NRW

Salmon For Tomorrow

Clywedog Flood Consequence Assessment

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Job number 290013

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Document verification

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Contents

1 Introduction

Natural Resources Wales (NRW) have appointed Ove Arup and Partners (Arup) to appraise and design fish passage improvements as part of the Salmon for Tomorrow 2 programme. This programme comprises multiple sites located across Wales with works comprising of a mix of new fish pass installations, modification of existing fish passage or in some cases weir removal. The project is funded by the European Fisheries Fund and the Welsh Government are aiming to improve spawning along 1500 km of waterways which is currently being impeded by weir structures.

This report provides information regarding the design of one of these sites: Cribynau weir on Afon Clywedog near Llanidloes, Grid Reference *SN94432 85506*. By removing the weir, 3.5km of fish passage will be opened up and natural river processes will be encouraged.

This assessment will consider the consequences of removing the weir on flood risk, any necessary mitigation measures.

2 Site Description

2.1 Site location

The Clywedog weir site is on the Afon Clywedog, approximately 3.5km downstream of the Clywedog reservoir. The Severn Trent managed reservoir's flow regulation has significant influence on the hydrology of the Clywedog. The reservoir traps sediment before it can be transported downstream, resulting in this section of the river being depleted in gravels that would support salmon spawning. It has been suggested that gravel could be reintroduced to the watercourse during construction works to improve habitat for migratory salmonids (NRW, 2020).

Table 1. Site Details

Site Name	Clywedog
Site Area (ha)	Approx. 2.5 ha
Existing Land Use	Greenfield
OS NGR	SN94432 85506

Figure 1: The weir location is circled in red on the Afon Clywedog.

2.2 Existing weir

The weir is at the base of a steep valley with dense vegetation and rocky banks. The site was previously used as a gauging station, but no longer serves any functional purpose. The weir consists of a central low flow channel between raised walls, with the main body of the weir at a higher level on either side. Concrete wing walls are built into each bank. Submerged gabion baskets extend 10 to 15m upstream of the main weir with a central channel to accommodate low flows.

2.3 Proposed design

The proposed design at Clywedog is a complete weir removal. This will allow fish passage and have the maximum benefit to river naturalisation, as well as reducing future maintenance liabilities for NRW. The proposed design is shown in Appendix A.

The removal will include the following permanent works:

- Demolition of the concrete weir, base and wing walls. Material reuse or disposal will be decided between the contractor, landowner and NRW.
- The left wing wall removal will include removal of the remainder of the recorder house structure.

- Wing walls will be demolished to the bedrock level. Given the presence of shallow bedrock, riverbank erosion as a result of weir removal is likely to be limited, however where necessary erosion protection will be specified.
- The 10-15m of gabions and rockfill mattress upstream of the weir will be removed from the channel upstream of the weir and disposed of. Material may be suitable for reuse locally, however it is likely to be disposed of offsite.
- Sediment is currently held behind the weir and will likely require removal to facilitate the demolition. Sampling of the sediment will determine the waste classification for reuse. Sediment will generally be allowed to redistribute naturally over time.
- Pending discussion with the caravan park owners, the existing access steps to the recorder house are likely to be blocked off with thorny shrubbery or removed to prevent public access to the river in future.

3 Flood Risk Assessment

Annual Exceedance Probability (AEP) is the chance that a naturally hazardous event will occur annually. AEP is typically expressed as a percentage with bigger rainfall events occurring less often thus are exceeded less often and therefore have a lower annual exceedance probability. For example a 1% AEP has a potential frequency of 1:100 years, whilst a 0.1% AEP has a potential frequency of 1:1000 years.

Flood Zone mapping illustrates the risks that locations are under considering different types of flood events.

Flood Zone 3 refers to areas with a 0.1%-1% chance of flooding for a given type of flood event in a given year, including the effects of climate change.

Flood Zone 2 refers to areas with a greater than 1% chance of flooding for a given type of flood event in a given year, including the effects of climate change.

3.1 Review of existing flood risk data

As the watercourse is downstream of the Clywedog Reservoir, the flows are well regulated. Discussions with the reservoir owners (Severn Trent Water) and NRW have confirmed that releases from the reservoir for regulatory purposes are often carried out and come with some prior warning, however flood releases for drawdown and dam safety purposes are not.

Only a small portion of the floodplain, directly downstream of the existing weir is shown to be in Flood Zone 2, as shown in Figure 2.

