Natural Resources Wales

Salmon For Tomorrow 2

Clywedog Geomorphology Assessment

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Ove Arup & Partners Ltd
4 Pierhead Street
Capital Waterside
Cardiff CF10 4QP
United Kingdom
www.arup.com

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		Name	Rhodri Thomas	Tom Styles	Robin Campbell
		Signature	Rhodri Thomas	Tom Styles (J)	
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			Prepared by	Checked by	Approved by
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1 Introduction

Ove Arup & Partners Limited (Arup) has been commissioned by Natural Resources Wales (NRW) to undertake an assessment of the geomorphology of the Afon Clywedog surrounding a redundant gauging weir (hereafter referred to as 'the Site'; Figure 1). The weir is located to the north-west of Llanidloes at National Grid Reference: SN94432 85506 (Figure 1). Works are being considered to enable access for migratory fish to 3.5km of suitable spawning and juvenile salmonid habitat upstream and are likely to consist of weir removal and stabilisation and enhancement of the surrounding riverbed and banks.

This report presents the findings of the assessment and has been prepared to document the baseline geomorphology and identify the geomorphological opportunities, constraints and risks associated with the proposed works. It has been written as the result of survey effort undertaken in February 2021 and is produced solely for the benefit of NRW and no liability is accepted for any reliance placed on it by any other party.

Figure 1: Disused gauging weir on the Clywedog – the asset under consideration for removal. Looking upstream from the true left bank.

2 Methodology

2.1 Desk study

A desk study was undertaken to identify any existing geomorphological information relating to the Site and the wider Afon Clywedog.

The following sources have informed the study:

- A geomorphological walkover and assessment of the Clywedog undertaken in April 2013 by Oly Lowe (NRW);
- Ordnance Survey historic and present-day mapping;
- Google Streetview;
- British Geological Survey datasets including Geoscour Open and the 1:625k Geology mapping;
- National River Flow Archive: 54013 – Clywedog at Cribynau[1]; and
- National River Flow Archive: 54081 – Clywedog at Bryntail[2].

2.2 Geomorphology walkover survey

The aim of the Geomorphology Walkover Survey was to identify and map the geomorphological features and processes present across the Site. The survey followed the standard Fluvial Audit survey method[3].

The survey was undertaken on the 10th February 2021 by an Arup geomorphologist. The weather was cold and dry, with low river levels for the time of year. The survey reach extended over a 500m section of the river, including 200m upstream of the weir and 300m downstream of the weir.

The survey findings defined geomorphic reaches based on the features and process types mapped. These geomorphic reaches are shown on Figure 2 and described in Section 3.5.

[1] https://nrfa.ceh.ac.uk/data/station/info/54013
[2] https://nrfa.ceh.ac.uk/data/station/info/54081
[3] Environment Agency - Fluvial Audit (2005): https://www.therrc.co.uk/sites/default/files/files/Designated_Rivers/Axe/fluvial_audit_-_method_description_-_report_a_-_final_a01.pdf

3 Baseline Information

3.1 Water Framework Directive status and designations

The Site is in the Afon Clywedog – Clywedog Dam to R Severn WFD river waterbody (GB109054044760). As of 2018, the waterbody has an overall status of Moderate and is designated as heavily modified.

The waterbody is failing to reach Good status due to high levels of zinc as a result of abandoned mining. The mitigation measures assessment notes that the heavily modified designation is due to flow regulation from the Clywedog Dam which inhibits natural geomorphological processes.

3.2 Catchment setting

The Afon Clywedog is a tributary of the River Severn, which it joins 1,450m downstream of the weir in the town of Llanidloes. Upstream of the weir, the Clywedog occupies a 57km^2 upland catchment dominated by the Clywedog Dam and reservoir. The 72m high dam was constructed between 1963 and 1967 and is located approximately 3.9km upstream of the weir that is the focus of this study.

Land use is dominated by grassland (64%), woodland (21%) and heath/bog (8%)[1]. Mean annual rainfall is high at 1868mm (1961-1990) are there no settlements of note within the catchment. The reservoir is operated by Severn Trent Water and does not directly provide water supply but is used to regulate flow in the River Severn during the winter months and to ensure a minimum flow is maintained during summer months[4].

