**NOTE TO FILE**

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| JBA Project Code | 2026s0165 |
| Contract | Llanelltyd Sheet Pile Removal |
| Client | Natural Resources Wales |
| Day, Date and Time | 17/03/2026 |
| Author | James Nixon BSc MSc |
| Reviewer / Sign off | Natasha Todd-Burley BSc (Hons) PhD CGeog (Geomorph) FRGS |
| Subject | Llanelltyd Sheet Piling Geomorphological Assessment |

# 1 Introduction

## 1.1 Project Summary

JBA Consulting was commissioned by Natural Resources Wales (NRW) in 2026 to undertake a geomorphological assessment into a 100m section of failed sheet piling on the banks of the Afon Mawddach at Llanelltyd, near Dolgellau, North Wales. A 30m section of the piling has catastrophically failed along the right bank of the river leaving the sheet piling foundations dangerously exposed. The sheet piling was originally protecting part of a 1000m long earth embankment that acts as an informal flood bund for the farmland behind it. This embankment, the sheet piling and an outfall are an NRW legacy asset and are therefore inspected every two years, however the assets are not classed as a formal flood defence. The project aims to achieve a solution which eliminates future liability and withdraws maintenance obligations, addresses health & safety concerns, and reaches an agreement with the landowner. This project will ensure that NRW is meeting its regulatory and legal duties.

## 1.2 Purpose of this technical note

The purpose of this technical note is to present the findings of a baseline geomorphological assessment of the site and the reaches immediately up and downstream. The document will focus on the baseline conditions at the site and the potential response to anticipated works along this section of the Afon Mawddach.

## 1.3 Site Location

The site (Figure 1-1) is located approximately 700m downstream of where the A470 road crosses the Afon Mawddach at the village of Llanelltyd, and immediately upstream of the confluence where the Afon Wnion meets the Afon Mawddach.

