Drainage and Wastewater Management Plans (DWMPs)

Summary of the methodology for the Baseline Risk and Vulnerability Assessment (BRAVA) on:

Risk of Sewer Flooding due to Hydraulic Overload (Annualised Flood Risk)

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1. Introduction

1.1 Purpose

The purpose of this document is to provide a summary of the method for undertaking the Baseline Risk and Vulnerability Assessment (BRAVA) for the planning objective on the **risk of sewer flooding due to hydraulic overload (annualised flood risk)**.

The Baseline Risk and Vulnerability Assessment (BRAVA) is an important step in the development of Drainage and Wastewater Management Plans (DWMPs). It is an assessment of current and future risks for each of the planning objectives, and is undertaken for the sewer catchments that were flagged during the Risk Based Catchment Screening (RBCS).

All Water and Sewerage Companies (WaSCs) are required to complete a BRAVA and report to Water UK on the following six common planning objectives:

1. Risk of sewer flooding in a 1 in 50 year storm
2. Storm overflow performance
3. Risk of WTW compliance failure
4. Internal sewer flooding risk
5. Pollution risk
6. Sewer collapse risk

We identified two additional planning objectives that will help us identify current and future risks and have included these as 'bespoke' planning objectives for the DWMP:

7. Risk of Sewer Flooding due to Hydraulic Overload (Annualised Flood Risk) - which is the flood risk arising from different severities of rainfall
8. Wastewater Treatment Works (WTW) Dry Weather Flow (DWF) Compliance – to assess our compliance with the Environment Agency (EA) permit relating to the DWF arriving at a wastewater treatment works.

The purpose of this bespoke planning objective on the risk of sewer flooding due to hydraulic overload is to assess and understand the likelihood of flooding from sewers during different rainfall events (storms), and the resulting impact on homes and businesses. This objective is to identify where flooding from sewers could occur and the area of the flooding. We can then count the number of properties that are located within the predicted flooded area to provide a measure of the potential consequences arising from the flooding.

This risk assessment is used within the DWMP, alongside the risk assessment from the other planning objectives, to inform our decisions on future investment in the drainage and wastewater systems.

One of the benefits of this planning objective is to identify opportunities to work with other flood risk management authorities, for example, the Environment Agency and Lead Local Flood Authorities, to collaborate on resolving flooding issues together.

1.2 Definitions

The risk of sewer flooding due to hydraulic overload is defined as the likelihood in any given year that flooding, induced by a rainfall event, will occur from our drainage and wastewater networks and cause flooding. It is a metric that is used to measure the capability of our drainage systems to cope with peak flows induced by rainfall events. This means it considers multiple rainfall events (the hazard) and the number of properties that could be flooded (the consequence).

Where we have hydraulic models of a sewer catchment we will assess the likelihood and extent of flooding for storms with different severities (for example, 1, 2, 5, 10, 20 and 30 year rainfall return periods). Where models are not currently available, the risk assessment for the sewer catchments compares peak flows, based on the population size and surface runoff contribution, from the catchment to the hydraulic capacity of our sewers.

The 1 in 50 year rainfall event is excluded from this assessment as it is addressed by the national planning objective on the “risk of sewer flooding in a 1 in 50 year storm”.

1.3 Reporting Requirements

We are not required to report the BRAVA outcomes for our bespoke and additional planning objectives to Water UK. However, we will publish the results on our website for consideration by our customers and partner organisations.

2 Data Sources

The following is a short description of the source of the data that has been used to assess the risk of flooding due to hydraulic overload and where it has been obtained from.

2.1 Population growth and planned development

Population data for each of the sewer catchments is obtained from the Experian 7.1 database which provides current and projected (future) population levels across our operating region. This population data is collated for each sewer catchment for the 2020 baseline and 2025, 2030, 2035 and 2050 future planning horizons.

Data and information on future development has been collated from our Growth Planning Team which liaises with planning authorities on future developments. Planned or forecasted development sites proposed in Local Plans have been taken into account in the risk assessments for each future planning horizon.

Any differences identified between the Experian 7.1 population forecast and the model horizon has been resolved as a pro-rata adjustment to the remaining catchment population values.

