TeignConsult

Consulting Engineers

SEPTEMBER 2024

CATCHMENT STUDY
AND
PRELIMINARY FLOOD ALLEVIATION OPTIONS

MARKHAM CATCHMENT, IDE
DEVON

FOR
IDE PARISH COUNCIL

REPORT REF. NO.: 595/MKH/FAS1
V1– 27.09.2024

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1.0 INTRODUCTION

1.1 Study background

TeignConsult was commissioned by Ide Parish Council to undertake a flow study and investigate preliminary flood alleviation options for the Markham catchment which passes through the village. The catchment is a tributary of the Fordland Brook.

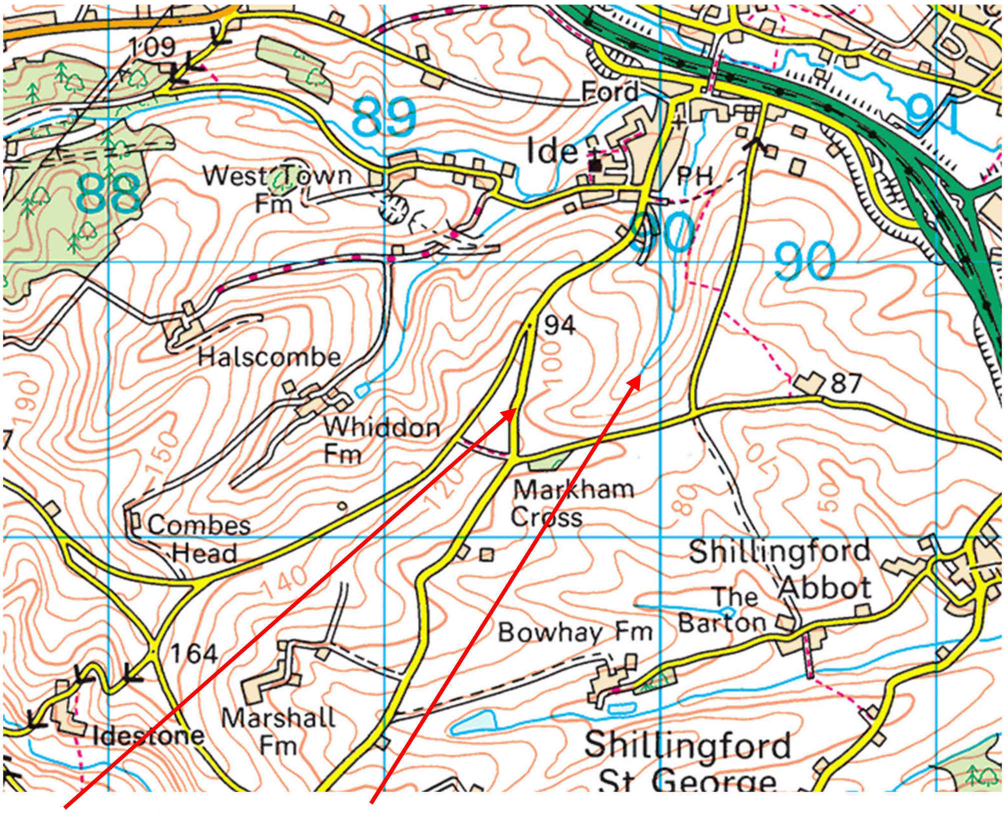
This study has looked at the sources of runoff that create the flooding witnessed in November 2023. This includes field runoff, highway runoff, watercourses, paved areas and topography or infrastructure that might route flows in or out of the natural watercourse catchment.

A walk through of the watercourse that emanates south of the village has been undertaken where access was possible. During this exercise check measurements of the pipes, culverts, and any other structures which impact on flood flow routes have been undertaken.

This study also draws on information collected by the author in 2006 as part of a planning application in the village. A 375mm diameter pipe conveys flow from south to north under a building off Fore St which then joins another pipe flowing along Fore St from the west before outfalling into the Fordland Brook. The survey information from 2006 is included in Appendix A.

1.2 Site location

The study extends from Idestone Cross in the south, Cuckoo Green in the southwest, Markham Cross in the southeast and Polehouse Lane in the east. The whole study area extends to just under 0.7km². The watercourse is shown on Ordnance Survey mapping over a 1.13km length, rising (issues) 210m west of Polehouse Lane and 550m northeast of Markham Cross. The local area is shown on the map below:



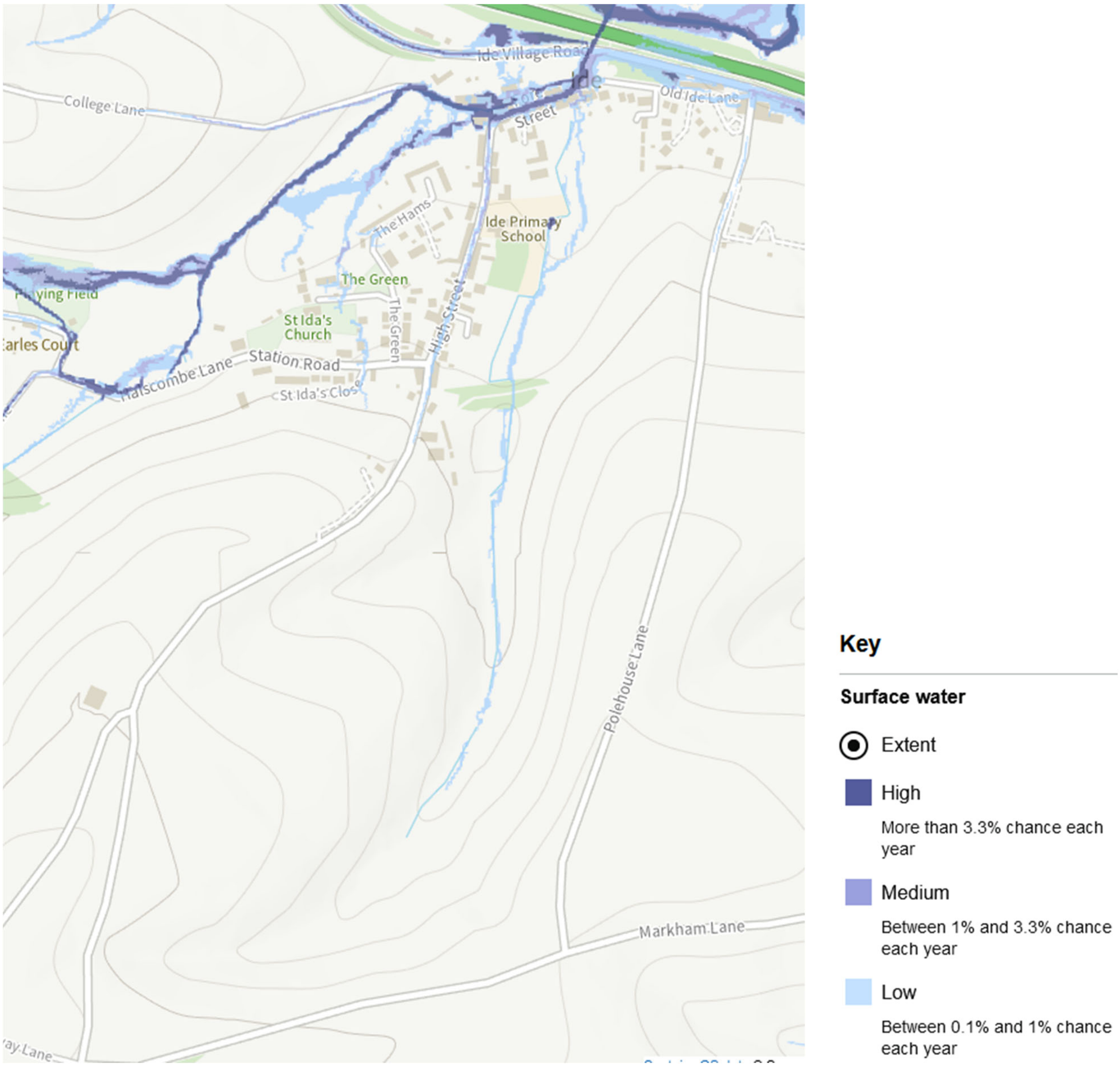
The valley upstream of the issues point also conveys flows as a highway drainage system outfalls at the location shown above to the valley bottom.

An old railway line on a 10m high embankment crosses the watercourse roughly 385m south of the 375mm culvert inlet. Flows are conveyed through a sprung arch culvert.

The study area extent and catchment areas are included on drawing SV1.

