1. Existing Overflow Capacity

Flood Assessment

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

Table 1: Brithdir Mawr Reservoir flood assessment: key considerations and assumptions

Consideration	Value / Assumption	Source / Comment
Catchment area (km^2)	1.97	FEH Online Service
Reservoir surface area (m^2)	7,000	Based on information from latest Section 10 Inspection Report (January 2018). This has been verified by the bathymetric survey completed on 6th February 2019.
SAAR (mm)	959	FEH Online Service
Storm event duration (hours)	4.25	Including a 0.5-hour routing lag allowance.
Main weir crest level (m AOD)	254.74	Following bathymetric survey completed on 6th February 2019.
Auxiliary weir crest level (mAOD)	254.82	Based on the bathymetric survey completed on 6th February 2019
Dam crest level (m AOD)	255.90	Based on the bathymetric survey completed on 6th February 2019
Wave wall crest level (mAOD)	256.50	Based on the bathymetric survey completed on 6th February 2019Assumed to act as inefficient broad-crested weir with a discharge coefficient C_d of 1.4.
Effective main weir width (m)	7.62	Based on latest Section 10 report
Main weir type	Broad-crested weir	Based on recent site visit on 10th January 2019.
Coefficient of discharge for main weir, C_d	1.7	Reflects sharp crested weir, with downstream nappe shape for improved hydraulic performance. Flow through weir is constrained by a restricted downstream channel.
Effective auxiliary weir width (m)	9.75	Based on latest Section 10 report
Main weir type	Crump profile	Based on latest Section 10 report and recent site visit on 10th January 2019.
Coefficient of discharge for main weir, C_d	2.19	Coefficient assumed for optimal Crump profile.

A summary of the results of the flood routing with the existing overflow arrangements is shown in Table 2 below.

Table 2: Brithdir Mawr Reservoir: summary of flood routing with existing overflow arrangement

Event	Rainfall depth (mm)	Peak inflow (m^3/s)	Peak outflow (m^3/s)	Max flood level (m AOD) Overflow = 254,.74 mAOD	Max flood rise (m)
Safety Check Flood (Summer PMF)	187	25.5	25.3	255.80	1.06
Design Flood (10,000-year flood)	143	11.03	10.95	255.36	0.62
1,000-year flood	103	7.59	7.52	255.23	0.49
150-year flood	80	5.43	5.37	255.14	0.40
100-year flood	42	2.53	2.47	254.99	0.25
10-year flood	22	1.27	1.22	254.91	0.17

Notes:

- Category A Dam: Design Event is 1 in 10,000-year flood; Safety Check is the PMF.
- The Design Flood (10,000-year flood) is passed with 1.18m freeboard available for waves
- The Safety Check Flood (PMF) is passed with 0.74m freeboard available for waves.

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.

