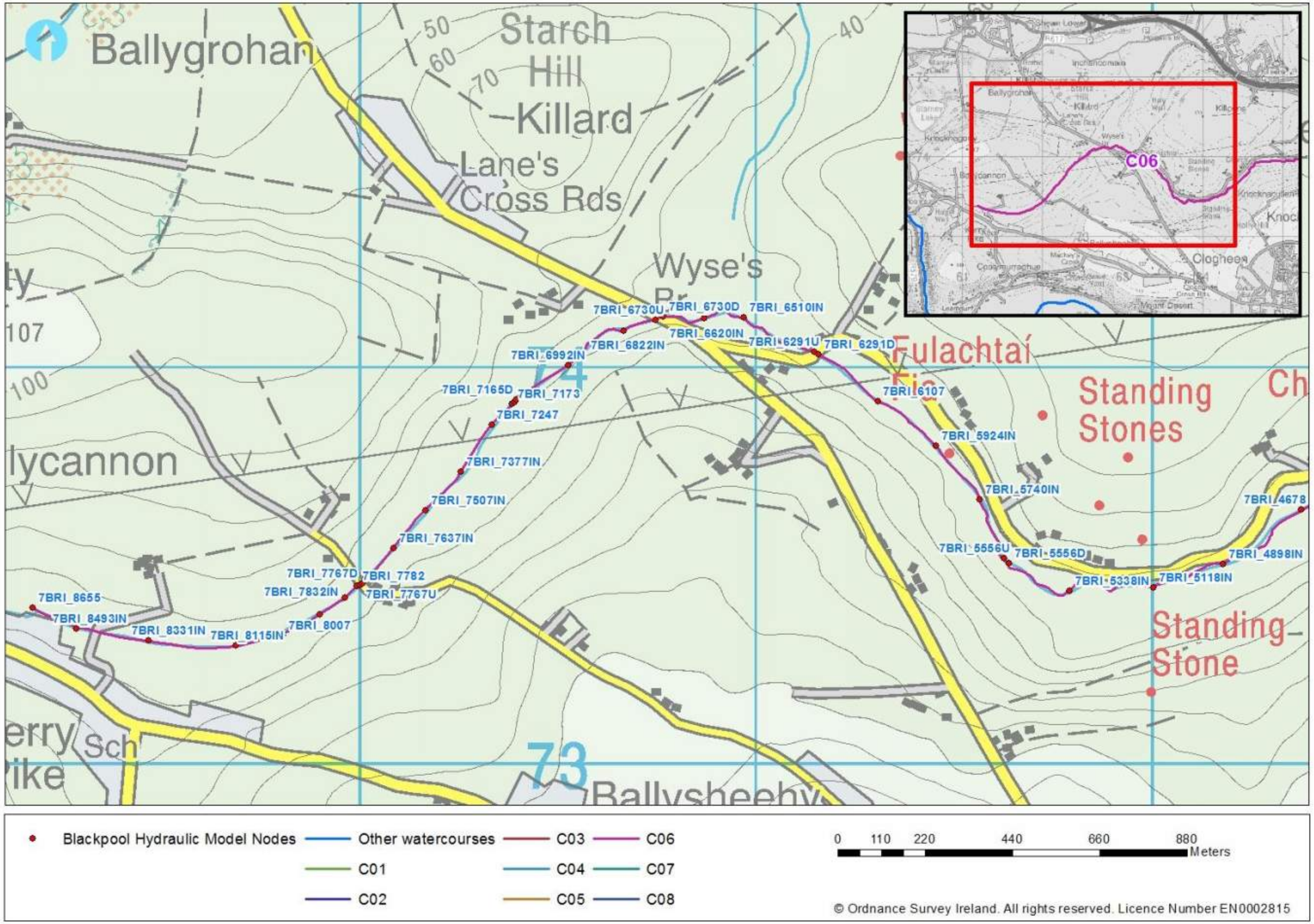
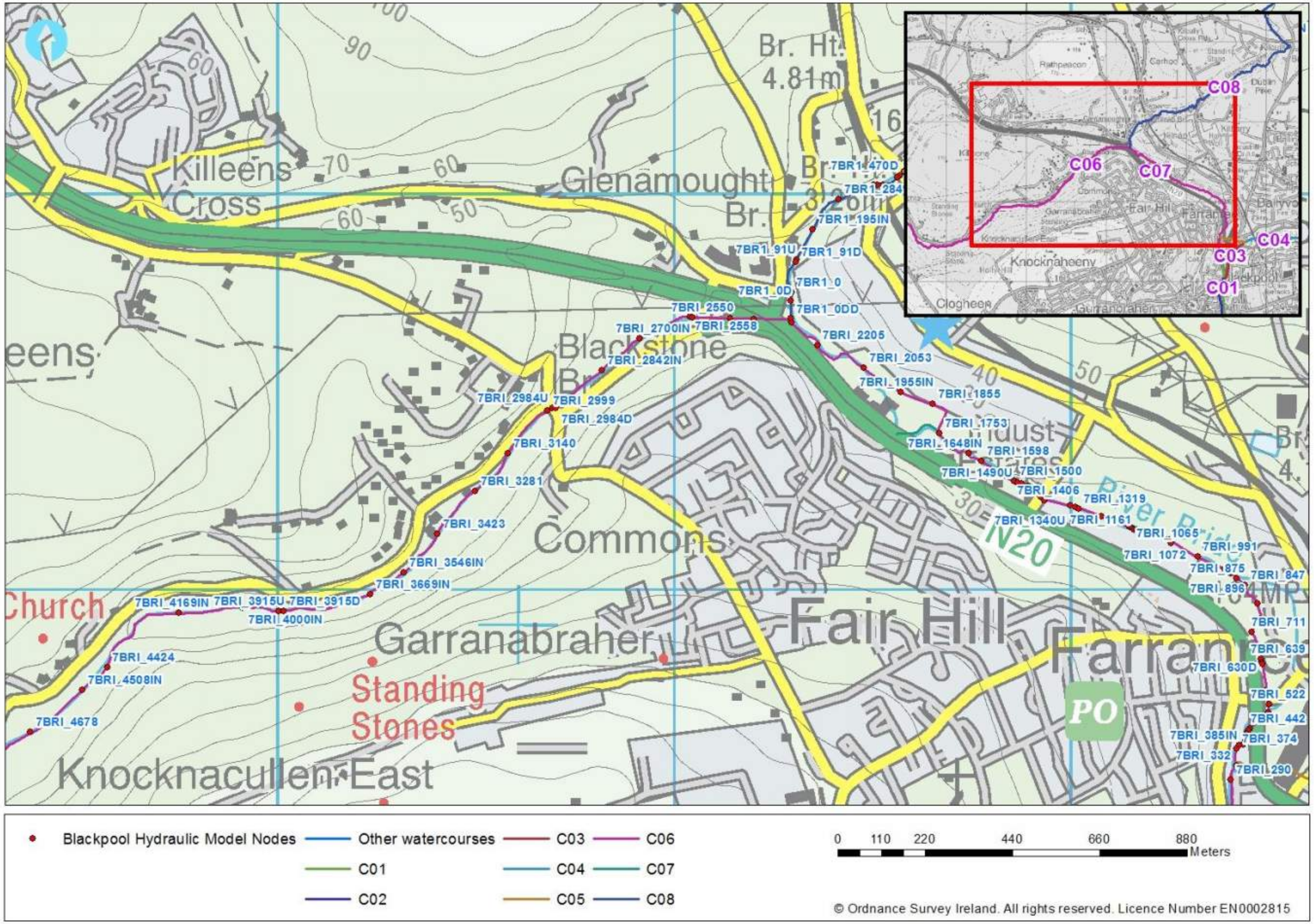
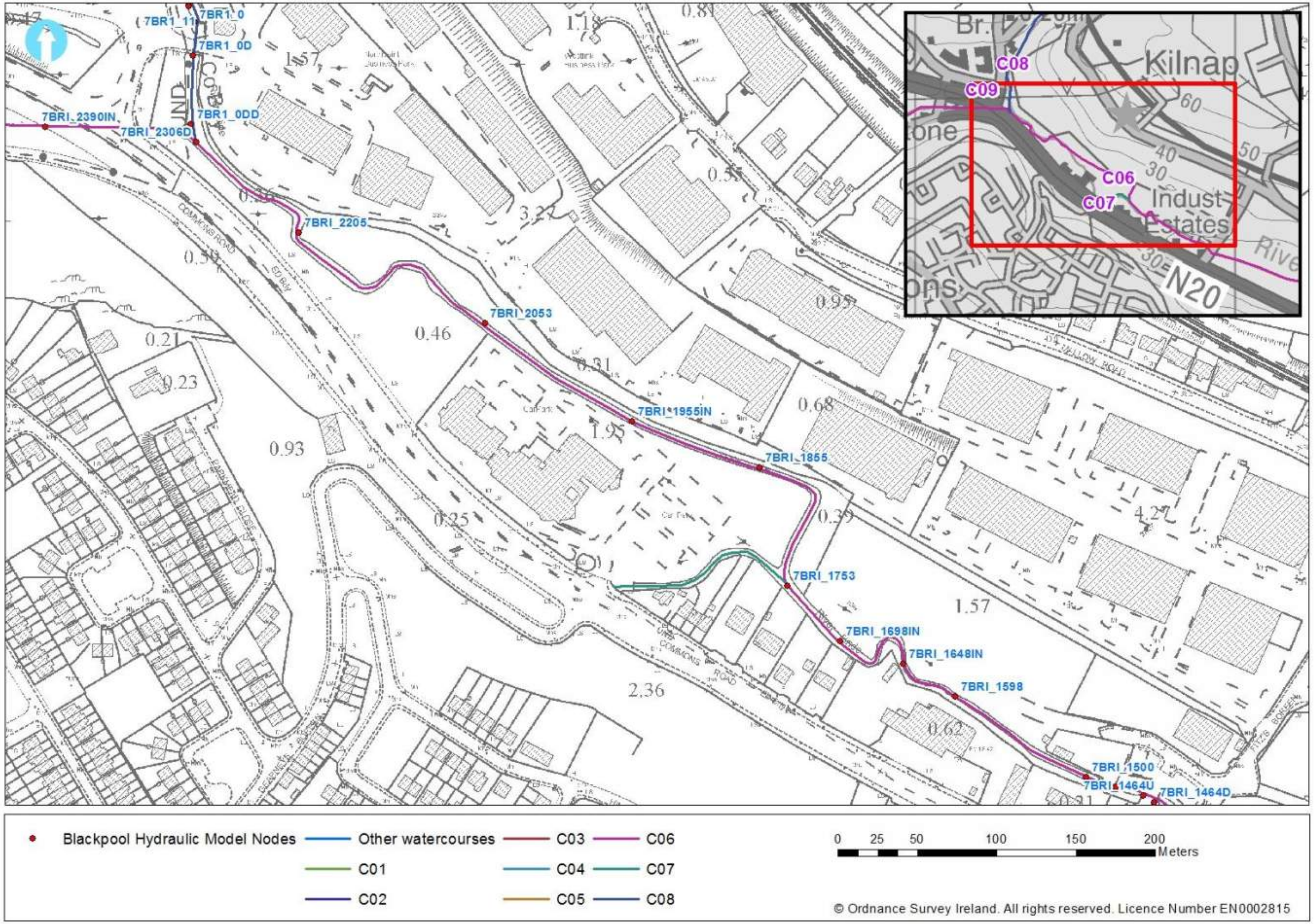
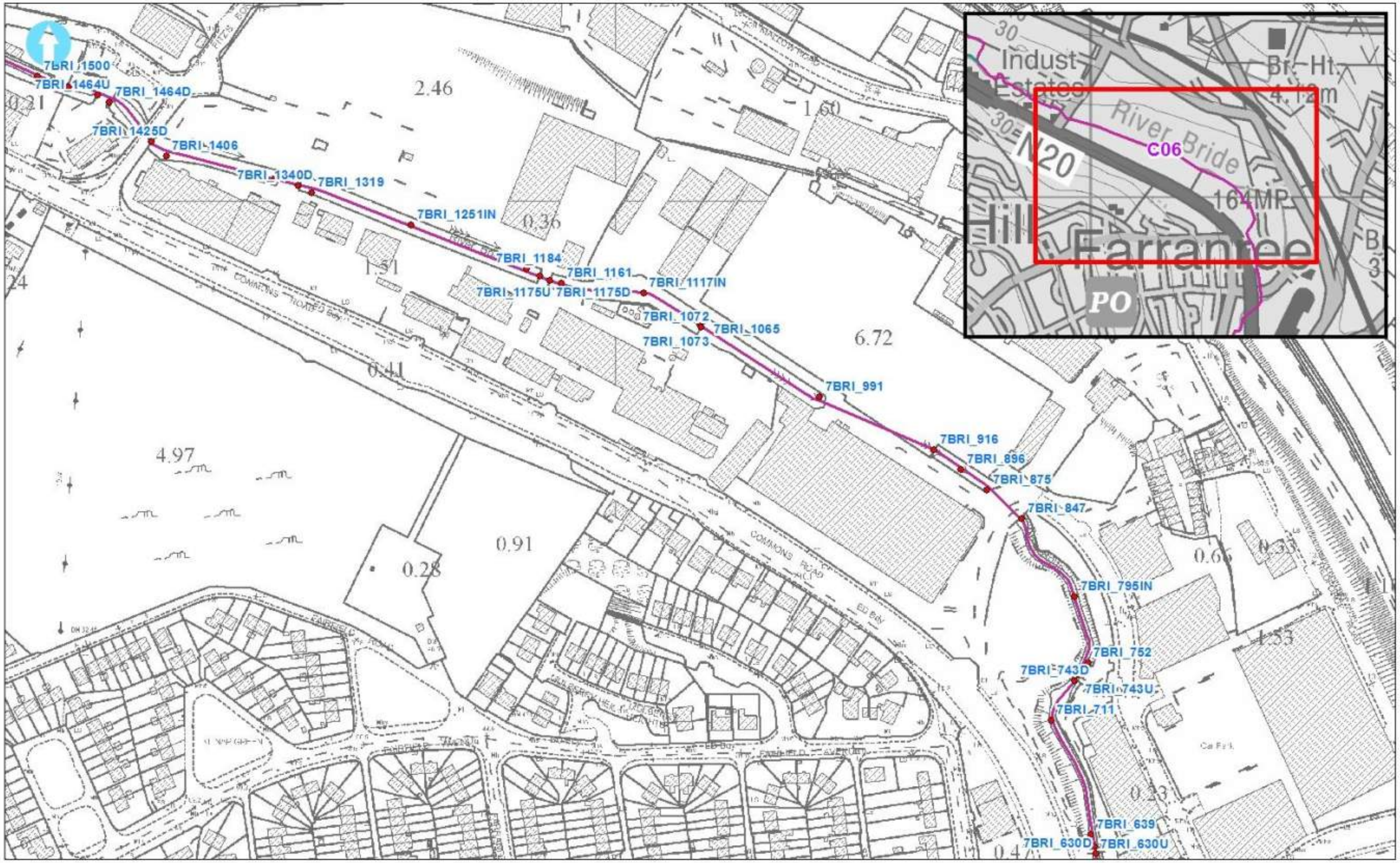
JBA consulting



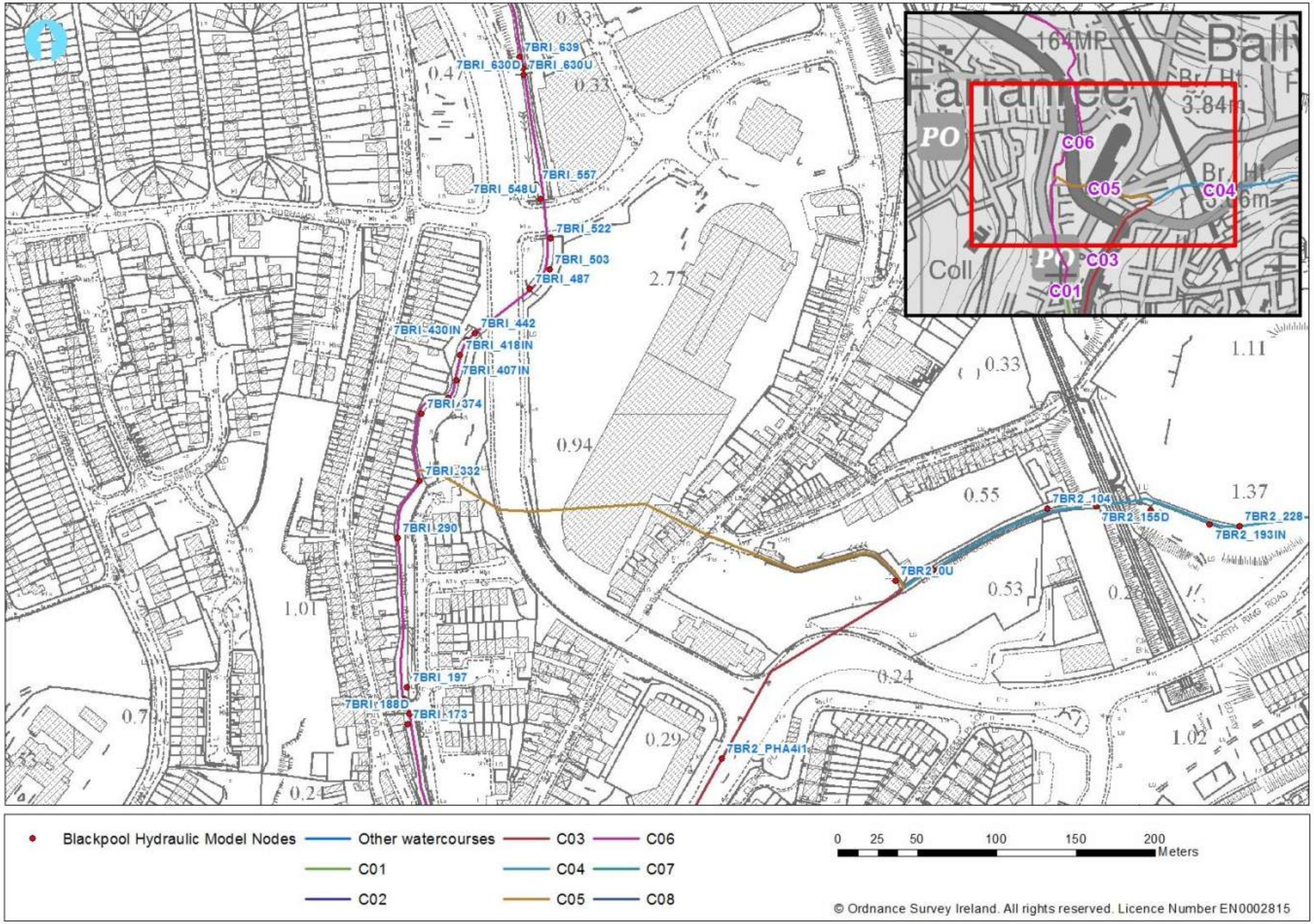

Killeens Cross
Glenamought Br.
Br. Ht. 4.81m
Blackstone Br.
Commons
Fair Hill
Farranree
Garranabraher
Standing Stones
Knocknacullen East
Church
N20
C08
C06
C07
C04
C03
C01
Knocknaheeny
Clogheen
7BR1_470D
7BR1_195IN
7BR1_91U
7BR1_91D
7BR1_0D
7BR1_0
7BR1_0DD
7BRI_2550
7BRI_2700IN
7BRI_2558
7BRI_2205
7BRI_2053
7BRI_2842IN
7BRI_1955IN
7BRI_1855
7BRI_2984U
7BRI_2999
7BRI_2984D
7BRI_1753
7BRI_1648IN
7BRI_1598
7BRI_3140
7BRI_1490U
7BRI_1500
7BRI_3281
7BRI_1406
7BRI_1319
7BRI_1340U
7BRI_1161
7BRI_3423
7BRI_1065
7BRI_991
7BRI_1072
7BRI_3546IN
7BRI_875
7BRI_847
7BRI_3669IN
7BRI_896
7BRI_4169IN
7BRI_3915U
7BRI_3915D
7BRI_4000IN
7BRI_711
7BRI_639
7BRI_630D
7BRI_4424
7BRI_4508IN
7BRI_522
7BRI_442
7BRI_4678
7BRI_385IN
7BRI_374
7BRI_332
7BRI_290
Blackpool Hydraulic Model Nodes
Other watercourses
C01
C02
C03
C04
C05
C06
C07
C08
0
110
220
440
660
880
Meters
© Ordnance Survey Ireland. All rights reserved. Licence Number EN0002815

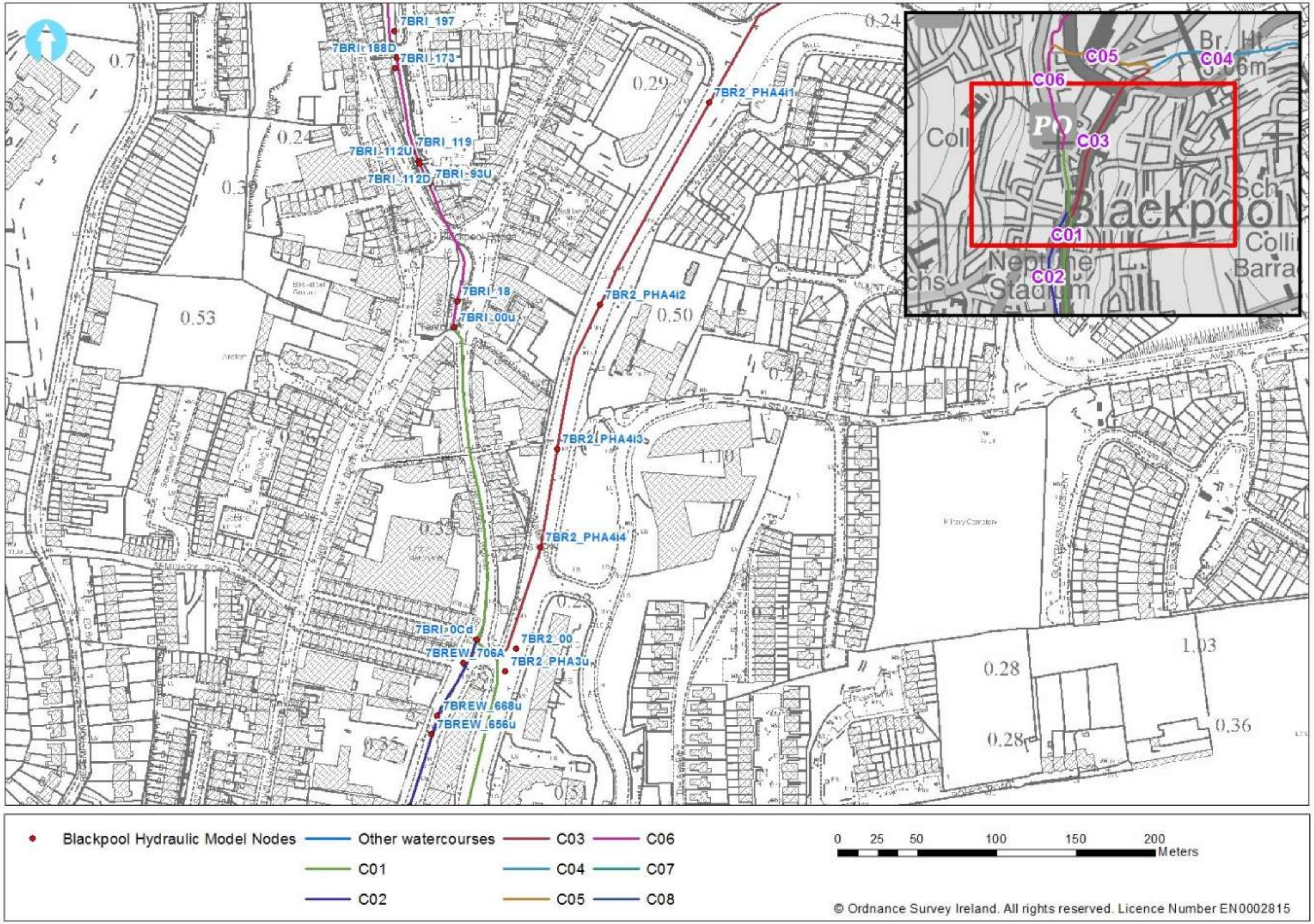

7BR1_11
7BR1_0
7BR1_0D
7BR1_0DD
7BRI_2390IN
7BRI_2306D
7BRI_2205
7BRI_2053
7BRI_1955IN
7BRI_1855
7BRI_1753
7BRI_1698IN
7BRI_1648IN
7BRI_1598
7BRI_1500
7BRI_1464U
7BRI_1464D
C08
C09
C06
C07
Kilnap
Indust
Estates
N20
Blackpool Hydraulic Model Nodes
Other watercourses
C01
C02
C03
C04
C05
C06
C07
C08
0 25 50 100 150 200
Meters
© Ordnance Survey Ireland. All rights reserved. Licence Number EN0002815



Blackpool Hydraulic Model Nodes; Other watercourses; C01; C02; C03; C04; C05; C06; C07; C08