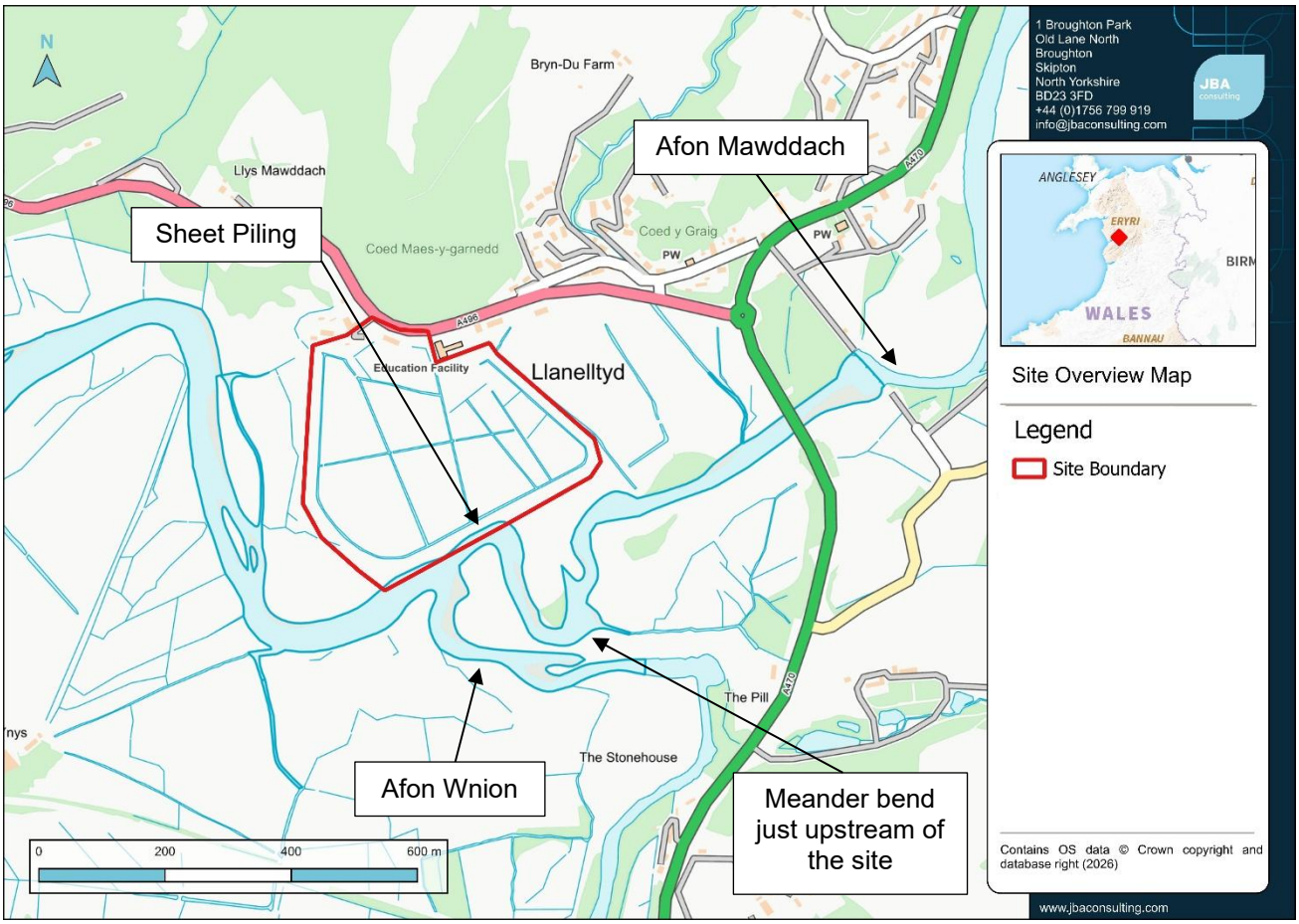


Figure 1-1 Site Overview Map

# 2 Desk Based Assessment

## 2.1 Topography

Upstream of the site the Mawddach flows in a realtively narrow constrained V-shaped valley, raising at ~442mAOD just to the north of the summit of Dduallt, before flowing west and northwest towards the village of Llanelltyd and the site (approximately 500m to the southwest of the village).

The topography of the site is very low lying at approximately 2.7mAOD, sitting in the bottom of a wide U-shaped valley where the Afon Wnion meets the Afon Mawddach. Here the floodplain is much wider than upstream at around 1.3km across the bottom of the valley. Downstream of the site the wide, low lying transitional floodplain continues for 11.5km to the mouth of the Mawddach near Barmouth.

## 2.2 Geology and soils

The site is underlain by the Maentwrog Formation-Mudstone, siltstone and sandstone bed rock formation. This is overlain by superficial deposits of Clay, silt and sand in Tidal flat deposits.

Soils at the site comprise of Loamy and clayey floodplain soils with naturally high groundwater, which leads to the site being very wet and having naturally poor drainage.

The Mawddach catchment generally consists of bed rock that has very low permeability and is relatively steep, leading to a flashy response during storms.

## 2.3 Hydrology, flow regime and Geomorphological response

Although the site itself is ungauged, there is a NRW gauge located around 6.5km upstream of the site (64010 - Mawddach at Tyddyn Gwladys). Daily flow data show that the Mawddach is highly responsive to heavy rainfall, raising and falling very quickly (Figure 2-1), which is expected with the catchment characteristics outlined above. Flashy flow regimes concentrate high flow energy within a short timeframe, generally increasing the potential for elevated erosion rates that can lead to a potential for increased channel change and an acceleration in the transport of sediment.

