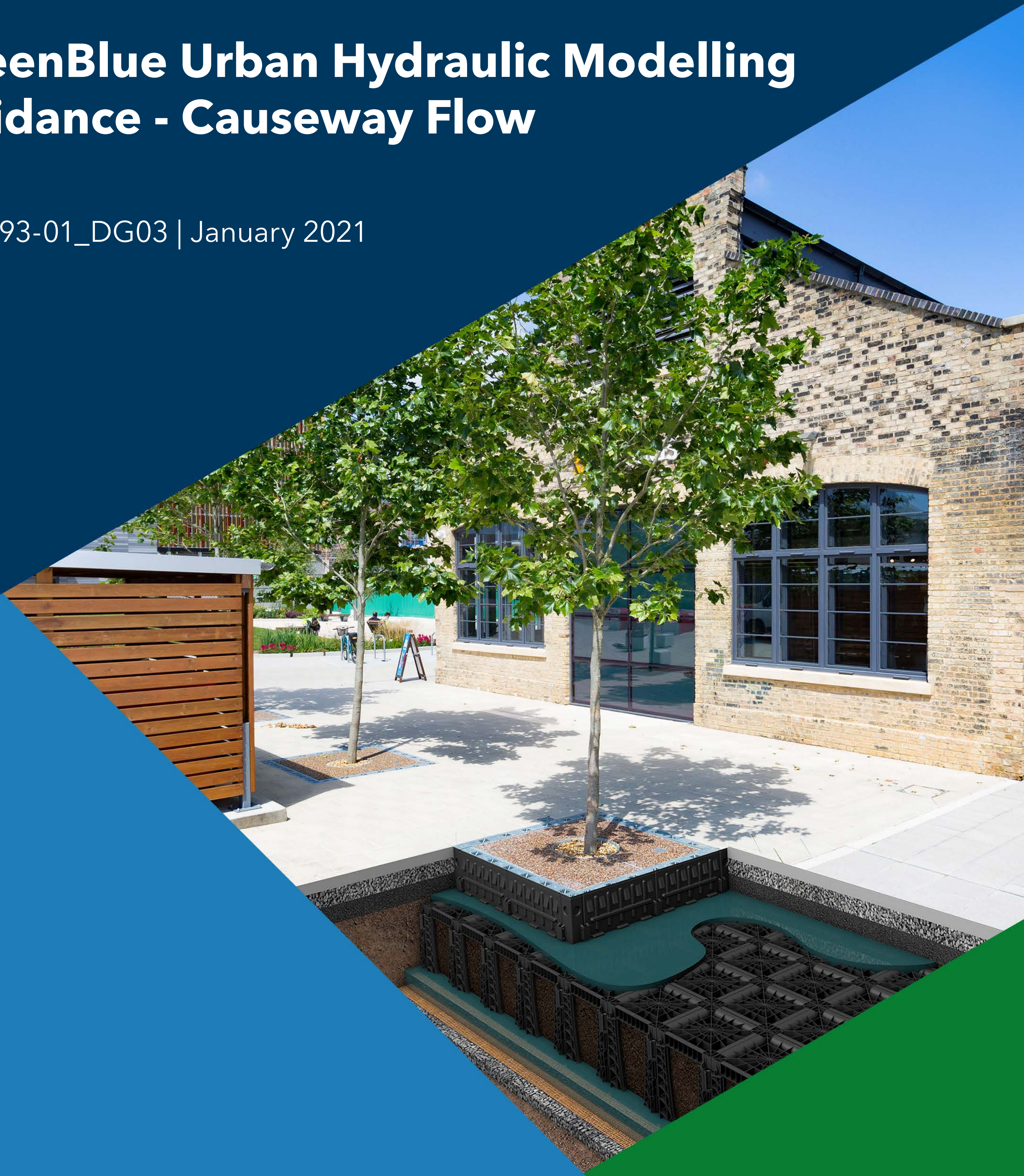
GreenBlue Urban Hydraulic Modelling Guidance - Causeway Flow

M01993-01_DG03 | January 2021



Establishing the future urban landscape through green & blue infrastructure.

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1 INTRODUCTION

1.1 Introduction to the guidance

This document provides guidance on representing the following GreenBlue Urban (GBU) SuDS installations within Flow hydraulic modelling software;

- HydroPlanter.
- ArborFlow Treepit systems.

This guidance document is based upon Causeway Flow software version 9.0 (hereafter 'Flow') and assumes that those who use it are proficient in the use of Flow and the processes involved in modelling attenuation / infiltration storage. Hydraulic modellers / engineers should satisfy themselves that sufficiently robust coefficients, units and parameters are used throughout the modelling process.

1.2 Structure of the guidance

The structure of this guidance is set out as follows;

- Section 2 - general workflows and items to be considered in the modelling process.
- Section 3 - contextualisation of the SuDS structures into modelling inputs.
- Section 4 - general modelling approaches when considering inflow, interception losses and outflow.
- Section 5 - modelling considerations specific to within Causeway Flow software.

