1. Existing Overflow Capacity

Flood Assessment

A high-level flood assessment has been carried out to check the current capacity of the overflow. A summary of the main considerations and assumptions is shown in Table 1 below.

Table 1: Cilcain Reservoirs 1 & 2 flood assessment: key considerations and assumptions

Consideration	Value / Assumption	Source / Comment
Catchment area (km^2)	3.13	FEH Online Service
Reservoir surface area (m^2)	Upper reservoir – 3,000m^2 Lower reservoir – 6,500m^2	Based on information from the bathymetric survey completed on 6th February 2019. Verified by the capabilities provided by Google Earth software.
SAAR (mm)	917	FEH Online Service
Storm event duration (hours)	4.75	Including a 0.5-hour routing lag allowance.
Main overflow weir crest level (m AOD)	239.175	Top Water Level. Based on a Bathymetric Survey performed in 2018.
Connecting overflow channel bed level (mAOD)	239.00	Top Water Level. Based on a Bathymetric Survey performed in 2018.
Main Dam crest level (m AOD)	240.00	Based on a Bathymetric Survey performed in 2018.
Dividing Dam crest level (mAOD)	240.00	Based on a Bathymetric Survey performed in 2018.
Effective main overflow weir width (m)	2.15	Weir length measured during site visit 10th January 2018.
Weir type	Broad-crested weir	Confirmed during site visit 10th January 2018.
Coefficient of discharge, C_d	1.7	Reflects sharp crested weir, with downstream nappe shape for improved hydraulic performance.
Connecting channel width (m)	2.35	Width measured during site visit 10th January 2018.

Further notes:

- FEH catchment parameters have been taken for the nearest point on FEH Web Service to the main embankment. Inflows to the components of the system are estimated by replacing the overall catchment area (3.13km^2) in the catchment characteristics with their respective manually estimated catchment areas.
    - Gross catchment area of Cilcain No. 1 reservoir estimated manually as 2.467km^2.
    - Direct catchment area of Cilcain No. 2 reservoir estimated manually as 0.040km^2.
    - Direct catchment area of the by-wash channel estimated manually as 0.583km^2

A summary of the results of the flood routing with the existing overflow arrangements is shown in Table 2 and Table 3 below. For simplicity, and to be conservative, this assessment has assumed that all the catchment inflows pass through the inlet to the upper reservoir i.e. no inflows passing through the by-wash channel.

Table 2: Cilcain No. 1 (Upper) Reservoir: summary of flood assessment results for the existing overflow arrangements

Cilcain No. 1 (Upper) Reservoir						
Event	**Rainfall depth**	**Peak inflow**	**Peak outflow via overflow**	**Peak outflow over crest**	**Max flood level** Overflow Level = 239.00mAOD Crest Level = 240.00mAOD	**Flood level exceeds dam crest by:**
	mm	**m^3/s**	**m^3/s**	**m^3/s**	**m AOD**	**m**
Safety Check Flood (PMF)	**190**	**27.00**	**5.90**	**20.70**	**240.44**	**0.44**
Design Flood (10,000-year flood)	**145**	**12.00**	**3.80**	**7.30**	**240.22**	**0.22**
1,000-year flood	108	8.20	3.10	4.10	240.15	0.15
150-year flood	82	5.90	3.10	2.00	240.10	0.10
100-year flood	44	2.70	2.50	0.00	240.00	0.00
10-year flood	35	1.37	1.23	0.00	239.69	0.00

Table 3: Cilcain No. 2 (Lower) Reservoir: summary of flood assessment results for the existing overflow arrangements