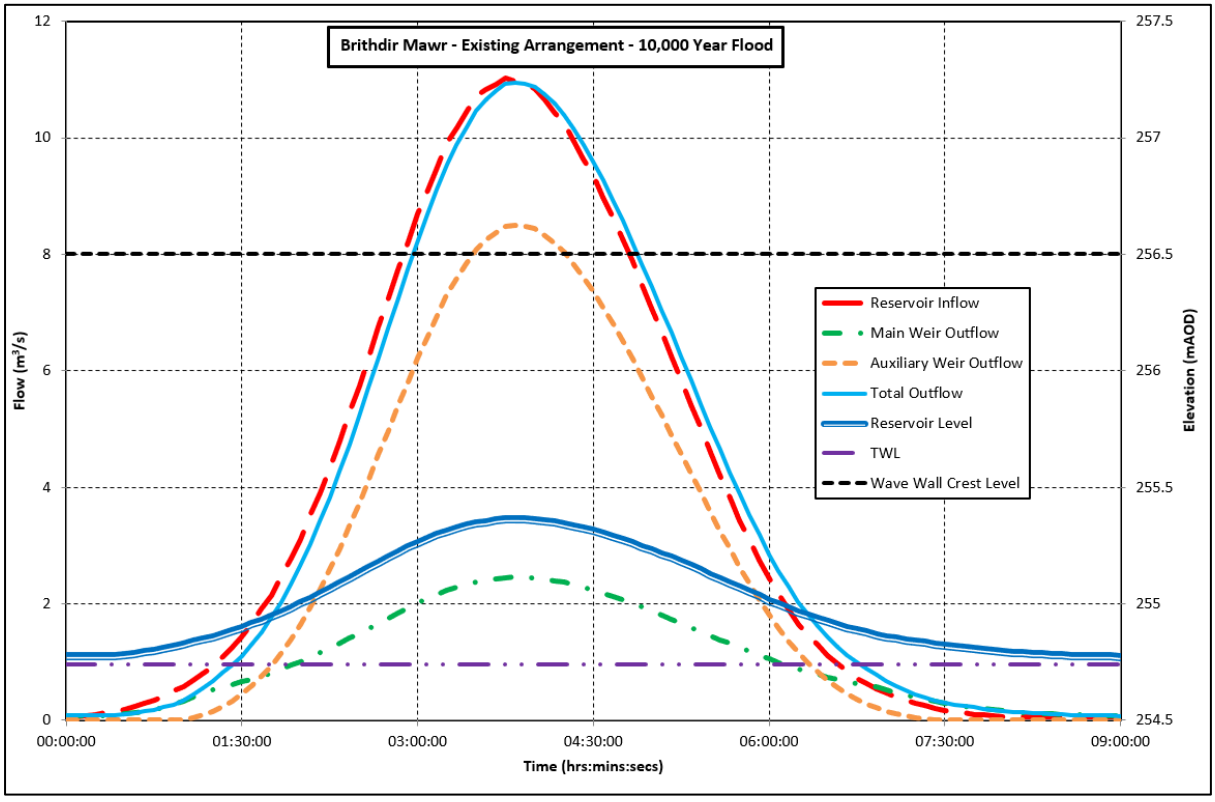

Figure 1: Flood routing results for the 10,000-year flood

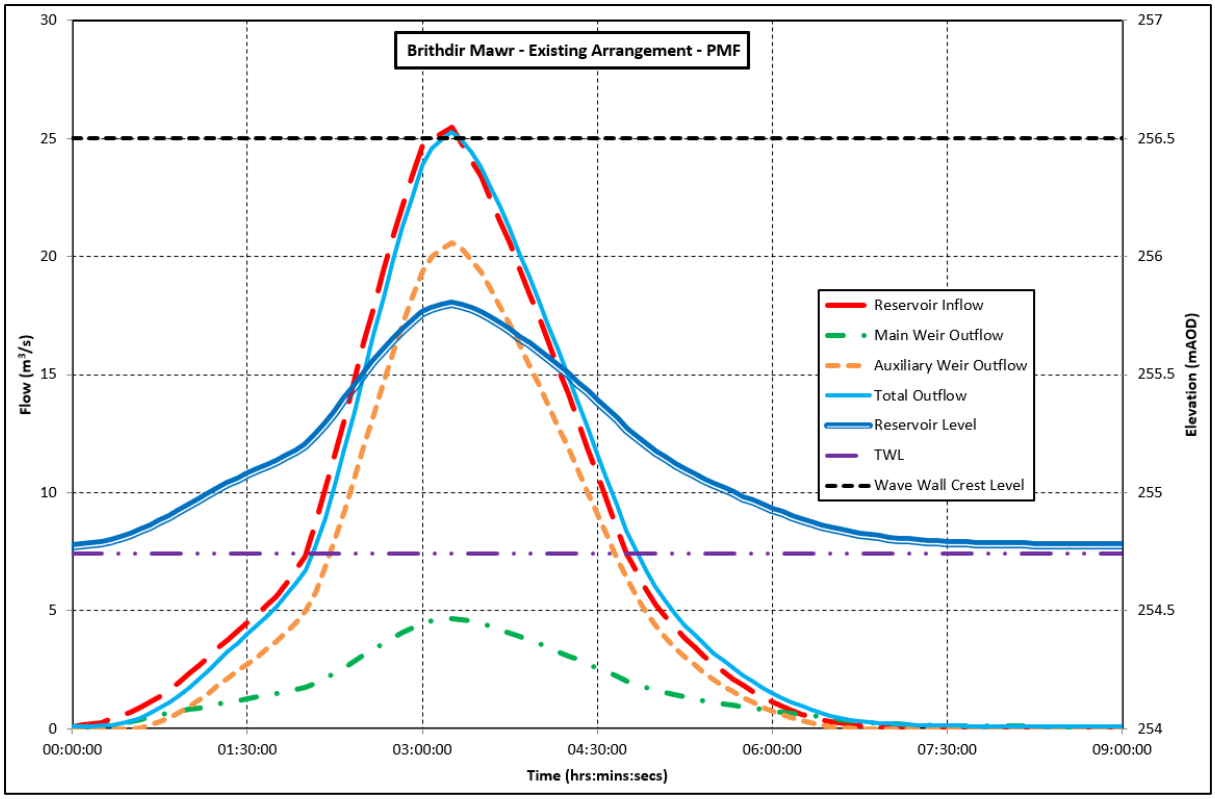

Figure 2: Flood routing results for the PMF

Wave Assessment

In terms of dam safety current practice requires consideration of the potential for wave overtopping, to help make an assessment of the possible impacts on the dam structure. The wave overtopping calculation depends on the following factors:

- the geometry of the upstream face;
- freeboard above wave-free water levels;
- wind speed at the site;
- the fetch across the reservoir to the dam over which waves would be developed.

The upstream face of the main embankment structure consists of a sloped section protected by stone pitching and a vertical wave wall higher up at the embankment crest.

The most significant fetch (length of water surface over which waves can develop) is estimated at 120m by taking a line from the location of the north western upstream inlet to the bend in the embankment.

Wave overtopping calculations have been carried out following the methodology in FRS4. The significant wave height (H_s) is estimated to be in the order of 0.12m. The results of the wave assessment are summarised in Table 3 below:

Table 3: Brithdir Mawr: results of the wave assessment

Event	Max flood level (m AOD)	Max flood rise (m)	Available Wave Freeboard (m)	Assessed wave overtopping rate (litre/s/m)
Safety Check Flood (PMF)	255.80	1.06	0.70	0.84
Design Flood (10,000-year flood)	255.36	0.62	1.14	0.26

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 B8, Engineering Options**.

Existing Downstream Flood Risk

The valley downstream of the reservoir runs through mostly farmland for approximately 1.8km before its intersection with the River Alyn. Two residential properties and one minor unclassified road are located close to the watercourse approximately 1.1km downstream of the reservoir. After about 1.4km another residential property may have a downstream flood risk. A water treatment works is located adjacent to the River Alyn approximately 2km downstream of the reservoir and about 200m downstream of the confluence between the Aber Eilun and the River Alyn.

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 Brithdir Mawr Reservoir is shown in Figure 4.

Table 4: Features downstream of dam

Estimated distance downstream (m)	Feature	Comments
1,100	Two residential properties and one minor unclassified road	Details of the conveyance structure underneath this road are unknown. It may be likely that this road and the property closest to the stream to the north will be flooded during major fluvial events and / or the uncontrolled release of water from Brithdir Mawr Reservoir in the event of a dam breach.
1,400	1 no. Residential property	Due to the high elevation of this property in relation to the stream bed level it is unlikely that it will be flooded during major fluvial events and / or the uncontrolled release of water from Brithdir Mawr Reservoir in the event of a dam breach.
2,000	Maes-y-groes Sewage Treatment Works adjacent to the River Alyn	The River Alyn runs past a STW which may be partially flooded during major fluvial events and / or the uncontrolled release of water from Brithdir Mawr Reservoir 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**.