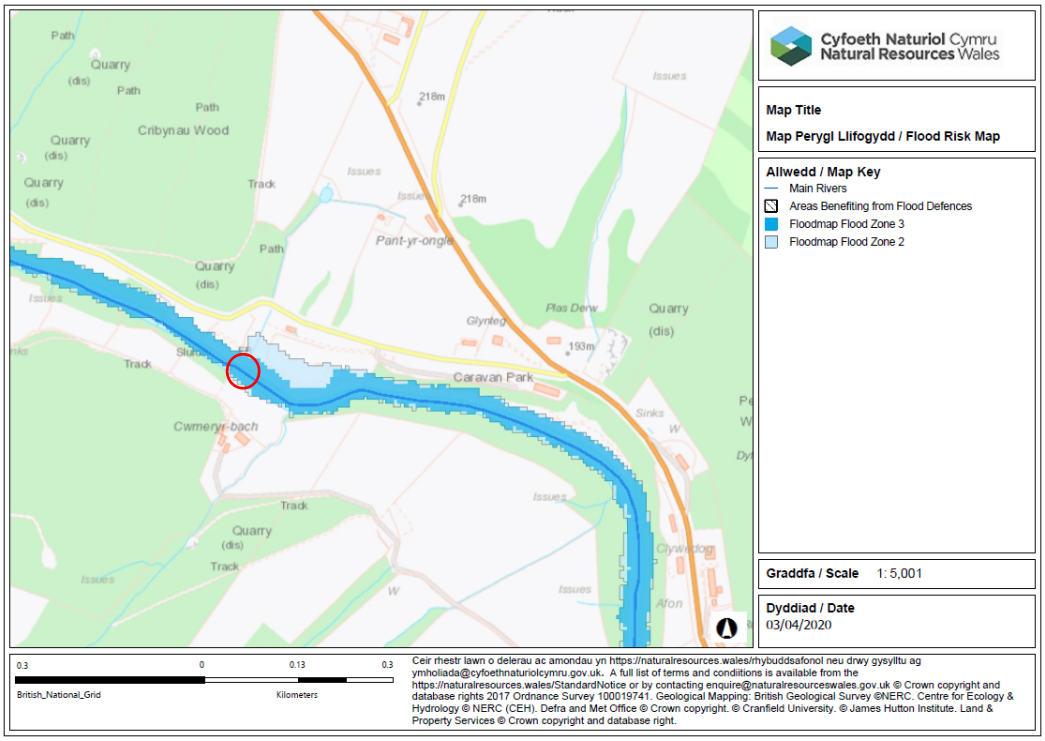


Figure 2. NRW Flood Zones

3.2 Historical flooding

There is no recorded flood history with the location of the existing weir.

4 Methodology

The modelling methodology was proposed to NRW in the *Clywedog Model Inception Report 290013-ARP-00-CL-RP-YX-0001* and agreed in January 2022.

4.1 Key assumptions

The following assumptions have been made:

- The impact on flood risk has been assumed to be greater for full removal than partial removal of the weir. For this reason, only full removal has been modelled.
- Hydrology for the 1%, 1% with an allowance for climate change (+CC) and 0.1% Annual Exceedance Probability (AEP) events were derived for the Clywedog. These have been assumed to be sufficient to investigate the impact on flood risk.
- Some riverbed re-levelling has been assumed at the weir location following weir removal. This is shown in Appendix B and occurs over a distance of approximately 15 m.

4.2 Hydrology

A hydrological assessment for the Clywedog has been undertaken. As noted previously, the flows at the existing weir will be heavily influenced by the upstream reservoir.

Attempts have been made to represent the impact of the weir using a small routing model – however Light Detection and Ranging (LIDAR) data did not cover the whole of the site, as such this was not possible.

The REFH2 method has been chosen to derive peak flow estimates. REFH2 has been chosen as it is the recommended method to be used when there is significant upstream storage in the catchment.

Peak flows have been derived at the downstream extent of the Clwyedog at its confluence with the River Severn and applied at the upstream extent of the model.

Peak flows derived as part of the hydrological assessment are provided in Table 2. The peak flows derived as part of this study are likely to be significantly overestimated, as the impact of the reservoir cannot be quantified at this stage.

Table 2: Peak flow estimates

Site code	1% AEP (m3s-1)	1%+CC AEP (m3s-1)	0.1% AEP (m3s-1)
Clywedog DS	132	171	205

4.3 Model build

The existing hydraulic 'River Severn in Powys' model, developed in 2006 by JBA Consulting on behalf of NRW was shared with Arup. The model is a 1D-2D Flood Modeller Pro (FMP) – TUFLOW model. However, the weir location in question was not represented in the model's extent.