1.3 EA flood risk area mapping

The EA do not map this watercourses with any fluvial (river / stream) flood risk. Instead, they map surface water flooding which is not necessarily related to a watercourse. These maps are more focused on topography, identifying valley features and flow routes during heavy rainfall. An extract of the map is included below which shows no flood risk south of the issues point:



2.0 SOURCES OF INFORMATION

2.1 Environment Agency (EA) information

EA records and reports have been reviewed and information utilised to assist the study:

- Digital LIDAR contour data;
- Devon Hydrology Studies 2012 & 2007;
- EA report SC090031/R4 Estimating flood peaks and hydrographs for small catchments - Estimating the median annual flood (QMED) in small catchments;
- EA sub-regional growth curve for Devon (early 1980's).

2.2 South West Water (SWW) information

SWW asset maps have been consulted on their website and this confirmed the village has various combined, foul, and surface water drainage systems. No outfalls to the watercourse in its upper reaches are recorded. The section of surface water pipe flowing from the west along Fore St and the length which conveys both the culverted watercourse flows and the urban drainage from the west are shown as SWW assets. The pipe under the building is not shown as a SWW asset as it only conveys Land and Highway drainage. We have approached SWW for information on their existing sewer depths, unfortunately they do not have much information on these pipes:

Combined Sewer (Red)	Cover Level	Invert Level
0601	20.71	19.21
1609	Not recorded	Not recorded
1611	Not recorded	Not recorded
1612	Not recorded	Not recorded
1601	20.935	18.565
Surface Water Sewer (Blue)	**Cover Level**	**Invert Level**
1602	Not recorded	Not recorded
1603	Not recorded	Not recorded

The SWW mapping is included in Appendix A.

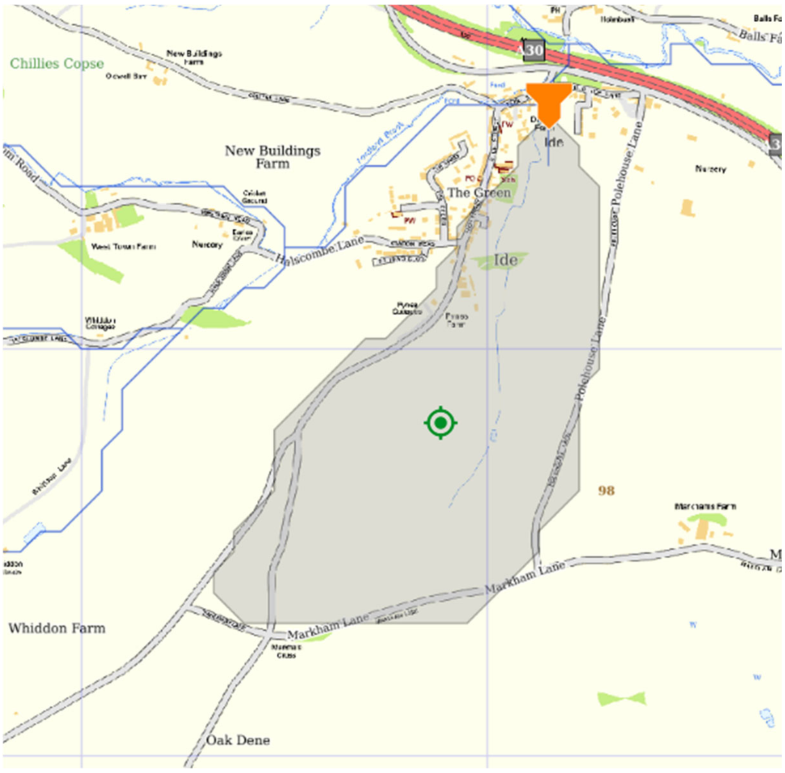
2.3 Former railway line culvert and 375mm culvert

The old railway line has a sprung arch culvert passing under the embankment south of the village. This culvert is approximately 33m long, 1.15m in width and 1.06m high. Based on the cross-sectional area of flow and gradient this culvert has a capacity of 2.5m^3/s.

The 375mm culvert conveying flows under the Fore St building has a capacity of 0.431m^3/s. The next section of culvert has a capacity of 0.533m^3/s but this also conveys flows from a pipe that joins from the west serving Fore St and Drakes Farm.

2.4 Hydrology & catchment areas

The Flood Estimation Handbook (FEH) mapping includes the suggested catchment area of the watercourse. The catchment mapping is shown below:



The Flood Estimation Handbook (FEH) provides maps of watercourse catchments based on contours alone and these are what hydrology studies are normally based on. These maps make no allowances for hedge banks or other physical boundaries which might divert flow in or out of the contour-based catchment areas. During the site walkover areas were identified that will require adjustments to the FEH sub-catchment area of the watercourse under consideration.

The FEH map catchment area shown above, 0.6625km² does not include the areas to the southwest that have been identified by the site walkover as flowing into the watercourse but does include areas in High St and Station Rd that are drained away from the watercourse by SWW or Highway drainage systems.

The catchment area has been adjusted to remove / add these areas and a new catchment area of 0.6673km² identified as the base for all future calculations. The area adjustments are shown on drawing SV1.

Using the contour survey information and walkover notes the fields, highway and other adjusted contributing areas have been measured off the Ordnance Survey maps so that an estimate of flows generated can be created for each location.

2.5 Calculating flow runoff

The EA constantly update the methods they recommend for determining flows in catchments. Sometimes the new studies recommend reverting to an old method that was previously in use until a study carried out 3 or 4 years ago.

The most recent report SC090031/R4 recommends going back to using the “FEH statistical” method first utilised circa 1999, superceding the Revitalised FEH method and Kjeldsen 2008 method which have been in use until recently. The report summary states:

8.2 Recommendations

QMED estimation

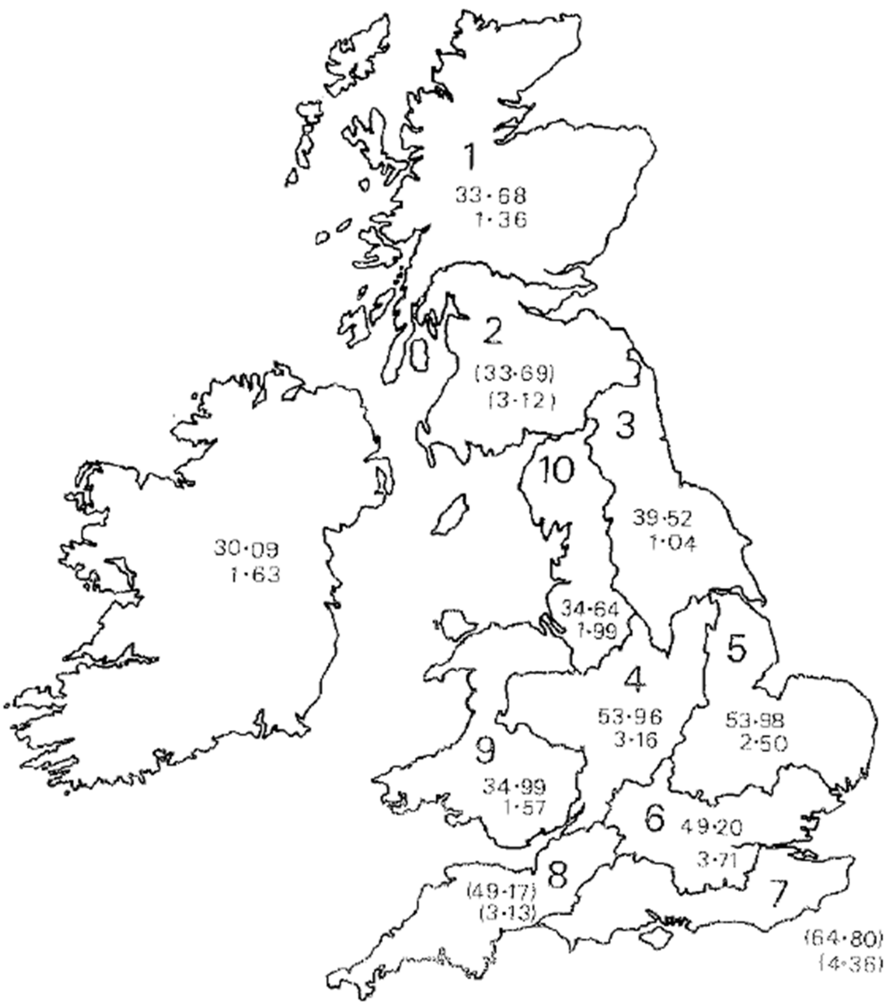
- Additional research carried out on a further screened data set and reported in Section 3 of the 'Small catchments overview report' (R0), leads to the recommendation to continue using the existing (2008) FEH statistical QMED equation to estimate QMED in small ungauged catchments. To avoid any doubt, this equation is repeated below (Equation 23).

Equation 23 - QMED equation

$$QMED = AREA^{0.8510} 0.1536^{\frac{1000}{SAAR}} FARL^{3.4451} 0.0460^{BFIHOST^2}$$

This method only provides a flow vale for the QMED (2 year) return period storm. From this storm the flows must be factored up using Regional Growth Factors (RGF) / Flood Frequency Curve to a range of flows from the 5 year up to the 100 year, or the design storm being assessed for a flood alleviation study.