2 MODELLING WORKFLOWS

2.1 GBU SuDS HydroPlanter

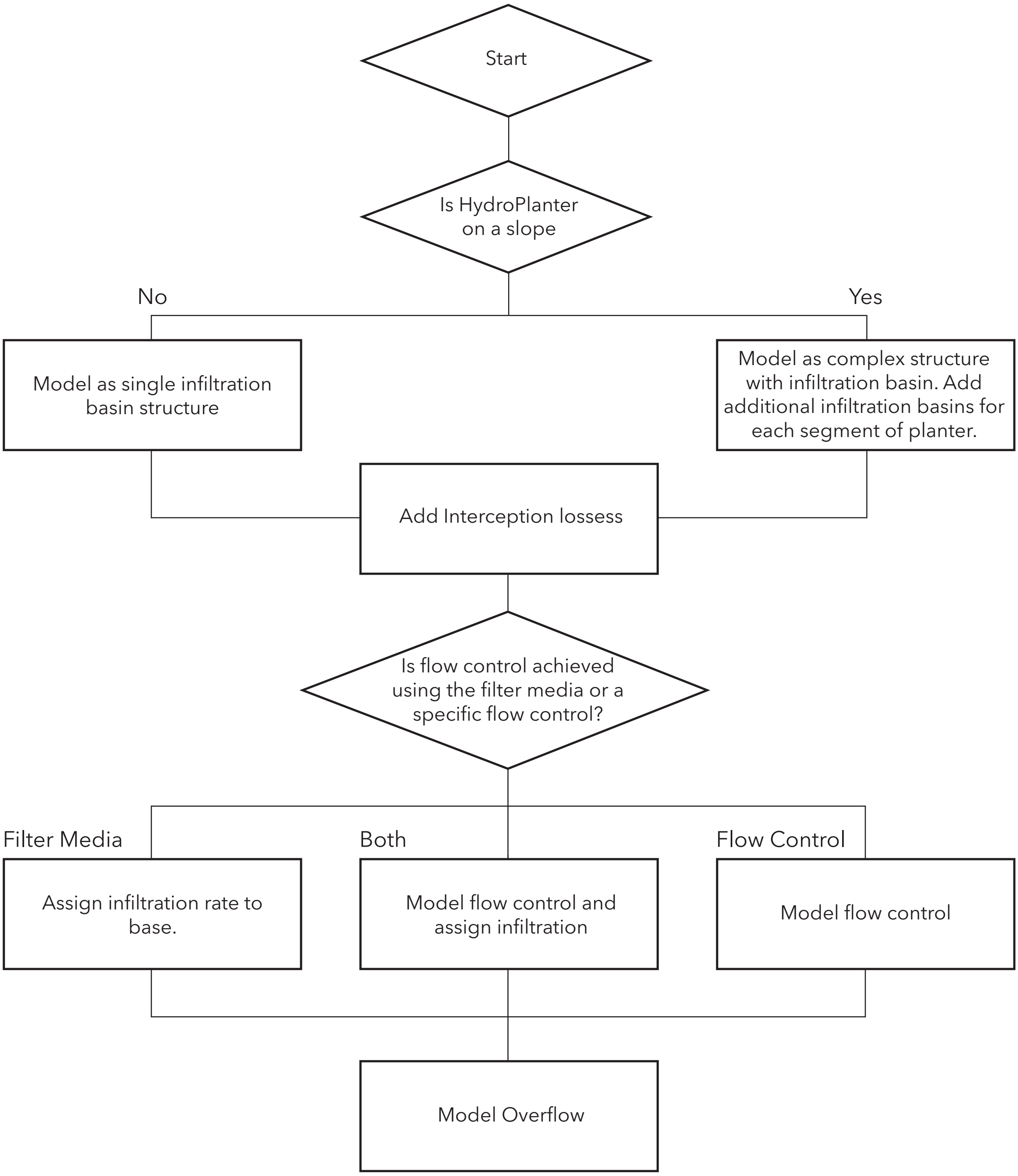


Figure 2-1: HydroPlanter Modelling Methodology

2.2 ArborFlow Treepit

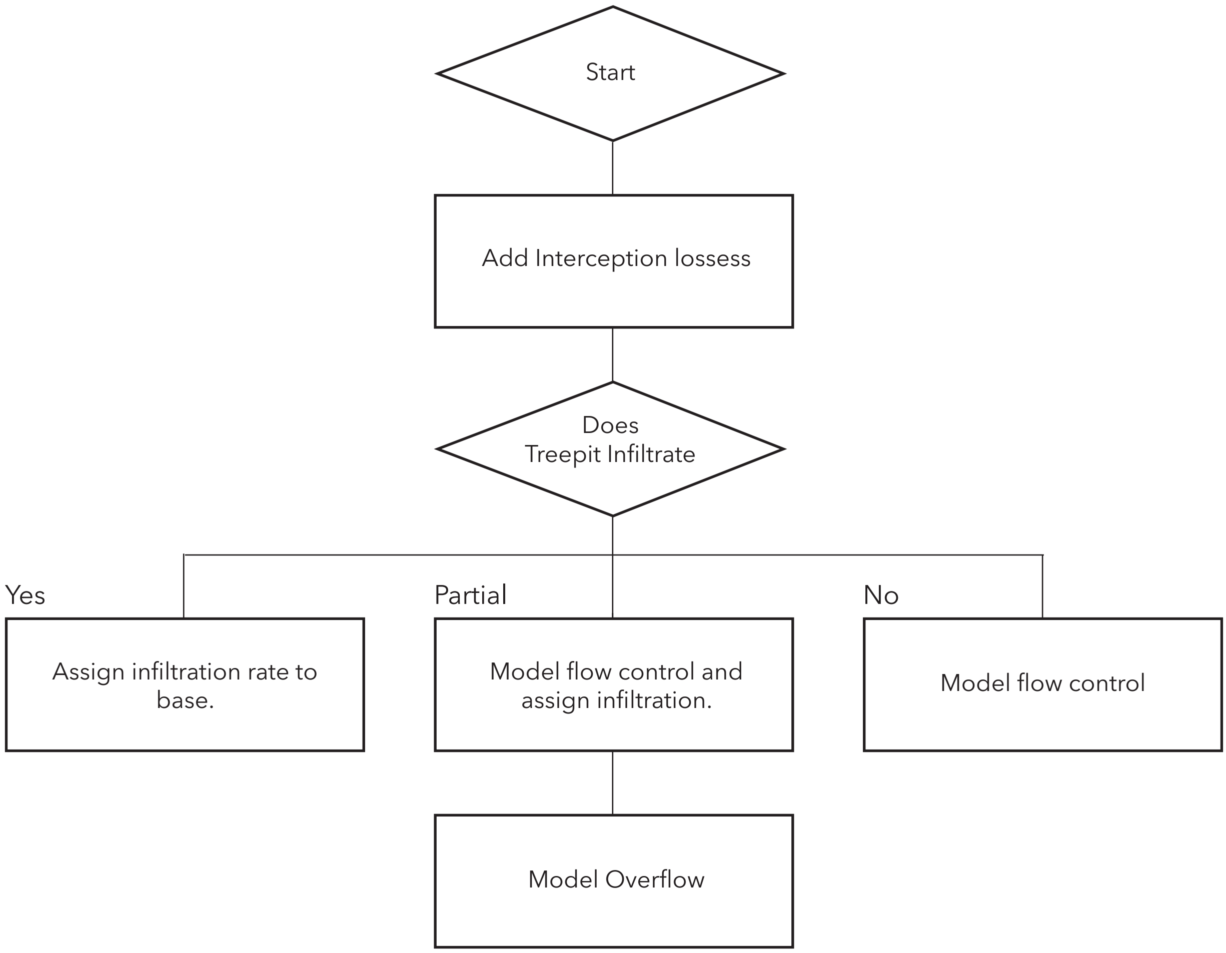


Figure 2-2: ArborFlow Treepit Modelling Methodology

3 GBU SUDS COMPONENT MODELLING

3.1 GBU SuDS HydroPlanter

Modelling advice is based upon the GreenBlue Urban HydroPlanter typical verge installation. The following figures show typical sections. Guidance on Soil (filter media) infiltration rates can be obtained in CIRIA SuDS Manual Table 30.3 and through discussions with GBU.

