BBLP & Herefordshire Council

ORLETON HYDRAULIC MODELLING TECHNICAL NOTE

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1 INTRODUCTION

WSP has been commissioned by Balfour Beatty Living Places and Herefordshire Council to produce a Technical Note to support the Hydraulic Modelling to reduce flooding of the B4361, Millbrook Way and subsequent properties within the village of Orleton.

This Technical Note report describes the methodology, assumptions made and highlights specific design considerations to enable Herefordshire Council and Orleton Parish Council to consider the next steps when tackling this flooding issue. WSP have utilised the Briefing Note produced by Orleton Parish Council, Appendix A, as the basis for the concept design as well as details regarding the existing drainage network and flow routes which have been crucial when building the model.

1.1 SCOPE OF WORK

Orleton Parish Council has developed a proposal to address part of the flooding issue in the village. The proposal provides spot levels, indicative catchment areas and the principals of the design however a more detailed hydraulic model is required to understand the water flow dynamics, design effective flood mitigation to reduce flooding along Millbrook Way whilst not increasing flooding where water is displaced to downstream.

WSP have been commissioned by Balfour Beatty Living Places working for Herefordshire Council to take this assessment which includes:

- Greenfield runoff calculations of both existing and proposed catchment areas based on available topographical information, indicative drainage network data and LIDAR,
- Build a hydraulic model based on the community proposal, existing network, rainfall data and hydraulically test system for a series of return periods.
- Review existing water collection and develop conceptual drainage collection design
- Undertake a desk-based analysis of proposal, reviewing the performance of the network and maximising water storage and limiting downstream flows

2 CONTEXT

The village of Orleton, located in North Herefordshire has faced significant challenges with surface water flooding for many years as highlighted with the Briefing Note, Appendix A.

Despite several schemes aimed at reducing flooding, the B4361, Maidenhead junction, Millbrook Way, residential and commercial properties still experience frequent flooding. The B4361 is a link road locally as well as being the designated diversion route for the A49 and Millbrook Way is the main entrance route into the village and therefore flooding of property / highway and road closures pose safety risks and significant disruption.

Currently all drainage and surface water from the B4361 at the Maidenhead junction flows east along Millbrook Way to the outfall into Brimfield Brook at Millbrook Way bridge. During periods of prolonged rainfall or intense storms, the river levels rise obstructing the outfall.

Orleton Parish Council has developed a proposal to address this issue, tackling the flooding, diverting flows away from this village and to discharge at a point where flows can outfall freely and without creating flooding to another location within the village.

2.1 PROPOSAL

The scheme proposed involves increasing the capacity of the highway drainage system, diverting water away from Millbrook Way by laying a carrier pipe system North-East along the B4361 and then East through the agricultural field before outfalling into the existing ditch to the north of the recreational ground.

Modifications to the existing carrier drain system as well as additional pipes and ditches will be required to convey the water. It has been acknowledged that significant volumes of water runoff the agricultural fields to the south west onto the B4361, therefore additional water collection is required to capture runoff and reduce overland flows following the natural exceedance route down Millbrook Way.

The conceptual hydraulic model aims to provide a viable solution to manage surface water and reduce future flooding, the model at this stage is not for construction as further surveys and iterations to the model and proposed design will be required.

2.2 FLOOD HISTORY

The Briefing Note provided by Orleton Parish Council (Appendix A) provides a detailed history of flooding in Orleton, focusing on the persistent and severe surface water flooding at the Maidenhead junction, the B4361 and Millbrook Way. In summary of this:

- **Pre-1960s**: The original ford at Millbrook Way allowed surface water runoff directly into the watercourse.
- **1960s**:
    - Construction of the Millbrook Way bridge elevated ground levels, creating drainage issues.
    - Introduction of mains water and sewerage led to village development, increasing impermeable surfaces without corresponding drainage capacity.
- **2021 and 2022**:
    - Following a S.56 notice served on Herefordshire Council, remedial measures were implemented in a two-stage approach.
    - Works included additional gullies, root cutting, upgrading of existing network on Millbrook Way.
- **Winter of 2023-2024:**
    - Significant flooding events occurred on several dates over the winter period, the dates of these events and the corresponding rainfall during the 24hour period are including illustrated in Table 2-1.

