Technical Note

Project:	**Niddrie Flood Study**	Job No:	**60617815**
Subject:	**Hydrological assessment and hydraulic modelling approach**		
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Introduction

AECOM has been commissioned by the City of Edinburgh Council to undertake a flood study for the Niddrie Burn and its main tributary: the Stenhouse Burn. The burn changes name throughout its reach, from the Swanston Burn to the Burdiehouse Burn to the Niddrie Burn to the Brunstane Burn. For the purposes of this study, the watercourse in its entirety will be referred to as the Niddrie Burn.

The study will assess fluvial, pluvial and tidal flood risk. Fluvial flood risk from the Niddrie and Stenhouse Burns will be assessed with the inclusion of the influence of the tidal conditions in the Forth Estuary at the downstream extent. Pluvial flood risk of the wider catchment will also be assessed.

The Swanston Burn flows west to east on the south side of Edinburgh city Bypass (A720), before crossing underneath the road where it becomes the Burdiehouse Burn. The Burdiehouse Burn flows north east through Burdiehouse and into Ellen's Glen where it is met by the Stenhouse Burn, which flows from west to east. Starting in Mortonhall, the Stenhouse Burn is culverted through to Gracemount where it flows east until its confluence with the Burdiehouse Burn.

After passing under Gilmerton road and flowing north east towards Edinburgh Royal Infirmary (ERI), the Burdiehouse Burn becomes the Niddrie Burn. Here the burn has undergone recent modifications as part of flood alleviation and restoration schemes. The burn continues past ERI, flowing north through Niddrie then east towards the A1. Whilst crossing under the A1, the burn again changes name to the Brunstane Burn. Here the watercourse continues to flow east through rural land and a golf course, before crossing under Musselburgh Road to its confluence with the Forth. The rainfall catchment for the watercourses is shown in **Figure 1**.