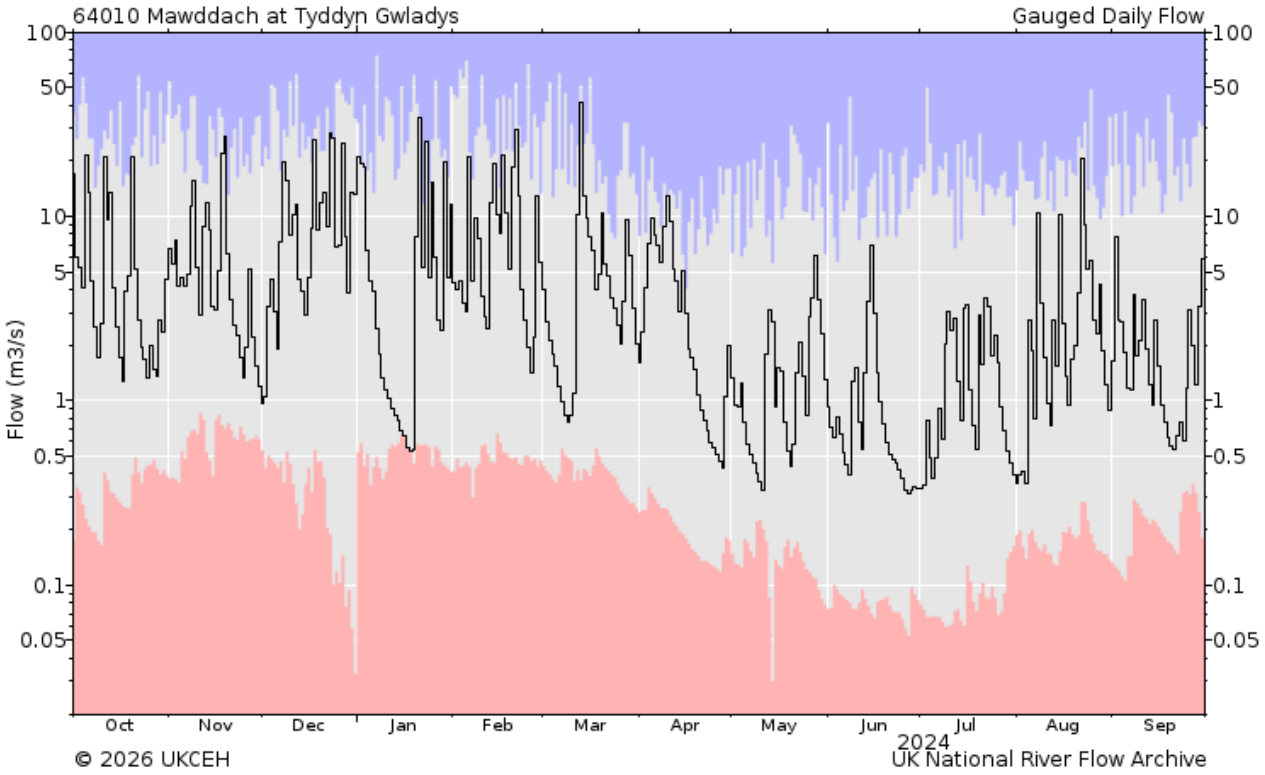


Figure 2-1 Mawddach at Tyddyn Gwladys Annual Hydrograph 2024 (National River Flow Archive, 2026)

## 2.4 Current land use at the site

The site is dominated by improved grassland that is managed inside the boundary of the informal flood bund and pockets of scrubland and floodplain marsh type habitat on the river side of the flood bund.

## 2.5 Historic trend analysis

Historical maps show that there has been constant but relatively slow planform change since the early to mid-19th century to the present day. The earliest map shows that the section of channel just downstream of the original Llanelltyd bridge was more sinuous than it is today (Figure 2-2), with a straighter planform appearing on this section of channel from the late 19th century, suggesting that this reach may have been straightened. The meander bend that was present in the early 19th century has migrated further downstream to its current location and become much more sinuous with a tighter apex on the planform. The positioning of this meander bend along the length of this reach has not changed significantly since the end of the 19th century, with it staying in roughly the same place just upstream of the confluence with the Afon Wnion (Figure 2-3). However, the planform has

continued to alter, with the meander bend and confluence with the Wnion changing shape slowly but constantly over the last ~130 years.