The hydrology of the Clywedog is heavily regulated by releases from the upstream reservoir, with the main effect being a dampened hydrograph: flood peaks are lower than typical and summer low flows are higher than typical to compensate flows in the River Severn. The natural hydrograph of the Clywedog would be flashy due to the low permeability bedrock that underlies the catchment. Gauged flows at the historic gauging weir range from 0.29m^3/s at Q95 to 7.59m^3/s at Q5[1].

The BGS GeoScour Open datasets describes the Clywedog catchment as:

- A system still undergoing landscape adjustment following the last glaciation;
- A catchment with mountainous terrain with severe, yet geographically-restricted glacial erosion. Fresh Quaternary deposits mainly restricted to valleys. Local occurrence of weathered bedrock.
- The 1:50k riverine layer describes the river reach containing the weir as 28% bedrock.

Based on NRW supplied geomorphology study: The headwaters and tributaries that feed the reservoir are relatively unmodified and typically exhibit a good

[4] https://www.hdcymru.co.uk/wonderful-water/our-visitor-sites/our-visitor-sites/llyn-clywedog/

degree of active geomorphological processes with pools, riffles and meanders evident. Bed material is well-sorted and dominated by coarse gravels with some cobbles and bedrock.

3.3 Historic features and changes

Available historic mapping from 1888 to the present day has been viewed to inform this section. Notable features and changes evidenced by the mapping are as follows:

- Construction of Clywedog Reservoir upstream of the weir in the 1960s.
- Numerous weirs related to mill races and other offtakes at various locations are shown on the 1888 OS mapping.
- The upper reaches of the Clywedog, much of which are now drowned by the reservoir show many sediment storage features (bars) on the 1888 OS mapping, indicating a significant coarse sediment supply.

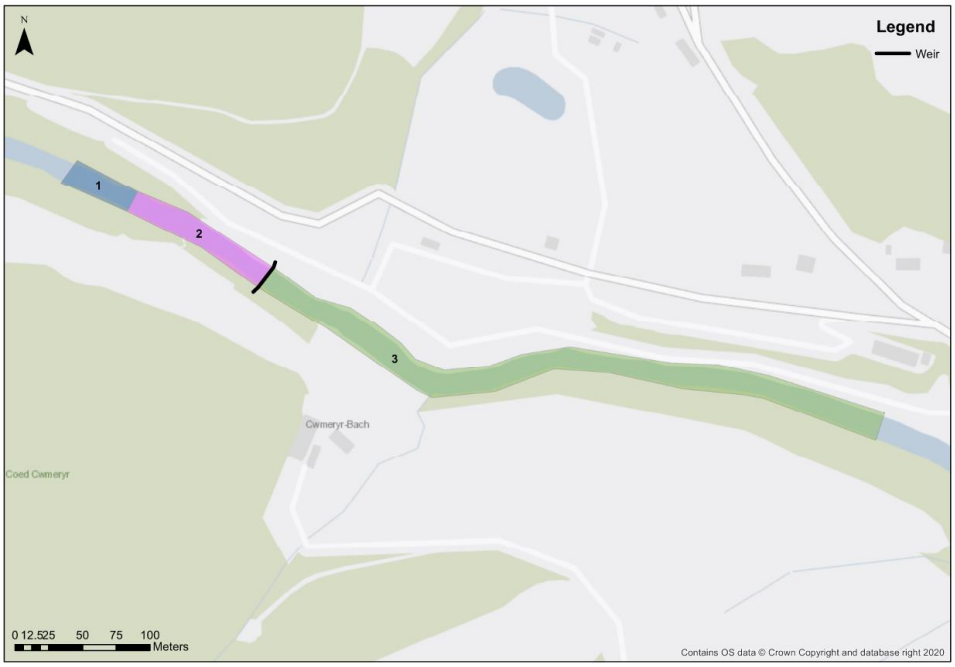
There is no evidence of changes in channel alignment or width surrounding the study weir over the period covered (1888-present) by the historic mapping.

3.4 Walkover survey

The Clywedog surrounding the disused gauging weir is dominated by a coarse bedload of cobbles and boulders with significant bedrock outcrops throughout the reach. Prior to the construction of the Clywedog Dam, it would have been a high energy system with a flashy hydrograph.

Three geomorphic reaches were delineated during the walkover survey, two upstream and one downstream of the weir. These are shown on Figure 2 and the characteristics of each are described in the following sections.

Figure 2: Distinct geomorphic survey reaches (1-3) mapped during the walkover.



