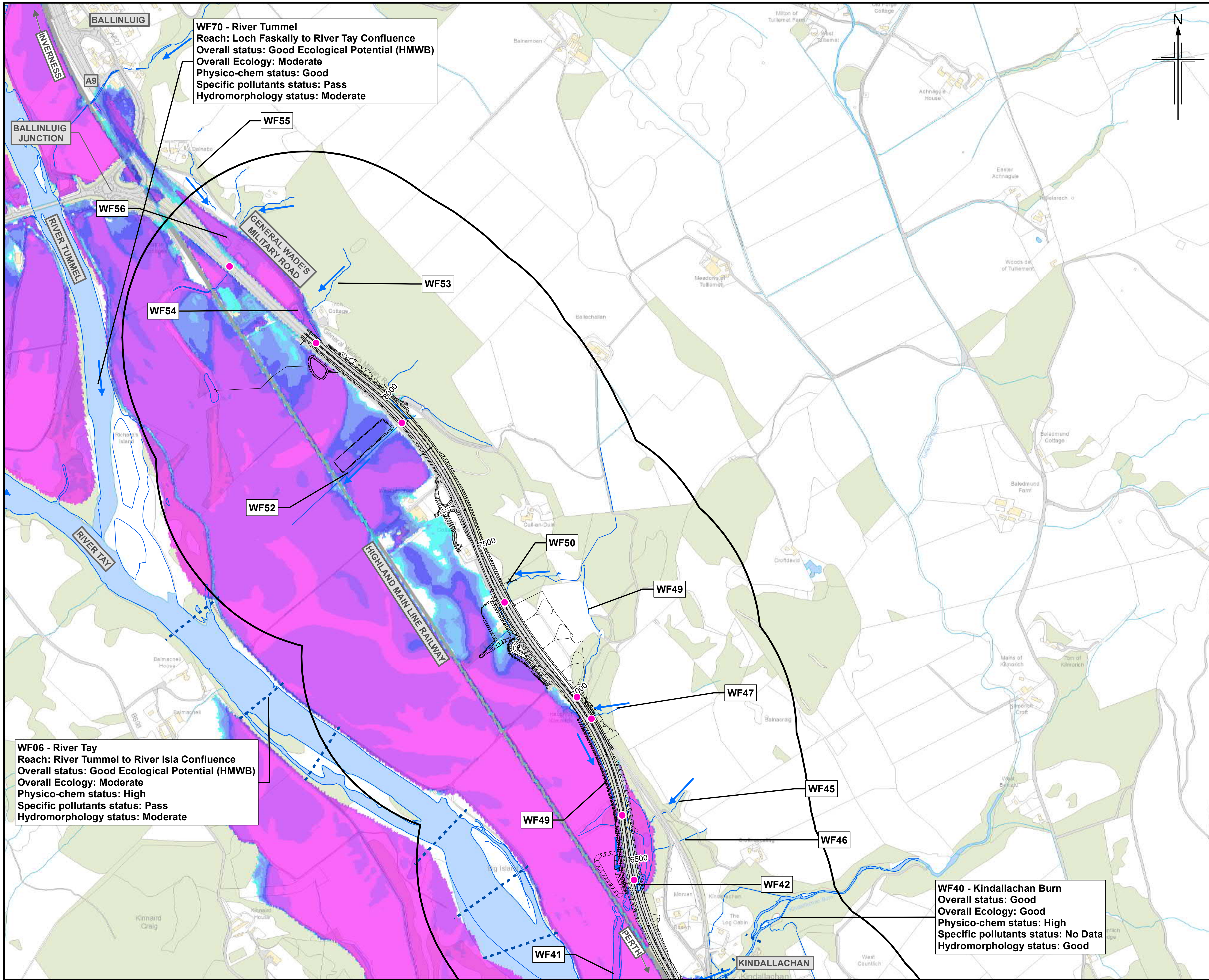
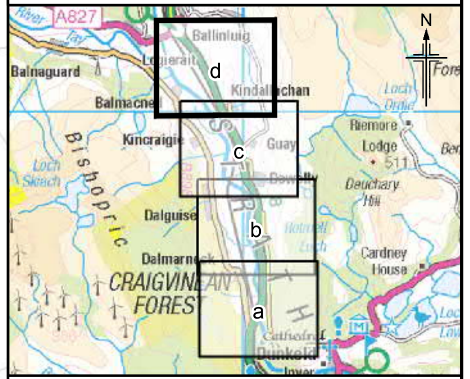


Figure 11.3.3d



Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- Flood model cross section

Modelled flood depths (m) during the 0.5% AEP (200-year) plus CC event in the proposed scheme (no mitigation) scenario

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK.
Tel: +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
COMHDHAIL ALBA

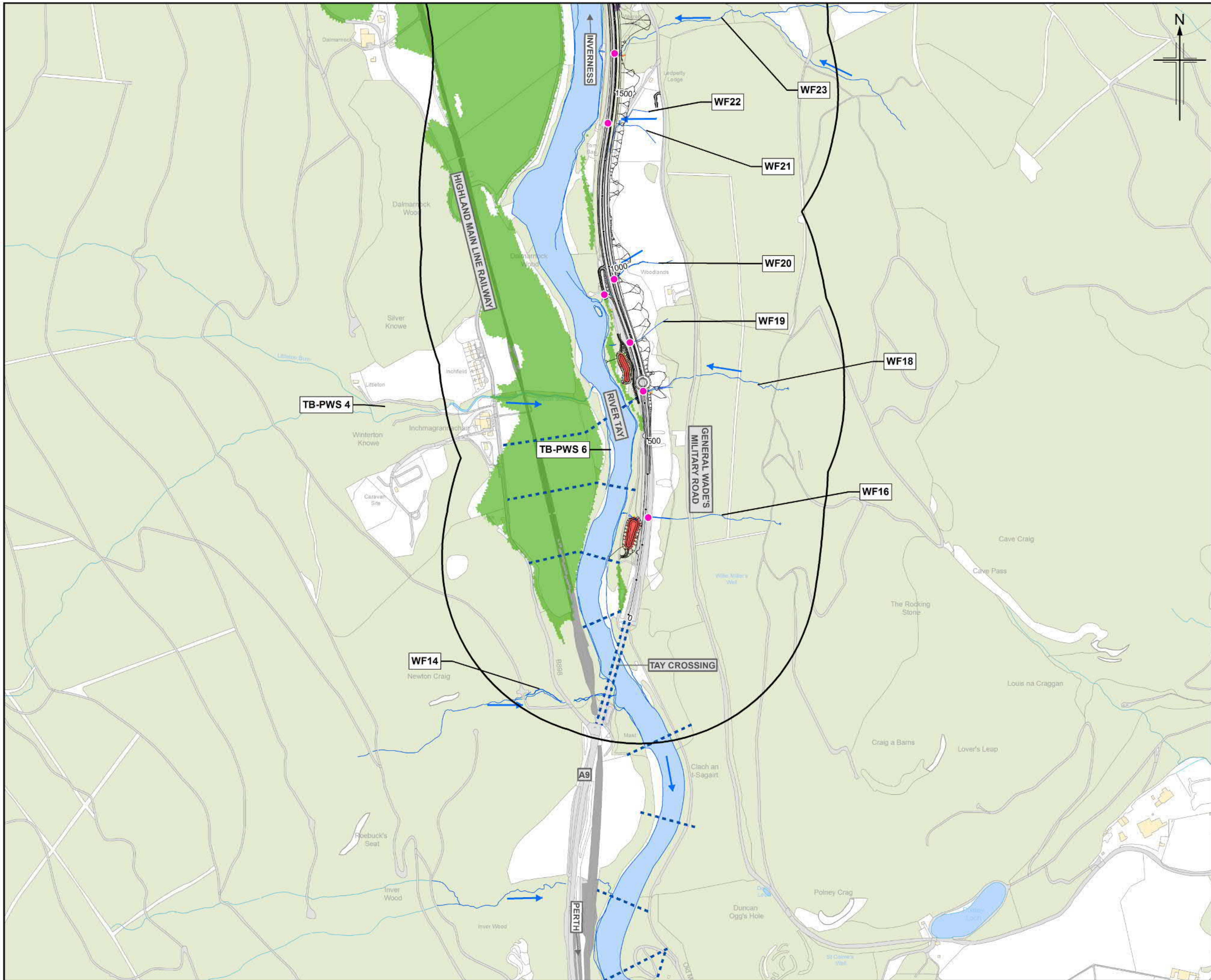
Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