2.2 Climate Change

For sewer catchments where we have a hydraulic model of the system, we have applied an uplift of 20% to design storms that account for the impact of climate change when assessing the long term (2050) planning horizon. There will be no distinction between summer and winter storms in the application of the climate change uplift.

This approach is based on the Capacity Assessment Framework (CAF) Guidance Document published by Water UK.

2.3 Hydraulic Models

We have a number of computer based hydraulic models of our sewer networks to support the management, maintenance and investment in these systems. We use a software platform called Infoworks ICM (Integrated Catchment Modelling) to model surface water and wastewater flows through our sewer networks.

141 of our 381 sewer catchments have hydraulic models. Generally the models are available for our largest and most complex sewer catchments and, collectively, our models cover the sewers serving over 90% of all our customers. Of these models, approximately 103 will be used for the first round of the DWMPs. The remaining 38 of the hydraulic models are being reviewed for suitability with the intention to use them in the future iterations of the DWMPs.

2.4 Urban Creep

Urban creep is the increase in impervious surface within an urban area due to extensions of properties or the addition of new paved areas which leads into increase in surface water runoff. The United Kingdom Water Industry Research (UKWIR) published a study on the “Impact of Urban Creep on Sewerage Systems” in 2010. The study sets out methods of estimating urban creep. We adopted a simplified version of Method 3 of the UKWIR study to estimate urban creep within our sewerage systems and used it as an input to network modelling to assess network capacity and risk of flooding.

The overall urban creep rate (m^2/annum) for a network model is calculated based on residential property types - Detached, Semi-Detached, Terraced, and Flats in accordance with UKWIR Method 3 (see Table 1 below). An urban creep uplift is calculated as a percentage of the mapped residential roof area based on the Ordnance Survey (OS) Master Map and OS Address Base Premium. Urban creep for a modelled sub-catchment is calculated by multiplying the modelled residential roof area by the urban creep uplift. Urban creep is then applied as paved area.

The verification date of our latest hydraulic model is used as the base year for creep calculations. The creep calculations assume a rate at which permeable areas change to impermeable areas through extensions to homes, or paving over front gardens to create car parking.

Table 1: Urban Creep rate for residential properties

Property Type	Urban creep Rate (m^2/property/year)	Data Source
Detached	0.795	UKWIR
Semi-Detached	0.366	UKWIR
Terraced	0.196	UKWIR
Flats	0	UKWIR
Residential - Default	0.738	UKWIR
Non Residential	0	UKWIR

For models where the residential and non-residential areas are not defined separately by land use, a model sub-catchment property count is required. In this case the creep area is calculated from the roof area and the urban creep uplift. A further modification is carried out based on the residential/non-residential roof area split to correct the urban creep calculation in mixed land use sub-catchments. This factor is not applied if it is not possible to carry out a reliable property count.

No urban creep is applied to non-residential properties or modelled sub-catchments with impermeable area <5% of the contributing area.

For non-modelled catchments, an urban creep of $4m^2$ per residential property from new developments was assigned based on our Developer Enquiries Modelling Procedure.

2.5 Historical Flooding – Current DG5 Properties

We maintain a database of properties where there has been a verified record of flooding from the sewer network. This is known as the DG5 register. The risk of internal or external flooding to properties on the DG5 “At Risk” Register is recorded in terms of three categories based on a 2 in 10 year, 1 in 10 year and 1 in 20 year frequency of flooding.

We extracted data on at risk properties in the DG5 register to determine the number of properties at risk in each wastewater catchment.

3 Method of Assessment

The following methodology has been developed for this risk assessment.

3.1. Process for Modelled Catchments

The risk of flooding is determined by using our hydraulic models to identify manholes where water could escape and cause flooding in 1 in 1, 2, 5, 10, 20 and 30 year rainfall events. The predicted volume of water escaping during each storm is calculated at each manhole. A zone (or area) around the manhole is then defined to show the potential extent of flooding by digitally mapping a circle from the centre of each affected manhole. The size of the circle (or buffer) is dependent on the volume of predicted flooding as follows:

- 15m radius for flood volumes below $25m^3$
- 30m radius for flood volumes up to $100m^3$
- 50m radius for flood volumes over $100m^3$

Within the modelling software, a Feature Manipulation Engine (FME) collates the results of the modelling and determines the flood buffer radius for each affected manhole. We then count the number of properties (with postal addresses) within the flood buffer zone and determine the total number of properties potentially at risk from flooding within that catchment. The approach counts multiple properties at a single address (for example, blocks of flats) in line with industry practice, although physical flood damage may be limited to the ground floor and basement addresses.