RGF existed in the 1975 Flood Studies Report for the 10 different regions of Great Britain:



Region	Return period						
	2	5	10	25	50	100	200
1	0.90	1.20	1.45	1.81	2.12	2.48	2.89
2	0.91	1.11	1.42	1.81	2.17	2.63	3.18
3	0.94	1.25	1.45	1.70	1.90	2.08	2.27
4	0.89	1.23	1.49	1.87	2.20	2.57	2.98
5	0.89	1.29	1.65	2.25	2.83	3.56	4.46
6/7	0.88	1.28	1.62	2.14	2.62	3.19	3.86
8	0.88	1.23	1.49	1.84	2.12	2.42	2.74
9	0.93	1.21	1.42	1.71	1.94	2.18	2.45
10	0.93	1.19	1.38	1.64	1.85	2.08	2.32
Great Britain	0.89	1.22	1.48	1.88	2.22	2.61	3.06
Ireland	0.95	1.20	1.37	1.60	1.77	1.96	2.14

Since then, EA SW Region, FEH methods (Wallingford software) and Devon Hydrology Studies (DHS) have all suggested certain RGF for different river catchments in the county. In the table above Devon is Region 8 and the 100 year RGF is 2.42 times the Mean Annual Flood (MAF is 2.33 year storm). In the early 1980's SWW Land drainage team (later to become National Rivers Authority and then the EA) suggested that the 100 year Devon factor should be 2.93 times MAF based on extensive local knowledge and study of the storms through the 1960's and 1970's.

The most recent DHS in 2012 grouped areas of the county into catchments, considering soil types, topography, historic rainfall, actual gauged flows, and catchment orientation.

The Markham catchment sits on the boundary between Trend C2a1 (Lower Exe and east devon watercourses) and C2a3 which covers the Matford Brook, Shutterton Brook and Duckaller watercourses west of the River Exe:

Trend C2a1 is based on actual River Clyst gauged flows at Clyst Honiton, Trend C2a3 is based on the FEH rainfall Runoff methodology, another historic method promoted by the EA back in the 1990's. The table below shows the range of RGF from different methods that the EA have suggested in the past as appropriate:

Comparison of RGF from Trends / FEH / EA SW Region				
Return Period	Trend C2a3 ex Shutterton	Trend C2a1 ex Clyst Honiton	FEH Software	EA SW Region - ex Steve Moore
	Derived RGF	Derived RGF	Derived RGF	Derived RGF
QMED	1.00	1.00	1.00	0.88
MAF			1.11	1.00
5	1.40	1.43	1.48	1.28
10	4.00	1.74	1.80	1.58
25	6.00	2.19	2.55	2.03
30		2.27	2.71	2.14
50	7.40	2.57	3.24	2.45
100	8.80	3.01	3.96	2.93
250	11.20	3.69		3.45

You can see that the 100-year RGF varies between 2.93 and 8.80 and the 25 year varies between 2.03 and 6.00.

The EA report also suggests that undertaking a pooled assessment with additional data from similar watercourses could be appropriate. We have found in the past that this constantly predicts flows with reasonable accuracy up to the 10-year flow but in the higher return period flows (100 year) the results underestimate the runoff by up to 50% from those observed and we do not propose to utilise it at this location.

At this location, the natural soils are permeable up to a point. The FEH predicts only 14.38% of rainfall runs off during any event, i.e. relatively porous. This does not allow for steepness of the catchment or when the soils become saturated. In this type of soil once this occurs the soil surface becomes a "sheet of glass" as the mudstone particles swell and close any voids in the soil makeup resulting in zero infiltration and full rainfall leaving the fields. This is the reason the larger RGF have been predicted for the higher return period storms in the Shutterton Brook.

This study area is located over Alphington Breccia soils. In the Shutterton Brook area the catchment is located over Alphington and Heavitree Breccias and Dawlish sandstones. The two additional soil types contain more fines and cohesive particles and are less granular. For this reason, we have chosen to use the FEH 2008 statistical QMED flow and apply the RGF from the FEH software as they are higher than the East Devon trend and EA SW region figures from the 1980's, but not as high as the Shutterton Brook study flows. This may mean the hydrology is more conservative than necessary when compared to the frequency of flooding that has occurred. The flows carried forward for the 0.6673km² catchment are:

Return Period	RGF	Design flows whole catchment (m³/s)
Q2 (QMED)	1.00	0.396
Q2.33 (MAF)	1.11	0.440
Q5	1.48	0.588
Q10	1.80	0.713
Q25	2.55	1.010
Q50	3.24	1.285
Q100	3.96	1.568
Climate change +46%		2.289

The EA may suggest if consulted that additional methods of calculation are considered, but this is outside of the scope of this report.

The flows can be proportioned back upstream to smaller sub catchment areas as part of any study. For each return period an equivalent flow in m^3 or litres / second / hectare is calculated for use once the potential alleviation areas have been identified. If an area is identified as a potential storage location or a new pipe/culvert is required, the proportional flows can be determined and compared with various pipe sizes or throttle devices to see what flows could be stored temporarily and what flows can be allowed to continue downstream without any other improvements.

For each sub-catchment area, a hydrograph can be generated using the critical storm duration calculated from the mapping. This will give a design flow in relation to rainfall roughly every 15 minutes. These flows can be used to calculate total volumes of runoff for consideration in flood alleviation measures.

2.6 Flow paths for runoff

During the walkovers 3 separate highway drainage outfalls were identified discharging to the upstream dry valley or the mapped watercourse.

a) There is a 100mm pipe from a single gully located 190m north of Markham Cross that outfalls to the dry valley upstream of the watercourse. The upstream catchment is circa 35.14ha;
b) There is a ditch and gully that diverts flows off the highway into the field approximately 225m south of Pynes Cottages, upstream catchment is up to 76.04ha;
c) There is a ditch that diverts flows off the highway into the field approximately 175m south of Pynes Cottages, upstream catchment is a short length of road and 0.05ha.

Locations a, b, and c, are marked on drawing SV01. North of c) the highway drainage is collected and conveyed north out of the watercourse catchment towards High St.

There are also several other highway gullies south of b) and c), but no outfall or continuous pipe network conveying flows could be located on site.

2.7 Highway areas

Only highway areas that discharge to the watercourse have been assessed in this study, other highway areas contributing to the gully systems in the village centre (High St / Fore St) have not been assessed in detail as flooding was not reported in 2023 from these sources.

If these systems are to be investigated further additional survey work will be undertaken to determine the size, depth and capacity of each pipe length and contributing area that flow to the gully system. This is a study that DCC Highways should undertake.

3.0 CATCHMENT AREAS, CULVERT DETAILS AND CAPACITIES

3.1 Catchment areas

The contributing catchment area to the watercourse has been adjusted using the site walkover information and contours. This total area upstream of the 375mm culvert has been has been split up into 3 areas based on topography, culvert locations and a potential storage area. This has allowed determination of the flows in each of the 3 separate sub-catchment areas. The catchments are shown on drawing SV2 and are as follows:

Catchment DS – Downstream railway culvert to 375mm pipe inlet, 10.149ha;

Catchment RWY – Upstream railway culvert to US catchment location, 37.822ha;

Catchment US – Upstream catchment across valley 575m northeast Markham Cross, 18.761ha;

Catchment US + RWY, 56.583ha

Each catchment area has been used to determine the range of flows between the 1 in 2-year (QMED) and the 1 in 100 year plus 46% (Climate change) rainfall event.