Drawing title

Environmental Statement
Fluvial Flood Depth Map
With Scheme (No Mitigation)
Sheet 4 of 4

Drawing Status	FINAL	
Scale	1:10,000 @ A3	DO NOT SCALE
Jacobs No.	B2140003	
BIM No.		
Drawing number	Figure 11.3.3d	Rev 0

Figure 11.3.4a



Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- Flood model cross section

Flood Level Difference (m) during the 0.5% AEP (200-year) plus CC event

- > -0.1 Major Beneficial
- -0.1 to -0.05 Moderate Beneficial
- -0.05 to -0.01 Minor Beneficial
- -0.01 to 0.01 Negligible
- 0.01 to 0.05 Minor Adverse
- 0.05 to 0.1 Moderate Adverse
- > 0.1 Major Adverse

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK
Tel: +44(0)141 243 8000
www.jacobs.com

Client: TRANSPORT SCOTLAND COMHDHAIL ALBA

Project: A9 DUALLING PERTH TO INVERNESS Tay Crossing to Ballinluig

Drawing title

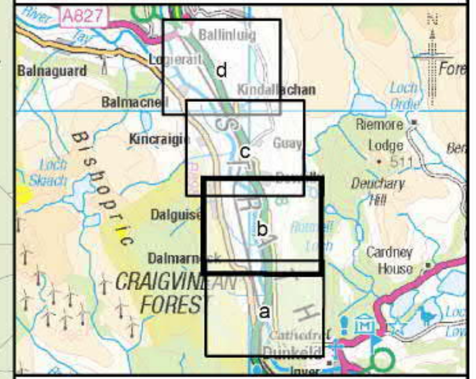
Environmental Statement
Fluvial Flood Depth Impact Map
With Scheme (No Mitigation)

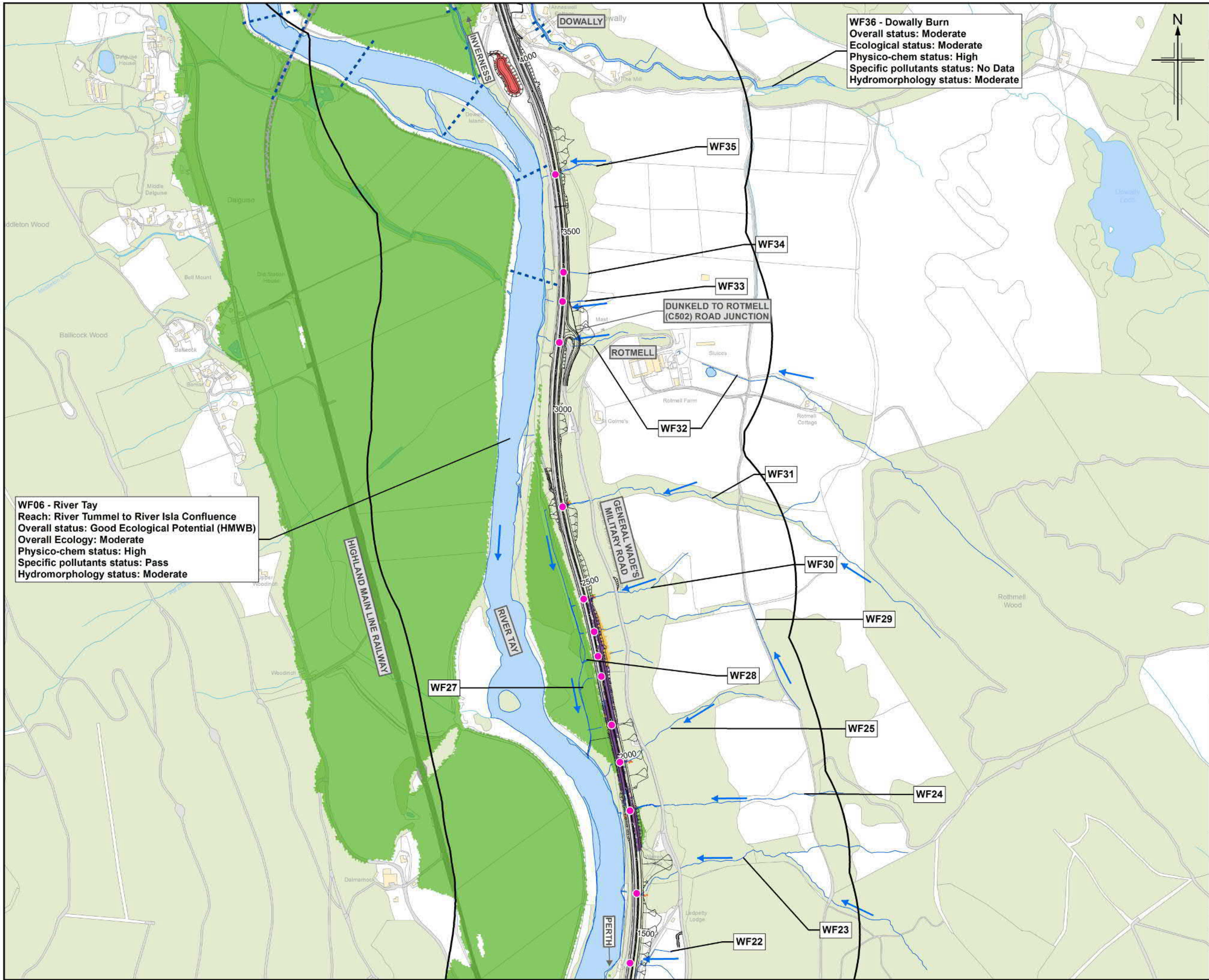
Sheet 1 of 4

Drawing Status	FINAL	
Scale	1:10,000 @ A3	DO NOT SCALE
Jacobs No.	B2140003	
BIM No.		
Drawing number	Figure 11.3.4a	Rev 0

0 0.25 0.5 1 kilometres

Figure 11.3.4b





Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- Flood model cross section

Flood Level Difference (m) during the 0.5% AEP (200-year) plus CC event

- > -0.1 Major Beneficial
- -0.1 to -0.05 Moderate Beneficial
- -0.05 to -0.01 Minor Beneficial
- -0.01 to 0.01 Negligible
- 0.01 to 0.05 Minor Adverse
- 0.05 to 0.1 Moderate Adverse
- > 0.1 Major Adverse

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK
Tel: +44(0)141 243 8000
www.jacobs.com

Client: TRANSPORT SCOTLAND COMHDHAIL ALBA

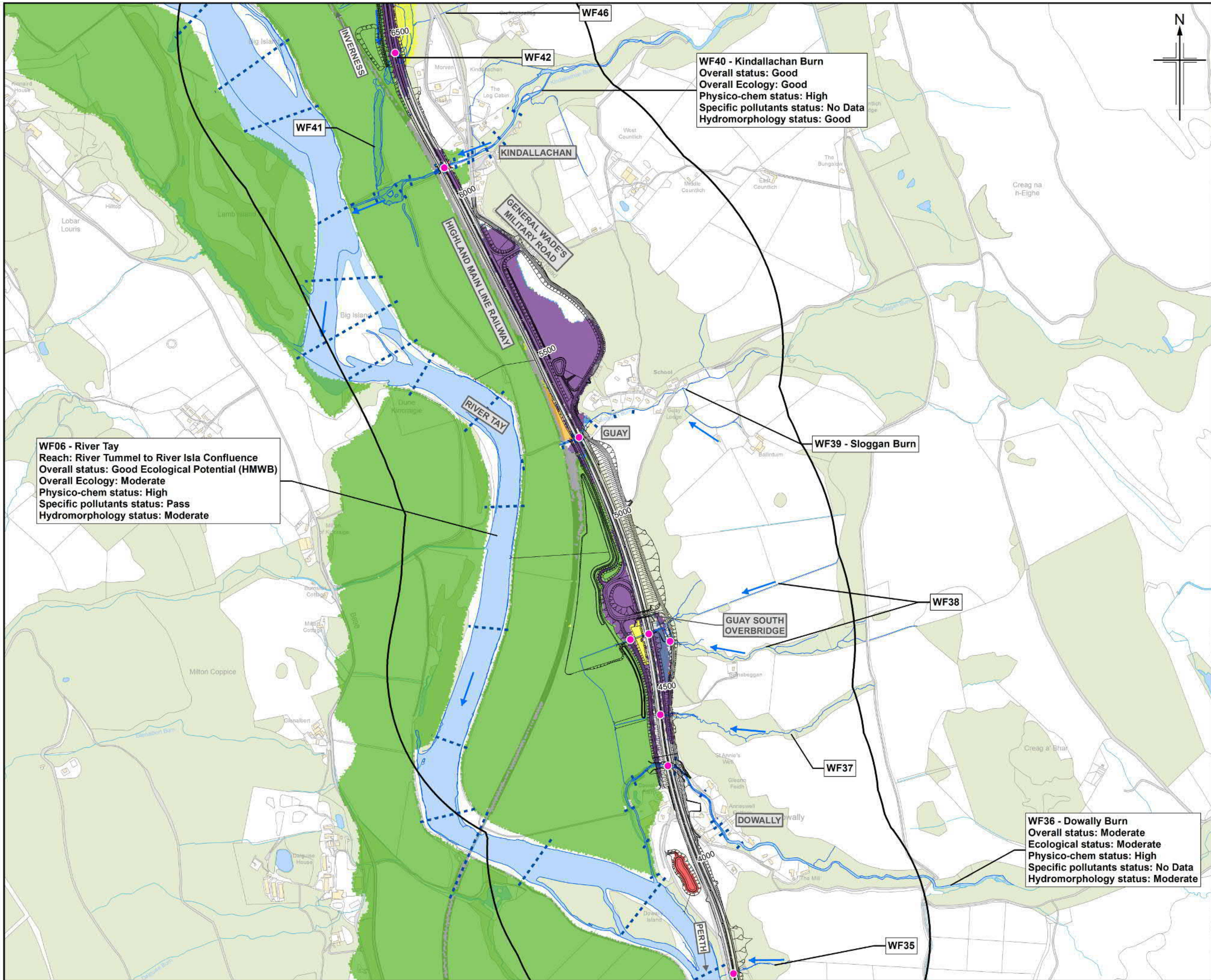
Project: A9 DUALLING PERTH TO INVERNESS Tay Crossing to Ballinluig

