Caerphilly County Borough Council

NANT CYLLA

Scour Feasibility Study

CONFIDENTIAL

.

Strategy for discussion

DATE: FEBRUARY 2020

QUALITY CONTROL

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1 SITE DESCRIPTION

The section of Nant Cylla in Ystrad Mynach from the Commercial Street culvert to the confluence with the River Rhymney has historically been affected by erosion and scour. Original protection structures along the watercourse are reaching the end of their life and are failing dramatically. The erosion has left the banks vulnerable to the effects of river scour and possible future undermining posing a risk to the banks and adjoining properties.

WSP has been commissioned by Caerphilly County Borough Council (CCBC) to carry out a feasibility study and to consider possible permanent scour protection options to mitigate the future risk of damage. The study reach of the Nant Cylla has been split into three different sections according to the watercourse characteristics; these are shown in Figure 1.

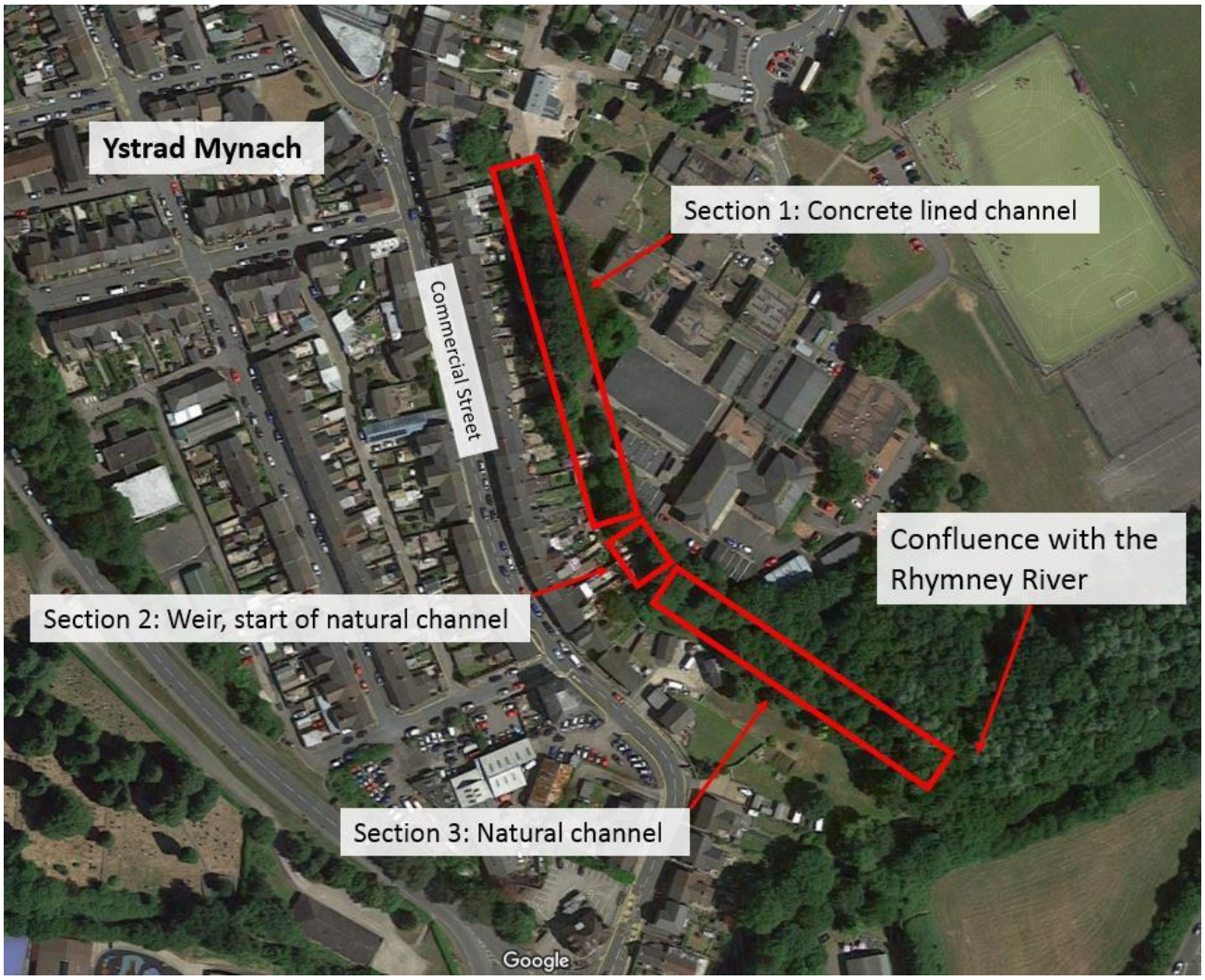

Figure 1 – Study Area

2 STUDY OBJECTIVES

The objectives of this feasibility study are summarised as follows:

- Undertake a river reconnaissance visit with representatives from CCBC along the Nant Cylla study area in order to review the site context, assess conditions and local constraints;
- Carry out a desk-based assessment reviewing existing information provided by CCBC to assess the likely causes and mechanisms of scour and the site constraints;
- Undertake a desktop appraisal and assessment of potential options for scour protection measures, outlining advantages and constraints and recommend a preferred solution;
- Consultation with CCBC and other key stakeholders to discuss the options report and agree the preferred option;
- Make recommendations to progress the design considering factors such as construction access; potential land take and availability; environmental impact; longer term robustness; stakeholder consultation and future maintenance.

3 INCOMING INFORMATION

The following information has been supplied by CCBC for use in this study. The information supplied at this stage is for information purposes only and has been used to support the feasibility study and optioneering stage and will need verifying as design progresses.

Drawings and Models:

- 2016 Gabion wall repair drawings;
- 2019 3D Survey Model and CAD files.

Legal Documents:

- Land ownership certificates for properties on Commercial Street;
- A3 size plan with ownership and Land Registry web data.

Photographs:

- Commercial street culvert works;
- Gabion wall failure;
- General photos 2014;
- General photos 2016;
- Historic flooding photos.

Reports:

- June 2006 - Inspection report for Commercial Street culvert;
- 2016/17 Confined Space Maintenance report.

Statutory Undertakers Apparatus:

- Western Power Distribution;
- Dwr Cymru / Welsh Water;
- Before you Dig;
- Openreach;
- Wales & West Utilities.

4 SITE VISIT

Engineers from WSP and CCBC undertook a river reconnaissance site visit to the Nant Cylla study area on Tuesday 27th August 2019 in order to establish the site context; review the condition of existing watercourse banks and scour protection structures; and identify local constraints to inform the development of options to mitigate the ongoing effects of scour.

The following key observations were made in each section of the study area.