Cilcain No. 2 (Lower) Reservoir						
Event	**Peak direct inflow**	**Peak inflow from upper res**	**Peak outflow via overflow**	**Peak outflow over crest**	**Max flood level** Overflow Level = 239.20mAOD Crest Level = 240.00mAOD	**Flood level exceeds dam crest by:**
	m^3/s	**m^3/s**	**m^3/s**	**m^3/s**	**m AOD**	**m**
Safety Check Flood (PMF)	0.50	**26.60**	**3.80**	**23.90**	**240.23**	0.23
Design Flood (10,000-year flood)	0.20	**11.10**	**3.20**	**7.20**	**240.10**	0.10
1,000-year flood	0.10	7.20	2.90	3.40	240.06	**0.06**
150-year flood	0.10	5.10	2.80	1.20	240.03	**0.03**
100-year flood	0.04	2.50	2.30	0.0	239.93	0.00
10-year flood	0.02	1.23	1.12	0.0	239.65	0.00

The flood routing hydrographs showing the results for the routing of Design Flood (10,000-year flood) and the Safety Check Flood (PMF) are shown in Figure 1 and Figure 2 below.

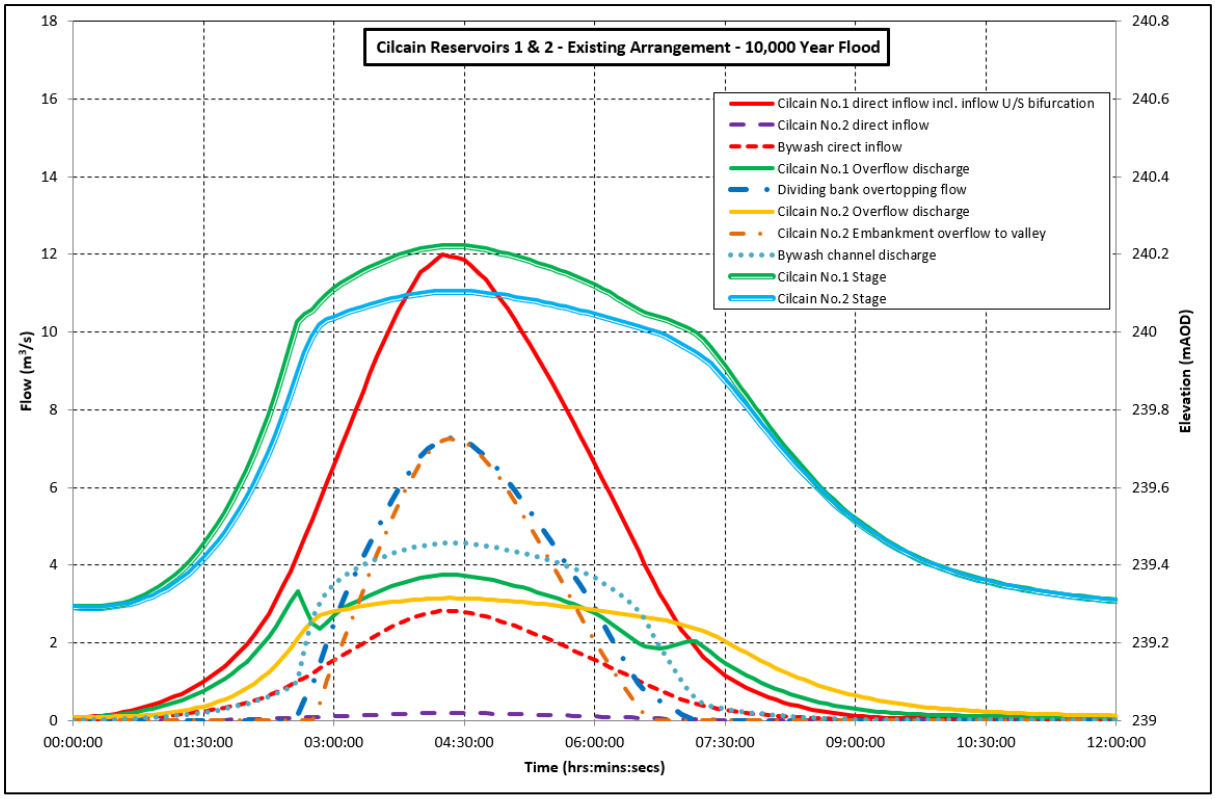

Figure 1: Flood routing results for the 10,000-year flood

