Jacobs

Grangemouth Flood Protection Scheme

Environmental Impact Assessment Report

Prepared by:
Jacobs
95 Bothwell Street
Glasgow, Scotland G2 7HX
United Kingdom
T +44 (0)141 243 8000
F +44 (0)141 226 3109
www.jacobs.com

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Acronyms

AEP	Annual Exceedance Probability
BGS	British Geological Society
CAR	Controlled Activity Regulations
CEMP	Construction Environmental Management Plan
CSM	Conceptual Site Model
EIA	Environmental Impact Assessment
FPS	Flood Protection Scheme
GBR	General Binding Rules
GI	Ground Investigation
GWDTE	Groundwater Dependent Terrestrial Ecosystems
MHWS	Mean High Water Springs
MImAS	Morphological Impact Assessment System
NGR	National Grid Reference
NMP	National Marine Plan
NPF	National Planning Framework
NRFA	National River Flow Archives
NVC	National Vegetation Classifcation
PWS	Private Water Supplies
QMED	Median Annual Flood Flow
RBMP	River Basin Management Plan
RSPB	Royal Society for the Protection of Birds
SAC	Special Area of Conservation
SAL	Single Activity Limit
SEPA	Scottish Environment Protection Agency
SPA	Special Protection Area
SSSI	Special Site of Scientific Interest
WEWS	Water Environment Water Services
WFD	Water Framework Directive
WHO	World Health Organisation

10 Water Environment

10.1 Introduction

This chapter considers the potential impacts and the significance of effects of the Scheme on the water environment's character, and includes assessment of the following:

- geomorphology (fluvial and estuarine);
- surface water quality and supply;
- flood risk;
- hydrogeology and water quality of groundwater bodies;
- groundwater dependent terrestrial ecosystems (GWDTEs); and
- private water supplies and abstractions.

The assessment is supported by the following appendices:

- Appendix C10.1: Fluvial Geomorphology;
- Appendix C10.2: Estuarine Geomorphology;
- Appendix C10.3: Flood Risk;
- Appendix C10.4: Groundwater;
- Appendix C10.5: Water Framework Directive (WFD); and
- Appendix C10.6 Impact Assessment Tables.

The assessment assumes the primary mitigation measures as modifications intrinsic to the design of the Scheme as set out in Table 4.2 of Chapter 4: The Scheme. Measures specific to reducing effects on the water environment include:

- the incorporation of toe protection at the seaward side of the proposed defences in Flood Cells 3 and 6 (those on the open estuary coast) to reduce erosion;
- embankments in preference to flood walls, to allow for a more natural bank form and consequently lower impact on hydromorphology;
- limiting the footprint of coastal defences where possible to minimise encroachment into the intertidal areas through adjustment of the defence alignment and steepening of defences;
- setting back as far from the banks as possible to reduce in-water working and allow maximum channel-floodplain connectivity and reduce the changes in velocity and resulting sediment transport; and
- specifying a sheet pile design / depth that allows for continued flow of groundwater.

10.2 Policy and legislative framework

10.2.1 Overview

This section identifies key water-related directives, legislation and policy relevant to this chapter. Legislation and policy governing the scope of assessment of potential Scheme impacts includes:

- Urban Waste Water Treatment Directive 91/271/EEC.
- Water Framework Directive (WFD) 2000/60/EC: Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.
- Water Environment and Water Services Act (Scotland) 2003, which transposes the WFD Directive into Scottish law (as amended by the Environment (EU Exit) (Scotland) (Amendment etc.) Regulations 2019 and the European Union (Withdrawal) Act 2018).
- Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) and the Water Environment (Miscellaneous) (Scotland) Regulations 2017.
- Flood Risk Management (Scotland) Act 2009.
- Marine (Scotland) Act 2010.
- National Planning Framework 4 (NPF4) (The Scottish Government 2023).
- Falkirk Local Development Plan 2 (Falkirk Council 2020).

10.2.2 National Planning Framework 4 (NPF4)

The Development Plan relevant to the Falkirk Council area is comprised of National Planning Framework 4 (NPF4) (The Scottish Government 2023) and the Falkirk Local Development Plan 2 (LDP2) (Falkirk Council 2020). NPF4 is the more recent publication, adopted by the Scottish Ministers in February 2023. LDP2 was adopted by Falkirk Council in 2020. Both plans are read together, however where there is any difference in policy content the more recent publication takes precedence, in this case NPF4. NPF4 is considered further in this section, while LDP2 is considered in Section 10.2.3 below.

NPF4 requires planning authorities to strengthen resilience to the impacts of climate change by avoiding areas at flood risk when producing their local development plans (LDPs). Development should consider all sources of flooding (coastal, fluvial, pluvial, groundwater, sewers and blocked culverts) and their associated risks.

The aims of NPF4 in relation to flooding are to:

- improve resilience to flood risk;
- make water resource use more efficient and sustainable; and
- increase the use of natural flood risk management.

NPF4 Policy 22 'Flood risk and water management' provides the framework for consideration of development proposals in relation to flood risk.

The purpose of the Scheme is to reduce flood risk to sensitive receptors within Grangemouth, which will improve resilience to flood risk.

10.2.3 Falkirk Council Local Development Plan 2 (LDP2): Adopted August 2020

LDP2 outlines three policies which have informed the assessment of the water environment. These are:

- PE22 The Water Environment: Aims to ensure integrity of water quality and habitat of the water environment, in line with the WFD, in addition to maintaining recreational amenity of water bodies.

This is implemented through support of the development of measures to improve the ecological status of the water environment including naturalisation of watercourses and a general presumption against developments which have a detrimental effect on the ecological quality or recreational amenity of the water environment.

- PE23 The Marine Planning and the Coastal Zone: Supports the policies of the National Marine Plan and the Regional Marine Plan, when prepared.
- PE24 Flood Management: The supporting text of this policy notes the Grangemouth Flood Protection Scheme as the highest priority action for the local authority within this policy area. The policy sets out the approach to other developments which may be at risk of flooding.

10.2.4 Marine planning policy

Scotland's National Marine Plan (NMP) (Scottish Government 2015) sets out strategic policies for the sustainable development of Scotland's marine resources out to 200 nautical miles. The Scottish Ministers must make authorisation and enforcement decisions, or any other decisions that affects the marine environment, in accordance with the NMP. Policies of the NMP of key relevance this chapter are as follows:

- GEN 1 General Planning Principle: "There is a presumption in favour of sustainable development and use of the marine environment when consistent with the policies and objectives of the plan".
- GEN 5 Climate change: "Marine planners and decision makers must act in the way best calculated to mitigate, and adapt to, climate change."
- GEN 8 Coastal process and flooding: "Developments and activities in the marine environment should be resilient to coastal change and flooding, and not have unacceptable adverse impact on coastal processes or contribute to coastal flooding."
- GEN 12 Water quality and resource: "Developments and activities should not result in a deterioration of the quality of waters to which the Water Framework Directive, Marine Strategy Framework Directive or other related Directives apply."

10.3 Methodology

10.3.1 Structure of assessment

The assessment of the water environment is structured as follows:

- Baseline (Section 10.4);
- Impact Assessment (Section 10.5);
- Mitigation (Section 10.6);
- Residual Impacts (Section 10.7);
- Interaction with other environmental disciplines (Section 10.8);
- Cumulative effects (Section 10.9);
- Potential enhancement/offsetting opportunities (Section 10.10); and

- Monitoring (Section 10.11).

The water environment is intrinsically linked to human health, ecological and geological receptors, which are considered in Chapter 6: Population and Human Health, Chapter 7: Biodiversity, and Chapter 11: Soils, Geology and Land Contamination.

A detailed WFD compliance assessment of the Scheme is presented in Appendix C10.5 (Annexes C10.5.1 – C10.5.3).

10.3.2 Study area

The study area for surface waters has been assessed as the whole extent of WFD baseline surface water bodies (SEPA, 2024a) overlapping the Flood Cells and their associated catchments. The study area for estuarine includes the Middle Forth, which extends between Kincardine Bridge upstream and the town of Bo'ness, downstream on the southern bank of the Forth and includes the tidal reaches of the River Carron, Grange Burn and River Avon. For groundwater, and associated receptors (such as GWDTE), a study area of up to 1km from the direct defences (such as flood walls, embankments, ground raising and demountable defences) has been defined. Details of the study area for each groundwater receptor are presented in Appendix C10.4: Groundwater.

10.3.3 Baseline data sources

10.3.3.1 Desk-based assessment

Desk based information used to inform the assessment is summarised within Table 10-1.

Table 10-1: Sources of Desk-based Information

Topic	Sources of Information
Mapping and spatial data	• 1:25,000 Ordnance Survey (OS) maps; • LiDAR topographical survey data (Scottish Government 2023); • Historical maps (National Library of Scotland, 2023); • British Geological Survey (BGS) 1:50,000 scale Digital Mapping (BGS, 2023); • SEPA Flood Maps (SEPA, 2022a);
Hydrological and Hydrogeological data	• SEPA RBMP data and classification results available on the SEPA Water Environment Hub (SEPA 2024a) and Water Classification Hub (SEPA 2024b); • The river basin management plan for the Scotland river basin district: 2015–2027 (Scottish Government 2015); • The River Basin Management Plan for the Scotland River Basin District 2021-2027 (Scottish Government, 2021); • National River Flow Archive (CEH, 2022); • SEPA river gauging data records (SEPA, 2022c); • Groundwater flood risk information (GeoSmart, 2019); • Private water supply and abstraction information from Falkirk Council (Consultation); • SEPA CAR licences (SEPA, 2020); and • Morphological Impact Assessment System (MImAS) baseline data for relevant watercourses (SEPA 2023) (Received from SEPA, January 2023).

10.3.3.2 Surveys

The assessment has been informed by geomorphological walkover surveys which were carried out on 10th -13th March 2016 (CH2M 2017) and updated coastal geomorphological surveys carried out on 10th - 11th April 2019. The assessment of GWDTEs has been informed by ecological surveys carried out in June 2019, followed by site visits to specific locations with potential groundwater dependence in 2020. Additional ecological surveys were undertaken in 2022/23. Further information on the ecological surveys can be found in Chapter 7: Biodiversity.

10.3.3.3 Consultation

Consultation with statutory stakeholders, including Falkirk Council and SEPA, was initially carried out at the scoping stage in 2019. Further consultation on a draft of the EIA Report was then undertaken in 2020 and 2023. Consultation of relevance to this Chapter is summarised in Table 10-2. Further information on stakeholder engagement can be found in Chapter 5 (Stakeholder Engagement) of this EIA Report and a summary of the scoping responses received from SEPA and Falkirk Council is presented in Appendix C3.2 (Scoping Responses).

Table 10-2: Summary of Stakeholder Consultation

Consultee	Date(s)	Aspect	Comments
Falkirk Council	26th June 2019	Scope of assessment	A workshop was held with Falkirk Council to agree the scope of the assessment.
SEPA	20th February 2019	Scope of assessment - Flood Risk	SEPA provided comment on the Scoping Report. Comment was provided on the requirement for CAR Licensing and opportunities to improve the condition of water bodies under WFD.
SEPA	24th June 2019	Scoping report, comments from Hydromorphology	SEPA provided comment on the implications of the Scheme on hydromorphology. Comment was also provided on the assessment approach and regulatory requirements.
SEPA	30th September 2020	Interim Advice regarding the Draft Environmental Impact Assessment Report	SEPA provided advice on the Draft Environmental Impact Assessment Report and accompanying appendices, particularly on the implications of the Scheme on fluvial geomorphology. SEPA also recommended further consideration to be given to the scope and nature of associated monitoring.
SEPA	13th November 2020	Advice regarding the Draft Environmental Impact Assessment Report	SEPA provided advice on the Draft Environmental Impact Assessment Report and accompanying appendices. SEPA also recommended further consideration to be given to fluvial geomorphology mitigation measures.

Consultee	Date(s)	Aspect	Comments
Marine Scotland	5th February 2020	Scope of assessment	Marine Scotland provided comment on the Scoping Report. In relation to the Water Environment chapter Marine Scotland advised a WFD assessment should be included within the EIAR and provided feedback regarding coastal processes methodology. In response to this feedback, a WFD assessment can be found in Appendix C10.5: Water Framework Directive and all recommendations concerning coastal processes have been considered in Appendix C10.2: Estuarine Geomorphology.
Marine Scotland	12th October 2020	Draft Environmental Impact Assessment Report	Marine Scotland provided comment on the Draft Environmental Impact Assessment Report, regarding the Water Environment. Marine Scotland is content with approach to the Hydraulic Modelling Report.
Falkirk Council	June 2023	Draft Environmental Impact Assessment Report	Falkirk Council provided minor comment on the Draft Environmental Impact Assessment Report updates which took place in early 2023.
SEPA	September 2023	Draft Environmental Impact Assessment Report	SEPA provided comment on the Draft Environmental Impact Assessment Report updates which took place in early to mid-2023. and accompanying appendices. SEPA provided further comment regarding fluvial geomorphology and water quality mitigation measures.

10.3.4 Discipline Specific Methodologies

10.3.4.1 Introduction

This Section presents a summary of methodologies used for specific disciplines within this chapter. Full details on discipline-specific assessment methodologies are presented within the appendices.

10.3.4.2 Estuarine Geomorphology

The detailed methodology for the assessment of impacts to Estuarine Geomorphology is presented in Appendix C10.2: Estuarine Geomorphology.

Flood Cells 1 to 6 have been assessed according to the level of tidal interaction. Estuarine processes control Flood Cells 3 and 6; Flood Cells 1, 2, 4 and 5 are tidally dominated by the River Carron (Flood Cells 1 and 2), Grange Burn (Flood Cell 4) and River Avon (Flood Cell 5). The baseline set out in Section 10.4.10 is informed by prior studies and modelling for the Forth Estuary.

Effects on wave climate have been scoped out of this assessment as there is no likely modification of local or far-field (estuary) wave climates. Impacts due to wave scour have been considered.

Areas of potential habitat loss were calculated using Geographical Information Systems (GIS) from Phase 1 habitat surveys and ecological designations for both temporary and permanent structures in conjunction with Chapter 7: Biodiversity.

Habitat loss as a result of the Scheme was calculated to assist in determining the impact on biodiversity and to inform the approach to mitigation/compensation. Whilst the exact area of habitat loss will be dependent on the construction methods used by the contractor, to inform the assessment, GIS software has been used to calculate temporary and permanent habitat loss, with the following approach being used:

- Temporary habitat loss during construction was calculated by subtracting the Permanent Works Footprint from the Site Boundary Footprint which includes all working areas, haul roads and compound sites.
- Permanent habitat loss to defence footprint is calculated from the Permanent Works Footprint.

10.3.4.3 Fluvial Geomorphology

The detailed methodology for the assessment of impacts to fluvial geomorphology is presented in Appendix C10.1: Fluvial Geomorphology.

A site walkover was undertaken in March 2016. Findings from the site walkover are complemented by a desk study, the latest classification of the WFD water bodies (SEPA, 2024a) and MImAS (Morphological Impact Assessment System – SEPA 2012) data as provided through consultation with SEPA (SEPA, 2023) to assign receptor importance.

The assessment of potential impacts on fluvial geomorphology involved the following:

- Qualitative assessment of the proposed activities to the channel bed morphology and substrate, channel banks and riparian zone.
- A semi-quantitative assessment of variation to channel width and depth, water flows, levels and transport erosion and deposition of sediment. This was undertaken using velocities from various return periods extracted from the numerical model at different channel locations along the receptors identified in Section 10.4 – Baseline.
- Hjulström analysis to identify any potential changes in the rate of sediment transport and the size of sediment transportable, eroded and deposited resulting from the Scheme changing flow velocities within the receptors.

As a conservative approach, the maximum velocity under baseline and 'with scheme' conditions returned from the modelled cross sections has been used. It is considered that under the maxima, changes to sediment dynamics, would occur. The Hjulström curve uses the modelled velocities to provide a visual assessment of the clast sizes potentially entrained under maximum flow conditions for the baseline and with Scheme 2-year and 200-year maximum velocities. Further details on sediment dynamics methodology can be found within Appendix C10.1 – Fluvial Geomorphology.

10.3.4.4 Surface Water Quality and Supply

A desk study was undertaken to identify existing surface water quality of the watercourses within the study area. This information was informed by the existing WFD status[1] (Physico-Chemical, Specific pollutants, Priority substances) (SEPA 2024b), likely catchment pressures (e.g., point source and diffuse pollution sources) and CAR licensed discharges. Assessment of potential impacts on water supply considered any disruption, pollution or severance of any surface water public or private water supplies or water supply infrastructure through potential conflicts between the Scheme and existing water supply infrastructure. Potential impacts to water quality were informed by appropriate technical guidance, including CIRIA C648 (CIRIA, 2006a), CIRIA C532 (CIRIA, 2001) and CIRIA C744 (CIRIA, 2015a).

10.3.4.5 Flood Risk

The purpose of the Scheme is to mitigate flood risk to existing sensitive receptors and, due to the number of receptors currently at risk of flooding, individual receptors/receptor types are not included in the baseline assessment. Individual or specific receptors/receptor types are only considered within the impact assessment where a change (increase or decrease) in flood depth and/or flood extent is experienced resulting from the Scheme.

The impact assessment for flood risk was conducted through a review of the hydraulic modelling which was undertaken to inform Scheme design and to identify potential adverse and beneficial impacts on flood risk. This included a desk study to compare the changes to flood extents and peak flood depths with the Scheme in place during the 'design flood event', defined as the 0.5% AEP (200-year) flood event. Comparison was made against the baseline modelling of the design flood event without the Scheme. The importance assigned to flood risk receptors is based on SEPA guidance LUPS GU24 (SEPA, 2022b). Magnitude of impacts are informed by typical threshold values used when assessing flood risk in the context of the EIA and are deemed to be appropriate based on professional judgement.

10.3.4.6 Groundwater Quality and Hydrogeology

A desk study was carried out to inform existing groundwater quality and levels using British Geological Survey (BGS) mapping, available ground investigation data, including groundwater monitoring, and groundwater flood risk data. No modelling or quantitative assessment was carried out and impacts to groundwater flows and levels during construction and operation were assessed based on the likelihood of excavations and permanent structures intercepting groundwater.

Potential GWDTEs were identified based on desk reviews of Phase 1 and UK Habitats survey data and using aerial photography within 250 m from the proposed working area. Further details on this process are outlined in Section 7.3 (Approach and Methods) of Chapter 7: Biodiversity. Targeted site visits undertaken in 2020 provided additional information for those locations identified by Phase 1 surveys. An assessment of likely groundwater dependency of potential GWDTEs was made based on the ecological and hydrogeological potential of each site (see Appendix C10.4: Groundwater).

[1] WFD status refers to the classification of indicators of quality of a watercourse by SEPA under various categories, including Physico-Chemical, Biological elements and Hydromorphology which in turn contribute to the assignment of an Overall status (from bad to good). For the purposes of assessment the most recent classifications are given. These classifications are updated on an annual basis by SEPA and are published on the Water Classification Hub (SEPA, 2022a).

10.3.5 Impact assessment

10.3.5.1 Importance

There is no sector-specific guidance for the assessment of the water environment for flood risk management schemes, therefore the assessment methodology has been adapted from the guidance presented within DMRB LA 113 Road Drainage and the Water Environment (Highways England et al., 2020a) and DMRB LA 104 Environmental Assessment and Monitoring (Highways England et al., 2020b). DMRB guidance is applied for roads, railways and other such linear infrastructure projects, therefore it is considered to provide an appropriate assessment framework for water environment given the linear nature of the Scheme. Where applicable, supporting information is provided within the relevant technical appendices.

For the purposes of the assessment, water supply is assessed as Very High or High importance only in relation to the number of properties/receptors a water resource is supplying.

The criteria for determining receptor importance are provided in Table 10-3.