Based on these area splits the design flows for various return periods are:

			Downstream (DS)	Upstream (US)	Railway arch (RWY)	US + RWY
Contributring area(s) ha		66.7325	10.149	18.761	37.822	56.583
Return Period	Derived RGF	m3/s	m3/s	m3/s	m3/s	m3/s
QMED	0.90	0.396	0.060	0.111	0.225	0.336
MAF	1.11	0.440	0.067	0.124	0.249	0.373
5	1.48	0.588	0.089	0.165	0.333	0.499
10	1.80	0.713	0.109	0.201	0.404	0.605
25	2.55	1.010	0.154	0.284	0.573	0.857
30	2.71	1.075	0.164	0.302	0.609	0.912
50	3.24	1.285	0.195	0.361	0.728	1.089
100	3.96	1.568	0.238	0.441	0.888	1.329
CC46%		2.289	0.348	0.643	1.297	1.941

3.2 Pipe / Culvert details and capacity

a) **375mm pipe** – The two lengths and falls have been input to MicroDrainage and the pipe capacities calculated as:

Pipe Number	Pipe Length (m)	Fall (m)	Slope (1:X)	Area (ha)	Time of Entry (mins)	Base Flow (l/s)	Pipe Rough. (mm)	US/IL (m)	US/CL (m)	Pipe DIA (mm)
1.000	40.360	1.860	21.7	3.184	5.00		0.600	21.530	23.000	375
1.001	18.380	1.294	14.2	0.754			0.600	19.670	20.450	375

Pipe Number	Rain (mm/hr)	TC (mins)	DS/IL (m)	Pro. Vel (m/s)	Pro. Depth (mm)	Velocity (m/s)	Cap (l/s)	Flow (l/s)
1.000	50.00	5.17	19.670	4.42	310	3.90	431.2	431.2
1.001	50.00	5.24	18.376	5.46	310	4.83	533.4	533.3

Pipe No 1.000 is under the building and PN1.001 is in the highway. Capacities are 431l/s and 533l/s, respectively.
From this it can be seen that the 375mm pipe has approximately MAF - 2.33-year return period capacity (440l/s) of the whole catchment.

b) **Railway culvert** – The length, fall and shape has been input to MicroDrainage and the culvert capacity calculated as:

Pipe Number	Pipe Length (m)	Fall (m)	Slope (1:X)	Area (ha)	Time of Entry (mins)	Base Flow (l/s)	Pipe Rough. (mm)	US/IL (m)	US/CL (m)	Pipe DIA (mm)
1.000	33.000	0.180	183.3	9.595	5.00		0.600	34.930	36.000	-9

Pipe Number	Rain (mm/hr)	TC (mins)	DS/IL (m)	Pro. Vel (m/s)	Pro. Depth (mm)	Velocity (m/s)	Cap (l/s)	Flow (l/s)
1.000	50.00	5.21	34.750	2.55	515	2.57	2500.2	1299.3

Create Section

Base Coordinates

X (m)	Y (m)
0.000	35.040
0.557	34.930
1.115	35.040

Cover Coordinates

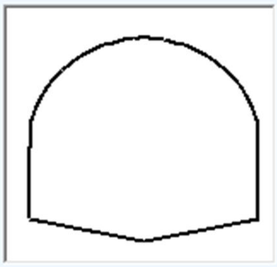
X (m)	Y (m)
0.000	35.040
0.001	35.415
0.007	35.555
0.032	35.623
0.057	35.677
0.082	35.719
0.107	35.755
0.157	35.811
0.207	35.855
0.257	35.890

Micro Drainage

OK

Cancel

Help



Pipe No 1.000 is the railway culvert and the capacity is 2500l/s.
From this assessment the railway culvert has greater capacity than the upstream catchment area (US+RWY) of 1941l/s in the Climate change event.
The client has provided the photograph below showing the railway culvert size:

4.0 FLOOD ALLEVIATION OPTIONS

4.1 General discussion

As part of the site walkover areas were considered where the valley features adjoin the watercourse might allow some nominal throttling back of the higher flows.

Most of the catchment areas upstream of railway culvert are a moderate to steep sided valley. This might provide suitable location(s) to create a dam and throttle the flow. Similarly, the railway culvert might be suitable for reduction of the cross-sectional area that allows full flow to pass downstream and store water behind the railway embankment if it is found to be structurally sound.

The following a series of preliminary options to demonstrate the scale of works needed to alleviate flooding of the properties in Fore St from this watercourse. There are many iterations / combinations of these that could be explored further.

We have based all of these options on a 1 in 100-year design event without any climate change influences.

4.2 Enlarging downstream pipe capacity

The existing catchment area below the railway embankment is 10.149ha and this contributes the flows detailed in the table below:

			Downstream (DS)
Contributring area(s) ha		66.7325	10.149
Return Period	Derived RGF	m3/s	m3/s
QMED	0.90	0.396	0.060
MAF	1.11	0.440	0.067
5	1.48	0.588	0.089
10	1.80	0.713	0.109
25	2.55	1.010	0.154
30	2.71	1.075	0.164
50	3.24	1.285	0.195
100	3.96	1.568	0.238
CC46%		2.289	0.348

The existing 375mm minimum pipe capacity has been calculated as 0.431m^3/s. This excludes the influence of any flows from the pipe along Fore St that joins part way along the length.

If an additional culvert were to be provided in combination to the 375mm pipe, with a direct outfall to the Fordland Brook it would need to convey 1.14m^3/s. MicroDrainage suggests a 58m length of 600mm pipe laid at 1:17.6 would provide 1.645m^3/s of additional capacity. PN2.000 provides the details below:

Pipe Number	Pipe Length (m)	Fall (m)	Slope (1:X)	Area (ha)	Time of Entry (mins)	Base Flow (l/s)	Pipe Rough. (mm)	US/IL (m)	US/CL (m)	Pipe DIA (mm)
2.000	58.000	3.300	17.6	1.000	5.00		0.600	21.700	23.000	600

Pipe Number	Rain (mm/hr)	TC (mins)	DS/IL (m)	Σ Imp. Area (ha)	Pro. Vel (m/s)	Pro. Depth (mm)	Velocity (m/s)	Cap (l/s)	Flow (l/s)
2.000	50.00	5.17	18.400	1.000	3.59	115	5.83	1647.6	135.4

This provides some additional climate change benefit but not to the full CC46% runoff predicted by the EA. Earthworks to divert excess flows to the new pipe inlet would be required in the upstream field, but these would be nominal. The pipe route considered is shown on drawing SV3.

We have not considered the impact on the Fordland Brook beyond the outfall of this potential new pipe. The next structure downstream in the Fordland Brook is a large rectangular box section culvert under the A30.

A 450mm pipe provides 0.774m^3/s of additional capacity, which provides alleviation up to the 1 in 50-year event.

We have checked some of the utility company records that are free to view to confirm any potential constraints:

a) There is a 180mm diameter low pressure gas main running along Fore St which would need to be crossed with the new pipe;
b) There a number of private underground electricity cables shown on the records which could be avoided if the records of their positions are correct;
c) There is a 4" watermain and a 150mm combined sewer running along Fore St that would need to be crossed. The potential new 600mm pipe gradient would pass over the foul sewer if the SWW records are correct;
d) Openreach records require payment to view.

Based on the normal depths of cover / depth to these services we do not envisage a clash between the gas or water main and the new pipe. Further investigation of the SWW sewer levels would be needed.

We are not allowed to reproduce the gas or electric service records in the report, but they can be viewed in person by an appointed representative of the Parish Council.

4.3 Railway culvert works and storage area

The existing railway culvert allows all upstream flows to be conveyed downstream with little attenuation.

We have shown that the catchment area north of the embankment generates 0.238m^3/s in the 100-year event. This leaves a potential flow of 0.193m^3/s that could pass through the railway culvert without surcharging the existing 375mm pipe. In the table below this equates to less than the QMED flow:

			Downstream (DS)	Railway arch (RWY)	US + RWY
Contributing area(s) ha		66.7325	10.149	37.822	56.583
Return Period	Derived RGF	m3/s	m3/s	m3/s	m3/s
QMED	0.90	0.396	0.060	0.225	0.336
MAF	1.11	0.440	0.067	0.249	0.373
5	1.48	0.588	0.089	0.333	0.499
10	1.80	0.713	0.109	0.404	0.605
25	2.55	1.010	0.154	0.573	0.857
30	2.71	1.075	0.164	0.609	0.912
50	3.24	1.285	0.195	0.728	1.089
100	3.96	1.568	0.238	0.888	1.329
CC46%		2.289	0.348	1.297	1.941

The hydrograph for each of the two catchments DS and US+RWY have been generated and the flows / volumes compared in a spreadsheet. The 100 year event runoff is estimated to last just over 6 hours with a peak flow occurring after 2.7 hours.

If the full flow of the DS catchment is allowed to discharge through the 375mm pipe and only the spare capacity from the US+RWY catchment area is allowed through the railway culvert in the 100-year storm we predict a storage volume of circa 9600m^3 attenuation storage is required. The calculation is included in Appendix B.

Overlaying this volume on the existing 0.5m LIDAR contours shown in the drawings calculates a storage depth of just under 4m above the culvert invert level of 34.93m is required. The soffit (top) of the culvert is just under 36.0m. Water would be impounded to around the 39m with a surcharge on the embankment face of 75m width. The top of the embankment is at 44.0m and the maximum north-south width is circa 35m.

This option would also allow for future climate change influence flows to be stored behind the embankment, but all storage volumes would need to be subject to geotechnical and structural assessment of the railway embankment.

This option assumes no excavation in the upstream field is carried out to provide storage at a lower level, so the surcharge height of the railway embankment is reduced. This option could be investigated further if a preliminary assessment of the railway embankment was undertaken.