It was therefore decided in December 2021 that a new hydraulic model should be created to model the effects of weir removal. The approach to the modelling was agreed in *290013-ARP-00-CL-RP-YX-0001 Model Inception Note* (Arup, 2021).

A topographic survey was previously conducted in March 2021 and detailed a 500m stretch of the Afon Clywedog, upstream and downstream of the weir location. To facilitate the hydraulic model build, an additional topographic survey extending further up and downstream of the weir, over a total distance of 1.5km with 16 in river sections, was carried out in February 2022, as specified by *290013-ARP-CP-CL-WO-CX-0002 Clywedog River in Channel Survey Specification*. See Figure 3.

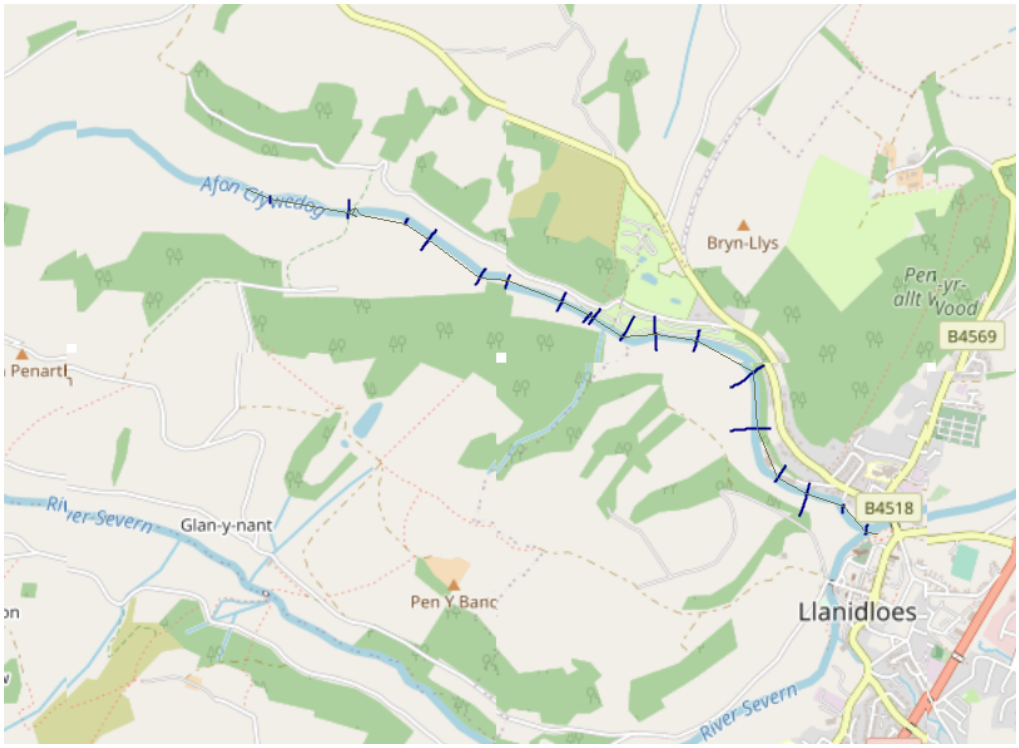


Figure 3. Topographic Survey extent carried out in February 2022

The 1D model was built using the topographically surveyed cross sections. 2m DTM LiDAR was used to extend the chainages where glass walling occurred. Interpolates were created between the section data every 50m.

The Manning's roughness values at each node were updated at each section in accordance with what was observed in photographs of the river extent and understanding of the weir condition and material from as-builts (Chow, 1959).

Two structures were modelled. The bridge with a trussed handrail was given a representative spill coefficient of 1.0. The weir was given a spill coefficient of 1.2.

4.4 Weir removal scenario

Following a review of the flood model by Arup, a weir removal scenario was created. This scenario was created by editing a baseline model as follows:

- The weir was removed from the baseline model,
- Adjustment of distance to the next cross section for immediate upstream and downstream cross sections to better represent the new channel profile in place of the spill unit. The survey chainage commented in the units was used to set the distance between them to be 17m,
- The bed was releveled to reduce the drop in bed levels after weir removal.

5 Assessment of Flood Risk

The 1D model built by Arup of the current river arrangement was run to ensure that the model was in good condition and for comparison with weir removal options.

Appendix B shows the long section comparison of bed level and the maximum water levels for the 100-year +CC event of the existing and proposed weir removal scenarios. This shows that weir removal reduces the maximum stage within the Clywedog for 400m upstream of the weir during the event.