3.4.1 Survey Reach 1

Table 1: Summary of the geomorphological walkover survey findings for Reach 1.

Feature		Description
Channel dimensions		Bankfull width ~ 11m Bank height ~ 2m Water width on day of survey ~ 7m Water depth on day of survey ~ 0.5m
Bank features	Left	Established trees, well vegetated. Significant channel shading. Steep, uniform bank.
	Right	Established trees, well vegetated. Steep hillslope. Significant channel shading.
Land use	Left	Woodland and footpath at top of bank – access from caravan site. No fencing.
	Right	Rough pasture, fencing at top of hillslope.
Flow type(s)		Glide-run sequences upstream of weir impoundment.
Substrate type(s)		Cobble and boulder sized material with significant bedrock outcrops. Limited structure and sorting.
Vegetation		No in-channel vegetation. Time of year may have prohibited seeing this.
Bars		None
Other features of interest		None noted.

Figure 3: Looking upstream at a uniform section of the Clywedog in Reach 1.

3.4.2 Survey Reach 2

Table 2: Summary of the geomorphological walkover survey findings for Reach 2.

Feature		Description
Channel dimensions		Bankfull width ~ 11m Bank height ~ 2m Water width on day of survey ~ 7m Water depth on day of survey ~ 1m
Bank features	Left	Established trees, well vegetated. Significant channel shading. Steep, uniform bank.
	Right	Established trees, well vegetated. Steep hillslope. Significant channel shading. Some fallen wood in the channel.
Land use	Left	Woodland and footpath/access road at top of bank – access from caravan site. Partial fencing.
	Right	Rough pasture, fencing at top of hillslope.
Flow type(s)		Ponded upstream of weir impoundment.
Substrate type(s)		Cobble and boulder sized material with significant bedrock outcrops. Reno mattresses directly upstream of weir itself.
Vegetation		No in-channel vegetation. Time of year may have prohibited seeing this.
Bars		None
Other features of interest		Disused gauging weir (the focus of the study) at the bottom of the reach. Large concrete structure with 3 section across the channel.

Figure 4: Looking upstream from the weir across Reach 2.

3.4.3 Survey Reach 3

Table 3: Summary of the geomorphological walkover survey findings for Reach 3.

Feature		Description
Channel dimensions		Bankfull width ~ 11m Bank height ~ 2m Water width on day of survey ~ 7m Water depth on day of survey ~ 0.5m
Bank features	Left	Uniform, grassed bank.
	Right	Established trees, well vegetated. Steep hillslope. Significant channel shading. Some fallen wood in the channel.
Land use	Left	No fencing. Caravan site to edge of bank.
	Right	Rough pasture, fencing at top of hillslope.
Flow type(s)		Glide-run sequences with occasional bedrock riffle sections.

Feature	Description
Substrate type(s)	Cobble and boulder sized material with significant bedrock outcrops. Some structure and sorting to form riffle features.
Vegetation	No in-channel vegetation. Time of year may have prohibited seeing this.
Bars	None
Other features of interest	Disused gauging weir (the focus of the study) at the top of the reach. Large concrete structure with 3 sections across the channel.

Figure 5: Looking upstream mid-way along Reach 3.

4 Geomorphological Risk Assessment

Weir removal can often result in morphological change either as a result of:

- Reinstatement of sediment transport – the removal of the barrier results in sediment being able to be transported downstream. An initial pulse of sediment may occur, although this can be managed as part of the demolition works. In the longer term, the reinstatement of sediment transport can be a significant benefit to habitat variety and quality downstream of the removed weir, but it can also result in increased flood risk and maintenance burden should sediment accumulate in areas sensitive to hydraulic capacity.
- Knickpoint propagation – the removal of a weir can result in morphological changes propagating upstream from the weir's former location as the river adjusts its gradient to match the new conditions. This manifests as a lowering of its bed upstream of the former structure and more limited bed raising downstream.
- Changes in water levels and flow velocities – these typically occur upstream of the structure following removal and can result in bed and bank erosion.

This section considers the likelihood and risk of these geomorphological changes as a result of the proposed weir removal at Clywedog weir.

4.1 Reinstatement of sediment transport

The reinstatement of sediment transport downstream of the weir does not raise any immediate concerns regarding sediment accumulation and potential flood risk or maintenance issues. There are no in-channel or flood defence assets immediately downstream of the weir, the nearest being ~1400m downstream where the Clywedog enters the River Severn in Llanidloes. The channel in this section to the confluence with the River Severn appears to be a transport reach with a relatively steep gradient and form constricted by steep valley sides.