Table 10-3: Receptor Importance Criteria and Typical Examples

Importance	Typical Examples
Very High	**Water feature has a very high quality and/ or rarity on a national and/ or international scale.**
	Surface Waters Water feature is classified by SEPA under the WFD, is achieving an overall WFD status of 'High' (baseline) and will maintain 'High' overall WFD status through the 2015-2021 or the 2021-2027 RBMP Cycles (future baseline); *Coastal/Estuarine:* A coastal/estuarine water body supporting a range of species and habitats sensitive to changes in erosion, sediment transport and deposition. Water body appears in complete equilibrium with natural erosion and deposition occurring at equal rates. Includes sites with international and UK statutory nature conservation designations (including SSSI and Ramsar sites) due to water-dependent ecosystems. Includes a diverse range of shoreline/estuarine morphology, including a variety of natural features such as sandbanks, creeks, intertidal mudflats and saltmarshes. Presents a lack of anthropogenic interruption and modification. Higher likelihood of morphological adjustment, such as excessive erosion and sediment deposition as a direct result of modification. *Fluvial Geomorphology:* Achieving 'High' status for Hydromorphology. Non-WFD classified watercourses may be applicable if they demonstrate qualities such as: A channel in stable equilibrium and exhibiting a range of natural morphological features (such as pools, riffles and bars). Diversity in morphological processes reflects unconstrained natural function, free from artificial modification or anthropogenic influence. *Surface Water Quality:* Achieving 'High' status for Physico-Chemical/Biological elements and 'Pass' for Overall chemistry. Protected/designated under International/European Union legislation such as a Special Area of Conservation (SAC),

Importance	Typical Examples
	Special Protection Area (SPA) and/or Ramsar site. Non-WFD classified water features may be applicable if part of a protected site. **Water Supply** Water supply resource or infrastructure extensively exploited for public, private domestic and/or agricultural and/or industrial use, feeding ten or more properties. **Flood Risk** Most Vulnerable Land Uses, including critical / essential infrastructure as defined in SEPA LUPS-GU24 (SEPA, 2018) at risk from flooding during the 0.5% AEP (200-year) or 0.5% AEP (200-year) plus CC event. Examples include police stations, hospitals, schools etc. **Groundwater** Groundwater aquifer with very high productivity. Exploitation of groundwater resource is extensive for public, private domestic and/ or agricultural use (i.e. feeding ten or more properties) and/ or industrial supply. Groundwater feeding GWDTE with a high or moderate groundwater dependence within areas of international or national environmental importance such as Ramsar, SACs, SPAs and Sites of Special Scientific Interest (SSSIs). Buildings of national importance, such as scheduled monuments, critical infrastructure and industrial buildings.
High	**Water feature has a high quality and/or rarity on a national scale.**
	Surface Waters Water feature is classified by SEPA under the WFD, is achieving 'Good' status or has established RBMP objectives (for a later RBMP cycle) to achieve 'Good' status in either the 2015-2021 or the 2021-2027 RBMP Cycles (future baseline). *Coastal/Estuarine:* A coastal/estuarine water body supporting a range of species and habitats sensitive to changes in erosion, sediment transport and deposition. Water body appears in complete equilibrium with natural erosion and deposition occurring at equal rates. Includes non-statutory sites of regional or local importance designated for water-dependent ecosystems. Includes a range of shoreline/estuarine morphology, including some natural features such as sandbanks, creeks, intertidal mudflats and saltmarshes. Presents a minor anthropogenic interruption and modification. Higher likelihood of morphological adjustment, such as excessive erosion and sediment deposition, as a direct result of modification. *Fluvial Geomorphology:* Achieving 'Good' status for Hydromorphology. Non-WFD classified watercourses may be applicable if they demonstrate qualities such as: A channel achieving near-stable equilibrium and exhibiting a range of natural morphological features (such as pools, riffles and bars). Diversity in morphological processes reflects relatively unconstrained natural function, with minor artificial modification or anthropogenic influence. *Surface Water Quality:* Achieving 'Good' status for Physico-Chemical/Biological elements and 'Pass' for Overall chemistry. Contains species protected under EC or UK legislation Ecology and Nature Conservation but is not part of a protected site. Non-

Importance	Typical Examples
	WFD classified water bodies may be applicable if protected species are present, indicating good water quality and supporting habitat. **Water Supply** Valuable water supply resource exploited for public, private domestic and/or agricultural and/or industrial use, feeding fewer than 10 properties. **Flood Risk** Highly Vulnerable Land Uses as defined in SEPA LUPS-GU24 (SEPA, 2018) at risk from flooding during the 0.5% AEP (200-year) or 0.5% AEP (200-year) plus CC event. Examples include dwelling houses, hotels, landfill and sites used for hazardous waste etc. **Groundwater** Groundwater aquifer with moderate/ high productivity. Exploitation of groundwater resource is not extensive (i.e., private domestic and/ or agricultural supply feeding less than ten properties). Groundwater feeding GWDTEs with a low groundwater dependence within areas of international or national environmental importance such as Ramsar, SACs, SPAs and SSSIs or groundwater feeding GWDTEs with a high or moderate groundwater dependence within a regional or local environmental importance such as Wildlife Sites and Sites of Interest for Nature Conservation. Buildings of regional importance, such as retail/commercial buildings, community facilities.
Medium	**Water feature has a medium quality and/or rarity on regional/local scale.**
	Surface Waters Water body not classified by SEPA under WFD. *Coastal/Estuarine:* A coastal/estuarine water body supporting some species and habitats sensitive to changes in erosion, sediment transport and deposition. Includes non-statutory sites of regional or local importance designated for water-dependent ecosystems. Moderate morphological diversity (geodiversity). Evidence of localised modification such as shoreline protection, but natural features such as sandbanks and intertidal flats are present. *Fluvial Geomorphology:* A channel currently showing signs of historical or existing modification and artificial constraints. attempting to recover to a natural equilibrium and exhibiting a limited range of natural morphological features (such as pools, riffles and bars). *Surface Water Quality:* May have evidence of a number of anthropogenic pressures and/or pollutant inputs from discharges and/or surrounding land-use relative to flow volume. **Water Supply** N/A **Flood Risk** Least Vulnerable Land Uses as defined in SEPA LUPS-GU24 (SEPA, 2018) at risk from flooding during the 0.5% AEP (200- year) or 0.5% AEP (200-year) plus CC event. Examples include shops, restaurants, offices, general industry etc.

Importance	Typical Examples
	Groundwater Groundwater aquifer with low productivity. No current known exploitation of groundwater as a resource and aquifer(s) properties make potential exploitation appear unlikely. Groundwater feeding GWDTEs with a low groundwater dependence within a regional or local designation such as a Wildlife Sites or Sites of Interest for Nature Conservation or groundwater feeding GWDTEs with a high or moderate groundwater dependence within areas of no environmental designation. Buildings of local importance, such as residential properties.
Low	Water feature has a low quality and/or rarity on local scale.
	Surface Waters Water body not classified by SEPA under WFD. *Coastal/Estuarine:* A coastal/estuarine water body which does not support any significant species sensitive to changes in erosion, sediment transport and deposition. No designated sites within water body. Water bodies exhibiting no morphological diversity (geodiversity); shoreline type is uniform and stable. Evidence of modification such as a sea defences, realignment and/or deepening. Very limited potential for morphological adjustment, such as erosion and sediment deposition, as a direct result of modification. *Fluvial Geomorphology:* A channel currently showing signs of extensive historical or existing modification and artificial constraints. There is no evidence of diverse fluvial processes and morphology and active recovery to a natural equilibrium (Fluvial Geomorphology). *Surface Water Quality:* May have evidence of a large number of anthropogenic pressures and/or pollutant inputs from licensed discharges and/or surrounding land-use relative to flow volume. **Water Supply** N/A. **Flood Risk** Water Compatible Land Uses as defined in SEPA LUPS-GU24 (SEPA, 2018) at risk from flooding during the 0.5% AEP (200-year) or 0.5% AEP (200-year) plus CC event. Examples include water and sewage infrastructure and pumping stations, docks, amenity open space, nature conservation sites, outdoor sports and recreation facilities etc. **Groundwater** Groundwater aquifer with no significant productivity. No known past or present exploitation of groundwater aquifer(s) as a resource. Groundwater feeding GWDTEs with a low groundwater dependence within areas of local environmental importance.

10.3.5.2 Magnitude

The magnitude of impacts is assessed on a scale of ‘Negligible’ to ‘Major Adverse’ using the typical examples provided in Table 10-4 as a guide.

To meet the requirements of the WEWS Act 2003, the magnitude accounts for the potential impacts on the WFD status of the water body or the supporting quality elements, as published on the SEPA Water Classification Hub (SEPA, 2024b).

Table 10-4: Magnitude Criteria for Impact Assessment

Magnitude	Typical Examples
Major Adverse	Results in a reduction in the quality and integrity and/or loss of the water feature as follows: **Surface Water** *Coastal/Estuarine:* Major adverse changes to the geomorphological elements of the coastal/estuarine water body including: Estuarine sediment regime - Major changes to any part of the shoreline, intertidal area and subtidal bed of the estuary leading to impacts to habitats and/or sensitive species resulting from changes in erosion, transport and deposition of suspended sediment and/or bedload. Shoreline, intertidal and subtidal morphology - Major changes to any part of the shoreline, intertidal area and subtidal bed of the estuary leading to a reduction in morphological diversity with consequences for geodiversity or ecological quality. Estuarine processes - Major changes/interruption to estuarine processes such as shoreline evolution or erosion and deposition. *Fluvial Geomorphology:* Loss of, or extensive adverse changes to the watercourse bed, banks and vegetated riparian corridor resulting in changes to existing morphological features and/or channel planform and cross section and/or natural fluvial processes. Impacts would be at the water body scale. For WFD classified water bodies, impacts have the potential to cause a long-term or permanent deterioration on Morphology status or prevent the achievement of 'Good' Morphology status at a water body scale due to a large increase in the extent of morphological pressures on the water body. *Surface Water Quality:* Construction works in-water and/or extensive construction works and/or operational activities adjacent to a watercourse or water body which are likely to risk a major, measurable shift from baseline water quality. Risk of adverse impacts on protected aquatic species. Construction works or operational activities on multiple tributaries of a watercourse or water body resulting in the risk of a significant cumulative impacts on water quality. Loss or extensive change to a designated nature conservation site. For WFD classified water bodies, water quality impacts have the potential to cause a long-term or permanent deterioration/reduction in WFD status/classification. **Water Supply** Long-term loss or change to surface water supply. **Flood Risk** A loss of flood storage and/or significant increase in flood risk (i.e., an increase in the 0.5% AEP peak flood level >100 mm). **Groundwater** Major or irreversible change to groundwater aquifer(s) flow, water level, quality or available yield which endangers the resources currently available. Groundwater

Magnitude	Typical Examples
	resource use / abstraction is irreparably impacted upon, with a major or total loss of an existing supply or supplies. Changes to water table level or quality would result in a major or total change in, or loss of, a groundwater dependent area, where the value of a site would be severely affected. Changes to groundwater aquifer(s) flow, water level and quality would result in major changes to groundwater baseflow contributions to surface water and/or alterations in surface water quality, resulting in a major shift away from baseline conditions such as change to WFD status. Dewatering effects create significant differential settlement effects on existing infrastructure and buildings leading to extensive repairs required.
Moderate Adverse	Results in a measurable change in the quality and integrity and/or the loss of the water feature as follows: **Surface Water** *Coastal/estuarine:* Moderate adverse changes to the hydromorphological elements of the water body including: Estuarine sediment regime - Moderate changes to any part of the shoreline, intertidal area and subtidal bed of the estuary caused by erosion (scour) and/or deposition leading to impacts to habitats and/or sensitive species as a result of changes in erosion, transport and deposition of suspended sediment and/or bedload. Shoreline, intertidal and subtidal morphology - Moderate changes to estuarine morphological diversity. Estuarine processes - Moderate changes/interruption to estuarine processes such as shoreline evolution or erosion and deposition. *Fluvial Geomorphology:* Adverse changes to on the water feature bed, banks and vegetated riparian corridor resulting in changes to existing morphological features and/or channel planform and cross section and/or natural fluvial processes. Impacts would be at the reach scale. For WFD classified water bodies, impacts may increase the extent of morphological pressures. For WFD classified water bodies, there is a potential to contribute to, but not cause a deterioration of Morphology status. *Surface Water Quality:* Construction works or operational activities adjacent to a watercourse which are therefore likely to risk a moderate, measurable shift away from baseline water quality. May result in temporary impacts on fisheries or designated species/habitats. For WFD classified water bodies, there is potential to contribute, but not cause a deterioration of Physico-Chemical, Biological elements, or Overall chemistry status. **Water Supply** Temporary disruption or deterioration in a water supply. **Flood Risk** An increase in flood risk (i.e., an increase in the 0.5% AEP peak flood level>50 mm). **Groundwater** Moderate long-term or temporary significant changes to groundwater aquifer(s) flow, water level, quality or available yield which results in moderate long term or temporarily significant decrease in resource availability. Groundwater resource use/abstraction is impacted slightly, but existing supplies remain sustainable. Changes

Magnitude	Typical Examples
	to water table level or groundwater quality would result in partial change in or loss of a groundwater dependent area, where the value of the site would be affected, but not to a major degree. Changes to groundwater aquifer(s) flow, water level and quality would result in moderate changes to groundwater baseflow contributions to surface water and/or alterations in surface water quality, resulting in a moderate shift from baseline conditions upon which the WFD status rests. Dewatering effects create moderate differential settlement effects on existing infrastructure and buildings leading to consideration of undertaking minor repairs.
Minor Adverse	Results in a minor measurable change in the quality or vulnerability of water feature as follows: **Surface Water** *Coastal/Estuarine:* No substantial changes to the hydromorphological elements of the coastal/estuarine water body: Estuarine sediment regime - No substantial changes to sediment transport resulting in negligible impacts on species or habitats as a result of changes to suspended sediment concentration or turbidity. No discernible impact to sediment patterns and behaviour over the development area due to either erosion or deposition. Shoreline, intertidal and subtidal morphology - No substantial impact to estuarine morphological diversity. Estuarine processes - No substantial changes/interruption to estuarine processes such as shoreline evolution or erosion and deposition. Any changes are likely to be localised. *Fluvial Geomorphology:* Slight adverse changes to/impacts on the water feature bed, banks and vegetated riparian corridor resulting in changes to existing morphological features and/or channel planform and cross section and/or natural fluvial processes. Impacts would be at the local scale. For WFD classified water bodies, impacts may result in a slight increase the extent of morphological pressures or occur where there are existing morphological pressures. Morphology status unaffected. *Surface Water Quality:* Construction works or operational activities within the watercourse catchment that may result in a risk of a minor, measurable shift from baseline water quality. No associated impacts on fisheries or designated species/habitats. **Water Supply** Not applicable as (detrimental) impacts to water supplies are only ever considered to have major or moderate adverse effects. **Flood Risk** A slight increase in flood risk (i.e., an increase in the 0.5% AEP peak flood level >10 mm). **Groundwater** Minor changes to groundwater aquifer(s) flow, water level, quality or available yield leading to a noticeable change, confined largely to the scheme area. Changes to water table level, groundwater quality and yield result in little discernible change to existing resource use. Changes to water table level or groundwater quality would result in minor change to groundwater dependent areas, but where the value of the site would not be

Magnitude	Typical Examples
	affected. Changes to groundwater aquifer(s) flow, water level and quality would result in minor changes to groundwater baseflow contributions to surface water and/or alterations in surface water quality, resulting in a minor shift from baseline conditions (equivalent to minor but measurable change within WFD status). Dewatering effects create minor differential settlement effects on existing infrastructure and buildings which may need to be monitored but where repairs may be avoidable.
Negligible	Results in an effect on water feature but of insufficient magnitude to affect its use or condition as follows: **Surface Water** *Coastal/Estuarine:* No discernible changes to the hydromorphological elements of the coastal/estuarine water body: Estuarine sediment regime - No discernible changes/interruption to estuarine processes such as shoreline evolution or erosion and deposition. Any changes are likely to be highly localised. Shoreline, intertidal and subtidal morphology - No substantial impact to estuarine morphological diversity. Estuarine processes - No discernible changes/interruption to estuarine processes such as shoreline evolution or erosion and deposition. Any changes are likely to be highly localised. *Fluvial Geomorphology:* Minimal or no measurable change from baseline conditions in terms of sediment transport, channel morphology and natural fluvial processes. Any impacts are likely to be highly localised. *Surface Water Quality*: Construction works or operational activities within the watercourse catchment that are not anticipated to result in a risk of a change in water quality. No associated impacts on fisheries or designated species/habitats. **Water Supply** Not applicable as (detrimental) impacts to water supplies are only ever considered to have major or moderate adverse effects. **Flood Risk** An insignificant increase in flood risk (i.e., an increase in the 0.5% AEP peak flood level <±10 mm). **Groundwater** Very slight change from groundwater baseline conditions approximating to a 'no change' situation. Dewatering effects create no or no noticeable differential settlement effects on existing infrastructure and buildings.

10.3.5.3 Significance

To determine the significance of an impact on the water resource receptor, the magnitude of the impact and the importance of the receptor are considered as per Table 10-5. Where more than one option is given, a single significance will be assigned.

Table 10-5: Criteria for Significance of Adverse Effects

Magnitude of Impact	Importance of Receptor			
	Very High	**High**	**Medium**	**Low**
Major Adverse	Very Large	Large or Very Large	Moderate or Large	Slight or Moderate
Moderate Adverse	Large or Very Large	Moderate or Large	Moderate	Slight
Minor Adverse	Moderate or Large	Slight or Moderate	Slight	Neutral or Slight
Negligible	Slight or Moderate	Slight	Neutral or Slight	Neutral

10.3.6 Assumptions and limitations

10.3.6.1 Estuarine Geomorphology

The assessment of estuarine geomorphology was implemented through the footprints of estuarine defences.

10.3.6.2 Fluvial Geomorphology

Baseline conditions were informed by site walkover observations highlighting key water features observed at the time of survey. Site-based information is supported by available desk-based information, including information received through consultation with SEPA.

Operation against the modelled baseline is dependent on the assumptions and limitations associated with flood modelling described in Section 10.3.6.4 below. At this stage, there has been no modelling of changes to channel flow velocities during construction and therefore a qualitative approach has been undertaken.

10.3.6.3 Surface Water Quality and Supply

The identification of abstractions, discharges and water supply infrastructure is based on best available information provided through consultation with local authorities, Scottish Water and SEPA.

10.3.6.4 Flood Risk

The hydraulic modelling of water bodies across the flood risk areas has been a complex and iterative process that has been subject to change as more data has become available. The extent of properties at risk from a 0.5% AEP (200-year) event has varied as a result over time, which has implications for the number and the location of properties that are estimated to be protected by the Scheme up to the design fluvial and/or tidal event. Full details on the hydraulic modelling methodology, assumptions and limitations are presented within Jacobs' Hydraulic Modelling Report (Jacobs, 2024a – available on request).

At this stage, fluvial and tidal hydraulic modelling informing the assessment is only available for the operation of the Scheme as the exact dimensions and methods to be used by the appointed contractors for the establishment of dry working areas are not yet known. These will be picked up at detailed design stage. Given this information is not available at this stage, a conservative, qualitative approach has been undertaken to inform the construction phase impact assessment. Further analysis will be undertaken at the detailed design stage.

In some cases, limitations to the applied modelling methodologies have resulted in changes to peak flood depths displaying on mapping where no changes will occur in reality. In these cases, professional judgement and qualitative assessment have been used to assess potential impacts. Where potential impacts are not as mapped these have been identified within the impact assessment presented in Appendix 10.3: Flood Risk.

Preliminary hydraulic modelling was undertaken to assess pluvial flood risk during operation of the Scheme. Details of the approach adopted, and assumptions and limitations are included in the Secondary Flood Risk Assessment (Jacobs, 2024b – available on request).

10.3.6.5 Groundwater

As ground investigations (GI) are currently ongoing, the groundwater study in Appendix C10.4 is limited to the GI information available at the time of reporting and historical data. The assessment will be updated as required in the future as more data become available. Groundwater monitoring data are limited in time and space and assumed groundwater depths have been derived from a combination of groundwater strike and groundwater monitoring information, which provides limited certainty and cannot rule out the presence of a shallower groundwater piezometric level.

Borehole logs and groundwater monitoring data have only been considered from ground investigations where final factual reports have been accepted, namely Phase 1 to Phase 8. Data from later rounds of ground investigation (including Phase 9 to Phase 12) have not been considered during this assessment but may inform subsequent hydrogeological assessments.

A preliminary assessment has been carried out to inform potential flow pathways with broad assumptions being made on groundwater levels and flows based on data from ground investigations Phase 1 to Phase 8, existing topography, geotechnical conditions and groundwater flood risk-mapping (GeoSmart, 2019).

In addition, a desk review of potential GWDTEs was carried out based on the Phase 1 and UK Habitats surveys, limited to a 100 m buffer from the Scheme alignment, and supported by aerial imagery up to 250 m, described in Section 7.3 of Chapter 7: Biodiversity. Hydrogeological field surveys undertaken in summer 2020 inspected those locations identified during the Phase 1 Habitat surveys, but not the subsequent UK Habitats surveys, however, the desk-based approach alone is considered robust enough for the assessment, as a conservative approach was adopted in attributing potential levels of groundwater dependency.

When assessing the potential impacts of the Scheme on the groundwater environment, the following assumptions have been made regarding the proposed design:

- excavations for direct defences (flood walls and embankments) would be no greater than 1.0 m in depth;
- excavations for replacement of bridge abutments would be no greater than 5.0 m in depth;
- it is assumed the haul roads will require only soil stripping, but no excavations;

- construction of new lock gates will take place within the concrete-lined lock at the entrance to Forth Ports and any necessary dewatering would not extend beyond the lock structure;
- ground improvement by the introduction of an additive to ground along the estuary frontage in Flood Cell 6 would extend no greater than 4.0 m below ground level (bgl). The additive would likely be a mixture of lime, cement and pulverised fly ash (PFA), which would not be a free-draining liquid. This additive would act like a grout and harden in-situ once emplaced, hence its potential to impact on groundwater quality would be negligible; and
- piling would be required beneath all flood walls and some embankments and most of the piling would be sheet piling. Piling depths are not certain at this outline design stage but will vary depending on ground conditions. For assessment purposes, piling depths have been based on reaching a maximum of 18.5 m bgl. Piling through improved ground along the estuary frontage in Flood Cell 6 would be bored piling up to a maximum depth of 4.0 m bgl.

10.4 Baseline

10.4.1 Surface water features

10.4.1.1 Introduction

The Scheme working areas are located within the following water bodies, which are classified as WFD water bodies (their IDs included) and their non-baseline water bodies:

- Middle Forth Estuary (200436);
- River Carron (Bonny Water confluence to Carron Estuary) (4200);
- Grange Burn/Westquarter Burn (3300);
- River Avon (Logie Water confluence to Estuary) (3100); and
- Island Farm Lagoon (Skinflats area) (200324).

In addition to these water bodies, the following named, non-baseline water bodies (as termed by SEPA) overlap the Flood Cells and are visible on the 1:25,000 OS mapping (see Figure B10.1):

- Tributary of the River Carron – Minor Tributary - Stirling Road
- Chapel Burn (Stenhousemuir);
- Mungal Burn (Falkirk);
- Bainsford Burn (Falkirk);
- Polmont Burn (Polmont);
- Millhall Burn (Polmont); and
- The Grange Burn Flood Relief Channel (Grangemouth).

The 1:25,000 scale OS mapping also shows numerous unnamed ditches and ponds identified throughout the study area.

Baseline surface water bodies within the study area and the status of each is shown in

Table 10-6. The following subsections provide descriptions of all named baseline and non-baseline watercourses (also see Appendix C10.1: Fluvial Geomorphology, Appendix C10.2: Estuarine Geomorphology, Appendix C10.3: Flood Risk and Appendix C10.5: Water Framework Directive).

Table 10-6: WFD Status of Baseline Surface Water bodies (2022 data;) (SEPA, 2024b)

Water body Name	SEPA ID	Flood Cells	Artificial Water Body (AWB) or Heavily Modified Water Body (HMWB) (Y/N)	Overall status	Overall chemistry	Priority substances	Overall ecology	Physico-Chemical	Biological elements	Specific pollutants	Hydro-morphology	Overall hydrology
Middle Forth Estuary	200436	1, 2, 3, 4, 5, 6	Y	Moderate ecological potential	-	-	Moderate	Good	Good	Pass	Moderate	-
River Carron (Bonny Water confluence to Carron Estuary)	4200	1	N	Poor	Pass	Pass	Poor	Moderate	Poor	Fail	Moderate	High
Grange Burn/ Westquarter Burn	3300	4	Y	Moderate ecological potential	-	-	Bad	Good	Good	Pass	Bad*	High
River Avon (Logie Water confluence to Estuary)	3100	5	N	Moderate	Pass	Pass	Moderate	Good	Moderate	Pass	High	High
Island Farm Lagoon – Skinflats. Firth of Forth	200324	5	N	Good	-	-	Good	Good	High	Pass	High	-

* Classifications shown on the SEPA Water Classification Hub (SEPA, 2024b), however this has been updated from Moderate to Bad for the impact assessment following MImAS testing and new modelling results by SEPA (SEPA 2023Middle Forth Estuary

10.4.1.2 Middle Forth Estuary

10.4.1.2.1 Overview

The Middle Forth Estuary WFD transitional (baseline) water body is located within the northern extents of the Scheme and includes the tidal reaches of the River Carron, Grange Burn and River Avon as well as the estuarine shoreline and has an area of approximately 38 km^2. In 2022, the Overall status of the water body was classified as Moderate ecological potential (SEPA, 2024b). The baselines for the River Carron, Grange Burn and River Avon are included within Sections 10.4.1.3, 10.4.1.8 and 10.4.1.9. The estuarine habitats associated with the Middle Forth Estuary are located within the Firth of Forth Special Protection Area (SPA), Site of Special Scientific Interest (SSSI) and Wetland of International Importance (RAMSAR).

