10.2 Flood Risk Assessment

Lomond Banks

Appendix 10.2 - Flood Risk Assessment

On behalf of

Project Ref: 332010549/FRA | Rev: - | Date: April 2022

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Document Control Sheet

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For and on behalf of Stantec UK Limited				

Revision	Date	Description	Prepared	Reviewed	Approved

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1 Introduction

1.1 Scope of Report

1.1.1 This Flood Risk Assessment (FRA) has been produced by Stantec UK ('Stantec') on behalf of our client, Flamingo Land Ltd, to support an outline planning application for a development on the southern shores of Loch Lomond at Balloch, including areas adjacent to the River Leven and surrounding Woodbank House.

1.1.2 The main objectives of this report are to assess the risk of flooding from all sources including fluvial, surface water, coastal/tidal, reservoirs, groundwater and the public sewer system.

1.1.3 The report is based on the available flood risk information for the site as detailed in **Section 1.2** and prepared in accordance with the planning policy requirements set out in **Section 1.3**.

1.1.4 Stantec has many years of experience in, amongst other areas, the assessment of flood risk, hydrology, flood defence and river engineering. The authors and reviewers of the document are all experienced engineers and members of chartered institutions such as the Chartered Institution of Water and Environmental Management (CIWEM) or the Institution of Civil Engineers (ICE).

1.2 Sources of Information

1.2.1 This FRA has been prepared based on the following sources of information:

- Topographic survey of the site undertaken by L& M Surveys in February 2018;
- Development proposals by Anderson Bell & Christie (see appendix A);
- Scottish Environment Protection Agency (SEPA) online Flood Maps;
- River Leven Flood Study by Jacobs, 2009;
- West Riverside, Balloch Flood Risk Assessment by Envirocentre, 2017;
- SEPA Flood Risk Management Strategies, 2015;
- Local Flood Risk Management Plan – Clyde and Loch Lomond Local Plan District, 2021; and
- SEPA National Flood Risk Assessment 2018.

1.3 Relevant Planning Policy

Scottish Planning Policy

1.3.1 Scottish Government planning policy on flooding is provided by Scottish Planning Policy (SPP) paragraphs 254–268 (Scottish Government, 2014). This policy is based on the following principles:

- Developers and planning authorities must give consideration to the possibility of flooding from all sources;
- New development should be free from significant flood risk from any sources;

- In areas characterised as “medium to high” flood risk for watercourses and coastal flooding new development should be focused on built up areas and all development must be safeguarded from the risk of flooding; and

- The storage capacity of functional flood plains should be safeguarded from further development. The functional floodplains comprise areas generally subject to an annual probability of flooding greater than 0.5% (1 in 200 year return period event).

1.3.2 Drainage is a material consideration and the means of draining a development should be assessed. Any drainage measures proposed should have a neutral or better effect on the risk of flooding both on and off the site.

1.3.3 SPP proposes a Risk Framework approach which identifies flood risk in three main categories:

- Little or no risk area (annual probability of flooding less than 0.1%): No constraints to development due to flood risk;

- Low to medium risk area (annual probability of flooding between 0.1% and 0.5%): Usually suitable for most developments but not essential civil infrastructure; and

- Medium to high risk area (annual probability of flooding greater than 0.5%): Generally not suitable for essential civil infrastructure such as hospitals, fire stations, emergency depots, etc.; as well as schools, care homes and ground-based electrical telecommunications equipment unless subject to an appropriate long term flood risk management strategy.

SEPA Guidance

1.3.4 SEPA has issued guidance in relation to preparing FRAs (SEPA, 2019). Technical requirements for FRAs depend on the complexity of the site with more complex or high risk sites requiring detailed assessments. In summary, FRAs must include the following:

- Background site data, including suitable plans and/or photographs;

- Historic flood information;

- Description of methodologies used;

- Identification of relevant flood sources;

- In the case of river flooding: assessment of river flows, flood levels, depths, extents, displaced flood storage volumes, etc;

- Assessment of culverts, sewers or other structures affecting flood risk;

- Consideration of climate change impacts;

- Details of required flood mitigation measures; and

- Conclusions on flood risk related to relevant national and local policies.

1.3.5 In addition to reporting requirements, the document also provides technical guidance on Flood Estimation Handbook (FEH) (CEH, 2022) methodologies and on land raising and compensatory storage.

Loch Lomond and Trossachs National Park Guidance & Policies

1.3.6 The Loch Lomond and Trossachs National Park (LLTNP) Local Development Plan was issued in December 2016 and covers the period from 2017-2026. This plan guides new development within the park and sets out policies which will be used to determine planning applications. A number of these polices with regards to the natural environment are relevant to this report, and so the assessment will take cognisance of the following policies:

- Natural Environment Policy 11 – Protecting the Water Environment;
- Natural Environment Policy 12 - Surface Water and Waste Water Management; and
- Natural Environment Policy 13 – Flood Risk.

1.3.7 In addition to the local plan, the Supplementary Guidance document on Design & Placemaking produced by the LLTNP will also be taken into account.

1.4 Caveats & Exclusions

1.4.1 This report has been prepared solely for this development. Therefore, no responsibility is accepted to any third party for all or any part of this report in connection with any other development.

1.4.2 No hydraulic modelling has been undertaken as part of this flood risk assessment, with results of previous assessments and analyses being used to inform the risk.

1.4.3 The areas stated in this document are indicative only and should not be considered as binding maxima and minima.

2 Site Setting

2.1 Site Description

2.1.1 The site comprises two distinct areas known respectively as West Riverside and Woodbank House. Old Luss Road is the interface between the two areas. The project boundary is presented in Figure **2**-**1**. The proposed site comprises a total area of c. 26.77 hectares.

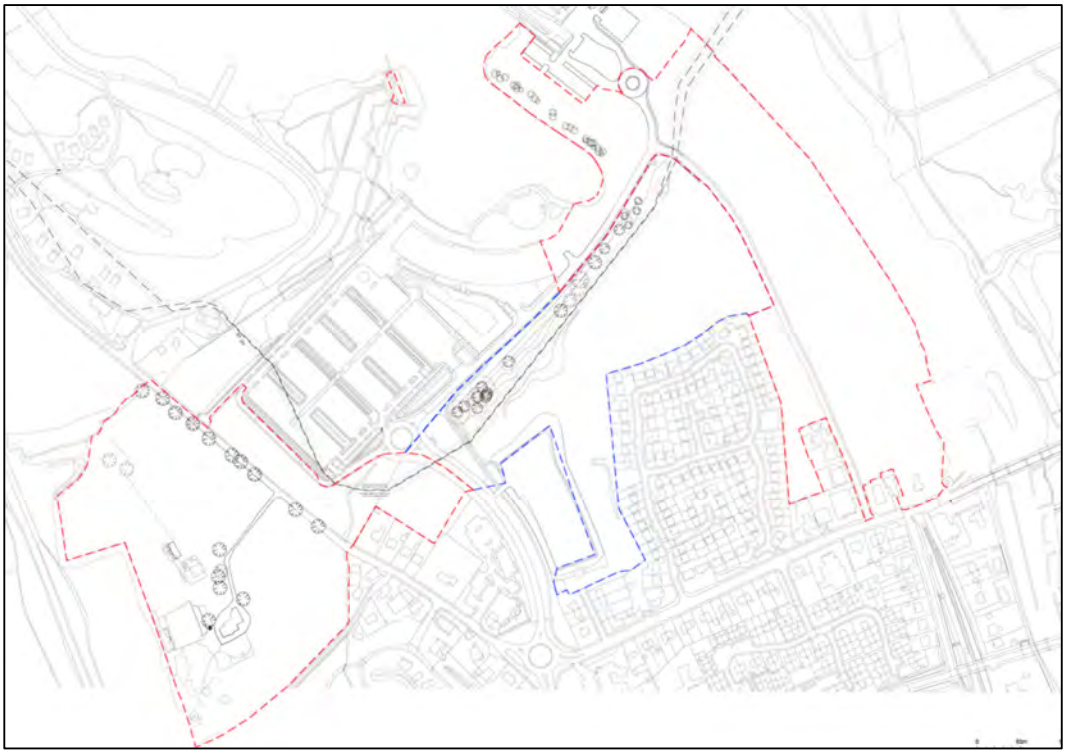

Figure 2-1 Site Location Plan

2.1.2 The West Riverside area is bounded generally by the River Leven to the East, Loch Lomond Shores and Loch Lomond to the north, Old Luss Road and Ben Lomond Way to the west and Balloch Road and the Clairinsh residential area to the south.

2.1.3 This area comprises woodland, existing footpaths and recreational parkland alongside the river with the northern river shoreline used for mooring boats and pontoons are present in the water for this purpose.

2.1.4 The Woodbank House area comprises the grounds of the former Woodbank Estate and is bounded generally by the A82 to the west, Old Luss Road to the east and the Lower Stoneymollan Road to the South.

2.1.5 The Woodbank House area of the site currently encompasses two relatively flat grassy fields in its eastern area which are bisected by an access track running from east to west. The track leads to an area of mixed woodland in the western area which has a more varied topography with levels generally rising to the west and becoming particularly steep in the north-west. Within the woodland are the remnants of Woodbank House, outbuildings and a walled garden. The buildings are in a state of advanced disrepair as a result of a fire (at the main hotel building) and subsequent dereliction.

2.1.6 Photographs from the site walkover undertaken in 2017 are presented in Appendix F

2.2 Topography

2.2.1 The general topography of the site falls from the west down to the east towards Loch Lomond and the River Leven. In the west of the site surrounding Woodbank House and adjacent to the A82, the ground is at a maximum elevation of approximately 45m AOD. From here the ground slopes down relatively steeply towards Old Luss Road, beyond which the ground levels off and undulates at 15-19m AOD. Adjacent to the shores of the Loch, the ground level is approximately 7.5m AOD.

2.2.2 The topography of the West Riverside area varies along its length. In the north adjacent to the Pierhead and the shores of the loch, the ground levels rise from approximately 8.5m AOD up to a maximum of 15.5m AOD at the top of an embankment which is currently heavily vegetated. Alongside the River Leven the top of bank levels are approximately 8.0m AOD with the ground then raising up to approximately 10.5-11.0m AOD. In the southern area where the existing tourist information centre is located, the ground levels are approximately 11.0-12.0m AOD, with a general fall in ground levels towards the river.

2.2.3 The site currently consists of a range of different uses including leisure and recreation (water sports) along the shores of the loch, several areas of car parking which serve the public slipways as well as the neighbouring Loch Lomond Shores development and areas of woodland and open parkland along the banks of the River Leven.

2.2.4 A tourist information and visitor centre is located at the south eastern point of the site, opposite Balloch train station and Sweeney's Cruises.

2.3 Hydrological Setting

2.3.1 There are four watercourses which have been identified as flowing through the site. The major watercourse is the River Leven which flows to the east of the site. To the west of the site there are two smaller unnamed watercourses which are described in more detail below. A fourth smaller watercourse is marked upon the Ordnance Survey mapping within the wooded area at Woodbank House. A plan showing the location of these watercourses is presented as Figure **2-2**.