The modelling assessment for future planning horizons (2025, 2030 and 2035) includes growth and urban creep allowances, and climate change uplifts on rainfall intensities for the surface runoff contribution.

The results are the number of properties at risk within each modelled sewer catchment for the 1 in 1, 2, 5, 10, 20 and 30 year rainfall return periods for each planning horizon (2020, 2025, 2030 and 2035). The expected number of properties at risk for each planning horizon within the catchment are then annualised and presented as number of properties at risk per annum as follows:

- Probability “P” of exceeding a rainfall event of specific return period “RP” is calculated using the equation (below):

  $$\text{Probability of rainfall event, } P = 1 - e^{(-1/RP)}$$

  This method is derived from Innovyze’s guidance “InfoWorks ICM RiskMaster: Calculation of Event Probability and Annual Damage” for calculating the probability of non-exceedance for a rainfall event and modified by us to estimate the likelihood of occurrence of an event of specific return period. Innovyze is an industry-leading developer of hydraulic modelling software.

- Annualised (per annum) number of properties at risk for specific rainfall return period = number of properties at risk from modelling x probability of rainfall event

- Annualised number of properties at risk per planning horizon for each modelled catchment = the aggregate of the annualised properties at risk for the 1 in 1, 2, 5, 10, 20 and 30 year rainfall return periods in the specific planning horizon.

The annualised number of properties at risk per planning horizon are tabulated per catchment and represented as a percentage of the total number of properties per catchment as reported by the hydraulic model. The percentages of properties at risk for the planning horizons across the modelled catchments are used to determine the assessment thresholds for the risk banding based on calculated quartiles, for example, 25th and 75th percentiles.

An example of the outputs from the calculation of annualised number of properties at risk of flooding is shown in the table below.

Rainfall Return Period	1 in 1 year	1 in 2 year	1 in 5 year	1 in 10 year	1 in 20 year	1 in 30 year	Total Annualised No. of properties at risk of flooding
No. of properties at risk	22	27	72	92	125	138	N/A
Annualised number of properties at risk of flooding	14	11	13	9	6	5	57

The results are presented based on the percentile thresholds and banding criteria (0, 1 or 2) as detailed in section 3.3 and 3.4.

In this methodology we have applied population increase, urban creep and climate change to assess the future flood risks. These three components will be investigated during the problem characterisation stage of the DWMP to determine which of these is the greatest influence on change to the annualised flood risk in the wastewater catchment.

3.2. Process for Non-Modelled Catchments

For non-modelled catchments, the assessment of the risk of flooding due to hydraulic overload compares the flow directly discharged to wastewater treatments works (WTW) within each catchment to the capacity of the rising mains or gravity sewers connecting to the inlet of the WTW. This enables a high-level hydraulic capacity estimate to be undertaken on the utilisation of the rising main or gravity sewer discharging to the inlet of the works, expressed as a capacity ratio of the flow discharged to the WTW / discharge pipe capacity.

The capacity ratio is used as an indicator for the risk of sewer flooding due to hydraulic overload and is determined for the baseline (2020) and future (2050) planning horizons.

Assessment of the capacity of non-modelled catchments has been created following the steps and assumptions below:

1. Identify rising mains or gravity sewer directly discharging to a WTWs from our GIS (MapInfo) system
2. Determine the current and future population equivalent (PE) contributing flow to the catchment / sub-catchment from our Experian 7.1 database. The population equivalent

(PE) is a measure of the number of customers served by a wastewater treatment works taking into account the local population and a measurement of trade effluent (expressed as an equivalent number of people).