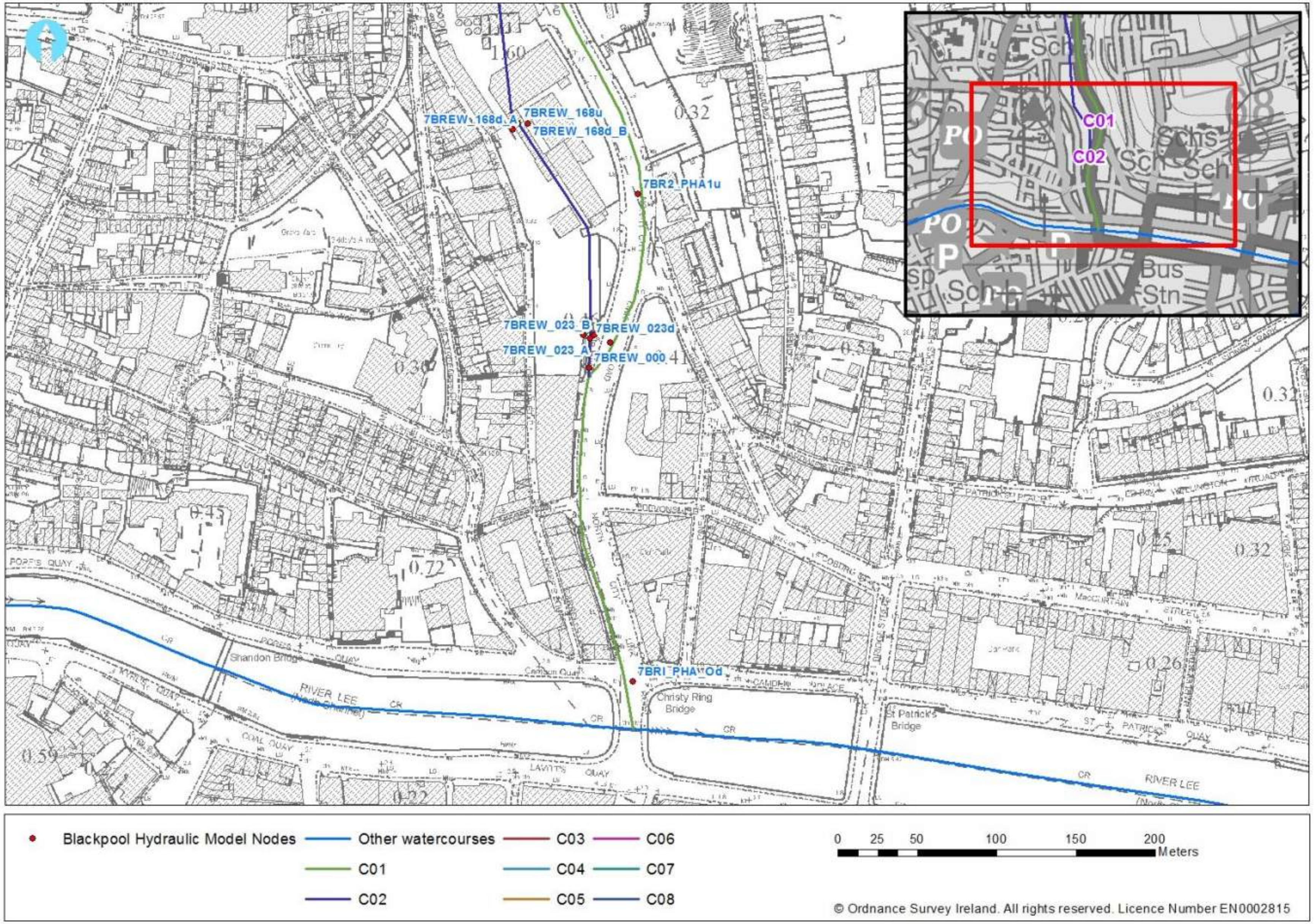
0 25 50 100 150 200 Meters

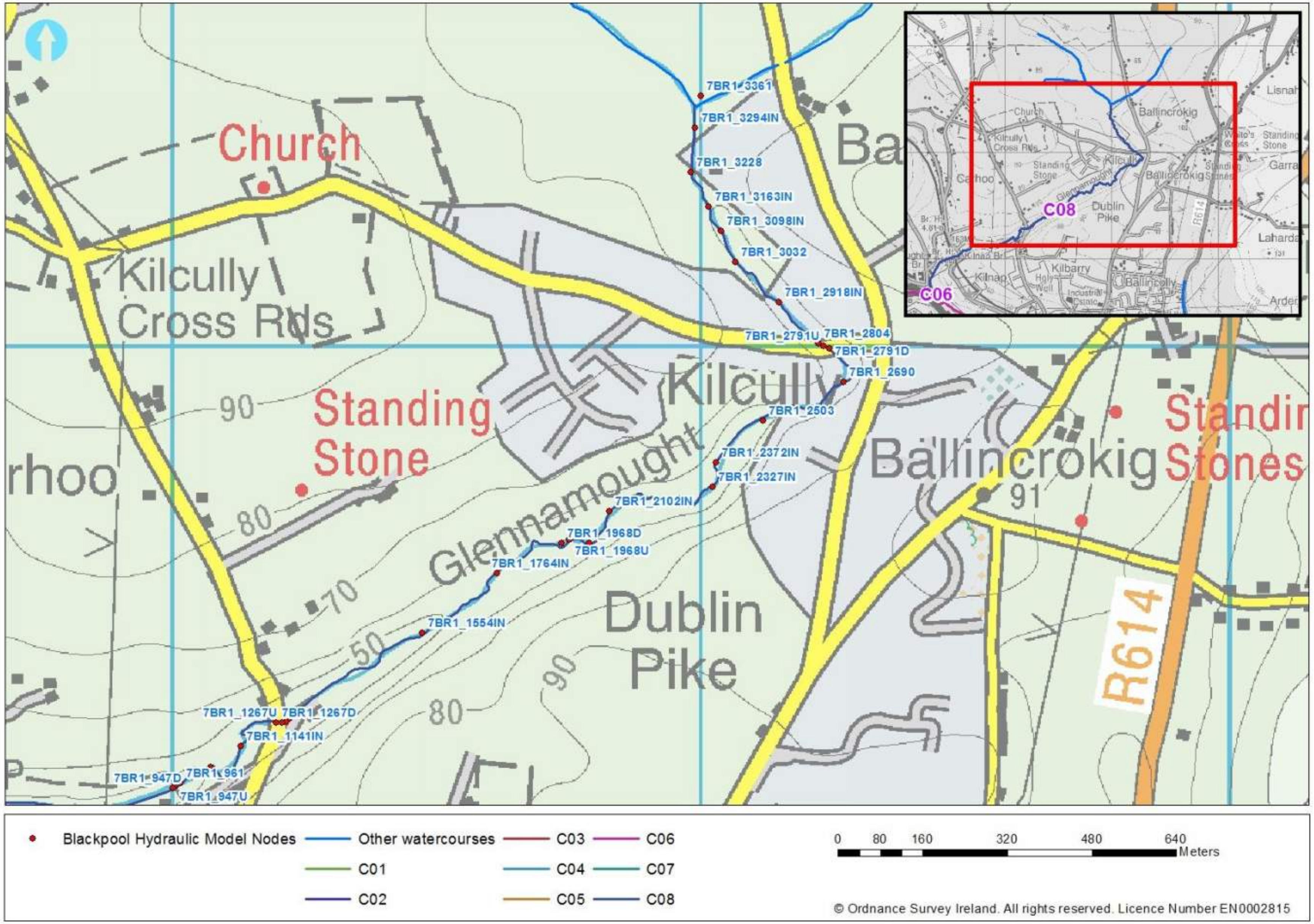

7BRI_639
7BRI_630D
7BRI_630U
7BRI_557
7BRI_548U
7BRI_522
7BRI_503
7BRI_487
7BRI_442
7BRI_430IN
7BRI_418IN
7BRI_407IN
7BRI_374
7BRI_332
7BRI_290
7BRI_197
7BRI_188D
7BRI_173
7BR2_104
7BR2_155D
7BR2_228
7BR2_193IN
7BR2_0U
7BR2_PHA4i1
C06
C05
C04
C03
C01
PO
Coll
164MP
Br. Ht.
3.84m
0.47
0.33
2.77
0.94
1.01
0.7
0.24
0.29
0.55
0.53
1.11
1.37
1.02
NORTH RING ROAD
Blackpool Hydraulic Model Nodes
Other watercourses
C01
C02
C03
C04
C05
C06
C07
C08
0
25
50
100
150
200
Meters
© Ordnance Survey Ireland. All rights reserved. Licence Number EN0002815


7BRI_197
7BRI_188D
7BRI_173
7BRI_119
7BRI_112U
7BRI_93U
7BRI_112D
7BRI_18
7BRI_00u
7BR2_PHA4i1
7BR2_PHA4i2
7BR2_PHA4i3
7BR2_PHA4i4
7BRI_0Cd
7BR2_00
7BREW_706A
7BR2_PHA3u
7BREW_668u
7BREW_656u
C01
C02
C03
C04
C05
C06
Blackpool
Blackpool Hydraulic Model Nodes
Other watercourses
C03
C06
C01
C04
C07
C02
C05
C08
0 25 50 100 150 200
Meters
© Ordnance Survey Ireland. All rights reserved. Licence Number EN0002815

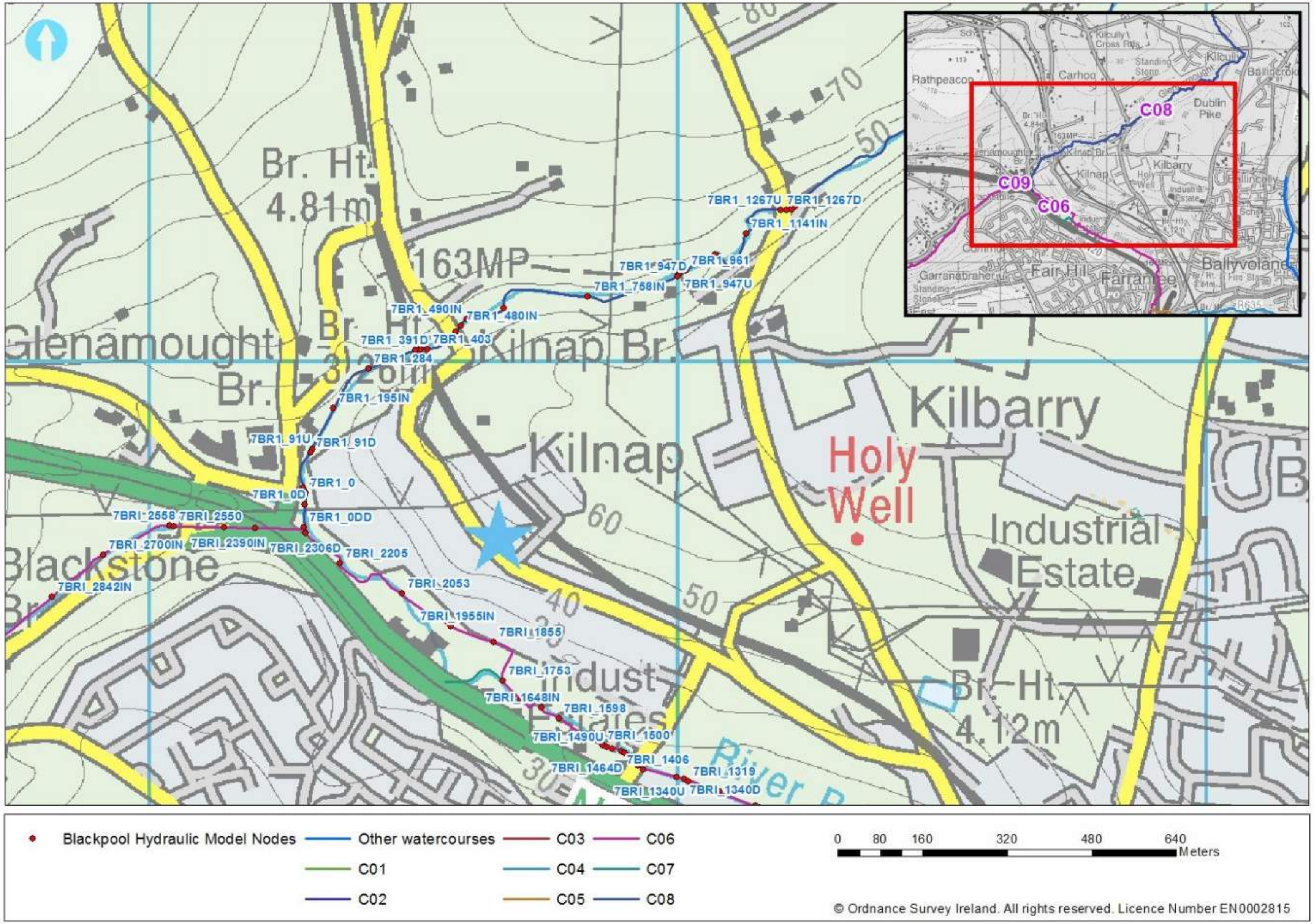
• Blackpool Hydraulic Model Nodes
Other watercourses
C01
C02
C03
C04
C05
C06
C07
C08

0 25 50 100 150 200 Meters

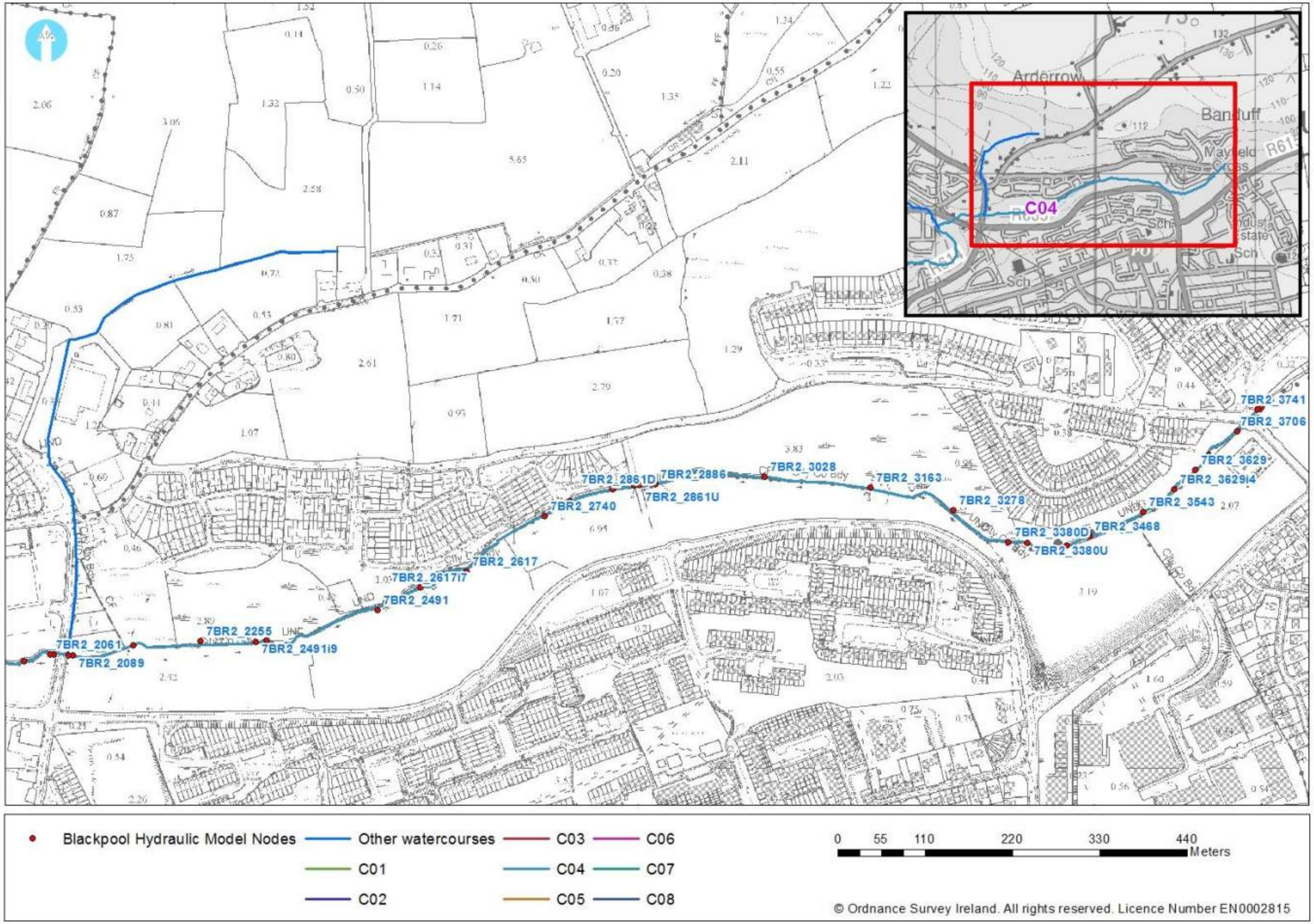

7BREW_168d_A
7BREW_168u
7BREW_168d_B
7BR2_PHA1u
7BREW_023_B
7BREW_023d
7BREW_023_A
7BREW_000
7BRI_PHA_Od
C01
C02
Shandon Bridge
RIVER LEE
Christy Ring Bridge
St Patrick's Bridge
POPE'S QUAY
COAL QUAY
LAVITT'S QUAY
Bus Stn
Blackpool Hydraulic Model Nodes
Other watercourses
C01
C02
C03
C04
C05
C06
C07
C08
0 25 50 100 150 200
Meters
© Ordnance Survey Ireland. All rights reserved. Licence Number EN0002815



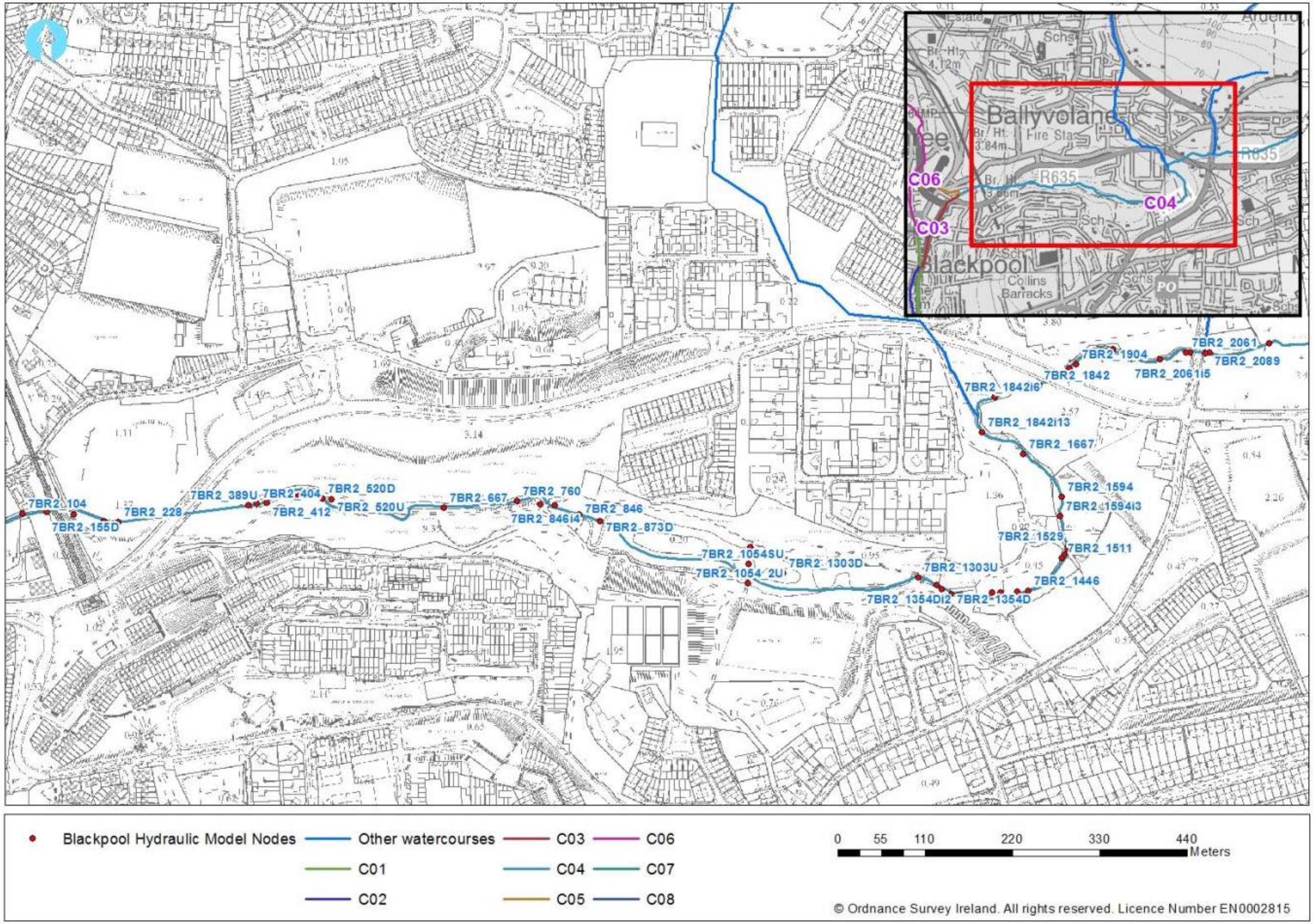
Church
Kilcully Cross Rds
Standing Stone
rhoo
Glennamought
Kilcully
Ballincrokig
Standing Stones
Dublin Pike
R614
Ba
90
80
70
50
91
7BR1_3361
7BR1_3294IN
7BR1_3228
7BR1_3163IN
7BR1_3098IN
7BR1_3032
7BR1_2918IN
7BR1_2791U
7BR1_2804
7BR1_2791D
7BR1_2690
7BR1_2503
7BR1_2372IN
7BR1_2327IN
7BR1_2102IN
7BR1_1968D
7BR1_1968U
7BR1_1764IN
7BR1_1554IN
7BR1_1267U
7BR1_1267D
7BR1_1141IN
7BR1_947D
7BR1_961
7BR1_947U
C08
C06
Blackpool Hydraulic Model Nodes
Other watercourses
C01
C02
C03
C04
C05
C06
C07
C08
0 80 160 320 480 640
Meters

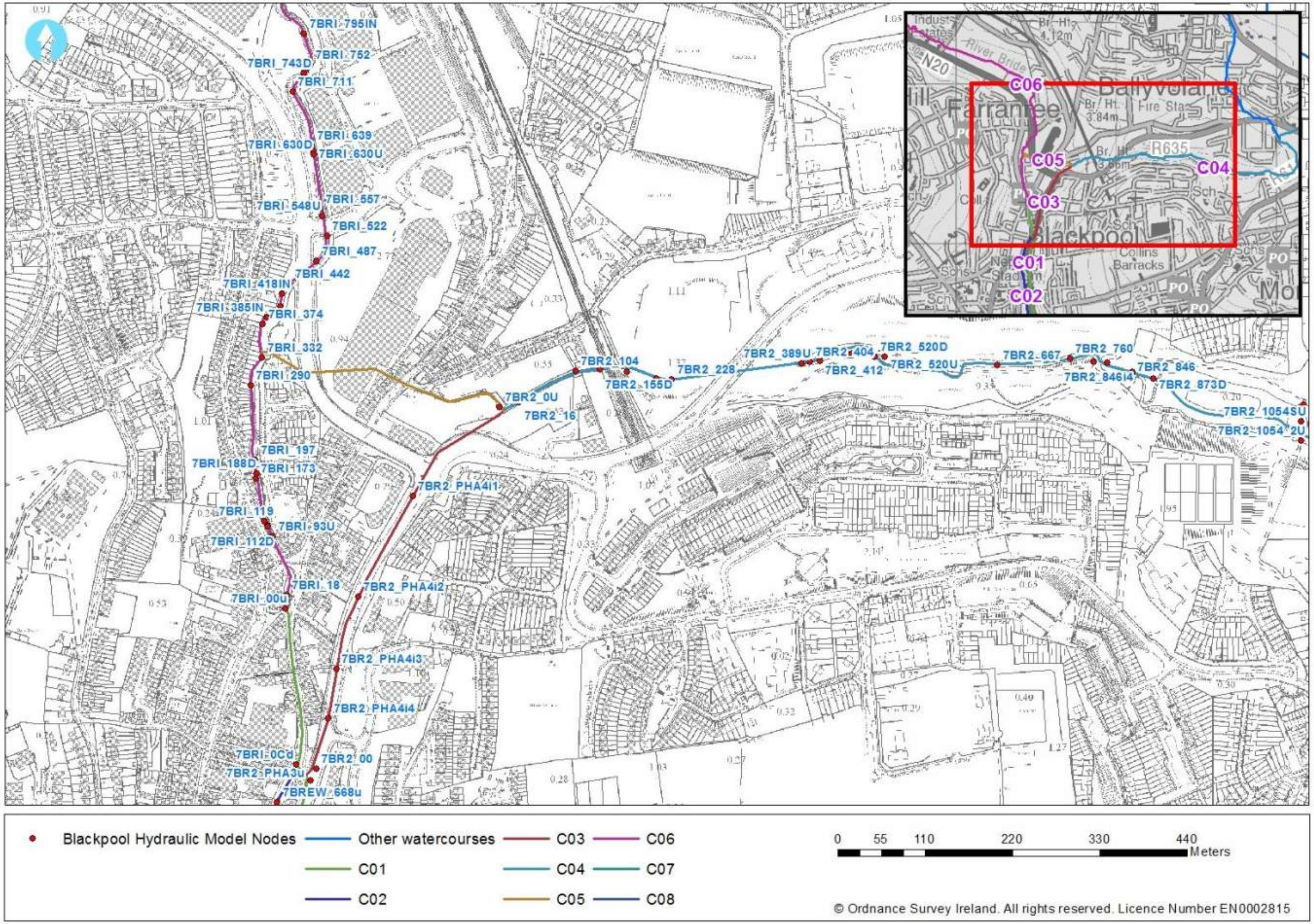

Blackpool Hydraulic Model Nodes
Other watercourses
C01
C02
C03
C04
C05
C06
C07
C08
0 80 160 320 480 640 Meters
© Ordnance Survey Ireland. All rights reserved. Licence Number EN0002815

JBA consulting



JBA consulting




7BRI_795IN
7BRI_752
7BRI_743D
7BRI_711
7BRI_639
7BRI_630D
7BRI_630U
7BRI_557
7BRI_548U
7BRI_522
7BRI_487
7BRI_442
7BRI_418IN
7BRI_385IN
7BRI_374
7BRI_332
7BRI_290
7BRI_197
7BRI_188D
7BRI_173
7BRI_119
7BRI_93U
7BRI_112D
7BRI_18
7BRI_00u
7BRI_0Cd
7BR2_PHA3u
7BREW_668u
7BR2_00
7BR2_PHA4i4
7BR2_PHA4i3
7BR2_PHA4i2
7BR2_PHA4i1
7BR2_0U
7BR2_16
7BR2_104
7BR2_155D
7BR2_228
7BR2_389U
7BR2_404
7BR2_412
7BR2_520D
7BR2_520U
7BR2_667
7BR2_760
7BR2_846
7BR2_846I4
7BR2_873D
7BR2_1054SU
7BR2_1054_2U
C06
C05
C04
C03
C01
C02
Blackpool Hydraulic Model Nodes
Other watercourses
C01
C02
C03
C04
C05
C06
C07
C08
0 55 110 220 330 440
Meters
© Ordnance Survey Ireland. All rights reserved. Licence Number EN0002815

E Flow Monitoring Survey Report

Blackpool Culvert Flow Survey 2014/2015

General Report:

Contents

Appendices:

1.0 Introduction:

Information was required by the OPW in relation to flow conditions within the Blackpool Culvert in Cork City, further to previous flooding events in Blackpool village. This information would help inform hydraulic models and support the overall design of any remedial works planned going forward. In particular information was required to understand the hydraulics occurring at the bifurcation section which is under the road junction by Maddens Buildings. At this point the newer section of culvert meets the old Brewery culvert, where most of the Bride River flow which had entered the culvert from Blackpool church entrance, is diverted to the Limerick road channel.

Fig 1: Entrance to Culvert at Blackpool Church after Rain Event

JBA Consulting drew up the survey contract requirements. Further to a tendering process, Water Technology Ltd proceeded with installation and testing work during March 2014.

In fact, the total period of monitoring continued to various extents, effectively from the middle of March 2014 to end of February 2015.

1.1 Work Schedule Summary

The work schedule is approximately broke down as follows:

Table 1: Work Schedule Summary:

Works	Dates	comment
Installation and preliminary testing	March April , May 2014	Initial delays due to unsafe high levels in culvert. Some further delays due to Health and Safety considerations and traffic management. Issues relating to ragging and debris created need for additional visits.
Official 4 month Contracts period	June, July, August, September, 2014	Monitoring before and after cleaning under bridge adjacent to Church and at bifurcation section of culvert. Predominantly low water levels during the contracts period with less significant rain events.
Extension period 1	October, November 2014	extension due to insufficient useful data during contracts period. Most significant rain events of survey were monitored in November 2014
Extension Period 2	December 2014, January, February 2015	further extension to install non-contact ultrasonic level monitors to overcome some ongoing issues of ragging and debris on immersed AV probes.