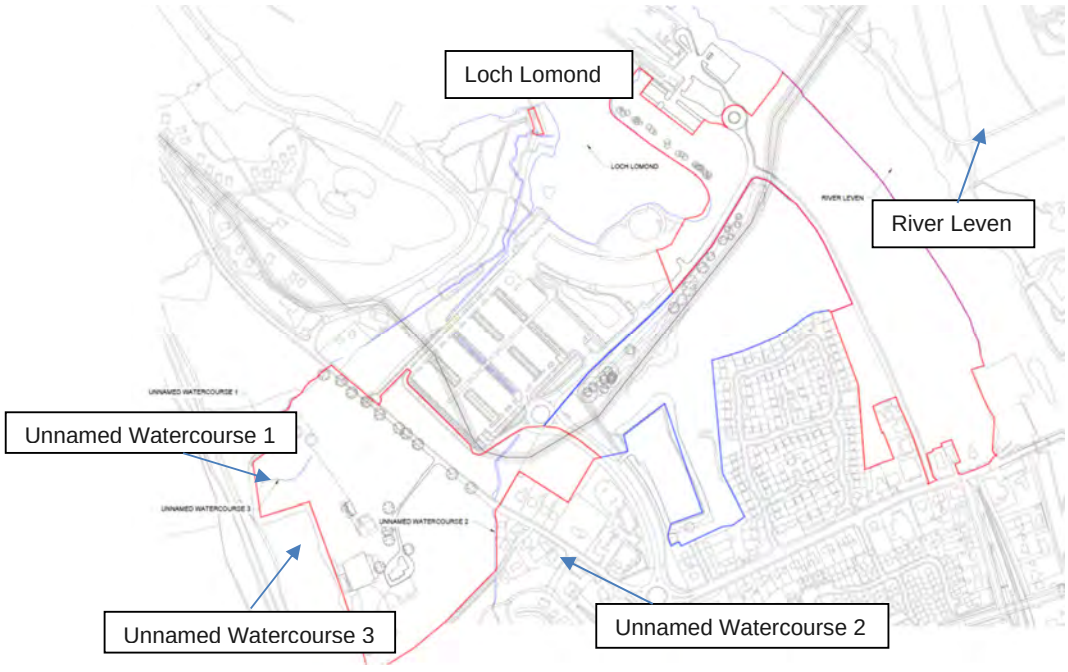

Figure 2-2 Watercourses on Site

River Leven

2.3.2 The River Leven flows to the east of the site in a southerly direction. It rises at the outflow from Loch Lomond to the north of the development site, and routes south through the towns of Balloch and Alexandria to outfall into the River Clyde at Dumbarton. The river is approximately 11.5km long and has tidal influence for approximately 5km upstream from its confluence with the River Clyde.

2.3.3 Adjacent to the site, the river is approximately 85-90m wide and contains a number of floating pontoons for mooring boats. Approximately 550m downstream of the Balloch Station area of the site, the River Leven Barrage is located. This is operated by Scottish Water and controls the outflow from the loch limiting the discharge and maintains water levels within Loch Lomond between 7 and 7.6m Above Ordnance Datum (AOD). However, it is not formally operated as a flood prevention structure.

2.3.4 Scotland's River Basin Management Plan (RBMP)(SEPA, 2021) classified the River Leven in 2020 as a heavily modified water body on account of physical alterations that cannot be addressed without a significant impact from an increased risk of subsidence or flooding. As such this has been classified as having Moderate ecological potential.

Unnamed Watercourse 1

2.3.5 The Unnamed Watercourse 1 rises in the hills to the west of the A82. The burn flows in an easterly direction along the north-western boundary of the Woodbank House area and passes beneath Old Luss Road before routing north of the existing car park and Loch Lomond Shores development. It outfalls into Loch Lomond at the end of a small headland in the bay north of the site.

Unnamed Watercourse 2

2.3.6 Unnamed Watercourse 2 also rises in the hills to the west of the site and the A82, and routes in an easterly direction towards Drumkinnon Farm. The burn flows through a small caravan park to the south of the Woodbank House site and below Lower Stoneymollan Road before routing along the eastern boundary of the Woodbank House area of the site. The burn then passes below Old Luss Road and routes north towards the car park of the Loch Lomond Shores complex. The burn routes through a number of culverts as it passes beneath access roads and flows through an open channel through the car park area.

2.3.7 Downstream of the car park the burn routes to the east and flows parallel with unnamed watercourse 1 towards Loch Lomond where it outfalls adjacent to the aerial adventure course.

Unnamed Watercourse 3

2.3.8 Within the Woodbank House area of the site a small watercourse is shown on plan routing in an easterly direction before it sinks, with no downstream route marked on the maps. During the site walkover there was water present within the channel however there was very little flow. The channel appeared to route into a culvert structure, but it is not known where this routes to or if it discharges into the unnamed watercourse 1. There were no visible signs of a culvert downstream across this area of the site.

Loch Lomond

2.3.9 Loch Lomond is located to the north of the site and has a surface area of approximately 71 km^2. Areas within and adjacent to the water body are designated Special Protection Areas (SPA), Sites of Special Scientific Interest (SSSI), Special Areas of Conservation (SAC), Ramsar Sites and National Nature Reserves. The loch is located wholly within the Loch Lomond and The Trossachs National Park and is used extensively for recreational use.

2.4 Existing Drainage Arrangements

2.4.1 It is understood that much of the existing foul drainage in the area is captured in combined sewers, which carry wastewater to the Ardoch Wastewater Treatment Works in Dumbarton. It is assumed that there is no existing surface water infrastructure on site

2.4.2 There is an existing pumping station on site, which is owned by Scottish Enterprise (SE) but is managed on their behalf by Saltire Property Management Ltd (SPM), who have a service agreement with the proprietors of Loch Lomond Shores. Limited information is available on the capacity or service agreements for the existing pumping station. The strategy therefore will make provision for a new pumping station, which will be subject to change should more information on the existing station become available and it can be ascertained that the proposed development can be accommodated within it.

2.5 Geology & Hydrogeology

Bedrock Geology

2.5.1 The British Geological Survey's (BGS) geological data (BGS, n.d.-a) (1:50,000 scale) indicates that the site is underlain by Teith Sandstone Formation. No fault lines are present within the site.

Drift Deposits

2.5.2 The BGS (BGS, n.d.-a) data indicates that the superficial deposits are predominantly formed of Glaciofluvial Deposits - Gravel, Sand and Silt, which cover the southern and western parts of the site. To the north and surrounding the shore of Loch Lomond the superficial deposits consist of Raised Marine Deposits of Holocene Age - Clay, Silt, Sand and Gravel.

Soils

2.5.3 Soil survey of Scotland 1:25,000 scale mapping (Soil Survey of Scotland Staff, n.d.) shows the site to be underlain by brown soils which have been stated to have parent materials of fluvioglacial sands and gravels derived from acid schists and Lower Old Red Sandstone sediments and lavas.

Hydrogeology

2.5.4 The Hydrogeological Map of Scotland (BGS, n.d.-b) shows that the site is underlain by the Strathmore Group, a moderate to highly productive aquifer with intergranular/fracture flow.

2.5.5 The Hydrogeological Maps highlight that superficial deposits classified as glaciofluvial are associated with high productivity intergranular flow, and raised marine deposits would be classified under low to moderate productivity with intergranular flow in the region of 0.1-10l/s.

2.5.6 The aquifer vulnerability is classed as 4a in the Groundwater Vulnerability dataset (Ó Dochartaigh, Doce, Rutter & MacDonald, 2011). Class 4a is groundwater which is described as being 'vulnerable to those pollutants not readily absorbed or transformed, and may have low permeability soil and less likely to have clay present in superficial deposits.'

2.5.7 Under the RBMP the development site is located within the *Loch Lomond and Leven Sand and Gravel (ID:150766)* and *Balloch (ID:150651)* groundwater bodies, both of which have overall classifications of Good.

3 Proposed Development

3.1.1 The development proposals include the following:

"Erection and operation of a tourism and leisure-led mixed-use development including: hotel and holiday lodge accommodation; controlled camping areas; leisure and recreational facilities; education and visitor interpretation facilities; refurbishment and renovation of Woodbank House and attendant structures (including new visitor and residential accommodation in the grounds); woodland play / adventure areas; hot food café / restaurant uses; transport infrastructure; public realm enhancements including footpaths, event spaces and cycleways; ancillary uses; landscaping; and supporting services/infrastructure (including drainage, potential flood mitigation measures, water supply and utilities)"

3.1.2 The proposed masterplan layout is presented in Appendix A

3.1.3 The West Riverside area of the site which runs parallel to the River Leven contains 43 woodland lodges set within the existing woodland and recreational parkland, along with associated non-vehicular access tracks, BBQ/picnic areas and a riverside walkway. Along the western edge of this area, parallel to Pier Road is a new monorail linking the Pierhead Area to Station Square.

3.1.4 In the northern Pierhead area the development includes a new 60 bed aparthotel, a water park, monorail terminal and a water sports hub.

3.1.5 At Station Square in the south east corner of the overall site, the existing tourist information centre is to be refurbished and adjacent to this the development will include a 32 bed budget accommodation, a craft brewery and visitor centre, restaurant, performance amphitheatre, monorail station and enhanced public square.

3.1.6 In the Woodbank area of the site 67 lodges are proposed in both the grazing land and in the woodland. Access to the majority of these lodges will be by foot with only emergency vehicle access where required. Woodbank house is to be fully refurbished to contain 15 flats as well as 6 self catering properties in within the ancillary buildings.

4 Overview Of Flood Risk

4.1 SEPA Flood Mapping

4.1.1 The SEPA Flood Maps (SEPA, 2022) which are available to view online highlight that the West Riverside area of the development would be at risk of fluvial flooding during the 0.5% AEP event. Small areas of surface water flooding were also noted across this area of the site, however these are considered to be low spots within the topography.

4.1.2 Within the Woodbank House area surface water flooding is indicated along the length of Unnamed Watercourse 2, and also accumulating within the low point in the grassed fields adjacent to Old Luss Road.

4.1.3 It is noted that the SEPA Flood Maps are indicative and of a strategic nature, and so this assessment takes into account all available data in the assessment of flood risk.

4.2 Previous Studies and Reports

River Leven Flood Study (Jacobs, 2009)

4.2.1 A hydraulic study of the River Leven has previously been undertaken by Jacobs which identified the potential flood risk from Loch Lomond and the River Leven along the full length of the river through the Vale of Leven. The original flood study was undertaken in 2001 and was then updated in 2003.

4.2.2 In December 2006, Loch Lomond experienced its highest recorded water level and this subsequently produced the highest flow in the River Leven at the Linnbrane gauging station, approximately 2km south downstream of the site. This event caused significant flooding in the areas surrounding the river. In 2009 the hydraulic model of the River Leven was updated to include more recent hydrological analysis as well as calibration of the model using the December 2006 event.

4.2.3 Plans showing the maximum modelled extents adjacent to the site from this river study are presented in Appendix B

4.2.4 The results of the modelling identified peak water levels for a range of return periods. These peak levels for the three cross sections adjacent to the site at the head of the river as presented in Table 4-1 below.

Table 4-1 Peak Water Levels from Jacobs Flood Study

Cross Section Reference	Peak Water Level (m AOD)				
	50% AEP	10% AEP	1% AEP	0.5% AEP	0.5% AEP+CC
XS_116	9.15	9.59	10.08	10.23	10.56
XS_227	9.15	9.59	10.08	10.24	10.57
XS_338	9.14	9.58	10.07	10.25	10.57
XS_412	9.13	9.57	10.06	10.22	10.55
XS_486	9.12	9.56	10.05	10.20	10.54
XS_579	9.11	9.55	10.03	10.19	10.53
XS_658	9.10	9.53	10.02	10.18	10.51
XS_749	9.08	9.52	10.01	10.16	10.50

Cross Section Reference	Peak Water Level (m AOD)				
	50% AEP	10% AEP	1% AEP	0.5% AEP	0.5% AEP+CC
XS_841US	9.07	9.50	9.99	10.14	10.48

4.2.5 This modelling has identified that the peak water levels in the 0.5% AEP+CC event range from 10.56-10.48 metres Above Ordnance Datum (mAOD) across the length of the development site.