Drawing title

Environmental Statement
Fluvial Flood Depth Impact Map
With Scheme (No Mitigation)

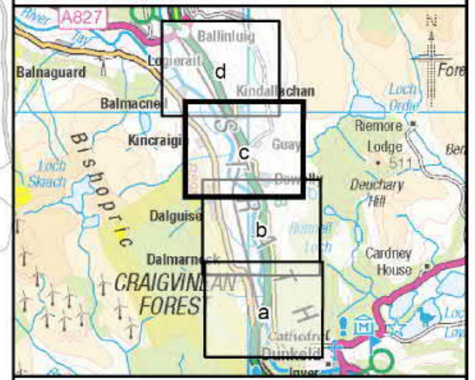
Sheet 2 of 4

Drawing Status	FINAL	
Scale	1:10,000 @ A3	DO NOT SCALE
Jacobs No.	B2140003	
BIM No.		
Drawing number	Figure 11.3.4b	Rev 0



0 0.25 0.5 1 kilometres

Figure 11.3.4c



Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- Flood model cross section

Flood Level Difference (m) during the 0.5% AEP (200-year) plus CC event

- > -0.1 Major Beneficial
- -0.1 to -0.05 Moderate Beneficial
- -0.05 to -0.01 Minor Beneficial
- -0.01 to 0.01 Negligible
- 0.01 to 0.05 Minor Adverse
- 0.05 to 0.1 Moderate Adverse
- > 0.1 Major Adverse

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK
Tel: +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

Drawing title

Environmental Statement
Fluvial Flood Depth Impact Map
With Scheme (No Mitigation)

Sheet 3 of 4

Drawing Status	FINAL		
Scale	1:10,000	@ A3	DO NOT SCALE
Jacobs No.	B2140003		
BIM No.			
Drawing number	Figure 11.3.4c	Rev	0

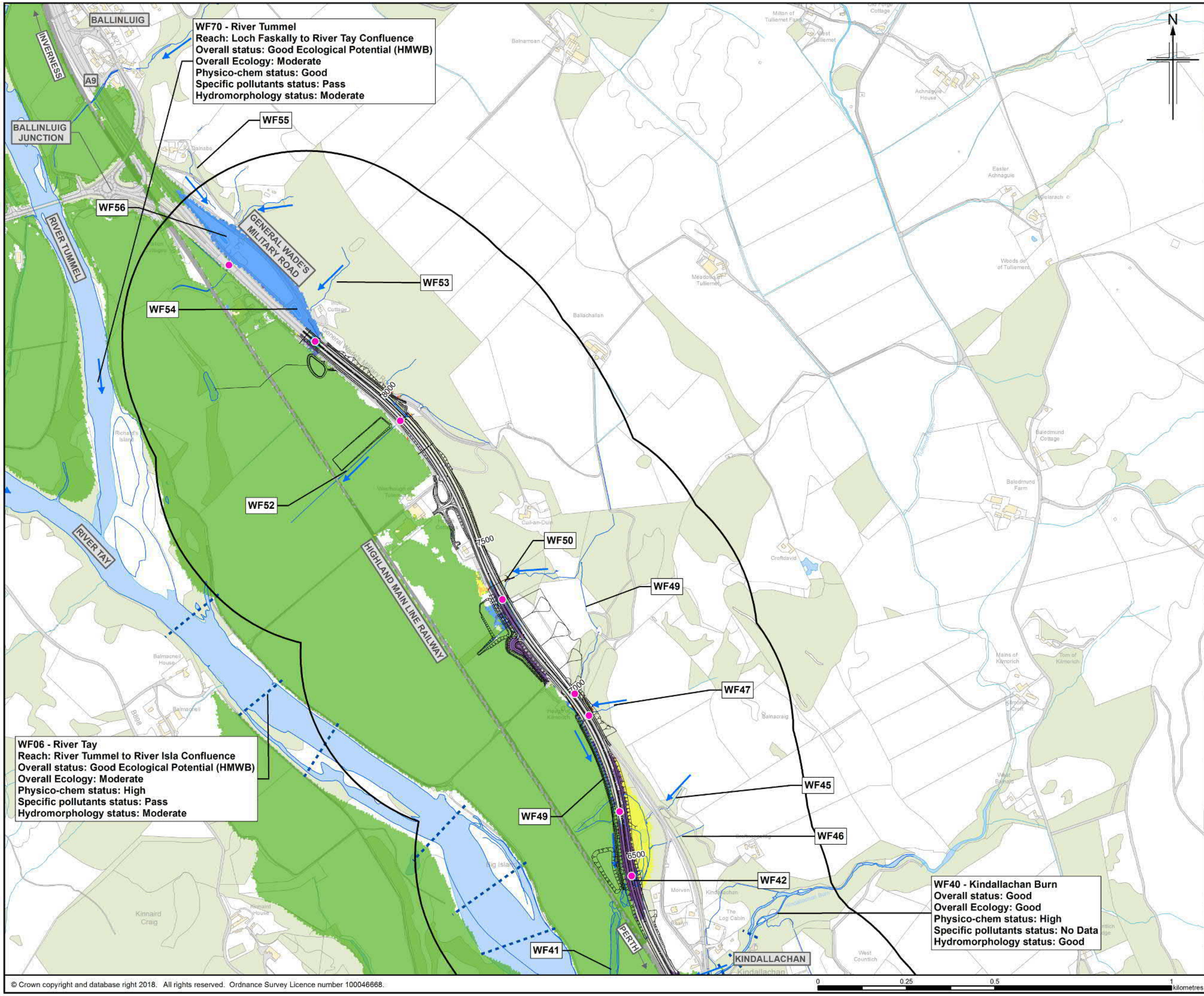
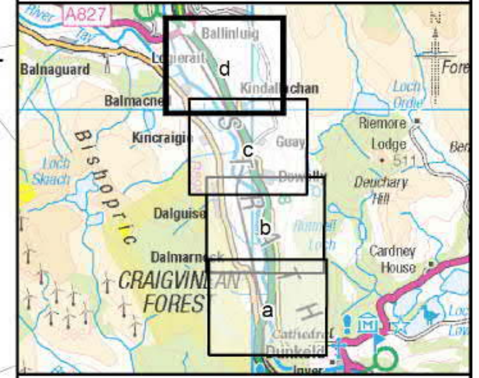


Figure 11.3.4d



Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- Flood model cross section

Flood Level Difference (m) during the 0.5% AEP (200-year) plus CC event

- > -0.1 Major Beneficial
- -0.1 to -0.05 Moderate Beneficial
- -0.05 to -0.01 Minor Beneficial
- -0.01 to 0.01 Negligible
- 0.01 to 0.05 Minor Adverse
- 0.05 to 0.1 Moderate Adverse
- > 0.1 Major Adverse