Appendix C shows the hydrograph 630m downstream of the weir for the 1 in 100-year +CC event for both the existing and weir removal options. There is negligible difference between the two hydrographs. It should be noted that there was minor instability at the start of each of the weir removal runs, however work will be done prior to detail design to address this and it is not anticipated to have any effect on model results.

Table 3 shows the difference in peak water level at each modelled 1D node in the modelled flood events. Note that negative values indicate a decrease in water level after weir removal and positive values indicate an increase in water level after weir removal. As shown peak water levels are reduced for 200m upstream post weir removal.

Table 3. Change in peak water levels (m) at modelled 1D nodes.

Chainage from Weir (m)	Flood Event (Annual Exceedance Probability)		
	1 in 100	1 in 100 +20% allowance for climate change	1 in 1000
1219 m Upstream of the Weir	0.000	0.000	0.000
937 m Upstream of the Weir	0.000	-0.001	0.000
937 m Upstream of the Weir	0.000	0.000	-0.001
733 m Upstream of the Weir	-0.001	-0.004	-0.006
633 m Upstream of the Weir	-0.004	-0.027	-0.037
411 m Upstream of the Weir	-0.020	-0.053	-0.068
310 m Upstream of the Wei4	-0.086	-0.164	-0.192
107 m Upstream of the Weir	-1.198	-1.460	-1.584
Upstream of Weir	-1.906	-2.200	-2.378
Downstream of Weir	0.000	0.000	0.000
138 m Downstream of the Weir	0.000	0.000	0.000
259 m Downstream of the Weir	0.000	0.000	0.000
404 m Downstream of the Weir	0.000	0.000	0.000
636 m Downstream of the Weir	0.000	0.000	0.000
836 m Downstream of the Weir	0.000	0.000	0.000
1037 m Downstream of the Weir	0.000	0.000	0.000
1157 m Downstream of the Weir	0.000	0.000	0.000
1292 m Downstream of the Weir	0.000	0.000	0.000
1419 m Downstream of the Weir	0.000	0.000	0.000

6 Conclusion

In conclusion, at this stage in the design, removal of the weir has been found to have minimal predicted impact on downstream flow rates and flood depths. As the model is 1D, flood extents have not been determined, however due to the low and controlled flows from the Clywedog Reservoir, it is reasonable to conclude that weir removal is unlikely to have significant impact on flood risk elsewhere.

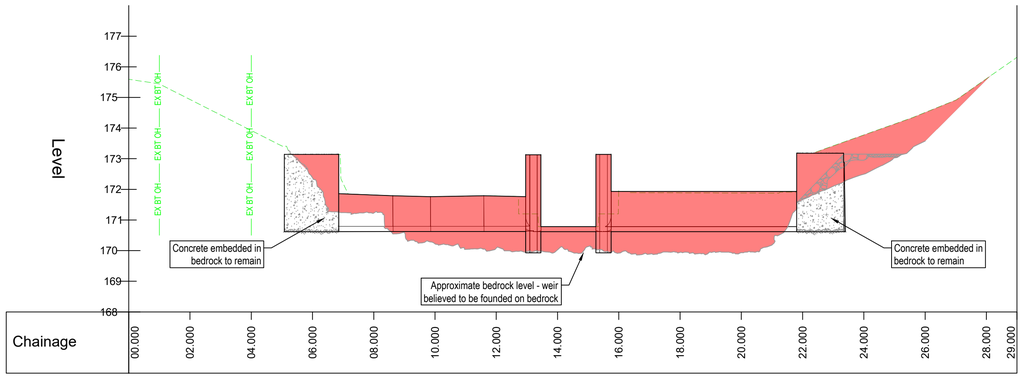
7 References

References

Arup. (2021). *290013-ARP-00-CL-RP-YX-0001 Model Inception Note.*
Chow, V. (1959). *Open Channel Hydraulics.* New York: McGraw-Hill.
NRW. (2020). *Project Brief.*
NRW. (2022, March 29). *Flood Map for Planning / Development Advice Map*. Retrieved from Natural Resources Wales: https://naturalresources.wales/flooding/flood-map-for-planning-development-advice-map/?lang=en