3. Calculate the peak flow from a foul only system as a function of PE and per capita consumption.
4. Identify if the catchment generates foul only or combined flows. The proportion of the combined system is a ratio of the length of combined sewers to the total length of sewers in the catchment.
5. If combined, make allowance for the contribution from runoff from hard surfaces as described below:
    - Use a typical plot size of $32m^2$ per property in our region to define the contribution of runoff from hard surfaces
    - Make an allowance for urban creep ($4m^2$ per property) based on the number of properties in the catchment in future planning horizons
    - Use a typical rainfall intensity to determine the contribution of surface runoff, allowing for a 20% climate change uplift on rainfall intensities for future (2050) planning horizon
    - Determine total flow by adding the contribution of foul and surface runoff flows.
6. Calculate the capacity of the existing rising main or sewer that discharges into the WTW inlet based on the minimum self-cleansing velocity of 0.75m/s.
7. For each non-modelled catchment, compare total flow to the WTW for the baseline and future planning horizons with the hydraulic capacity of the existing rising main or gravity sewer discharging to the WTW. This comparison is calculated as a capacity ratio of flow to WTW / hydraulic capacity of discharge pipe and is represented as a percentage.

The percentage capacity ratio for each non-modelled catchment is used to determine the assessment thresholds for the risk banding based on calculated quartiles (for example, 25th and 75th percentiles). The results are presented based on the percentile thresholds and banding criteria (0, 1 or 2) and moderated using historical flooding records as detailed in section 3.3 and 3.4. We will gain greater understanding in the next stages of the DWMPs whether these thresholds for risk bands are either overstating or understating the number of wastewater catchments at significant risk.

3.3. Process Charts – Modelled and Non-modelled Catchments

The processes for assessing modelled and non-modelled catchments for the baseline (2020) and future planning horizons are summarised in the charts shown in Figures 1 and 2 below.

Figure 1: Process flow chart for risk of sewer flooding (Modelled Catchments)