Section 1:

This section runs from the Commercial Street culvert outlet downstream to the concrete weir and recently repaired gabion walls in Section 2. In this section of the watercourse the bed of the channel is concrete lined and the bank retraining structures appear to be in generally good condition (a typical channel section is shown in Figure 2). The comparably smooth channel bed and banks in Section 1 allow water to be conveyed quickly downstream with reduced turbulence in the flow. The channel width in Section 1 is approximately 3m.

Figure 2 – Section 1: Concrete lined channel and bank retaining structures

Section 2:

At the end of Section 1 the river reverts to a more natural channel bed. The transition from the concrete lined channel bed in Section 1 to the natural channel bed in Section 3 is achieved via a concrete weir in Section 2.

This transition area has been significantly affected by scour which resulted in failure in of the bank retaining structures in 2017. The gabion baskets collapsed and gradually fell into the river bed, restricting the cross-sectional area of the river. This area was repaired in the summer of 2018 with new gabions baskets installed on new concrete foundations and riprap was placed on the bed directly downstream of the weir. However, a subsequent high flow event in October 2018 caused the riprap

to be washed downstream and a large scour hole developed at the base of the channel immediately downstream of the weir, leaving the concrete foundations of the gabions baskets exposed to erosion and at risk of being undermined (see Figure 3 and Figure 4).

Figure 3 – Section 2: Concrete weir

Figure 4 – Section 2: Gabion foundations exposed to scour

Section 3:

Downstream of the weir in Section 2, the river characteristics change. The bed of the river reverts to a more natural bed made of rocks and boulders. There is extensive erosion protection on both banks of the watercourse in Section 3 which constrains the channel laterally. The bank protection is a mix of rock filled gabions, rock filled gabions on concrete foundations, concrete walls and/or brick work in some locations. These protection measures are failing, and the ongoing effects of scour have exposed the concrete foundations in many locations, leaving the river banks at risk of undermining and collapse.

Figure 5 – Section 3: Typical photos of banks affected by scour

5 SITE CONSTRAINTS

5.1 INTRODUCTION

A number of key constraints have been identified within the study area as described below. The assessment of potential options takes these constraints into consideration to identify a feasible and practical design solution.

5.2 ACCESS

Access to the Nant Cylla watercourse in the study area is limited as there are no designated public access points to either bank of the watercourse. The west bank of Nant Cylla along Commercial Street is bordered by residential dwellings and business premises from the upstream culvert outlet (close to the junction of Commercial Street and Bedwlwyn Road) downstream to the confluence with the River Rhymney. The east bank of Nant Cylla is bordered by dense vegetation, beyond which is the Lewis Girls' School.

Access to the bed of the watercourse is made difficult by the steeply sloping banks on either side of the watercourse, formed by the constrained urban environment and existing scour protection structures. The movement of material, machinery and construction personnel along the bed of the watercourse itself is also difficult due to the narrow channel and presence of rocks and other obstructions along the channel bed in Sections 2 and 3 (refer to Figure 1). As a result, during any construction works, temporary accesses and site compounds will need to be provided at strategic points to minimise the requirements for manual handling of materials and equipment. Consideration of safe systems of work and manual handling are also required.

In Section 1, the watercourse bed is lined with concrete allowing comparatively easy movements up and down this section. However, further details on the construction of the concrete apron and allowable loadings are required to confirm the size of plant that could operate.

For the repair works carried out at Section 2 in 2018, a temporary access was agreed on the east bank via the grounds of Lewis Girls' School. Thus, for this feasibility study, it is assumed that temporary works access will be possible on the east bank of the watercourse. Vegetation removal will likely be required to establish temporary access tracks between the school and Nant Cylla.

Further consideration of access constraints and temporary works designs will be required as part of the design development of the chosen option.

5.3 PUBLIC ENCROACHMENT

There has been unauthorised encroachment over the Nant Cylla and on to the east bank of the watercourse.

Residents on Commercial Street have constructed various structures, including sheds, decking and gardens on both banks of the watercourse along with makeshift footbridges and garden extensions to access the structures on the east bank. These unauthorised structures place additional localised loading on the banks of the watercourse increasing the risks of bank collapse.

The makeshift structures are a construction access constraint as they limit the available head room and thereby the movements of material, equipment and personnel along the channel bed.

In addition, the poor condition of the structures also poses a health and safety risk to construction personnel in the event of impact or collapse.

Legal / planning issues associated with these encroachments are unclear at the moment. This should be confirmed with CCBC prior to start of the design as these could influence decisions and affect potential solutions.

5.4 ENVIRONMENTAL CONSTRAINTS

CCBC and local residents have confirmed that fish (trout) are present in Section 3 of the Nant Cylla, up to the concrete weir structure behind No 36 Commercial Street (Section 2). The stream is also understood to provide a spawning area for fish.

Therefore, the recommended scour protection options should seek to maintain the current habitats in Nant Cylla and structures provided as part of the solution should support fish passage where required. Further consultation should be undertaken with NRW and the Council's biodiversity officers to confirm the preferred option and as the design develops.

Discussions thus far with the LLFA have highlighted that options that are sustainable / environmentally friendly are favoured where practically possible; and that the preferred option taken forward to construction will not require SAB approval, only Consent to work in an ordinary watercourse.

Proposed options will require engineering works within the stream. There are water quality risks associated with potential silt displacement and the use of imported and potentially hazardous materials. Water quality risks will need to be considered early in the design process and mitigated during the works using appropriate construction methods and temporary works.

5.5 UTILITIES

Utility record plans were obtained by CCBC using "Linesearch Before U Dig" and supplied to WSP. At this stage the information supplied is indicative only and should be confirmed as the design is developed. The exact locations of all statutory undertaker apparatus should be determined and confirmed prior to any works commencing on onsite.

Th utility record plans obtained are included in Appendix A.

The following utilities providers have confirmed that they have assets within the study area:

Dwr Cymru / Welsh Water:

- A rising main is located between the back of properties on Commercial Street and the west bank of Nant Cylla in the gardens of the properties. The rising main runs from Commercial Street culvert to the River Rhymney.
- Rising mains cross the Nant Cylla at three separate points at the downstream end of the watercourse (in Section 3). All rising mains appear to converge at a point south of the White Rose Cottages' garden before crossing the River Rhymney.

Western Power Distribution:

- Three low voltage overhead lines cross the Nant Cylla approximately to the rear of No 26 Commercial Street. On the east bank of the watercourse there is an external PME (Protective Multiple Earthing) following which the power lines are buried and carry on towards the school grounds.