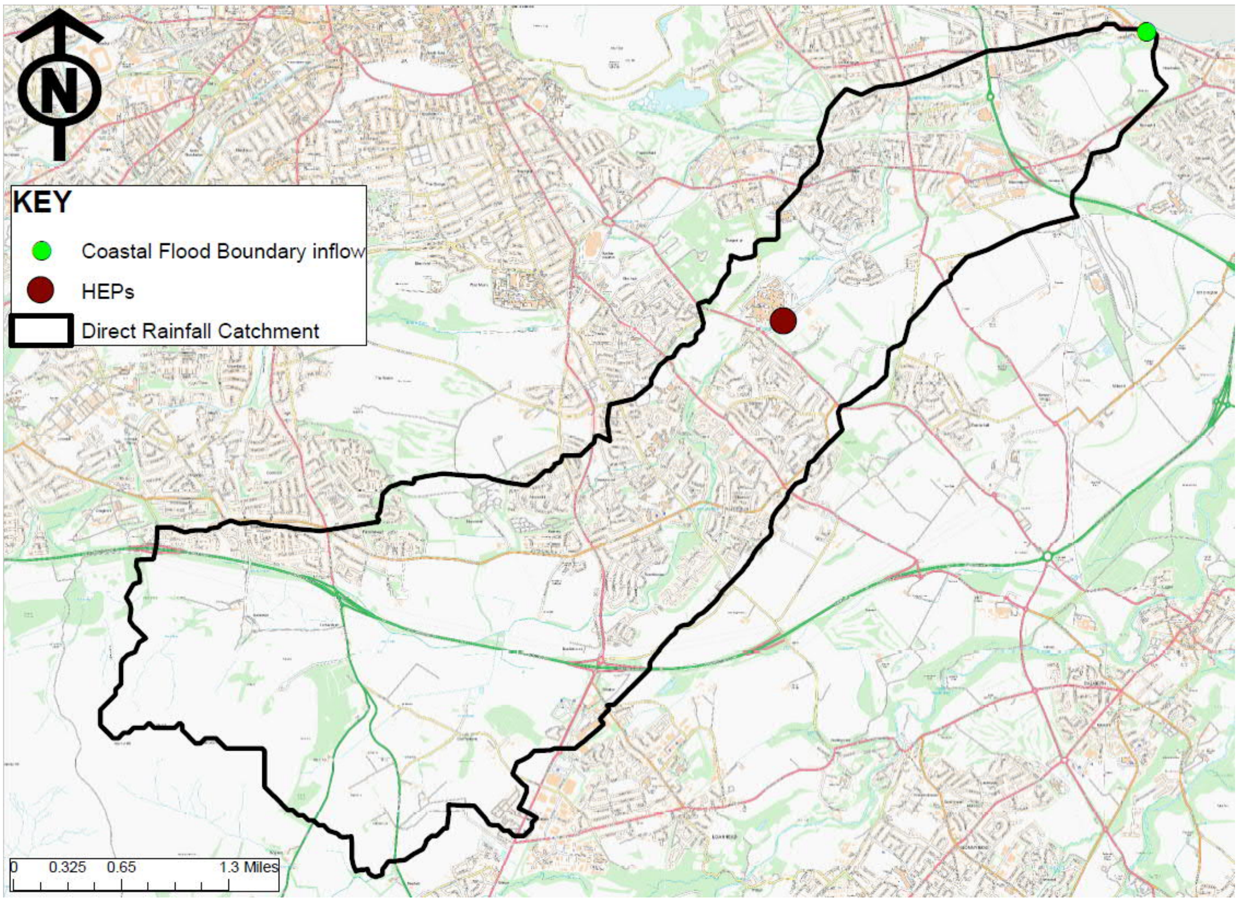

Figure 1 - Map of Direct Rainfall Catchment and coastal inflow location

Early stages of the project include a data review and gap analysis of all relevant information and to establish baseline flood conditions. Hydrological assessments will be required across the study area and at the coastal boundary. These inflows will then be added to a single 1D/2D hydraulic model.

This technical note sets out our intended approach for the hydrological assessment and hydraulic modelling.

Hydrological assessment

Hydrological analysis will provide direct rainfall estimates for input to the hydraulic models, rather than point inflows into the watercourses. This will allow for pluvial flooding to also be assessed across the wider catchment. The assessment will be based on the Flood Estimation Handbook (1999), which provides industry standard methods for fluvial flood estimation. This will be complimented with further guidance such as The Revitalised Flood Hydrograph Model v2.3, SEPA's *Flood Modelling Guidance for Responsible Authorities* and *Climate change allowances for flood risk assessment in land use planning.*

Catchment areas for the entire watercourse have been determined using the FEH Web service (https://fehweb.ceh.ac.uk/). It will be checked and modified if required using LiDAR contour data and by assessing the surface water drainage network. Further amendments may be made if necessary, following a walk-over survey. Hydrology will generally be determined to the downstream extent of the watercourse then applied to the upstream extent.

A hydrological assessment will be undertaken to the downstream boundary of the Niddrie Burn at the Forth Estuary, allowing for a flow reconciliation exercise to be undertaken. The calculated direct rainfall will be applied to the catchment, and parameters will be adjusted so that the calculated peak flow at the downstream extent of the model is matched.

Peak downstream flows

To establish the peak flows at the downstream extent of the Niddrie Burn, at the confluence with the Forth, the most up to date versions of softwares will be utilised along with the most recent data such as catchment descriptors and WINFAP files.

Flood Estimation Handbook statistical methodology is considered appropriate for deriving peak flows on the Niddrie Burn catchments due to its medium size. Based on the FEH download, the Niddrie catchment is 25.55km^2.

The statistical method is based on first establishing the QMED, the median flow, and then developing a growth curve based on similar gauged catchments so that all required peak flow return periods can be assessed.

There are several gauges on the Niddrie Burn, however none have a sufficient length of record to be used in establishing QMED. Therefore, QMED will be established by donor adjustment. A growth curve will then be calculated in WIN-FAP using hydrologically similar catchments to determine the flood frequency curve.

The Revitalised Flood Hydrograph Method 2 (ReFH2) will also be undertaken to the downstream extent of the model as a comparison to the flow estimates generated using the Statistical method. ReFH2 is now accepted by SEPA as it incorporates a larger Scottish dataset, includes more small-catchment data, utilises the most up to date 2013 rainfall DDF (Depth, Duration, Frequency) model data and incorporates an improved method for assessing urban losses. It should be noted that there are some instances where the ReFH2 should be used with caution, and a full review of the catchment descriptors will be undertaken in advance of the hydrological analysis.

Both methods will be undertaken before deciding on the preferred method for establishing peak flows at the downstream extent of the model. The derived peak flow will be used to reconcile the direct rainfall inflow.

Direct rainfall

ReFH2 software will be used to establish rainfall to be applied over the catchment. Given the short record length of gauged data, the default rainfall event hyetograph will be used and applied to the model. Both storm profiles will be run to assess flooding however, given the urbanised nature of the catchment, the ReFH2 summer profile will likely be adopted.

If possible, ReFH2 model parameters will be improved using local/donor data and/or anecdotal flood reports.

Peak flows produced at the downstream extent of the model will be assessed using the default rainfall and parameters. Parameters within the ReFH2 will be adjusted where required so that the flows can be reconciled to the peak flows established at the downstream extent of the model as outlined above.

Joint probability

The likelihood of an event occurring on the Niddrie Burn at the same time as on the River Forth will be established through sensitivity testing as there is insufficient local data to undertake a full joint probability analysis.

