



Lovelock Mitchell Architects

**Proposed
Development at Ipsen
Biopharm, Wrexham
Industrial Estate,
Wrexham**

**Hydraulic Modelling Technical
Report**

March 2018

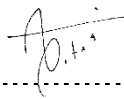


Lovelock Mitchell Architects

Hydraulic Modelling Technical Report

March 2018

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Date: March 2018
Reference: V-R6472/MOD
Status: Issue 3

Approved for
Release By



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1 Introduction

Ipsen Biopharm is seeking to build an extension to the existing chemical production plant located on the Wrexham Industrial Estate. In order to complement a Flood Consequences Assessment and fulfil the requirements of Natural Resources Wales (NRW) and Wrexham County Borough Council (WCBC), OPUS have undertaken a Hydraulic Model for the existing fluvial conditions and simulate possible blockage and flood flow path scenarios. This was undertaken to assess the risk of flooding to the existing production plant and the proposed development on site.

1.1 Location

The site location is shown in Figure 1 below and is centred at Ordnance Survey National Grid Reference (OS NGR) 337489, 350407. The site is located on the north-western part of Wrexham Industrial Estate. It is bounded by Cytec to the North, Ash Road N to the East, the junction between Ash Road N and Abenbury Way to the South and Abenbury Way to the West.

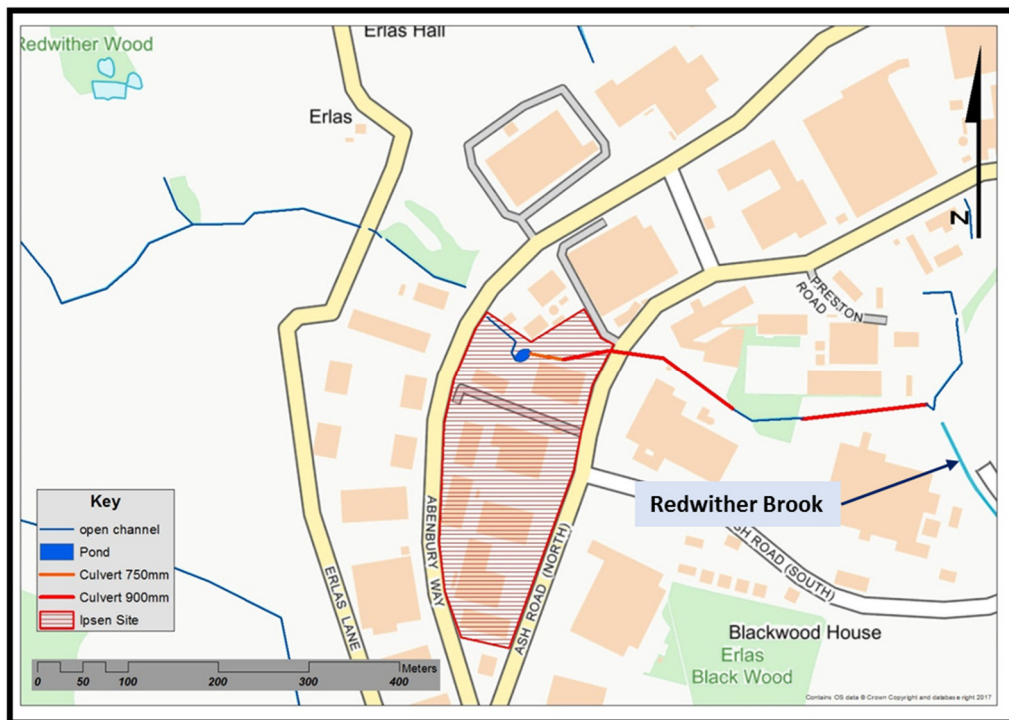


Figure 1 Ipsen Biopharm. Source: OS Vector Map District

The site is currently crossed by a small unnamed watercourse which runs from West-Northwest to East and through a small greenfield area and a pond. Flow levels at this pond are controlled by a weir followed by a culvert entrance headwall and inlet grating arrangement. The watercourse is culverted under the parking area and crosses Ash Road N.

The inlet is formed by an approximate length of 35m, 750mm diameter culvert followed by a 900mm for the remaining 190m. In total the culvert length is approximately 225m.

The unnamed watercourse is a tributary of the Redwither Brook and is located approximately 440m downstream of the pond.

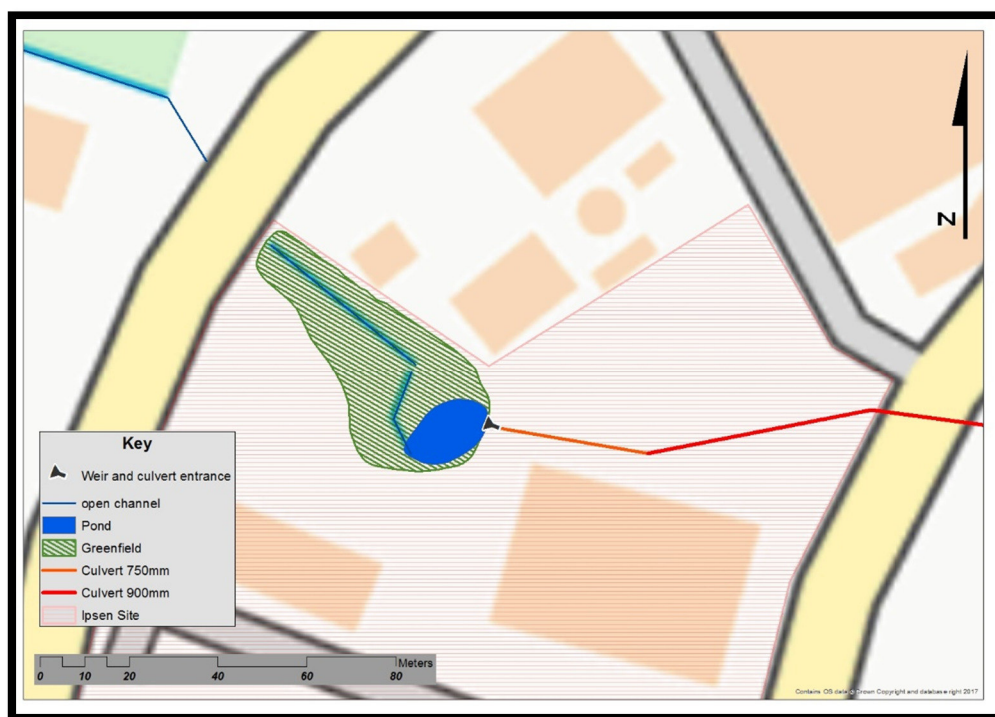


Figure 2 Site layout plan. Source: OS Vector Map District

Site levels have been reviewed as part of the watercourse topographic survey which is included in Appendix A.

2 Hydrology

2.1 Catchment & Watercourse Characteristics

As the unnamed watercourse of interest for this study is less than 0.5 km² in area and it is a tributary of the Redwither Brook. No catchment characteristics in FEH Web Service for this particular site were found. Therefore the analysis has been undertaken on an adjacent catchment with similar characteristics with flows proportioned to the catchment size to develop this study.

The catchment descriptors from the FEH Web Service are presented in Appendix B, whilst a plan of the catchment area is shown in Figure 3 below;

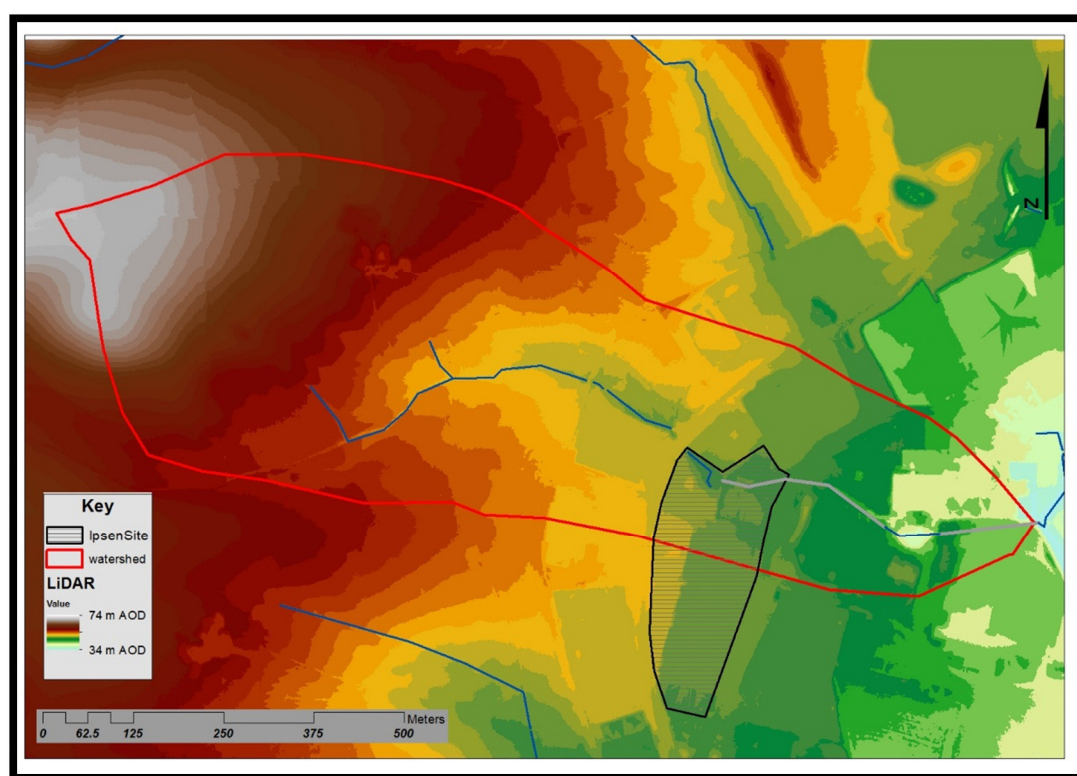


Figure 3 Catchment Plan. Source: Lle Geoportal for Wales.

2.2 Hydrological Assessment

The Flood Estimation Handbook (FEH) Statistical method was deemed the most suitable for the derivation of design flows for this study with hydrographs and the critical storm obtained from Revitalised FEH Rainfall Runoff method (ReFH1) and scaled to the peak flow values calculated using the FEH Statistical method. The ReFH1 hydrograph was developed using Flood Modeller Pro (FMP) hydraulic modelling software. The results of this assessment are presented in the Flood Estimation Calculation Record in Appendix C.

Hydraulic models were run to assess the potential effects of climate change for this purpose, the 100 year return period event was run with additional flow to represent climate change. Current guidelines by the Natural Resources Wales require that a +30% allowance (central estimate) and also a +45% allowance (upper end estimate) for the Dee catchment. This supersedes precautionary contingency allowances provided in Table 1 of Technical Advice Note 15: Development and Flood Risk (TAN15) Guidance document. The hydraulic modelling as part of this study has adopted a conservative approach and allowed for 75% climate change allowance to the 100year event.

2.3 Applied Flows

Figure 4 below illustrates how the return period affects the hydrograph with Table 1 giving the calculated peak flows for key events on watercourses.