2.0 Methodology of Approach:

The primary purpose of the survey was to monitor levels and velocities at all 4 channels close to the bifurcation at Maddens buildings during rain events. The substantive points of interest are

- determine if there is any surcharging or restriction to free flowing movement during rain events.
- Calculate flows to estimate the flow distribution throughout the bifurcation during rain events.
- Provide rainfall, level and velocity data to inform and compare to the hydraulic model. This included a level logger under the bridge by Blackpool Church

Coinciding with this on-line monitoring the culvert was entered regularly to clean and maintain the probes, check the levels and document the sediment and debris found within the bifurcation area.

Fig 2 shows the general layout of the bifurcation with 4 channels. The bride river enters the culvert at Blackpool church. Various flow loggers were installed on this channel. All flow loggers on this channel are referred to as Flow Monitor 1 location, (FM1).

Flow also enters the bifurcation from the new culvert under the Limerick Rd. This flow logger is referred to as Flow Monitor 3, (FM3).

Flow exits the bifurcation predominantly through the new culvert under the Limerick Road. The flow logger on this section is referred to as Flow Monitor 4, (FM4).

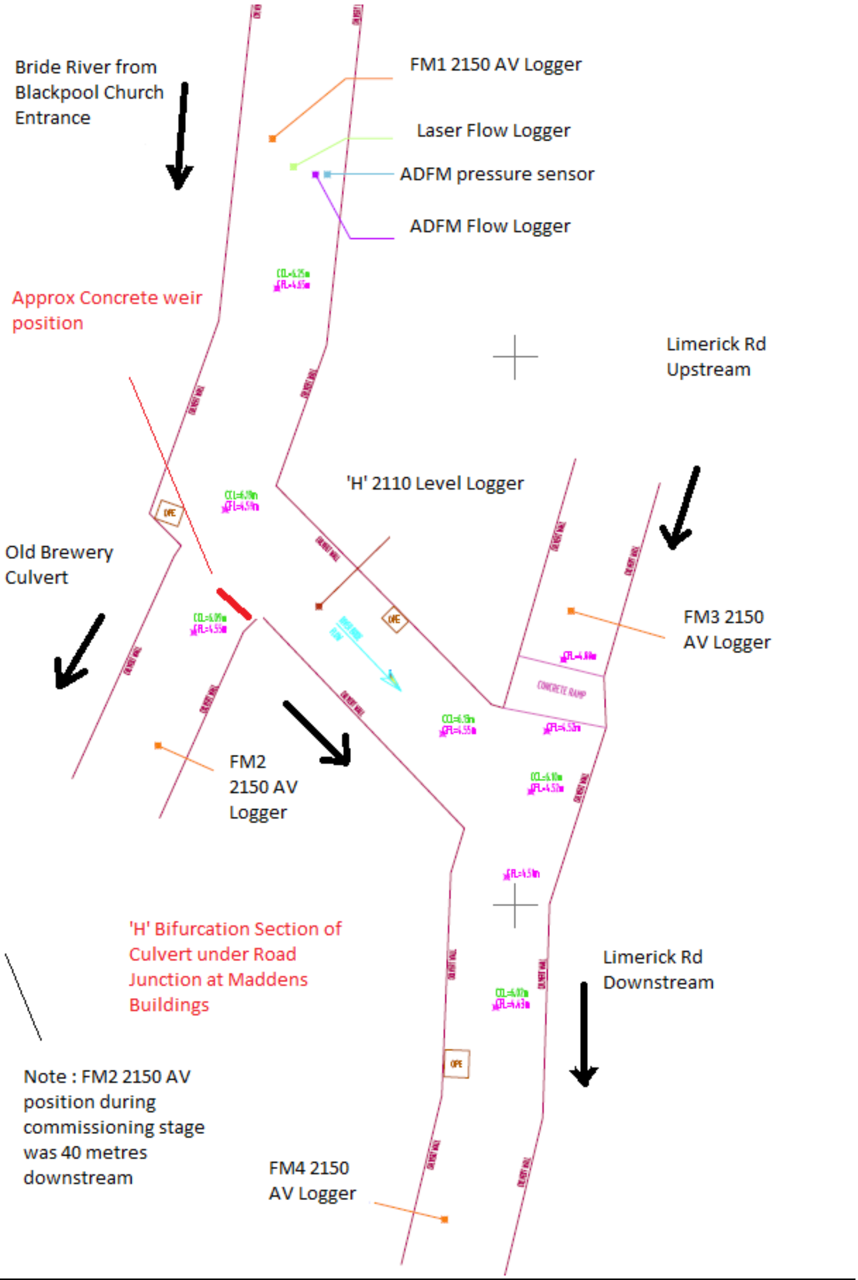
Flow also exits through the old brewery channel. The flow logger is referred to as Flow Monitor 2, (FM2). This logger was initially installed 40 metres beyond the bifurcation in an attempt to find a more suitable section of channel for flow measurement. Prior to the contracts period, it was moved back close to the bifurcation, to remove the possibility of errors from storm pipe discharges entering the Brewery culvert.

A level logger was placed within the bifurcation and is referred to as H level.
In December 2014 this level logger was repositioned in the FM2 channel.

2.1 Location of Level and Flow Loggers:

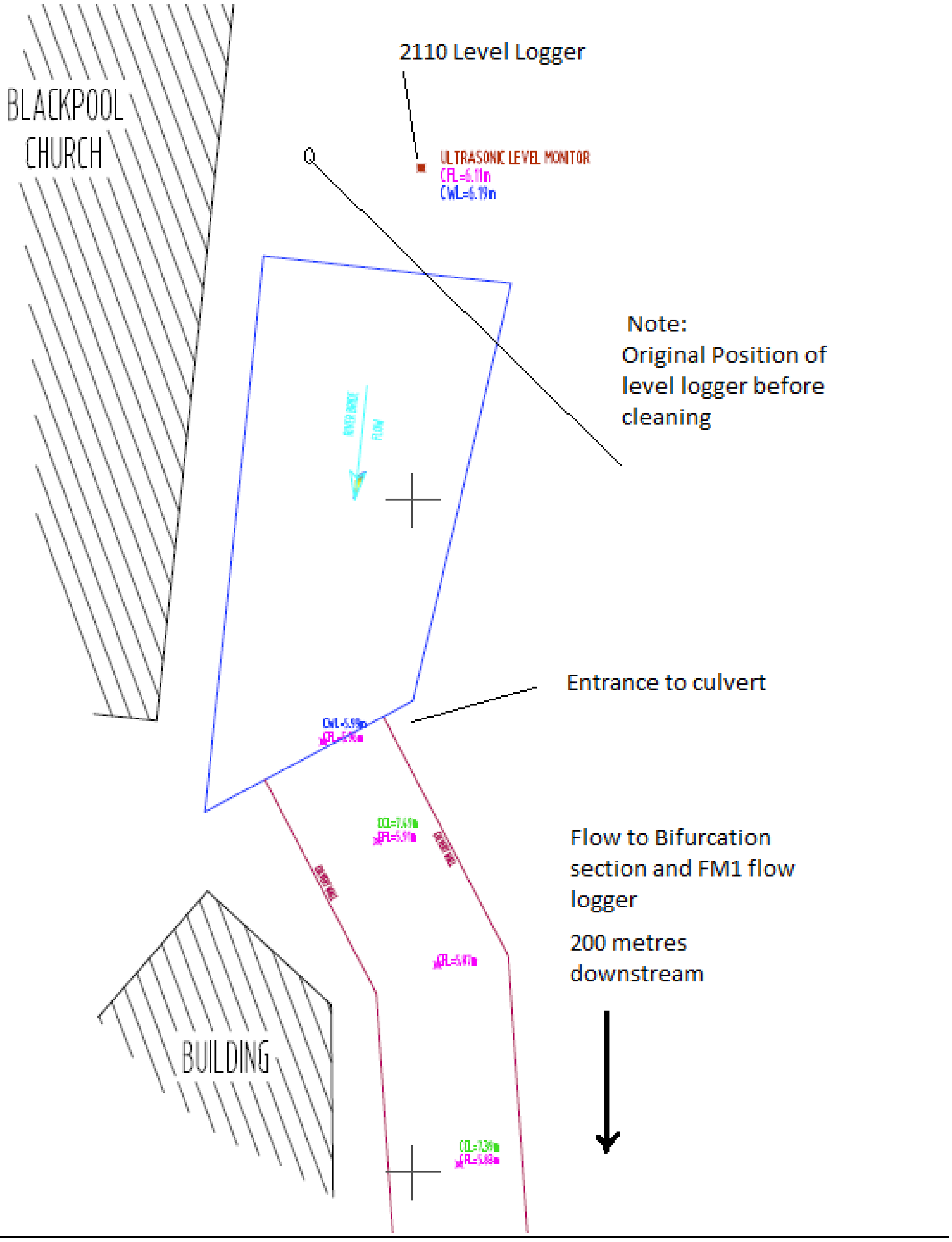
Fig 2 shows both the type and location of each logger at the bifurcation. Some equipment such as the ADFM flow profiler and pressure sensor were installed temporarily while the 2150 loggers were installed for the duration of the survey.

Fig 2: Location of all loggers in 4 culvert channels at Bifurcation.



An Isco 2110 Ultrasonic level logger was also placed under the bridge adjacent to Blackpool church at the location shown in diagram below

Fig 3: location of ultrasonic level logger under Bridge at Blackpool Church



2.2 Rain Gauges Locations:

3 x Isco 674 0.1 mm tipping bucket Rain Gauges were placed at Whitechurch, Clogheen and in the Garda station at Mayfield Garda Station respectively. The rain gauge at the Garda station was removed after the initial contract period in October.

Fig 4:   locations of rain gauges:

2.3 M OD (Malin) for Logger positions:

A Topographical Survey was carried out by NCW Surveys working on behalf of Water Technology Ltd on the 21st August. M OD (Malin) at the probe positions are seen in Fig 5 to 8 and in table 2 on page 11.

Fig 5: M OD (Malin) for flow loggers at FM1 on River Bride culvert at bifurcation

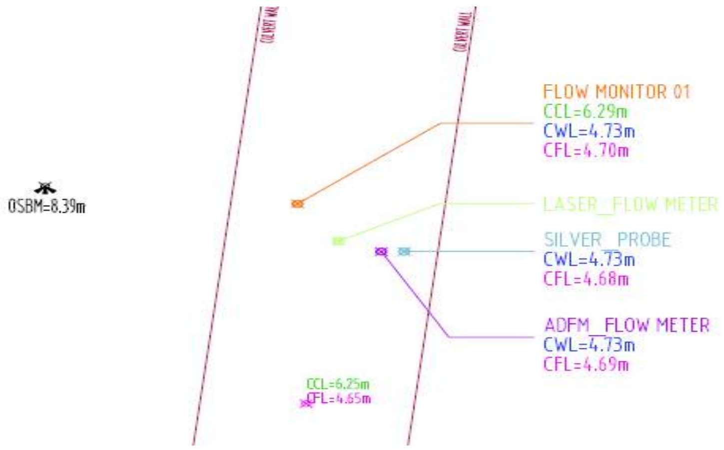


Fig 6: M OD (Malin) for flow loggers FM2 and FM3 and H Level at bifurcation

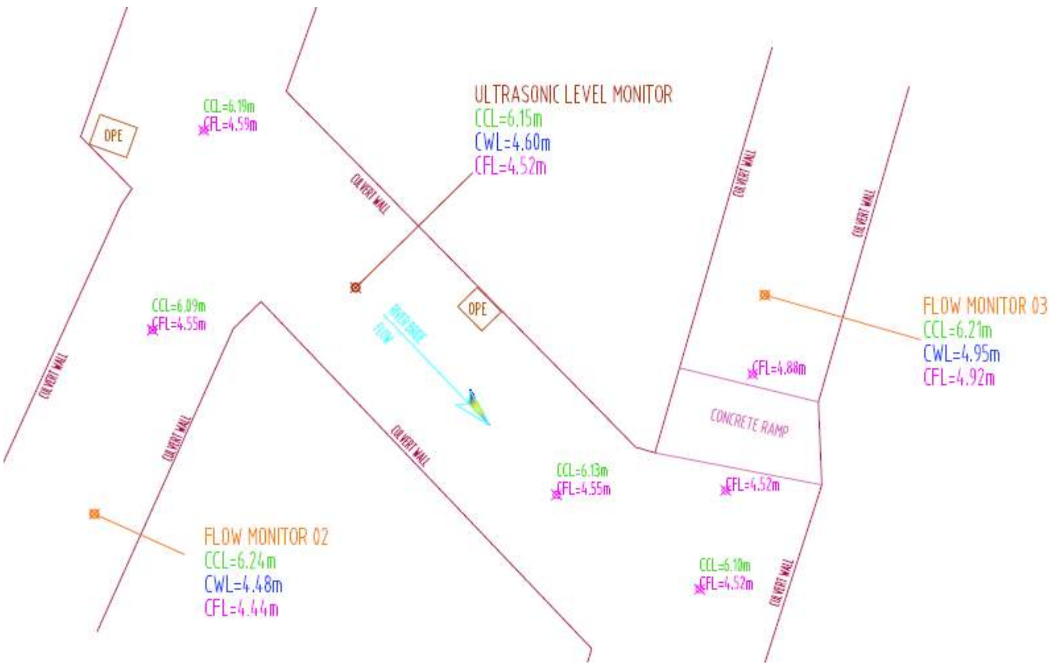


Fig 7: M OD (Malin) for flow logger at FM4 at bifurcation

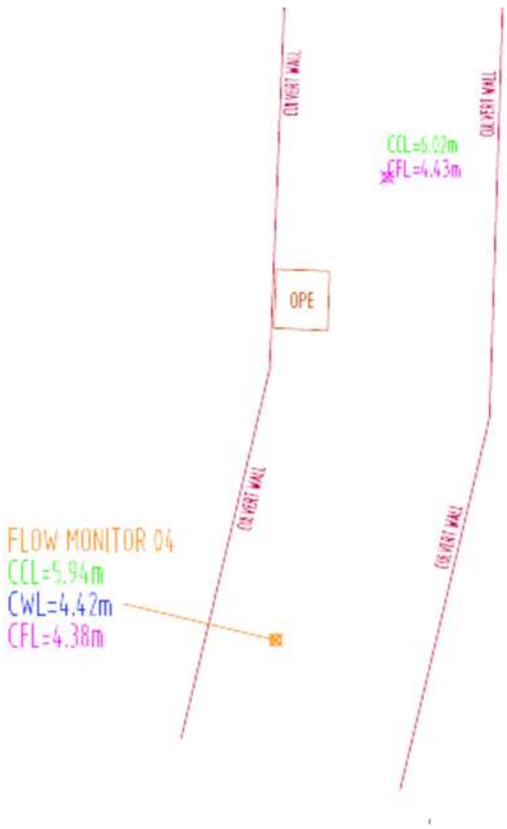
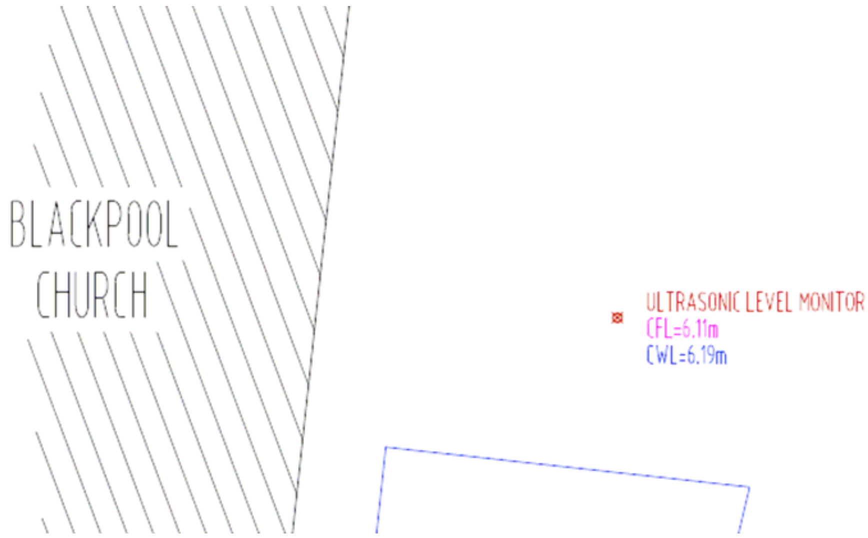


Fig 8: M OD (Malin) for level logger at Blackpool Church



All OD Malin level for loggers can be summarised as seen in Table 2 below.

Table 2: M OD (Malin) for all loggers:

OD (Malin)	Aug 2014
	Culvert Floor level (CFL)
Logger	**m**
Church 2110 US level Logger	6.19
FM1 2150 AV Flow Logger	4.7
Laser 2160 Logger	4.68
ADFM Profiler	4.69
FM2 2150 AV Flow Logger	4.44
FM3 2150 AV Flow Logger	4.92
FM4 2150 AV Flow Logger	4.38
H section 2110 US level Logger	4.52

3.0 Equipment used:

3.1 Selection Criteria:

The general flow conditions within the culvert are typically low level but high velocity. Typical winter levels outside wet conditions were 0.1 to 0.15 m with velocities of 0.8 to 1.5 m/s. Typical mid summer water levels could be 0.03 to 0.07 m with velocities of 0.3 to 0.9 m/s.

Low level /high velocity clean water is very difficult to measure using the Doppler principle in reality. Fast flowing low level water causes a splash effect at the probe face and can create a small local standing wave in front of the probe which can even be intermittent. Clean water requires more depth than dirty water to provide an adequate signal to calculate a meaningful velocity. In fact the more accurate velocity profilers such as the ADFM require a minimum depth of 0.22 m before a velocity is recorded. Typically readings below this would be considered not accurate for measurement by these devices.

The Isco 2150 AV Flow loggers were proposed for the survey as in general the levels were more suitable for this type of logger. However, it was agreed that 1 x ADFM Velocity Profiler would be installed for a period at the Bride River culvert at FM1 position. This was to act as a benchmark and provide accurate flows during the important rain events. In fact, there was only one event monitored when the ADFM was installed, that had sufficient level for the ADFM to operate. This was during the early testing stage during a rain event on the 25th April 2014. This event did show a close comparison between the 2150 AV logger and the ADFM. This was important data to provide some confidence in the 2150 AV loggers. The ADFM probe had to be returned to its suppliers in September.

In July 2014 a new product from Isco known as the 2160 Laser became available and was installed at the FM1 location on the 31st July. This uses a radar type technology, working on the Doppler principle, to measure both the velocity and level. This non-contact technology proved to be very important during subsequent rain events, in particular, the more significant events in post contract period of November 2014.
In December, an additional ultrasonic probe was mounted at FM4 and the ultrasonic probe in the bifurcation was moved to FM2 location.

3.2 Equipment Description:

The following is a brief description of each item of equipment and its location. Full data sheets are available in appendices.

3.2.1 Isco 2150 Area Velocity Flow Module.

Note: Installed at FM1 FM2 FM3 and FM4 mounted 1.5 to 2 m from the side wall using 500 mm flat plate metal.

Isco's area velocity sensor mounts at the bottom of the channel and uses Doppler technology to directly measure average velocity in the flow stream. An integral pressure transducer measures liquid depth to determine flow area. Flow rate is then calculated by multiplying the area of the flow stream by its average velocity.

Fig 9: Isco 2150 Area Velocity Flow Logger

Fig 10: Isco 2150 Area Velocity Doppler velocity measurement profile

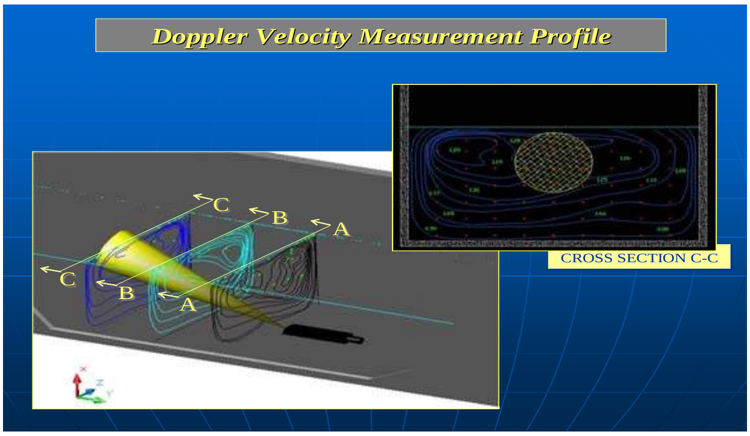


Fig 11: Isco 2150 Area Velocity Doppler velocity description

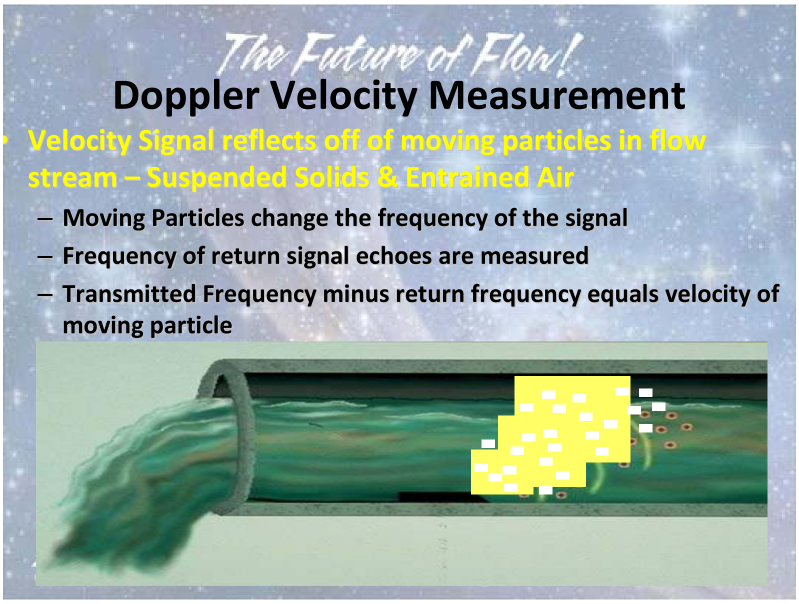
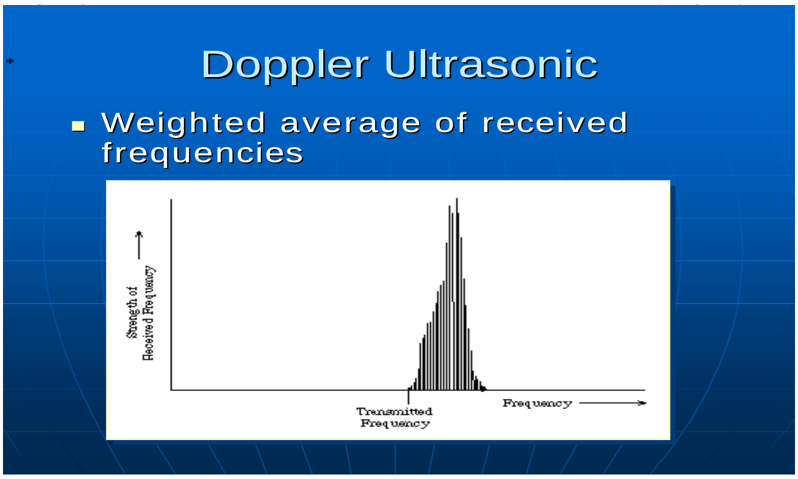


Fig 12: Isco 2150 Area Velocity weighted average description



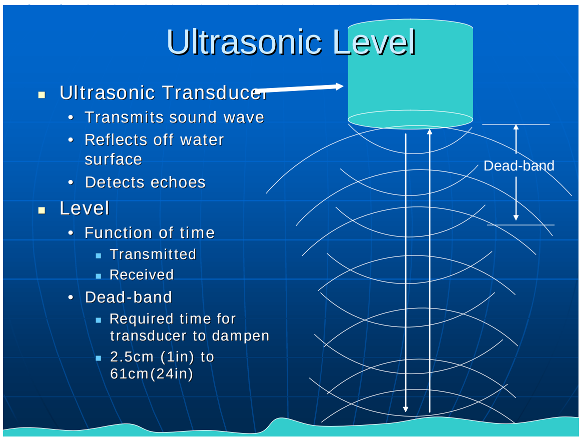
3.2.2 Isco 2110 Ultrasonic Level Module.

Note: Installed at Blackpool Church and in Bifurcation cross section supported off bridge and culvert ceiling respectively. Installed at FM4 and FM2 from October 2014 to end of February 2015

The 2110 Ultrasonic Module provides accurate non-contact water level measurement, using built-in software to calculate flow in weirs, flumes and streams. With the 2110, an ultrasonic sensor mounted above the flow stream transmits sound waves, which are reflected by the waters surface. The elapsed time between transmitted and returned signals determine the liquid level.

Fig 13: Isco 2110 Ultrasonic level logger

Fig 14: Isco 2110 Ultrasonic level logger principle of measurement



3.2.3 Isco ADFM Velocity profiler.

Note: Installed at FM1 location between April to September 2014- mounted 1.5 to 2 m from the side wall using 50 mm flat plate metal

The ADFM is an acoustic – based flow meter, using current profiling technology to measure flow in large pipes and channels. It implements the Doppler principle to measure velocity accurately and transmits short, acoustic pulses rather than a long continuous wave train.

Fig 15: Isco ADFM Pro 20 Velocity Profiler and beam angles

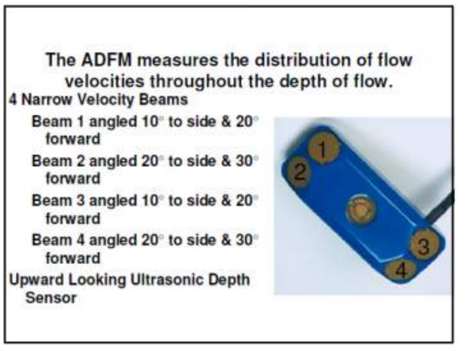
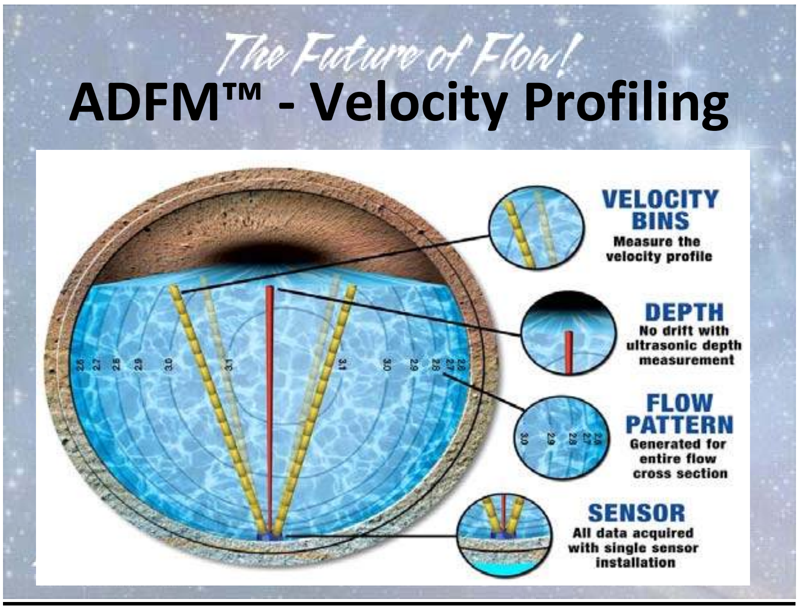


Fig 16: Isco ADFM Pro 20 Velocity Profiler principle of operation



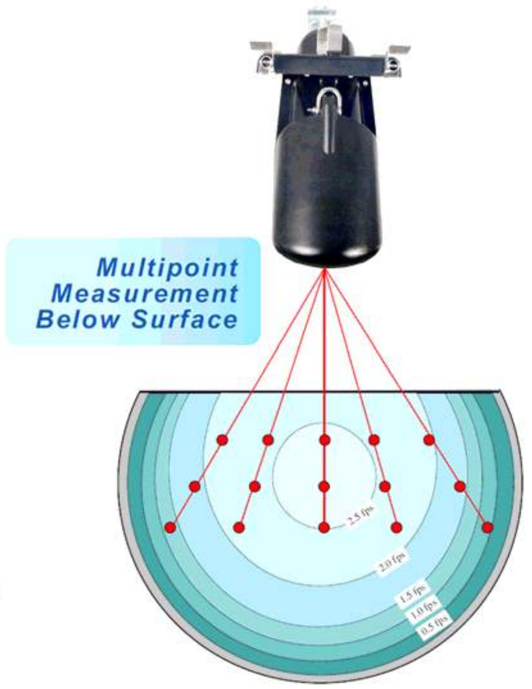
3.2.4 Isco 2160 Laser Flow Logger.