Hydrological Update (Envirocentre, 2017)

4.2.6 Following the review of the Jacobs Flood Study, an assessment was then undertaken to determine whether the design flows derived in early 2009 remain valid taking into account more recent flow records since then. Additional flow data was requested from SEPA for the Linnbrane Gauging station on the River Leven, which was in the form of Annual Maximum (AMax) flow data and covered the period from 2000-2015. A copy of this up to date flow data, along with the previous AMax data is presented in Appendix C

4.2.7 The modelling within the Jacobs report was calibrated based upon the peak flood event in 2006, and so any subsequent peak flow events since then may have had an impact upon the flow estimation for the River Leven.

4.2.8 Figure 4-1 illustrates the AMax flow data for the full records of the Linnbrane Gauging station and shows that since the event in 2006, there have been no significant flood events of a similar or greater magnitude. Additional information received as part of this update is highlighted in red in the graph below.

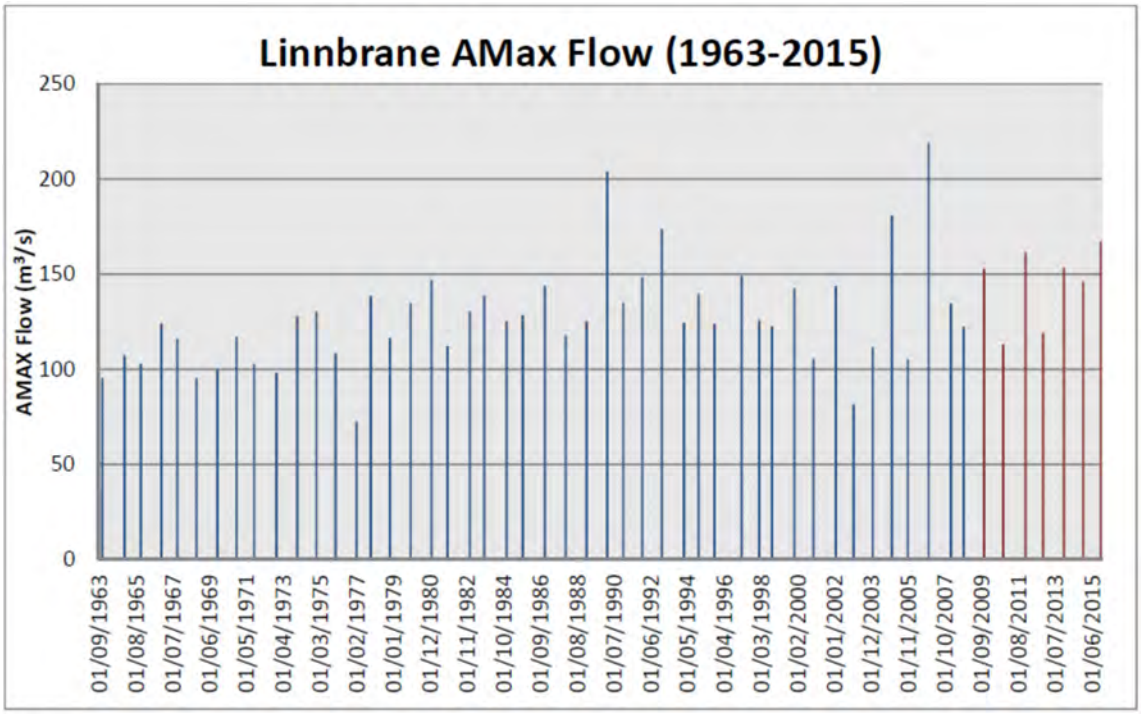

Figure 4-1 AMax Flow from Linnbrane Gauging Station

4.2.9 The value of the median annual maximum flow (Qmed) from the dataset used in the Jacobs Flood Study in 2009 was estimated to be 124.173m^3/s, and with the additional years data included in the calculations the Qmed increased to 124.945m^3/s. This is an increase of only

0.6%. Applying the growth curve used in the Jacobs Flood Study to this revised figure of Qmed gives a difference in peak 0.5% AEP flow of 1.44m^3/s. Based upon the relationships within the Jacobs Flood Study and the previous modelling between the 0.5% AEP event and the 0.5% AEP+CC, where an additional 20% was added to the flows, the estimated impact on peak flood levels from the updated Qmed calculations is estimated to be only 2mm.

4.2.10 As the flood levels within the Jacobs report are listed to the nearest centimetre it is considered that this updated hydrological assessment will have no impact upon the peak levels listed within the Jacobs Flood Study.

Second Hydrological Update (Envirocentre, 2018)

4.2.11 Following consultation with SEPA regarding the updated hydrology to include the additional AMax data, SEPA flagged concerns with the gauged data from the Linnbrane gauging station. SEPA's hydrometry team flagged the concerns due to lack of spot gauging with which to validate the ratings curve and so additional hydrological calculations were undertaken.

4.2.12 Flow estimates for peak flows in the River Leven were generated using three different methodologies – WINFAP single-site analysis, WINFAP pooled analysis and the FSR rainfall-runoff analysis. Comparison of these methodologies with the Jacobs flood study highlighted that the WINFAP methods compared reasonably well and so these methods were adopted.

4.2.13 This hydrological analysis concluded that the peak 1 in 200 year return period flows would increase by between 2% - 9% depending on the method of analysis (single-site analysis and pooling group respectively). The Jacobs 2009 report included model scenarios for the 1 in 200 year, 500 year (equivalent to 1 in 200 year + 11%) and 200 year future climate scenario (1 in 200 year plus 20%). These three model scenarios were considered to remain appropriate to inform the masterplan development.

4.2.14 This hydrological update is presented in Appendix D

Flood Risk Clarifications (Envirocentre, Dec 2018)

4.2.15 Additional subsequent consultation between SEPA and Envirocentre in 2018/2019 was carried out to determine design peak flood levels at the Pierhead area of the site, and in particular the mechanisms of flooding relating to Loch Lomond and the River Leven. This ensured that the latest topographical survey information was used to determine levels and extents.

4.2.16 The estimated peak flood levels at the Pierhead area were calculated to be:

- 1 in 200 year = 10.24m AOD
- 1 in 200 year + 20% CC = **10.57m AOD**
- 1 in 500 year = 10.45m AOD
- 1 in 200 year Loch Lomond level = 10.51m AOD.

4.2.17 This resulted in the adoption of the 1 in 200 year+20% CC level from the River Leven as the design flood event and so development should be located outwith the extents of this event. Correspondence with SEPA confirmed that this approach was acceptable and concluded that:

- No buildings are proposed within the functional floodplain of the River Leven;
- The only aspect of the development within the functional floodplain of the River Leven is a small area of car parking. This is similar to the existing use in this area and is considered an appropriate land use in terms of flood risk vulnerability;

- The apart hotel at the pierhead has finished floor levels of 11.5 metres above Ordnance Datum (mAOD), which includes a freeboard provision above the design flood level (10.57 mAOD); and

- All other buildings will have finished floor levels above the design flood level, including an allowance for climate change and an appropriate freeboard.

4.2.18 These additional flood risk clarifications also dealt with the request from SEPA in June 2018 for information relating to the proposed flood extents within the Woodbank House area of the site.

4.2.19 As noted in Section 2.3 the Unnamed Watercourse 2 flows along the southern/southeastern boundary of the Woodbank House area. The watercourse enters this area through a twin 0.5-0.6m diameter culvert below Lower Stoneymollan Road, flows in a straight canalised channel and exits through a triple pipe arrangement with similar dimensions below Old Luss Road.

4.2.20 Should all culverts be running at full capacity then no backing up of flows should occur as the downstream culvert would convey a greater volume of water due to the additional pipe. However from information received during the previous study it was determined that the downstream triple pipe arrangement was significantly blocked with silt and debris and so flows would be restricted.

4.2.21 In order to determine the potential flow routes should culvert maintenance be neglected and the blockages remain, an assessment of ground levels was undertaken. This established that at the downstream culvert where is passes below Old Luss Road, the right bank is lower than the left bank by approximately 300mm, and so overtopping would route into the gardens of the adjacent property and on to the road prior to it overtopping the left banks and into the site.

4.2.22 Regardless of this flow path, it was still recommended that a buffer of 5m be maintained from the edge of the watercourse to ensure that no part of the proposed development will be at medium – high likelihood of flood risk.

4.2.23 These additional flood risk clarifications are presented in Appendix E

4.3 Sources of Flooding

Groundwater Flooding

4.3.1 There is limited information available to fully assess the risk of flooding from groundwater across the site. SEPA's online Flood Risk Management Maps (SEPA, 2022a) highlights areas where groundwater flooding would influence the duration and extent of flooding from other sources, rather than show where groundwater alone could cause flooding.

4.3.2 This map indicates that the whole of the site is not covered by a groundwater zone and thus would be low risk according to that mapping.

4.3.3 Groundwater within the Pierhead area of the site is likely to be the highest across the whole development area due to its proximity to both Loch Lomond and the River Leven, however it is not considered that groundwater flooding alone would be a high risk. Should the water levels in the loch and river rise, groundwater would likely rise as a consequence, but it is considered that fluvial flooding from the surface features would affect the site prior to any groundwater issues occurring.

4.3.4 As such it is considered that groundwater flood risk across the site is **low**.

Coastal Flooding

4.3.5 The lower reaches of the River Leven are tidally influenced where it meets the River Clyde at Dumbarton. The tidal influence extends approximately 5-6km upstream to Dalquhurn Point. The closest part of the development site to this is approximately 6.5km further to the north.

4.3.6 The lowest point on the development site is situated at an elevation of 8-8.5m AOD.

4.3.7 Due to the elevation and distance from the sea, flood risk from coastal sources is considered to be **low**.

Sewer Flooding

4.3.8 No records of flooding from sewers have been received from consultation undertaken for this assessment.

4.3.9 Large areas of the site are currently undeveloped and there are limited existing sewers routing through the site.

4.3.10 As such it in considered that flood risk from sewer flooding is **low**.

Surface Water (Pluvial) Flooding

4.3.11 SEPA's online Flood Risk Management Maps highlight a number of locations across the site that may be prone to pluvial flooding.

4.3.12 In the West Riverside area of the site there are small parcels pluvial flooding shown adjacent to the Pierhead area, within the woodland area parallel to the river and along Balloch Road adjacent to the existing tourist information centre. All of these locations coincide with topographic low spots in the ground and do not appear to be linked to overland flow pathways from other sources of flooding. The flood risk in these areas is considered to be **low to medium.**

4.3.13 The majority of the ground through the West Riverside and Station Square areas of the site is relatively flat and so it is expected that surface water accumulation would be shown. Through design and construction of appropriate surface water drainage systems, avoiding locating buildings in the low spots on site and elevating finished floor levels above the surrounding ground levels, the risk of pluvial flooding can be minimised.

4.3.14 Within the Woodbank House area of the site pluvial flooding is indicated along the routes of the unnamed watercourses 1 and 2, as well as within the low spot adjacent to Old Luss Road where there is a topographic low spot. The risk of pluvial flooding in this area of the site is considered to be **medium** in localised areas.

4.3.15 The majority of this area of the site is steeply sloping from the A82 in the west down to Old Luss Road in the east. The pluvial flooding indicated following the watercourses is due to the modelling techniques of the SEPA flood maps highlighting the depressions of the burn channels and so any risk from those features is related to fluvial flood risk, covered below.