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK
Tel: +44(0)141 243 8000
www.jacobs.com

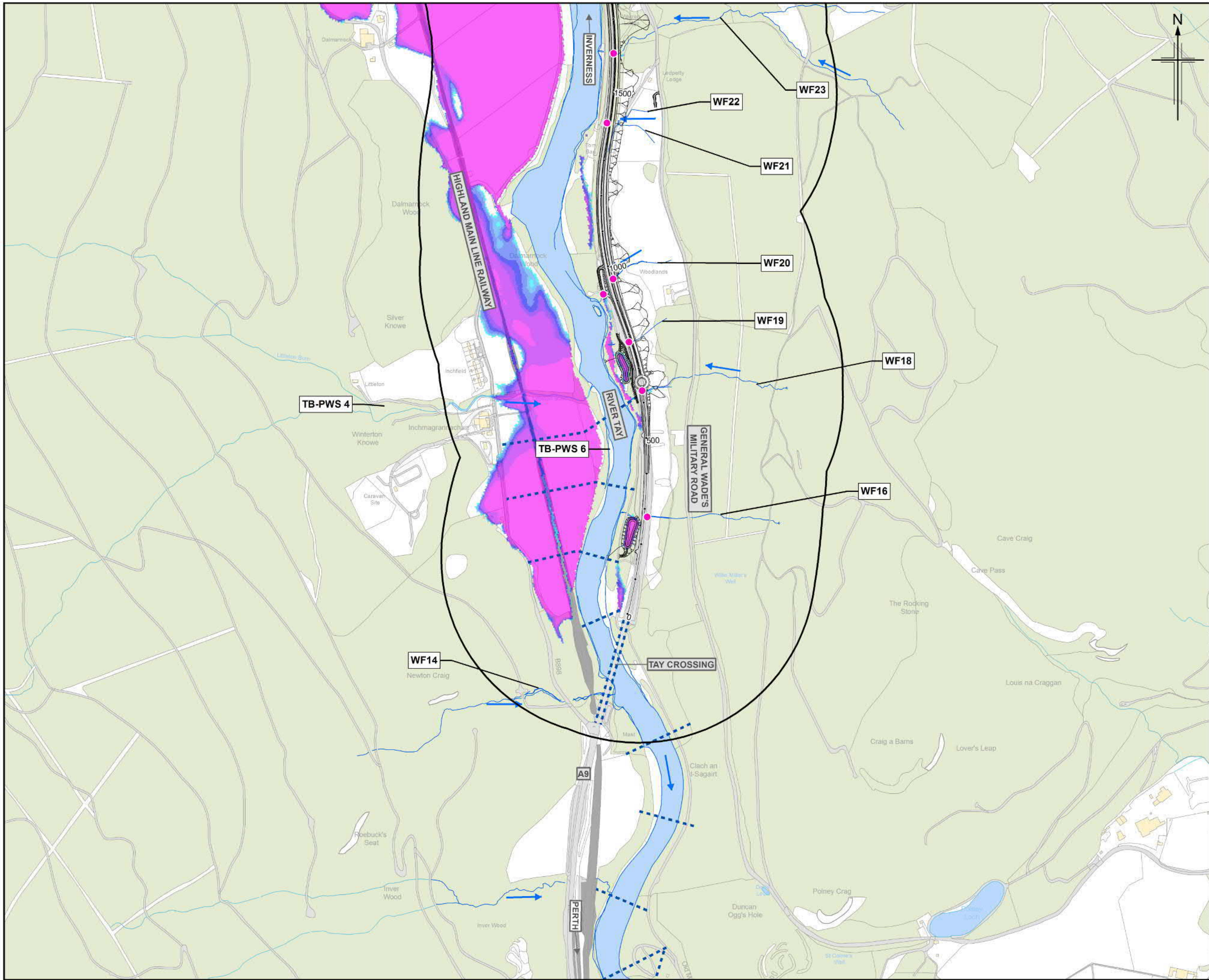
Client
TRANSPORT SCOTLAND
COMHDHAIL ALBA

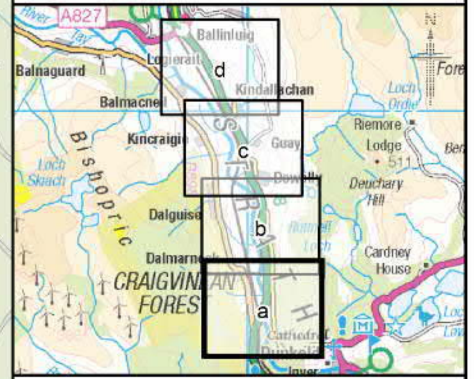
Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

Drawing title
Environmental Statement
Fluvial Flood Depth Impact Map
With Scheme (No Mitigation)
Sheet 4 of 4

Drawing Status	FINAL		
Scale	1:10,000	@ A3	DO NOT SCALE
Jacobs No.	B2140003		
BIM No.			
Drawing number	Figure 11.3.4d		Rev 0

Figure 11.3.5a





Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- Flood model cross section

Modelled flood depths (m) during the 0.5% AEP (200-year) plus CC event in the proposed scheme (with mitigation) scenario

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK
Tel: +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

Drawing title

Environmental Statement
Fluvial Flood Depth Map
With Scheme (With Mitigation)

Sheet 1 of 4

Drawing Status	FINAL	
Scale	1:10,000 @ A3	DO NOT SCALE
Jacobs No.	B2140003	
BIM No.		
Drawing number	Figure 11.3.5a	Rev 0

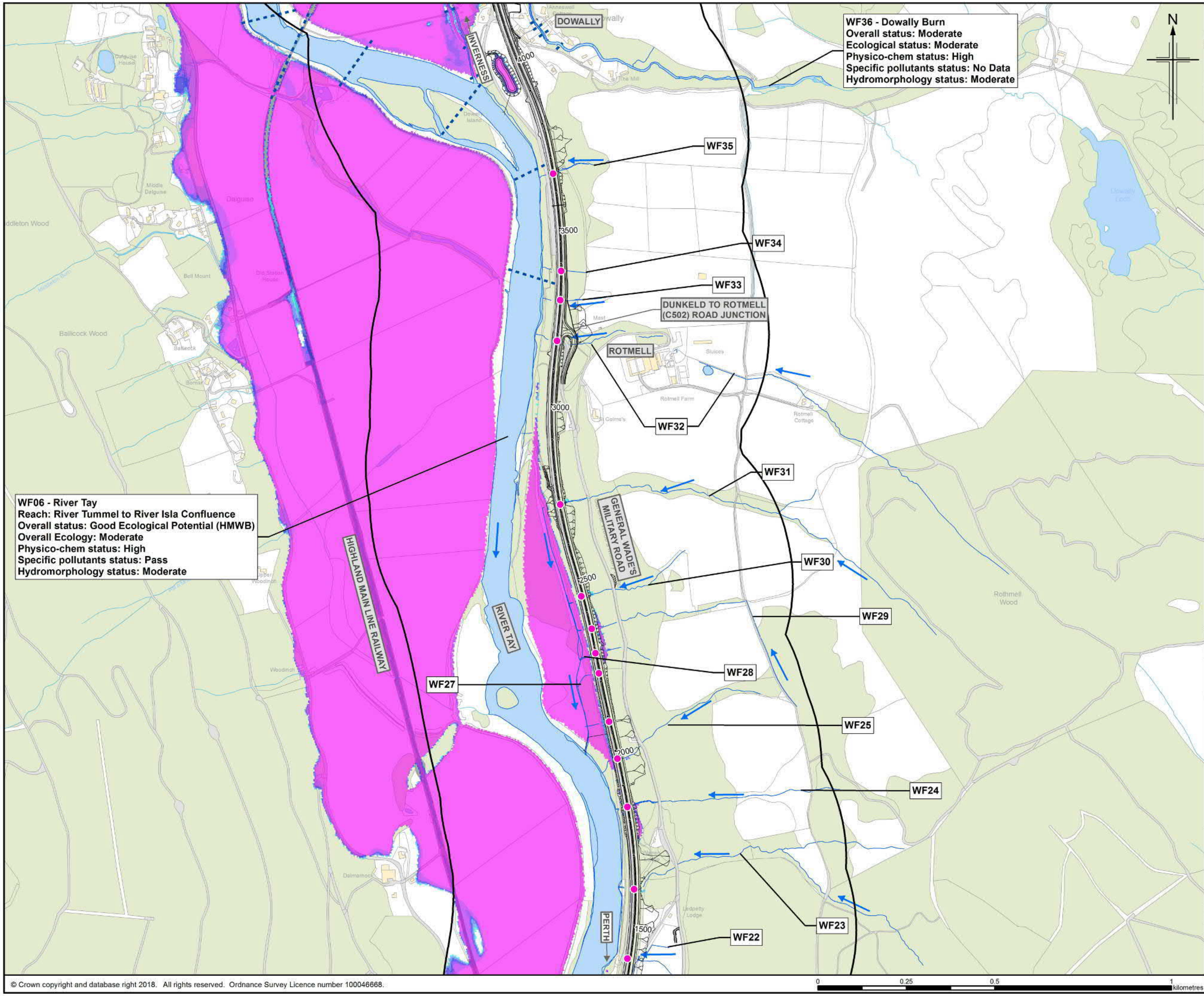
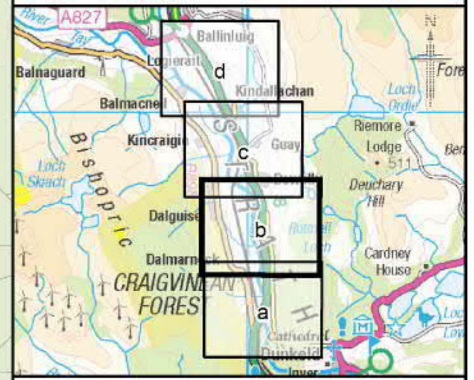