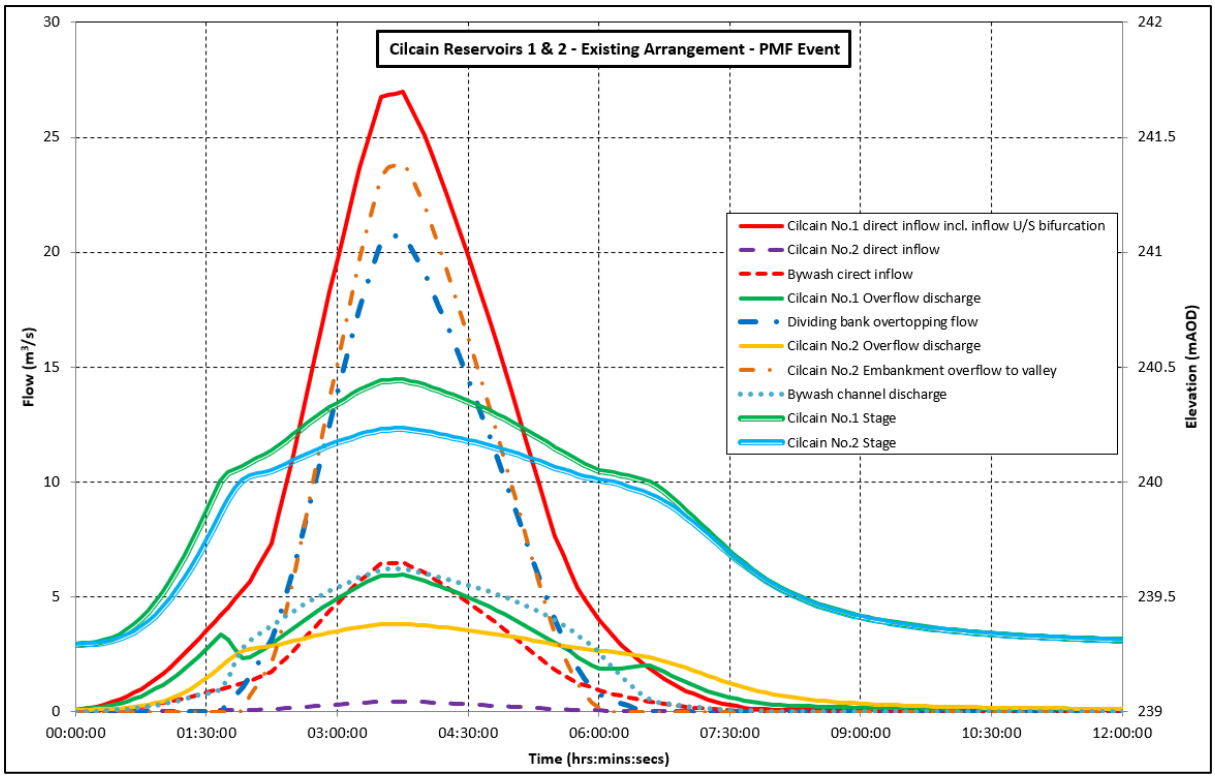

Figure 2: Flood routing results for the PMF

The implications of the flood assessment on the reservoir retained, and discontinuance options, and the resultant downstream flood risk are considered in detail in **Appendix 8, Engineering Options**.

Wave Assessment

The flood assessment showed that the stillwater flood level during the Design Flood and Safety Check Flood would result in overtopping of both dam crests. The most significant fetch (length of water surface over which waves can develop) is estimated at 95m by taking a line down the centre of the reservoir. The significant wave height (Hs) is estimated to be in the order of 0.1m. Therefore, no further assessment in this respect has been carried out.

It should be noted that wave freeboard will be an important consideration if the reservoirs are to be retained and this is discussed in more detail in **Appendix 8, Engineering Options**.