4.3.16 The lowest ground levels in the Woodbank House area of the site is located adjacent to Old Luss Road, on the southern side of the stone wall which bounds the site. Any surface runoff from the woodland or fields up slope of this would route to and accumulate at this location.

4.3.17 It is recommended that no buildings be located within this low spot within the site, and a buffer be maintained along the boundary with Old Luss Road where the existing stone wall presents a barrier to any overland flows.

River & Watercourse (Fluvial) Flooding

West Riverside, River Leven and Loch Lomond

4.3.18 As noted in Section 4.2 extensive consultation has been undertaken with SEPA regarding flood flows and levels along the River Leven adjacent to the site. The hydrological analysis, including several updates of the methodologies used to estimate the flows, has determined that at the Pierhead area where the proposed aparthotel and visitor hub is to be located the peak 1 in 200 year +20%CC River Leven flood level is **10.57m** AOD.

4.3.19 The flood extents from this event are plotted on the proposed masterplan presented in Appendix A.

4.3.20 The flood extents are shown to cover the area of existing car parking at the slipway and a small strip of land to the east of the roundabout at this location. The maximum depth in this location is estimated to be approximately 500mm.

4.3.21 As the River Leven routes south along the boundary of the site, the peak flood levels are indicated to meet the top of bank levels but not route into the woodland and recreational parkland where the proposed forest lodges are shown.

4.3.22 In the southeast corner of the site at Station Square, the peak 1 in 200 year +20%CC river level is estimated to be **10.48m** AOD. Based upon the topographical survey the ground levels within this area of the site vary from approximately 11.45mAOD adjacent to the existing tourist information centre, down to approximately 8.40mAOD adjacent to the river banks and the jetty, however the areas of the jetty and riverbank are outwith the development boundary.

4.3.23 Therefore there it is considered that there are a number of localised areas that are at medium to high risk of flooding, at the Pierhead and adjacent to, but not in, Station Square.

Potential Mitigation

4.3.24 As noted in section 4.2, previous consultation with SEPA and subsequent assessment concluded that:

- All development will be consistent with the SEPA guidance on flood risk land use vulnerability;
- No buildings will be located within the functional floodplain of the River Leven, or any other watercourses within the masterplan area; and
- Finished floor levels of buildings in the vicinity of the functional floodplain of the River Leven, or any other watercourses within the masterplan area, will be above the design flood level of the 1 in 200 year return period event including an allowance for climate change and an appropriate freeboard.

4.3.25 The proposed masterplan layout as presented in Appendix A illustrates that all new buildings are located outwith the functional floodplain of the Riven Leven, with only the car parking areas at the Pierhead partially affected. The car parking is however considered an appropriate land use in terms of flood risk vulnerability.

4.3.26 The aparthotel and visitors hub at the Pierhead should have a minimum finished floor level set above the peak flood level with an allowance for freeboard, which is recommended at 11m AOD.

4.3.27 At Station Square the existing buildings are not currently within the functional floodplain, however it is recommended that any new buildings have a finished floor levels also set above the design flood level with an allowance for freeboard. The minimum recommended level is 11m AOD.

Woodbank House

4.3.28 The unnamed watercourse 1 which flows along the north of the Woodbank site runs in a steeply sloping channel within a defined channel corridor. The watercourse then passes below Old Luss Road in a small stone culvert which was estimated to be approximately 0.35-0.4m wide by approximately 0.6-0.7m high. Although the flows may not be large within the burn during storm events, there is the possibility of the small culvert becoming blocked with debris and restricting the flows. Should flows back up from this culvert, they would inundate the area surrounding the culvert inlet until they overtopped onto the road above. A stone wall is located above the right bank, along the northern boundary of the Woodbank site, which would prevent flows from routing into the development site, and would direct flows onto Old Luss Road. Once on the road they would route in a south-easterly direction with the fall in the road, however they would not route into the site due to the stone wall continuing around its boundary.

4.3.29 Assessment of the potential flood routing from the unnamed watercourse 2 was previously undertaken during consultation with SEPA. This is covered in Section 4.2.

4.3.30 This highlighted that should the culvert beneath Old Luss Road become blocked due to debris or lack of maintenance, the flow route would be initially out of the right, lower bank and into the gardens of the adjacent property and on to the road prior to it overtopping the left banks and into the site.

4.3.31 Notwithstanding of this potential flow route, it is considered that the area immediately surrounding the inlet to the culvert below Old Luss Road is at low-medium risk of fluvial flooding due to blockages.

4.3.32 Due to the topography of the rest of the Woodbank House site, the fluvial flood risk is considered to be low.

Potential Mitigation

4.3.33 Although the flood risk to the site is considered to be generally low, the risk of blockage at the culvert beneath Old Luss Road on unnamed watercourse 2 could mean that a small area of the site may be at risk of inundation. As such it is recommended that no development is located immediately adjacent to this watercourse and the culvert inlet, and a buffer of at least 5m is maintained. This buffer is required for all development adjacent to waterbodies, however in this location, if feasible, this buffer should be maximised. This will ensure that any new development would not be affected by the watercourse, and conversely the development would have no impact upon the water environment.

4.3.34 Additionally it may be beneficial to ensure the inlet arrangement to the culvert beneath Old Luss Road for the unnamed watercourse 2, includes measures to prevent blockages, such as a trash screen to trap debris. This would aim to ensure that the culvert pipes below the road would not become blocked and would reduce the fluvial flood risk to both the new site and the adjacent existing properties.

5 Conclusions

5.1.1 This flood risk assessment was undertaken for the proposed development of a mix of leisure uses, tourism related retail and holiday accommodation on the shores of Loch Lomond, Balloch, West Dunbartonshire. A walkover survey, together with a desktop assessment and review of previous studies associated with the site were all undertaken to assess the flood risk from fluvial, pluvial, coastal and groundwater sources.

5.1.2 The assessment has identified that the areas in the northeast of the site adjacent to the head of the River Leven and Loch Lomond would be at risk of fluvial flooding during the 1 in 200 year +20% CC event, and the area surrounding the existing tourist information centre is located immediately adjacent to the 1 in 200 year +20% CC flood extents. Potential mitigation measures have been identified, including locating the development outwith any floodplains, raising of finished floor levels above the surrounding ground and constructing effective drainage and appropriate landscaping to direct any flooding away from buildings.

5.1.3 Surface water flooding may affect some localised low points on site, but this risk can be managed through the provision of appropriate sustainable drainage systems (SuDS) and landscaping.

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Appendix A Illustrative Masterplan

This indicative layout drawing has been prepared to help inform parties of the potential extent and appearance of development on this site. The layout fits within the parameters set out in the parameters drawing AL(0)005 J, but should not be interpreted as a definitive layout for the development. It is one possible implementation of the parameters. The layout and design of the final development may differ.

anderson bell + christie
Sketch Illustrative Masterplan for Lomond Banks
Not to scale
29.04.22

Appendix B Jacobs Flood Study Extents Plan

Drawing number / Rev
B1888300-LP-001

Key

- 1% AEP (100 year return period)
- 0.5% AEP (200 year return period)
- 0.2% AEP (500 year return period)
- New Flood Wall
- New Flood Embankment
- 0.5m Depth of water for 1%AEP

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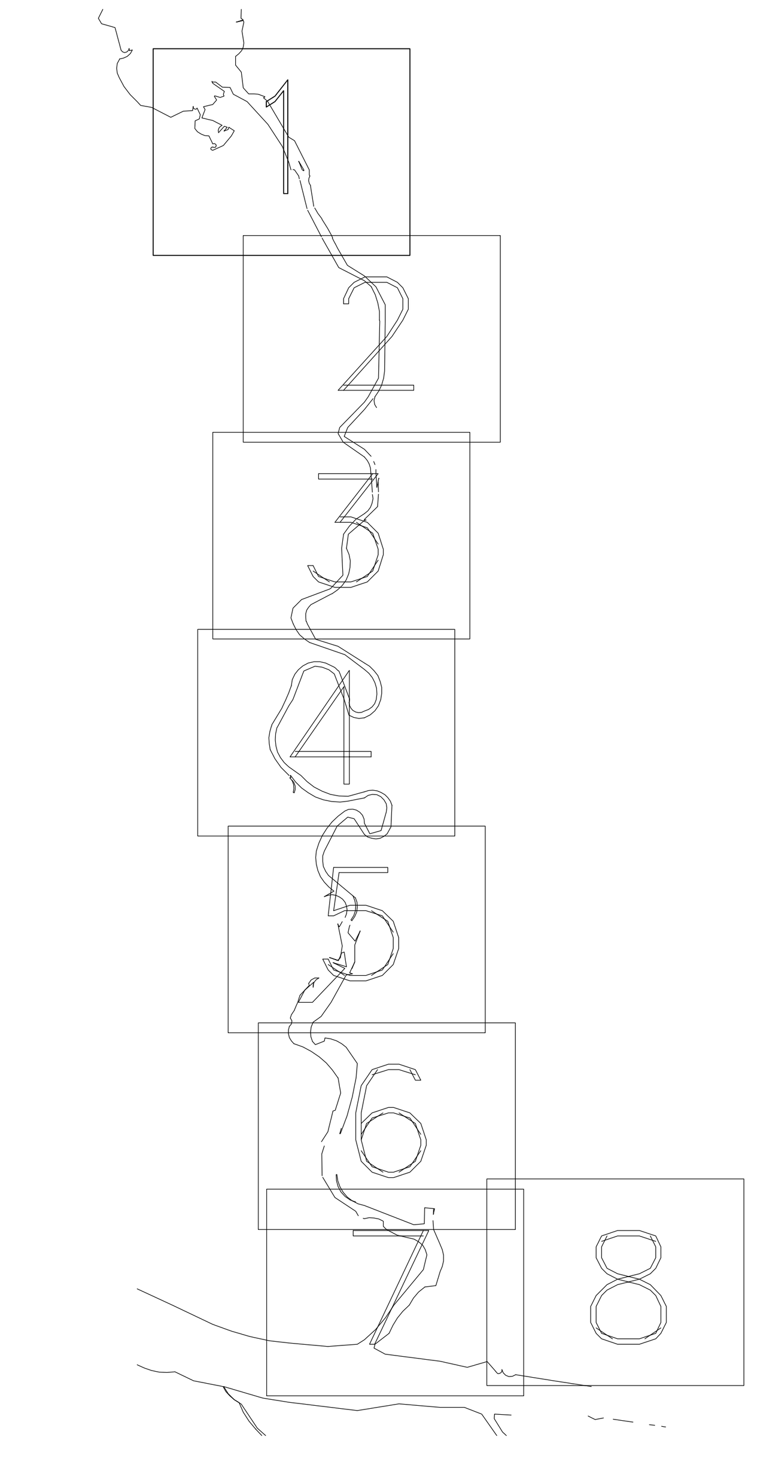
2. The extent of inundation is indicative only, and is based on limited ground level survey information.



Rev	Rev. Date	Purpose of revision	Drawn	Checked	Approved
0	DEC 08	REVIEW OF FIRST ISSUE	DL	JS	BS

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Project
RIVER LEVEN FLOOD STUDY
REVIEW & UPDATE OF ORIGINAL WORK

Drawing title
LOCATION PLAN AND
INDICATIVE EXTENT OF INUNDATION AND
LOCATION OF POSSIBLE FLOOD DEFENCES
SHEET 1 OF 8

Drawing status

Scale	1:2500 @ A1	DO NOT SCALE
Jacobs No.	B1888300	
Client no.		

