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River Vyrnwy River Restoration Flood Consequences Assessment DRAFT Report

Canal and River Trust



Quality information

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Canal Failure

Canal failure occurs when a canal system breaches or overtops, either due to intense rainfall or structural issues unrelated to weather. These events can be dangerous, as they release large volumes of water at high speed. Failures typically affect canal sections elevated above the surrounding ground, especially where structures or watercourses pass beneath. The canal's design influences flooding, with an initial rapid flow peak followed by a slower reduction as the canal's capacity limits how much water can escape at the breach point.

Fluvial Flooding

Fluvial flooding happens when a river exceeds its capacity, causing water to overflow its banks. It can also occur if downstream obstructions, such as blockages or structures, restrict water flow, creating a backup that overflows the riverbanks. Urban development on natural floodplains worsens the problem by confining the river's path and reducing natural drainage.

Groundwater Flooding

Groundwater flooding occurs when rising water tables cause water to emerge at specific points or across wider areas, inundating the surface. This type of flooding can be prolonged and often impacts low-lying areas or underground spaces like basements and underpasses. In urban settings, it can lead to significant property damage, environmental risks, and issues with ground stability.

Reservoir Failure

Reservoir failure involves the sudden release of large amounts of water, often moving at high speeds, leading to deep and extensive flooding. While such events can be catastrophic, they are highly unlikely due to strict management under the Reservoirs Act 1975, which applies to reservoirs holding over 25,000 cubic meters of water above ground level. Flood risks are modelled using the Environment Agency's reservoir inundation maps to identify **potential maximum flood extents.**

Sewer Flooding

Sewer flooding happens when incoming water exceeds the sewer system's capacity or when blockages or collapses reduce capacity. In surface water sewers that discharge into watercourses, high water levels in the receiving watercourse can cause backflows, leading to surcharges at ground level through drains or manholes. This type of flooding can damage properties and roads and pose health risks due to contaminants in the floodwater.

Surface Water Runoff

Surface water runoff refers to water flowing over the ground before entering drainage systems. It typically occurs during heavy rainfall that exceeds the ground's infiltration capacity. Runoff is common on slopes or impermeable surfaces, whether naturally due to soil and geology or as a result of development, such as paved areas and roads.

Tidal Flooding

Tidal flooding occurs when high tides coincide with low-pressure storm systems, raising sea and tidal water levels that overwhelm coastal and river defences. Strong winds can exacerbate this by pushing water further inland along tidal river basins. Rising sea levels are expected to make tidal flooding more frequent and severe in the future.



1.1 Background and Objectives

The Canal and River Trust commissioned Dynamic Rivers to undertake a Flood Consequences Assessment (FCA) to support works for a river and floodplain restoration optioneering and design for the River Vyrnwy at Llanymynech (SJ 25664 19718 – SJ 26145 19429). The site extent is shown in Figure 1.1.



Figure 1.1. Restoration area on the River Vyrnwy Floodplain. (Copyright Google Earth 2024.)

The site is shown to be located within Flood Zone C2 (an area without significant flood defence infrastructure, Figure 1.2) on the Development Advice Map and Defended Flood Zone 2 and 3 (Medium and High Probability, Figure 1.3) on the NRW Flood Map for Planning, therefore a FCA is required to support the proposed restoration works.





Figure 1.2. TAN15 Development Advice Map



Figure 1.3. NRW Flood Map for Planning



The aim of this report is to assess the potential flood risk to the site, the impact of the proposed restoration on flood risk elsewhere, and the proposed measures which could be incorporated to mitigate the identified risk. This report has been prepared in accordance with the guidance contained in Planning Policy Wales (PPW) and Technical Advice Note 15 (TAN15): Development and Flood Risk.

This FCA has been supported by, and should be read in conjunction with the hydraulic modelling presented in the Optioneering and Design Report (Dynamic Rivers December 2024).

1.2 Approach / Scope of Works

The scope of works has been as outlined below for this FCA:

- Undertake a site reconnaissance visit to assess current layouts, levels and surrounding land uses. This work was undertaken at the optioneering and design phase, prior to preparation of this FCA;
- Assess flood risk from all sources using best available information, including review of NRW data and mapping, topography and historical records;
- Assess previous relevant available third-party studies, local authority plans or strategies;
- Advise on flood mitigation measures (where necessary);
- Prepare FCA report.

This report takes into account the following national and local policies:

- Planning Policy Wales (PPW) (2018)¹;
- Technical Advice Note 15: development and flood risk (TAN15) (2004)²;
- CL-03-16 Flood Consequence Assessments: Climate change allowances.³
- Shropshire Council Local Development and Planning Policies.

1.3 Sources of Information

The following sources of information have been reviewed and assessed for the purpose of this FRA:

- NRW online flood maps⁴;
- Shropshire Council Level 1 Strategic Flood Risk Assessment (SFRA).

1.4 **Project Limitations**

The NRW Climate Change Guidance was updated in 2016, therefore it is possible that the data shown on the Development Advice Maps and the NRW Flood Map for Planning does not take into account the implications of climate change. For sites on the periphery of defended areas and/ or in close proximity to Flood Zone 3, further work may be required to more accurately determine the flood risk.

¹ https://gov.wales/Sites/default/files/publications/2019-02/planning-policy-wales-edition-10.pdf

² https://gov.wales/Sites/default/files/publications/2018-09/tan15-development-flood-risk.pdf

³ https://gov.wales/climate-change-allowances-and-flood-consequence-assessments-cl-03-16

⁴ https://flood-map-for-planning.service.gov.uk/



2 Site Description

2.1 Existing site conditions

Google Aerial Imagery (Figure 1.1 above) shows that the site comprises an area of floodplain associated with the River Vyrnwy. The floodplain landcover is mostly improved grassland and is characteristic of overlydrained river systems with little colonising wetland habitat. The River Vyrnwy forms the northern and eastern boundary to the site. The Montgomery Canal, adjacent agricultural land and grounds associated with the historic Pentreheylin Hall form the southern boundary, with an overflow ditch from the Montgomery Canal forming the western boundary.

A topographic survey was supplied by the client (Figure 2.1), this shows the site slopes gradually west to east from approximately 65.9 to 65.7m AOD. Highlighted within the topographical survey are two lower areas on the eastern boundary draining towards the River Vyrnwy, these are paleochannel features and form the locations to target the proposed river restoration works.



Figure 2.1. Client provided topographic survey extent. Two paleochannel features are highlighted.

The nearest watercourses are the main River Vyrnwy and the canal drainage ditch, both forming boundaries to the site. The Nant Melin, a small tributary of the Vyrnwy, is approximately 250m east from the site. The nearest artificial waterbody is the Montgomery Canal which forms part of the southern boundary to the site.

The site is underlain by superficial deposits (Figure 2.2) comprising river alluvium. This was confirmed across the site from the client GI, supplied in March 2024 which indicated an unconsolidated mixture of silts, clays, sands and gravels.



Figure 2.2. British Geological Survey (BGS) 1:50,000 superficial deposit mapping.

According to the NRW's Aquifer Designation data (Figure 2.3), obtained from BGS's online mapping November 2024, the superficial deposit is classified as a Secondary A Aquifer.



Figure 2.3. Aquifer designation mapping for the site (British Geological Survey).

Secondary A Aquifers are 'permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers'. These are generally aquifers formerly classified as minor aquifers. Any available groundwater from this Secondary A aquifer will contribute to sustaining wetland habitat within the proposed river restoration scheme at the site.

The NRW's 'Source Protection Zones' data (Figure 2.4), obtained from DataMap Wales online mapping November 2024, indicates that the Site is not located within a Groundwater Source Protection Zone.



Figure 2.4. DataMap Wales source protection zone map at the site.

The proposed river restoration comprises excavating two large backwater features, including cut channels connecting with the River Vrynwy on the eastern boundary of the site. Within these backwater channels are branch or 'chute' channels as well as localised point bar and island features, these features provide habitat diversity. On the western boundary, two chute channels will be created by shallow excavation, to direct water towards the backwater features. The ditch will be infilled to a level just below the chute levels so that any overflow from the canal is diverted through the backwater features rather than discharged directly to the River Vrynwy. This will provide temporary attenuation of canal overflows supporting the hydrological function of any associated wetland habitat. A kested hedge is created along the southern boundary to reuse some arisings and provide a diverse hedgerow habitat, this will be planted with a native seed mix as specified within the design drawings. The kested hedge will be formed by creating a small, low-level bund, this will divert higher velocity flow away from the third-party land. The draft construction layout is provided in Figure 2.5.



Figure 2.5. Draft construction layout.

The proposals are for localised river restoration features, there will be no net increase in hard standing area as all earthworks will be completed with natural material. Post-construction, wetland vegetation is expected to colonise the features, with an aquatic plant species *Lurionim natans* being transplanted from the Montgomery Canal into the area. There will be a permanent increase in wetted extent with 1ha of ponded water within the features at low (summer) flow, this will increase in extent with larger seasonal river flow.

The restoration is water compatible and will form part of the functional river system once completed.

A net excavation of approximately 63,000m³ of alluvial material is proposed to complete the works. Management of spoil is being undertaken by the client; however, it is proposed to remove all material from identified flood zones aside from the kested hedge and ditch infills.



Relevant Planning Policy and Guidance

3.1 Introduction

The aim of this section of the report is to discuss the main aspects of the local and national planning policies that are relevant to any proposed development on the site and relevant guidance and legislation.

3.2 Assessment of Flood Risk

The flood risk from fluvial (Main Rivers) and coastal flooding is assessed using the Welsh Government, TAN15, Development Advice Maps and the NRW 'Flood Map for Planning' (flood risk from rivers or the sea).

The Development Advice Maps define three development advice zones as follows:

- Zone A: Considered to be at little or no risk of fluvial or tidal/coastal flooding.
- Zone B: Areas known to have been flooded in the past evidenced by sedimentary deposits.
- Zone C: Based on Environment Agency extreme flood outline, equal to or greater than 0.1% (river, tidal or coastal) (i.e.: greater than 1 in 1,000 chance of flooding in any one year). Zone C is divided into C1 and C2.
 - C1 is areas of the floodplain which are developed and served by significant infrastructure, including flood defences.
 - C2 is Areas of the floodplain without significant flood defence infrastructure.

The NRW 'Flood Map for Planning' defines three zones of different flood risk, the third of which is subdivided into two categories:

- Zone 1 "Low probability of flooding" This zone comprises land assessed as having a less than 1 in 1,000 annual probability of river or sea flooding (<0.1%);
- Zone 2 "Medium probability of flooding" This zone comprises land assessed as having between a 1 in 100 and 1 in 1,000 annual probability of river flooding (1% 0.1%), or between a 1 in 200 and 1 in 1,000 annual probability of sea flooding (0.5% 0.1%) in any year;
- Zone 3a "High probability of flooding" This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year; and
- Zone 3b "Functional floodplain" A sub-part of Zone 3, this zone comprises land where water has to flow or be stored in times of flood. This zone is not normally included within the national Flood Map for Planning and is calculated where necessary using detailed hydraulic modelling.

3.3 Planning Policy Wales

Development Vulnerability Classification

The proposed river and floodplain restoration is considered to be 'water compatible' development in accordance with Figure 2 of the Welsh Government's Technical Advice Note 15 – Development and Flood Risk (TAN15).



TAN15 states that water compatible development can be considered in Flood Zone C2.

Although the proposed river restoration is considered water compatible and therefore acceptable within Flood Zone C2, hydraulic modelling work has been utilised to assess the performance of the design and to ensure this does not impact flooding elsewhere. This modelling provides evidence that no buildings associated with the river restoration are situated in the 0.1% AEP fluvial flood extent and that there is no increase to flood risk off-site associated with the proposals. Therefore, for completeness, hydraulic modelling works are discussed below to support this FCA.

3.4 Local Policy

The Shropshire Council Local Plan Core Strategy contains the following policy relating to flood risk and water management:

Policy CS18: Sustainable Water Management

'Developments will integrate measures for sustainable water management to reduce flood risk, avoid an adverse impact on water quality and quantity within Shropshire, including groundwater resources, and provide opportunities to enhance biodiversity, health and recreation, by ensuring that:

- Planning applications and allocations in the Site Allocations and Management of Development (SAMDev) DPD, are in accordance with the tests contained in PPS25, and have regard to the SFRAs for Shropshire;
- New development is designed to be safe, taking into account the lifetime of the development, and the need to adapt to climate change. Proposals should have regard to the design guidance provided in the SFRAs for Shropshire;
- All development within local surface water drainage areas, as identified by the Water Cycle Study, and any major development proposals, demonstrate that
- Surface water will be managed in a sustainable and coordinated way. Proposals will be supported by either a Surface Water Management Statement or Plan, depending on the scale of the development;
- All developments, including changes to existing buildings, include appropriate sustainable drainage systems (SUDS) to manage surface water. All developments should aim to achieve a reduction in the existing runoff rate, but must not result in an increase in runoff;
- New development improves drainage by opening up existing culverts where appropriate;
- Proposals within areas of infrastructure capacity constraint, as identified by the Water Cycle Study and the Implementation Plan, and any major development, demonstrates that there is adequate water infrastructure in place to serve the development;
- New development enhances and protects water quality, including Shropshire's groundwater resources;
- New development, including changes to existing buildings, incorporate water efficiency measures, in accordance with the sustainability checklist in Policy CS6, to meet the water efficiency objectives within the Shropshire Water Cycle Study to protect water resource es and reduce pressure on wastewater treatment infrastructure'

Policies within the Local Plan Core Strategy are focused on ensuring development do not adversely impact water quality and flooding. Temporary water storage will occur within the proposed backwater features, either during fluvial flood or from the overtopping Montgomery Canal, this can be considered as a minor net benefit. The principle of the restoration is to create a functional and naturalised river and wetland habitat,



contributing to biodiversity and associated water quality benefits and, is therefore considered to be compliant with CS18.

3.5 Climate Change

Although the river restoration is considered acceptable within Zone C2, hydraulic modelling has been used to develop the design. For due diligence a climate change uplift has been applied to the 1% AEP flood event. A 25% (central estimate for change anticipated by 2080s) Climate Change (CC) allowance for flood risk has been applied based on published tables by the Welsh Government for the Severn Basin River District.

3.6 Tidal Flood Risk

The site is situated at a minimum of 65m AOD and is significantly above sea level. Therefore, there is no risk from tidal flooding.

3.7 Fluvial Flood Risk

The nearest watercourse is the River Vyrnwy which is located on the northern and eastern boundaries of the site. Other watercourses in the area include the Nant Melin, however this is approximately 250m downstream from the site and the small ditch to western boundary which does not have a permanent source of flow.

The site is situated within Flood Zone C2 (Figure 1.2 above).

Fluvial flooding will occur when the River Vyrnwy overtops its banks during or following a large rainfall event. The site is known to flood with drone videos available on YouTube⁵⁶ showing flooding in January 2024 and previously in 2023 and 2022, the entire valley is at frequent flood risk. It is an important requirement for the river restoration to function naturally, that backwaters are inundated infrequently, this is not considered a flood risk, rather, a functional and connected backwater system.

The NRW 'Historical Flood Map' (Figure 3.1) indicates that the site was inundated during 1998, 2000, 2002 and 2004, however, as per drone footage available on YouTube, more recent flooding is known to have occurred but may not yet be recorded by NRW.

⁵ https://www.youtube.com/watch?v=nfnTUVDY8zs&t=8s

⁶ https://www.youtube.com/watch?v=EP8zCz8JvpY&t=26s



Figure 3.1. Historic Flood Outlines at the site from DataMap Wales.

Modelled Flood Data and Climate Change

Estimated flood levels for the River Vyrnwy have been obtained through hydraulic modelling undertaken by Dynamic Rivers in 2024, the hydrology approach and hydraulic model build are summarised in the optioneering and design report provided in Appendix A. As the site topography and channel gradient vary from west to east, so do predicted flood levels across the site. A summary of the modelled flood levels at the upstream, central and downstream site locations along the Vyrnwy is provided in Table 3.1. Figures 3.2 through 3.5 show modelled flood depths across the site for baseline and restored conditions.

The Welsh Government Draft 'Flood Consequence Assessments: Climate Change Allowances' guidance states that water compatible development is permitted within Flood Zone C2. However, as hydraulic modelling has been undertaken to inform the design, climate change has been investigated as well. A climate change uplift has been applied to the 1% and 0.1% AEP flood events. A 25% (central estimate for change anticipated by 2080s) Climate Change (CC) allowance for flood risk has been applied based on published tables by the Welsh Government for the Severn Basin River District.