6 SCOUR PROTECTION STRATEGIES

6.1 INTRODUCTION

The Nant Cylla in the study area is channelized and laterally constrained by the existing urban environment and scour protection structures. In conjunction with the steep bed slope this creates a watercourse environment characterised by high flow velocities and increased scour effects. In its current state the Nant Cylla watercourse has limited scope for dissipating energy laterally and is therefore dissipating more energy vertically; resulting in the channel becoming ever more incised; undermining existing erosion protection measures and banks; and leading to potential bank collapse overtime.

Scour is a natural phenomenon caused by the erosive action of flowing watercourses on erodible beds. More dramatic scour can occur during high flows however on this reach of the Nant Cylla, it is believed that ongoing scour of sediments is also occurring during low and medium flow conditions.

The effect of the ongoing scour is to undercut the bed and foundations of existing erosion protection structures and this is a significant contributing factor to accelerated deterioration of the bed and banks during high flow conditions. Scour is progressively weakening the stability of the protection structures and failures in high flow conditions can then occur without warning and result in sudden damage.

Therefore, the ongoing scour effects from the low and medium flows are a large part of the problem and the options developed in this study have been considered in this context. Slowing down the scour effects from low to medium flows will contribute to protecting against erosion during high flow conditions.

In developing the approach to managing the prevailing scour in Nant Cylla two principal overarching strategies have been identified: Strategy 1 – Remove Scour Effects; and Strategy 2 – Manage Scour Effects. These two strategies are discussed in the following section.

6.2 STRATEGY 1 - REMOVE SCOUR EFFECTS

Widen the channel and regrade banks to create a more natural channel lessening the effects of scour.

Strategy 1 is considered to be a more sustainable long-term solution as Nant Cylla would be brought back to a more natural state with less or no reactive options or maintenance needed going forward.

In Section 1, the watercourse channel cannot be practically modified to accommodate these changes due to the proximity of existing properties bordering the channel. However, this section could be retained and modified to maximise energy dissipation.

An engineered solution would also be required in Section 2 of Nant Cylla, at the transition from the concrete channel bed in Section 1 to the more natural (less modified) watercourse in Section 3.

Widening the Nant Cylla channel and regrading and slackening the gradient of the east bank in Section 3 would increase the channel flow capacity and thereby reduce the flow velocities and effects of scour in this section. Reduced channel velocities would also support the use of more natural scour protection solutions where needed.

Strategy 1 would require significant land take along Section 3 on the east bank of the watercourse in order to sufficiently widen the channel bed and slacken the bank gradients. As part of this, existing

erosion protection structures would need to be removed from Section 3 and unusable material taken off site.

Where there is insufficient space to widen the channel to eliminate the need for scour protection, partial widening may help to reduce velocities and allow for less engineered protection solutions.

The extent of channel widening and bank regrading required in Section 3 will be dependent on a number of constraints. The effectiveness of the widening in reducing flow velocities and the risk of scour would need to be determined through hydraulic assessment of the Nant Cylla during the design stage.

6.3 STRATEGY 2 – MANAGE SCOUR EFFECTS

Provide engineering solutions within existing watercourse to manage the ongoing effects of scour.

Strategy 2 is considered to be a less sustainable medium-term solution to better manage the effects of scour in the Nant Cylla and would still require reactive maintenance going forward. Under this strategy measures would be provided to limit the extent of undermining and protect the banks and channel bed from erosion within the current footprint of the watercourse.

In Strategy 2, engineering solutions would be kept within the existing watercourse channel and banks, with less land required than in Strategy 1. The options considered in this strategy would seek to reduce the effects of scour, accepting to a degree that scour will continue to occur overtime, through the use of more robust engineering options to better dissipate energy in the channel and manage the flows of water downstream.

The scour effects are currently taking place in Section 2 and in Section 3 the more natural (less modified) section of Nant Cylla. However, there are significant opportunities for energy dissipation interventions in Sections 1 and 2 of the watercourse to remove as much energy as possible from the watercourse upstream. This will mean that less energy will need to be dealt with in Sections 2 and 3, thus adding value to the solutions provided in Section 3.

It should be noted that Strategy 2 would not remove the scour issues completely but will attempt to manage them in-situ. As such, Strategy 2 is not considered to be a permanent / long term solution. The effects of scour will remain in Section 2 and 3 and regular inspections, maintenance and remedial works will be needed overtime.

7 OPTIONS ASSESSMENT

7.1 REMEDIAL WORK TO EXISTING SCOUR PROTECTION STRUCTURES

Notwithstanding the overarching strategy taken forward (Strategy 1 or Strategy 2), there is a requirement to review the condition of existing scour protection structures and undertake remedial works to structures in a poor condition.

A high-level assessment of the remedial interventions required to the existing scour protection structures in each section of Nant Cylla are provided below. More detailed assessments would be required as the proposed scour protection strategy is developed and the interaction between proposed and existing scour protection structures is better understood.

The additional scour protection options considered in each section of the watercourse, outside of the remedial options below, are provided in section 7.2 of this report with a review of these options provided in section 7.3.

SECTION 1:

In Section 1 the watercourse has a concrete apron which forms a continuous scour protection feature with the retaining features at each bank. This provides limited opportunity for scour to develop and as a result the channel bed and bank structures are in reasonable condition (compared with Sections 2 and 3) with no obvious signs of scour defects requiring immediate attention.

There are no visible issues with existing scour protection structures in Section 1. Therefore, no remedial work is currently proposed.

SECTION 2:

Section 2 is highly vulnerable to scour as it is located at the transition between the concrete channel (Section 1) and the natural bed (Section 3). The watercourse is carrying significant energy at this point due to limited opportunity for the watercourse to dissipate energy in the smooth concrete channel section upstream.

Section 2 has been significantly affected by scour. This resulted in the recent failure of existing gabion bank protection. Repairs were carried out in the summer of 2018 with new gabion baskets installed on new concrete foundations and rock (riprap) material placed on the channel bed. However, subsequently the riprap bed material was washed downstream, during a high flow event in October 2018 and a large scour hole has now developed in the channel immediately downstream of the existing concrete weir. In its current state the foundations of the recently installed gabion baskets are exposed to erosion and at risk of being undermined. Further intervention is therefore required to shore up existing scour protection structures in this location.

Remedial engineering works are required to existing scour protection structures in Section 2 to better dissipate the watercourse energy accumulated in Section 1.

SECTION 3:

Section 3 is the least modified section of Nant Cylla in the study area. The watercourse bed is typically formed from native rocks and boulders and material passed downstream from the upper reaches of the watercourse. The east and west banks of the watercourse are typically protected by rock gabions with smaller sections of concrete wall and natural banks. These scour protection measures are

generally in a poor condition. Scour has exposed the concrete foundations and sub soil in places leaving the banks of the watercourse at risk of further undercutting and collapse.

The existing scour protection structures in Section 3 are in generally poor condition. Remedial engineering works are required along the whole of Section 3 to the confluence with the River Rhymney.