Table 2-1: 24hour rainfall totals corresponding with flood events experienced in Orleton. ***(Brief Note Courtesy of Orleton Parish Council, August 2024)***

Experience Flood Event	24hour Rainfall (Data from EA Brimfield Rain Gauge / Station ID443286)
12.10.2023	22mm
19.10.2023	30.2mm
03.12.2023	22.4mm
02.01.2024	21.2mm
08.02.2024	21.8mm

3 METHODOLOGY

The hydraulic model process involves several key steps.

3.1 DATA COLLECTION

3.1.1 CATCHMENT AREA OVERVIEW

The initial step is to identify the catchment area. LIDAR (Light Detection and Ranging) data has been used to determine the topography. The catchment high / low points have been identified and catchment areas mapped, see Appendix B: Catchment Plan.

A secondary review process have been used to sense-check the catchments, Civils 3D Flow Pathway Analysis and Google Earth have been used for this, Figure 3-1.

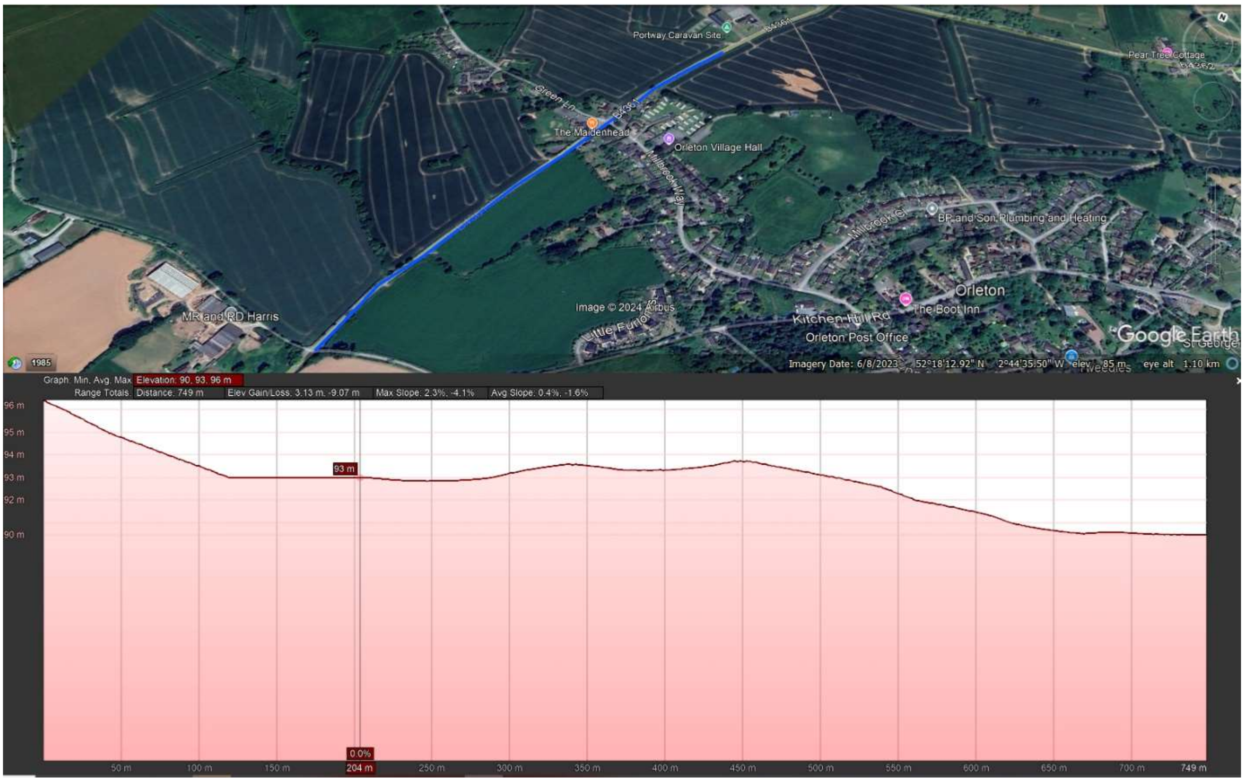


Figure 3-1: Flow pathway analysis *(Google Earth Pro, August 2024)*

Approximately 57 hectares discharge via the ditch in the existing scenario and an additional 6.5ha is proposed to be incorporated. These areas have been split into two categorises at this stage of the design process; Rural and Urban, see Table 3-1.