		Maximum Water Level (m AOD)				
Grid reference	Description	5% AEP*	1% AEP	1% AEP CC**	0.1% AEP	0.1% AEP CC**
325658 E 319708 N	Upstream Baseline	66.37	66.57	66.74	66.98	67.18
	Upstream Restored	66.36	66.55	66.72	66.96	67.16
325945 E 319670 N	Centre Baseline	66.07	66.27	66.42	66.64	66.84
	Centre Restored	66.06	66.25	66.40	66.63	66.82
326132 E 31944 N	Downstream Baseline	65.87	66.10	66.28	66.51	67.72
	Downstream Restored	65.88	66.12	66.30	66.52	66.73

Table 3.1. NRW Estimated Flood Levels for the baseline and restored conditions of the site.

*Annual Exceedance Probability

** Climate Change

As shown in Table 3.1 and Figure 3.2, the site is fully inundated during a 5% AEP flood event and greater, with the flood depths across the site shown to be typically 0.5-1m, with areas around the paleochannel features up to 2m. As the whole valley extent is inundated, flood extent does not increase significantly with greater return periods, however flood depth does. For the 1% AEP event (Figure 3.6) flood depths are typically 0.7-1.0m across the site and up to 2m in the paleochannel features. For the extreme 1% AEP+(CC) and 0.1% AEP events, depths are similar and typically in excess of 1m across the site and, the paleochannel features experience flood depths in excess of 2m.

When considering the proposed river restoration, there is a negligible change to predicted flood levels away from the site. Local to the site there are minor reductions in predicted maximum flood level at the upstream and central areas of the site (10-20mm) for the majority of modelled AEP's (Table 3.1). The reductions are caused by extra flood storage capacity associated with the large backwater features. There are minor increases in modelled water level, equating to an increase of 10-20mm depth at the downstream extent of the site. This minor increase in depth occurs as flow is released from the backwater slightly more energetically than the baseline condition, this is very localised to the area at the downstream extent of the southern backwater and not considered an increase in flood risk. Flood depths across the floodplain area of the site are comparable with baseline, with minor localised changes generally small reductions in extent.

Within the created backwater features predicted flood depths increase compared with the existing site paleochannel features, as is intended with the design. Values are around 2.6-3.2m during the 5% AEP, 2.7-3.4m during the 1% AEP, 2.8-6.3m during the 1% AEP+CC, 2.8-3.7m during the 0.1% AEP event and 3.7-4.1m in the 0.1% AEP+CC.





Figure 3.2. 5% AEP predicted flood depths at the site during baseline (top) and restored conditions (bottom). White polygon represents site boundary with depth range classification inset to the right.





Figure 3.3. 1% AEP predicted flood depths at the site during baseline (top) and restored conditions (bottom). White polygon represents site boundary with depth range classification inset to the right.





Figure 3.4. 1% AEP+(CC) predicted flood depths at the site during baseline (top) and restored conditions (bottom). White polygon represents site boundary with depth range classification inset to the right.





Figure 3.5. 0.1% AEP predicted flood depths at the site during baseline (top) and restored conditions (bottom). White polygon represents site boundary with depth range classification inset to the right.





Figure 3.6. 0.1% AEP+CC predicted flood depths at the site during baseline (top) and restored conditions (bottom). White polygon represents site boundary with depth range classification inset to the right.



Flood Velocity

Flood velocity across the site is typically 0.4-0.8m/s during the 5% AEP flood event (Figure 3.7) under baseline site conditions. During restored conditions, there is slightly more energetic flow through the backwater features, this is caused by flood flow being concentrated through the backwater features under restored conditions whereas under baseline conditions this flow dissipates across the floodplain. There is an associated increase in maximum velocity to 1.2m/s within the northern backwater. This increase in velocity during flood conditions will reduce the amount of fine sediment deposited into the backwaters, providing a degree of self-cleansing and helping to sustain designed capacity of the features. During the 1% AEP predicted flood (Figure 3.8) the maximum velocity through the northern backwater increases from 0.8m/s to 1.0m/s, elsewhere velocity is typically 0.4-0.8m/s. During the extreme 1% AEP+CC, 0.1% AEP and 0.1% AEP+CC events (Figure 3.9-3.11), for the restored site conditions, maximum velocity through the northern backwater is 1.5m/s, elsewhere velocity is typically 0.5-1m/s.

The site is at significant existing fluvial flood risk. The combination of predicted flood depth and velocity at the site are considered hazardous to life during all predicted flood events. This is true for the baseline condition without any river restoration features modelled. Whilst the proposed river restoration increases both flood depth and velocity at the site, this is an intended function of the restoration and, there is no increase in flood risk at the site that affects people or property. The site will remain privately owned following completion of the restoration works and should not be accessed during flood conditions.





Figure 3.7. 5% AEP predicted flood velocity at the site during baseline (top) and restored conditions (bottom). White polygon represents site boundary with depth range classification inset to the right.





Figure 3.8. 1% AEP predicted flood velocity at the site during baseline (top) and restored conditions (bottom). White polygon represents site boundary with depth range classification inset to the right.





Figure 3.9. 1% AEP+CC predicted flood velocity at the site during baseline (top) and restored conditions (bottom). White polygon represents site boundary with depth range classification inset to the right.





Figure 3.10. 0.1% AEP predicted flood velocity at the site during baseline (top) and restored conditions (bottom). White polygon represents site boundary with depth range classification inset to the right.





Figure 3.11. 0.1% AEP+CC predicted flood velocity at the site during baseline (top) and restored conditions (bottom). White polygon represents site boundary with depth range classification inset to the right.



3.8 Surface Water Flood Risk

The NRW 'Flood Risk from Surface Water' map (Figure 3.12) indicates that the site is at very low, medium and high risk of surface water flooding, meaning it has between a 0.1% and greater than 3.3% annual probability of flooding. Medium and high areas of surface water flood risk are associated with the topographically lower paleochannel features on site, these features capture rainfall and gradually discharge it back to River Vyrnwy.

Following completion of the river restoration works, rainfall will continue to accumulate within the backwater features and discharge back to the River Vyrnwy. The temporary attenuation of rainfall on site will contribute to the hydrological wetland function of the backwater features. As the site will remain private land following completion of the restoration works, there is no increase in surface water flood risk associated with the proposals as there are no human receptors.



Figure 3.12 NRW Surface Water Flood risk map at the site.

3.9 Groundwater flood risk

An online search for groundwater flood risk near to the site yielded no results. Any groundwater emergence near to the site would follow the topography, eventually discharging to the River Vyrnwy and away from site. The Client GI indicated that groundwater was struck between 2-3.2m below site levels, this corresponds with the observed River Vyrnwy water level which was around 3m below the floodplain during the site walkover, groundwater is therefore significantly below the floodplain at the site. Any future rise in groundwater levels will contribute positively to the hydrological wetland function of the backwater features and is considered a benefit rather than a risk.



The site is not at risk from groundwater flooding.

3.10 Artificial sources of flood risk

Sewer flooding

Client supplied service searches (December 2023) indicated that there are no public surface water sewers crossing the site.

There is a disused, private surface water sewer crossing the site, which has been identified by the client. This surface water sewer used to service the adjacent hall buildings but is now considered abandoned. Design proposals recommend severing this sewer at the location of the southern backwater, this will allow any seepage flow which gets into the sewer to discharge towards the backwater and contribute to the hydrological wetland function of the site.

The site is not at risk from sewer flooding.

Reservoir and Canal Flooding

The Montgomery Canal forms part of the southern boundary to the site. Flooding of the site could occur if the canal breached or overtopped, however, as the site is water compatible there is no significant flood risk to human receptors should this occur. If a canal breach or overtopping event occurred following construction of the river restoration, floodwater would flow overland and through the backwater features, being temporarily attenuated, before discharging to the River Vyrnwy.

The site is situated approximately 33km downstream from Lake Vyrnwy, a reservoir, should the reservoir breach, the site could flood. Flooding from a breach of Lake Vyrnwy is likely to result in a similar flood extent to the 1% AEP or 0.1% AEP predicted fluvial flood extent discussed above. NRW state that reservoir flooding is extremely unlikely to happen. All large reservoirs must be inspected and supervised by reservoir panel engineers. As the enforcement authority for the Reservoirs Act 1975 in England, NRW ensure that reservoirs are inspected regularly, and essential safety work is carried out.

It can therefore be concluded that there is very low risk of flooding from artificial sources.

3.11 Summary of flood risk

It can be concluded that fluvial flooding from the River Vyrnwy is the main source of flood risk to the site. The site is a water compatible river restoration and flooding of the proposed backwater features is an intended function of the proposal to encourage natural function.

3.12 Mitigation

As the proposed river restoration is considered water compatible it is not necessary to propose mitigation to make the site flood resilient or defend against flooding. However, proposals assume that all material excavated to create the restoration features will be removed from the active flood zone. Should proposals change and there be a requirement to spread material within active flood areas, this work would require an updated flood modelling assessment and potential mitigation to prevent flood risk being made worse elsewhere.



Flood Warnings cover this area. Although the site is unlikely to be frequently accessed, the client may wish to access the site for any maintenance or ecological monitor works. Site users should register to receive flood warnings. Flood Warnings is a free service that provides prior warning of a fluvial flood event. If a fluvial flood from the River Vyrnwy is anticipated then the site should not be accessed.

3.13 Impact on Flood Risk Elsewhere

The proposals are for a water compatible river and floodplain restoration, the restoration will create backwater features which will result in a net export of earth material from the flood zone. The proposals are therefore not considered to impact flood risk elsewhere and this has been demonstrated in the modelling undertaken.

For due diligence, the hydraulic modelling has been utilised to provide a suite of flood extent comparison maps (Figure 3.13 to 3.16) as well as a comparison of the River Vrynwy hydrograph monitored just downstream from the site location (Figure 3.18) to confirm that there is no increase in flood risk elsewhere.



Figure 3.13. 5% AEP flood extent change for modelled scenario, blue = baseline, red = restored (where red is visible indicates flood extent increase compared to baseline, purple indicates no change and blue indicates reduction in flood extent).





Figure 3.14. 1% AEP flood extent change for modelled scenario, blue = baseline, red = restored (where red is visible indicates flood extent increase compared to baseline, purple indicates no change and blue indicates reduction in flood extent).



Figure 3.15. 1% AEP+CC flood extent change for modelled scenario, blue = baseline, red = restored (where red is visible indicates flood extent increase compared to baseline, purple indicates no change and blue indicates reduction in flood extent).





Figure 3.16. 0.1% AEP flood extent change for modelled scenario, blue = baseline, red = restored (where red is visible indicates flood extent increase compared to baseline, purple indicates no change and blue indicates reduction in flood extent).





Figure 3.17. 0.1% AEP+CC flood extent change for modelled scenario, blue = baseline, red = restored (where red is visible indicates flood extent increase compared to baseline, purple indicates no change and blue indicates reduction in flood extent).



Figure 3.18. Downstream flood hydrograph change for the baseline and restored scenario. Showing no change throughout the full modelled range of flood return periods.

3.14 Residual flood risk and gauging station concerns

Downstream Boundary

NRW pre-application comments were received by the Canal and River Trust in December 2024 and provided to Dynamic Rivers in January 2025. Within the comments there was a query relating to the location and approach to downstream model boundary. The boundary location has been specified here as it is an embanked section of road, i.e. an existing break within floodplain hydraulics which causes flow to back up and provides a sensible location for a downstream boundary. The simple backwater calculation taken from Chapter 7 of the EA Fluvial Design Guide7 is 0.7 x depth / slope, the bankfull depth near the downstream boundary location is 3.06m and the channel gradient varies from 0.00125m/m 0.000136m/m. Taking the lowest value of gradient this is equivalent to a backwater distance of 15.75km.

⁷ <u>https://www.gov.uk/flood-and-coastal-erosion-risk-management-research-reports/fluvial-design-guide</u>



Constructing a hydraulic model of 15.75km to assess the relative changes associated with a net excavation of material from the flood zone is considered a disproportionate model extent for the assessment. The downstream boundary is already 1.5km further downstream from the site. Ultimately an additional 15km model length would result in major increases to model run times with potential project delay and potential additional costs to the client.

For the model build a gradient of 0.001m/m (1 in 1000m) has been adopted for the downstream boundary as is generally representative of the low gradient River Vyrnwy towards the location of the downstream model boundary. To investigate the influence on water levels at the downstream extent of the site related to the choice in downstream boundary, a sensitivity test on the gradient applied to the boundary was undertaken. The test involves varying the gradient applied to the downstream boundary condition by +/- 20%, i.e. a significant change, to assess any significant change in water level. The test was simulated for both baseline and proposed restoration site conditions, the results of the assessment are shown in Table 3.2.

Table 3.2. Changes to modelled water level for the baseline and proposed option scenario at the downstream extent of the site. Based on varying downstream boundary gradient +/-10%.

Description	1% AEP CC
Downstream Baseline (normal conditions)	66.28
Downstream Baseline (-20% slope DS boundary)	66.33
Downstream Baseline (+20% slope DS boundary)	66.24
Downstream Restored	66.29
Downstream Baseline (-20% slope DS boundary)	66.35
Downstream Baseline (+20% slope DS boundary)	66.25

The results in Table 3.2 show that whilst varying the downstream boundary gradient has an influence on water levels at the site, this influence is minimal <100mm change across both +/- change and normal slope scenarios. Furthermore, the change in water levels is comparable between baseline and the proposed option scenario and therefore the choice of boundary condition is not considered to be more significant for flood risk assessment for either baseline or proposed site conditions. To reiterate, the proposed site once constructed will provide a minor localised increase in flood storage and will not be accessed by the public. Due to the wide range of modelled return periods simulated to support this FCA, there is confidence that minor sensitivity to the downstream boundary location does not affect the assessment of flood risk at the site.

Llanymynech gauging station

NRW also recommended the need to demonstrate that there is no negative backwater affect from the restoration proposal which could affect gauging performance of the Llanymynech station.

The proposed restoration involves a net removal of material from the floodplain downstream from the location of the Llanymynech gauging station. Changes to normal water levels within the River Vyrnwy will be negligible post-construction as the option does not raise the bed level above the existing water table. The main hydraulic control i.e. influence on backwater at the Llanymynech gauge is the Montgomery canal (aqueduct) and the adjacent road bridge, which cause flow to back up during floods, neither of these existing structures will be modified as a result of the restoration works. A comparison of modelled water levels at the location of the Llanymynech gauge (approximate grid reference: 325294 E, 319610 N) for low flow (Q95 summer and Q10 winter) through to flood flow (2yr to 1000yr) is presented in Table 3.3 and Figure 3.20, both the table and graph illustrate no change to water levels across a full range of flows at the gauge location.



Table 3.3. Modelled water levels for baseline and proposed restoration conditions at the Llanymynech gauging station location.

Return			Water level baseline (m	
period	Notation	Flow	AOD)	Water level option (m AOD)
0.05	Q95	2.44	63.13	63.13
0.1	Q10	50.53	64.42	64.42
2	2yr	235.5	66.39	66.39
20	20yr	400.7	66.74	66.74
100	100yr	539.1	67.04	67.04
1000	1000yr	891.1	67.60	67.60



Figure 3.20 Comparison of modelled water levels at the Llanymynech gauging station. Low flows to QMED (2yr) inset on smaller graph for legibility.


4 Conclusions and Recommendations

4.1 Conclusions

- The Canal and River Trust commissioned Dynamic Rivers to undertake a Flood Consequences Assessment to support works for a river and floodplain restoration optioneering and design for a River Vyrnwy at Llanymynech (SJ 25664 19718 SJ 26145 19429).
- The site is shown to be located within Flood Zone C2 (an area without significant flood defence infrastructure, Figure 1.2) on the Development Advice Map and Defended Flood Zone 2/3 (Medium/High Probability, Figure 1.3) on the NRW Flood Map for Planning therefore a FCA is required to support the restoration.
- The risk of flooding from all sources has been assessed and the flood risk to the site. The main potential source of flooding at this site is fluvial flooding from the River Vyrnwy.
- Hydraulic modelling has been undertaken and shows that the site is at flood risk during a 5% AEP flood event and greater, the proposed river restoration will not change this risk.
- As the proposed river restoration is considered water compatible it is not necessary to propose
 mitigation to make the site flood resilient or defend against flooding. However, proposals assume that
 all material excavated to create the restoration features will be removed from the active flood zone by
 the client. Should proposals change and there be a requirement to spread material within active flood
 areas, this work would require an updated flood modelling assessment and potential mitigation to
 prevent flood risk being made worse elsewhere.
- Flood risk is not impacted away from the site so mitigation to protect people or assets of site is not required.
- Flood Warnings cover this area. Although the site is unlikely to be frequently accessed, the client may
 wish to access the site for any maintenance or ecological monitor works. Site users should register to
 receive flood warnings. Flood Warnings Alerts is a free service that provides prior warning of a fluvial
 flood event. If a fluvial flood from the River Vyrnwy is anticipated then the site should not be accessed.
- The risk of changing hydraulics at the Llanymynech gauging station has been assessed and the proposed works are not considered to cause a change in backwater affected which would influence flow gauging.
- The sensitivity of modelled water levels to choice of downstream boundary has been considered. A sensitivity test of the boundary gradient has been undertaken and changes to water level are shown to be minor at the site, the assessment of flood risk at the site is therefore not considered to be sensitive to the approach to the choice of downstream boundary.