7.2 SCOUR PROTECTION OPTIONS

The scour protection options presented here are in addition to the remedial works outlined in section 7.1 of this report.

SECTION 1:

- **No action**

Leave Section 1 of Nant Cylla in its current state. It is currently in good condition with no obvious scour related issues.

- **Removal of concrete channel bed**

Remove existing concrete channel bed in Section 1 to create a more natural watercourse, slow flows and better dissipate water energy.

- **Check weirs**

Provide artificial check weirs / dams in the channel to slow flows and dissipate more energy in Section 1 and reduce the scour effects in Sections 2 and 3 of the watercourse.

- **Energy dissipation structures**

Install energy dissipation structures, or baffles, in the bed and banks of the channel to better replicate the roughness of a natural watercourse and reduce the scour effects in Sections 2 and 3. In-situ or precast baffles could be cast or dowelled in to the existing channel bed and banks to artificially increase channel roughness; typical example shown in Figure 6.

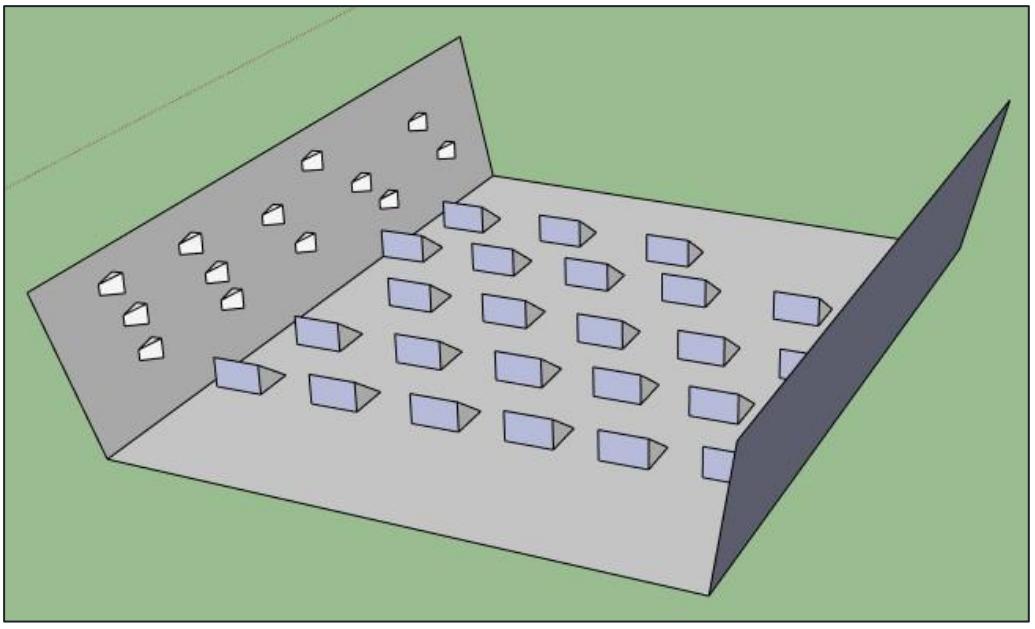

Figure 6 – Example of channel energy dissipation structures

SECTION 2:

- **Replace riprap**

Undertake remedial works to replace the rock riprap material that has been recently washed downstream. Rock specification will need to be reviewed to ensure it can withstand high flow conditions and provide adequate energy dissipation. The feasibility of installing larger size riprap will need to be assessed.

- **Formalise stilling basin**

Formalise basin in between the two recently installed gabion walls, and a transition feature at the downstream end to create a more formal stilling basin structure. This would better manage the effects of scour in Section 2 and downstream to Section 3 and dissipate energy from Section 1.

Further energy dissipation features, such as baffles, could be cast in the proposed bed to help with energy dissipation. The stilling basin could also potentially be enlarged, depending on land take, to further increase energy dissipation potential.

- **Energy dissipation / rock weir**

Retain existing channel width between the gabion walls and install a “rock weir” to connect Section 1 to Section 3. The rock weir would start at the concrete apron/ weir at the downstream end of Section 1 and fall at a low gradient to merge with the natural bed in Section 3. Due to the restricted access to the bed of the watercourse, it may not be possible to bring rocks large enough to resist high velocities. Thus, for constructability reasons, a new concrete channel base would likely be required with smaller rocks / boulders to be cast in-situ within the base to ensure that they are not washed away during high energy flows. This would better manage the effects of scour in Section 2 and downstream to Section 3 and dissipate energy from Section 1 in low to medium flow conditions; a typical section through a rock weir is shown in Figure 7.

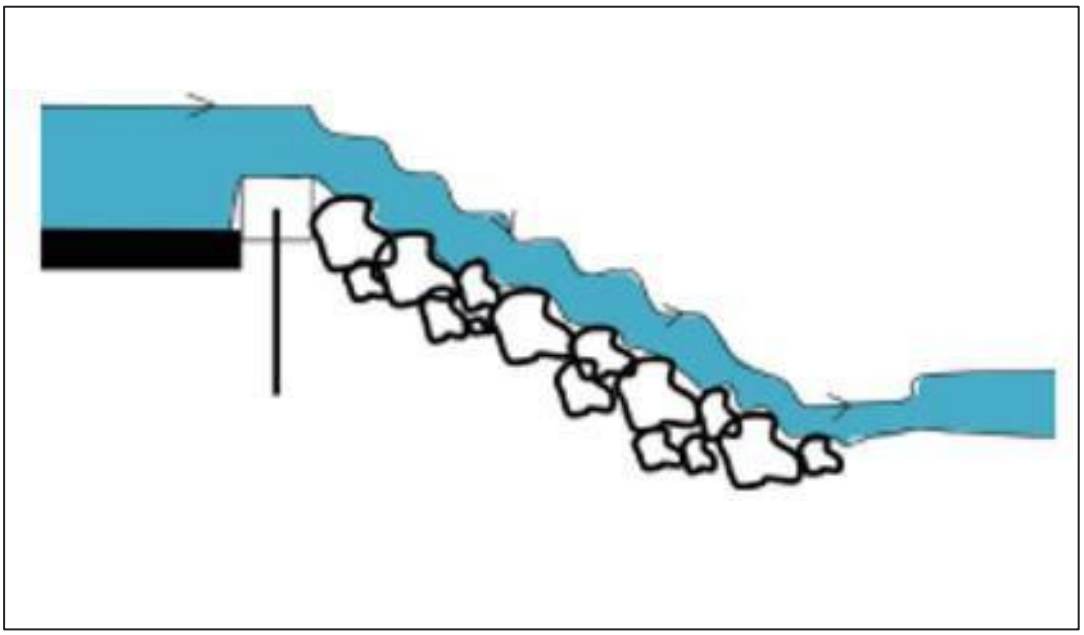

Figure 7 – Typical rock weir section

SECTION 3:

- **Replace existing scour protection**

Undertake works to replace existing scour protection measures like for like and undertake other repairs where necessary to improve the generally poor condition of the existing scour protection in Section 3. This option represents enhanced renewal and replacement of existing scour protection structures over and above the remedial works outlined in section 7.1 of this report.