Appendices

Appendix A –Proposed Weir Removal Design



Cross Section 1 - Existing Weir Crest
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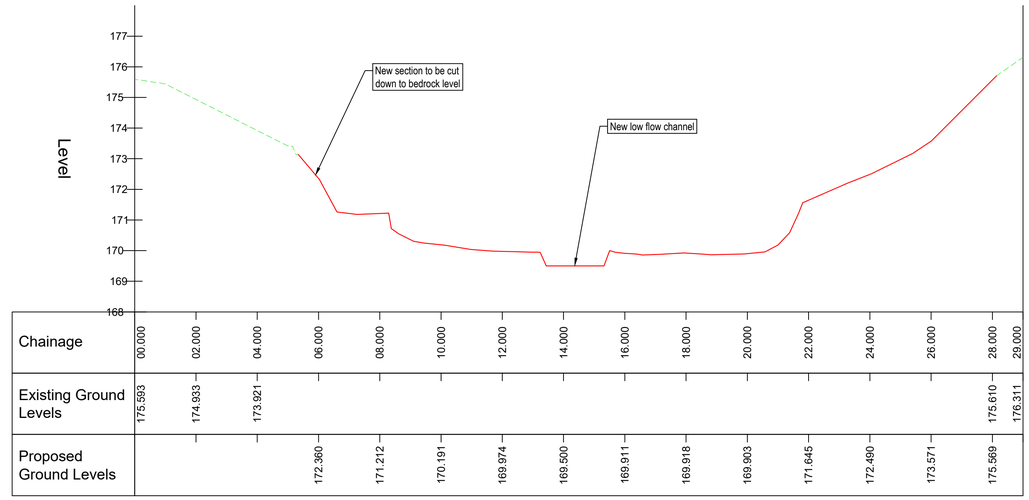

Cross Section 1 - Proposed
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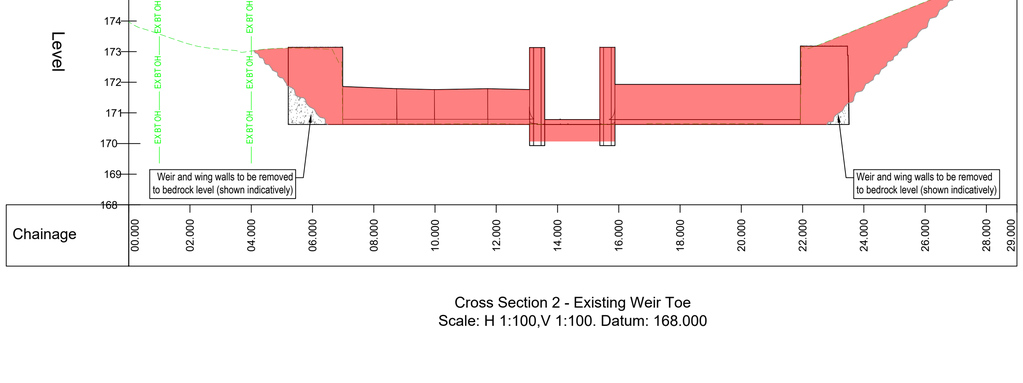
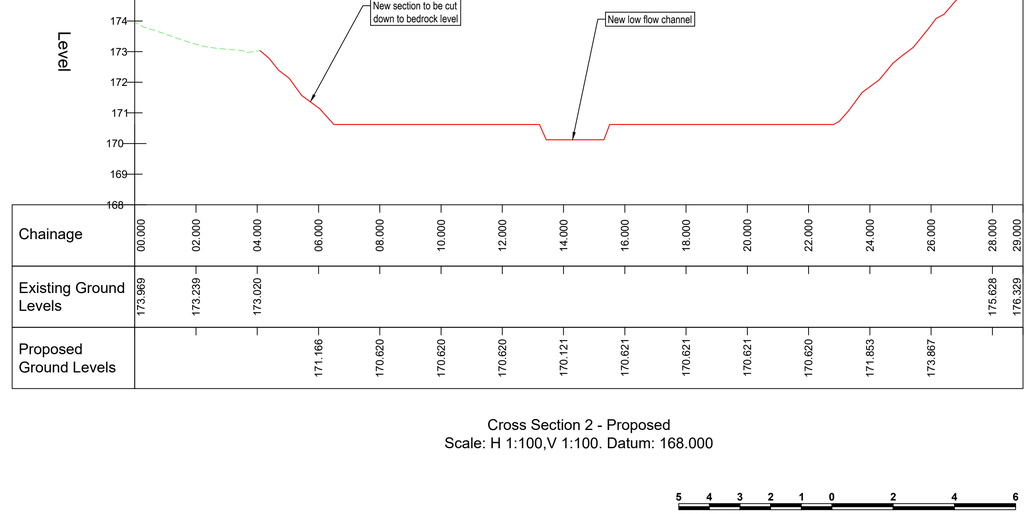