4.2 Recommendations

• The client and any potential site users who may need to access the site for maintenance or ecological monitoring work must sign up to flood warnings. Should a flood warning for the River Vyrnwy be in place, the site must not be accessed.



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RIVERS

Vyrnwy Audit, Optioneering and Design

FINAL Report

Canal & River Trust



Quality information

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Terminology	Meaning
2D modelling	Two-dimensional hydraulic modelling
Bed shear stress	Measure of the force exerted by moving water on the river bed
Bedload transport	Process of movement of sediment along the bed of a watercourse
Geomorphology	The study of the physical features of the surface of the earth and
	associated processes
Hydromorphology	The physical character and water content of water bodies
LIDAR	Light Detection and Ranging Data (provides a topographical surface)
Sediment transport	Process of movement of sediment along a watercourse



1 Introduction and Methodology

1.1 Background and Objectives

Canal & River Trust (herein referred to as the client) commissioned Dynamic Rivers to undertake river and floodplain restoration along River Vyrnwy using process-based principles that will allow the river and valley bottom to develop and function more naturally (Figure 1.1). The site comprises an elevated floodplain on the right bank of the River Vyrnwy and an area of improved grassland for grazing. The client plan to purchase the land and grazing can potentially be removed to allow natural floodplain vegetation to recover and associated wetland habitat to develop providing wet conditions allow (Figure 1.1).



Figure 1.1. Restoration area on the River Vyrnwy Floodplain. (Copyright Google Earth 2024.)

1.2 Approach

We have gained a detailed understanding of the state, activity and sensitivity of the study watercourses through the study reach, through the review of archival maps and aerial photography illustrating system functioning over both historical and recent time. This was combined with a walkover that helped confirm the landscape features identified during the desk study, identifying sediment sources and sinks, geomorphological units and identifying geomorphological processes linked to the sediment transport and the likely channel change regime. All data were reviewed against the hydraulic modelling outputs.

We have also reviewed potential natural and artificial constraints to the proposed works and the walkover and desk study findings have been used to verify options from a geomorphological process perspective.



We have quantified the geomorphological and flood risk impacts of the preferred option, using a 2D hydraulic model (HEC-RAS) for the river, utilising Natural Resources Wales (NRW) LiDAR data and survey from NRW model data (flow information was obtained using a gauged value and AutoRefH approach). The 2D modelling approach has been applied across both the river and valley bottom allowing inundation areas to be mapped. Data from the flow modelling across the flow regime in the form of shear stress was used to confirm impacts to the flow and sediment regime and to ensure they are appropriate for a naturally functioning watercourse of this type. The model was also used to determine impacts on the flood hydrograph downstream by monitoring the flow at the downstream end of the model and comparing it to the baseline outputs.



2 Data Review and Fluvial Audit

2.1 Desk Study and Field Audit – System Functioning

The River Vyrnwy is generally an active single thread, gravel/cobble river with a moderate gradient, with evidence of extensive floodplain reworking preserved in the landscape (Figure 2.1). It has been modified in the past and displays evidence of channel straightening to the west of the study site (Figure 2.2). Activity levels at the study site appear reduced with little change to the planform of the river between the 1880 Ordnance Survey map and present (Figure 2.3). However, there are sinuous reaches in the locality of the study reach and where the channel becomes generally more laterally active with clear evidence of channel bar growth and riffle/rapid presence (Figure 2.4). The development of the sinuous reach within the study area is further demonstrated in historic Google Earth imagery (Figure 2.5) and demonstrates that increased deposition in the channel will result in local erosion and impacts to in-channel processes.

These features were observed on site, with active bar gravels evident as a result of the developing features (Figure 2.6). Bank erosion occurring in response to development of these features was also noted on site (Figure 2.7).



Figure 2.1. LiDAR of the wider River Vyrnwy landscape.





Figure 2.2. Historically straightened reach of the River Vyrnwy (Copyright Google Earth 2024).



Figure 2.3. River Vyrnwy contemporary and historic (1880) planform.





Figure 2.4. Dynamic sinuous reaches of River Vyrnwy; TOP – study reach, BOTTOM – further downstream. Copyright Google Earth 2024.



Figure 2.5. River Vyrnwy contemporary barform dynamics (Copyright Google Earth 2024).



Figure 2.6. Active bar gravels on the River Vyrnwy along the study reach.



Figure 2.7. Right bank erosion on the River Vyrnwy along the study reach.

Inspection of the LiDAR data for the study reach and associated floodplain suggests that the main river is well connected to its floodplain at the study site (Figure 2.8) with a width/depth ratio of 40, however river depth is likely to be underestimated in these data as the LIDAR data appears to provide a poor representation of the channel depth (this was found to be the case as a result of the supplied NRW model for the study reach).



Figure 2.8. Cross-section through the River Vyrnwy.

Figure 2.9 illustrates the spatial variation in connectivity with a clear central band of better-connected floodplain that could act as a seasonal channel or backwater route and this is supported through preliminary rainfall modelling (Figure 2.10) that also identifies this line as a lower area on the floodplain. The rainfall accumulation pattern also suggests several other areas which would be appropriate for open water and/or wetland creation.





Figure 2.9. Spatial connectivity variation across the study site on the River Vyrnwy.



Figure 2.10. Rainfall accumulation zones across the study site on the River Vyrnwy.

A long section through the possible new channel or backwater line (Figure 2.11) suggests that it will be a low gradient secondary flow route and may be prone to medium to long term deposition of gravels, however, this is not considered to the unnatural for a watercourse of this type.



Figure 2.11. Long section through the floodplain of the River Vyrnwy.

The site visit and fluvial audit confirmed that the river channel bed along the study site is significantly lower (Figure 2.12) than that represented in the LIDAR that provides a constraint on the likely frequency of wetting into any features considered for the target floodplain area, as described in the optioneering section below.



Figure 2.12. Image showing depth of channel compared to floodplain.

The floodplain area within the study area is generally improved grassland that has been grazed (Figure 2.13). There are evident palaeo channels that are wetter at least during the winter months due to them being a topographic low within the floodplain area (Figure 2.14). Wrack lines in the hedge around the property to the south suggests significant recent out of bank flooding during the winter months.





Figure 2.13. General floodplain condition in the target restoration area.





Figure 2.14. Palaeo channel just to the north of the study area holding water following winter rainfall (TOP) and drier palaeo through the study area itself (BOTTOM).

There is a ditch draining from south to north into the Vyrnwy that is capturing flow from a sluice structure linked to the canal to the south of the site area (Figure 2.15). It is understood from the Canal & River Trust that the current constant flow coming from this sluice structure is a result of a failure of the structure and current bypassing of flow around it and into the ditch (Figure 2.16), as witnessed on site. This ditch has been targeted for works on the assumption that flow will continue into this ditch into the future as this will help to wet a wider area of floodplain and create more wetted area that is an overall target of the restoration scheme for the Trust. It is also assumed that the ditch will receive minor baseflow from the surrounding superficial geology following rainfall events.



Figure 2.15. Target ditch general character as it approaches the Vyrnwy.



Figure 2.16. Flow bypassing the sluice structure from canal into the target ditch.

In summary, it would appear that there are opportunities to restore the river and floodplain in the target area along the River Vyrnwy. A constantly flowing channel through the study site is unlikely feasible due to the significant height discrepancy between the existing channel bed and floodplain (subsequently confirmed by received NRW model). However, other options are available, including targeting of the ditch flow, as described in the optioneering section below. It is likely that gravel deposition will be enhanced in the main channel and across the floodplain, enhancing system variety and dynamism in the process.



3 Optioneering and Modelling

3.1 Optioneering

A number of reconnection options were considered at the site to the connectivity between the River Vyrnwy and the floodplain. Optioneering considered backwater creation to enhance seasonal wetness by exploiting the already lower areas of the site and blocking the ditch to the west of the site.

Initial optioneering efforts were aimed at maximising potential suitable habitat for Luronium natans to compensate for Montgomery Canal works being undertaken by the Client, works are aiming to establish suitable habitat within offline reserves. Habitat requirements for Luronium initially considered two states of the plant which exists as one form in deeper water and another towards marginal muddy areas.

Habitat requirement initially targeted creating open water ponded depth to a depth of 2m within restoration features, this was taken as a guide for suitable habitat for Luronium natans from Natural England literature reviewed by Dynamic Rivers. Site constraints and principally the significantly elevated floodplain above the channel showed that achieving this ponded depth at summer flows was not possible. Discussion between Dynamic Rivers, NRW and the client ecology teams suggested that the habitat target could be relaxed to 1m ponded depth of open water during summer. This assumption is based on examples in France where the plant has thrived in ditch environments with much shallower depths. Subsequently, it was advised by the client ecologist that the species could survive in much shallower water for a significant duration of time, should the 1m depth not be achievable during summer and the target was relaxed to 1m depth during winter flow following agreement with the client. Alongside the aim of habitat creation, the client and NRW are ambitions to produce as close to a naturally functioning river restoration as possible.

Options 1 and 2 were initial river restoration focused ideas, targeting historic features on site, these options did not provide enough ponded water and it was agreed to assess Option 3 which was less naturalised but may provide the habitat required. Option 3 was then discounted during stakeholder discussion due to being similar to other offline reserves within the catchment which had proved a maintenance burden for the client, without offering any wider naturalisation benefit. Option 4 a and b considered exploiting the historic paleochannel features to create localised over excavated habitat and reconnect a historic river feature, however the option did not provide enough habitat to be viable. Option 5 is an extended and over-excavated development on option 4, whilst targeting the paleochannel locations to re-use historic river feature, it also creates a large inset area consisting of gravel island, bar and multi thread chute-backwater channels to provide a diverse habitat template, the large cut means during winter flow a larger ponded area will exist.

Options considered include:

- Option 1 backwater creation and palaeo channel excavation. Initial naturalised option with deep sections of open water to provide habitat for *L. natans*.
- Option 2 extension of Option 1 to increase deepness of features, with extra chute channel from the Vyrnwy. Aims to target summer connectivity.
- Option 3 large pond style excavation connected via backwater channel. Option not naturalised but aimed at maximising habitat potential for *L. natans.*
- Option 4a Southern palaeo channel backwater excavation aimed at targeting natural function whilst maximising habitat for *L. natans.*
- Option 4b Amendments to 4a to change slopes and depths, less naturalised morphology but deeper ponded flow for habitat.



• Option 5 – Large backwater excavation with chute channels, bars and sinuosity. Inset from floodplain but analogous to elsewhere on the Vyrnwy, particularly bar backwater development downstream from the site.

3.1.1 Character and Impacts

The audit and modelling work undertaken to inform the optioneering resulted in the identification of the following significant constraints and opportunities:

- Significant channel and floodplain disconnection restricting vegetation community development;
- Significant channel and floodplain disconnection preventing the Vyrnwy and floodplain from connecting in all but flood flow;
- Existing palaeo channels and lower sections of the site offer opportunity to increase floodplain connectivity with reduced excavation compared with elsewhere on site;
- The ditch to the west of the site with minor baseflow offers an opportunity to increase surface wetness (also currently supplemented by flow from the canal).

3.2 Option 1

The initial option comprised two moderately sized backwater features, with varied excavation elevations to help develop ponded flow of differing depths and develop diverse wetland habitat. Greater than 1m deep open water sections towards the centre of the features were intended to provide habitat for L. natans, similar deep open water excavations were proposed along a palaeo channel feature to the south of the site. Chute channels from the western ditch were included to push additional flow into the floodplain and features.



Figure 3.1. Option 1 backwater and palaeo channel excavations

- **3.2.1** Impacts and recommendations
 - Option was discounted following initial analysis showing habitat suitability was poor, not pursued in favour of deepening excavations.

Recommendation: Do not pursue

3.3 Option 2

The Option 1 backwater arrangement was further developed and extended to provide an opportunity to maximise connectivity to the Vyrnwy at summer flows, opportunities for material disposal were also considered and the option is shown in Figure 3.2. A chute channel from the Vyrnwy was added and ditch infilling downstream from both ditch chutes was added to encourage flow to spill into the floodplain.



Figure 3.2. Option 2 backwater and palaeo channel excavations extended. Hatching is opportunity for low-height material spreading with orange representing river terrace extensions to re-use arisings.

- **3.3.1** Impacts and recommendations
 - Option was discounted due to volume of cut required and not providing ideal habitat target for *L. natans.*

Recommendation: Do not pursue

3.4 Option 3

During presentation of the Option 2 connected backwater arrangement, it was discussed that the chute from the Vyrnwy caused winter flow velocity to exceed 1m/s, this is not ideal for *L. natans* and excavation volumes were significant whilst still not providing significant amounts of suitable habitat. It was agreed with the Client to test a 'less naturalised' option but with the view of solely maximising available open water habitat. Therefore, a large pond connected to the Vyrnwy with a backwater feature was tested. Ditch blocking, chutes and southern palaeo channel excavation were all retained. The option is shown in Figure 3.3 below.



Figure 3.3. Option 3 overlarge backwater pond feature.

- 3.4.1 Impacts and recommendations
 - Option was discounted due to volume of cut being significant and not providing ideal habitat target for *L. natans.*
 - Additionally, the project team comprising client and Dynamic Rivers agreed this option does not provide a naturalised opportunity for a river restoration at the site and it was agreed to focus on prioritising restoration rather than being guided solely by appropriate *L. natans* habitat creation.

3.4.2 Option 4a

Following presentation of Option 3, which resulted in a significant amount of potential excavation and still not providing 4ha of 1m depth open water, it was agreed that the excavation depth required to achieve 4ha surface area of 1m depth open-water is likely unachievable. This is caused by the significant disconnection of the Vyrnwy to the majority of the site during summer and normal winter flow, as such an infeasible amount of arising volume would be generated to connect these flows and achieve 1m flow depth. It was agreed to re-investigate palaeo channel excavation, but focus on one location and over-excavate the feature to provide a naturalised backwater feature that also provides some habitat for *L. natans*. This option is presented in Figure 3.4 below.





Figure 3.4. Option 4a over excavated palaeo channel with berms and bars providing a naturalised option whilst also providing *L. natans* habitat. Different blue colours indicate different average depth of bench/slope features and grey features represent bar features.

- 3.4.3 Impacts and recommendations
 - Option was reviewed internally within Dynamic Rivers and agreed to discuss with the client team for possible progression.
 - It was also agreed to test a modified morphology version of the option with differences to benches/slope in the feature (Option 4b) to try and increase habitat for *L. natans* whilst reducing potential arisings.
 - Option ultimately discounted in favour of Option 5 due to overall gains.

Recommendation: Do not pursue



This option is a modified version of the over-excavated palaeo channel (Option 4a) which aims to provide more habitat availability for *L. natans* within a similar footprint, the option also reduced the potential volume of excavated material and is demonstrated in Figure 3.5.



Figure 3.5. Option 4b second iteration of single over-excavated palaeo channel feature, intention to increase habitat and reduce cut versus Option 4a. More uniform benches than Option 4a at different elevations represented by different shades of blue colouring.

3.5.1 Impacts and recommendations

- Option was presented to client but agreed it still produced a significant amount of excavation for limited habitat benefit.
- It was agreed with the client team for Dynamic Rivers to undertake a final option variation targeted on a naturalisation driven approach to the backwater creation, with the *L. natans* habitat availability not being a principal direction guiding in the option (see subsequent Option 5).
- Additionally, the project team comprising client and Dynamic Rivers agreed that Option 4a and 4b do not provide the best opportunity for a naturalised option at the site and it was agreed to further focus on prioritising restoration rather than being guided solely by creation by *L. natans* habitat.
- Option ultimately discounted in favour of Option 5.



Following presentation of the Option 4 over-excavated paleochannel options, it was agreed to test an option which works better with natural processes for the site rather than being solely driven by creation of *L. natans* habitat. Option 5 has been developed utilising analogue information from the dynamic reach of the Vyrnwy downstream from the site which includes a bar/backwater section (Figure 3.6). This option comprises two backwater features, with the southern feature having two backwater branches. Within the backwater excavation channels there are bar features with chute channels, and a vegetated island within the southern feature. Option 5 provides a significant improvement in diversity of features and habitat types compared to other options considered, which will provide various wet and semi-wet locations. This will continue to evolve post-construction following sequences of erosion and deposition as well as vegetation establishment across the features.