- **Green engineering**

Install sustainable green engineering measures in Section 3. These could consist of soft engineering techniques such as trees, coir and fibre rolls and matts, log dams and planting.

Green engineering's strengths rely on it establishing through growth and becoming stronger over time as vegetation and roots establish and act as reinforcement. This requires that the watercourse is not subject to high velocity flows while the structures establish.

- **Energy dissipation structures**

Increase the roughness of the channel and dissipate energy through installing engineered structures in the watercourse. By dissipating energy, the scour effects in Section 3 would be reduced, helping to maintain the banks and bed of the watercourse in a better condition. Structures could include:

- Rock weirs at regular intervals. These would lower the gradient of the watercourse, creating "steps", which would contribute to reducing velocities. Flow energy would be dissipated while going over the rock weir structures. Due to the restricted channel access smaller rocks may need to be cast into the watercourse channel on a local concrete base to avoid them being washed out during storm conditions; alternatively, gabion rock mattresses could also be used.
- Incorporate meanders. Meanders could be incorporated within the existing width of the watercourse. Due to the restricted channel access, these would likely need to be created using cast-in boulder structures on a local concrete base, to avoid smaller rocks being washed out during storm conditions. Meanders would contribute to dissipate energy and reduce velocities at the base of the banks thus reducing the ongoing scour effects from lower flows.

Existing erosion protection structures may be retained and repaired in some locations where required. Typical details are shown in Figure 8 and Figure 9.

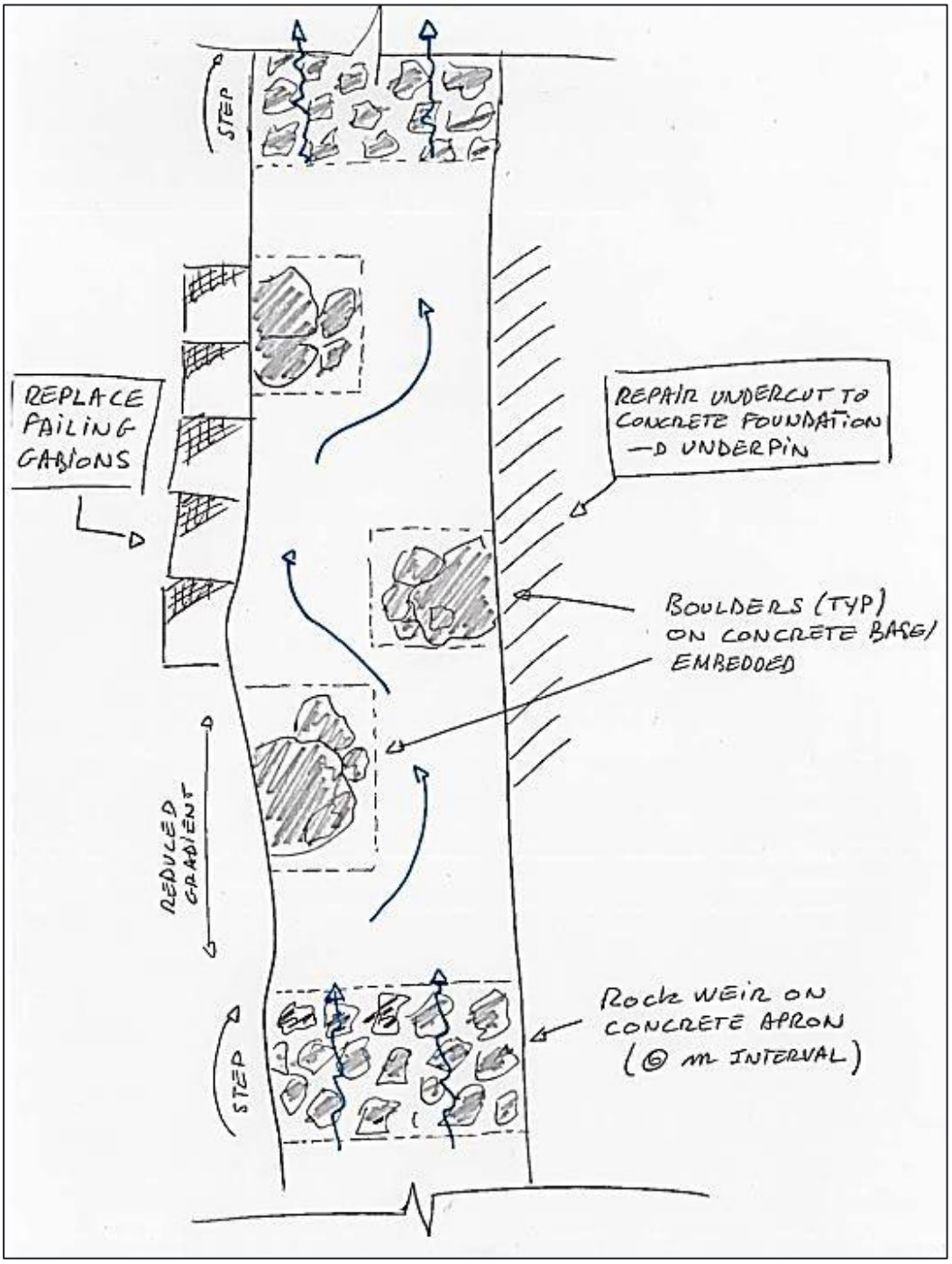

Figure 8 – Energy dissipation structures / rock weirs and meanders (typical)