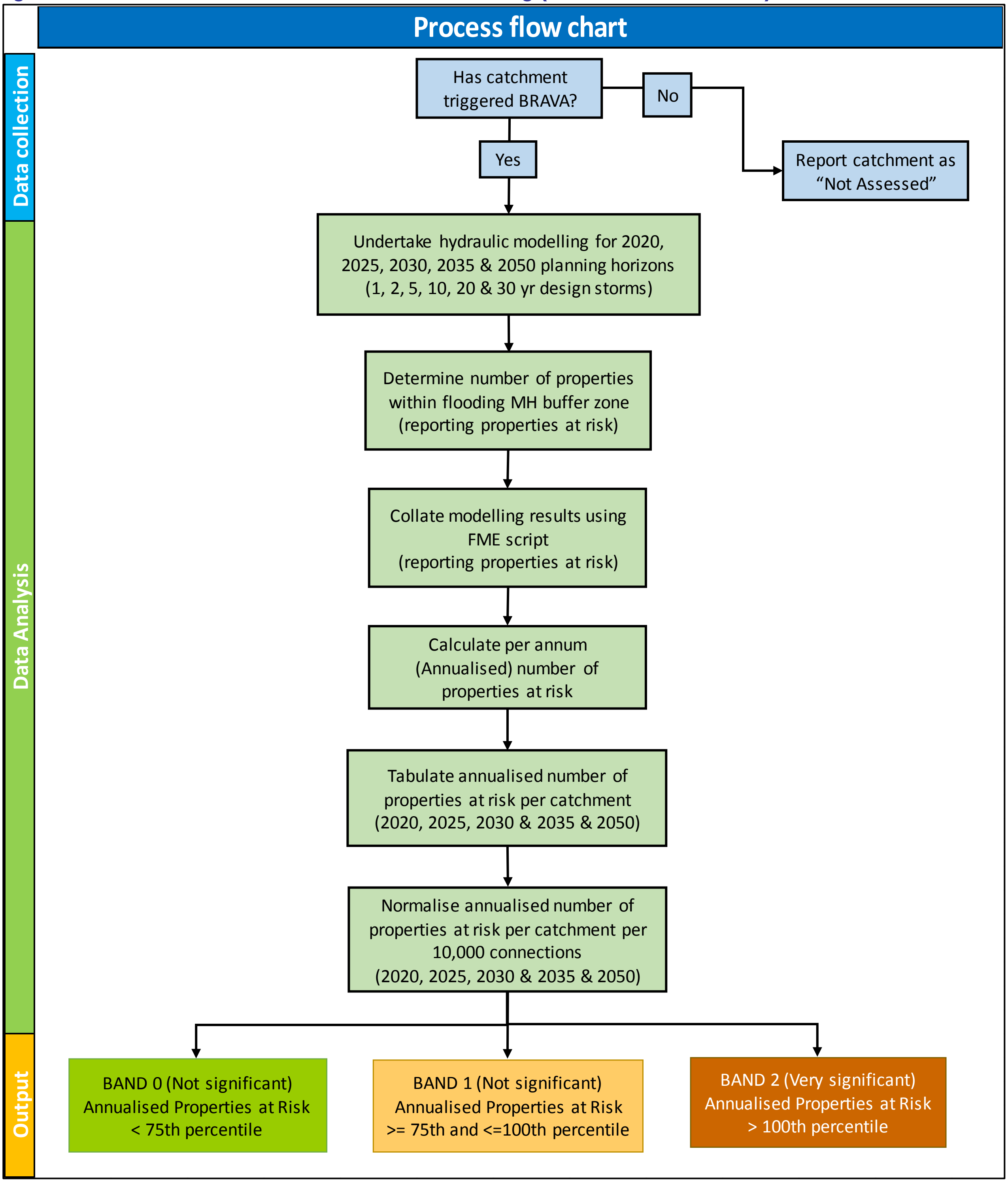
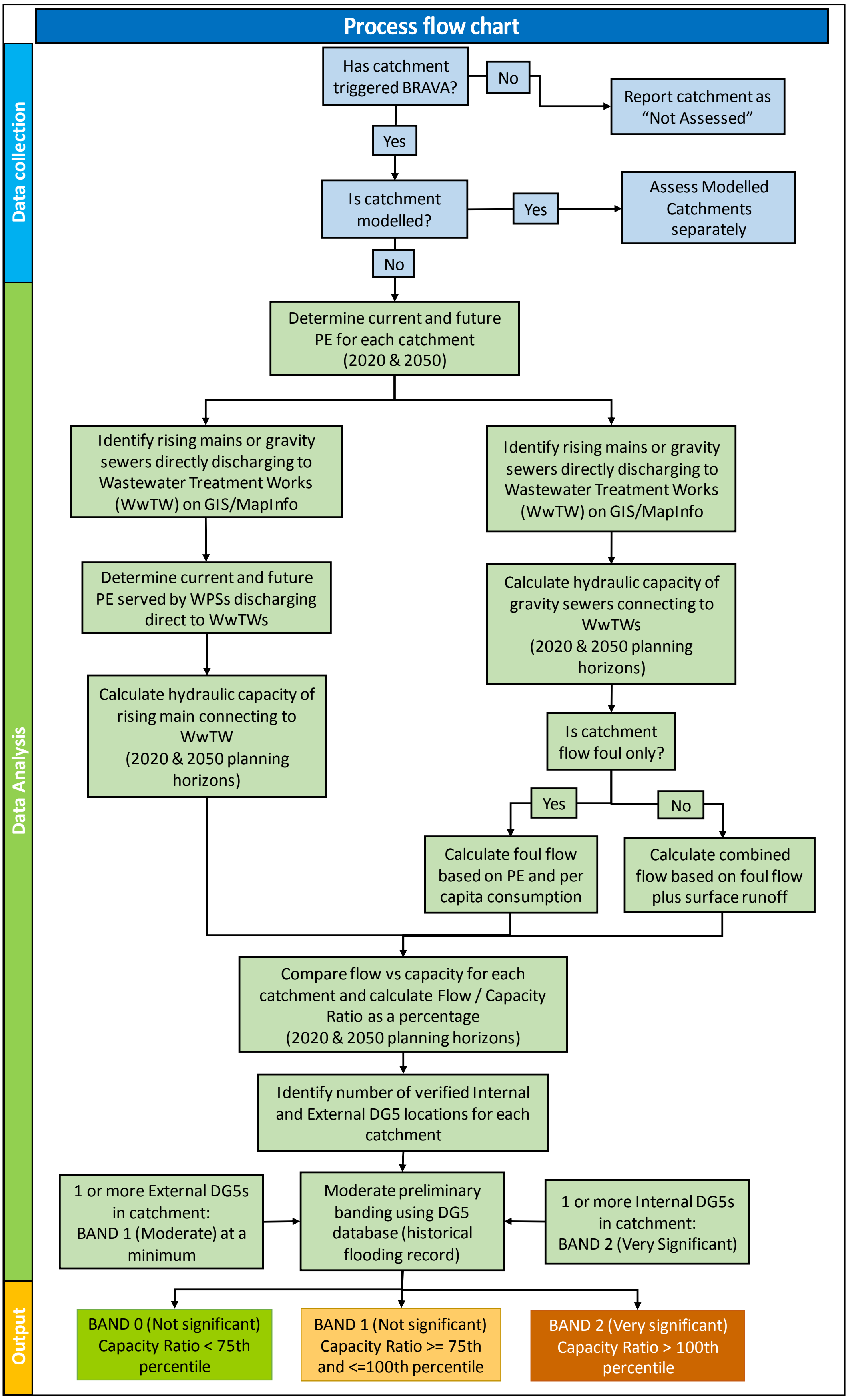


