TECHNICAL NOTE

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1. Introduction

RSK / Binnies were commissioned by Aberdeenshire Council to carry out a flood study in Kintore. This technical note forms part of the initial work to gather data and review the available hydrology in line with current SEPA guidance and industry best practise. The purpose of this document is to summarise the findings from the review of the hydrology previously developed for the existing models in this area.

At Kintore, an existing model of the sewer network was available and was held by Scottish Water; and an existing model of the River Don was available and was held by Aberdeenshire Council.

2. Existing Fluvial Model Hydrology

The input hydrology was developed by JBA Consulting in January 2019 for use in the hydraulic modelling for the Inverurie and Port Elphinstone Flood Protection Studies (FPS). The hydrology was required as input to the 1D/2D hydraulic model of the River Urie between Old Rayne and its confluence with the River Don at Inverurie, and the River Don between Haughton gauging station and downstream of Parkhill gauging station for use in flood mapping. Figure 1 shows the hydrological catchments considered by JBA Consulting along these reaches.

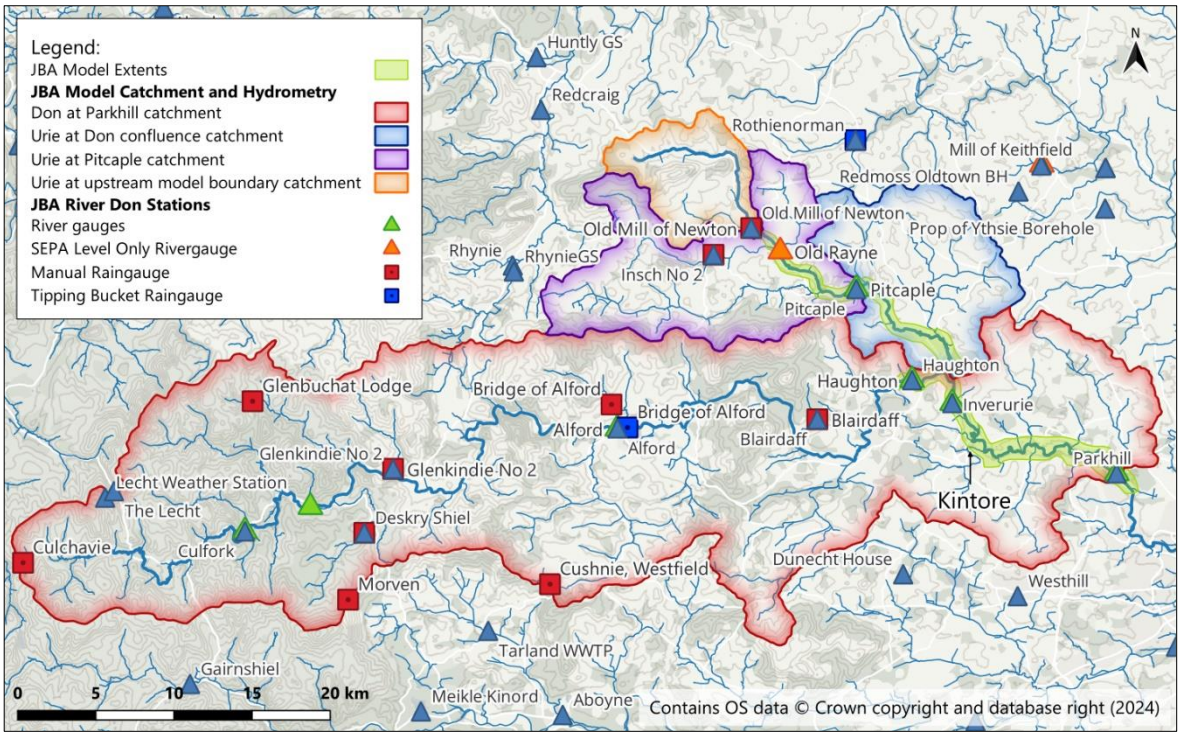

Figure 1 – JBA model catchments and gauging stations

2.1 Hydrology Schematisation