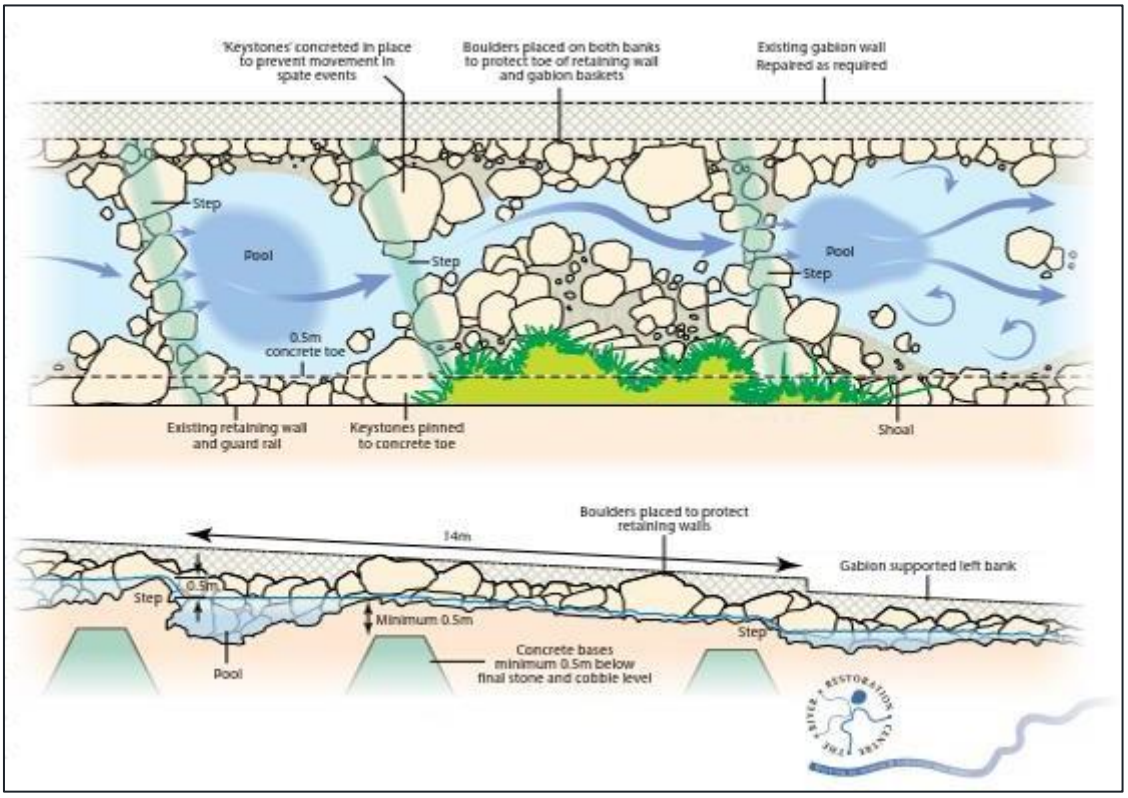

Figure 9 – Rock weirs at intervals (typical)

- **Widen channel and regrade banks**

Widening the channel and re-grading the banks in Section 3 would increase the capacity of the watercourse and reduce velocities and scour effects. Reduced velocities would allow for incorporation of green engineering solutions such as fibre (coir) rolls and matts, log dams and planting, as well as rock weirs and meanders as described above. This strategy is a more sustainable long-term solution with the watercourse being brought back to a more natural state with less or no reactive maintenance required.

This option was discussed with CCBC and it was suggested that channel widening could likely be accommodated on the east bank, provided the land take requirement does not exceed 10m. There may be scope for further land take on this bank, up to say 20m, but this is less likely to be feasible.

The viability of this option is dependent on the width available for widening and the treatment of the bank slopes. The amount of land take available would need to be confirmed to assess whether sufficient for this option to be acceptable.

The extent and effect of widening on scour would need to be assessed at design stage.

Widening of the west bank would not be possible as this land is in private ownership. Thus, erosion protection works would still be required on the west bank to limit erosion. However, velocities would be reduced as a result of the channel widening and scour effects on the west bank of the watercourse would therefore be reduced.

A higher level of scour protection may be required on the western bank of the watercourse at the bend in the channel, at Ty Lloyd / Tyr Llan / Penffordd, as there is a higher risk of scour at this location.

Widening would therefore only take place on the eastern bank of the watercourse (see example of possible channel widening in Figure 10). The land on the eastern bank is understood to be publicly owned. Widening of the channel would extend toward the school and into the adjacent wooded area.

The overall feasibility of widening the channel would need to be confirmed through review of existing ground levels on the east bank of the watercourse and the possibility of re-grading existing ground without causing bank instability will need to be assessed and confirmed. Topographic and ground investigation surveys on the east bank would therefore be required.

The existing area of woodland on the east bank of the watercourse would also need to be removed to allow the channel to be widened. Additional woodland removal may also be necessary to support reprofiling of surrounding ground and provide access for ground work machinery. Areas cleared of vegetation may require replanting on completion of the works.

In this option it may also be possible to retain and reuse some of the excavated material on site, however, it is expected that a large percentage of this material will need to be taken of site. Volumes will be confirmed at design stage.