Significant gravel accumulation is noted immediately downstream of Long Bridge in Llanidloes, ~100m downstream of the Severn-Clywedog confluence (Figure 6). NRW have indicated that this presents an ongoing maintenance concern related to flood risk and performance of the nearby river gauging station. In the long term, the increase in sediment reaching this location as a result of weir removal is likely to be minimal as most of this sediment is likely derived from the Severn. Despite this, shorter-term issues related to the initial sediment pulse moving downstream should be considered during the design.

Additionally, the accumulated sediment behind the weir should be tested for contaminants prior to any works to ensure the initial 'pulse' of sediment that could be released does not result in pollution. In the longer term, the sediment supply of the Clywedog is inhibited by the dam upstream.

Figure 6: Accumulated gravel downstream of the Severn-Clywedog confluence in Llanidloes.

4.2 Knickpoint propagation

2m-resolution LiDAR topography has been used to derive the river long section to determine whether the river's gradient has locally adjusted to the presence of the weir and understand the extent of the likely river response. The LiDAR data will not have accurately collected the riverbed levels but changes in the water surface will still demonstrate changes in gradient relevant at this scale.

This long section is shown on Figures 7 (reach scale) and 8 (sub-reach scale). It shows that the weir has had a very limited effect upon the long section of the river and therefore it can be assumed that the river's long section response to weir removal would be limited to the immediate vicinity of the weir (i.e. ~150m upstream / ~100m downstream) of the structure.

Figure 7: Riverbed levels with distance downstream obtained from LiDAR (blue line). This shows that at this scale the weir has little to no discernible effect upon the long profile of the Clywedog.