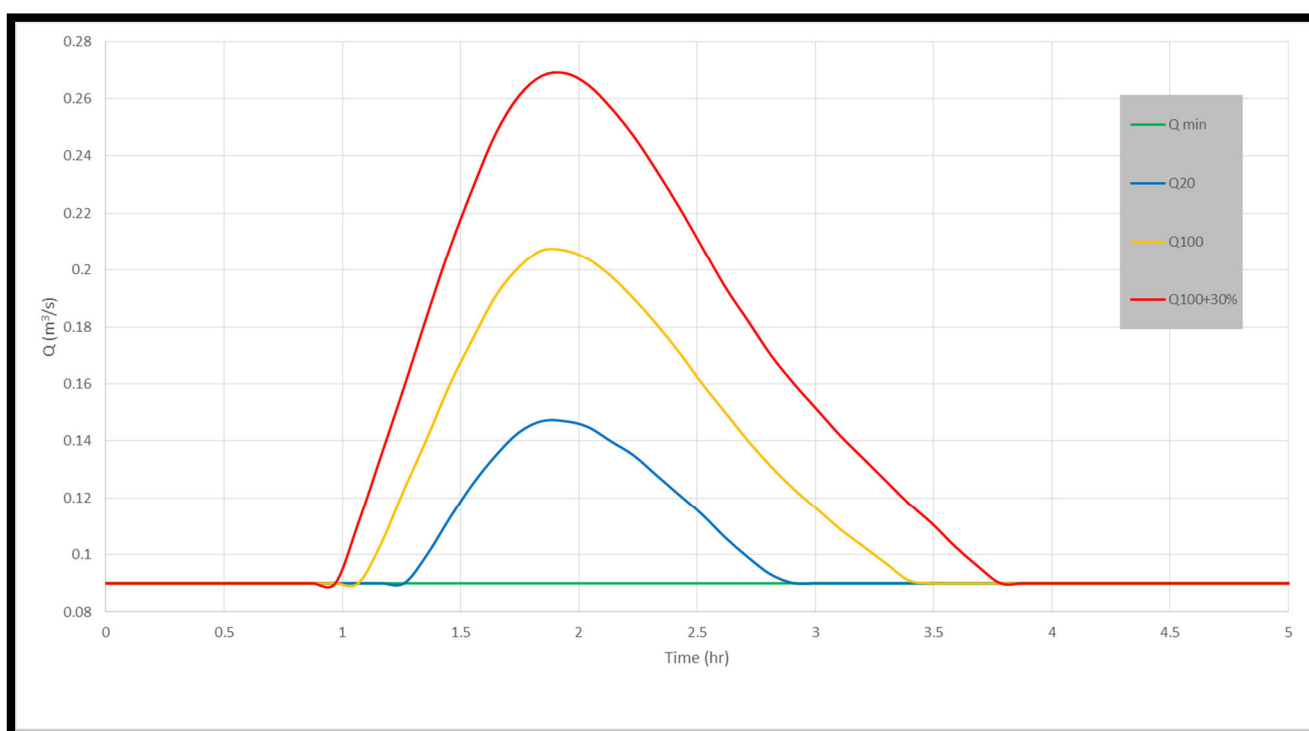


Figure 4 Hydrographs calculated

Return Period (yrs)	Peak Flow (m ³ /s)
2	0.070
20	0.147
100	0.207
100+30%CC	0.269
100+75%CC	0.362
1000 Morris	0.412

Table 1 Peak Flows

In order to prevent the 1D model from drying out and becoming unstable a minimum flow has been set on the applied hydrographs of 0.09 m³/s (90 l/s).

3 Hydraulic Model Configuration

Opus have developed a 1D-2D hydraulic model of the watercourse to investigate the response of the watercourse to flood events (including a blockage scenario). Therefore the following Sections 3.1 to 3.8 (inclusive) describe the model development.

The constructed model consists of a Tuflow model linked with a Flood Modeller Pro (FMP née ISIS) network with inflows applied to the top of the network and a normal boundary applied to the bottom of the domain. The active area covers 0.27 km² (27 ha) with a 1 metre cell size. Water is able to leave the model at the model boundaries where appropriate and inflows are applied using hydrology derived via statistical analysis. The model is sufficiently large enough to model all significant flows and boundary conditions are sufficiently distant from the site of interest for any boundary effects to normalise.

3.1 Topographic Data

Outputs from hydraulic models are dependent on how accurately the channel sections are represented and whether any obstructions to flow or structures have been described. An appropriate survey is therefore an important component of any hydraulic model. A topographic survey was commissioned for this project and undertaken in September 2017 by PM Surveys UK with the data provided in Appendix A. The watercourse is a well-defined channel which reaches a pond area just before been channelized through a 225m long culvert. The pond area, the parking area and the road can have floodplain behaviour therefore the model requires a 2D component as a representation of the floodplain. The 2D domain has been constructed from 1m DTM LiDAR obtained from the **Lle Geoportal** for Wales.

3.2 Tuflow Model Configuration

The 2D model extent cover 130 m upstream from the top end of the 1D domain, 110 m downstream of the 1D domain. The downstream edge was set with a head-flow (HQ) type boundary to allow water to flow out of the model with the gradient set based on LiDAR.

For this Tuflow model version 2016-03-AB-iSP-w64 was used with a 2.0 second timestep. Model simulations have been run for 6 hours. The Manning's roughness coefficient was set at 0.035 for the entire area before being overwritten based upon land use classifications digitized manually. Table 2 below details the standard classifications applied.

Tuflow Code	Manning's Value	Description
1	0.035	General Surface
2	0.040	Grass Open Land
3	0.100	Buildings
4	0.020	Roads and Paved Ares
5	0.040	Railway*
6	0.045	Mixed surfaces and gardens
7	0.040	Open Carparks
8	0.200	Multi-storey carparks*

* N/A no such feature in current area

Table 2 Tuflow Manning's Values

3.3 Digital Terrain Model (DTM)

The DTM consists of an array of points with elevations representing the surface and forms the basis on which structures and relevant features can be added. The DTM was abstracted from 1 metre resolution (DTM) LiDAR data, which can be seen in Figure 5 below;

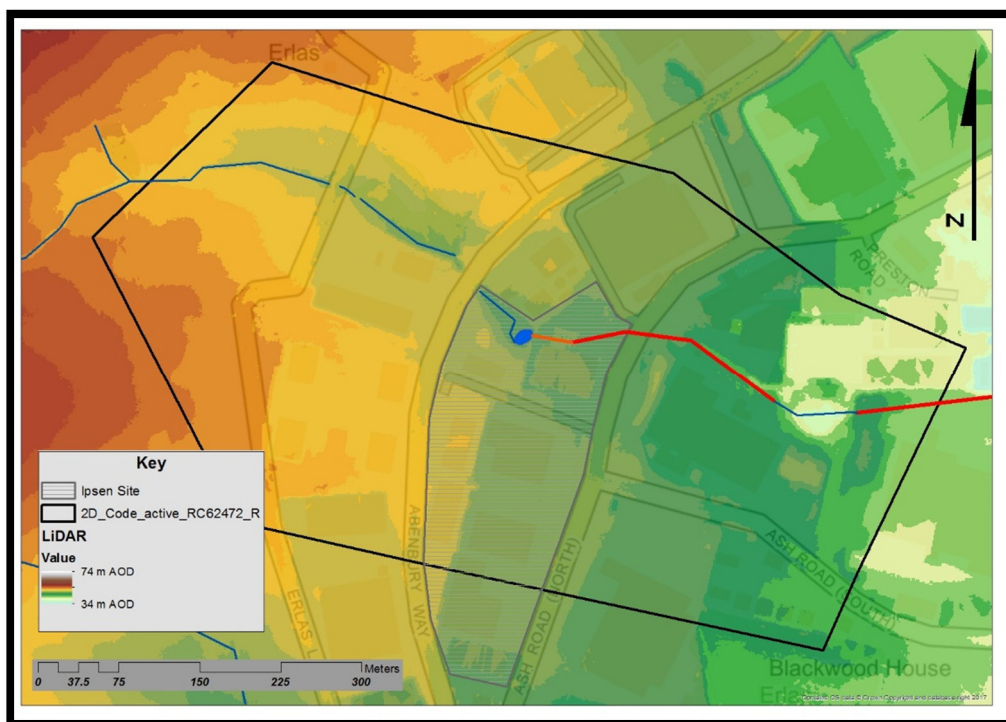


Figure 5 LiDAR and Active Area

In addition to the stream represented in the 1D domain and linked to the 2D domain, the topography of the 2D domain also needs consideration. The base topography has been created from LiDAR with a 1 metre cell size; this has been patched, amended the bank level of the watercourse from the FMP section file set via a 'z-line' and extra contour lines obtained from topographical survey to give it more detail at the pond area.

3.4 Flood Modeller Pro Configuration

The Flood Modeller Pro version 4.3.6458.29637 was used for this study with a 1 second timestep. The model was developed from the topographic survey information specified and commissioned by Opus as part of this study. These data were extracted and imported into Flood Modeller Pro to form river units. Structures were then added manually giving careful consideration to the selection of unit and associated parameters. Details of the model build process as recorded in the model build log are presented in Appendix D.

3.4.1 Flood Modeller Pro Labelling Convention

The reaches on this model have been labelled with a three letter code to identify site, (i.e. IPS), followed by an underscore to separate the Five digit chainage number, showing the distance from the downstream end of the channel in metres (plus 490 metres). For example IPS_00800 is 310 metres from the end of the modelled reach. This labelling convention has some variations within the model with “c” denoting a culvert and “s” for spill. The same manner the region of interest at the Pond was labelled with a P after the underscore and the number of reaches that was divided to its detailed modelling until the spill/culvert at downstream.

3.4.2 Flood Modeller Pro Key Parameters

The main parameter to consider in a 1D hydraulic model is the roughness value, in this model roughness coefficients (Manning’s n) were estimated during the walking visit. The roughness¹ values for the channel were 0.04 for both the bed and the banks, with the culverts set to 0.030.

3.5 Model Inflows & Outflows

Design inflow hydrographs were derived for each event of interest through the methodology described in Section 2.2.

Hydraulic models depend on a water level to be specified at the downstream limit. Ideally this should be where a reliable stage-discharge rating is available which is rarely possible. It is accepted practice to extend the model downstream of the study reach to a point where the uncertainty in the boundary water levels should not significantly influence the results at the location of interest. The downstream model boundary was represented by a “Normal” boundary unit which sets the energy slope parallel with the river bed slope over the lower sections of study reach. The primary point of interest for this model is the pond and its interaction with the culvert inlet, from which the boundary is located sufficiently downstream at approximately 280 m distant to the point of interest.

3.6 Assumptions & Limitations

3.6.1 Assumptions

The representation of any complex system by a model requires a number of assumptions to be made. In case of a one dimensional hydraulic model of a river system it must be assumed that:

- The sections accurately represent the watercourse.

¹ Chow, V.T. (1959). *Open Channel Hydraulics*. New York: McGraw- Hill

- The predicted flows are an accurate representation of a specific event
- Model parameters can be satisfactorily determined (including roughness & structures).
- A stable numerical solution can be achieved.

Further for the 2D component of the model it must be assumed that:

- The LiDAR and cell size actively represent the topography and its flowpaths.
- The Digitized layer of the land use and roughness accurately represent such features.
- Embankments, bunds and ground features are impermeable.
- The head only transfer of water between domains is representative.
- There is no significant 3D component to water movement.

3.6.2 Model Limitations

Hydraulic models are ideally calibrated using gauged flow data in addition to observations of water level during flood events at numerous locations, such data is rarely available. The FMP model itself may be considered appropriate for flows up to bank full capacity. The FMP model alone is not appropriate for considering floodplain flow as only the channel is represented. However when linked with the 2D TufLOW model, the model is appropriate for modelling more complex out-of-bank flows.

Sensitivity modelling was undertaken and is discussed in the results, the sensitivity tests suggest that the model generally is within acceptable limits. This is outlined in Section 4.3 of this report.

3.7 Model Stability

A few changes were required to improve stability in the model. Changes required in the modelling included:

- Applying an automated Priessman slot in FMP;
- Orifice units were added instead normal inlet/outlet unit to improve the stability of the Modell
- 60% blockages reduced timestep to 0.25s for 1D model
- Levelling off the pond below the weir crest
- Applying a 0.09 m³/s minimum flow.

After these alterations the model is considered adequately stable as based on the Flood Modeller Pro .bmp outputs, however there is concern with the stability of the thousand year event.