Hydrology was estimated as a peak flow and inflow hydrograph on the River Urie at Pitcaple, the River Don at Haughton and on the River Don at Parkhill to align with the location of SEPA gauging stations. Tributaries with a catchment area greater than 3km^2 were also assessed and added as lateral inflows. Figure 2 shows the schematisation of the model in this regard. Note that the Tauch Burn, which also forms part of the Kintore Flood Study, has been included here; however, the Loch Burn and Torry Burn have not been included and will need to be added.

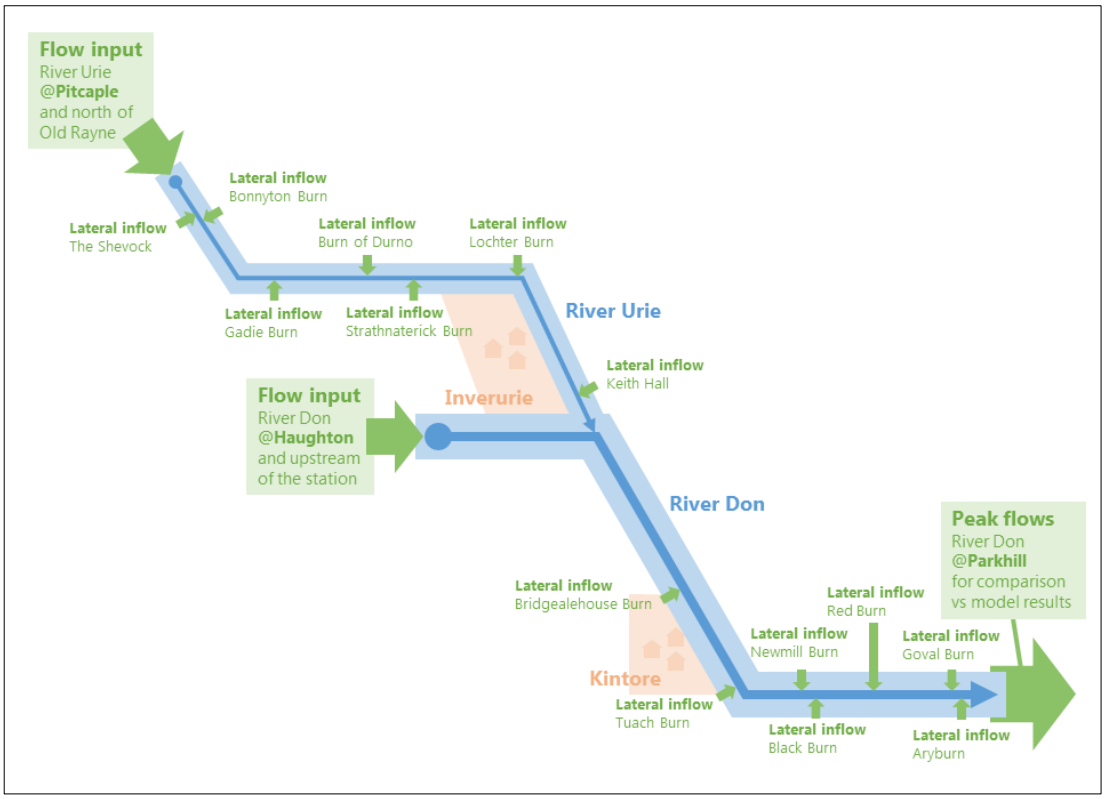

Figure 2 – Hydrograph inputs schematisation

2.2 Estimation Methods

Fluvial flow estimates for the Inverurie and Port Elphinstone FPS were conducted using the Flood Estimation Handbook (FEH), which defines three primary methods of flow estimation:

a. **Statistical Method**: This method estimates the median annual maximum flood (QMED) at the site and applies a growth curve derived from one of either:

   i. A pooling group of hydrologically similar gauged catchments.

   ii. Single site analysis of a nearby gauge.

   iii. An enhanced single site approach combining the two.

b. **Rainfall Runoff Method**: This method uses design rainfall combined with a unit hydrograph specific to the site. It has been updated to the Revitalised Flood Hydrograph method (ReFH2).

c. **Hybrid Methods**: These involve a combination of the Statistical and Rainfall Runoff methods.