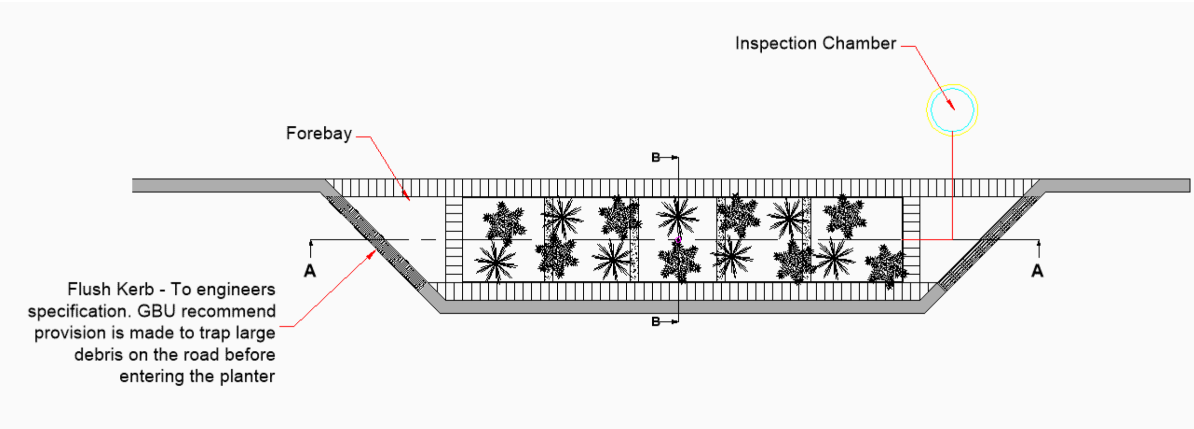


Figure 3-1: HydroPlanter Plan Area

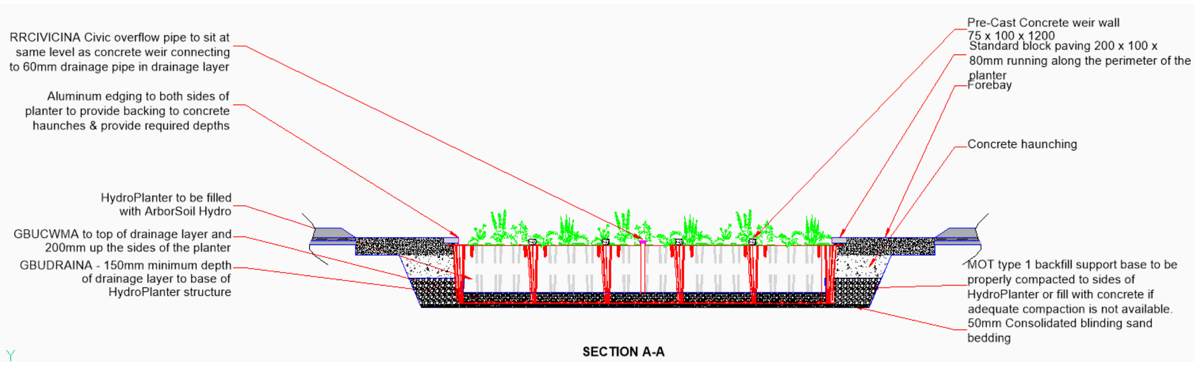


Figure 3-2: HydroPlanter Section A-A

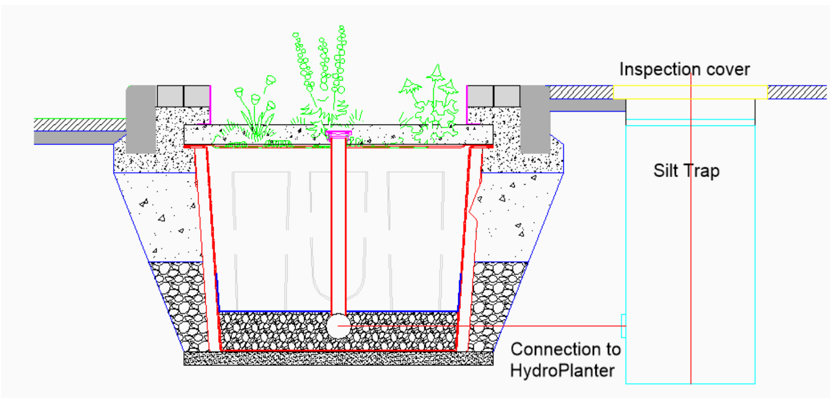


Figure 3-3: HydroPlanter Section B-B

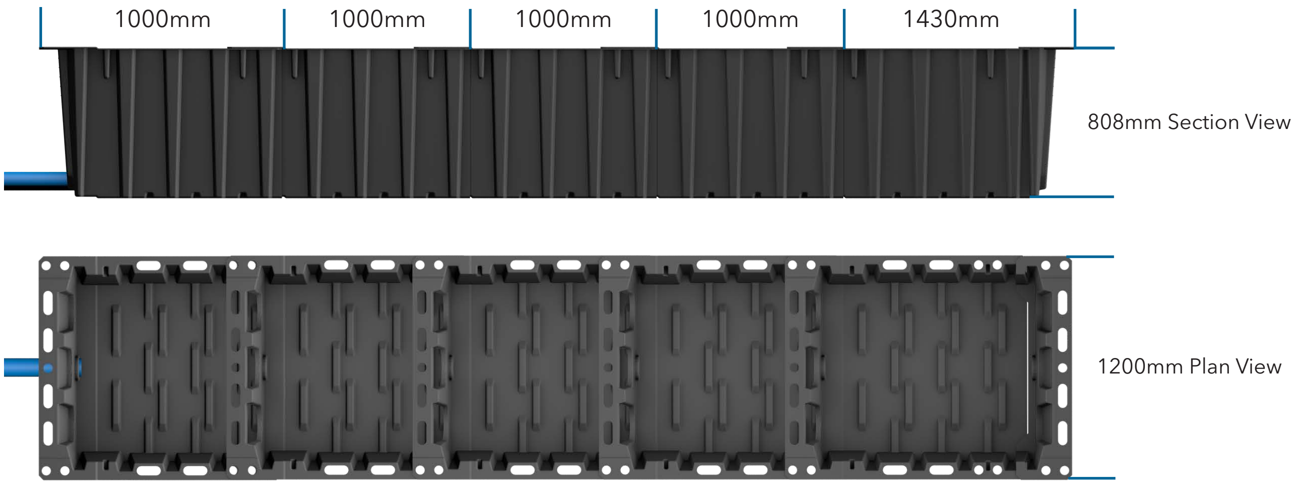


Figure 3-4: HydroPlanter Dimensions

Figure 3 5 shows the SuDS feature contextualised into key modelling components, detailed in Table 3 1. It is noted that the filter media has the potential to provide the outflow control through the delay of flow passing through the soil layer. The rate of control with depend on various factors including the soil specification and extent of antecedent wetness of the soil.

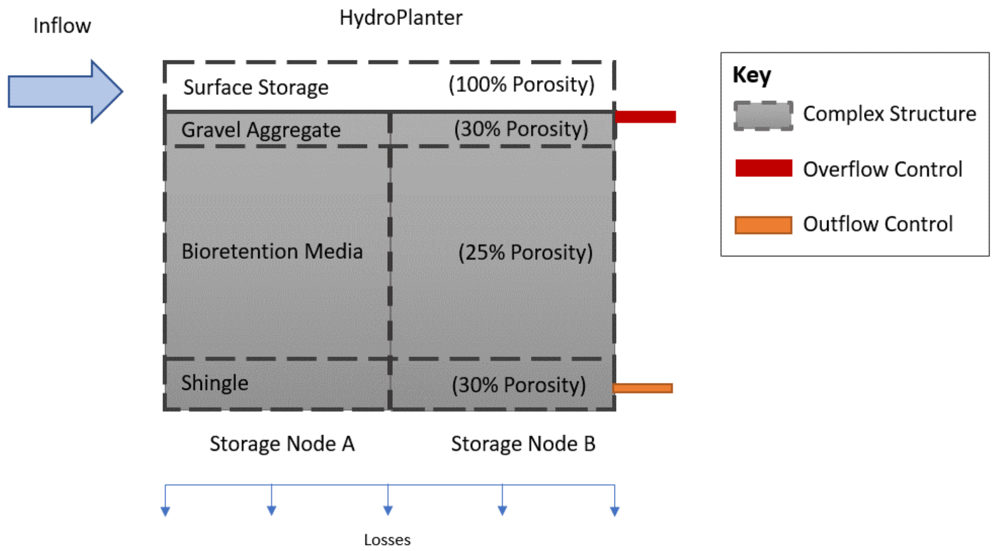


Figure 3-5: Conceptualised HydroPlanter as Model Components

Table 3-1: HydroPlanter Representation within Model

Component	Representation in Model	Described in Section
Inflows	Inflows to the system through generation of runoff and application to the SuDS feature.	4.1
Surface Storage Gravel Aggregate Bioretention Media Shingle Aggregate	Represented by an infiltration basin using a complex structure. The SuDS feature plan area is defined at specified levels corresponding with interface between layers. Porosity of individual layers represented by manipulation of plan area.	5.2, 5.3
Outflow Control	The scale of the applications where this will be used in means that only simple orifices are likely to be required. Flow can also be controlled as flow passes through the soil profile.	4.4.1, 4.4.3
Overflow Control	Usually represented by a weir overflow as per manufacturers specifications. Where flow is controlled through the soil profile the overflow is integral to the structure of the HydroPlanter.	4.4.2
Interception Losses	A 'dummy reservoir' is applied within the Flow storage tab which is set at an invert level below that of the GBU component.	4.2.1, 5.2

3.2 GBU SuDS Treeplanter - ArborFlow

Figure 3-6 and Figure 3-7 shows typical plan area and cross-sectional details of the ArborFlow system.