Figure 10-1: Middle Forth Estuary (view north-west at Carron Estuary. Photograph taken from shoreline adjacent to North Shore Road).

10.4.1.2.2 Estuarine Geomorphology

The Middle Forth Estuary is designated for its intertidal muds, saltmarsh, maritime grasslands, heath and fen, cliff slopes, shingle and brackish lagoons, as shown in Chapter 7: Biodiversity Figure B7.1 Ecological Designations (Jacobs and Arup, 2009a).

In the Middle Forth Estuary, the relatively high suspended sediment concentrations (SSC) supply intertidal areas (mudflats and saltmarshes) with fine material on each tide, particularly where the estuarine channel narrows, such as at Grangemouth (ABPmer, 2018). This narrowing also promotes turbulent flows and a resuspension of sediment (ABPmer, 2014). SSC in the Forth estuary around Grangemouth vary between approximately 150 mg/l on neap tides to 350 mg/l on spring tides (BTDB, 1966; ABPmer, 2018), although peak concentrations at the Grangemouth entrance can reach up to approximately 2,000 mg/l.

Under WFD, both the Hydromorphology and Morphology status of the water body are classified as Moderate according to the latest available 2022 data (SEPA, 2024b). The Middle Forth Estuary is classified as a 'heavily modified' water body due to physical alterations of the estuary including land reclamation, shoreline realignment and navigational dredging (SEPA, 2024a). Geomorphological changes in the Middle Forth Estuary have been influenced by anthropogenic pressures (particularly to service the Port of Grangemouth) which include sea defences, bridges in the tidal sections of watercourses, piers and other construction. Intertidal habitat loss due to land reclamation in the estuary is estimated at between 33% and 50% over an approximate 160-year period (RSPB, 2012).

The study area for estuarine geomorphology is sub-divided into the following areas:

- Middle Forth Estuary (estuarine shoreline and downstream extents on River Carron from National Grid Reference (NGR) NS 93089 82835, Grange Burn from NS 94571 82533 and River Avon from NS 95605 81129).
- Navigation channel of Forth Estuary.

Based on the above, and the criteria provided in Table 10-3 for estuarine geomorphology, the Middle Forth Estuary has been assigned an importance of Very High. The estuarine reaches of the waterbodies which discharge to the Middle Forth (Lower Carron Estuary, Lower Grange Burn Estuary and the Lower Avon Estuary) are assigned High importance. The Navigation channel of the Forth Estuary has been assigned an importance of Low.

10.4.1.2.3 Surface Water Quality

In 2022, SEPA classified the water body as having an overall status of Moderate ecological potential with Good Physico-Chemical status, Moderate Overall ecology status, and Good status for Biological elements. The water body encompasses designated areas, including the Firth of Forth SPA, SSSI and Wetland of International Importance (RAMSAR).

All watercourses within the study area discharge (either directly or indirectly) to the Middle Forth Estuary. Contaminants affecting water quality include sediments; dissolved organic carbon; suspended solids and contaminants bound to them (such as heavy metals and phosphorus); diffuse sources with high levels of nutrients (including nitrogen and phosphorus); and oil and related compounds.

Table 10-7 below (see also Figure B10.2 in Appendix B) sets out the contaminant discharges from the Falkirk (Dalderse) Wastewater Treatment Works (Dis-01 to Dis-05) to the tidal reaches of the River Carron and the Kinneil Kerse Wastewater Treatment Works (Dis-09 and Dis-10) to the tidal reaches of the River Avon (as identified following consultation with Scottish Water under CAR licence numbers CAR/L/1003809 and CAR/L/1015407). Consultation with SEPA also identified discharges from the Falkirk Sewerage Network to the tidal reaches of the River Carron (CAR/L/1026165, Dis-11 to Dis-29) and the Kinneil Kerse Sewerage Network (CAR/L/1026134, Dis-30 to Dis-35) to the tidal reaches of the River Avon and Grange Burn (CAR/L/1026134) additional discharge to the tidal reach of the River Carron under CAR licence number CAR/L/1001367 (Dis-08).

Table 10-7: Discharges to the Middle Forth Estuary

Figure ID	CAR licence no.	National Grid Reference (NGR)	Name/ Reference	Activity (SEPA Description)
Dis-01	CAR/L/1003809	NS 9036 8233	Falkirk STW, Combined Sewer Overflow	Discharge of sewage from a combined sewer overflow
Dis-02		NS 9037 8233	Falkirk STW, Settled Storm Sewage Overflow After Primary Tank	Discharge from a settled storm sewage overflow
Dis-03		NS 9037 8233	Falkirk STW, Settled Storm Sewage Overflow – Storm Tank	Discharge of sewage from a settled storm sewage overflow

Figure ID	CAR licence no.	National Grid Reference (NGR)	Name/ Reference	Activity (SEPA Description)
Dis-04		NS 9037 8233	Falkirk STW, Emergency Overflow	Discharge of sewage from an emergency overflow
Dis-05		NS 9044 8230	Falkirk STW, Final Effluent	Discharge of treated sewage
Dis-06	CAR/L/1001367	NS 9423 8312	NuStar Tank Storage, Grangemouth Docks	Other Effluent
Dis-07	CAR/R/1027574	NS 9382 8246	Exit Booths, Port of Grangemouth	Sewage (Private) Secondary
Dis-08	CAR/R/1027573	NS 9453 8249	Drivers Reception Area, Port of Grangemouth	Sewage (Private) Secondary
Dis-09	CAR/L/1015407	NS 9630 8130	Kinneil Kerse STW, Final Effluent	Discharge of treated sewage
Dis-10		NS 9630 8130	Kinneil Kerse STW, Settled Storm Sewage Overflow	Discharge of sewage from settled storm sewer overflow
Dis-11 to Dis-21	CAR/L/1026165	NS 8868 8251	Bainsford, Cobblebrae CSO	Discharge from a combined sewer overflow
		NS 8926 8265	Carronshore, Carronside SPS CSO	
		NS 8907 8297	Carronshore, Chapel Burn NO1 CSO	
		NS 8907 8297	Carronshore, Chapel Burn NO2 CSO	
		NS 8948 8276	Carronshore, South Dock Street CSO	
		NS 8923 8242	Falkirk, Lomond Drive CSO	
		NS 8818 8236	Falkirk, New Carron Village North CSO	
		NS 9103 8232	Skinflats WWPS Yonderhaugh CSO 1975 NS908828	
		NS 9149 8240	Grangemouth, Dalgrain SPS CSO No 1	
		NS 9161 8234	Grangemouth, Dalgrain SPS CSO No 2	
		NS 9107 8220	Grangemouth, Glensburgh WWPS CSO	
Dis-22 to Dis-29		NS 8926 8265	Carronside WWPS NS892828	Discharge from an emergency overflow
		NS 8947 8310	Castle Avenue WWPS	
		NS 9103 8232	Skinflats WWPS 1975 NS908828	
		NS 8947 8310	Cuttyfield WWPS 1992 NS892834	
		NS 8895 8279	Bryce Avenue WWPS NS890828	
		NS 8836 8243	Carronshore WWPS	
		NS 9156 8233	Grangemouth, Dalgrain WWPS	
		NS 9107 8220	Grangemouth, Glensburgh Road WWPS	
Dis-30 to	CAR/L/1026134	NS 9454 8031	Grangemouth Bowhouse CSO NS934804	Discharge from a combined sewer overflow
		NS 9442 7972	Polmont, Northfoot SPS CSO	

Figure ID	CAR licence no.	National Grid Reference (NGR)	Name/ Reference	Activity (SEPA Description)
Dis-32		NS 9287 8111	Zetland Park WWPS	
Dis-33 to Dis-35		NS 9454 8031	Bowhouse WWPS NS934805	Discharge from an emergency overflow
		NS 9442 7972	Northfoot WWPS 2000 NS942796	
		NS 9287 8111	Zetland Park WWPS	

The majority of the outfalls are located within the tidal reaches of the River Carron and River Avon, and therefore any effluent discharges associated with these outfalls will be subject to mixing and dilution in the estuarine/transitional zones. Several outfalls are located within fluvial sections of the River Avon, River Carron, Westquarter Burn Polmont Burn and minor tributaries associated with these water bodies; these are detailed in the corresponding section for each watercourse.

Based on the above, the presence of internationally designated protected areas and the criteria provided in Table 10-3, the Middle Forth Estuary has been assigned an importance of Very High for surface water quality.

10.4.1.3 River Carron

10.4.1.3.1 Overview

The River Carron is approximately 36 km long and originates in the Campsie Fells to the west. It drains an area of approximately 192 km^2 into the Firth of Forth via the Carron Estuary at Grangemouth.

The nearest gauging stations on the River Carron to the study area are the Carron at Headswood (NGR NS 831818) approximately 3 km upstream of the Scheme extent and Bonny Water at Bonnybridge (NGR NS 824803) approximately 5 km upstream. Data from the National River Flow Archives (CEH, 2022) for each gauging station are summarised in Table 10-8. The Hydraulic Modelling Report (Jacobs 2024a – available on request) estimated the median annual flood flow (QMED) for the River Carron at the tidal limit as 130.34 m^3/s.

Table 10-8: River Carron gauging station data (CEH, 2019)

Gauging Station	Catchment Area	Base Flow Index	Mean Flow	Q10	Q95
Headswood	122.30 km^2	0.34	3.53 m^3/s	8.54 m^3/s	0.59 m^3/s
Bonnybridge	50.50 km^2	0.48	1.31 m^3/s	2.76 m^3/s	0.30 m^3/s

The River Carron (Bonny Water confluence from Carron Estuary) (ID: 4200) is classified as Poor Overall status in the most recent 2022 data.

Figure 10-2: River Carron (at Carron Bridges).

10.4.1.3.2 Estuarine Geomorphology

The lower reaches of the River Carron (downstream Flood Cell 1 into Flood Cell 2) are affected by the tidal limit and therefore exhibit estuarine character and form part of the Middle Forth Estuary WFD water body. These reaches, from the upstream tidal limit to the upper tidal extents of the Skin Flats Nature reserve (NGR NS 93089 82835), are hereafter referred to as the 'Lower Carron Estuary'.

The Lower Carron Estuary consists of a single tidal channel approximately 5 km long which widens from approximately 20 m in the upper reach to 60 m wide in the lower reaches. Near the M9 and A905 road bridges, the channel is intercepted by the Queen Elizabeth II Canal by Carron Sealock 2, and an extension to the canal adjacent to the Helix Sealock 1, which was constructed between 2012-2014. In Flood Cell 1 residential development is close to the left bank and land use along the right bank is predominantly wooded parkland. The Lower Carron Estuary (at Flood Cell 2) widens to form a meandering tidal channel approximately 60 m wide, across a floodplain through predominantly wooded parkland. The channel is confined on both banks by high embankments. Adjacent to the tidal channel are mudflats and the southern banks of the Carron are eroding most notably on the outside bends of the channel.

Observations made during site visits in May 2016 and April 2019 from the eastern bank showed that the existing defences in this location were in poor condition, with a considerable area of rip rap, debris, and detritus along the foreshore. This area is likely to be exposed to both locally generated waves and tidal currents.

Based on the above, and the criteria provided in Table 10-3, the Lower Carron Estuary has been assigned an importance of High for estuarine geomorphology.

10.4.1.3.3 Fluvial Geomorphology

The fluvial WFD water body extent of the River Carron (Bonny Water confluence to Carron Estuary) is approximately 7 km long and lies within the upstream area of Flood Cell 1. The watercourse holds an Overall status of Poor and Moderate Hydromorphology status under the WFD. The watercourse has objectives to achieve Good for future WFD cycles.

Channel width of the River Carron varies but is on average approximately 30 m, with a sinuous planform, meandering across a wide floodplain used as agricultural land. Although within a wide floodplain, the channel is disconnected from its floodplain via steep left and right embankments through the majority of the reach within Flood Cell 1. The watercourse displays a range of diverse morphological features including pools, riffles and glides. Lateral and mid-channel (vegetated and non-vegetated) bars are present. This morphological diversity generated from diverse bars, and morphological features promotes varied flow types.

Morphological pressures affecting the river and the wider catchment include alterations for renewable energy production and flow regulations for abstraction, purification and distribution of water at Carron Valley Reservoir in the upper catchment. There are several major pressures on flows and levels throughout the catchment, including impoundment, abstraction, purification and distribution of water at Carron Valley Reservoir in the upper catchment, and impoundment due to weirs in the lower catchment. Run-off and flow patterns are significantly affected by the reservoirs and run-off is increased by effluent returns (CEH, 2016). Pressures in the lower catchment also include modification to the bed and banks including bank protection and bridge structures. There are also historic weirs located at NGR NS 87914 82310 and NS 85598 81994. The MImAS baseline score shows approximately 38% of the water body's total capacity (including morphological and riparian vegetation) is currently used.

Based on the above, and the criteria provided in Table 10-3, the River Carron (fluvial) has been assigned an importance of High for fluvial geomorphology.

10.4.1.3.4 Surface Water Quality

In the latest 2022 WFD classification, the River Carron (Bonny Water confluence to Carron Estuary) was classified as a Pass for Overall chemistry and Priority substances and as a Fail for Specific pollutants.

In the upper catchment, land use is mainly moorland and plantation forestry and may input potential pollutants including sediment, dissolved organic carbon and nutrients into the watercourse. In lower reaches, land use is predominantly pastoral and urban/industrial development with major road networks and infrastructure.

Potential pollutants from the urban and agricultural land uses could include suspended solids and contaminants bound to them (such as heavy metals and phosphorus); diffuse sources with high levels of (agricultural) nutrients (nitrogen and phosphorus); de-icing salt (chloride) from road gritting; and oil and related compounds.

Consultation with Scottish Water has identified surface water discharges from the Falkirk (Dalderse) Wastewater Treatment Works to the tidal reach of the River Carron under CAR licence number CAR/L/1003809, presented in Table 10-7. These outfall locations are situated in the tidal reach of the River Carron, therefore mixing and dispersion within estuarine waters will take place.

In addition, consultation with SEPA identified the following surface water discharges associated the Falkirk Sewerage Network (CAR/L/1026165) to the fluvial River Carron:

- Falkirk, Cauldhame Farm CSO (Dis-36) – combined sewer overflow at NGR NS 8753 8181.
- Larbert, Larbert Low Level CSO (Dis-37) – combined sewer overflow at NGR NS 8717 8205.
- Larbert, Larbert Low Level SPS (Dis-38) – emergency overflow at NGR NS 8717 8205.

Given the size of the River Carron, any discharges are likely to be diluted and would be subject to downstream dilution due to mixing of estuarine/transitional water below Mean High Water Springs as flows enter the Middle Forth waterbody.

In 2022, the River Carron (Bonny Water confluence to Carron Estuary) was also assigned Poor status for Overall ecology and Biological elements. However, the River Carron provides habitat for a range of fish species including salmonids, European eel, flounder and lamprey. Further upstream, the River Carron flows through the Carron Glen SSSI from NGR NS 75332 84267 to NS 79686 83004, then into the Firth of Forth SSSI downstream at NGR NS 93087 82805.

Based on the above, and the criteria provided in Table 10-3, the River Carron has been assigned an importance of High for surface water quality.

10.4.1.3.5 Tributary – Chapel Burn (Stenhousemuir)

Chapel Burn is a relatively small watercourse and is not classified under the WFD. The watercourse has its source between King's Wood and Baxter Wood approximately 3 km north-west of Larbert. The catchment area, as delineated on the Flood Estimation Handbook (FEH) web service, is 1.30 km2, however, given the complex urban nature of the catchment, this only includes the area between the confluence with the River Carron (NGR NS 86214 81616 and the golf course at Stenhousemuir (NGR NS 85823 81210). A desk review of historical mapping suggests the true catchment area of the watercourse may be larger than reported on FEH.

The watercourse drains in a south-easterly direction through Larbert before discharging to the River Carron. The catchment area is characterised by predominantly agricultural land and woodland within the upper reaches. Downstream of the Forth Valley Royal Hospital, the catchment is almost entirely urban, as the watercourse flows through the settlements of Larbert, Stenhousemuir, Carron and Carronshore. The riparian zone is fragmented for the length of the watercourse and absence in places where urban development encroaches on the channel banks.

Chapel Burn exhibits a predominantly straightened planform for most of its length. There is evidence of historic channel realignment around Forth Valley Royal Hospital and along Old Denny Road and culverting through North Broomage, Stenhousemuir Primary, Ochilview Park stadium and Larbert Cemetery.

As outlined in Chapter 7: Biodiversity (Section 7.4.5.2), Chapel Burn provides limited habitat for aquatic species.

Consultation with SEPA did not identify any direct discharges to Chapel Burn.

Based on the above, and the criteria provided in Table 10-3, the Chapel Burn has been assigned an importance of Medium for surface water quality and fluvial geomorphology.

10.4.1.3.6 Tributary – Mungal Burn (Falkirk)

Mungal Burn is a small watercourse with a catchment area of 2.90 km^2 up to its confluence with the River Carron. The watercourse is not classified under the WFD. Based on historic mapping, its source is anticipated to be immediately south of the Bantaskin Estate (NGR NS 87243 80126), approximately 1 km west of Falkirk High station. However, due to the extensive culverting and development of the area, including the Union Canal and Forth and Clyde Canal bisecting the catchment in the mid-late 19th Century, the precise source and course of the watercourse is unclear. Between the reach upstream of the Union Canal and downstream of the Forth and Clyde Canal, the watercourse flows in a northerly direction through Summerford. Downstream of the Forth and Clyde Canal, it then continues in a northerly direction in a predominantly open channel from the south-west of Camelon (Falkirk) to Mungal (Falkirk), where it is culverted for approximately 800 m prior to discharging to the River Carron.

For approximately 900 m from its source, the catchment land use is characterised by predominantly agricultural land and woodland, however, downstream of this, land use is almost entirely urban. The riparian zone is limited for the length of the watercourse, and where there is an open channel, Mungal Burn exhibits a predominantly straightened planform, with limited reaches of increased sinuosity.

As described in Chapter 7 – Biodiversity, site visits for aquatic ecology showed some habitat for juvenile salmonids. Consultation with SEPA did not identify any discharges to Mungal Burn.

Based on the above, and the criteria provided in Table 10-3, the Mungal Burn has been assigned an importance of Medium for surface water quality fluvial geomorphology.

10.4.1.3.7 Tributary – Bainsford Burn (Falkirk)

Bainsford Burn is a small watercourse and is not classified under the WFD. Based on historic mapping, its source is anticipated to be in the Merchiston area of Falkirk. Mapping indicates the watercourse is culverted multiple times within the highly urbanised catchment. This makes delineating the precise source and catchment area of the watercourse difficult. The only open channel reach of the watercourse is downstream of Abbots Road Roundabout, where the watercourse flows for approximately 1 km prior to discharging into the River Carron. Upstream of this location the watercourse is entirely culverted. The catchment land use is predominantly urban, with woodland surrounding the open channel section upstream of the River Carron confluence. The riparian zone is continuous through the open channel section, through which the watercourse exhibits a predominantly sinuous planform.

Consultation with SEPA has identified one surface water discharge from Scottish Enterprise Forth Valley to Bainsford Burn at NGR NS 8970 8205 described as Surface Water (SW) Commercial, Ind & Other under CAR licence number CAR/S/1021361 (Dis-039 on Figure B10.2).

Based on the above, and the criteria provided in Table 10-3, the Bainsford Burn has been assigned an importance of Medium for surface water quality and fluvial geomorphology.

10.4.1.3.8 Tributary of River Carron – Minor Tributary – Stirling Road

A tributary of the River Carron crosses Stirling Road at approximate NGR NS 86207 81610 within Flood Cell 1. The watercourse displays a catchment area of 3.67 km^2 up to its confluence with the River Carron and is not classified under the WFD. Historic mapping indicates the watercourse has its source at the confluences of a series of land drain features which converge north of Greenrig Strip. The watercourse drains northwards as a single thread channel through woodland prior to crossing the Union Canal in culvert. North of the Union Canal, the watercourse flows through the urban areas of south-west Falkirk, to Falkirk Golf Course prior to flowing below Stirling Road and discharging to the River Carron. The riparian zone upstream of the A9 consists of dense mature deciduous vegetation along both banks; this thins along the right bank through the golf course where the channel appears to be confined within embankments.

The watercourse exhibits a predominantly straight planform for most of its length and appears to have been historically straightened. Localised increases in sinuosity are observed within the vicinity of the golf course indicating a degree of active fluvial processes and an attempt to recover within the confines of the current channel.

Consultation with SEPA identified a combined sewer overflow discharge (Camelon, Carmuirs Avenue CSO at NGR NS 8554 8076 (Dis-40)) associated the Falkirk Sewerage Network (CAR/L/1026165) to the watercourse.

Based on the above, and the criteria provided in Table 10-3, the minor watercourse at Stirling Road has been assigned an importance of Medium for surface water quality and fluvial geomorphology.

10.4.1.4 Grange Burn/ Westquarter Burn

10.4.1.4.1 Overview

The Westquarter Burn has a catchment area of 18.40 km^2 upstream of the M9 and has its source in a network of artificial drainage channels west of Gardrum Moss, approximately 2 km south-west of Shieldhill. It flows in a north-easterly direction beneath the Union Canal (where it is intersected by Glen Burn at NGR NS 90271 78359) and through Westquarter prior to being culverted beneath the M9. It meets Polmont Burn at the M9 crossing, however flow from Westquarter Burn continues along Grange Burn and flow from Polmont Burn continues along the Grange Burn Flood Relief Channel.

There are no gauging stations on Westquarter Burn or Grange Burn, however, hydrological calculations have been undertaken for Westquarter Burn based on catchment descriptors using donor catchments following the process set out by the Flood Estimation Handbook (FEH). The QMED flow (i.e. the median flow, equivalent to a 50% or 1 in 2-year AEP) on Westquarter Burn at the M9 culvert was calculated as 12.10 m^3/s (CH2M, 2018 unpublished).