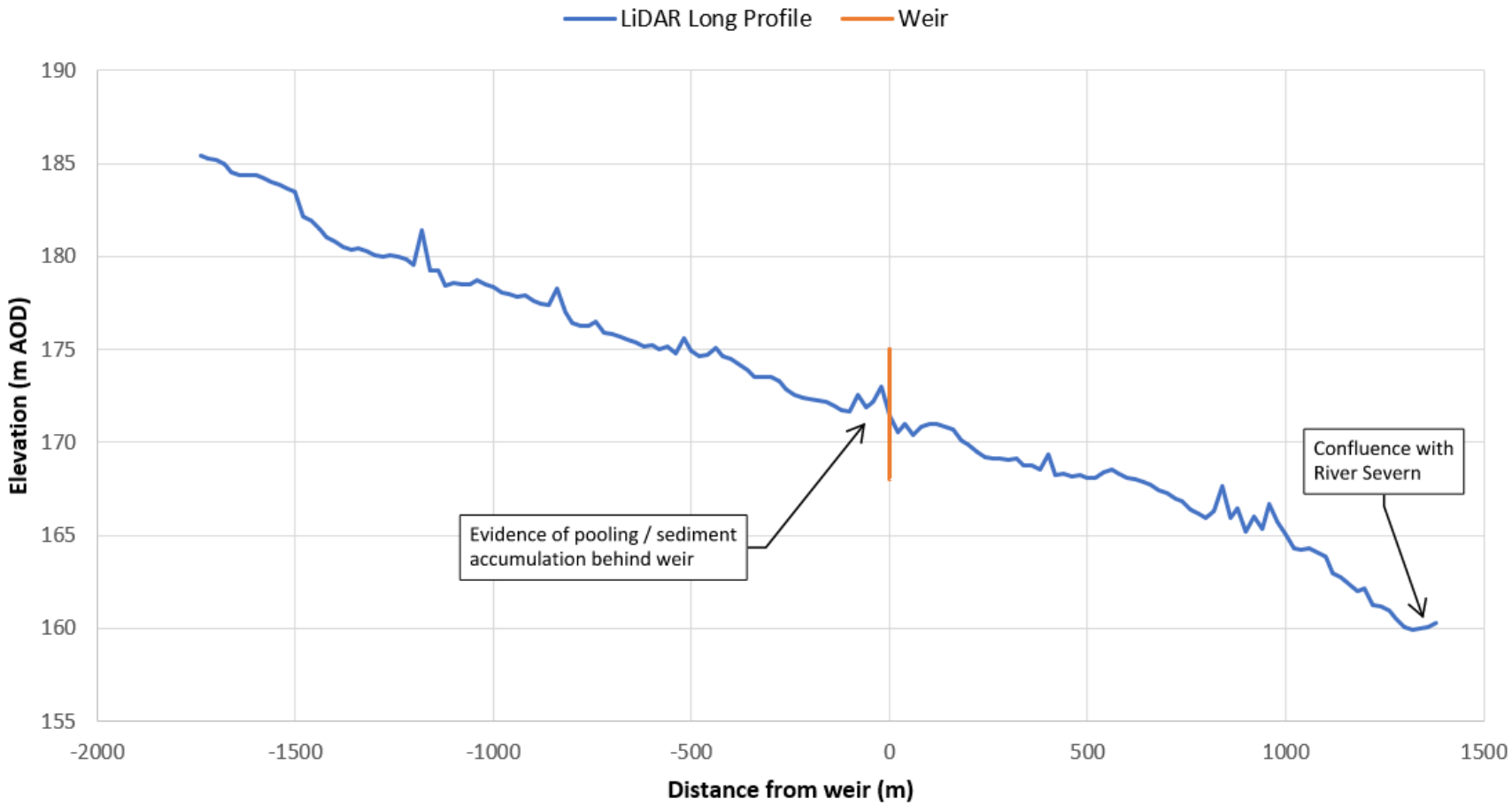


Figure 8: Riverbed levels with distance downstream obtained from LiDAR (blue line). At this reach scale the long profile shows some accumulation of sediment behind the weir (red box), although this is limited to an approximate 100m length of river.

4.3 Changes in water levels and flow velocities

The gradient of the Clywedog is relatively steep (0.0075 m/m) through the reach containing the weir and therefore the impounded reach created upstream of the structure only extends ~100m upstream (Figure 8). This gradient is commonly associated with a pool-riffle or plane-bed morphology. The Clywedog exhibits a plane-bed morphology due to channel and flow modification and its lack of upstream sediment supply (inhibited by the dam).

The riverbanks surrounding the weir are steep and the relatively constant upstream water levels created by the weir may provide some support to the riverbanks through the impounded reach. Weir removal may therefore result in some localised slumping at the base of the riverbanks over ~100m upstream of the weir. Despite this, riverbank erosion as a result of weir removal is likely to be limited given the presence of bedrock in the banks at many locations surrounding the weir.

Morphological changes as a result of changes in water velocity following weir removal are a more significant concern in this setting. It is recommended that hydraulic modelling is undertaken should weir removal be taken forward as an option at this site. Velocities would be anticipated to increase upstream of the weir which may induce some changes in the channel, although again this would be limited by the bedrock in the riverbed and banks.

5 Conclusions and Recommendations

This assessment has noted that the geomorphological risks of weir removal at Clywedog are manageable. The Clywedog is an upland, heavily regulated system with significant areas of bedrock forming the channel which means that the risk of bed or bank erosion following weir removal is low.

Should the weir removal option progress to design and construction, the following recommendations should be incorporated into these stages:

- **Testing of the sediment accumulated upstream of the weir –** there is a risk that the sediment which has accumulated upstream of the weir may contain elevated levels of pollutants which may be released in the initial sediment 'pulse' if the weir was removed. Sampling and testing of this sediment is recommended as soon as possible to understand this risk.
- **Hydraulic modelling to confirm anticipated changes in water level and velocity across a range of flows** – to capture changes in flood risk, velocity distribution and to ensure a low flow channel can be maintained.
- **Investigation of the potential for changes to the riverbank**, given the proximity of mobile homes, a private road and footpath that may be at risk from changes in bank stability. The likelihood of change in the immediate vicinity of the weir wing wall is low given the presence of bedrock but the bank composition may differ upstream and downstream of this area.
- **Riverbed reprofiling in the vicinity of the weir** – to achieve a stable profile the sediment that has accumulated behind the weir should be reprofiled as part of the works. This may require some disposal of material offsite. Contamination testing of this material is recommended to ensure it is suitable for disposal. It is also recommended that the riverbed reprofiling is supervised by a geomorphologist.
- **Bank protection works surrounding the removed structure -** design of erosion protection works in the area immediately surrounding the removed weir, particularly if the wing walls are also removed. Where possible (e.g. following contamination testing), this should make use of site-won riverbed material that has accumulated behind the weir to reduce material import/export.