Existing Downstream Flood Risk

The valley downstream of the reservoirs for the first 1.4km runs mostly through farmland that comprises two unclassified roads, one agricultural property and approximately 10 residential properties. After 2.6km, at the confluence of Nant Gain with the River Alyn, the approximately 10 residential properties are located adjacent to the watercourse with Cilcain Road passing over the stream. Approximately 3.15km downstream of the reservoirs the watercourse runs past a Water Treatment Works (WTW) and a set of approximately 50no. static caravans and 1no. residential properties about 3.7km further downstream.

The description in Table 4 below is based on the published 1:25,000 scale Ordinance Survey maps (available on the internet) and Google Earth. Figure 3 below shows the features that are described in Table 4. There are long term flood risk maps available from the Cyfoeth Naturiol Cymru (Natural Resources Wales) website and these have been used to assist with the estimation of flood risk to downstream features. A copy of the flood risk map for Cilcain Reservoirs 1 & 2 is shown in Figure 4.

Table 4: Features downstream of dam

Estimated distance downstream (m)	Feature	Comments
900	Minor unclassified road over stream and one agricultural property adjacent to Nant Gain stream	Details of the conveyance structure underneath this road are unknown. A photo taken during the site visit on 10th January 2019 shows that the road is quite low at the stream location, and it is therefore likely to be flooded during major fluvial events and / or the uncontrolled release of water from Cilcain Reservoirs 1 & 2 in the event of a dam breach.
1,400	Minor unclassified road over stream and about 10 residential properties adjacent to Nant Gain stream	Details of the conveyance structure underneath this road are unknown. It may be likely that this road and some of the surrounding properties will be flooded during major fluvial events and / or the uncontrolled release of water from Cilcain Reservoirs 1 & 2 in the event of a dam breach.
2,600	Cilcain Road over stream and about 10 residential properties adjacent to River Alyn.	Details of conveyance structure underneath Cilcain Road are unknown. Google Street View not available on such a remote track. It may be likely that this road and the adjacent properties will be flooded during major fluvial events and / or the uncontrolled release of water from Cilcain Reservoirs 1 & 2 in the event of a dam breach.
3,150	Water Treatment Works adjacent to the River Alyn	The River Alyn runs passed a WTW which is likely to be flooded during major fluvial events and / or the uncontrolled release of water from Cilcain Reservoirs 1 & 2 in the event of a dam breach.
3,700	Static caravan park and one residential property adjacent to River Alyn	Approximately 50 static caravans and one residential property are situated adjacent to the River Alyn. Due to the steepness of the valley in this location, it is possible that water levels will rise significantly and that these properties will be flooded during major fluvial events and / or the uncontrolled release of water from Cilcain Reservoirs 1 & 2 in the event of a dam breach.

The downstream flood risk associated with the reservoir retained and discontinuance options is considered in detail in **Appendix 8, Engineering Options**.