The Grange Burn Flood Relief Channel moderates discharge downstream; at events greater than the 50% AEP (2-year) event, flood waters from Westquarter Burn spill over a weir structure into the Grange Burn Flood Relief Channel, where they are combined with flows from Polmont Burn. Runoff to the watercourse downstream of this point is increased by a number of sewage and storm water outfalls into the channel.

The Grange Burn (Figure 10-3) is approximately 14 km in length (including Westquarter Burn) and drains a lowland area of approximately 24 km^2 (including the Westquarter Burn catchment) into the Firth of Forth. Land use is a mixture of pastoral and urban in the lower catchment. Grange Burn is classified by SEPA under the WFD collectively with its tributary, Westquarter Burn. In the most recent classification of 2022, the WFD status of the Grange Burn/Westquarter Burn is as Moderate ecological potential (SEPA, 2024b).

Figure 10-3: Grange Burn (at Zetland Park)

10.4.1.4.2 Estuarine Geomorphology

The lower reaches of the Grange Burn (from Zetland Park at approximate NGR NS 92840 81337) are tidal and estuarine in nature and the watercourse joins the Middle Forth Estuary WFD water body at approximately NGR NS 95364 83223. However, the downstream boundary of the Lower Grange Burn Estuary, which marks the transition to the Middle Forth Estuary, is taken as the boundary between Flood Cell 4 and 6 (NGR NS 94571 82533) as this is the point at which the river becomes less confined, discharging in to the wider Middle Forth. This reach is referred to as the 'Lower Grange Burn Estuary'.

The Lower Grange Burn Estuary consists of a single tidal channel 2.40 km long. The channel has been straightened, measuring approximately 8 m wide and is embanked as part of previous flood defence works. Where natural, the banks are steep, uniform and stable, consisting of clay, silt and fine sands with occasional gravel lenses. Site observations note minor undercutting of the banks. Throughout this reach, the channel displays limited morphological diversity. Bed sediment consists of silts and sands with occasional sporadic fine gravel deposits. Flow velocities within the tidal reach appear relatively similar during ebb and flood and are influenced by tidal cycles within the Middle Forth Estuary.

Based on the above, and the criteria provided in Table 10-3, the Lower Grange Burn Estuary has been assigned an importance of High for estuarine geomorphology.

10.4.1.4.3 Fluvial Geomorphology

The Westquarter Burn is within Flood Cell 4. From Gardrum Moss to approximately 600 m west of the Pirleyhill Bridge at Shieldhill, the Westquarter Burn exhibits a largely straight planform. From this point to the confluence with Polmont Burn, Westquarter Burn is relatively sinuous and flows unconstrained across a wide floodplain. Channel width ranges from approximately 6-8 m with a largely continuous mature deciduous riparian corridor.

The Grange Burn (Flood Cell 4) commences at the outlet of the existing culvert below the M9. Downstream of the M9, the channel is up to 6 m wide and approximately 5 km long prior to discharging to the Middle Forth Estuary. The channel has been straightened and embanked as part of previous flood defence works; there are, however, signs of some adjustment and increased sinuosity, resulting from localised erosion within artificial constraints.

The channel has grassy, mostly tree-lined embankments on both sides, and along much of its length, these disconnect the channel from the floodplain. The banks are fairly steep, uniform and generally stable with limited morphological diversity along the length of the channel.

The river is heavily modified with morphological alterations to the channel bed and banks (SEPA 2024a). In the most recent 2022 classification, the Grange Burn/ Westquarter Burn WFD water body achieved Bad status for both Hydromorphology and Morphology (SEPA, 2024b). The MImAS assessment on the baseline situation shows approximately 119% of the water body's total capacity is currently used.

Based on the above, and the criteria provided in Table 10-3, the Grange Burn has been assigned an importance of High for fluvial geomorphology.

10.4.1.4.4 Surface Water Quality

In the latest 2022 WFD classification, the Grange Burn/ Westquarter Burn was classified as a Good Physico-chemical status and Pass for Specific pollutants.

Within the upstream catchment for Westquarter Burn, land use is mainly moorland and plantation forestry and may input potential pollutants including sediment, dissolved organic carbon and nutrients into the watercourse.

The catchment for Grange Burn is predominantly pastoral and urban/industrial development with major road networks and infrastructure. Potential pollutants from the urban and agricultural land uses could include suspended solids and contaminants bound to them (such as heavy metals and phosphorus);

diffuse sources with high levels of (agricultural) nutrients (nitrogen and phosphorus); de-icing salt (chloride) from road gritting; and oil and related compounds.

Other pressures include diffuse pollution from livestock farming and sewage disposal. It is also an Urban Waste Water Treatment Directive sensitive area. The Grange Burn flows into the Firth of Forth SSSI in the lower tidal reaches.

In the 2022 WFD classification, the Grange Burn/ Westquarter Burn was also assigned Bad status for Overall ecology and Good status for Biological elements. Grange Burn provides a limited amount of habitat for small or juvenile fish but does provide clear passage to Westquarter Burn upstream of the A9.

Consultation with SEPA has identified two surface water discharges to Grange Burn CAR licence numbers CAR/R/1027574 (Dis-07) and CAR/R/1027573 (Dis-08) to the tidal Grange Burn. These are presented on Figure 10.2 and summarised in 7. In addition, consultation with SEPA identified surface water discharges associated the Kinneil Kerse Sewerage Network (CAR/L/1026134) to the Westquarter Burn (Dis-41 to Dis-44), as detailed in Table 10-9.

Table 10-9: Discharges to Grange Burn

Figure ID	NGR	Name/ Reference	Activity (SEPA Description)
Dis-41	NS 8949 7709	Falkirk, Cross Brae CSO	Discharge from a combined sewer overflow
Dis-42	NS 9143 7920	Westquarter, Park Crescent CSO	
Dis-43	NS 9168 7909	Westquarter, Hillside Terrace CSO	
Dis-44	NS 9186 7916	Alder Grove, Westquarter	

Consultation with SEPA and Falkirk Council also identified one surface water abstraction (Abs-02) of a maximum of 200m^3 per day from Grange Burn at NGR NS 9284 8133 under CAR licence number CAR/R/5000750. This abstraction was required for the filling of the pond/pool within Zetland Park and is not considered to be in regular use. This abstraction is discussed further in Section 10.4.2.

Based on the above, and the criteria provided in Table 10-3, the Grange Burn (and associated tributaries) has been assigned an importance of High for surface water quality.

10.4.1.5 River Avon

10.4.1.5.1 Overview

The River Avon (Figure 10-4) is approximately 41 km in length and drains a lowland catchment of approximately 188 km^2 from its headwaters near Greengairs, North Lanarkshire flowing in a north-easterly direction to the Firth of Forth near Grangemouth. The bedrock comprises moderately permeable Carboniferous sedimentary rocks, predominantly overlain by superficial deposits of boulder clay and alluvium. Land use is dominated by grassland, arable agriculture and forest with a few small former coal-mining towns. Major pressures include the extensive moorland drainage schemes in the upper catchment, industrial and agricultural abstractions and point source pollution from sewage disposal (especially downstream of the Logie Water Confluence).

Runoff into the channel is increased by effluent returns (CEH, 2019). There is some storage of water in Linlithgow Loch, Lochcote Reservoir, Forrestburn Reservoir and Loch Ellrig. However, these pressures are not sufficient to impact on the overall hydrology status of the River Avon which is classified as ‘High’ under the WFD.

There is a gauging station (17005) on the River Avon within the extents of the Scheme at Polmonthill (NGR NS 951796). Data from the National River Flow Archive (NRFA) indicate that at the gauging station, which has an upstream catchment area of 195.30 km^2, the Q95 flow is 0.69 m^3/s, mean flow is 4.18 m^3/s and the Q10 flow is 9.81 m^3/s. The NRFA also reports the Base Flow Index, which is a measure of how much groundwater contributes to river flow, as 0.41. Hydraulic modelling (CH2M, 2018 unpublished) estimated the QMED of the River Avon at Polmonthill to be 86.70 m^3/s.

The River Avon (Logie Water Confluence to Estuary) is classified under the WFD. In 2022, its Overall status was classified as Moderate.

Figure 10-4: River Avon (Photograph taken at Inveravon).

10.4.1.5.2 Estuarine Geomorphology

The lower reaches of the River Avon comprise part of the Middle Forth Estuary. The upper tidal reach of the Avon, located within Flood Cell 5 at NGR NS 94639 79722, is a constrained channel with steep muddy banks and narrow mudflats (<40 m) along the right bank only. Narrow strips of eroding saltmarsh also exist within some of the more sheltered sections. The channel widens downstream of the A904 bridge, characterised by a stable shoreline consisting of a tidal channel fringed by mudflats and an isolated section of saltmarsh present along the inside bend of the left bank (NGR NS 95532 80729).

Based on the above, and the criteria provided in Table 10-3, the Lower River Avon Estuary has been assigned an importance of High for estuarine geomorphology.

10.4.1.5.3 Fluvial Geomorphology

The River Avon flows southwards through managed wooded and agricultural land within Flood Cell 4. The watercourse displays a sinuous single thread planform upstream of the A905. Towards the A905, the valley opens out, and land use is a mixture of pastoral and arable agriculture on the adjacent floodplain. Riparian vegetation consists of dense mature deciduous trees, grasses and shrubs which line the left and right banks upstream of the A905.

Channel width varies but is on average approximately 20 m wide and confined by steep valley sides. The left bank appears steeper throughout the upstream reach and is densely vegetated with deciduous tree cover. Bedrock is exposed within the channel approximately 400 m upstream of the existing A905 bridge along the right bank. The channel bed is composed of sands, gravels, cobbles and boulders and channel morphology is predominantly pool-riffle with sporadic glides and pools on meanders. The morphological features and coarse sediment contribute to the creation of varied flow types and active morphological processes.

Modifications include infrastructure and development, notably the A905 road bridge crossing and nearby industrial buildings which encroach on the channel floodplain. Immediately upstream of the road bridge, the flood relief channel of the Grange Burn discharges into the River Avon during high flow. The right bank of the River Avon, opposite the confluence with Grange Burn Flood Relief Channel, is protected by rock gabions. Embankments on the left of the channel downstream of the road bridge interrupt the channels connection it its natural floodplain.

The water body is currently achieving High status for both Hydromorphology and Morphology quality elements under the WFD. The MImAS assessment on the baseline situation shows approximately 2.6% of the water body's total capacity is currently used and is therefore within 2.5% of the morphological condition limit between 'High' status and 'Good' status for hydromorphology.

Based on the above, and the criteria provided in Table 10-3, the River Avon (fluvial) has been assigned an importance of Very High for fluvial geomorphology.

10.4.1.5.4 Surface Water Quality

In the latest 2022 WFD classification, the River Avon (Logie Water confluence to Estuary) was classified as a Pass for Overall chemistry and Priority substances and Specific pollutants.

In the upper catchment, land use is mainly pastoral, with some areas of plantation forestry and may input potential pollutants including sediment, dissolved organic carbon and nutrients into the watercourse, while in its lower reaches land use is a mixture of pastoral and urban/industrial development with major road networks and infrastructure.

Potential pollutants from the urban and agricultural land uses could include suspended solids and contaminants bound to them (such as heavy metals and phosphorus); diffuse sources with high levels of (agricultural) nutrients (nitrogen and phosphorus); de-icing salt (chloride) from road gritting; and oil and related compounds.

Consultation with Scottish Water has identified surface water discharges from the Kinneil Kerse Wastewater Treatment Works to the tidal reach of the River Avon under CAR licence number CAR/L/1015407, presented in Table 10-7. These outfall locations are situated in the tidal reach of the River Avon, which is part of the Middle Forth Estuary WFD water body, therefore mixing with estuarine waters will take place. In addition, consultation with SEPA identified the following surface water discharges associated with the Kinneil Kerse Sewerage Network (CAR/L/1026134) to the fluvial River Avon:

- Polmonthill, Polmonthill SPS CSO (Dis-45) – combined sewer overflow at NGR NS 9522 7961.
- Polmonthill, Polmonthill SPS (Dis-46) – emergency overflow at NGR NS 9522 7961.

Given the size of the River Avon, any discharges are likely to be diluted and would still be subject to downstream dilution due to mixing of estuarine/transitional water prior to the Middle Forth waterbody. In 2022, the River Avon (Logie Water confluence to Estuary) was also assigned Moderate status for Overall ecology and Biological elements. The River Avon flows through numerous SSSIs including the Slamannan Plateau SSSI between the source and Jawhills (NGR NS 79167 74635 to NS 81915 73232), Carriber Glen SSSI (NGR NS 96460 75292 to NS 96879 75375) and Avon Gorge SSSI (NGR NS 96405 78767 to NS 95288 79683) between the Logie Water Confluence and the estuary. Avon Gorge SSSI is designated for upland mixed ash woodland and lists water management and water quality as negative pressures to the SSSI (NatureScot, 2023).

Based on the above, and the criteria provided in Table 10-3, the River Avon has been assigned an importance of Very High for surface water quality.

10.4.1.5.5 Tributary - Polmont Burn (Polmont)

Polmont Burn is a relatively small watercourse with a catchment area of approximately 5.7 km^2 upstream of the M9 crossing and has its source close to the source of Westquarter Burn, in a network of artificial drainage channels west of Gardrum Moss, approximately 1.7 km south-west of Shieldhill. It flows in a north-easterly direction through the settlement of Brightons, beneath the Union Canal and through Polmont prior to the M9 crossing. Downstream of this location Polmont Burn flows into the Grange Burn Flood Relief Channel and then into the River Avon. Polmont Burn is not classified under the WFD.

From its source to approximately 600 m west of the B8028 crossing, the planform of Polmont Burn is predominantly straight through Gardrum Moss (historic peat works) and agricultural fields. Downstream of this point, Polmont Burn exhibits a sinuous planform and has a continuous riparian corridor to the confluence with Westquarter Burn.

Upstream of Braes High School (Brightons), the catchment is predominantly agricultural. Downstream of the school, the catchment is urban through the settlements of Brightons and Polmont. There are no gauging stations on Polmont Burn, QMED flow at the M9 culvert was calculated as 3.40 m^3/s (CH2M, 2018 unpublished).

Consultation with SEPA identified a combined sewer overflow discharge (Polmont, R/O 10 Miller Park CSO at NGR NS 9348 7818 (Dis-47)) associated the Kinneil Kerse Sewerage Network (CAR/L/1026134) to the watercourse.

Based on the above, and the criteria provided in Table 10-3, the Polmont Burn has been assigned an importance of Medium for surface water quality and fluvial geomorphology.

10.4.1.5.6 Tributary – Millhall Burn (Polmont)

Millhall Burn is a relatively small watercourse with a catchment area of approximately 7 km^2 upstream of its confluence with the River Avon. Millhall Burn is not classified under the WFD. Its source is close to the source of both Polmont Burn and Westquarter Burn, in a network of artificial drainage channels east of Gardrum Moss approximately 1 km south-west of California, Falkirk. It is called Gardrum Burn from its source to the crossing beneath the Union Canal, Gilston Burn to Millhall Reservoir and Millhall Burn downstream of Millhall Reservoir to the confluence with the Grange Burn Flood Relief Channel.

From its source to the crossing beneath Blackbraes Road (B8028), the planform of Gardrum Burn is predominantly straight through Gardrum Moss (historic peat works) and agricultural fields. Downstream of California, Falkirk, to the crossing beneath the Union Canal, Gardrum Burn exhibits a sinuous planform. The watercourse has a continuous riparian corridor aside from an approximate 700 m reach through Rumford, Falkirk. Downstream of the Union Canal crossing (where the watercourse is named Gilston Burn), there is evidence of artificial straightening along field boundaries and the riparian corridor becomes more fragmentary. Downstream of the M9, flow from (the now) Millhall Burn is diverted into Millhall Reservoir, re-entering the straightened channel approximately 200 m downstream. Through Polmont Woods, Millhall Burn exhibits a predominantly sinuous planform to the crossing beneath Grange Road; downstream to the confluence with the River Avon, the planform is artificial.

There are no gauging stations on Millhall Burn, however flow is likely to be regulated by inflows and outflows from Millhall Reservoir.

Consultation with SEPA identified the following surface water discharges associated with the Kinneil Kerse Sewerage Network (CAR/L/1026134) to Millhall Burn:

- Polmont, Millhall Nursery CSO (Dis-48) – combined sewer overflow at NGR NS 9389 7925.
- Polmont, south side of M9 CSO (Dis-49) – combined sewer overflow at NGR NS 9450 7876.
- Polmont, north side of M9 CSO (Dis-50) - combined sewer overflow at NGR NS 9450 7876.

Based on the above, and the criteria provided in Table 10-3, the Millhall Burn has been assigned an importance of Medium for surface water quality and fluvial geomorphology.

10.4.1.6 The Grange Burn Flood Relief Channel (Grange Burn)

The Grange Burn Flood Relief Channel (Figure 10-5) is an artificial channel constructed in the 1960s. The channel conveys flows from Polmont Burn to the River Avon and during high flows in the upper Grange Burn the channel also diverts flows from the Westquarter Burn/Grange Burn to the River Avon. The channel is approximately 2 km in length, running parallel south of Rannoch Road, before crossing under the A905 and following the road until it's confluence with the River Avon. Flow in the Grange Burn Flood Relief Channel is entirely controlled via inflows from Polmont Burn. During 50% AEP (2-year) flood event and above, Westquarter Burn currently overtops a weir structure immediately downstream of the existing M9 crossing.

Grange Burn Flood Relief Channel is not classified under WFD, however as the inflow to the channel is predominantly from Polmont Burn it is assumed to have similar existing pressures in relation to surface water quality.

Consultation with SEPA did not identify any discharges to the Grange Burn Flood Relief Channel.

Based on the above, and the criteria provided in Table 10-3, the Grange Burn Flood Relief Channel has been assigned an importance of Medium for surface water quality and Low for fluvial geomorphology.

Figure 10-5: Grange Burn Flood Relief Channel (at Inchrya Park).

10.4.1.7 Island Farm Lagoon (Bothkennar Pools)

Bothkennar Pools are freshwater (northern) and saline (southern) lagoons. The southern lagoon is tidal and is partially connected to the tidal reach of the River Carron via a drain with flow control measures on the outfall structure approximately 500 m upstream of the confluence with the Firth of Forth. The pools are classified by SEPA as a transitional water body (ID 200324) under the WFD and named Island Farm Lagoon - Skinflats. Island Farm Lagoon has a water body area of 0.11 km^2.

In the latest 2022 classification (SEPA, 2024b), the Island Farm Lagoon - Skinflats was classified as Good for Overall status, Pass for Specific pollutants, Good status for Overall ecology and High for Biological elements. The Bothkennar Pools are within the Firth of Forth SPA, SSSI and RAMSAR sites.

Consultation with SEPA did not identify any discharges to Island Farm Lagoon.

Based on the above, and the criteria provided in Table 10-3, Island Farm Lagoon has been assigned an importance of Very High for surface water quality.

Figure 10-6: Island Farm Lagoon (Bothkennar Pools).

10.4.2 Water supply

The study area does not overlap any part of a Nitrate Vulnerable Zone (NVZ), the nearest being over 40 km away and in a different catchment and over a different groundwater body. No assessment of the impact of the site on NVZ's is required.

There are no surface water Drinking Water Protected Areas within the study area, the nearest being around 14 km upstream of the Scheme extent at for Flood Cell 1, and no assessment of the impact on surface water Drinking Water Protected Areas is required.

The drinking water supply zones within the study area include:

- Turret A Zone (Flood Cell 1);
- Carron Valley B Zone (Flood Cell 1);
- Carron Valley A Zone (Flood Cell 2, 3 and 4);
- Turret/Balmore/Carron Valley Zone (Flood Cell 3, 4, 5 and 6); and
- Balmore E Zone (Flood Cell 5 and 6).

No information is publicly available at this stage about the source of drinking water in these zones, or how waste water from the study area is handled, however, a review of available utilities mapping of Scottish Water supply assets shows a dense network of water supply pipelines (gravity pipes, syphons and rising mains) in the study area.

Consultation was undertaken with Falkirk Council to identify any private water supplies and abstractions within 850 m of the Scheme, however, none were identified. Consultation was also undertaken with SEPA to identify any CAR authorised abstractions, which identified one groundwater abstraction - Abs-01 within Forth Ports and one surface water abstraction Abs-02 in Zetland Park (required for the filling of the pond/pool within Zetland Park and is not considered to be in regular use). Consultation with Forth Ports determined that Abs-01 is a historical abstraction which is no longer in use and has thus not been considered further during this assessment. Based on the criteria provided in Table 10-3, Abs-02 has been assigned an importance of High.

A review of 1:3,000 OS mapping in conjunction with consultation with Falkirk Council identified five possible wells within the study area. These are also identified on Figure B10.2. Based on the criteria provided in Table 10-3, these wells have been assigned an importance of High.

In addition, consultation with Scottish Water in July 2019 established the locations of Wastewater Treatment Works (WwTW) infrastructure and outfalls in the study area: the Kinneil Kerse WwTW to the east of Grangemouth (NGR NS 96133 81038) and the Dalderse WwTW to the west of Grangemouth (NGR NS 90334 82173). Both are licenced for discharges to the River Avon (Kinneil Kerse WwTW) and River Carron (Dalderse WwTW). Based on the criteria provided in Table 10-3, these abstractions have been assigned an importance of Very High.

The River Carron, the River Avon and the Grange Burn are all designated as Urban Wastewater Treatment Directive sensitive areas.

10.4.3 Flood risk

The Flood Risk Management Strategy for the Forth Estuary Local District Plan (SEPA, 2015a) identified that for the Falkirk, Grangemouth, Laurieston, Denny, Redding, Dunipace, Carron and Stenhousemuir (10/11) Potentially Vulnerable Area (PVA) there are approximately 2,000 residential and 330 non-residential properties at risk of flooding. The majority of flood risk originates from rivers (51%) with 21% originating from surface water (i.e. when the capacity of the drainage network is exceeded) and 28% from coastal sources. In December 2021, the Flood Risk Management Plan Forth Estuary Local Plan District (SEPA, 2021) was published after a period of consultation. In this document the Falkirk and Grangemouth (02/10/10) PVA is split into eight areas for further assessment (target areas), and the Bo'ness (02/10/11) PVA into two target areas. The target areas relevant to the Scheme are presented in Table 10-10.

Table 10-10: Summary of target areas within the Scheme from the Flood Risk Management Plan Forth Estuary Local Plan District (SEPA, 2021).