A suitably sized orifice / pipe arrangement will be needed to "plug" or throttle the larger railway culvert flows. A simple pipe at the same gradient as the railway culvert could be a standard 375mm diameter pipe which is predicted to allow 0.148m^3/s of flow to pass. This is the pipe full flow without any head pressure above the pipe soffit that could push additional flows downstream. This option would mean grouting up of the pipe surround between the new pipe and old culvert profile. This arrangement would need to be modelled to confirm the actual size.

Alternatively, a 250mm diameter orifice constructed in reinforced concrete or steel across the culvert entrance would allow a peak flow of 193l/s to pass downstream. This has been tested in MicroDrainage with the contributing area flows and LIDAR contour data. The output is included in Appendix B.

This impounding area is shown on drawing SV3.

4.4 Upstream storage area

During the site walkover we initially considered an upstream storage area in the valley downstream of the southernmost highway outfall (location "a" in Paragraph 2.6). Having now produced the catchment split flows it can be seen that the area between the US boundary and the railway culvert (37.822ha) has a greater QMED flow (0.225l/s) than can be allowed to pass downstream through the railway culvert (193l/s) to the 375mm pipe at the rear of Fore St.

			Downstream (DS)	Upstream (US)	Railway arch (RWY)	US + RWY
Contributring area(s) ha		66.7325	10.149	18.761	37.822	56.583
Return Period	Derived RGF	m3/s	m3/s	m3/s	m3/s	m3/s
QMED	0.90	0.396	0.060	0.111	0.225	0.336
MAF	1.11	0.440	0.067	0.124	0.249	0.373
5	1.48	0.588	0.089	0.165	0.333	0.499
10	1.80	0.713	0.109	0.201	0.404	0.605
25	2.55	1.010	0.154	0.284	0.573	0.857
30	2.71	1.075	0.164	0.302	0.609	0.912
50	3.24	1.285	0.195	0.361	0.728	1.089
100	3.96	1.568	0.238	0.441	0.888	1.329
CC46%		2.289	0.348	0.643	1.297	1.941

On this basis no major benefit would be achieved by creating a southern / upstream storage area without delivering a similar scheme to the plugging of the existing railway culvert.

There will be another location upstream of the railway embankment where a dam could be created and the flow / volume adjusted to suit the flow criteria required at the existing 375mm pipe. However, if you look at the 2.5m contours in the LIDAR you will see that the valley sides are steeper at 1:5 as you progress south meaning that the depth of storage will increase for the same volume required. The valley sides are flatter at 1:10.4 immediately upstream of the railway culvert.

This option has not been progressed any further as there are numerous locations between 10m and 170m upstream of the railway embankment toe where a dam could be created and achieve a throttle of flows.

Any catchment flows generated between the alternative dam site and railway embankment would need to be considered in sizing the new dam and an alternative throttle size for the railway culvert.

Any location should however capture the two highway outfalls at b) and c).

4.5 Alternative alleviation options

Smaller pipe at downstream outfall

There will also be the option of a smaller new outfall pipe if clashes with utility services are found to be too onerous in terms of costs to divert or avoid the services.

This option could just provide a higher return period of downstream flow or be linked to a smaller storage area upstream of the railway embankment.

Lesser standard of alleviation

Instead of considering the 100-year flow (plus a climate change allowance) the standard could be lowered to say 1:75 if the railway embankment is found to be structurally sound for a 1m head of water on the upstream face and no additional excavation is carried out.

Property Level Protection

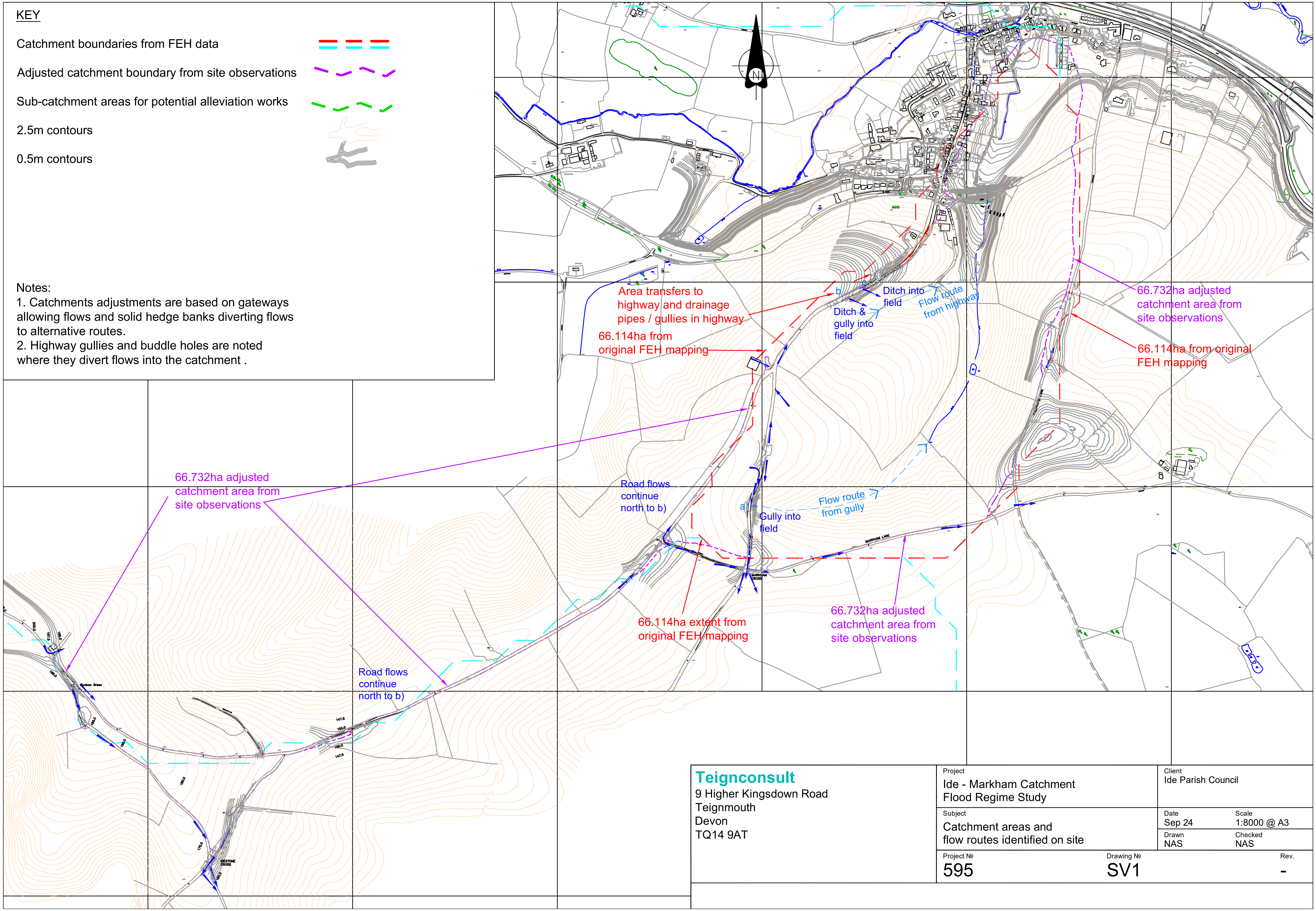
If all of the above options are found to be too costly or the landowner(s) are unwilling to allow the land to be used for the benefit of the community then funding through individual property protection obtained by Devon County Council LLFA would be another option. The process is explained on the link below:

https://www.devon.gov.uk/floodriskmanagement/flood-resilience/property-flood-resilience-funding-scheme/