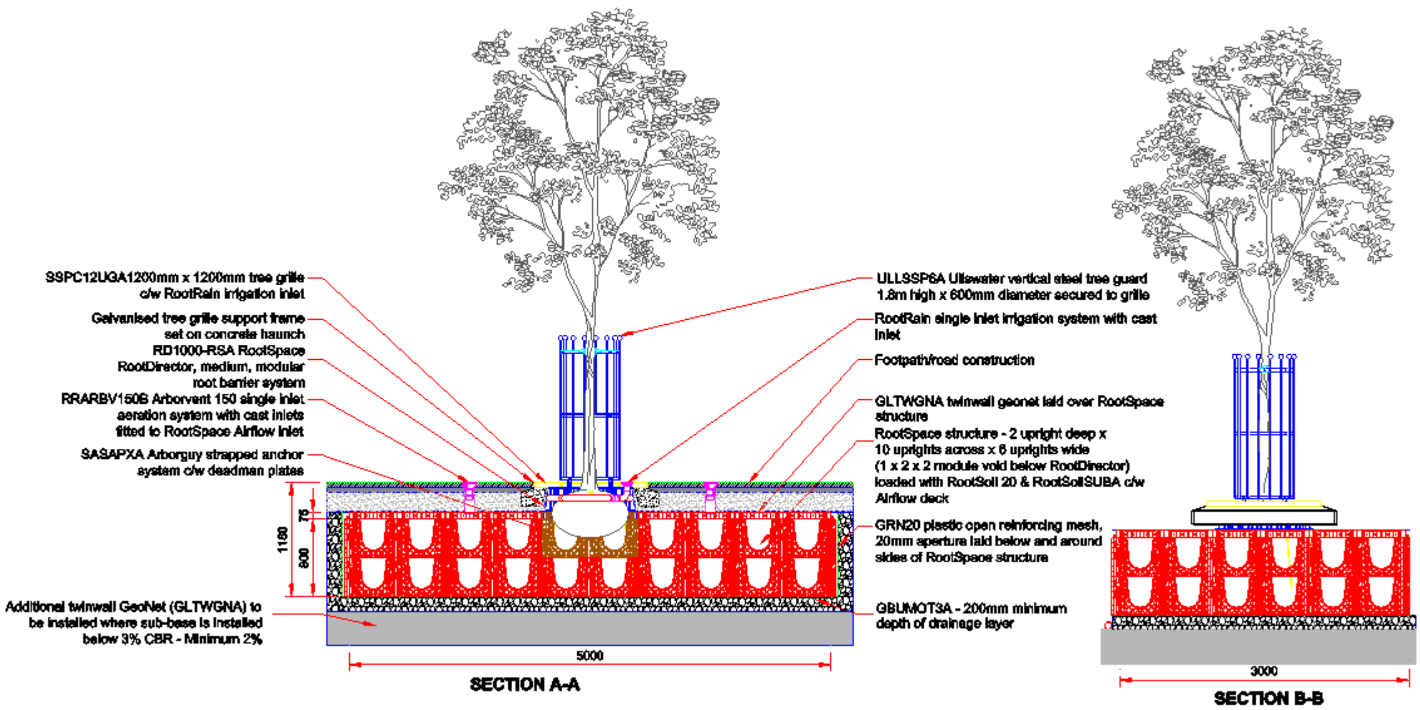


Figure 3-6: Typical GreenBlue Urban ArborFlow Section

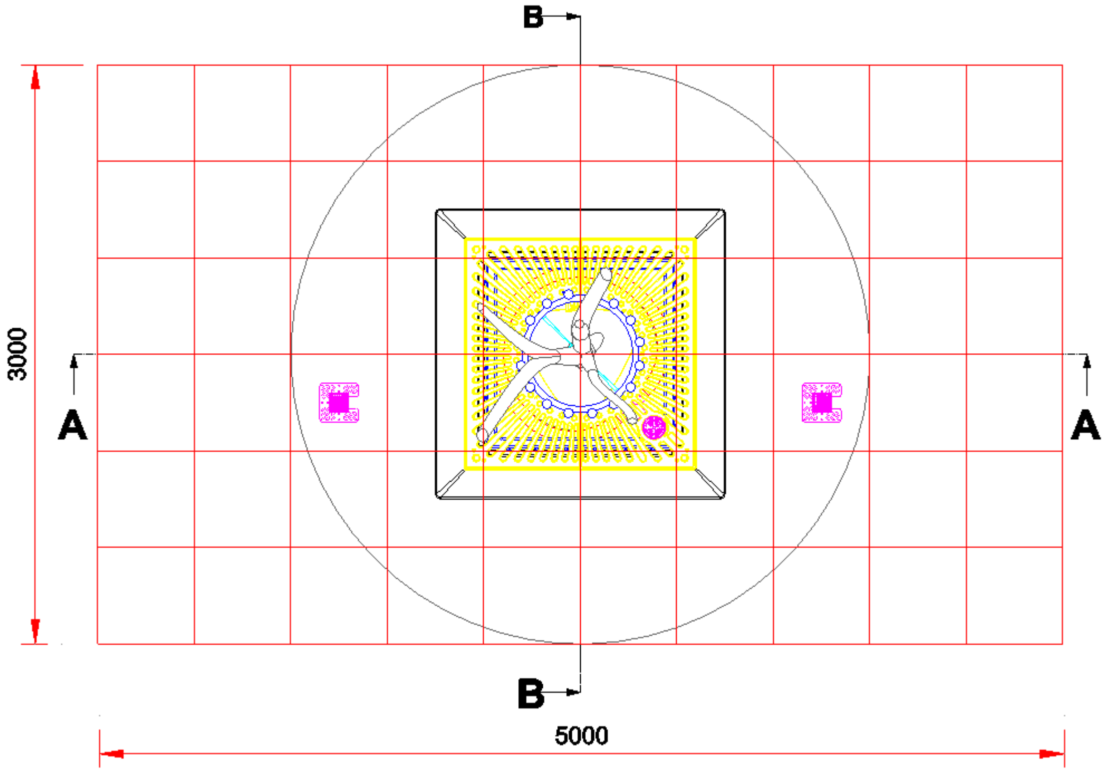


Figure 3-7 Typical GreenBlue Urban ArborFlow Plan Area

Figure 3-8 shows the SuDS feature contextualised into key modelling components, detailed in Table 3-2. It is important to understand that the filter media can provide the outflow control, particularly in small contributing catchments (area which drains to the HydroPlanter or ArborFlow treepit).

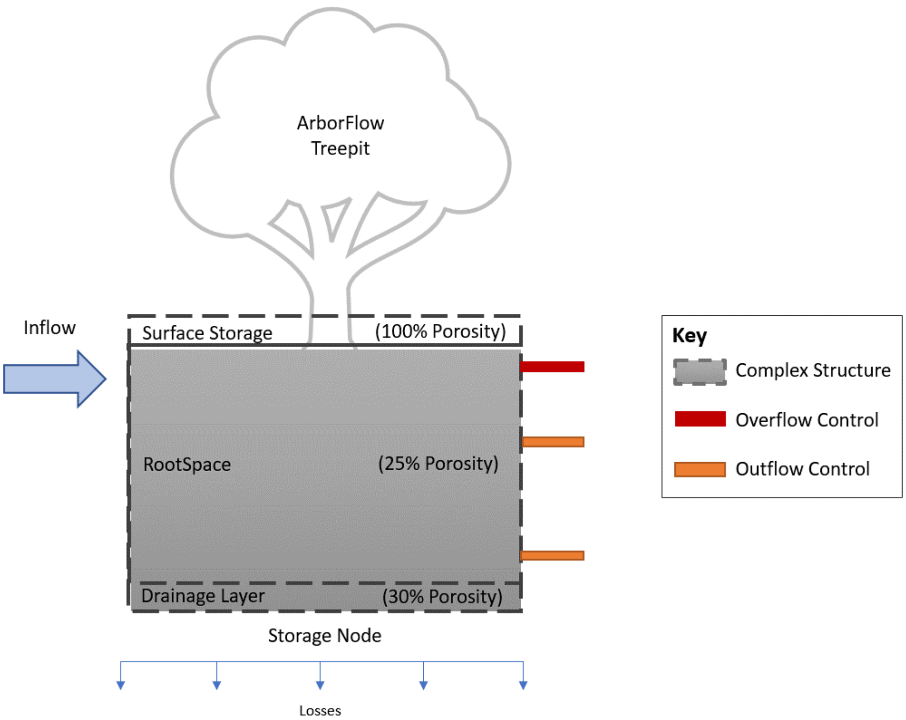


Figure 3-8 Conceptualised ArbowFlow Treepit as Model Components

Table 3-2 ArborFlow Treepit Representation within Model

Component	Representation in Model	Described in Section
Inflows	Inflows to the system through generation of runoff and application to the SuDS structure.	4.1
RootSpace Structure	Represented by a depth / area / inf area structure. The SuDS feature plan area is defined at specified levels corresponding with interface between layers. Porosity of individual layers represented by manipulation of plan area.	5.2, 5.4
200mm Drainage Layer		
Outflow Control	The scale of the applications where this will be used in means that only simple orifices are likely to be required. Flow will also be controlled as flow passes through the soil profile.	4.4.1, 4.4.3
Overflow Control	Usually represented by a weir overflow as per manufacturers specifications.	4.4.2
Interception Losses	A 'dummy reservoir' is applied within the Flow storage tab which is set at an invert level below that of the GBU component.	4.2.1, 5.2

4 GENERAL MODELLING APPROACHES

4.1 Establishing Inflows

Rate and volume of inflows to the model should be established via standard practices using the 'design setting' tab in Causeway Flow software. FEH2013 rainfall data for England, Wales, Scotland and Northern Ireland can be obtained from fehweb.ceh.ac.uk

4.2 Representing Interception Losses

Interception storage is the difference in the total volume of rainfall runoff that enters a HydroPlanter or ArborFlow treepit but does not leave via the positive discharge outlet. This term is also referred to as interception losses.

The extent of interception losses that occur in response to any individual rainfall event will be variable due to various factors (e.g. antecedent wetness conditions, season etc.) at the time of the rainfall event.

It is considered that the loss likely to be generated is comparable to 20 mm of rainfall per 1 m2 plan area of the HydroPlanter or ArborFlow treepit, dependent upon various aspects such as antecedent conditions and design of the system.

It is considered prudent to undertake a sensitivity test analysing the flow model with and without the effects of interception losses to enable understanding the influence of interception and sensibility check the figures being used within the model.

4.2.1 Modelling Interception Storage – Attenuation Systems

The modelling of interception storage can be rationalised and represented as a "dummy" reservoir, where virtual storage is created below the level of the outlet. Flows entering the system will fill the reservoir before flows start to exit the system via the flow control. The volume of the reservoir will relate to the volume of interception losses being allocated within the design.

This approach is suitable when considering single rainfall event simulations, or a range of rainfall events when for example undertaking critical duration analysis, where the baseline conditions are present at the start of each individual analysis.