The ditch blocking and associated chutes are retained to provide a potential source of floodplain wetting and the kested hedge is proposed to provide a benefit to terrestrial ecology whilst utilising a small amount of arisings for construction. The raised ground associated with the kested hedge holds some flow on the Vyrnwy site during flood flows and prevents this from passing downstream onto adjacent land, however the effect is minor as flow exceeds channel capacity along the length of the Vyrnwy during flood flow.



Figure 3.6. Option 5 complex backwater arrangement comprising over-excavation of palaeochannels and diverse inset feature arrangement.

3.6.1 Impact and recommendations

 Following presentation of the option to the client team and subsequent discussion with Natural Resources Wales it was agreed to develop this option into a design given that this option works best with natural processes for the site, providing a significant complexity of habitat creation and balancing volumes of cut material against cost.



Recommendation: Proceed to design

3.7 Option 5 Revision 1

Between March and October 2024, the client held discussions with Dynamic Rivers and externally regarding the predicted habitat area provided by Option 5. Discussions considered alternative options to provide additional habitat during average summer flows. In October 2024 the client confirmed to Dynamic Rivers that funding for removal of additional material may be available, and the intention is to increase excavation for the Option 5 design. The additional funding would cover a maximum of 65,000m³ excavated material and the target for suitable habitat was 250mm of ponded water during average summer flows.

Dynamic Rivers have reviewed the Option 5 layout, the concept remains comparable with the previous iteration but the bed of the backwater features has been lowered and, adjacent slopes have been adjusted to reduce the overall cut volume. Due to a boundary change supplied by the client in January 2025 the upstream section of ditch blocking and associated chute have been removed and the southern backwater ties into the existing floodplain slightly further to the east. The other ditch blocking, chutes and kested hedge remain unchanged. The Northern Backwater has been lowered to a bed level of 62.83m AOD and the larger southern backwater has been lowered to a bed level of 62.83m AOD and the larger retaining the full width of the backwater bed features, this resulted in approximately 72,000m² of cut, a final iteration narrowed the backwater channels and shortened the southernmost backwater bed extent reducing cut to approximately 63,000m³. The updated final design is presented in Figure 3.7.



Figure 3.7 Final Design (Option 5) Revision 1



3.8 Comparison of *L. natans* habitat

Prior to agreement to pursue Option 5, the potential habitat for *L. natans* for each option was compared alongside the volume of potential arisings and presented to the client team. The results show that none of the tested options achieve 4ha of potential habitat and there is a strong positive agreement between the volume of arisings and the potential habitat availability (Figure 3.8).

As discussed with the team, the arisings are the likely main cost in all of the options and are likely to exceed the project budget in order to achieve 4ha of *L. natans* habitat. This finding further supports the choice for Option 5 which although not the smallest volume of arisings of the options developed, is by far the most naturalised, and morphologically and ecologically diverse option.



Figure 3.8. *L. natans* predicted habitat availability compared with excavation volume. This chart was produced prior to updating the modelling with NRW data, which subsequently reduced river levels and all habitat areas will have subsequently reduced, meaning the reality of achieving 4ha at the site would require even further excavation.

3.9 Modelling of final option

Flow modelling has been undertaken of the final option to inform any design iteration requirements such as managing erosion risk and establish impacts to wetting frequency and extent that could be created across the site. The final option modelled comprises the ditch blocking with chutes, backwater creation with inset features and kested hedge along the south eastern boundary.



3.10 2D flow model construction

To help inform the preferred option for the River Vyrnwy, a 2D HEC-RAS (v6.4) model of the study reach has been developed, using a combination of freely available LiDAR data, client supplied survey data and channel cross-section data from the Natural Resources Wales hydraulic modelling. Peak flow data was taken directly from the Llanymynech gauging station Trends Explorer using the National River Flow Archive (NRFA) website trends explorer, and hydrographs were generated using an AutoRefH approach scaled to the relevant flood peak, we have assumed this is acceptable to NRW. The model was developed at a 4m cell size for the overall domain refined to 2m for the site, Vyrnwy and surrounding floodplain. 1m refinement was initially tested however run times became unmanageable, because of the large site area and surrounding floodplain area but 2m is still considered high resolution.

The modelling has enabled assessment of the impacts to in-channel processes and the hydrological regime. The model has also assessed the impact on flood risk both locally and downstream through use of a flow monitoring line at the downstream extent of the model.

The model extent (also showing grid orientation) and resulting model surface is shown in Figure 3.9 below.



Figure 3.9. Model extent and domain. Red polygon shows 2m refinement region within overall domain.

3.11 Hydrology

Flow inputs to the upstream end of the 2D model domain for the River Vyrnwy were derived from the National River Flow Archive trends explorer for the Llanymynech gauging station, hydrograph shapes were derived from an AutoRefH (RefH2) approach with peaks scaled to the appropriate flow. The resulting flows are shown in Table 3.2 below. Summer and winter flows were also taken from the Llanymynech gauging station daily flow data. Inflows applied to the ditch have been estimated as 0.1m³/s based on the field audit.



Table 3.2. Hydrological inflows for River Vyrnwy.

Return Period	Flow (m ³ /s)
Summer (Q95)	2.35
Winter (Q10)	50.43
1 in 2yr	328.6
1 in 20yr	580.8
1 in 100yr + Climate Change	1061.5

3.12 Backwater Option 5 Model Outputs

The approach to the floodplain restoration of the River Vyrnwy at the site has been to excavate large backwater features which will encourage seasonal flow connectivity, particularly winter flow. Prior to selection of Option 5, four backwater Options were tested which aimed to maximise the potential habitat availability for *L. natans.* None of those tested achieved the 4ha habitat target, and all these previous options were discounted for being less naturalised than Option 5. Within the backwater excavations there are morphological complexities comprising gravel bars, chute channels, a vegetated island and a range of different backwater side slope gradients, all providing a morphologically diverse template for potential habitat development and analogous to features seen elsewhere on the River Vyrnwy.

The Final Design produced in March 2024 only connected during winter flow, with the northern backwater feature inundating to 0.12m depth at approximately the Q10 average winter flow on the Vyrnwy. Inundation of the southern backwater to a depth of 0.1m occurred around a moderate to high Q5 winter flow. At Q5 the inundated depth in the northern backwater increased to 0.36m.

With the November 2024 updates, both backwaters inundate when flow on the Vyrnwy is 2.35m³/s, a typical summer flow (Q95), shown in Figure 3.10. Modelled summer depth in both backwater features is 260mm, slightly greater than the habitat target of 250mm during summer flows. During typical winter flow, 50.4m³/s (Q10), ponded depth increases to 1.2m in the northern backwater and 1.1m in the southern backwater (Figure 3.11). During summer flow approximately 1ha of wetted area is ponded above 250mm, increasing to 2.6ha at winter flow, providing a seasonally variable open water habitat area of 1 to 2.6ha.



Baseline Typical Summer Flow (Q95)





Figure 3.10. Q95 average summer flow and Q5 high winter flow, baseline and option conditions, showing connected backwaters with ponded flow to depth of at least 250mm with the option.

Baseline Typical Winter Flow (Q10)



Preferred Option Typical Winter flow (Q10)



Figure 3.11. Q10 average winter flow, baseline and option conditions, showing connected backwaters with ponded deeper ponded flow during winter conditions.

3.13 Ditch blocking and chute channels

To maximise available water for inundation of the backwater features and for general increased wetting of the target floodplain area, blocking of the western ditch on site including targeted chute creation has been considered. This aims to push flow east into the floodplain and into the backwater features.

Flow modelling shows that the minor intervention associated with blocking the ditch and chute channel creation has the potential to increase surface wetness significantly (Figure 3.12), due to the spread of the flow as it exits the ditch and features that flow subsequently activates from west to east. The wetness benefit will be dependent on the volume of ditch flows that can be discharged through the chute features, which would vary seasonally and depend on canal levels and sluice operation.



During the site walkover it was noted that a baseflow entered the ditch on the western extent of the site, flow bypassed the culvert and flows into the ditch and downstream. As above, optioneering initially intended to exploit this source of flow by blocking the ditch downstream and utilising the natural west-east gradient of the floodplain at the site to encourage flow across the valley floor and towards any open water river restoration features. This source of flow would provide a critical secondary source of flow to support *L. natans* when flows from the Vyrnwy were too low to connect with the features. It would also provide a source of flow to support other wetland habitat types by increasing surface wetness of the valley floor. Subsequent discussion with the client identified the source of flow to be a leak occurring from a sluice on the canal which has since been fixed, optioneering had initially assumed this source of flow would be permanent and could help sustain the wetland. The client has since advised that leak has been fixed and that there is no longer a baseflow to the ditch. Discussion around sustaining a flow from this location via alterations to the sluice control has been undertaken between Dynamic Rivers and the client team. The outcome of discussions around the sluice is that whilst technically possible to adjust the outflow from the canal via the structure, there are significant obstacles making this not desirable and it cannot be considered within the design, these are:

- Water flowing from the sluice is likely to impact on water levels in the canal.
- Levels in the canal could be managed by taking more flow from the Tanat Feed stream to the north, this would require an abstraction licence and is an option which could be complicated by being away from the site.
- The client has identified the possibility of designing additional off takes intended to take flood flow from the canal between the Tanat Feeder and the site to mitigate flooding issues and provide flow during winter. This is technically complex particularly if works away from the site need to divert flow to the site.
- All suggested options, whilst may provide multiple benefit are not naturalised solutions and will require significant third-party discussion.



Figure 3.12. Backwater feature inundation from ditch blocking via chute activation, estimated flow in ditches.



3.14 Preferred Options and Summary

The preferred option comprises the large backwater features with inset bar, chute and vegetated island features and ditch blocking with chute channels to spill flow west to east. The restoration will function seasonally, with differing inundation depths and adjacent surface wetness occurring throughout the year. Following November 2024 changes to the design, the features will be permanently inundated to a shallow depth during summer, becoming inundated to greater depths during winter and flood flows.

The ditch blocking and chute driven surface flow is dependent on an infrequent flow source associated with the canal overflow, there will also be a very minor baseflow contribution to the ditch location. It is recommended that future hydrological management of the Montgomery Canal considers allowing a sustained baseflow through the sluice to maximise the potential surface wetness and input flow into the backwater features increasing the diversity of wetland type habitat. The inundated extents during average summer and winter flows are shown above in Figure 3.10 and 3.11, with the 1 in 2yr flood shown in Figure 3.13 and a comparison of flow change for the 1 in 2yr event monitored at the downstream end of the site is provided in Figure 3.14.

Baseline Flood Flow 1 in 2yr



Preferred Option Flood Flow 1 in 2yr



Figure 3.13. Site flood conditions during 1 in 2yr flood – no significant changes apart from depth increases.



Figure 3.14. Monitored hydrograph at downstream end of model – 1 in 2yr flow impact.



3.15 Potential costs for removal of soil

Agreement to progress to design occurred prior to receipt of the most up to date bed levels from the NRW model, discussed in the modelling section below. Although unexpected, the new data was showed the modelled average summer (Q95) water levels to be around 1m lower adjacent the site than the original modelling had indicated. This results in summer and average winter flows being disconnected from the preferred option features. Features still connect at larger winter flows (as discussed above) and the backwater/paleochannel restoration is considered to function as a natural river feature, however the habitat availability for *L. natans* during summer and the majority of winter is impacted.

To better connect summer flows, discussion between Dynamic Rivers and the client considered overexcavation of the designed features. This approach has not been designed at this stage due to the ballpark costs associated with this work, summarised below:

- The existing preferred option generates a cut volume around 35,000m³, understood to be close to the client construction budget.
- To over excavate a 2hectare area to achieve 1m ponded depth during summer, 2m additional vertical cut is required. This would result in an additional volume of 40,000m³ more than doubling the original cut volume. Dynamic Rivers advised (email June 2024) ballpark costs would exceed £2million for this work.
- Subsequent discussion between Dynamic Rivers and Ebsford Environmental contracting (verbal and email discussion August 2024) suggest fees close to £3million for this work, note these are ballpark estimates.
- Due to the substantial costs associated with the extra excavation, Dynamic Rivers recommend investigating works in the adjacent site to the east if *L. natans* habitat availability is the guiding decision. If this site could be purchased, efforts to re-activate an area of historic paleochannel using tributary the Nant Melin could be investigated. These works are likely to be smaller in scope than works at the Vyrnwy site but provide a larger restored area of river habitat likely suitable for *L. natans*. A concept layout map for this works is provided as Appendix A, however no design work has been undertaken to support this.

For information purposes, if a lesser cut depth were to be pursued this equates to 5,000m³ per 250mm, assuming 2hectare area. 2hectare approximates to the area of open water within the backwater features



4 Design

4.1 Final Option

Following liaison with the client and updates in November 2024, Figure 4.1 below shows the final design option for the River Vyrnwy site for the preferred floodplain restoration elements.

The options proposed work with the principles of floodplain reconnection, river and floodplain naturalisation, and habitat and feature improvements.

There is a field drain on site crossing the location where the features are proposed, this feature is understood to be a historic surface water drain associated with the previous hall building on adjacent land. It is proposed to sever this feature on site, should any field runoff make its way into the drain upstream from the site, this will be discharged into the features locally providing a source of minor flow.

It is proposed to re-purpose excavated gravels to form bar features within the larger backwater excavations, due to the majority of the site being within the active flood zone there are limited opportunities for spreading of material. Initial discussions with Ebsford Environmental contractors have been undertaken and disposal opportunities are being considered elsewhere, it is likely the majority of spoil will need to be disposed of at cost.

Dependent on flow volumes, topography and water levels, it could take a considerable amount of time for reconnected/created features and the floodplain to become wet following completion of the works. This is an unknown and the risk cannot be removed as part of the design process. Features and the floodplain could be drier than anticipated.

Unknown and hidden drainage could impact the functioning of reconnected areas and created features. This is an unknown and the risk cannot be removed as part of the design process. Features and the floodplain could be drier than anticipated.

If spreading of the material can be achieved on-site this must be done outside of the active flood zone area. When spreading material and tracking over any archaeologically sensitive areas (where applicable), this should be undertaken using Low Ground Pressure Plant. An archaeological watching brief may be required.




Figure 4.1. Overview design drawing for the River Vyrnwy floodplain site.

4.2 2D Flow Model Construction

To help refine the preferred design for the study reach of the River Vyrnwy, described above, a 2D HEC-RAS (v6.4) model of the study reach has been developed, using the NRW model data described in Section 3 above (it should be noted that there remains some uncertainty in levels as sedimentation and vegetation has occurred along the reach and the Vyrnwy NRW model data is likely therefore subject to some change since it was surveyed) so this may impact on predicted inundation at seasonal levels if the River Vyrnwy levels are generally higher than suggested by the NRW model, if channel levels are higher there will be an increase in the duration and frequency of inundation. This is unlikely to significantly impact material excavation volumes as the excavation is proposed within the improved grassland floodplain which is considered well represented by LiDAR levels.

Flood flow information was developed by undertaking an ungauged FEH-statistical assessment at the site, using the Llanymynech gauging station as a donor site, the full calculation record is provided within Appendix B. Low flow information was taken from the Llanymynech gauging station, representing more than 99% of the catchment area to the site location. The model was developed at a 4 m cell size and a 2 m refinement region cell size to enable suitable representation of the channel and floodplain around the site.

The purpose of the modelling was to appraise and finalise the preferred design identified above for the study areas. This enabled assessment of the impacts to in-channel processes and the hydrological regime and iteration of these features to provide the acceptable benefits. The model has also assessed the impact



on flood risk both locally and downstream through use of a flow monitoring line at the downstream extent of the model.

The model has been built using a Digital Elevation Model (DEM) across the model domain that provides a ground elevation value for each grid cell. The model extent (also showing grid orientation) and resulting model surface for the proposed options is shown in Figure 4.2 below.



Figure 4.2. Final model extent for the River Vyrnwy study reach.

4.3 Model Bed Level Discrepancy

The optioneering work was undertaken whilst waiting for NRW to supply the correct hydraulic model data. There are two models for the area, the River Vyrnwy hydraulic model (MWH 2015) and the Severn/Vyrnwy Confluence hydraulic model (JBA Consulting 2011). The River Vyrnwy hydraulic model ends approximately half way down the site, just upstream of the gravel bars in the river and the Severn/Vyrnwy confluence hydraulic model covers the full site to downstream boundary model location. NRW originally supplied the River Vyrnwy model only, so bed levels downstream from the gravel bar locations through to the downstream boundary were estimated by adjusting the LiDAR bed levels by the average difference in bed level between LiDAR and the River Vyrnwy model bed levels, which was considered a fair assumption at the time.