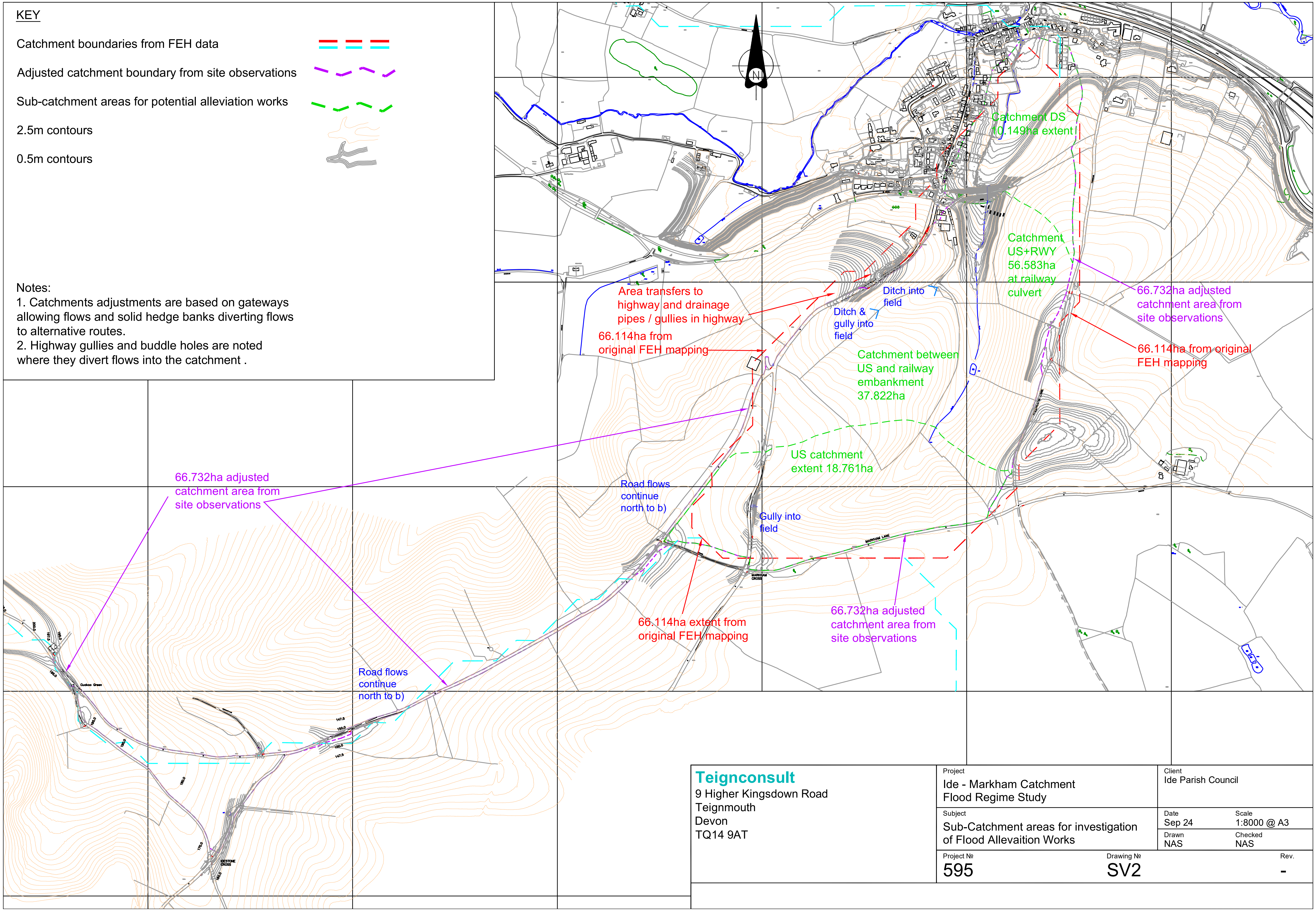
5.0 CONCLUSIONS

a) The existing 375mm pipe under the properties in Fore St has a capacity of circa 0.43m^3/s, equivalent to the Mean Annual Flood (1 in 2.33-year return period) based on the applied catchment hydrology;
b) The existing railway embankment culvert upstream of the village can convey a flow greater than the 1 in 100year plus 46% climate change allowance towards the 375mm pipe;
c) The catchment areas that contribute to the watercourse are slightly different to the mapped FEH website and have been adjusted;
d) A larger area of highway is contributing to the catchment in the upper reaches of the study area, but less highway areas are contributing to the catchment as it approaches the village edge and High St from the south;
e) An additional 600mm culvert and earthworks at the downstream end of the catchment to provide additional flow capacity to the Fordland Brook would be required to provide 100-year plus an element of climate change design flow capacity;
f) The option to use the railway embankment to throttle flows as a standalone solution would need storage of circa 10,000m^3 and a throttle of approximately 250mm diameter constructing in the existing culvert inlet. This option could involve excavating the field upstream of the railway embankment to create a lesser depth of storage and surcharge on the existing embankment;
g) Other areas for constructing a dam across the watercourse within the catchment upstream of the railway exist but the valley side slopes are steeper, and a greater depth of water would be required as the downstream catchment area flowing directly to the existing 375mm pipe would be larger;
h) The utility services and sewers in Fore St should be investigated further to confirm the information provided by each utility company.

DRAWINGS



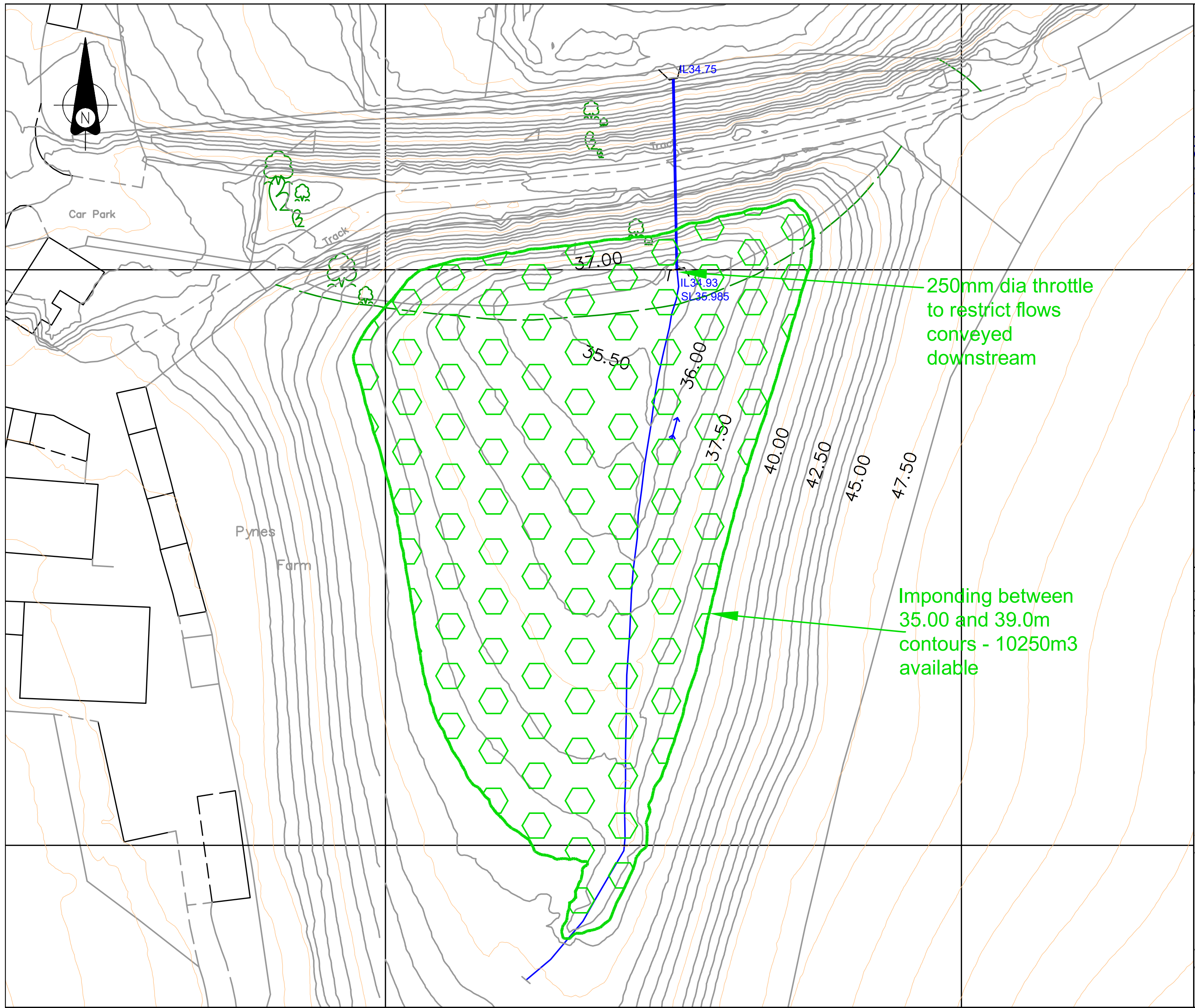
KEY
Catchment boundaries from FEH data
Adjusted catchment boundary from site observations
Sub-catchment areas for potential alleviation works
2.5m contours
0.5m contours
Notes:
1. Catchments adjustments are based on gateways allowing flows and solid hedge banks diverting flows to alternative routes.
2. Highway gullies and buddle holes are noted where they divert flows into the catchment .
N
Area transfers to highway and drainage pipes / gullies in highway
66.114ha from original FEH mapping
Ditch into field
Flow route from highway
Ditch & gully into field
66.732ha adjusted catchment area from site observations
66.114ha from original FEH mapping
66.732ha adjusted catchment area from site observations
Road flows continue north to b)
Gully into field
Flow route from gully
66.114ha extent from original FEH mapping
66.732ha adjusted catchment area from site observations
Road flows continue north to b)
MARKHAM LANE
Teignconsult
9 Higher Kingsdown Road
Teignmouth
Devon
TQ14 9AT
Project
Ide - Markham Catchment
Flood Regime Study
Client
Ide Parish Council
Subject
Catchment areas and
flow routes identified on site
Date
Sep 24
Scale
1:8000 @ A3
Drawn
NAS
Checked
NAS
Project №
595
Drawing №
SV1
Rev.
-