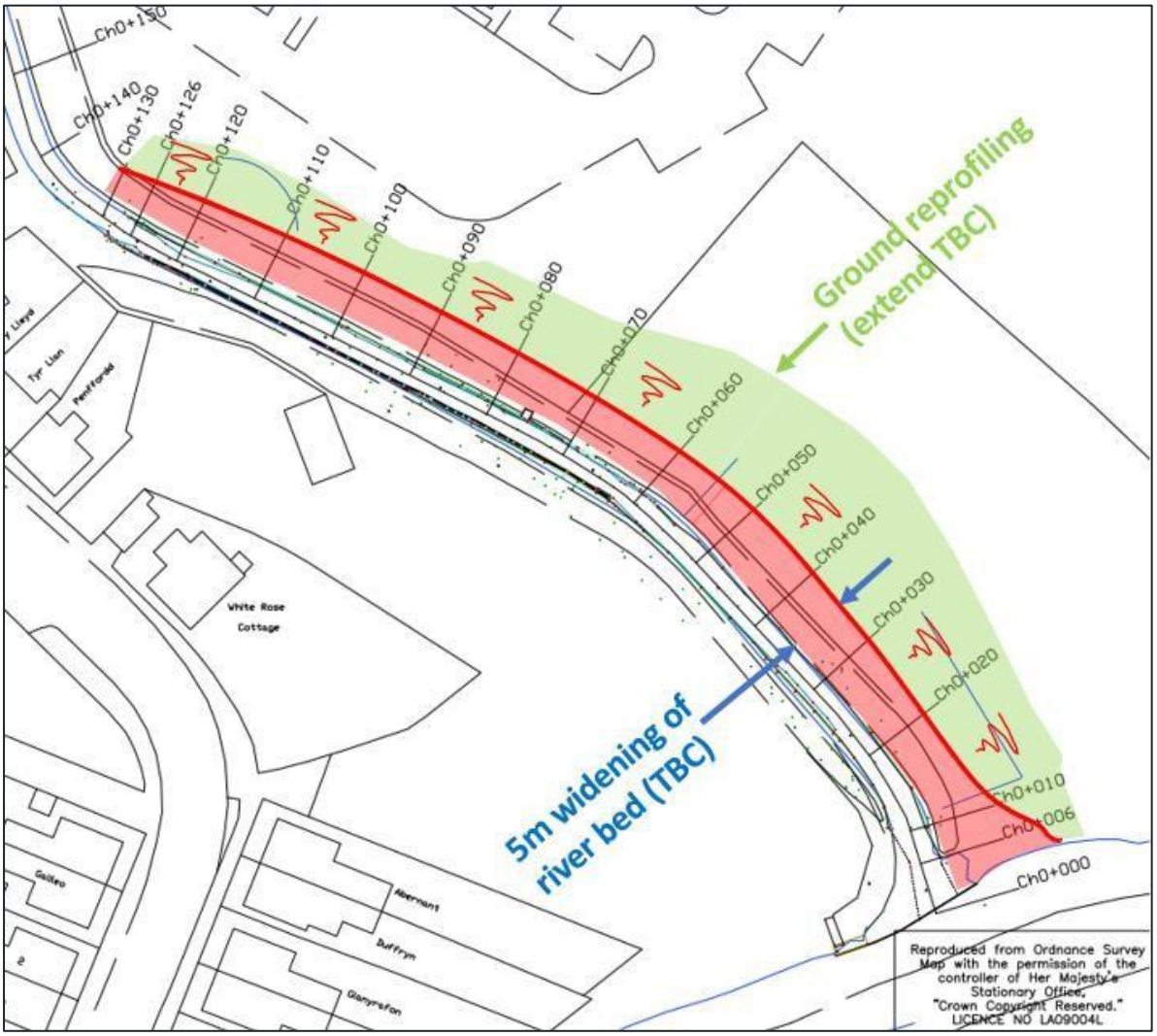

Figure 10 – Example of possible widened channel (channel profile to be confirmed)

7.3 REVIEW OF OPTIONS

This review has been undertaken on the scour protection options presented in section 7.2 of this report. The review considers a range of criteria including technical, environmental, economic, construction and operation and maintenance considerations with each option given an indicative Low, Medium or High rating depending on its suitability.

Option	Advantages	Disadvantages	Rating
SECTION 1			
No action	• No cost • Low risk	• Does nothing to address scour issues downstream • No energy dissipation • Very high energy passed downstream to Sections 2 and 3	**Low**
Remove concrete channel bed	• Higher energy dissipation • Retain more flow in Section 1 of watercourse • Ecological benefit for fish and other flora/ fauna extended up to culvert outlet.	• High cost • Structural risk • Increased scour at existing culvert outlet • Increased potential for bank scour • Access difficult • Manual handling of material • Services may need diverting	**Low**
Check weirs	• Good energy dissipation in low to medium flows • Reduces flow velocities • Provides benefit to downstream sections	• Overtopped in high flow conditions • Structural risk to existing concrete bed • Access difficult • Manual handling of material • Risk of flows backing up in culvert and elevated water level to be assessed. •	**Medium**
Energy dissipation structures to bed and walls	• Good energy dissipation in low to medium flows on base of channel • Reduces flow velocities • Only solution that provides some level of energy dissipation in high flow conditions due to baffle installed at high level on channel walls • Provides benefit to downstream sections • Limited maintenance requirements • Long design life	• Structural risk to existing concrete bed and earth retaining structures to be assessed • Risk of flows backing up in culvert and elevated water level to be assessed. • Access difficult • Manual handling of material •	**High**

Table 1 – Section 1: Review of scour protection options

Option	Advantages	Disadvantages	Rating
SECTION 2			
Replace riprap	• Low cost • Known works access point on east bank due to works undertaken recently	• Limited impact on scour issues downstream • Regular ongoing inspection and maintenance required • Manual handling of material • Size could be restricted by access constraints • Could be washed out with high flows.	**Low**
Formalise stilling basin	• Good energy dissipation in low to medium flows • Reduces flow velocities • Provides some level of energy dissipation in high flow conditions • Provides benefit to downstream sections • Known works access point on east bank due to works undertaken recently • Engineered structure - longer design life	• Moderate cost • Requires additional land take • Risk of scour at transition to Section 3 • Does not enhance natural habitat / aesthetics • Reduced impact in high flows • Manual handling of material • Maintenance required to maintain performance	**Medium**
Energy dissipation / rock weir	• Good energy dissipation in low to medium flows • Can be constructed without additional land take • Reduces flow velocities • Provides some level of energy dissipation in high flow conditions • Provides benefit to downstream sections • Known works access point on east bank due to works undertaken recently • Engineered feature - longer design life • Less scour risk on transition to Section 3 • Replicates natural features	• Moderate cost • Reduced impact in high flow conditions • Manual handling of material • Condition of existing gabions to be monitored	**High**

Table 2 – Section 2: Review of scour protection options

Option	Advantages	Disadvantages	Rating
SECTION 3			
Replace existing scour protection	• Utilises and improves existing scour protection structures • Natural bed of watercourse retained in current state	• Moderate cost • Has limited impact on energy dissipation and passes problems downstream • Limited design life • Regular inspection and maintenance required • Access difficult • Manual handling of material	**Low**
Green engineering	• Utilises soft engineering / natural materials • Multiple ecological benefits to fish and other flora/ fauna in watercourse • Provides space for the growth of vegetation when placed	• Moderate cost • Requires relatively high levels of monitoring • Strong only once fully established • Risk of damage before fully established • Reduced impact in high flow conditions • Access difficult • Manual handling of material	**Low**
Energy dissipation structures (rock weirs and meanders at intervals) - In combination with repairs to existing scour protection structures.	• Good energy dissipation in low to medium flows • Reduces bed slope (creates steps) - reduces flow velocities • Scour effect reduced along Section 3 • Reduced detrimental effect on natural habitat / environment • Flexibility in construction methods/ techniques	• Moderate cost • Requires careful consideration of placement of structures so as not to increase scour risk elsewhere • May require initial monitoring regime to confirm effectiveness • Regular inspection and maintenance required • Access difficult • Manual handling of material • Services may need diverting	**Medium**
Widen channel and regrade banks in combination with rock weirs, meanders and green engineering	• Increases watercourse capacity • Reduces velocities and scour effects in channel • Increased potential for green engineering solutions • Beneficial for ecology and aesthetic of the watercourse • Longer term solution • Less or no reactive maintenance	• High cost • Significant land take required • Removal of established woodland • Existing services to be diverted • Large amount of material to be removed and disposed of • Significant and heavy plant movements required • Access difficulties compounded by level of access required • Services may need diverting	**Medium**

Table 3 – Section 3: Review of scour protection options

8 RECOMMENDED STRATEGY AND PREFERRED OPTIONS

The recommended scour protection strategy for Section 1 and 2 of Nant Cylla is Strategy 2:

Providing engineering solutions within existing watercourse to manage the ongoing effects of scour.