PVA	Target area	Main source of flooding	Receptors at risk
Falkirk and Grangemouth (02/10/10)	Carron and Carronshore (target area 211)	River flooding, with additional risk from coastal and surface water flooding.	Approximately 1,400 people and 670 homes and businesses. (Likely to increase to 1,900 people and 920 homes and businesses by the 2080s due to climate change.)
	Falkirk (target area 228)	Surface water flooding, with additional risk from river flooding.	Approximately 2,300 people and 1,300 properties. (Likely to increase to 3,400 people and 1,800 properties by the 2080s due to climate change.)
	Grangemouth west (target area 232)	Coastal flooding, with additional risk from river and surface water flooding.	Approximately 10,000 people and 6,000 homes and businesses. (Likely to increase to 17,000 people and 9,300 homes and businesses by the 2080s due to climate change.)
	Larbert and Stenhousemuir	Surface water flooding, with	Approximately 740 people and 410 homes and businesses.

	(target area 243)	additional risk from river flooding.	(Likely to increase to 1,100 people and 590 homes and businesses by the 2080s due to climate change.)
	Polmont, Redding and Westquarter (target area 308)	Surface water, with additional risk from river.	Approximately 870 people and 440 homes and businesses. (Likely to increase to 1,000 people and 520 homes and businesses by the 2080s due to climate change.)
Bo'ness (02/10/11)	Grangemouth east (target area 262	Coastal, with additional risk from river and surface water.	Approximately 230 homes and businesses.

The highest risk of river flooding is from the River Carron in the Carron/Carronshore area and the Grange Burn in Grangemouth. The highest risk of coastal flooding is from the Firth of Forth in Grangemouth, and Carron/Carronshore. The highest risk of surface water flooding is in Falkirk, Denny and Cumbernauld.

Scheme-specific baseline flood modelling was carried out for coastal and fluvial 0.5% (200-year) events. The results of this modelling are presented in Figure B10.9 and show peak flood depths of over 4.0 m within Flood Cells 1 and 2. Within Flood Cells 3, 4, 5 and 6 peak flood depths are up to 2.0. m depth, with localised areas of up to 3.50 m depth. Further details on baseline flood risk are presented in Appendix C10.3 and supporting documents. This modelling has identified 2750 residential and 1200 non-residential properties at risk of combined tidal and fluvial flooding during a 0.5% AEP (200-year) event.

Due to the nature of the Scheme, the importance of receptors within the study area is highly variable. The assigned importance of specific receptors is presented where relevant within Section 10.5.6 and Appendix C10.3: Flood risk.

Groundwater flooding baseline data are discussed in Section 10.4.4.

10.4.4 Hydrogeology

As described in detail in Chapter 11: Soils, Geology and Land Contamination, BGS mapping (BGS 2019) shows the study area is underlain by superficial geology comprising predominantly Raised Tidal Flat Deposits of Holocene Age and Intertidal Deposits, with localised deposits of Alluvium and Raised Marine Deposits to the eastern and southern extents of the study area (Figure 11.2). Underlying bedrock comprises the Passage Formation and Upper Limestone Formation, belonging to the Clackmannan Group, and the Scottish Lower Coal Measures Formation, belonging to the Scottish Coal Measures Group.

Of the superficial deposits, tidal deposits (Raised Tidal Flat Deposits and Intertidal Deposits) are not considered to be a significant aquifer (BGS, 2019). Alluvial deposits are indicated as moderate to high productivity while Raised Marine Deposits are low to moderate productivity, both with intergranular flow (Figure 10.3). The study area is dominated by bedrock aquifers classified as moderate to high productivity utilising both intergranular and fracture flow (Figure 10.4). A summary of the hydrogeological characteristics within the study area is provided in Appendix C10.4.

10.4.5 Groundwater quality

As shown in Figures B10.5a and B10.5b, the chemical status for WFD groundwater bodies within the study area is classified as Good for all Superficial aquifers within the study area (Avon Sand and Gravel, Carron Sand and Gravel, Pow Burn and Stenhousemuir Sand and Gravel). Carboniferous aquifers are typically of Poor Chemical status (Falkirk, Kinneil, Grangemouth and Stenhousemuir), excluding the Castle Cary aquifer which is of Good status. Aquifers with Poor status have been assessed as having poor electrical conductivity or manganese concentrations, suggesting saline intrusion or pollution within the water bodies.

10.4.6 Groundwater levels and flows

Groundwater levels have been monitored during the Ground Investigation works carried out for the Scheme at various stages between 2014 and 2022.

In general, available groundwater strike and monitoring information indicates groundwater levels are shallower in tidal areas (Figure B10.6), and in places groundwater levels have also been recorded as fluctuating with tidal influence. Artesian conditions were encountered in Flood Cell 1, the southern part of Flood Cell 4 and Flood Cell 5. Details on groundwater conditions recorded in each Flood Cell are provided in Appendix C10.4.

Groundwater flood risk mapping (GeoSmart, 2019, Figure B10.7) shows groundwater flood risk is mostly classified as moderate, with some areas of lower risks (i.e. low and negligible). The likelihood of shallow groundwater being present within the study area increases with increased flood risk classifications. The predominate classification of moderate, indicates shallow groundwater within the study area is likely.

Groundwater flow paths are likely to be complex due to the naturally layered nature of the aquifers, which tends to impart preferential horizontal flow, and the predominance of fracture flow (BGS, 2011). Groundwater may be present under unconfined or confined conditions at various depths, and different groundwater heads are seen in different aquifer layers.

The presence of springs provides an indication that groundwater is at or near the surface. Springs and water "issues" were identified through a desk study review of 1:3,000 scale OS mapping. The desk study found 30 springs that are predominantly located within the southern and eastern-most extents of the study area (Figure B10.2). No springs were identified during ecological walkover surveys. Further details on groundwater depths and flows within the study area are presented in Appendix C10.4.

10.4.7 Groundwater Dependent Terrestrial Ecosystems (GWDTEs)

Eighteen areas of potential GWDTEs were identified within 250 m of the Scheme by a desk review of existing ecological surveys and a hydrogeological survey carried out in summer 2020 (see Annex A of Appendix C10.4: Groundwater). A hydrogeological review was carried out on these areas assigning a likely groundwater dependency (see Table 10-11).

Table 10-11: Summary of GWDTE in the study area

Likely Groundwater Dependency	No. of Features
Low	1
Moderate	7
High to moderate	10

10.4.8 Buildings

Dewatering activities have the potential in certain conditions to generate subsidence effects on buildings. As described in Chapter 1 (Introduction), the Scheme is within an urban area and is within the vicinity of over 3,000 residential and non-residential properties in addition to industrial properties. There are community facilities located within the study area (see Chapter 6: Population and Human Health) as well as 42 historical buildings (see Chapter 13: Cultural Heritage).

10.4.9 Summary of receptor importance

With consideration of all the aforementioned baseline conditions, the following key receptors, presented in Table 10-12, have been identified and the importance of each receptor has been determined in accordance with the criteria described in Table 10-3.

Table 10-12: Summary of receptor importance (tributaries / components shown in italics)

Receptor Category	Receptor Name	Attribute	Indicator/ Features	Importance
Coastal/ Estuarine Surface Waters	Middle Forth Estuary	Estuarine Geomorphology	Designated as SPA, Ramsar and SSSI.	Very High
	Navigation channel of Forth Estuary		Navigation channel of a high socio-economic importance, due to upstream ports being dependent upon the navigation channel, but with high capacity to accommodate change.	Low
	Lower Carron Estuary		Objectives to achieve 'Good' Overall status. Intertidal areas of River Carron are not designated. It is an estuarine receptor with moderate capacity to accommodate change.	High
	Lower Grange Burn Estuary		Objectives to achieve 'Good' Overall status. Intertidal areas of Grange Burn are not designated. It is an estuarine receptor with moderate capacity to accommodate change.	High
	Lower River Avon Estuary		Objectives to achieve 'Good' Overall status. Intertidal areas of River Carron are not designated. It is an estuarine receptor with moderate capacity to accommodate change.	High
	Middle Forth Estuary	Surface Water Quality	'Good' Physico-Chemical status, 'Good' Biological elements status, designated as Ramsar, SPA and SSSI.	Very High
	Island Farm Lagoon	Surface Water Quality	'Good' Physico-Chemical status, 'High' Biological elements status, designated as Ramsar, SPA and SSSI, RSPB non-statutory Reserve.	Very High

Receptor Category	Receptor Name	Attribute	Indicator/ Features	Importance
Fluvial Surface Waters	River Carron	Surface Water Quality	'Pass' for Overall chemistry, 'Moderate' Physico-Chemical status, 'Poor' Biological elements status.	High
		Fluvial Geomorphology	Designated 'Moderate' Hydromorphology status and 'Moderate' overall status with objectives to achieve 'Good' status for future WFD cycles.	High
	Grange Burn/ Westquarter Burn	Surface Water Quality	'Good' Physico-Chemical status, 'Good' Biological elements status, within designated Ramsar, SPA and SSSI sites.	Very High
		Fluvial Geomorphology	Designated 'Bad' Hydromorphology status. And 'Moderate' Overall status with objectives to achieve 'Good' Overall status	High
	River Avon	Surface Water Quality	'Pass' for Overall chemistry, 'Good' Physico-Chemical status, 'Moderate' Biological elements status, within designated SSSI site.	Very High
		Fluvial Geomorphology	Designated 'High' Hydromorphology status and 'Moderate' Overall status with objectives to achieve 'Good' Overall status.	Very High
	The Grange Burn Flood Relief Channel	Surface Water Quality	Not classified under WFD and does not directly discharge into any areas with environmental designations.	Medium
		Fluvial Geomorphology	Not designated under the WFD. Artificial channel which exhibits no morphological diversity.	Low
	Tributaries of River Carron: Minor Tributary – Stirling Road Chapel Burn Mungal Burn Bainsford Burn	Surface Water Quality	Not classified under WFD and does not directly discharge into any areas with environmental designations.	Medium
		Fluvial Geomorphology	Not classified under WFD. Channel exhibit evidence of active fluvial process included bank erosion and deposition of limited morphological features indicating an attempt to recover to natural equilibrium within artificial constraints.	Medium

Receptor Category	Receptor Name	Attribute	Indicator/ Features	Importance
	Tributaries of River Avon: Millhall Burn Polmont Burn	Surface Water Quality	Not classified under WFD and does not directly discharge into any areas with environmental designations.	Medium
		Fluvial Geomorphology	Not classified under WFD. Channel exhibit evidence of active fluvial process included bank erosion and deposition of limited morphological features indicating an attempt to recover to natural equilibrium within artificial constraints.	Medium
Water Supply	Scottish Water Public Water Supply	N/A	Scottish Water Public Water Supply is considered to be critical infrastructure and is therefore assigned the highest importance.	Very High
	Well 1 to Well 5	N/A	Usage unknown and presence unconfirmed. The locations do not correspond to any known licensed abstractions.	High
	Abs-01	N/A	Historic groundwater abstraction	None
	Abs-02	N/A	Surface water abstraction for filling of pond / pool in Zetland Park. Use considered to be infrequent.	High
Groundwater Resource	Raised Tidal Flat Deposits of Flandrian Age	N/A	Not a significant aquifer, based on BGS mapping. Within the WFD Avon Sand and Gravel, Carron Sand and Gravel and Pow Burn and Stenhousemuir Sand and Gravel aquifers of 'Good' Overall status.	Low
	Intertidal Deposits	N/A	Not a significant aquifer, based on BGS mapping, and not associated with a WFD aquifer.	Low
	Till	N/A	Not a significant aquifer, based on BGS mapping. Within the WFD Avon Sand and Gravel, Carron Sand and Gravel and Pow Burn and Stenhousemuir Sand and Gravel aquifers of 'Good' Overall status.	Low
	Peat	N/A	Not a significant aquifer, based on BGS mapping. Within the WFD Avon Sand and Gravel, Carron Sand and Gravel and Pow Burn and	Low

Receptor Category	Receptor Name	Attribute	Indicator/ Features	Importance
			Stenhousemuir Sand and Gravel aquifers of 'Good' Overall status.	
	Raised Marine Deposits	N/A	Low to moderate productivity with intergranular flow, based on BGS mapping. Within the WFD Avon Sand and Gravel, Carron Sand and Gravel and Pow Burn and Stenhousemuir Sand and Gravel aquifers 'Good' Overall status.	High
	Alluvium	N/A	Moderate to high productivity with intergranular flow, based on BGS mapping. Within the WFD Avon Sand and Gravel, Carron Sand and Gravel and Pow Burn and Stenhousemuir Sand and Gravel aquifers of 'Good' Overall status.	High
	Glaciofluvial Ice Contact Deposits	N/A	High productivity with intergranular flow, based on BGS mapping. Within the WFD Avon Sand and Gravel, Carron Sand and Gravel and Pow Burn and Stenhousemuir Sand and Gravel aquifers of 'Good' Overall status.	High
	Upper Limestone Formation	N/A	Moderate productivity with intergranular and fracture flow, based on BGS mapping. Within the WFD Grangemouth and Kinneil aquifers of 'Poor' Overall status.	High
	Passage Formation	N/A	High productivity with significant intergranular flow, based on BGS mapping. Within the WFD Grangemouth and Castle Cary aquifers of respectively 'Poor' and 'Good' Overall status.	High
	Scottish Lower Coal Measures Formation	N/A	Variable productivity, ranging from Moderate to High, with both intergranular and fracture flow, based on BGS mapping. Within the WFD Falkirk, Kinneil, Grangemouth and Stenhousemuir aquifers of 'Poor' status and Castle Cary aquifer of 'Good' status.	High

Receptor Category	Receptor Name	Attribute	Indicator/ Features	Importance
	Scottish Middle Coal Measures Formation	N/A	Moderate productivity with intergranular and fracture flow, based on BGS mapping. Limited spatial extent within the study area. Within the WFD Falkirk aquifer of 'Poor' Overall status.	High
GWDTE	GW20	N/A	Likely low groundwater dependence. Not located within a designated area	Low
	GW05, GW06, GW10, GW11, GW12, GW13, GW16, GW17, GW18, GW19, GW21, GW22, GW23, GW25, GW26	N/A	Likely moderate or high groundwater dependence. Not located within a designated area.	Medium
	GW03 and Spring 25 (Compound Receptor)	N/A	GWDTE of likely high groundwater dependence. Located within Carron Dams SSSI and LNR. Spring marked on OS mapping, supplies drainage channel within Carron Dams.	Very High
	GW24 and Springs 21-23 (Compound receptor)	N/A	Likely high groundwater dependence. Located within Firth of Forth SPA, SSSI and Ramsar.	Very High
Springs	Springs 1-20, 24 and 26-30	N/A	Marked as issues on OS mapping. Supplies small drainage channel which are of low hydrological value.	Low
Buildings	Residential	N/A	Buildings are considered to be of local value.	Medium
	Retail/Commercial and Community Facilities	N/A	Buildings are considered to be of regional value.	High
	Industrial Buildings, Critical Infrastructure and Scheduled Monuments	N/A	Buildings are considered to be of national value.	Very High

Receptor Category	Receptor Name	Attribute	Indicator/ Features	Importance
	and Listed Buildings			

10.4.10 Future baseline

The SEPA Water Environment Hub provides target conditions for the 2021-2027 RBMP cycle for all baseline water bodies. Predicted overall conditions are summarised in for baseline surface water, and in Table 10-14 for groundwater bodies. Predictions for overall conditions consider assumptions of the future quality of various parameters including, but not limited to, fish access, water flows and levels, physical condition, water quality and ecological condition.

Table 10-13: WFD target conditions for surface and transitional water bodies present within the study area (SEPA, 2024a)

Receptor	Middle Forth Estuary	River Carron (Bonny Water confluence to Carron Estuary)	Grange Burn/ Westquarter Burn	River Avon (Logie Water Confluence to Estuary	Island Farm Lagoon – Skinflats Firth of Forth
2014 Overall Condition	Moderate	Poor	Moderate	Moderate	High
2021 Projected Overall Condition	Moderate	Poor	Moderate	Moderate	High
2027 Projected Overall Condition	Good	Good	Good	Moderate	High
Long-term Projected Overall Condition	Good	Good	Good	Good	High

Table 10-14: Baseline Groundwater Bodies within Study Area (SEPA, 2024a)

Water body Name	Falkirk	Castle Cary	Grangemouth	Avon Sand and Gravel	Carron Sand and Gravel	Stenhousemuir	Kinneil	Pow Burn and Stenhousemuir Sand and Gravel
2014 Overall Condition	Poor	Good	Good	Good	Good	Poor	Poor	Good
2021 Projected Overall Condition	Poor	Good	Good	Good	Good	Poor	Poor	Good
2027 Projected Overall Condition	Poor	Good	Good	Good	Good	Poor	Poor	Good
Long-term Projected Overall Condition	Good	Good	Good	Good	Good	Good	Good	Good

Long-term projected conditions for watercourses may also be influenced by increases in flow as a result of climate change. In the Forth river basin region, peak river flows are predicted to experience an increase of up to 56% by 2100, while coastal water bodies within this catchment are currently predicted to experience a cumulative sea-level rise of 0.86 m between 2017 to 2100 (SEPA, 2022b).

Given that most of the intertidal areas of the Forth are currently constrained by coastal defences, losses of intertidal area due to coastal squeeze could potentially occur in the estuary over the next 100 years and beyond. Under present-day conditions most mudflats and saltmarshes in the study area appear to be accreting. Evidence of accretion within the Skinflats to the north of Grangemouth has been provided by SNH (2019), which showed an advance of the MHWS in this area since the 1890s.

The rate of Sea Level Rise (SLR) that could lead to the erosion of saltmarshes and mudflats is not likely to be reached until 2070. Therefore, no coastal squeeze is currently occurring, nor is it likely to occur for the next 47 years. After this time the potential losses of intertidal habitat represent coastal squeeze in locations backed by anthropogenic structures or reclaimed land. Any losses against areas of naturally occurring high land would represent natural change rather than coastal squeeze.

10.5 Impact assessment

10.5.1 Introduction

The impact assessment has been undertaken in accordance with the methodology outlined in Section 10.3 for both the construction and operation phases of the Scheme. The construction activities (based on an outline construction methodology) are provided in Chapter 4: The Proposed Scheme. A summary of significant impacts (i.e. those identified as being of Moderate significance or greater) is provided in the following subsections; the corresponding detailed impact assessments are presented in Appendices C10.1 to C10.5. A full impact assessment summary table (containing both significant and non-significant impacts) can be found in Appendix C10.6: Impact Assessment Tables.

Based on the Scheme design, no construction or operation impacts are anticipated for Bainsford Burn and Island Farm Lagoon (Bothkennar Pools) and therefore are scoped out of further assessment.

Cumulative impacts are considered in Section 10.9 and consider the overall impact of multiple effects, e.g., where several minor adverse effects to a single receptor may result in an overall significant effect. Cumulative impacts of other developments are presented in Chapter 15.

10.5.2 Estuarine geomorphology

10.5.2.1 Construction phase

The anticipated temporary construction footprint for the Scheme varies between approximately 5 m to 50 m seaward and landward of the proposed defence alignment, with 2.01 ha located within the Firth of Forth SPA, Ramsar and SSSI. This section assesses the potential construction impacts of the Scheme on geomorphological features and processes. Impacts on aquatic and terrestrial habitats are considered within Chapter 7: Biodiversity.

Given the nature of the works required, i.e. flood defences adjacent to and on the bank top, it is assumed that the majority of construction works located within the intertidal sections of the River Avon and River Carron will take place from the landward areas. However, it may be necessary to erect some temporary working areas on the wet side (included within the construction areas). In Flood Cell 6, some land reclamation will be required for flood defences and associated temporary construction zones, with some construction work below the Mean High Water Springs (MHWS) elevation.

Potential impacts of the Scheme during construction include the following:

- changes in both erosion/accretion rates and locations in the intertidal and subtidal areas arising from changes in tidal flows (speed and direction) i.e., increased erosion around working platforms where the tidal channel is constrained and accretion within the wider estuarine environment;
- morphological changes due to direct disturbance of intertidal areas by heavy machinery operating on the intertidal areas, potentially causing erosion. This could become a permanent effect depending on the location, degree of disturbance and the reinstatement works; and
- changes in the morphology due to erosion of the intertidal sections and release of sediments into the navigation channel.

All effects are anticipated to be of Slight Adverse significance or below during Scheme construction. A more detailed assessment of impacts on estuarine geomorphology is presented in Appendix C10.2: Estuarine Geomorphology and Appendix C10.6: Impact Assessment Tables.

10.5.2.2 Operation phase

This section assesses the potential operation impacts of the Scheme on geomorphological features and processes. The potential permanent impacts of the Scheme within each Flood Cell is considered for the following potential permanent effects:

- losses of intertidal habitat due to changes in defence footprint and alignment;
- changes in water levels within tidal reaches of the tributaries which discharge to the Middle Forth Estuary;
- changes to baseline currents;
- changes in estuarine morphology due to changes in tidal currents and accretion/erosion; and
- changes in estuarine geomorphology response under a scenario of climate change.

All effects are anticipated to be of Slight Adverse significance or below during Scheme operation. A more detailed assessment of impacts on estuarine geomorphology is presented in Appendix C10.2: Estuarine Geomorphology and Appendix C10.6: Impact Assessment Tables.

10.5.3 Fluvial geomorphology

10.5.3.1 Construction phase

Flood protection works are generally in or adjacent to watercourses and therefore pose a risk to the geomorphology of the channel and adjacent floodplain.

Working adjacent to the channel (i.e. within 20 m and along the bank tops and bank face) will be required to construct flood defences. Additionally, in-water working areas will also be required to construct flood defences raised bridge structures and extended culvert..

It is anticipated that in-water working areas will be created using a geotechnical solution consisting of filled geotextile bulk bags from which a working platform would be formed. At this stage only estimated widths of the in-water areas are known. As a conservative approach it is assumed the working platforms would span 50% of the watercourse width where the total watercourse width is <10 m, and 25% of the watercourse width on channels >10 m. This would allow a proportion of flow to pass alongside the working area and continue downstream throughout the duration of the in-water works. Works would be completed from one bank/channel side and then the bag work would be removed and installed along the opposite bank to complete any additional works required.

A summary of the potential construction phase impacts is provided below with further detail provided in Appendix C10.1: Fluvial Geomorphology.

Temporary in- and near-channel working has the potential for the following impacts to be realised:

- temporary removal of natural bed and bank material under the footprint of any in-water works altering bed structure and composition;
- increased fine sediment delivery to the channel leading to smothering of natural bed material and morphological features if present;
- temporary alteration to natural bank faces and riparian zone as a result of construction works along the bank face and tops; and
- temporary reduction of channel cross-sectional area as a result of in-water working. This has the potential to impact water flows and levels within and downstream of working areas with a potential subsequent effect on sediment dynamics and continuity of sediment during the construction period.