Where Time Series Rainfall (continuous analysis which includes multiple rainfall events) is applied to the simulation the hydraulic model should include a mechanism which would allow the dummy reservoir to empty. As TSR analysis is not applied widely by the design industry, the mechanism of emptying the dummy reservoir is not explored further by this Guide.

4.3 Modelling Flow Through the System

The hydraulic model should take consideration of the soil specification within the HydroPlanter / ArborFlow structure and catchment draining to the HydroPlanter / ArborFlow units when considering how critical it is to represent the time lag which would be applied to the flow as it passes through the HydroPlanter / ArborFlow unit. Primary considerations are outlined as follows:

- During most rainfall events, the soil in the HydroPlanter / ArborFlow units would be expected to be 'dry' prior to rainfall commencing. The initial rainfall would therefore be intercepted and would cause a lag in response to rainfall at the point of discharge from the HydroPlanter / ArborFlow units. However, once the filter media has become saturated there may not be significant time lag from the time that flow enters the system to the point where flow discharges from the HydroPlanter / ArborFlow unit.

- Where flows out of the system are controlled via a flow control structure or infiltration into the ground, this is likely to become the controlling factor for restriction of flows through the system. The control rate (flow control or infiltration rate to underlying soils) should be compared with the flow rate through the HydroPlanter / ArborFlow soils to determine the controlling factor.

For the majority of installations which will have small catchments, a flow control is unlikely to be necessary as flows will be slowed as it passes through the soil structure. BGU advise an infiltration rate of 80 – 100 mm/hr for the soils used in the HydroPlanter or ArborFlow treepit.

Causeway Flow software does not have the ability to model the lag in response as flow passes through the soil structure of either the HydroPlanter or ArborFlow systems. Where representation for the soil slowing the flow is necessary to assess the impact on the receiving drainage network, it is possible to mimic the process of flow passing through the soil profile using a 'dummy' flow control. This will require the modeller to manually assess the likely rate of flow through the soil and size a dummy flow control to simulate this process.

This will only be necessary for installations where there is an outflow via positive discharge to a receiving drainage network. It is not considered necessary where the system is designed to fully infiltrate, as the infiltrating rate is likely to be the controlling factor.

4.4 Modelling Outflow

Flows out of the HydroPlanter / ArborFlow will either be via infiltration, positive gravity pipe discharge, or a combination of both.

4.4.1 Outflow Control

Where a flow control is provided which restricts outflow, this will surcharge flows upstream and utilise the available storage present within the structure of the HydroPlanter / ArborFlow systems. Flow software has the capability to model a wide range of outflow controls. For small contributing catchments a flow control should not be necessary, nor would it be considered practical.

The sizing of the flow control opening(s) will be dependent upon the controlled flow rate required for the depths of water generated for the critical return periods – generally 1 in 100 year and 1 in 1 year (with allowance for climate change).

With the capture of silt and floating debris which occurs as flows pass through the HydroPlanter / ArborFlow systems, the risk of blockage of the flow control can be minimised and small opening sizes (suggested down to 20 mm diameter) are considered achievable. Consideration should also be given to the requirements of the Local Authority (LA) or Water and Sewerage Company (WaSC). The LA may stipulate a minimum opening size. The Design and Construction Guidance (DCG) used by WaSCs identifies a minimum opening size of 50 mm where the flow control is well protected from blockage. The engineer / hydraulic modeller should check with LA / WaSC (as appropriate) as to what the local requirements are for the site location.

The invert of the outflow control should be at or below the invert of the storage to allow for full drain down, (and situated above the 'dummy' reservoir if the model is intended to represent interception losses). The sizing of the control opening(s) will be dependent upon the controlled flow rate required to be achieved and the type of flow control selected.

The following shows an example of the specification of an Orifice Outflow Control within Flow at a designated node (S2). The designer inputs the required invert level, design flow and maximum / design flow as well as the diameter of the orifice. To model an outflow which includes an overflow alongside a control, a 'complex multistage flow control' is established. This allows input of a weir (shown in Figure 4-1) in addition to the orifice control.

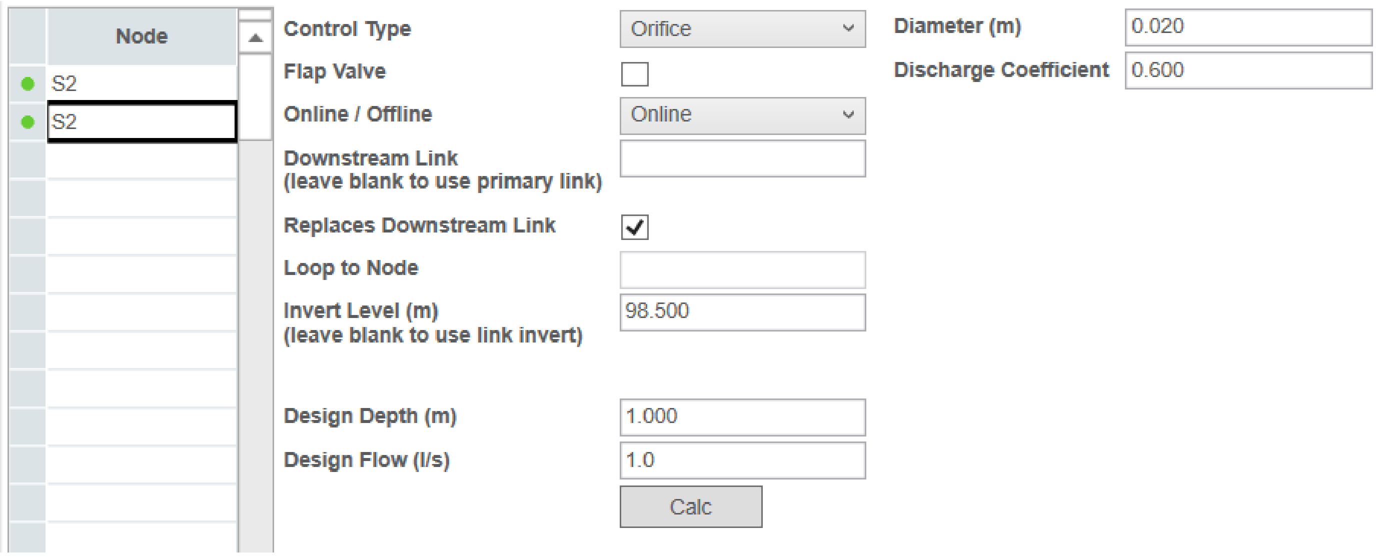


Figure 4-1 Orifice Outflow Control

4.4.2 Overflow Control

If required, a weir can be used to represent a high-level overflow to the downstream outlet (refer to Figure 3-5 for conceptual overview). The width of the weir would be set to the physical dimensions of the overflow. The co-efficient of discharge is specified at a typical value (0.59 – 0.61) and can be changed as per the weir type where the weir is not sharp crested.

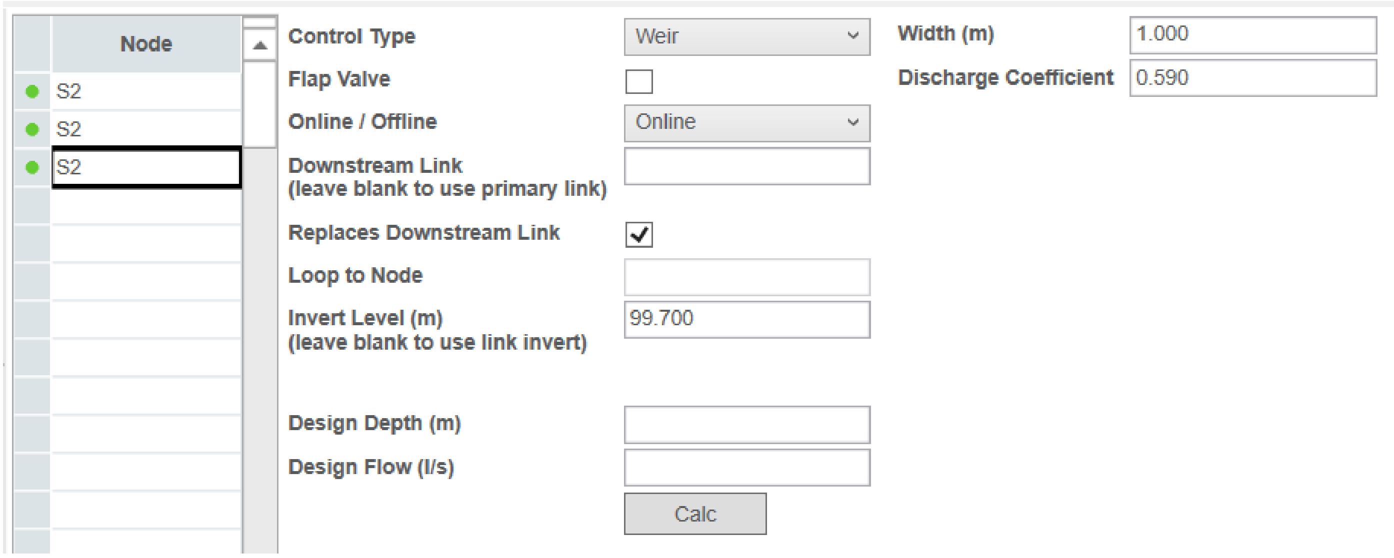


Figure 4-2 Weir Overflow Control

4.4.3 Modelling Outflow as Infiltration

Where favourable ground conditions exist for infiltration, flows can be discharged to ground.