Optioneering and steering group discussion eventually confirmed a final design which provided ponded water at 1m depth during target flow conditions, however this was based on the Vyrnwy Model and bed level assumptions. When NRW later supplied the Severn/Vyrnwy confluence model the bed levels from the NRW model were extracted and incorporated into the Dynamic Rivers model. These levels were lower than anticipated and once the models had been simulated and results reviewed, showed a general reduction in modelled water level of 1m towards the downstream extent of the site, which results in disconnecting the features during summer flow. The final design remains consisted but flow from the River Vyrnwy now connects at approximately a Q5 winter flow (approximately 18 days a year). This flow connection frequency



is still considered to function more naturally than a large pond type feature, however *L. natans* habitat may be compromised particularly below winter flow.

4.4 Model Run Parameters

Default parameters were used in the 2D HEC-RAS model setup. Simulated depths, velocities, water level, bed shear stress, and flow were output to assess flood extents across the model domain. Monitoring lines were used at the downstream end of the model to determine likely downstream flood risk impacts. Model outputs were sensibility checked. The downstream boundary of the model is a normal depth boundary, with the rating calculated using the underlying model surface information.

Manning's 'n' roughness values

Manning's 'n' roughness coefficients have been applied to the 2D model surface and have been informed through published information with regards to appropriate roughness values¹. These values are (Table 4.1):

Table 4.1. Model roughness values

Model domain feature	Manning's 'n' value
Open channel – moderate energy river system with some in-channel roughness	0.045
Floodplain – some high grass and light brush/vegetation cover, generally similar across whole model domain. Lots of improved grassland	0.045

4.5 Hydrology

Flood flow inputs to the upstream end of the 2D model domain for the River Vyrnwy were developed using an FEH-statistical and ReFH2 assessment, documented within Appendix B. Low flow values were taken from the Llanymynech gauging station. For the purposes of this modelling assessment, a 1 in 100yr plus allowances (25% uplift²) for climate change, 1 in 20yr and 1 in 2yr return period flood event have been run through the model as well as representative low flows Q95 (typical summer) and Q10 (typical winter), again taken from the NRFA gauge information for the Llanymynech gauging station. The corresponding flows were:

River Vyrnwy flows:

- 1 in 100yrCC 673.9m³/s
- 1 in 20yr 400.7 m³/s
- 1 in 2yr 235.3 m³/s
- Q95 2.35 m³/s

¹ Chow, V.T. (1959) Open Channel Hydraulics. McGraw-Hill, New York



• Q10 – 50.43 m³/s

Additional flood flow return periods were simulated to support the Flood Consequences Assessment which should be read in conjunction with this report these are:

River Vyrnwy flows:

1 in 100yr – 539.1 m³/s

1 in 1000yr – 891.1m³/s

1 in 1000yrCC – 1113.9m³/s

4.6 Utility information

A services search has been conducted/provided for the site by the client and those supplied are shown in the design drawings against the proposed design. Best endeavours have been used to transfer the map information to the design drawings but some error in the location of these may be present as a result. Service searches could be incomplete. Dynamic Rivers accept no liability for the presence of services on site.

No utilities are likely to be directly impacted by the proposed works. However, there is an existing field drain crossing the site, this feature will be broken out/ severed as part of the proposed excavation works for the scheme. Other services may be crossed under or over during the excavation works and contractor should be aware of their presence.

There are utilities following the local road networks which contractors should be aware of if tracking over with heavy machinery.

A services search should be undertaken prior to works commencing on site. All services should be considered carefully by the contractor undertaking the works in terms of safe working procedures, access and crossing these utilities, with appropriate liaison with the service provider. It should be noted that standard services searches do not identify all local land drains. If encountered, these should be managed on site by the contractor and client. The contractor should review the services search drawing prior to construction and for potential access routes as some may be crossed to deliver the works. The client and/or contractor should undertake another services search prior to the works. The contractor should undertake a C.A.T4 / radio-detection scan, in liaison with the provider, and locate these services prior to excavation commencing if deemed required.

Contractors should be made aware of their location as it is possible that some may be crossed / passed under to undertake the proposed works. The contractor should set up goalposts in the vicinity of overhead lines so that machinery operators are aware of its presence and work with limiters. They should also locate any buried services before excavation begins in liaison with the service provider. Track mats may be required across buried services.

There is one known land drain pipe crossing the site, the alignment of this drain has been assumed based on on-site manholes. The design includes severing this structure to allow any flow to spill into the features as well as reducing the efficiency of fine sediment transport for the structure into the Vyrnwy. It has been assumed that this land drain can be broken without consequence and it is understood that the client is seeking landowner approval for these works which should be agreed prior to construction. Dynamic Rivers accept no liability or responsibility for any services present or impacted as a result of any works undertaken on site.



Other private services, such as land drains not already mapped, that are not picked up by utilities service searches, could be encountered during the works. This should be monitored and managed by the contractor and client on site.

Service searches do not always show manhole presence. There is a risk of water flowing across manholes and underground services more frequently, and to greater depths, as a result of floodplain reconnection works. Wetter floodplain areas also may occur around overhead services. Pylon locations are not always plotted on supplied service searches. This could mean that some pylons have been missed. This should be reviewed by the contractor on site prior to works commencing.

4.7 Final Design

The preferred restoration design option is shown in Figure 4.1 above following liaison with the client. Detailed design drawings have been produced alongside a Method Statement that outlines how a contractor might deliver the works, a Designers Risk Register that highlights all risks related to the project and a Bill of Quantities.

The below sections outline the bed shear stress review that has been undertaken to understand the influence of the proposed design, wetting impact as a result of the preferred restoration scheme, and the flood risk impacts as a result of the preferred scheme design.

4.8 Bed Shear Stress

Baseline bed shear stress model outputs show that generally under extreme flows values range between 20-80 N/m² (Figure 3.21) within the River Vyrnwy channel study reach, with higher shear stresses through the reach upstream from the site where the channel is narrower and straighter. Across the floodplain, shear stresses reach around 20-30 N/m² but are generally much lower. Within the feature locations, shear stress is typically <10 N/m² under baseline conditions and there are negligible changes with the restoration features considered. There is a very minor increase to shear stress in-channel local to the connection of the southern backwater feature for the 1 in 100yr plus climate change event (Figure 4.4) and for the low order 2yr flood event, but this is considered minor and is due to the significant wetted area under baseline conditions (Figure 4.4 and Figure 4.5). This increase occurs on the falling limb of the hydrograph as ponded flows recede, the increase is only 10-20 N/m² over 30-40 N/m² at the location and remain well within typical values for the overall reach, however this is likely to locally influence patterns of erosion and deposition within the channel as part of natural processes over time.

Most cohesive soils, especially when vegetated, resist over 100 N/m² and outputs show that we are generally within this range (typically less than 10 N/m²) for both lower and higher order flows across the floodplain (Figure 4.4 and Figure 4.5). However, flow concentration will still instigate low level headcutting as part of natural processes associated with floodplain reconnection, chute channels and associated development. Gravels/cobbles and fine sediments are likely to deposit within the channel (as they do currently) at a slightly greater rate due to the improved floodplain connectivity, and across reconnected backwaters more readily. At the point downstream from the large backwater, deposition may occur at a slightly reduced rate due to the minor increase in shear stress. This is part of natural processes and is encouraged as part of the scheme. The backwaters created are low energy features and may be subject to some infilling over time, again this is a natural process for features of this type and is part of the evolution of the floodplain area. These features will be seasonally wet, although may retain water all year round dependent on rainfall and any flow from the ditch to the west of the site. Natural processes and associated



erosion and deposition may change the flood regime and pattern over time. This should be continued to be monitored as part of a monitoring programme following construction.





Figure 4.4. Predicted extreme shear stress (N/m²) levels across the baseline (TOP) and restored (BOTTOM) scenario along the River Vyrnwy study reach.





Figure 4.5. Predicted low order flood shear stress (N/m²) levels across the baseline (left) and restored (right) scenario along the River Vyrnwy study reach.



4.9 Predicted habitat development

Dynamic Rivers have undertaken a predicted wet floodplain habitat assessment into areas of floodplain which could potentially develop into functional wet grassland, fen/mire or other wetland type habitat using the floodplain wetting tolerance ranges suggested by Wheeler et al. (2004)³. Due to the disconnection of summer flows within the River Vyrnwy from the floodplain at the site, it is unlikely that a diverse mix of valley floor wetland habitat will develop, due to the over-dry floodplain. The tool did indicate that the margins of the backwater could potentially develop into swamp type habitat. *L. natans* may succeed within the initial stages of swamp habitat development, but there is a risk of out-competition by other swamp preferential species as part of natural biotic processes and it is unlikely to survive due to succession without intervention (management).

4.10 Flood Risk

Flood modelling for the current and restored site scenarios has been undertaken to determine the fluvial flood risk impacts as a result of the proposed scheme along the River Vyrnwy. This has been undertaken for the 1 in 100yr plus allowances for climate change, 1 in 20yr and 1 in 2yr return period flows. Low flows and associated restoration impacts are discussed in the section above with to preferred option selection.

Figures 4.6 to 4.8 demonstrate the flood extent changes for each of the flood return periods listed above, with baseline shown in blue and the restored scenario shown in red (no change areas are shown in purple).

There are no notable changes in flood extents for the 1 in 100yr plus allowances for climate change (Figure 4.6) and 1 in 20yr events (Figure 4.7) due to the significant flooded area already occurring under baseline conditions and introduced features generally being drowned out under these flow conditions. Figure 4.8 shows some very localised changes in flood extent for the lower order 1 in 2yr event, mainly due to the additional capacity within the floodplain associated with the excavation of backwater features, but the difference is minor and localised to the site and features. Flood water depths will be greater in excavated features compared to baseline for all modelled return periods.

The flooding regime could change over time as the river and floodplain naturalises and responds to the proposed works. This is part of natural processes. Any excess spoil will need to be spread elsewhere out of active flood zone areas or removed from site. There will be a period of time where works are partly complete. If a flood were to occur at this point during the construction, then unpredicted flooding could occur. This risk cannot be removed as part of the design process.

³ Wheeler, B.D., Gowing, D.J.G., Shaw, S.C., Mountford, J.O. and Money, R.P., 2004. Ecohydrological guidelines for lowland wetland plant communities - <u>gean0205bipz-e-e.pdf (publishing.service.gov.uk)</u>





Figure 4.6. 1 in 100yrCC flood extent change for modelled scenario, **blue** = baseline, **red** = restored (where red is visible indicates flood extent increase compared to baseline, **purple** indicates no change and blue indicates reduction in flood extent).





Figure 4.7. 1 in 20yr flood extent change for modelled scenario, **blue** = baseline, **red** = restored (where red is visible indicates flood extent increase compared to baseline, **purple** indicates no change and blue indicates reduction in flood extent).





Figure 4.8. 1 in 2yr flood extent change for modelled scenario, **blue** = baseline, **red** = restored (where red is visible indicates flood extent increase compared to baseline, purple indicates no change and blue indicates reduction in flood extent).

Downstream (flow monitored at the downstream end of the model), the impact of the proposed works for the 1 in 100yrCC, 1 in 20yr and 1 in 2yr events is negligible in terms of the peak hydrograph flow (Figures 4.9 to 4.11). There is negligible change to the hydrograph shape and peak flow, therefore there is no significant modelled increase in downstream flood risk as a result of the proposed restoration works.



Figure 4.10. Downstream flood hydrograph change for the 1 in 100yrCC baseline and restored scenario.



Figure 4.11. Downstream flood hydrograph change for the 1 in 20yr baseline and restored scenario.



Figure 4.12. Downstream flood hydrograph change for the 1 in 2yr baseline and restored scenario.

4.11 Residual flood risk and gauging station concerns

Downstream Boundary

NRW pre-application comments were received by the Canal and River Trust in December 2024 and provided to Dynamic Rivers in January 2025. Within the comments there was a query relating to the location and approach to downstream model boundary. The boundary location has been specified here as it is an embanked section of road, i.e. an existing break within floodplain hydraulics which causes flow to back up and provides a sensible location for a downstream boundary. The simple backwater calculation taken from Chapter 7 of the EA Fluvial Design Guide4 is 0.7 x depth / slope, the bankfull depth near the downstream boundary location is 3.06m and the channel gradient varies from 0.00125m/m 0.000136m/m. Taking the lowest value of gradient this is equivalent to a backwater distance of 15.75km.

Constructing a hydraulic model of 15.75km to assess the relative changes associated with a net excavation of material from the flood zone is considered a disproportionate model extent for the assessment. The downstream boundary is already 1.5km further downstream from the site. Ultimately an additional 15km model length would result in major increases to model run times with potential project delay and potential additional costs to the client.

⁴ <u>https://www.gov.uk/flood-and-coastal-erosion-risk-management-research-reports/fluvial-design-guide</u>



For the model build a gradient of 0.001m/m (1 in 1000m) has been adopted for the downstream boundary as is generally representative of the low gradient River Vyrnwy towards the location of the downstream model boundary. To investigate the influence on water levels at the downstream extent of the site related to the choice in downstream boundary, a sensitivity test on the gradient applied to the boundary was undertaken. The test involves varying the gradient applied to the downstream boundary condition by +/- 20%, i.e. a significant change in water level. The test was simulated for both baseline and proposed restoration site conditions, the results of the assessment are shown in Table 4.2.

Table 4.2.	Changes	to modelled	water I	evel for	the	baseline	and	proposed	option	scenario	at	the
downstrea	am extent	of the site. Ba	ised on	varying	dow	nstream I	boun	dary gradie	ent +/-10)%.		

Description	1% AEP CC
Downstream Baseline (normal conditions)	66.28
Downstream Baseline (-20% slope DS boundary)	66.33
Downstream Baseline (+20% slope DS boundary)	66.24
Downstream Restored	66.29
Downstream Baseline (-20% slope DS boundary)	66.35
Downstream Baseline (+20% slope DS boundary)	66.25

The results in Table 4.2 show that whilst varying the downstream boundary gradient has an influence on water levels at the site, this influence is minimal <100mm change across both +/- change and normal slope scenarios. Furthermore, the change in water levels is comparable between baseline and the proposed option scenario and therefore the choice of boundary condition is not considered to be more significant for flood risk assessment for either baseline or proposed site conditions. To reiterate, the proposed site once constructed will provide a minor localised increase in flood storage and will not be accessed by the public. Due to the wide range of modelled return periods simulated to support this FCA, there is confidence that minor sensitivity to the downstream boundary location does not affect the assessment of flood risk at the site.

Llanymynech gauging station

NRW also recommended the need to demonstrate that there is no negative backwater affect from the restoration proposal which could affect gauging performance of the Llanymynech station.

The proposed restoration involves a net removal of material from the floodplain downstream from the location of the Llanymynech gauging station. Changes to normal water levels within the River Vyrnwy will be negligible post-construction as the option does not raise the bed level above the existing water table. The main hydraulic control i.e. influence on backwater at the Llanymynech gauge is the Montgomery canal (aqueduct) and the adjacent road bridge, which cause flow to back up during floods, neither of these existing structures will be modified as a result of the restoration works. A comparison of modelled water levels at the location of the Llanymynech gauge (approximate grid reference: 325294 E, 319610 N) for low flow (Q95 summer and Q10 winter) through to flood flow (2yr to 1000yr) is presented in Table 4.3 and Figure 4.13, both the table and graph illustrate no change to water levels across a full range of flows at the gauge location.



Table 4.3. Modelled water levels for baseline and proposed restoration conditions at the Llanymynech gauging station location.

Return			Water level baseline (m	
period	Notation	Flow	AOD)	Water level option (m AOD)
0.05	Q95	2.44	63.13	63.13
0.1	Q10	50.53	64.42	64.42
2	2yr	235.5	66.39	66.39
20	20yr	400.7	66.74	66.74
100	100yr	539.1	67.04	67.04
1000	1000yr	891.1	67.60	67.60



Figure 4.13 Comparison of modelled water levels at the Llanymynech gauging station. Low flows to QMED (2yr) inset on smaller graph for legibility.