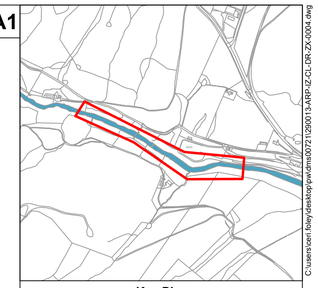
Cross Section 2 - Existing Weir Toe
Scale: H 1:100,V 1:100. Datum: 168.000



Cross Section 2 - Proposed
Scale: H 1:100,V 1:100. Datum: 168.000

5 4 3 2 1 0 2 4 6
SCALE 1:100
(m)

A1



Key Plan
Scale 1:10,000

Nodiadau / Notes

1. All dimensions in millimetres and all levels in metres to ordinance datum (Newlyn) unless stated otherwise.
2. Do not scale from this drawing. Only figured dimensions and levels are to be used.
3. Material from gabions to be disposed of responsibly off site.
4. See drawing 290013-ARP-IZ-CL-DR-ZK-0002 for plan section extent.
5. Information on existing structures taken from 1958 construction drawings provided by NRW - refer to Site Information.

Legend

- Proposed demolishing works
- Proposed Ground/Bed Level
- Existing Ground/Bed Level

Legend - Utilities

- EX BT OH — Existing BT (Overhead)

OS Ref: 294440,285513

Rev	Date	By	Chkd	Appd
P01	29.04.22	CF	PS	RG

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Cyfoeth Naturiol Cymru Natural Resources Wales

Enw a Rhif y Prosiect CNC / NRW Project Name and Number

CE0603-509

SALMON FOR TOMORROW PHASE 2 CLYWEDOG

Teitl Lluniad / Drawing Title

CROSS SECTIONS: DEMOLITION AND PROPOSED

Graddfa yn A1 / Scale at A1
1:100

Rhan / Role
General

Addasrwydd / Suitability	Statws / Status
For Information	S2
Rhif y Prosiect Arup / Arup Project Number	Adolygiad / Rev
290013	P01

Rhif y Lluniad / Drawing Number

290013-ARP-IZ-CL-DR-ZX-0004

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A1

Some regrading / erosion protection could be required pending modelling and stability analysis

Steep banks on each side

Substantial sediment is held behind the weir and will require some regrading. Sampling to determine waste classification for reuse.

Cross Section 1 - Weir Crest

Cross Section 2 - Weir Bottom

Access from caravan site to removed weir to be blocked off

Wing wall to be excavated to the bed rock

Weir to be removed to the bed rock

Weir extent

Limited regrading to facilitate weir removal - sediment generally to be allowed to redistribute naturally

Gabions and rockfill mattress to be removed

Remove rockfill. Remove wingwalls to bed level

FE.MRF 1.2m

CONCRETE WEIR

STONE & GRAVEL RIVER BED

STEPS

River Clywedog

River Clywedog

SCALE 1:100
(m)

NOTES ABOUT STATUTORY UTILITY PROVIDERS RETURNS

1. THE POSITIONS OF THE EXISTING SERVICES ON THIS DRAWING HAVE BEEN INTERPRETED FROM INFORMATION RECEIVED FROM THE STATUTORY UNDERTAKERS (LINESEARCH 23/11/21).
2. NO UTILITIES SHOWN ON AVAILABLE STATUTORY UNDERTAKER RECORDS IN PROXIMITY TO PROPOSED WORKS: VIRGIN MEDIA, WALES AND WEST UTILITIES.
3. THIS DRAWING HAS BEEN PRODUCED BASED ON THE ABOVE INFORMATION SOURCES. STATUTORY UNDERTAKER PLANS INDICATED THE PRESENCE OF A UTILITY SERVICE. THEIR LOCATIONS ARE INDICATIVE AND SHOULD NOT BE RELIED UPON FOR ACCURACY.
4. EXACT LOCATIONS OF UTILITIES SHOULD BE CONFIRMED ON SITE. THE CONTRACTOR SHOULD VERIFY, THROUGH POSITIVE IDENTIFICATION, THE LOCATION OF UTILITIES RECORDED IN CLOSE PROXIMITY TO THE WORKS.
5. THE CONTRACTOR SHOULD ANTICIPATE ADDITIONAL SERVICES CONNECTING TO THE PROPERTIES AND / OR STREET FURNITURE SUCH AS LAMPPOSTS THAT ARE NOT GENERALLY COVERED BY THE RETURNS FROM INDIVIDUAL STATUTORY AUTHORITIES.

Key Plan

Scale 1:10,000

Nodiadau / Notes

1. All dimensions in millimetres and all levels in metres to ordinance datum (Newlyn) unless stated otherwise.
2. Do not scale from this drawing. Only figured dimensions and levels are to be used.
3. Material from gabions to be disposed of responsibly off site.
4. See 290013-ARP-IZ-CL-DR-ZX-0004 for section details.