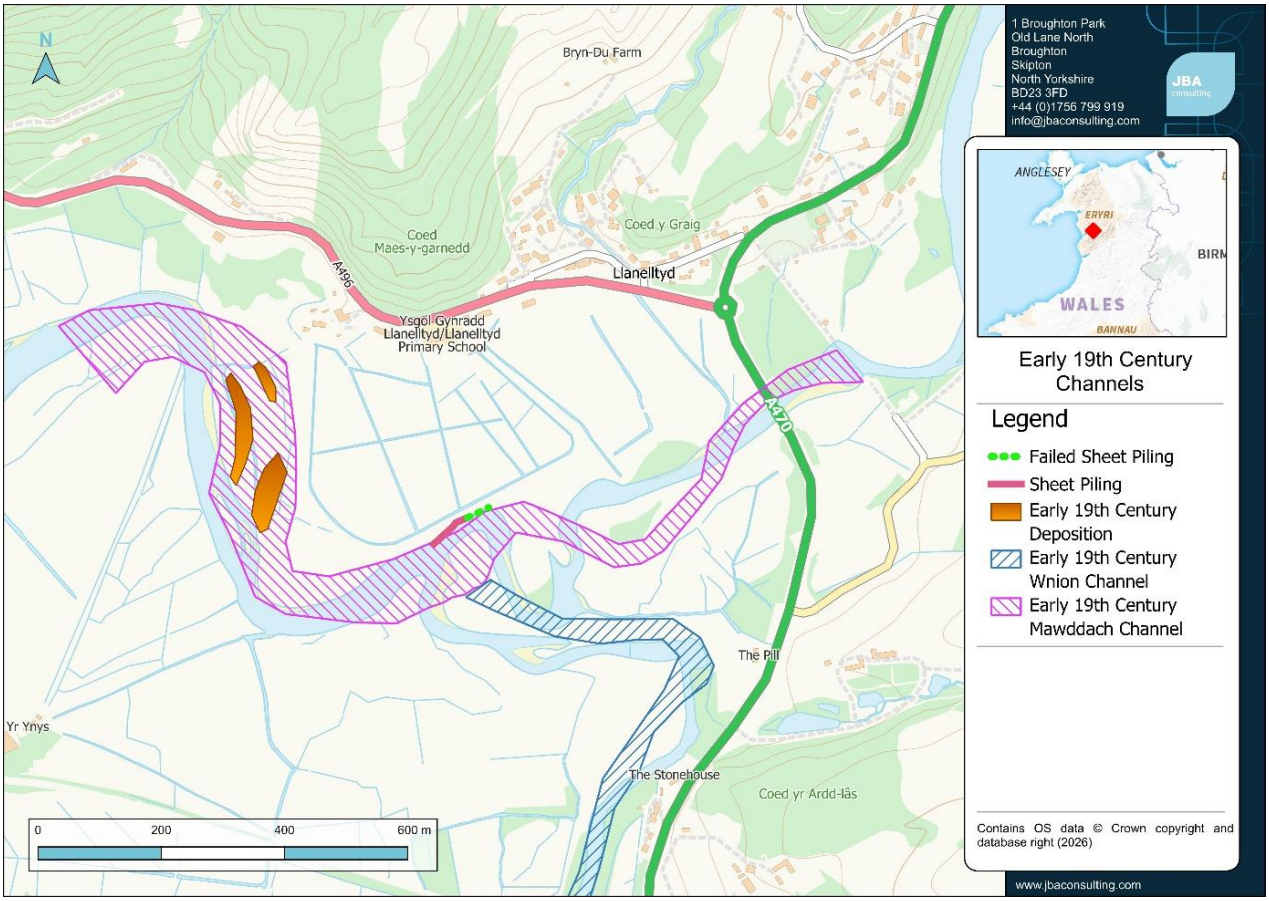


Figure 2-2 Channels of the Afon Mawddach and Afon Wnion in the early 19th century