- Rural – To simplify the modelling process at this stage, this category includes agricultural land, residential development and roadside verge. A Percentage Impervious Area (PIMP) value of 30% has been applied.
- Urban – this consists of the carriageway and a 100% PIMP value has been applied.

Table 3-1: Catchment Areas and Percentage Impervious Area (PIMP)

Description	Area (ha)	PIMP
Existing Rural Catchment	55.9	30%
Existing Urban Catchment	0.9	100%
Proposed Rural Catchment	6.2	30%
Proposed Urban Catchment	0.3	100%

The proposal is to redirect flows away from Millbrook Way and towards the existing ditch located to the north of the playing field, therefore the adjacent areas draining towards the ditch have been considered while modelling.

In the later stages of the design process, the existing flows generated from this catchment will be used to limit flows generated as a result of the proposals.

3.1.2 DRAINAGE NETWORK REVIEW

The Briefing Note along with desk-based analysis has been used to identify the existing drainage network. The Briefing Note details overland flow routes and network connectivity at both Maidenhead Junction and Portway Junction which have been used in the modelling and shown in Appendix C: Existing Drainage Layout.

There are two existing carrier drains from the B4361 across the field into the brook, these are believed to be 300mm diameter. However, within the model these have been deliberately sized as 600mm diameter, see Section 3.2.1 for modelling details.

The existing ditch has a culverted 300mm outlet discharging into Brimfield Brook, this limits flows into the brook and has been incorporated into the design. The ditch is approximately 2.00m wide by 2.00m deep, these dimensions have been incorporated into the model.

At this conceptual stage, it was not deemed suitable to undertake extensive site surveys to check this information due to time constraints and cost.

Should the initial modelling provide the scheme is viable a comprehensive survey of the existing drainage infrastructure, topography, and hydrology will be conducted. This includes mapping current drainage routes, asset connectivity and condition surveys, ground penetrating radar surveys and assessments of soil permeability.

3.1.3 RAINFALL DATA

In hydraulic models, rainfall data plays a crucial role in simulating and predicting water flow and behaviour in various systems. The FEH22 rainfall depth-duration-frequency model is the UK Centre for Ecology and Hydrology's latest tool for estimating flood frequency in the United Kingdom. This model provides estimates of the intensity, duration, and frequency of rainfall events at any location in the UK.

FEH22 data is preferred over its predecessor FEH and FSR because it includes a larger calibration dataset, covers more recent years to capture extreme weather events, and has improved spatial density with more gauging stations, making it a more reliable choice for rainfall and flood estimation.