The engineering solutions in Section 1 and 2 would be kept within the existing channel and banks and will aim to dissipate as much energy as possible within the upstream section of the watercourse; so that less energy will be passed downstream to Section 3.

The recommended scour protection strategy for Section 3 of Nant Cylla is Strategy 1.

Widen the channel and regrade banks to create a more natural channel lessening the effects of scour.

This approach will reduce the flow velocities and effects of scour in Section 3. The reduced channel velocities would also support the use of more natural scour protection solutions where needed. Whilst there are significant delivery constraints and risks with this strategy it is considered the benefits of a more sustainable long term solution make this worthwhile.

The preferred engineering options to use in line with the strategies recommended are detailed below. Reference should also be made to the supporting options plan included in Appendix B.

SECTION 1:

Although there are no presenting scour effects in this section of Nant Cylla, the smooth channel bed and wall surfaces contribute to increase the velocity of the water as it flows downstream. The preferred option for Section 1 is to reduce the amount of energy passed on to the downstream sections of the watercourse.

The existing concrete channel bed and walls provide an opportunity to install energy dissipation structures relatively easily. Such structures will maximise the potential to reduce channel velocities in this section and decrease the energy passed downstream to Sections 2 and 3.

The recommended option in Section 1 is to install energy dissipation structures or baffles tied in to the bed and banks of the existing concrete lined channel.

SECTION 2:

This section of Nant Cylla is subject to intense energy due to fast flowing water which currently enters it from Section 1 upstream. The preferred option for Section 1 will reduce the energy in the watercourse when it reaches Section 2. The preferred option for Section 2 is to dissipate as much of the remaining energy as possible prior to it flowing downstream to Section 3, the more natural section of the watercourse, where the effects of scour are significant.

Previous riprap options have failed when subjected to the high energy flows in flood conditions, which is likely due to restrictions on the maximum stone size that could be used. Due to the restricted channel access it is impractical to import large diameter rocks. Thus, a more robust engineering solution is currently favoured with rocks cast into a concrete channel bed.

The recommended option in Section 2 is to install an energy dissipation structure. The structure should be a rock weir type with embedded boulders.

It is also recommended that the channel is widened at this location, if possible, to allow a larger energy dissipation structure to be installed and further reduce the energy within the watercourse before it passes downstream to Section 3.

SECTION 3:

This section of Nant Cylla has more natural features and is therefore susceptible to scour. Previous erosion protection measures used have failed over time due to the high channel velocities and high levels of energy created upstream; which are sustained by the narrow channel bed and steep banks.

Widening of the channel in Section 3 would reduce flow velocities and scour effects significantly. This would also allow more natural engineering solutions to be implemented. The watercourse would be brought back to a more natural state with less maintenance required over the longer term.

The recommended option for Section 3 is to widen the channel in combination with additional scour protection measures. The measures will include:

- **Widen channel bed and regrade eastern bank**

Widening the channel and re-grading the banks to increase the capacity of the watercourse and reduce velocities and scour effects.

- **Renewal of existing scour protection on western bank**

Enhanced renewal and replacement of existing scour protection measures, undertaking repairs where necessary, to improve the condition of the existing scour protection.

- **Incorporate natural scour protection measures**

The reduced channel velocities will allow more natural engineering solutions to be utilised. Rock weirs and meanders will be replicated and where appropriate sustainable green engineering measures will be installed, such as: trees, coir and fibre rolls and matts, log dams and planting.

9 OPTIONS COST REVIEW

As requested by CCBC two high level cost estimates have been prepared.

Cost estimate for Strategy 1: This includes costs for the preferred options in Section 1 and 2; the cost for widening the channel bed and regrading the eastern bank in Section 3 and incorporating natural scour protection measures; and enhanced renewal of existing scour protection on the western bank of the watercourse in Section 3 where there is no available land to regrade the bank.

Cost estimate for Strategy 2: This includes costs for the preferred options in Section 1 and 2; and enhanced renewal of existing scour protection on the eastern and western bank of the watercourse in Section 3.

The costs presented at this stage of the study are preliminary estimates only. These should be reviewed during design development, once the extent of widening achievable in Strategy 1 has been confirmed; and further ground investigations, surveys and consultation has taken place. The estimates have been developed with reference to standard price books (CESMM) and estimates for similar works on previous schemes. An allowance is included for identified risk items, however no specific Optimism Bias is included at this stage.

A summary of the cost estimates for Strategy 1 and 2 are provided in Table 4 and 5 respectively. A more detailed breakdown for each strategy is provided in Appendix C.

Item	**Estimated Cost**
Preliminaries	£22,983
Section 1: Energy dissipation baffles	£22,392
Section 2: Energy dissipation rock weir	£22,949
Section 3: Channel widening, regrade eastern bank, renewal of existing scour protection (west bank), rock meanders and green engineering	£306,634
Contingencies	£93,739
Design & Site Supervision	£93,739
Risk Allowance	£240,000
Total Estimated Works Costs	**£802,436**

Table 4 – Cost Estimate for Strategy 1

Item	Estimated Cost
Preliminaries	£17,006
Section 1: Energy dissipation baffles	£22,392
Section 2: Energy dissipation rock weir	£22,949
Section 3: Renewal of existing scour protection (east and west banks)	£106,426
Contingencies	£42,193
Design & Site Supervision	£42,193
Risk Allowance	£95,000
Total Estimated Works Costs	**£348,160**

Table 5 – Cost Estimate for Strategy 2

10 RECOMMENDATIONS

10.1 TO FINALISE THIS STUDY AND CONFIRM PREFERRED OPTION

- Consult with Natural Resources Wales (NRW) to review recommended option and establish WFD requirements in relation to fish passage;
- Confirm the land available on the east bank of the watercourse for widening the channel in Section 3 and consult with landowners (Lewis Girls' School) on land take and access;
- Confirm position in relation to private landownership on west bank of watercourse and encroachment; and associated means of access to the channel.
- Consult with NRW and CCBC to determine the expected planning and consent requirements for the scheme.

10.2 TO PROGRESS DESIGN

- Undertake hydraulic assessment of preferred option to confirm hydraulic parameters for detailed design;
- Undertake further surveys (topographic, condition, ecological) and Ground Investigations to support the detailed design;
- Undertake intrusive investigations to confirm the structural characteristics of the concrete lined channel in Section 1 and verify its suitability for the installation of proposed energy dissipation baffles;
- Confirm temporary and permanent accesses to the watercourse for the construction phase and to support ongoing operation and maintenance;
- Consult statutory undertakers with assets in the vicinity of the proposed works to identify whether diversions will be necessary.

Appendix A

UTILITY RECORDS

Appendix B

PREFERRED OPTION PLAN

Appendix C

OPTION COST ESTIMATES

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