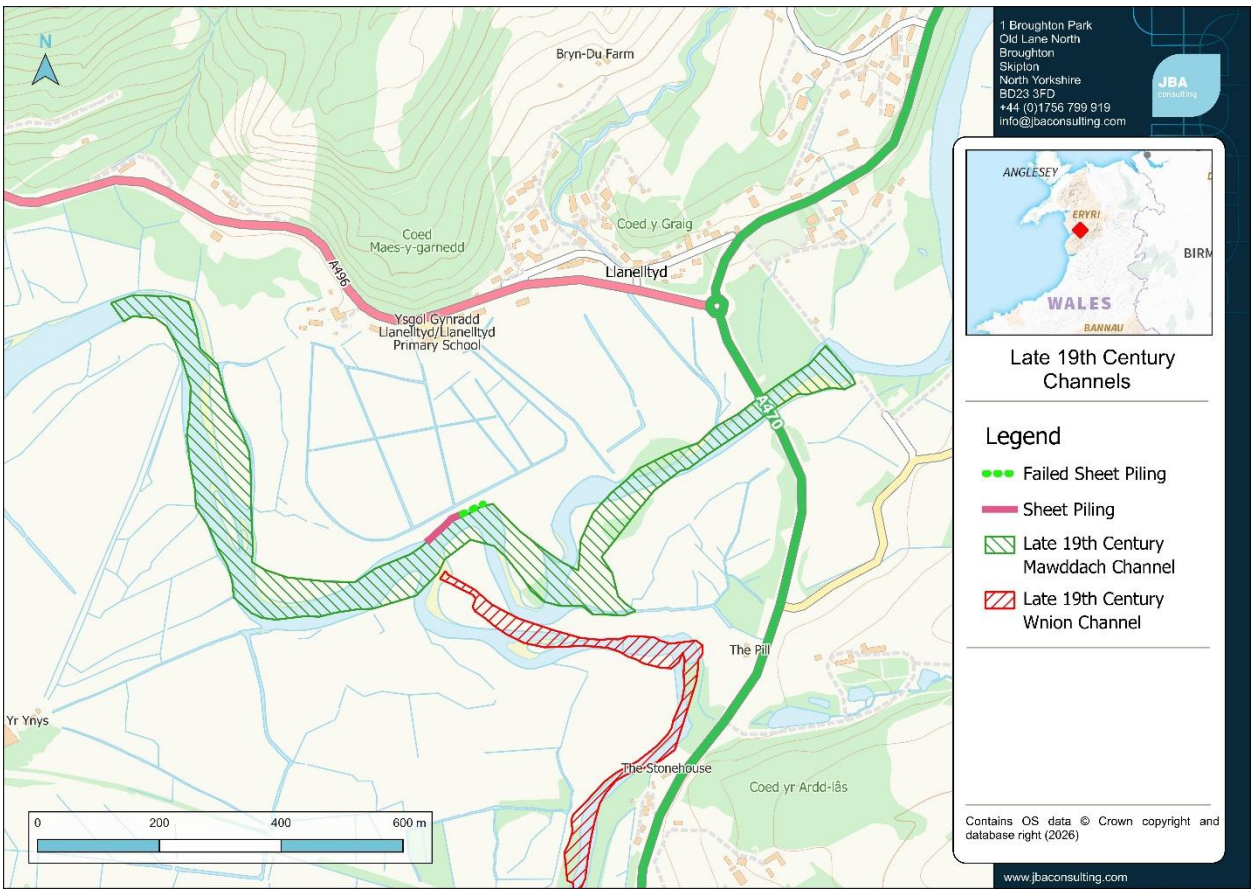


Figure 2-3 Channels of the Afon Mawddach and Afon Wnion in the early 19th century

While changing shape, the meander bend upstream of the site of sheet piling has been slowly migrating to the south eroding the bank between the channel of the Mawddach and Wnion. This has reduced in width over the years and is now 4 to 5m wide and is likely to keep migrating until it breaks through into the channel of the Wnion, forming a braided type of channel in this section, which fits with how parts of the lower Wnion are currently presenting.

The earliest maps available (early 19th century) also suggest that more deposition is now occurring just upstream of the site with the increased sinuosity, instead of around 600m downstream of the sheet piling, where historic mapping from the early 19th century suggests more in-channel deposition with a much wider channel (Figure 2-2).

It is clear from historical aerial imagery and Lidar data that the Wnion and Mawddach are both very active systems that have migrated significantly over history.

# 3 Llanelltyd Sheet Piling Site Assessment

## 3.1 Introduction

A geomorphological assessment was undertaken on the 17 February 2026 in dry and clear weather conditons. The river here is tidally influenced and the tide was starting to turn after high tide as the surveyors got to site, which meant the water level was high during most of the visit. The reach with the sheet piling as well as immediately up and downstream was surveyed. A wider survey was unable to be undertaken due to time and access constraints.

## 3.2 Site of sheet pile failure

The site of interest consists of a 100m of sheet piling along the right bank of the Afon Mawddach, 30m of which has catastrophically failed. The sheet piling is located on the outside of a sharp 90-degree meander bend, with the worst failure in the sheet piling located just downstream of the apex of the bend (See Figure 3-1, Figure 3-2 and Figure 3-3).

Figure 3-1 Section failed sheet piling in the middle of the image between the white arrows (Left bank looking downstream)

The failure of the sheet piling has left part of the bank exposed on a section of bend with the highest velocity flow; this has caused erosion of the bank between the sheet piling and the informal flood bund (see Figure 3-3). The flood bund had also suffered extensive erosion and was breached, but was temporarily repaired by the landowner. The erosion of the bank has left the tie-rod foundations of the sheet piling dangerously exposed in the river (see Figure 3-4), which are now underwater obstacles when the tide is up and pose a risk to people using the river for water sports.