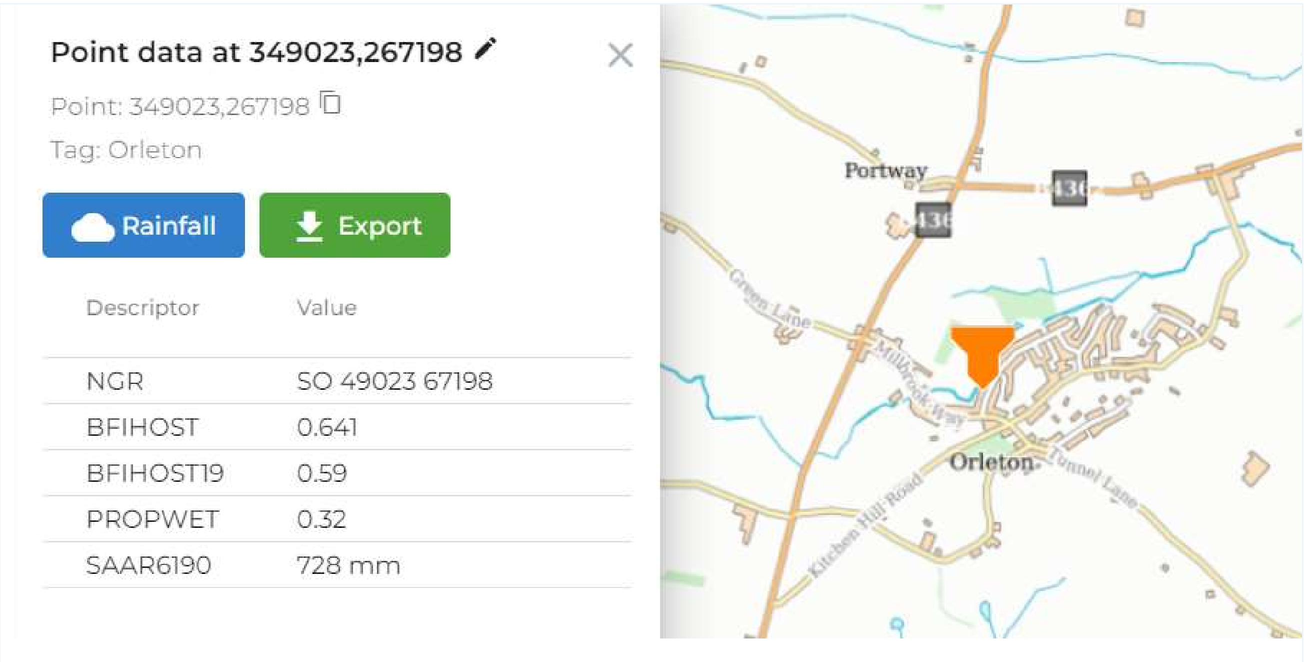


Figure 3-2: FEH22 Rainfall Data *(UK Centre for Ecology and Hydrology, August 2024)*

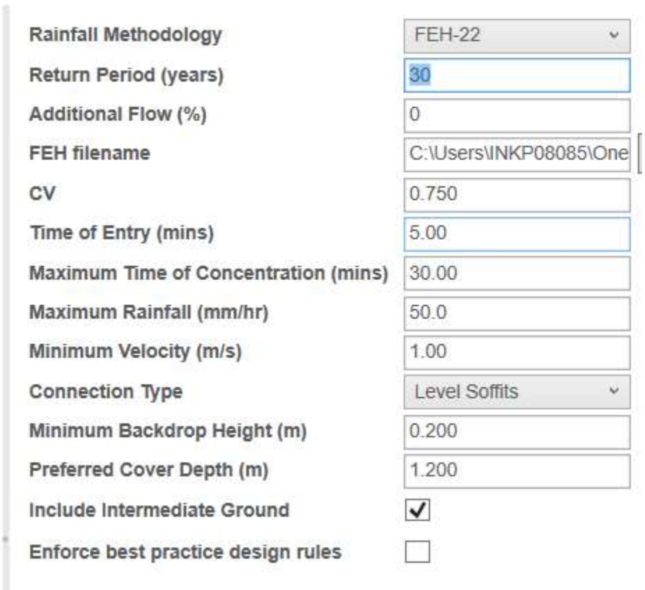
3.2 HYDRAULIC MODELLING

WSP have opted to use the modelling software, Causeway Flow. This is a sophisticated software tool employed to simulate surface water flows and evaluate the performance of the existing drainage system. This step was crucial for identifying bottlenecks, areas prone to flooding, and potential points of failure within the system.

Causeway Flow is WSP's preferred hydraulic modelling software and was chosen for this project. Causeway Flow complies with UK Policy, the licencing allows for the most accurate FEH22 rainfall data to be incorporated, and advanced design capabilities.