Because of the difference in mechanism, one fluvial and one tidal, the conditions leading to an event are likely to be dissimilar and a large event on the Niddrie Burn is unlikely to coincide with a large event in the Forth. That does not however mean that levels in the Forth will not impact flooding in the Niddrie Burn. Flood risk within the lower reach of the Niddrie Burn may be influenced by the water level in the Forth Estuary; the worst-case situation being the peak flow in the watercourse and a high tide. It should be noted that the watercourse is relatively incised around the coast which may reduce the tidal influence on flooding from the watercourse.

A rigorous analysis of joint probability of coincidence in peaks would require gauged data on the Niddrie Burn and a tidal gauge close to the downstream extent on the Forth. The likely approach will therefore use sensitivity analysis in the hydraulic modelling to assess the impact through a suite of simulations. This assessment will be detailed and provided to CEC and SEPA prior to final simulations.

Climate change

Outlined in their Flood Modelling Guidance for Responsible Authorities, SEPA commissioned CEH to undertake a study assessing Scottish catchments vulnerability to climate change. Based on the medium emission scenario 2080s, 67th percentile, the Forth catchment is reported to have a 27% change in flood peak as shown in tables 10-1, with the high emission scenario 2080s, 67th percentile reported to have a 40% change in flood peak.

SEPA have also published guidance on climate change allowances for flood risk assessments. Whilst the guidance for Flood Studies applies a more adaptive approach to climate change uplift, it was useful to compare uplift recommendations. For the study area, it is recommended that peak flow be uplifted by 35% on larger watercourses and that peak rainfall be uplifted by 40% on smaller watercourses.

For this study it is proposed that an uplift of 40% is applied to peak rainfall on entire catchment. This in in line with SEPA guidance and City of Edinburgh Council policy.

Hydraulic modelling

Model build

Direct rainfall inflow generated from the hydrological analysis will be input into a hydraulic model covering the watercourses and the surrounding areas to assess peak water levels, floodplain extents and overland flow paths. The Direct Rainfall Catchment can be seen in **Figure 1**, the study area forms a smaller section of this catchment, extending between the Bypass and the coastal extent.

A river cross section topographic survey has been commissioned for the entire required reach of the Niddrie Burn. This will extend from the Bypass to the tidal extent at the Forth. Section spacing will be in accordance with SEPA's *Flood Modelling Guidance for Responsible Authorities.* Surveyed sections will include all in-channel structures as well as any relevant lateral structures that may impact flood routes. LiDAR has been obtained for the majority of the area and will form the basis of the 2D domain, with minor updates to topography based on surveyed data. Once the first simulations have been undertaken, updates to the LiDAR may be undertaken if the LiDAR is not found to represent features such as bridge embankments of artificial structures correctly. The LiDAR will be ground truthed using survey information to confirm its suitability. Small sections of the catchment are not included in the LiDAR dataset and these will be covered using an alternative ground surface such as Nextmap. These missing sections cover a very small portion of the upstream catchment and it will not alter the rainfall model.

Roughness will be applied to the 2D domain to represent different land uses and buildings will be represented by raising the building footprint by 300mm to represent the threshold level and by applying a porous polygon with 10% porosity to represent run off from the roof. Infiltration zones, with appropriate runoff coefficients and infiltration rates will be applied to represent different land use type.

Given the influence of urban runoff in the catchment, it is proposed that the model be constructed in InfoWorks ICM software to improve stability. CEC have also requested that the model be constructed in ICM so that it could potentially be tied in with the wider Edinburgh Integrated Catchment Study. A suitable mesh size will be chosen and likely refined to a smaller resolution in areas seen to be at flood risk to improve outputs. The model will be run in hydrodynamic mode, modelling the full flood hyetographs as opposed to just a steady peak rainfall which will allow for a proper assessment of flood pathways and floodplain storage for the entire range of return periods. This will form the baseline model to assess existing flood risk in the study area.

The standard flow, roughness, structure coefficient and blockage sensitivity runs will be undertaken as set out in SEPA guidance.

Calibration and verification

Our model will be calibrated to observed flood data where possible including gauged data (rainfall, level and flow), observed flood extents and photographs. We currently have information from several rain gauges in the catchment as well as level gauges on the Stenhouse Burn and at the ERI. There gauges have between 2 and 10 years of data. A recently installed flow gauge at the ERI will also be used if possible. We will focus on the most recent events that have caused property flooding and will calibrate the models to replicate these events where possible. The points where calibration will be undertaken. A Hydrological Estimation Point (HEP), which is located at the ERI, are shown in **Figure 1**.

Where full model calibration is not possible (e.g. due to an absence of gauged data), we will verify the model against anecdotal reports of flooding and other qualitative information that will be obtained from SEPA and CEC. We will also undertake sensitivity testing of the assumptions made in our model development (e.g. structure coefficients, downstream boundary conditions and Manning's n roughness values) to inform our assessment of confidence levels in the results used for scheme appraisal.