Figure 3-2 Map showing the positioning of the sheet piling, failed sheet piling and area of erosion

Figure 3-3 Section of failed sheet piling and the extent of subsequent lateral channel movement and scour. White line represents where the existing bank line and sheet piling was, with the red area representing the extent of scour. (right bank looking upstream)

Figure 3-4 Foundation tie rods of the failed sheet piles still in place, just visible below the high tide (right bank looking downstream)

The sheet piling is likely to have originally failed due to a combination of deterioration/ rusting of the sheet piling combined with high velocity helical flows on the outside of the meander bend. It can be inferred that the majority of erosion took place while the water levels were lower than when observed on site, suggesting that the toe of the sheet piling will have scoured out first leading to a failure of this section of the structure.

The presence of the sheet piling along this section will have exacerbated the processes that caused it to fail. With reduced roughness along this bank face and no bank material for the river to scour, helical flows on the outside of this sharp bend will have caused the river to erode into its bed instead of the bank and over deepen on the outside of the bend, potentially leading to undercutting of the sheet piling. In addition, this section of channel is narrower and more constrained than up and downstream of the sheet piling, which is likely due to the river not being able to laterally migrate to the north (stopped by the hardened bank). The river is still depositing material along the left bank slowly reducing the width of the channel and increasing velocities.

The bed material in this section was observed as being poorly sorted, with medium to fine gravels present. At the time of visit, the section of channel next to the site appeared relatively featureless, however aerial imagery shows bar deposits along the left bank, likely exposed at low tide.

Figure 3-5 The downstream section of sheet piling beginning to fail (right bank looking upstream).

Figure 3-6 Outfall in the sheet piling missing a flap valve (right bank looking upstream).

The downstream section of sheet piling was also visibly beginning to fail, with sections of it leaning out towards the channel as can be seen in Figure 3-5. This may have also been from the toe of the sheet piling starting to destabilise along with the metal work rusting.

There was also a surface water outfall present in the sheet piling. The outfall was discharging at the time of the visit with surface water from the farmland behind the flood embankment. The outfall was missing a flap valve (see Figure 3-6) meaning the water can flow back up through the structure at times of higher flows.

The riparian vegetation along the right bank was fairly degraded, appearing to have been managed at points. It mostly consisted of soft rush species and longer grass. The left-hand bank had more substantial species of rushes with some larger shrubs and trees.

### 3.3 Upstream of the site

Upstream of the site, the Mawddach shows more variation within the channel, with an abundance of in-channel features including lateral, point and mid-channel bars (see Figure 3-7). This includes more flow biotypes as well, with runs, glides, and some riffles. At lower tide levels more riffles are likely to be present in this system given the healthy supply of sediment.

Figure 3-7 Some vegetated mid-channel bars on the Afon Mawddach (right bank looking upstream)

The sediment observed here was poorly sorted, fine to medium sized gravels, with a proportion that were sub-rounded to sub-angular (see Figure 3-8). This could indicate that the bed has likely been deposited in variable conditions and transported through the system relatively quickly, most likely due to the flashy nature of the Mawddach. There are also a lot of fines within the system, with a great deal deposited on some of the exposed point bars in this section (see Figure 3-9).

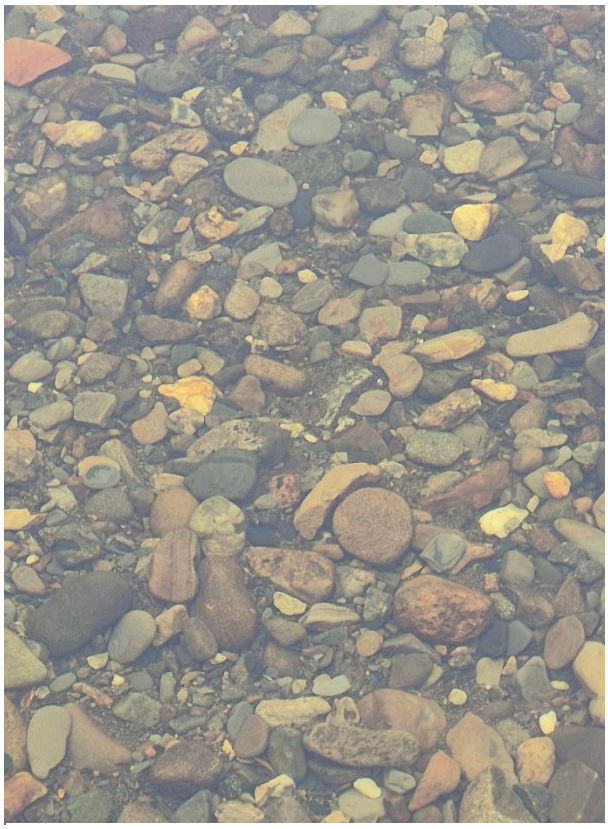

Figure 3-8 Poorly sorted bed material in the Afon Mawddach (right bank looking downstream)