The types of construction phase impacts and potentially significant effects (Moderate Adverse or greater) on fluvial geomorphology are summarised in

Table 10-15. A detailed assessment of impacts to the fluvial geomorphology of specific watercourses is presented in Appendix C10.1: Fluvial Geomorphology and Appendix C10.6: Impact Assessment Tables.

10.5.3.2 Operation phase

The potential operation phase effects of the Scheme would include:

- changes to the structure and substrate of the channel bed as a result of new flood defences and in-water structures including culverts and flow control structures;
- change to natural bank form and a reduction in-water diversity as a result of new flood defences adjacent to and on the channel banks;
- changes in water flows and levels as a result of new defences modifying channel cross-sectional area during specific flood events; and
- potential for alteration to sediment dynamics including transport, erosion and deposition as a result of increased flow velocities and discharges associated with the Scheme.

Types of operation phase impacts and potentially significant effects (Moderate Adverse or greater) on fluvial geomorphology are summarised in

Table 10-15. A detailed assessment of impacts to the fluvial geomorphology of specific watercourses is presented in Appendix C10.1: Fluvial Geomorphology and Appendix C10.6: Impact Assessment Tables.

Table 10-15: Summary of significant pre-mitigation impacts on fluvial geomorphology during construction and operation.

Type of Impact	Description	Receptor	Importance	Magnitude	Significance of effect
Construction					
Change to structure and substrate of bed	Loss of natural bed due to construction works adjacent to and within channel working to construct flood walls or erosion protection	Grange Burn/ Westquarter Burn	High	Moderate Adverse	Moderate
		Millhall Burn	Medium	Moderate Adverse	Moderate
Change to bank form and riparian zone	Changed to the form of the banks from their current state due to construction of new flood defences	Grange Burn/Westquarter Burn	High	Moderate Adverse	Moderate
		Millhall Burn	Medium	Moderate Adverse	Moderate
Change to channel width and depth variation, water flows, levels and continuity of sediment transport	Change to channel cross-sectional area as a result of in-water working. Potential to alter flow velocities and sediment dynamics	Grange Burn/ Westquarter Burn	High	Minor Adverse	Moderate
		Millhall Burn	Medium	Moderate Adverse	Moderate
Operation					
Change to structure and substrate of bed	Permanent change to or loss of natural bed material under the footprint of new structures	Grange Burn/ Westquarter Burn	High	Minor Adverse	Moderate
Change to bank form and riparian zone	Permanent change/modifications to natural bank form				

10.5.4 Surface water quality

10.5.4.1 Construction phase

The main construction works (i.e., the working areas on the riverbank and within the river bed) may increase suspended sediment delivery (and potentially any pollutants bound to sediment) to the water bodies as well as causing alterations to the hydrological conditions of the receptor. Potential increased sediment and pollutant delivery might also occur to a lesser extent due to enabling works (involving utilities diversion, vegetation clearance and tree felling).

Typical impacts associated with construction activities on surface water quality and resultant effects of Moderate Adverse or greater significance are summarised in Table 10-16 below. A detailed assessment of impacts and resultant effects of Minor Adverse or less significance on surface water quality is presented in Appendix C10.6: Impact Assessment Tables.

Table 10-16: Summary of pre-mitigation significant effects on surface water quality during construction

Type of Impact	Description	Receptor	Importance	Magnitude	Significance of Effect
Sediment delivery from runoff (material stockpiles and working areas)	Impact on Physico-Chemical status and Biological elements status due to an increased input of sediment-laden runoff during construction from: runoff from site compounds or working areas; runoff from any areas of exposed ground and stockpiles of construction materials; and mobilisation of silt during flood conditions during construction.	River Carron	High	Moderate Adverse	Large
		Grange Burn (including Westquarter Burn)	High	Major Adverse	Very Large
		Minor watercourse at Stirling Road	Medium	Major Adverse	Large
		Mungal Burn			
		Chapel Burn			
		Millhall Burn			
		Grange Burn Flood Relief Channel			
		Middle Forth Estuary	Very High	Moderate Adverse	Very Large
River bed disturbance (from in-water works)	Disturbance of sediment on the riverbed and subsequent impact on Physico-Chemical status and Biological elements status caused by: in-water working, primarily through vehicles tracking within the watercourse, causing increases in suspended sediment; placement of imported material to create the working platforms; and	Grange Burn (including Westquarter Burn)	High	Major Adverse	Very Large
		Minor watercourse at Stirling Road	Medium	Major Adverse	Large
		Mungal Burn			
		Chapel Burn			
		Millhall Burn			

Type of Impact	Description	Receptor	Importance	Magnitude	Significance of Effect
	mobilisation of imported material during a flood event. Relining of Grange Burn Flood Relief Channel with concrete and shotcrete. This may include: breaking out of existing channel where required; filling of voids and broken out areas; and installation of shotcrete.	Grange Burn Flood Relief Channel			
Accidental spillage of oils, fuels, chemicals, cementitious materials etc.	Release of potentially polluting material (organic compounds, metals, concrete, greases, oils and other chemicals/compounds) from plant or stored materials during the construction of the Scheme may result in the deterioration of the water quality of these surface waters, as well as surface waters further downstream.	Middle Forth Estuary	Very High	Major Adverse	Very Large
		River Carron	High	Moderate Adverse	Large
		Grange Burn (including Westquarter Burn)	High	Major Adverse	Very Large
		River Avon	Very High	Minor Adverse	Large
		Minor watercourse at Stirling Road	Medium	Major Adverse	Large
		Mungal Burn			
		Chapel Burn			
		Polmont Burn	Medium	Moderate Adverse	Moderate
		Millhall Burn	Medium	Major Adverse	Large
		Grange Burn Flood Relief Channel			
		Middle Forth Estuary	Very High	Moderate Adverse	Very Large

Type of Impact	Description	Receptor	Importance	Magnitude	Significance of Effect
Disturbance of potentially contaminate d bed-sediment (from lock gate replacement)	Release of potentially contaminated bed sediment from disturbance of the sediment from replacement works may result in the deterioration of the water quality of connected surface waters. Potential temporary increase in suspended sediment concentrations.	Middle Forth Estuary	Very High	Moderate Adverse	Very Large

10.5.4.2 Operation

Water quality impacts during the operation phase of the Scheme can be related to changes in hydrology. Potential resultant effects include:

- the mobilisation of leachable contaminants; and
- the alteration of pathways for contaminants due to implementation of seepage cut-off measures (such as sheet piling).

Operation phase impacts on water quality due to the mobilisation of pre-existing contamination and creation/alteration of contaminant pathways have been considered via a Conceptual Site Model presented in Chapter 11: Soils, Geology and Land Contamination.

10.5.5 Surface water supply

10.1.1.10 Construction phase

Changes to surface water quality, described in Section 10.1.1.10, may also result in impacts to the quality of private or public water supplies. Impacts to water may also occur through changes to supply quantity or severance of supply.

Impacts associated with construction activities on water supply and resultant effects of Moderate Adverse or greater significance are summarised in Table 10-17 below.

A detailed assessment of impacts and resultant effects of Minor Adverse significance on water supply is presented in Appendix C10.6: Impact Assessment Tables.

Table 10-17: Summary of pre-mitigation significant effects on water supply during construction

Type of Impact	Description	Receptor	Importance	Magnitude	Significance of Effect
Severance of, or damage to public water supply infrastructure. Pollution of public water supply.	Potential to cause severance of, damage to or pollution of public water supply as the Scheme intersects water supply infrastructure. There are approximately: • 24 direct clashes, 8 potential clashes in Flood Cell 1; • 13 direct clashes, 3 potential clashes in Flood Cell 2; • 3 direct clashes in Flood Cell 3; • 64 direct clashes, 9 potential clashes in Flood Cell 4; • direct clashes, 1 potential clash in Flood Cell 5 and • 2 clashes in Flood Cell 6.	Scottish Water Public Water Supply	Very High	Major Adverse	**Major adverse**
	Potential to cause severance of, damage to or pollution of abstraction as the Scheme intersects the source at Grange Burn. Abstraction used infrequently.	Abs-02	High	Minor	Slight adverse

10.5.5.1 Operation

Water supply impacts during the operation phase of the Scheme relate to changes to water quality of supply as described in Section 10.5.4.2.

All effects are anticipated to be of Minor Adverse significance or below during operation of the Scheme.

10.5.6 Flood risk

Groundwater flooding risks are discussed in Section 10.5.7.

10.5.6.1.1 Construction

Tidal currents and fluvial flows may be restricted or altered during construction, in localised areas, due to the presence of in-water working areas. This may result in a loss of channel capacity or floodplain storage and potential subsequent increases in flood depth due to the displacement of water. Construction is anticipated to take place over approximately 10 years with a phased approach, therefore the likelihood of a flood event within each works phase is considered to be low.

Should a flood event occur during construction the displacement of water from in-water working areas is considered unlikely to result in any discernible increase to flood depth or extent within coastal areas, in particular Flood Cells 3 and 6. There is however, potential for flood depths and extents to be greater during construction within watercourses and tidal channels. Any displacement of water within these areas is likely to be localised and would be dependent on the extent of reduction of channel capacity.

In addition to the flood risk to construction activities, there is also the potential for temporary additional risk to flood risk receptors, such as community facilities, commercial buildings, residential properties and industrial areas through the displacement of flood water.

There will be an inherent risk of flooding to the proposed construction activities and flood risk receptors during the construction phase. The inundation protection to be adopted during construction will be subject to the contractor's temporary works design. These risks have been assigned a magnitude of Very High, resulting in a potential effect of Very Large Adverse significance.

10.5.6.2 Operation

10.5.6.2.1 Pluvial

Preliminary pluvial modelling predicted that increases to surface water ponding during a 0.5% AEP (200-year) 1-hour storm event would be minimal. There may be increases of greater than 1.0 m depth in isolated locations during the 6-hour storm event. However, the majority of pluvial flooding would experience an increase of up to a maximum of 0.30 m depth in comparison to the baseline scenario. Peak flood depths, with scheme, during a 6-hour storm event are presented in Figure B10.12. Increases of less than 0.10 m are considered to be negligible and are therefore not shown on mapping.

From the 6-hour flood, there are several properties where risk of being flooded above threshold level is increased when the defences are in place. Most of the surface water flooding to the properties is only increased by 0.20 m, however, there are some properties that have a higher level of flooding. These include the farm buildings at the confluence of Grange Burn and the River Avon, and some of the buildings within the petrochemical plant. Based on these findings, the magnitude of potential impacts during the operation phase regarding surface water flooding are anticipated to be of Very High magnitude, resulting an effect of Very Large significance.

10.5.6.2.2 Fluvial and tidal

Decreases of peak flood depths up to 2.50 m during the design flood event are present throughout the study area (Figure B10.11b), including several large areas where flooding is removed, during the operation of the Scheme. Some localised areas also show decreases greater than 4.00 m. It is estimated that the Scheme would benefit some 2750 residential and 1200 non-residential properties currently at risk of flooding, including nationally important infrastructure.

Impact magnitude for reduction of flood risk varies, however is very large for the majority of areas, resulting in effects of Moderate or Large Beneficial to Very Large Beneficial significance, dependent on the sensitivity of the receptor. A detailed assessment of all beneficial impacts to flood risk is presented in Appendix C10.3: Flood Risk and Appendix C10.6: Impact Assessment Tables.

Due to the nature of the Scheme, localised areas are anticipated to experience an increase in peak flood depths during the design flood event (Figure 10.11a). This is due to increased attenuation of flood waters within floodplain areas required to mitigate flood risk to more sensitive receptors. Receptors noted within these floodplain areas are generally considered to be water compatible land uses, as defined in SEPA LUPS-GU24, and have therefore been assigned 'Low' importance in line with Table 10-3. Impacts on these receptors are assessed in Table 10-18. It should also be noted that the majority of areas where increases are noted are already at risk of flooding during the modelled design flood event in the baseline scenario.

The degree of change in flood depth to these Low importance receptors within the baseline 0.5% AEP (200-year) flood extent is typically >50 mm, which, following the examples in Table 10-4 results in an impact magnitude of Moderate or Major Adverse. Following

Table 10-6 this results in significant effects of Moderate Adverse to Very Large Adverse significance. However, given the receptors are considered water compatible uses and a majority of these areas are currently at flood risk in the baseline scenario, the reported impacts are considered to be overly conservative.

Only two areas that are assigned Low importance with respect to their land use (small, isolated areas within Rannoch Park and an area of vacant land to the north of Inchyra Lodge) are not currently within the baseline 0.5% AEP (200-year) flood extents and will experience estimated peak depths of 0.01-1.0m during operation, resulting in an effect of Moderate Adverse significance.

Table 10-18: Summary of adverse impacts to receptors of Low importance (Water Compatible Uses) associated with flood risk during operation

Watercourse	Description	Receptor	Importance	Magnitude	Significance of Effect
River Carron	Increase of up to 0.001-0.5 m within existing 0.5% AEP flood extent	River Carron floodplain Camelon Riverside Nature Site Abbotshaugh Community Woodland Cobblebrae Community Woodland Langlees Community WoodlandCore Paths	Low	Major Adverse	Moderate Adverse
		Queen Elizabeth II Canal within the River Carron floodplain			Slight Adverse

Watercourse	Description	Receptor	Importance	Magnitude	Significance of Effect
Forth Estuary	Increase of up to 0.01 to 0.1m within existing 0.5% AEP flood extent	Lock gates, woodland and wetland areas at Grangemouth Docks	Low	Moderate	Slight Adverse
Grange Burn	Increase of up to 0.01-0.50 m within existing 0.5% AEP (200-year) flood extents.	Grange Burn floodplain	Low	Major Adverse	Moderate Adverse
	Localised increases observed do not reflect a wider scale change in the flood risk and are likely related to the influence of the nearby boundary conditions.	Grange Burn floodplain	Low	Negligible	Neutral
River Avon	Increase of up to 0.01-2.50 m within existing 0.5% AEP (200-year) flood extents.	River Avon floodplain, Settlement ponds Core Paths	Low	Major Adverse	Moderate Adverse
Polmont Burn/ Westquarter Burn	Increase of up to 0.01-1.0 m within existing 0.5% AEP (200-year) flood extents.	Westquarter Burn/Polmont Burn floodplain Core Paths	Low	Major Adverse	Moderate Adverse
Grange Burn Flood Relief Channel	Increase of up to 0.01-1.0 m within existing 0.5% AEP (200-year) flood extents.	Rannoch Park Grange Burn Flood Relief Channel floodplain (right bank), including area north of Inchrya Lodge Core Paths	Low	Major Adverse	Moderate Adverse
	Localised increases along the Flood Relief Channel left bank although these do not reflect a wider scale change in the flood risk.	Grange Burn Flood Relief Channel floodplain (left bank)	Low	Negligible	Neutral

Within localised areas, receptors of Medium to Very High importance (i.e., Travelling People's site, two residential properties, commercial buildings (dance studios), a caravan parka former pumping station and access road) are anticipated to experience increases of peak flood depths during the design flood event. All receptors are within the baseline 0.5% AEP (200-year) flood extent, during which they will experience up to 2.0 m increase in flood depth. The path of the Antonine Wall Scheduled Monument will also be affected by changes in flood depth, this is discussed further in Chapter 13: Cultural Heritage. Table 10-19 provides a summary of adverse impacts to Medium to Very High importance receptors.

Table 10-19: Summary of adverse impacts to Medium to Very High importance receptors flood risk during operation

Watercourse	Description	Receptor	Importance	Magnitude	Significance of effect
River Carron	Increase of up to 0.01-0.50 m within existing 0.5% AEP (200-year) flood extents.	Industrial, commercial (Dance Studios) and two residential properties at Stirling Road Agricultural land	High	Major Adverse	Very Large Adverse
	Increase of up to 0.01-0.50 m within existing 0.5% AEP (200-year) flood extents.	Caravan park and plant nursery	Very High	Moderate Adverse	Very Large Adverse
River Avon	Increase of up to 0.01-1.50 m within existing 0.5% AEP (200-year) flood extents.	Travelling people's site Pumping station Agricultural land Access road	Very High	Major Adverse	Very Large Adverse
	Increase of up to 0.01-1.5 m within existing 0.5% AEP (200-year) flood extents.	Agricultural land	Medium	Major Adverse	Large Adverse
	Increase of up to 0.10-1.0 m within existing 0.5% AEP (200-year) flood extents.	Sewage Pumping station and associated access Agricultural land Milnholm Farm / Residential stables east	Medium	Major Adverse	Large Adverse

Watercourse	Description	Receptor	Importance	Magnitude	Significance of effect
		of Reddoch Road			
Polmont Burn/ Westquarter Burn	Increase of up to 0.10-2.5 m within existing 0.5% AEP (200-year) flood extents.	Agricultural land	Medium	Major Adverse	Large Adverse
Forth Estuary	Localised increases can be seen along the coastline although these do not reflect a wider scale change in the flood risk and are likely related to the influence of the nearby boundary conditions.	Agricultural land	Medium	Negligible	Neutral
	Increase of up to 0.01-0.50 m within existing 0.5% AEP (200-year) flood extents.	Agricultural land	Medium	Major Adverse	Large Adverse

A detailed assessment of all adverse impacts on flood risk is presented in Appendix C10.3: Flood Risk. Impacts of changes to flood risk during operation as a result of the Scheme on the community are presented in Chapter 6: Population and Human Health.

10.5.7 Groundwater

10.5.7.1.1 Introduction

Full details of the assessment of potential impacts to groundwater levels and flows during construction and operation are included in Appendix C10.4: Groundwater and Appendix C10.6: Impact Assessment Tables. The following sub-sections set out the conclusions of the assessment for each of the issues considered.

10.5.7.2 Construction phase

10.5.7.2.1 Excavation Works

Potential impacts from dewatering of excavations during construction which may result in changes to groundwater levels and flows, on groundwater resources, groundwater features (such as abstractions, GWDTEs and springs), baseflow to watercourses and the built environment are assessed as being of Neutral to Large significance. A detailed assessment of impacts and resultant effects of dewatering on all groundwater resources and features is presented in Appendix C10.6: Impact Assessment Tables.

Impacts associated with dewatering of excavation works and resultant effects of Moderate significance are summarised in Table 10-20 below.

Table 10-20: Summary of pre-mitigation significant effects on groundwater receptors from excavation works during construction

Type of Impact	Description	Receptor	Importance	Magnitude	Significance of Effect
Changes to groundwater levels and flows due to dewatering of excavations for bridge abutments (up to 5m depth)	Dewatering of excavations for bridge abutments adjacent to the River Carron, Grange Burn and Millhall Burn have the potential to impact on baseflow to these watercourses.	River Carron Grange Burn Millhall Burn	Very High	Minor Adverse	Moderate
	Dewatering of excavations for bridge replacements in Flood Cells 1 and 4 has the potential to create minor differential settlement, due to the limited depth of excavations and localised extent of associated groundwater drawdown.	Retail/ Commercial and Community Facilities	High	Minor Adverse	Moderate
		Industrial Buildings, Critical Infrastructure and Scheduled Monuments	Very High	Minor Adverse	Moderate

10.5.7.2.2 Sheet Piles

Construction of sheet piles may create pathways for the transport of contaminants to high permeability horizons of superficial deposits, which would result in minor adverse impacts to groundwater resources with a significance of Slight at the scale of the aquifer.

Sheet piles may also intersect horizons of artesian groundwater, resulting in changes to groundwater levels and flows. This may result in impacts of minor adverse magnitude and Slight to Moderate significance on groundwater resources, at the scale of the aquifer.

Intersection of artesian groundwater by sheet piles may result in the flow of groundwater at surface, which has the potential to cause flooding which may result in minor adverse impacts on nearby built environment receptors and Slight to Moderate significance effects.

A detailed assessment of impacts and resultant effects on groundwater quality and levels from construction of sheet piles is presented in Appendix C10.6: Impact Assessment Tables, and potential significant impacts are summarised in Table 10-21.

Table 10-21: Summary of pre-mitigation significant effects on groundwater receptors from installation of sheet piles during construction

Type of Impact	Description	Receptor	Importance	Magnitude	Significance of Effect
Risk of flooding due to intersection of artesian groundwater by sheet piles	Proposed sheet piles may intersect artesian groundwater in Flood Cell Working Areas 1-2, 5-1 and 6-4, which has the potential to create pathways for groundwater to release at surface and may lead to flooding.	Retail/ Commercial and Community Facilities	High	Minor Adverse	Moderate
		Industrial Buildings, Critical Infrastructure and Scheduled Monuments	Very High		

10.5.7.2.3 Direct Impacts

The proposed works may have direct impacts on features of the groundwater environment, including abstractions, GWDTEs and springs. Two springs (Spr-13 and Spr-16) have been identified to lie within the footprint of temporary site compounds. The loss of these features would have a potential Major Adverse magnitude with a resulting Slight significance. One GWDTE (GW22) lies partially within the permanent works footprint, and loss of a portion of this receptor has been assessed to have a potential impact of moderate magnitude with a resulting Moderate significance, while a further GWDTE (GW12) lies partially within the footprint of temporary site compounds, and loss of a portion of this receptor has been assessed to have a potential impact of moderate magnitude with a resulting Moderate significance.

A detailed assessment of direct impacts and resultant effects on groundwater features is presented in Appendix C10.6: Impact Assessment Tables, and potential significant impacts are summarised in Table 10-22 below.

Table 10-22: Summary of pre-mitigation significant effects on groundwater receptors from installation of sheet piles during construction

Type of Impact	Description	Receptor	Importance	Magnitude	Significance of Effect
Loss of feature due to direct impact of construction.	Located partially within the permanent works footprint and therefore part of the GWDTE is likely to be removed as a result of the works.	GW22	Medium	Moderate Adverse	Moderate
	Located partially within the temporary works footprint (site compound) and therefore part of the GWDTE is likely to be	GW12	Medium	Moderate Adverse	Moderate

Type of Impact	Description	Receptor	Importance	Magnitude	Significance of Effect
	removed as a result of the works.				

10.5.7.2.4 Accidental Spillages and Leakages

Groundwater vulnerability mapping indicates there will be localised areas to the east and south of the study area, underlying Flood Cells 1, 4 and 5, which will be vulnerable to any pollutants released during construction. However, the majority of groundwater within the study area will not be "vulnerable to any accidental spillages, uncontrolled run-off and increased sedimentation likely to occur during construction" (BGS, 1988b) and are only considered vulnerable to "conservative pollutants in the long-term when continuously and widely discharged/leached".