Drawing number: B1888300-LP-001 Rev: 0

This drawing is not to be used in whole or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

Predicted Peak Water Level (mAOD)

Node	50%AEP Q&T	20%AEP Q&T	10%AEP Q&T	4%AEP Q&T	2%AEP Q&T	1%AEP Q&T	0.5%AEP Q&T	0.2%AEP Q&T	0.5%AEP+CC Q&T	0.5%AEP+ Narrow Channel	0.5%AEP Q&T
XS_0	9.17	9.45	9.62	9.81	9.96	10.11	10.27	10.48	10.61		10.27
XS_116	9.15	9.43	9.59	9.78	9.93	10.08	10.23	10.44	10.56		10.23
XS_227	9.15	9.43	9.59	9.78	9.93	10.08	10.24	10.45	10.57		10.24
XS_338	9.14	9.42	9.58	9.77	9.92	10.07	10.23	10.44	10.57		10.23
XS_412	9.13	9.41	9.57	9.76	9.91	10.06	10.22	10.43	10.55		10.22
XS_486	9.12	9.40	9.56	9.75	9.90	10.05	10.20	10.41	10.54		10.20
XS_579	9.11	9.38	9.55	9.74	9.89	10.03	10.19	10.40	10.53		10.19
XS_658	9.10	9.37	9.53	9.73	9.87	10.02	10.18	10.39	10.51		10.18
XS_749	9.08	9.36	9.52	9.71	9.86	10.01	10.16	10.37	10.50		10.16
XS_841US	9.07	9.34	9.50	9.69	9.84	9.99	10.14	10.35	10.48		10.14
XS_841DS	9.06	9.33	9.49	9.68	9.83	9.98	10.13	10.34	10.46		10.13
XS_968	9.04	9.31	9.47	9.66	9.80	9.94	10.10	10.31	10.43		10.10
XS_1039U	9.01	9.29	9.44	9.63	9.77	9.91	10.06	10.26	10.39		10.06
XS_1039D	9.01	9.28	9.43	9.62	9.76	9.90	10.05	10.25	10.38		10.05
XS_1136	8.98	9.25	9.41	9.59	9.73	9.87	10.02	10.22	10.34		10.02
XS_1136U	8.91	9.19	9.34	9.53	9.67	9.80	9.95	10.15	10.27		9.95
XS_1136D	8.90	9.17	9.32	9.51	9.65	9.78	9.92	10.12	10.22		9.94
XS1	8.89	9.16	9.31	9.49	9.63	9.76	9.91	10.10	10.20		9.91
XS2	8.85	9.14	9.30	9.48	9.62	9.76	9.91	10.10	10.21		9.91
XS3	8.63	8.90	9.05	9.22	9.35	9.47	9.61	9.78	9.88		9.61
XS4	8.52	8.81	8.96	9.14	9.27	9.40	9.54	9.72	9.82		9.54
XS5	8.38	8.68	8.84	9.03	9.16	9.30	9.44	9.63	9.73		9.44
XS6	8.27	8.57	8.74	8.92	9.06	9.20	9.34	9.53	9.63		9.34
XS7	8.16	8.46	8.63	8.81	8.95	9.09	9.24	9.42	9.53		9.24
XS8	8.03	8.32	8.50	8.68	8.82	8.96	9.10	9.28	9.37		9.10
XS9	7.89	8.18	8.36	8.55	8.70	8.84	8.98	9.16	9.25		8.98
XS10	7.83	8.10	8.28	8.47	8.62	8.76	8.90	9.08	9.17		8.90
XS11	7.76	8.05	8.23	8.43	8.58	8.72	8.87	9.06	9.16		8.87
XS12	7.69	7.97	8.15	8.35	8.50	8.64	8.79	8.97	9.06		8.79
XS13	7.65	7.93	8.11	8.32	8.46	8.61	8.76	8.94	9.04		8.76
XS14	7.61	7.89	8.07	8.27	8.42	8.57	8.72	8.91	9.00		8.72
XS15	7.52	7.79	7.96	8.15	8.29	8.43	8.57	8.74	8.82		8.57

Predicted Peak Water Level (mAOD)

Node	50%AEP Q&T	20%AEP Q&T	10%AEP Q&T	4%AEP Q&T	2%AEP Q&T	1%AEP Q&T	0.5%AEP Q&T	0.2%AEP Q&T	0.5%AEP+CC Q&T	0.5%AEP+ Narrow Channel	0.5%AEP Q&T
XS16	7.35	7.62	7.78	7.96	8.10	8.24	8.38	8.54	8.62		8.38
XS17	7.25	7.52	7.67	7.84	7.98	8.12	8.26	8.43	8.51		8.26
XS18	7.07	7.34	7.48	7.65	7.78	7.91	8.05	8.22	8.30		8.04
XS19	7.01	7.30	7.44	7.62	7.73	7.84	7.97	8.13	8.21		7.97
XS20	6.92	7.21	7.35	7.53	7.66	7.79	7.94	8.13	8.22		7.94
XS21	6.74	7.04	7.18	7.35	7.47	7.59	7.74	7.93	8.02		7.74
XS22	6.55	6.85	6.97	7.12	7.21	7.30	7.41	7.56	7.63		7.41
XS23	6.39	6.71	6.81	6.94	7.03	7.12	7.22	7.35	7.42		7.21
XS24	6.35	6.67	6.78	6.91	7.00	7.09	7.19	7.32	7.39		7.18
XS25	6.26	6.63	6.76	6.90	7.01	7.11	7.22	7.38	7.45		7.22
XS26	6.17	6.52	6.65	6.80	6.91	7.01	7.13	7.29	7.36		7.13
XS27	6.03	6.34	6.45	6.59	6.69	6.78	6.88	7.01	7.08		6.88
XS28	5.88	6.23	6.34	6.50	6.60	6.70	6.82	6.98	7.05		6.82
XS29	5.82	6.19	6.31	6.47	6.57	6.68	6.81	6.96	7.04		6.80
XS30	5.74	6.08	6.20	6.36	6.46	6.57	6.71	6.87	6.95		6.70
XS31	5.58	5.91	6.03	6.19	6.28	6.40	6.55	6.74	6.82		6.55
XS32	5.39	5.65	5.76	5.89	5.97	6.06	6.18	6.34	6.43		6.18
XS33	5.32	5.53	5.63	5.74	5.80	5.86	5.93	6.04	6.10		5.93
XS34	5.20	5.39	5.48	5.57	5.60	5.64	5.69	5.76	5.80		5.69
XS35	5.11	5.27	5.34	5.43	5.44	5.47	5.50	5.57	5.62		5.50
XS36	5.06	5.24	5.32	5.44	5.46	5.49	5.54	5.66	5.73		5.54
XS37	4.97	5.20	5.33	5.49	5.52	5.57	5.64	5.77	5.84		5.64
XS38	4.87	5.06	5.15	5.26	5.38	5.49	5.62	5.77	5.85		5.62
XS39	4.63	4.90	5.05	5.22	5.36	5.48	5.61	5.77	5.85		5.62
XS40	4.62	4.87	5.02	5.21	5.35	5.47	5.60	5.77	5.85		5.61
XS41	4.46	4.75	4.94	5.16	5.30	5.44	5.58	5.75	5.83		5.59
XS42	4.36	4.65	4.84	5.08	5.22	5.36	5.50	5.68	5.77		5.51
XS43	4.29	4.51	4.67	4.89	5.03	5.19	5.33	5.52	5.62		5.34
XS44	4.23	4.46	4.61	4.80	4.92	5.04	5.17	5.34	5.43		5.19
XS45	4.03	4.27	4.44	4.65	4.78	4.92	5.04	5.21	5.29		5.06
XS46	3.94	4.19	4.35	4.57	4.71	4.85	4.97	5.14	5.21		5.00
XS47	3.91	4.14	4.31	4.52	4.66	4.80	4.93	5.09	5.17		4.95

Predicted Peak Water Level (mAOD)

Node	50%AEP Q&T	20%AEP Q&T	10%AEP Q&T	4%AEP Q&T	2%AEP Q&T	1%AEP Q&T	0.5%AEP Q&T	0.2%AEP Q&T	0.5%AEP+CC Q&T	0.5%AEP+ Narrow Channel	0.5%AEP Q&T
XS48	3.77	4.01	4.17	4.37	4.50	4.63	4.75	4.89	4.96		4.81
XS49	3.67	3.89	4.04	4.24	4.36	4.48	4.57	4.69	4.75		4.69
XS50	3.58	3.79	3.93	4.14	4.26	4.42	4.55	4.71	4.79		4.70
XS51	3.50	3.70	3.84	4.03	4.15	4.29	4.40	4.54	4.60		4.60
XS52	3.48	3.68	3.83	4.03	4.15	4.19	4.29	4.44	4.52		4.57
XS53	3.46	3.66	3.82	4.02	4.14	4.18	4.26	4.37	4.50		4.48
XS54	3.45	3.66	3.82	4.01	4.13	4.18	4.25	4.37	4.50		4.48
XS55	3.44	3.65	3.81	4.01	4.13	4.17	4.25	4.36	4.49		4.44
XS56	3.43	3.64	3.80	4.00	4.12	4.17	4.25	4.36	4.49		4.39
XS57	3.41	3.63	3.79	3.99	4.11	4.16	4.24	4.35	4.48		4.24
XS58	3.40	3.62	3.79	3.99	4.12	4.16	4.24	4.35	4.49		4.29
XS59	3.40	3.62	3.79	3.99	4.11	4.16	4.24	4.35	4.48		4.27
XS60	3.40	3.62	3.79	3.99	4.12	4.16	4.24	4.35	4.49		4.29
XS61	3.39	3.62	3.79	3.99	4.11	4.16	4.24	4.35	4.48		4.27
XS62	3.38	3.61	3.78	3.98	4.11	4.15	4.23	4.34	4.48		4.24
XS63	3.38	3.61	3.77	3.97	4.10	4.14	4.23	4.33	4.47		4.24
XS64	3.37	3.60	3.76	3.96	4.09	4.13	4.23	4.33	4.46		4.24
XS65	3.36	3.59	3.76	3.95	4.08	4.13	4.22	4.32	4.46		4.22
XS66	3.35	3.58	3.74	3.94	4.07	4.11	4.21	4.32	4.45		4.21
XS67	3.34	3.57	3.74	3.93	4.06	4.11	4.21	4.31	4.45		4.21
XS69	3.33	3.56	3.72	3.92	4.05	4.10	4.20	4.31	4.44	4.20	4.20
XS70	3.31	3.54	3.71	3.90	4.04	4.09	4.19	4.30	4.43	4.20	4.19
XS73	3.27	3.50	3.67	3.87	4.00	4.06	4.15	4.25	4.39	4.15	4.15
XS74	3.26	3.49	3.66	3.86	4.00	4.05	4.14	4.24	4.38	4.14	4.14
XS75	3.25	3.48	3.65	3.85	3.99	4.04	4.13	4.23	4.37	4.13	4.13
XS76	3.24	3.47	3.64	3.84	3.98	4.03	4.12	4.22	4.36	4.12	4.12
XS77	3.24	3.47	3.64	3.84	3.98	4.03	4.12	4.22	4.36	4.12	4.12

3.24	indicates that the water level is determined by the tide only
4.60	indicates that the water level is determined by the tide and the flow
9.17	indicates that the water level is determined by the flow only

Appendix C River Leven Updated Hydrological Data (AMax)

Time stamp	AMax [m³/s]
30-Sep-63	37.265
25-Nov-63	94.977
17-Jan-65	107.01
02-Nov-65	102.306
19-Dec-66	123.705
27-Oct-67	115.714
20-Oct-68	94.977
12-Nov-69	99.529
05-Nov-70	116.7
22-Oct-71	102.306
13-Dec-72	97.697
30-Jan-74	127.79
31-Jan-75	129.855
23-Jan-76	107.962
10-Feb-77	72.058
10-Nov-77	138.261
18-Nov-78	116.009
10-Dec-79	134.344
03-Jan-81	146.683
27-Nov-81	111.808
12-Jan-83	130.126
19-Oct-83	138.447
08-Dec-84	124.991
07-Oct-85	127.916
05-Dec-86	143.398
13-Jan-88	117.524
07-Feb-89	124.9
11-Mar-90	203.581
06-Jan-91	134.59
08-Jan-92	147.929
24-Jan-93	173.425
14-Mar-94	124.173
13-Dec-94	139.489
27-Oct-95	123.629
02-Mar-97	148.608
16-Feb-98	125.629
25-Oct-98	122.182
09-Dec-99	142.154
13-Dec-00	105.156
12-Feb-02	143.398
28-Jan-03	81.082
13-Jan-04	111.363
10-Jan-05	180.584
12-Nov-05	104.901
14-Dec-06	218.845
01-Feb-08	134.365
26-Oct-08	122.029
27-Nov-09	152.652
13-Nov-10	112.453
05-Jan-12	161.108
31-Dec-12	118.784
04-Jan-14	152.926
15-Jan-15	145.763
10-Dec-15	166.972

Appendix D Second Hydrological Update – Envirocentre, February 2018

West Riverside Hydrological analysis

1.1 Introduction

Further to the Flood Risk Assessment that was undertaken in July 2017 (EnviroCentre report no: 7621), and meetings between Peter Brett Associates and SEPA, there were concerns raised by SEPA regarding the gauged data used within the previous modelling (Jacobs, 2009), and the confidence in the results output from this.