Figure 3-9 Point bar with a large quantity of fine sediment in the foreground (right bank looking upstream)

The channel is more disconnected from the floodplain than downstream, with generally higher and steeper banks observed in this section of the river. This upstream reach exhibited a significant amount of active erosion with bare banks visible throughout, that appeared to be relatively friable. One section of erosion of note was the section of bank between the Mawddach and the Wnion that showed evidence of full bank scour (see Figure 3-10). There are also the remains of a fence or potential failed bank protection along this section of bank, likely to try and stop the two rivers meeting. The banks appear relatively consolidated but have been subject to significant erosion suggesting a high energy environment.

Figure 3-10 Section of eroded bank face between the Afon Mawddach and the Afon Wnion. A fence/ failed bank protection is visible in the form of posts in front of the bank face

Riparian vegetation was generally more substantial here than downstream, with a range of larger tree species, shrubs and rush species, mainly due to less vegetation management in the area.

### 3.4 Downstream of the site

Downstream of the site the Afon Mawddach appeared to be relatively featureless compared to upstream, with no in-channel features exposed at the time of the visit, but as it was surveyed at high tide, some features may have been hidden. It is clear from the visit and desk-based data that there is far more sediment storage upstream of the site, which has likely reduced the size of the features downstream of the site. The channel is wider here with the confluence of two rivers and generally appeared to be better connected to the floodplain than upstream and appeared more of a transitional/ estuarine type of waterbody from this point moving downstream.

The Afon Wnion joins the Afon Mawddach immediately downstream of the site and was observed to have caused erosion along the left bank at the mouth of the Wnion and more crucially on the right bank immediately downstream of the 100m of sheet piling. This erosion has started to destabilise the other (downstream) end of the of the sheet piling leading to its deterioration and imminent failure (see Figure 3-11). Aerial imagery from 2006, shows that the bank here has retreated around 6-10m, due to the flow velocity out of the Wnion. This is also an increasing threat to the section of sheet piling that is yet to fully fail.

Figure 3-11 Evidence of basal scour and slumping causing deterioration and failure of the sheet piling at the downstream end of the site (right bank looking downstream)

Figure 3-12 View of the confluence between the Afon Mawddach and Afon Wnion (right bank looking downstream)

Like at the site, the riparian vegetation was relatively degraded on the right bank, appearing to have been managed or cut at some point in the recent past. It mainly consists of poor-quality grassland and soft rushes, being very wet. The left bank was similar but with more reed species.

# 4 Design optioneering and anticipated Geomorphological response

## 4.1 Proposed design/removal options

1. Full 100m sheet pile removal.
2. Cutting down the 100m sheet pile down to as low as possible (down to silt bed level).
3. Leaving 70m of piling to be left in situ and removing the full 30m length of pile.
4. Cutting down the 30m of failed piling to bed level to remove immediate risk.

### 4.1.1 Full 100m sheet pile removal (option 1)

This option would completely remove all hard bank protection from this section of bank leaving it as a natural bank once again. From a hydromorphological perspective this would be a direct positive for the river and for Water Framework Directive (WFD) status, as an artificial bank is being removed, allowing for a restoration of natural channel geometry and local hydrodynamics along this section of channel. Its removal will allow for a slight widening of the channel and reinstate a bank with higher roughness, which will encourage the creation of more in channel features such as a point bar on the opposite bank and will also allow the river to naturally adjust as it has historically done in this active system. This will allow for the creation of more habitat within the channel and riparian zone.

With full removal, erosion along the right bank is highly likely to continue, mainly at the upstream end of the sheet piling where it has already taken place. Lateral movement is anticipated along much of the length of the section, but with the other sections of sheet pile removed, the erosive flow will no longer be focused on one area of bank through the failed 30m section. This means that the channel movement is likely to be slower and more controlled with the entire section of piling removed as the river now has more bank face to exert its energy upon.