Figure 6 below shows the mass balance error plot as recorded in the 2D Tuflow domain. This shows that the values remain within the generally considered acceptable limits of +/- 1%, with the exception of the Q1000 (0.1%AEP).

In particular to Q1000 (0.1%AEP), this model experienced a Cumulative Mass Balance Error only marginally exceeded for approx. 10 min during the initial wetting of the 2D domain and shortly reverts back to the desired range, the maximum Cumulative Mass Balance Error % (MBE%) whilst $Q_i + Q_o > 5\%$ is -0.82% This suggests that these results are acceptable provided suitable care is taken with their interpretation.

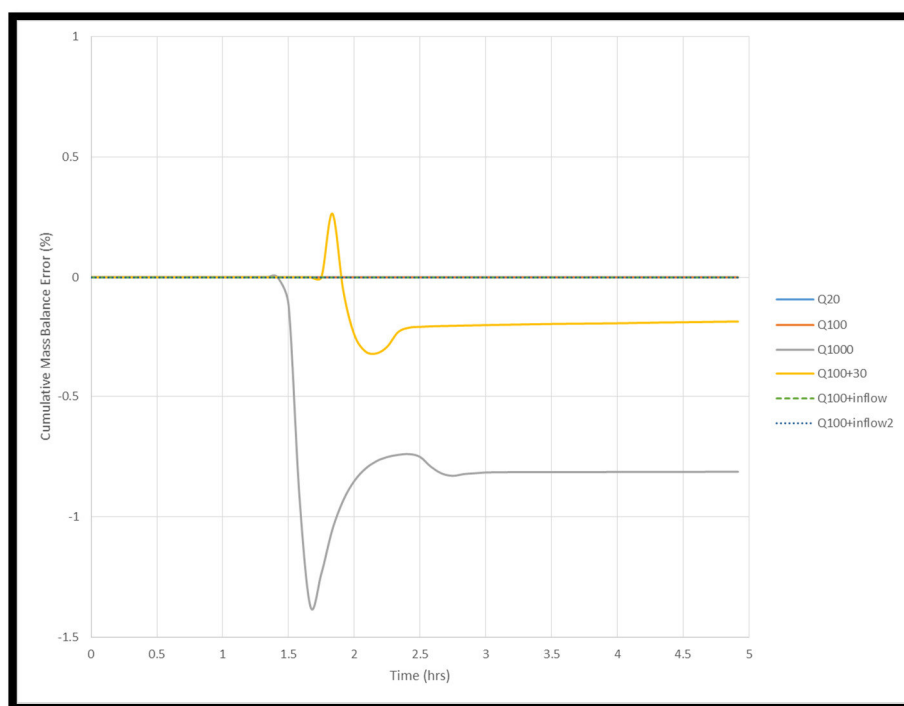


Figure 6 Mass Balance Error curve

With suitable care these results may be used to indicate mitigation which is their desired purpose, furthermore the 0.1% (Annual Exceedance Probability) AEP simulation may be considered acceptably stable at approximately the flow level desired and a sense check between these simulations confirms that the results are in accordance with the expectations which gives confidence in their suitability to inform this study.

3.8 Model Simulations

The following Table 3 below summary model runs.

Name	Sensitivity	Run?
Q20	-	✓
Q100	-	✓
100yr Blockage 30%	-	✓
100yr Blockage 60%	-	✓
100yr Blockage 90%	-	-
1000yr Blockage 30%	-	✓
1000yr Blockage 60%	-	✓
1000yr Blockage 90%	-	-
Q100_mMannings	-20% Mannings	✓
Q100_pMannings	+20% Mannings	✓
Q100_mBound	-20% Boundary	✓
Q100_pBound	+20% Boundary	✓
Q100+20q	+20% Discharge	✓
Q100-20q	-20% Discharge	✓
Q100+30%	-	✓
Q100+75%	-	✓
Q1000	-	✓
Q100+inflow	-	✓
Q100+inflow2	-	✓

Table 3 Model Simulations

The names of each model are based on the return period in years of the flow applied.

In addition to the above, further model runs include sensitivity tests i.e.: +/- 20% to Mannings (i.e. 0.04 baseline becomes 0.048 and 0.032) and +/- 20% outflow gradient.

In accordance with current industry guidance from Welsh Government and the NRW, the blockage model considered three scenarios for two different return periods 30%, 67% and 95% reduction in cross sectional area on the culvert upstream from the site (Section 00775c) from the start of the 100 year and 1000 year event. Due to model instability issues, only the 30% and 60% have been able to be run for the 100year and 1000year events. This is discussed further in Section 4.2 of this report.

Two further events have been allowed for assuming existing impermeable area at Ipsen site direct to the culvert system as follows;

- Additional 0.025 m³/s at constant flow calculated with the catchment descriptors and the reduction area to the approximately 1.3 ha impermeable area which can drain to the 750mm diameter culvert – *Q100+inflow*.
- The Worst Case scenario with an additional 0.24 m³/s calculated with SuDS, and added as lateral inflow at the 750mm diameter culvert – *Q100+inflow2*.

4 Results

This section reviews the key simulation results with mapped outputs provided in Appendix E (and listed in section 6) show the maximum depths across the site. In reference to this project the key results are from the 100+30% event, 100+75% and 1000year events. The depths resulting in the pond in the more extreme events and the blockage event are also of interest.

The flood mechanism identified by the modelling suggest that at 2 hours into the simulated flood, water backs up at the shallow areas of the pond about 0.13m (13cm) and overtop the left bank, but this is retained in the landscaped area (greenfield area). The constraint produced by the foot-bridge jointly with the negative slope of the bed causes that the waters overspill of about 0.066m (6.6cm). The water remains over the greenfield area and none of the water spills over the road, parking or the working areas on the site. The water ponds to a level of approximately 36.417m AOD, and current site levels are around 37m AOD

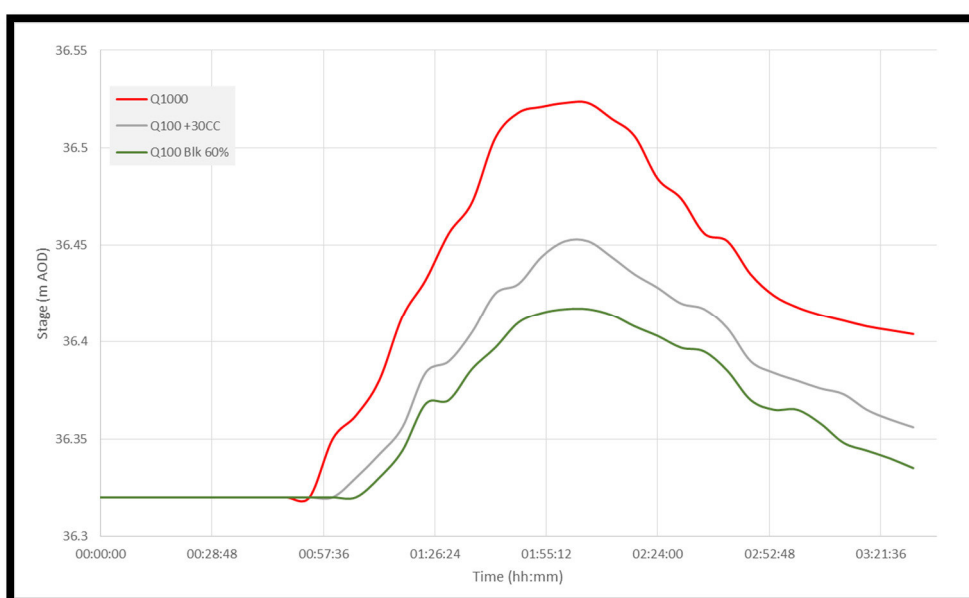


Figure 7 Predicted Stage - Time graph at pond

4.1 Existing Scenarios

The most narrow area is located at the left bank of the pond and it is one of the points where it is very likely to experience the highest water levels. Another key area is at the foot-bridge which is located upstream of the pond around 15 m. Hydraulically, this bridge represents a constraint in the flow that will be denoted in flows greater than Q100, but due to its location, it does not cause any flooding on the developed area of the site.

The modelling results shows that at **Q20** event, the Pond area experiences relatively shallow flooding of about 6 cm at peak stage, without affecting other parts of the site.

For **Q100** which represents a peak flow approximately 0.207 m³/s (207 l/s), the same shallow area of the left bank illustrated the highest water level of about 0.097 m (~10 cm), again without causing any flooding on site.

For **Q100+inflow** and **Q100+inflow2**, two special scenarios were modelled to allow for the existing surface water drainage system on site drains to the culverted watercourse. This inflow was located at the inlet of the 750mm diameter culvert to simulate the accumulation of flow in that reach, assess any reduction of capacity and calculate the possible consequences of that scenario. For both scenarios the simulations show that the maximum water depth is about 0.097 m and is located at the left bank of the pond, similar to the Q100 event.

For **Q100+30%CC**, **Q100+75%CC** and **Q1000year events** the results illustrated that the most affected zone due to the increase of flow is the existing pond area and the footbridge in the landscaped area so fte site, upstream of the proposed development site. None of the scenarios modelled caused any flooding on the existing and proposed developed areas of the site. The modelled flood levels are summarised in Section 4.2, Table 4 of this report.

4.2 Blockage Scenarios

Due to model instability issues, only the culvert blockage scenarios for 30% and 60% for the Q100+ climate change and Q1000 events were performed to show the flowpaths and water depths for those cases. The 90% blockage scenario was attempted but from the .bmp, the simulation crashed out at 1.53 hours before the flood peak and therefore did not generate usable results.

The blockage scenarios were introduced at the entrance of the 750mm diameter culvert. For 30% blockage, the net diameter is 628mm and for 60% blockage this diameter is reduced to 475mm, for 90% this diameter is reduced to 170mm. To avoid unnecessary model runs, the scope of works included blockages scenarios for the 1% and the worst case scenario out of the 1% + climate change and the 0.1% events. Therefore the model only considered blockages for the 100year and 1000year events.

Figure 8 below shows the location of the blockages applied to the culvert entrance on site.

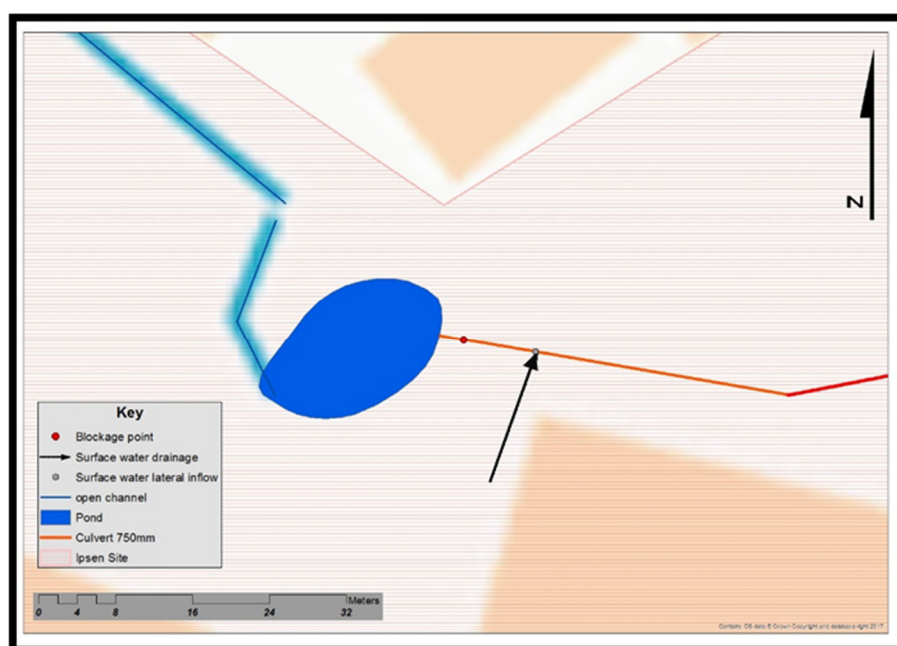


Figure 8 Location of Blockage and Lateral Inflow scenarios

Table 4 below shows a summary of the blockage scenarios modelled and results.