Ground infiltration rates need to be established at the proposed plane of infiltration using BRE365 methods or similar. It is recommended that testing should be carried out in consideration of the Guidance set out within The SuDS Guide Chapter 25.

Flows exiting the HydroPlanter / ArborFlow can therefore be modelled to infiltrate through the base of the system within the storage tab in flow software - refer to Section 5.2 for further information. Note that GBU HydroPlanter / ArborFlow systems are lined at the sides – therefore side infiltration should be set to zero.

The safety factor should be set to between 1.5 and 10 depending upon the characteristics of the site (refer to Table 25.2 from CIRIA C753).

5 CAUSEWAY FLOW MODELLING

Causeway Flow software allows analysis of a full surface water drainage system including links (pipes / swales), nodes (manholes / junctions), flow controls and storage.

The software will automatically open the design settings tab on start up. Rainfall data (FSR / FEH / IDF), inflow criteria and design parameters are set as per standard methods / practice and can be amended later in the design process if necessary.

5.1 Storm Network Generation

Prior to adding any storage structure to the model, a surface water network of a minimum of two nodes and a link must be established. An example of the nodes and links tabs are shown in Figure 5 1 and Figure 5 2. The "network" can be further developed to model a series of GBU components within a proposed design.

If only one GBU component is being modelled, two nodes should be set up with one link, with the first node replicating the inflow and the second replicating the outflow. Designers should ensure that "dummy" features are sufficiently sized to not impact flows.

Name	Area (ha)	T of E (mins)	Add Inflow (l/s)	Cover Level (m)	Diameter (mm)	Width (mm)	Easting (m)	Northing (m)	Depth (m)	Notes
S1	0.100	5.00		100.000	1200				1.400	
S2	0.100			100.000	1200				1.431	Area is entering an outfall

Figure 5-1 Nodes Tab within Flow Software

Name	US Node	DS Node	Length (m)	ks (mm) / n	US IL (m)	DS IL (m)	Fall (m)	Slope (1:X)	Dia (mm)	T of C (mins)	Rain (mm/hr)
1.000	S1	S2	10.000	0.600	98.600	98.569	0.031	322.6	200	5.25	58.5

Figure 5-2 Links tab within Flow Software

Node (manhole) numbers are specified by the user within the nodes tab and link (pipe) numbers are automatically generated as the user specifies upstream and downstream nodes for each link. Lengths, gradients, and cover levels are taken from site surveys and / or proposed design details. Contributing impermeable areas are applied to nodes as per drainage design. Other section types such as ditches, swales, twin pipes etc. can be specified within the link types tab and selected accordingly. As further nodes / links are added, the software will "optimise" to suit previously specified parameters within the design setting tab, such as "preferred cover depth" and "minimum velocity".

5.2 Storage

Within Flow, storage structures are added by selecting the Storage tab. A Depth/Area/Inf Area structure within the Flow Storage Dropdown list allows the definition of a storage shape using level / plan areas. HydroPlanter and ArborFlow systems can be represented using multiple storage structures applied to one node which creates layers of different structures which then build an overall depth / volume storage relationship to be modelled in that node. In this case a separate structure shall represent each section of the planter when compartmentalised across a slope.

Manipulation of the plan area in each layer allows for representing the volumetric losses for each layer of the construction due to varying porosities.

The storage tab is shown in the following figure.

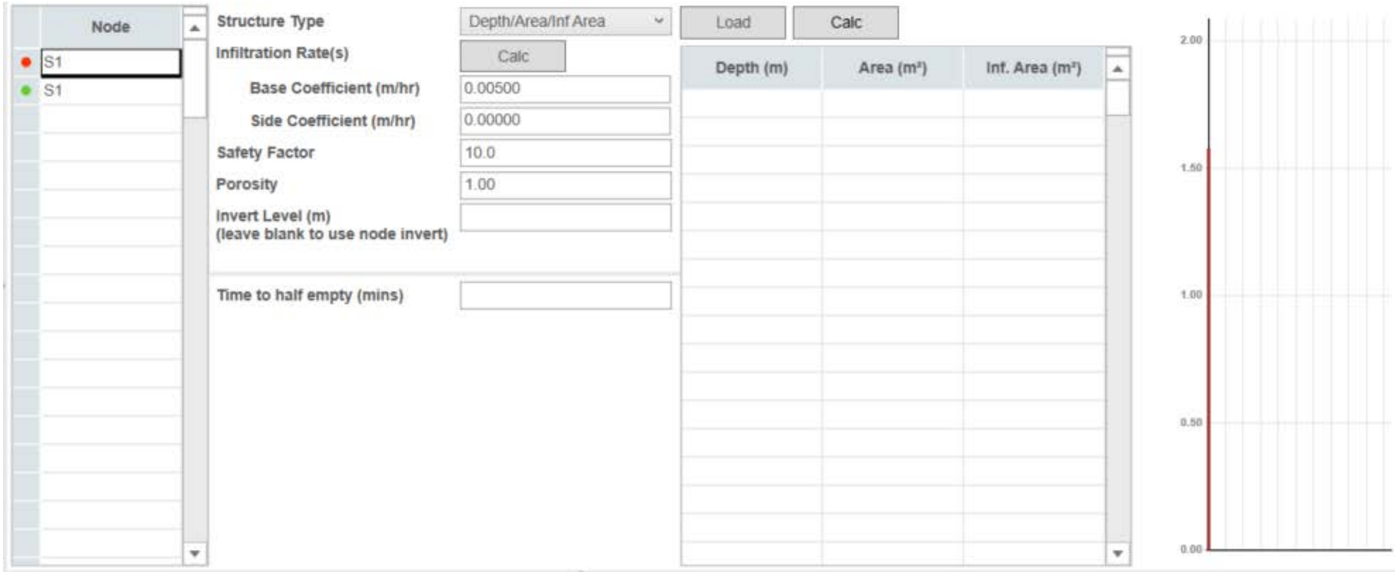
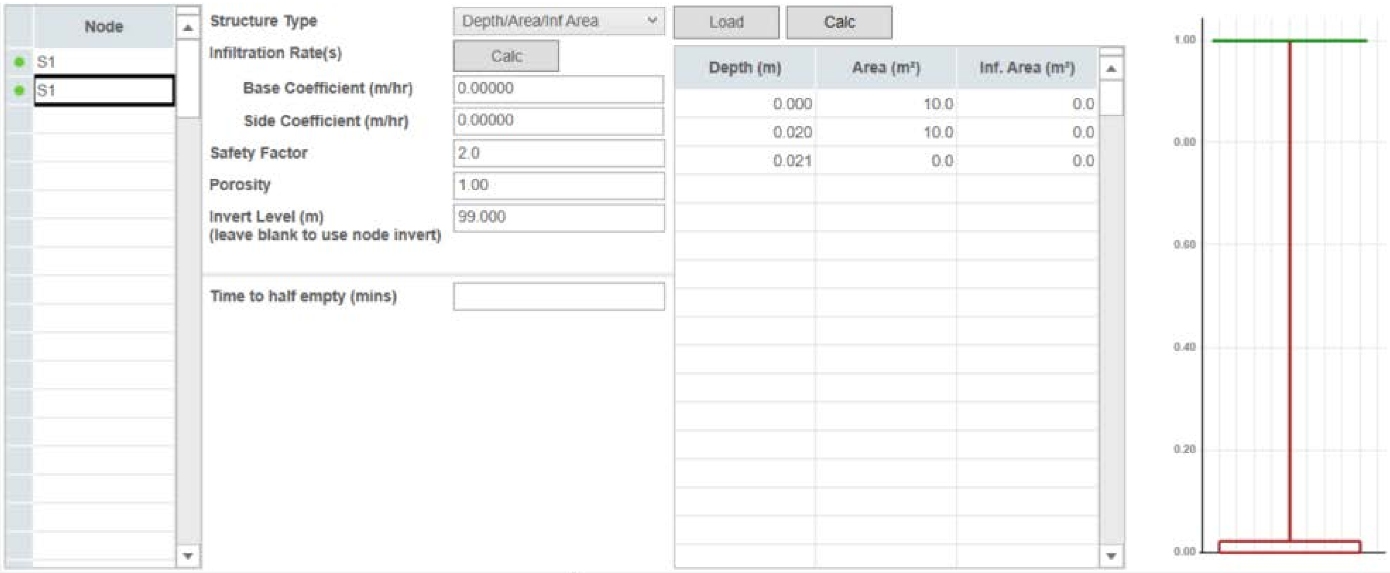