From assessing the channel width upstream and historical change, the channel is anticipated to widen by around 5-20m along this section after removal, most likely around the top 30m section where the sheet piling has already failed.

### 4.1.2 Cutting down the 100m sheet pile down to as low as possible (down to silt bed level) (option 2)

For this option the piling and foundations will be lowered so they no longer present an immediate danger to users of the river, while appearing that the sheet piling has been removed. This option would provide some hydromorphological improvements by partially restoring the natural bank and allowing for some more natural variation. However, any remaining foundations of the piling are likely to be quickly exposed by erosive flows, which will likely exacerbate basal scour along the bank, increasing bank instability and reinstating an underwater hazard for recreational users of the river.

The advance of basal scour is likely to be slowed slightly with the retainment of some sheet piling, however with the upstream piling failed the scour is likely to occur from the upstream side and behind the sheet piling as it is outflanked and eroded from behind.

### 4.1.3 Leaving 70m of piling to be left in situ and removing the full 30m length of pile (option 3)

This option would only remove the severely failed 30m section including the foundations but leave the more intact sheet piling in place in the downstream section. This solution would provide an improvement for hydromorphology by reinstating part of the natural bank and an increase in safety on the river by removing the failed foundations.

With this option, flow energy is still likely to be directed at a small section of bank, the only section without protection, meaning the flow is more likely to continue to quickly erode this part of the bank. In addition, the removal of the failed section will likely leave the section of bank behind the remaining sheet piling more exposed to erosive flows that are likely to outflank and erode the foundations of the sheet piling from behind (see Figure 4-1), resulting in a higher likelihood that this piling will rapidly fail as it is already deteriorating.


Figure 4-1 Shows how erosive flows can be directed to the bank behind the downstream sheet piling (flow is represented in blue arrows) (photo take from right bank looking downstream)

### 4.1.4 Cutting down the 30m of failed piling to bed level to remove immediate risk (option 4)

As stated, this option would remove any of the exposed sheet piling, likely leaving some of the unexposed foundations or parts of the piling in place. Again, this strategy would likely remove the immediate danger of exposed piling in this section, but continued scour is likely to expose any part of the piling that is not immediately removed, potentially retaining liability from the asset if the exposed sections are an underwater hazard.

Like option 3 this will also leave the rest of the sheet piling exposed to erosive flows from the upstream side and behind, resulting in a higher likelihood of rapid failure once the works have been undertaken.

As with option 3 this would also reinstate a small section of bank and allow for some planform variation and hydromorphological improvements.

# 5 Conclusion

In summary, with the list of design options having been assessed from a Geomorphological perspective, the options are numbered in a descending order of preference, with option 1 the most preferred and option 4 is the least. Option 1 completely removes any liability for NRW, provides significant hydromorphological and ecological improvements, and would contribute towards an improved WFD status. With all of these options the river is likely to laterally migrate northwards towards the informal flood bund, and potentially completely through it under certain conditions. This is estimated to be between 5 to 20m of lateral movement, however the floodplain is flat so more movement is possible. The time frame of movement is difficult to estimate, but based on channel evolution since the sheet piling has failed, movement could be rapid e.g. during a large flood event. However, historical data would suggest that extensive movements of the platform are unlikely to occur quickly, with the planform of the channel in this reach taking around 140 years to move approximately 50m. It is worth noting that the channel of the Afon Mawddach appears to be close to cutting through to the Afon Wnion, as mentioned in Section 2.5. If this happens, it is likely that a proportion of flow from the Afon Mawddach would be directed down the remaining channel of the Afon Wnion, by passing the sheet piling and area of erosion all together. At this point it is likely that the site will be at significantly less danger of being eroded or further lateral migration.

It should also be noted that there were limitations that impacted the collection of data while on site for this geomorphological assessment, with the main being the time that the surveyors had access to the site. This resulted in the tide being at slack water and subsequently at the start of going out (towards the end of the visit) during the survey. This meant the riverbed the toe of the scoured section of bank where the sheet piling has failed were more difficult to see. The accessible downstream section was limited due to access constraints and very wet land that was unsuitable to walk across.

## 6 References

National River Flow Archive . (2026). *64010 - Mawddach at Tyddyn Gwladys*. Retrieved from National River Flow Archive : https://nrfa.ceh.ac.uk/data/station/info/64010