For both the River Urie and River Don, the FEH Statistical method was chosen due to the large, rural nature of the catchments and the availability of high quality gauge records. Adjustments were made to catchment area and URBEXT catchment descriptor values, with the FEH CD-ROM BFIHOST values found to be reasonable compared to geological data. Catchment descriptors are now more

frequently updated using the FEH Web Service, and these will need to be reviewed again for the Kintore Flood Study.

The following sections review the hydrological estimation in further detail at each of the inflow locations shown in Figure 2.

2.3 River Don at Haughton

Peak flow estimates at Haughton were reviewed as part of the 2017 '*Don to Inverurie Flood Mapping*' project by JBA Consulting. The SEPA gauging station at Haughton (station number 11002) had 45 years of annual maxima (AMAX) data (1972-2016) at the time of this study. JBA conducted a rating review using hydraulic modelling, applying the new rating across the full record.

Two methods were considered for flood estimates: enhanced single site analysis (ESS) and single site (SS) analysis. Both methods used a Generalised Logistic (GL) distribution for the growth curve, with additional tests using the Generalised Extreme Value (GEV) distribution. A QMED value of 111.7 m^3/s at Haughton, derived from observed AMAX data, was accepted.

Historical context was provided by considering the largest event on record (January 2016, ~396 m^3/s). The SS analysis was found to be more consistent with this historical data, leading to its adoption. A 24% climate change allowance was applied to the 0.5% AEP event, per SEPA guidance at the time of the study.

The River Don at Haughton gauge is situated approximately 10km upstream of Kintore and will have recorded additional data since its use in the Inverurie and Port Elphinstone Flood Studies. Therefore, a similar approach to that adopted in these studies (which has already been agreed by SEPA) should be taken but the peak flow and hydrograph shape re-assessed to take account of the data available from more recent flood events.

2.4 River Urie at Pitcaple

The SEPA gauging station at Pitcaple (station number 11004) had 29 years of AMAX data (1988-2017) at the time of this study. SEPA conducted a rating review using a linked 1D/2D hydraulic model, resulting in a new high flow rating. Both enhanced single site analysis (ESS) and single site (SS) analysis were considered for flood estimates. The updated AMAX series was used to calculate peak flows.

Two methods were considered for flood estimates: enhanced single site analysis (ESS) and single site (SS) analysis. For both methods, a Generalised Logistic (GL) distribution was used for the growth curve, with additional tests using the Generalised Extreme Value (GEV) distribution. A QMED value of 31.25 m^3/s at Pitcaple, derived from observed AMAX data, was accepted.

The highest event on record (November 2009, ~94 m^3/s) was used to provide historical context. The ESS approach using the GL distribution was adopted due to its consistency with historical data and the relatively short record length at Pitcaple meant that the SS approach would not be acceptable for the lower frequency floods. A 24% climate change allowance was applied to the 0.5% AEP event, per SEPA guidance at the time of the study. Design peak flow estimates upstream of Pitcaple were derived using the same growth curve with QMED adjusted using the Pitcaple gauge data as the

donor. A check using the statistical pooling method was then also performed but ultimately the ESS with GL distribution remained as the preferred estimation approach.

The River Urie at Pitcaple gauge is situated approximately 20km upstream of Kintore and will have recorded additional data since its use in the Inverurie and Port Elphinstone Flood Studies. Therefore, a similar approach to that adopted in these studies (which has already been agreed by SEPA) should be taken but the peak flow and hydrograph shape re-assessed to take account of the data available from more recent flood events.