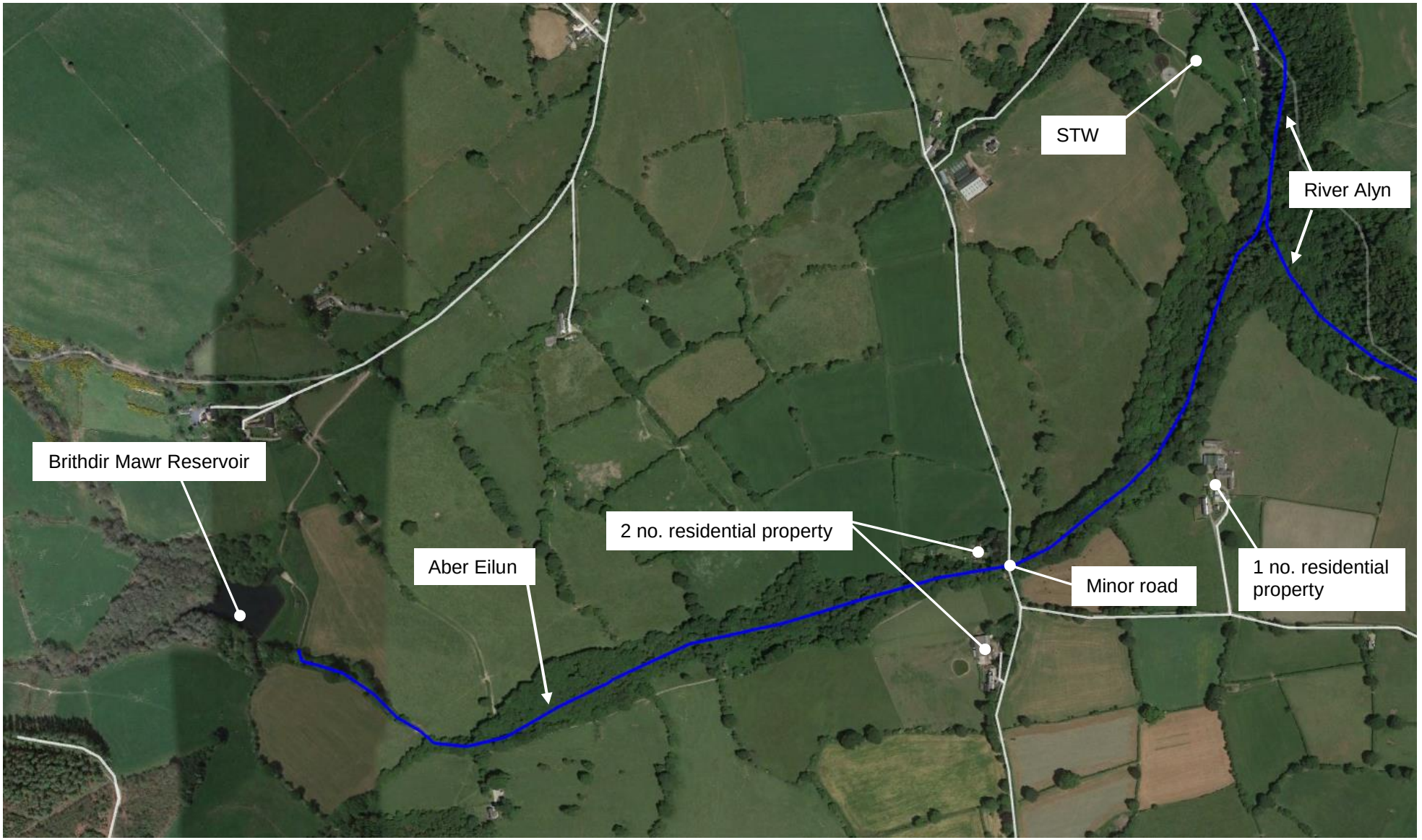

Figure 3: Features downstream of the dam (courtesy of Google Earth)