Figure 11.3.5b



Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- Flood model cross section

Modelled flood depths (m) during the 0.5% AEP (200-year) plus CC event in the proposed scheme (with mitigation) scenario

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK
Tel. +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

Drawing title
Environmental Statement
Fluvial Flood Depth Map
With Scheme (With Mitigation)

Sheet 2 of 4

Drawing Status	FINAL		
Scale	1:10,000	@ A3	DO NOT SCALE
Jacobs No.	B2140003		
BIM No.			
Drawing number	Figure 11.3.5b		Rev 0

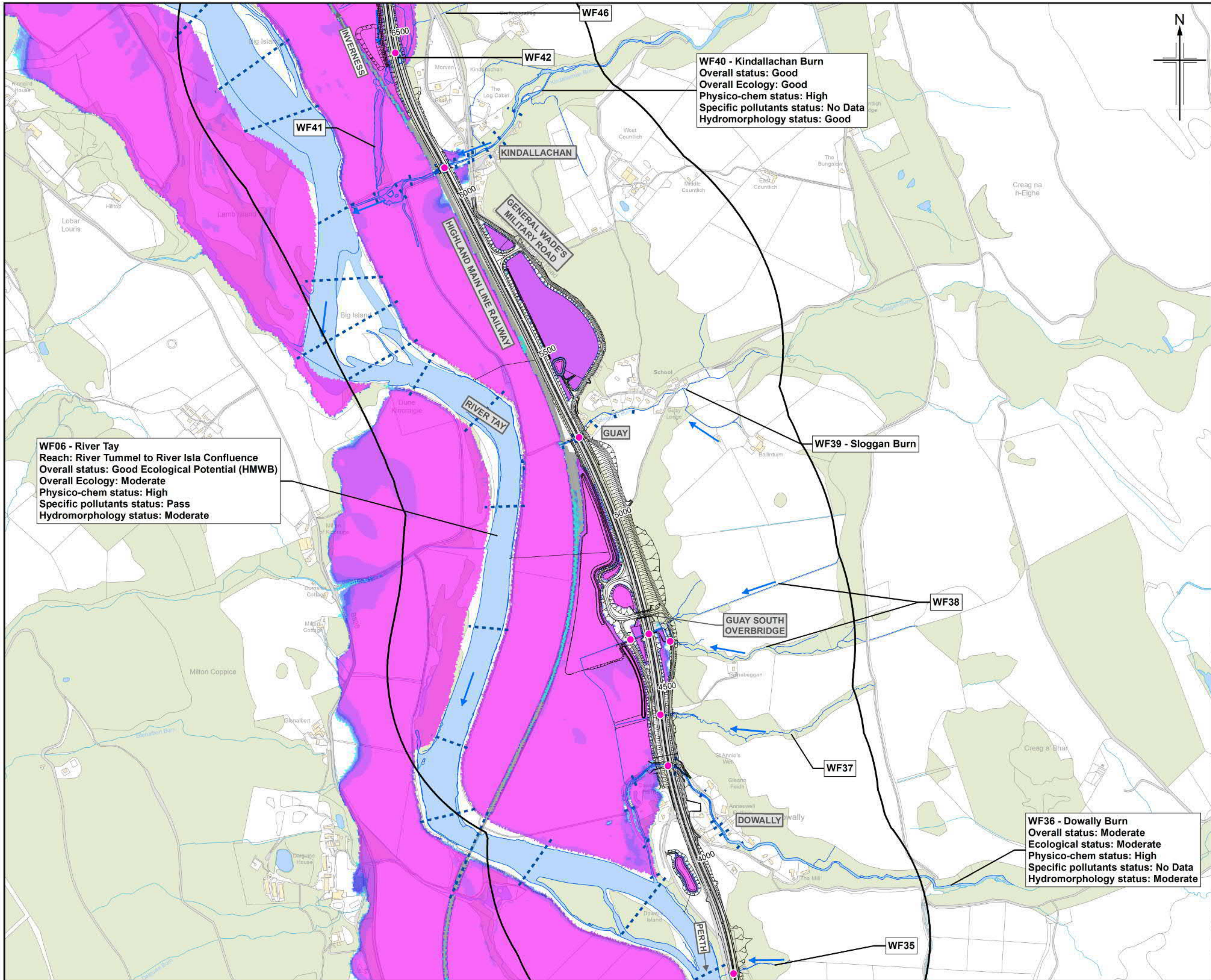
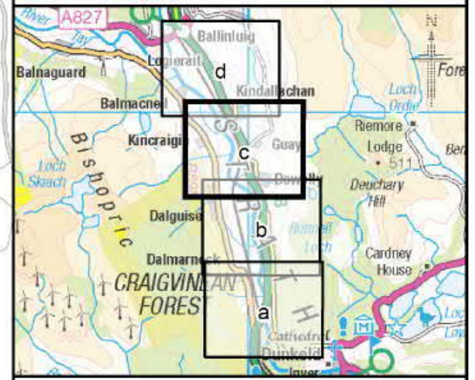


Figure 11.3.5c



Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- Flood model cross section

Modelled flood depths (m) during the 0.5% AEP (200-year) plus CC event in the proposed scheme (with mitigation) scenario

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK
Tel: +44(0)141 243 8000
www.jacobs.com

Client

TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

Project

A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

Drawing title

Environmental Statement
Fluvial Flood Depth Map
With Scheme (With Mitigation)

Sheet 3 of 4

Drawing Status	FINAL		
Scale	1:10,000	@ A3	DO NOT SCALE
Jacobs No.	B2140003		
BIM No.			
Drawing number	Figure 11.3.5c		Rev 0