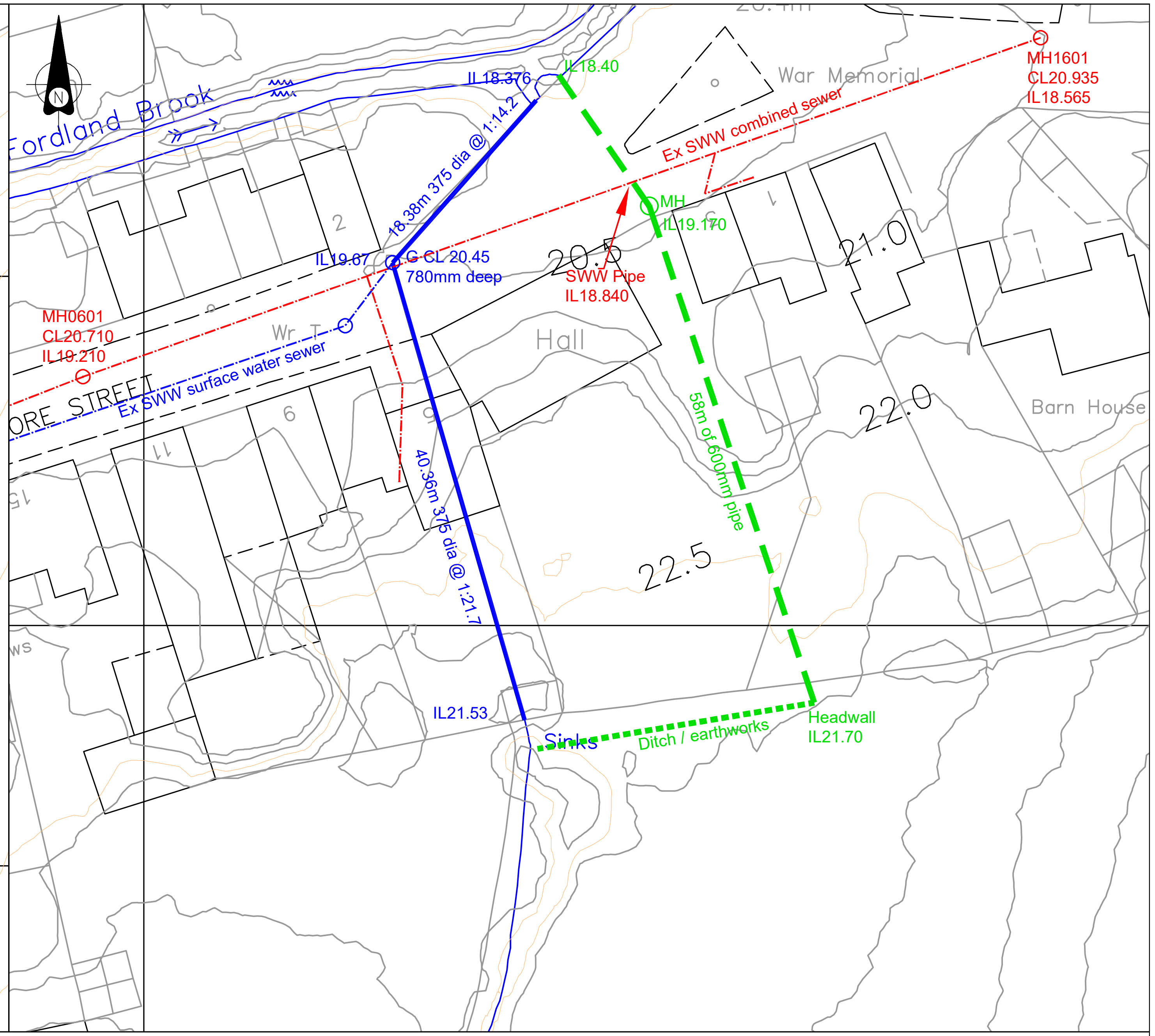
Notes:
1. Catchments adjustments are based on gateways allowing flows and solid hedge banks diverting flows to alternative routes.
2. Highway gullies and buddle holes are noted where they divert flows into the catchment .

Teignconsult
9 Higher Kingsdown Road
Teignmouth
Devon
TQ14 9AT

Project: Ide - Markham Catchment Flood Regime Study	Client: Ide Parish Council	
Subject: Sub-Catchment areas for investigation of Flood Allevaition Works	Date: Sep 24	Scale: 1:8000 @ A3
	Drawn: NAS	Checked: NAS
Project №: 595	Drawing №: SV2	Rev.: -



Impounding area upstream railway culvert / embankment
Scale 1:1000



Additional culvert at north end of catchment to Fore St
- 58m of 600mm diameter plus ditch earthworks
Scale 1:500

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9 Higher Kingsdown Road
Teignmouth
Devon
TQ14 9AT

Project: Ide - Markham Catchment Flood Regime Study

Client: Ide Parish Council

Subject: Flood Alleviation Options - Downstream Pipe and Railway Storage

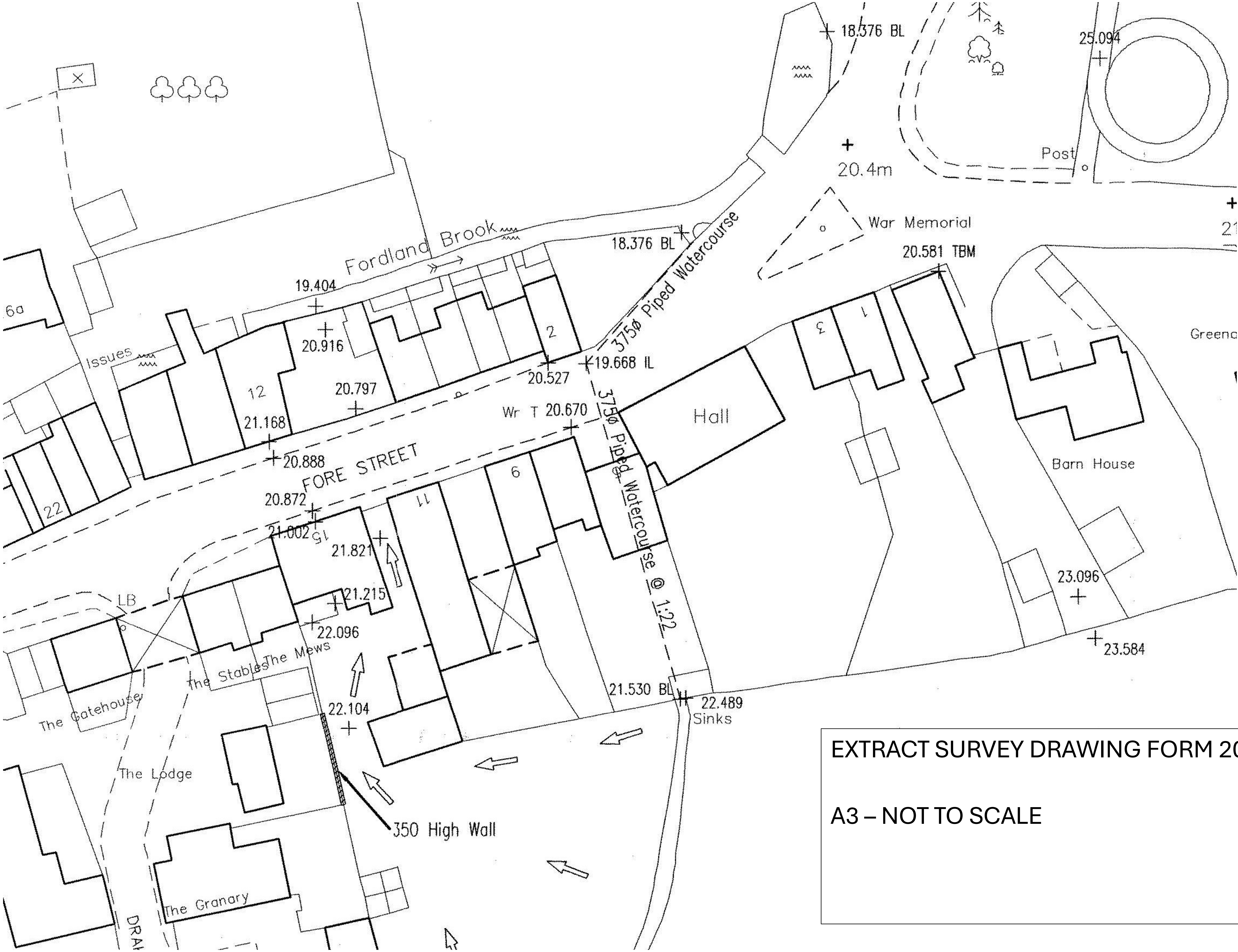
Date: Oct 24
Scale: As shown @ A3
Drawn: NAS
Checked: NAS