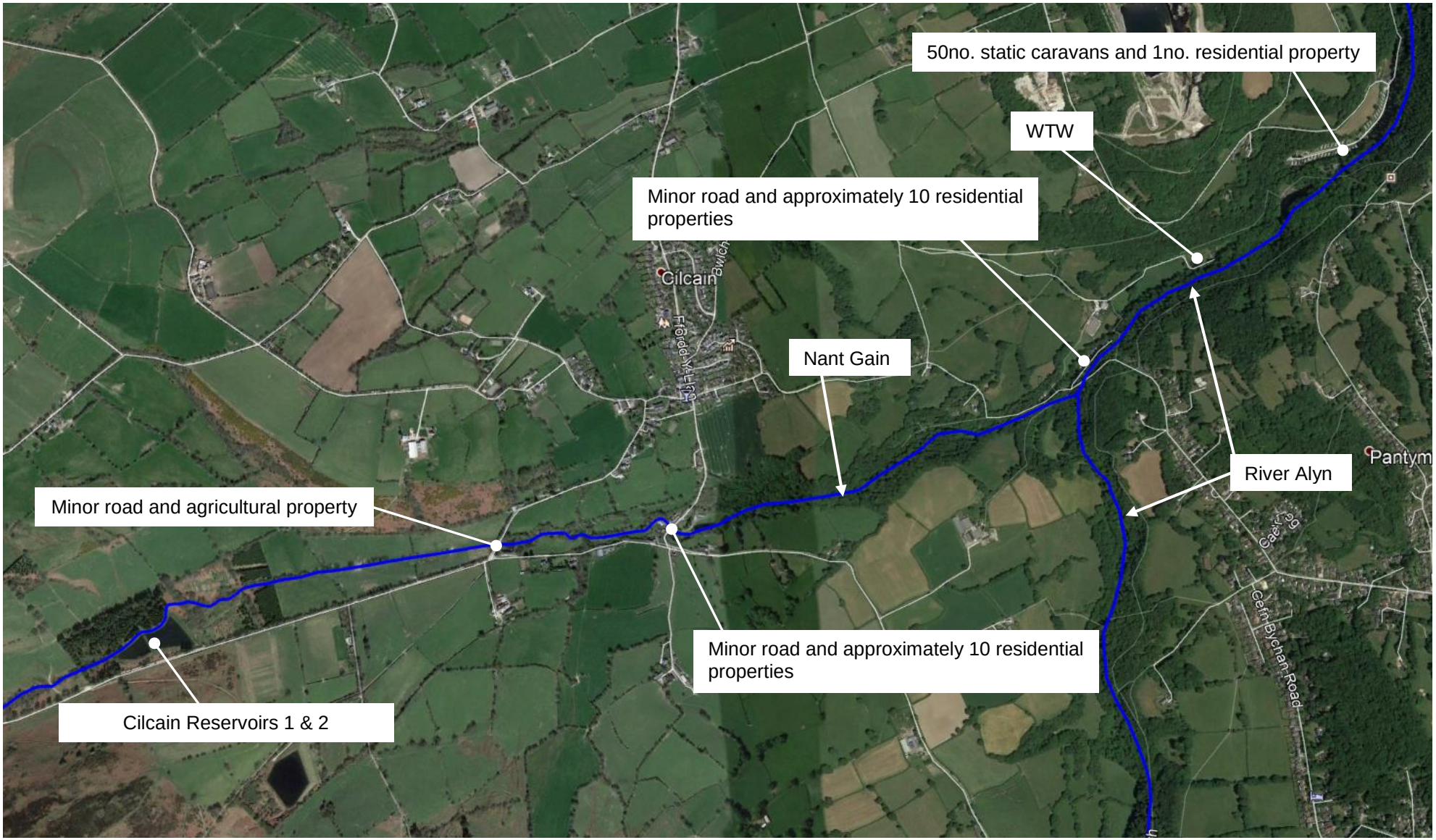

Figure 3: Features downstream of the dam (courtesy of Google Earth)