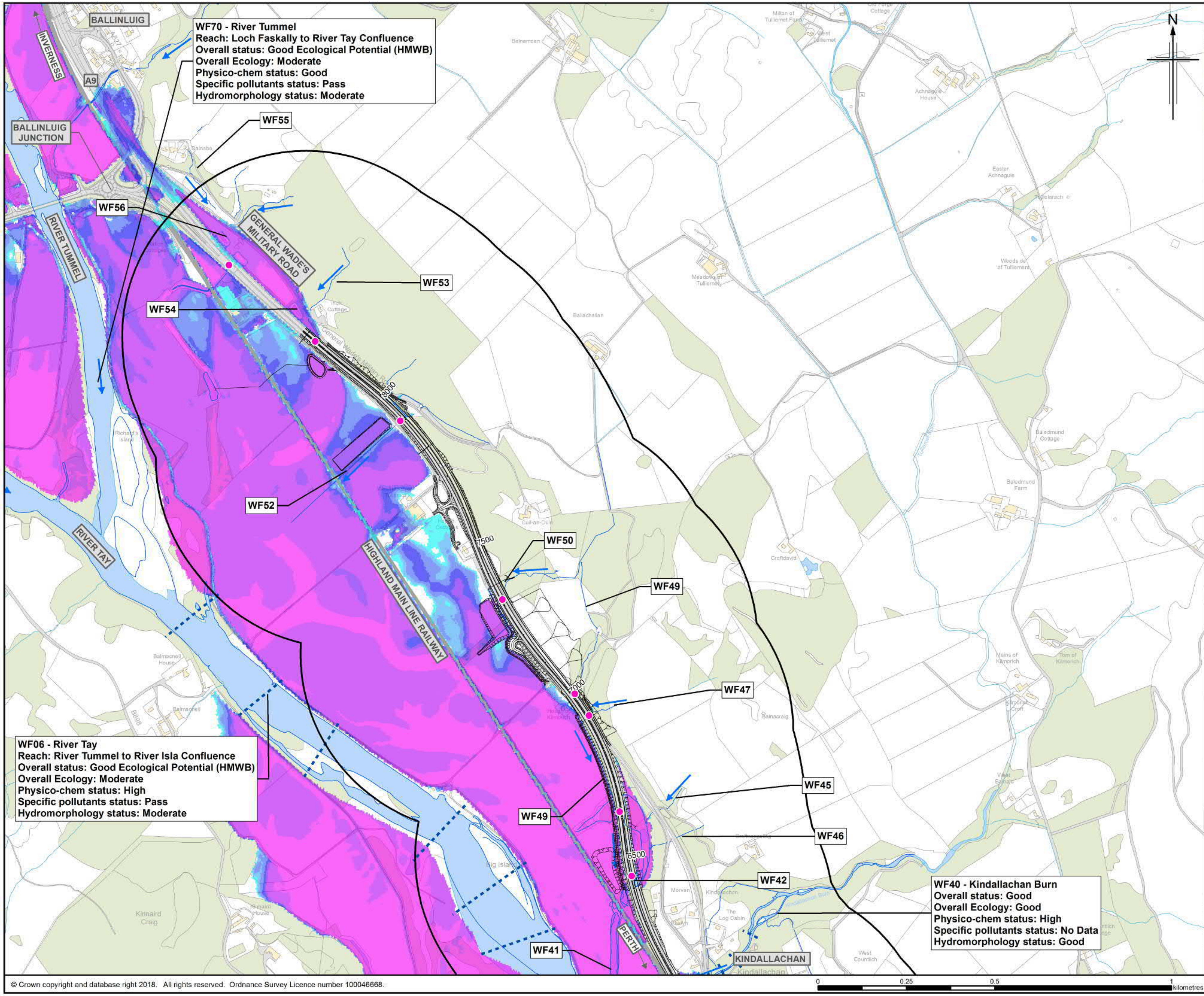
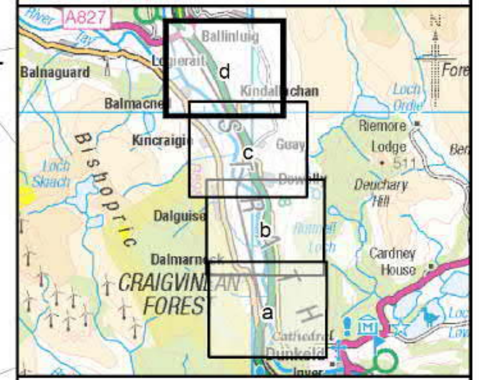


Figure 11.3.5d



Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- Flood model cross section

Modelled flood depths (m) during the 0.5% AEP (200-year) plus CC event in the proposed scheme (with mitigation) scenario

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK
Tel +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

Drawing title

Environmental Statement
Fluvial Flood Depth Map
With Scheme (With Mitigation)

Sheet 4 of 4

Drawing Status	FINAL		
Scale	1:10,000	@ A3	DO NOT SCALE
Jacobs No.	B2140003		
BIM No.			
Drawing number	Figure 11.3.5d	Rev	0

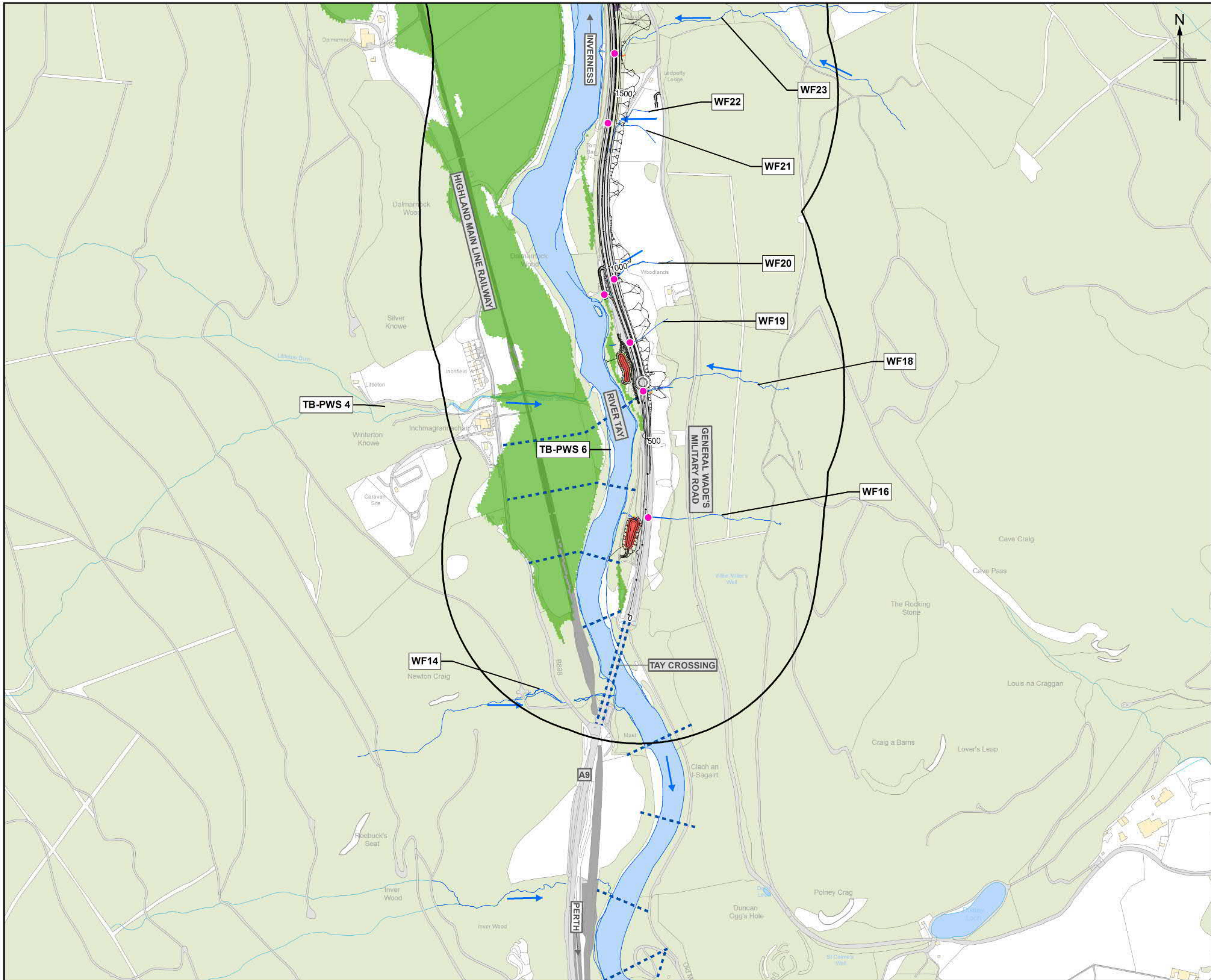
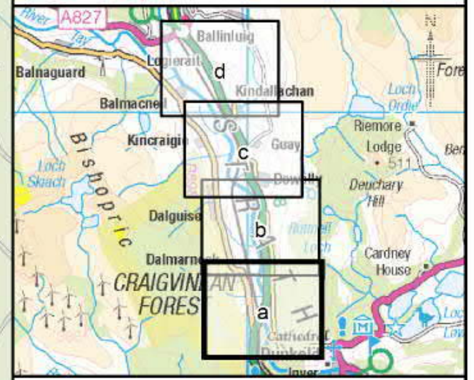


Figure 11.3.6a



Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse Crossing
- Flood model cross section

Flood Level Difference (m) during the 0.5% AEP (200-year) plus CC event

- > -0.1 Major Beneficial
- -0.1 to -0.05 Moderate Beneficial
- -0.05 to -0.01 Minor Beneficial
- -0.01 to 0.01 Negligible
- 0.01 to 0.05 Minor Adverse
- 0.05 to 0.1 Moderate Adverse
- > 0.1 Major Adverse