2.5 River Don at Parkhill

The SEPA gauging station at Parkhill (station number 11001) had 49 years of AMAX data (1969-2018) at the time of this study. SEPA commissioned additional survey work and developed a 1D/2D hydraulic model to define the updated rating curve. The updated high flow rating was applied to the SEPA AMAX series above the gauged range.

Both enhanced single site analysis (ESS) and single site (SS) analysis were considered for flood estimates. A Generalised Logistic (GL) distribution was used for the growth curve, with additional tests using the Generalised Extreme Value (GEV) distribution. A QMED value of 153 m^3/s at Parkhill, derived from observed AMAX data, was applied.

Historical context was provided by considering the largest event on record (January 2016, ~576 m^3/s). The SS analysis was found to be more consistent with historical data, leading to its adoption. Both GL and GEV distributions were applicable, but the GL distribution was chosen for consistency with the upper Don modelling. A 24% climate change allowance was applied to the 0.5% AEP event, per SEPA guidance.

The observed data was used to quantify the 95% confidence limits applicable to the SS curves (a process known as bootstrapping) in WINFAP. The GL distribution showed a narrower confidence band for most annual probability events, supporting its adoption for the Parkhill gauge data.

The River Don at Parkhill gauge is situated approximately 15km downstream of Kintore and will have recorded additional data since its use in the Inverurie and Port Elphinstone Flood Studies. Therefore, a similar approach to that adopted in these studies (which has already been agreed by SEPA) should be taken but the peak flow and hydrograph shape re-assessed to take account of the data available from more recent flood events.

2.6 Critical Storm Duration

In the Inverurie and Port Elphinstone FPS, flood risk was considered from both the Rivers Urie and Don, typically due to the same catchment-wide storm events. JBA's analysis for the Inverurie and Port Elphinstone FPS showed that peak flow timings for three AMAX events were similar for both rivers. Therefore, a single, consistent storm duration of 39 hours was considered sufficient for estimating flood risk, eliminating the need for separate runs for the Urie and Don. This finding should be reviewed and re-confirmed with SEPA for the Kintore FPS as it is likely to remain applicable here due to the close relative proximity of Kintore and Inverurie/Port Elphinstone within the River Don hydrological catchment.

2.7 Lateral Inflows / Minor Watercourses

Peak flow estimates and hydrographs for the River Don and River Urie tributaries were required for the hydraulic model in this study. Major lateral inflows were represented using ReFH units in Flood Modeller Pro (FMP), with the catchment areas adjusted for additional inflows required to be captured. Calibration runs used data from rain gauges at Milton of Noth, Rhynie, Rothienorman, and Westhill.

For the annual probability events a 39-hour storm duration was applied to the ReFH2 estimation to match the peak flow values on the Rivers Don and Urie. This is not necessarily the peak storm duration that would cause flooding from these tributaries, and as the focus of the Kintore FPS includes specific assessment on the Tauch Burn (alongside the Loch Burn and Torry Burn) an assessment of the critical duration for flood risk from these minor watercourses will be required.

2.8 Climate Change Allowances

Climate change allowances were incorporated into the peak flow estimates to account for future changes in rainfall and flood risk. A 24% climate change allowance was applied to the 0.5% annual exceedance probability (AEP) (1 in 200-year) flood event, following SEPA guidance for Local Authority studies in North East Scotland region. This adjustment was consistently applied across different methods and locations, including the River Don at Haughton and Parkhill, and the River Urie at Pitcaple. This figure should be reviewed for its current applicability using SEPA's most recent *Climate Change Allowances for Flood Risk Assessment* document.

3. Existing Scottish Water Model Hydrology

Scottish Water provided their sewer network model covering Kintore in Infoworks ICM v.2025 format. This existing model contained both the winter and summer FEH13 storm events for a range of durations between 30 minutes and 1 day. The 1 in 1, 2, 5, 10, 20, 30 and 50-year return period events for this range of storm durations were provided with the model. The 1 in 100, 200 and 1000-year events were not included in the model, but will be required as part of the Kintore Flood Study.