Figure 2: Process flow chart for assessing risk of flooding (Non-Modelled Catchments)



3.4. Outputs from the BRAVA

The BRAVA outputs are an estimate of the risk of flooding due to hydraulic overload for the baseline (2020) and future planning horizons in our sewer catchments based on the following metrics:

- Modelled Catchment – annualised number of properties at risk of flooding for the 2020, 2025, 2030, 2035 and 2050 planning horizons, presented as a percentage.

- Non-Modelled Catchment – the capacity ratio of flow from a catchment / hydraulic capacity of the sewer discharging to WTW for the 2020 and 2050 planning horizons, presented as a percentage.

3.4.1 Modelled Catchments

The assessment criteria for banding modelled catchments using the annualised number of properties at risk is shown in the table below:

Assessment Criteria / Thresholds	Band	
Equal to or less than 25th percentile of the percentage of annualised properties at risk: (<= 25th percentile)	0	*Not Significant*
Between 25th - 75th percentile of the percentage of annualised properties at risk: (> 25th percentile and < 75th percentile)	1	*Moderately Significant*
Equal to or greater than 75th percentile of the percentage of annualised properties at risk: (>= 75th percentile)	2	*Very Significant*

The outputs from this risk assessment were checked and validated with our records of properties on the DG5 register where an internal or external flood has been recorded. This was undertaken to ensure that risks identified in the past are adequately considered in this assessment and ensure that the assessment has not been skewed due through a model over-prediction.

Where a wastewater catchment was assessed to be in band 0 but had records of properties flooded, these catchments were moderated and moved to band 1. This applied to 5 catchments. The catchments in band 2 were checked for records of flooding. Four of the catchments have no records of historic flooding, and three only have one flood record. These will be considered further in the problem characterisation stage to determine the causes of these catchments being assessed as a very significant risk.

3.4.2 Non-Modelled Catchments

The assessment criteria for banding non-modelled catchments using the capacity ratio of flow is shown in the table below:

Assessment Criteria / Thresholds	Band	
Capacity Ratio less than 75% (Capacity Ratio < 75%)	0	*Not Significant*
Capacity Ratio between 75% and 100% (Capacity Ratio >=75% and <=100%)	1	*Moderately Significant*
Capacity Ratio greater than 100% (Capacity Ratio > 100%)	2	*Very Significant*

Where our high level capacity assessment indicates there is adequate capacity in the sewer network or moderate risk of flooding (Band 1), our risk assessment results are moderated to account for catchments that have properties currently at risk of sewer flooding on the DG5 register. The risk banding outputs are moderated such that:

- any non-modelled catchment in Band 0 (Not Significant) or Band 1 (Moderately Significant) but containing one or more verified Internal DG5 properties is moderated to Band 2 (Very Significant)
- any non-modelled catchment assessed to be in Band 0 (Not Significant) but containing one or more verified External DG5 properties is moderated to Band 1 (Moderately Significant)
- any non-modelled catchment with one or more verified External DG5 properties is considered a minimum of Band 1 (Moderately Significant).