5 Conclusions and Recommendations

5.1 Conclusions

- Canal & River Trust commissioned Dynamic Rivers to undertake river and floodplain restoration along River Vyrnwy using process-based principles that will create dynamic backwater features and the river and floodplain to function more naturally. A ditch to the west of the site will be blocked at present no flow will go down this ditch but future client about hydrological management of the Montgomery Canal could be pursued and the sluice feeding this ditch could be exploited to maximise potential wetted habitat throughout the year.
- The River Vyrnwy is generally an active single thread, gravel/cobble river with a moderate gradient, with evidence of extensive floodplain reworking preserved in the landscape. It has been modified in the past and displays evidence of channel straightening to the west of the study site. Activity levels at the study site appear reduced with little change to the planform of the river between the 1880 Ordnance Survey map and present. However, there are sinuous reaches in the locality of the study reach and where the channel becomes generally more laterally active with clear evidence of channel bar growth and riffle/rapid presence. The development of the sinuous reach within the study area is further demonstrated in historic Google Earth imagery and demonstrates that increased deposition in the channel will result in local erosion and impacts to in-channel processes.
- Two main naturalisation options comprising backwater creation and ditch blocking are proposed to provide river restoration and habitat creation, within these overarching approaches there are additional features to provide dynamism. These include:
 - Chute driven floodplain flow from the western ditch, intermittent flow dependent on supplied flow to ditch;
 - Bar features with chute channels inset;
 - o An island to allow natural vegetation succession;
 - o Variable slopes to provide structural complexity of backwater features;
 - o Chute driven backwater flow into gravel bars;
 - Sinuosity within backwater channels;
 - o A kested hedge to provide naturalised terrestrial vegetation;
 - o Over-excavation of palaeo channel locations.
- The approach to the restoration at the River Vyrnwy has been large scale excavation with smaller features inset into larger backwater features. Large scale excavation is required to ensure that flow connectivity to the River Vyrnwy is possible at winter flows. To ensure the river restoration functions naturally the reach downstream from the site with bar and backwater development has been utilised to provide an analogue. Although the backwater features are larger in extent than those developing downstream, they are characteristic of the River Vyrnwy. Ditch infilling and chute driven floodplain and feature activation provides another potential source of flow into the features, although this will be infrequent, future hydrological management of the Montgomery canal sluice which feeds this ditch could exploit this sluice to maximise flows into the ditch and restoration features.



- The backwater features created as a result of these options will result in a medium-term change to the sediment regime, this will be localised to downstream from the features within the Vyrnwy caused by a change in the shear stress field. The area where floodplain excavation is proposed will become seasonally wetter and be inundated with flow from the River Vyrnwy during winter.
- A land drain crossing the site will be severed which will provide an opportunity to input additional minor flow into the backwater features and increase surface wetness of the adjacent floodplain.
- The options proposed work with the principles of floodplain reconnection, valley floor wetting, river and floodplain naturalisation, and habitat and feature improvements.
- A services search has been undertaken by the client for the River Vyrnwy and surrounding site area, no main infrastructure utilities were found crossing the site which would impact the design. There are utilities following the local road networks which contractors should be aware of if tracking over with heavy machinery. Dynamic Rivers accept no liability or responsibility for any services present or impacted as a result of any works undertaken on site.
- A services search should be undertaken prior to works commencing on site. All services should be considered carefully by the contractor undertaking the works in terms of safe working procedures, access and crossing these utilities, with appropriate liaison with the service provider. It should be noted that standard services searches do not identify all local land drains. If encountered, these should be managed on site by the contractor and client. The contractor should review the services search drawing prior to construction and for potential access routes as some may be crossed to deliver the works. The client and/or contractor should undertake another services search prior to the works. The contractor should undertake a C.A.T4 / radio-detection scan, in liaison with the provider, and locate these services prior to excavation commencing if deemed required.
- Baseline bed shear stress model outputs show that generally under extreme flows values range between 20-80 N/m² within the River Vyrnwy channel study reach, with higher shear stresses through the reach upstream from the site where the channel is narrower and straighter. Across the floodplain, shear stresses reach around 20-30 N/m² but are generally much lower. Within the feature locations shear stress is typically <10N/m² under baseline conditions and there are negligible changes with the restoration features considered. There is a very minor increase to shear stress in channel local to the connection of the southern backwater feature for the 1 in 100yr plus climate change event or the low order 2yr flood event, due to the significant wetted area under baseline conditions. This increase occurs on the falling limb of the hydrograph as ponded flows recede, the increase is only 10-20N/m² over 30-40N/m² at the location and remain well within typical values for the overall reach, however this is likely to locally influence patterns of erosion and deposition within the channel as part of natural process over time.
- Most cohesive soils, especially when vegetated, resist over 100 N/m² and outputs show that we are within this range (less than 10 N/m²) generally for both lower and higher order flows across the floodplain. However, flow concentration will still instigate low level headcutting as part of natural processes associated with floodplain reconnection, chute channels, palaeo extension features and associated development. Gravels/cobbles and fine sediments are likely to deposit within the channel (as they do currently) at a slightly greater rate due to the improved floodplain connectivity, and across reconnected backwaters more readily. At the point downstream from the large backwater deposition may occur at a slightly reduced rate due to the minor increase in shear stress. This is part of natural processes and is encouraged as part of the scheme. The backwaters created are low energy features and may be subject to some infilling over time, again this is a natural process for features of this type and is part of the evolution of the floodplain area. These features will be



seasonally wet, although may retain water all year round dependent on rainfall and any flow from the ditch to the west of the site. Natural processes and associated erosion and deposition may change the flood regime and pattern over time. This should be continued to be monitored as part of a monitoring programme following construction.

- Modelling shows a minor and localised reduction near to the site for the 1 in 2yr flood extent compared with baseline. There is no perceptible change for the 1 in 20 and 1 in 100yrCC events due to the significant flooded area of the River Vyrnwy floodplain under baseline and proposed design conditions.
- Modelling has shown that for the updated Option 5 Revision 1, during typical summer flow (Q95) there is approximately 1ha of flow ponded to at least 250mm depth within the backwater features, this increases to 2.6ha during typical winter flow (Q10). There is therefore 1 to 2.6ha of seasonally variable habitat available for *L. natans* resulting from the November 2024 updated final design.
- Dynamic Rivers have undertaken a predicted wet floodplain habitat assessment into areas of floodplain which could potentially develop into functional wet grassland, fen/mire or other wetland type habitat using the floodplain wetting tolerance ranges suggested by Wheeler et al. (2004). Due to the disconnection of summer flows within the River Vyrnwy from the floodplain at the site, it is unlikely that a diverse mix of valley floor wetland habitat will develop, due to the over-dry floodplain. The tool did indicate that the margins of the backwater could potentially develop into swamp type habitat. L. natans may succeed within the initial stages of swamp habitat development, but there is a risk of out-competition by other swamp preferential species as part of natural biotic processes and it is unlikely to survive due to succession without intervention (management).
- Dependent on flow volumes, topography and water levels, it could take a considerable amount of time for reconnected/created features and the floodplain to become wet following completion of the works. This is an unknown and the risk cannot be removed as part of the design process. Features and the floodplain could be drier than anticipated.
- Unknown and hidden drainage could impact the functioning of reconnected areas and created features. This is an unknown and the risk cannot be removed as part of the design process. Features and the floodplain could be drier than anticipated.
- Any excess spoil will need to be spread elsewhere out of active flood zone areas or removed from site. When spreading material and tracking over any archaeologically sensitive areas (where applicable), this should be undertaken using Low Ground Pressure Plant. An archaeological watching brief may be required.
- The flooding regime could change over time as the river and floodplain naturalises and responds to the proposed works. This is part of natural processes. Proposed spreading areas should be outside of the NRW and modelled flood zones. Any excess spoil will need to be spread elsewhere out of active flood zone areas or removed from site. There will be a period of time where works are partly complete. If a flood were to occur at this point during the construction, then unpredicted flooding could occur. This risk cannot be removed as part of the design process.

5.2 Recommendations

• It is critical that the hydraulic regime across the site is in line with the newly created features to ensure the site will function, it is recommended that Dynamic Rivers supervises the site works during construction, as detailed in the accompanying Method Statement.



- A services search has been undertaken by the client for the River Vyrnwy and surrounding site area, no main infrastructure utilities were found crossing the site which would impact the design. There are utilities following the local road networks which contractors should be aware of if tracking over with heavy machinery. Dynamic Rivers accept no liability or responsibility for any services present or impacted as a result of any works undertaken on site.
- It is strongly recommended the client and/or contractor should undertake a services search prior to the works and undertake additional C.A.T4 / radio-detection scanning before commencing works.
- It is recommended that the client considered future hydrological management of the Montgomery Canal so that the sluice discharging flows to the western ditch can be opened wider and/or more frequently. Any additional flows from the canal sluice will be discharged via the chute channels and into the backwater features providing additional flow availability benefit.



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1. Appendix A

On the Powys land to the east of the Vyrnwy site, the main stream the Nant Melin discharges directly to the River Vyrnwy as does a small tributary to the eastern extent of the site (Figure A.1). Both of these watercourses could be exploited to provide a source of flow to this site which has a paleochannel feature running through it at a lower elevation to the surrounding valley floor. The presence of a pond feature to the east of this area suggests an elevated water table at the site, making it a potentially ideal location for wetland development.



Figure A.1 – Powys land existing hydrological function

There is an existing paleochannel feature on site, the base of this feature is typically 1m below adjacent ground levels. The modified condition of the Nant Melin and small tributary to the east to improve flow conveyance away from the site are preventing the paleochannel area from wetting up.

There is potential to create a wetland habitat template on site which is not dependent on the water level within the River Vyrnwy (Figure A.2), by raising the bed levels of the two modified tributaries on site.

The area indicated as paleochannel excavation approximates to around 0.9ha. This could be less than 1m deep cut as providing variance in levels across the feature is preferential.

Topographic data suggests the presence of an abandoned alluvial fan from the valley side tributary the Nant Melin, this feature could be reactivated and incorporated into the design of the site to split flows naturally between the two paleochannel locations meanwhile restoring the historic river feature.

The potential area of wetland indicated is the assumed passive response to the restoration, this area is situated below the adjacent valley floor levels and will become permanently wetter. Depending on specific ground levels there may be pockets of open water here or wet marginal ground.

A kested hedge is proposed at the upstream extent of the paleochannel feature to prevent flows backing up onto the Vyrnwy site. However, could part of this site be included within the overall land purchase then the paleochannel feature which extends onto the Vrynwy site could also be included to increase the



extent of restored feature. Additional kested hedges could be constructed from cohesive arisings to manage flows from spilling to third party land as required.

L. natans should be able to occupy this new wetland habitat and, if required localised deeper excavations within the features could be created to ensure deeper ponded sections of open water. Other species may still outcompete the *L. natans* as part of natural succession which is an unavoidable natural process.



Figure A.2 – Powys land change to hydrological function with proposed restoration works. Black arrows are potential hydrological function post-restoration.



2. Appendix B





Flood estimation – calculation record Site/project name:

Date:

Introduction

This document is a supporting document to the Natural Resources Wales Flood Estimation Technical Guidance Note V3. It provides a template for recording calculations and decisions made during flood estimation. It will often be complemented by more general hydrological information given in a project report. The information given here should be enough to enable the work to be reproduced in the future.

Note 1: Table, content or page layout can be adapted to best present relevant information. Additional rows should be added to, or removed from tables as appropriate.

Note 2: Probability of flood occurrence is traditionally expressed within Hydrology as a Return Period, this is the average time between years with at least one larger flood. It can also be expressed as Annual Exceedance Probability (AEP), and this is often more appropriate to use when communicating with non-hydrologists. Return Period has been retained within this document but can be replaced with AEP if wished.

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Approval

	Name	Qualifications	Date	Competence level	
Calculations prepared by:	Rory Clements	BSc (Hons) CGeog (Geomorph)	01/02/2025	Senior Hydrologist	
Calculations checked by:	Rob Williams	PhD	02/02/2025	Senior Hydrologist	
Calculations approved by:	Seb Bentley	BSc Msc	03/02/2025	Principal Hydrologist	

Competence levels:

level 1 – hydrologist with minimum approved experience in flood estimation

level 2 - senior hydrologist

level 3 – senior hydrologist with extensive experience of flood estimation

Abbreviations

AEP	Annual exceedance probability
AMAX	Annual maximum flow
AREA	Catchment area (km ²)
BFI	Base flow index
BFIHOST	Base flow index derived using the HOST soil classification
BFIHOST19	Base flow index derived using the revised (2019) HOST soil classification
DPLBAR	Mean drainage path length (km)
DPSBAR	Mean drainage path slope (m/km)
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FPEXT	Floodplain extent

HOST	Hydrology of soil types soil classification
NRFA	National river flow archive
POT	Peaks over a threshold
QMED	Median annual maximum flow (with Annual Exceedance Probability of 50% / return period 2 years)
ReFH	Revitalised flood hydrograph method – used for rainfall runoff method
SAAR	Standard average annual rainfall (mm)
SPR	Standard percentage run-off
Тр	Time to peak
URBEXT2000	Index of urban extent in the year 2000
WINFAP	Windows Frequency Analysis Package – can be used for FEH statistical peak flow method

1. Method statement

1.1 Overview of requirements for flood estimates

Item	Comments
Give an overview which includes:purpose of study	The purpose of this flood estimation calculation is to provide a single inflow (one calculation point) for a hydraulic model of the River Vyrnwy at Llanymynech. The hydraulic model will assess the impact of a proposed river restoration scheme on fluvial flood risk.
 names of river/s location number of calculation points and if 	Flood risk review is being undertaken for completeness in support of design development, the river restoration proposal results in a net removal of material from active flood zones and is not considered to pose a flood risk or be at flood risk from the River Vyrnwy.
peak flows or hydrographs are required	Peak flows and hydrographs are required. WINFAP-FEH 5 (v5.2.9) and ReFH 2.3 (v3.3.8) have been utilised for this works.
 previous relevant calculations availability of flood history 	The site and adjacent flood plain is at known flood risk, with numerous press and video (youtube records) online from the previous 5 years. The River Vyrnwy floodplain at the site is predominantly rural and receptors are typically agricultural land with pockets of habitation within local villages.

1.2 Overview of catchment

Item	Comments
Brief description of catchment, including key features needing consideration or	The River Vyrnwy catchment at the site is a predominantly rural catchment, the catchment is relatively large at 783.5km ^{2.} The large catchment area provides confidence in the FEH

Item	Comments
reference to section in accompanying report.	boundary and it is not necessary to check and update the boundary using a GIS watershed analysis (Figure 1).
Map/s should be presented here or in section 2.1 of this report.	The Llanymynech gauging station is situated immediately upstream from the site location and provides the best opportunity for donor site and leading pooling group stations within the FEH-web service.
	There is one large reservoir within the catchment namely the Lake Vyrnwy, however, the lake only impounds approximately 10% of the catchment area and is not considered to have a major attenuating influence on flood flow at the site, this is illustrated by a FARL value of 0.97.
	The catchment is underlain by superficial deposts of unsorted glacial till, mixed permeability alluvium and river sand and glacial sand and gravel. Underlying the superficial deposits are multiple bedrock formations typically comprising impermeable mudstone, sandstone and siltstone ¹ . The superficial geology is considered low productivity aquifers (Figure 1) and is considered only moderately permeable, as such has a moderate BFIHOST19 value of 0.41.
	The catchment incorporates both headwaters and piedmont zones and is therefore relatively steep with an average catchment slope (DPSBAR) of 160.9m/km.
	A moderately high SAAR value of 1335m indicates substantial annual rainfall occurs within the River Vyrnwy catchment.

¹ Geology mapping has been reviewed on the British Geological Survey Geoindex using 1:625,000 scale mapping due to the large catchment size <u>https://mapapps2.bgs.ac.uk/geoindex/home.html</u>

Item	Comments
	Figure 1. River Vyrnwy catchment at the site. Drainage network and large lake/reservoir waterbodies shown. Catchment screenshot from the FEH web service. BGS aquifer productivity mapping underlays showing low productivity. The online search for flood records found local press and YouTube entries for several large flood events within the last 5 years (date of search 29/01/2025), these occurred between

Item	Comments	
	December and February and are indicative that fluvial flooding tends to be seasonally (winter) driven.	

1.3 Source of flood peak data

Item	Comments	
Was the NRFA Peak Flows dataset used? If so, which version?	Version 13, released August 2024. This contains data up to water year 2022-23 at most sites.	

1.4 Gauging stations (flow or level)

Within, or near to, the study area. Most stations will be included on National River Flow Archive (NRFA), but other stations may also be available.

Watercourse	Station name	NRFA number	Grid reference	Catchment area (km²)	Location relative to study area (eg, within), note any significant differences in catchments (eg URBEXT)
River Vyrnwy	Llanymynech	54028	SJ252196	778	Immediately upstream from site location and useful for donor and pooling Long term AMAX dataset to 1969

1.5 Data available at each gauging station

Station name or number	Start and end date on NRFA	Suitability (Pooling/ QMED/ Neither)?	Update for this study?	Comments on data availability (quality is covered in next section). If not a QMED or pooling station then describe how data will be used e.g. for Tp calculation or QMED calculation from daily mean flow
54028	1969- present	Both	No	A review of hydrograph shape from ReFH2 will be undertaken against observed events for the 2024 year (latest available online).