Figure 5-3 Storage Creation Tab

1. **Structure Type** – set to Depth/Area/Inf Area
2. **Infiltration Coefficient Base** - rate of infiltration (m/hr) from the structure into the ground.
3. **Infiltration Coefficient Side** – rate of infiltration (m/hr) from the structure through the side walls of the planter, assumed to be zero.
4. **Safety factor** – Infiltration safety factor per table 25.2 from CIRIA C753. Effective infiltration flow equates to infiltration co-efficient / safety factor.
5. **Porosity** – Porosity reflects the infill of the structure with media. A porosity of 0.25 represents 25% voids and 75% of the storage taken up by solids (e.g. gravels or soils). As both the GBU HydroPlanter and ArborFlow Tree Pit system have varying porosity, this value is set as 1.0 as and porosity is defined using depth / plan area relationships - refer to above notes.
6. **Invert level** – assume as the base of the lowest segment of the system being modelled. Should the GBU system be on a slope (in the case of HydroPlanter), the average invert level of the lowest segment should be used. Should interception losses be represented within the model the designer should ensure that the invert level is made lower to account for this but the depth of the “dummy reservoir” subtracted to determine the actual invert of the GBU system.
7. **Time to half empty** – following a simulation run this will demonstrate the length of time the structure takes (in minutes) to drain to half volume.

Surface storage areas (above ground level) may also be included within the structure and given a porosity of 100%.

Interception losses can be represented using an additional tank with no infiltration at the invert of the structure, as shown on Figure 5-4.



Depth (m)	Area (m²)	Inf. Area (m²)
0.000	10.0	0.0
0.020	10.0	0.0
0.021	0.0	0.0

Figure 5-4 'Dummy' Reservoir Storage Inclusion

5.3 Modelling GBU HydroPlanter

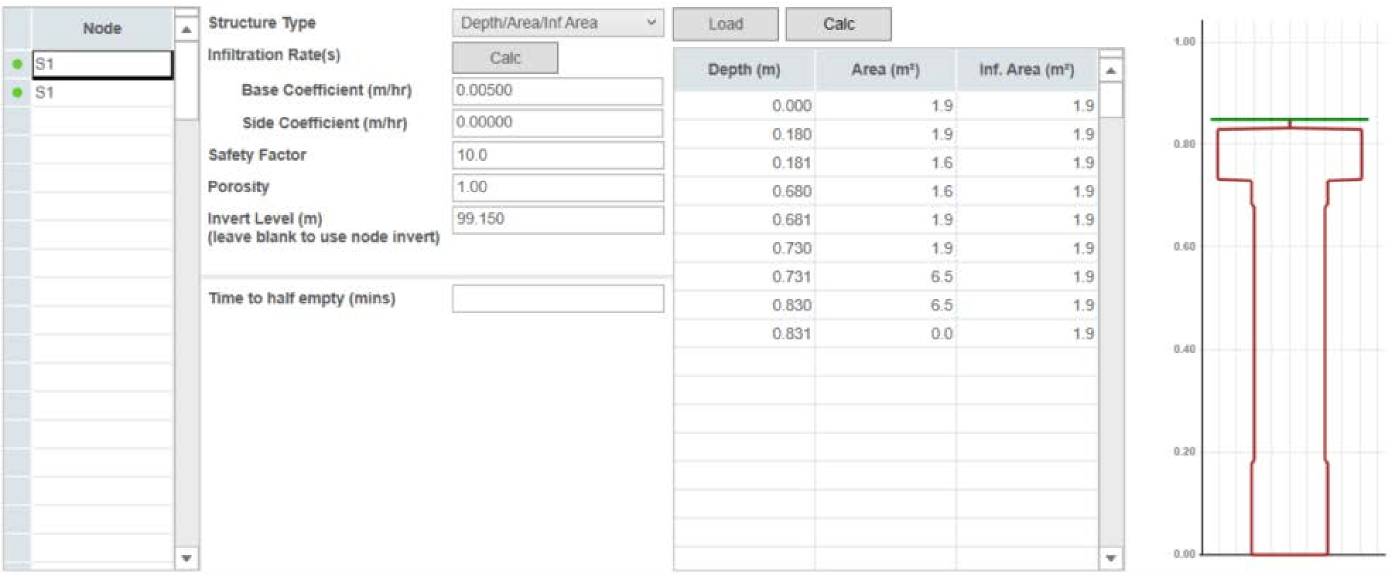
The method of modelling the HydroPlanter is as follows:

1. Determine compartment / cell size (plan area). It is noted that where HydroPlanters are located on a slope the planter may be hydraulically sub-divided into 2 or more compartments by adding additional storage structures to the node.

2. Determine the average invert across the compartment area. This will act as the base invert level (and the point from which the inverts of each change in layer will be taken). Refer to Figure 5 6.

3. Define the depth of each layer and the void porosity. The void porosity is multiplied by the cell size / plan area. This provides a proportional area the given depth / invert which will provide storage.

4. Repeat the definition of areas at each layer change up to and including top kerb level. Volumes exceeding the spill level will be treated as lost in this instance.



Depth (m)	Area (m²)	Inf. Area (m²)
0.000	1.9	1.9
0.180	1.9	1.9
0.181	1.6	1.9
0.680	1.6	1.9
0.681	1.9	1.9
0.730	1.9	1.9
0.731	6.5	1.9
0.830	6.5	1.9
0.831	0.0	1.9