3.2.1 DESIGN STANDARDS AND ASSUMPTIONS

A detailed design for the existing and proposed drainage network have been developed, incorporating pipes, ditches, swales, culverts, and other necessary infrastructure. The network is designed for a 30-year return period, ensuring the system was capable of handling peak flow rates, reducing flood risk, and ensuring efficient water conveyance. Design Settings are displayed in Figure 3-3.



Rainfall Methodology	FEH-22
Return Period (years)	30
Additional Flow (%)	0
FEH filename	C:\Users\INKP08085\One
CV	0.750
Time of Entry (mins)	5.00
Maximum Time of Concentration (mins)	30.00
Maximum Rainfall (mm/hr)	50.0
Minimum Velocity (m/s)	1.00
Connection Type	Level Soffits
Minimum Backdrop Height (m)	0.200
Preferred Cover Depth (m)	1.200
Include Intermediate Ground	✓
Enforce best practice design rules	☐

Figure 3-3: Design Settings *(Causeway Flow, September 2024)*

The Design Manual for Roads and Bridges (DMRB) is a comprehensive set of standards and guidelines used in the UK for the design, assessment, and operation of roads. The DMRB guidelines for drainage asset design has been incorporated into the model;

- 1200mm diameter chambers are assumed and proposed.
- Minimum pipe cover depth of 0.9m has been considered
- Pipes to be a minimum of 600mm, due to significant flows rather than DMRB
- Cover levels of chambers have been generated using the LIDAR data

As mentioned in 3.1.2, there are two existing 300mm diameter pipes around the field discharging into the brook. Within the existing model scenario and simulations, these 300mm diameter pipes have been mimicked. However, within the proposed model the system has been deliberately upsized to 600mm diameter pipes, this is to ensure the proposed model captures the maximum volume of existing runoff, in the simulations with 300mm diameter pipes the existing system was flooding and not able to capture the water as overland flow.

3.2.2 FLOW CALCULATIONS

The design model includes both ditches and carrier pipes, to calculate flow rate for these different equations / calculation methods have been used. The Colebrook-White and Manning equations are both used in fluid mechanics to calculate flow characteristics, but they serve different purposes and are applied in different contexts:

1. Colebrook-White Equation: Used to determine the Darcy-Weisbach friction factor for turbulent flow in pipes, it uses both the roughness of the pipe and the Reynolds number of the flow. The equation is implicit, meaning it requires iterative methods or approximations to solve. Commonly used for full-flowing pipes or ducts where the flow is turbulent.

2. Manning Equation: Used primarily for open channel flow, such as rivers, streams, and partially full pipes. It is simpler to use and provides an empirical relationship between the flow rate, channel slope, and roughness. The equation is explicit, making it easier to solve directly without iteration. Widely used for designing open drainage systems and natural waterways.

Due to this, Colebrook-White equation have been used for the piped system and Manning equation for the swales and ditches.

3.2.3 CLIMATE CHANGE ALLOWANCES

Climate change allowances are predictions of anticipated changes in environmental factors; wind, rain, wave height etc., these allowances are used to help increase resilience to flooding and coastal change by incorporating future climate scenarios into planning and development processes.

In the UK, the Environment Agency provides guidance on how to use these allowances in flood risk assessments and strategic flood risk assessments. At a local level, Herefordshire Council has produced the SUDS Handbook and Highways Development Design Guide. There are no specific Climate Change allowances in either of these Herefordshire documents and therefore defer to the “Wye MC Management Catchment peak rainfall allowances” (Figure 3-4), for the 30-year return period, the Central allowance the Climate Change allowance is 25% which will be used within the model and scenario tests.