It was proposed that to provide confidence in the gauged data, and with the results from the Jacobs study, additional hydrological analysis would be undertaken, and this technical note covers the outputs from this analysis.

1.2 Linnbrane Gauging Station

The SEPA gauging station No. 85001 (Leven @ Linnbrane) is located approximately 1.3km downstream on the River Leven from the Loch Lomond Barrage at Balloch. The size of the catchment at the gauging station is 786.1 km2 with the predominant feature being Loch Lomond. The station uses a velocity-area relationship to determine flows in a channel approximately 35 m wide. The flow regime was natural until loch outfall control weir was built in 1971, it is now substantially regulated during summer. The Barrage does not operate in winter, and does not affect high flows. The normal surface area of Loch Lomond is estimated at 70 – 71 km².

Figure 1.1 shows the overview of the location of the Loch Lomond and River Leven catchment at Linnbrane, it is shaded light semi-transparent grey. It stretches from Crianlarich in the north to Stirling in the east to Dumbarton in the south.

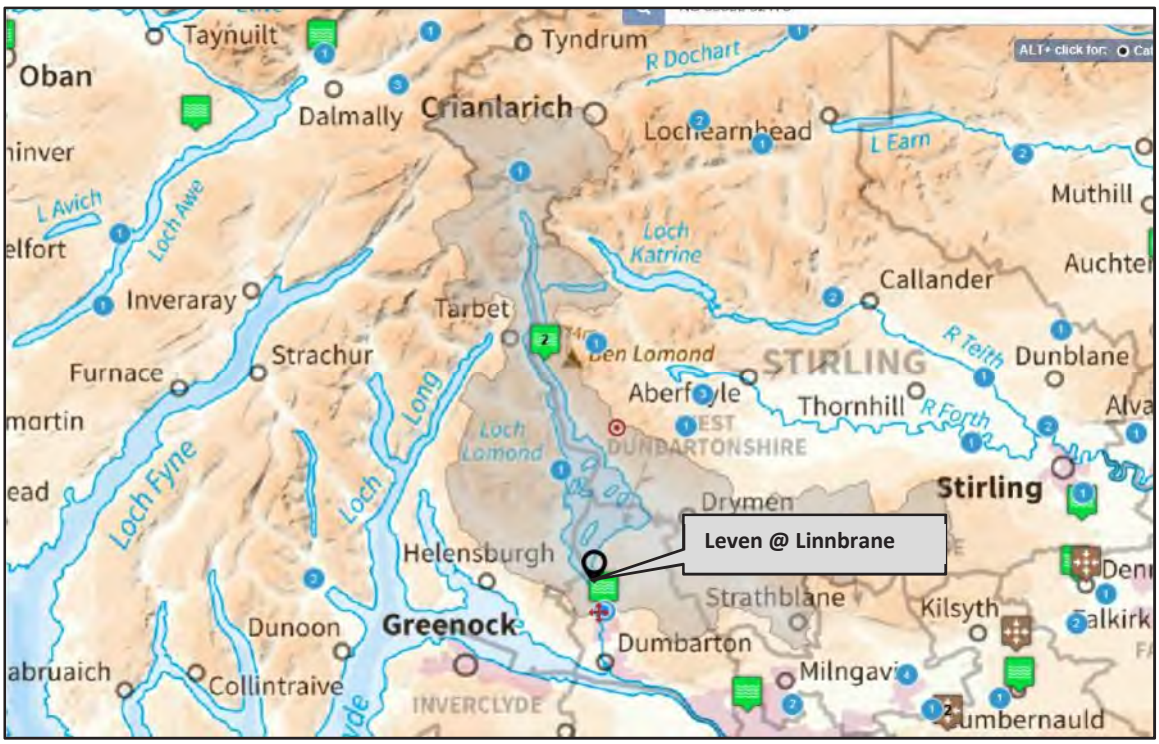


Figure 1-1: Overview of the Loch Lomond & River Leven catchment Linnbrane

1.2.1 Gauging Station Limitations

SEPA's Hydrometry team have flagged concerns with relation to the gauged data from the Linnbrane station due to lack of spot gauging data with which to validate the ratings curve, and that there may be areas of unstable bed which could skew the ratings curve.

SEPA have installed new equipment at the gauge, but this has only been in place for a short period and so this will take another few years to gather enough data to be able to calibrate it sufficiently.

In order to improve confidence in the flow data used within the flood risk assessment, additional hydrological analysis has been undertaken.

1.3 Flood Frequency & Flow magnitude Estimation

For the purposes of the proposed development it is required to estimate the flows corresponding to various flood frequencies in order to predict the probable flood levels and therefore aerial extents. Annual maximum (AMAX) flow data at Linnbrane gauging station (85001) was requested from SEPA. The flow estimations will be affected by the presence of a large loch upstream which would affect the outflows by delaying the arrival of peak flows which will also be naturally attenuated as they are routed through the loch-reservoir. For this station this is complicated further because the outflows from Loch Lomond are regulated in summer by the River Leven Barrage. Therefore, rainfall-runoff methods that are purely based on catchment descriptors would tend to deviate quite substantially from the observed or gauged flows.

The above notwithstanding, it was decided to estimate flows using Flood Estimation handbook (FEH) methods that SEPA approves of in order to carry out a comparative analysis in selecting the flows to be used for estimating flood levels with more confidence. Invariably, all the methods do use catchment descriptors (CDs) in some way, either quantitatively or qualitatively. Therefore, the FEH Web Service (CEH, 2015) was utilised to obtain the necessary CDs. FEH vol. 4 restates and shows situations in which the Flood Studies Report (FSR) rainfall-runoff (R-R) method can be applied. In Section 7.3.2 FEH (vol. 4) states the following: "*Where there is a real choice between the FSR R-R method and the statistical approach, the decision is a matter of judgement and in many cases users will wish to consider both. Indeed, for practical application, it is often necessary to reconcile, over the return periods of interest, the flood frequency curve synthesised by the FSR R-R method, preferably augmented by flood event analysis, with that observed or synthesised by statistical techniques*."

For determining flood levels for the site of interest, which is on the southwestern shores of Loch Lomond, the following three FEH methodologies have been adopted.

1. WINFAP FEH Single Site analysis;
2. WINFAP FEH Pooled Site analysis; and
3. FSR Rainfall-Runoff analysis.

The first two are statistical techniques while the 3rd uses CDs to derive certain critical parameters like time-to-peak to synthesise a flood hydrograph. The FSR R-R has an in-built benefit of including the lag time due to the reservoir to allow for some of the flood water going into storage before flowing out, however as noted above the outputs from this are likely to be affected by the restricted flows from the loch from the River Leven Barrage.

1.3.1 WINFAP Single Site Analysis

Using the WINFAP FEH 4 software, the AMAX flow data that was requested and obtained from SEPA, which was 54 years long was analysed to produce a flood frequency curve. Two distributions, the Generalised Logistic

(GL), which is considered suitable for most of the UK flow data and the Generalised Extreme Value (GEV) distribution, which often produces good results were used to provide an internal check of the analysis outcome. Some of the relevant output print outs from this analysis are included in Appendix B.

1.3.2 WINFAP Pooled Analysis

Using the WINFAP FEH 4 software, the same AMAX flow data that was requested and obtained from SEPA, which was 54 years long for the Linnbrane gauging station was pooled together with other similar stations based on their CDs to create a longer AMAX series of up to 500 years. This is an enhanced pooled analysis as it included the subject site's record in the analysis. Similarly, a flood frequency curve was accordingly produced using the same two distributions, GL and GEV. Again, some of the relevant output print outs from this analysis are included in Appendix C.

1.3.3 FSR Rainfall-Runoff Analysis

Design flood estimation using the FSR R-R method involves applying and appropriate design storm and associated antecedent conditions to a unit hydrograph and losses model of the catchment. It is appreciated that the presence of the Loch Lomond reservoir can lead to some difficulties in methodology. The effect of the reservoir is to lag (i.e. delay) and attenuate (i.e. reduce the amplitude, whilst maintaining the volume) the flood hydrograph from the catchment. For more information on the application of this method to reservoired applications reference can be made to FEH (vol. 4) Chapter 8. Suffice to state here that in reservoired applications, the design storm duration (D) is extended by adding the reservoir response time RLag to the catchment response time or time-to-peak, T_p. Where there is no reservoir $D = T_p(1+SAAR/1000)$; and with reservoir $D = (T_p + RLag)(1+SAAR/1000)$.

In the absence of the exact relationship between the storage in the Loch Lomond and outflow to carry out full reservoir routing calculations, a simplified approach has been used. The estimated surface area of Loch Lomond is approximately 70 km^2 (70*10^6 m^2). An increase in the loch water level of 0.1 m (10 cm) will increase the volume stored by 7*10^6 m^2. The max peak flow at Linnbrane recorded on 14/12/2006 is 218.8 m^3/s. Routing this rate of inflow into the loch to determine how long it will take to raise the water level in the Loch Lomond by 0.1 m as a measure of the minimum Rlag between the peak inflow hydrograph and peak of attenuated outflow hydrograph. This results in Rlag of 8.9 hours as a starting point. In reality an event of such magnitude is likely to result in a bigger change in the storage level which will take much longer than 9 hours to realise. The River Leven Barrage is designed to regulate water levels in Loch Lomond between 7 mAOD (min) and 7.6 mAOD (max), according to a SEPA document[1], which represents a change in the water level of 0.6 m.

For normal or regular flows it will take much longer than 9 hours to produce an increase of 0.1 m in the water level. For instance, for a QMED flow of 125 m^3/s to produce 0.1 m in the water level, it will take approximately 15.6 hours. Consequently, the Rlag was set to 16 hours. The FSR R-R analysis was then carried out for a winter rainfall profile. It was observed that the FSR R-R values were significantly higher than their corresponding counterparts. To allow for a more realistic comparison the peak flows of the FSR R-R were rescaled using the ratio of the QMED (data) to the 2-year FSR R-R peak flow of 0.6883 as a scaling factor to the peak flows for all return periods.