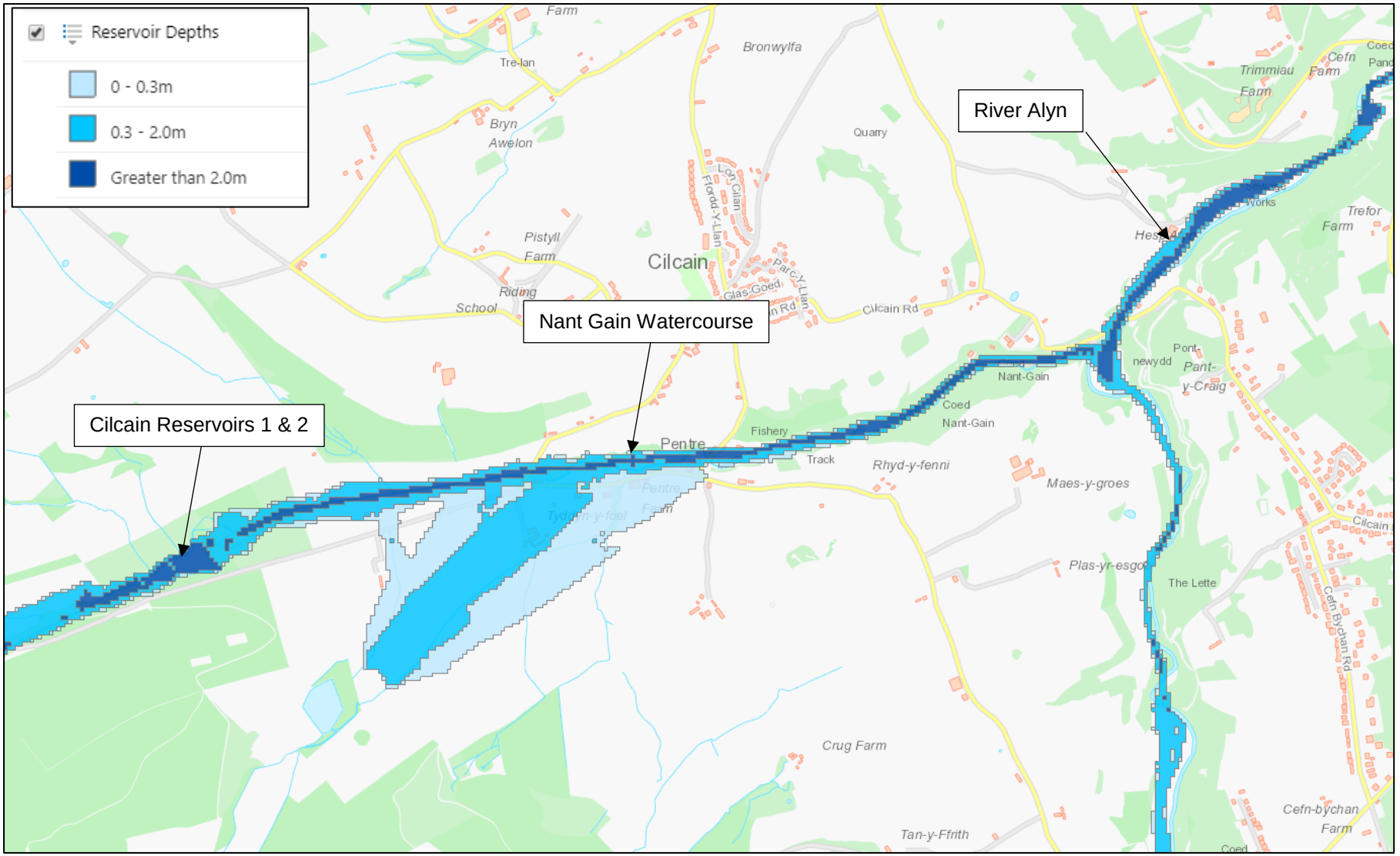

Figure 4: Reservoir Flood Risk Map (courtesy of Cyfoeth Naturiol Cymru (Natural Resources Wales) website).

2. Reservoir Breach Modelling and Mapping (uncontrolled release of water) – Initial Findings

Black and Veatch are currently finalising a modelling and mapping project for the uncontrolled release of water from the DCWW reservoirs. This project uses the Environment Agency 2016 national inundation mapping specification. This Project is due to be completed at the end of March 2019 and so full results are not yet available. Preliminary results for Cilcain Reservoirs 1 & 2, provided by DCWW ('Initial Results from Mapping to inform North Wales discontinuance studies' dated 14th March 2019), are reproduced below in Table 5.

In accordance with the EA2016 specification the modelling considers two scenarios:

Dry day scenario: reservoir fails, releasing the impounded volume at top water level (overflow level) on a dry day, with no additional background flows. The full impact of the resulting downstream flooding is considered.

Wet day scenario: reservoir fails, releasing the impounded volume, with a raised water level during a concurrent flood event, and thus the volume released is greater than the dry day scenario. The resulting downstream flooding is compared against the flooding caused by the prevailing flood (fluvial) event.