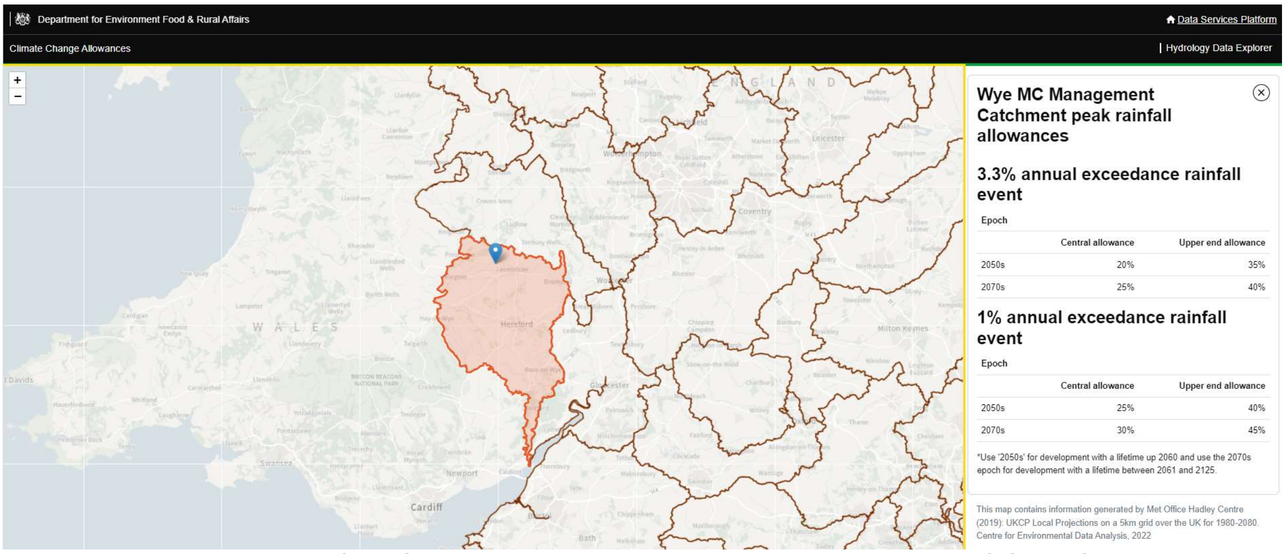


Figure 3-4: Climate Change Allowances ***(Hydrology Data Explorer; August 2024)***

3.3 PROPOSED NETWORK

3.3.1 WATER CAPTURE AND COLLECTION SYSTEMS

Gullies are typically designed to capture and channel surface water away from roads and areas prone to flooding. In the UK, gullies are typically designed for a return period of 1 in 5 years. This means they are engineered to handle rainfall events that have a 20% chance of occurring in any given year. This design standard ensures that the drainage system can effectively manage frequent rainstorms, reducing the risk of surface water flooding on roads and pavements. Given that flooding is experienced more frequently than this in this project, the collection system is crucial and additional capture and conveyance is proposed.

Existing gullies are connected to a carrier drain which flows down Millbrook Way and outfalls into Brimfield Brook. As mentioned previously, this exacerbated the flooding in this area. Additional gullies and channel drains are proposed as additional the collection feature along the B4361 with an alternative outfall as described in Section 3.3.2.

From site observations and a desk-based study there doesn't appear to be any water collection system on Green Lane, a steep narrow lane with a substantial impermeable area (700m2) flowing towards Maidenhead Junction. To address this, gullies with high-capacity gratings (trio / super gullies) are proposed for both sides of the lane. Further details of the positioning of these gullies will be required during the detail design as there are a number of buried services within this vicinity which will limit the locations feasible, as mentioned in Section 4.3.

The flooding of Orleton is in part the result of rural runoff, therefore swales are proposed along field boundaries to capture water before it flows into the highway, where the potential risk to the public is significantly increased. These swales will be connected to the downstream network via formalised headwalls and pipes.

3.3.2 WATER CONVEYANCE

Surface water carrier pipes are commonly used to convey water through a site underground to an outfall into a watercourse or brook. The sizing of surface drainage carrier pipes involves several key factors to ensure efficient water management and prevent flooding. The main considerations which have been incorporated into the model are:

- Flow Rate: The expected volume of water that needs to be transported, this is influenced by the catchment area and rainfall intensity.
- Pipe Material: Different materials have varying roughness coefficients, which affect the flow rate.
- Slope: The gradient of the pipe affects the velocity of water flow.
- Regulatory Requirements: Compliance with Design Manual for Roads and Bridges (DMRB).
- Future Capacity: Considering potential increases in water flow due to climate change.