Figure 5-5 HydroPlanter Storage Array

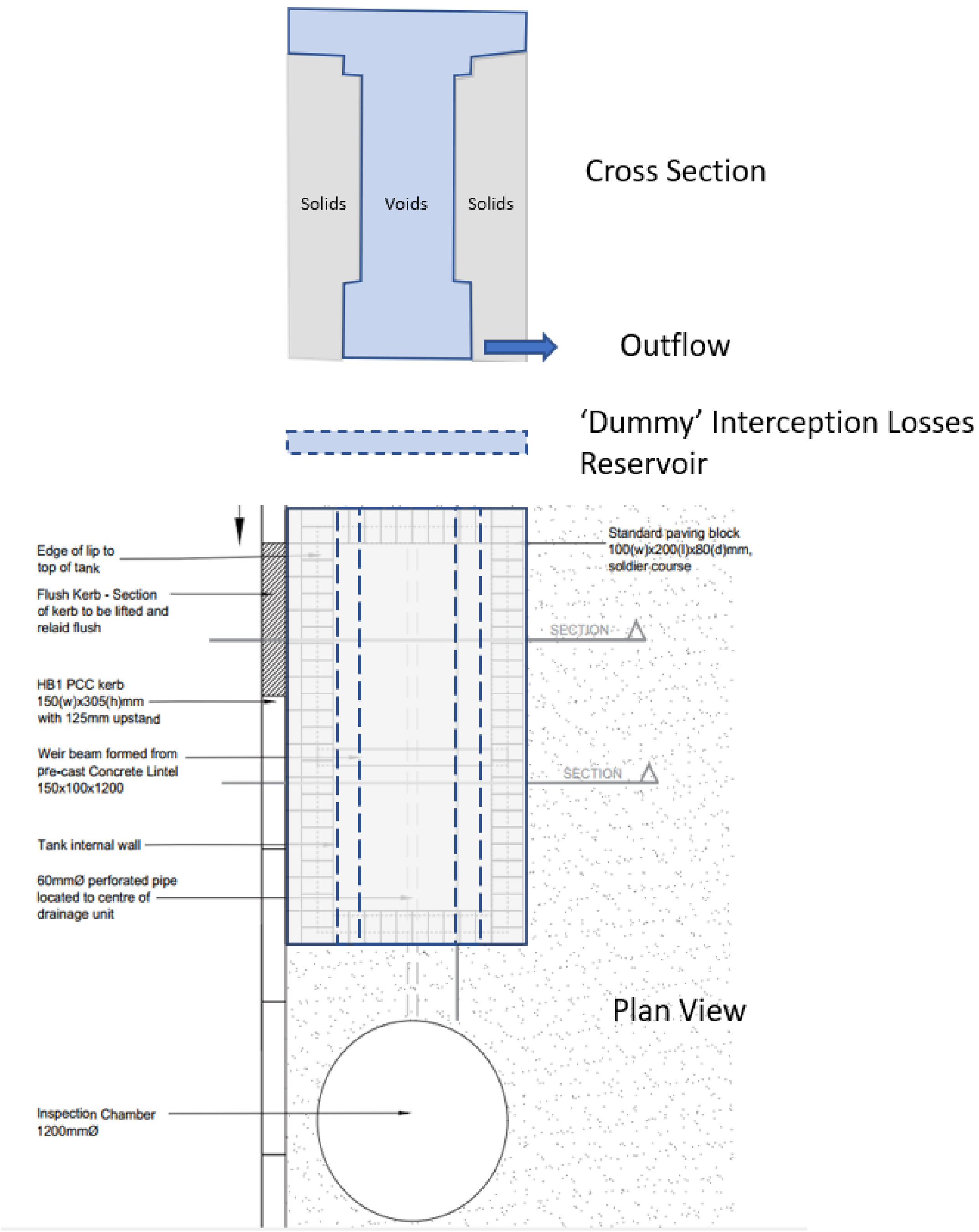


Figure 5-6 HydroPlanter Plan View and Cross-Sections

On sloping sites, the HydroPlanter is split into compartments to more effectively utilise the storage within the HydroPlanter. Flow are transferred between compartments either through an underdrain (day to day flow) or a weir (when capacity of the underdrain and storage node is exceeded.

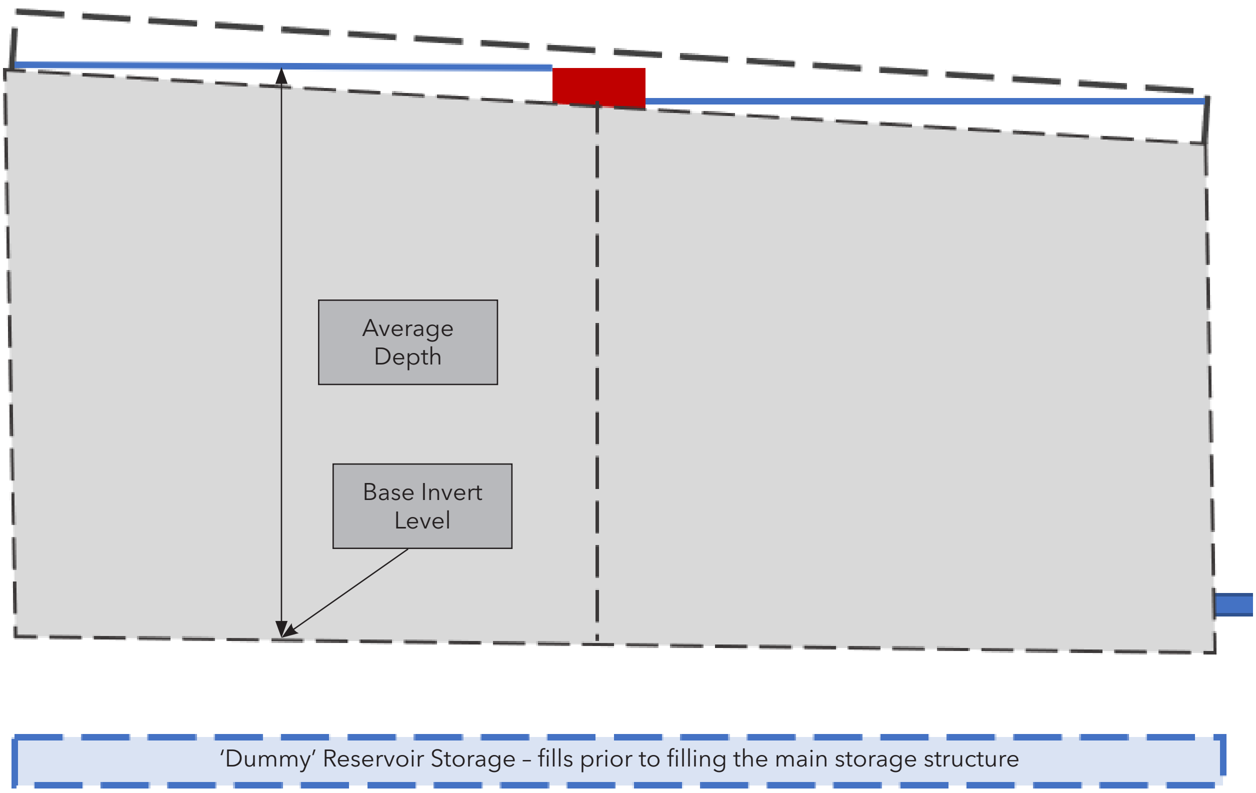


Figure 5-7 HydroPlanter on Sloping Site

5.4 Modelling GBU ArborFlow

Similarly to the HydroPlanter, a Depth / Area / Infinfiltration Area structure should be used to define the storage shape using level / plan area relationships. Representation of volume of voids can be achieved by specifying a porosity of 1 but reducing the plan area of each layer to reduce the volume accordingly. Interception losses can also be applied as per the methodology presented in section 5.2.

GBU ArborFlow treepits have a standard cross-sectional area. To allow for the storage provided within the ArborFlow, the following storage array is suggested, taking account of the porosities of the respective layers. The method of modelling the ArborFlow is as follows:

1. Determine compartment / cell size (plan area).
2. Define the depth / invert of each layer.
3. Define the void porosity. The void porosity is multiplied by the cell size / plan area. This provides a proportional area against the given depth / invert which will provide the storage volume.
4. Repeat the definition of areas at each layer change up to and including the spill level.

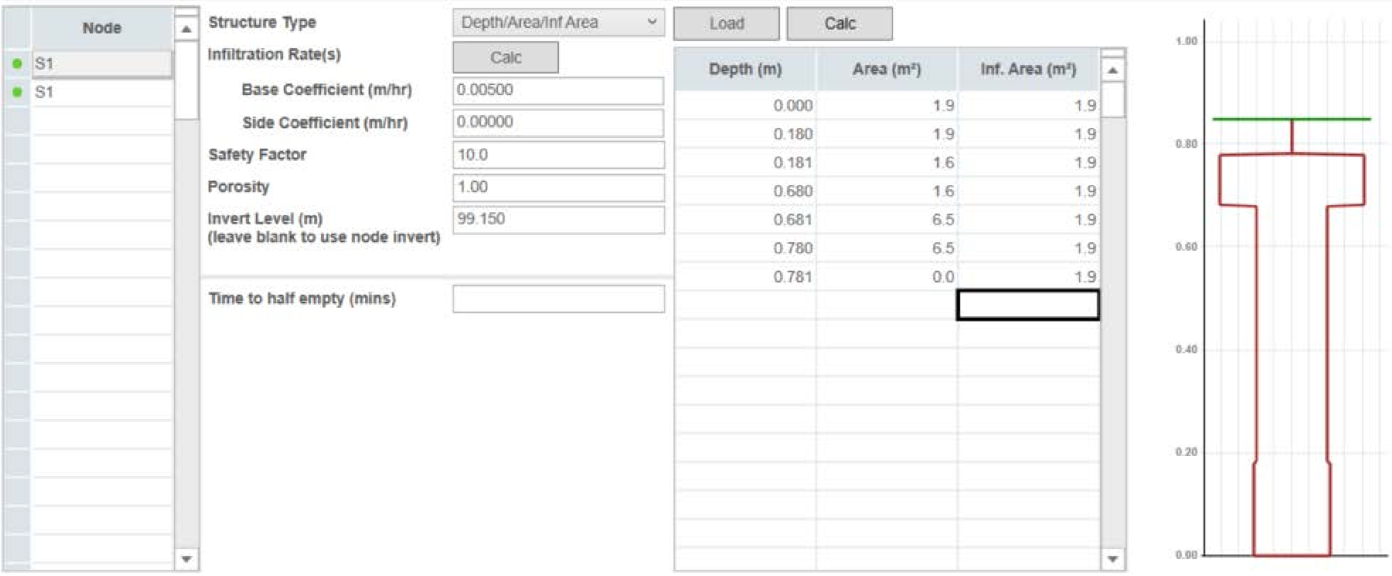


Figure 5-8 ArborFlow Storage Array

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