Project №: 595
Drawing №: SV3
Rev.: -

APPENDIX A

Survey Data and SWW Sewer Records

1. Survey Levels and culvert information from 2006 FRA
2. SWW Public sewer records



EXTRACT SURVEY DRAWING FORM 2006 FRA

A3 – NOT TO SCALE

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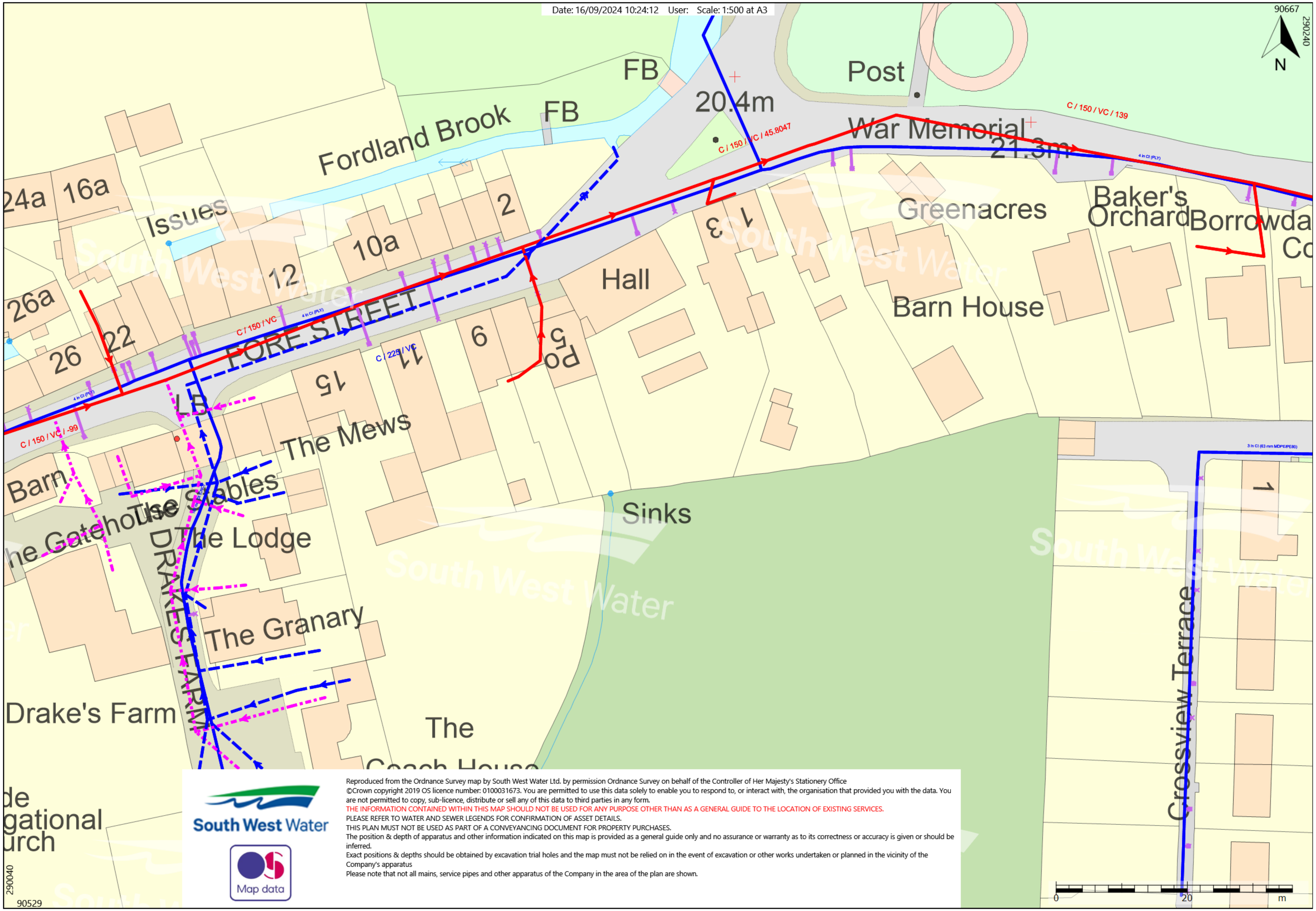

APPENDIX B

Calculations of flow / storage

1) Hydrology for catchment areas
2) Railway culvert upstream storage – circa 9600m^3
3) Orifice sizing from MicroDrainage

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The Flood Estimation Handbook, produced by the Institute of Hydrology in 1999 effectively replaced Flood Studies Report in the UK.
The following QMED equation is from 2008
EA report SC090031/R4 para 8.2 has updated the methodology for small catchments to:
Qmed = AREA^0.851 x 0.1536(1000 / SAAR) x FARL^3.4451 x 0.0460^(BFIHOST x BFIHOST), m3/s
Calculation should be for a minimum of 50ha and then prorata to site area
where:
Qmed is the median annual flow rate; the 1:2 year event.
AREA is the area of the catchment in ha.
SAAR is the standard average annual rainfall for the period 1941 to 1970 in mm.
FARL is a reservoir attenuation function and is set at 1.0 and therefore has effectively been ignored.
This means that areas with water bodies which attenuate the runoff will over-predict the greenfield runoff rate.
BFIHOST is the base flow index derived using the HOST classification.

		Site location	Site area
0.6673	Area (ha)	50.000	66.7325
km2	SAAR	872	
	FARL	1.000	
	BFIHOST	0.882	
m3/s	QMED =	0.2968	0.396
l/s	or l/s	296.8	396.2

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@SPR equivalent urban area = 9.596 ha

			Downstream (DS)	Upstream (US)	Railway arch (RWY)	US + RWY
Contributing area(s) ha		66.7325	10.149	18.761	37.822	56.583
Return Period	Derived RGF	m3/s	m3/s	m3/s	m3/s	m3/s
QMED	0.90	0.396	0.060	0.111	0.225	0.336
MAF	1.11	0.440	0.067	0.124	0.249	0.373
5	1.48	0.588	0.089	0.165	0.333	0.499
10	1.80	0.713	0.109	0.201	0.404	0.605
25	2.55	1.010	0.154	0.284	0.573	0.857
30	2.71	1.075	0.164	0.302	0.609	0.912
50	3.24	1.285	0.195	0.361	0.728	1.089
100	3.96	1.568	0.238	0.441	0.888	1.329
CC46%		2.289	0.348	0.643	1.297	1.941

Catchment at Railway culvert 56.583ha

Hydrograph comparison

Time	DS Pk 0.238 m3/s	US+RWY Pk 1.329 m3/s	Diff m3/s	Vol m3
0.000	0.004	0.024	0.020	
0.247	0.005	0.031	0.026	20.5
0.494	0.008	0.048	0.040	29.3
0.741	0.015	0.082	0.067	47.6
0.988	0.026	0.145	0.119	82.7
1.235	0.046	0.256	0.210	146.3
1.482	0.077	0.431	0.354	250.8
1.729	0.115	0.643	0.528	392.1
1.976	0.155	0.864	0.709	550.0
2.223	0.192	1.072	0.880	706.5
2.470	0.222	1.239	1.017	843.4
2.717	0.238	1.329	1.091	937.2
2.964	0.235	1.314	1.079	964.8
3.211	0.219	1.224	1.005	926.5
3.458	0.195	1.089	0.894	844.3
3.705	0.165	0.926	0.761	735.8
3.952	0.134	0.752	0.618	613.1
4.199	0.103	0.576	0.473	485.1
4.446	0.073	0.413	0.340	361.5
4.693	0.048	0.271	0.223	250.3
4.940	0.029	0.163	0.134	158.7
5.187	0.017	0.096	0.079	94.7
5.434	0.01	0.058	0.048	56.5
5.681	0.007	0.038	0.031	35.1
5.928	0.005	0.028	0.023	24.0
6.175	0.004	0.024	0.020	19.1

Total attenuation 9576 m3

LIDAR contour areas / volume

Culvert	
Invert level	34.93
soffit level	35.985

Contour mAOD	Area m²	Volume m3
35.0	10	
35.5	287	74.3
36.0	936	305.8
36.5	1601	634.3
37.0	2350	987.8
37.5	3170	1380.0
38.0	4081	1812.8
38.5	5090	2292.8
39.0	5958	2762.0
39.5		
40.0		

Total volume 10250

Model Details

Storage is Online Cover Level (m) 40.000

Tank or Pond Structure

Invert Level (m) 35.000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	10.0	1.000	936.0	2.000	2350.0	3.000	4081.0	4.000	5958.0
0.500	287.0	1.500	1601.0	2.500	3170.0	3.500	5090.0		

Orifice Outflow Control

Diameter (m) 0.250 Discharge Coefficient 0.600 Invert Level (m) 34.930