Table 5: B&V Average Societal Life Loss (ASLL) following failure of Cilcain Reservoirs 1 & 2

B&V Average Societal Life Loss (ASLL using Risk Assessment for Reservoir Safety Management (RARS) Methodology)				**Comments**
Dry Day	Wet Day	Fluvial Only	Incremental Wet Day (compared to fluvial)	
0.008	1.24	1.09	0.15	Very low figures

The preliminary results indicate that Cilcain Reservoirs 1 & 2 could be classified as a Category A reservoir when taking into account the wet day scenario total ASLL (Average Societal Life Loss) and not the incremental loss, and the standards-based approach provided in Floods and Reservoir Safety (ICE 2015 4th edition). The reservoirs could be categorised differently depending on how the next Inspecting Engineer views the significance of the higher wet day and incremental wet day scenario ASLL numbers in relation to the low dry day scenario ASLL number, and whether they apply to the standards or risk-based approach for categorisation provided in Floods and Reservoir Safety.

As the results of the Black and Veatch study are only preliminary, and taking into account the standards based approach for categorisation provided in Floods and Reservoir Safety, it is assumed that Cilcain Reservoirs 1 & 2 will be a Category A reservoir for the purposes of this study. The spillway upgrade works associated with the retain option have therefore been based on satisfying the design flow requirements for a Category A reservoir.

3. Existing Drawdown Capacity

Guidance

Guidance on the drawdown capacity required for an embankment dam such as Cilcain No. 1 & 2 is given in the "Guide to Drawdown Capacity for Reservoir Safety and Emergency Planning (Environment Agency, 2017), and also in CIRIA Report 148 (CIRIA, 1996).

In accordance with the guidance it is suggested that sufficient drawdown capacity is provided to allow the reservoir to be drawn down at an initial rate of 5% of water depth in one day and 33% of water depth in 3 days under a Q_{50} inflow (the inflow to the reservoir that is exceeded on 50% of the days in a typical year). The second requirement of 33% of water depth drawn down in 3 days assumes the Canal & River Trust approach (refer to Section 6.6.3 and Table 6.4 in the Guide).

Reservoir inflows

The inflows to the upper reservoir are not currently controlled and therefore need to be considered during the drawdown assessment. Generally, if gauged flow data from similar catchments are available, the daily inflows can be estimated by adjusting the gauged data according to the catchment

area of the gauging station relative to the catchment area of the reservoir. Care must be taken to ensure that the catchment characteristics of the chosen gauging station(s) are similar to that of the catchment containing the reservoir. The Guide to Drawdown Capacity for Reservoir Safety and Emergency Planning (EA, 2017) regards this approach as sufficient for use during calculation of drawdown capacity.

Alternatively, a software package developed by Wallingford HydroSolutions Ltd namely LowFlows 2 can be used to estimate flow regimes in ungauged catchments. The LowFlows 2 package was used to generate the flow regime at Cilcain Reservoirs 1 & 2 and the results are shown in Table 6 below.

Table 6: Results of the inflow assessment for Cilcain Reservoirs 1 & 2 using the LowFlows 2 software package

Exceedance Flow Q_x[1]	**Value (m^3/s)**
Q_{95}	0.008
Q_{70}	0.017
Q_{50}	**0.030**
Q_{10}	0.103
Q_5	0.134
Notes: [1]This is the flow rate exceeded on x% of days in a typical year	

Existing Drawdown Arrangements

No permanent operable drawdown facilities could be located on site. The existing scour outlet and supply outlet are both non-operational. The valves, believed to be butterfly valves, have likely seized and the spindles have snapped. One of the bottom outlets was located along the toe of the main embankment of the lower reservoir during the site visit on 10th January 2019.

It is concluded that there are currently no permanently installed facilities that are able to draw down the reservoir water level. The drawdown capacity at Cilcain Reservoirs 1 & 2 would fully rely on temporary equipment brought to site.

Existing Drawdown Capacity

There is currently no existing permanent drawdown capacity at Cilcain Reservoirs 1 & 2.

The implications of the existing installed drawdown capacity at Cilcain No. 1 & 2 in relation to the reservoirs retained and discontinuance options are considered in detail in **Appendix 8, Engineering Options**.