The impacts to superficial groundwater resources from accidental spills or leakages of pollutants may result in Moderate Adverse changes to groundwater quality, which have the potential to be long-term. The presence of superficial deposits will provide some protection to the underlying bedrock groundwater resources, where the impacts of accidental spills or leakages may result in Minor Adverse changes to groundwater quality, with the exception of the Passage Formation, where proposed sheet piles in Flood Cell 4-South and Flood Cell 5 have the potential to create a pathway through the superficial deposits, elevating the magnitude to Moderate.

Accidental spills or leakages also have the potential to impact upon GWDTEs, abstractions, wells and springs, the magnitude of which will depend on the intervening topography and distance from the incident. The magnitude of potential impacts to receptors such as these have been identified as Negligible to Major Adverse resulting in significance of Neutral to Large.

A detailed assessment of impacts and resultant effects on groundwater quality is presented in Appendix C10.6: Impact Assessment Tables (Table C10.6.4).

Impacts on groundwater quality associated with construction activities and resultant effects of Moderate to Large significance are summarised in Table 10-23 below. The risk to groundwater receptors from the mobilisation of historical contaminated land is considered in Chapter 11: Soils, Geology and Contamination.

Table 10-23: Summary of pre-mitigation significant effects on groundwater receptors from changes to groundwater quality during construction

Type of Impact	Description	Receptor	Importance	Magnitude	Significance of Effect
Accidental spillage of fuels, oils, chemicals, cementitious materials, mobilisation of suspended solids etc.	The use of potentially polluting substances (through vehicle movements, material storage and movements and concrete pouring) may result in contamination of groundwater, particularly during excavation or via	Raised Marine Deposits	High	Moderate Adverse	Large
		Alluvium	High	Moderate Adverse	Large
		Passage Formation	High	Moderate Adverse	Large

Type of Impact	Description	Receptor	Importance	Magnitude	Significance of Effect
	accidental spillage of vehicular oils, hydraulic fluids, and fuels in highly permeable areas. Excavations below the water table have the potential to increase suspended solids in the groundwater. However, due to the filtering effect of the low permeability aquifers, migration of suspended solids would be minimal. Attenuation of contaminants in low permeability superficial deposits will reduce the impact of contamination incidents in the bedrock strata located at depth. Sheet piles in Flood Cell 4-South and Flood Cell 5 have the potential to intersect bedrock of the Passage Formation and create pathways for contaminants to bypass superficial deposits. The magnitude of potential impacts in this formation are thus elevated to the same magnitude as for the superficial deposits. Proximity to construction activities and permeability of underlying aquifer material would have the greatest effect on the magnitude of potential impacts to GWDTEs and associated springs.	Scottish Lower Coal Measures Formation	High	Minor Adverse	Moderate
		Scottish Middle Coal Measures Formation	High	Minor Adverse	Moderate
		GW10, GW13, GW16 and GW17	Medium	Moderate Adverse	Moderate
		GW12, GW22 and GW23	Medium	Major Adverse	Large
		GW24 and Springs 21-23	Very High	Moderate Adverse	Large

10.5.7.3 Operation phase

10.5.7.3.1 Groundwater Levels and Flows

Operation phase impacts to the groundwater environment are considered to be localised in nature, and effects may include both increases and decreases to groundwater levels, due to the presence of permanent below-ground structures. Changes in groundwater levels and flows may result in effects on groundwater supply to GWDTEs, abstractions, springs and groundwater baseflow to watercourses, which would be variable based on topography and the distance of the receptors from the Scheme. Impacts to the majority of these receptors have been assessed as Slight significance and below. However, impacts to certain receptors may be greater, where the importance is Very High or magnitude of impact is Moderate. Impacts associated with operation activities on groundwater levels and flows, and resultant effects of Moderate or Large significance are summarised in Table 10-24 below.

A detailed assessment of all impacts and resultant effects is presented in Table C10.6.7 of Appendix C10.6: Impact Assessment Tables.

Table 10-24: Summary of pre-mitigation significant effects on groundwater receptors from changes to groundwater flows and levels during operation

Type of Impact	Description	Receptor	Importance	Magnitude	Significance of Effect
Changes to groundwater levels and groundwater flow direction due to piling	Potential change to groundwater base flow to the River Carron in Flood Cell 1 would be moderate, due to alteration to direction of groundwater flow and changes to groundwater levels, particularly those areas underlain by Alluvium.	River Carron	Very High	Moderate Adverse	Large
	GW24 and Springs 21-23 lie partially within the Firth of Forth SSSI, SPA and Ramsar site. Proposed sheet piles cut obliquely across the likely regional groundwater flow path which may intercept a portion of the groundwater flowing towards this compound receptor. However, the underlying aquifer is low-permeability Intertidal Deposits, and therefore the potential impacts on the receptor would be minor.	GW24 and Springs 21-23	Very High	Moderate Adverse	Large
	GW16 and GW22 are located immediately downgradient of	GW16 and GW22	Medium	Moderate Adverse	Moderate

Type of Impact	Description	Receptor	Importance	Magnitude	Significance of Effect
	proposed sheet piles, which have the potential to reduce groundwater levels and flows contributing to the GWDTEs.				

10.5.7.3.2 Groundwater Flooding

Operation phase impacts to groundwater flood risk would be localised to the areas upgradient of new, permanent, below-ground structures such as sheet piles. Groundwater flooding poses a risk to the built environment, including residential, commercial and industrial buildings, along with community facilities, critical infrastructure and scheduled monuments. Impacts to these receptors have been assessed as Moderate to Very Large significance and are summarised in Table 10-25 below, and Appendix C10.6: Impact Assessment Tables.

Table 10-25: Summary of pre-mitigation significant effects on groundwater receptors from changes to groundwater flood risk during operation

Type of Impact	Description	Receptor	Importance	Magnitude	Significance of Effect
Changes to groundwater flood risk due to piling	Sheet piles have the potential to increase groundwater flood risk in Flood Cell 1, Flood Cell 4-North and Flood Cell 6, where sheet piles are proposed downgradient of receptors in relation to local and regional groundwater flow paths.	Residential buildings	Medium	Moderate Adverse	Moderate
		Retail/ Commercial and Community Facilities	High	Moderate Adverse	Large
		Industrial Buildings, Critical Infrastructure and Scheduled Monuments	Very High	Moderate Adverse	Very Large

10.5.7.3.3 Groundwater Quality

No direct impacts to groundwater quality are anticipated from the operation of the Scheme, as there would be no ongoing use of polluting materials or contaminated discharges to the ground. As such potential impacts on groundwater quality are not foreseen.

Operation phase impacts to groundwater quality due to the mobilisation and alteration of contaminant pathways have been considered via Conceptual Site Models which are presented in Chapter 11: Soils, Geology and Land Contamination.

10.6 Mitigation

10.6.1 Construction phase

10.6.1.1 Secondary mitigation

Secondary mitigation measures are elements of additional mitigation required to further reduce the impacts of the Scheme. Table 10-26 presents a summary of secondary mitigation applicable to the Water Environment.

Table 10-26: Construction Phase Secondary Mitigation

Item No.	Topic	Mitigation Description
Construction		
W1	General	Preparation of a Construction Environment Management Plan (CEMP) prior to commencement of works.
W2		Suitably qualified and experienced Environment Clerk of Works and Geomorphological Clerk of Works will be appointed to oversee the implementation of mitigation and monitoring of water environment during construction.
W3	Fluvial Geomorphology	Any material added to the channel to aid construction (i.e., during the formation of temporary in water working areas) will be of a geological composition similar to that of the existing sediment (i.e. derived from local borrow pits). The material will be clean, and not contain high quantities of silt. Where possible, the added material will be removed at the end of the works. Post excavation, natural bed material will be physically separated from construction fill to stop mixing. Imported sediment to aid construction will be of a size that is unlikely to mobilise during a flood event or will be configured such that it cannot be mobilised. Natural bed material will be reinstated post construction.
W4		Implementation of measures to reduce the extent of fine sediment transportation, such as: • minimising the extent of in-water working, and work from the bank side as far as practicable to reduce disturbance and damage to riverbeds and addition of excess sediment to the channel; • putting in place mitigations such as 'silt skirts' where construction must take place in or near areas of fine-grained sediments; and • disturbance of areas of fine-grained, easily transportable (by water) material would be avoided as far as practicable.
W5		Separating the working areas from the channel with working platforms which allow flow to bypass the works and minimise the width of the temporary working platforms within the channel, to allow single plant access with occasional passing places rather than a continuous 'two-lane' platform.
W6		Works will be undertaken (as far as practicable) during periods of low flow. All in-water works will be undertaken outwith fish spawning seasons.
W7		Limit the removal of vegetation from the riparian corridor and retain trees on banks and bank top as far as practicable during construction. Retain fallen trees and large wood on banks and in-water margins where practicable; retain root balls as a minimum during construction to aid the stability of the banks.
W8		Bank reinstatement following bank disturbance due to excavation of embankments, flood wall piling and shallow ground improvements.

Item No.	Topic	Mitigation Description
W9		Regular monitoring of any change to the channel bed and banks will be undertaken, particularly in the vicinity of the working platforms throughout the construction process. This will be undertaken using fixed point photography, with site surveys should any change be identified. If change does occur this will be reported to SEPA. If required, any mitigation will be agreed with SEPA.
W10		A detailed methodology and accompanying construction method statement for the restoration of the channel bed to the previous levels, including existing forms, will be created. The methodology statement will include detailed reconnaissance and topographic survey undertaken before the works commence and the full methodology will be agreed with SEPA. Bed restoration will be implemented as soon as possible during or after the period of works.
W11	Flood Risk	The Contractor(s) will implement the following mitigation measures during construction: • in-water working areas will be agreed with SEPA and Marine Scotland through the production of method statements, with the design, timing and location of works aiming to reduce the impact on flood risk, water flows and levels as far as practicable; • develop a flood response plan for all activities to be located within the functional floodplain (defined here as the 0.5% AEP (200-year) flood extent); • any temporary works within the functional floodplain will be made resistant or resilient to flood impacts; • if reasonably practicable, plant and material will be stored outside the 10% AEP (10-year) flood extent; • In advance of extreme flood events (e.g., 0.5% AEP (200-year), in-water working areas will be evacuated and allowed to flood to prevent any increases in flood levels from constriction of flows.
W12	Surface Water Quality	Water quality monitoring on affected watercourses will be undertaken one year prior to construction and during construction. The monitoring regime will include (but not be limited to) monthly laboratory analysis of determinants to be agreed in consultation with SEPA and visual inspections. Water quality criteria and standards to be achieved for all site discharges during construction, and sampling locations, will be agreed in consultation with SEPA.
W13		In relation to construction site runoff and sedimentation, the Contractor(s) will produce and adhere to Pollution Prevention Plans which will include, but may not be limited to: • avoid unnecessary stockpiling of materials and exposure of bare surfaces, limiting/phasing topsoil stripping wherever practicable; • use of silt fences, bunds, filter trenches, check dams, settlement lagoons, soakaways and other sediment trap structures as appropriate;

Item No.	Topic	Mitigation Description
		• use an appropriate grade of material on temporary haul routes and in-water working areas that will be clean and will be durable under heavy trafficking; • monitor, maintain and regrade routes where necessary; • limit the amount of tracking adjacent to watercourses and avoid creation of new flow paths; • provision of wheel washes at appropriate locations (in terms of proposed construction activities) and >10 m from water features where practicable; • protocols will be developed for ceasing or reducing construction activities during periods of high rainfall to reduce the risks of erosion, sedimentation and pollution; • protection of soil stockpiles using bunds and silt fencing, locate stockpiles >10 m from water features where practicable; • concrete mixing and washing areas will be located > 10 m from water features (where practicable), have settlement and re-circulation systems for water reuse; and have a contained area for washing out and cleaning of concrete batching plant or ready-mix lorries; • chemical, fuel and oil storage will be undertaken within a site compound, which will be located on stable ground at a low risk of flooding and >10 m from any watercourse, where practicable; • quick setting products (cement, concrete, and grout) will be used for structures that are in or near to watercourses; and • equipment and materials will be removed wherever possible from the in-river working platforms. The Contractor(s) will provide sufficient security to minimise the risk of vandalism to equipment and materials which may release pollutants into the water environment. These Plans will form part of the CEMP and will be submitted to SEPA for approval prior to construction as part of the CAR Construction Site Licence authorisation or CAR Licensing process.
W14		During replacement of the lock gates, a dry working area will be established, where possible to minimise the risk of disturbance, resuspension, and migration of potentially contaminated bed material into the eastern channel or into the Middle Forth (which is a SSSI and SPA). Where practical, this bed material will be dredged/excavated and disposed of at an appropriately licensed facility. Should dredging be required prior to the establishment of a dry working area, this will be undertaken in calm conditions and avoid surge conditions.

Item No.	Topic	Mitigation Description
		Booms or silt curtains will be deployed to prevent the migration of dredged material. This may include one or more booms and/or bubble screens and/or silt curtains at each entrance and exit of the locks. Consultation with Marine Scotland may be required, see Mitigation Item W15 below.
W15		For works within areas identified as potentially containing contaminated land and sediment the Contractor(s) will reduce the risk of surface water pollution to an acceptably low level through: • further site investigation to determine the level of contamination prior to start of construction; • the installation of temporary treatment facilities to enable removal of pollutants from surface waters; and • further consultation with Marine Scotland and Forth Ports may be required subject to the results of any further site investigation in areas where sediment may be dredged and disposed of. This includes (but is not limited to) the area surrounding the lock gate replacement at the entrance to the Eastern Channel at Grangemouth Docks, where potentially contaminated bed sediments may be present. Assessment of any site investigation results (bed sediment samples) against Marine Scotland Action Levels (Marine Scotland, 2017) may be required.
W16	Private Water Supplies and Abstractions	In relation to service diversions and to avoid damage to existing services from excavations and ground penetration, including temporary severance of public and private water supplies through potential damage to infrastructure, the Contractor(s) will: • locate and map all private or public water supply assets and other service infrastructure prior to construction; • take measures to prevent damage to services and to avoid pollution during service diversions, excavations and ground works; and • liaise with Scottish Water to request suitable mitigation is implemented if services are disrupted or diverted by the works.
W17	Groundwater	Where artesian groundwater conditions have been identified, the design depth of sheet piles will terminate above bedrock, to avoid the release of artesian groundwater during construction. Based on the outcome of the detailed dewatering and groundwater flow assessments, as well as findings associated with contamination outlined in Chapter 11: Soils, Geology and Land Contamination, additional mitigation measures may be required to treat groundwater. If a requirement for additional mitigation measures is identified, proposed measures will be discussed with SEPA prior to finalisation.
W18		Detailed assessment of potential settlement effects on buildings at risk. Where further assessment establishes a potential subsidence risk to buildings, the Contractor(s) will carry out monitoring during construction and implement appropriate mitigation where necessary.

Item No.	Topic	Mitigation Description
W19		Additional National Vegetation Classification (NVC) survey will be undertaken for GW22 and GW12 to improve the characterisation and confirm the presence of GWDTE. This will include the exact delineation of the GWDTE vegetation. Detailed design will avoid encroaching or keep to a minimum direct footprint onto GWDTE vegetation.
W20		A risk assessment for the use of cementitious materials within 50 m of any excavations or highly permeable areas, which may lead to seepage into groundwater aquifers. To reduce the potential effect on groundwater quality, concrete will be batched off-site where practical.
W21		Groundwater abstracted to facilitate excavations will be returned to watercourses immediately downstream of the works.

10.6.1.2 Tertiary Mitigation

Construction of the Scheme would include tertiary mitigation in the form of good practice undertaken by the Contractor(s) to reduce impacts to the water environment during construction. These should include:

- adherence to appropriate guidance outlined in Table 10-27 (**Mitigation Item W22**);
- compliance with the conditions of the Marine Licence and any CAR Construction Site Licence authorisation (**Mitigation Item W23**);

Table 10-27: Relevant guidance for the construction phase

Body or Organisation	Guidance	Consultation
SEPA	Pollution Prevention Guidelines (PPGs) and Guidance for Pollution Prevention (GPPs), in particular: • PPG 1: Understanding your environmental responsibilities – good environmental practices (SEPA 2013b) • GPP 2: Above ground oil storage tanks (SEPA 2018a) • GPP 5: Works and maintenance in or near water (SEPA 2017c) • GPP 8: Safe storage and disposal of used oils (SEPA 2017d) • PPG 18: Managing fire water and major spillages (SEPA 2000) • GPP13: Vehicle washing and cleaning (SEPA 2021a) • GPP 21: Pollution incident response planning (SEPA 2017b) • GPP 22: Dealing with spills (SEPA 2018c) • GPP 26: Safe Storage of Drums and Intermediate Bulk Containers (SEPA 2021b)	Consultation with SEPA on the following: • Construction Environmental Management Plan; • Surface Water Management Plan; • Detailed construction method statements in relation to all in-water working areas required during construction.
	WAT-SG-67: Assessing the Significance of Impacts – Social, Economic and Environmental (SEPA 2017a)	
	WAT-RM-11: Licensing Groundwater Abstractions Including Dewatering (SEPA, 2017e)	
	WAT-RM-16: Hydrogeologist input to groundwater abstraction assessment (SEPA, 2013a)	
	WAT-SG-21: Environmental Standards for River Morphology (SEPA, 2012)	
	WAT-SG-23: Engineering in the Water Environment Good Practice Guide – Bank Protection Rivers and Lochs (SEPA, 2008)	
	WAT-SG-25: Engineering in the Water Environment Good Practice Guide – River Crossings (SEPA, 2010)	

Body or Organisation	Guidance	Consultation
	WAT-SG-29: Engineering in the Water Environment: Good Practice Guide: Temporary Construction Methods (SEPA, 2009b)	
	WAT-SG-44: Riparian Vegetation Management (SEPA, 2009c)	
	WAT-PS-06-02: Culverting of Watercourses – Position Statement and Supporting Guidance (SEPA, 2015b)	
	Groundwater Protection Policy for Scotland, Version 3 (SEPA, 2009a)	
	The Water Environment (Controlled Activities) (Scotland) Regulations (2011) (as amended) (CAR). A Practical Guide (SEPA 2011)	
Scottish Government	Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) and Compliance with the conditions of any Controlled Authority Regulation (CAR) Construction Site Licence authorisation.	N/A
CIRIA	C532: Control of water pollution from construction sites (2001)	N/A
	C624: Development & Flood Risk – Guidance for the Construction Industry (2004)	
	C635: Designing for Exceedance in Urban Drainage – Good Practice (2006b)	
	C648: Control of water pollution from linear construction projects: Technical Guidance (2006a)	
	C649: Control of Water Pollution from Linear Construction Projects: Site Guide (2006c)	
	C744: Coastal and marine environmental site guide (second edition) (2015a)	
	C741: Environmental good practice on site guide (fourth edition) (2015b)	
	C750: Groundwater control: design and practice (2016a)	
	C763: River weirs – Design, maintenance, modification and removal (2016b)	
	C786: Culvert, screen and outfall manual (2019)	
Marine Scotland	Pre-disposal Sampling Guidance Version 2 (Scottish Government) (Marine Scotland, 2017).	Consultation with Marine Scotland may be required in relation to any sediment dredging/disposal required during lock gate replacement.

10.6.2 Operation phase

10.6.2.1 Secondary mitigation

No mitigation measures to reduce the significance of water quality at the operation phase are proposed as the assessment has indicated that the significance of effects prior to mitigation are Slight or Neutral.

Secondary mitigation measures to reduce the significance of impacts to groundwater presented for construction (Table 10-26) will also reduce the significance of impacts during operation.

Secondary mitigation measures required to mitigate against impacts on fluvial geomorphology, therefore affecting the potential for watercourses to reach their WFD targets, are presented in Table 10-28.

Table 10-28: Operation Phase Mitigation

Item No.	Topic	Mitigation Description
W24	Fluvial Geomorphology	A separate program of river restoration measures on the Grange Burn/Westquarter Burn shall be committed to, which will identify and undertake measures to improve the morphological diversity of the channel banks and bed, encourage natural recovery and improve riparian habitat. Subject to further investigation, design and consultation with SEPA and other relevant stakeholders, potential measures may include (but not be limited to) removing or softening existing bank protection where present, reprofiling of the banks, creation of alternate berms and planting of riparian vegetation in highly modified reaches of the watercourse, such as the reach from approx. NGR NS 92685 80288 to NS 92827 81371.
W25		Soften existing hard bank protection (e.g., willow spiling) and appropriate marginal planting on the Grange Burn/Westquarter Burn from Zetland Park to Bo'ness Rd, between NGR NS 92827 81371 to NS 92993 81990.
W26		Monitoring of the watercourses should be carried out to identify if there are any operational geomorphological issues associated with the Scheme, such as any impacts on watercourse stability (e.g., areas of excessive erosion or deposition) triggered by the Scheme. This will enable any such issues identified to be investigated and remediated as early in the operational phase as possible. Further details are provided in Appendix C10.1 – Fluvial Geomorphology.
W27	Estuarine Geomorphology	Soften banks on the Grange Burn (3300-Grange Burn/Westquarter Burn) during reinstatement from Bo'ness Rd to the estuary, between NGR NS 92993 81990 and NS 94587 82541. Soft bank protection includes pre-planted coir matting or rolls which supports riparian vegetation to quickly re-establish.
W28		Reprofile the banks on the Grange Burn / Westquarter Burn along Grange Burn Road between NGR NS 93036 82090 and NGR NS 94587 82541 to restore morphological diversity to the channel. Slope

Item No.	Topic	Mitigation Description
		reprofiling extent will limit the impact on tree and shrub cover on the north bank.
W29	Flood Risk	Further pluvial modelling will be undertaken at the detailed design stage to inform the impact of surface water flooding on receptors. Where necessary, additional surface water drainage will be implemented, for example additional storage, higher capacity drainage or pumping stations. Any detailed assessment will also consider the interaction of proposed flood defences with existing surface water drainage and the Scottish Water network.
W30		Discussions have taken place with stakeholders which may be impacted due to increases in tidal and fluvial peak flood depths or extent during the 0.5% AEP (200-year) event during the development of the Scheme. Ongoing consultation will take place after publication of the Scheme and through further detailed design to assess appropriate mitigation.
W31	Groundwater	A detailed hydrological – hydrogeological assessment of the terrestrial portion of the Firth of Forth SSSI, SPA and Ramsar will be carried out prior to construction. In particular, the detailed assessment will investigate the proportion of groundwater and run-off that contributes to sustaining this protected environment, with a view to adjust the design detailed of the proposed direct defence (with below ground structure) east of the existing treatment work. If required, a Water Compensation Strategy will be put in place to redirect lost water towards the impacted area. Subject to the outcomes of this assessment, monitoring may be required.
W32		A detailed hydrogeological assessment of baseflow groundwater contributions to the River Carron in Flood Cell 1 will be undertaken to support the re-direction of groundwater abstracted during temporary works to the River Carron and compensate baseflow losses. Based on the outcome of the detailed dewatering and groundwater flow assessments as well as findings associated with contamination outlined in the Chapter 11: Soils, Geology and Land Contamination chapter, additional mitigation measures may be required to treat groundwater. If a requirement for additional mitigation measures is identified, proposed measures will be discussed with SEPA prior to finalisation.
W33		To mitigate against a potential increase in groundwater level reaching the ground surface, filter drains will be placed on the upgradient side of the defences to intercept rising groundwater, should it occur, with gravity outfalls to the nearest watercourse. The filter drains will be regularly maintained to ensure they are operational at all times. The filter drains will be sized to ensure they evacuate groundwater volumes sufficiently so that no new groundwater flooding events occur as a result of the Scheme. The detailed design stage will therefore need to be

Item No.	Topic	Mitigation Description
		supported by a more detailed groundwater flow and level risk assessment. Based on the outcome of the detailed dewatering and groundwater flow assessments as well as findings associated with contamination outlined in the Chapter 11: Soils, Geology and Land Contamination chapter, additional mitigation measures may be required to treat groundwater. If a requirement for additional mitigation measures is identified, proposed measures will be discussed with SEPA prior to finalisation.
W34		An updated NVC survey and a hydrogeological survey will be carried out for potential GWDTE sites GW16, GW22 and GW24 to confirm the areas of GWDTE and support a detailed site characterisation.
W35		Additional ground investigation and groundwater level monitoring will be carried out along the proposed sheet pile section to the southwest of GW24. This investigation will extend further west, outside the footprint of the proposed sheet piles, to enable a robust characterisation of the groundwater flow component feeding GW24.
W36		Using information collected in W34 and W35, a detailed CSM complemented by a freshwater balance will be undertaken for GW24. A Water Compensation Strategy will be developed to ensure that freshwater groundwater flow losses are compensated by water being redirected towards GW24.
W37		Sheet pile detailed design will be developed in cognisance of information gathered in W34, W35 and W36 to allow a sufficient proportion of groundwater to reach GW16, GW22 and GW24.