4 RESULTS AND OPTIONS

4.1 RESULTS

Extensive scenario testing under various rainfall conditions was conducted for the existing network and proposed network, this was done to compare flows and review how the model responded to additional flows. The existing peak flows with 0% CC are shown in Table 4-1.

Table 4-1: Existing Critical Storm Flow Rates

	RETURN PERIOD (year)	CRITICAL STORM (mins)	PEAK FLOW (l/s)	FLOOD VOLUME (m3)
EXISTING SCENARIO	2	180 min summer	474	135
	5	120 min winter	584	325
	30	180 min summer	890	938
	100	180 min summer	937	1683

The simulations for the proposed model included future climate change projections, ensuring the design is robust against a range of potential scenarios. The model has been simulation tested for Summer and Winter storms, four return periods, as well as many storm durations, see Figure 4-1.

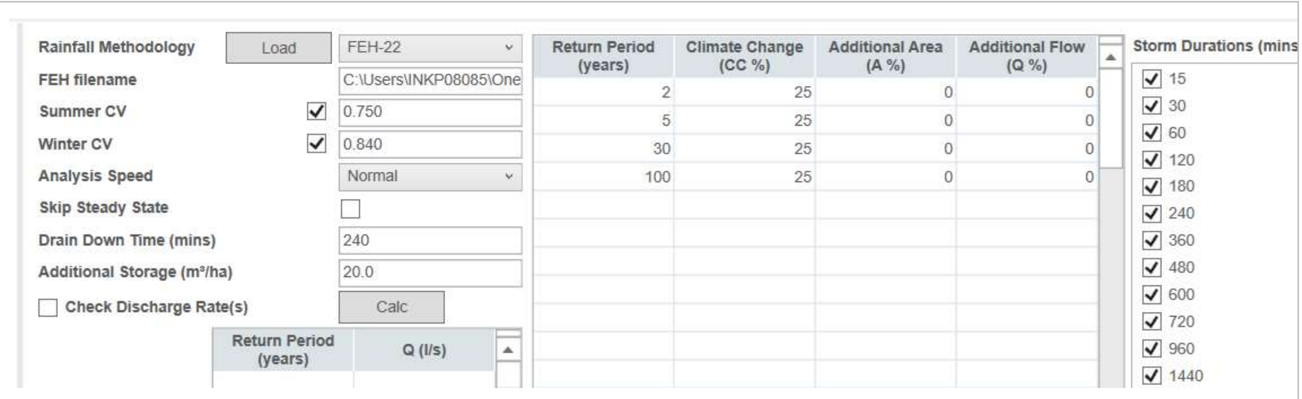


Figure 4-1: Simulation Settings

When designing a drainage system, it is essential to consider the impact on downstream communities. Therefore, flow control mechanisms within the existing ditch before the outfall into Brimfield Brook has been incorporated. Complex flow control structures consisting of a weir and orifice have been included within the existing ditch, these are located at intervals within the ditch to cascade water, allowing additional storage, details of which can be found in Table 4-2. This approach utilises the existing ditch as a storage area to manage and attenuate flow, ensuring that downstream areas are protected from potential flooding and excessive runoff.

Table 4-2: Proposed Flow Control Details

Node	Online control type	CL	IL	Dia/ width	Remarks
37	Orifice	84.6	82.47	450mm	Weir 600mm above IL
	Weir		83.07	1000mm	
40	Orifice	83.1	81.1	450mm	Weir 600mm above IL
	Weir		81.7	1000mm	

4.2 OPTIONS

Much of the proposed network is the same for the two options being considered. The water collection proposal and conveyance along the B4361 is consistent while the conveyance across the field from MH 10 / Point D of the Parish Briefing Note differs, see Appendix D for further detail.

Option 1: Open Ditch

Connecting the highway drainage system from the B4361 to the existing manhole behind the sport pavilion with an open ditch. This option requires regular though easy-to-access maintenance, provides biodiversity benefits and has a larger capacity compared the piped network.