Note: Installed at FM1 location between August 2014 to February 2015

The Isco 2160 Laser Flow Logger remotely measures flow in open channels with non-contact Laser Doppler Velocity technology and non-contact Ultrasonic Level technology. The sensor uses advanced technology to measure velocity with a laser beam at single or multiple points below the surface of the stream.

Fig 17: Isco 2160 Laser Flow Logger

Fig 18: Isco 2160 Laser Flow Logger velocity measurement description



3.2.5 Isco 674 Rain Gauge

Note: Installed at White Church, Clogheen and Mayfield Garda Station in open flat surface.

The Isco Rain Gauges accurately measures rainfall by using a tipping bucket. The rain gauge has an 0.2 m opening on top to collect rain. Rain falls through a screen into a funnel and onto a tipping mechanism that records each tip as .1mm of rainfall.

Fig 19: Isco 674 Tipping bucket rain gauge

3.2.6 Isco 2105 GPRS Modem and Interface Module.

Note: Installed on most loggers and rain gauges -mounted inside lid of nearest adjacent manholes in culvert installations.

The 2105 Interface Module has a built in modem which pushes data at 2 minute intervals to a central server on the internet. Data is accessed using Flow link Pro software. The 2105 stacks, on top of the Isco 2150 AV and 2110 Ultrasonic loggers.

Fig 20: Isco 2105 GPRS Modem and interface Module

3.2.7 Flowlink Pro Server with website access

All loggers and rain gauges were attached to the 2105 GPRS modems which in turned pushed the data to a server hosted by Water Technology. This data was available in real-time throughout the server period. This allowed us to monitor rain events as they occurred.

Fig 21: Image from Flowlink Pro WEB UI page

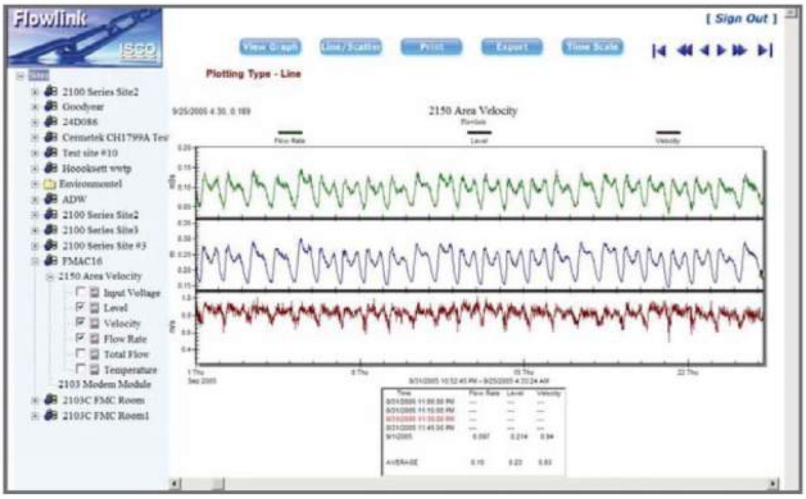
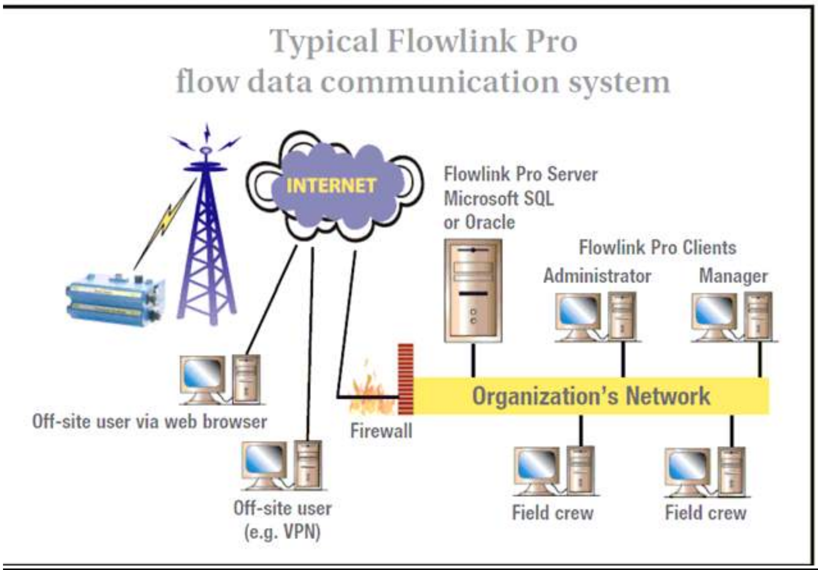


Fig 22: Flowlink Pro typical flow data communications system



Please note that all data sheets relating to equipment used, which includes accuracy specifications and ranges, are included in the Appendices.

4. Equipment Reliability and Limitations:

4.1 Reliability:

Overall the loggers worked well apart from the ragging issue. The 2110 Ultrasonic level loggers were reliable throughout. On a few occasions 2150 AV probes were changed at FM4 and FM1 throughout the survey but overall were reliable apart from the fore-mentioned ragging issue. The Laser flow logger worked reliably when water level was above 0.1 m. The ADFM had limited use because levels were below its required minimum level for measurement. The rain gauges work well, although there were incidents of funnel clogging resulting in some periods of data losses. This problem was more prevalent in the late summer and autumn months due to seed and leaves segments getting through the screen and blocking the funnel.

4.2 Ragging Issue:

The 2150 AV loggers were proposed initially because they were considered more suitable for the levels witnessed in the culvert. There were concerns prior to the survey about their accuracy at higher levels, (e.g. > 0.5m). However, it became clear at a very early stage that an unexpected issue of ragging on the probes was going to be the main issue.

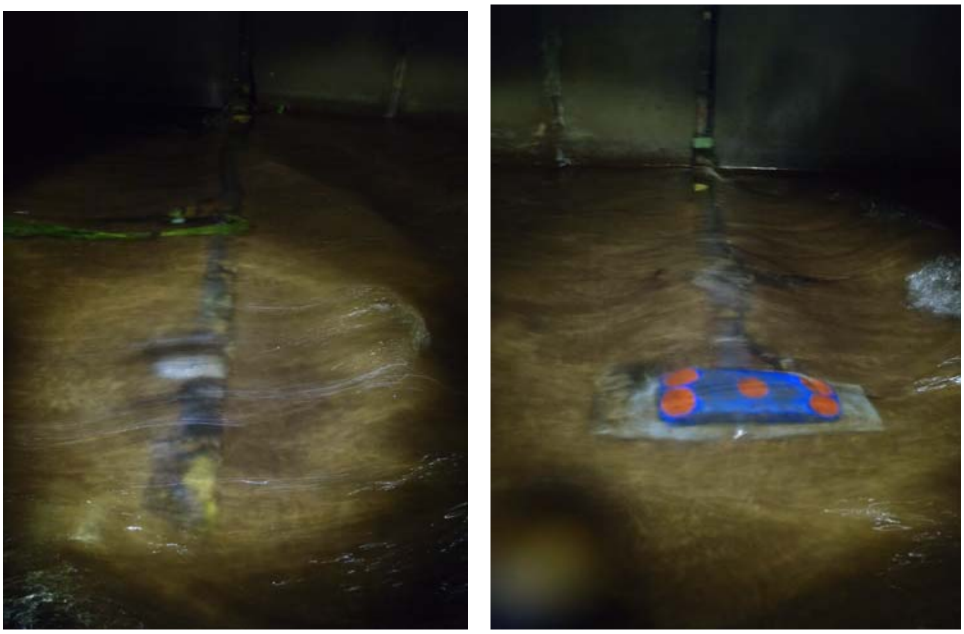
Fig 23: Ragging of AV probes was a common problem.

Fig 23 above taken at FM1 in low level shows how this ragging could completely block any meaningful velocity data. The ragging and debris was also creating errors with level measurement by creating localised small standing waves at the locations of the probes. This issue was most problematic at probe locations FM1 and FM4.
This issue could have potentially stopped the survey proceeding beyond the initial test period. It was decided however that with more frequent entries to clean the probes, and with proper data management that the survey should proceed. The introduction of the Laser Flow Logger in August and additional ultrasonic level monitor at FM4 and FM2 in October did provide good data. In general the ragging issue became more manageable from November 2014 to February 2015, when the flows were higher.

4.3 Intermittent Wave Observations.

A strange phenomenon was witnessed at all the sites from time to time. This was the intermittent occurrence of a wave effect in the locations of the probe. In fact these waves were evident periodically throughout the culvert and seemed to move location. Why this seemed strange, was that on certain occasions the level at the probe could seem quite static, but on other occasions, at more or less the same flow conditions, a wave would be present. Sometime these waves were upstream of the probe, sometimes over the probe, and other times seemed to sweep across the channel. Initially we assumed the probe installations might be causing these waves, however it was very hard to pin point exactly why this wave would be present on one occasion and not another, when the conditions seemed similar. It did occur more when the levels were slightly higher, (e.g water levels of 0.15m at FM1 and FM4). It proved difficult to take accurate level and velocity measurements when these waves were present. It was not uncommon to have a water level varying between 0.13 and 0.17 m for example, which has the potential to introduce a large error. It was decided due to this issue that in general, unless a probe was being moved or replaced, that we would record all data and only offset the levels subsequently if several measurements confirmed a correction was required.

Fig 24: Wave effect evident at FM1 2150 AV and ADFM probes.



4.4 Comparison between 2150 and ADFM Velocity profiler:

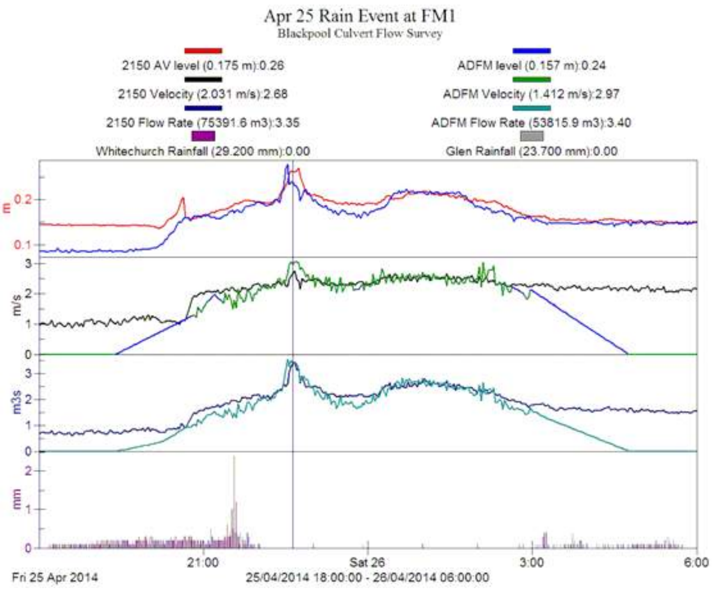
1 X Isco Pro 20 ADFM Velocity Profiler was included as part of the kit to provide data which could validate the 2150 AV loggers during rain events. The ADFM profiler has a general overall accuracy specification of 2% of measurement. However ADFM measurements only start above water levels of 0.2m, (4.88 M OD), thus, very little data was collected. The ADFM profiler was initially only to be made available for a month, but it subsequently was left in place between the middle of April and end of September 2014. The ADFM was installed at FM1 site adjacent to the 2150 logger

Fig 25: Isco Pro 20 ADFM probes at FM1.

One good event was monitored by the ADFM on the 25th April, albeit for a short duration. On this occasion levels were sufficiently high enough for the ADFM to start monitoring for approximately a 6 hour period. Comparisons between the 2150 AV logger and the ADFM during the event are seen in Fig 26 below.

This event provided confidence in the 2150 AV loggers. Unfortunately there was no further event during the summer months with, adequately high levels, to collect ADFM velocity data for comparisons.

Fig 26: Comparison between ADFM and 2150 AV at FM1 during rain event on 25th April 2014.



4.5 Isco Laser 2160 Flow Logger:

The laser logger is a new ISCO product and became available in mid July. Due to the fact that the Laser measures velocity in a non- contact manner, thus eliminating the issue of ragging, we were anxious to acquire and deploy this device at the first possible opportunity. One Laser logger was installed on the 27th July at the same location as the FM1 2150 AV logger, and remained in place until the completion of all logging in the culvert.

Fig 27: Isco 2160 Laser Flow Logger at FM1 .

The laser logger is a new ISCO product and became available in mid July. Due to the fact that the Laser measures velocity in a non- contact manner, thus eliminating the issue of ragging, we were anxious to acquire and deploy this device as at the first possible opportunity. One Laser logger was installed on the 31st July at the same location as the FM1 2150 AV logger, and remained in place until the completion of all logging in the culvert.

While the Laser didn’t read velocities under water levels of 0.1 m, velocity data was found to be steady and as expected when levels rose above 0.1m, (4.78 M OD). The Laser flow logger provided essential data for the more significant rain events in November.

Fig 28: Laser data for high rain events on 13th and 14th November 2014

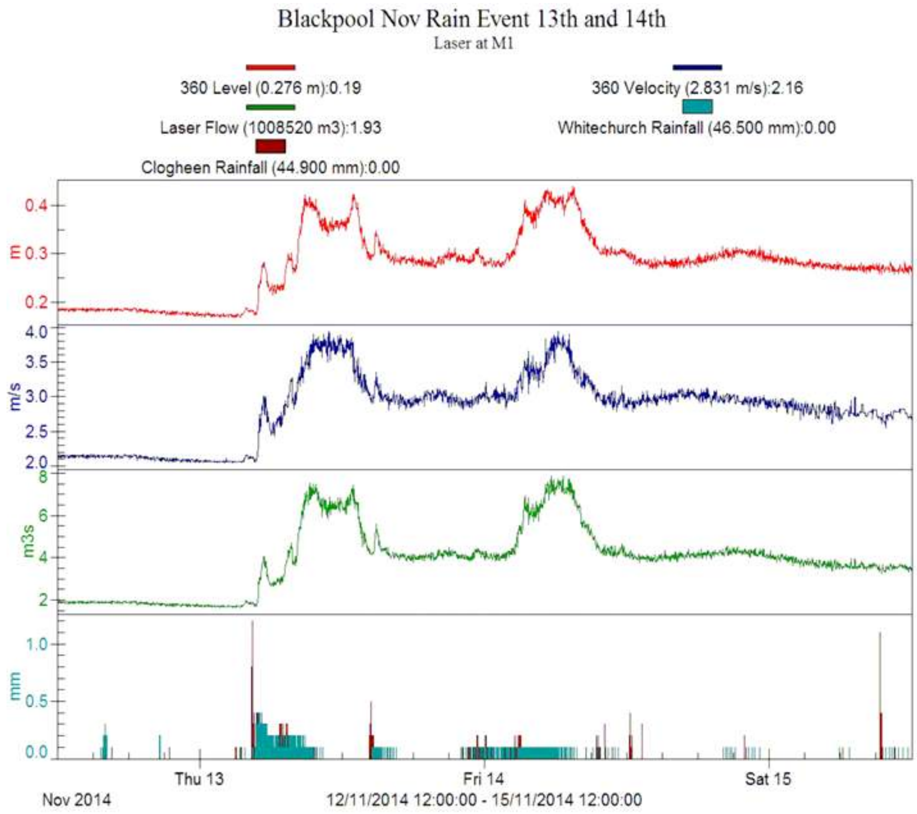
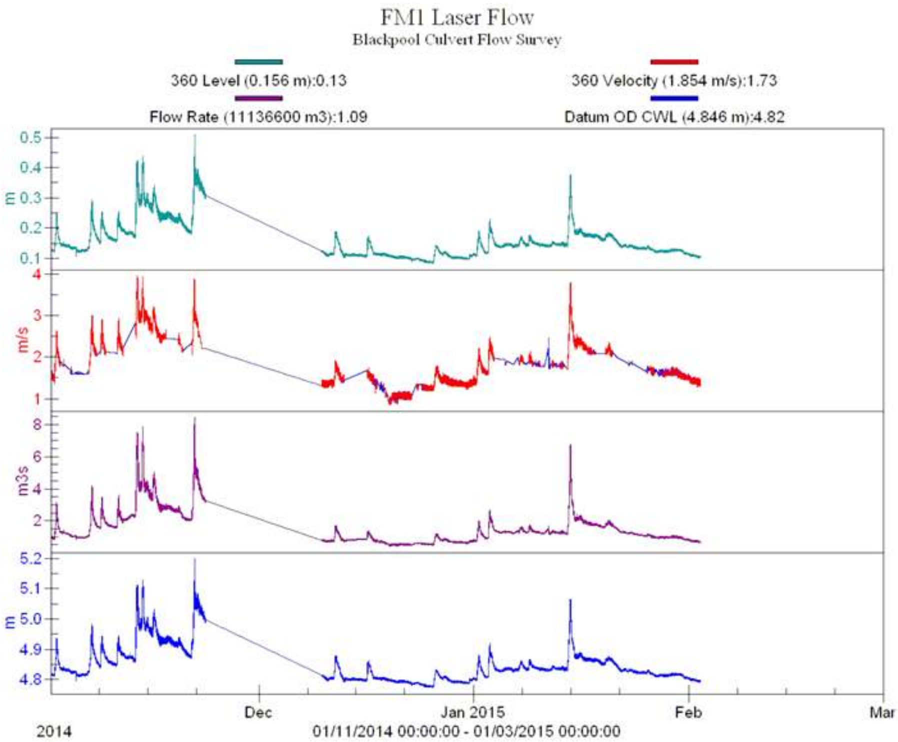


Fig 29 shows the Laser level, velocity and flow data during November 2014 through to February 2015. Flows are significantly higher in November.
Datum OD in the graph is M OD, (Malin). Data is missing for a period between end of November, to 9th December, due to battery failure, during a period when we were not able to get into the culvert.

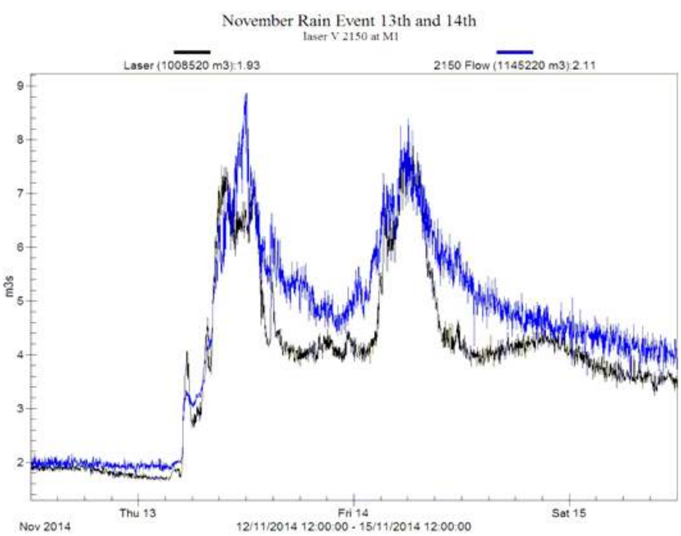
Fig 29: Laser data from November 2014 to February 2015



4.6 Comparisons between the Laser and 2150 AV Logger at FM1:

A comparison of flows between the Laser and 2150 at FM1 are seen in Fig 30 below which show a reasonable correlation at the peak flows.
However, since the Laser data was generally more reliable, we used data logged on the Laser for flow comparisons, rather than that logged on the 2150 at the FM1 location.

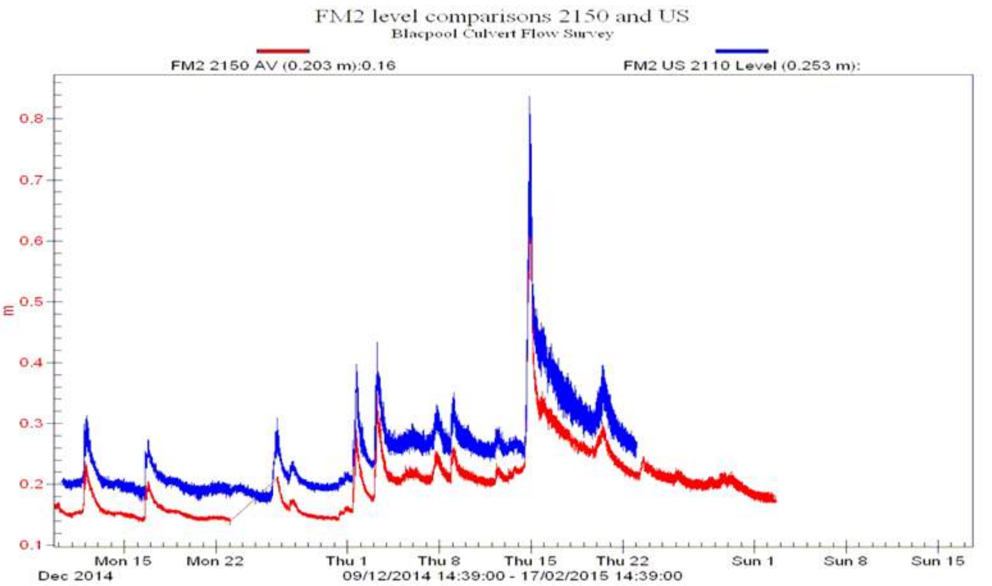
Fig 30: Laser data for high rain events on 13th and 14th November 2014



4.7 Isco 2110 Ultrasonic Level at FM2 Brewery Culvert in Dec 2014:

On the 9th December the Ultrasonic level logger in the culvert was moved as requested to the FM2 channel. This was installed in the channel, 3 meters upstream of the 2150 V logger, as this was a suitable mounting point in the ceiling, and the flow was less turbulent at this point. The levels followed the same trends closely, although the ultrasonic levels in general are higher as seen in figure 31.

Fig 31: Isco 2110 Ultrasonic, (US), Level Logger compared to 2150 AV logger at FM2



4.8 Isco 2110 Ultrasonic Level Logger at FM4 from Dec 2014:

A new 2110 level logger was positioned 3 m upstream of the 2150 AV probe at FM4 on the 9th December 2014. A new 2150 AV logger was also installed to compare results. Level comparisons are seen in Fig 32 below.

Fig 32: Level comparison at FM4 between new 2150 AV and new 2110 Ultrasonic

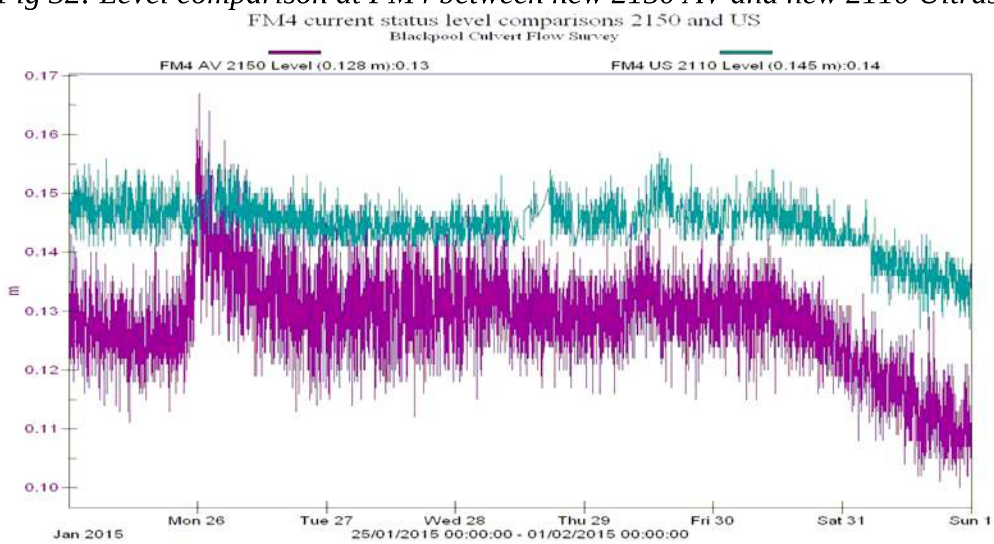
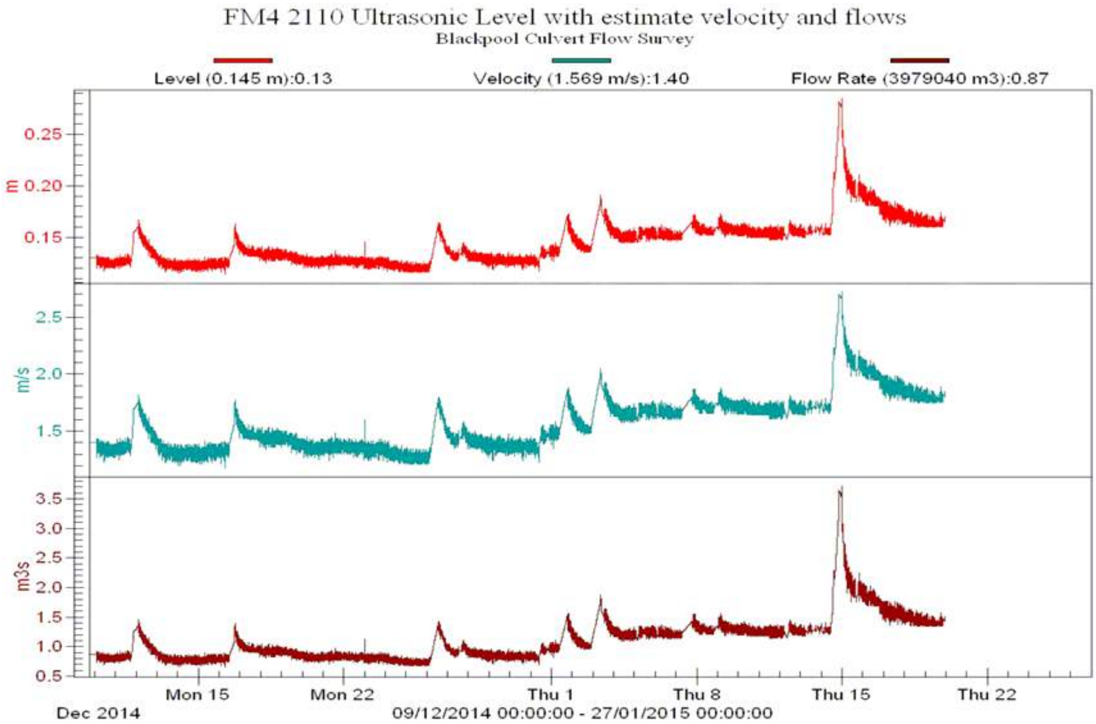


Fig 33: FM4 new ultrasonic 2110 level logger Level data and derived velocity and flow Dec 2014 and January 2015

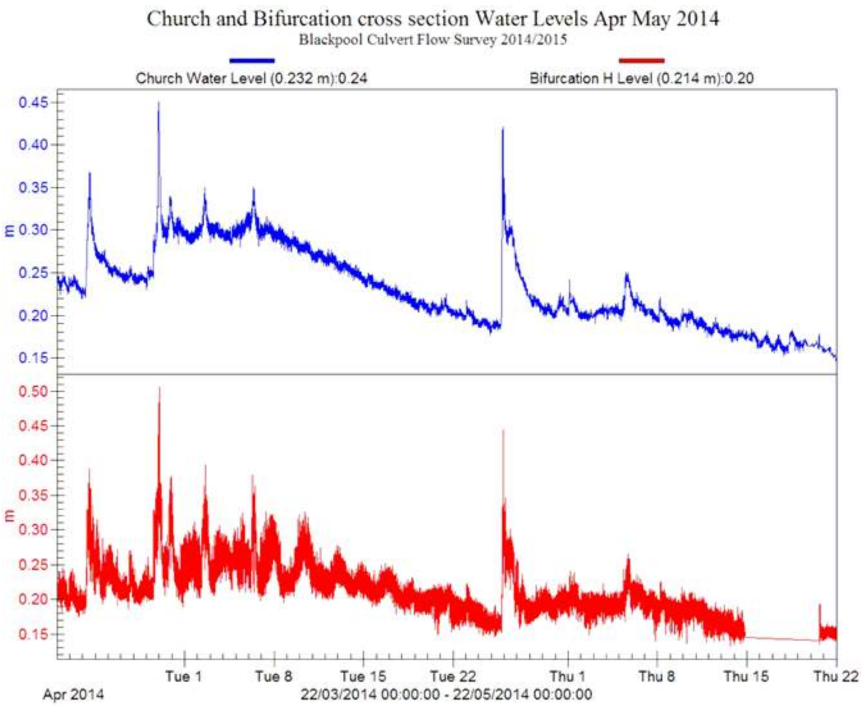


5.0 Culvert Conditions:

<u>5.1 Culvert Conditions before cleaning March to June 2014</u>

Early months of 2014 prior to start of survey were wet, resulting in higher levels in the culvert between January and March 2014. This delayed entering the culvert until the middle of March. In general levels dropped within the culvert approaching the summer months.
Fig 34 shows water levels under the bridge at the church and also the levels in the cross section at the bifurcation before any cleaning was carried out under the bridge or in the culvert.