1.6 Data quality at each gauging station

Station name or number e.g. degree of extrapolation, availability of recent flow gaugings, amount of scatter in the gaugings, bank full level and out of bank flow



1.7 Other data available and how it has been obtained

Consider flood history and local data if available.

Type of data	Source of data	Details and reference/link to relevant reports
Historic flood data	Online searches	 Some examples are linked above, a google search identifies historic entries of flooding near Llanymynech and the A483 downstream from the site. Drone footage on Youtube shows the wider area around the site to be flooded several tuimes within the last few years https://www.youtube.com/results?search_query=flooding+llanymynech The NRW flood alert for the River Vyrnwy at Llanymynech is frequently activated during winter https://flood-warning.naturalresources.wales/Detail/101FWFWN253 The NRW flood alert for the wider River Vrnwy catchment is frequently activated during winter https://flood-warning.naturalresources.wales/Detail/101WAFVY10
15-min river level/flow and rainfall data for events (if carrying out Tp or ReFH analysis)	NRW data website used to download 15 minute level data for Vyrnwy gauge	Three events occurring during 2024 have been investigated to inform hydrograph shape compared with the default ReFH2 design hydrograph. Time to peak and duration have been adjusted. The events selected are not the largest events for 2024, but are isolated events so comparable with design hydrograph methods. All larger events indicated at least two separate flood peaks within the hydrograph and have been discounted for in this context.
Results from previous studies	None known	

1.8 Initial choice of approach

lte	em	Comment	
0	utline the conceptual model. Address questions such as:	The main site of interest is a river restoration site downstream from the Llanymynech bridge, it is part of the wider Montgomery	
•	Where are the main sites of interest?	Canal restoration.	
•	What is likely to cause flooding at those locations? (e.g. peak flows, flood volumes, combination of peaks, groundwater, snowmelt, tides)	The main driver of flooding at the site is fluvial flooding, the site is understood to experience semi-regular fluvial flooding alongside the majority of the River Vyrnwy catchment. The site is a	
•	Might those locations flood from runoff generated on part of the catchment only e.g. downstream of a reservoir?	functional river restoration and ultimately will create slightly more storage for flood waters locally. Flood peak and hydrograph volume are responsible for flooding at the site, other sources of water e.g. groundwater or surface water are limited.	
A	ny unusual catchment features to account for? For example:	This is a large catchment, with the catchment are to the gauge at Llanymynech account for over 99% of the total site catchment	
•	highly permeable (BFIHOST> 0.65)	area.	
•	highly urbanised – consider choice of method carefully; consider aritifical drainage and storm sewer inflow and outflows	The catchment is moderately impermeable, slightly influenced by a reservoir which impounds approximately 10% of the catchment	
•	small catchment (<40 km ²) – small catchment pooling method	and moderately steep.	
•	pumped watercourse – consider lowland catchment version of rainfall-runoff method	The site is predominantly rural URBEXT2000 is zero.	
•	major reservoir influence – consider flood routing	All descriptors are considered representative and within normal	
•	extensive floodplain storage – consider choice of method carefully		

lte	em	Comment
In	itial choice of method(s) and reasons	FEH hybrid will be applied.
•	Will method often known as FEH Hybrid be used for peak flow estiamtes? (Statisical for QMED to 1% AEP, then growth factor from ReFH applied to 1% event for events to 0.1% AEP)	ReFH2 will be utilised for hydrograph calculation, a review of duration and time to peak will be undertaken.
•	If not appropriate, describe why and give details of the other method/s to be used.	inflow.
•	What method will be used for hydrograph calculation?	
•	Will the catchment be split into sub-catchments/intervening areas? If so, how will flows for intervening areas be estimated?	
So	oftware to be used including version number	WINFAP FEH 5 (v5.2.9) and ReFH2.3 (v3.3.8)
2. Locations where flood estimates are required

2.1 Map of study area, including subject site(s) and gauging stations (where applicable).



Figure 3. Site location shown with orange marker. Llanymynech gauging station and metadata shown inset. From FEH Web Service 2025.

2.2 Summary of subject sites

The table below lists the locations of subject sites. Use site codes in all subsequent tables to save space.

Site code	Watercourse	Site Name (description)	Easting	Northing	AREA on FEH Web Service (km ²)	Revised AREA if altered (km ²)	Peak flow, hydrograph or both required?
001	River Vyrnwy	Vyrnwy at Llanymynech	326400	319400	783.5	783.5	Both

2.3 Important catchment descriptors at each subject site (incorporating any changes made)

Site code	AREA (km²)	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	FARL	FPEXT	PROPWET	SAAR (mm)	URBEXT 2000
001	783.5	0.41	36.91	160.9	0.97	0.51	0.053	1335	0.0009

2.4 Checking catchment descriptors

Item	Comment
Record how catchment boundary was checkedDescribe any changesAdd maps if needed	The catchment boundary is large so less likely to be erroneous. It has been visually checked against OS mapping and OS terrain data and is found to be representative.
 Record how catchment descriptors were checked, especially soils Describe any changes Include a before and after table if necessary 	The catchment BFIHOST19 value of 0.41 has been visually checked against BGS Geoindex Geology mapping and Landis Soilscapes mapping. The catchment has parcels of freely draining soils within the lower reaches, blanket bog in the upper reaches and impeded draining in the upper to mid reaches. The superficial geology underlying the catchment is mixed permeability glacial and alluvial material, with impermeable mudstone, sandstone and siltstone underlying the superficial deposits. Generally these descriptions are compatible with a moderately permeable BFIHOST value.



Method for updating URBEXT	Catchment is predominantly rural with no major developing warranting an
 Refer to WINFAP Urban Adjustment procedures/guidance 	update of URBEXT2000. Urban adjustment has been applied with no changes to flows.

3. Statistical method

3.1 Donor stations and QMED adjustment factors

Note that donor catchments will usually be rural but may be urban provided the data is deurbanised prior to the adjustment process. Include a map if necessary.

Station name	NRFA station number	Record Length	Is station hydrologically connected to subject site? Ie, upstream / downstream	Gauged QMED (m³/s)	Deurbanised Gauged QMED (A) (m ³ /s)	Catchment descriptors QMEDrural (B) (m ³ /s)	Adjustment ratio (A/B)	Chosen or rejected
(Vyrnwy @ Llanymynech)	54028	45	Almost immediately upstream from site	264.248	264.011	315.134	0.84	Chosen
(Tanat @ Llanyblodwel)	54038	48	A tributary of the Vyrnwy	79.320	79.247	114.253	0.69	Chosen
(Severn @ Montford)	54005	69	Downstream significantly	307.379	306.027	532.007	0.58	Chosen
(Hirnant @ Plas Rhiwedog)	67013	12		24.081	24.081	37.842	0.64	Chosen
(Ceiriog @ Brynkinalt Weir)	67005	24		30.000	29.962	58.390	0.51	Chosen

(De Ma	e @ nley Hall)	67015	51		227.000	226.045	365.080	0.62	Chosen
Co •	mments Mention; dis and	stance from	subject si	ite (based on catchment centroi	d), whethe	r they are on the	e same, adjace	ent or nearby w	atercourse
•	features wh	ich may im	pact applic	cability, eg FARL , quality of floo	d peak dat	ta, length of reco	ord.		
All	sites have c been retaine all sites hav	omparable ed within th e good data	FARL, 67 e group. A a records.	015 is slightly lower at 0.93 but All donor sites are relatively close	last in the g e to the Vy	group and other rnwy Catchmen	descriptors mathematic descriptors mathematication description of the cathematic description of the descript	atch very well s chment area c	so all have ontext and
Adj	ustment for overestimat	catchment ing flow.	descriptor	s against QMED gauged agrees	s well at all	l donor sites, wit	h a reduction i	ndicating that (QMEDcds is

3.2 Overview of estimation of QMED at each subject site

- Methods: CD: catchment descriptors alone, DT: data transfer, BCW: catchment descriptors and bankfull channel width, FV: flow variability (using flow duration statistics)
- Urban adjustment procedures should be applied regardless of whether the subject site is rural or urban.
- If more than one donor has been used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the table.
- Edit table columns/add rows as needed

Site code	QMEDrural from CDs (m ³ /s)	Method	NRFA numbers for donor site/s used	Distance between centroids (km)	Distance attenuation alpha factor used? If not explain why below.	Weighting of donor station for QMED adjustment if amended from default	Final adjustment factor applied to site QMED (calculate from QMEDs if WinFap used)	Final estimate of QMEDrural (m ³ /s)	Final estimate of QMEDurban (m ³ /s)
001	261.861	Donor	54028 54038	0.10 9.82	Yes as default	Retained as default	0.83	261.63	261.86
			54005	12.13					
			67013	17.14					
			67005	19.93					
			67015	21.88					
Distan	ce attenuation	n alpha fao	ctor comme	ents		1		1	L

Are the values of Final QMED and QMED adjustment factors consistent, for example at successive points	There is only one site location estimated however, the trend in donor sites adjustment supports the value and the final adjustment value is similar to
along the watercourse and at confluences?	that at the Llanymynech gauging station immediately upstream.

3.3 Derivation of pooling groups

- Several subject sites may use the same pooling group.
- The composition of pooling groups should be presented in the Appendix.

Pooling group name	Site for which pooling group was derived	If applied to more than on site, list their codes	Method: Single Site / with History, Enhanced Single Site or Pooled / Small Catchment Pooled? Include reasons for choice of method	Changes made to default pooling group, with reasons Include any sites that were investigated but retained in the group
P001	001		Pooled	The default pooling group has been reviewed but not adjusted.
Were non-flood year adjustments made to any stations? if so give details		r o any details	Only two stations have non f two stations within the group changes have been made.	lood years, totally three non flood years. These were the lowest ranking and therefore have minimal influence on derived growth curves, no

URBEXT2000 threshold used to create pooling group(s).	We recommend that this is set to 0.3 to make maximum use of available data and that growth curves are deurbanised appropriately
Have pooling group growth curves been deurbanised?	All stations within the group have URBEXT2000 values of 0.006 or lower, essentially no urban influence. Deurbanised growth curves were investigated but not selected as no change in predicted growth curves occurred compared with rural estimates.

3.4 Derivation of flood growth curves at subject sites

- A pooling group derived at one location can be applied to estimate growth curves at several ungauged sites. However, each site may have a different urban adjustment, and therefore different growth curve parameters.
- Urban adjustments to growth curves should use the latest methodologies in WINFAP
- Any relevant frequency plots from WINFAP, particularly showing any comparisons between single-site and pooled growth curves (including flood peak data on the plot) should be shown in an Appendix.

Site code	Pooling group name	Distribution used and reason for choice	Was an urban adjustment made	Growth factor for 100- year return period (1% AEP) event
001	P001	Generalised Logistic, FEH recommended for UK catchments	Investigated but shown to make negligible difference to rural estimates	2.335

3.3 FIDDU ESTIMATES HOM THE STATISTICAL METHOD	3.5	Flood	estimates	from	the	statistical	method
------------------------------------------------	-----	-------	-----------	------	-----	-------------	--------

Site code	Flood pea	Flood peak (m ³ /s) for the following return period or AEP events									
	2 50%	5 20%	10 10%	20 5%	30 3.3%	50 2%	75 1.3%	100 1%	200 0.5%	500 0.2%	1000 0.1%
001	261.6	332.0	384.7	442.5	462.7	479.9	531.5	576.5	611.0	703.4	849.8

4. Revitalised flood hydrograph (ReFH) method for peak flow estimation

This section records calculations for peak flow estimates and will generally use default parameters. If different calculations are subsequently made for hydrographs, details should be recorded in section 5.

4.1 Design events for ReFH method for peak flow estimation

Site code	Season of design event (summer or winter)	Recommended Storm duration (hours)
001	Winter	15

Was FEH22 used for design rainfall statistics? If not, why?	Yes
Comments	

4.3 Peak flow estimates from the ReFH method

		Flood p	eak (m³/s	s) for th	e followin	ig return	periods ((in years)	or AEP				
Site code	Urban/ rural?	2 50%	5 20%	10 10%	20 5%	30 3.3%	50 2%	75 1.3%	100 1%	200 0.5%	500 0.2%	1000 0.1%	100:1000 1%:0.1% ratio
001	Urban	235.3	300.7	349.3	400.7	432.9	476.0	512.3	539.1	607.68	706.3	786.3	0.689
How do pea estimates.	k flows co	ompare to	statistica	I									

5. Revitalised flood hydrograph (ReFH) method for model inflow hydrographs

5.1 Parameters for ReFH model for model inflow hydrographs

This section records calculations for model inflow hydrographs, parameters may have been calibrated and storm durations changed.

If parameters are all estimated from catchment descriptors, they are easily reproducible, so it is not essential to record them here –Just enter 'all' under site code and 'Catchment descriptors' under method. Table can be amended as needed.

Site code	Details of method	CD Tp (hours)	Adjusted Tp if different (hours)		
	 Catchment descriptors (CD) 				
	 Tp (Time to peak) calculation 				
	 Optimisation (Calibration Utility) 				
001	Catchment descriptors with time to peak and duration reviewed	6.49	10		

Description of any Tp calculation or calibration work, add references to other documents where appropriate	Default catchment descriptors e 15- minute level data for the Vyr data explorer. This data was rev months however many of these events which were driven by one hydrographs. These events occu To compare hydrograph shape, ReFH hydrograph by the peak fit hours for comparison of shape, gauged data described by Arche Reviewing the event hydrograph catchment descriptors, it is evide peak are likely underestimated. as the two are dependent. A val result in a hydrograph synthesis FEH-statistical and adjusted 100 predicted peak flow due to adjust	stimated a time to peak of 6.49 a mwy at Llanymynech is available viewed, numerous large flow eve are caused by two or more storr e flow event only have been sele urred on 18 February, 27 March the level hydrographs were scal low, making the hydrographs din this is similar to the approach fo er et al., 2010 ² . Ins (Figure 5 below) alongside the ent that the recommended ReFF Adjustments were made to the s ue of 10hrs for time to peak and which matches very well with th Doyr estimate will be adopted for stments is not considered to imp	and a storm duration of 15 hours. e for the previous 12 months on the NRW ents have occurred within the last 12 m events coinciding. The three largest ected for review against ReFH design and 16 October 2024. led by the peak of each event and the nensionless. Peaks were aligned to zero r design hydrograph synthesis from le default ReFH2 hydrograph from 12 hydrograph volume and time to flood storm duration and time to peak iteratively, associated 22hrs for storm duration he average hydrograph shape in Figure 5. design flows so the influence on act the assessment.

² Archer, D., Foster, M., Faulkner, D. and Mawdsley, J., 2000, October. The synthesis of design flood hydrographs. In *Proc. ICE/CIWEM Conf. Flooding–Risks and Reactions. Terrace Dalton, London.*



5.2 Design events for ReFH method for model inflow hydrographs

Storm duration (hours)	ARF	Source of Storm Duration and ARF	Why Chosen
22	0.87	ARF calculated based on time to peak and duration adjustments	Details above on time to peak and duration review due to gauged hydrograph shape at the Llanymynech gauge near to the site.
Were hydrographs scaled to alternative peak flow estimates? If so, give details			Yes, FEH-statistical will be adopted as there is a good degree of confidence in the estimates due to location of the Llanymynech gauge upstream from the site.
Provide link/refe or provide in ap	erence to pendix	location of hydrographs	Design hydrographs are provided below

6. Final peak flow and hydrograph estimates

6.1 Comparison of peak flow estimates from different methods

This table compares peak flows from the ReFH method, FEH Statistical method and any available previous study at each site for two key return periods. Note and explain any significant difference from previous studies.

	QMED (50% /	AEP)			100-year return period / 1% AEP			
Site code	Statistical	ReFH	Previous Study	Comment	Statistical	ReFH	Previous Study	Comment
001	261.6	265.3	N/a	Statistical is higher and agrees with gauging's at Llanymynech	611.0	539.1	N/a	Higher statistical estimate agrees with long-term flood record at Llanymynech although data record only 54 years.