The network has no flooding in in the 30-year + 25%CC option however some flooding is experienced in the 100-year +25%CC event. Flood volume of 277m3 is predicted in one of the existing ditch sections and 20m3 in proposed pipe system along the B4361.

Option 2: Piped system

Connecting the highway drainage system from the B4361 to the existing manhole behind the sport pavilion with an 600mm pipe. This option although harder to maintain typically requires less seasonal maintenance as there is no vegetation, it requires less land-take however does create additional flooding within the model.

The network model has minor flooding in the 30-year + 25%CC option, flood volumes of 33m3 are predicted in the carriageway. There is also flooding is experienced in the 100-year +25%CC event. Flood volume of 303m3 is predicted in one of the existing ditch sections and 127m3 in proposed pipe system.

The model results for the critical storm for each return period as well as the subsequent peak flows generated for each of the Options are shown in Table 4-3. Peak flows from both of the proposed options are lower than those generated from the existing network for each return period, therefore demonstrating no increase to flood risk downstream. Full details of the model outputs can be found in Appendix E.

Table 4-3: Proposed Critical Storm Flow Rates

	RETURN PERIOD (year)	CRITICAL STORM (mins)	PEAK FLOW (l/s)
OPTION 1 - DITCH	2	30 min winter	425.6
	5	30 min winter	485.3
	30	30 min winter	556
	100	30 min summer	563
OPTION 2 - PIPED SYSTEM	2	30 min winter	425
	5	30 min winter	483
	30	30 min winter	554
	100	30 min winter	563.3

4.3 CONSTRAINTS

The site has several constraints which limit the design options available, the significant constraints are:

- **Utilities:**
  - The presence of existing utilities, particularly the foul and water systems, pose a significant constraint, see Appendix F: Utilities Plan. The design must ensure that the new drainage infrastructure does not interfere with or compromise the existing foul or water system.
  - Further Clash Detection and Design Iterations will be required in the Detailed Design stage to ensure the buildability of the proposal. Careful planning and coordination with utility providers are essential.

- **Land Management**:
  - The proposed swales and ditch / pipe network are located within private third-party land.
  - Landowner negotiations and agreement must be given prior to any Detail Design as the co-operation of the landowners is fundamental to the scheme.

- **Ecological:**
  - The proposed works require localised hedge removal and earthworks excavation, these activities have the potential to disturb nesting birds, badgers or newts for example.
  - In order to ensure the works are not having a detrimental impact on existing wildlife, an ecological survey will be required.

5 CONCLUSIONS AND RECOMMENDATIONS

A hydraulic model for Orleton has been produced, it provides the conceptual detail with assumptions and constraints which require further investigation during the detailed design. The Model Options provide solutions to the flooding issues of B4361, Millbrook Way and within Orleton itself, whilst not increasing flood risk to the downstream community. Two proposed models and design options have been produced for the client to consider.

Based on the conceptual analysis and design process, the following recommendations are made:

- Community Engagement: Initial landowner / property owner discussions are required as proposed water collection features and conveyance systems are within third party land ownership
- Topographical survey: this is to include detailed survey of the proposed swales, existing highway and existing ditch
- Ecological survey: to ascertain if there is a risk of encountering protected species which might affect scheme, method statements or seasonal delivery.
- Existing Drainage Connectivity and Condition Survey: Confirm of the existing network and conditions of the existing features is required as elements are proposed to be retained
- Clash Detection: Several potential clashes have been identified within this conceptual modelling, as part of the detailed design process, these should be investigated further, and a 3D analysis of intersection points be undertaken.
- Detailed Design: the model and proposed drainage network have been produced based on the information available to prove the concept is feasible. Further modelling and detailed design will be required.

APPENDIX A: ORLETON PARISH COUNCIL BRIEFING NOTE

APPENDIX B: CATCHMENT AREA

APPENDIX C: EXISTING DRAINAGE SYSTEM

APPENDIX D: PROPOSED DRAINAGE PLANS

APPENDIX E: CAUSEWAY FLOW – MODEL OUTPUTS

APPENDIX F: UTILITIES PLAN

PUBLIC