Fig 34: Level recorded at Church and in Bifurcation section between April and May 2014



5.2 Debris on Concrete wall at entrance to Old Brewery Culvert, (FM2):

There was a concrete wall at the bifurcation at the entrance to the old Brewery line, (FM2). The wall was 0.3m high and jutted out 2 m approx across the entrance, covering about half of the entrance to the old brewery culvert. One assumes the purpose of the wall initially was to divert a large proportion of the flow from the Bride River (FM1), across to the new Limerick Rd Culvert.

Fig 35: Concrete wall at entrance to old brewery culvert (FM2).

The wall trapped debris as can be clearly seen from Fig 36 below. This debris included household rubbish that must have been dumped into the River Bride and had flowed to this point. However it was noted from monitoring the debris and sediment at the bifurcation, that it was the basically the same debris there at all stages. There were no new large items of debris specifically noted from visit to visit before its removal.

Fig 36: Debris trapped on wall at entrance to old brewery culvert (FM2).

Fig 37: Debris trapped on wall at entrance to old brewery culvert (FM2) looking back from FM2 probe.

Fig 38: Debris trapped on wall at entrance to old brewery culvert (FM2) looking from cross section in bifurcation.

5.3 Stone and Silt Accumulations:

Accumulations of silt and stones did not noticeably change over the period of the survey. In general FM1, FM3 and FM4 are free of debris with some sporadic stones scattered around the channels. The diagram below indicates where there were small accumulations of stones, typically between 0.05 and 0.1 m approx in height, at several locations. These accumulations remained in place throughout the survey with no noticeable change.

Flow crosses the bifurcation from FM1 to FM4 by sweeping to the far south wall of the cross section, (city end). Flow is almost static at the north wall of the cross section, (Blackpool end). There is some stones built up in this area but levels did not seem to vary particularly throughout the survey.

Unlike the new culverts, (at FM1, FM3, and FM4), which have level concrete floors; FM2 has a natural earth floor. Water channels from side to side at certain parts of the channel, resulting in accumulation of stones at various points along the channel. This is similar to conditions found in any natural stream.

Fig 39: Location of stone and sediment at bifurcation

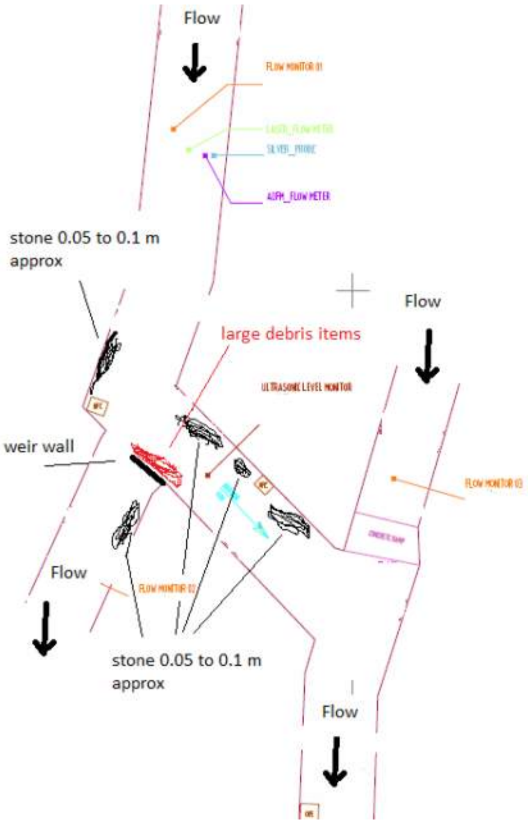


Fig 40 below looks back from the Limerick Road FM3/FM4 side towards the Watercourse Road FM1/FM2 culvert across the bifurcation when levels when were very low. The low water levels show clearly the stone accumulation predominantly at the north wall side of the cross section. Some of the larger items stones seen in this photograph were cleared, presumably at the same time the wall was removed.

Fig 40: Stone accumulation in cross section at bifurcation during low levels:

Fig 41 taken during high flow conditions in November shows there is still a relatively small accumulation of stones on the north end wall side of the bifurcation cross section**.** Flow is predominantly on the south end wall side only.

Fig 41: Stone accumulation in cross section at bifurcation during High Flows in November:

Fig 42 shows an accumulation of stones along the FM1 channel just before the entrance to the old Brewery Culvert, (FM2). The trolley and ladder in the background are part of our survey equipment.

Fig 42: Stones at FM1 location before entrance to brewery channel, (FM2):

By August levels within the culvert were very low with almost no flow, (level of 0.02m (4.46 M OD), entering Old Brewery Culvert FM2. Most of the flow at this point did seem to cross the bifurcation from FM1 to Limerick Road Culvert FM4.

Fig 43: Location to brewery channel, (FM2), In August shows almost no flow entering:

5.4 Culvert Conditions after the wall and debris were removed:

Work began on cleaning the stones and silt under the bridge at Blackpool church in late June and subsequently within the culvert itself in August.

At the bifurcation the concrete wall at the entrance to the old brewery culvert was removed along with most of the debris that had accumulated at this location in late August.

Most of the flow tended to cross the bifurcation at low flows and this did not seem to change after the wall was removed.

The metal reinforcement structure of the wall was not removed. Debris started catching and building up on this as seen in Fig 44.

Fig 44: Reinforcement structure left after wall was removed at entrance to Brewery Channel.

Fig 45: Reinforcement structure left after wall removed

In July and August levels and velocities within the culvert were very low. By mid July water levels were as low as 0.03m at FM3 and barely covering the AV probe. Almost no flow was entering the old Brewery Culvert, (FM2), at this stage.

Fig 46 shows the 2150 AV probe in FM2 old brewery channel. Almost no flow was noted in this culvert at this time during dry conditions.

Fig 46: AV probe in old brewery channel, (FM2).

Fig 47 shows FM3 AV probe before and after cleaning during summer conditions

Fig 47: FM3 AV Probe before and after cleaning during low water levels

5.5 Level, velocities and flows from June to September 2014

The following graphs show the overall level velocity and flow data at the 4 culvert points FM1,FM2,FM3,FM4the contracts period June to September. In all cases OS Datum refers to M OD (Malin).

Fig 48: 2150 AV Logger at FM1 June to September

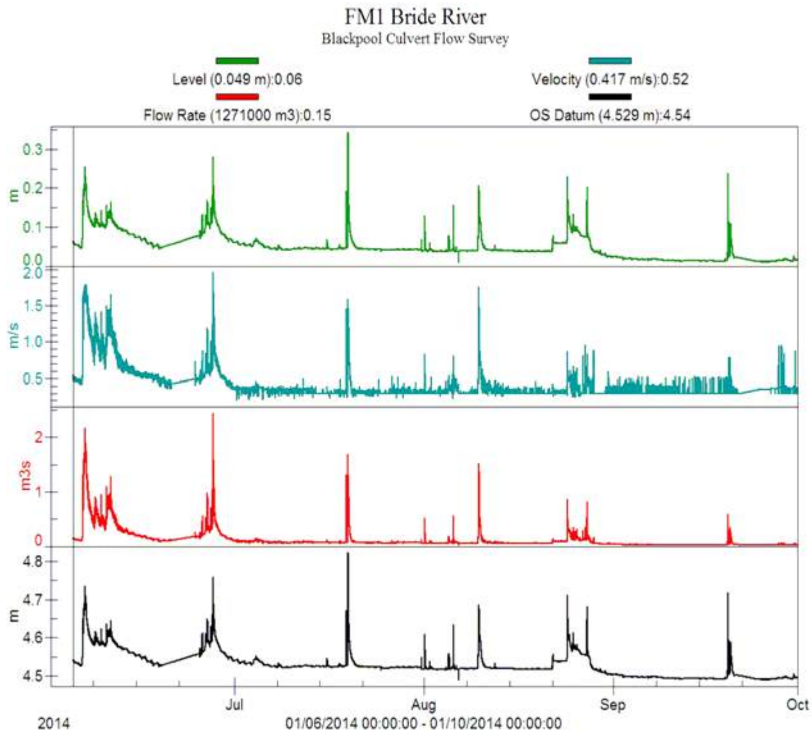


Fig 49: Laser Logger at FM1 August to September

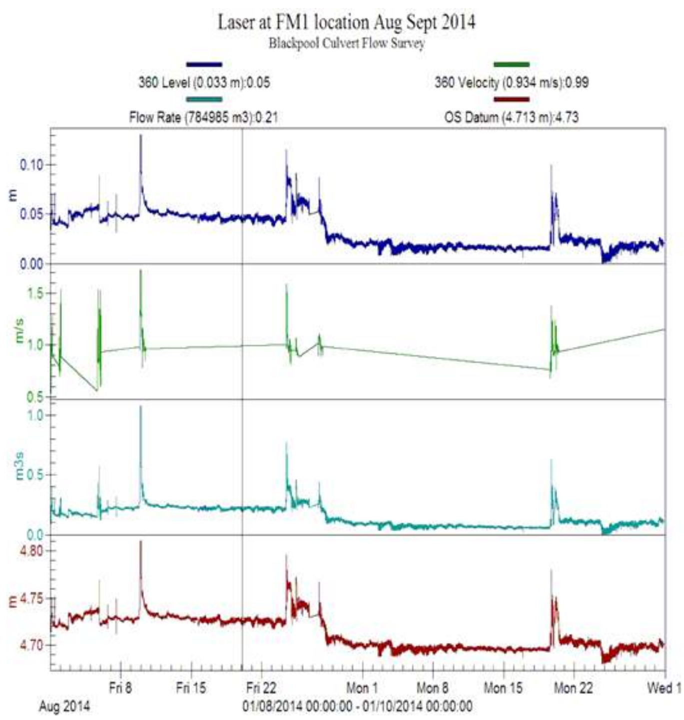


Fig 50: 2150 AV Logger at FM2 June to September

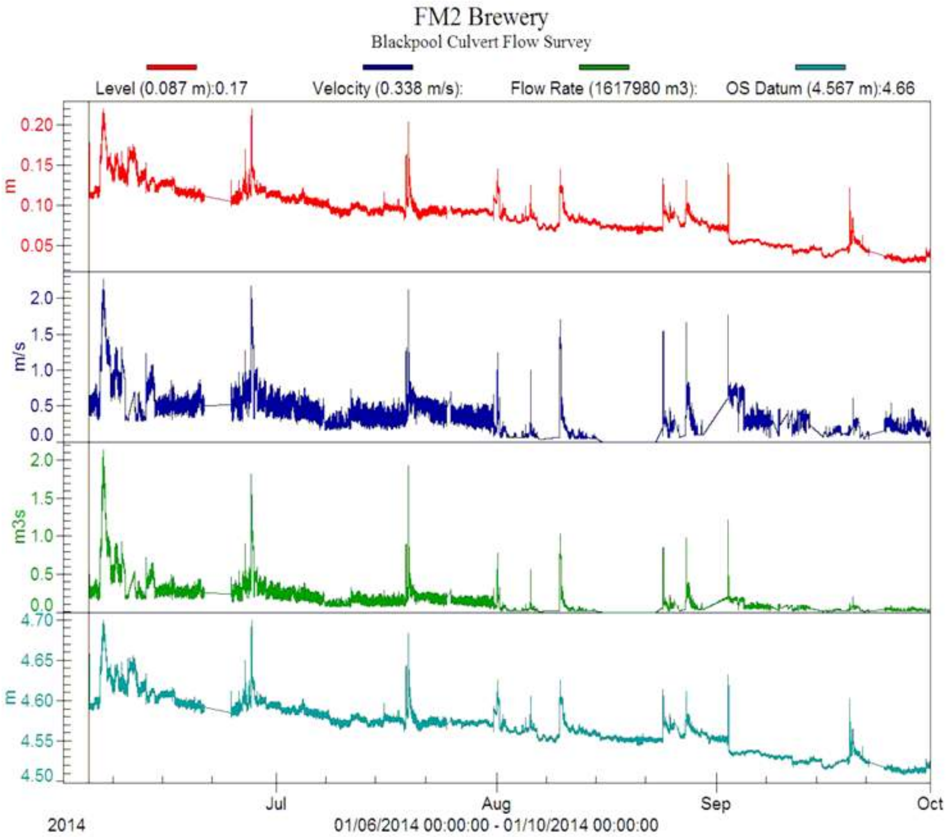


Fig 51: 2150 AV Logger at FM3 June to September

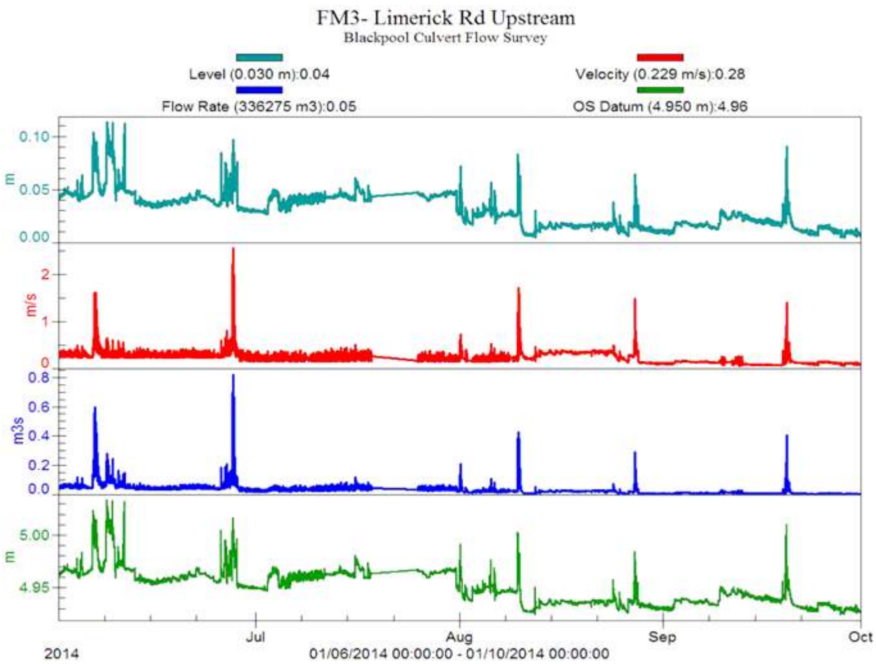
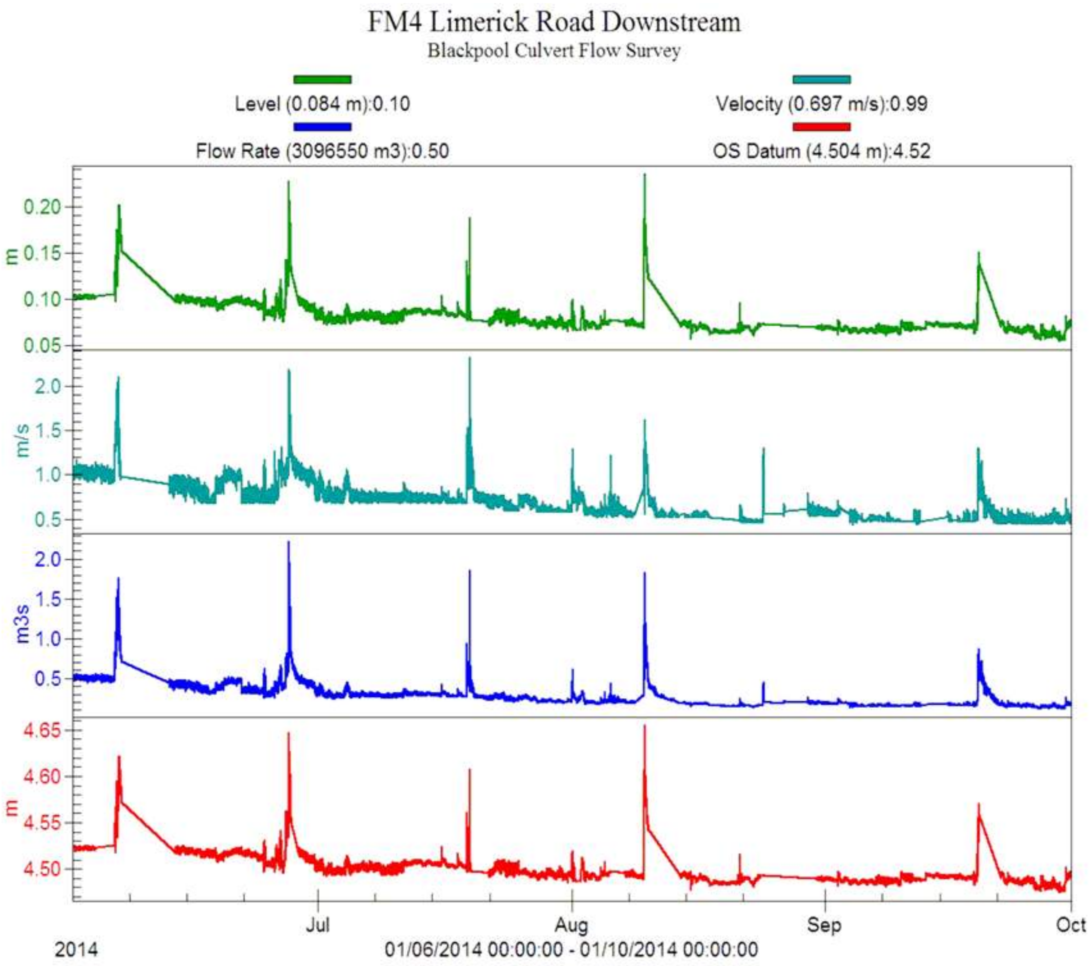


Fig 52: 2150 AV Logger at FM4 June to September



5.6 Culvert Conditions in autumn and winter months

In October water levels started to rise again. Fig 53 below taken on the 8th October, shows how debris had accumulated on the remained reinforcement structure of the removed wall. This was having some effect on flow distributions at this stage. In fact flow conditions appeared similar to those observed back in April and May before the wall was removed.

Fig 53: fouling on reinforcement structure in October:

After a heavy rain event in January 2015 we can see a standing wave at the bifurcation at the side of the entrance to the old Brewery Culvert, (FM2), as seen in Fig 54. The debris trapped on the remained reinforcement structure, where the wall was originally, would appear to be contributing to this. Despite this, a considerable percentage of the flow can be seen entering the old brewery channel during these higher flows. This is the most recent or last photograph at this important location, taken during high flow conditions, during the survey.

Fig 54: Standing wave at entrance to brewery channel ,(FM2) on 16th November after recent heavy rain events.

6.0 Conditions at Blackpool Church throughout survey

Prior to cleaning, flow under the bridge was spread more or less across the channel in a slow moving manner. Initially we had mounted the ultrasonic level probe on the church side of the bridge.

Fig 55: bridge at Blackpool Church before cleaning

A large amount of stone, silt and rubbish was removed from under the bridge and surrounding areas by Cork City Council, starting in June 2014. Fig 56 taken on the 12th June shows the extent of this work.

Fig 56: bridge at Blackpool Church during cleaning works

After cleaning was complete, water flowed only in the centre and road side under the bridge, as seen in the photo graph below. The water level was generally lower than before cleaning but at a higher velocity. We repositioned our level monitor under the centre of the bridge at M OD floor level 6.19 m. Only levels after cleaning relate to this M OD as the original level probe position and associated water levels may have an offset.

<u>Fig 57: bridge at Blackpool Church after cleaning:</u>

Figure 58 shows the levels recorded before and after the cleaning period.

<u>Fig 58 Levels recorded under the bridge before and after cleaning</u>

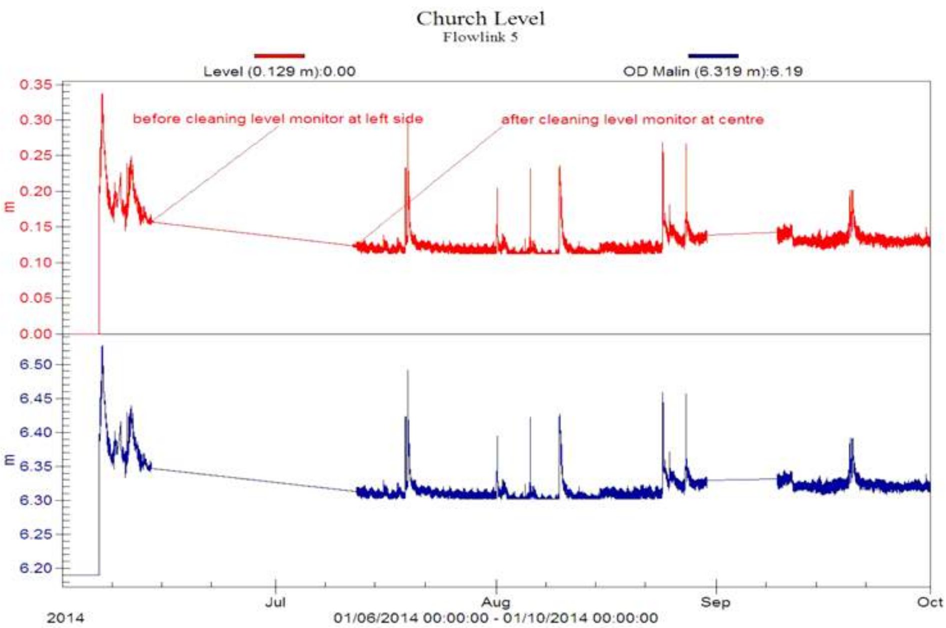


Fig 59 taken shortly after the rain event on 14th November, below shows the conditions at the entrance of the culvert after the highest recorded rain event. This is reported on further in section 10.1

Fig 59: Entry to culvert at Blackpool Church after rain event on the 14th November

Fig 60: Conditions at Blackpool Church after rain event on the 14th November

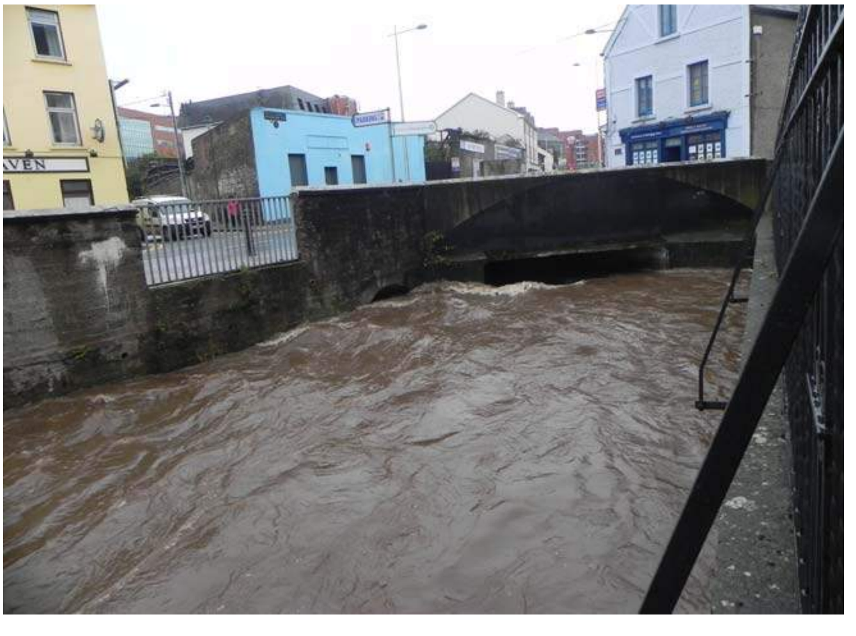


Fig 61: Bridge at Blackpool Church after rain event on the 14th November

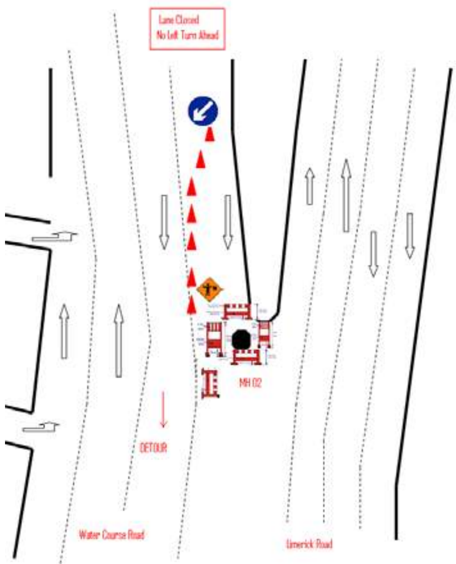
Fig 62: Flow witnessed Heineken Brewery after rain event on 14th November

7.0 Health and Safety

Entering the culvert to carry out the works required carefully considered risk assessments and method statements. The original plan as outlined from the tender stage was to gain access through manholes at junction at Maddens buildings right into the bifurcation area. An appropriate traffic management plan with approval from Cork City Council and Blackpool Garda Station was required. A traffic management plan was submitted to Cork City Council, to enter the culvert at MH02 in fig 63 and 64 below. While the plan was accepted in principle, permission was initially only granted for entry before 7 am Sunday mornings, on instruction from Blackpool Garda Station. This was due to the high and continuous volume of traffic at this junction.