[1] *Loch Lomond & Vale of Leven PVA (11/01) - Clyde & Loch Lomond, p.23.*

1.3.4 Comparison

From the two WINFAP analyses, both the GL and GEV distributions fitted the plot data reasonably well, but overall, the GL produce a better fit than the GEV, especially for higher return period events. Therefore, the peak flood flows produced by the GL frequency curve are used for comparison. The resulting flows obtained for all three methodologies, along with the flows used in the Jacobs study, are summarised in Table 1.1, which presents flood peak flows or design flows for a number of annual exceedance probabilities (AEP) corresponding to return periods of interest. Potential change in stream flows with climate change (CC) is normally accounted for by increasing the present 1 in 200 year (0.5% AEP) flood event flow by 20%, as standard for the UK (SEPA, 2015). Therefore, Table 1 also includes the 0.5% +CC flow estimate which is an increase of 20% over the 0.5% AEP flows.

Table 1-1: Estimated summer peak flood flow rates

Return period (years)	Annual Exceedance Probability (%)	Peak Flood Flows (m^3/s)			
		Jacobs Flood Study (2009)	**WINFAP Single-site analysis**	**WINFAP Pooled analysis**	**FSR Rainfall-Runoff analysis (rescaled)**
2	50	*123*	125.0	125.0	125.0
5	20	*146*	146.9	149.1	165.5
10	10	*161*	161.7	165.8	193.4
25	4	*180*	181.8	189.0	227.9
50	2	*196*	198.3	208.1	256.9
100	1	*213*	216.0	229.2	283.5
200	0.5	*231*	235.4	252.4	311.3
500	2	*257*	263.8	287.1	359.1
200 + CC	0.5 + CC	*277.2*	282.5	302.9	373.5

On comparison of the flow estimates obtained by the three methodologies, it is apparent that the flows derived by the FSR R-R approach are consistently higher than for the two statistical approaches, which compare reasonably well. The FSR R-R flows would be considered to be outliers and would serve only as the upper bound for sensitivity checks. Comparing the WINFAP estimates with the flows used within the Jacobs flood study, they also appear to tie up reasonably well, with only a marginal increase in flows in the more conservative Pooled analysis.

From the Jacobs flood study, an analysis of the relationship between peak flows and peak water levels has been undertaken to determine the impact of increasing flows on the peak water levels at differing return periods. Based upon this, the peak water levels in the 200 yr+CC event only increase by 30-40 mm with the Single Site analysis and up to 180mm for the Pooled Analysis. Based upon the topography of the site and the previously plotted flood extents, this would only have the impact of offsetting the maximum flood extents by approximately 1-3m in some localised areas within the site. The proposed masterplan has been developed to ensure that all new development is outwith the functional floodplain, and building finished floor levels have a minimum level of 11m AOD across the site.

A copy of the flood extents plan showing the 1 in 200 year+CC and 1:500 year extents is included within Appendix D.

APPENDICES

A ANNUAL EXCEEDANCE PROBABILITY-RETURN PERIOD CONVERSION

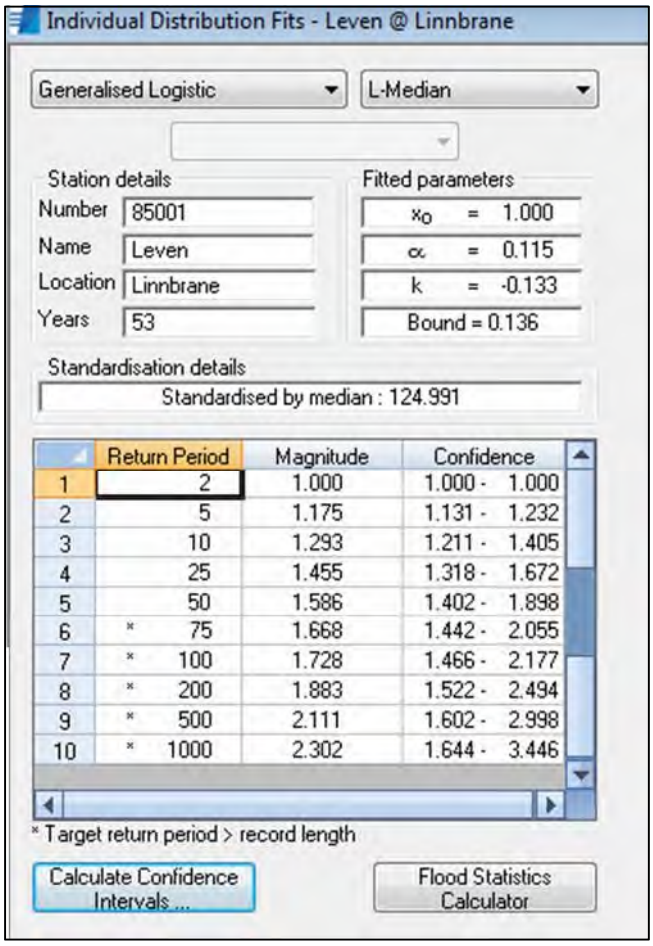
Relationship between annual exceedance probability and return periods

Annual exceedance probability, AEP (%)	Return period, T (year)	Probability of occurrence over a 50 year period (%)	Comment
50	2	100	Median annual flood, in the long-term this occurs every other year, on average.
20	5	100	
10	10	99	
5	20	92	
3.3	30	82	Typical design standard for urban drainage systems.
2	50	64	
1	100	39	
0.5	200	22	Typical design conditions standard for river or coastal flooding for most developments. Defines “functional floodplain” under Scottish Planning Policy.
0.2	500	10	
0.1	1,000	4.9	Typical design conditions standard for sensitive or vulnerable developments/contexts.

The annual exceedance probability of particular flood conditions is the chance these conditions (or more severe) occur **in any given year**.

The return period of a flood is the **long-term average** period between flood conditions of such magnitude (or greater).

B OUTPUT OF WINFAP FEH SINGLE SITE ANALYSIS



Individual Distribution Fits - Leven @ Linnbrane

Generalised Logistic | L-Median

Station details

Number	85001
Name	Leven
Location	Linnbrane
Years	53

Fitted parameters

x_0	= 1.000
α	= 0.115
k	= -0.133
Bound = 0.136	

Standardisation details

Standardised by median : 124.991

	Return Period	Magnitude	Confidence
1	2	1.000	1.000 - 1.000
2	5	1.175	1.131 - 1.232
3	10	1.293	1.211 - 1.405
4	25	1.455	1.318 - 1.672
5	50	1.586	1.402 - 1.898
6	* 75	1.668	1.442 - 2.055
7	* 100	1.728	1.466 - 2.177
8	* 200	1.883	1.522 - 2.494
9	* 500	2.111	1.602 - 2.998
10	* 1000	2.302	1.644 - 3.446

* Target return period > record length

Calculate Confidence Intervals ... | Flood Statistics Calculator

Individual Distribution Fits - Leven @ Linnbrane

Generalised Extreme Value | L-Median

Station details

Number	85001
Name	Leven
Location	Linnbrane
Years	53

Fitted parameters

u	= 0.935
α	= 0.180
k	= 0.058
Bound = 4.027	

Standardisation details

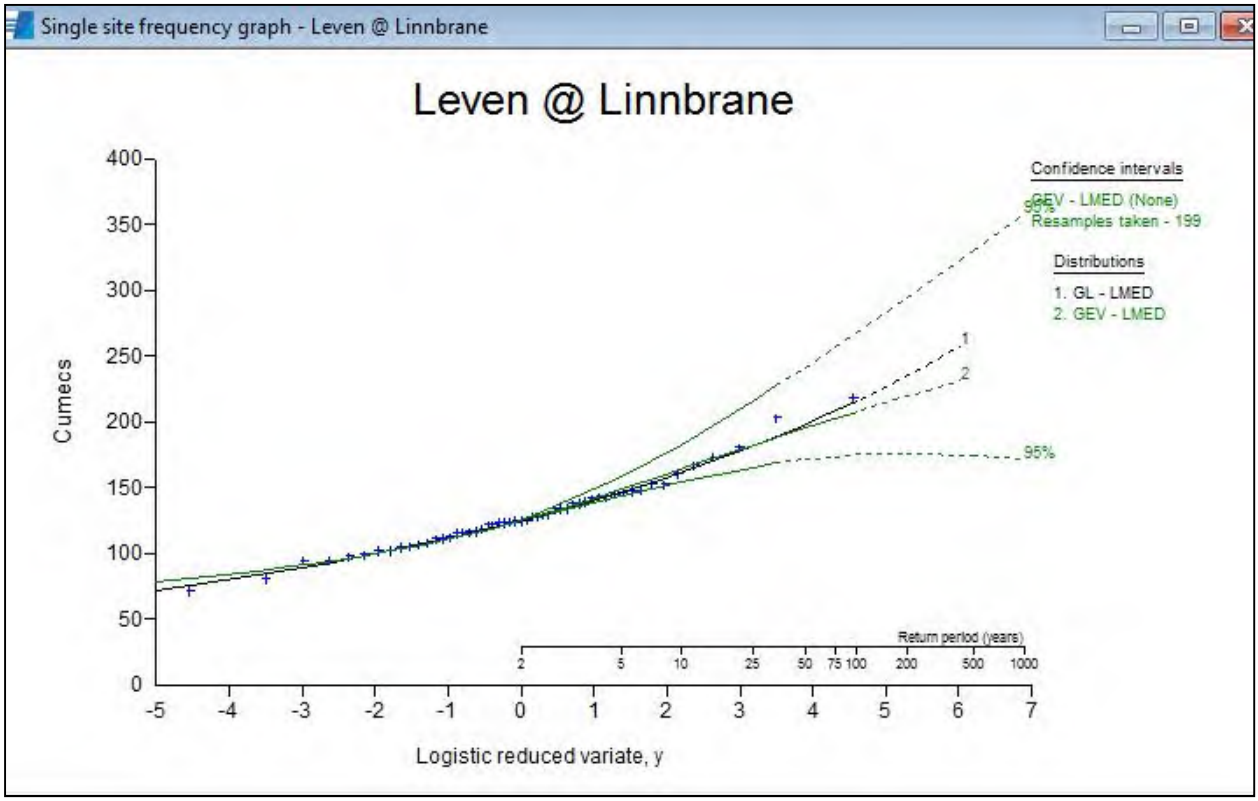
Standardised by median : 124.991

	Return Period	Magnitude	Confidence
1	2	1.000	1.000 - 1.000
2	5	1.194	1.137 - 1.252
3	10	1.315	1.225 - 1.427
4	25	1.461	1.308 - 1.667
5	50	1.564	1.353 - 1.850
6	* 75	1.622	1.371 - 1.959
7	* 100	1.662	1.385 - 2.036
8	* 200	1.756	1.403 - 2.226
9	* 500	1.874	1.411 - 2.481
10	* 1000	1.960	1.402 - 2.677

* Target return period > record length

Calculate Confidence Intervals ...