Name	Stage (m AOD)	Depth (m)	Existing development m AOD	Proposed development m AOD
Q20	36.379	0.059	37.05	36.74
Q100	36.417	0.097		
Q100+30% CC	36.452	0.132		
Q100+75%CC	36.504	0.184		
Q100+inflow	36.417	0.097		
Q100+inflow2	36.417	0.097		
Q1000	36.523	0.203		
Blockage Scenarios				
Q100 blk 30%	36.417	0.097		
Q100 blk 60%	36.417	0.097		
Q100 blk 90% **	N/A	N/A		
Q1000 blk 30%	36.523	0.203		
Q1000 blk 60%	36.630	0.310		
Q1000 blk 90% **	N/A	N/A		

** Simulation unstable.

Table 4 Key Model Maximum Results at Access

The Q100 at 30% and 60% blockage scenarios show similar results as the previous simulations without obstruction for the same return periods.

For the Q1000 and 30% blockage, similar results were obtained as the Q1000 without blockage. This model experienced a Mass Balance Error (MBE) only marginally exceeded (> 1%) for approximately 10 min during the initial wetting of the 2D domain and shortly reverts back to the desired range.

For Q100 scenario at 90% blockage the simulation crashed out at 1.53 hours before the peak flow occurred at approximately 2 hours. The same unstable result was obtained for the Q100 event with a 90% blockage. Efforts were made to avoid the model crashing without successful results.

4.3 Sensitivity Results

Additional simulations were modelled to investigate whether the model is overly sensitive to key parameters (namely roughness, boundary and flow). These simulations consists in the following:

- +/- 20% in the 1D Roughness parameter –Roughness
- +/- 20% in the slope gradient at downstream boundary -Gradient
- +/- 20% in Q100 flow -Flow

These values suggest that the model is relatively robust with +/- 20% sensitivity to the **Flow** conditions.

To the +/- 20% **Roughness** resulted in a negligible difference in water levels.

For the +/-20% **Gradient** the results shows that the model is slightly susceptible, plus 20% gradient shows MBE exceeded during initiate the wetting of 2D domain, and returns to desired range.

Figure 9 below shows Cumulative Mass Balance Error (MBE) for sensitivity analysis.

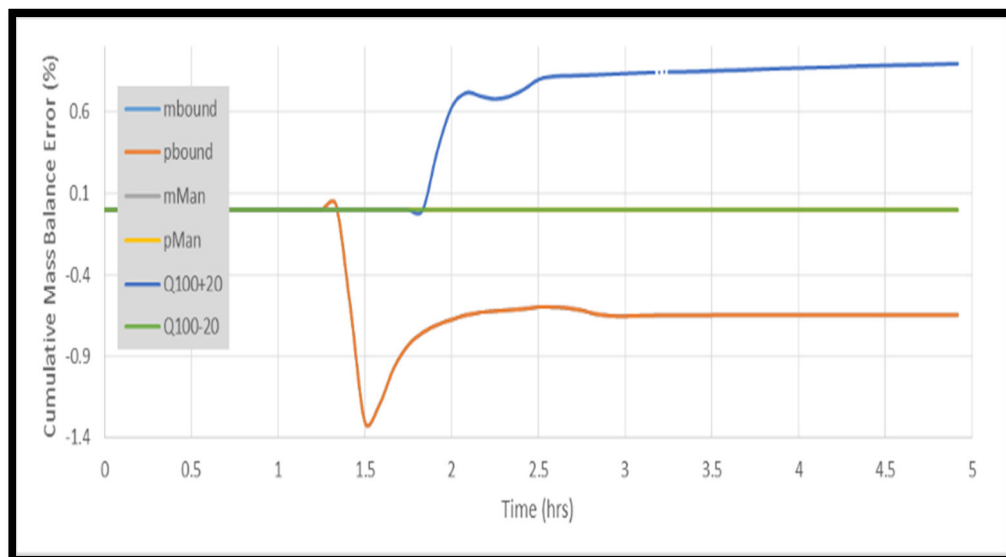


Figure 9 Sensitivity analysis MBE%

5 Summary

This report has assessed the risk of fluvial flooding at Ipsen Biopharm site to different return period design flows and to different blockage scenarios. The following conclusions can be made from this study:

- Water is predicted to pond upstream of the spill/culverts increasing the water level in the existing greenfield area (pond) only. The existing and proposed car parking and buildings on the site are not affected for the modelled events
- The footbridge is predicted to overflow in the greater flow events ($>Q_{100}$), although the excess of water will remain in the Greenfield area and not affect other parts of the site.
- The culverts have sufficient capacity to transport up to Q_{1000} with water levels rising up to 20.3 cm at the pond area only, without affecting other parts of the site.
- The 30% and 60% blockage scenarios have demonstrated that the existing culvert has sufficient capacity to drain the $Q_{100}+CC$ and the Q_{1000} year events flows without causing any flooding on the site.

6 Drawing List

This section provides a table detailing the accompanying drawings contained in Appendix E.

Table 5 List of Accompanying Drawings & Mapped Outputs

<i>Drawing Name</i>	<i>Drawing Number</i>
<i>Existing Unblocked Q20 Maximum Depths</i>	V/R6472/01/G
<i>Existing Unblocked Q100 Maximum Depths</i>	V/R6472/02/G
<i>Existing Unblocked Q100+30%CC Maximum Depths</i>	V/R6472/03/G
<i>Existing Unblocked Q100+75%CC Maximum Depths</i>	V/R6472/10/G
<i>Existing Unblocked Q1000 Maximum Depths</i>	V/R6472/04/G
<i>Existing Unblocked Q100+inflow2 Maximum Depths</i>	V/R6472/05/G
<i>Existing Blocked 30% Q100 Maximum Depths</i>	V/R6472/06/G
<i>Existing Blocked 60% Q100 Maximum Depths</i>	V/R6472/07/G
<i>Existing Blocked 30% Q1000 Maximum Depths</i>	V/R6472/08/G
<i>Existing Blocked 60% Q1000 Maximum Depths</i>	V/R6472/09/G

7 Appendices

Appendix A

Topographic Survey

Appendix B

Catchment Descriptors

Appendix C

FEH Calculation Record

Appendix D

Model Build Log

Appendix E

Flood Maps

Appendix A

Topographic Survey



Site Grid North

Symbols/Abbreviations (Where Applicable):

- +AV: AIR VALVE
- +BB: BELISHA BEACON
- +BH: BOREHOLE
- +BM: BENCHMARK
- +BOL: BOLLARD
- +B/S: BUS STOP
- +CAM: CAMERA
- +CS: CABLE STAY
- +CATV: CATV INSPECTION CHAMBER
- +CBOX: ELECTRICITY BOX, CABLE BOX, ETC.
- +CCTV: C.C.T.V CAMERA
- +C.PIT: CATCH PIT
- +EC: ELECTRICITY COVER
- +EP: ELECTRICITY POLE
- +ER: EARTH ROD
- +FH: FIRE HYDRANT
- +FP: FLAG POLE
- +G: GULLY
- +G: GULLY (ROUND)
- +GV: GAS VALVE
- +IC: INSPECTION COVER (SQUARE)
- +IC: INSPECTION COVER (ROUND)
- +IL: INVERT LEVEL
- +KO: KERB OUTLET
- +L: LETTER BOX
- +LC: LIGHTING COLUMN
- +LP: LAMP POST
- +LP/B: LAMP POST/BUS STOP
- +MH: MANHOLE (SQUARE)
- +MH: MANHOLE (ROUND)
- +MKR: MARKER
- +OP: POST
- +RE: RODDING EYE
- +R/S: ROAD SIGN
- +S/P: SIGN POST
- +SNP: STREET NAME PLATE
- +ST: STOP TAP
- +SV: STOP VALVE
- +TCB: TELEPHONE CALL BOX
- +TL: TRAFFIC LIGHT
- +TP: TELEGRAPH POLE
- +TP/EP: TELEGRAPH POLE/ELECTRIC POLE
- +T/C: TELECOM INSPECTION COVER
- +WO: WATER OUTLET
- +WM: WATER METER
- +X: GATE
- +X: DEFINED POINT
- +X: CONTROL POINT
- +X: TREE (CONIFEROUS)
- +X: TREE (DECIDUOUS)
- +X: FOLIAGE
- +X: HEDGE
- +X: DPC 99.99m DAMP PROOF COURSE LEVEL
- +X: EL 99.99m EAVES LEVEL
- +X: FL 99.99m FLOOR LEVEL
- +X: RL 99.99m RIDGE LEVEL
- +X: SL 99.99m SOFFIT LEVEL
- +X: TL 99.99m THRESHOLD LEVEL

FENCE DESCRIPTIONS:

- B/W: BARBED WIRE FENCE
- C/B: CLOSE BOARDED FENCE
- C/L: CHAIN LINK FENCE
- C/P: CHESTNUT PALING FENCE
- CONC/P: CONCRETE PANEL FENCE
- I/R: IRON RAILING FENCE
- P/R: POST AND RAIL FENCE
- P/W: POST AND WIRE FENCE
- P/C: POST AND CHAIN FENCE
- S/PAL: STEEL PALSADE FENCE
- S/B: SAFETY BARRIER
- T/PAL: TIMBER PALSADE FENCE

Revision Information

Rev	Date	Description

INFORMATION

1) Ordnance Survey co-ordinates and level are derived from OSTN02 and OSGB02, transformed from WGS84.

2) Only services located during the site survey are shown on this plan. Further investigation may be required to ascertain the full extent of the site services.

3) Copyright of this drawing remains the property of PM Surveys UK Ltd. Do not scale from this drawing. In the event of any discrepancy, refer only to PM Surveys UK Ltd.

NOTES

Ordnance Survey Bench Mark Used

Location	Type	Value (m)
1		
2		

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Project

Ipsen Biopharm

Project No: PMS17120

Sheet: A0

Scale: 1:200

Surveyed By: DJ AL

Drawn By: JW

Approved By: PM

Issued: 27/09/17

Appendix B

Catchment Descriptors

VERSION	"FEH CD-R Version	3 exported a	10:37:19 GMT	Wed	04-Oct-17
CATCHMEN	GB	336600	350450 SJ 36600 50450		
CENTROID	GB	336065	350672 SJ 36065 50672		
AREA	0.5075				
ALTBAR	67				
ASPBAR	118				
ASPVAR	0.69				
BFIHOST	0.689				
DPLBAR	0.7				
DPSBAR	37.1				
FARL	1				
FPEXT	0.0049				
FPDBAR	0.02				
FPLOC	-999999				
LDP	1.55				
PROPWET	0.51				
RMED-1H	9.6				
RMED-1D	29.8				
RMED-2D	36.6				
SAAR	721				
SAAR4170	730				
SPRHOST	25.31				
URBCONC1	-999999				
URBEXT199	0				
URBLOC199	-999999				
URBCONC2	-999999				
URBEXT200	0				
URBLOC200	-999999				
C	-0.02417				
D1	0.31767				
D2	0.38726				
D3	0.31524				
E	0.28493				
F	2.40732				
C(1 km)	-0.025				
D1(1 km)	0.314				
D2(1 km)	0.395				
D3(1 km)	0.319				
E(1 km)	0.284				
F(1 km)	2.395				

Appendix C

FEH Calculation Record

Introduction

This document provides a record of the calculations and decisions made during flood estimation. It will often be complemented by more general hydrological information given in a project report. The information given here should enable the work to be reproduced in the future.