Fig 63: Manholes to enter the culvert under bifurcation at junction at Madden Buildings.

Fig 64: Schematic of road traffic plan to enter through Manhole 2 at junction at Maddens Buildings:



Initial traffic management time restrictions proved to be a bit impractical to achieve all works required so it was decided that we would consider entry through the culvert entrance at Blackpool church. In fact all entries were subsequently carried out through the Blackpool church entrance prior to November 2014.

Entering at Blackpool church culvert entrance required walking through the culvert in a slightly bend position for 200 metres to the bifurcation area, which is under the junctions at Maddens Buildings. Particular thought to a workable rescue plan and a reliable communications procedure had to be considered due to the distance travelled from the entry point. The risk assessment and method statement was revised several times to address any concerns that arrived by the work team and those raised by our safety consultant, Mr. Eugene Mc Carthy. There were several specific safety meetings at Water Technology to consider the Blackpool project.

Some of the revised controls included in the method statement on entering the culvert from Blackpool church included.

- A custom built high wheel trolley which could be used as a rescue cart in case of emergency.
- A team of 4 required, with third man entering for communications and as part of rescue team. The fourth man is permanently on standby at the entrance to the culvert for the entry period, and in 5 minute contact with third man.
- Each entrant to have 10 minute breathing rescue kit, individual gas monitor, bump helmet with strap and light, small first aid and spare battery pack and mobile phone

Fig 65: WTL team including rescue trolley and equipment prior to entering the culvert at Blackpool church.

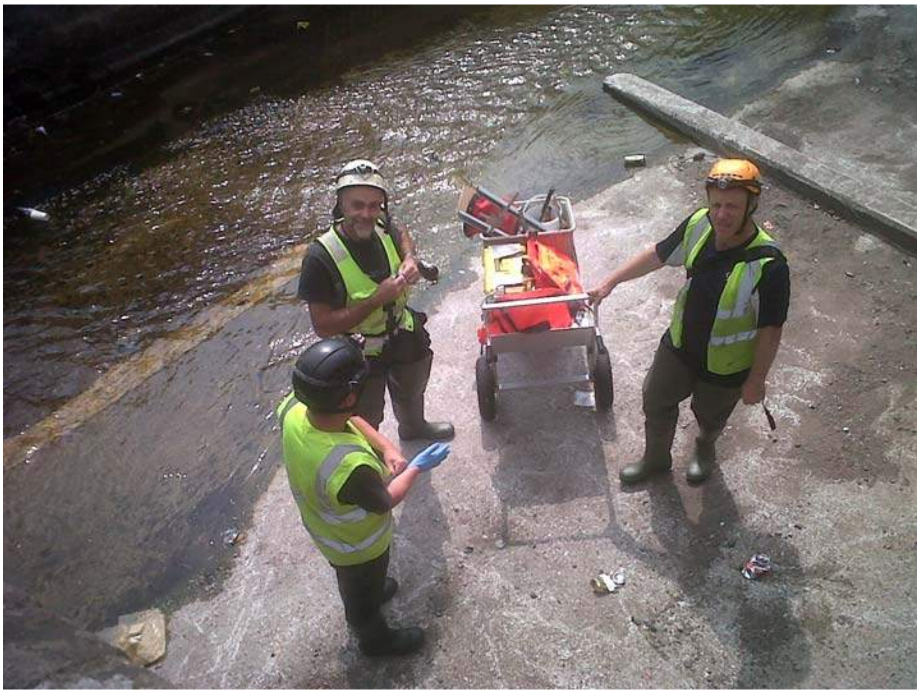


Fig 66: Exiting the culvert at Blackpool church with rescue trolley after visit

A static stainless steel safety line was run from the entrance to all monitoring points. Mobile phones and walkie talkies were used at various stages, however, both were found to be unreliable at times. This was considered a serious issue as reliable communications with the entrants was a top priority. As a back- up measure a rope and 2 bell system was installed between the entrance and the FM1 logger manhole. This was rang and answered every 5 minutes as part of our procedures. This old fashioned method of communications worked very reliably and was used from June onwards.

Fig 67: Standby man post with communications bell and safety line at Blackpool church culvert entrance

By mid November levels in the culvert had risen to make it unsafe to enter through the Blackpool church entrance. After the significant rain events on the 13th and 14th November it became quite urgent to get into the culvert to retrieve vital data and change batteries, which were low in power. After approaching Cork City Council again, permission was given to enter after 23:00, using the previous submitted traffic management plan. This manhole entry was subsequently used for all entries between November until the full equipment removal and completion of the survey in March 2015.

Fig 68: Entering the culvert through Manhole 2 at maddens building at 23:00

New controls required as part of the new manhole entry point included

- 5 man team required, 2 men above ground, 3 entrants
- Tripod winch and harness to enter
- Additional strong fixed lamp in bifurcation area
- Lanyard to tie off to safety line due to higher levels and velocities

Method statements and traffic management plans are available in the Appendices.

As per regulations, all team members had appropriate training, including confined space, safe pass, manual handling. A vaccine inoculation program was also administered from the company doctor, to ensure all team members were up to date. Entry sheets were filled in and signed with each team member with a tick list of all required PPE and controls. These entry sheets can be made available in the appendices if required.

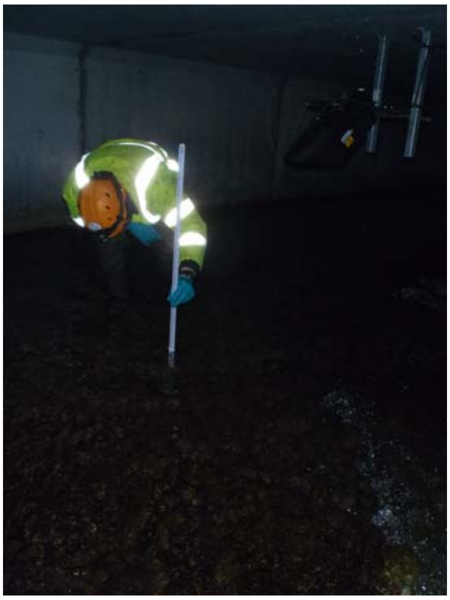
It is good to report that no health and safety incidents occurred throughout the survey.

8.0 Calibration and Quality Assurance Procedures.

8.1 Routine level checks and velocity checks.

Spot level and velocity checks were carried out during most entrances.
Level was measured by dipping the same measuring stick each time.
Care was taken to stand to side to try not effect the level during measurement. Where wave like conditions were encountered it was documented.

Fig 69: Level spot checks with measuring stick in culvert



Velocity was calculated by 2 methods. On some entries it was measured using an Isco 2150 AV logger with display wizard and AV probe mounted to pole. Measurements were taken in the vicinity of the probe. Due to low levels it was usually only possible to take full depth measurements. During summer months, when the levels were too low to achieve reliable data from a doppler velocity method, velocities were approximated by timing floating debris over a distance. This test would typically be carried out at various points in the vicinity of the probe to ensure consistency.
Spot check sheets were filled in during the testing within the culvert. The last version of these spot check sheets are seen in Table 3

Table 3: Level/velocity spot check entry sheets.

Blackpool Entrance Checks							
Date:							
Culvert Entry Time							
	Measured Level	**Measured Velocity**	**Time**	**logger L/V ?**	**photo?**	**ragging?**	**comment**
Church Level 2110							
FM1 2150							
FM2 2150							
FM3 2150							
FM4 2150							
H Level 2110							
ADFM							
signed:							

Later in the survey the manual recorded data was entered into worksheets for comparison to data that was logged, and to make correction when necessary.

8.2 High water level velocity checks.

Data collected from the ADFM and the Laser Flow loggers provided critical data at the peak velocities.

On the 21st June, cross section level- velocity profiling was carried out, after a rain event, to collect data at higher water levels. Spot checks were carried out on the 22nd December 2014, and also on the 19th and 22nd January 2015, when levels were relatively high. Table 4 shows results of the tests on these dates. Levels were typically adjusted in the reports.

Table 4: results of spot checks during December and January entries

date 22/12/2014

Spot Level checks

Meter	Level	Time	on logger	adjustment	comment
FM1 2150 AV	0.11	23:48	0.1	-0.01	
FM1 Laser	0.1	23:40	0.1	0	
FM2 2150 AV	0.16	n/a	0.167	0.007	
FM2 2110 US	0.18	n/a	0.19	0.01	
FM3 2150 AV	0.06	n/a	0.055	-0.005	
FM4 2150 AV	0.14	00:31	0.098	-0.042	this rectified later
FM4 2110 US	0.14	n/a	0.123	-0.017	

date 19/01/2015

Spot Level checks

Meter	Level	Time	on logger	adjustment	comment
FM1 2150 AV	0.16 to 0.17	23:40	0.174	0.009	high and turbulent
FM1 Laser	0.14 to 0.15	23:46	0.174	0.029	high and turbulent
FM2 2150 AV	0.27	12:50	0.296	0.026	high and turbulent
FM2 2110 US	0.27	n/a	0.317	0.047	high and turbulent
FM3 2150 AV	0.06	n/a	0.064	0.004	high and turbulent
FM4 2150 AV	0.17 to 0.24	00:20	0.175	-0.025	wave at probe
FM4 2110 US	0.15 to 0.16	n/a	0.175	0.02	high and turbulent

date 22/01/2015

Spot Level checks

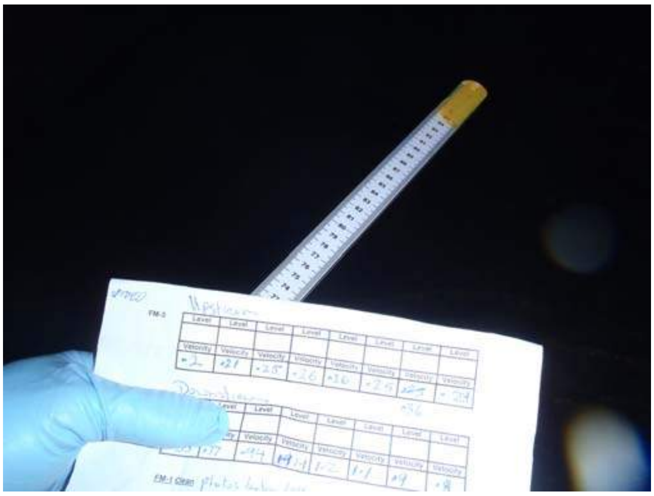
Meter	Level	Time	on logger	adjustment	comment
FM1 2150 AV	0.15 to 0.17	23:18	0.123	-0.037	some ragging
FM1 Laser	0.14 to 0.17	23:20	0.141	-0.014	moving level
FM2 2150 AV	0.24 to 0.26	23:21	0.256	0.006	moving level
FM2 2110 US	0.26 to 0.28	23:22	0.24	-0.03	moving level
FM3 2150 AV	0.1 to 0.12	n/a	0.08	-0.03	wave in front of probe
FM4 2150 AV	0.2 to 0.22	23:24	0.117	-0.093	to be confirmed on next entry
FM4 2110 US	0.18 to 0.2	23:26	0.147	-0.048	to be confirmed on next entry

8.3 Level Velocity Cross Section Profiling

On 23rd April, and 12th and 23rd June 2014, cross section level velocity profiling was done.

Levels and velocities were measured in sections across the channel. Flows were calculated by adding the calculated volume sections.

Fig 70: completing velocity profiling sheet



A sample of the level velocity profiling can be seen in Table 5 and 6 below.

Table 5: Level Velocity Profiling results from 27th June –FM1 and FM2

27th June — Level Velocity Profiling

	FM-1 from Blackpool Church	Left to Right								Average/Totals			
4.8	4.8 metres wide				2150 Postion approx			ADFM Postion Approx					2150 log
	distance from side (Metres)	0.1	0.85	1.6	2.35	3.1	3.85	4.6	4.7				
	segment width (Metres)	0.1	0.75	0.75	0.75	0.75	0.75	0.75	0.1				
		Level	level	Level	Level	Level	Level	Level	Level				
	measurement (Metres)	0.15	0.16	0.12	0.115	0.095	0.155	0.15	0.15	0.14	m		0.182
		velocity	velocity	velocity	velocity	velocity	velocity	velocity	velocity				
	velocities m/s	1.47	1.67	1.67	1.54	1.51	1.38	1.32	1.32	1.49	m/s		1.6
	segment flows m3/s	0.02	0.20	0.15	0.13	0.11	0.16	0.15	0.02	0.94	m3/s	by segments	1.06
										0.98	m3/s	by averages	

	FM-2 Brewery	Left to Right								Average/Totals			
4.35	4.35 metres wide				2150 Postion approx								2150 log
	distance from side (Metres)	0.1	0.8	1.5	2.2	2.9	3.6	4.3	4.33				
	segment width (Metres)	0.1	0.7	0.7	0.7	0.7	0.7	0.7	0.03				
		Level	level	Level	Level	Level	Level	Level	Level				
	measurement (Metres)	0.05	0.105	0.19	0.23	0.2	0.16	0.1	0.1	0.14	m		0.149
		velocity	velocity	velocity	velocity	velocity	velocity	velocity	velocity				
	velocities m/s	0	0.001	0.33	1.23	0.57	0.57	0.23	0.23	0.40	m/s		1.54
	segment flows m3/s	0.00	0.00	0.04	0.20	0.08	0.06	0.02	0.00	0.40	m3/s	by segments	0.458
										0.24	m3/s	by averages	

Table 6: Level Velocity Profiling results from 27th June –FM3 and FM4

	FM-3 N20 Mallow side	**Left to Right**								Average/Totals			
4	**4.0 metres wide**				**2150 Postion approx**								**2150 log**
	distance from side (Metres)	0.1	0.7	1.3	1.9	2.5	3.1	3.7	3.9				
	segment width (Metres)	0.1	0.6	0.6	0.6	0.6	0.6	0.6	0.2				
		Level	level	Level	Level	Level	Level	Level	Level				
	measurement (Metres)	0.065	0.065	0.009	0.1	0.11	0.12	0.12	0.1	**0.09**	m		**0.087**
		velocity	velocity	velocity	velocity	velocity	velocity	velocity	velocity				
	velocities m/s	2.02	2.01	2.18	2.35	2.09	1.99	1.71	0.32	**1.83**	m/s		**2.02**
	segment flows m3/s	0.01	0.08	0.01	0.14	0.14	0.14	0.12	0.01	**0.66**	m3/hr	by segments	**0.24**
										0.63	m3/s	by averages	

	FM-4 N20 Cork side	**Left to Right**								Average/Totals			
4.7	**4.35 metres wide**				**2150 Postion approx**								**2150 log**
	distance from side (Metres)	0.1	0.85	1.6	2.35	3.1	3.85	4.6	4.65				
	segment width (Metres)	0.1	0.75	0.75	0.75	0.75	0.75	0.75	0.05				
		Level	level	Level	Level	Level	Level	Level	Level				
	measurement (Metres)	0.17	0.2	0.17	0.16	0.2	0.18	0.17	0.17	**0.18**	m		**0.182**
		velocity	velocity	velocity	velocity	velocity	velocity	velocity	velocity				
	velocities m/s	0.45	1.45	1.75	1.72	1.72	1.87	1.66	1.49	**1.51**	m/s		**1.8**
	segment flows m3/s	0.01	0.22	0.22	0.21	0.26	0.25	0.21	0.01	**1.39**	m3/s	by segments	**1.55**
										1.26	m3/hr	by averages	

	Fm -1 and Fm-3		Fm-2 and F-4	
By profiling	1.60	m3/s	1.79	m3/s
2150 AV measured	1.29	m3/s	2.01	m3/s

FM2 flow by equation: Y = 6.15(X)-.4585

9.0 Calculating Flows:

Measuring points FM1, FM3 and FM4 are rectangular channels with flat floor beds. While there were some variations, in general water levels were reasonably well distributed across the channel. Thus, where good level and velocity data was achieved by either the 2150 AV loggers, the ADFM Profiler, or the Laser, flow was derived by assuming a regular rectangular channel profile.

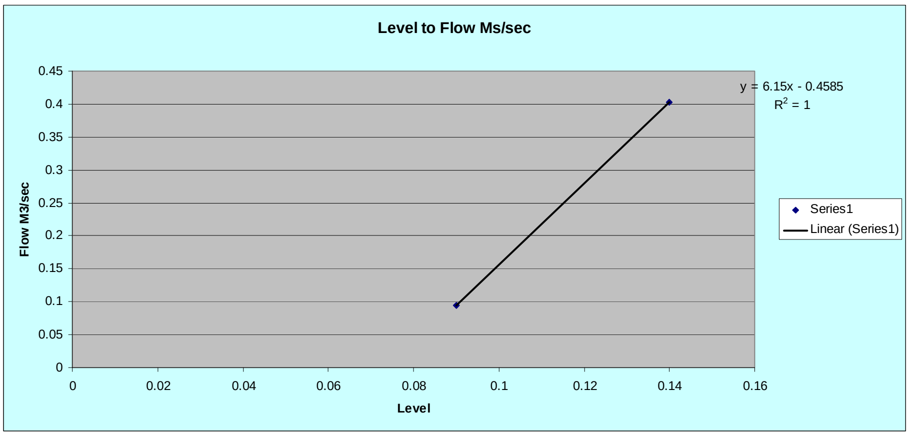
Cross sectional area = water depth, (m) x width of channel, (m)
Flow m3/s = Velocity (m/s) x Cross sectional area (m2)

9.1 FM2 Old Brewery Culvert Flow Calculations:

At the FM2 location in the old Brewery culvert the channel floor was natural and irregular.

A simple flow conversion was derived from some velocity profiling data acquired in the month of June as seen in fig 71.

Fig 71: simple level to flow relationship at FM2



This compared well to calculating flows based on a regular rectangular channel of even level distribution, as we had done in the other culverts. For flow estimates and balancing flows calculated using the standard rectangular channel was used subsequently.

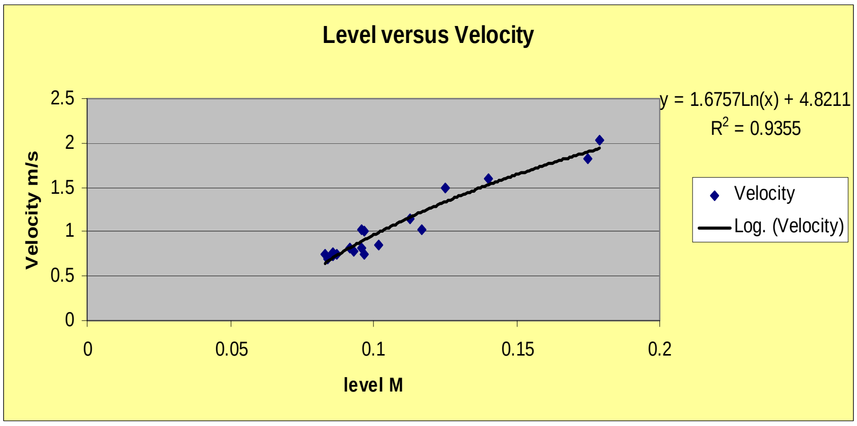
Table 7: comparison with flow estimates with level to flow equation and assumption of standard rectangular channel.

2150 Level	2150 Velocity	4.35 metre Rectangular	Level to Flow Equation
M	m/s	m3/s	m3/s
0.18	0.78	0.61	0.65
0.5	1.17	2.54	2.62
0.62	1.4	3.78	3.35
0.21	0.94	0.88	0.86
0.26	1.05	1.19	1.14
0.13	0.49	0.28	0.34
0.09	0.2	0.08	0.095
0.14	0.4	0.24	0.4025

9.2 Using Derived velocity at FM4 to compensate for probe ragging.

Ragging on the probe at FM4 seemed to be a particular issue, resulting in peak velocities not being logged during the more significant rain events. By analysing section of level and velocities from this logger for other events, we derived a relationship between level and velocity. This derived velocity was used on occasion where there were gaps in the measured velocity. In particular it was used for the November rain events where good level data was available but insufficient velocity data.

Fig 72: level to velocity relationship at FM4



10.0 Noteworthy Events:

10.1 Major Rain Events on 13th and 14th Nov 2014.

After a dry summer, October and November were wet months resulting in the water levels increasing. Levels recorded in the river Bride at Blackpool church had increased from 0.13 m, (6.32 M OD), to 0.3 m, (6.49 M OD), between the start of October and the 12th November with a total rainfall of 260 mm recorded over this period approximately,
The most significant rain event occurred on the 13th November starting at 4 am. A second significant event occurred that evening between the 13th and the 14th resulting in a second peak early morning on the 14th. 50mm of rainfall was logged between 13th and 14th.

Fig 73: High Flow at the Culvert Entrance at Blackpool Church the morning after second rain event on the 14th November

Levels recorded as high as 0.8 m, (6.99 M OD), on the level gauge under the bridge at the church which is the highest recorded since monitoring started last March. In Fig 73 above, the photograph was taken at 10 am approx on the 14th Nov, when the levels logged under the bridge at this time would have decreased back to 0.4 m, (6.59 M OD). Thus we can assume the level at the entrance during the previous 14th Nov peak of 0.75 m, (6.94 M OD), logged 4 hours prior to this could have been noticeably higher. There is a standing wave noted on left side of channel in Fig 74.

Fig 74: Standing wave at left side of culvert Channel

Fig 75: Rainfall and Church Level prior to Rain Event (October and up to 12th November)

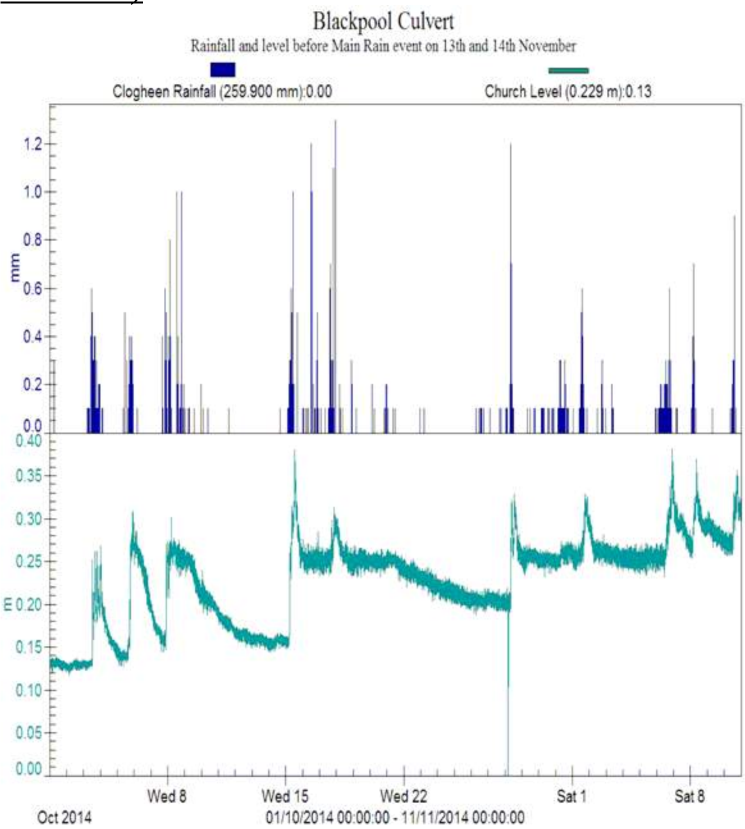
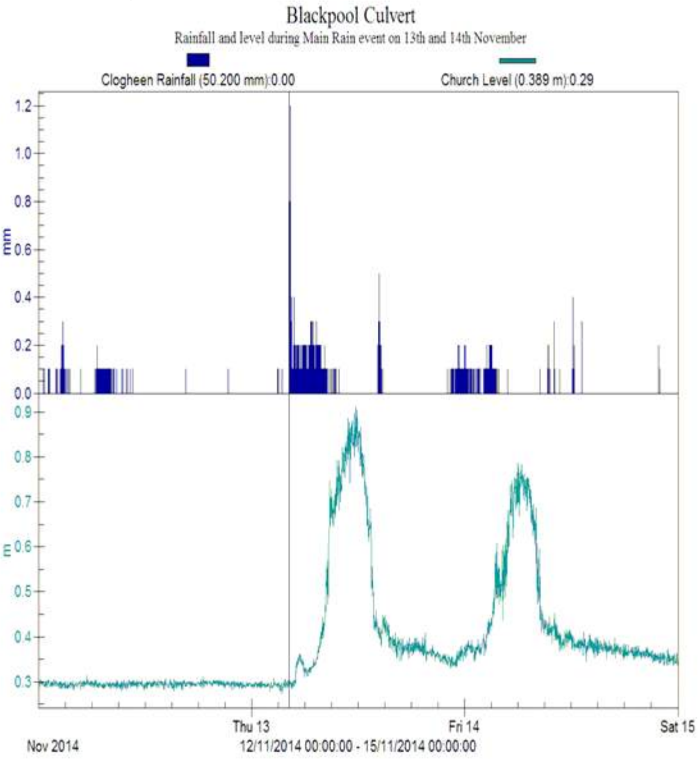


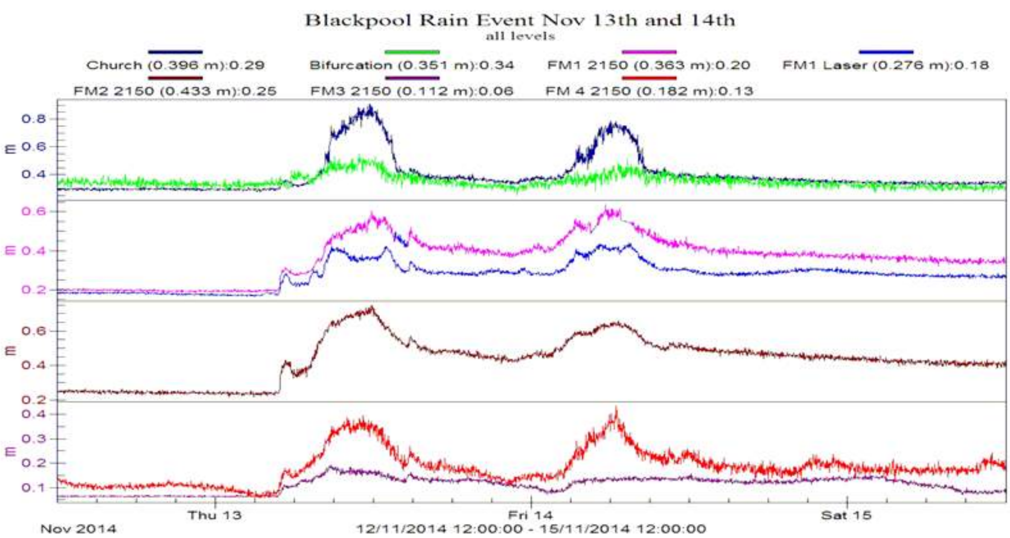
Fig 76: Rainfall and Level at Blackpool Church during Rain Event (13th and 14th November)



10.1.1 All Levels during Rain Event:

Levels logged during these two rain events in November were the highest recorded at all locations during the survey. A noticeable high level of 0.7 m (5.14 M OD), recorded in the old Brewery culvert (FM2- brown line in graph).