3.1 Hydrology Schematisation

Hydrological (rainfall) inputs have been applied entirely to defined subcatchments. No direct rainfall exists in the model (either entirely, or outside subcatchments) and therefore overland flow is only generated at arbitrarily selected manhole locations which is not the optimum representation when looking at overland flows. Furthermore, larger subcatchment sizes may produce inaccurate results as this approach does not account for key overland flow routes, such as roads. Thus, an improved method for accounting for surface water flow that either enters the network or flows overland through direct rainfall should be considered.

Ground infiltration model is included in the model, the two subcatchments representing this parameter are located at Inverurie, and therefore, do not impact model results for overland flow in Kintore. Ground infiltration represents the process by which water from the surface seeps into the ground and eventually enters drainage systems through cracks and other openings. This type of infiltration is distinct from stormwater runoff, which quickly responds to rainfall events. Instead, ground infiltration occurs more gradually, as water slowly permeates the soil and underlying materials before making its way into the drainage infrastructure. This residual flow can significantly

contribute to the overall volume of water in drainage systems, often exceeding the combined inflows from stormwater runoff and domestic or trade sources. Inclusion of this at Kintore should be considered, although this is unlikely to be critical for the quantification of overland flow from heavy rainfall events and due to out-of-bank flow from minor watercourses.

No hydrological inputs to fluvial watercourses were supplied with the model.

3.2 Data Provenance

Rainfall generation was based on FEH13 catchment data, which captures the hydrological characteristics of the area. Design rainfall profiles based on the FEH13 dataset were generated in ICM, utilising ReFH2 software. An antecedent depth of 10mm was applied uniformly to all events to account for pre-existing ground wetness. To reflect seasonal variations, summer events included an evaporation rate of 3mm/day and an antecedent precipitation index (API) of 0.17mm, while winter events used a reduced evaporation rate of 1mm/day and a higher API of 0.87mm.

3.3 Climate Change Allowances

Kintore falls within SEPA's North-East Scotland river basin region, and the uplift on peak rainfall intensity to the year 2080 is +37% as advised by the most recent climate change allowances. The uplift on peak river flows to the year 2100 is +34%. Note that uplifts for watercourses with catchment areas smaller than 30km^2 utilise the +37% uplift figure on peak rainfall intensity.

No climate change allowances are included within the provided model and these should, therefore, be added.

4. Summary of Outcomes

The following are required updates to enable the hydrology to be updated such that it is suitable for use in the Kintore Flood Study:

- Catchment descriptors used should be reviewed using the FEH Web Service data.
- Hydrological estimation to be completed for the Torry Burn and Loch Burn.
- Hydrological estimation to be updated for the Tauch Burn, using the Inverurie & Port Elphinstone approach (already agreed with SEPA) as a starting point.
- Re-assess peak flow and hydrograph shape data at the River Don (Parkhill), River Don (Haughton) and River Urie (Pitcaple) gauges.
- Most recent climate change allowances will be applied to the fluvial peak inflows generated.
- The storm duration value of 39 hours should be reviewed and re-confirmed with SEPA as being applicable to Kintore.
- Estimation of the critical duration for flood risk from the Tauch Burn, Torry Burn and Loch Burn will be required.
- The 1 in 100, 200 and 1000-year return period events will be added to the model.
- FEH22 rainfall will be estimated for all return period events.
- Most recent climate change allowances will be applied to the FEH22 rainfall generated.
- The critical storm duration needs to be defined for heavy rainfall events over the urban area.

The following are suggested updates which may enhance the model outputs in the Kintore Flood Study:

- Removal of storm subcatchments and application of direct rainfall onto the model mesh.
- Consider the inclusion of ground infiltration in the ICM model.