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1	METHOD STATEMENT -----	3
2	LOCATIONS WHERE FLOOD ESTIMATES REQUIRED -----	6
3	STATISTICAL METHOD -----	7
4	REVITALISED FLOOD HYDROGRAPH (REFH) METHOD -----	11
5	DISCUSSION AND SUMMARY OF RESULTS -----	12
6	ANNEX - SUPPORTING INFORMATION -----	14

Approval

	Signature	Name and qualifications	For Natural Resources Wales staff: Competence level (see below)
Calculations prepared by:		Alejandro Ortiz MSc	Hydrology and Hydraulic Modeller
Calculations checked by:		Richard Curtis BEng Msc	Senior Hydraulic Modeller
Calculations approved by:			

Competence levels:

- Level 1 – Hydrologist with minimum approved experience in flood estimation
- Level 2 – Senior Hydrologist
- Level 3 – Senior Hydrologist with extensive experience of flood estimation

ABBREVIATIONS

AM	Annual Maximum
AREA	Catchment area (km ²)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
CFMP	Catchment Flood Management Plan
CPRE	Council for the Protection of Rural England
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FSR	Flood Studies Report
HOST	Hydrology of Soil Types
NRFA	National River Flow Archive
POT	Peaks Over a Threshold
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
SAAR	Standard Average Annual Rainfall (mm)
SPR	Standard percentage runoff
SPRHOST	Standard percentage runoff derived using the HOST soil classification
Tp(o)	Time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
URBEXT2000	Revised index of urban extent
WINFAP-FEH	Windows Frequency Analysis Package – used for FEH statistical method

1 Method statement

1.1 Overview of requirements for flood estimates

Item	Comments
Give an overview which includes: - Purpose of study - Approx. no. of flood estimates required - Peak flows or hydrographs? - Range of return periods and locations - Approx. time available	Flood frequency analysis of a unnamed river tributary of the Redwither Brook is necessary to inform the potential flood risks associated with the culvert beneath the site and its capacities, possible blockage scenarios its flood zones and flowpaths. Peak flows will be produced via statistical method to fit the peak, hydrographs will be derived from ReFH.

1.2 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	As the unnamed watercourse of interest for this study is quite small and it's a tributary of the Redwither Brook, none characteristics in FEH Web service for this particular site where located, therefore the analysis has been undertaken on an adjacent catchment with similar characteristics with flows ratio to the catchment size to develop this study and the FCA

1.3 Source of flood peak data

Was the NRFA Peak Flows dataset used? If so, which version? If not, why not? Record any changes made	Yes – Version 5 No modifications were made to the dataset
--	--

1.4 Gauging stations (flow or level)

(at the sites of flood estimates or nearby at potential donor sites)

Water-course	Station name	Gauging auth #	NRFA #	Grid ref	Catch area (km ²)	Type	Start & end of record
Dee (Cheshire)	Clywedog at Bowling Bank		67025	SJ395482	98.6	Simple Crump	10/'75
Dee (Cheshire)	Alyn at Pont-y-Capel		67008	SJ335540	227.1	Asymmetrical compound crump	01/'65
Conway and Clwyd	Clwyd at Ruthin Weir		66005	SJ121592	95.3	Non-standar concrete weir	01/'70
Dee (Cheshire)	Dee at Erbistock Rectory		67002	SJ356413	1028	Velocity-area	01/'32 – 12/'70
Dee (Cheshire)	Dee at Manley Hall		67015	SJ348414	1013.2	Compound Crump weir	10/'37

1.5 Data available at each flow gauging station

Station name	Start and end of data on NRFA Peak Flows	Update for this study?	Suitable for QMED?	Suitable for pooling ?	Data quality check needed?	Other comments on station and flow data quality – e.g. information from NRFA Peak Flows, trends in flood peaks, outliers.
67025	10/'75		No	No		Not suitable for pooling
67008	01/'65		Yes	Yes		Unsuitable Area and SAAR
66005	01/'70		Yes	Yes		Unsuitable Area and SAAR
67002	01/'32 – 12/'70		No	No		Not suitable for pooling
67015	10/'37		No	Yes		Unsuitable for Area, SAAR, FARL, BFHOST and SPRHOST
Give link/reference to any further data quality checks carried out			http://nrfa.ceh.ac.uk/data/station/info/			

1.6 Rating equations

Station name	Type of rating e.g. theoretical, empirical; degree of extrapolation	Rating review needed?	Reasons – e.g. availability of recent flow gaugings, amount of scatter in the rating.
Give link/reference to any rating reviews carried out			

1.7 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available?	Source of data and licence reference.	Date obtained	Details
Check flow gaugings (if planned to review ratings)					
Historic flood data – give link to historic review if carried out.					
Flow data for events					
Rainfall data for events					
Results from previous studies					
Other data or information (e.g. groundwater, tides)					

1.8 Initial choice of approach

Is FEH appropriate? (it may not be for very small, heavily urbanised or complex	FEH statistical method to obtain peak flows, although catchment is too small to be identified in the CEH
---	--

catchments) If not, describe other methods to be used.	catchment descriptors, this method of transfer is considered more suitable (e.g. than IoH124) in accordance with SC090031										
Outline the conceptual model, addressing questions such as: - Where are the main sites of interest? - What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides...) - Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? - Is there a need to consider temporary debris dams that could collapse?	Ipsen Biopharm at Wrexham Industrial Estate is main site of interest. The site is crossed by a small –unnamed- watercourse which is stored in a pond and then transported through a culvert to the Redwither Brook downstream, therefore any possible blockage will reduce the conveyance. Site is approximately 36 m AOD, therefore not tidal.										
Any unusual catchment features to take into account? e.g. - highly permeable (BFIHOST>0.65) – consider permeable catchment adjustment for statistical method if SPRHOST<20% - highly urbanised – consider FEH Statistical or other alternatives; consider method that can account for differing sewer and topographic catchments - pumped watercourse – consider lowland catchment version of rainfall-runoff method - major reservoir influence (FARL<0.90) – consider flood routing - extensive floodplain storage – consider choice of method carefully	<table> <tr> <td></td> <td>Calculated</td> </tr> <tr> <td>BFIHOST >0.65</td> <td>(0.6890)</td> </tr> <tr> <td>SPRHOST > 20</td> <td>(25.31%)</td> </tr> <tr> <td>URBEXT2000 < 0.125</td> <td>(0.000)</td> </tr> <tr> <td>FARL > 0.9</td> <td>(1.000)</td> </tr> </table> No known pumps Unlikely extensive FP One small pond (likely not accounted for in FARL) could be rated down to 0.99, but is included in model simulation. Whilst BFIHost is > 0.65 SPRHost is > 20.		Calculated	BFIHOST >0.65	(0.6890)	SPRHOST > 20	(25.31%)	URBEXT2000 < 0.125	(0.000)	FARL > 0.9	(1.000)
	Calculated										
BFIHOST >0.65	(0.6890)										
SPRHOST > 20	(25.31%)										
URBEXT2000 < 0.125	(0.000)										
FARL > 0.9	(1.000)										
Initial choice of method(s) and reasons Will the catchment be split into subcatchments? If so, how?											
Software to be used (with version numbers)	WINFAP-FEH version 3.0.003										

2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

2.1 Summary of subject sites

Site code	Watercourse	Site	Easting	Northin g	AREA on FEH Web Service (km ²)	Revised AREA if altered
RC6472	Unnamed	Ipsen Biopharm	336065	350672	0.51	
Reasons for choosing above locations		Site of interest				

2.2 Important catchment descriptors at each subject site (incorporating any changes made)

Site code	FA RL	PROPWE T	BFIHOS T	DPLBA R (km)	DPSBA R (m/km)	SAA R (mm)	SPRHOS T	URBE XT	FPEXT
RC6472	1	0.51	0.689	0.70	37.1	721	25.31	0.000	0.0049

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (refer to maps if needed)	Catchment compared against Terrain 50 contouring
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	According to the British Geological Survey and Landis Soilscales, the catchment is composed by two different soil types, upstream the catchment by Freely draining slightly acid sandy soils and lower catchment is composed by slowly permeable seasonally wet loamy and clayey soils
Source of URBEXT	FEH webservice 2000 listed in document
Method for updating of URBEXT	N/A

3 Statistical method

3.1 Search for donor sites for QMED (if applicable)

Comment on potential donor sites Mention: - Number of potential donor sites available - Distances from subject site - Similarity in terms of AREA, BFIHOST, FARL and other catchment descriptors - Quality of flood peak data Include a map if necessary. Note that donor catchments should usually be rural.	Detailed in S 1.4
--	-------------------

3.2 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing or rejecting	Method (AM or POT)	Adjustment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjustment ratio (A/B)
Which version of the urban adjustment was used for QMED at donor sites, and why? Note: The guidelines recommend great caution in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.8).						

3.3 Overview of estimation of QMED at each subject site

Site code	Method	Initial estimate of QMED (m ³ /s)	Data transfer						Final estimate of QMED (m ³ /s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroid s d _{ij} (km)	Power term, a	Moderated QMED adjustment factor, (A/B) ^a	If more than one donor		
							Weight	Weighted average adjustment	
RC6472		0.080							0.080
Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?									

Site code	Method	Initial estimate of QMED (m ³ /s)	Data transfer						Final estimate of QMED (m ³ /s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids s _{dij} (km)	Power term, a	Moderated QMED adjustment factor, (A/B) ^a	If more than one donor		
							Weight	Weighted average adjustment	
Which version of the urban adjustment was used for QMED, and why?				No urban adjustment needed					
Notes Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer; CD – Catchment descriptors alone. When QMED is estimated from POT data, it should also be adjusted for climatic variation. Details should be added. When QMED is estimated from catchment descriptors, the revised 2008 equation from Science Report SC050050 Error! Bookmark not defined. should be used. If the original FEH equation has been used, say so and give the reason why. The guidelines recommend great caution in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.8). The adjustment method used in WINFAP-FEH v3.0.003 is likely to overestimate adjustment factors for such catchments. In this case the only reliable flood estimates are likely to be derived from local flow data. The data transfer procedure is from Science Report SC050050. The QMED adjustment factor A/B for each donor site is given in Table 3.3. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is (A/B) ^a times the initial estimate from catchment descriptors. If more than one donor has been used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the penultimate column.									

3.4 Derivation of pooling groups

The composition of the pooling groups is given in the Annex. Several subject sites may use the same pooling group.

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons Note also any sites that were investigated but retained in the group.	Weighted average L-moments, L-CV and L-skew, (before urban adjustment)
RC6472	RC6472		49006 Camel @ Camelford – Short record, only eight years long, resulting in discordancy; hence removed. 49005 Bollingey @ Bolingey Cocks Bridge – Short record, only 5 years of data, result in discordancy; hence removed. 47022 Tory Brook @ Newnham Park – no major concerns other than China Works affecting FARL. Although suitable this site was removed to Lower Z values and improve homogeneity. 206006 Annalong @ Recorder – Only recommended for pooling given representative curve, relatively high SPR. Although suitable this site was removed to Lower Z values and improve homogeneity. 27073 Brompton @ Snainton Ings - Heterogeneous & Discordant due to the unusually low SPRHost	L-moments 0.236 L-skewness 0.291
Notes Pooling groups were derived using the revised procedures from Science Report SC050050 (2008). Amend if not applicable. The weighted average L-moments, before urban adjustment, can be found at the bottom of the Pooling-group details window in WINFAP-FEH.				

3.5 Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (3.4)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape) after adjustments	Growth factor for 100-year return period
RC6472	P	RC6472	GL (preferred to GEV)			3.209

Notes

Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis

A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters.

Urban adjustments to growth curves should use the version 3 option in WINFAP-FEH: Kjeldsen (2010).