Legend

- Proposed bank regrade extent
- Proposed demolishing works
- Existing gravel

Legend - Utilities

- Existing BT (Overhead)

OS Ref: 294440,285513

Rev	Date	By	Chkd	Appd
P01	29.04.22	CF	PS	RG

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Natural Resources Wales

Enw a Rhif y Prosiect CNC / NRW Project Name and Number

CE0603-509

SALMON FOR TOMORROW PHASE 2 CLYWEDOG

Teitl Lluniad / Drawing Title

PROPOSED WORKS GENERAL ARRANGEMENT

Graddfa yn A1 / Scale at A1

1:100

Rhan / Role

General

Addasrwydd / Suitability	Statws / Status
For Information	S2

Rhif y Prosiect Arup / Arup Project Number	Adolygiad / Rev
290013	P01

Rhif y Lluniad / Drawing Number

290013-ARP-IZ-CL-DR-ZX-0002

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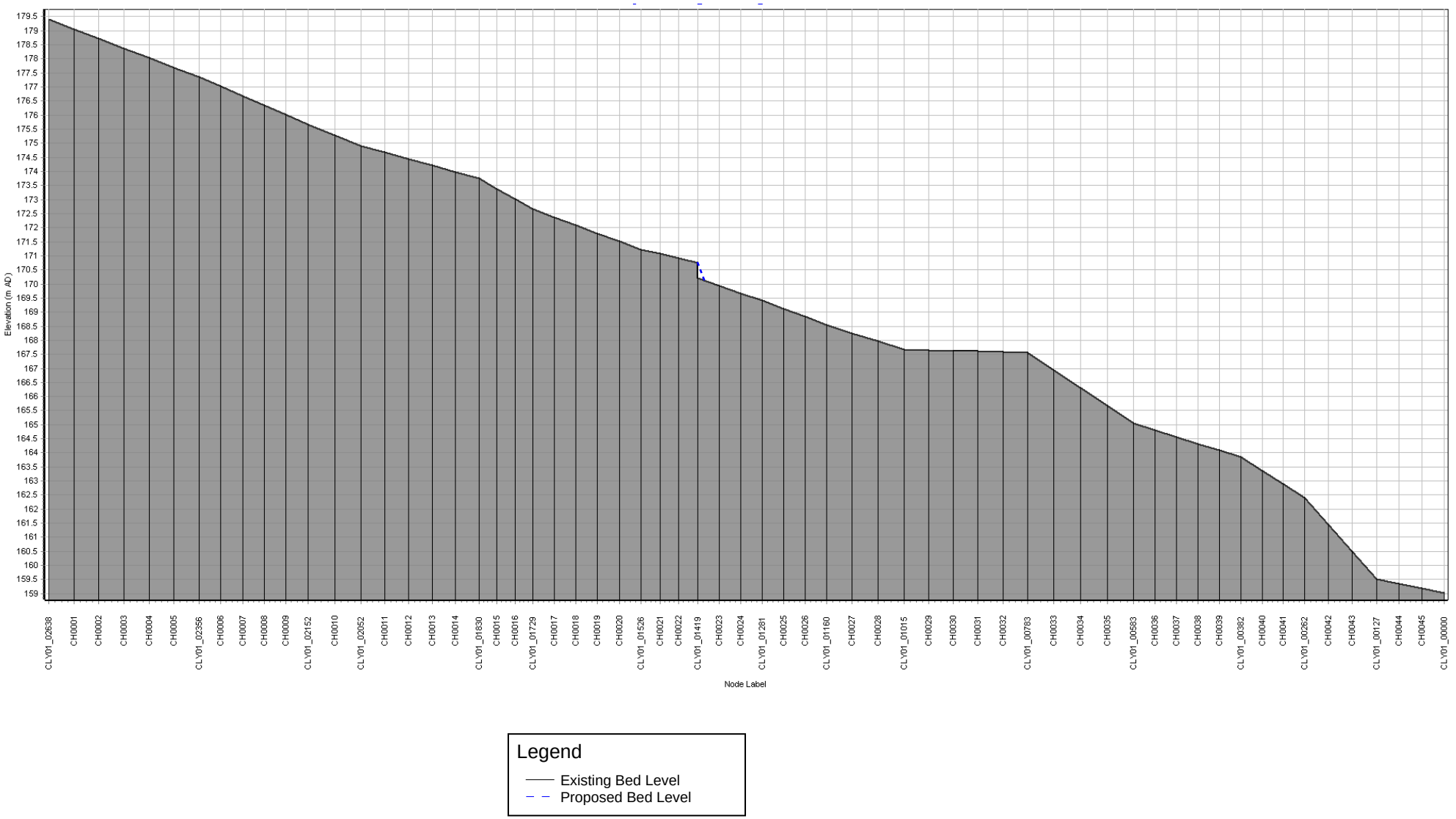
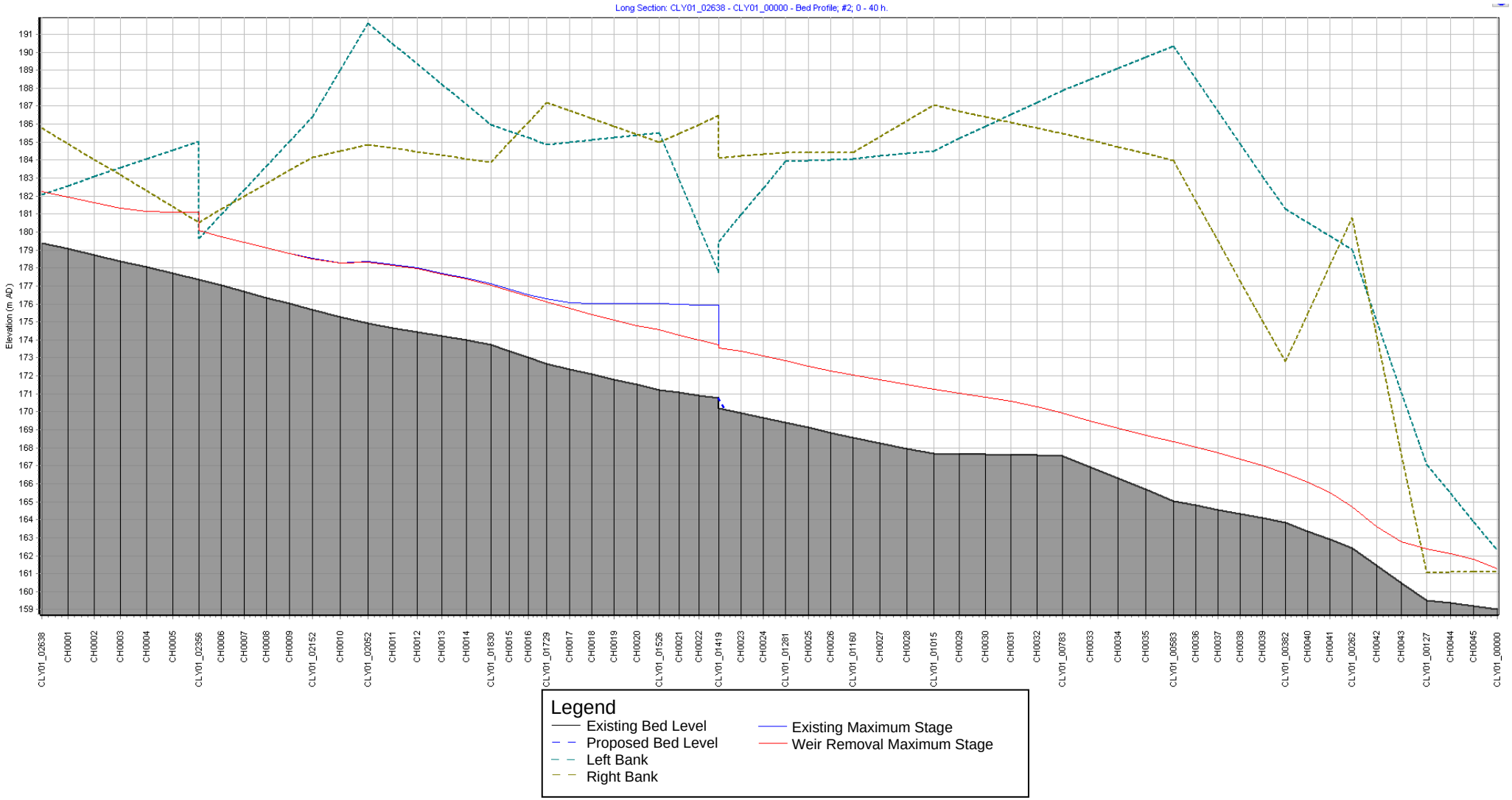
Appendix B –Modelled Long Sections



Legend

- Existing Bed Level
- Proposed Bed Level

Appendix C – Maximum Stage Model Results



Appendix D – 1 in 100Yr +CC Hydrograph Results