Fig 77: All levels recorded during Rain Events on the 13th and 14th November



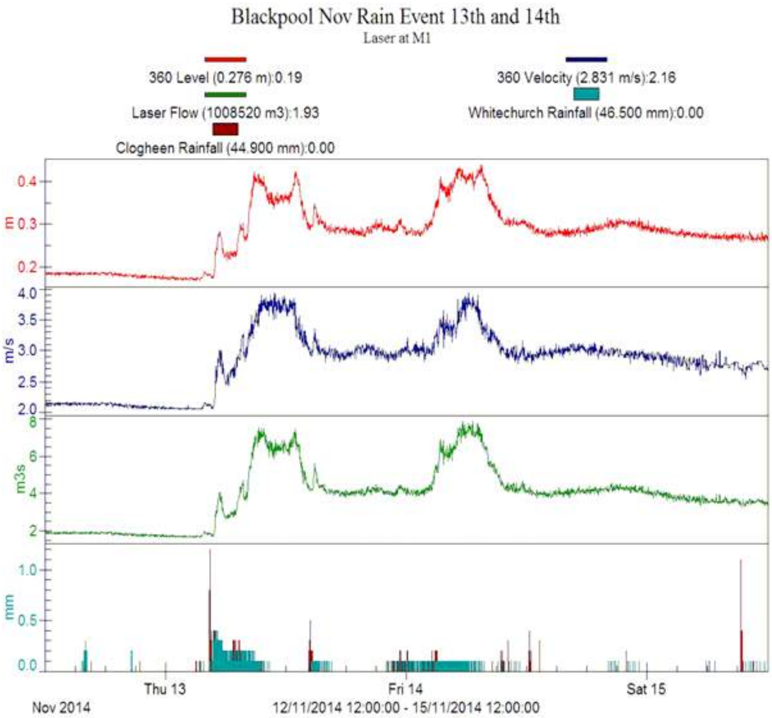
A peak level of 0.7 m, (5.4 M OD), was recorded at the FM1 location on the 2150 AV flow logger. However the laser flow meter which is located within a few meters of the 2150 probe recorded a peak of 0.4 m, (5.1 M OD) approx. The laser is mounted directly above the centre of the culvert while the 2150 is more to the side. The data would seem to indicate that there are higher levels at this side of the channel where the 2150 probe is located, although some of this may be due to localised ragging issues or possibly a slight localised standing wave caused by the probe itself during high velocities. The pink, (2150) and blue, (laser) trend above in Fig 77 shows a slightly higher level before the events on the 2150 but a significantly higher level during the event and after. Both the 2150 AV and Laser had good level to velocity profiles with similar flow rate trends. The Laser flow meter has a particularly good level to velocity correlation and in general we have used this data as our benchmark as we can be generally confident that there are no localised debris issues at this measuring location since it is non- contact sensor.

10.1.2 Laser Flow Logger at FM1

Fig 78: Laser Flow Logger at FM1

The laser flow logger recorded a peak flow of 7 m3/s with peak velocity at 3.8 m/s, during the first rain event on the 13th Nov. There is a dip in the level in the middle of the peak which may indicate channelling of higher flows to the side of the channel.

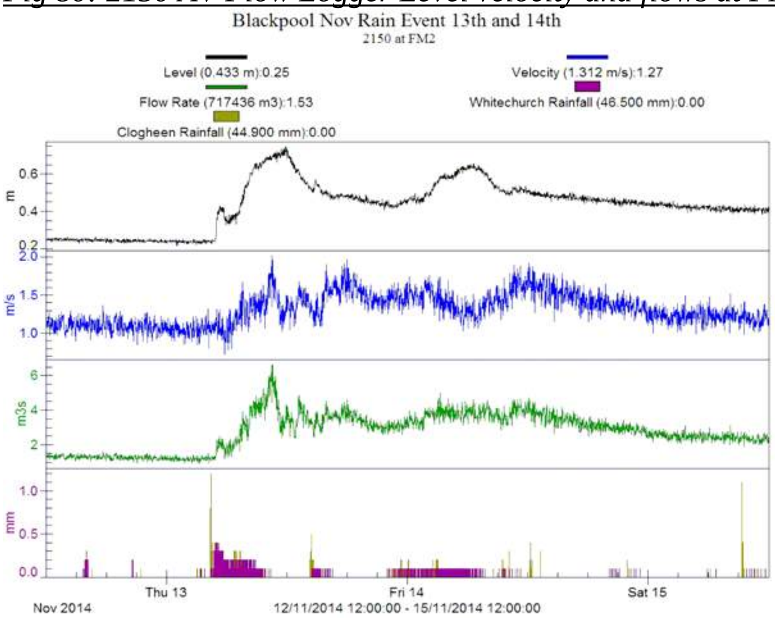
Fig 79: Laser Flow Logger Level velocity and flows at FM1 during Rain Events:



10.1.3 2150 AV Flow Logger at FM2 (Brewery channel):

Good quality level and velocity data was logged at FM2 with a peak level of 0.7 m, (5.14 M OD), during the rain event on the 13th corresponded with a velocity of 1.9 m/s. The Brewery channel is partly natural with an uneven gravel floor which makes it difficult to estimate flows accurately. However if we assume it to be a standard rectangular channel for estimation as described in section 9.1, it would calculate at a peak flow of 6 m3/s approx.

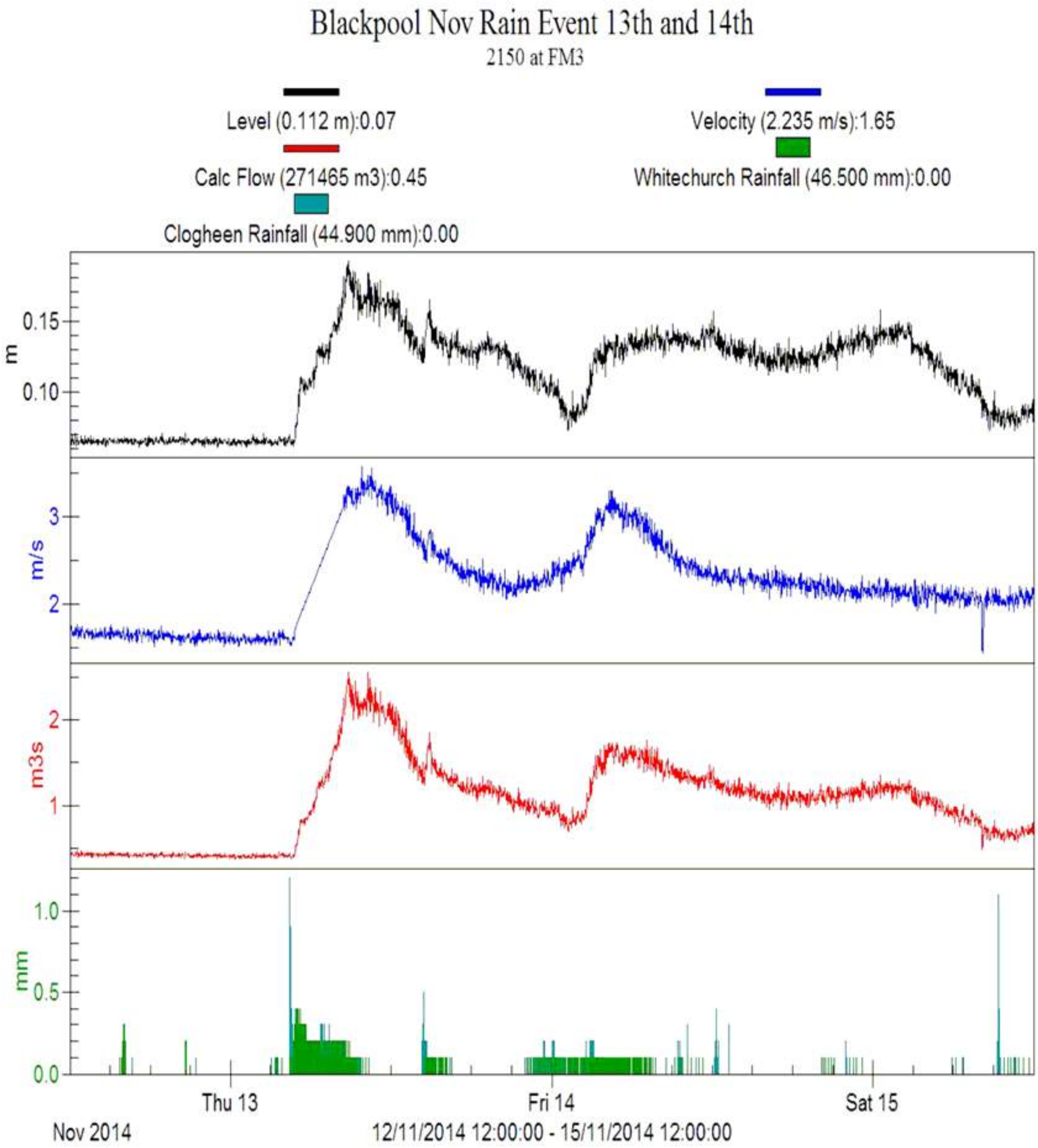
Fig 80: 2150 AV Flow Logger Level velocity and flows at FM2 during Rain Event:



10.1.4 2150 AV Flow Logger at FM3:

Fig 81 shows the level velocity and data logged during the rain events measured at FM3. Data at FM3 required a small amount of correction of velocity, which stopped logging for several hours due to ragging. The probe had some rags on the probe when we entered the culvert later on the 16th November which may have affected the quality of both level and velocity; in particular the level data was a bit erratic after the events. However, for the most part, the data looked good during the peaks themselves. A peak flow rate of 2.4 m3/s was recorded coinciding with a logged velocity of 3.32 m/s.

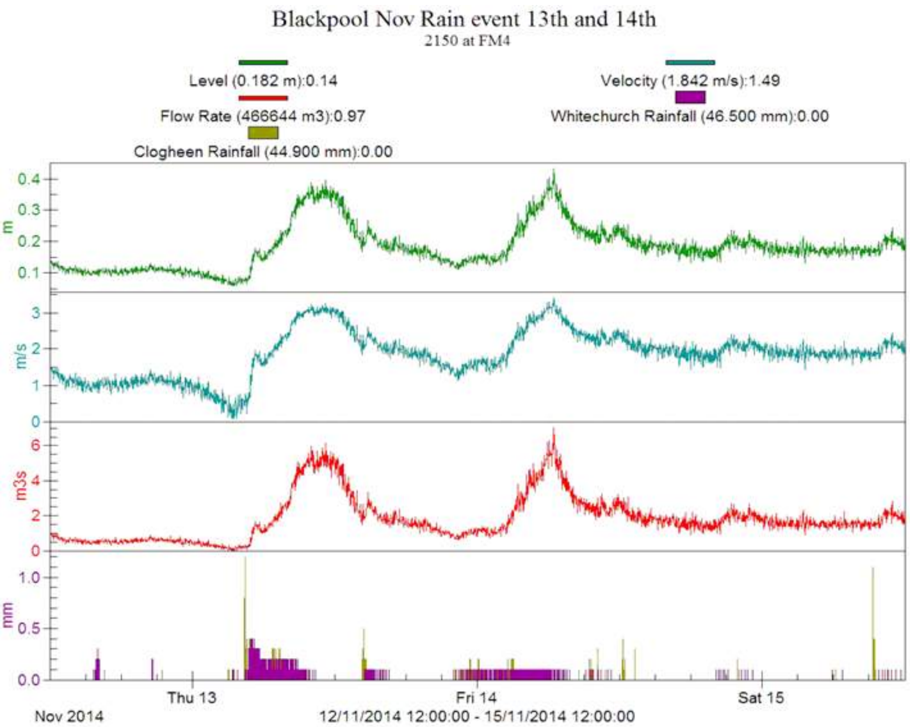
Fig 81: 2150 Flow logger Level, Velocity and Flow data during rain events at FM3



10.1.5 2150 AV Flow Logger at FM4:

Velocity data was not usable at FM4 due to ragging shortly into the start of the first rain event, however level data was intact. Velocity data was derived as described in section 9.2. We further derived flows based on this velocity result. The resultant peak data during the first event was level 0.34 m, (4.72 M OD), derived velocity 3 m/s , derived flow rate 4.84 m3/s

Fig 82: 2150 Flow Logger at FM4 with Level and derived Velocity and Flow data



10.1.6 Flow Balancing during rain event:

Fig 83 shows a graph of all flows logged during the Rain Event, noting that in the case of FM2 we are assuming a regular rectangular channel for our estimate and FM4 uses a derived velocity. Fig 84 adds the flows from FM3 and FM1 and FM4 and FM2 to consider flow balancing.

Fig 83 All Flows during Rain Event

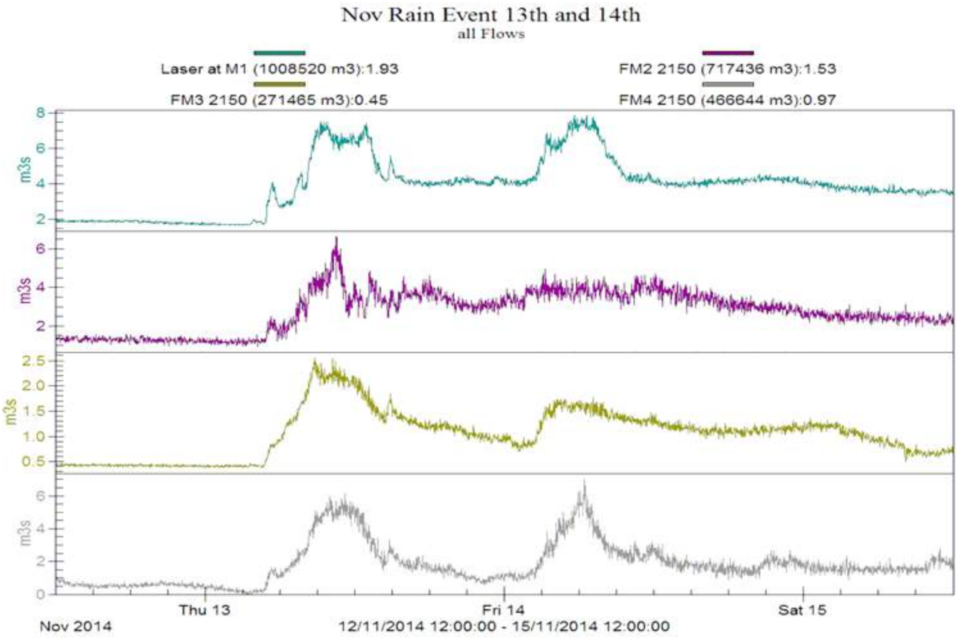
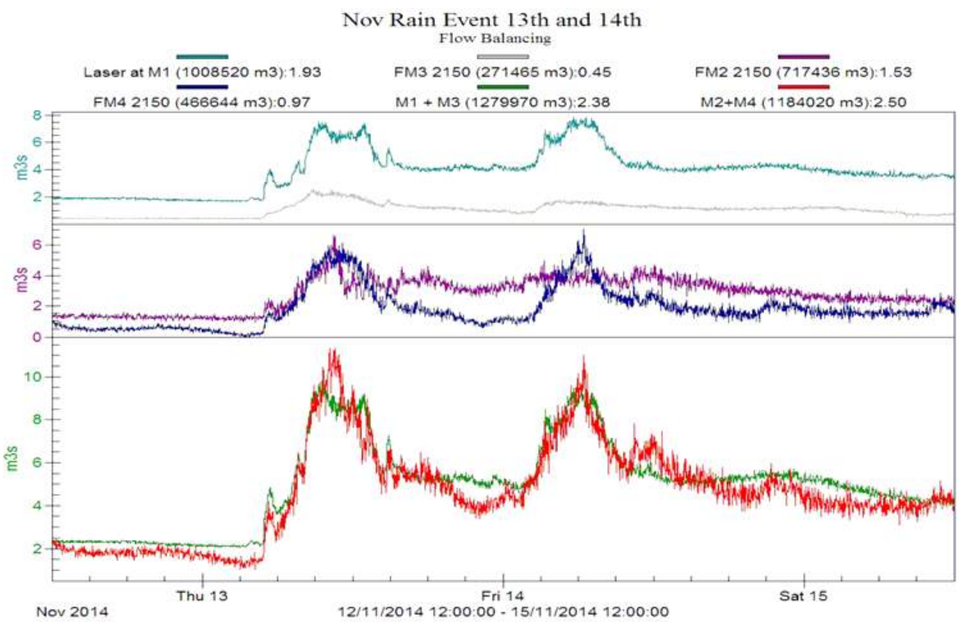


Fig 84: Flow Balancing Estimates by adding Flows



If we assume accuracy with FM1 and FM3, our derived flows at FM2 and FM4 would indicate an 8% underestimation. If we consider the total volumes the flow balancing percentages would calculate as seen in Table 8 below.

Table 8: Flow balancing percentages during rain event based on Total Volume FM1+FM3

	Nov 13th and 14th Rain Events					
	Total Volume Estimates					
	FM1	**FM3**	**FM2**	**FM4**	**M1+M3**	**M2+M4**
M3	1008520	271465	717436	466644	1279985	1184080
%	79%	21%	56%	36%	100.00%	

The flow estimates would further indicate that 71% of the flow in M1 carried out on down the M2 brewery line, while 29% cross the bifurcation to FM4.

Fig 85 below shows a picture of the bifurcation looking back towards the flow going right to left from FM1 (church culvert), to FM2 , (Brewery). This picture was taken during the entry on Sunday afternoon the 16th November at 16:00 approx. At this time levels were still relatively high, with Church bridge level at 0.3 m, (6.49 M OD), with Laser level at 0.25 m, (4.93 M OD), with velocity of 2.46 m/s. The photograph would support the conclusion that the majority of the flow could have carried straight down the brewery culvert during the rain event.

Fig 85 : Photograph in Bifurcation looking at FM1 to FM2 at 16:00 on Sunday 16th November

10.2 Rainfall Event 14th January 2015

This was an unusual event as the day started with a few centimeters of snow covering the catchment. Later in the day a storm with heavy wind and rain occurred. All snow quickly melted and one assumes contributed to the flows entering the culvert**.** A problem occurred with the Whitechurch Rain gauge which was resolved in the middle of the event. However, as the Whitechurch rain data set was incomplete the Clogheen rain data was used for the report. Data was also retrieved from Cork Airport which compared well to the Clogheen data. Figure 86 below shows hourly rainfall sums with Cork Airport recorded 30.3 mm of rainfall while Clogheen recorded 32.7 mm during the event.

Fig 86: Rainfall during 14th January Rain Event:

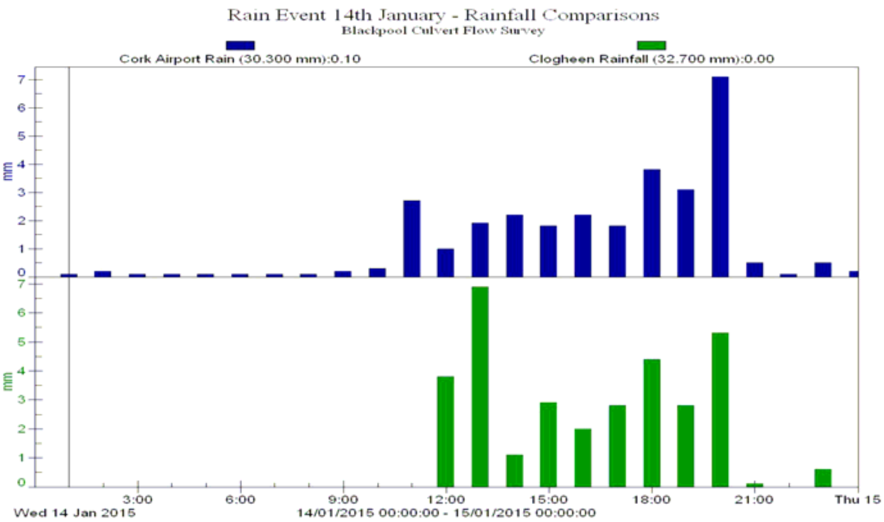
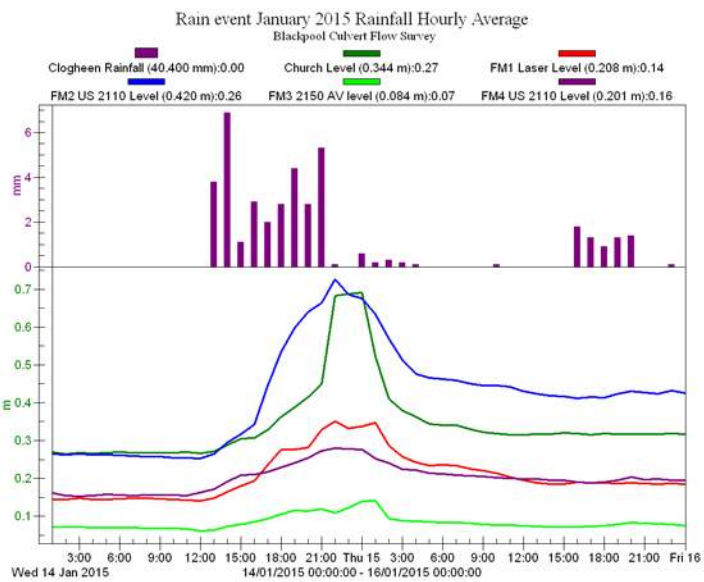


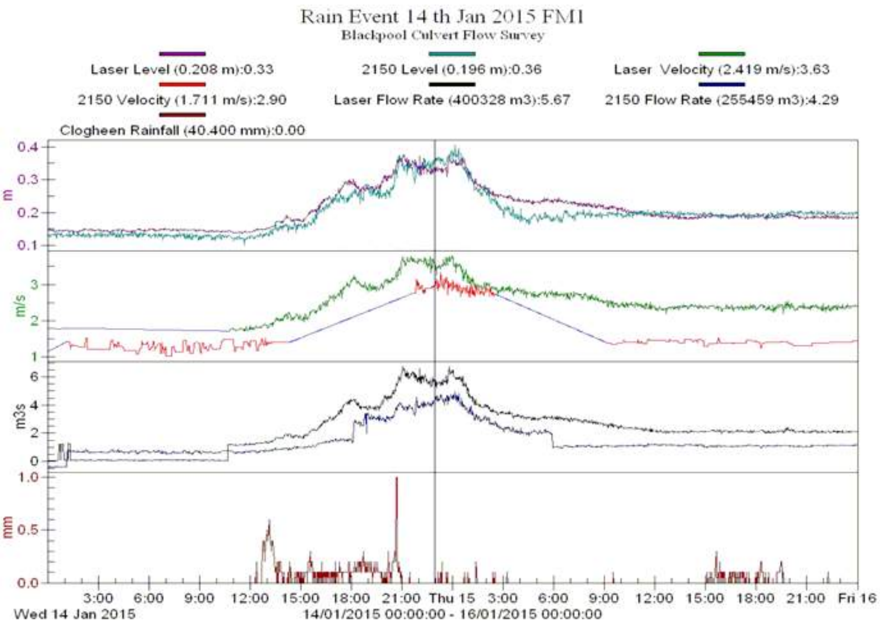
Figure 87 : Rainfall and levels during 14th January Rain event- (hourly average)



10.2.1 FM1: Rain Event 14th Jan Laser and 2150 AV :

Both Laser and 2150 AV show a peak level of 0.34 m approx, (5.04 M OD fpr 2150 and 5.02 M OD for Laser. The 2150 velocity data locked out during the increase but did record at the peak level for a period. However the Laser worked better and this is used as the benchmark for calculating an accurate flow at FM1. The max flow recorded by the Laser logger was 6 m3/s approx.

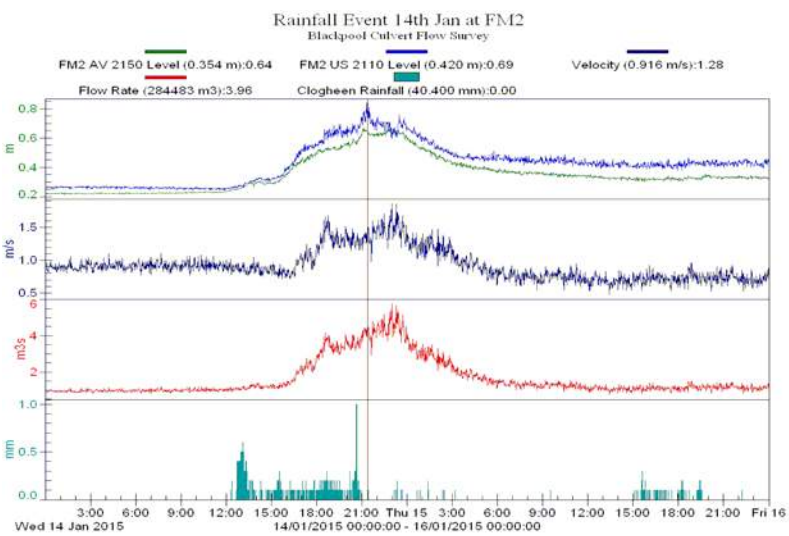
Fig 88: Rain Event 14th January at FM1- Level Velocity and Flows



10.2.2 FM2: Rain Event 14th January 2150 AV

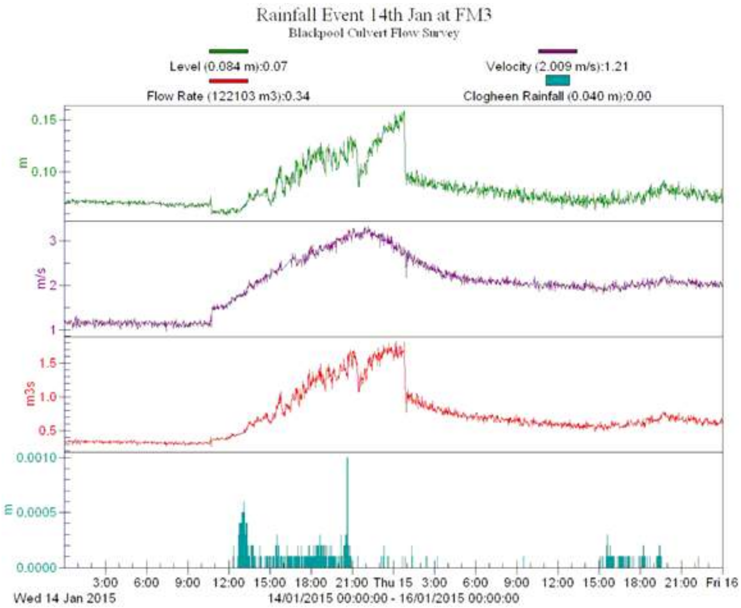
Ultrasonic 2110 Logger (US) and 2150 AV

Fig 89: Rain Event 14th January at FM2- Level, Velocity and Flows



10.2.3 FM3: Rain Event 14th January 2150 AV:

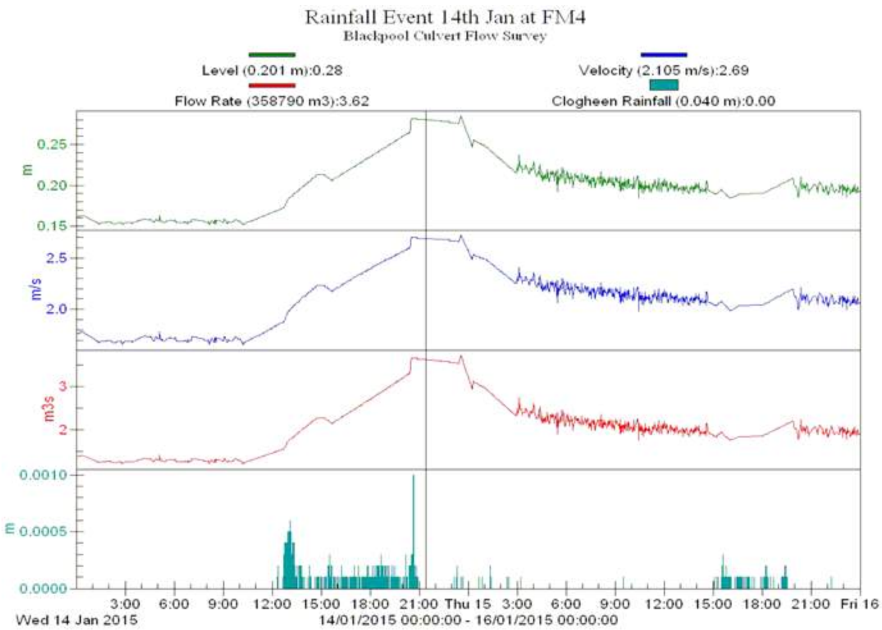
Fig 90: Rain Event 14th January at FM3- Level Velocity and Flows



10.2.3 FM4: Rain Event 14th January New 2110 Ultrasonic

At FM4 we recorded levels with the newly fitted Ultrasonic Flow logger which is placed 3 m upstream of the old 2150 AV position. We used an equation derived from previous level ,velocity data to convert levels to velocities and subsequently to flows in order to provide an estimate of the flow rates at FM4. This is used for flow balancing calculations.