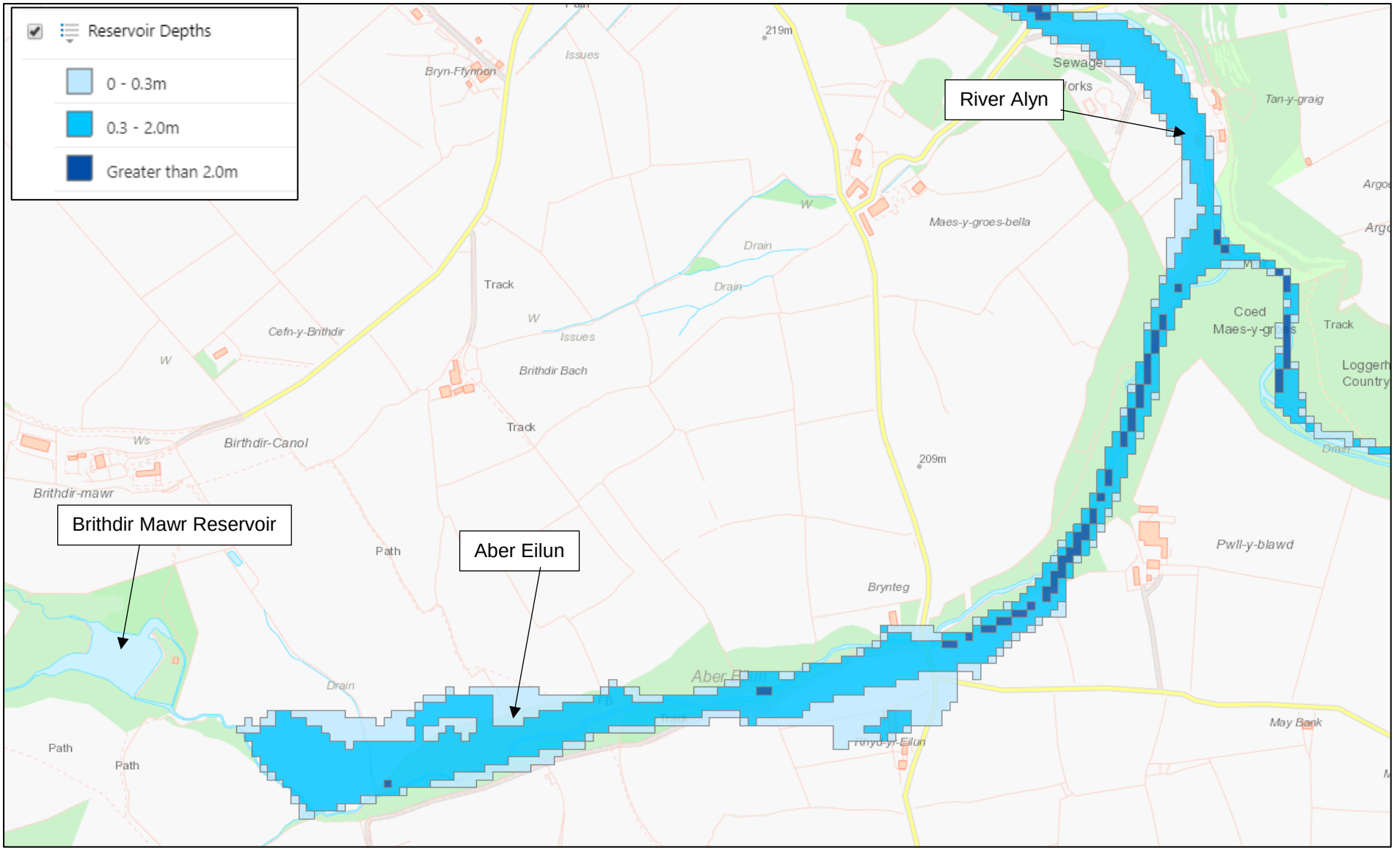

Figure 4: Reservoir Flood Risk Map (courtesy of Cyfoeth Naturiol Cymru (Natural Resources Wales) website).

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 Brithdir Mawr reservoir, 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 Brithdir Mawr Reservoir

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)	
0.006	1.3	1.1	0.2	Very low figures

The preliminary results indicate that Brithdir Mawr reservoir 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 the current Inspecting Engineer classification of the Brithdir Mawr places it as a Category A reservoir, we have assumed that the reservoir will remain as a Category A reservoir for the purposes of this study.

3. Existing Drawdown Capacity

Guidance

Guidance on the drawdown capacity required for an embankment dam such as Brithdir Mawr 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 reservoir cannot be controlled and therefore need to be considered during the drawdown assessment. Generally, if gauged flow data from similar catchments is 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 Brithdir Mawr Reservoir and the results are shown in Table 6 below.

Table 6: Results of the inflow assessment for Brithdir Mawr Reservoir using the LowFlows 2 software package

Exceedance Flow Q_x[1]	**Value (m^3/s)**
Q_{95}	*0.005*
Q_{70}	*0.012*
Q_{50}	***0.022***
Q_{10}	*0.080*
Q_5	*0.107*
Notes: [1]This is the flow rate exceeded on x% of days in a typical year	

Existing Drawdown Arrangements

There are two outlet pipes, a scour and an old redundant water supply main, passing through the dam within a tunnel. The scour is a 10in diameter cast iron pipe which is reported to have a capacity of approximately 0.22m^3/s. The water supply main is an 8in diameter cast iron pipe which has been blanked off.

It is concluded that there is a permanently installed scour valve at the reservoir that is able to draw down the reservoir water level at an adequate drawdown rate as recommended in the most recent guidance discussed above. It has been estimated that the reservoir can be lowered by 300mm in just over 2 hours and by 1m in approximately 7 hours. In addition, the reservoir can be emptied down to the scour invert level in approximately 1 day and 5 hours. It is therefore unlikely that additional temporary equipment would need to be brought to site to assist with drawdown. If the old water supply main can be brought back to an operable condition, the reservoir's drawdown capability could be significantly increased.

Existing Drawdown Capacity

There is currently an existing permanent drawdown capacity at Brithdir Mawr Reservoir which is provided by the 10in diameter cast iron scour arrangement passing through the dam.

The implications of the existing installed drawdown capacity at Brithdir Mawr Reservoir in relation to the reservoirs retained and discontinuance options are considered in detail in **Appendix 8, Engineering Options**.