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK
Tel: +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

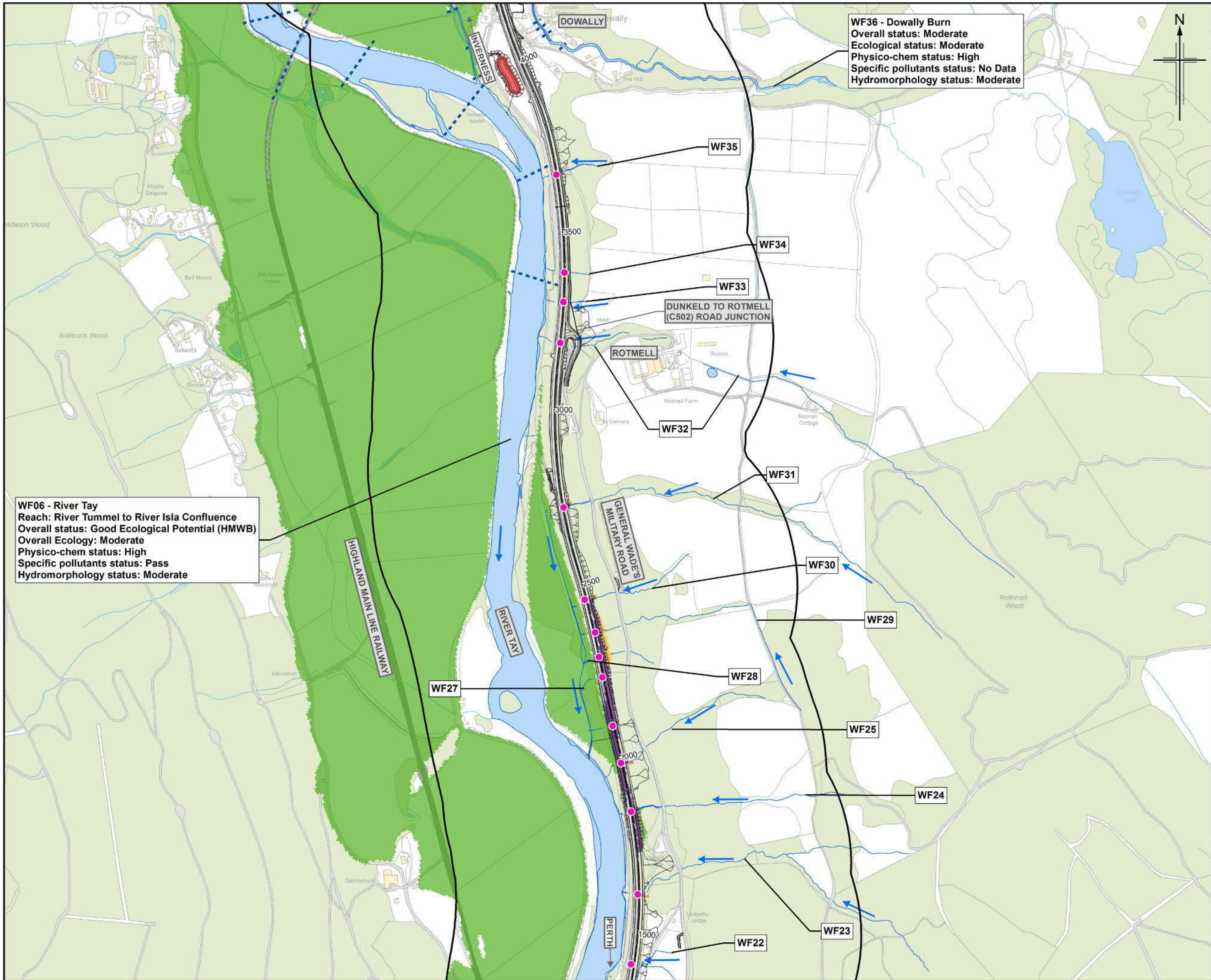
Drawing title

Environmental Statement
Fluvial Flood Depth Impact Map
With Scheme (With Mitigation)

Sheet 1 of 4

Drawing Status	FINAL
Scale	1:10,000 @ A3 DO NOT SCALE
Jacobs No.	B2140003
BIM No.	
Drawing number	Figure 11.3.6a
Rev	0

0 0.25 0.5 1 kilometres



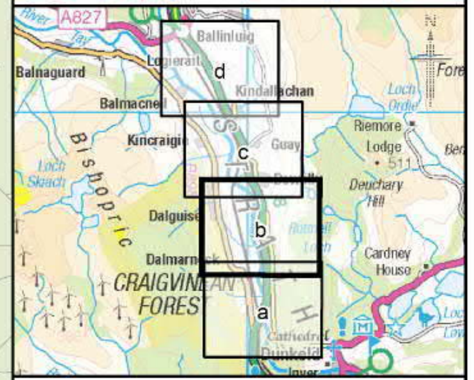


Figure 11.3.6b

Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse Crossing
- Flood model cross section

Flood Level Difference (m) during the 0.5% AEP (200-year) plus CC event

- > -0.1 Major Beneficial
- -0.1 to -0.05 Moderate Beneficial
- -0.05 to -0.01 Minor Beneficial
- -0.01 to 0.01 Negligible
- 0.01 to 0.05 Minor Adverse
- 0.05 to 0.1 Moderate Adverse
- > 0.1 Major Adverse

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK
Tel: +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

Drawing title

Environmental Statement
Fluvial Flood Depth Impact Map
With Scheme (With Mitigation)

Sheet 2 of 4

Drawing Status	FINAL		
Scale	1:10,000	@ A3	DO NOT SCALE
Jacobs No.	B2140003		
BIM No.			
Drawing number	Figure 11.3.6b		Rev 0

0 0.25 0.5 1 kilometres

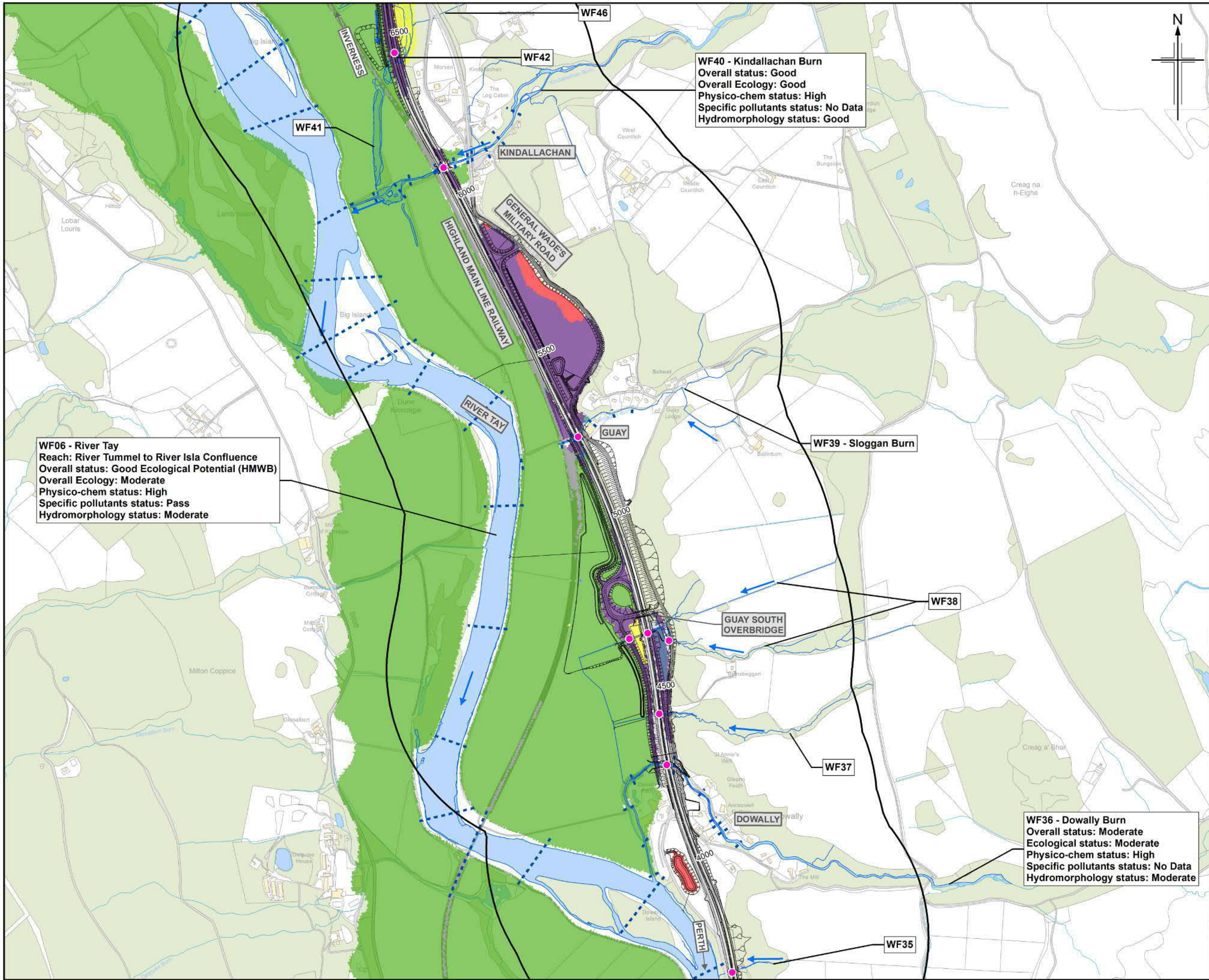
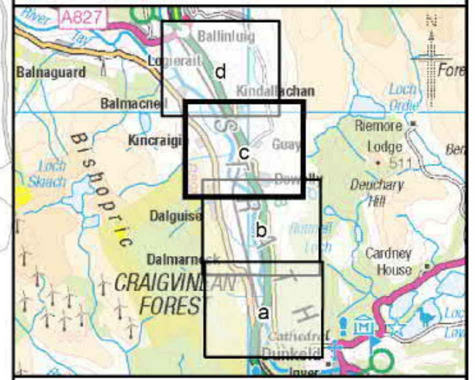