10.6.2.2 Tertiary mitigation

Mitigation Item W38: Detailed design of any permanent culverts will ensure adherence to relevant design standards and good practice guidance, such as SEPA WAT-SG-25: Engineering in the Water Environment Good Practice Guide – River Crossings (SEPA, 2010), wherever practical.

Mitigation Item W39: Watercourse crossing designs will take account, but not be limited to the following:

- appropriate hydraulic design to mitigate flood risk impacts, as assessed against an appropriate flood event;
- appropriate design of culvert structures and watercourse modifications (e.g., realignments) with respect to fluvial geomorphology, and riparian and aquatic ecology;
- an experienced fluvial geomorphologist will input into the design of all watercourse crossings and associated engineering activities where appropriate;
- the design of culverts and associated watercourse modifications will incorporate, wherever practical:
  - the channel cross section through culverts will be profiled to replicate the existing channel shape (and width) up to the predicted Q_{MED} water level where appropriate;

  - maintenance of the existing channel gradient to avoid erosion at the culvert inlet and outlet;
  - avoidance of reduction of watercourse length through shortening of watercourse planform;
  - where possible, culvert lengths will be kept to a minimum and will align of with the existing watercourse; and
  - implementation of energy dissipation (e.g., stilling basins) and sediment retention measures where necessary; depressing the invert of culverts to allow for reinstatement of natural bed with embedment of the culvert invert to a depth of at least 300mm.
- wherever practicable the re-planting of vegetation around culverts where required shall be undertaken. Vegetation will tie in with natural vegetation, where the trees are removed during construction, re-planting is of particular importance; and
- post-scheme construction appraisal will be undertaken to identify if there are issues that can be addressed as early in the operation phase as possible.

Mitigation Item W40: Operation of the Scheme would include tertiary mitigation in the form of good practice undertaken by the maintenance workers to reduce impacts to the water environment. These should include adherence to the following appropriate guidance:

- C786 Culvert, screen and outfall manual Culvert Design and Operation Guide (CIRIA, 2019);
- C720 Culvert design and operation guide supplementary technical note on understanding blockage risks (CIRIA, 2013);
- C763 River Weirs – Design, maintenance, modification and removal (CIRIA, 2016); and
- WAT-SG-44 - Engineering in the Water Environment Good Practice Guide: Riparian Vegetation Management (SEPA, 2009c).

10.7 Residual effects

10.7.1 Introduction

Following implementation of the secondary mitigation measures outlined in Section 10.6, the potential for significant effects on surface waters and groundwaters will be avoided/prevented, reduced or offset.

The residual significant effects likely to occur during either the construction or operation phases following the application of mitigation measures are identified below.

10.7.2 Construction phase

10.7.2.1 Estuarine geomorphology

Residual effects of **Slight Adverse significance** or below are expected during the construction phase.

10.7.2.2 Fluvial geomorphology

Residual effects of **Slight Adverse significance** or below are expected during the construction phase provided all proposed mitigation measures are effectively implemented.

10.7.2.3 Flood risk

Residual effects of **Slight Adverse significance** or below are expected during the construction phase, provided all proposed mitigation measures are effectively implemented. It is noted that detailed construction flood modelling should be carried out, as outlined in the mitigation section above, to confirm the potential impacts to changes in flood risk.

10.7.2.4 Surface water quality and supply

Residual impacts of **Slight Adverse Significance** or below are expected during the construction phase provided all proposed mitigation measures are adhered to.

10.7.2.5 Groundwater

Residual impacts of **Slight Adverse significance** or below are expected during the construction phase, provided all proposed mitigation measures are effectively implemented. As outlined in the mitigation section above, further hydrogeological assessment will be required to confirm the potential impacts to changes in groundwater levels.

10.7.3 Operation phase

10.7.3.1 Estuarine geomorphology

Residual effects of **Slight Adverse significance** or below are expected during the operation phase.

10.7.3.2 Fluvial geomorphology

Residual effects of **Slight Adverse significance** or below are expected during the operation phase, provided all proposed mitigation measures are effectively implemented.

10.7.3.3 Flood risk

Overall, the residual effects associated with reduced flood risk across the Scheme area will be of **Very Large Beneficial significance** during the operation phase. However, there are localised areas within the Scheme where isolated effects of up to **Very Large Adverse significance** have been identified as detailed in Table 10-29 below.

Table 10-29: Summary of adverse impacts to Medium to Very High importance receptors flood risk during operation

Watercourse	Description	Receptor	Importance	Magnitude	Significance of effect
River Carron	Increase of up to 0.01-0.50 m within existing 0.5% AEP (200-year) flood extents.	Industrial, commercial (Dance Studios) and two residential properties at Stirling Road Agricultural land	High	Major Adverse	Very Large Adverse
	Increase of up to 0.01-0.50 m within existing	Caravan park and plant nursery	Very High	Moderate Adverse	Very Large Adverse

	0.5% AEP (200-year) flood extents.				
River Avon	Increase of up to 0.01-1.50 m within existing 0.5% AEP (200-year) flood extents.	Travelling people's site Pumping station Agricultural land	Very High	Major Adverse	Very Large Adverse
	Increase of up to 0.01-1.5 m within existing 0.5% AEP (200-year) flood extents.	Agricultural land	Medium	Major Adverse	Large Adverse
	Increase of up to 0.10-1.0 m within existing 0.5% AEP (200-year) flood extents.	Sewage Pumping station and associated access Agricultural land	Medium	Major Adverse	Large Adverse
Polmont Burn/ Westquarter Burn	Increase of up to 0.10-2.5 m within existing 0.5% AEP (200-year) flood extents.	Agricultural land	Medium	Major Adverse	Large Adverse
Forth Estuary	Increase of up to 0.01-0.50 m within existing 0.5% AEP (200-year) flood extents.	Agricultural land	Medium	Major Adverse	Large Adverse

For these areas, further consultation is required with affected parties to identify mitigation that is practical and appropriate to the level of flood risk and is in line with **Mitigation Item W39**. These discussions have taken place during development of the Scheme and will continue post publication on an individual basis depending on the level of residual flood risk to assess appropriate mitigation. This mitigation will be implemented once agreed.

With regard to pluvial flood risk during operation, as outlined in the mitigation section above, modelling will be carried out to confirm whether potentially significant impacts may arise and establish whether feasible mitigation may be required.

10.7.3.4 Surface water quality and supply

No residual effects are anticipated during the operation phase.

10.7.3.5 Groundwater

The detailed design stage of the Scheme will be progressed with consideration for the local groundwater setting, and mitigation required to limit impacts on groundwater will be embedded within the design as necessary. A further hydrogeological assessment, as outlined in the mitigation section above, will be required to confirm the potential impacts to changes in groundwater levels. Therefore, depending on the outcome of this assessment and embedded design solutions, the residual impact to GW24 and associated springs could be **Slight to Moderate Adverse significance**. Residual effects of **Slight Adverse significance** are anticipated for the remaining groundwater environment receptors during the operation phase for all groundwater receptors.

10.8 Interaction with other environmental disciplines

The effects of the Scheme on the water environment are closely linked to, and in some instances interdependent on those identified in Chapter 7: Biodiversity and Chapter 11: Soils, Geology and Land Contamination in the following ways:

- impacts (adverse or beneficial) to water quality are likely to affect biodiversity and nature conservation;
- impacts (adverse or beneficial) from implementation of mitigation measures on water environment receptors on biodiversity or landscape;
- where contaminated land is present, changes to water (surface waters and groundwater) flows and levels during construction or operation may result in the reduction or increase of mobilisation of contaminants to the water environment; and
- inter-discipline cumulative impacts to surface water features during construction and operation, due to the impacts to geomorphology, water quality, flows and levels (surface water and groundwater) presented in this chapter. For example, effects in relation to flow conditions are likely to be directly correlated with effects to geomorphology.

No residual impacts of **Moderate Adverse significance** or above relating to the above interactions are expected during the construction or operation phase.

10.9 Cumulative effects

Impacts to water environment receptors are reported for the whole watercourse or receptor and, due to the interlinked nature of impacts to receptors, are considered within the wider context for each water environment discipline rather than in isolation.

The effect of the Scheme on the overall WFD status of each watercourse is presented in Appendix C10.5: Water Framework Directive Assessment, which takes account of each individual component of the WFD status, including Hydromorphology, Biology and Water Quality. As a result, no additional, same-project additive cumulative effects are considered likely for water environment receptors.

There is potential for cumulative effects due to other projects affecting the same water environment receptors as the Scheme. A summary of relevant developments and potential cumulative impacts is presented in Chapter 15: Cumulative Effects and are presented in Table 10-30. Assuming good practice and relevant guidance is adhered to, no residual cumulative effects of **Moderate Adverse significance** or above are predicted during the construction or operation phases.

Table 10-30: Potential Cumulative Effects

Planning Application / Marine Licencing Application	Potential Cumulative Effect
P/20/0029/FUL Formation of Car Park, Reconfiguration of Existing Car Parks, Provision of Temporary	The proposed development is located approximately <5m from Chapel Burn. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, given the scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.

Planning Application / Marine Licencing Application	Potential Cumulative Effect
Parking and Associated Infrastructure	
P/20/0044/FUL Erection of 82 Dwellinghouses and 24 Flatted Dwellings	The proposed development is located approximately <5m from a tributary of Bonny Water, which flows into the River Carron. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, it is anticipated that sufficient construction mitigation measures including treatment and attenuation will be implemented during construction of the development and sufficient dilution would take place within the River Carron prior to any pollution reaching the Scheme area. Therefore, no change to the pre-mitigation or residual significance of effects are anticipated.
P/20/0111/FUL Installation of Modular Building for Use as Pre-School Nursery (Class-10 Non-Residential Institution)	The proposed development is located approximately 63m from Polmont Burn. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, given the scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.
P/20/0305/FUL Extension to Restaurant and Erection of Decking	The proposed development is located approximately <5m from Polmont Burn. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, given the scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.
P/20/0460/FUL Change of Use and Alterations to House (Class 9) to Hotel (Class 7) with Ancillary Manager's Flat	The proposed development is located approximately 100m from Polmont Burn. However, given the nature and scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.
P/20/0493/PPP Mixed Use Development, Including Residential, Employment, Commercial and Retail Use, Open Space and Landscaping with Associated Infrastructure	The proposed development encompasses Gilston Burn, which becomes Millhall Burn. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, it is anticipated that sufficient construction mitigation measures including treatment and attenuation will be implemented during construction of the development. Therefore, no change to the pre-mitigation or residual significance of effects are anticipated.
P/20/0545/FUL Road Improvements, Construction of Shared Use Footbridge,	The proposed development includes works within the Middle Forth Estuary. There is potential for polluted and/or sediment-laden run-off or accidental spillages to the estuary during construction. However, it is anticipated that given the significant distance between the development

Planning Application / Marine Licencing Application	Potential Cumulative Effect
Associated Earthworks, Landscaping and Surface Water Drainage Works	and the Scheme and the provision of sufficient construction mitigation measures including treatment and attenuation construction of the development, no cumulative effects or changes to the pre-mitigation or residual significance of effects are anticipated.
P/20/0595/LBC Demolition and Reconstruction of Piled Viaduct Section of Bridge, Formation of Temporary Bridge, Replacement Safety Barrier, Refurbishment of Timber Jetties, Replacement Bridge Drainage System, Installation of Navigation Lights and General Maintenance Works	The proposed development includes drainage improvement works which discharge to a ditch, which flows into the tidal reach of the River Carron near the Scheme. Further drainage improvement works discharge to the existing surface water drainage network, which likely connect to other watercourses included in this assessment. There is potential for cumulative impacts to surface water quality due to polluted and/or sediment-laden run-off or accidental spillages to these watercourses during construction if construction of the Scheme and the development overlap. However, it is anticipated that sufficient construction mitigation measures including treatment and attenuation will be implemented during construction of the development which would limit any pollution reaching the Scheme area. Therefore, no change to the pre-mitigation or residual significance of effects are anticipated.
P/20/0647/FUL Siting of Modular Building, Installation of Disability Ramp and Extension to Car Park	The proposed development is located approximately <5m from Gardrum Burn, which becomes Gilston Burn and then Millhall Burn. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, given the scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.
P/21/0061/FUL Extension to Dwellinghouse	The proposed development is located approximately 9m from Millhall Burn. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, given the scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.
P/21/0200/FUL Extension to Dwellinghouse	The proposed development is located approximately <5m from the River Carron. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, given the scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.
P/21/0301/MSC Erection of 96 Dwellinghouses and Associated Infrastructure and Landscaping Works (Matters Specified under	The proposed development is located approximately <5m from Manuel Burn, which is a tributary of the River Avon. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, it is anticipated that sufficient construction mitigation measures including treatment and attenuation will be implemented during construction of the

Planning Application / Marine Licencing Application	Potential Cumulative Effect
Application P/17/0347/PPP)	development and sufficient dilution would take place within the River Avon prior to any pollution reaching the Scheme area. Therefore, no change to the pre-mitigation or residual significance of effects are anticipated.
P/21/0373/FUL Construction of a Hazardous Waste Cell	The proposed development is located adjacent to minor drains, which discharge into the River Avon. There is potential for cumulative impacts to surface water quality due to sediment-laden runoff or accidental spillages during construction if construction of the Scheme and the development overlap. However, it is anticipated that sufficient construction mitigation measures including treatment and attenuation will be implemented during construction of the development. It is anticipated that sufficient monitoring and treatment of any operational discharges from the Hazardous Waste Cell, including leachate, would take place.
P/21/0382/FUL Change of Use of Woodland to Form Motorhome and Campsite, Siting of Toilet Blocks, Management Building and Ancillary Development	The proposed development is located approximately <5m from Westquarter Burn. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, given the scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated. Therefore, no change to the pre-mitigation or residual significance of effects are anticipated.
P/21/0566/FUL Erection of 228 Dwellinghouses with Associated Infrastructure, Landscaping and Engineering Works (Site A)	The proposed development encompasses Little Denny Burn, which is a tributary of the River Carron. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, it is anticipated that sufficient construction mitigation measures including treatment and attenuation will be implemented during construction of the development and sufficient dilution would take place within the River Carron prior to any pollution reaching the Scheme area. Therefore, no change to the pre-mitigation or residual significance of effects are anticipated.
P/21/0610/FUL Alterations and Extension of Existing Changing Rooms and Storage Building to Form Community Hall	The proposed development is located approximately <5m from Gardrum Burn, which becomes Gilston Burn and then Millhall Burn. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, given the scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.
P/21/0621/FUL Change of Use of and Alterations to Stable	The proposed development is located approximately 26m from Westquarter Burn. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the

Planning Application / Marine Licencing Application	Potential Cumulative Effect
Block to form Dwellinghouse	development overlap. However, given the scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.
P/21/0656/PPP Development of Land for Residential Use	The proposed development is located approximately 23m from Polmont Burn. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, it is anticipated that sufficient construction mitigation measures including treatment and attenuation will be implemented during construction of the development. Therefore, no change to the pre-mitigation or residual significance of effects are anticipated.
P/21/0717/PPP Development of Land for Residential Use	The proposed development is located approximately 8m from Gardrum Burn, which becomes Gilston Burn and then Millhall Burn. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, it is anticipated that sufficient construction mitigation measures including treatment and attenuation will be implemented during construction of the development. Therefore, no change to the pre-mitigation or residual significance of effects are anticipated.
P/21/0726/FUL Siting of Modular Building, Installation of Disability Ramp and Extension to Car Park	The proposed development is located approximately <5m from Gardrum Burn, which becomes Gilston Burn and then Millhall Burn. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, given the scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.
P/22/0042/MSC Construction of 225 Dwellinghouses, Associated Infrastructure, Drainage and Landscaping	The proposed development is located approximately 100m from the River Avon. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, it is anticipated that sufficient construction mitigation measures including treatment and attenuation will be implemented during construction of the development. Therefore, no change to the pre-mitigation or residual significance of effects are anticipated.
P/22/0174/FUL Alterations and Extension to Changing Facilities and Provision of Overflow Parking	The proposed development is located approximately 80m from Mungal Burn, which becomes Gilston Burn and then Millhall Burn. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, given the scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.

Planning Application / Marine Licencing Application	Potential Cumulative Effect
P/22/0282/FUL Extension to Nursing Home	The proposed development is located approximately <5m from the River Carron. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, given the scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.
P/22/0286/FUL Extension to Falkirk Crematorium Office and Visitor Hub	The proposed development is located approximately 16m from the River Carron. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, given the scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.
P/22/0362/FUL Alterations and Extension to Changing Facilities	The proposed development is located approximately 80m from Mungal Burn. However, given the nature and scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.
P/22/0436/FUL Installation of Solar Array (No. 1400 Ground-Mounted and Associated Infrastructure)	The proposed development is located adjacent to the River Carron. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, given the scale of the development, no change to the pre-mitigation or residual significance of effects are anticipated.
P/22/0558/PPP Development of Land for Residential Use, Landscaping and Open Space	The proposed development is located approximately <5m from Chapel Burn. There is potential for cumulative impacts to surface water quality due to sediment-laden run-off or accidental spillages to the burn during construction if construction of the Scheme and the development overlap. However, it is anticipated that sufficient construction mitigation measures including treatment and attenuation will be implemented during construction of the development. Therefore, no change to the pre-mitigation or residual significance of effects are anticipated.
00008842 Water Injection Maintenance Dredging - Grangemouth and Leith Locks	The proposed works had a completion date of 09/08/2023. As such, given the timing of the works, no cumulative effects of significance on the Middle Forth Estuary water body are anticipated.
00009021 Sediment Sampling - Grangemouth, Stirlingshire	The proposed works had a completion date of 03/04/2021. As such, given the timing of the works, no cumulative effects of significance on the Middle Forth Estuary water body are anticipated.

10.10 Potential enhancement/ offsetting opportunities

Mitigation Item W24 will provide the opportunity for the implementation of enhancements as part of a separate program of river restoration measures on the Grange Burn. This shall be committed to and measures to improve the morphological diversity of the channel banks and bed, encourage natural recovery and improve riparian habitat will be identified and undertaken.

Chapter 7: Biodiversity has identified areas for riparian planting to achieve positive effects for biodiversity which align with those areas identified in Mitigation Items W27, W28, W29 and W30 of this chapter. Riparian planting will be provided along the following sections of Grange Burn.

- Section of the Grange Burn extending beyond Working Areas – NS 92685 80288 to NS 92706 80968;
- Working Area 4-5 and section of the Grange Burn extending beyond Working Areas – NS 92684 80946 to NS 92827 81371;
- Working Areas 4-5, 4-6 – NS 92827 81371 to NS 92993 81990; and,
- Working Areas 4-7, 4-7, 4-9 – NS 92993 81990 to NS 94587 82541.

10.11 Monitoring

10.11.1 Construction phase

Regular monitoring of any change to the channel bed and banks of watercourses should be undertaken (**Mitigation Item W9**), particularly in the vicinity of the working platforms throughout the construction process. This should be undertaken using fixed point photography, with site surveys should any change be identified. If change does occur this should be reported to SEPA. If required, any mitigation should be agreed with SEPA.

Water quality monitoring on affected watercourses shall be undertaken one year prior to construction and during construction. The monitoring regime shall include (but not be limited to) monthly laboratory analysis of determinants to be agreed in consultation with SEPA and visual inspections. Water quality criteria and standards to be achieved for all site discharges during construction, and sampling locations shall be agreed in consultation with SEPA (**Mitigation Item W12**).

Monitoring of ground conditions beneath any buildings at risk of subsidence shall be carried out one year prior to construction, during construction and one-year post-construction. Further post-construction monitoring shall be continued if deemed necessary during assessment at the detailed design stage **(Mitigation Item W18).**

Where deemed necessary by further hydrogeological assessment (**Mitigation Item W31)**, the quantity and quality of groundwater supply to potential GWDTEs may require monitoring prior to construction.

10.11.2 Operation phase

Monitoring of the watercourses shall be carried out to identify if there are any operation phase geomorphological issues associated with the Scheme, such as any impacts on watercourse stability (e.g. areas of excessive erosion or deposition) triggered by the Scheme. This will enable any such issues identified to be investigated and remediated as early in the operation phase as possible. This shall be carried out using fixed-point photography and comparison (**Mitigation Item W28**). Further details on these requirements are presented in Appendix C10.1: Fluvial Geomorphology.

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