Flood Statistics Calculator



C OUTPUT OF WINFAP FEH POOLED ANALYSIS

Growth Curve Fittings

Standardisation details

Standardised by median

Growth Curve L-moments

L-CV 0.126 L-skewness 0.153

Fitted parameters

	Location	Scale	Shape	Bound
GL	1.000	0.125	-0.153	0.182
GEV	0.930	0.193	0.027	8.126

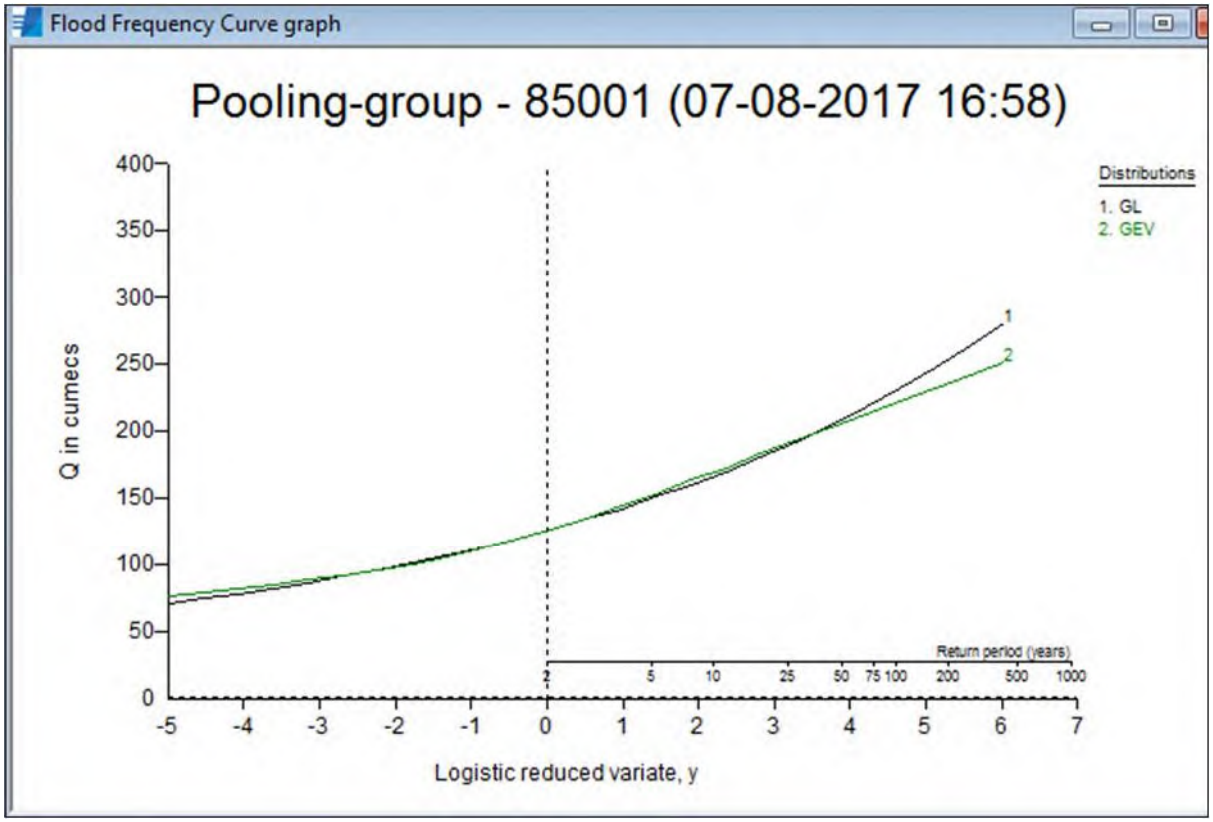
Return periods

	GL	GEV
2	1.000	1.000
5	1.193	1.213
10	1.327	1.351
25	1.512	1.521
50	1.665	1.644
75	1.762	1.715
100	1.833	1.764
200	2.019	1.882
500	2.297	2.033

Fittings for FFC

Return periods

	GL	GEV
2	124.991	124.991
5	149.131	151.637
10	165.813	168.840
25	188.957	190.086
50	208.119	205.502
75	220.176	214.330
100	229.158	220.520
200	252.406	235.206
500	287.055	254.167
1000	316.640	268.192



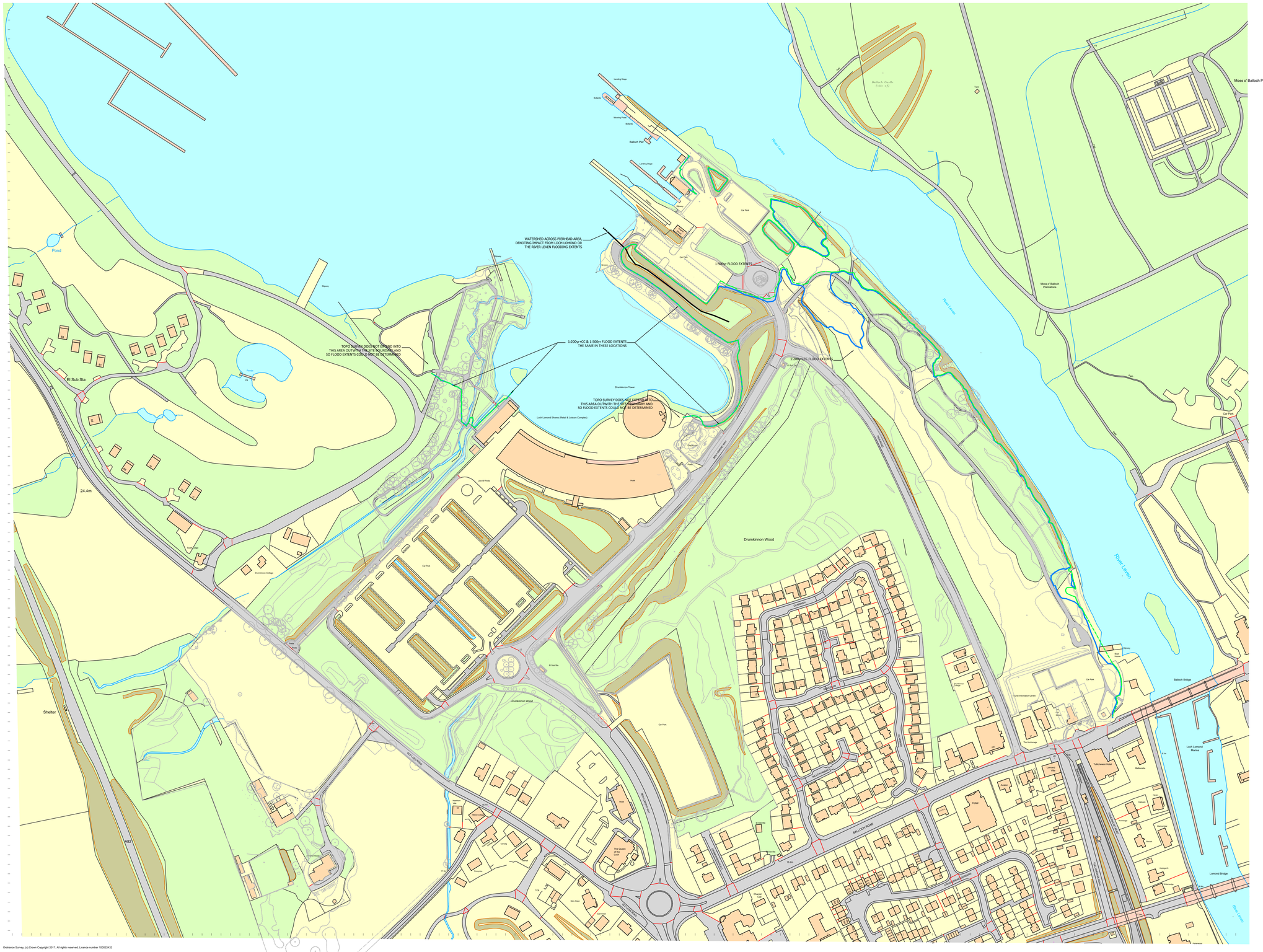
APPENDIX D – FLOOD EXTENTS PLAN

Notes

LEGEND

1 IN 200yr + 20%CC FLOOD EXTENTS

1 IN 500yr FLOOD EXTENTS



Do not scale this drawing

Rev	Date	Amendment	Initials

ENVIROCentre
Craighall Business Park, Eagle Street, Glasgow, G4 9XA
Tel: 0141 341 5040
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Client
TSL Contractors Limited

Project
West Riverside Balloch

Title
Combined Flood Extents Map

Status
FINAL

Drawing No. 168659-018

Revision

File path: k:\168659\jdrgs\cad

Scale 1:500 @ A1

A1

Date 07/08/2017

Drawn	Checked	Approved
DW	CGF	CGF

SEPA
Scottish Environment Protection Agency
Buidheann Dion Àrainneachd na h-Alba

Our ref: PCS/157036
Your ref:

If telephoning ask for:
Brian Fotheringham

Mr D Warren
EnviroCentre Limited
Craighall Business Park
8 Eagle Street
Glasgow
G4 9XA

07 February 2018

By email only to: DWarren@envirocentre.co.uk

Dear Sir

Hydrological Analysis – West Riverside Site, Balloch
Jacobs Study & River Leven Gauging Station
Pre-application advice

Thank you for your consultation email which SEPA received on 17 January 2018, in respect of the above issues.

We have given due consideration to the further information you provided and would offer the following revised comments for your information.

1. Flood risk comments

1.1 We would confirm based on the information supplied with this consultation that if we were to be formally consulted through the planning process on the proposed development we would be unlikely to object on flood risk grounds. Notwithstanding this we would expect West Dunbartonshire Council to undertake their responsibilities as the Flood Risk Management Authority.

1.2 Our pre-application advice relies on the accuracy and completeness of the information supplied with this consultation. Should finalised development proposals differ in any future planning application we reserve the right to alter our position if we are of the opinion that the amended proposals would not meet with the principles of Scottish Planning Policy.

Technical Report

1.3 We acknowledge our involvement in pre-planning discussions on a potential development in the Balloch area. As part of these proposals a previously undertaken Flood Risk Assessment (FRA) has been used to assist in determining the potential flood risk issues at the site. In this respect we raised concerns about the quality of the gauged data used as part of the hydrological modelling. We accept that further hydrological analysis has subsequently been done and we would make the following comments on this additional information.

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Holytown, North Lanarkshire ML1 4WQ
tel 01698 839000 fax 01698 738155
www.sepa.org.uk • customer enquiries 03000 99 66 99

1.4 The design flows have considered Rainfall Runoff or the Statistical method (single site and Pooling Group). We have also undertaken a comparison using ReFH2.2. The flow estimates are in line with our calculations and a number of return periods have been considered. We would be in agreement that the Statistical method is the most appropriate and sensitivity analysis has been undertaken to determine how any changes in flow effect flood levels. The analysis suggests that flood levels would only be increased by between 30-180mm. This should not lead to a significant alteration of the existing flood conditions given the existing topography of the site.

1.5 Whilst we maintain some concerns about the quality of the gauged data the updated analysis has suggested no major variation in design flows or extents. We would therefore be in agreement with the recommendation that all development should be outwith the functional floodplain. It is assumed that in this instance the floodplain will be defined as the 200 year plus climate change.

Caveats & Additional Information

1.6 The SEPA Flood Maps have been produced following a consistent, nationally-applied methodology for catchment areas equal to or greater than 3km2 using a Digital Terrain Model (DTM) to define river cross-sections and low-lying coastal land. The maps are indicative and designed to be used as a strategic tool to assess flood risk at the community level and to support planning policy and flood risk management in Scotland. For further information please visit http://www.sepa.org.uk/environment/water/flooding/flood-maps/.

1.7 Please note that we are reliant on the accuracy and completeness of any information supplied by the applicant in undertaking our review, and can take no responsibility for incorrect data or interpretation made by the authors.

If you have any queries relating to this letter, please contact me by telephone on 01698-839336 or by e-mail to planning.sw@sepa.org.uk

Yours faithfully

Brian Fotheringham
Senior Planning Officer
Planning Service