Figure 11.3.6c



Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse Crossing
- Flood model cross section

Flood Level Difference (m) during the 0.5% AEP (200-year) plus CC event

- > -0.1 Major Beneficial
- -0.1 to -0.05 Moderate Beneficial
- -0.05 to -0.01 Minor Beneficial
- -0.01 to 0.01 Negligible
- 0.01 to 0.05 Minor Adverse
- 0.05 to 0.1 Moderate Adverse
- > 0.1 Major Adverse

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK
Tel: +44(0)141 243 8000
www.jacobs.com

Client
TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

Project
A9 DUALLING
PERTH TO INVERNESS
Tay Crossing to Ballinluig

Drawing title

Environmental Statement
Fluvial Flood Depth Impact Map
With Scheme (With Mitigation)

Sheet 3 of 4

Drawing Status	FINAL		
Scale	1:10,000	@ A3	DO NOT SCALE
Jacobs No.	B2140003		
BIM No.			
Drawing number	Figure 11.3.6c	Rev	0

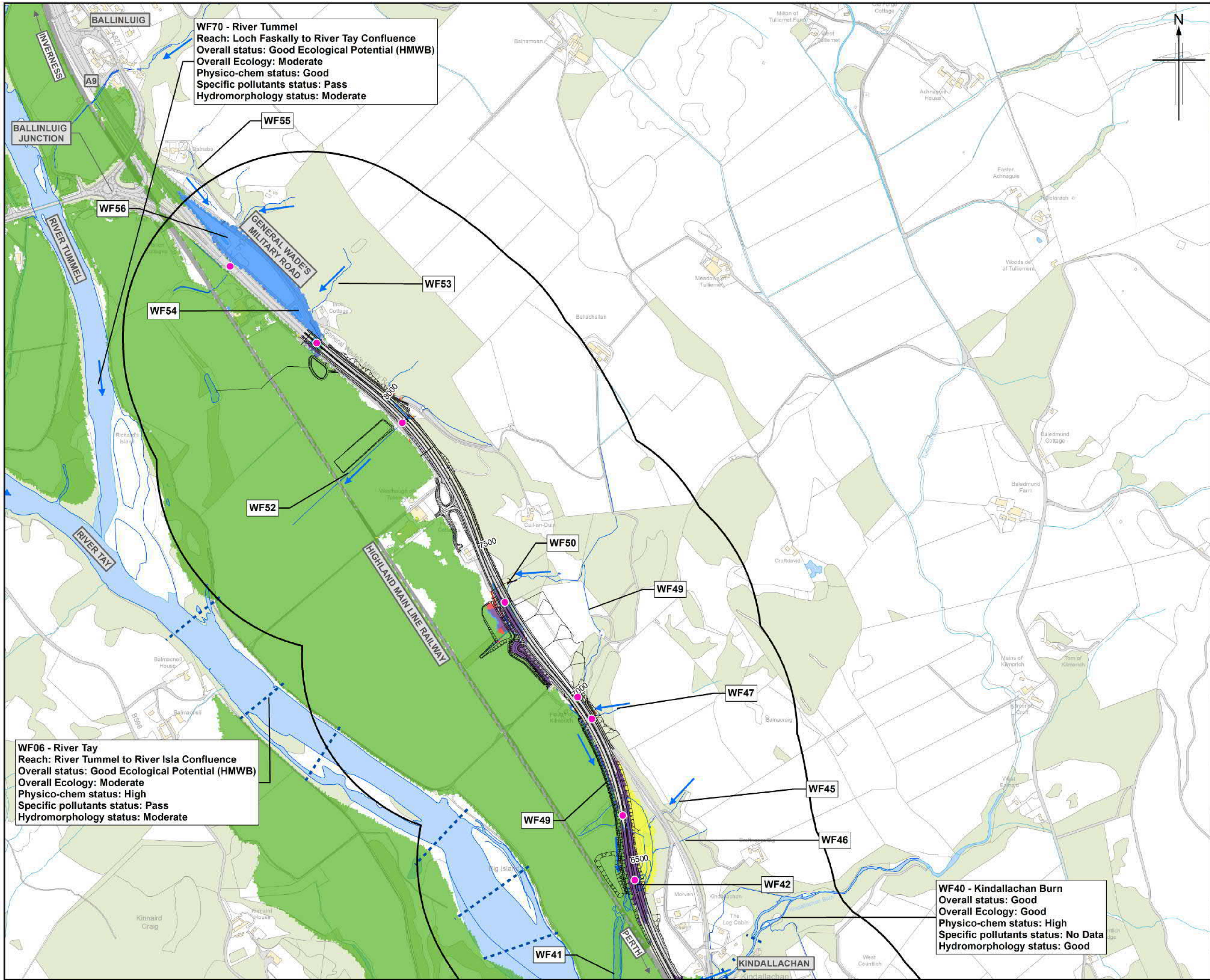
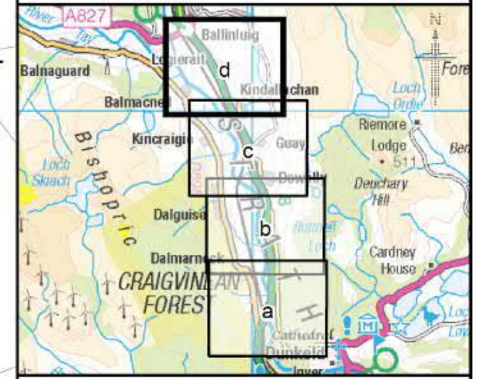


Figure 11.3.6d



Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse Crossing
- Flood model cross section

Flood Level Difference (m) during the 0.5% AEP (200-year) plus CC event

- > -0.1 Major Beneficial
- -0.1 to -0.05 Moderate Beneficial
- -0.05 to -0.01 Minor Beneficial
- -0.01 to 0.01 Negligible
- 0.01 to 0.05 Minor Adverse
- 0.05 to 0.1 Moderate Adverse
- > 0.1 Major Adverse

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	JUL 2018	ES Publication	RW	CS	DL	AJG

JACOBS
95 Bothwell Street, Glasgow, G2 7HX, UK
Tel: +44(0)141 243 8000
www.jacobs.com

Client: TRANSPORT SCOTLAND, CÒMHDHAIL ALBA

Project: A9 DUALLING PERTH TO INVERNESS, Tay Crossing to Ballinluig

Drawing title

Environmental Statement
Fluvial Flood Depth Impact Map
With Scheme (With Mitigation)

Sheet 4 of 4

Drawing Status	FINAL	
Scale	1:10,000 @ A3	DO NOT SCALE
Jacobs No.	B2140003	
BIM No.		
Drawing number	Figure 11.3.6d	Rev 0