Growth curves were derived using the revised procedures from Science Report SC050050 (2008). **Amend if not applicable.**

Any relevant frequency plots from WINFAP-FEH, particularly showing any comparisons between single-site and pooled growth curves (including flood peak data on the plot), should be shown here or in a project report.

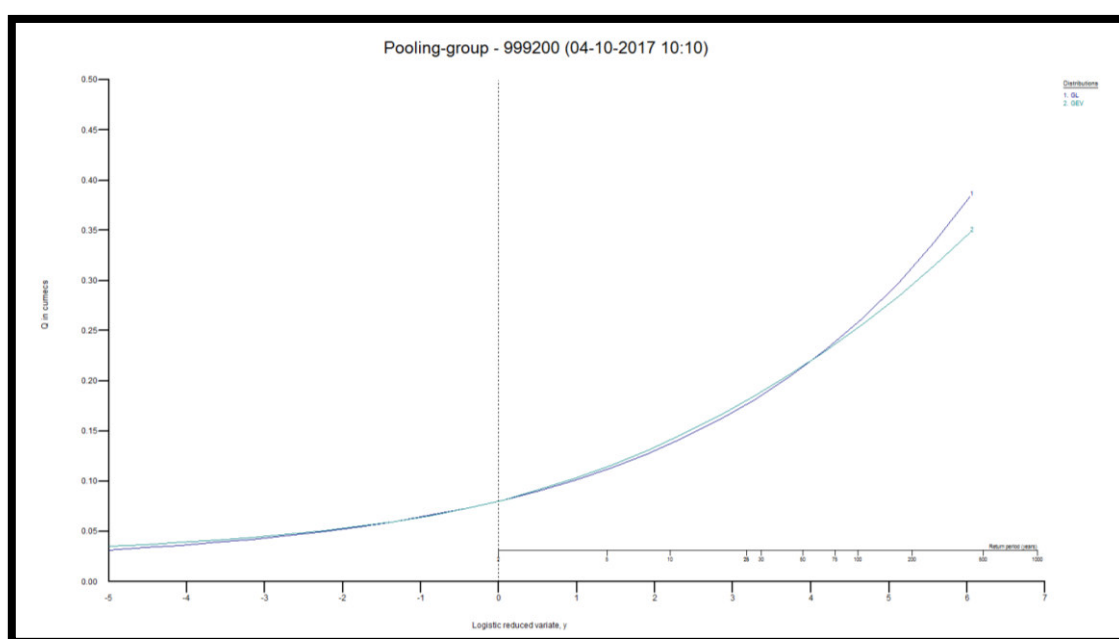


Figure 1 Flood Frequency Cruves – GL (Black) and GEV (Blue). Source: Winfap-FEH 3

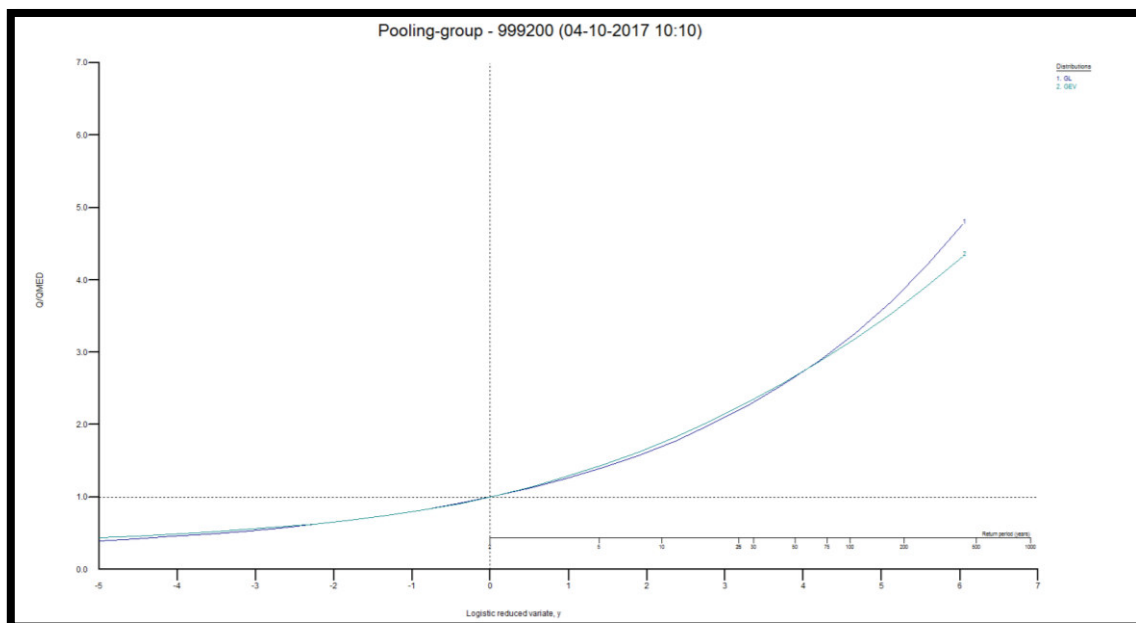


Figure 2 Growth curve Q/Q_{med} GL (Black), GEV (Blue). Source: Winfap-FEH 3

3.6 Flood estimates from the statistical method

Site code	Flood peak (m ³ /s) for the following return periods (in years)								
	2	10	25	30	50	100	200	500	1000
RC6472	.070	0.137	0.177	0.186	0.214	0.258	0.312	0.403	0.489

4 Revitalised flood hydrograph (ReFH) method

4.1 Parameters for ReFH model

Note: If parameters are estimated from catchment descriptors, they are easily reproducible so it is not essential to enter them in the table.

Site code	Method: OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer (give details)	T _p (hours) Time to peak	C _{max} (mm) Maximum storage capacity	BL (hours) Baseflow lag	BR Baseflow recharge
RC6472	CD	0.956	492.320	28.343	1.969
Brief description of any flood event analysis carried out (further details should be given below or in a project report)					

4.2 Design events for ReFH method

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)	Storm area for ARF (if not catchment area)
RC6472	R	Winter	1.649	
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			No change to durations expected. Scaled to stat analysis also for Morris	

4.3 Flood estimates from the ReFH method

Site code	Flood peak (m ³ /s) for the following return periods (in years)				Flood Modeller Pro
	2	30	100	1000	
RC6472	0.176	1.676	0.484	0.875	

5 Discussion and summary of results

5.1 Comparison of results from different methods

This table compares peak flows from the ReFH method with those from the FEH Statistical method at each site for two key return periods.

Site code	Return period 2 years			Return period 100 years		
	Statistical	ReFH	Ratio (ReFH / Statistical)	Statistical	ReFH	Ratio (ReFH / Statistical)
RC6472	0.080	0.176	2.2	0.258	0.484	1.876

5.2 Final choice of method

Choice of method and reasons – include reference to type of study, nature of catchment and type of data available.	Statistical peak flow estimates are typically preferred to the ReFH methods. The Generalised Logistic (GL) extrapolation is preferred over GEV. Catchment though small with high BFIHost is considered acceptable for statistical method.
--	---

5.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	Catchment descriptors have initially been used to estimate the value of Qmed based on the updated method for determining Qmed provided in Science Report SC050050/SR and Environment Agency Operational Instruction document 940_08 issued on 14 th April 2008. Assumes statistical method is suitable for small catchment
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed	Although Stat estimates for 200 and 500 years have been listed pooling group was (~500 yrs) and should therefore be used with caution if required. 1000yr estimate is derived from Morris method in final results.
Give what information you can on uncertainty in the results – e.g. confidence limits for the QMED estimates using FEH 3 12.5 or the factorial standard error from Science Report SC050050 (2008).	
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	Results have been derived from detailed investigation and therefore should be suitable for other studies in the area. The determination of the 1000 year flood peak flow needs further calibration data to be valuable to future studies. Care needs to be taken with the high BFIHost and this should be considered in future studies
Give any other comments on the study, for example suggestions for additional work.	

5.4 Checks

Are the results consistent, for example at confluences?	
What do the results imply regarding the return periods of floods during the period of record?	
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	Yes see S 3.5 Growth factor of 3.209
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	
What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies?	100 yr stat = (258 l/s)/(51ha) = l/s/ha = 5.06 l/s/ha
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	
Are the results compatible with the longer-term flood history?	N/A
Describe any other checks on the results	Natural Resources Wales for North Wales determines climate change allowances (c = 30%, u = 75%)

5.5 Final results

Discuss here how you have ratioed down (by how much) and why to create the final results for the catchment of interest

Site code	Flood peak (m ³ /s) for the following return periods (in years)								
	2	25	30	50	100	100+30%	100+75%	200	Morris
RC6472	0.070	0.163	0.163	0.188	0.207	0.269	0.362	0.275	0.412

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, name of hydraulic model, or reference to table below)

Separate .ied files in modelling folder

6 Annex - supporting information

6.1 Pooling group composition

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	1.972	38	1.84	0.165	0.331	1.144
45816 (Haddeo @ Upton)	3.762	22	3.489	0.314	0.415	0.73
27051 (Crimple @ Burn Bridge)	3.898	43	4.514	0.219	0.154	1.157
28033 (Dove @ Hollinsclough)	4.021	36	4.225	0.24	0.415	1.038
91802 (Allt Leachdach @ Intake)	4.314	34	6.35	0.153	0.257	0.798
54022 (Severn @ Plynlimon Flume)	4.628	38	14.988	0.156	0.171	1.726
71003 (Croasdale Beck @ Croasdale Flume)	4.641	37	10.9	0.212	0.323	0.238
25011 (Langdon Beck @ Langdon)	4.709	28	15.878	0.238	0.318	1.191
25003 (Trout Beck @ Moor House)	4.746	42	15.142	0.172	0.293	0.433
25019 (Leven @ Easby)	4.751	37	4.989	0.342	0.39	1.007
26802 (Gypsy Race @ Kirby Grindalythe)	4.819	16	0.112	0.274	0.274	0.557
49005 (Bollingey Stream @ Bolingey Cocks Bridge)	4.886	5	5.777	0.288	0.256	0.901
27010 (Hodge Beck @ Bransdale Weir)	5.085	41	9.42	0.224	0.293	0.057
44008 (South Winterbourne @ Winterbourne Steepleton)	5.189	36	0.434	0.418	0.344	2.3
22003 (Usway Burn @ Shillmoor)	5.310	13	16.17	0.282	0.311	1.105
203046 (Rathmore Burn @ Rathmore Bridge)	5.399	33	10.77	0.136	0.104	1.617
Total		499				
Weighted means		499		0.236	0.291	