Fig 91: Rain Event 14th January at FM4- Level calculated Velocity and calculated Flows



10.2.4 Flow Balancing for Rain Event 14th January 2014:

Flows at FM4 are derived from the ultrasonic level logger using an algorithm created from previous level velocity data. FM2 is a natural channel but for flow calculating purposes we assume a rectangular channel with an even floor level.

Fig 92: Rain Event 14th January Flow Calculation Summary Graph

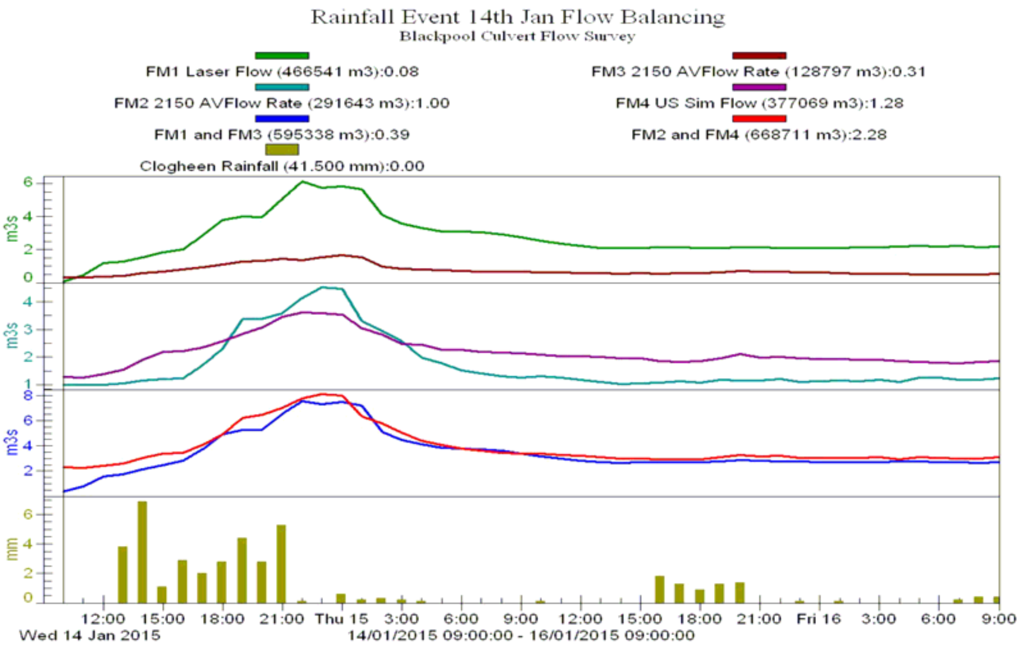


Table 9: Flow totals and Percentage distribution during 14th Jan Rain Event

Site Name	FM1 Laser Flow	FM2 4th Nov	Flow Monitor 3.	FM4 stack 190115		
Label	FM1 Laser Flow Rate	FM2 2150 AV Flow	Fm3 2150 AV Flow	FM4 2150 AV Flow	FM1+FM3	FM2+FM4
Units	m3	m3	m3	m3	m3	m3
25/01/2015 00:00	278606	191315	78467.2	210932	357073	402247
26/01/2015 00:00	187935	100328	50329.7	166137	238265	266464
Totals	**466541**	**291643**	**128796.9**	**377069**	**595338**	**668711**
%	**78.37%**	**48.99%**	**21.63%**	**63.34%**		

Flow totals calculated with a combined over read on FM 2+FM4 of 12.32%
Our calculations arrive at 37.49 % of the FM1 Bride River flow crossing bifurcation to FM4.

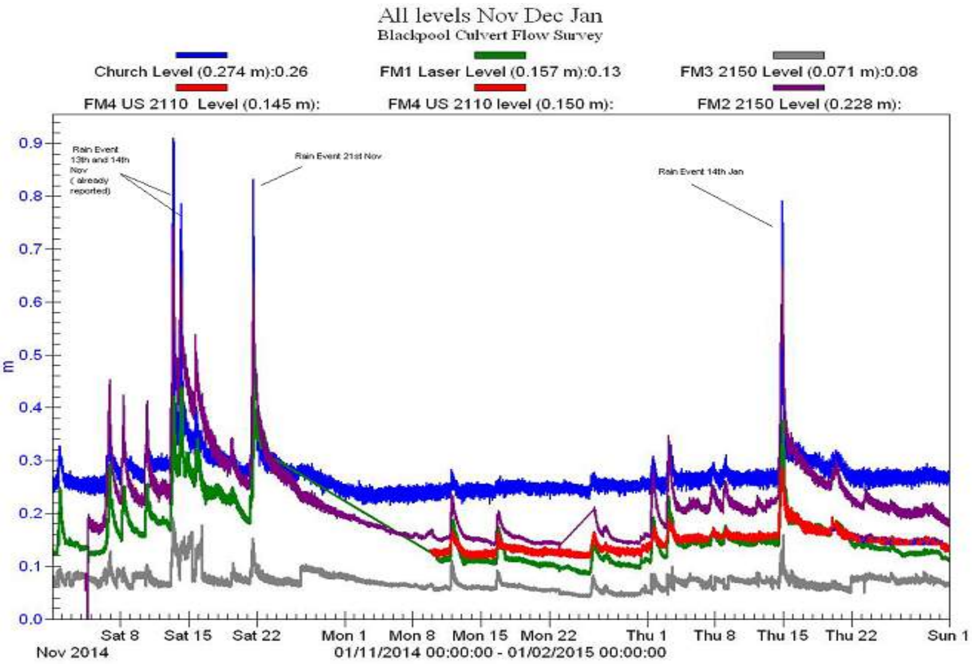
Table 10: Flow M3 and percentages crossing Bifurcation during 14th Jan rain event

Crossing Bifurcation from FM1 to FM4		**174898**	**37.49%**
over-estimation at FM2+FM4		**73373**	**12.32%**

10.3 Comparisons between Main Rain Events-Nov to Jan

The most significant rain events the 13th and 14th 2014 as described in section 10.1. Another significant event occured on the 21st November. Section 10.2 decribed the event on the 14th January 2015. Fig 100 compares the levels at all sites throughout this period. The blue trend displays the level recorded at Blackpool church which shows peaks between 0.8 and 0.9 m, (6.99 and 7.09 M OD), during the main rain events. The next most significant levels within the culvert are recorded in the FM2 old brewery line, (purple trend), with levels between 0.6 m and 0.7 m, (5.04 and 5.14 M OD).

Fig 93: All level recorded Nov Dec Jan



10.4 Flow Balancing in dry weather January 2015

Table 11 displays the calculated totals between 25th and 31st of January with flow balancing percentages.

Table 11 : Flow totals between the 25th and 31st January with flow balancing and percentages

Site Name	FM1 Laser Flow	FM2 4th Nov	Flow Monitor 3.	FM4 stack 190115		
Label	FM1 Laser Flow Rate	FM2 2150 AV Flow	Fm3 2150 AV Flow	FM4 2150 AV Flow	FM1+FM3	FM2+FM4
Units	m3	m3	m3	m3	m3	m3
25/01/2015 00:00	99595.2	37289.6	32911.1	86976.8	132506	124266
26/01/2015 00:00	93288	37168.4	29527.2	72738.8	122815	109907
27/01/2015 00:00	93019.7	37281.7	27816.8	78394.8	120837	115677
28/01/2015 00:00	83298.3	36309.3	20969.5	74459.5	104268	110769
29/01/2015 00:00	83282.9	35026.7	25229.9	73834.3	108513	108861
30/01/2015 00:00	85706.4	36135.5	26574.4	75288.6	112281	111424
31/01/2015 00:00	84534.8	37647.6	23852	71856.1	108387	109504
Totals	**622725.3**	**256858.8**	**186880.9**	**533548.9**	**809607**	**790408**
%	**76.92%**	**31.73%**	**23.08%**	**65.90%**		

These near end of survey calculations, would indicate that 58.75% of the Bride River flow entering the culvert at FM1 is crossing the bifurcation to FM4- Limerick Road in relatively dry weather conditions. This is significantly higher than calculations during wet weather which has calculated between 29 and 45 % of flow crossing the bifurcation for the three most recent rain events analyzed. This percentage has increased over the three analyzed rain events which could be due to the additional debris gathering at the entrance at FM2 – old brewery channel.

Table 12: Flow crossing bifurcation from FM1 to FM4 in January dry weather analyses.

Crossing Bifurcation from FM1 to FM4		**365866.5**	**58.75%**

11.0 Conclusions:

11.1 General Findings:

No rain event was recorded that would appear to have come close to causing flooding at Blackpool.

Despite some significant rain events, in particular, the rain event logged on the 13th and 14th November, there was no evidence of surcharged conditions recorded on any of the culverts near the bifurcation. All events recorded synchronised level and velocity increases, consistent with normal gravity flow.

The photographs taken at the entrance to the culvert at Blackpool church, at 10 am on the 14th November, 4 hours after the peak of the rain event, may be significant. The photograph shows a relatively high water level at the entrance. The level recorded under the bridge at the church when the photograph was taken was 0.4 m, (6.59 M OD). The church level at the peak of the event, 4 hours previous, was 0.75m, (6.94 M OD). The assumption is that flow could be restricted at the entrance during a very significant rain event.

Flow balancing estimates calculated indicate 30 to 40% of the flow measured at FM1 crossed the bifurcation to FM4, during the heaviest recorded rain events in November 2014 and January 2015. An estimate at lower flows calculated at 57% crossing from FM 1 to FM4. Visual inspections confirmed that almost all the flow crossed the bifurcation during the low levels in the summer.

Comparions of flow distribution before and after the wall was removed, at the entry to the old brewery culvert,(FM2), are inconclusive. This is due to the fact that the remaining reinforcement structure had fouled before the heavier rain in November, which created a similar dam effect as the original wall. At low levels, the flow predominatly crossed the bifurcation with or without the wall being present.

11.2 Current Conditions within the culvert

In general, present conditions within the culvert at the bifucration are reasonably clean and there is no noticable disinprovement since the cleaning work in August. Stone and sediment deposits appear much the same since this work in August.

The only issue is that the remaining reinforcement structure where the old wall was at the entrance to the old brewery channel, (FM2) , remains fouled as reported.

11.3 Current Conditions at Blackpool Church:

The work done last June in clearing out the stone and sediment under the bridge and surrounding areas by Cork City Council, and associated contractors, was excellent and very thorough. Water is free flowing and conditions remain predominatly clean at this location.

11.4 Limitations of the Survey Work

The amount of debris and ragging within the culvert was unexpected and in hind sight was not very suitable for immersion type probes, without considerable maintenance. It was dissapointing that the laser flow loggers were not available prior to the survey as this proved a good non -contact solution to provide both velocity and level data. In general only non- contact technology should be considered for future work in our opinion.

11.5 Monitoring in the Future:

Going forward, if further monitoring was required, a combination of ultrasonic level loggers and Laser Logger(s) could be considered. Ultrasonic level loggers at the 4 channels at the bifurcation could provide reliable level data. It would be possible to feed all probe cables out to a secure box at Blackpool church to reduce the amount of entries and to make battery changes and telemetry much more managable.

The Isco 2160 Laser flow logger, possibly placed a short distance within the culvert entrance at Blackpool church, could be considered as a good overall monitor and as as a flood warning system device.

Water Technology Ltd would like to thank all our associates on this project, in particular JBA Consulting, NCW Surveys Ltd, Cork City Council, An Garda Siochanna and others who helped us throughout.
Water Technology would also like to thank the generous people of Blackpool village who were supportive throughout the works.

This report was complied by Finbarr O Riordan and Lian O Riain of Water Technology Ltd.

Appendice A: List of entry dates

ENTRY DATES	PERSONNEL	ACTIVITY
14/03/2014	Liam O'R, Martin Dunne, F O Riordan	Installation of equipment.
22/03/2014	Liam O'R, Martin Dunne, F O Riordan	Installation of equipment.
19/03/2014	Liam O'R, Martin Dunne, F O Riordan	Installation of equipment.
20/03/2014	Liam O'R, Martin Dunne, F O Riordan	Installation of equipment.
21/03/2014	Liam O'R, Martin Dunne, F O Riordan	Installation of equipment.
03/04/2014	Liam O'R, Martin Dunne, F O Riordan	Installation of equipment.
23/04/2014	Liam O'R, Martin Dunne, F O Riordan	reboot ADFM, level velocity profiling, cleaning
24/04/2014	Liam O'R, Martin Dunne, F O Riordan	adjust levels, times,profiling
16/05/2014	Liam O'R, Martin Dunne, Paul O' Dwyer, Denis O' Connell.	Check levels, Clean probes, Replace battery and correct time on level 1.01, Take pictures of probes, Replace all 4 area velocity probes, Stack FM2 at manhole location, Move FM 2 back up towards the H junction,
20/05/2014	Liam O'R, Martin Dunne, Sean o Riordan, Denis O' Connell.	levels, cleaning , batteries, photos
26/05/2014	Liam O'R, Paul O' Dwyer, Finbarr O' Riordan, Martin Dunne.	moved FM2, cleanprobes etc
11/06/2014	Liam O'R, Paul O' Dwyer, Finbarr O' Riordan, Martin Dunne.	clean, new 2105 modem, download ADFM
12/06/2014	Liam O'R, Paul O' Dwyer, Finbarr O' Riordan, Martin Dunne.	removed ADFM, level velocity profiling
19/06/2014	Liam O'R, Paul O' Dwyer, Finbarr O' Riordan, Martin Dunne.	reinstalled ADFM
24/06/2014	Liam O'R, Paul O' Dwyer, Finbarr O' Riordan, Martin Dunne.	levels, cleaning , batteries, etc
25/6/2014	Liam O'R, Paul O' Dwyer, Denis O' Connell, F O riordan	levels, cleaning , batteries, photos
27/06/2014	Liam O'R, Sean O'Riordan, Denis O' Connell, Finbar O' Riordan.	change ADFM batteries, level velocity profiling
11/07/2014	Liam O'R, Paul O' Dwyer, Finbarr O' Riordan, Martin Dunne.	levels, cleaning , batteries, photos
25/7/2014	Liam O'R, Paul O' Dwyer, Finbarr O' Riordan, Martin Dunne.	levels, cleaning , batteries, etc
31/07/2014	Liam O'R, Martin Dunne, Finbarr O' Riordan, Denis O' Connell.	Check battery levels, Take pictures of probes in situ, Check levels for all sites and record, clean probes of debris, Install the new 2160 laser flow and meter, check the parameters of other flow meters and change if necessary, remove the ADFM back to the office and review.
06/08/2014	Liam O'R, Martin Dunne, Finbarr O' Riordan, Denis O' Connell.	fiitted Laser Flow Logger at FM1
14/08/2014	Liam O'R, Martin Dunne, Finbarr O' Riordan, Denis O' Connell.	download laser, replace FM1 battery
21//8/2014	Liam O Riain , Martin Dunne, 2 personnel from New survey company	OD Survey

26/08/2014	Liam O'R, Paul O' Dywer, Sean O Riordan, Finbarr O' Riordan.	FM1 velocity not accurate, change FM1 and laser to same level, Fix- ADFM probe to the floor, clean probes of debris, check levels of all sites and record, replace batteries if low, take pictures of probes in situ.
02/09/2014	Liam O' R, Finbarr O' Riordan, Martin Dunne, Sean O' Riordan.	replace ADFM batteries, download, clean etc.
10/09/2014	Liam O' R, Martin Dunne, Sean O' Riordan, Finbarr O' Riordan.	levels, cleaning , batteries, etc
24/9/2014	Finbarr O' Riordan, Martin Dunne, Peter Wiseman, Sean O' Riordan.	levels, cleaning , batteries, etc
07/10/2014	Liam O'R, Martin Dunne, Sean O Riordan, Finbarr O' Riordan.	Review sites after previous 24 hr heavy rain event, power back up laser which is down, Clean probes of debris, Replace batteries if low, Take pictures of probes in situ.
8/10/2014	Liam O'R Paul O' Connell Martin Dunne, Finbarr O' Riordan.	levels, cleaning , batteries, etc
14/10/2014	Liam O' R, Paul O' Connell, Finbarr O' Riordan, Sean O' Riordan	levels, cleaning , batteries, etc
21/10/2014	Liam O' R, Paul O' Connell, Finbarr O' Riordan, Sean O' Riordan	levels, cleaning , batteries, etc
24/10/2014	Liam O' R, Alan Creed, Martin Dunne, Finbarr O' Riordan.	levels, cleaning , batteries, etc
16/11/2014	Liam O' R, Denis O' Connell, Paul O D, Sean O' Riordan, Finbarr O' Riordan.	Entry through manhole, retrieve data FM1 and FM2
09/12/2014	Liam O' R, Denis O' Connell, Martin D, Sean O' Riordan, Finbarr O' Riordan.	Entry through manhole, retrieve data FM1 and FM2, Install US probes at FM4 and FM2, clean probes take levels and photos
22/12/2014	Liam O' R, Denis O' Connell, Martin D, Sean O' Riordan, Finbarr O' Riordan.	Entry through manhole, retrieve data FM1 and FM2, clean probes, take levels and photos, change batteries
19/01/2015	Liam O' R, Denis O' Connell, Martin D, Sean O' Riordan, Finbarr O' Riordan.	Entry through manhole, retrieve data FM1 and FM2,change batteries take levels, remove old FM4 AV and carry out firmware upgrade,remove new ultrasonic logger at FM4 and retrieve data, stack new ultrasonic FM4 logger with old FM4 2150 on the same push data modem, take photographs,Clean debris off AV probes
22/01/2015	Liam O' R, Denis O' Connell, Martin D, Sean O' Riordan, Finbarr O' Riordan.	Entry through manhole, retrieve data FM1 and FM2 and FM2 ultrasonic,take levels, fit new AV probe at FM4, Clean debris off AV probes

Appendice B: Samples of spot level velocity check sheets:

Blackpool Entrance Checks

Date: 17th June 2014

Culvert Entry Time 14:00

	Measured Level	Measured Velocity	Time	logger L/V ?	photo?	ragging?	comment
Church Level 2110	.14-.17		14:30	.167			
FM1 2150	.09	.7	16:30	.093/.64	Yes	Yes	
FM2 2150	.13	.6		.12/.6	Yes	No	silting
FM3 2150	.04	.2	13:10	.045/.23	Yes	Yes	debris
FM4 2150	.09-.11	1.0	16:00	.105/.892	Yes	clean	Wading
H Level 2110	.16-.18	—	15:10	.166	Yes	N/A	
ADFM							
signed:							

Blackpool Entrance Checks							
Date: 19 Jan	2015						
Culvert Entry Time 22:00							
	Measured Level	Measured Velocity	Time	logger L/V ?	photo?	ragging?	comment
FM1 2150	.16 - .17		23:40	.174	Yes	some ragging	Turbulent flows
FM1 Laser	.14 – .15		23:46	.174	Yes	moving level	Turbulent
FM2 2150	.27		00:50	.296	Yes	~~Sediment~~ No	Turbulent
FM2 US 2110	.27		00:50	.314	Yes	No	Turbulent
FM3 2150	.06		00:20	.064	Yes	slight	Turbulent
FM4 2150	.17 - .24		00:20	.175	Yes	slight	Wave at probe
FM4 US 2110	.15 - .16		00:20	.175	Yes	No	Turbulent
signed:	Liam O Riordan						

Blackpool Entrance Checks							
Date: 22 Dec	2014.						
Culvert Entry Time 22:00							
	Measured Level	Measured Velocity	Time	logger L/V ?	photo?	ragging?	comment
FM1 2150	·11		23·48	·1	Yes	Yes	Large Amt ragging
FM1 Laser	·1		23:40	·1	Yes	NO	
FM2 2150	·16		00·05	·167	Yes	Yes	slow building up
FM2 US 2110	·18		00:05	·19	Yes	No	
FM3 2150	·06		00:15	·055	Yes	Yes	Sediment on probe
FM4 2150	·14		00·30	·098	Yes	Yes	slight
FM4 US 2110	·14		00·30	·123	Yes	No	
signed:	[signature]						

Blackpool Entrance Checks							
Date: 24 June	2014						
Culvert Entry Time 13:00							
	Measured Level	**Measured Velocity**	**Time**	**logger L/V ?**	**photo?**	**ragging?**	**comment**
Church Level 2110	·12-·14		15:00	·129			
FM1 2150	·08	·5	15:15	·075/·48	Yes	Yes	Restart loggers
FM2 2150	·11	·6	15:30	·104/·506	Yes	No	Sedimentation
FM3 2150	·04	·3	14:30	·042/·27	Yes	Yes	Extraneous
FM4 2150	·09	·8	14:30	·088/·44	Yes	Yes	tree branches
H Level 2110	·12-·13		15:50	·13	Yes	N/A	
ADFM							
signed:							

Blackpool Entrance Checks							
Date: 10th - 9 - 14							
Culvert Entry Time 9:00							
	Measured Level	Measured Velocity	Time	logger L/V ?	photo?	ragging?	comment
Church Level 2110	·14		9·30	·145			
FM1 2150	·015	·3	11·30	·015/·3	Yes	Yes	low levels
FM2 2150	·04	·2	00:00	·05/·24	Yes	No	Submerged.
FM3 2150	·02	·1	10:00	·025/·14	yes	Yes	low levels.
FM4 2150	·07	·5	10:00	·073/·47	yes	yes	low fouling.
H Level 2110	·10	—	11:10	·109	—	—	
ADFM							
signed:							

with heavy
lowering.
6 pm.

Blackpool Entrance Checks							
Date: 26 Aug 2014							
Culvert Entry Time 13:00							
	Measured Level	Measured Velocity	Time	logger L/V ?	photo?	ragging?	comment
Church Level 2110	·08-·09		15:00	·093			
FM1 2150	·07	·30	16:30	·074/.3	Yes	Yes	Changed flow rates.
FM2 2150	·08	·1	16:30	·08/·09	Yes	No	low
FM3 2150	·01	·1	14:00	.007/138	Yes	Yes	Tiny flows
FM4 2150	.06	.6	14:00	·04/.554	yes	yes	[illegible]
H Level 2110	·11 - ·12	—	14:00	·126	Yes	No	
ADFM							
signed:							

Appendice C: Samples of culvert entry sheets

Blackpool Entry Checklist

Equipment	Yes	No	Signature (Check)	Date	Signature (Entrant)
Gas Detection	✓			14th Oct 2014	
Head light	✓✓				
Helmet	✓✓				
Gloves Nitrite	✓✓				
Gloves Kevlar	✓✓				
Safety Waders	✓✓				
Back up safety supplies including First Aid Kit	✓✓				
10 min Oxygen escape mask	✓✓				
Moblie phone fully charged	✓✓				
Rope communication	✓✓✓				

Standby Person

Print Name: Sean O'Riordan

Signature:

Date: 14 Oct 14

	Blackpool Entry Checklist				
Equipment	Yes	No	Signature (Check)	Date	Signature (Entrant)
Gas Detection	✓				
Head light	✓				[illegible]
Helmet	✓				
Gloves Nitrite	✓				[illegible]
Gloves Kevlar	✓				
Safety Waders	✓				
Back up safety supplies including First Aid Kit	✓				[illegible]
10 min Oxygen escape mask	✓				[illegible]
Moblie phone fully charged	✓				
Rope communication	✓				

Standby Person
Print Name: F O Riordan
Signature: [illegible]
Date: 16 / 11 / 2014

Blackpool Entry Checklist

Equipment	Yes	No	Signature (Check)	Date	Signature (Entrant)
Gas Detection	✓				[illegible]
Head light	✓				[illegible]
Helmet	✓				
Gloves Nitrite	✓				
Gloves Kevlar	✓				[illegible]
Safety Waders	✓				
Back up safety supplies including First Aid Kit	✓				
10 min Oxygen escape mask	✓				
Moblie phone fully charged	✓				
Rope communication	✓				

Standby Person

Print Name: [illegible]

Signature: [illegible]

Date: 14/1/2015

Blackpool Entry Checklist

Equipment	Yes	No	Signature (Check)	Date	Signature (Entrant)
Gas Detection	✓				[illegible]
Head light	✓				[illegible]
Helmet	✓				
Gloves Nitrite	✓				[illegible]
Gloves Kevlar	✓				
Safety Waders	✓				[illegible]
Back up safety supplies including First Aid Kit	✓				
10 min Oxygen escape mask	✓				
Moblie phone fully charged	✓				
Rope communication	✓				

Standby Person

Print Name: F O Riordan

Signature: [illegible]

Date: 22/1/2015

	Blackpool Entry Checklist				
Equipment	**Yes**	**No**	**Signature (Check)**	**Date**	**Signature (Entrant)**
Gas Detection	✓			22 Dec	
Head light	✓				[signature]
Helmet	✓				[signature]
Gloves Nitrite	✓				
Gloves Kevlar	✓				
Safety Waders	✓				
Back up safety supplies including First Aid Kit	✓				[signature]
10 min Oxygen escape mask	✓				
Moblie phone fully charged	✓				
Rope communication	✓				

Standby Person

Print Name: LIAM O RIGIN   Finbarr O Riordan

Signature: [signature]

Date: 22 Dec '14