6.2 Final peak flow estimates

	Flood pea	ood peak (m ³ /s) for the following return periods (in years) or AEP										
Site code	2	5	10	20	30	50	75	100	200	500	1000	
	50%	20%	10%	5%	3.3%	2%	1.3%	1%	0.5%	0.2%	0.1%	
001	235.3	300.7	349.3	400.7	432.9	476.0	512.3	539.1	607.7	706.3	891.1	
State choice of method, ie Hybrid approach (Statistical for QMED to 100 year, ReFH growth factor from 100yr applied to statistical 100yr, for rarer events)			The FE been ac estimate gauge <i>I</i>	H statistica lopted as los at this s AMAX imm	al method FEH statis site and th nediately u	with ratio stical provi e estimate ipstream.	adjusted (des a grea es up to 50	RefH 100/ ater degre)yrs agree	(1000 * FE e of confid very well	H-stat 10 lence in p with the L	0) 1000yr has eak flow lanymynech	

Statistical	
ReFH	

6.3 Uncertainty

Give what information you can on uncertainty in the flood estimates

For example, using the methods detailed in 'Making better use of local and historic data, and estimating uncertainty in FEH design flood estimation (FEH Local) SC130009

Site Code	95% confidence interval factor for QMED (eg 0.48- 2.1 for ungauged locations with 0 donors)	95% confidence interval factor for 100 year (1% AEP) flood	Comments, include comments on QMED estimation method, gauging station relative location/s, record length, data quality, consistency between stations, flood history and catchment characteristics
001	132.3 to 517.5	300.7 to 1241.5	FSE has been estimated using the 6 donor equation on page 6 of Uncertainty in FEH Methods ³ . The resulting FSE value for Qmed is 1.406 and 1.425 for the 100yr flood.

6.4 Hydrographs for modelling

How were these calculated, for example, scaling ReFH hydrographs to final flow estimates, adjusting Cini? include	Hydrograph shape generated by RefH catchment descriptors, with adjusted Tp and storm duration. Scaled to FEH statistical flow
link/reference to hydrographs.	estimates.

³ <u>https://www.hydrosolutions.co.uk/app/uploads/2021/11/Uncertainty-in-FEH-methods-v1.1.pdf</u>

ervening areas are atch downstream resulting The hydrographs will be applied as a lumped inflow at the upstream extent of a hydraulic model, due to the relatively small site extent only a single inflow location is specified.
resulting site extent only a single inflow location is speci

6.5 Checks

Are the results consistent, for example at confluences?	QMED agrees with the gauged flow at the Llanymynech gauge slightly upstream.
What do the results imply regarding the return periods of floods during the period of record?	Estimates up to the 50yr return period are comparable with the AMAX record at the Vyrnwy at Llanymynech gauging station providing confidence in estimates up to this event. Beyond this it is not possible to compare as the station only has a 54yr data record.
What is the 100-year growth factor? Is this realistic?	2.335, within typical range
(The guidance suggests a typical range of 2.1 - 4.0)	
If 1000-year flows have been derived, what is the range of ratios for the 1000-year flow	The 0.1% / 1% AEP event ratio for the methods is:
over 100-year flow?	FEH Statistical – 1.47
	ReFH2 – 1.65

What is the range of specific runoffs (I/s/ha)? Are there any inconsistencies?	 2yr - 0.3l/s/ha 100yr - 0.78l/s/ha The ranges are comparable with plot scale greenfield runoff estimates for rural catchments, the estimates are on the slightly lower side which is likely due to some permeability within the lower reaches of the catchment and slacker gradient
	reducing runoff intensity.
How did the results compare with those of other studies?	None known
Explain any differences and conclude which results should be preferred	
Are the results compatible with the longer- term flood history?	The results compare well with the Llanymynech gauge up to a 50yr return period, records of flooding in the area in recent years suggest the results correlate well.
Describe any other checks on the results	The trends explorer for Llanymynech was reviewed, the trends explorer suggests a climatically driven positive trend in flow at the Llanymynech gauge, however consultation with NRW (Demcember 2024 and January 2025) suggested there is not enough confidence to rely on this for flow estimation. The consultation and responses are attached below.

6.6 Assumptions and limitations

List the main assumptions made specific to the study	Flows rely on gauged data from the Llanymynech gauge for
	improved confidence, however all flows are statistical estimates
	and will contain a degree of error. Assessing a range of flood

	flows with climate change allowances helps understand uncertainty across the flood hydrograph range.
Discuss any particular limitations	
For example, applying methods outside the range of catchment types for which they were developed	
Comment on the suitability of the results for future studies For example, at nearby locations or for different purposes	The results from this study are applicable to future work, however, as is recommended if significant time since this assessment or large flood events have occurred on the Vyrnwy the flows should be reviewed.
Give any other comments on the study For example, suggestions for additional work	The work are for comparative purposes for a assessing work which is a net export of material from a flood zone and have been determined for comparative purposes at this site.

Appendix: supporting information

Please include details of your pooling group(s)

Pooling group composition

QMED and pooling group composition are attached as a separate PDF exported from WINFAP.

Additional supporting information

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

 Date of creation:
 07-01-2025 15:07:14

 Software:
 WINFAPVersion: 5.2.9014 (11448)

 Peak Flow dataset:
 Peak Flow Dataset 11.0.0

 Supplementary data used:
 No

Site details

Site number: 2108853198 FEH_Catchment_Descriptors_326400_319400_v5_0_1 Site name: Site location: SJ 26400 19400 326400 Easting: Northing: 319400 Catchment area: 783.47 km² SAAR: 1335 mm BFIHOST19: 0.413 FPEXT: 0.053 FARL: 0.969 URBEXT2000: 0.0009

Site data

At-site data

At-site data present: No

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Analysis settings

Urbanisation settings

User defined: No Urban area: 1.10 km² PRimp: 70.00% Impervious Factor: 0.300 UAF: 1.00090

Growth curve settings

 Distance Measure Method:
 Standard

 Pooling group URBEXT2000 Threshold:
 0.030

 Deurbanise Pooling Group L-moments:
 Yes

QMED settings

Use at-site data: No Method: Donor Station(s)

Growth curve data and results

Pooling group AM data

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised
54028 (Vymwy @ Llanymynech)	0.013	45	264.248	0.160	0.160	0.221	0.221
84004 (Clyde @ Sills of Clyde)	0.215	66	210.636	0.170	0.170	0.235	0.235
79002 (Nith @ Friars Carse)	0.225	64	447.365	0.129	0.130	0.176	0.175
56001 (Usk @ Chainbridge)	0.248	60	373.400	0.174	0.175	0.210	0.209
62001 (Teifi @Glanteifi)	0.263	62	213.000	0.219	0.220	0.374	0.373
12003 (Dee @ Polhollick)	0.300	30	301.394	0.136	0.136	0.064	0.064
84018 (Clyde @ Tulliford Mill)	0.334	38	247.738	0.170	0.170	0.222	0.222
23004 (South Tyne @ Haydon Bridge)	0.337	62	452.368	0.149	0.150	0.203	0.203
47001 (Tamar @ Gunnislake)	0.340	65	265.128	0.179	0.180	0.245	0.244
21003 (Tweed @ Peebles)	0.345	62	180.883	0.207	0.207	0.294	0.294
Total		554					

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Pooling group suitability

Station	Suitability for QMED	Suitability for pooling	Years	Non-flood years	Percentage non-flood years	Mann Kendall (MK)	MK significance (%)	Discordancy	Comments
54028 (Vymwy @ Llanymynech)	Yes	Yes	45	0	0.00			0.257	
84004 (Clyde @ Sills of Clyde)	Yes	Yes	66	0	0.00			0.105	
79002 (Nith @ Friars Carse)	Yes	Yes	64	0	0.00			1.481	
56001 (Usk @ Chainbridge)	Yes	Yes	60	0	0.00			2.249	
62001 (Teifi @Glanteifi)	Yes	Yes	62	0	0.00			1.390	
12003 (Dee @ Polhollick)	Yes	Yes	30	0	0.00			2.404	
84018 (Clyde @ Tulliford Mill)	Yes	Yes	38	0	0.00			0.551	
23004 (South Tyne @ Haydon Bridge)	Yes	Yes	62	0	0.00			0.409	
47001 (Tamar @ Gunnislake)	Yes	Yes	65	1	1.54			0.212	
21003 (Tweed @ Peebles)	Yes	Yes	62	2	3.23			0.941	

Pooling group catchment descriptors

Station	Area	SAAR	FPEXT	FARL	URBEXT2000	BFIHOST19
54028 (Vymwy @ Llanymynech)	779.143	1339	0.052	0.969	0.001	0.412
84004 (Clyde @ Sills of Clyde)	742.265	1223	0.062	0.964	0.002	0.407
79002 (Nith @ Friars Carse)	797.705	1461	0.050	0.991	0.002	0.389
56001 (Usk@Chainbridge)	913.247	1367	0.044	0.980	0.006	0.559
62001 (Teifi @Glanteifi)	897.585	1379	0.049	0.995	0.005	0.463
12003 (Dee @ Polhollick)	697.505	1231	0.038	0.986	0.000	0.404
84018 (Clyde @ Tulliford Mill)	938.362	1205	0.062	0.966	0.002	0.404
23004 (South Tyne @ Haydon Bridge)	749.895	1147	0.044	0.989	0.002	0.321
47001 (Tamar @ Gunnislake)	920.220	1215	0.044	0.993	0.005	0.445
21003 (Tweed @ Peebles)	698.120	1140	0.051	0.974	0.003	0.466

Pooling Group Rejected Stations

Station Distance Years of data QMED AM L-CV Observed L-CV Deurbanised L-SKEW Observed L-SKEW Deurbanised Comments

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Bound

0.271

-1.872

Growth curve L-moments

Distribution Los	ation	0	01		Dered		
Rural fitted parameters							
Rural L-Skewness:	0.226		Urban L-S	Skewness:	0.226		
Rural L-CV:	0.169		Urban L-C	V:	0.169		

Distribution	Location	Scale	Shape	н	Bound
GL	1.000	0.165	-0.226		0.270
GEV	0.911	0.240	-0.086		-1.882
KAP3	0.955	0.198	-0.163	-0.400	-0.260

Goodness of fit

GL: 0.8415 *

GEV: -0.8282 * P3: -2.6526

GP: -4.8469

KAP3: 0.2665 *

* Distribution gives an acceptable fit (absolute Z value < 1.645)

Heterogeneity

Standardised test value H2: -0.6387

The pooling group is acceptably homogeneous and a review of the pooling group is not required.

Urban fitted parameters

GL

GEV

KAP3

Distribution Location Scale Shape H

0.165 -0.226

0.239 -0.086

0.198 -0.163 -0.400 -0.258

1.000

0.911

0.955

Standardised growth curves

Rural				Urban			
Return period	GL	GEV	KAP3	Return period	GL	GEV	KAP3
2	1.000	1.000	1.000	2	1.000	1.000	1.000
5	1.269	1.294	1.280	5	1.269	1.294	1.280
10	1.470	1.506	1.487	10	1.470	1.505	1.487
20	1.691	1.722	1.708	20	1.691	1.721	1.707
25	1.769	1.793	1.783	25	1.768	1.793	1.783
30	1.834	1.852	1.846	30	1.834	1.852	1.846
50	2.031	2.022	2.033	50	2.031	2.021	2.032
75	2.204	2.161	2.191	75	2.203	2.161	2.191
100	2.335	2.263	2.310	100	2.335	2.262	2.310
200	2.689	2.518	2.619	200	2.688	2.517	2.619
500	3.248	2.878	3.084	500	3.248	2.878	3.084
1000	3.755	3.170	3.484	1000	3.755	3.170	3.484

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method



Pooling-group - SJ 26400 19400 (07-01-2025 15:06) - rural

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method



Pooling-group - SJ 26400 19400 (07-01-2025 15:06) - urban

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

QMED data and results

Donor selection criteria	
Only sites suitable for QMED:	Yes
URBEXT2000:	< 0.030
Donor adjusted FSE:	1.084
No. of donors:	6

Donor stations

Station	Distance	Use QMED obs deurbanised	QMED obs	QMED deurbanised	QMED CDs urban	QMED CDs rural
54028 (Vymwy @Llanymynech)	0.10	Yes	264.248	264.011	315.134	315.134
54038 (Tanat @ Llanyblodwel)	9.82	Yes	79.320	79.247	114.253	114.253
54005 (Severn @ Montford)	12.13	Yes	307.379	306.027	532.007	532.007
67013 (Himant @ Plas Rhiwedog)	17.14	Yes	24.081	24.081	37.842	37.842
67005 (Ceiriog @ Brynkinalt Weir)	19.93	Yes	30.000	29.962	58.390	58.390
67015 (Dee @ Manley Hall)	21.88	Yes	227.000	226.045	365.080	365.080

Donor suitability

Station	Suitability for QMED	Suitability for pooling	Years	Non-flood years	Percentage non-flood years	Mann Kendall (MKZ)	MKZ significance (%)	Comments
54028 (Vymwy @ Llanymynech)	Yes	Yes	45	0	0.00			
54038 (Tanat @ Llanyblodwel)	Yes	Yes	48	0	0.00			
54005 (Severn @ Montford)	Yes	Yes	69	0	0.00			
67013 (Hirnant @ Plas Rhiwedog)	Yes	No	12	2	16.67			
67005 (Ceiriog @ Brynkinalt Weir)	Yes	No	24	0	0.00			
67015 (Dee @ Manley Hall)	Yes	Yes	51	0	0.00			

Donor catchment descriptors

Station	Area	Centroid X	Centroid Y	SAAR	FPEXT	FARL	URBEXT2000	BFIHOST19
FEH_Catchment_Descriptors_326400_319400_v5_0_1 @ SJ 26400 19400)	783.467	307842	318668	1335	0.053	0.969	0.001	0.413
54028 (Vymwy @ Llanymynech)	779.143	307743	318661	1339	0.052	0.969	0.001	0.412
54038 (Tanat @Llanyblodwel)	241.125	312720	327196	1274	0.038	0.996	0.001	0.427
54005 (Sevem @ Montford)	2026.770	310948	306939	1147	0.092	0.977	0.004	0.444
67013 (Himant @ Plas Rhiwedog)	32.470	296007	331068	1756	0.018	1.000	0.000	0.351
67005 (Ceiriog @ Brynkinalt Weir)	111.718	317500	336107	1198	0.023	1.000	0.001	0.403
67015 (Dee @ Manley Hall)	1008.740	303097	340024	1367	0.046	0.934	0.004	0.402

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Unused Donor stations

Station	Distance	URBEXT	Use QMED obs deurbanised	QMED obs	QMED deurbanised	QMED CDs urban	QMED CDs rural	Centroid X	Centroid Y	Area	SAAR	BFIHOST19	FARL	Years of data	QMED suitability	Pooling suitability
64001 (Dyfi @ Dyfi Bridge)	26.49	0.001	Yes	321.713	321.488	323.402	323.402	284142	306845	464.605	1835	0.413	0.995	59	Yes	No
64011 (Cerist @ Llaw'r Cae)	27.20	0.000	Yes	6.137	6.137	9.655	9.655	280806	315666	5.350	2159	0.364	1.000	25	Yes	No
67018 (Dee @ New Inn)	27.40	0.000	Yes	77.099	77.073	75.025	75.025	283267	330791	53.383	2022	0.289	1.000	23	Yes	No
54014 (Severn @ Abermule)	29.81	0.004	Yes	188.094	187.241	217.686	217.686	300198	289854	574.538	1256	0.420	0.970	53	Yes	Yes

QMED

Rural: 261.626 m³/s

Urban: 261.861 m³/s

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Flood Frequency Curve

Rural Flood Fre	equency Cur	ve		Urban Flood Frequency Curve						
Return period	GL (m³/s)	GEV (m³/s)	KAP3 (m³/s)	Return period	GL (m³/s)	GEV (m³/s)	KAP3 (m³/s)			
2	261.626	261.626	261.626	2	261.861	261.861	261.861			
5	332.017	338.654	334.819	5	332.278	338.916	335.080			
10	384.671	393.935	388.999	10	384.961	394.228	389.289			
20	442.529	450.413	446.797	20	442.857	450.748	447.128			
25	462.719	469.070	466.499	25	463.062	469.421	466.845			
30	479.875	484.520	483.053	30	480.232	484.885	483.413			
50	531.453	528.896	531.829	50	531.852	529.304	532.232			
75	576.512	565.365	573.300	75	576.952	565.812	573.745			
100	610.953	591.960	604.343	100	611.426	592.439	604.820			
200	703.433	658.667	685.183	200	704.003	659.232	685.753			
500	849.767	752.992	806.788	500	850.508	753.697	807.518			
1000	982.286	829.375	911.516	1000	983.199	830.208	912.399			





Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method



Pooling-group - SJ 26400 19400 (07-01-2025 15:06) - urban

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Appendix

Station record parameters

Flood seasonality: SJ 26400 19400 (07-01-2025 15:06) - rural



Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method



Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method



L-moment ratios - SJ 26400 19400 (07-01-2025 15:06) - urban
Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

L-moment ratios - SJ 26400 19400 (07-01-2025 15:06) - urban



Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Pooling group growth curves



Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Catchment descriptors



Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method