6.2 Additional supporting information

Appendix D

Model Build Log

No	Name	type	Notes	File location
1	V_RC6472_IPSEN_Final_V3.dat	.dat	Final version of the 1D model	rc6400s\rc6472-ipsen-biopharm-fca\4-Technical\Calculations\Water\IPSEN_1D\Build
2	V_RC6472_IPSEN_Final_V5_Inflow.dat	.dat	1D model with lateral inflow Worst Case scenario	rc6400s\rc6472-ipsen-biopharm-fca\4-Technical\Calculations\Water\IPSEN_1D\Build
3	V_RC6472_IPSEN_Final_V6_Inflow.dat	.dat	1D model with lateral inflow Worst Case scenario	rc6400s\rc6472-ipsen-biopharm-fca\4-Technical\Calculations\Water\IPSEN_1D\Build
Sensitivity analysis			Notes	File location
4	V_RC6472_IPSEN_Final_V3+Manning.dat	.dat	plus 30% Manning values at 1D model	rc6400s\rc6472-ipsen-biopharm-fca\4-Technical\Calculations\Water\IPSEN_1D\Build
5	V_RC6472_IPSEN_Final_V3-Manning.dat	.dat	minus 30% Manning values at 1D model	rc6400s\rc6472-ipsen-biopharm-fca\4-Technical\Calculations\Water\IPSEN_1D\Build
Blockage scenarios			Notes	File location
6	V_RC6472_IPSEN_Final_V3_30Blk.dat	.dat	Assumed 30% blockage scenario ~ 628mm D	rc6400s\rc6472-ipsen-biopharm-fca\4-Technical\Calculations\Water\IPSEN_1D\Build
7	V_RC6472_IPSEN_Final_V3_60Blk.dat	.dat	Assumed 60% blockage scenario ~ 475mm D	rc6400s\rc6472-ipsen-biopharm-fca\4-Technical\Calculations\Water\IPSEN_1D\Build
8	V_RC6472_IPSEN_Final_V3_90Blk.dat	.dat	Assumed 90% blockage scenario ~ 220mm D	rc6400s\rc6472-ipsen-biopharm-fca\4-Technical\Calculations\Water\IPSEN_1D\Build
ISIS Event File			Notes	File location
9	IPSEN_20yr_unblocked.ief	.ief	20 yr return period	MODEL_IPSEN_Final\IPSEN_1D\Run
10	IPSEN_100yr_unblocked.ief	.ief	100 yr return period	MODEL_IPSEN_Final\IPSEN_1D\Run
11	IPSEN_100yr_plusinflow.ief	.ief	100 yr return period plus inflow in pipes	MODEL_IPSEN_Final\IPSEN_1D\Run
12	IPSEN_100yr_plusinflowWC.ief	.ief	100 yr return period plus inflow in pipes WC	MODEL_IPSEN_Final\IPSEN_1D\Run
13	IPSEN_100yr+30CC_unblocked.ief	.ief	100 + CC (30%) yr return period	MODEL_IPSEN_Final\IPSEN_1D\Run
14	IPSEN_100yr+75CC_unblocked.ief	.ief	100 + CC (75%) yr return period	MODEL_IPSEN_Final\IPSEN_1D\Run
15	IPSEN_1000Yr_unblocked.ief	.ief	1000 yr Morris return period	MODEL_IPSEN_Final\IPSEN_1D\Run
16	IPSEN_100yr_30blockage.ief	.ief	100 yr return period 30% blockage	MODEL_IPSEN_Final\IPSEN_1D\Run
17	IPSEN_100yr_60blockage.ief	.ief	100 yr return period 60% blockage	MODEL_IPSEN_Final\IPSEN_1D\Run
18	IPSEN_100yr_90blockage.ief	.ief	100 yr return period 90% blockage	MODEL_IPSEN_Final\IPSEN_1D\Run
19	IPSEN_1000yr_30blockage.ief	.ief	1000 yr return period 30% blockage	MODEL_IPSEN_Final\IPSEN_1D\Run
20	IPSEN_1000yr_60blockage.ief	.ief	1000 yr return period 60% blockage	MODEL_IPSEN_Final\IPSEN_1D\Run
21	IPSEN_1000yr_90blockage.ief	.ief	1000 yr return period 90% blockage	MODEL_IPSEN_Final\IPSEN_1D\Run
ISIS Event Data			Notes	File location
22	MinusBoundary.ied	.ied	Sensitivity analysis -20% gradient	MODEL_IPSEN_Final\IPSEN_1D\Flows
23	PlusBoundary.ied	.ied	Sensitivity analysis +20% gradient	MODEL_IPSEN_Final\IPSEN_1D\Flows
24	Tr20.ied	.ied	20 yr return period event	MODEL_IPSEN_Final\IPSEN_1D\Flows
25	Tr100.ied	.ied	100 yr return period event	MODEL_IPSEN_Final\IPSEN_1D\Flows
26	Tr100Plusinflow.ied	.ied	100 yr return period event plus inflow at culvert	MODEL_IPSEN_Final\IPSEN_1D\Flows
27	Tr100PlusinflowWC.ied	.ied	100 yr return period event plus inflow at culvert Worst Case	MODEL_IPSEN_Final\IPSEN_1D\Flows
28	Tr100+20sa.ied	.ied	Sensitivity analysis 100 yr return period +20%	MODEL_IPSEN_Final\IPSEN_1D\Flows
29	Tr100+CC.ied	.ied	Sensitivity analysis 100 yr return period +100%	MODEL_IPSEN_Final\IPSEN_1D\Flows
30	Tr100-20sa.ied	.ied	Sensitivity analysis 100 yr return period -20%	MODEL_IPSEN_Final\IPSEN_1D\Flows
31	Tr1000Morris.ied	.ied	1000Morris yr return period event	MODEL_IPSEN_Final\IPSEN_1D\Flows
Sensitivity Analysis			Notes	File location
32	IPSEN_100yr_+20SA.ief	.ief	Plus 20% flow CC	MODEL_IPSEN_Final\IPSEN_1D\Run
33	IPSEN_100yr_-20SA.ief	.ief	Minus 20% flow CC	MODEL_IPSEN_Final\IPSEN_1D\Run
34	IPSEN_100yr_MinManning.ief	.ief	Plus 20% Manning	MODEL_IPSEN_Final\IPSEN_1D\Run
35	IPSEN_100yr_PlusManning.ief	.ief	Minus 20% Manning	MODEL_IPSEN_Final\IPSEN_1D\Run
36	IPSEN_100yr_MinusBoundary.ief	.ief	Minus 20% gradient	MODEL_IPSEN_Final\IPSEN_1D\Run
37	IPSEN_100yr_PlusBoundary.ief	.ief	Plus 20% gradient	MODEL_IPSEN_Final\IPSEN_1D\Run

Tuflow Control Files

	Name	File	Location	Note
1	<i>RC6472_171005_IPSEN_~s~_~e~.tcf</i>	<i>.tcf</i>	MODEL_IPSEN_Final_V6\IPSEN_2D\Tuflow\runs	Tuflow Control File, projection, events, output format, stime steps
2	<i>RC6472_Event.tef</i>	<i>.tef</i>	MODEL_IPSEN_Final_V6\IPSEN_2D\Tuflow\runs	Tuflow Event File, where every event is called
3	<i>RC6472_171005_IPSEN.tgc</i>	<i>.tgc</i>	MODEL_IPSEN_Final_V6\IPSEN_2D\Tuflow\model	Tuflow Geometry Control, Load the DTM, cell size, active/inactive cells
4	<i>RC6472_IPSEN.tbc</i>	<i>.tbc</i>	MODEL_IPSEN_Final_V6\IPSEN_2D\Tuflow\model	Tuflow Boundary Control, gradient values & Boundary conditions DS
5	<i>RC6472_IPSEN_Mannings.tmf</i>	<i>.tmf</i>	MODEL_IPSEN_Final_V6\IPSEN_2D\Tuflow\model	Tuflow Material File, Manning value for each feature

Shape files

No	Name	Content	Location
1	Projection.shp	Input/Output projection shp British National Grid (EPSG 27700)	MODEL_IPSEN_Final\IPSEN_2D\Tuflow\model\QGIS\Projection.shp
2	2d_mat_IPSEN_R.shp	materials, manning digitized by hand	MODEL_IPSEN_Final\IPSEN_2D\Tuflow\model\QGIS\2d_mat_IPSEN_R.shp
3	ISIS_network_FM_L.shp	FloodModeller network Cross sections	MODEL_IPSEN_Final\IPSEN_2D\Tuflow\model\QGIS\ISIS_network_FM_L.shp
4	ISIS_nodes_RC62472_P.shp	Nodes from FloodModeller	MODEL_IPSEN_Final\IPSEN_2D\Tuflow\model\QGIS\ISIS_nodes_RC62472_P.shp
5	2d_zln_RC62472_BankTop_L.shx	2D bank Left and Right Banks (boundary active area)	MODEL_IPSEN_Final\IPSEN_2D\Tuflow\model\QGIS\2d_zln_RC62472_BankTop_L.shx
6	2d_zln_RC62472_BankTop_P.shx	2D bank Left and Right bank points (joining points)	MODEL_IPSEN_Final\IPSEN_2D\Tuflow\model\QGIS\2d_zln_RC62472_BankTop_P.shx
7	2D_Code_Inactive_RC62472_R.shp	2D inactive area code 0 means inactive	MODEL_IPSEN_Final\IPSEN_2D\Tuflow\model\QGIS\2D_Code_Inactive_RC62472_R.shp
8	2D_Code_active_RC62472_R.shp	2D active area code 1 means active	MODEL_IPSEN_Final\IPSEN_2D\Tuflow\model\QGIS\2D_Code_active_RC62472_R.shp
9	sj3750_dtm_1m.asc	LiDAR topography of region (1m)	MODEL_IPSEN_Final\IPSEN_2D\Tuflow\model\DTM\sj3750_dtm_1m.asc
10	2d_bc_HQ_RC6472_L.shp	Boundary condition downstream current condition	MODEL_IPSEN_Final\IPSEN_2D\Tuflow\model\QGIS\2d_bc_HQ_RC6472_L.shp
11	2d_bc_HQ_RC6472_minus20_L.shp	Boundary condition downstream-sensitivity analysis 20% plus gradient	MODEL_IPSEN_Final\IPSEN_2D\Tuflow\model\QGIS\2d_bc_HQ_RC6472_minus20_L.shp
12	2d_bc_HQ_RC6472_plus20_L.shp	Boundary condition downstream-sensitivity analysis 20% minus gradient	MODEL_IPSEN_Final\IPSEN_2D\Tuflow\model\QGIS\2d_bc_HQ_RC6472_plus20_L.shp
13	2d_bc_hx_RC62472_L.shp	2D cross section connection CN or bank boundary HX	MODEL_IPSEN_Final\IPSEN_2D\Tuflow\model\QGIS\2d_bc_hx_RC62472_L.shp
14	2d_loc_RC62472_L.shp	Boundary condition downstream current condition	MODEL_IPSEN_Final\IPSEN_2D\Tuflow\model\QGIS\2d_loc_RC62472_L.shp
15	2d_zln_RC62472_FFL_R.shp	Features from FFL from survey	MODEL_IPSEN_Final_V3\IPSEN_2D\Tuflow\model\QGIS\2d_zln_RC62472_FFL_R.shp
16	2d_zln_RC62472_contour_L.shp	Contour lines from Topographical survey	MODEL_IPSEN_Final_V3\IPSEN_2D\Tuflow\model\QGIS\2d_zln_RC62472_contour_L.shp
17	2d_zln_RC62472_feature_L.shp	Features, banks, walls from topographical survey	MODEL_IPSEN_Final_V3\IPSEN_2D\Tuflow\model\QGIS\2d_zln_RC62472_feature_L.shp
18	DataSurvey.shp	Spot points and FFL	MODEL_IPSEN_Final_V2\IPSEN_2D\Tuflow\model\QGIS\DataSurvey.shp
19	contoursTS.shp	Contours from Topo survey	MODEL_IPSEN_Final_V2\IPSEN_2D\Tuflow\model\QGIS\contoursTS.shp

Event File

				.ied			
Event		.dat	.ief	in	peak flow	out (2d)	Run?
1	IPSEN_20yr_unblocked.ief	V_RC6472_IPSEN_Final_V3.dat	IPSEN_20yr_unblocked.ief	Q20	0.147	Exist	Y
2	IPSEN_100yr_unblocked.ief		IPSEN_100yr_unblocked.ief	Q100	0.207	Exist	Y
3	IPSEN_100yr_plusinflow.ief	V_RC6472_IPSEN_Final_V5_Inflow.dat	IPSEN_100yr_plusinflow.ief	Q100	0.207	Exist	Y
4	IPSEN_100yr_plusinflowWC.ief	V_RC6472_IPSEN_Final_V6_Inflow.dat	IPSEN_100yr_plusinflowWC.ief	Q100	0.207	Exist	Y
5	IPSEN_100yr+30CC_unblocked.ief	V_RC6472_IPSEN_Final_V3.dat	IPSEN_100yr+30CC_unblocked.ief	Q100+30CC	0.269	Exist	Y
6	IPSEN_100yr+75CC_unblocked.ief		IPSEN_100yr+75CC_unblocked.ief	Q100+75CC	0.362	Exist	Y
7	IPSEN_1000Yr_unblocked.ief		IPSEN_1000Yr_unblocked.ief	Q1000 Morris	0.412	Exist	Y
8	IPSEN_100yr_30blockage.ief	V_RC6472_IPSEN_Final_V3_30Blk.dat	IPSEN_100yr_30blockage.ief	Q100	0.207	Ex30Blk	Y
9	IPSEN_100yr_60blockage.ief	V_RC6472_IPSEN_Final_V3_60Blk.dat	IPSEN_100yr_60blockage.ief	Q100	0.207	Ex60Blk	Y
10	IPSEN_100yr_90blockage.ief	V_RC6472_IPSEN_Final_V3_90Blk.dat	IPSEN_100yr_90blockage.ief	Q100	0.207	Ex90Blk	N
11	IPSEN_1000yr_30blockage.ief	V_RC6472_IPSEN_Final_V3_30Blk.dat	IPSEN_1000yr_30blockage.ief	Q1000 Morris	0.412	Ex30Blk	Y
12	IPSEN_1000yr_60blockage.ief	V_RC6472_IPSEN_Final_V3_60Blk.dat	IPSEN_1000yr_60blockage.ief	Q1000 Morris	0.412	Ex60Blk	Y
13	IPSEN_1000yr_90blockage.ief	V_RC6472_IPSEN_Final_V3_90Blk.dat	IPSEN_1000yr_90blockage.ief	Q1000 Morris	0.412	Ex90Blk	N
14	IPSEN_100yr_+20SA.ief	V_RC6472_IPSEN_Final_V3.dat	IPSEN_100yr_+20SA.ief	Q100+20%	0.248	Exist	Y
15	IPSEN_100yr_-20SA.ief	V_RC6472_IPSEN_Final_V3.dat	IPSEN_100yr_-20SA.ief	Q100-20%	0.248	Exist	Y
16	IPSEN_100yr_MinManning.ief	V_RC6472_IPSEN_Final_V3-Manning.dat	IPSEN_100yr_MinManning.ief	Q100	0.207	Exist	Y
17	IPSEN_100yr_PlusManning.ief	V_RC6472_IPSEN_Final_V3+Manning.dat	IPSEN_100yr_PlusManning.ief	Q100	0.207	Exist	Y
18	IPSEN_100yr_MinusBoundary.ief	V_RC6472_IPSEN_Final_V3.dat	IPSEN_100yr_MinusBoundary.ief	Q100	0.207	Exist	Y
19	IPSEN_100yr_PlusBoundary.ief	V_RC6472_IPSEN_Final_V3.dat	IPSEN_100yr_PlusBoundary.ief	Q100	0.207	Exist	Y

Appendix E

Flood Maps



Legend

Flood Depth (m)

0.00m
0.05m
0.10m
0.15m
0.20m
0.25m
0.30m
0.35m
0.40m
0.45m
0.50m
Existing Pond High Water Level

**OPUS**

Wrexham Office
+44 1978 368100

Opus House, Yale Business
Village, Wrexham Tech.
Park, Wrexham LL13 7YL

AO	VM	MAW	25.10.17
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V-R6472.01	1:1000 @ A3
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IPSEN BIOPHARM
FLOOD CONSEQUENCES
ASSESSMENT

5% AEP EVENT

V/R6472/01/G	01	A
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Legend

Flood Depth (m)

0.00m
0.05m
0.10m
0.15m
0.20m
0.25m
0.30m
0.35m
0.40m
0.45m
0.50m
Existing Pond High Water Level

**OPUS**

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AO	VM	MAW	25.10.17
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V-R6472.02	1:1000 @ A3
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IPSEN BIOPHARM FLOOD CONSEQUENCES ASSESSMENT
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1% AEP EVENT

V/R6472/02/G	02	A
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Legend

Flood Depth (m)

0.00m
0.05m
0.10m
0.15m
0.20m
0.25m
0.30m
0.35m
0.40m
0.45m
0.50m
Existing Pond High Water Level

**OPUS**

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AO	VM	MAW	25.10.17
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V-R6472.03	1:1000 @ A3
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IPSEN BIOPHARM
FLOOD CONSEQUENCES
ASSESSMENT

1% AEP + CC

V/R6472/03/G	03	A
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Legend

Flood Depth (m)

0.00m
0.05m
0.10m
0.15m
0.20m
0.25m
0.30m
0.35m
0.40m
0.45m
0.50m
Existing Pond High Water Level

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AO	VM	MAW	25.10.17
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V-R6472.04	1:1000 @ A3
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IPSEN BIOPHARM
FLOOD CONSEQUENCES
ASSESSMENT

0.1% AEP EVENT

V/R6472/04/G	04	A
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Legend

Flood Depth (m)

0.00m
0.05m
0.10m
0.15m
0.20m
0.25m
0.30m
0.35m
0.40m
0.45m
0.50m
Existing Pond High Water Level

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AO	VM	MAW	25.10.17
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V-R6472.05	1:1000 @ A3
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IPSEN BIOPHARM
FLOOD CONSEQUENCES
ASSESSMENT

1% AEP EVENT WITH SURFACE WATER
DRAINAGE- INFLOW2

V/R6472/05/G	09	A
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Legend

Flood Depth (m)

0.00m
0.05m
0.10m
0.15m
0.20m
0.25m
0.30m
0.35m
0.40m
0.45m
0.50m
Existing Pond High Water Level

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Park, Wrexham LL13 7YL

AO	VM	MAW	25.10.17
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V-R6472.06	1:1000 @ A3
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IPSEN BIOPHARM
FLOOD CONSEQUENCES
ASSESSMENT

1% AEP EVENT WITH 30% INLET
BLOCKAGE

V/R6472/06/G	06	A
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Legend

Flood Depth (m)

0.00m
0.05m
0.10m
0.15m
0.20m
0.25m
0.30m
0.35m
0.40m
0.45m
0.50m
Existing Pond High Water Level

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AO	VM	MAW	25.10.17
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V-R6472.07	1:1000 @ A3
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IPSEN BIOPHARM
FLOOD CONSEQUENCES
ASSESSMENT

1% AEP EVENT WITH 60% INLET
BLOCKAGE

V/R6472/07/G	07	A
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Legend

Flood Depth (m)

0.00m
0.05m
0.10m
0.15m
0.20m
0.25m
0.30m
0.35m
0.40m
0.45m
0.50m
Existing Pond High Water Level

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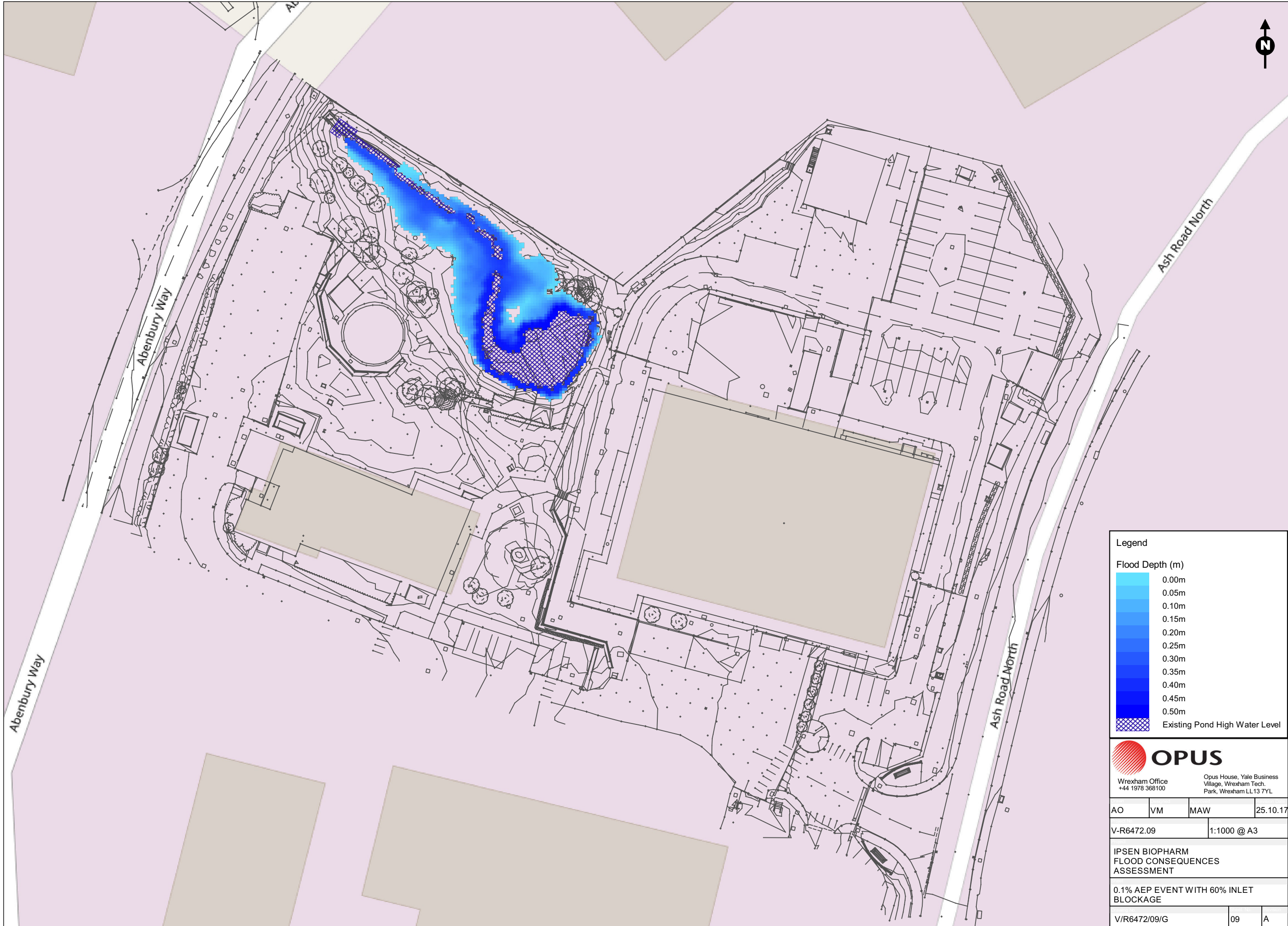
AO	VM	MAW	25.10.17
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V-R6472.08	1:1000 @ A3
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IPSEN BIOPHARM
FLOOD CONSEQUENCES
ASSESSMENT

0.1% AEP EVENT WITH 30% INLET
BLOCKAGE

V/R6472/08/G	08	A
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Legend

Flood Depth (m)

0.00m
0.05m
0.10m
0.15m
0.20m
0.25m
0.30m
0.35m
0.40m
0.45m
0.50m
Existing Pond High Water Level

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AO	VM	MAW	25.10.17
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V-R6472.09	1:1000 @ A3
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IPSEN BIOPHARM
FLOOD CONSEQUENCES
ASSESSMENT

0.1% AEP EVENT WITH 60% INLET
BLOCKAGE

V/R6472/09/G	09	A
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Legend

Flood Depth (m)

0.00m
0.05m
0.10m
0.15m
0.20m
0.25m
0.30m
0.35m
0.40m
0.45m
0.50m
Existing Pond High Water Level

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AO	VM	MAW	25.10.17
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V-R6472.05	1:1000 @ A3
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IPSEN BIOPHARM
FLOOD CONSEQUENCES
ASSESSMENT

1% AEP EVENT WITH 75% CC SURFACE
WATER DRAINAGE- INFLOW2

V/R6472/05/G	10	A
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